Geological and lithogeochemical investigations of the Cat Creek area in the Neoarchean Bird River greenstone belt, southeastern Manitoba (part of NTS 52L12)

by X.M. (Eric) Yang, H.Paul Gilbert and Michel G. Houlé[1]

Manitoba Geological Survey, 360-1395 Ellice Avenue, Winnipeg, MB R3G 3P2, Canada

[1]Geological Survey of Canada, 490, rue de al Couronne, Québec, QC G1K 9A9

Summary

The Cat Creek area in the northern arm of the Bird River greenstone belt is situated approximately 145 km northeast of Winnipeg in southeastern Manitoba. The study area is underlain by a suite of typical greenstone assemblages within a continental-margin setting adjacent to the Mesoarchean Maskwa Lake Batholith. The rock assemblages consist of a tonalite-trondhjemite-granodiorite suite; supracrustal rocks that include mafic to felsic volcanic and synvolcanic intrusive rocks, and epiclastic and minor volcaniclastic rocks; the Mayville mafic–ultramafic layered intrusion; and late peraluminous granitoid rocks and related pegmatites. The Mayville intrusion consists of an east-trending lopolith approximately 10.5 km in length and up to 1.5 km in width. The intrusion is emplaced in a mid-ocean-ridge basalt (MORB) sequence to the south and west and is in structural contact with granitoid rocks to the east. To the north, the Mayville intrusion is emplaced in metasedimentary and intercalated volcaniclastic rocks, and is locally structurally juxtaposed against granitoid rocks. Although the Mayville intrusion has recently been the focus of ongoing mineral exploration because it hosts a significant amount of platinum group element (PGE)-Ni-Cu-Cr mineralization, some key metallogenic questions remain to be answered.

This study presents the preliminary results of geological mapping conducted at a scale of 1:12 500 by the Manitoba Geological Survey in 2012, together with new petrological, lithogeochemical and geochronological data acquired within the last year. Twelve map units have been identified in the Cat Creek area: 1) Maskwa Lake Batholith granitoids; 2) MORB-type basalts and synvolcanic intrusive rocks; 3) metasedimentary rocks and thin intercalated volcaniclastic rocks; 4) to 10) the Mayville mafic-ultramafic intrusion consisting of basal mafic-ultramafic rocks (melagabbro, pyroxenite; Unit 4), heterolithic breccias (Unit 5), gabbroic anorthosite to anorthosite (Unit 6), leucogabbro (Unit 7), gabbro (Unit 8), diabasic to gabbroic rock (Unit 9) and quartz diorite to tonalite (Unit 10); 11) granitoids (tonalite-trondhjmite-granodiorite; garnet-muscovite-bearing granite); and 12) pegmatites. The mapping and geochemical study suggest that the MORB-type basalts and related intrusive rocks, as well as the Mayville intrusion, may have been emplaced in an extensional back-arc environment characterized by a relatively thin crust (~21 km) and a continental-margin setting. The present geological map data indicate that the Neoarchean Mayville intrusion (U-Pb zircon age of 2743 Ma) consists dominantly of anorthositic gabbro, gabbroic anorthosite and anorthosite, with subordinate melagabbro and pyroxenite at the base and gabbro at the top. This intrusion is similar to Archean anorthosite complexes elsewhere, and can be subdivided into a lower heterolithic breccia zone and an upper anorthosite to leucogabbro zone. The geochemical signature of the Mayville intrusion suggests the parental magma(s) was an alumina-enriched tholeiitic type that may have been derived from a high degree of partial melting of the subcontinental lithospheric mantle; it may have experienced assimilation and fractional crystallization during its emplacement within the supracrustal rock succession. An early sulphide saturation event triggered by crustal contamination and/or introduced external sulphur is likely to have generated magmatic sulphide Ni-Cu-PGE mineralization at the base of the intrusion. The injection of a new batch(s) of a mafic–ultramafic melt may have resulted in PGE and chromite mineralization at transitional zones between various phases within the intrusion. In addition, calcic anorthosite in the Mayville intrusion may represent a potential source for the manufacture of aluminum-bearing chemicals.

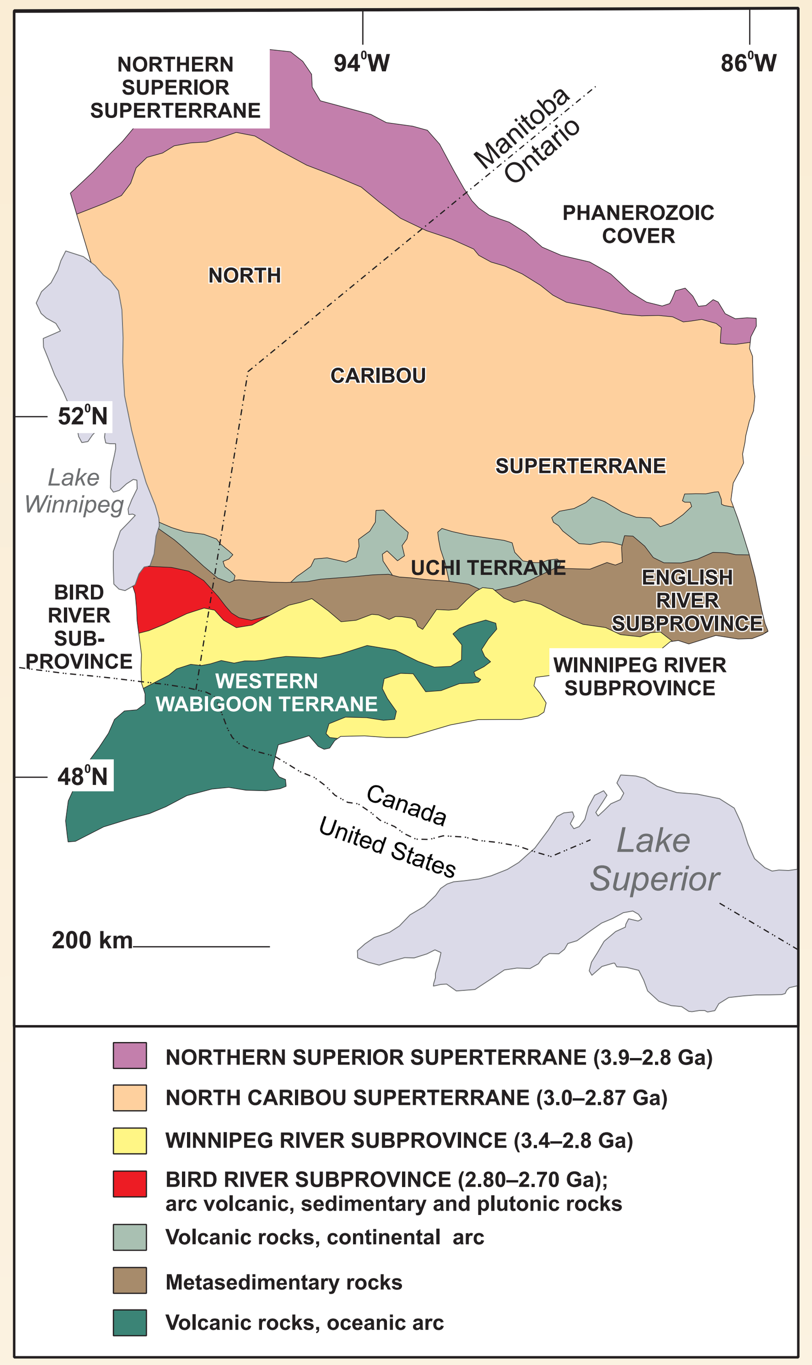


Fig. 1 Simplified geology of the western Superior Province, showing the location of the Neoarchean Bird River greenstone belt (BRGB; after Gilbert, 2007).

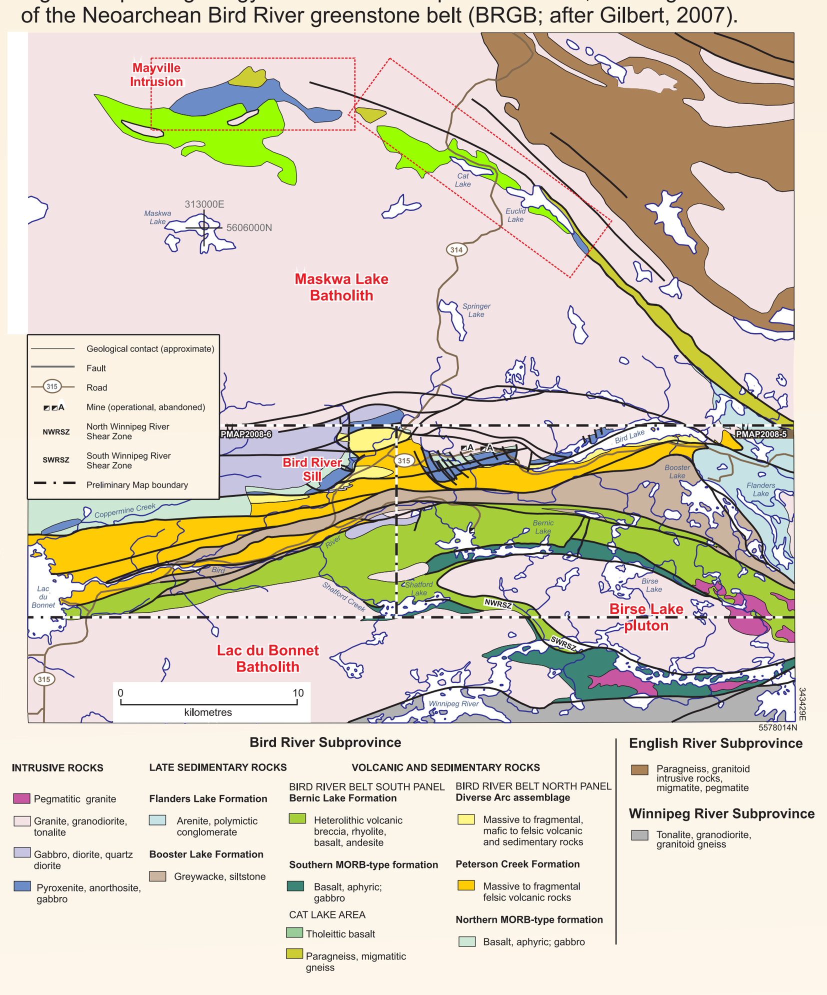


Fig.2 Simplified geology of the Neoarchean Bird River greenstone belt, showing the location of the Mayville mafic–ultramafic intrusion and the Bird River Sill (compiled from Bailes et al., 2003 and Gilbert et al., 2008).

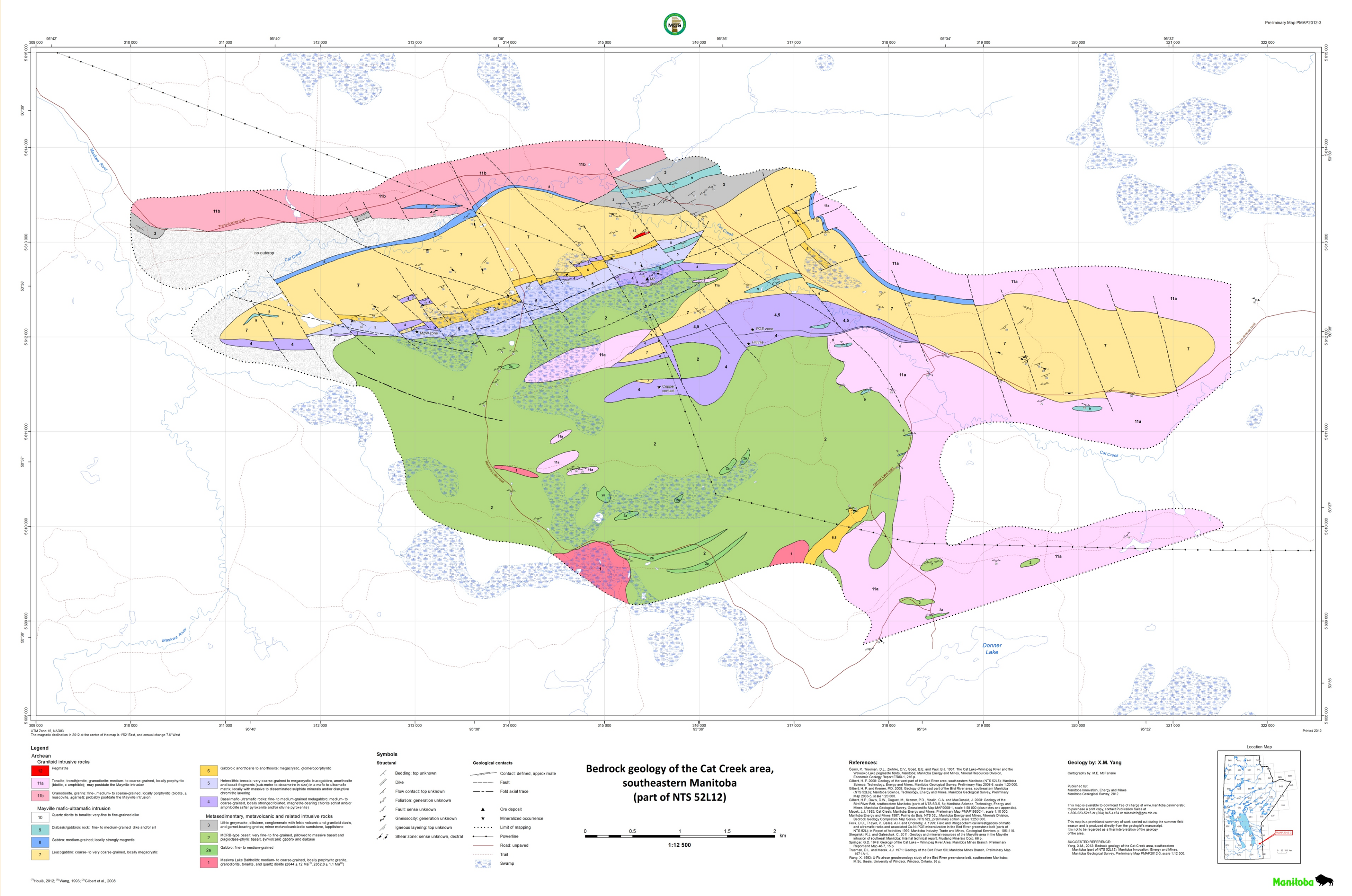
Introduction

The Manitoba Geological Survey completed a 1:12 500 scale mapping in 2012, focussing on improving understanding geological evolution and geodynamic setting of the Cat Creek area in the northern arm of the Bird River greenstone belt. This mapping program provides new insight into the metallogeny of magmatic PGE-Ni-Cu-Cr mineralization associated with the Mayville mafic-ultramafic intrusion. This on-going mapping program has been in collaboration with the Geological Survey of Canada via TGI-4 program, supported by mining companies including Mustang Minerals Corp.

Geological setting

The Cat Creek area is located in the northern arm of the Bird River greenstone belt that is situated between the English River and Winnipeg River subprovinces of the western Superior Province (Figs. 1 and 2). Magmatic PGE-Ni-Cu-Cr mineralization is genetically associated with the Mayville intrusion, a layered mafic-ultramafic body, up to 1.5 km in width, 10.5 km long. Based on Peck et al. (2002), the Mayville intrusion is subdivided into two zones, i.e., a Heterolithic Breccia Zone (HBX), and an upper anothositic to Leucogabbro Zone (ALZ). Various rock types displaying varied textures occur in the HBX that contains disseminated sulphide minerals (pyrrhotite, pentlandite, chalcopyrite +/-pyrite) and locally semimassive to massive sulphide mineralization, particularly at the base contact. Chromitite bands locally occur. The ALZ rarely contains disseminated sulphide. Although metamorphosed to greenschist to amphobolite facies, igneous textures are well preserved.

Based on field relationships and internal textural variations, the Mayville intrusion is an overturned Neoarchean intrusion. New mapping data indicate that the Mayville intrusion is subdivided into seven units (Fig. 3), and may have cooled from north to south. An investigation of lithogeochemical data and petrography of 58 samples taken from the mapping project has been in progress. A geochronology sample collected from differentiated phase present in the HBX is dated to be 2743 Ma using U-Pb zircon technique by the Geological Survey of Canada funded TGI 4 program (see Houlé et al., 2012, poster presentation), consistent with the Bird River Sill (Gilbert et al. 2008).



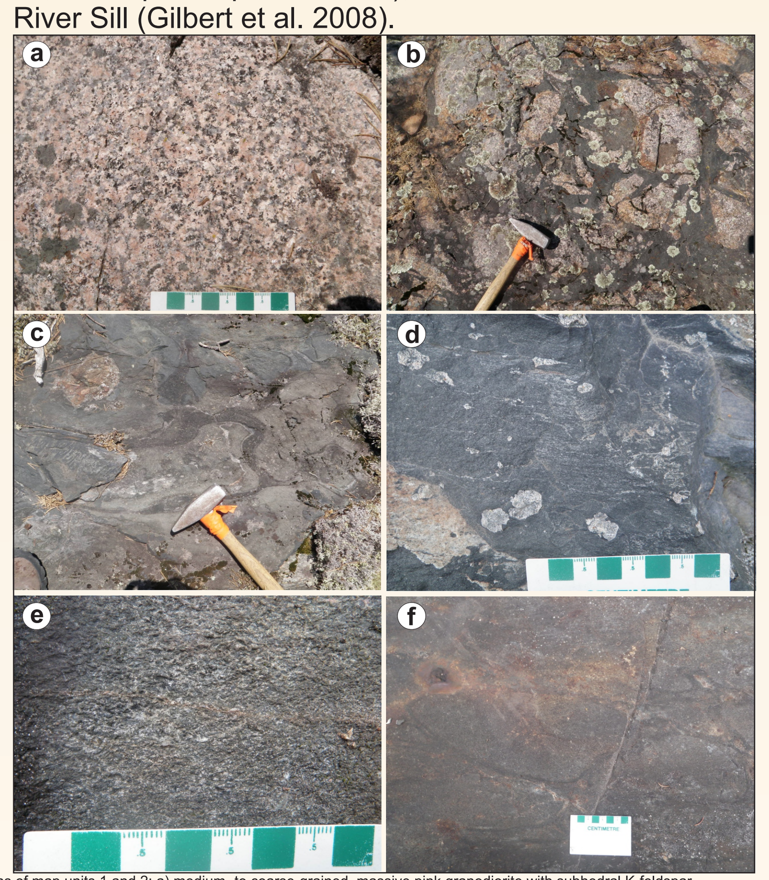


Fig. 4: Field photographs of map units 1 and 2: a) medium- to coarse-grained, massive pink granodiorite with subhedral K-feldspar phenocrysts, Maskwa Lake Batholith (unit 1); b) Maskwa Lake Batholith granodiorite breccia (unit 1) at the contact zone with basalt; fragments are cemented by very fine grained basalt (unit 2), suggesting that this phase of the Maskwa Lake Batholith is older than the basalt; c) pillowed basalt flow (unit 2) with granitoid xenolith similar to the Maskwa Lake granodiorite; d) plagioclase-phyric basalt (unit 2) cut by a late fine-grained granitoid dike (lower left corner); e) fine-grained massive gabbro (unit 2a) as a dike in MORB-type basalt; f) pillowed foliated basalt (unit 2) with iron-oxide–stained surface and disseminated pyrrhotite.

Local geology

Twelve map units were identified in the Cat Creek area:1) Maskwa Lake Batholith granitoid rocks; 2) MORB-type basaltic and synvolcanic intrusive rocks; 3) metasedimentary rocks and thin intercalated volcaniclastic rocks; 4) to 10) mafic–ultramafic rocks of the Mayville intrusion, consisting of basal melagabbro and pyroxenite (unit 4), heterolithic breccias (unit 5), gabbroic anorthosite to anorthosite (unit 6), leucogabbro (unit 7), gabbro (unit 8), diabasic to gabbroic rocks (unit 9) and quartz diorite to tonalite (unit 10); 11) granitoid rocks (TTG; garnet-muscovite-bearing granite); and 12) pegmatites.

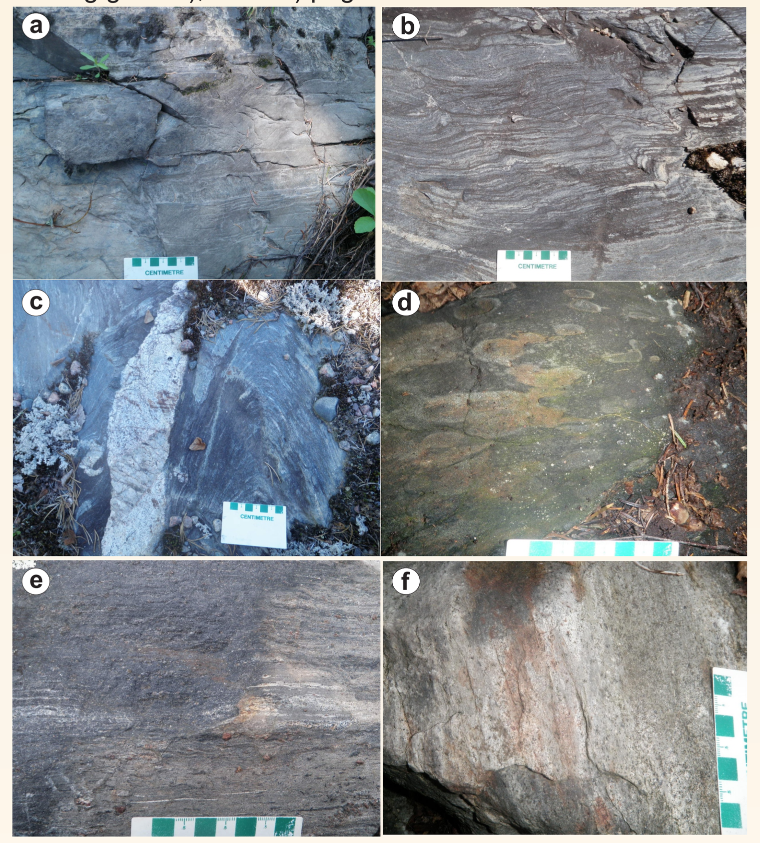


Fig.5: Field photographs of map unit 3, exhibiting lithological characteristics and/or field relationships, Cat Creek area, southeastern Manitoba: a) well-bedded greywacke; b) folded gneiss containing felsic veins that are both parallel and discordant to the foliation plane; c) folded gneiss, cut by a late granite dike; d) volcaniclastic breccia or debris flow; e) laminated garnet-porphyroblastic greywacke; f) well-bedded siltstone and greywacke containing disseminated pyrite.

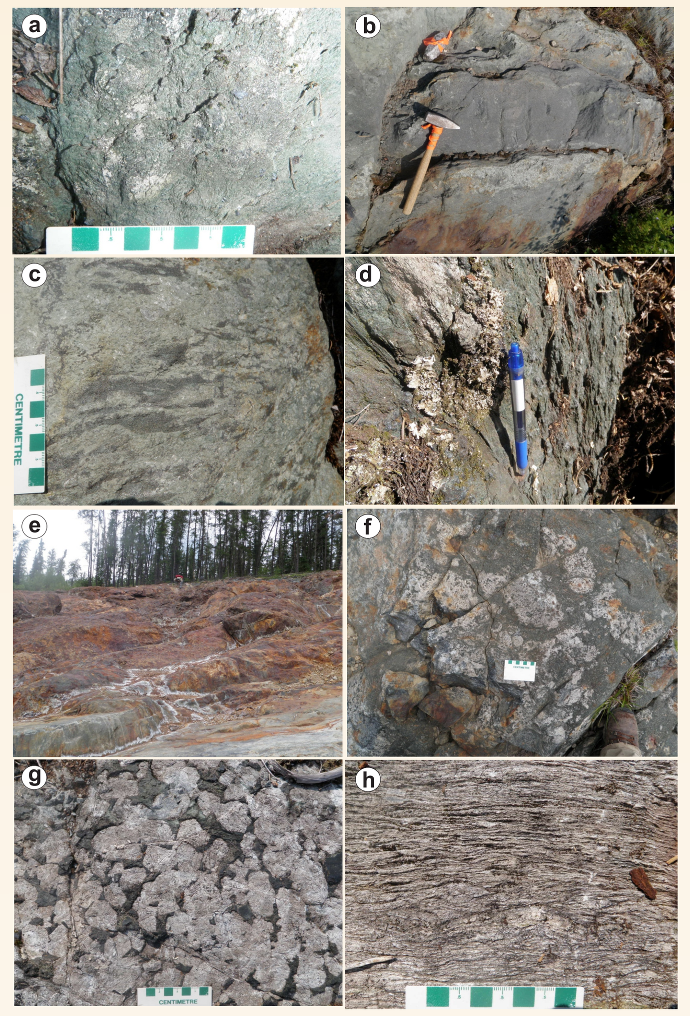


Fig.6: Field photographs of the Mayville intrusion, showing lithological characteristics and/or field relationships, Cat Creek area, southeastern Manitoba: a) foliated chlorite-magnetite-amphibole schist (after pyroxenite) with strong magnetic property (unit 4); b) disrupted, ~40 cm thick chromitite band in pyroxenite; c) magnetite stringers in pyroxenite; d) sulphide-bearing chlorite-amphibole schist (after pyroxenite; unit 4) without notable magnetism; e) mineralized heterolithic breccia zone at the M2 deposit (unit 5); f) leucogabbro to anorthosite fragments and/or breccia cemented by melagabbro matrix in the heterolithic breccia zone (unit 5); g) megacrystic anorthosite (unit 6); h) sheared gabbroic anorthosite with mylonitic characteristics (unit 6).

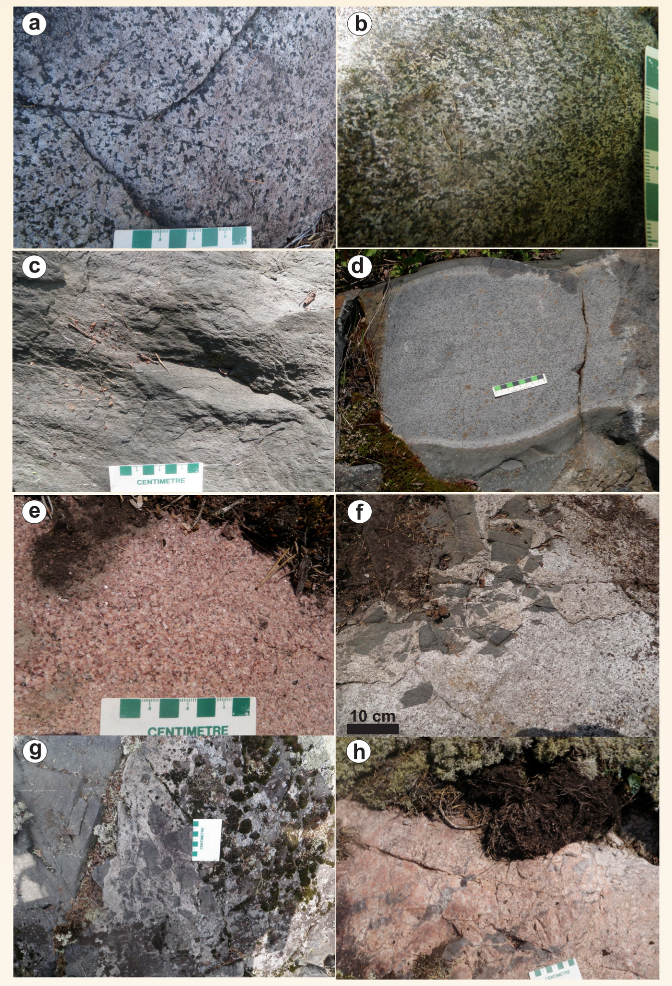


Fig. 7: Field photographs of map units exhibiting lithological characteristics and/or field relationships (units 7–10 in the Mayville intrusion), Cat Creek area, southeastern Manitoba: a) coarse-grained leucogabbro (unit 7); b) medium-grained, massive gabbro (unit 8) with notable magnetism; c) fine-grained diabase (unit 9); d) fine-grained quartz diorite dike (unit 10) with chilled margins, cutting pyroxenite and gabbro in the heterolithic breccia zone; e) fine- to medium-grained garnet-muscovite–bearing granite (unit 11b); f) and g) medium-grained granodiorite (unit 11a) intruding very fine grained basalt (unit 2) and containing basalt fragments; h) pink pegmatite (unit 12).

Lithogeochemistry

Based on discrimination diagrams, the magma source for the Mayville intrusion is subalkaline and exhibits a tholeiitic affinity (Figs. 8 and 9), typical of a magmatic-arc or island-arc setting. On the TiO_2/MnO versus Mg# plot, most Mayville intrusion rocks plot exclusively in the volcanic-arc field. In the Zr/Y versus Zr discrimination diagram, however, these samples plot in both the oceanic- and continental-arc fields, consistent with a transition from oceanic/arc to continental-arc environment, as suggested by Gilbert (2007) and Gilbert et al. (2008). Granitoids could be formed in volcanic arc to collisional setting (Fig. 10).

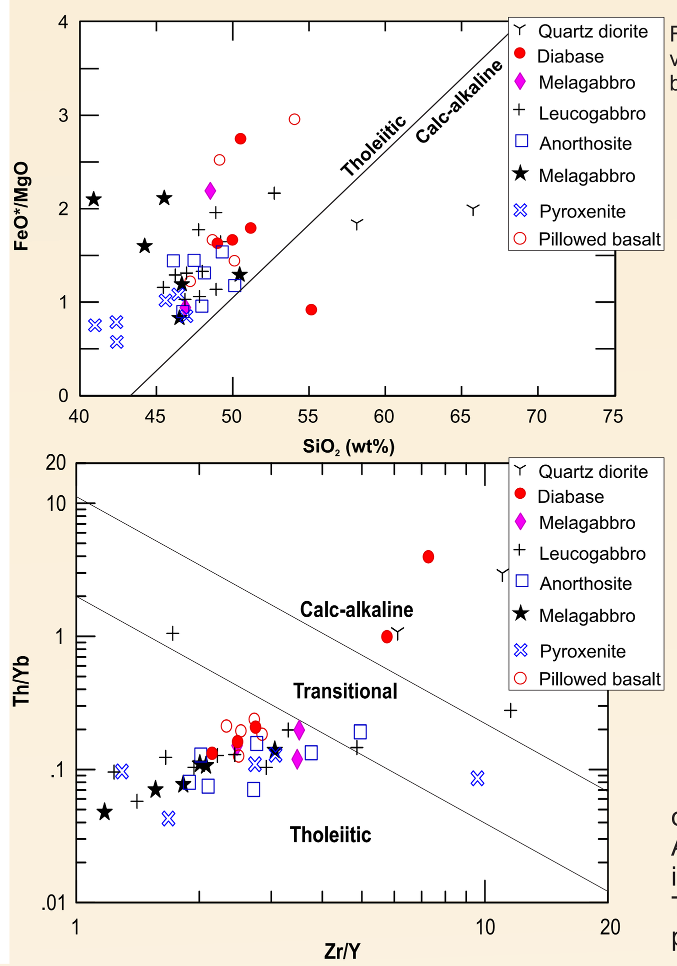


Fig.8: Discrimination diagrams for rocks of the Mayville mafic–ultramafic intrusion, Cat Creek area, southeastern Manitoba: a) FeOT/MgO versus SiO_2 (wt. %; boundary between tholeiitic and calcalkaline rock series from Miyashiro, 1974); b) Th/Yb versus Zr/Y (boundaries between tholeiitic, transitional and calcalkaline from Ross and Bédard, 2009).

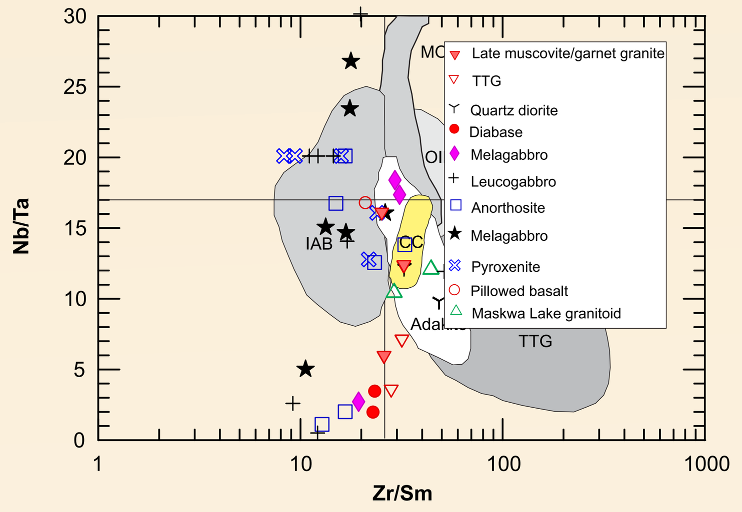


Fig. 9: Discrimination diagram of Nb/Ta versus Zr/Sm for Archean TTG, continental crust (CC), and modern midocean ridge basalts (MORB), ocean island basalts (OIB), island arc basalts (IAB). The discrimination fields are from Foley et al. (2002), and the primitive mantle values of Na/Ta and Zr/Sm are respectively 17 and 26.

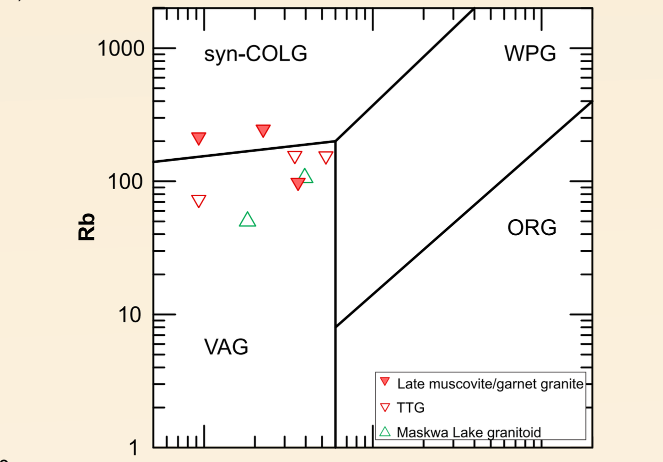


Fig. 10: Plot of Rb (ppm) vs. Yb+Ta (ppm) for granitoids in the Cat Creek area. The fields of VAG (volcanic arc granitoids), syn-COLG (syn-collisional granitoids), WPG (within-plate granitoids), and ORG (ocean ridge granitoids) from Pearce et al. (1984)..

Geochemical signatures of the Mayville intrusion, coupled with field relationships such as the chaotic nature of the heterolithic breccia zone and the presence of fragments of leucogabbro and anorthosite from the overlying ALZ that contains xenoliths of gneiss, suggest that the Mayville intrusion may have been formed by multiple injections of tholeiitic magma that underwent fractional crystallization and some assimilation of the country rocks. The magma generated beneath a relatively thin (<25 km) lithosphere may have begun to crystallize calcic plagioclase, which then rose and segregated to form one or more anorthositic layers.

These layers may subsequently have been broken up due to gravity instabilities or tectonic setting and, in part, became entrained within batches of late, turbulent magma at or close to the top of the magma chamber. Fractional crystallization and assimilation of the country rocks concurrent with magmatic emplacement would be an important requirement for segregating magmatic Ni-Cu-PGE sulphide mineralization (Lightfoot and Naldrett, 1999; Lesher et al., 2001). Plots of the Mayville intrusion rocks on the Ni versus Cu/Zr diagram display a trend consistent with sulphide segregation and fractional crystallization, suggesting that the intrusion was saturated with sulphide minerals. Saturation, segregation and accumulation of sulphide minerals may have resulted in PGE-Ni-Cu concentration and mineralization, particularly in the basal part of the intrusion, and in the contact and transitional zones between different phases in the lower portions of the intrusion. Although differentiation and crustal contamination may result in sulphide saturation in the residual magmas, an external source of sulphur appears necessary to trigger sulphide saturation and segregate significant amounts of sulphide mineralization. Although early sulphide saturation in magmas is evident, an external source for sulphur has not yet been identified. Metasediments to north of the intrusion is a possible S source.

Conclusions

In summary, the Mayville intrusion is one of the major layered mafic–ultramafic intrusions in the BRGB. Based on preliminary analytical results, it is interpreted as an evolved mafic intrusion of tholeiitic affinity that exhibits some contamination signatures. Preliminary assessment of its geochemical characteristics using tectonic discrimination diagrams suggests a magmatic-arc system as the tectonic setting of the intrusion. The Mayville intrusion hosts one Ni-Cu-(PGE) deposit within the heterolithic breccia zone (M2 deposit) and significant PGE and chrome mineralization.

Detailed geological mapping, together with geochemical and geochronological investigations indicate that the intrusion's metallogeny, and the potential for base- and precious-metal mineralization associated with mafic–ultramafic intrusions in the BRGB. The study discusses the relationship between Cr and Ni-Cu-PGE sulphide mineralization in these intrusions.

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