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Geology of the Mountain Grove pluton, Central Metasedimentary Belt, Grenville Province, Ontario

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Abstract: The predominantly mafic Mountain Grove pluton, one of the youngest and most northwesterly members of the 1180–1150 Ma Frontenac plutonic suite, comprises two distinct intrusions. Both cut a previously folded succession of amphibolitic schist, siliceous schist, and marble. Coarse-grained norite and leuconorite characterize the northern unit, whereas hornblende gabbro and diorite with subordinate commingled monzonite and syenite characterize the southern, younger one. Commingled intrusions in the northern unit and its country rocks, and foliated biotite quartz syenite to the south, are probably both related to the southern unit. The northern unit likely formed from relatively uncontaminated magma, whereas the southern unit evolved from gabbro by magma mixing, incomplete where commingled. Copper-nickel-iron sulphide mineralization is associated with the northern unit, and sphalerite with marble enclaves in the southern unit. The Mountain Grove pluton is intruded by the Leggat Lake and McLean granite-syenite plutons to the east and southwest respectively.

Résumé : Le pluton de Mountain Grove à dominante mafique, un des membres les plus jeunes et les plus au nord-ouest de la suite plutonique de Frontenac (de 1 180 à 1 150 Ma), comporte deux intrusions distinctes qui recoupent une succession plissée antérieurement de schiste amphibolitique, de schiste siliceux et de marbre. L'unité nord est caractérisée par de la leuconorite et de la norite à grain grossier et l'unité sud, plus jeune, par de la diorite et du gabbro à hornblende avec une composante moins importante de monzonite et de syénite mélangées. Les intrusions mélangées dans l'unité nord et dans ses roches encaissantes, de même que la syénite quartzique à biotite foliée au sud, sont probablement associées à l'unité sud. L'unité nord s'est probablement formée à partir de magma relativement peu contaminé alors que l'unité sud a évolué à partir d'un gabbro par mélange de magmas, incomplet aux endroits où se trouvent des dykes mélangés. Des sulfures de cuivre, de nickel et de fer sont associés au pluton nord et de la sphalérite avec des enclaves de marbre est asociée au pluton sud. Le pluton de Mountain Grove a été recoupé par les plutons de granite-syénite de Leggat Lake de McLean à l'est et au sud-ouest respectivement.

INTRODUCTION

This paper reports the results of remapping the Mountain Grove pluton, situated in Sharbot Lake domain in the central part of the Central Metasedimentary Belt, Grenville Province of Ontario (Fig. 1). Sharbot Lake domain is the southeasternmost division of Elzevir terrane, which is characterized by deformed and variably metamorphosed, mid-Mesoproterozoic (1300–1225 Ma) volcanic and carbonate supracrustal rocks and calc-alkaline plutonic rocks. Elzevir terrane has been termed the “Composite Arc Belt” by Carr et al. (in press). Sharbot Lake domain is bounded to the northwest by the southeast-dipping, late Grenvillian, extensional Robertson Lake shear zone, and to the southeast by the older Maberly shear zone, also southeast-dipping but with oblique, westerly thrust shear sense. Frontenac terrane, in the hanging wall of the Maberly shear zone, is characterized by a highly deformed marble-quartzite-pelite association, lacking metavolcanic rocks, that has been metamorphosed to granulite facies. The majority of plutonic rocks in Frontenac terrane are younger (1180–1150 Ma; van Breemen and Davidson, 1988; Marcantonio et al., 1990; A. Davidson and O. van Breemen, unpub. data, 1999) than those in the ‘Composite Arc Belt’; they have alkaline affinities and are referred to collectively as the Frontenac suite.

Recent fieldwork and concomitant U-Pb zircon dating has confirmed Wynne-Edwards’ (1965) contention that “Frontenac-type” plutonic rocks also occur in what is now referred to as Sharbot Lake domain, as well as within the Maberly shear zone (Corfu and Easton, 1997; A. Davidson and O. van Breemen, unpub. data, 1999). Among these are the Bennett Bay, Silver Lake, Oso, and Mountain Grove plutons (Fig. 1). Older plutonic rocks are also present in Sharbot Lake domain (Hinchinbrooke, Lavant complex, part of the Pakenham complex, in the range 1270–1225 Ma; Wallach, 1974; Corfu and Easton, 1997; T. Praamsma, unpub. data, 1999), but have not been identified in Frontenac terrane. Younger plutons in the range 1090–1065 Ma (Skootamatta suite; Easton, 1992) are present throughout Elzevir and Frontenac terranes.

Various lines of evidence suggest that the Frontenac suite was emplaced while the Maberly shear zone was tectonically active (Davidson, 1996). For example, plutons of this suite within the shear zone are elongate parallel to the shear-zone fabric and are locally severely deformed, yet do not share the metamorphic history of their enclosing supracrustal rocks. Moreover, they contain no evidence of subsequent metamorphic overprint, even where deformed at high temperature within the Maberly zone — their zircon ages are commensurate with titanite ages obtained from their country rocks and

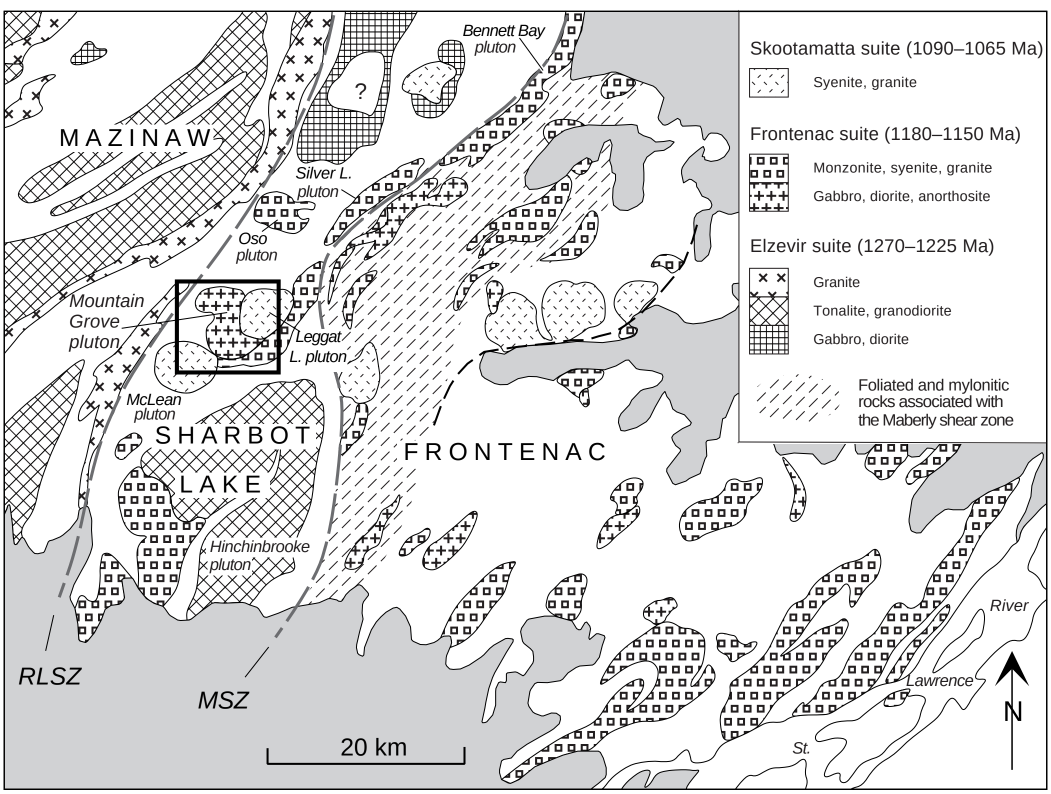

*Figure 1. Location of the Mountain Grove pluton with respect to terranes and their boundaries in the Frontenac Axis, Ontario (*modified after *Davidson, 1996). Sharbot Lake and Mazinaw are domains of Elzevir terrane; RLSZ and MSZ are Robertson Lake and Maberly shear zones respectively, and bound Sharbot Lake domain.*

only a little older than hornblende $^{40}Ar/^{39}Ar$ cooling ages (Cosca et al., 1992). Frontenac suite plutonic rocks are deformed only within the Maberly shear zone; plutons in the Sharbot Lake footwall and in the Frontenac terrane hanging wall beyond the influence of the bounding Maberly shear zone are not deformed.

To understand the nature of the synemplacement deformation of the Frontenac suite plutons in the Sharbot Lake–Frontenac boundary zone, it is advantageous to know their undeformed character. Two plutons in the Sharbot Lake footwall have been studied with this in mind, the coeval (1155 Ma) Oso and Mountain Grove plutons. The Oso pluton was studied in 1998 by Ijewliw (1999), who documented a wide compositional range from noritic gabbro through monzodiorite and monzonite to quartz syenite within this 20 km^2 complex intrusion, suggesting a contaminated suite developed from mixing of gabbroic magma and crustal melts. The Mountain Grove pluton, in contrast, was previously mapped (Wolff, 1979; Wolff and Smith, 1981) as a single body of gabbroic rock, thus offering a better chance of documenting the nature of the parent, perhaps mantle-derived magma.

SETTING OF THE MOUNTAIN GROVE PLUTON

The undeformed Mountain Grove pluton (Fig. 2) intrudes across the core of a steeply east-plunging synform, one of a number of major, east-trending folds that characterize Sharbot Lake domain. Its northwest contact lies within a kilometre of the late Grenvillian, extensional Robertson Lake shear zone, but has not been affected by it. The country rock protoliths are a variably deformed and metamorphosed succession comprised of three major units, mafic to intermediate volcanic rocks, volcaniclastic and SEDEX-type sedimentary rocks, and carbonate sedimentary rocks; the succession lacks a clastic sediment component. Although facing directions are not preserved, the consistent occurrence of the mafic metavolcanic unit in the cores of antiforms and of marble in the synforms suggest that the structural succession is also stratigraphic; it is clear that the succession has not been repeated by thrusting or recumbent folding. Regional metamorphism progresses from lower amphibolite facies in the north to

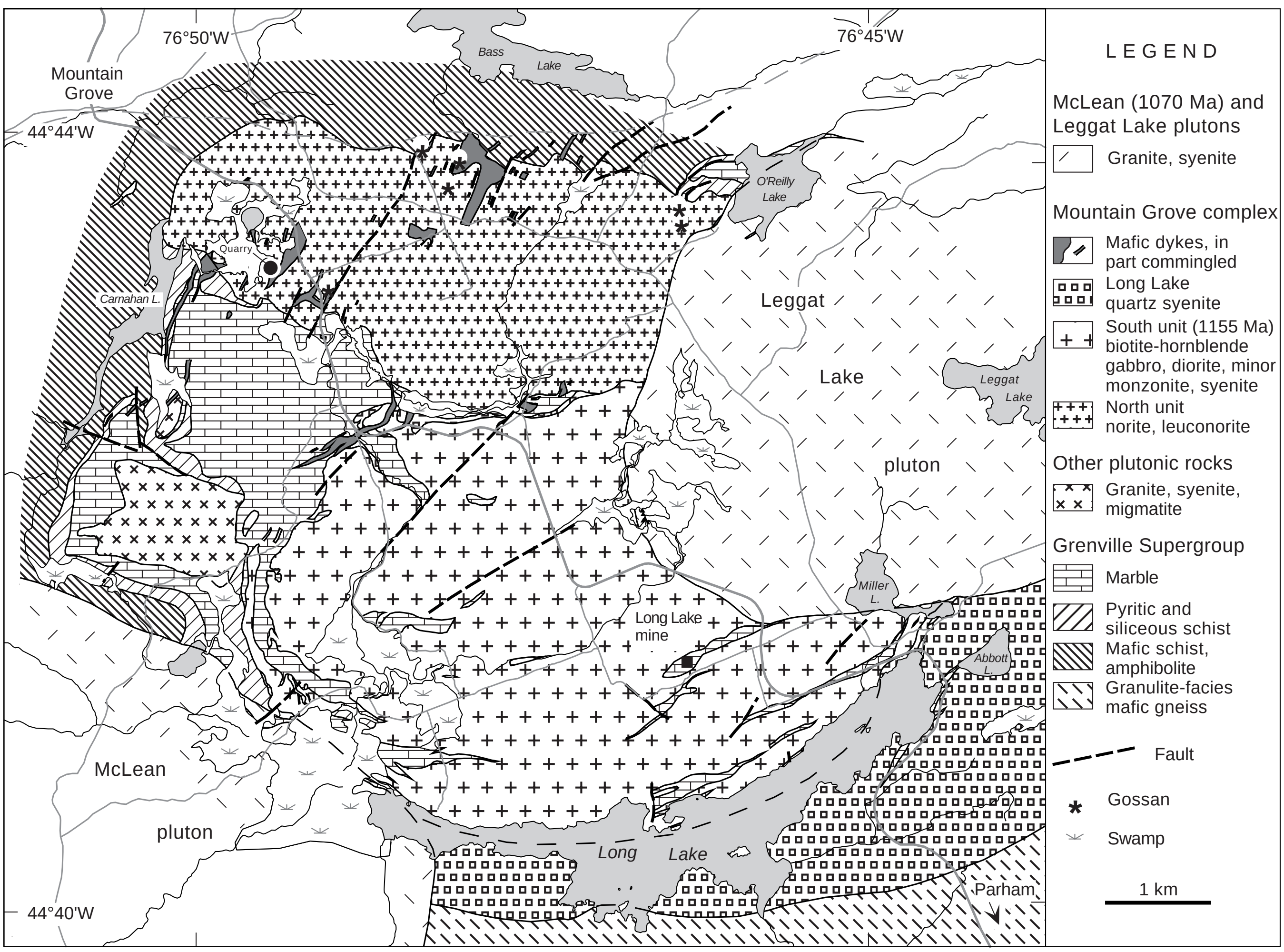

Figure 2. *Detailed geological map of the Mountain Grove composite pluton.*

two-pyroxene granulite facies south of the intrusion, and predates emplacement of the Mountain Grove and other, younger plutonic rocks.

CURRENT FINDINGS

The Mountain Grove pluton was originally mapped as a single body composed of a variety of gabbroic rocks with a minor component of monzonite in places, particularly in the south (Wolff and Smith, 1981). This summer's remapping has demonstrated that the pluton is in fact two separate intrusions, a northern unit of coarse-grained noritic gabbro and leuconorite, and a southern unit of relatively fine-grained hornblende gabbro and diorite, associated with minor monzonite and syenite. The two are for the most part separated by an eastward-narrowing screen of marble and rusty-weathering pyritic schist, east of which the southern unit intrudes the northern one (Fig. 2). In addition, predominantly northeast-trending dykes, apparently related to and emanating from the southern unit, intrude the northern unit and its country rocks.

Northern unit

The northern unit underlies an elongate area, trending east, roughly 5 km long and as much as 2.5 km wide. Its eastern contact is with the younger Leggat Lake granite pluton, but gabbro mapped farther east by Wynne-Edwards (1965) may represent its continuation. Outcrops of the northern unit are generally small, low lying, and rubbly. Many outcrops of these noritic rocks are extraordinarily coarse grained, with plagioclase laths up to 3 cm long ophitically encased in orthopyroxene grains as much as 5 cm across (Fig. 3). Grain size increases very abruptly inward from the contact, although locally the northern contact with rusty-weathering metasedimentary rocks is obscured by the development of a coarse, hornblende-rich, sulphide-bearing skarn. Hornblende and minor biotite have partly or wholly replaced the original igneous pyroxene grains in most places. Unhydrated parts tend to have weathered to grus; where fresh, as in roadcuts and a quarry, the norite is black, and aligned, dark plagioclase laths define a primary igneous foliation. Irregularly developed compositional layering is uncommon, and included rafts of country rock schist or marble are rare.

Southern unit

In contrast to the northern unit, biotite-bearing hornblende gabbro and diorite of the southern unit underlie broad expanses of relatively smooth outcrop, and do not form grus. This unit for the most part is fine to medium grained and equigranular, but locally contains plagioclase phenocrysts (Fig. 4) or poikilitic hornblende megacrysts. It is associated in most places with a small proportion of monzonite in the form of discrete narrow layers (centimetre to metre scale) or to larger, irregular patches (decimetre to hectometre scale), distinguished by their content of K-feldspar megacrysts. The monzonite layers are steeply inclined and some are internally foliated, even though the enclosing rocks are massive. Both phases, however, become increasingly foliated toward the south contact. In some places equigranular diorite grades to megacrystic monzonite via an intermediate monzodiorite phase. Rarely, the two principal phases show a commingling relationship in which interconnected bulbous masses of the mafic phase are finer grained than the surrounding monzonite. Larger masses of monzonite grading to syenite are concentrated near the northern margin of this unit; locally they have a mylonitic fabric adjacent to their contacts with massive marble, and syenite apophyses cutting across layering in marble may also be internally foliated parallel to their contacts.

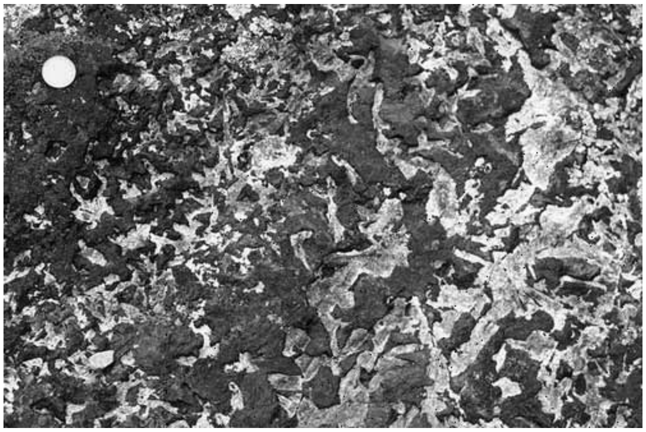

Figure 3. *Extremely coarse-grained noritic gabbro, northern unit of the Mountain Grove pluton. Coin is 1.9 cm in diameter.*

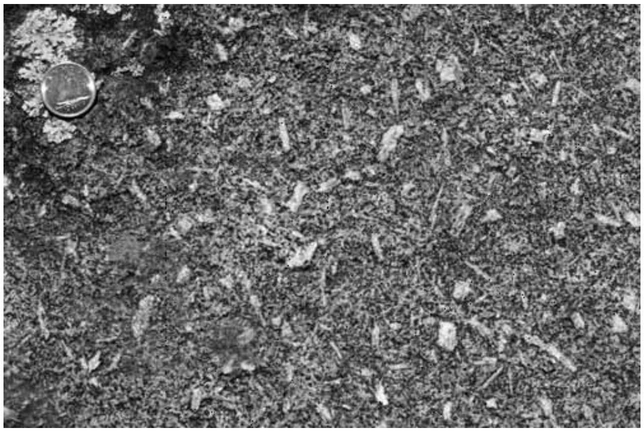

Figure 4. *Hornblende diorite with plagioclase phenocrysts, southern unit of the Mountain Grove pluton. Coin is 1.8 cm in diameter. Relatively fine grain size of groundmass is typical of the southern unit.*

An important feature of the southern unit is the inclusion within it of large, elongate rafts of marble, some of which are connected laterally to the country rock. Marble in these enclaves and along the west contact has in part recrystallized to grain size in excess of 5 cm and locally contains concentrations of coarse tremolite or wollastonite. The contacts with marble rafts are parallel to foliation in the intrusive rocks, yet cut across layering and small folds in the marble which preserve an undisturbed continuation of country rock structure.

Dykes

The northern unit and its country rocks are intruded by numerous dykes (many more than are shown in Fig. 2, especially in the central part of the northern unit), ranging from a few centimetres to several tens of metres wide, as well as irregular masses of mafic rock of various types. Some dykes are composed entirely of fine- to medium-grained gabbro with ophitic texture, but most are of fine- to very fine-grained mafic rock ranging from hornblende gabbro with scattered plagioclase phenocrysts to biotite-hornblende diorite in which biotite is the phyric component. Many of the dykes display classic commingling structure between lobate masses of the mafic phase chilled against an anastomosing network of somewhat coarser felsic rock (Fig. 5). Such dykes commonly include angular xenoliths of coarse-grained gabbro which invariably lie within the felsic phase. The proportion of the commingled phases varies, and in some dykes the felsic phase greatly predominates, attains medium grain size, and ranges in composition from monzonite to quartz syenite. Dykes of this suite, most of which are vertical and trend northeast, cut cleanly across the outer contact of the northern unit and may extend a kilometre or more into the country rocks. Some dykes are in whole or in part internally foliated parallel to their contacts and cut across the structure and lithological contacts of their wall rocks. Commingled dykes are virtually absent within the southern unit, the exception being near the northwest contact of this unit with marble (Fig. 2).

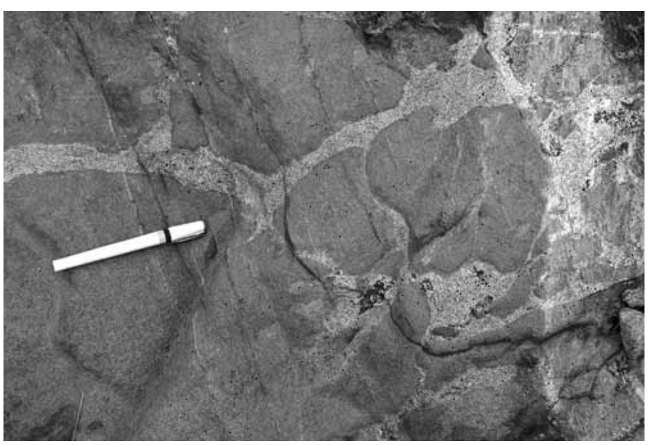

Figure 5. *Commingled rock in composite dyke intruding norite of the northern unit. Note chilled margin of mafic phase against anastomosing network of coarser felsic phase containing small inclusions of hornblende norite. Pen is 13.5 cm long.*

Long Lake syenite

An east-northeasterly elongate mass of medium-grained quartz syenite lies along the south side of the southern unit, widening eastward and continuing well beyond the area shown in Figure 2 (Wynne-Edwards, 1965, unit A). Its contact with the southern Mountain Grove unit lies mainly beneath Long Lake, but where exposed in a roadcut at the northeast end of this lake, it is seen to be in sharp contact with diorite; the two rock types show neither a dyking relationship nor any evidence of chilling one against the other. The Long Lake quartz syenite ranges from medium grained and massive to partly recrystallized and well foliated parallel to its long axis. It is very similar in appearance to the monzonite and syenite concentrated along the northern margin of the southern Mountain Grove unit. At its south contact, foliated syenite of the main intrusion and syenitic dykes with internal concordant foliation cut cleanly across minor structures and undeformed, orthopyroxene-bearing leucosomes in granulite-facies mafic gneiss.

McLean and Leggat Lake plutons

The McLean pluton is a subcircular intrusion composed primarily of massive, leucocratic biotite syenite, quartz syenite, and granite. It was first mapped by Wolff and Smith (1981), but was not separated from the Long Lake quartz syenite; the two can be easily distinguished, however, on the basis that east-trending foliation in the Long Lake quartz syenite is truncated by massive McLean syenite. The latter intrudes an outlying arm or satellite of the southern Mountain Grove unit and forms dykes within it (Fig. 2).

To the east the Leggat Lake pluton is composed almost entirely of massive biotite leucogranite, very similar in appearance to the granitic phase of the McLean pluton. Darker monzonitic phases, not distinguished in Figure 2, are present in the core close to Leggat Lake. In the vicinity of O'Reilly Lake, Leggat Lake granite dykes cut across commingled dykes within norite of the northern Mountain Grove unit (Fig. 6). Unlike the McLean, however, the Leggat Lake pluton has a narrow, marginal, foliated zone in which inclusions of country rock, mainly derived from the Mountain Grove intrusions, have been softened and elongated parallel to the steep outer contact.

Other intrusions

The geological map of the Long Lake area (Wolff and Smith, 1981) shows a protrusion of granite projecting northward from the McLean pluton into marble just west of the southern Mountain Grove unit. This was investigated to see whether or not it might be another phase of Mountain Grove intrusion. Two small, discrete plutons were identified. The larger, southern one is composed of massive, pale pink, medium-

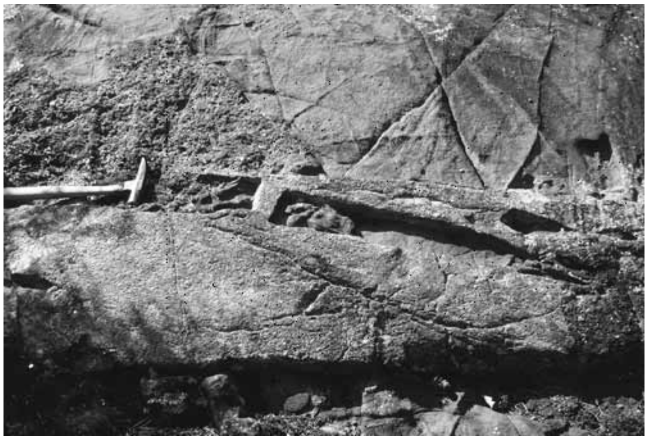

Figure 6. Branching dyke of Leggat Lake leucogranite (below and to the right of the hammer) intrudes norite (above hammer) and fine-grained mafic dyke rock northeast of O'Reilly Lake. Hammer is 33 cm long.

grained, two-mica granite which is intimately associated at mesoscopic scale with irregular masses and ghostly inclusions (skialiths) of white, migmatitic quartz-feldspar-mica gneiss, rusty-weathering schist, and minor quartz-rich rocks. Its shape suggests that it is a swelling formed by repeated injection of anatectic granite into a unit of siliceous schist within marble. The much smaller northern unit has a similar association but contains much less included material and is composed mainly of massive pink syenite closely resembling some phases of the McLean pluton. It must be older than the McLean, however, because it is intruded by the same commingled dykes that cut across the northern Mountain Grove unit. Commingled dykes were not noted in the larger migmatitic granite body to the south.

GEOCHRONOLOGY

A sample of monzodiorite from the southern Mountain Grove unit near its southwest contact has given a U-Pb zircon age of 1155 ± 3 Ma, interpreted on the basis of zircon morphology to date the time of igneous crystallization (A. Davidson and O. van Breemen, unpub. data, 1999). It is not known, however, whether the older northern unit has a similar or significantly older age. A sample from the core of the McLean pluton has a U-Pb zircon age of 1070 ± 3 Ma (A. Davidson and O. van Breemen, unpub. data, 1999), recording a much younger intrusive event in this region, allied in age to the pan-Central Metasedimentary Belt Skootamatta suite (Easton, 1992). Although not dated, the Leggat Lake granite to the east is considered on lithological grounds also to belong to this suite. The $^{40}Ar/^{39}Ar$ amphibole and biotite ages from the dated Mountain Grove locality reflect the age of the nearby McLean pluton (Grammatikopoulos et al., 1997).

MINERAL DEPOSITS

One producing mine (the Long Lake zinc mine; Fig. 2) and several prospects for base metals and industrial minerals are located within and marginal to the Mountain Grove intrusions; *see* Wolff (1979) for a full summary. Small gossans abound in the rusty-weathering schist units and adjacent norite near the contact of the northern unit. Several old pits expose heavily oxidized material, mainly derived from pyrite, pyrrhotite, and chalcopyrite, from which assays revealed local concentrations of Ni and Cu. Drilling, however, did not reveal sufficient tonnage to warrant further exploitation. Gossans developed in rusty schist removed from this contact appear to have developed from pyrite alone. Sphalerite-rich mineralization, however, along with minor amounts of galena, chalcopyrite, and magnetite, is associated with marble near the contact of the southern unit and particularly in marble rafts included within it. In the same environment, the potential for wollastonite extraction has been explored at the southwest contact, and wollastonite was noted at several unexplored localities nearby. A small quarry for crushed stone has been cut into massive, fresh, coarse-grained leuconorite in the northern unit a few hundred metres west of the Mountain Grove–Parham highway (Fig. 2); although potentially an attractive building or facing stone of the 'black granite' type, joints and fractures probably preclude extraction of large blocks.

SUMMARY AND COMMENTS

The Mountain Grove pluton, previously mapped as a single body of gabbro, is composed of two separate intrusions, the northern one of coarse-grained norite and related rocks being older than (and conceivably unrelated to) the southern one of relatively fine-grained gabbro, diorite, and minor, in part commingled monzonite and syenite. Numerous fine-grained mafic and commingled dykes intrude the northern unit and its country rocks. Given the commonality between the diorite-monzonite association in the southern unit and the similarly bimodal nature of the commingled dykes, it is reasonable to interpret that the two are related; both are clearly younger than the coarse noritic rocks of the northern unit. It is also probable that the Long Lake quartz syenite is an integral part of the southern Mountain Grove unit. This interpretation is supported by the fact that the syenitic phase along the northern margin of the southern unit is very similar in composition and appearance to the quartz syenite at Long Lake. The disposition of foliation within the southern unit, some commingled dykes, and the Long Lake syenite with respect to older, undisturbed structures in the country rocks suggests that this foliation is synplutonic rather than being a manifestation of postintrusion deformation.

The noritic rocks of the northern unit, even where hornblende has largely replaced igneous pyroxene minerals, preserves primary igneous texture and evidence that its original minerals represent crystallization from at least a relatively uncontaminated magma, probably of mantle derivation. In contrast, the mafic rocks of the southern unit rarely contain identifiable pyroxene, the femic silicate minerals being hornblende and biotite; except where porphyritic (Fig. 4), plagioclase lath structure is rarely evident, and the rocks are either equigranular or contain hornblende poikiloblasts. Distinction between gabbro and diorite is difficult to make in the field, and there is a gradation between the two, as there is to monzodiorite. These attributes suggest that even the more mafic rocks of the southern unit have been derived through variable contamination by felsic material. The occurrence of commingled structure between diorite and monzonite or syenite indicates that two melts were available, and that magma mixing was not everywhere complete. The latter is particularly true with respect to the smaller commingled dykes external to the southern unit, in which the two magmas froze before complete mixing was achieved.

The northeastward continuation of the Long Lake quartz syenite beyond the area of Figure 2 (Wynne-Edwards, 1965, unit A) turns northward and develops a through-going, moderately southeast-dipping mylonitic foliation as it merges with the southwest continuation of the Maberly shear zone (Davidson and Ketchum, 1993). There has been some debate whether the Maberly shear zone continues south along the east side of the Hinchinbrooke tonalite (Fig. 1) or passes westward north of it (*see* discussion *in* Easton and Davidson, 1994, p. 61–62). Re-examination of the granulite-facies gneiss south of the Long Lake quartz syenite confirms that the fabric within this gneiss unit dips moderately north rather than east or southeast, is not a shear-zone-related mylonitic foliation, and developed before formation of orthopyroxene-bearing leucosome units, which themselves predate emplacement of the Long Lake quartz syenite. It is therefore concluded that the southwestern continuation of the Maberly shear zone does not pass north of the Hinchinbrooke pluton but must lie east of it. Moreover, granulite facies in the country rocks continues for many kilometres to the south (Wolff and Smith, 1981), and so is not a manifestation of contact metamorphism adjacent to either the Long Lake–Mountain Grove or McLean intrusions. Distribution of regional metamorphism in southern Sharbot Lake domain defines a marked southward increase in metamorphic grade, oblique to the northeast-southwest boundaries of this domain, and was established before intrusion of the Frontenac suite.

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