GS2017-3

Preliminary results of bedrock mapping at Bigstone Lake and Knight Lake, northwestern Superior province, Manitoba (parts of NTS 53E11, 12, 13, 14)

by M.L. Rinne

In Brief:

- Correlative stratigraphic units identified at Knight Lake and Bigstone Lake
- High-grade, vein-hosted gold mineralization is controlled by late shears in mafic rocks
- Results point to untested structural targets for shear-hosted gold east of Bigstone Lake

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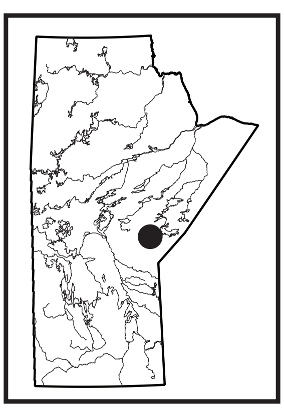

Summary

The Manitoba Geological Survey (MGS) resumed 1:20 000 scale bedrock mapping of the Bigstone Lake greenstone belt, continuing eastward into Knight Lake. Building on previous work, results from the 2017 field season included: 1) recognition of a corridor of late dextral shear zones separating the western and eastern parts of the greenstone belt; 2) delineation of correlative stratigraphic units at Knight Lake and Bigstone Lake; 3) constraints on the relative timing of late-shear deformation events; and 4) documentation of a series of quartz-calcite-sulphide±gold veins associated with the late-shear deformation. Visible gold was found in the youngest vein set, identified on the basis of crosscutting relationships, representing one of three currently known gold occurrences that are distributed across 1.5 km of dominantly mafic and carbonate±sericite-altered rocks east of Bigstone Lake. These findings highlight the potential for more widespread gold mineralization in the Bigstone Lake greenstone belt.

Introduction

Precambrian rocks mapped in 2017 form part of the Bigstone Lake greenstone belt (BLGB), a deformed package of Archean supracrustal rocks that extends approximately 50 km along strike (Figure GS2017-3-1). Despite demonstrated potential for several mineralization styles—with known occurrences of zinc, copper and gold at surface, and in drillcore—detailed exploration work in the BLGB was last undertaken between 1986 and 1989 (Assessment Files 94359, 94022, Manitoba Growth, Enterprise and Trade, Winnipeg).

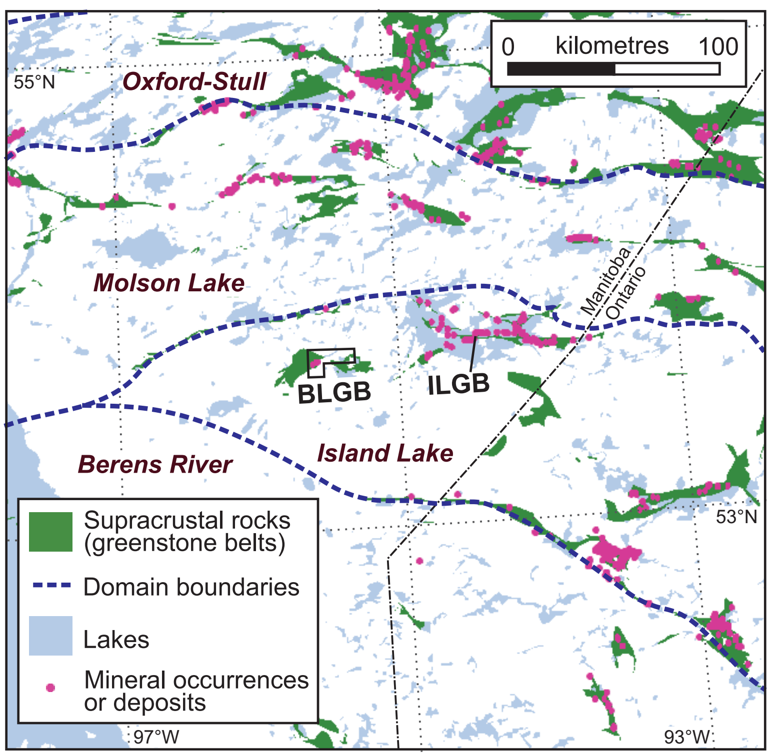

Figure GS2017-3-1: *Simplified geological domains of the northwestern Superior province, showing the locations of greenstone belts and the 2017 mapping area (outlined). Domain names are in italics and are labeled as shown in Pilkington and Thomas (2001). Mineral occurrences shown are mostly Au, Cu, Ni, Ag or Zn; occurrences shown in the Island Lake greenstone belt include two known gold deposits. Abbreviations: BLGB, Bigstone Lake greenstone belt; ILGB, Island Lake greenstone belt.*

Fieldwork completed in 2017 marks the second year of a mapping project that aims to

- document the supracrustal rocks of the Bigstone, Wass and Knight lakes areas primarily through shoreline mapping, supplemented by geochemical and geochronological analyses;
- investigate regional stratigraphic and structural relationships; and
- provide a modern assessment of mineral potential in the area, including volcanogenic massive sulphide (VMS), magmatic Ni-Cu-PGE and lode-gold styles of mineralization.

Previous mapping and exploration work undertaken in the study area was described by Rinne et al. (2016b). This summer, 1:20 000 scale shoreline mapping was carried out over 24 days in the eastern part of Bigstone Lake and the northern part of Knight Lake. Five inland traverses were completed in the eastern part of Bigstone Lake, mostly along topographic lineaments in the vicinity of known gold occurrences. One inland traverse was carried out off the southwestern end of Bigstone Lake in order to investigate a gossanous outcrop visible in satellite imagery. The field season was cut short by a wildfire at Knight Lake.

Regional geology

The BLGB forms part of the Island Lake domain of the northwestern Superior province (Figure GS2017-3-1) and may have been contiguous with supracrustal rocks of the Island Lake greenstone belt, now separated from the BLGB by younger granitoid plutons. Major stratigraphic units of both the Island Lake and Bigstone Lake greenstone belts are divided by most workers into the older Hayes River group, dominated by mafic arc-derived flows and intrusions, and the younger Island Lake group, comprising sedimentary and subordinate volcanic units atop a basal conglomerate (Herd et al., 1987; Stevenson and Turek, 1992). The supracrustal units are generally thought to have been emplaced ca. 2.9–2.7 Ga, although ages are currently better constrained in the Island Lake belt (Neale, 1985; Turek et al., 1986; Herd et al., 1987; Stevenson and Turek, 1992; Parks et al., 2014).

Local geology

Units mapped during the 2017 field season are described in this section from oldest to youngest interpreted age. The ordering of units described in this section corresponds mostly to units shown on PMAP2016-4 (Rinne et al., 2016a), with the exception of the fine-grained gabbro to melagabbro unit (assigned to a lower stratigraphic position), the exclusion of three units not seen in the 2017 mapping area (pyroxenite, ultramafic lapilli tuff and tonalite), and the addition of two units that were not documented in the 2016 mapping area (namely medium-grained gabbro and intermediate volcanic units). All of the rocks have been metamorphosed to upper-greenschist to lower-amphibolite facies; the 'meta' prefix is omitted for brevity.

Lower stratigraphic sequence (Hayes River group)

Rocks of the lower sequence occupy the outermost (north and south) supracrustal portions of both the Bigstone Lake, and the Knight and Wass lakes areas (Figure GS2017-3-2), reflecting a belt-scale syncline. Assigned to the informal Hayes River group, the lower sequence is dominated by mafic to ultramafic flows and intrusions, with subsidiary felsic volcanic and sedimentary units.

Lower mafic volcanic flows

Mafic flows of the lower sequence comprise aphyric, variolitic pillowed basalt and less abundant massive, plagioclase-phyric basalt. The rocks are grey-green to dark grey-green on fresh surfaces and grey-green to lighter grey on most weathered surfaces. Most of the lower basalt outcrops mapped in 2017 were highly strained; where preserved, pillows are typically <40 cm thick and elongated at ~10:1 aspect ratios parallel to the S_3 foliation. Massive, plagioclase-phyric basalt outcrops contain sparse plagioclase phenocrysts <0.5 mm long and, in several locations, are transitional to the fine-grained gabbro described below. Rare interflow greywacke, mudstone and oxide-facies iron formation form a minor component of the lower mafic volcanic unit, typically forming beds <50 cm thick (Rinne et al., 2016b).

Fine- to medium-grained gabbro to melagabbro

Mappable units of massive, fine- to medium-grained gabbro to melagabbro are widespread at several stratigraphic levels throughout the lower stratigraphic sequence (Rinne et al., 2016b; Figure GS2017-3-2). In 2017, gabbro was documented in highly strained outcrops along Wapatinasing Narrows (Figure GS2017-3-2; location f) and the northeastern part of Knight Lake (location i). The gabbro is grey-green on fresh and weathered surfaces, and contains approximately equal parts plagioclase and (chlorite- and actinolite-replaced) pyroxene crystals 1–2 mm long, along with trace amounts of finely disseminated pyrite in a few locations. Although most of the gabbro mapped in 2017 is mafic in composition, gabbro outcrops documented in 2016 were noted to contain gradations from mafic to ultramafic compositions (Rinne et al., 2016b). Medium-grained melagabbro identified inland from the southwestern corner of Bigstone Lake (west of Figure GS2017-3-2) has gradational contacts with komatiitic basalt (Figure GS2017-3-3a) and may thus represent a thick mafic–ultramafic flow. Elsewhere, contacts with adjacent rocks were not observed.

Lower felsic volcanic and volcaniclastic rocks

Felsic volcanic units occur throughout the lower mafic stratigraphy at Bigstone, Knight and Wass lakes (Figure GS2017-3-2; Neale, 1985; Rinne et al., 2016b). Among felsic outcrops described in 2017, most occur at Knight Lake and consist of felsic ash to lapilli tuff, with light grey-beige weathered surfaces and grey fresh surfaces. These rocks contain 50–80% subrounded cream-coloured fragments 0.5–1 mm long (rarely up to 1 cm), along with 1–5% subrounded quartz fragments 1–4 mm

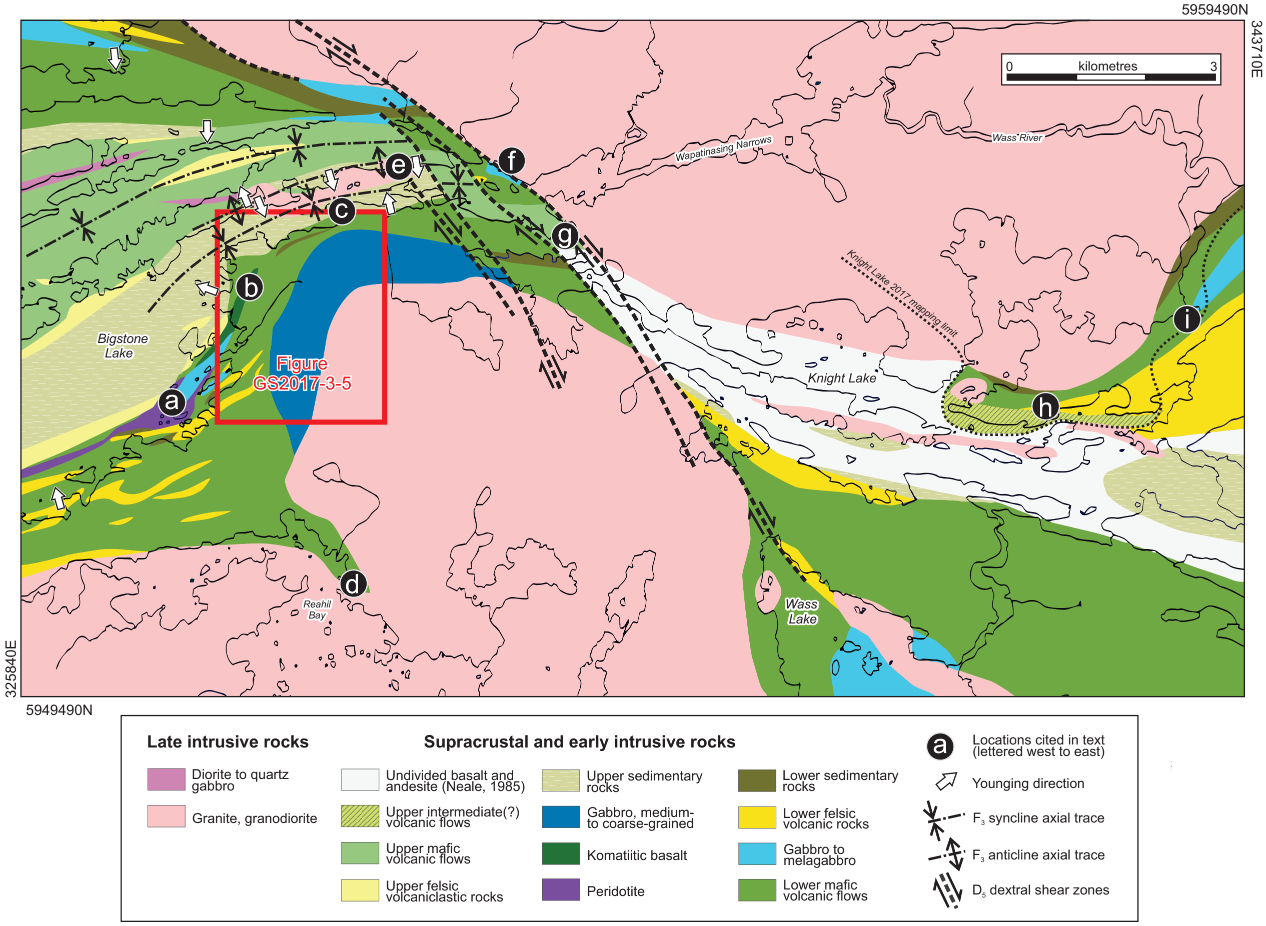

Figure GS2017-3-2: *Simplified geology of the eastern part of Bigstone Lake (modified from Rinne et al., 2016a) and the Knight Lake area (with units south of the 2017 mapping limit mostly after Neale, 1985). Inland geology is based mostly on historical drill data (1938–1988) and traverse stations recorded by McIntosh (1941), Ermanovics et al. (1975), Neale (1984, 1985) and Assessment File 94359 (Manitoba Growth, Enterprise and Trade, Winnipeg). The light grey unit at Knight Lake contains unsubdivided basalt and andesite identified by Neale (1985); it was not visited in 2017. The UTM co-ordinates are in NAD83, zone 15N.*

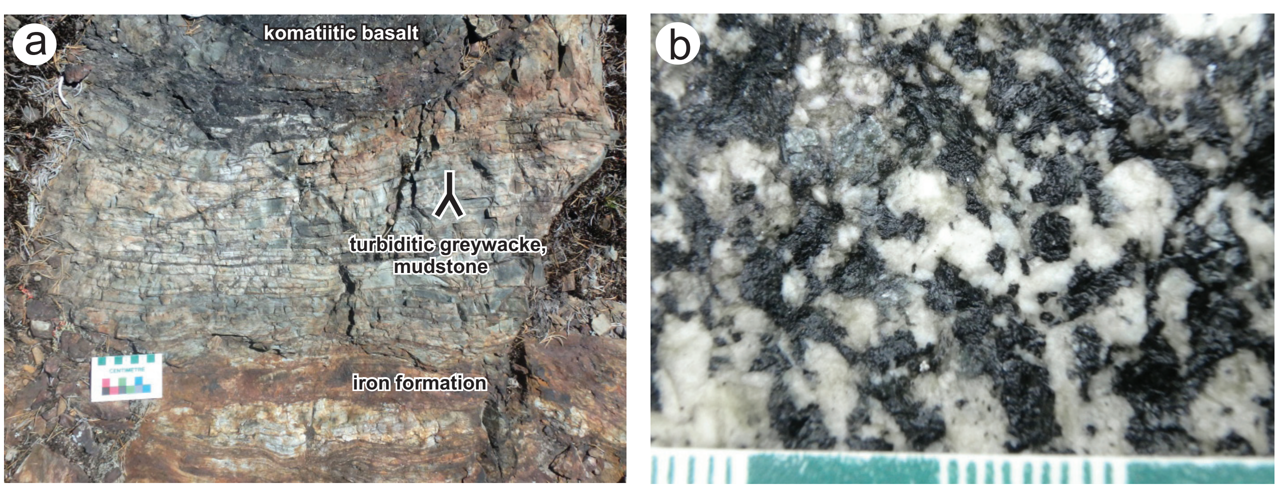

Figure GS2017-3-3: *Outcrop photographs of Bigstone Lake greenstone belt units mapped in 2017, showing **a)** oxide-facies iron formation conformably overlain by turbiditic greywacke and mudstone (younging to top of image) and komatiitic basalt, which grades over several metres to medium-grained melagabbro; **b)** medium- to coarse-grained gabbro, which is host to several quartz-carbonate-sulphide±gold veins (see 'Gold mineralization' section).*

across in a felsic-ash matrix. Two stations at Knight Lake contain well-stratified lapilli tuff to tuff breccia, with ungraded layers 2–30 cm thick transposed parallel to the dominant east-north-east-trending foliation.

Four outcrops of plagioclase-phyric dacite were identified along the east-central part of Knight Lake (Figure GS2017-3-2; location h). The rocks contain a fine-grained, quartz-rich groundmass surrounding 20–35% white, subhedral plagioclase phenocrysts 0.1–1 cm long. The dacite is interpreted to be cogenetic with the adjacent and felsic volcaniclastic rocks described above; however, contacts were not observed.

Lower sedimentary rocks

Sedimentary rocks are rare in the lower stratigraphic sequence, with thin (<50 cm) layers forming a minor component of the previously described lower mafic volcanic unit and thicker packages forming mappable units in only a few locations (Figure GS2017-3-2). Turbiditic greywacke and mudstone make up approximately 95% of the lower sedimentary unit; the remainder consists of rare iron formation and pelitic mudstone.

In 2017, turbiditic greywacke–mudstone beds of the lower sequence were described to be in intrusive contact with granodiorite along the northern margin of the greenstone belt at Knight Lake (Figure GS2017-3-2; north of location i). The grey feldspathic greywacke to darker grey mudstone occurs in beds 0.1–8 cm thick that have been transposed along, and isoclinally folded about, an intense north-northeast-trending foliation; structural facing at this location is ambiguous. The rocks transition along strike to the northeast to a felsic tectonite of presumed sedimentary origin.

Large exposures of the lower sedimentary unit were also identified inland from the southwestern corner of Bigstone Lake (west of the area shown in Figure GS2017-3-2). A northeast-trending ridge, visible as a conspicuous rust-coloured feature in high-resolution satellite imagery, was found to contain a sequence of oxide-facies iron formation, turbiditic greywacke–mudstone and komatiitic basalt to melagabbro (Figure GS2017-3-3a). The iron formation occurs in a northeast-trending package at least 5 m in exposed thickness, with approximately equal parts magnetite and quartz (interpreted as recrystallized chert) beds up to 5 cm thick, along with sparse beds of garnetiferous pelitic mudstone. To the southeast, it transitions conformably to a package of turbiditic greywacke–mudstone <1 m thick (Figure GS2017-3-3a) and is in turn overlain by massive komatiitic basalt that transitions over several metres to medium-grained, massive melagabbro. The northwestern contact of the komatiitic basalt is sharp, subtly undulating and crosscuts bedding; this is interpreted as the basal contact of either a thick flow or sill.

Peridotite

Ultramafic rocks occur in the southwestern and eastern parts of Bigstone Lake (Rinne et al., 2016b). Continued mapping of small islands near the eastern shore of Bigstone Lake (Figure GS2017-3-2; location a) revealed relatively unaltered and low-strain examples of peridotite cumulates, mostly pale olive-green on weathered and fresh surfaces. The rocks contain 80% round olivine cumulus crystals ~0.5 mm across and vary from nonmagnetic to weakly magnetic, with no visible sulphides.

Komatiitic basalt

Mafic–ultramafic volcanic rocks were encountered at three shoreline stations in 2017: two on islands adjacent to the peridotite cumulate described above (forming units too small to display in Figure GS2017-3-2); and another inland of the eastern shore of Bigstone Lake (Figure GS2017-3-2; location b). The rocks are aphanitic, highly strained and were identified on the basis of their darker grey-green colour on fresh surfaces. Geochemical results from pillowed outcrops of this unit sampled in 2016 confirm their primitive composition (e.g., 21–24 wt. % MgO; 44–45 wt. % SiO_2; 900–1200 ppm Ni). Contacts with adjacent units were not observed.

Medium- to coarse-grained gabbro

A large intrusion of medium- to coarse-grained and mostly equigranular gabbro occurs inland of the eastern shore of Bigstone Lake (Figure GS2017-3-2). Weathered surfaces are mottled grey-green to beige and fresh surfaces are grey-green, where least altered (Figure GS2017-3-3b). The rock contains an average of 45% pyroxene and 55% plagioclase crystals that vary from 1 to 4 mm across, along with secondary actinolite and chlorite. The gabbro is homogeneous, aside from local strain partitioning and secondary veins and alteration (see 'Gold mineralization' section). A sharp and irregular intrusive contact with basalt was observed at one location, dipping steeply to the east-southeast.

The medium- to coarse-grained gabbro unit is crosscut by granodiorite dikes at several locations and predates the D_3 deformation event, which is manifest in most gabbro outcrops as a weak northeast-trending penetrative S_3 foliation. The unit may be cogenetic with the gabbro and basalt units described above (e.g., a thick synvolcanic sill emplaced during continued development of the overlying volcanic stratigraphy), or it may represent a later, unrelated episode of mafic magmatism. Pending geochemical analyses may help to resolve its relationship with the host stratigraphy.

Upper stratigraphic sequence (Island Lake group)

The upper sequence rocks at Bigstone, Knight and Wass lakes were interpreted by Herd et al. (1987) as stratigraphically equivalent to the Island Lake group, a dominantly sedimentary package that overlies the Hayes River group in the Island Lake greenstone belt. Neale (1984, 1985) tentatively assigned the upper sequence rocks to a separate group, mostly on the basis of the volcanic units they include (which do not form a major component of the Island Lake group; Neale, 1984). The terminology of Herd et al. (1987) is used in this report; investigations into stratigraphic correlations with the Hayes River and Island Lake groups, including U-Pb geochronology, are ongoing.

Upper sedimentary rocks

Rocks of the upper sedimentary unit dominate the older (stratigraphically lower) part of the Island Lake group. The unit consists mostly of turbiditic greywacke–mudstone and locally contains a basal conglomerate. In 2017, the upper sedimentary unit was described at several locations in the eastern part of Bigstone Lake. The unit was not observed in outcrop farther to the east, although Neale (1985) documented several turbidite packages at Knight Lake (south of the mapping limit in Figure GS2017-3-2).

Polymictic conglomerate

Five outcrops of polymictic conglomerate were identified in 2017 along the southern and eastern shorelines of the eastern part of Bigstone Lake, including one highly strained example within 30 m of the inferred unconformity between the upper sedimentary unit and lower mafic volcanic unit (Figure GS2017-3-2; location c). The conglomerate is grey-green to light tan on weathered surfaces, grey to dark grey on fresh surfaces, poorly sorted and crudely bedded to massive. Rounded to subangular clasts 0.5–15 cm long make up 30–60% of the outcrops and are supported in a fine- to medium-grained quartzofeldspathic greywacke matrix. Clast populations resemble those of the conglomerate units documented in 2016 along the southern and northwestern shorelines of Bigstone Lake (Rinne et al., 2016b). The clasts include: grey, fine-grained to pebbly feldspathic greywacke; white, crystalline quartz clasts (possibly vein quartz); light tan to light grey, aphanitic clasts of felsic composition (possibly derived from felsic igneous rocks); and dark grey-green, aphanitic and aphyric mafic clasts (interpreted as basalt derived from the lower mafic volcanic units).

On the basis of clast types and stratigraphic position, the basal conglomerate mapped in 2017 is interpreted as equivalent to polymictic conglomerate or scarp-facies breccia described in the southwestern and northwestern parts of Bigstone Lake (Rinne et al., 2016b) and could thus mark the unconformity between the Hayes River and Island Lake groups; however, this contact has not been observed.

Coarse quartz sandstone

A distinctive coarse sandstone subunit was identified in 2017 along some southeastern shorelines in the eastern part of Bigstone Lake (stations north and west of location b in Figure GS2017-3-2). The sandstone is grey to light tan on weathered surfaces, dark grey to grey-beige on fresh surfaces and occurs in ungraded beds ranging from 2 to 70 cm in exposed thickness. Subangular quartz grains 0.5–3 mm across are distinctive, making up about 60% of the rock, and are supported in a semipelitic mudstone to fine-grained sandstone matrix. Conformable contacts with turbiditic greywacke–mudstone were observed at several locations; contacts with other units were not observed.

Feldspathic greywacke–mudstone turbidite

Most outcrops of the upper sedimentary rocks described in 2017 consist of planar-bedded turbidites, comprising fine-grained feldspathic greywacke and mudstone. The rocks are grey to dark grey on fresh and weathered surfaces and interbedded in a few locations with garnetiferous metapelite beds <40 cm thick, chloritic laminae, and coarse and ungraded quartz sandstone beds. The turbidite beds, commonly transposed parallel to the major S_3 fabric, range from 1 to 30 cm in thickness. Where graded bedding is well preserved, the beds exhibit reversals in younging direction that define a series of belt-parallel F_3 isoclinal folds (Figure GS2017-3-2).

Upper felsic volcaniclastic rocks

The upper felsic unit was identified at only one station in 2017, on the eastern shore of Bigstone Lake (~300 m west of location b in Figure GS2017-3-2). The small outcrop in this location consists of felsic lapilli tuff that contains densely packed plagioclase fragments 0.5–2.5 mm across, in a felsic, fuchsite-altered ash matrix and includes a layer of monomictic felsic volcanic breccia 40 cm thick, with plagioclase-phyric fragments up to 20 cm long. Although contacts were not exposed, conformity with the adjacent upper sedimentary unit was previously documented nearer the centre of Bigstone Lake (Rinne et al., 2016b). Felsic lapilli tuff was also noted to occur conformably throughout the upper mafic volcanic unit (Figure GS2017-3-2).

Upper mafic volcanic flows

The upper mafic flow unit consists of pillow basalt flows that have least altered compositions identical to the lower flow unit. A key distinguishing feature is the presence of abundant (<20%) vesicles in low-strain outcrops of the upper flows. Along the southeast-trending structural corridor at the eastern end of Bigstone Lake (e.g., location g in Figure GS2017-3-2), primary features have been destroyed by deformation. The locations of the upper mafic volcanic packages in this corridor are inferred to preserve stratigraphic continuity with the greenstone belt to the west and east.

Upper intermediate(?) volcanic flows

Highly strained outcrops along the eastern half of Knight Lake (south of location h in Figure GS2017-3-2) were described in the field as either intermediate tectonite or strongly foliated pillowed andesite. In comparison to least altered basalt, these rocks appear slightly lighter grey-green on both weathered and fresh surfaces. Contacts with adjacent units were not identified.

Neale (1985) noted “extensive silicification” in rocks exposed in central Knight Lake, implying the possibility that the ‘intermediate’ rocks are altered basalt as opposed to primary andesite. The upper intermediate volcanic unit could therefore be equivalent to mafic flow units in either the upper or lower sequence. Further work (including the acquisition of geochemical data from least altered equivalents and detailed mapping to establish the nature of the contacts between basalt and silicified basalt) should help to constrain both the primary composition and stratigraphic position of this unit.

Late intrusive rocks

Diorite to quartz gabbro

Porphyritic diorite dikes crosscut all supracrustal units at Bigstone Lake (Rinne et al., 2016b). Examples described in 2017 are light grey dikes up to 60 cm wide, with approximately 10% plagioclase phenocrysts (1–12 mm long) and 10% hornblende phenocrysts (1–6 mm long) in a light grey, fine-grained quartzofeldspathic groundmass. All diorite dikes were overprinted by a steeply dipping S_3 foliation and are in places tightly folded about northeast- to east-trending F_3 axial planes. Quartz gabbro, a rare intrusive phase grouped with the diorite intrusions (Rinne, 2016b), was not encountered during the 2017 field season.

Granite to granodiorite

In addition to thin (<1 m) granitoid dikes occurring throughout the BLGB, granitoid intrusions and contacts were examined along Reahil Bay (Figure GS2017-3-2; location d), the eastern part of Bigstone Lake (near locations e and f), several locations along the northeastern margin of the BLGB at Knight Lake (along the bay north of location h) and 22 widely spaced locations along the Wapatinasing Narrows and Wass River (Figure GS2017-3-2). As described by Rinne et al. (2016b), the intrusions are dominantly medium grained and vary in composition from granodiorite to syenogranite. Consistent with earlier field observations, all contacts between the BLGB and its surrounding granitoid batholith(s) appear to be intrusive and predate D_3 deformation. Granitoid dikes (commonly tightly folded about F_3 axial planes) typically become more abundant within supracrustal units nearest the margins of the greenstone belt; similarly, fine-grained mafic xenoliths up to 2 m across, interpreted to be derived from the BLGB, are more common within granitoid outcrops nearest the greenstone belt.

Late mafic dikes

Minor mafic dikes, which are too small to display as a separate map unit, occur throughout the BLGB, including some that crosscut the previously described diorite dikes (Rinne et al., 2016b). Almost all occurrences are grey-green, aphanitic and aphyric dikes <30 cm thick. A few thicker examples were documented in 2017, notably four fine-grained gabbro dikes up to 1.2 m wide that crosscut the granodiorite batholith in Wapatinasing Narrows. The late mafic dikes, representing the latest intrusive phase recognized in the BLGB, predate D_3 deformation.

Structural geology

Rocks of the BLGB record a complex structural history, as summarized by Rinne et al. (2016b). Results of the 2017 field season are relevant mostly to the D_3, D_5 and D_6 events, as discussed below.

D_3 deformation

The lower stratigraphic units of the BLGB trace the limbs of a broadly northeast- to east-trending and steeply dipping regional F_3 syncline (Figure GS2017-3-2). At Bigstone Lake, the surface trace of the regional F_3 syncline is inferred to extend along the centre of the upper mafic volcanic unit (the northernmost syncline shown in Figure GS2017-3-2). At Knight Lake and Wass Lake, the axial trace of the regional syncline has not yet been defined, but its general location is indicated by the repetition of lower stratigraphic units along the north and south portions of the BLGB (Figure GS2017-3-2; Neale et al., 1986). The syncline is accompanied throughout the BLGB by parasitic F_3 anticlines and synclines; in areas mapped in 2017, these axial planes were not well resolved outside of turbidite-bearing units.

A penetrative and steeply dipping S_3 foliation is the dominant structure in most outcrops, and is broadly parallel to the F_3 axial planes in Figure GS2017-3-2. Moving west to east, the dominant trend of the S_3 foliation in the BLGB varies from

- northeast in the centre of Bigstone Lake (near location a);
- east in the eastern part of Bigstone Lake (location g);
- east-southeast in the western and central parts of Knight Lake (south of location h); to
- northeast in the northeastern part of Knight Lake (location i).

Outside of the BLGB, a pervasive S_3 foliation is commonly observed near batholith margins. However, toward batholith centres most of the granitoid outcrops were noted to contain only steeply dipping spaced cleavages that trend southeast and north-northeast; these are respectively interpreted to correspond to the D_5 and D_6 deformation events.

D_5 deformation

D_5 deformation is expressed throughout the western part of the BLGB as a series of dominantly southeast-trending and steeply dipping shear zones (Rinne et al., 2016b), and is interpreted to be responsible for the regional dextral offset between supracrustal units at Bigstone Lake and Knight and Wass lakes. Rather than a single fault or shear zone (an interpretation offered by Herd et al., 1987), results from 2017 suggest that the regional offset along the centre of the map area was accommodated by a series of dextral shear zones and related planar fabric, resulting in a highly strained corridor containing several offset panels (Figure GS2017-3-2). Rocks in this corridor (e.g., between locations e, f, and g in Figure GS2017-3-2) commonly show a well-developed spaced shear-band cleavage with dextral asymmetry (e.g., Figure GS2017-3-4a). Minor (<20 cm wide) southeast-striking dextral D_5 shears were identified at several stations throughout the structural corridor, and are interpreted to mirror the regional D_5 structure.

D_6 deformation

Northeast- to north-northeast-trending and steeply dipping shear zones from 1 cm to 5 m wide were measured at nine stations in the eastern half of Bigstone Lake. The late shear zones crosscut all previously identified structures (e.g., Figure GS2017-3-4a, b) and show evidence of sinistral

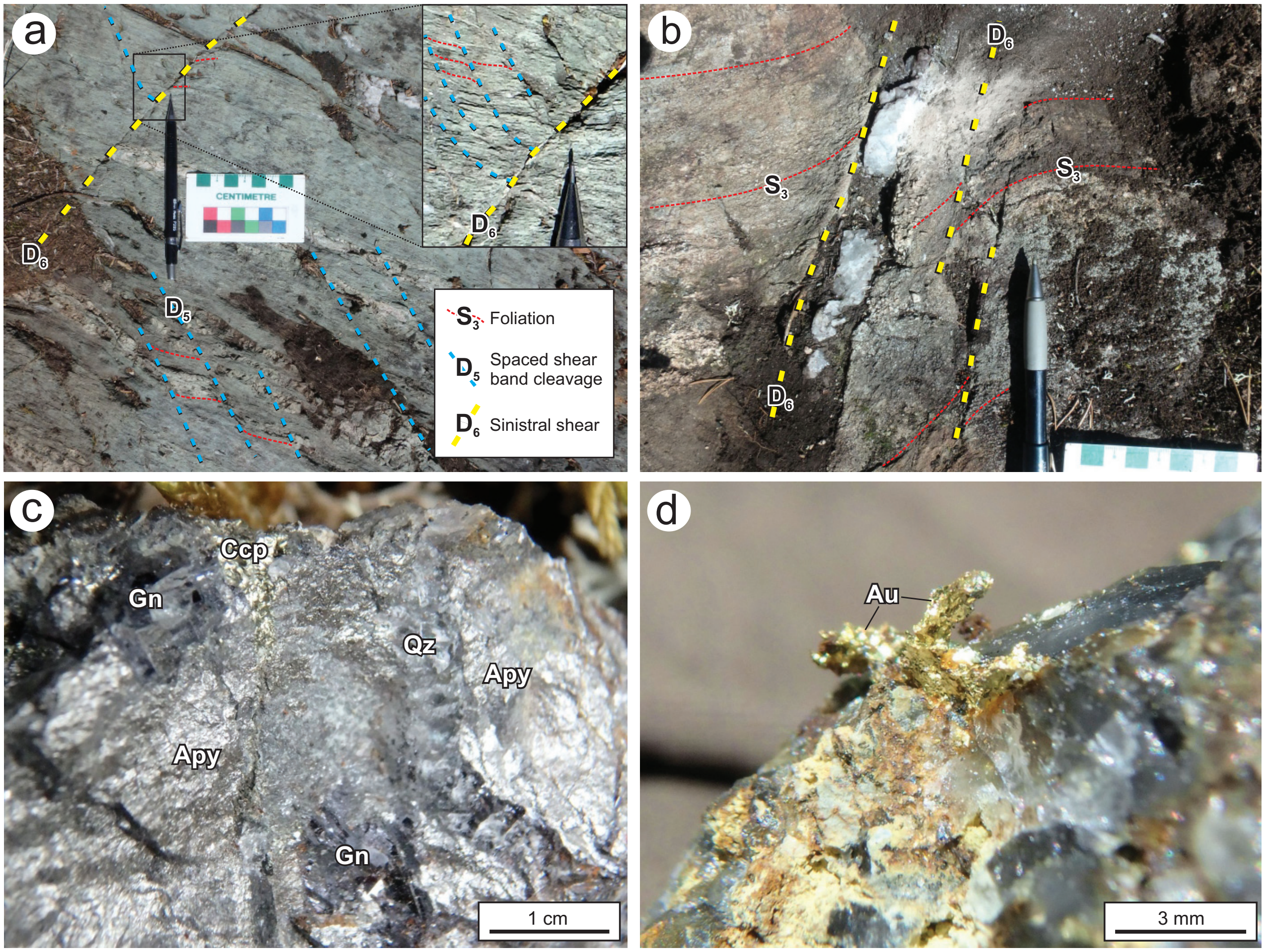

Figure GS2017-3-4: *Photographs illustrating relationships between late-stage shear structures and base-metal–sulphide±gold vein mineralization in the Bigstone Lake greenstone belt:* ***a)*** *S_3 foliation and D_5 shear-band cleavage planes showing deflection along the margins of a minor sinistral D_6 shear;* ***b)*** *north-northeast-trending quartz vein (+trace pyrite) hosted within and parallel to D_6 shear zones showing sinistral deflection of the S_3 foliation;* ***c)*** *arsenopyrite (Apy), galena (Gn) and chalcopyrite (Ccp) in a north-northeast-trending quartz (Qz) vein that ranges up to 60 cm wide;* ***d)*** *wire-gold aggregate exposed on the broken surface of a quartz-calcite-galena-pyrite-chalcopyrite vein.*

movement. Although crosscutting relationships documented so far indicate that D_6 occurred after D_5, further study may indicate mutually crosscutting relationships consistent with a conjugate array of both dextral and sinistral structures. Inland mapping results suggest that the D_6 (and probably D_5) shear structures controlled the locations of vein-hosted gold mineralization.

Gold mineralization

Exploration history

Surface exploration was carried out between 1934 and 1938 in areas east of Bigstone Lake, resulting in the discovery of the Diamond Queen gold occurrence (Figure GS2017-3-5a). In 1938, God's Lake Gold Mines Ltd. bored a series of closely spaced drillholes along the two veins (Figure GS2017-3-5b) to depths of between 19 and 77 m (Assessment File 91148).

Noranda Exploration Company Ltd. collected surface samples from the area from 1983 to 1986. They recognized a 'zone of carbonatization and quartz-carbonate veining' spatially associated with the gabbro contact, along which they discovered a quartz-sulphide vein 50 cm wide that assayed 72.3 ppm Au (Assessment File 94359). The discovery was made approximately 1.5 km north-northeast of the main Diamond Queen vein (Figure GS2017-3-5a) and likely corresponds (based on a hand-drawn sample-location map) with occurrence 7 in Figure GS2017-3-5b. Despite noting promising results, Noranda carried out no drilling on the gold occurrences and abandoned the Bigstone Lake property after 1986.

2017 field mapping results

Several inland traverses were completed in 2017 in order to confirm the gold occurrences, document the vein assemblages and wallrock alteration, investigate the timing and structural

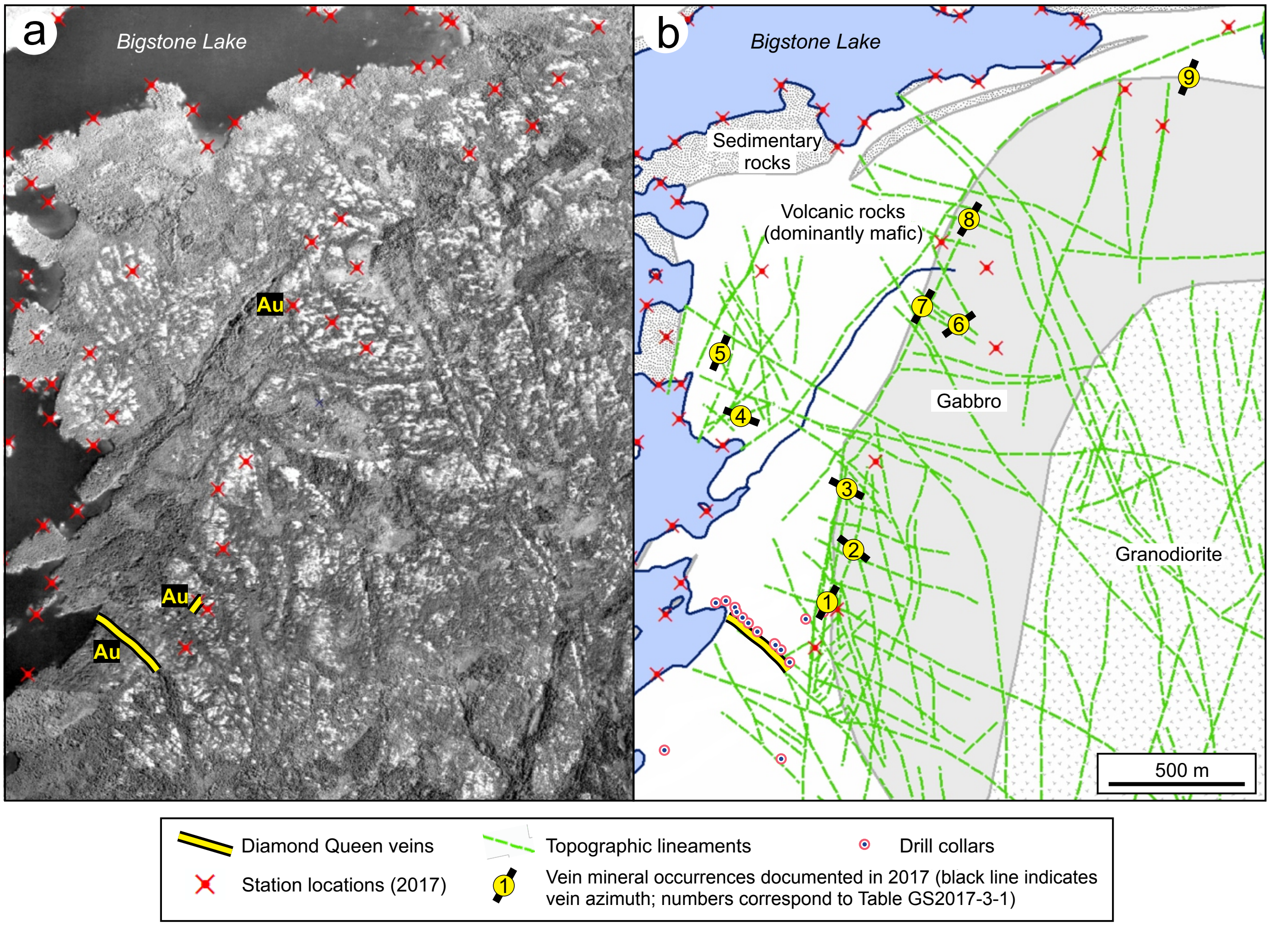

Figure GS2017-3-5: *Locations of quartz-sulphide±gold vein occurrences associated with late shears east of Bigstone Lake:* ***a)*** *airphoto imagery with three known gold occurrences indicated;* ***b)*** *simplified geology, with topographic lineaments, and vein occurrences documented in 2017 numbered south to north. Lineaments are interpreted from airphoto and high-resolution satellite imagery, many likely corresponding to southeast- and north-northeast-trending shear structures that are respectively associated with D_5 and D_6 deformation. The locations of the two Diamond Queen gold veins and adjacent shallow drilling are based on a reassessment of hand-drawn shorelines in Assessment File 91148, Manitoba Growth, Enterprise and Trade, Winnipeg.*

controls on the mineralization, and examine selected north-northeast- and southeast-trending topographic lineaments. Relevant findings are summarized in Table GS2017-3-1 and Figure GS2017-3-5b, and include the recognition of two dominant gold-bearing vein sets, which are described below.

East-southeast- to southeast-trending veins

The main Diamond Queen vein is the first-discovered and largest of the three known gold-mineralized veins in the BLGB, traced in 1938 to a strike length of approximately 350 m (Table GS2017-3-1; Figure GS2017-3-5; McIntosh, 1941; Assessment File 91148). This vein is reported to dip steeply toward the northeast, and contains quartz, pyrite, chalcopyrite and gold (McIntosh, 1941). A planned visit was not possible during the 2017 field season.

Minor quartz-pyrite±chalcopyrite±chlorite veins up to 30 cm wide were described at three locations north of the Diamond Queen vein (occurrences 2–4 in Table GS2017-3-1 and Figure GS2017-3-5b). Striking 114–126° and dipping 69–81° to the southwest, they are hosted within and/or trend parallel to dextral D_5 shear structures. They are potentially related to the southeast-trending Diamond Queen vein on the basis of their similar orientation and contained mineral assemblage; assay results are pending.

North-northeast- to northeast-trending veins

Several quartz-calcite-galena-pyrite-chalcopyrite-arsenopyrite±gold veins were found mostly within 100 m of the contact between gabbro and basalt (Figure GS2017-3-4c, d; occurrences 1 and 5–9 in Table GS2017-3-1 and Figure GS2017-3-5b). The veins range in thickness from 1 cm to 2 m wide, strike 020–034°, and dip 77–88° to the southeast (excepting occurrence 6, which dips steeply to the northwest; Table GS2017-3-1). A few of the north-northeast-trending veins were noted to occur within, but do not appear to have been deformed by, sinistral D_6 shear zones (Figure GS2017-3-4b; Table GS2017-3-1);

Table GS2017-3-1: Summary of vein occurrences east of Bigstone Lake. Numbered occurrences were documented in 2017, with locations shown in Figure GS2017-3-5b. Minor occurrences are included where they illustrate relevant structural relationships.

Vein occurrence	Description (vein mineral assemblage, orientation, associated structures)
Diamond Queen	Quartz-pyrite-chalcopyrite-gold vein, up to 1 m wide; striking average 310/80° to the northeast (McIntosh, 1941; Assessment File 91148). The main Diamond Queen vein was traced by drilling and trenching in 1938 to a strike length of approximately 350 m. Not visited in 2017.
1	Quartz-calcite-galena-pyrite-chalcopyrite-arsenopyrite-gold vein, average 30 cm wide, thinning locally to ~2 cm; striking average 025/79° to the southeast. Trace visible gold occurs in irregular or wiry aggregates <5 mm long (Figure GS2017-3-4d). Assay results are pending. Wallrock is sericite-chlorite-quartz-pyrite schist, interpreted as sericite-altered basalt. Likely corresponds to the northernmost extension of the smaller of two Diamond Queen veins, which was traced in 1938 to a strike length of ~50 m (Assessment File 91148).
2	Quartz-pyrite-chalcopyrite (trace) vein, red, 15 cm wide; striking 126/82° to the southwest.
3	Quartz-chlorite-pyrite vein, 30 cm wide; striking 118/69° to the southwest. Vein contains a D6 cleavage at 202/83° west.
4	Quartz-pyrite veins, 1–6 cm wide; occurring within D_5 dextral shear zones striking 114/81° to the southwest.
5	Quartz-chlorite-pyrite veins, 1–5 cm wide; occurring within D_6 sinistral shear zones striking 024/77° to the southeast.
6	Quartz-galena-chalcopyrite-arsenopyrite vein, 40–60 cm wide; striking 236/78° to the northwest (Figure GS2017-3-4c).
7	Quartz-galena-pyrite-chalcopyrite veins, 10–60 cm wide; striking between 020/84° to the east and 031/80° to the southeast. Wallrock is calcite-altered gabbro. Previously sampled and tagged with flagging tape (label illegible); location roughly matches sample collected by Noranda Exploration Company Ltd. in 1986, with reported 72.3 ppm Au (Assessment File 94359).
8	Quartz-pyrite-chalcopyrite-galena-arsenopyrite ± sphalerite ± secondary covellite veins, 0.2–2 m wide; striking between 025/80° and 034/85° to the southeast. Wallrock is weakly calcite-altered gabbro.
9	Quartz-pyrite (trace) vein 1–3 cm wide; occurring within a D_6 sinistral shear zone striking 023/88° to the southeast (Figure GS2017-3-4b).

the veins are therefore interpreted to have formed during, or possibly following, the D_6 deformation event.

One vein containing visible gold (occurrence 1), identified in 2017 near the centre of a mostly swamp-filled lineament, was traced for approximately 10 m along strike to the south-southwest to a submerged and heavily revegetated blast pit ~1 m wide. Historical drilling plans (God's Lake Gold Mines Ltd.; Assessment File 91148) indicate that this gold occurrence represents the north-northeast portion of the smaller of two Diamond Queen veins defined in 1938 (Figure GS2017-3-5a). The Diamond Queen veins were previously recorded (Manitoba Mineral Resources, 2013) to occur approximately 1 km north of their location indicated in Figure GS2017-3-5.

Alteration

Most of the quartz-sulphide±gold veins mapped in 2017 are hosted in weakly calcite-altered gabbro. Although the distribution of stations is not sufficient to define alteration zones, Noranda geologists noted a zone of carbonate alteration along the dominantly north-northeast-trending gabbro contact (Assessment File 94359). This spatial relationship may indicate that carbonate alteration occurred during development of the north-northeast-trending D_6 structures and veins, although it is also possible that this alteration may be more regional and could entirely predate the D_6 deformation.

The hostrock to the previously described gold-bearing vein (occurrence 1) is tentatively interpreted as altered basalt, based on a small (~10 cm wide) exposure of north-northeast-foliated sericite-chlorite-quartz-pyrite schist and an adjacent outcrop of relatively unaltered massive basalt. Haloes of sericite are commonly documented in the wallrock to Archean shear-hosted gold deposits (e.g., Groves et al., 1998), often representing the most proximal alteration facies. A visit in 2018 is planned to assess the wallrock alteration in better exposed outcrop, and to sample and document the main Diamond Queen vein.

Exploration implications

The available evidence suggests significant potential for lode-gold mineralization east of Bigstone Lake. The most prominent structures in the area are expressed as swamp-filled or densely vegetated valleys (Figure GS2017-3-5a), which presents a challenge for surface exploration. However, modern mapping methods can reveal vectors to buried mineralization and most of the area remains unexplored by drilling (Figure GS2017-3-5b). The exploration targets discussed in this section, relating mostly to the density and refraction of probable controlling structures, are largely untested.

The density of topographic lineaments in Figure GS2017-3-5b could denote increased structural complexity and associated potential for vein development along the western half of the gabbro unit, particularly near occurrence 1. However, interpreted lineament density is only locally relevant as sections of the map area are obscured by overburden. Zones of densely spaced shears could, for example, lie below cover in the creek valley that trends north-northeast of the main Diamond Queen vein (i.e., between occurrences 3 and 4, or west of gold occurrences 1 and 7). Digital elevation models produced from LiDAR (light detection and ranging) data have proven useful for tracing structure in many Archean gold districts and can help to 'see through' the masking effects of vegetation and thin overburden.

Some of the most prominent east-southeast- to southeast-trending lineaments show clockwise refraction moving southeast across the contact from basalt to gabbro, or in a few cases through the centre of the gabbro unit. Examples include the lineaments north and east of occurrence 3 and east of occurrence 8 (Figure GS2017-3-5b). Clockwise bends along dextral brittle–ductile shears are likely zones of structural dilation and vein infill; a nearly identical scenario has been described at the Rice Lake mine in the Rice Lake greenstone belt of southern Manitoba, wherein the thickest gold-bearing vein segments are associated with the deflection of shears across a gabbro sill contact (Anderson, 2013; D.A. Rhys, unpublished technical report prepared for Harmony Gold (Canada) Inc., 2001).

Several of the north-northeast-trending lineaments occur near or along the gabbro contact (Figure GS2017-3-5b). Any bends or irregularities along the gabbro margin could have generated splays or dilatant zones in contact-parallel shears. Areas of interest in Figure GS2017-3-5b include the curving gabbro contact between occurrences 8 and 9; the gabbro margin north of occurrence 3; and the zone of possible curvilinear splays south of occurrence 1.

At the Rice Lake mine, the shears that host significant gold mineralization have also produced measurable offsets of the host gabbro unit (Anderson, 2013; D.A. Rhys, unpublished technical report prepared for Harmony Gold (Canada) Inc., 2001). Detailed mapping of the gabbro contact at Bigstone Lake, including careful attention paid to evidence of offset, could therefore prove to be an effective strategy to identify new drilling targets. A detailed mapping program may also lead to the recognition of chemically favourable units (e.g., iron formation), alteration zonation (e.g., transitions from chlorite-calcite to vein-proximal ankerite-sericite-pyrite), systematic patterns in pathfinder-element concentrations (e.g., W, As, Bi, B) or other vectors to lode-gold mineralization (Ames et al., 1988; Groves et al., 1998).

Economic considerations

Submarine bimodal volcanic rocks of the BLGB exhibit many characteristics that imply broad potential for VMS mineralization, as discussed in Rinne (2016b). Ultramafic units in the lower stratigraphic package are also possible hosts to magmatic Ni-Cu (±PGE, Cr) mineralization, perhaps similar to the Nickel Island occurrence hosted in potentially equivalent ultramafic units at Island Lake.

Calcite and sericite alteration, in addition to calcite and Cr-bearing mica alteration assemblages documented regionally (Rinne et al., 2016b), may be important guides to lode-gold mineralization in the BLGB (e.g., MacGeehan and Hodgson, 1982; Moritz and Crocket, 1990; Groves et al., 1998). Results from this summer's fieldwork confirm the occurrence of visible gold in quartz-calcite-sulphide veins, and demonstrate that the mineralization is controlled by late shears within a package of dominantly mafic and carbonate (±sericite)-altered stratigraphy. Collectively, these features warrant further attention including, but not limited to, subsurface investigations north-northeast of the Diamond Queen veins.

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References

Ames, D.E. 1988: Stratigraphy and alteration of gabbroic rocks near the San Antonio gold mine in the Rice Lake area, southeastern Manitoba; M.Sc. thesis, Carleton University, Ottawa, Ontario, 202 p.

Anderson, S.D. 2013: The Rice Lake mine trend, Manitoba: regional setting, host rock stratigraphy and structural evolution of a classical Archean orogenic gold system; Mineralogical Association of Canada-Geological Association of Canada, Joint Annual Meeting, Winnipeg, MB, May 22–24, 2013, Field Trip Guidebook FT-A1; Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, Open File OF2013-4, 47 p.

Ermanovics, I.F., Park, G., Hill, J. and Goetz, P.A. 1975: Geology of Island Lake map area (53E), Manitoba and Ontario; Geological Survey of Canada, Report of Activities, Part A, Paper 75-1A, p. 311–316.

Groves, D.I., Goldfarb, R.J., Gebre-Mariam, M., Hagemann, S.G. and Robert, F. 1998: Orogenic gold deposits: a proposed classification in the context of their crustal distribution and relationship to other gold deposit types; Ore Geology Reviews, v. 13, p. 7–27.

Herd, R.K., Currie, K.L. and Ermanovics, I.F. 1987: Island Lake area, Manitoba and Ontario; Geological Survey of Canada, Map 1646A, scale 1:250 000, with descriptive notes.

MacGeehan, P.J. and Hodgson C.J. 1982: Environments of gold mineralization in the Campbell Red Lake and Dickenson mines, Red Lake district, Ontario; *in* Geology of Canadian Gold Deposits, R.W. Hodder and W. Petruk (ed.), Canadian Institute of Mining and Metallurgy Special Volume 24, p. 184–207.

Manitoba Mineral Resources 2013: Bedrock geology, Manitoba; *in* Map Gallery–Geoscientific Maps, Manitoba Mineral Resources, URL <http://web33.gov.mb.ca/mapgallery/mgg-gmm.html> [September 2017].

McIntosh, R.T. 1941: Bigstone Lake area; Manitoba Mines and Natural Resources, Mines Branch, Publication 38-1, 12 p., map at 1:63 360 scale.

Moritz, R.P. and Crocket, J.H. 1990: Mechanics of formation of the gold-bearing quartz-fuchsite vein at the Dome mine, Timmins area, Ontario; Canadian Journal of Earth Sciences, v. 27, no. 12, p. 1609–1620.

Neale, K.L. 1984: Bigstone Lake project; *in* Report of Field Activities 1984, Manitoba Energy and Mines; Mineral Resources, p. 126–128.

Neale, K.L. 1985: Geological investigations in the Knight Lake–Bigstone Lake area; *in* Report of Field Activities 1985, Manitoba Energy and Mines; Geological Services/Mines Branch, p. 200–202.

Neale, K.L., Bardsley, J.G. and Lemoine, R.M. 1986: Bigstone Lake; Manitoba Energy and Mines; Minerals Division, Preliminary Map 1986B-1, scale 1:20 000.

Parks, J., Lin, S., Davis, D.W., Yang, X.-M., Creaser, R.A. and Corkery, M.T. 2014: Meso- and Neoarchean evolution of the Island Lake greenstone belt and the northwestern Superior Province: Evidence from lithogeochemistry, Nd isotope data, and U–Pb zircon geochronology; Precambrian Research, v. 246, p 160–179.

Pilkington, M. and Thomas, M.D. 2001: Magnetic and gravity maps with interpreted Precambrian basement, Manitoba: Geological Survey of Canada, Open File 3739, 4 maps, scale 1:1 500 000.

Rinne, M.L., Anderson, S.D. and Reid, K.D. 2016a: Bedrock geology of Bigstone Lake, Manitoba (parts of NTS 53E12, 13), Manitoba Growth, Enterprise and Trade, Manitoba Geological Survey, Preliminary Map PMAP2016-4, scale 1:20 000.

Rinne, M.L., Anderson, S.D. and Reid, K.D. 2016b: Preliminary results of bedrock mapping at Bigstone Lake, northwestern Superior province, Manitoba (parts of NTS 53E12, 13); *in* Report of Activities 2016, Manitoba Growth, Enterprise and Trade, Manitoba Geological Survey, p. 51–62.

Stevenson, R.K. and Turek, A. 1992: An isotopic study of the Island Lake Greenstone Belt, Manitoba: crustal evolution and progressive cratonization in the Late Archean; Canadian Journal of Earth Sciences, v. 29, p. 2200–2210.

Turek, A., Carson, T.M., Smith, P.E., Van Schmus, W.R. and Weber, W. 1986: U-Pb zircon ages for rocks from the Island Lake greenstone belt, Manitoba; Canadian Journal of Earth Sciences, v. 23, p. 92–106.