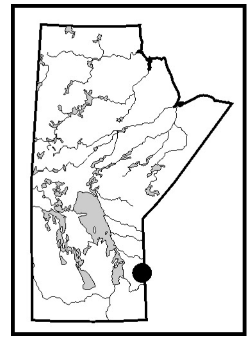
GS-15 Update and economic significance of geological mapping in the Garner–Gem lakes area, Rice Lake greenstone belt, southeastern Manitoba (NTS 52L11 and 14)

by S.D. Anderson



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Summary

In the 2006 field season, a six-week program of 1:20 000 scale bedrock mapping was completed in the Gem Lake area in order to extend detailed mapping coverage into the poorly understood and complex areas east of the Manigotagan River between Garner Lake and Gem Lake, and south of Gem Lake between Lily Lake and Slate Lake. This work, which included concurrent sampling for lithogeochemistry and U-Pb geochronology, has resulted in a better understanding of the rock types, stratigraphy, structure and deformation history of the various supracrustal assemblages in the Garner–Gem lakes area. The nature, distribution and stratigraphic setting of FII–FIII rhyolite (Anderson, 2005), which exhibits evidence of volcanic-hosted massive sulphide (VHMS) potential, have also been significantly clarified. In addition, this work provides an improved geological context for a series of locally auriferous stockwork-breccia quartz-vein systems north of Gem Lake. One of these systems can be traced for 1.2 km along strike and appears to be developed along a brittle fault in the footwall of a first-order, domain-bounding shear zone that coincides with a map-scale transition from greenschist- to amphibolite-facies regional metamorphism. Similar transitions are spatially associated with major lode-gold deposits in other Archean greenstone belts and are considered to indicate areas of enhanced exploration potential.

Introduction

The Rice Lake greenstone belt is situated in the western Uchi Subprovince of the Archean Superior Province, and is flanked to the north by the ca. 3.0 Ga North Caribou continental terrane and to the south by ca. 2.69 Ga paragneiss and granitoid plutons of the English River Subprovince (Figure GS-15-1). The Rice Lake belt consists mainly of Meso- and Neoarchean, mafic to intermediate volcanic and volcaniclastic rocks, constituting several distinct lithotectonic assemblages (e.g., Poulsen et al., 1996; Bailes et al., 2003). In the southeastern Rice Lake belt, these assemblages include the Mesoarchean Garner assemblage and the Neoarchean Bidou, Gem and Edmunds assemblages, which provide a punctuated record of magmatism, sedimentation and orogenesis spanning roughly 200 m.y.

In 2002, the Manitoba Geological Survey initiated a program of bedrock mapping, structural analysis, lithogeochemistry, Sm-Nd isotope studies and U-Pb geochronology in the geologically complex and poorly understood Garner–Gem lakes area, which is located 45 km southeast of Bissett, Manitoba, in the southeastern extremity of the Rice Lake greenstone belt (Figure GS-15-1). This area contains key exposures of the principal supracrustal assemblages in the southeastern Rice Lake belt, and thus represents an important area for understanding the tectonostratigraphy, tectonic evolution and metallogeny of the belt as a whole (e.g., Corkery, 1995). The results of fieldwork completed at Garner Lake in 2002 and 2003 were summarized by Anderson (2002, 2003a) and presented on Preliminary Map PMAP2003-1 (Anderson, 2003b). Anderson (2005) summarized the preliminary results of reconnaissance geological mapping and lithogeochemistry in the Gem Lake area, which was completed during portions of the 2003, 2004 and 2005 field seasons.

In 2006, approximately 6 weeks of 1:20 000 scale geological mapping were conducted at Gem Lake in order to extend the mapping coverage outward from the shoreline bedrock exposures mapped during the 2003–2005 reconnaissance work. The mapping was mainly focused on the poorly understood area east of the Manigotagan River between Garner Lake and Gem Lake (Figure GS-15-2) and the geologically complex Lily–Slate lakes area south of Gem Lake. The goals of this mapping program were to 1) gain a better understanding of the rock types, stratigraphy, structure and deformation history of the various supracrustal assemblages, with particular emphasis on their contact relationships; 2) further document the nature and distribution of FII and FIII (Lesher et al., 1986) rhyolitic volcanic rocks described by Anderson (2005) and assess their VHMS potential; and 3) update the lithostratigraphic, tectonic and metallogenic framework for the southeastern Rice Lake belt.

To complement the existing geochemical database, 30 representative samples of least-altered volcanic rock types were collected in 2006 and analyzed for a full suite of major, trace and rare earth elements (REE) by instrumental neutron activation and inductively coupled plasma–mass spectrometry. In addition, two samples of felsic volcaniclastic rocks were collected for U-Pb geochronological analysis to further constrain the age of volcanism and sedimentation in the southeastern Rice

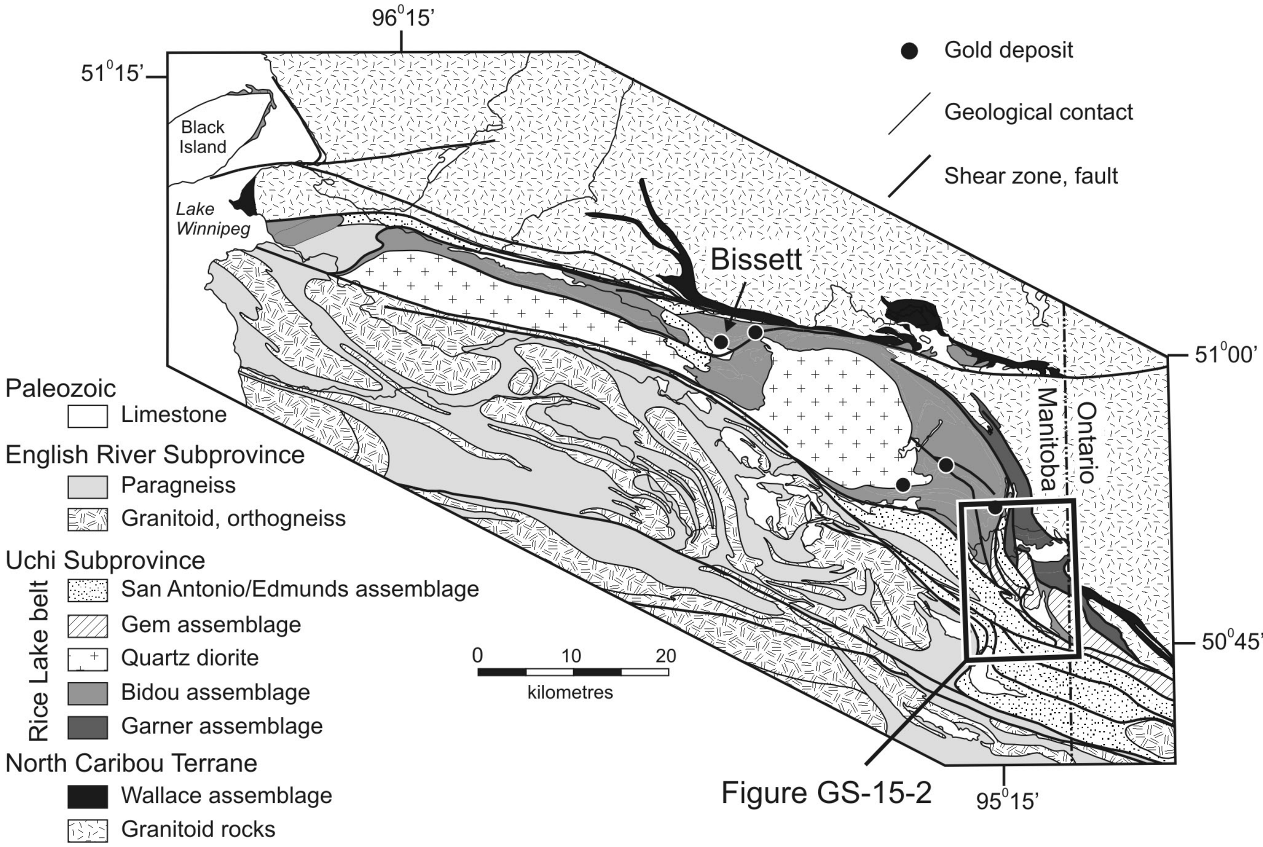

Figure GS-15-1: *Simplified regional geology of the Rice Lake greenstone belt, showing the principal lithotectonic assemblages and the location of Figure GS-15-2.*

Lake belt. In this report, the results of the 2006 mapping program are incorporated with the results of previous mapping and lithogeochemistry to provide an updated geological framework for the Garner–Gem lakes area.

Structural framework

As described by Anderson (2003a, 2004), mesoscopic overprinting relationships indicate at least six generations of ductile deformation structure in the eastern portion of the Rice Lake greenstone belt. In the Garner–Gem lakes area, the map patterns of the various supracrustal assemblages define a series of generally northwest-trending, relatively low-strain lithostructural domains, separated by a complex network of ductile and ductile-brittle high-strain zones (Figure GS-15-2). Of these, the Beresford Lake Shear Zone (BLSZ) represents the most significant and apparently long-lived structural discontinuity (e.g., Brommecker, 1996; Anderson, 2003a). East of the BLSZ, generally north-younging rocks of the Garner assemblage are juxtaposed to the south across the West Garner Shear Zone (WGSZ) with generally west-younging rocks of the Bidou and Gem assemblages. The Garner assemblage is juxtaposed to the east, across the East Garner Shear Zone (EGSZ), with an extensive granitoid domain of uncertain age and affinity.

Mesoscopic evidence of extreme transposition is abundant throughout the mapped area and, on a macroscopic scale, is indicated by the fact that stratification within many of the lithostructural domains is oriented oblique to the trend of the bounding shear zones. West of the BLSZ, macroscopic map patterns and younging criteria in the Neoarchean succession, comprising the Bidou, Gem and Edmunds assemblages, define the regional-scale Beresford Lake anticline (BLA), which is the dominant structural feature in the core of the Rice Lake belt. The BLA is a tight, upright, doubly plunging, F_3-generation fold that trends northwest and is overturned to the southwest. The BLA is associated with a regionally developed, axial-planar, S_3 flattening fabric that dips subvertically and contains a steeply plunging L_3 elongation lineation. The S_3 fabric is consistently overprinted at a counter-clockwise angle by a penetrative, regional, S_4 crenulation cleavage. The resulting L^3_4 intersection lineation is pervasive in the map area and is generally oriented subparallel to L_3. Both of these fabrics are overprinted at a clockwise angle by a variably developed shear band or fracture cleavage that exhibits a consistent dextral sense of asymmetry or offset, and is particularly well developed adjacent to the BLSZ. This fabric is attributed to D_5 deformation. In the southeastern portion of the Rice Lake belt, all of these fabrics

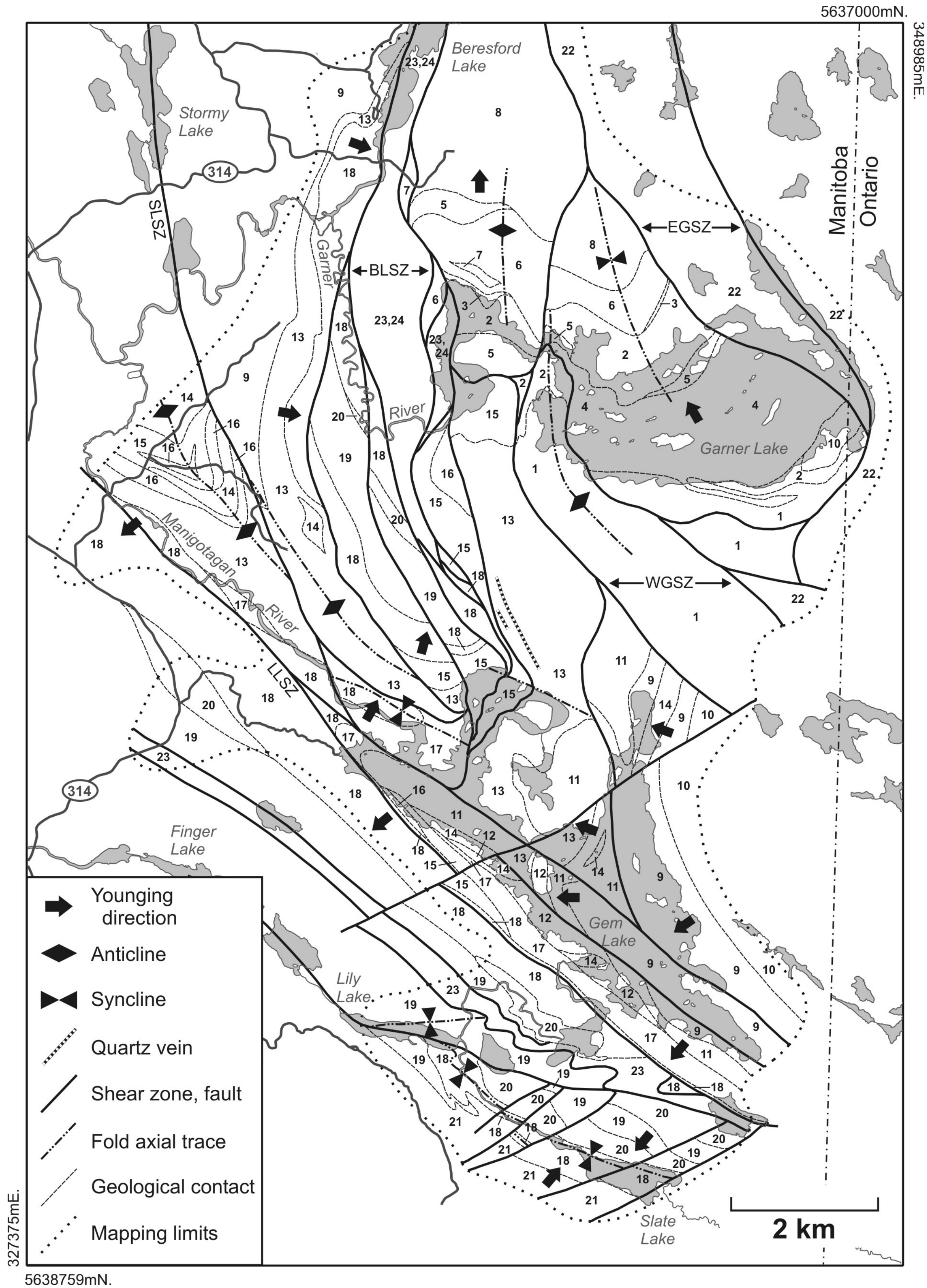

Figure GS-15-2: *Simplified geology of the Garner–Gem lakes area, southeastern Rice Lake greenstone belt. Refer to Table GS-15-1 for unit codes and descriptions. Abbreviations: BLSZ, Beresford Lake Shear Zone; EGSZ, East Garner Shear Zone; LLSZ, Long Lake Shear Zone; SLSZ, Stormy Lake Shear Zone; WGSZ, West Garner Shear Zone.*

Table GS-15-1: Assemblages, unit codes and rock-types, Garner–Gem lakes area, southeastern Rice Lake greenstone belt.

24. Gabbro, diorite; post-tectonic dikes
23. Tectonite, phyllonite, mylonite; chlorite-sericite ± ankerite altered
22. Undivided granitoid intrusive rocks and orthogneiss

EDMUNDS ASSEMBLAGE (ca. 2705–2710 Ma)

21. Basalt and basaltic andesite
20. Conglomerate
19. Subarkose, quartz greywacke
18. Greywacke-mudstone turbidite

Depositional contact

GEM ASSEMBLAGE (ca. 2720 Ma)

17. White to light grey dacite; feldspar-phyric
16. Bedded epiclastic rocks
15. Basalt and basaltic andesite
14. Gabbro, diorite
13. Buff to grey dacite and rhyolite; quartz and feldspar-phyric
12. Grey to black rhyolite; aphyric
11. Buff to white to pink rhyolite; quartz-phyric to aphyric
10. Leucogranite

Depositional contact

BIDOU ASSEMBLAGE (ca. 2730 Ma)

9. Intermediate to felsic volcanic and volcaniclastic rocks

Tectonic contact

GARNER ASSEMBLAGE (ca. 2870–2900 Ma)

Garner Lake extrusive complex (ca. 2870 Ma)

8. Calcalkalic basalt and basaltic andesite
7. Mg-tholeiitic basalt
6. Ultramafic komatiite and komatiitic basalt

Garner Lake intrusive complex (2870 Ma)

5. Mafic intrusive rocks
4. Ultramafic intrusive rocks

Garner Narrows unit (ca. 2883–2898 Ma)

3. Iron formation
2. Intermediate to felsic volcaniclastic rocks
1. Heterolithic volcaniclastic and epiclastic rocks

are overprinted by open, east- or northeast-trending F_6 folds and coeval east-southeast-trending, dextral high-strain zones.

The domain-bounding shear zones contain early zones of cohesive mylonite and ultramylonite that contain steeply plunging stretching and quartz-ribbon lineations, and preserve kinematic evidence of northeast-over-southwest dip-slip shear. These fabrics are generally overprinted by chloritic mylonite and tectonite that contain shallow lineations and well-developed kinematic indicators on horizontal surfaces, indicating transcurrent shear deformation. These relationships are interpreted to indicate that the main shear zones record at least two increments of ductile, noncoaxial deformation. At Gem Lake, structures associated with late-stage transcurrent shear deformation (regional D_5-D_6), including east-south-east-trending dextral high-strain zones, mesoscopic and macroscopic z-asymmetric folds, and late brittle faults, overprint and reactivate early high-strain fabrics. The resulting complex map patterns, which more than likely include complexities related to primary deposition in an active volcanic-arc terrane, as well as the effects of early (i.e., F_3) transposition, remain poorly resolved.

Metamorphic mineral assemblages west of the BLSZ and southwest of the WGSZ indicate peak metamorphism in the low- to middle-greenschist facies. South of Garner Lake, the hornblende and garnet isograds closely coincide with the WGSZ, and indicate an abrupt increase to peak amphibolite-facies metamorphism northeast of the shear zone, consistent with observed northeast-over-southwest kinematic indicators.

Description of units

The geology of the Garner–Gem lakes area is described below in order of decreasing known or inferred age of the constituent rock units. Unit numbers in this report correspond to those on Preliminary Map PMAP2006-7 (Anderson, 2006). For simplicity, only the principal map units are shown on Figure GS-15-2. The reader is referred to PMAP 2006-7 (Anderson, 2006) for the locations and distributions of the subunits described below.

Garner assemblage

The Mesoarchean Garner assemblage extends north and southeast of Garner Lake, and is subdivided into the Garner narrows unit and the Garner Lake intrusive and extrusive complexes. The Garner narrows unit is thought to form a conformable, north-younging stratigraphic succession that is at least 3.0 km thick and consists of heterolithic volcaniclastic and epiclastic rocks (unit 1) at the base, overlain to the north by intermediate to felsic volcaniclastic rocks (unit 2) and capped by iron formation (unit 3). The Garner narrows unit is intruded by peridotite (unit 4) and gabbro (unit 5) of the Garner Lake intrusive complex (GLIC). The Garner Lake extrusive complex (GLEC) disconformably overlies the Garner narrows unit and consists of a north-facing succession, more than 3.0 km thick, of subaqueous komatiitic (unit 6), Mg-tholeiitic (unit 7) and calcalkalic basalt (unit 8) flows and related subvolcanic intrusive rocks that are interpreted to be comagmatic with the underlying intrusive complex.

Garner narrows unit

Heterolithic volcaniclastic and epiclastic rocks (unit 1)

The base of the Garner assemblage is interpreted to be defined by a highly tectonized, heterogeneous package of volcaniclastic and epiclastic rocks that is best exposed along the southern and western shorelines of the east basin of Garner Lake, where it is intruded by peridotite and gabbro of the GLIC. This unit is also observed in widely spaced outcrops in the poorly exposed area south of Garner Lake and is interpreted to stratigraphically underlie volcaniclastic rocks of unit 2. Most outcrops exhibit intense L-S tectonite fabrics, with local evidence of extreme transposition; consequently, the stratigraphic thickness, internal stratigraphy and structure of this unit remain poorly resolved.

The southern portion of this unit consists mainly of heterolithic breccia and tuff-breccia, composed mainly of mafic to intermediate volcanic detritus (subunit 1a) with minor intercalations of intermediate to felsic breccia and tuff-breccia. To the northeast, these rocks appear to be overlain by an ~300 m thick unit of homogeneous rhyolite crystal tuff (subunit 1b) that weathers buff or grey and locally contains a faint stratification defined by beds of crystal-lapilli tuff up to 10 cm thick. These rocks are overlain by a unit of volcanic conglomerate (subunit 1c) that ranges up to at least 400 m thick and contains a very heterolithic population of angular to well-rounded, matrix-supported clasts that range up to 50 cm across. Along the western shoreline of Garner Lake, the conglomerate is interstratified and apparently overlain by a 200 m thick unit of thin-bedded feldspathic greywacke and mudstone (subunit 1d). The greywacke beds, which are typically less than 10 cm thick, are very fine to medium grained and contain 10 to 30% broken plagioclase crystals, with <5% quartz. Normal-graded beds are common and mainly fine toward the west. The overall features of unit 1 appear to be consistent with deposition in proximity to an actively eroding volcanic-arc terrane.

Intermediate to felsic volcaniclastic rocks (unit 2)

Intermediate to felsic volcaniclastic rocks crop out along the north and, to a lesser extent, south shores of Garner Lake, and form a section more than 1 km thick. The predominant rock types are dacite and rhyolite breccia and tuff-breccia (subunit 2a), with subordinate layers of lapilli tuff and crystal tuff, which define a roughly east-trending stratification in this unit. The breccia is characterized by a coarse, monolithic fragmental texture defined by very angular to subrounded, generally equant, unsorted fragments that range in size up to 25 cm (typically 1–5 cm). The fragments consist of light grey, aphanitic to fine-grained dacite and rhyolite that contain up to 5% plagioclase and/or hornblende phenocrysts. In Garner narrows, this unit consists mainly of massive, light grey dacite crystal tuff, which contains up to 15% subhedral plagioclase crystals, with minor intercalations of light green, aphyric andesite tuff-breccia (subunit 2b) and thinly layered quartz arenite, iron carbonate and fine-grained ferruginous argillite (subunit 2c). Uranium-lead analyses of zircons from a sample of relatively coarse plagioclase-phyric tuff indicate that emplacement most likely occurred between ca. 2883 and 2898 Ma (Anderson, unpublished data, 2003). Geochemically, these rocks exhibit an affinity to modern calcalkaline continental-arc volcanism.

Iron formation (unit 3)

Unit 2 is overlain to the north by a laterally discontinuous iron formation. In western Garner Lake, this unit consists of thinly layered magnetite-chert iron formation (subunit 3a) that can be traced along strike for more than 700 m and ranges up to 50 m thick. The contact with the underlying dacite was observed in one location and appears depositional. To the east, the iron formation is considerably less thick, not as laterally continuous and includes magnetite, silicate and local sulphide facies (subunit 3b). The iron formation everywhere separates dacitic volcaniclastic rocks from overlying spinifex-textured komatiite flows, and is interpreted to mark a significant depositional hiatus subsequent to arc magmatism.

Garner Lake intrusive complex

Ultramafic intrusive rocks (unit 4)

The main body of the GLIC, which underlies the main basin of Garner Lake, consists of 100 to 400 m thick layers of rusty brown–weathering serpentinized peridotite (subunit 4a) and dark green-black clinopyroxenite (subunit 4b) that strike generally east and northeast, and dip moderately to the north (Scoates, 1971). Peridotite appears to predominate in the south, whereas clinopyroxenite predominates in the north. This portion of the complex was not examined in detail during the present mapping program, and the interested reader is referred to Scoates (1971) for a more detailed description.

Mafic intrusive rocks (unit 5)

The northern portion of the GLIC is quite heterogeneous and consists mainly of fine- to medium-grained melanocratic gabbro and medium- to coarse-grained leucogabbro (subunit 5a), with minor glomeroporphyritic gabbro (subunit 5c). Pegmatitic leucogabbro (subunit 5b) occurs within these rocks as irregular segregation pods with diffuse contacts, or as narrow (<2 m thick) dikes, locally with sharp planar contacts. The dikes are generally concordant with the igneous layering in the underlying ultramafic rocks and are interpreted to represent a late-stage magmatic segregation phase that formed, largely in situ, in the upper portion of the GLIC (Scoates, 1971). In the western portion of the complex, medium- to coarse-grained, buff to grey hornblende diorite, quartz diorite and tonalite (subunit 5d) are present along the northern contact, and characteristically exhibit a pseudofragmental texture that is interpreted to result from cataclastic deformation. A sample of the hornblende quartz diorite yielded a U-Pb zircon date of ca. 2870 Ma (Anderson, unpublished data, 2003), which overlaps the 2871 ±1 Ma age obtained by Davis (1994) from a pegmatitic gabbro sill in the main body of the complex and is considered to closely approximate the age of the GLIC. These ages also provide a minimum age for the Garner narrows dacitic volcaniclastic rocks.

Garner Lake extrusive complex

Ultramafic komatiite and komatiitic basalt (unit 6)

The base of the GLEC consists of an ~800 m thick, north-younging succession of ultramafic komatiite and komatiitic basalt flows. The komatiite weathers dark green to black to rusty brown, and is typically massive with a fine- to coarse-grained subophitic texture (subunit 6a). The massive flows contain minor intercalations of pillowed komatiitic basalt, as well as rare interflow breccia units and magnetite iron formation. These rocks typically contain less than 35% fine-grained plagioclase, which is interstitial to acicular crystals of actinolite (after pyroxene). Spinifex-textured komatiite (subunit 6b) occurs in irregular zones or discrete layers within massive komatiite. In these zones, the spinifex texture is defined by randomly oriented, acicular crystals of actinolite (after pyroxene) that range up to 5 cm long and form radiating clusters up to 10 cm across. In the southern portion of this subunit, the komatiite contains sills, dikes and irregular bodies of serpentinized peridotite and pyroxenite, which are interpreted to be roughly comagmatic with the komatiitic flows.

Mg-tholeiitic basalt (unit 7)

In the western portion of the GLEC, the komatiitic flows contain significant volumes of Mg-tholeiitic basalt flows, with minor intercalated flow breccia and interflow magnetite iron formation. Pillowed flows predominate over massive flows, and both are typically aphyric and nonamygdaloidal. The Mg-tholeiitic basalt weathers light green-grey to emerald green, and is characterized by a fine- to medium-grained, subophitic, equigranular texture. In some locations, these rocks contain a medium- to coarse-grained, spinifex-like texture defined by fibrous actinolite (after pyroxene) crystals up to 0.5 cm long.

Calcalkalic basalt and basaltic andesite (unit 8)

The upper portion of the GLEC consists of a north-younging succession of calcalkalic basalt and basaltic andesite flows that ranges up to at least 1.5 km thick. The basalt weathers light green-grey to buff and is typically aphyric and nonamygdaloidal, with a fine- to medium-grained, subophitic texture. Pillowed flows predominate over massive flows. The pillows are bun shaped and range in size from 0.1 to 0.5 m across, with well-defined, less than 3 cm thick, dark green to black aphanitic selvages and local calcsilicate alteration. The cores of the pillows are locally strongly epidotized and locally contain up to 20% light grey to pink variolites up to 3 cm in diameter. In rare instances, the pillow cores are also plagioclase phyric, with up to 5% plagioclase crystals.

Bidou assemblage

The Neoarchean Bidou assemblage consists of a thick (≥5.5 km) sequence of subaqueously deposited supracrustal rocks. The lower portion consists of laterally continuous units of massive and pillowed, mid-ocean-ridge basalt (MORB)–like tholeiitic basalt flows, alternating with units of well-bedded feldspathic greywacke, mudstone, chert and minor volcaniclastic rocks. These rocks occupy the core of the Rice Lake greenstone belt and are intruded by ca. 2730 Ma (Turek et al., 1989) quartz diorite dikes associated with the Ross River pluton. The uppermost unit of the Bidou assemblage, referred to as The Narrows Formation (Campbell, 1971), comprises a 2.5 km thick succession of coarse volcaniclastic rocks composed mainly of ca. 2730 Ma (Turek et al., 1989), calcalkaline, plagioclase-phyric andesite and dacite. Only the uppermost portion of The Narrows Formation occurs in the mapped area. These rocks (unit 9) crop out west of the BLSZ, on the east limb of the BLA. Similar rocks crop out along the east side of Gem Lake and are tentatively correlated with The Narrows Formation, although here they contain a laterally continuous unit of pillowed basaltic andesite and andesite flows that has not been observed west of the BLSZ.

Intermediate to felsic volcanic and volcaniclastic rocks (unit 9)

West of the BLSZ, The Narrows Formation consists of a thick (~1.0 km) succession of coarse volcaniclastic rocks that dips steeply to the west-northwest and is composed almost exclusively of light green to grey to locally buff, plagioclase-phyric andesite and dacite. Pebble and cobble volcanic conglomerate, with minor interbeds of feldspathic sandstone (subunit 9b), are the predominant rock types and are interstratified with discontinuous units of dacite breccia, tuff-breccia and lapilli tuff (subunit 9a). Younging criteria in two locations indicate tops to the east. The volcanic conglomerate is typically stratified on the outcrop scale and contains subangular to well-rounded clasts of texturally variable andesite and dacite that are typically less than 50 cm in maximum dimension (Figure GS-15-3a), but locally range up to more than 2.0 m across. The volcanic breccia is more monolithic

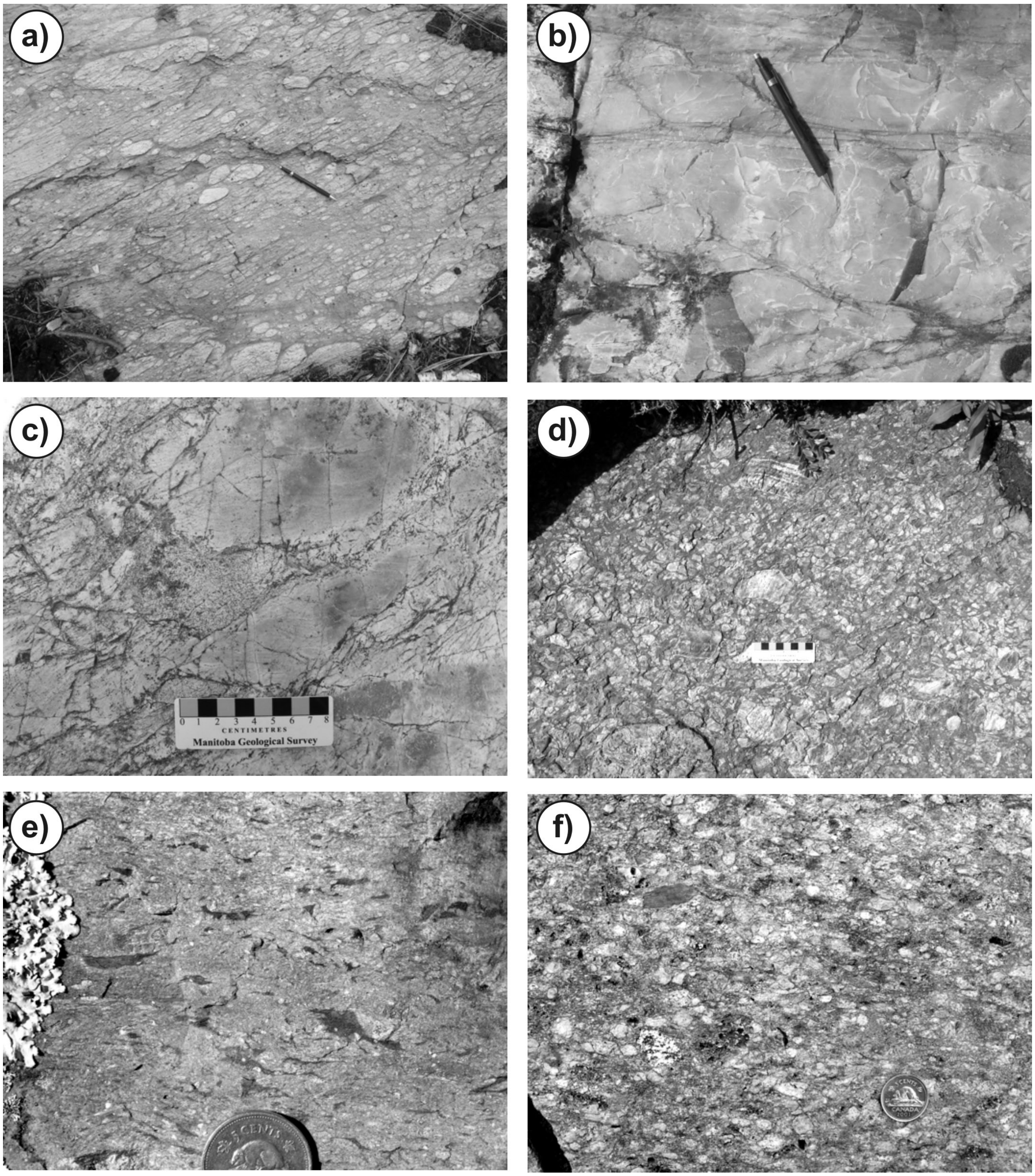

Figure GS-15-3: *Outcrop photographs of bedrock exposures from Gem Lake:* ***a)*** *layered dacite conglomerate (subunit 9b);* ***b)*** *massive white flow rhyolite (subunit 11a);* ***c)*** *intrusion breccia, composed of aphyric white rhyolite and fine-grained pink leucogranite (subunit 11d);* ***d)*** *tuff-breccia, composed of flow-banded rhyolite lapilli and blocks (subunit 12a);* ***e)*** *eutaxitic texture defined by dark, porphyritic fiamme in grey rhyolite lapilli tuff (subunit 12b);* ***f)*** *massive, heterolithic lapilli tuff (subunit 13d).*

and massive, and contains mainly angular to subrounded clasts.

East of the BLSZ, similar rocks define a homoclinal panel, up to 1.0 km thick, that dips to the southwest and west. Younging criteria consistently indicate that these rocks are upright. In this location, subunit 9a predominates at the base of the section and is overlain to the west by rocks of subunit 9b. Pillowed flows and minor pillow breccia composed of light green-grey to brown, aphyric to sparsely feldspar-phyric andesite (subunit 9c) define a 100 to 200 m thick unit that can be traced discontinuously for ~2.0 km along strike and appears to roughly coincide with the transition from subunit 9a to 9b. The pillows are bun shaped to amoeboid and typically range in size from 0.1 to 1.0 m, although an ~5.0 m long amoeboid 'mega-pillow' was observed in one outcrop. The pillows have well-defined dark green, aphanitic selvages that are less than 2 cm thick and have local calcsilicate alteration. Minor (<5%) interpillow material consists of chloritic epidotized hyaloclastite. The cores of the pillows are locally strongly epidotized and contain up to 20% round, quartz and/or epidote amygdules, 0.2 to 1.0 cm diameter.

Gem assemblage

The Neoarchean Gem assemblage overlies The Narrows Formation and consists of a thick succession of primary and variably reworked felsic to mafic volcanic flows and pyroclastic rocks that, at Gem Lake, ranges up to at least 2.0 km thick. Map patterns and contact relationships suggest a complex internal stratigraphy, which remains poorly understood. Given the relative lack of younging criteria and the complex, intense structural overprint, it remains possible that at least some of this complexity is due to structural repetition via out-of-sequence faulting or isoclinal folding. Hence, for the purpose of this report, the sequence of units described below should be taken as provisional.

At Gem Lake, the lower portion of the assemblage consists mainly of rhyolitic volcanic, volcaniclastic and intrusive rocks composed of high-silica, FII- and FIIIa-type (Lesher et al., 1986) tholeiitic rhyolite. On the basis of texture and colour, two units are distinguished: buff to white to pink quartz-phyric to aphyric rhyolite (unit 11) and overlying grey to black aphyric rhyolite (unit 12). Leucogranite plutons (unit 10) that intrude the Bidou and Garner assemblages along the eastern margin of the belt are chemically and texturally similar to the overlying unit 11 rhyolite, and are thus tentatively interpreted to be the subvolcanic equivalent. These rocks are overlain by a thick heterogeneous succession of coarse volcaniclastic rocks, with minor occurrences of flow-banded to massive flows composed of buff to grey, sparsely porphyritic, tholeiitic dacite and rhyolite (unit 13). Unit 14 consists of gabbro sills and dikes, which are compositionally and texturally similar to pillowed basalt and basaltic andesite flows and associated coarse volcaniclastic rocks of unit 15. These rocks are intimately intermixed and overlain by discontinuous intervals of well-bedded, heterolithic epiclastic rocks (unit 16). The uppermost portion of the Gem assemblage is locally marked by white to buff to light green-grey dacitic volcaniclastic rocks of calcalkalic affinity (unit 17).

Leucogranite (unit 10)

A small stock of equigranular biotite leucogranite (subunit 10a) is exposed in the southeastern portion of Garner Lake, where it discordantly intrudes the contact between the Garner narrows unit and serpentinized peridotite of the GLIC. The leucogranite is light pink to grey-white and is typically characterized by a fine- to medium-grained, equigranular phaneritic texture with less than 10% very fine grained biotite. The pluton is remarkably homogeneous and lacks xenoliths or late-stage crosscutting dikes. Along the margins, it contains a moderate to strong L>S fabric that is coaxial to the regional S-L fabric in the country rocks. A sample of this unit, collected during the 2003 field season for U-Pb geochronology, yielded a preliminary U-Pb zircon age of ca. 2723 Ma (Anderson, unpublished data, 2004).

At Gem Lake, the eastern margin of the mapped area is defined by a large leucogranite pluton that intrudes dacitic volcaniclastic rocks of unit 9. A narrow zone of hornfels is developed in the country rocks along the contact. The leucogranite is light pink to white and typically exhibits a medium-grained porphyritic texture defined by euhedral to subhedral phenocrysts of feldspar and distinctive blue-grey quartz (subunit 10b). Quartz phenocrysts range up to 5.0 mm and typically account for 20 to 40% of the rock. The matrix is very fine grained to aphanitic and contains <5% fine-grained biotite and magnetite.

Buff to white to pink rhyolite, quartz-phyric to aphyric (unit 11)

In the eastern portion of Gem Lake, the base of the Gem assemblage is defined by white- to pale yellow–weathering, aphyric rhyolite flows that range from massive (Figure GS-15-3b) to brecciated to flow banded and are associated with coarse monolithic breccia (subunit 11a). These rocks typically exhibit weak to moderate sericite alteration, with up to 5% finely disseminated to veinlet-controlled pyrite mineralization that is evidenced by patchy, moderate to intense gossan development on weathered outcrop surfaces. Along the south shore of Gem Lake and on islands and the main peninsula in the central part of the lake, these rocks are overlain by a heterogeneous interval of bedded epiclastic rocks (subunit 11b), which locally includes thin-bedded siliceous mudstone, laminated black chert, thick-bedded rhyolitic sandstone, monolithic rhyolite breccia and heterolithic pebble conglomerate or tuff-breccia. The latter rock type ranges up to 50 m thick on the east side of the large island in central Gem Lake and characteristically includes clasts of amygdaloidal basalt. Younging criteria indicate tops to the west. Along strike to the north, these rocks overlie a massive, ~150 m thick unit of coarsely quartz-phyric rhyolite breccia (subunit 11c) that locally exhibits a well-developed eutaxitic texture defined by up to 25% evenly distributed, dark grey-brown wispy fiamme (collapsed pumice?) and thus resembles a welded ignimbrite. Davis (1994) obtained a U-Pb zircon age of 2722 ±2 Ma from this breccia.

Toward the north, unit 11 is dominated by a white- to light pink–weathering intrusion breccia (subunit 11d) composed of white to grey, massive to flow-banded rhyolite and pink leucogranite (Figure GS-15-3c). These rocks were described as comagmatic "rhyolite agglomerate" and "felsite" by Weber (1971). The rhyolite contains up to 5% feldspar, 0.5 to 2.0 mm in size, and blue quartz phenocrysts in an aphanitic siliceous matrix, whereas the leucogranite is fine to medium grained and equigranular, and contains 10 to 20% blue quartz and 1 to 3% disseminated to fracture-controlled magnetite. The leucogranite forms the matrix to coarse breccia composed of angular, locally interlocking fragments of rhyolite, and also occurs as crosscutting dike-like bodies that contain rhyolite xenoliths. These rocks are tentatively interpreted to represent a near-surface subvolcanic intrusion (i.e., cryptodome).

Grey to black rhyolite, aphyric (unit 12)

Unit 12 consists of a distinctive package of dark grey to black, aphyric rhyolite flows and associated coarse fragmental rocks (subunit 12a) that is very well exposed along the south shoreline of Gem Lake, where it can be traced for ~2.5 km along strike. The rhyolite flows characteristically exhibit spectacular conchoidal fracture, flow banding and possible flow folding, and range up to 200 m in thickness. In the central portion of this unit, the flows are overlain to the southwest by a 50 to 60 m thick unit of massive, coarse monolithic breccia and tuff-breccia, which is composed of unsorted, angular, matrix-supported fragments of flow-banded grey rhyolite in a chloritic tuff matrix. Similar breccia units, ranging up to 30 m thick at the lateral extents of the rhyolite flows, may represent flow-foot breccia (Figure GS-15-3d). Subunit 12a is overlain by, and locally intercalated with, a distinctive unit of rhyolitic lapilli tuff and tuff-breccia (subunit 12b) that is characterized by a coarse eutaxitic texture defined by very irregular, wispy fiamme of dark grey to brown, sparsely quartz- or feldspar-phyric rhyolite, which are interpreted to represent collapsed pumice lapilli (Figure GS-15-3e). The top of unit 12 is defined by a well-stratified unit of epiclastic rocks (subunit 12c) that locally ranges up to 100 m thick and includes well-bedded, medium- to coarse-grained sandstone, mudstone and heterolithic pebble to cobble conglomerate composed mainly of grey rhyolite detritus. Graded beds and channels indicate tops to the southwest. The general features of this unit are consistent with effusive and pyroclastic rhyolite volcanism in a subaerial to shallow subaqueous setting.

Buff to grey dacite and rhyolite, sparsely quartz and feldspar-phyric (unit 13)

The main body of the Gem assemblage consists of a very heterogeneous package of felsic volcanic and volcaniclastic rocks that is composed mainly of buff to light grey, aphanitic to sparsely feldspar-phyric dacite and rhyolite. These rocks typically contain 2 to 5% of <2 mm, euhedral, white feldspar crystals in an aphanitic, siliceous, dark grey-black matrix with rare quartz phenocrysts. Fragmental buff to grey rhyodacite (subunit 13b), which typically consists of faintly stratified breccia, tuff-breccia, lapilli tuff and tuff, is the predominant rock type west of the BLSZ. These rocks range up to 500 m thick and include minor massive to flow-banded flows (subunit 13a) and intervals of well-bedded monolithic lapilli tuff, tuff and tuff-breccia (subunit 13c). East of the BLSZ, on the main peninsula in Gem Lake, these rocks are subordinate to thick intervals of heterolithic lapillistone and lapilli tuff (subunit 13d; Figure GS-15-3f), which typically lack mesoscopic evidence of stratification and include up to 10% basalt lapilli.

Gabbro, diorite (unit 14)

Units 11 to 13 are intruded by dikes and sills of gabbro and diorite that range up to 200 m thick in several locations. These rocks range from light green to dark green-black and from very fine to medium grained. Individual outcrops are typically massive, homogeneous and equigranular (subunit 14a). Along the south shore of Gem Lake, an ~200 m thick sill of dark green, fine-grained gabbro locally contains round quartz amygdules up to 0.5 cm across, indicating near-surface emplacement. Along the east limb of the BLA, thick sills of gabbro and diorite are characterized by a coarsely porphyritic texture defined by randomly oriented, closely packed, lath-shaped crystals of plagioclase that range up to 1.0 cm in size (subunit 14b; Figure GS-15-4a). Similar textures are observed in overlying pillowed flows, as well as in rounded gabbroic cobbles in overlying polymictic conglomerate of the Edmunds assemblage (Figure GS-15-4b).

Basalt and basaltic andesite (unit 15)

Unit 15 consists of volcanic and volcaniclastic rocks of basalt and basaltic andesite composition, which are interstratified with units 13, 16 and 17, and are only locally

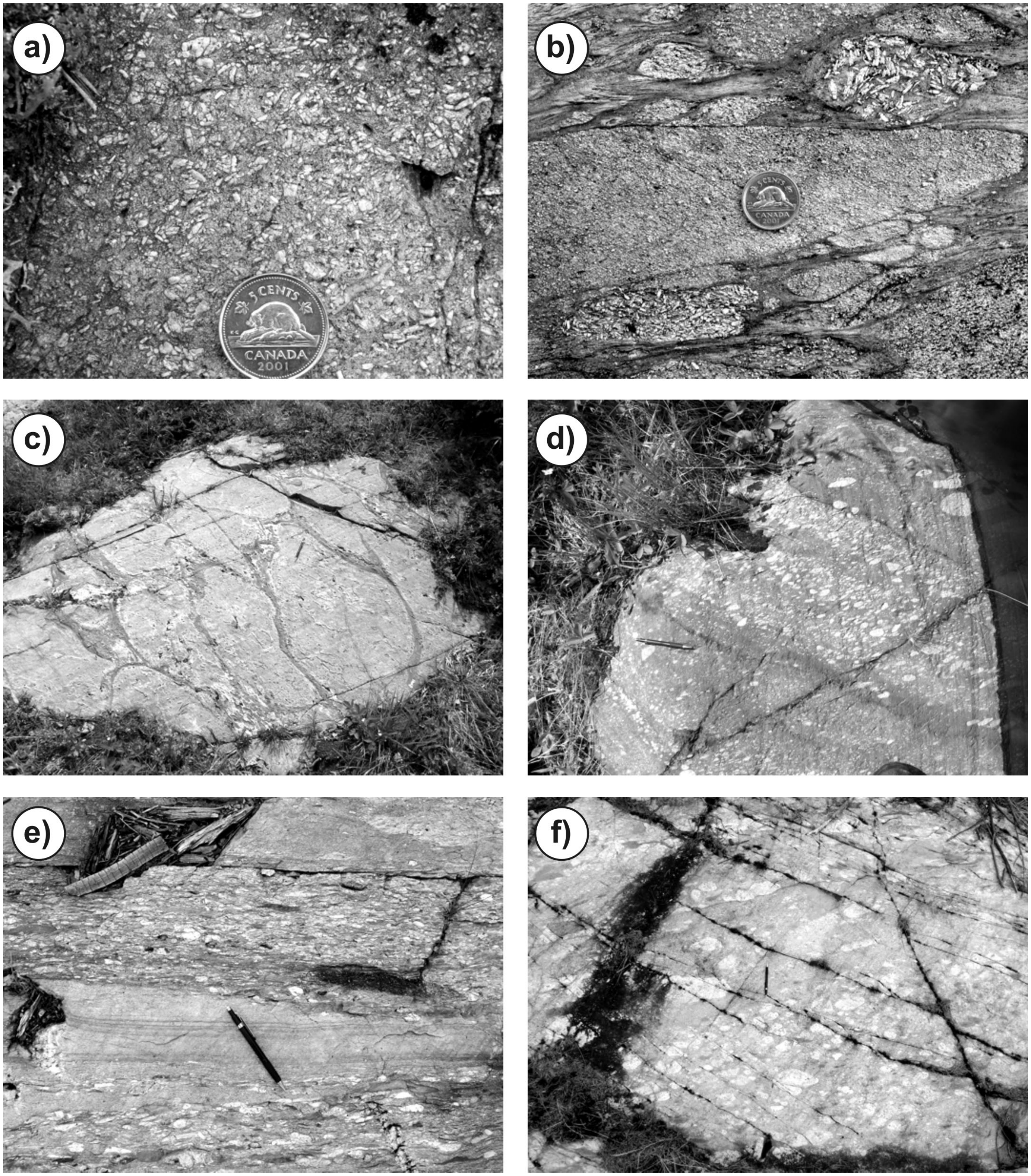

Figure GS-15-4: *Outcrop photographs of bedrock exposures from Gem Lake and Slate Lake:* ***a)*** *porphyritic gabbro (subunit 14b);* ***b)*** *porphyritic gabbro clasts in conglomerate (subunit 18b);* ***c)*** *pillowed basaltic andesite (subunit 15a);* ***d)*** *bedded pebble conglomerate (subunit 16b);* ***e)*** *bedded quartz greywacke and polymictic pebble conglomerate (subunit 19b; note scour at the base of the upper conglomerate bed, indicating tops upward in photo);* ***f)*** *faintly layered monolithic dacite conglomerate (subunit 20b).*

of sufficient thickness and strike length to define mappable units. These rocks are dark green to light grey-green to buff, fine to medium grained, and aphyric to coarsely plagioclase phyric. The plagioclase-phyric rocks contain 5 to 40% euhedral plagioclase crystals that are typically 1 to 5 mm in size but locally range up to 1.0 cm. Massive and pillowed flows (subunit 15a), which range up to 40 m thick, locally define the top of the Gem assemblage along the south shore of Gem Lake, and on the east limb of the BLA. On the west limb of the BLA, the flows are farther down-section, below a thick succession of fragmental dacite (unit 13). The pillowed flows typically exhibit well-preserved, bun-shaped pillows up to 1.5 m across, with only minor (<5%) interpillow hyaloclastite (Figure GS-15-4c). The flows characteristically contain 1 to 5%, round to slightly elongate, evenly distributed quartz amygdules that range up to 7.0 cm in size. In the northwest arm of Gem Lake, extending north to the west end of Garner Lake, this unit consists of monolithic (subunit 15b) and heterolithic (subunit 15c) fragmental rocks composed of variably plagioclase-phyric basalt and basaltic andesite.

Bedded epiclastic rocks (unit 16)

Basalt and basaltic andesite of unit 15 are locally intercalated with mappable units of thin-bedded, feldspathic greywacke-mudstone turbidite (subunit 16a) and thick-bedded, heterolithic, pebble to boulder conglomerate with minor coarse-grained sandstone (subunit 16b; Figure GS-15-4d). The best examples of this unit occur adjacent to the Manigotagan River on the west limb of the BLA, along strike to the southeast from similar rocks that were described in detail by Seneshen and Owens (1985) and Seneshen (1986, 1990). The greywacke beds are fine to medium grained and range up to 1.0 m thick, with locally well-developed normal grading and channels. Crossbedded greywacke is locally intimately intercalated with pillowed, vesicular mafic flows (e.g., Seneshen and Owens, 1985), indicating coeval mafic volcanism and sedimentation in a shallow subaqueous depositional environment. The conglomerate is matrix supported, poorly sorted and contains subangular to well-rounded clasts that are typically 10 to 30 cm in diameter but locally range up to 2.0 m. Swarms of fine-grained basalt and basaltic andesite dikes, which have well-developed chilled margins and are locally vesicular, are a characteristic feature of this unit and are interpreted as subvolcanic feeders for the associated mafic volcanic rocks.

Buff to white to light grey dacite, feldspar-phyric (unit 17)

This unit is best exposed is several large outcrops at the outlet of the Manigotagan River in northwestern Gem lake, and is also well exposed along the top of the high outcrop ridge that extends along the south shoreline of Gem Lake. In both locations, these rocks lie in sharp, clearly depositional contact with thin-bedded greywacke-mudstone turbidite of the overlying Edmunds assemblage. Massive dacitic crystal tuff, which weathers light grey-green to white to buff, is the predominant rock type and contains minor intercalations of monolithic breccia, tuff-breccia and lapilli tuff. The crystal tuff contains up to 20% of 2 to 5 mm, subhedral feldspar crystals, as well as 1 to 3% of <1.5 mm, anhedral quartz 'eyes'. These rocks are distinguished from the underlying tholeiitic felsic volcanic rocks of units 11 to 13 by their calcalkalic geochemical affinity. A sample of this material, from 15 m stratigraphically below the basal contact of the Edmunds assemblage along the Manigotagan River, was collected in 2006 for U-Pb geochronological analysis to constrain the age of the uppermost, calcalkalic portion of the Gem assemblage.

Edmunds assemblage

The Neoarchean Edmunds assemblage is at least 2.5 km thick and is composed of basinal siliciclastic rocks that consist mainly of monotonously bedded greywacke-mudstone turbidite (unit 18), with subordinate units of coarse quartz greywacke (unit 19), conglomerate (unit 20), and basalt (unit 21). The lower portion of the Edmunds assemblage is marked by a 1.2 km thick coarsening-upward cycle, suggesting deposition in a progradational subaqueous fan. Contact relationships indicate a significant depositional hiatus and erosional unconformity at the base of the Edmunds assemblage (Anderson, 2005). Uranium-lead dating of detrital zircons and crosscutting plutons (e.g., Corfu et al., 1995) constrain deposition to the ca. 2.71 ro 2.70 Ga time interval.

Greywacke-mudstone turbidite (unit 18)

The lower portion of the Edmunds assemblage consists of a thick succession of well-bedded greywacke-mudstone turbidite. In general, thinly interbedded mudstone and fine-grained greywacke (subunit 18a), with minor chert, predominate near the base of the assemblage, and are overlain up-section by thick-bedded, medium- to coarse-grained greywacke (subunit 18b), which contains subordinate interbeds of mudstone and polymictic pebble conglomerate. In several locations, the basal contact of the assemblage is well exposed and defined by a unit of thin-bedded to laminated cherty mudstone that is typically 1 to 2 m thick but locally ranges up to more than 100 m thick in places along the Manigotagan River, suggesting that a relatively sediment-starved, quiescent interval preceded basin infilling. Normal-graded beds and soft-sedimentary deformation features are common in these rocks.

Subarkose, quartz greywacke (unit 19)

Unit 19 consists of buff to light grey, medium to very coarse grained subarkose and quartz greywacke that typically contain 10 to 25%, angular to subrounded quartz grains and granules. On the east limb of the BLA, remarkably massive and homogeneous quartz greywacke (subunit 19a) ranges up to more than 100 m thick, with only rare mudstone beds and minor diffuse pebble lags defined by mudstone rip-ups and quartz pebbles. More commonly, these rocks consist of thickly bedded quartz greywacke (subunit 19b), with subordinate to subequal interbeds of polymictic conglomerate and thin-bedded greywacke and mudstone (Figure GS-15-4e). Individual quartz greywacke beds range up to 1.5 m thick and are separated by thin (<10 cm) beds of fine-grained greywacke or mudstone. These beds characteristically exhibit normal size grading and well-developed basal lag deposits composed of angular mudstone rip-up clasts, and more rounded lithic clasts and quartz pebbles. Lenticular layers of polymictic conglomerate range up to more than 2 m thick and contain unsorted, typically subangular to well-rounded, matrix-supported clasts that range in size up to 20 cm. South of Lily Lake, these rocks include a 1–5 m thick layer of magnetite-chert iron formation (subunit 19c) that can be traced for ~800 m along strike.

Conglomerate (unit 20)

Polymictic conglomerate (subunit 20a) forms layers up to at least 25 m thick within the massive to thick-bedded quartz greywacke of unit 19. This conglomerate ranges from matrix to clast supported, and massive to well layered on the scale of individual outcrops. It contains subangular to well-rounded, pebble- to cobble-sized clasts in a matrix of medium- to coarse-grained quartz greywacke. The clasts are mainly representative of the underlying volcanic rocks, suggesting relatively local provenance. Nevertheless, well-rounded clasts of coarse-grained tonalite and medium- to coarse-grained orthoquartzite, which do not appear to be of local provenance, are also locally common and suggest a probable source area in the ca. 3.0 Ga North Caribou Terrane. This inference is supported by the presence of ca. 3.0 Ga detrital zircons in a sample of Edmunds assemblage greywacke collected for detrital zircon U-Pb analysis (Anderson, unpublished data, 2005).

In the area between Slate Lake and Gem Lake, monolithic dacite conglomerate (subunit 20b), which was previously mapped as “rhyodacitic tuff-breccia” of the Gem assemblage by Weber (1971), is interstratified at a variety of scales with thick-bedded quartz greywacke (subunit 19b) and polymictic conglomerate (subunit 20a). This conglomerate, which ranges up to 400 m thick north of Slate lake, is massive to very faintly layered and composed of unsorted, well-rounded to subangular, matrix-supported clasts of buff- to light green–weathering, plagioclase-phyric dacite (Figure GS-15-4f). The clasts range in size up to 1.5 m but are typically 5 to 10 cm. No examples of obviously second-cycle (i.e., volcaniclastic) dacite clasts were observed. The matrix consists of medium- to coarse-grained feldspathic wacke that contains 30 to 40% subhedral feldspar crystals <1.5 mm in size. Locally, the conglomerate contains rare clasts of green plagioclase-porphyritic andesite. Along the upper and lower contacts, this conglomerate is locally heterolithic and contains minor interbeds of polymictic conglomerate and thin-bedded greywacke and mudstone. The overall features of these rocks are suggestive of subaqueous debris flow deposits that, on the basis of the apparent absence of second-cycle detritus, may have been sourced from an active (i.e., ca. 2.71 Ga) volcanic arc. A sample of this material was collected for U-Pb geochronological analysis of the detrital zircon population.

Basalt and basaltic andesite (unit 21)

This unit is most extensively exposed south of the Manigotagan River, between Lily Lake and Slate Lake. It consists mostly of mafic tectonite, composed of strongly foliated chlorite-carbonate phyllonite that is mainly derived from pillowed basalt and basaltic andesite flows (subunit 21a) and subordinate coarse fragmental rocks (subunit 21b). These rocks are buff to rusty brown to green, fine grained, and aphyric to locally sparsely feldspar phyric. Pillows preserved in low-strain enclaves within the tectonite are bun shaped to amoeboid, nonamygdaloidal and less than 1.0 m in maximum dimension, with <2 cm thick chloritic selvages and <5% interpillow material (mainly carbonate). South of the Manigotagan River between Lily and Slate lakes, the basalt lies in sharp concordant contact with overlying thin-bedded greywacke-mudstone turbidites that, along strike south of Lily Lake, contain interlayers of mafic crystal tuff. Basalt dikes are observed to crosscut all of the Edmunds assemblage rocks described previously, indicating that mafic volcanism was coeval with sedimentation.

Rocks of unknown lithotectonic affinity

Undivided intrusive rocks (unit 22)

At Garner Lake, the eastern limit of the mapped area is defined by a northwest-trending domain of undivided granitoid plutonic rocks and mixed orthogneiss, the western margin of which is defined by a 100 to 300 m thick zone of amphibolite-facies tectonite and mylonite that contains a penetrative and pervasive S-L fabric defined by acicular hornblende porphyroblasts (the East Garner Shear Zone). East of the shear zone, variably foliated hornblende-biotite quartz diorite, granodiorite and granite (subunit 22a) are the predominant rock types, and are transposed into thick domains of felsic orthogneiss (subunit 22b). Macroscopic lenticular domains of mafic orthogneiss (subunit 22c), which include enclaves of serpentinized peridotite and pyroxenite, are likely derived from the GLIC (units 4 and 5). This interpretation is supported by contact relationships along the northeastern margin of the GLIC, where hornblende-biotite granodiorite dikes are observed to crosscut melanocratic gabbro, and both are overprinted by the prominent gneissic fabric that characterizes the East Garner Shear Zone.

Tectonite, phyllonite, mylonite (unit 23)

In the central portion of the map area, the BLSZ contains thick zones of strongly altered tectonite, phyllonite and mylonite (unit 23), for which the precursor rocks are uncertain. The alteration minerals consist of strongly foliated, fine- to medium-grained chlorite and sericite, with abundant calcite and ankerite, and subordinate pyrite and chalcopyrite. The most intense alteration is characterized by up to 50% ankerite, which locally occurs as strongly boudinaged and discontinuous veins that range up to 50 cm thick and contain minor quartz, chlorite, sericite, calcite, pyrite and chalcopyrite. These alteration zones range up to more than 100 m thick and occur over a strike length of more than 9.0 km. In the area northwest of Garner Lake, macroscopic lenticular domains of lesser deformed and altered wallrock within the altered tectonite consist mainly of komatiitic and Mg-tholeiitic basalt flows, with strongly transposed segments of magnetite-facies iron formation of the adjacent GLEC.

Gabbro, diorite (unit 24)

Dikes of light grey, fine- to medium-grained gabbro and diorite are observed throughout the mapped area, but are particularly abundant along the trace of the BLSZ, where they are observed to discordantly cut penetrative tectonite and mylonite fabrics. The cores of the dikes exhibit an equigranular subophitic texture and are locally weakly plagioclase porphyritic. In several locations, the central portions of these dikes also contain subrounded to angular xenoliths of vein quartz up to 10 cm across. The contacts of the dikes are typically planar and parallel, with well-developed chilled margins up to 5 cm thick. In one location in the western portion of Garner Lake, delicate apophyses of diorite extend outward from the contact of a diorite dike that crosscuts chlorite-sericite-ankerite-altered tectonite along the eastern margin of the BLSZ. The apophyses, which are <1.0 cm thick, extend outward into the tectonite country rock for up to 15 cm and are apparently undeformed. These dikes are interpreted to postdate significant regional deformation in the southeastern Rice Lake greenstone belt.

Economic considerations

As described by Anderson (2005), felsic flows and vent-proximal fragmental volcanic rocks in the Gem assemblage are composed of FII- and FIIIa-type (Lesher et al., 1986) tholeiitic dacite, rhyolite and high-silica rhyolite, which exhibit high-field-strength-element signatures indicative of extension-related, within-plate volcanism. These rocks are provisionally interpreted to record subaerial to shallow subaqueous volcanism associated with the initiation of a ca. 2.72 Ga arc-rift basin within the Bidou volcanic arc. Type FII and FIII rhyolites host several important VHMS deposits in the Superior Province (Lesher et al., 1986), and the association of extension-related volcanism and VHMS deposits has been well documented in the literature (e.g., Lentz, 1998; Syme, 1998; Syme et al., 1999). These attributes indicate that, in addition to the demonstrated potential for orogenic lode-gold deposits, the Gem Lake area is prospective for VHMS deposits. The present study provides a much improved stratigraphic and structural context to further evaluate the VHMS potential of these rocks.

The area east of the Manigotagan River between Garner Lake and Gem Lake contains several documented occurrences of auriferous quartz-carbonate veins, most of which have been briefly examined by the author. All of the examined occurrences are hosted by discrete, ductile and brittle-ductile shear zones in close spatial association with the major southeast-trending, domain-bounding, high-strain zones that dominate the map pattern in the Garner–Gem lakes area. Hence, proximity to these zones appears to represent an important, property-scale exploration parameter. Detailed surface prospecting along these zones, with emphasis on sites of potential chemical or structural favourability, will prove useful in identifying additional exploration targets.

As described by numerous authors, lode-gold deposits in greenstone terranes typically show a distinct spatial association with zones of transition from lower to upper greenschist-facies regional metamorphism, which broadly coincide with the contemporaneous transition from brittle to ductile deformation (e.g., Kerrich and Cassidy, 1994). In this regard, the West Garner Shear Zone (WGSZ), which coincides with an abrupt, northeastward change from greenschist- to amphibolite-facies metamorphism, may be a particularly attractive exploration target. North of Gem Lake, the footwall of the WGSZ contains several zones of stockwork-breccia quartz veins, hosted by dacitic fragmental rocks (unit 13). One of these vein systems was briefly described by Russell (1952), who noted the occurrence of pyrite and arsenopyrite in quartz-carbonate veins. Noranda Exploration Co. Ltd. (Assessment File 92840) reported values of 15.5 and 5.1 g/t Au from grab samples of arsenopyrite-bearing quartz vein material from possibly the same zone, although subsequent sampling yielded a best result of 2.1 g/t Au. Two of these vein systems were examined during the 2006 field season, and appear to be developed on, and locally overprinted by, north-northwest-trending brittle faults that contain shallowly plunging slickenline lineations. The larger system was traced along strike for 1.2 km (Figure GS-15-2). In this system, a central quartz-breccia vein, which is typically 0.2 to 0.5 m thick, is bounded by 0.5 to 3 m thick zones of intensely silicified and crackle-textured wallrock (Figure GS-15-5a, b), and fringed outward by complex arrays of quartz-stockwork veins. The central breccia vein consists of smoky grey or white quartz that contains 1 to 2% finely disseminated to blebby pyrite, with a trace of chalcopyrite. Four samples of this material collected by the author failed to return any significant Au values. Perhaps significantly, these samples also lacked the coarse arsenopyrite noted by previous

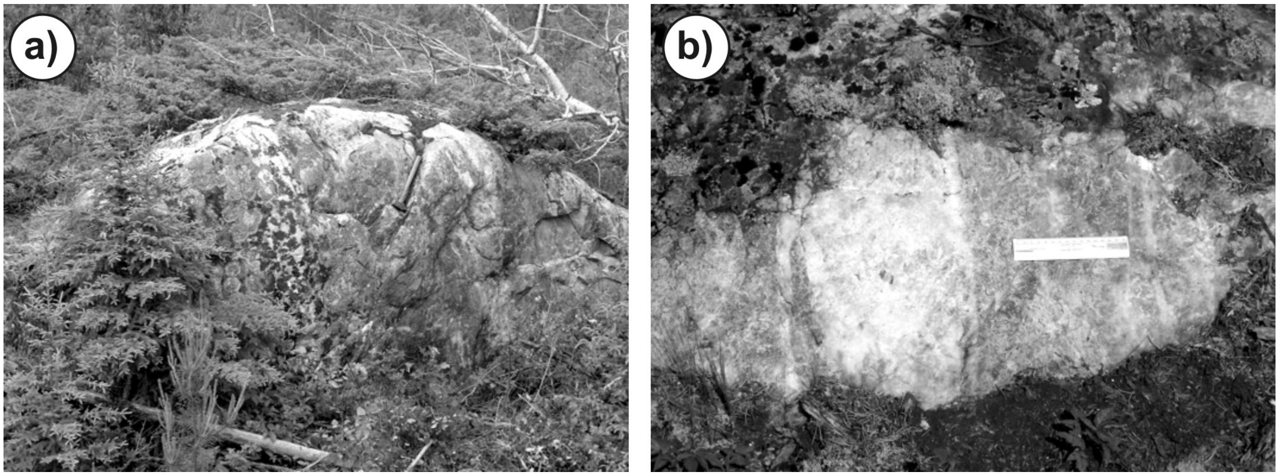

Figure GS-15-5: *Outcrop photographs of stockwork-breccia quartz veins north of Gem Lake:* ***a)*** *quartz-breccia vein (white) bounded by 2 to 3 m thick zones of intensely silicified wallrock;* ***b)*** *detail of quartz-breccia vein and crackle-textured, silicified wallrock.*

authors. In any case, the large extent of these vein systems suggests that the footwall of the WGSZ was a significant locus for hydrothermal fluid flow that, at least locally, appears to have transported and deposited gold.

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