Geology of the Bird River Belt

A regional mapping project in the Neoarchean Bird River greenstone belt of southeastern Manitoba was initiated by the Manitoba Geological Survey in 2005. This project is focused on the stratigraphy and volcanic geochemistry of the supracrustral rocks, as well as an evaluation of the economic potential of the various tectonostratigraphic components. Several concurrent mapping projects are underway in the same area, based at the University of Waterloo (Duguet at al., 2006; Mealin et al., 2006; Kremer and Lin, 2006). Geochronologic investigations were also initiated to complement the mapping and three new age dates have so far been obtained (Duguet at al., 2006; Gilbert, 2006). Geological mapping at 1: 20 000 scale has been carried out in the east part of the Bird River Belt (BRB) from Booster Lake to the area west of Bird Lake, where arc-type, volcanic and sedimentary rocks are predominant (Figure 1). The arc-type rocks are separated into north and south panels by younger turbidite deposits (Booster Lake Formation) that extend through the central part of the greenstone belt. Current mapping has indicated the need for a re-assessment of the stratigraphic subdivisions that were previously defined within the arc-type sequence by Trueman (1980), who also correlated parts of the north and south panels of the BRB. New geochemical data show that this correlation is invalid.

Geochemistry

Arc-type assemblage

Three geochemically defined, volcanic suites in the arc-type assemblage have so far been recognized –

1) BRB north panel calc-alkaline suite, which extends for 35 km throughout the greenstone belt.

2) BRB south panel tholeiitic suite (equivalent to the central part of the Birse Lake section - see Figure 8).

3) BRB south panel evolved tholeiitic suite (equivalent to the north part of the Birse Lake section - see Figure 8).

Extended element plots of volcanic rocks in these 3 geochemical suites are shown in Figures 2 and 3; note that all geochemical plots in this poster are of volcanic rocks of mafic to intermediate composition. All rocks display Th enrichment, negative Nb anomalies and negatively sloping rare earth element (REE) profiles that are hallmarks of modern arc-type volcanic rocks. A progressive decrease in the slope and increase in REE content (excluding Th) is evident from the calc-alkaline suite in the north panel to the tholeiitic and evolved tholeiitic suites in the south panel. The tholeiitic vs calk-alkaline affiliations of the 3 arc-type volcanic suites are illustrated in the Jensen cation diagram (Figure 4) and the discriminant ternary plot Irving and Baragar (Figure 5).

MORB-type volcanic rocks

Pillowed basalt and associated gabbro extend along the north flank of the BRB (Lamprey Falls Formation; Gilbert, 2005) and similar rocks occur in the Winnipeg River area, separated from the main part of the BRB by the Birse Lake granitoid pluton (Figure 1). In addition to these localities, MORB-type basalt also occurs in the south part of the Birse Lake section (Figure 8), immediately north of the Birse Lake pluton. The north margin of this basaltic suite is inferred to be in fault contact with the mafic to felsic arc-type rocks in the central and north parts of the Birse Lake section. Compared to the Lamprey Falls Formation at the BRB north flank and in the Winnipeg River area, the MORB-type rocks in the south part of the Birse Lake section are slightly less depleted in REE , but otherwise all 3 of these MORB suites are compositionally similar. Rare earth element profiles are flat, except for moderately increased Th relative to MORB (Figure 6); average SiO$_2$ (49%) and TiO$_2$ (1.1%) are lower in the MORB-type basalts compared to the arc-type basaltic rocks in the central and northern Birse Lake section (SiO$_2$ = 53.8%; TiO$_2$ = 1.7%). The MORB-type Lamprey Falls Formation has been compared to modern back-arc basin basalts (Gilbert, 2005). All arc and MORB like volcanic rock suites in the BRB are plotted in the Wood (1980) ternary diagram (Figure 7). Rocks in the arc field are subdivided, showing the distinction between the calk-alkaline north panel suite and the tholeiitic south panel suite that is characterized by relatively higher REE contents (notably Zr). All MORB-type rocks are tightly constrained in a field displaced toward the margins of the N-MORB and E-MORB fields, due to moderate Th enrichment.

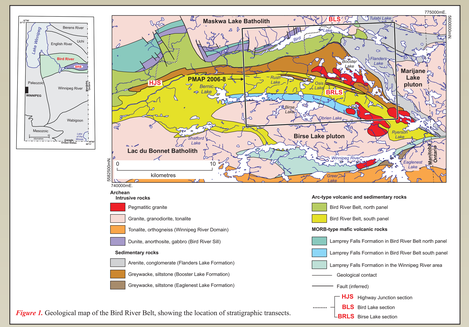


Figure 1. Geological map of the Bird River Belt, showing the location of stratigraphic transects.

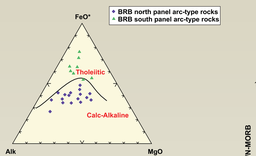


Figure 5. AFM ternary diagram of arc-type volcanic rocks in both the north and south panels of the BRB.

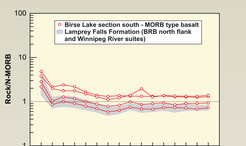


Figure 6. N-MORB-normalized extended element plots of MORB-type rocks in the BRB in both the Bird River and Winnipeg River areas.

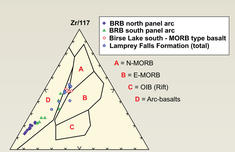


Figure 7. Th-Zr-Nb discriminant diagram (Wood, 1980) with plots of all geochemically defined volcanic suites in the BRB.

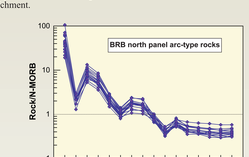


Figure 2. N-MORB-normalized extended element plot of the BRB north panel calc-alkaline suite of arc-type rocks.

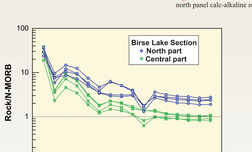


Figure 3. N-MORB-normalized extended element plots of the BRB south panel tholeiitic suite (Birse Lake section central part) and evolved tholeiitic suite (Birse Lake section north part).

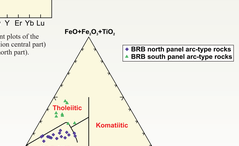
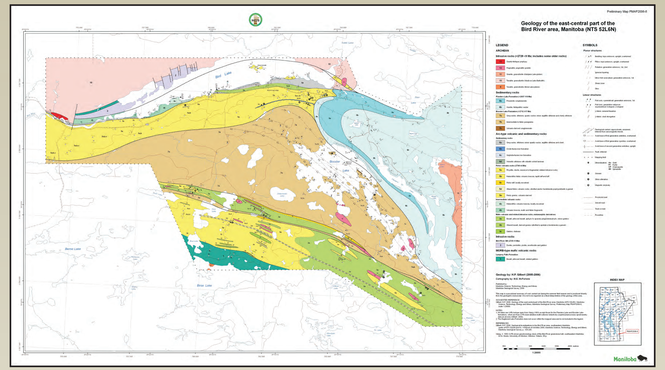


Figure 4. Jensen cation diagram of arc-type volcanic rocks in both the north and south panels of the BRB.



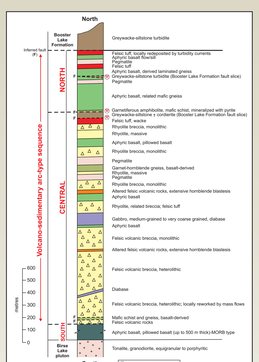


Figure 8. Birse Lake section (synonymous with BRB south panel).

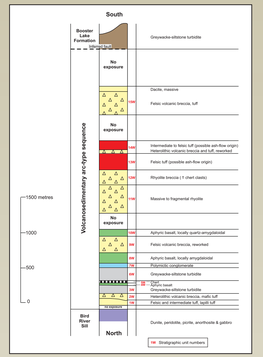


Figure 9. Highway Junction section, BRB north panel.

Stratigraphy

BRB south panel: Birse Lake section

The south panel of the BRB in the area east of Bernic Lake consists of a diverse assemblage of rhyolitic and basaltic rocks that are intruded by the Birse Lake pluton to the south and are juxtaposed by a major fault against turbidites of the Booster Lake Formation to the north (Figure 1; Table 1). At both the north and south flanks of this volcanic sequence, basaltic units up to 0.5 km thick display well-preserved north-facing pillows. The sequence between the flanking mafic units consists of felsic volcanic rocks, subordinate andesite and basalt. Geochemical data indicate this central felsic to mafic sequence and the flanking basaltic units are three, compositionally distinct volcanic rock suites that are probably in fault contact (south, central and north parts of the Birse Lake section in Figure 8).

A conformable metasomatic zone in the central part of the Birse Lake section east of Osis Lake (Figure 1) is associated with a ground magnetic anomaly and contains several mineralized, pyritic units over a 10 m wide interval. A coarsely porphyroblastic, 18 m thick unit of chlorite-sericite-cordierite-bearing gneiss occurs south of the mineralized units. A conspicuous aeromagnetic anomaly that coincides with the mineralized zone extends along strike for more than 10 km from Osis Lake to the area west of Ryerson Lake (Figure 1).

BRB north panel

The BRB north panel consists of a diverse, arc-type volcanosedimentary sequence that is flanked to the north by the MORB-like Lamprey Falls Formation (Figure 1). The latter consists of massive to pillowed, aphyric basalt flows, related breccia and subordinate mafic tuff and gabbro that are separated from the arc type sequence by an inferred major fault. Two transects were made through the volcanosedimentary sequence in the BRB north panel (Figure 1); a western transect ('Highway Junction section'- Figure 9) and an eastern transect ('Bird Lake section' - Figure 10). Detailed lithological descriptions of individual rock units in these two transects are provided in MGS Data Repository Item DRI2006002 [available online to download free of charge at www2.gov.mb.ca/itm-cat/freedownloads.htm].

Highway Junction section (Figure 9)

The 3.75 km Highway Junction section contains fifteen separate map units in a predominantly south-facing sequence. The northernmost 0.65 km part of this section comprises seven units that consist exclusively of sedimentary and reworked volcaniclastic rocks, except for a minor unit of aphyric pillowed basalt. Localized folding is indicated approximately 0.5 km above the base by a north-facing scoured contact within south-facing turbidite beds. The remaining part of the Highway Junction section consist of felsic and subordinate mafic flows and volcanic fragmental rocks that were locally redeposited by subaqueous mass flows.

Bird Lake section (Figure 10)

The north part of the Bird Lake section consists of a 0.65 km thick, turbidite-type sequence. A 200 m thick felsic volcanic member occurs within this epiclastic unit, which is provisionally correlated with the lower, mixed sedimentary and volcaniclastic part of the Highway Junction section. The turbidite sequence is overlain, in turn, by an aphyric, pillowed basalt unit and a 6 m thick, mineralized oxide-facies iron formation associated with mafic gneiss and porphyroblastic metasiltstone. The south part of the Bird Lake section consists of massive to fragmental rhyolite and subordinate heterolithic volcanic breccia.

Southwest Bird Lake area

A sequence of heterolithic breccia and turbidite deposits in the southwest part of Bird Lake (units 7E, 8E in Figure 10) are of uncertain age and stratigraphic position relative to units 1E to 6E in the Bird Lake section. The heterolithic volcanic breccia contains a variety of fragment types assumed to be derived from the arc-type volcanic sequence, and is interpreted as a mass flow. At several localities, the fragmental deposit contains sporadic clasts with a penetrative foliation that appears to predate emplacement of the mass flow. Cordierite porphyroblasts are locally conspicuous both in the matrix of the volcanic breccia and in strata-bound zones within the overlying turbidite unit.

Geochronology

New U/Pb isotope data on zircons from metasedimentary rocks in the eastern BRB confirm previous interpretations that a significant age difference exists between the arc-type assemblage in the BRB and younger sedimentary rocks of the Booster Lake and Flanders Lake formations (Table 1 and Figure 1). The youngest analyzed detrital zircon in a sample of Booster Lake Formation turbidite yielded a subconcordant age of 2712± 17 Ma, which currently serves as the best estimate for the maximum age of deposition. Comparing this with the 2740±4 Ma age for a felsic volcanic unit in the arc-type assemblage (Wang, 1993) suggests an approximate 30 m.y. age difference between the Booster Lake Formation and older arc-type rocks in the BRB. Uranium-lead isotope analysis of zircons from the Flanders Lake Formation supports this observation, but the data do not establish the relative ages of the Booster Lake and Flanders Lake formations. The youngest concordant zircon age obtained for the Flanders Lake Formation is 2697±18 Ma, tentatively suggesting a slightly younger maximum age for deposition of the Flanders Lake Formation relative to the age of Booster Lake turbidite sedimentation.

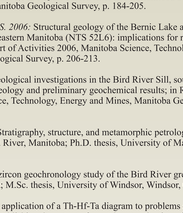


Figure 10. Bird Lake section, BRB north panel.

LATE INTRUSIVE ROCKS

Granite, pegmatite, granodiorite, tonalite, quartz diorite (Lac du Bonnet batholith, **2660 ±3 Ma**)

SEDIMENTARY ROCKS

FLANDERS LAKE FORMATION (**2697 ±18 Ma**)
Lithic arenite, polymictic conglomerate

Fault, inferred

BOOSTER LAKE FORMATION (**2712 ±17 Ma**)
Greywacke-siltstone turbidite, conglomerate

Unconformity, inferred

INTRUSIVE ROCKS

MISCELLANEOUS INTRUSIONS
Gabbro, diorite, quartz-feldspar porphyry; granodiorite (Maskwa Lake batholith II: **2725 ±6 Ma**) (Pointe du Bois batholith: **2729 ±9 Ma**)

METAVOLCANIC AND METASEDIMENTARY ROCKS – ARC ASSEMBLAGE (2740 ±4 Ma)

Mafic to felsic volcanic and related intrusive rocks; greywacke-siltstone turbidite, chert, oxide-facies iron-formation, polymictic conglomerate; derived gneiss and schist

INTRUSIVE ROCKS

BIRD RIVER SILL (**2745 ±5 Ma**)
Dunite, peridotite, picrite, anorthosite and gabbro

Fault, inferred

METAVOLCANIC AND METASEDIMENTARY ROCKS

LAMPREY FALLS FORMATION
Basalt (aphyric to plagioclase-phyric; locally pillowed, amygdaloidal, or megacrystic), related volcanic breccia

Fault, inferred

EAGLENEST LAKE FORMATION
Greywacke-siltstone turbidite

OLDER INTRUSIVE ROCKS

Granodiorite (Maskwa Lake batholith I: **2782 ±11 Ma; 2844 ±12 Ma**)

Table 1. Table of Formations.

Plate O. Blue, subhedral to euhedral cordierite porphyroblasts in fine-grained matrix of dimictic volcanic breccia (unit 7E in Bird Lake section, BRB north panel).

Plate M. Garnet and oval cordierite porphyroblasts in meta-siltstone (unit 4E in Bird Lake section BRB, north panel).

Plate N. Felsic volcanic blocks aligned within tuff and lapilli tuff (unit 7E in Bird Lake section BRB, north panel).

Plate P. Greywacke-siltstone turbidite with graded bedding: Booster Lake Formation.

Plate Q. Greywacke-siltstone turbidite with bedding-foliation discordance: Booster Lake Formation.

Plate R. Pillowed basalt with metasomatic alteration domains: Lamprey Falls Formation at Winnipeg River.

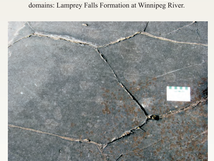


Plate S. Pillowed basalt with polygonal cooling fractures: Lamprey Falls Formation at Winnipeg River.

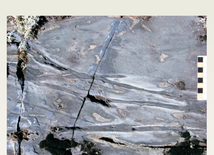


Plate A. Pillowed basalt: Birse Lake section, south part.

Plate C. Pillowed basalt: Birse Lake section, north part.

Plate E. Scoured chert laminae and rip-ups in feldspathic greywacke (unit 3W in Highway Junction section, BRB north panel).

Plate G. Polymictic conglomerate with basalt and gabbro fragments (unit 7W in Highway Junction section, BRB north panel).

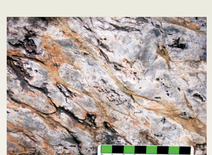


Plate I. Anastomosing fractures attributed to thermal contraction during cooling of a massive rhyolite flow (unit 11W in Highway Junction section, BRB north panel).

Plate K. Chert rip-up in lapilli tuff, interpreted as a reworked volcaniclastic deposit (14W in Highway Junction section, BRB north panel).

Plate B. Felsic volcanic breccia: Birse Lake

Plate D. Laminated green-weathering tuff scoured by sediment gravity flow that deposited the overlying lapilli tuff bed (unit 1W in Highway Junction section, BRB north panel).

Plate F. Bedded chert within 23 m thick member (unit 5W in Highway Junction section, BRB north panel).

Plate H. Bedded chert boulder in polymictic conglomerate (unit 7W in Highway Junction section, BRB north panel).

Plate J. Felsic clasts with irregular, ragged shapes within crystal-lithic tuff of possible ash-flow origin (unit 13W in Highway Junction section, BRB north panel).

Plate L. Rhyolite breccia of autoclastic origin (unit 2E in Bird Lake section, BRB north panel).

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by
H.P. Gilbert

Manitoba