Bedrock geology of the eastern extension of the Rice Lake mine trend, Rice Lake greenstone belt, Manitoba



Introduction

The Rice Lake mine trend is located 155 km northeast of Winnipeg Manitoba, in the central portion of the Archean Rice Lake greenstone belt of the western Superior province. The trend is hosted by Neoarchean volcanic, volcaniclastic, epiclastic and subvolcanic intrusive rocks, and includes several significant gold deposits, the largest of which than 3 million oz. Au (Ginn and Michaud, 2013) and past production of 1.7 million oz. Au, the Rice Lake mine trend is the most significant lode gold camp in Manitoba.

In 2002, the MGS initiated a program of 1:20 000 scale bedrock and Sm-Nd isotopic analysis in select portions of the Rice Lake belt, wit the intention of providing an improved geological context and predictive framework for mineral exploration. Bedrock mapping of the Rice Lake 2008 (Anderson, 2008). Detailed stratigraphic and structural mapping of the mine trend at 1:5 000 scale took place in 2011 (Anderson, 2011a-c), utilizing high-resolution LiDAR imagery and orthorectified aerial photographs provided by San Gold Corporation

opportunity to extend new detailed mapping farther east, into an area last examined by the MGS more than 60 years ago (Russell, 1948). The 2013 study area encompasses 16 km² and extends south from

the drift-filled valley of the Wanipigow River to the north margin of the Ross River pluton. The mapping, at 1:10 000 scale, was complete during a two-week period in June 2013 using detailed orthorectified aerial photographs for navigation and plotting. This poster summarizes the preliminary results of this work with emphasis on lithostratigraphy of the Neoarchean supracrustal succession.

In October 2011, shortly after completion of the detailed mapping

trend was significantly improved by a forest fire that burned northward

program, the quality of bedrock exposure along strike east of the mine

across a 6.5 km wide swath of favourable stratigraphy. The "Long Lake"

burn overlaps the easternmost portion of the area mapped at 1:20 000

scale by the MGS in 2004–2005 and provided an exceptional

Regional geology and structural setting

The Rice Lake belt comprises Neoarchean and Mesoarchean supracrustal rocks and associated intrusions at the westernmost extent of the Uchi subprovince (Card and Ciesielski, 1986; Stot and Corfu, 1991) of the western Superior province (Figure 1). In Manitoba, the Uchi subprovince is flanked to the north by the metaplutonic Berens River subprovince and to the south by granitoid plutonic rocks of the English River subprovince (Card and

The Berens River subprovince and the Mesoarchean portions of the Uchi subprovince constitute the continental North Caribou terrane (NCT), which is regarded as the protocratonic nucleus of the western Superior province (e.g., Stott and Corfu, 1991; Thurston et al., 1991; Percival et al., 2006a, b)

Neoarchean rocks in the Uchi and English River subprovinces are interpreted to represent a north-verging accretion complex that developed over a span of approximately 50 m.y. along the south margin of the NCT (e.g., Stott and Corfu, 1991; Poulsen et al., 1996; Percival et al., 2006a, b; Anderson, 2008, 2013a, b). The Rice Lake belt is structurally bounded by the Wanipigow fault (WF) on the north and Manigotagan fault on the south (Figure 2).

East of Rice Lake, the south margin of the NCT consists mostly of Mesoarchean tonalite and granodiorite (Turek et al., 1989; Bailes et al., 2003) and is juxtaposed to the south with the Rice Lake belt across the WF. In the study area, the WF is largely concealed beneath a thick glacial cover along the valley of the Wanipigow River.

Immediately south of the WF, the Rice Lake belt consists of and volcaniclastic rocks, associated subvolcanic intrusions and derived epiclastic rocks.

Although previously considered part of the ca. 2.75–2.73 Ga Bidou assemblage, these rocks have been re-assigned to the ca. 2.73–2.72 Ga Gem assemblage on the basis new constraints from regional bedrock mapping, lithogeochemistry and U-Pb geochronology (Anderson, 2013a, b).

In the comparatively well studied section that hosts the Rice Lake mine trend (Figure 3), the Gem assemblage includes three distinct lithostratigraphic units (Rainy Lake road, Townsite and Round Lake). In contrast to the basinal-marine setting inferred fo was likely deposited in a more dynamic, shallow-water setting unconformably overlain by fluvial-alluvial rocks of the San Antonio assemblage (Figure 3).

As described by Anderson (2008, 2013b), the structural evolution of the area involved synvolcanic faulting (D₁) and early regional tilting (D₂) of the Bidou and Gem assemblages into a nearvertical orientation prior to the deposition (<2705 Ma; Percival et al., 2006a) of the unconformably overlying San Antonio

Following inversion and thrust imbrication of the San Antonio assemblage (D₃), regional ductile deformation in a kinematic frame of northeast-southwest shortening produced a pervasive planarlinear (S-L) shape fabric, upright doubly plunging folds (including

reverse oblique-slip kinematics (D₄). Most of the major gold deposits in the mine trend are hosted by conjugate arrays of brittle-ductile shear zones and associated fault-fill and extension veins emplaced in the late increments of this

The latest episode of regional deformation (D₅) accommodated northwest–southeast shortening of the belt and was associated with strongly partitioned dextral transcurrent shear deformation along the Wanipigow and Manigotagan faults and their subsidiary

Uchi subprovince

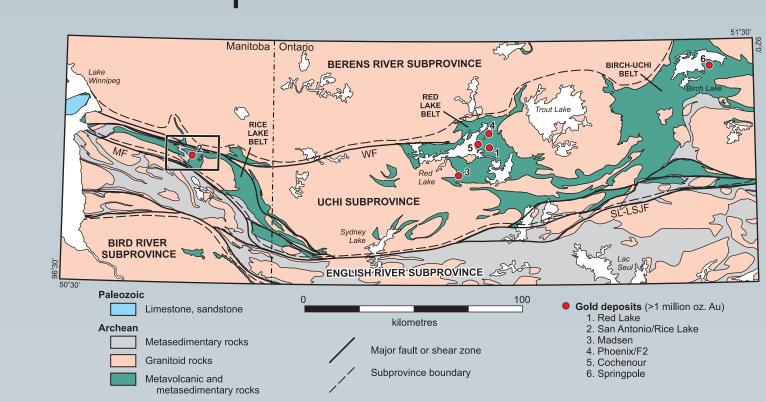


Figure 1: Regional geological setting of the Rice Lake belt in the western Uchi subprovince, showing the locations of major gold deposits. Abbreviations: MF, Manigotagan fault; SL-LSJF, Sydney Lake -Lake St. Joseph fault; WF, Wanipigow fault.

Rice Lake greenstone belt

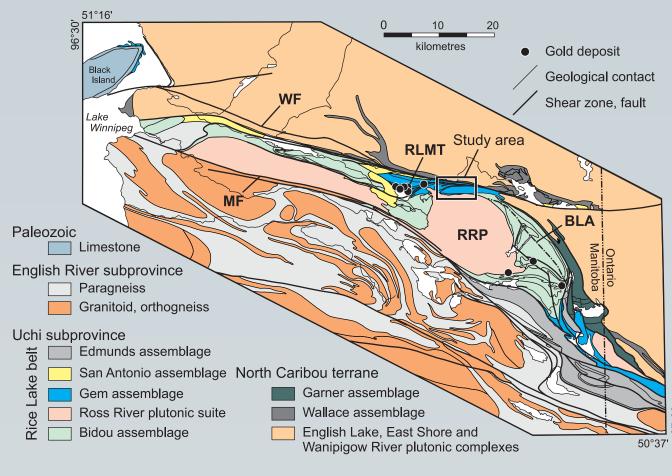


Figure 2: Simplified regional geology of the Rice Lake belt, showing the principal lithotectonic assemblages, major structures and gold deposits, and the location of the study area in relation to the Rice Lake mine trend (RLMT). Abbreviations: BLA, Beresford Lake anticline; MF, Manigotagan fault; RRP, Ross River pluton; WF, Wanipigow fault.

Rice Lake area

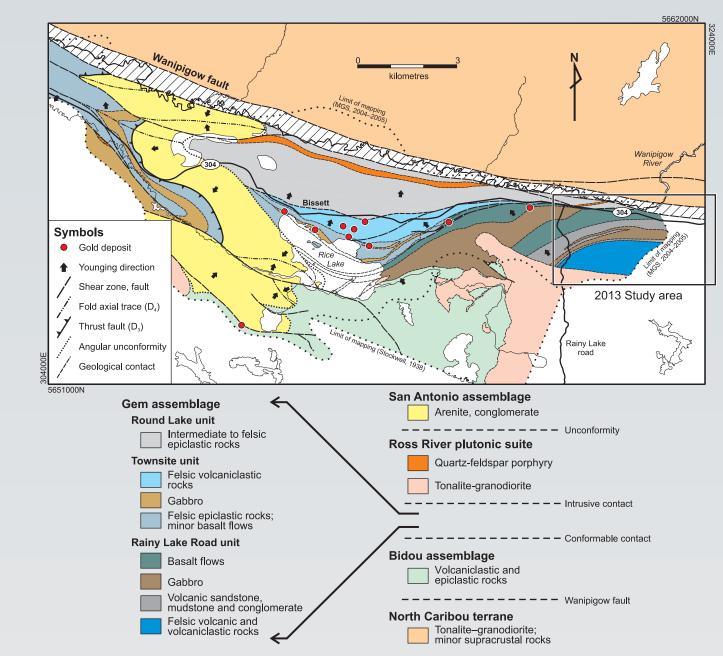


Figure 3: Simplified geology of the Rice Lake mine trend (after Anderson, 2008) showing the 2013 study area, which extends approximately 2 km beyond the eastern limit of this map.

a: Report of Activities 2011, Manitoba Geological Survey, p. 94-1 b: Report of Activities 2011, Manitoba Geological Survey, p. 11 011c: Manitoba Geological Survey, Preliminary Map PMAP2011-3. 013a: Manitoba Geological Survey, Geoscientific Report GR2013-1, 135 Anderson, S.D. 2013b: Manitoba Geological Survey, Open File OF2013-4, 47 p.
Bailes, A.H., Percival, J.A., Corkery, M.T., McNicoll, V.J., Tomlinson, K.Y., Sasseville, C., Rogers, N.,
Whalen, J.B. and Stone, D. 2003: Manitoba Geological Survey, Open File OF2003-1. Card, K.D. and Ciesielski, A. 1986: Geoscience Canada, v. 13, p. 5–13. Ginn, D. and Michaud, M. 2013: Technical report on the Rice Lake mining complex, Bissett, Manitoba; Sa

Percival, J.A., McNicoll, V. and Bailes, A.H. 2006a: Canadian Journal of Earth Sciences, v. 43, p. 895–927. Percival, J.A., Sanborn-Barrie, M., Skulski, T., Stott, G.M., Helmstaedt, H. and White, D.J. 2006b: Poulsen, K.H., Weber, W., Brommecker, R. and Seneshen, D.N. 1996: GAC-MAC, Joint Annual Meeting, May 27–29, 1996, Winnipeg, Manitoba, Field Trip A4 Guidebook, 106 p. Russell, G.A. 1948: Mines Branch, Preliminary Report 47-1, 15 p. Stott, G.M. and Corfu, F. 1991: Ontario Geological Survey, Special Volume 4, pt. 1, p. 145–236. Sun, S.-s. and McDonough, W.F. 1989: Geological Society Special Publication No. 42, p. 313–345. Thurston, P.C., Osmani, I.A. and Stone, D. 1991: Ontario Geological Survey, Special Volume 4, pt. 1, p. 81–142. Turek, A., Keller, R., Van Schmus, W.R. and Weber, W. 1989: Canadian Journal of Earth Sciences, v. 26,

Generation 3 Slickenstriae, generation 5 Generation 3 Generation 5

Bedding, upright

Pillows, upright

Igneous layering

Flow contact

Minor fold axis

Bedding, tops unknown 🕺 Z asymmetric, generation 5

Mineral occurrence Pyrrhotite Pyrite Provincial road Pyrite, chalcopyrite Sphalerite, pyrrhotite, chalcopyrite

Named gold occurrence

PMAP2013-6

mine trend, Rice Lake greenstone belt, southeastern Manitoba Structural geology

Preliminary Map PMAP2013-6

Geology and structure of the eastern extension of the Rice Lake

(part of NTS 52M3, 4)

Basalt; aphyric, massive to pillowed; locally amygdaloidal

Intermediate to felsic tuff breccia, lapilli tuff; minor pink felsic dikes

Supracrustal rocks (Round Lake unit

c) Plagioclase-quartz-phyric

) Plagioclase-quartz-phyric

Plutonic rocks (Ross River pluton)

a) Homogeneous
b) Intrusion breccia

Hypabyssal intrusions (mostly dikes; intrude units 1-5)

Biotite-hornblende granodiorite, tonalite (coeval aplite)

Supracrustal and related intrusive rocks (Rainy Lake Road unit)

c) Pillow-fragment breccia, flow breccia

e) Felsic lapilli tuff, tuff breccia

Dacite; plagioclase-phyric

This map is a provisional summary of work carried out during the summer field

This map is available to download free of charge at www.manitoba.ca/minerals

Anderson, S.D. 2013: Geology and structure of the eastern extension of the

Rice Lake mine trend, Rice Lake greenstone belt, southeastern Manitoba

season and is produced directly from the geologist's manuscript. It is not to be

egarded as a final interpretation of the geology of the area.

part of NTS 52M3, 4); Manitoba Mineral Resources

anitoba Geological Survey, Preliminary Map PMAP2013-6,

a) Coherent
 b) Fragmental

Geology by: S.D. Anderson (2013)

Manitoba Mineral Resources

Manitoba Geological Survey, 2013

Quartz-phyric rhyolite

Primary planar structures in the study area include beds, magmatic layers and flow contacts (collectively referred to as 'primary layering'), as well as dike and sill margins. Primary layering dips steeply toward the north throughout most of the study area, but shows a gradual change in orientation toward the southwest, where it dips moderately to the northwest (Figure 10a). With the exception of minor fold limbs, primary layering is upright everywhere

Dike margins strike subparallel or at a shallow counterclockwise angle to bedding (Figure 10b), in keeping with the geometric relationships observed along strike to the west in the Rice Lake

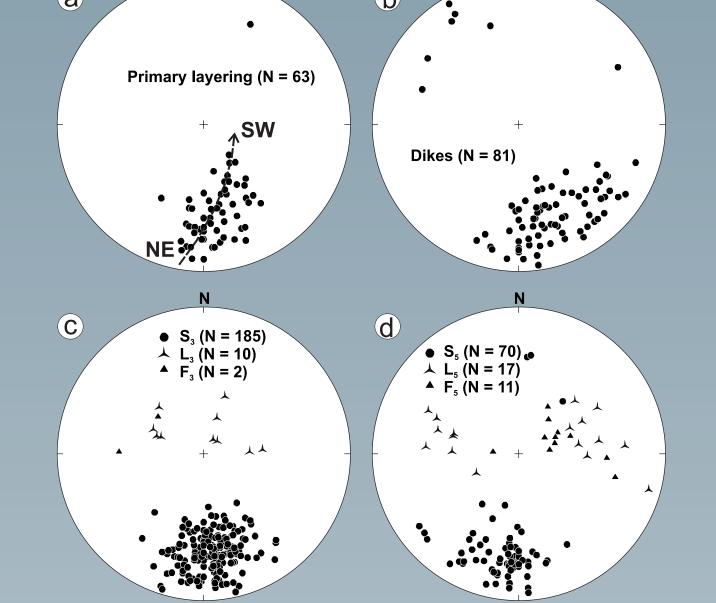
Apart from synsedimentary structures, the earliest deformation structure identified in the study area is a pervasive planar-linear (S-L) shape fabric defined by flattened and stretched primary features Figure 11a, b), which corresponds to the third generation (G₃) of regional deformation structures

is interpreted to result from flattening or drag along the south margin

south, the G₅ fabrics are penetrative in discrete shear zones that splay to the southeast off the footwall of the WF

The G₅ shear zones typically trend west-northwest, dip steeply to the north (Figure 10d) and are characterized by penetrative mylonitic S₅ foliations and packets of strongly asymmetric F₅ Z folds, the hinges of which have highly variable orientations and are locally curvilinear or sheath-like. Dextral kinematic indicators are well developed on horizontal outcrop surfaces and typically include S-C 11c). Stretched clasts, quartz ribbons or ductile striations define a lineation (L₅; Figure 11d) that plunges more shallowly than the local L₃ stretching lineation (Figure 10d).

Along the south margin of the WF, the L₅ lineation plunges west in the east, indicating a complex strain geometry that may relate to incomplete overprinting of the early L fabric (G₃) or G₅ deformation that was transpressional in character.



poles to bedding, flow contacts and igneous layers ('primary layering'), showing a gradual change in orientati from steeply north-dipping in the northern and eastern portions of the area, to shallowly northwest-dipping in the angular relationship to primary layering; c) G_3 fabric elements, showing the steep plunge of the L_3 stretching lineation; d) G_5 fabric elements, showing the shallow to moderate plunge of the L_5 lineation.



Figure 11: Outcrop photographs of deformation structures in the RLR unit: a) penetrative planar S₃ fabric (defined by flattened clasts) showing an angular relationship to bedding (S₀) on the north limb of the F₃ Beresford Lake anticline; b) hinge of a small-scale F₃ fold, showing the near orthogonal relationship between bedding (S₀) and the S₃ shape fabric defined by flattened mudstone rip-up clasts; c) thick G₅ high-strain zone near the south margin of the Wanipigow fault showing penetrative mylonitic foliation, asymmetric boudins and spaced shear-band cleavage; orientation of associated S-C fabric and shear bands (C'), and the sense of shear (dextral) are indicated (ellipse indicates hammer for scale); d) shallowly west-plunging L₅ lineation (black arrow) defined by stretched clasts and ductile striations in the south margin of the Wanipigow fault; steps (white arrows) indicate dextral-reverse oblique-slip in this location.

Local geology

p. 23–30. Wood, D.A. 1980: Earth and Planetary Science Letters, v. 50, p. 11–30.

Coordinate System: NAD 1983 UTM Zone 15N

Most of the 2013 study area is underlain by felsic volcanic subvolcanic gabbro sills corresponding to the Rainy Lake Road (RLR) unit of the Gem assemblage (PMAP2013-6, above). The stratigraphy of the RLR unit is shown in Figure 4. It is intruded at the base by the synvolcanic Ross River pluton and dips moderately to steeply north on the north limb of the Beresford Lake anticline (Figure 2). Photographs of representative outcrops of each map unit are shown in Figures 5, 6, 7 and 8.

The RLR unit is interpreted to record extension and incipient rifting of the Bidou assemblage, leading to the development of a short-lived, fault-bounded marine basin that was rapidly infilled by submarine turbidites and Fe-tholeiitic basalt flows, the latter of which are chemically analogous to modern back-arc basin basalt (Figure 9; Anderson, 2008, 2013b).

The lateral and vertical organization of lithofacies in the middle and upper sections of the RLR unit are fully compatible with this hypothesis. Examples include 1) the eastward fining and thinning of the volcanic conglomerate layer at the base of the middle section (subunits 3a, 3b), indicating increasing distance from the basin-bounding fault to the west, and 2) the marked upward increase in the proportion of pillowed over massive basalt flows, indicating waning eruption rates.

The northern portion of the study area includes a faultbounded panel of volcaniclastic rocks that is tentatively correlated with the Round Lake unit, and is structurally juxtaposed to the north with tectonized supracrustal rocks of unknown affinity along the WF, none of which are described

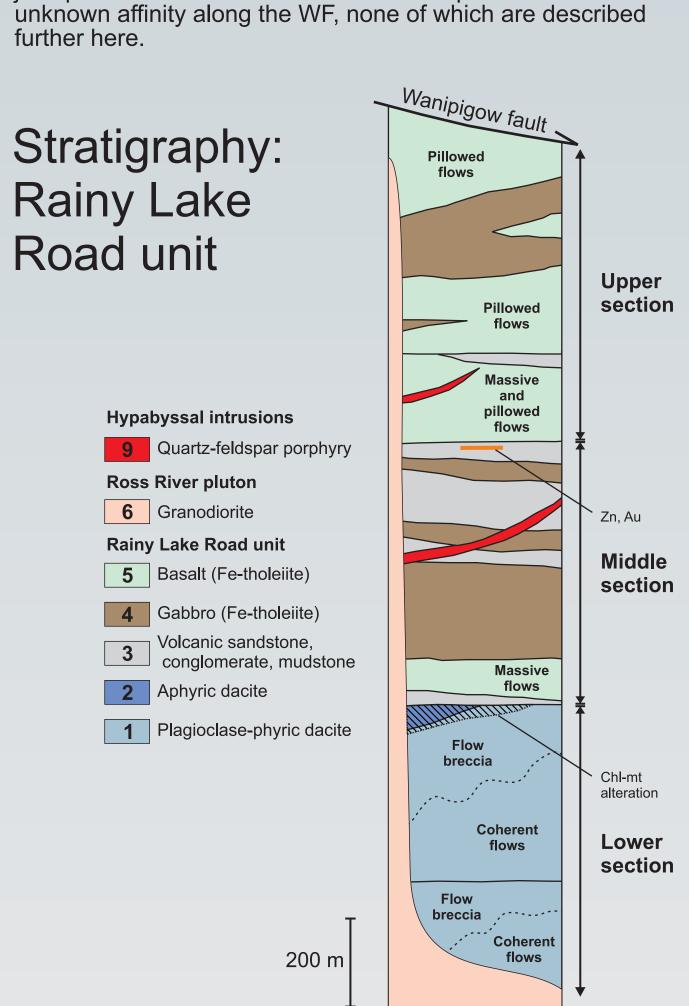


Figure 4: Schematic lithostratigraphy of the Rainy Lake Road (RLR) unit of the Gem

assemblage. For clarity, only the thickest hypabyssal dikes (unit 9) are shown.



Figure 5: Outcrop photographs of units 1 and 2 in the lower section of the RLR unit: a) sharp undulating contact (arrows) between coherent (C) and brecciated (B) dacite of unit 1; b) aphyric dacite breccia of subunit 2b, showing angular cuspate clasts and chloritic tuff matrix (arrow indicates pencil for scale).



each photo): a) heterolithic boulder volcanic conglomerate (subunit 3a) in the western (fault-proximal) portion of unit 3, showing crude normally graded angular to well-rounded clasts; b) heterolithic pebble volcanic conglomerate (subunit 3b) in the eastern (fault-distal) portion of unit 3, showing planar normally graded beds; c) planar-bedded volcanic sandstone and mudstone (subunit 3c); sandstone bed is normally graded but contains reversely graded mudstone rip-up clasts; d) thin, normally graded, volcanic sandstone beds and laminated mudstone beds showing well-developed load structures (subunit 3c); e) planar bed of felsic lapilli tuff showing compound (reverse to normal) size grading of angular rhyolite lapilli (subunit 3e); f) detail of e) showing weakly compacted, densely vesicular, pumice lapilli, indicating coeval felsic volcanism during

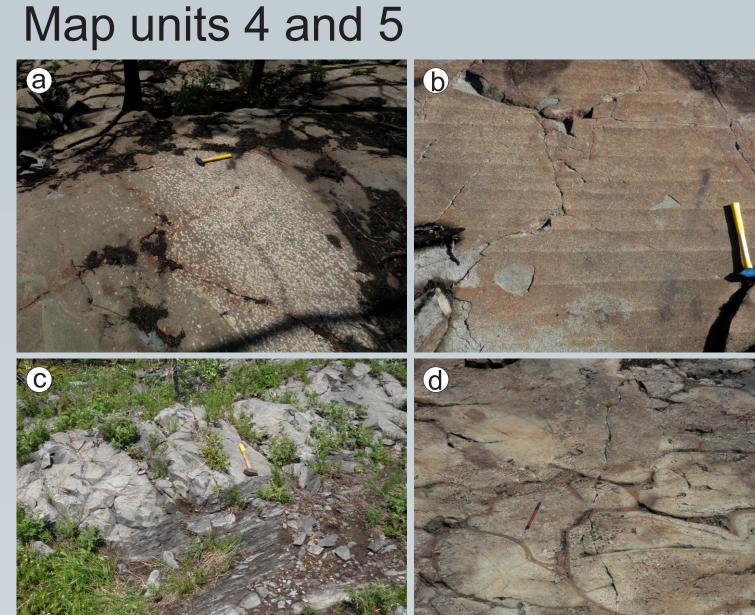




Figure 8: Outcrop photographs of the Ross River pluton: a) homogeneous granodiorite-tonalite (subunit 6a) from the inner margin, showing probable cognate xenoliths; b) intrusion breccia (subunit 6b) from the outer margin, showing angular xenoliths of gabbro in foliated granodiorite-tonalite.

Figure 9: Select geochemical data from key

volcanic and intrusive rocks in the RLR unit

Figure 7: Outcrop photographs of units 4

and 5 in the middle and upper sections of the

each photo): a) plagioclase-crystal-rich layer

RLR unit (hammer or pencil points north in

in mesogabbro (subunit 4b), interpreted to

accumulation of crystals beneath a density

barrier in the cooling magma; b) rhythmic

mesogabbro (subunit 4c); c) massive basal

magmatic layering of leucogabbro and

flow (subunit 5a) showing sharp contact

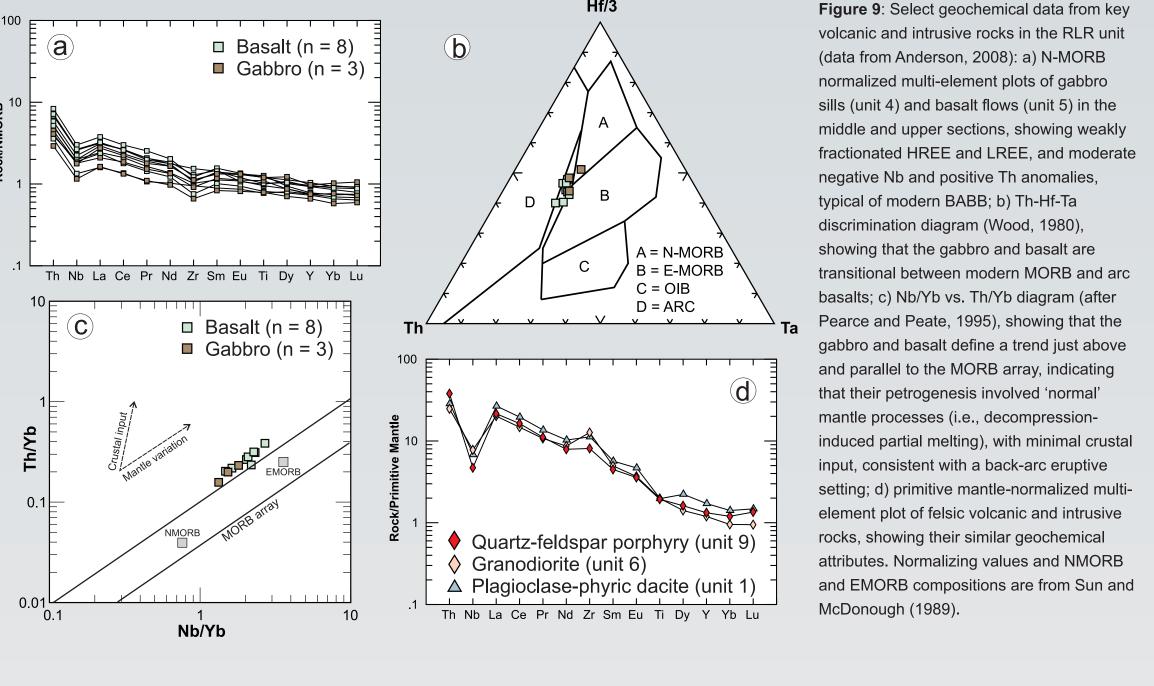
flow (subunit 5b).

(below hammer) with underlying volcanic

conglomerate (subunit 3a); d) pillowed basalt

result from upward movement and

Geochemistry



(data from Anderson, 2008): a) N-MORB normalized multi-element plots of gabbro sills (unit 4) and basalt flows (unit 5) in the middle and upper sections, showing weakly fractionated HREE and LREE, and moderate negative Nb and positive Th anomalies, typical of modern BABB; b) Th-Hf-Ta discrimination diagram (Wood, 1980), showing that the gabbro and basalt are transitional between modern MORB and arc basalts; c) Nb/Yb vs. Th/Yb diagram (after gabbro and basalt define a trend just above and parallel to the MORB array, indicating that their petrogenesis involved 'normal' mantle processes (i.e., decompression induced partial melting), with minimal crustal input, consistent with a back-arc eruptive setting; d) primitive mantle-normalized multielement plot of felsic volcanic and intrusive attributes. Normalizing values and NMORB

Economic implications

Orogenic gold
Given its proximity to the known eastern extent of the Rice Lake area is considered to have excellent potential for quartz-carbonate vein (i.e., orogenic) gold deposits. It includes several significant occurrences of this type, most notably the On the Mark, Romano and

each is hosted by fault-fill and extensional quartz-carbonate veins in spatially associated with the Ross River pluton, hosted by granodiorite-tonalite of the inner margin (On the Mark and Romano) or by dacitic volcanic rocks immediately to the north (Salerno) indicating that structural anisotropy and competency contrast across the pluton margin may have been an important local control on gold

This scenario is analogous to that documented in the Rice Lake mine trend, where the major gold deposits preferentially occur within chemically favourable or competent rock types or along major strength-anisotropies. By analogy with the mine trend, the middle and upper sections of the RLR unit should be very favourable exploration targets: both include gabbro sills and basalt flows of Fe-tholeiitic composition, which are among the most important hosts to orogenic competent rock types, including gabbro and felsic porphyr and contain very pronounced strength-anisotropies due to the large compositional variations between primary layers. It is therefore suggested that future exploration should be focused on establish the locations of favourable structural sites in the middle and upper sections of the RLR unit, by way of detailed structural mapping and geophysical surveys.

Volcanic-hosted massive sulphide

The Gem assemblage presents a highly prospective host for hallmarks of extensional geodynamic settings in major VHMS districts elsewhere. The middle section of the RLR unit is interpreted to represent a relatively restricted marine basin that formed in the hangingwall of a synvolcanic subsidence structure located along strike to the west, in a location now occupied by an apophysis of the Ross River pluton (Figure 13). The middle section contain occurrences of stringer-style chlorite-garnet alteration, solid sulphide chalcopyrite) in coarse epiclastic deposits (Figure 14), indicating that hydrothermal circulation, seafloor discharge (exhalation) and localized sulphide deposition did indeed accompany basin infilling probably in close proximity to a fault-controlled discharge site.

As reported by Anderson (2008), grab samples of sulphidic along the Rainy Lake road returned up to 5.5% Zn and 1.9 ppm Au indicating potential for a base- and precious-metal-rich exhalative

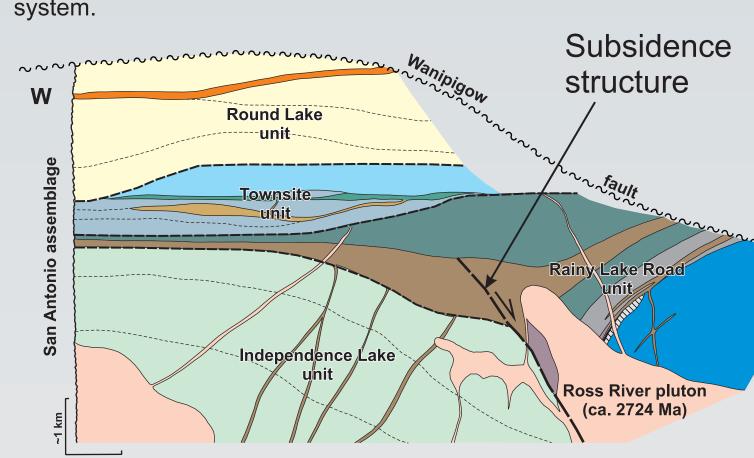


Figure 13: Schematic lithostratigraphy of the Rice Lake section of the Gem assemblage (vertical section, looking toward present-day north). For simplicity, the geology north of the Wanipigow fault and west of the San Antonio assemblage is excluded. The heavy dashed line indicates the approximate location of the postulated synvolcanic fault east of Rice Lake.

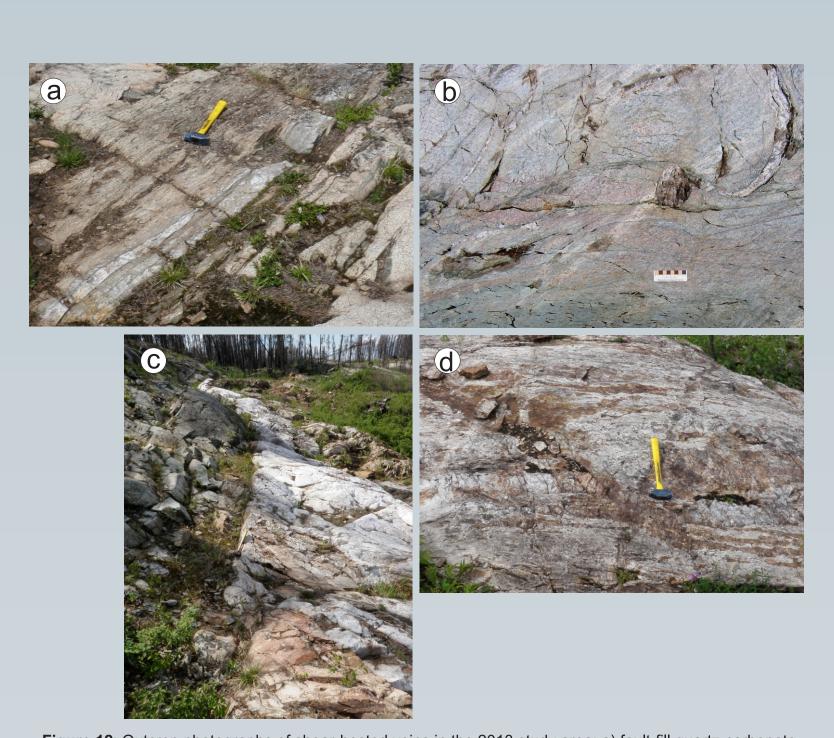


Figure 12: Outcrop photographs of shear-hosted veins in the 2013 study area: a) fault-fill quartz-carbonatetourmaline veins at the On the Mark showing, hosted by a discrete brittle-ductile shear zone in the inner margin of the Ross River pluton; b) auriferous quartz-carbonate veins at the Romano showing, hosted by extension ractures on the margin of a brittle-ductile shear zone in the inner margin of the Ross River pluton; c) thick quartz-carbonate vein at the Salerno showing, hosted by a discrete brittle-ductile shear in dacitic volcaniclastic ocks immediately north of the north contact of the Ross River pluton; d) fault-fill quartz-carbonate-pyrite veins and intense sericite-ankerite-pyrite alteration associated with discrete brittle-ductile shear zones in quartzeldspar porphyry within the Wanipigow fault (these veins have locally been trenched, but are not known to be

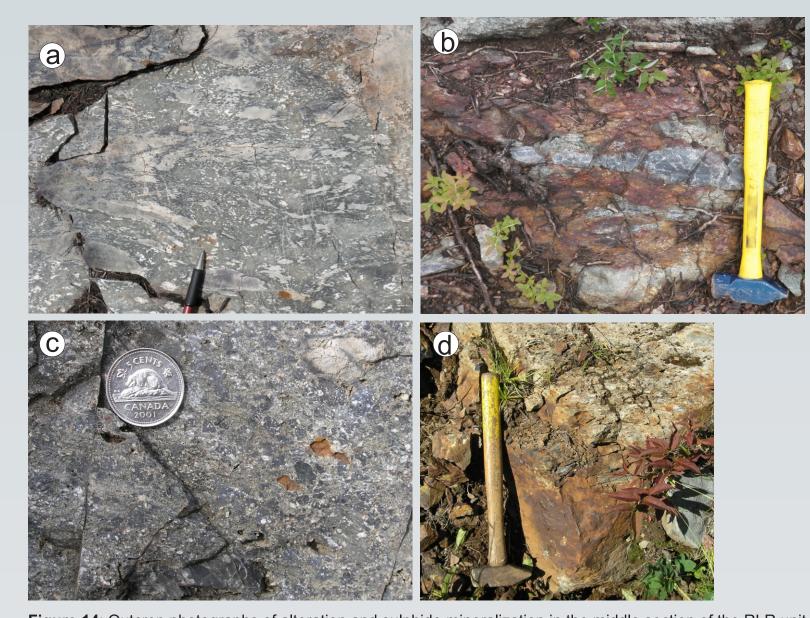


Figure 14: Outcrop photographs of alteration and sulphide mineralization in the middle section of the RLR unit. indicating VHMS potential: a) semi-pervasive chlorite alteration; b) sulphidic mudstone (exhalite); c) solid sulphide clasts (pyrrhotite-chalcopyrite) in volcanic conglomerate; d) sulphidic (sphalerite-pyrrhotite) and uriferous zone at the base of a normally-graded bed of volcanic conglomerate

