The geology and geochemistry of the Agnew Intrusion: implications for the petrogenesis of early Huronian mafic igneous rocks in central Ontario, Canada

Volume I

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A thesis submitted in total fulfillment of the requirements for the degree of Doctor of Philosophy

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(Produced on acid-free paper)
I herewith certify to the best of my knowledge that this thesis, submitted to the University of Melbourne for the degree of Doctor of Philosophy, comprises only my original work, except where due acknowledgement has been made in the text.

I also submit that this thesis is less than 100,000 words in length, exclusive of figures, tables, references, appendices, and maps.

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July, 1996
"BE COMFORTABLE WITH UNCERTAINTY"

W. F. McDonough, 1992
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ABSTRACT

The Early Proterozoic Agnew Intrusion is a well-preserved leucogabbro-noritic to gabbro-noritic layered intrusion that is a member of the East Bull Lake suite of layered intrusions (ca. 2490—2470 Ma) occurring in central Ontario. These intrusions are related to the development of the Huronian Rift Zone, which may be part of a much more widespread rifting event that involved the Fennoscandian Shield. Structural data suggest that these intrusions have been subjected to ductile deformation and are erosional remnants of one or more sill-like bodies originally emplaced along the contact between Archaean granitic rocks of the Superior Province and an Early Proterozoic Huronian continental flood basalt sequence in the Southern Province.

The Agnew Intrusion, with a present exposure of 50 km\(^2\), has a maximum thickness of 2100 m and is subdivided into three major series: the Marginal Series, composed predominantly of ~200 m of olivine-normative, leucogabbro-noritic rocks; the Lower Series, comprising ~800 m of olivine-normative gabbro-norites, lesser leucogabbro-norites, and local olivine gabbro-norites, and; the Upper Series, featuring a ~1100 m rock succession grading from plagioclase-phryic gabbro-norites and leucogabbro-norites, through Fe-Ti oxide-rich leucogabbros, to ferrosyenites and alkali-feldspar granites. Ultramafic rocks are absent from the Agnew Intrusion. Upper greenschist to amphibolite transition zone facies metamorphism has variably modified the primary igneous mineralogy of the Agnew Intrusion, but generally preserved the igneous texture of the rock. Plagioclase (An\(_{79-51}\)) is the dominant primocryst mineral phase throughout the entire stratigraphic sequence and exhibits igneous zonation patterns that are indicative of crystallization at varying pressures, suggesting that parental magmas to the intrusion entered the Agnew chamber charged with significant amounts of intratelluric plagioclase. The primary mafic mineralogy has been pseudomorphically replaced by Ca-amphibole. However, detailed petrography of the amphiboles, combined with Pearce element ratio data and graphical projections of the OL-PLAG-CPX-QTZ tetrahedron, show that plagioclase was sequentially joined by olivine, orthopyroxene, and clinopyroxene in the crystallizing assemblage.

The similar REE and multi-element patterns exhibited by Agnew Intrusion rocks indicate that most of its stratigraphic sequence can be derived from a single parental magma composition and fractionated derivatives thereof. This composition is shown to correspond with that of the Streich Dyke, a 50- to 300-m wide gabbro-noritic dyke that crops out to the northwest of the Agnew Intrusion and almost links it to the neighbouring East Bull Lake Intrusion. The Streich Dyke is characterized by a moderately primitive (Mg\# = 0.64), high-Al\(_2\)O\(_3\) (17 wt.\%), low-TiO\(_2\) (0.45 wt.\%), subalkaline basalt composition with calc-alkaline affinities. It exhibits LREE- and LILE-enrichment with distinct negative HFSE anomalies, as well as high PGE concentrations with very low S contents indicative of a magma that crystallized under S-undersaturated conditions. Although the Streich Dyke parental magma
was highly fertile, its very low S contents ensured that sulfide precipitation in the Agnew Intrusion only occurred very late in the crystallization sequence. The presence of significant PGE-Cu-Ni mineralization within the Agnew Intrusion was, therefore, restricted to localized marginal regions in which the magma underwent earlier S-saturation prior to substantial mafic mineral crystallization within the interstitial liquid to plagioclase primocrysts. Field and geochemical evidence suggest that early S-saturation was probably induced by local crustal contamination of the magma. Potential for reef-type PGE-Cu mineralization, produced by closed-system magmatic fractionation, may also exist near the top of the Agnew Intrusion.

A thin, well-layered rock unit within the Agnew Intrusion, the Olivine Gabbro-norite Subzone, represents the only portion of the intrusion that can not be derived from a Streach Dyke (or evolved equivalent) composition, requiring a different parental magma. Field-based relationships and rare-earth and incompatible element ratio data are consistent with a comagmatic association between the Olivine Gabbro-norite Subzone and the extensive Matachewan dyke swarm that occurs to the north; there is no cogenetic relationship between the Matachewan dyke swarm and the main portion of the Agnew Intrusion sequence.

The Agnew Intrusion is believed to have been emplaced during an active, mantle plume-driven, rifting event that formed the Huronian Rift Zone. However, the mantle plume, which initiated rifting, did not contribute significantly to early Huronian magmatism, but only provided the heat source for the partial melting of the overlying lithospheric mantle. The two parental magmas to the Agnew Intrusion have lithospheric mantle signatures, and were derived either from two distinct source compositions or through different degrees of partial melting of a single garnet-bearing mantle source.
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