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Geology of the South Mountain Batholith, Southwestern Nova Scotia

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Coastal exposure of Harrietsfield muscovite-biotite monzogranite at Chebucto Head, south of Halifax (Photo by Reg Morrison, DNR).

PREFACE

The South Mountain Batholith of southwestern Nova Scotia is the largest granitoid batholith in the Appalachian Orogen with an approximate area of 7300 km^2. The batholith has been the focus of numerous studies commencing with mapping and mineral exploration around the turn of the century and continuing with extensive mineral exploration, geochemical and petrological studies to the present. Geological mapping has ranged from detailed studies in localized areas to reconnaissance surveys of portions of the batholith. The South Mountain Batholith project was conducted by the Department of Natural Resources as part of the 1984-1989 Canada-Nova Scotia Mineral Development Agreement and represented the first comprehensive mapping programme for the entire granite body. The chief goal of the project was to gain insight into the mineral potential of the batholith, particularly in light of the discovery of the East Kemptville polymetallic-Sn deposit and the Millet Brook U-Cu-Ag deposit in the late 1970's and early 1980's. This report is a direct result of the mapping and follow-up studies that were conducted by M.C. Corey, L.J. Ham, R.J. Horne and the author during the project.

The report is accompanied by a 1:250,000 scale multi-coloured compilation map (Nova Scotia Department of Natural Resources Map 94-01).

This Report is Dedicated to the Memory of

J. Stackhouse who lost his life while working as a geologist in 1977.

He is missed.

ABSTRACT

Geological mapping of the South Mountain Batholith of southwestern Nova Scotia was conducted as part of the 1984-1989 Canada-Nova Scotia Mineral Development Agreement. A rock classification scheme was developed for subdividing granitic rocks. The scheme combined the relative proportions of quartz-alkali feldspar-plagioclase, modal proportions of biotite ($\pm$cordierite$\pm$garnet) and muscovite, grain size and texture. Seven main rock types were established using this scheme, including (in decreasing order of mafic mineral content): mafic porphyry, biotite granodiorite, biotite monzogranite, muscovite-biotite monzogranite, coarse- and fine-grained leucomonzogranite and muscovite$\pm$topaz leucogranite.

A total of 260 discrete granite map bodies were delineated in the batholith. These bodies were grouped into 49 map units based on field relationships and composition. Each map unit was assigned a prominent place name or geographical feature and a rock name (e.g. East Kemptville leucogranite).

The 49 map units were assigned to 13 plutons, based on field relationships and compositional variations. Five plutons are classed as early Stage I, comprising biotite granodiorite and biotite monzogranite with minor fine-grained leucomonzogranite. These were the first plutons to be emplaced. Stage I plutons were intruded by a series of eight Stage II plutons, comprising muscovite-biotite monzogranite, coarse- and fine-grained leucomonzogranite and muscovite leucogranite with minor biotite granodiorite and biotite monzogranite.

Contacts between Stage I and II plutons are not well exposed but, where observed, are mostly intrusive. Contacts between the coarser grained megacrystic units in Stage II plutons are mostly intrusive, but some were noted to be gradational. Contacts between biotite monzogranite and biotite granodiorite in Stage I plutons were noted to be both intrusive and gradational. Late-staged fine-grained leucomonzogranite and leucogranite mostly intrude the megacrystic units with the exception of a few porphyry bodies in the New Ross Pluton that are in gradational contact with the megacrystic leucomonzogranite and represent textural variations of the host.

Detailed petrographic studies of the six main rock types indicate that rocks of the various plutons have similar mineralogical characteristics. For example, the presence of biotite, muscovite, aluminosilicate (e.g. andalusite), cordierite, garnet and tourmaline, in virtually all of the plutons, is consistent with the "characteristic" mineral assemblage for peraluminous granites. Biotite decreases in abundance from approximately 25% in biotite granodiorite to $<0.1\%$ in some muscovite leucogranite bodies. In contrast muscovite increases in the same rock sequence from trace amounts in granodiorite to 28% in some leucogranites. Topaz is absent in all rocks except some leucogranites (e.g. $\leq 8\%$ in the East Kemptville leucogranite). Cordierite is a minor constituent in most rocks but may constitute up to 5% of the mode in some muscovite-biotite monzogranite and coarse-grained leucomonzogranite units. Garnet is present in trace amounts in many rock units but is most abundant in late-staged leucomonzogranite dykes. Hornblende has not been observed in any of the rocks of the batholith. The only occurrence of magnetite in the entire batholith is in a single hydrothermally altered sample of albite-magnetite breccia from a drill hole near the East Kemptville deposit. The ubiquitous occurrence of accessory ilmenite, along with muscovite and low Mg/Fe biotite, is consistent with the "ilmenite-series" granitoids.

Detailed investigations indicate that although most major rock-forming mineral phases are of magmatic origin, many minerals also formed by xenocrystic, hyperaluminous or metasomatic processes at various stages in the evolution of the batholith. Therefore the exact origin of a mineral phase in any given rock must be evaluated individually.

In spite of the overall textural and mineralogical similarities throughout the batholith, several plutons display unique petrographic features. For example, the ubiquitous metasomatic garnet (reaction relationship with biotite) in both the fine- and coarse-grained leucomonzogranite rocks of the Big Indian Lake pluton is rare to absent in the other twelve plutons. Similarly, trace amounts of secondary, metasomatic sillimanite (mostly fibrolite) are unique to the Big Indian Lake pluton. Accessory titanite and epidote occur as inclusions, along with zircon, apatite, monazite and ilmenite, in biotite of the Davis Lake pluton and a cumulate phase from the Big Indian Lake pluton. Neither titanite nor epidote has been reported in any of the other eleven plutons. These mineralogical features suggest that different physico-chemical conditions (T, P_{H2O}, fO_2, bulk composition) prevailed in the various plutons.

A set of 597 samples, representing the complete compositional range for the batholith, was analyzed for major elements and a suite of 21 trace elements. Perhaps the most striking feature of the geochemistry of the batholith is the overall similarity in composition throughout the batholith. All rocks are peraluminous (i.e. molecular $Al_2O_3/(CaO+K_2O+Na_2O)>1$) and have relatively high SiO_2 and low CaO with ranges from 67.12% (SD-1.73) and 1.94% (SD-0.46), respectively, in granodiorite to 73.62% (SD-0.89) and 0.39 (SD-0.14), respectively, in leucogranite rocks. The major element chemistry and normative composition of the major rock types indicate a sequence from least evolved biotite granodiorite to most evolved leucogranite that reflects the petrographic features of the different rock types. This sequence is marked by systematic decreases in TiO_2, Fe_2O_3, MnO, MgO, CaO, K/Rb and normative anorthite, enstatite, ilmenite, hematite, rutile and colour index and increases in SiO_2, normative quartz, A/CNK and Thornton-Tuttle differentiation index. The concentration of P_2O_5 is generally consistent from granodiorite to fine-grained leucomonzogranite with a sudden increase in leucogranite units. This sequence is also marked by systematic decreases in several compatible trace elements (i.e. Ba, Sr, Zr, V, Hf, Sc and La) and increases in several incompatible trace elements (i.e. Rb, Ta, U, Li, F, Sn and W).

Despite the overall compositional similarities throughout the batholith, it is possible to distinguish among individual plutons. This implies that the batholith probably constitutes numerous discrete plutons that coalesced to form a contiguous batholith, in contrast to earlier studies that proposed the entire batholith formed from a single parental magma.

Perhaps one of the most important implications of the geochemical data is the delineation of cryptic normal and reverse compositional zoning in both Stage I and II plutons.

In spite of a definitive sequence of emplacement for the plutons and their units, an evaluation of published geochronological data indicates that all plutons were intruded and crystallized during a very short time interval (<5 million years) at 370 Ma.

Various structural characteristics, including the shape and distribution of plutons, the coincidence of several Stage II plutons with major fault zones, and the orientation of primary and secondary structural features (e.g. megacryst alignment, joints, veins), indicate that the batholith was subject to regional stresses associated with the waning stages of the Acadian Orogeny.

Mineral occurrences can be classed into five types including: greisen-type (e.g. East Kemptville); vein-type (e.g. New Ross Mn Mines; Millet Brook); breccia-type (e.g. Tobeatic Shear Zone); pegmatite-type (e.g. several occurrences in the New Ross Pluton); and peribatholithic (e.g. the Duck Pond Sn deposit). Similarly, the style of mineralization in the sundry plutons is interpreted as reflecting the protolith composition and the physico-chemical conditions that prevailed during their crystallization. Accordingly, the economic potential of the 13 plutons must be evaluated individually.

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Table of Contents

Chapter 4

Chapter 5

Chapter 6

List of Plates