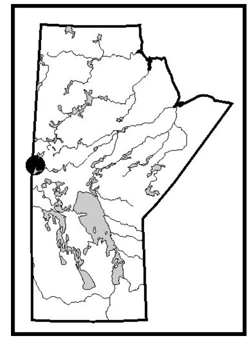
GS-3 Wonderland gabbro: U-Pb age and geological implications, Manitoba (NTS 63K12NE)

by A.H. Bailes and P. Theyer[1]



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Summary

The Wonderland gabbro is one of several gabbroic bodies in the Bear Lake Block of the Flin Flon Belt that are spatially associated with small Ni- and PGE-rich sulphide zones, including the McBratney Ni-PGE-Au occurrence. A genetic association between the Ni-PGE-Au mineralization and these intrusions is difficult to establish with certainty, but elevated (>200 ppb) grab sample Pt-Pd concentrations from the Wonderland gabbro point to a possible primary association with this mineralization. The 1839.9 ±3.9 Ma age of the intrusion indicates that it postdates juvenile oceanic arc volcanism of the host Bear Lake basalts by at least 45 million years. The Wonderland gabbro is, within error, the same age as the 1847 ±6 Ma ultramafic intrusion that hosts the magmatogenic PGE-rich Namew Lake Cu-Ni sulphide deposit. The association of this suite of syn- to post-Missi intrusions with Ni and PGE mineralization raises the possibility that an intrusive event of this age could be a significant and only partly explored metallogenic episode in the Flin Flon Belt.

Introduction

The volcanic rocks of the Flin Flon Belt are intruded by numerous generations of gabbroic intrusions. Most of them belong to three suites. The first suite comprises the oldest and most abundant intrusions, which are synvolcanic feeders to 1.91 to1.88 Ga juvenile oceanic arc volcanism. The second suite includes mafic phases of 'successor arc', 1.87 to1.845 Ga calcalkaline granitic plutons. The third suite is the least abundant and contains post-1.845 Ga intrusions that locally intrude ca. 1.84 Ga fluvial, alluvial and turbiditic sedimentary rocks of the Missi and Burntwood groups. Nickel-bearing sulphide mineralization has been reported from some of this third suite of intrusions (e.g., Rice Island on Wekusko Lake). This suite may also include the 1847 ±6 Ma (Cumming and Krstic, 1991) ultramafic intrusion, which contains the magmatogenic Cu-Ni-Co-PGE-rich Namew Lake massive sulphide deposit.

Geological setting

The Flin Flon Belt, which belongs within the juvenile (internal) zone of the Trans-Hudson Orogen (Figure GS-3-1), is a collision zone formed during the 2.0 to 1.8 Ga amalgamation of several Archean microcontinents into a supercontinent, Laurentia (Hoffman, 1988). This collage of 1.92 to 1.88 Ga tectonostratigraphic assemblages was assembled during the 1.88 to 1.87 Ga intra-oceanic accretion and subsequent 1.84 to 1.78 Ga terminal collision of the bounding Archean cratons (Lucas et al., 1996). It includes juvenile arc (~68%), juvenile ocean floor (~20%), and minor (~12%) oceanic plateau, ocean island basalt, 'evolved' plutonic arc and undivided rocks (Syme and Bailes, 1993; Stern et al., 1995a, b; Syme et al., 1999). Oceanic arc assemblages include tholeiite, calcalkaline and rare shoshonite and boninite suites (Stern et al., 1995a) almost identical to those forming in modern intra-oceanic arcs (e.g., Gill, 1981).

The Wonderland Gabbro belongs to a cluster of gabbro, diorite and quartz diorite plugs and stocks that cut the Bear Lake basaltic andesite flows east of Big Island Lake (known unofficially as Manistikwan Lake). They occur in the Bear Lake Block, which is one of several fault-bounded blocks of pre-1.88 Ga juvenile arc volcanic rocks in the central Flin Flon Belt (Figure GS-3-2). Each of these blocks displays a unique stratigraphy and, in some cases, a distinct geochemical character (Bailes and Syme, 1989). Similar gabbroic intrusions are found in other fault-bounded blocks (Bailes and Syme, 1989) suggesting that this suite of mafic intrusions may be younger than 1.87 Ga and postdate the 1.88 to 1.87 Ga intra-oceanic accretion event. No intrusions comparable to the Wonderland gabbro are present in the ca. 1.845 Ga Missi Group fluvial-alluvial sedimentary rocks prompting Bailes and Syme (1989) to include them in their "Pre-Missi Intrusive Rocks".

Wonderland gabbro

The elongate north-trending 0.5 by 1.5 km Wonderland gabbro plug is crudely zoned from a light brown weathering gabbro in the east to a buff brown to reddish brown weathering quartz diorite in the west (Bailes and Syme, 1989; Theyer and Heine, 2002). The gabbro is interpreted to be younger than the east-younging Bear Lake flows because its zonation indicates a west top that is opposite to that of the host flows. The Wonderland gabbro is an inhomogeneous body comprising a variety

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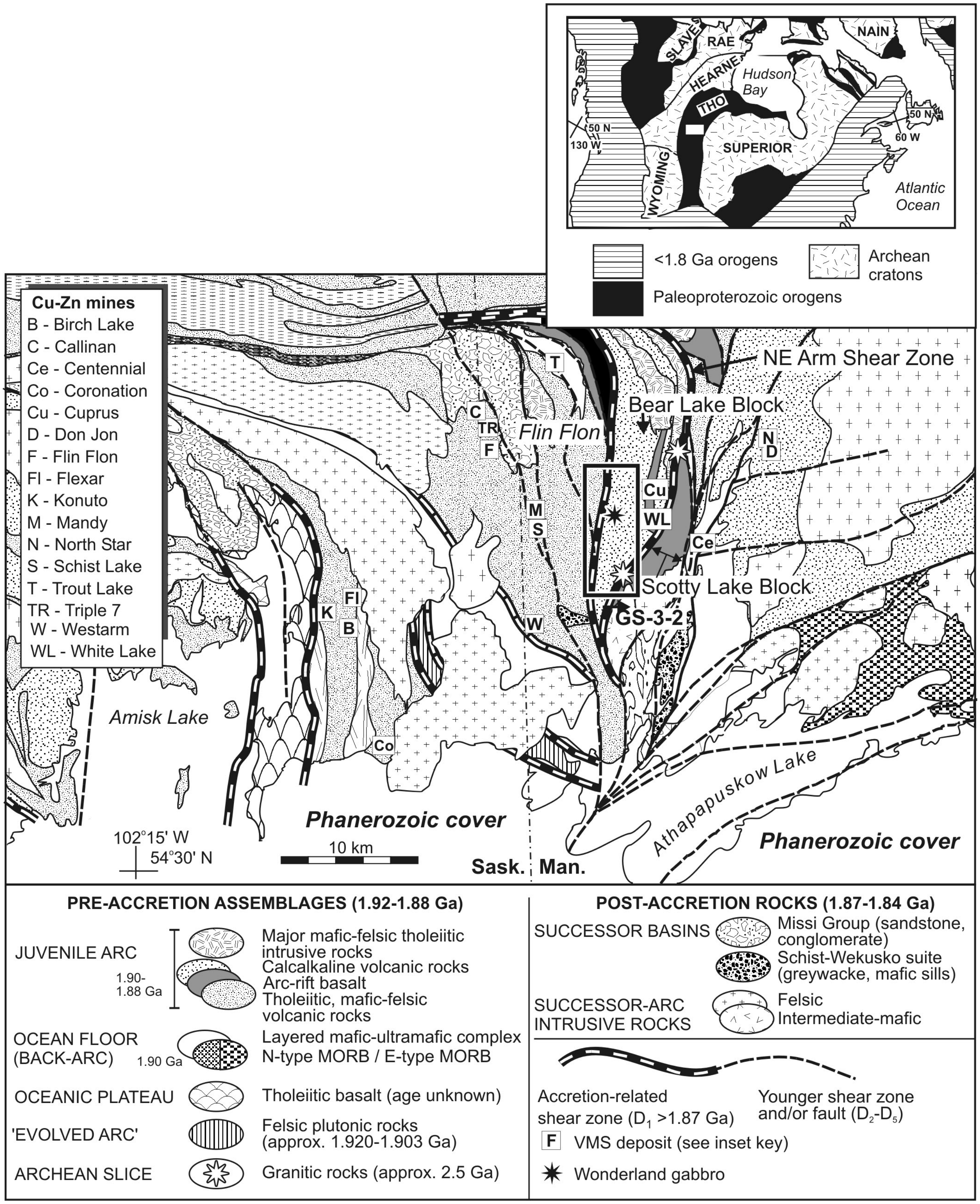

Figure GS-3-1: *Geology of the central portion of the Flin Flon Belt, showing the location of the Wonderland gabbro in the Bear Lake Block (*after *Syme et al., 1996). Box indicates area covered by Figure GS-3-2. Inset map shows the location of the Flin Flon Belt within the Trans-Hudson Orogen.*

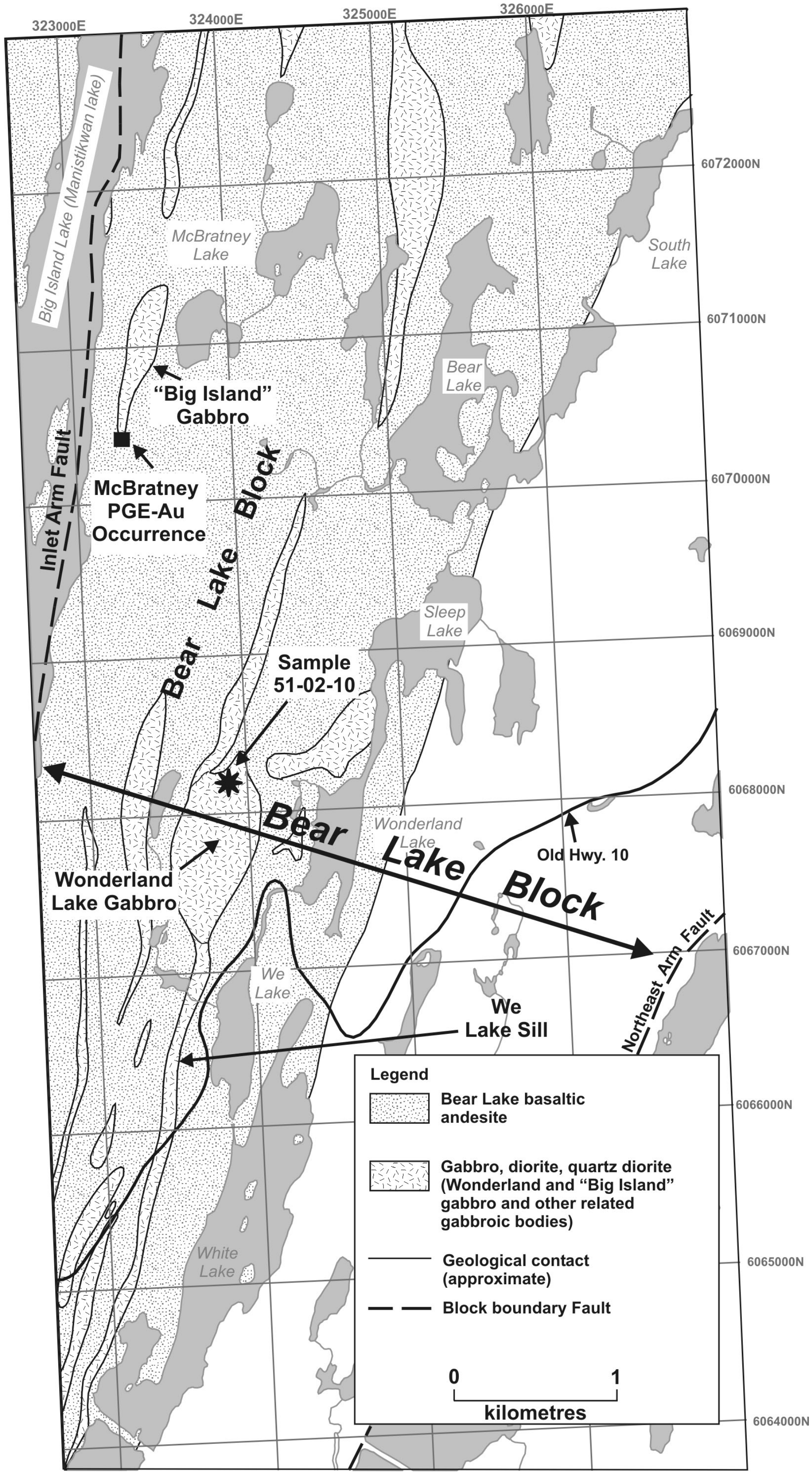

Figure GS-3-2: *Location of the Wonderland Gabbro, 'Big Island gabbro' and other similar gabbro, diorite and quartz diorite intrusions (*after *Bailes and Syme, 1989) in the Bear Lake Block. The location of the geochronology sample site is indicated by the asterisk. Place names in parentheses are unofficial.*

of rock types, including granite, diorite and gabbro (Theyer and Heine, 2002). Randomly located areas of hybrid granitic to dioritic rocks, characterized by melanocratic inclusions, schlieren and bands contained in a more felsic matrix are common. These features were interpreted by Theyer and Heine (2002) to result from magma mixing. Olivo et al. (2002) came to the same conclusion based on similar observations in the 'Big Island gabbro'.

Discrete, sharply defined sulphide-bearing zones, up to several metres in size and containing up to 10% coarse-grained, recrystallized pyrite, occur in the central part of the Wonderland Gabbro. The sulphide-bearing zones are likely magmatogenic, as their composition and the amount and type of alteration are comparable to those of the non-mineralized host gabbro. The sulphide-bearing gabbro is recognized by its distinctly finer grain size and its red and brown limonitic oxidation on weathered surfaces.

The sulphide zones, both within and spatially associated with this suite of gabbro intrusions, have been known for some time. Interest in them was sparked in 1991, when Hudson Bay Exploration and Development Co. Ltd. drilled a sulphide zone spatially associated with the 'Big Island gabbro' (Figure GS-3-2). In this drillhole, they intersected 16.8 m assaying 8.92 g/t Pd, 1.8 g/t Pt, 1.1% Cu and 0.6% Ni. Follow-up work by Fort Knox Gold Resources Inc. in 2000 and 2001 (Assessment File 73880, Manitoba Science, Technology, Energy and Mines, Winnipeg) further defined the extent of this mineralized zone, commonly known as the McBratney Lake Ni-PGE-Au occurrence. Channel sampling intersected high-grade zones of 5.0% Cu, 4.7% Ni, 9.5 g/t and 30 g/t Pd over 1.75 m, and 6.1% Cu, 4.2% Ni, 9.4 g/t and 31.2 g/t Pd over 1.35 m.

As part of their exploration program, Fort Knox Gold Resources Inc. prospected other gabbroic bodies within this suite of intrusions. They did this on the premise that a genetic affiliation between the PGE-Au mineralization and the gabbro intrusions might exist. Samples from the Wonderland gabbro were of great interest, as 50% of the 18 samples collected displayed elevated (>200 ppb) Pt-Pd, with 3 samples returning over 500 ppb Pt-Pd (A.F. 73880). Although not conclusive, this does support a potential genetic link between the intrusions and the PGE mineralization.

Because of the potential economic importance of this suite of gabbro intrusions (Theyer, 2001; Theyer and Heine, 2002), the Manitoba Geological Survey decided to date this intrusion and, by inference, the associated Ni-PGE-Au mineralization. The interpretation of the age of the Ni-PGE-Au mineralization is, however, complicated by the fact that the mineralization at the McBratney Lake occurrence appears to be hydrothermal in origin and related to carbonate-chlorite vein and replacement zones (Olivo et al., 2002; Olivo and Theyer, 2004).

Sampling and geochronology

The geochronology sample (51-02-10; 6068276N, 323925E, UTM zone 14, NAD 83) is from a pegmatitic pod within the mixed, transitional contact between the gabbro and quartz diorite zones of the Wonderland gabbro. The pegmatitic pods in this zone are characterized by coarse, 1 to 3 cm lath-shaped pyroxenes (replaced by amphibole) in a coarse-grained matrix composed of plagioclase and quartz.

Approximately 30 kg of the pegmatitic Wonderland gabbro was processed for U-Pb dating at the University of Alberta Radiogenic Isotope Facility in Edmonton. The sample was milled using standard crushing (jaw crusher followed by Sico® disk mill) techniques. Isolation of zircon was accomplished by Wilfley Table, heavy liquid and magnetic mineral separation techniques. Individual zircon crystals were selected from mineral concentrates for U-Pb analysis based on clarity and grain morphology using a binocular microscope. Zircon crystals with fractures, alteration or inclusions were avoided where possible during the selection process. Selected mineral grains or fractions were dissolved in acids, and purified aliquots of U and Pb were obtained using anion exchange chromatography. The isotopic compositions of U and Pb were determined on a solid-source thermal ionization mass spectrometer. All ages are calculated using the following decay constants: 1.55125×10^{-10} per year for ^{238}U and 9.8485×10^{-10} per year for ^{235}U. The uncertainties associated with all age calculations reported in the text are quoted at two sigma.

Abundant apatite, a small amount of colourless zircon, plus trace euhedral pyrite and molybdenite were recovered from this sample. The zircon grains typically consist of fragments and shards with a few prismatic sections present. Most of the crystals were recovered in quite magnetic Frantz splits. Seven zircon fractions were selected from this sample, but fraction 1 failed. The U-Pb results for six zircon fractions (consisting of between 6 and 28 fragments) are presented in Table GS-3-1 and on a concordia diagram in Figure GS-3-3. All six fractions display a similar chemical composition with moderate to high U (461–1496 ppm) and Th (414–1173 ppm) contents and relatively high Th/U (0.65–0.90). These high Th/U ratios are typical for primary zircon crystallizing from a mafic magma.

The zircon analyses are generally discordant (6.8–32.2%) with $^{207}Pb/^{206}Pb$ ages that vary between 1723 and1862 Ma. The analyses are seemingly collinear, but a regression calculation indicates there is slight scatter and using all six analyses yields an age with large uncertainties. A regression calculation using the three most precise analyses (3, 4, 7) yields an upper intercept age of 1839.9 ±3.9 Ma (mean standard weighted deviation (MSWD) = 0.18) and a lower intercept age of 406 ±20 Ma.

Table GS-3-1: U-Pb Zircon Results, Wonderland Gabbro, Sample 51-02-10.

Description	Weight (µg)	U (ppm)	Th (ppm)	Pb (ppm)	Th/U	TCPb (pg)	$^{206}Pb/^{204}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	% Dis
2z: sl pink elongated striated (7)	8.5	626	493	228	0.79	13	7718	0.331209 ±32	4.9007 ±49	0.11389 ±4	1751.0 ±1.6	1802.4 ±0.9	1862.3 ±0.6	6.8
3z: col elongate striated shards (11)	21.9	461	414	167	0.09	85	2230	0.29855 ±40	4.5677 ±65	0.11096 ±6	1684.1 ±2.0	1743.4 ±1.2	1815.2 ±1.0	8.2
4z: lt pink elongate striated shards Fe staining (14)	27.9	1246	940	388	0.75	475	1201	0.25862 ±36	3.8698 ±60	010852 ±8	1482.8 ±1.9	1607.4 ±1.3	1774.7 ±1.3	18.4
5z: col elongate euh frags (6)	606	1028	771	305	0.75	186	550	0.23408 ±35	3.4694 ±67	0.10749 ±16	1355.9 ±1.8	1520.3 ±1.6	1757.3 ±2.8	25.3
6z:col elongate striated frags (28)	39.1	1496	1173	372	0.78	259	2953	0.20758 ±28	3.0192 ±42	0.01549 ±4	1215.9 ±1.5	1412.5 ±1.1	1722.8 ±0.6	32.2
7z: col elongate euh to subhed frags	6.1	1169	761	343	0.65	49	2346	0.25468 ±33	3.7971 ±53	0.10826 ±5	1461.0 ±1.7	1592.1 ±1.1	1770.3 ±0.8	19.5

All errors reported to 1 s

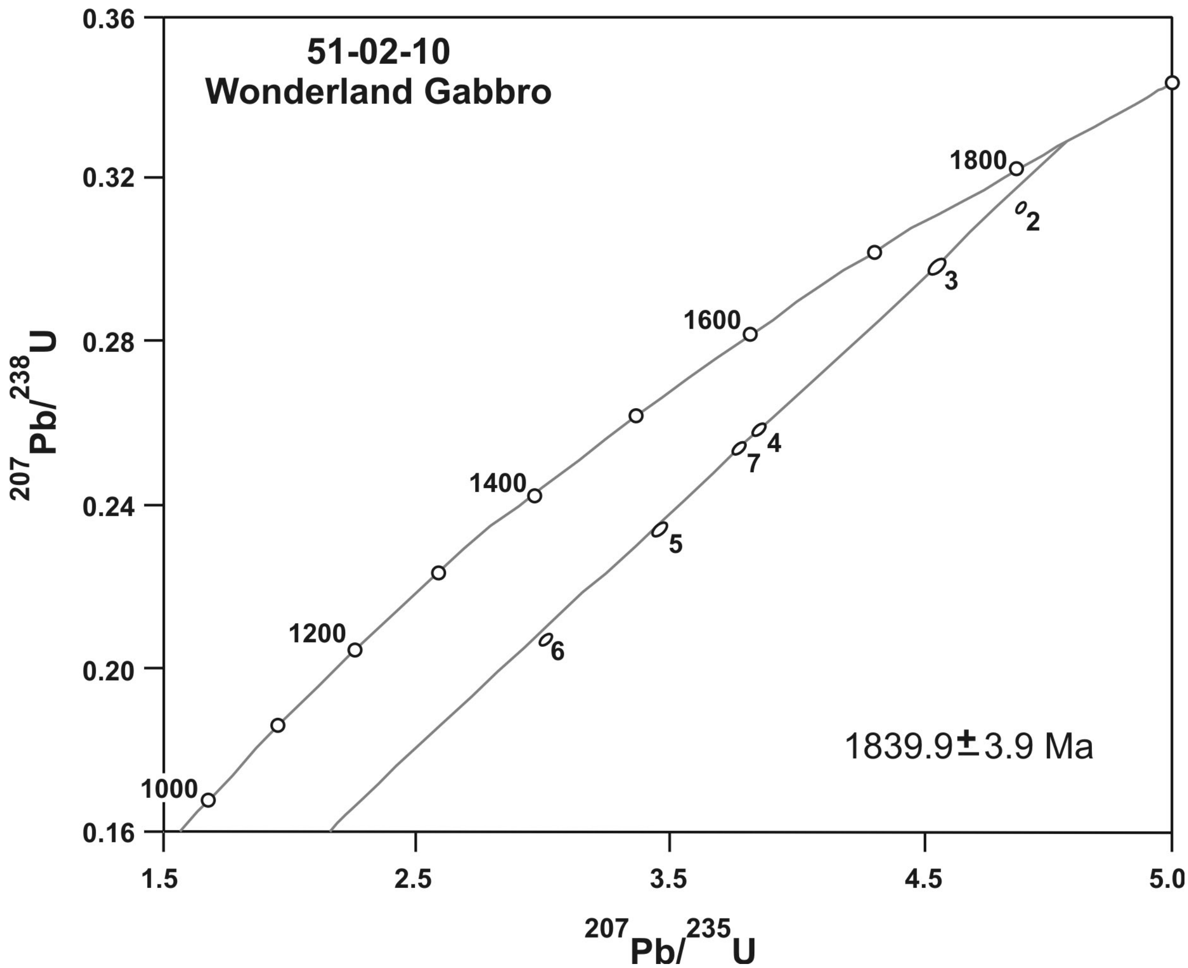

Figure GS-3-3: Concordia diagram of U-Pb zircon isotopic analyses from the quartz diorite pegmatite phase of the Wonderland gabbro (sample 51-02-10). Analytical uncertainty is 1σ standard error.

Implications and economic considerations

The new U-Pb zircon age from the Wonderland gabbro is interpreted to represent the age of crystallization of the intrusion. The age indicates that the Wonderland gabbro postdates the 1.92 to 1.88 Ga juvenile arc volcanism, the 1.87 to 1.845 Ga 'successor arc' magmatism and deposition of the ca. 1.845 Ga Missi and Burntwood sedimentary rocks. The age is also, within error, comparable to that of the 1847 ±6 Ma ultramafic intrusion that hosts the Namew Lake magmatogenic Ni-Cu-Co and PGE-rich sulphide deposit. Although very speculative at this point, the Ni and PGE association of this suite of syn- to post-Missi intrusions raises the possibility they may be part of a significant metallogenic event that has yet to be adequately explored.

Other intrusions of this age include the 'Boundary intrusions' in the vicinity of the Flin Flon Cu-Zn sulphide mine at Flin Flon and the Chisel Lake gabbro near the Chisel Lake Zn-Cu orebody at Snow Lake. The age of the Chisel Lake gabbro is inferred from its crosscutting relationship with isoclinal folds that are interpreted to be the same age as similar folds affecting ca.1.84 Ga Burntwood greywacke turbidite units. A sample of a pegmatitic quartz diorite pod from the Chisel Lake gabbro intrusion has been submitted for U-Pb zircon dating to test this assumption. The extent of the post-1.84 Ga mafic intrusive event is difficult to assess because of its similarity to the ubiquitous 1.92 to 1.88 Ga synvolcanic gabbroic intrusions of the Flin Flon Belt. Given the potential of this mafic intrusive event for hosting Ni and PGE mineralizations, identifying these intrusions and documenting their distribution is important for mineral exploration in the belt.

References

Bailes, A.H. and Syme, E.C. 1989: Geology of the Flin Flon–White Lake area; Manitoba Energy and Mines; Geological Services, Geological Report GR87-1, 313 p.

Cumming, G.L. and Krstic, D. 1991: Geochronology at the Namew Lake Ni-Cu deposit, Flin Flon area, Manitoba, Canada: a Pb/Pb study of whole rocks and ore minerals; Canadian Journal of Earth Sciences, v. 28, no. 9, p. 1328–1339.

Gill, J.B. 1981: Orogenic Andesites and Plate Tectonics; Springer-Verlag, New York: 390 p.

Hoffman P.F. 1988: United Plates of America, the birth of a craton: Early Proterozoic assembly and growth of Proto-Laurentia, Annual Review of Earth and Planetary Sciences, v. 1, p. 543–603.

Lucas, S.B., Stern, R.A., Syme, E.C., Reilly, B.A. and Thomas, D.J. 1996: Intraoceanic tectonics and the development of continental crust; 1.92–1.84 Ga evolution of the Flin Flon Belt, Canada; Geological Society of America Bulletin, v. 108, p. 602–629.

Olivo, G.R. and Theyer, P. 2004: Platinum-group minerals from the McBratney PGE-Au prospect in the Flin Flon greenstone belt, Manitoba, Canada; Canadian Mineralogist, v. 42, p. 667–681.

Olivo, G., Theyer, P. and Bursztyn, N. 2002: Platinum group element investigations in the Flin Flon greenstone belt: petrography and mineralogy of the McBratney Lake PGE-Au occurrence (NTS 63K13), Manitoba; *in* Report of Activities 2002, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 94–99.

Stern, R.A., Syme, E.C., Bailes, A.H. and Lucas, S.B. 1995a: Paleoproterozoic (1.90–1.86 Ga) arc volcanism in the Flin Flon Belt, Trans-Hudson Orogen, Canada; Contributions to Mineralogy and Petrology, v. 119, no. 2–3, p. 117–141.

Stern, R.A., Syme, E.C. and Lucas, S.B. 1995b: Geochemistry of 1.9 Ga MORB- and OIB-like basalts from the Amisk collage, Flin Flon Belt, Canada; evidence for an intra-oceanic origin; Geochimica et Cosmochimica Acta, v. 59, no. 15, p. 3131–3154.

Syme, E.C., Lucas, S.B. and Stern, R.A. 1999: Contrasting arc and MORB-like assemblages in the Paleoproterozoic Flin Flon Belt, Manitoba, and the role of intra-arc extension in localizing volcanic-hosted massive sulphide deposits; Canadian Journal of Earth Sciences, v. 36, no. 11, p. 1767–1788.

Syme, E.C. and Bailes, A.H. 1993: Stratigraphic and tectonic setting of early Proterozoic volcanogenic massive sulfide deposits, Flin Flon, Manitoba; Economic Geology, v. 88, p. 566–589.

Syme, E.C., Bailes, A.H., Stern, R.A. and Lucas, S.B. 1996: Geochemical characteristics of 1.9 Ga tectonostratigraphic assemblages and tectonic setting of massive sulphide deposits in the Paleoproterozoic Flin Flon Belt, Canada; *in* Trace Element Geochemistry of Volcanic Rocks: Applications for Massive Sulphide Exploration, A.H. Bailes (ed.), Geological Association of Canada, short course notes, v. 12, p. 279–327.

Theyer, P. 2001: Platinum-group element investigations in the Flin Flon greenstone belt: McBratney Lake occurrence and Josland Lake intrusion (parts of NTS 63K/9, /13); *in* Report of Activities 2001, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 33–39.

Theyer, P. and Heine, T.H. 2002: Platinum group element investigations in the Flin Flon greenstone belt: regional geology of the McBratney Lake PGE-Au occurrence and part of the Mikanagan Lake Sill (NTS 63K13), Manitoba; *in* Report of Activities 2002, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 87–93.