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ABSTRACTS

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"DEVONO-CARBONIFEROUS MAGMATISM, DEFORMATION, METAMORPHISM, AND RELATED MINERALIZATION IN THE ATLANTIC PROVINCES"

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The occurrence of primary magmatic layering within the Big Indian Lake pluton, Hants County, Nova Scotia

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Geological observations of drill core combined with preliminary petrographic observations and microprobe analysis suggest that the Big Indian Lake pluton is in part a layered peraluminous granite. The pluton occurs within the South Mountain Batholith approximately 40 km northwest of Halifax. It is comprised of four texturally variable granitic facies, which in order of decreasing abundance are: (1) megacrystic to moderately equigranular monzogranite and leucomonzogranite; (2) porphyritic biotite monzogranite; (3) equigranular leucomonzogranite; and (4) microgranite. The most compelling evidence of igneous layering is provided by intersections of a plagioclase-rich rock containing 50 to 90% euhedral plagioclase crystals and millimetre- to centimetre-thick, modally-enriched bands of biotite and apatite. Intersections of the plagioclase-rich rock within the drill core range from <1 to 45 m thick and are separated vertically by sections of granodiorite and biotite-monzogranite. Contacts of the plagioclase-rich rock with other facies of the pluton are usually gradational and are marked by a progressive increase in biotite and decrease in euhedral plagioclase crystals. Rare, sharp contacts with granodiorite are marked by biotite-rich metasedimentary(?) xenoliths. Similar xenoliths occur within the plagioclase-rich rock restricted to discrete xenolith-rich zones. The occurrence of discrete zones of desilicification, chloritization, and saussuritization within the plagioclase-rich rock indicate infiltration by late- to post-magmatic fluids. The drill core shows a transition from thick, massive plagioclase-rich rock near the surface to progressively lesser plagioclase-rich rock and more abundant granodiorite and biotite monzogranite into predominately leucomonzogranite and microgranite at depth. The plagioclase crystals are characterized by well-developed normal and oscillatory zoning and preliminary microprobe analyses have revealed core compositions of An_{51}. The plagioclase crystals are supported by a framework of interstitial minerals including: quartz, K-feldspar, albite, biotite, apatite, cordierite, muscovite, chlorite, and sphene. Their modal abundance ranges from 50% to <5%. The interstitial minerals are commonly euhedral and have sharp grain boundaries with the plagioclase crystals. Detailed petrographic and geochemical studies to determine the origin and significance of the aforementioned features are currently in progress.

Middle Paleozoic granite plutonism in southern Newfoundland

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Granitic and associated intermediate to mafic plutonism of Devonian to Early Carboniferous age is well represented in southern Newfoundland where the Burgeo and North Bay intrusive suites have intruded late Precambrian to Late Silurian gneisses, sedimentary and volcanic rocks. The batholiths are dominated by syn- to late tectonic biotite ± hornblende granodiorite and granite and late to post-tectonic muscovite-biotite granite. A radiometric age of 396 Ma (U-Pb zircon) was obtained from a late phase of the North Bay Granite Suite. Syn- to late tectonic phases of the Burgeo Intrusive Suite have been dated at 428 and 415 Ma (U-Pb zircon), respectively. A brecciated granite from the Ramea Islands has been dated at 417 Ma (U-Pb zircon).

Completely post-tectonic granites extend along the south coast for 200 km. These texturally-variable biotite granites rarely contain hornblende. They cross-cut all the major tectonic features that define the various terranes. The granites are highly evolved, contain miarolitic cavities and gas breccias, and were emplaced at high structural levels. These granites display geochemical and lithological layering and the François Granite comprises two overlapping, composite, ring complexes. The Chetwynd Granite is dated at 390 Ma (U-Pb); the François Granite at 378 Ma (U-Pb); the Harbour Breton Granite at 340 Ma (Rb-Sr); the Ackley Granite at 367 to 353 Ma (Ar-Ar).

Geochemical variation in the Silurian-Devonian composite batholiths indicates calc-alkaline trends from gabbro through tonalite and granodiorite to granite. The highly evolved granites are all high-silica granites (average 72-76% SiO_2) with the more evolved phases displaying very high Rb:Sr ratios (>100). Epsilon Nd ratios indicate that the granites within the Avalon Zone have positive ε Nd, whereas the Dunnage-Gander Zone granites are negative. This has been interpreted as reflecting major differences in the crust. This change coincides with the Hermitage Bay Fault but not perfectly with the Dover Fault.

Mineralization is mainly associated with the high-silica granites. The Mo deposits at Rencontre Lake and Sn-W-Mo greisens at Sage Pond lie along the southern margin of the Ackley Granite. The François Granite features highly anomalous radioactivity although no significant U or Th values or alteration have been found. The Chetwynd Granite is adjacent to the Hope Brook gold mine and may have been involved in the remobilization of gold. The Burgeo Intrusive Suite may be the source of extensive W + base-metal-bearing quartz veins at Grey River. Extensive Mo-W mineralization, at Granite Lake, occurs within an extensively altered phase of the North Bay Intrusive Suite and also in epithermal quartz-wolframite veins in adjacent granodiorite.

Metallogeny of the Jacquet River area, northern New Brunswick

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Post-Acadian (Lower Devonian) extensional tectonics resulted in the development of a large half-graben structure infilled by sedimentary and mafic to felsic volcanic and volcanoclastic rocks. The basement to the graben is floored by folded Silurian (and locally) Ordovician metasedimentary rocks. The volcanic rocks were brought to the surface along extensional fractures in proximity to the main graben fault zones. Small felsic domes (flows and agglomerates) were extruded into a subaerial to very shallow marine environment along these graben structures. Mafic volcanism produced extensive flows and tuffs capping the rhyolite domes and filling the floor of the half-graben structure. The mafic flows interfinger with overlying calcareous shales and limestones and are succeeded in turn by a second generation of felsic volcanism.

The half-graben structure is bordered by several reverse faults in the western part of the half-graben and a number of extensional fractures developed to the east in proximity to a monoclinal fold (down-warp) along the hinge zone of the half-graben. These contrasting structures are reflected in differing styles of base-metal mineralization across the half-graben.

Base-metal-bearing fluids appear to have been introduced during the late stages of the first period of felsic volcanism. Along the western margin of the half-graben, epithermal base-metal sulphides (primarily Pb, Zn, Ag, and minor Cu) occur within quartz-carbonate vein-stockworks and breccia (agglomerate) matrices. Minor banded, massive lenses of sulphides in the agglomerates and tuffs indicate that the metalliferous brines reached surface. The banded sulphides were preserved from rapid oxidation by a quick capping of mafic volcanic flows. Along the eastern margin of the half-graben, metalliferous brines permeated the hinge zone of the half-graben along the extensional fractures developed during the down-warping. Minor contemporaneous felsic and mafic dykes are also associated with this zone. Base metals occur in wide extensional quartz veins and in stratabound skarn (manto) deposits where fluids and dykes have intersected Silurian limestones. Continuing epithermal activity during the extrusion of the mafic volcanic rocks produced minor mineralization and alteration (e.g., celadonite) within the mafic flows. A second minor epithermal event at the end of the mafic volcanism resulted in deposition of Cu-Ba-bearing veins in the mafic flows and Cu disseminations and veinlets within the uppermost flow-top breccias and intercalated sedimentary rocks.

Petrogenesis, age and economic potential of gabbroic intrusions in southern New Brunswick and southeastern Cape Breton Island

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The Mechanic Settlement and Duck Lake plutons in southern New Brunswick are layered intrusions that range in composition from olivine pyroxenite to diorite; the smaller Devine Corner pluton is composed entirely of gabbro. The relationship of the Hamilton Lake diorite exposed southwest of the main body of the Mechanic Settlement pluton is not clear due to poor exposure. However, the diorite may compose the upper part of the pluton. Layering in the Mechanic Settlement pluton trends northeast and dips southeast and consists of mineral layering on the hand-specimen scale and interlayering of rock types on outcrop scale. Cumulate textures are well developed in most samples in both the Mechanic Settlement and Duck Lake plutons with cumulate phases including spinel (only in Duck Lake), chromite, olivine, clinopyroxene, orthopyroxene, and plagioclase. Abundance of hydrous minerals indicates that crystallization probably took place under relatively high water pressure. Major- and trace-element data show that olivine and pyroxene dominated the crystallization sequence and that the plutons are tholeiitic.

Gabbroic rocks of the St. Peters area in Cape Breton Island vary in composition from olivine gabbro to gabbro to hornblende-bearing gabbro. Other gabbroic plutons in southeastern Cape Breton Island occur near Baleine, Cape Breton, Louisbourg, Black Rock, and Gabarus. They consist of clinopyroxene and plagioclase with minor amphibole, biotite, quartz, apatite, and magnetite. Olivine occurs only in the St. Peters gabbros. Major- and trace-element data indicate that the St. Peters gabbros are alkaline and formed in a within-plate setting. In contrast, the other gabbros are tholeiitic but their tectonic setting is uncertain.

The age (or ages) of these plutons is still uncertain but may be Devonian.

Geological, geochemical, and fluid inclusion studies of the Gays River Pb-Zn deposit, southern Nova Scotia: a carbonate-hosted replacement deposit of Carboniferous age

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The Gays River Pb-Zn deposit (reserves 2.4 million tonnes 6.3% Pb, 8.7% Zn) is one of several significant Pb-Zn deposits hosted by Carboniferous rocks of Atlantic Canada. Mineralization is hosted by a dolomitized, Windsor Group (Viséan) carbonate-reef complex developed upon a basement high composed of Cambro-Ordovician metaturbiditic sedimentary rocks of the Meguma Group. The local mine stratigraphy (bottom to top) includes: (1) mixed psammites and pelites of the Meguma Group overlain unconformably by (2) a basal breccia unit consisting of Meguma Group clasts cemented by dolomitized limestone, (3) a complex package consisting of dolomitized carbonate lithologies (i.e., carbonate build-up), (4) evaporite (gypsum, anhydrite), and (5) a mixture of variably consolidated, Cretaceous-aged sedimentary debris (the "trench sediments"). Mineralization consists of both massive and disseminated ore, with the former by far the most important volumetrically and it is localized to the front of the reef rather than the saddle. The massive ore consists almost exclusively of fine-grained, Fe-poor sphalerite and Ag-poor galena and is formed from constant volume replacement of the dolostone; its thickness varies from several centimetres up to a few metres. In the central and western part of the deposit the massive ore generally has trench material as the hanging wall, while evaporite forms the hanging wall in the eastern part of the deposit. Important features of the ore include: (1) a primary control reflecting the locus of the precursor dolostone it replaced, (2) a limited vertical extent (ca. 86% of ore contained in 60 m vertical interval), and (3) ore textures suggestive of supersaturation and constant volume replacement origin. The disseminated ore, occurring both as a partial replacement and infilling of primary porosity, forms a broad halo of variable thickness beneath the apron of massive ore. Distribution of the breccia units suggests that it does not have a primary influence on the mineralization.

New S isotopic analysis, while confirming results of previous work, also indicates that there is a slight depletion in ^{34}S for galena mineralization in the breccia unit versus massive replacement ore ($\delta^{34}S_{gal}$-9.5 vs. 12.5). REE analyses of dolostone, massive and disseminated ore and sparry calcite indicate several reservoirs for REE and that massive ore has inherited the REE signature of the dolostone. Fluid inclusion studies indicate salinities of <25 wt. % equivalent NaCl with a large apparent range in T_H (60°->250°C). Preliminary interpretation of the data suggests that mineralization precipitated from saline brines of ca. 150° to 160°C and that the high T_H values possibly reflect (1) dissolved carbonic species in the fluid and/or (2) post-entrapment modification.

New insights into the generation, emplacement, and magmatic evolution of the South Mountain Batholith, Nova Scotia

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The South Mountain Batholith of southwestern Nova Scotia is a composite, peraluminous batholith ranging in composition from biotite granodiorite to muscovite ± topaz leucogranite. Recent geological mapping has provided new insights into the evolution of the batholith. Granitic rocks have been assigned to thirteen discrete plutons that can be grouped into early (Phase 1) plutons comprising mostly granodiorite and monzogranite and late (Phase 2) plutons comprising mostly leucomonzogranite and leucogranite. Despite a systematic sequence of emplacement for the rocks of these plutons, an evaluation of published geochronological data indicates that the entire batholith was emplaced and crystallized during a very short time interval (<5 million years) at ca. 370 Ma. Various structural features, including the shape and distribution of plutons and the orientation of primary features (e.g., megacryst alignment, joints, veins), indicate that the batholith was subject to regional stresses associated with the Acadian Orogeny during, and following, its emplacement and crystallization.

The various rock types within the plutons have broadly similar compositions; however, detailed petrographic and geochemical studies indicate unique features that possibly reflect compositional variations within the protolith. Similarly, the style of mineralization within the sundry plutons is interpreted to reflect a combination of protolith composition and differences in the physio-chemical conditions that prevailed during crystallization of individual plutons.

A review of recent petrogenetic studies of granulite gneiss and mafic intrusions in the eastern Meguma Terrane provides a mechanism for generation of the large volume of granitic magma required for the South Mountain Batholith. This mechanism involves the melting of upper crustal rocks, possibly of the Avalon Terrane, which were subducted to lower crustal P-T conditions beneath the Meguma Terrane during continent/continent collision related to the Acadian Orogeny. The presence of mantle-derived mafic intrusions suggests that underplating by mantle magma may have contributed to crustal melting.

Endogranitic Sn potential beneath the Nigadoo River base-metal vein/lode deposit, northern New Brunswick

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The abandoned Nigadoo River Mine is located about 15 km northwest of Bathurst in the Nigadoo River Synclinorium, part of the Tobique-Chaleur tectonostratigraphic zone. Initially discovered in 1953, development at the Nigadoo deposit continued until 1958. The northwesterly trending Main and Anthonian vein-systems (A and C zones, respectively) produced approximately 1.9 million tonnes grading 2.2% Pb, 2.1% Zn, 0.2% Cu, and 90 g/t Ag, mostly from the 1075 m long, 640 m deep, and 1 m wide A-Zone. The deposit is centred upon the Nigadoo Porphyry and crosscuts both the porphyry and enclosing country rocks, which consist of northeast-trending, steeply dipping, greenish grey calcareous slates, siltstones, and limestones of the Late Silurian LaPlante Formation. In general, the Nigadoo Porphyry is a steep-walled, quartz-orthoclase porphyritic plug that has been sericitized, chloritized, and locally silicified by vein-forming hydrothermal fluids.

The Nigadoo Porphyry was considered to be synorogenic, but recent mapping and radiometric dating indicate that it is post-tectonic and probably Late Devonian in age like other Sn-W-Mo-bearing granites in central and southern New Brunswick. Quartz-feldspar porphyry, which is texturally identical to the Nigadoo Porphyry, is a late phase in the nearby Antinouri Lake Granite (371 ± 4 Ma; U-Pb zircon). Zn-Pb-Cu-Ag vein mineralization is, in part, hosted in texturally similar porphyry at the old Keymet Mine, located about 10 km north of the Nigadoo mine.

Previously published literature suggested three stages of vein formation: (1) early pyrite-pyrrhotite-sphalerite-arsenopyrite veins; (2) the main stage sulphide veins; and (3) late-stage carbonate veins. In general, the main stage sulphides are coarse-grained and consist of monoclinic pyrrhotite, hexagonal pyrrhotite, pyrite (marcasite), Fe-rich sphalerite (≈22 mole % FeS), galena, chalcopyrite, arsenopyrite, cassiterite, stannite, argentiferous tetrahedrite, and native bismuth. In addition, there are several complex Ag-Pb-Bi-Sb sulphosalts. Needle-cassiterite occurs within the pyrrhotite (hex)-arsenopyrite-rich parts of the lode, that predominate below the 270 m level. Textural evidence indicates complex sulphide replacements within the lode, as well as late-stage shearing of the sulphides. The sulphide assemblage reflects formation from a low-temperature (200°-300°C) and low-pressure [<50 MPa (500 bars)] hydrothermal fluid with low $f(S_2)$, low $f(O_2)$, and low pH. This type of hydrothermal fluid is commonly responsible for the formation of tin-sulphide lode deposits worldwide. Furthermore, the narrow range of $\delta^{34}S$ isotopic values of 1.4 ± 1.0‰ (n=11; published data) obtained on various sulphides is consistent with a magmatic origin for the mineralizing fluid. Closed-system sulphur isotopic fractionation of pyrite and pyrrhotite from an H_2S-dominated, magmatically-derived hydrothermal fluid is consistent with the isotopic compositions found in the veins.

Unfortunately, Sn was not routinely assayed during the mining operation. However, reported Sn contents of the first Zn, Pb, and Cu concentrates were 0.02%, 0.1%, and 0.2%, respectively. It was also reported that the highest In and Bi contents were coincident with the porphyry-hosted portion of the vein/lode. If the Nigadoo lodes are analogous to the Mount Pleasant base-metal-tin lodes (0.25 million tonnes grading 2.3% Zn, 0.36% Pb, 0.3% Cu, and 0.6% Sn), then there should be endogranitic Sn at depth as there is at Mount Pleasant (2.14 million tonnes grading 0.81% Zn, 0.45% Sn, 0.06% W, and 0.03% Mo). However, an endogranitic tin zone at Nigadoo could be considerably larger than the one at Mount Pleasant if the size of the base-metal lodes is any indication.