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GS-5
Structural study of the Ogama-Rockland gold deposit, southeastern margin of the Ross River pluton, Rice Lake greenstone belt, southeastern Manitoba (NTS 52L14)
by X. Zhou, S. Lin and S.D. Anderson
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The following figure has been revised (page 66):

Figure GS-5-5**: Outcrop photographs of fault-fill veins in the area of Ogama-Rockland gold deposit:* ***a) *thin, laminated quartz vein in a discrete ductile shear zone;* ***b)*** *example of a possible conjugate shear zone and fault-fill vein system.*

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by X. Zhou[1], S. Lin[1] and S.D. Anderson

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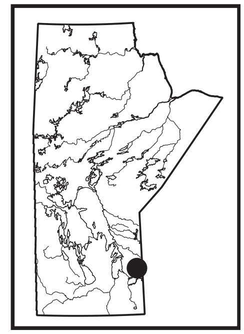

Summary

The Archean Rice Lake greenstone belt is the most important lode gold district in Manitoba and lies in the western part of the Uchi Subprovince of the Superior Province. Unlike most gold deposits in the Rice Lake belt, which are hosted by layered gabbro sills, basalt flows or volcaniclastic rocks, the Ogama-Rockland gold deposit is hosted by granitoid intrusive rocks. This deposit is situated in the southeastern margin of the Ross River pluton, which consists mostly of granodiorite and tonalite, with minor quartz diorite, monzogranite and alkali-feldspar granite. The contacts of these different intrusive phases are typically gradational. Numerous quartz-feldspar porphyry dikes, aplite dikes (some of which contain central quartz veins) and a complex network of quartz veins crosscut the various phases of plutonic rocks.

Auriferous quartz (-carbonate) veins associated with the Ogama-Rockland deposit have a close spatial relationship with west-northwest- to northwest-striking, subvertical, dominantly dextral, brittle-ductile to ductile shear zones. Minor north-trending, subvertical, sinistral brittle-ductile shear zones are also associated with quartz veins. The shear-zone rocks are mostly granitoid mylonite, mica-quartz schist or K-feldspar-porphyroclast–bearing chlorite schist. The veins are mostly massive, but locally exhibit laminated or banded internal textures and asymmetric fabrics that indicate the same sense of shear as the hosting shear zones. They were most likely emplaced late during shearing. The ongoing detailed structural analysis of these veins will provide important new information to constrain exploration models, and will help draw attention to intrusion-hosted, shear-related, vein-type gold mineralization in the Rice Lake belt.

Introduction

In the summer of 2012, a Ph.D. thesis project was initiated in the Long Lake area of the Rice Lake greenstone belt with the goal of increasing understanding of the lithological and structural setting of intrusion-hosted, shear zone–related, lode-gold deposits. This project is designed to provide important new constraints for exploration modelling in this highly prospective area, and to shed light on the regional structural evolution and metallogeny of the Rice Lake belt. It is being funded by a Collaborative Research and Development grant from the Natural Sciences and Engineering Research Council of Canada in partnership with Bison Gold Resources Inc. and with in-kind support from the Manitoba Geological Survey.

In the first field season of what is designed as a three-year mapping project, the first author carried out 1:1000 scale geological mapping within the southeastern margin of the Ross River pluton in the vicinity of the past-producing Ogama and Rockland mines. Bedrock exposure is excellent in this area and many key outcrops have recently been stripped and washed by Bison Gold Resources Inc. Four of these outcrops were mapped in detail during this study (1:50 scale) and clearly show crosscutting and overprinting relationships among various intrusive phases of the pluton and brittle-ductile shear zones and associated auriferous vein systems. During this work, more than 100 samples were collected for petrographic and microstructural analysis, as well as for U-Pb geochronological studies; analytical results are pending.

This report provides descriptions of the various intrusive phases in the southeastern margin of the Ross River pluton in the area of the Ogama and Rockland mines. We also emphasize the structural features of auriferous quartz veins associated with brittle-ductile shear zones. The relative age relationships of plutonic rocks, quartz-feldspar porphyry dikes, aplite dikes and gold-bearing quartz veins, as well as brittle-ductile shear zones and brittle shear fractures, are also briefly discussed.

Regional geology

The Rice Lake greenstone belt is located approximately 170 km northeast of Winnipeg in the western portion of the Uchi Subprovince of the western Superior Province (Figure GS-5-1). It consists of Meso- and Neoarchean mafic, intermediate and felsic volcanic and sedimentary rocks and subvolcanic intrusions (Poulsen et al., 1996; Bailes et al., 2003; Anderson, 2008). It is flanked on the north by the Wanipigow River plutonic complex of the granitoid-dominated North Caribou Terrane. To the south, the supracrustal rocks are flanked by the Manigotagan Gneissic Belt of the English River Subprovince. The northern boundary of the Rice Lake greenstone belt is defined by the Wanipigow and Beresford

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Lake shear zones, whereas the southern boundary is defined by the Manigotagan Shear Zone, all of which are east- to southeast-trending, subvertical, crustal-scale faults showing apparent dextral displacements (Poulsen et al., 1996; Anderson, 2008). The supracrustal rocks are divided into several distinct lithotectonic assemblages, which include the Mesoarchean Wallace assemblage, and the Neoarchean Bidou, Gem, Edmunds and San Antonio assemblages (e.g., Poulsen et al., 1996; Bailes et al., 2003; Anderson, 2008). The basalt-dominated Bidou assemblage defines the core of the Rice Lake belt and is intruded by the tonalite-dominated Ross River pluton, which has yielded U-Pb zircon ages of 2728 ±8 Ma (Turek et al., 1989) and 2724 ±2 Ma (Anderson, 2008).

Descriptions of rock units

The geology in the vicinity of the Ogama and Rockland mines has been investigated by many workers (e.g., Stockwell and Lord, 1939; Campbell, 1971; Paulus and Turnock, 1971; Zwanzig, 1971; Brommecker, 1991, 1996). Descriptions of the mining history and underground geology, as well as reviews of the regional geology and gold deposits, were provided by Stockwell and Lord (1939) and Poulsen et al. (1996). The area is underlain by pillowed and massive basalt flows and gabbro sills of the Bidou assemblage, and tonalitic–granodioritic intrusive rocks of the Ross River pluton (Zhou et al., 2012).

Bidou assemblage

Basalt (unit 1)

This unit is located in the southern portion of the study area, along the south margin of the Ross River Pluton. Most outcrops are massive; however, some outcrops show pillow-like structures varying from 15 to 30 cm in diameter (Figure GS-5-2a). Fine-grained basalt usually forms the interiors of the pillows and grades outward into finer grained, lighter coloured rims, which contain abundant carbonate. These rocks have light grey to black weathered surfaces and pale green fresh surfaces. They are aphanitic to fine grained and aphyric to sparsely feldspar-phyric (<3%), with numerous vesicles locally. The feldspar phenocrysts are euhedral to subhedral and range up to 2 mm long. The vesicles range from 1 to 3 mm in diameter and are partly filled with smoky quartz, especially near the contact with the pluton (Figure GS-5-2b).

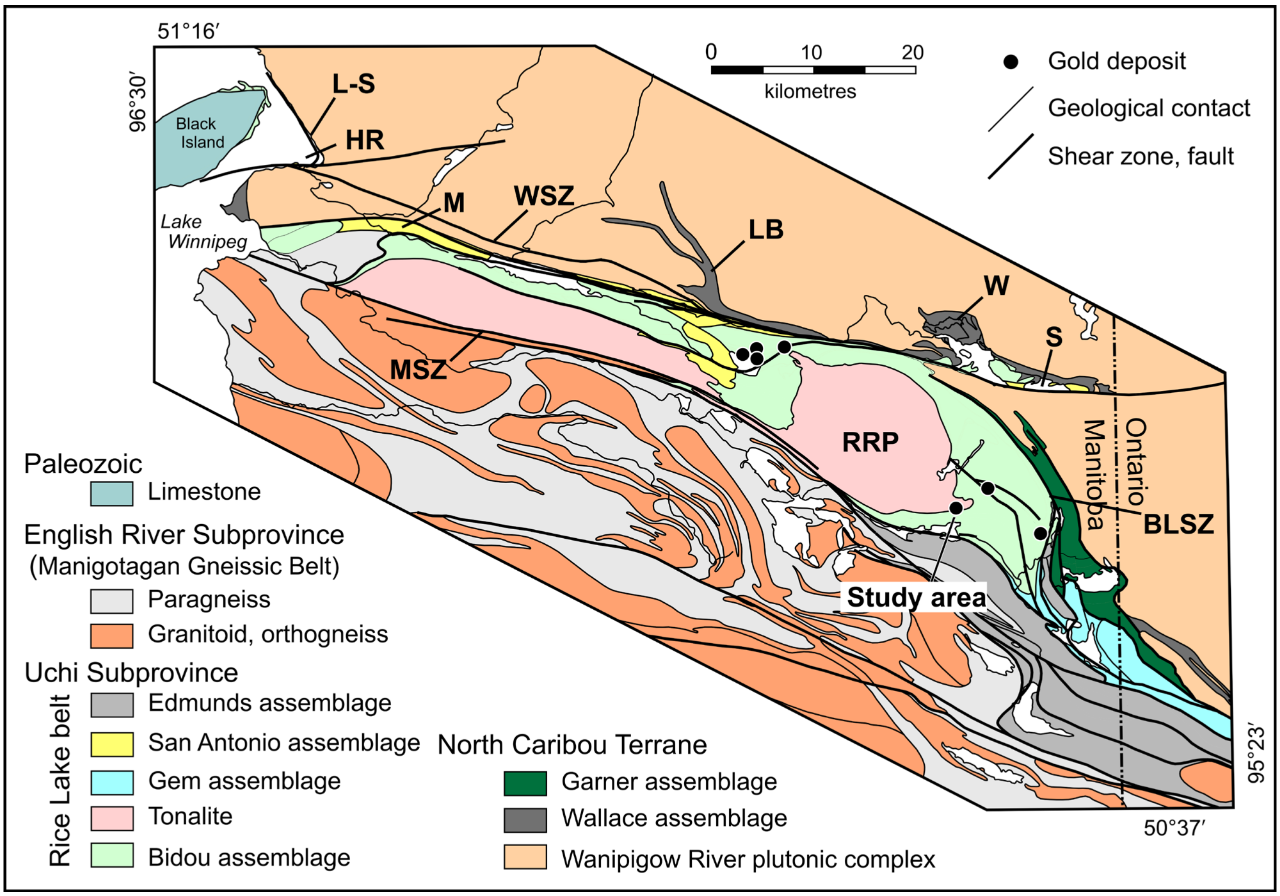

Figure GS-5-1: *Simplified geology of the Rice Lake greenstone belt, southeastern Manitoba, showing the principal lithotectonic assemblages, major gold deposits and location of the study area (modified from Anderson, 2011). Abbreviations: BLSZ, Beresford Lake Shear Zone; HR, Hole River assemblage; LB, Little Beaver assemblage; L-S, Lewis-Storey assemblage; M, Manigotagan assemblage; MSZ, Manigotagan Shear Zone; RRP, Ross River pluton; S, Siderock assemblage; W, Wallace assemblage; WSZ, Wanipigow Shear Zone.*

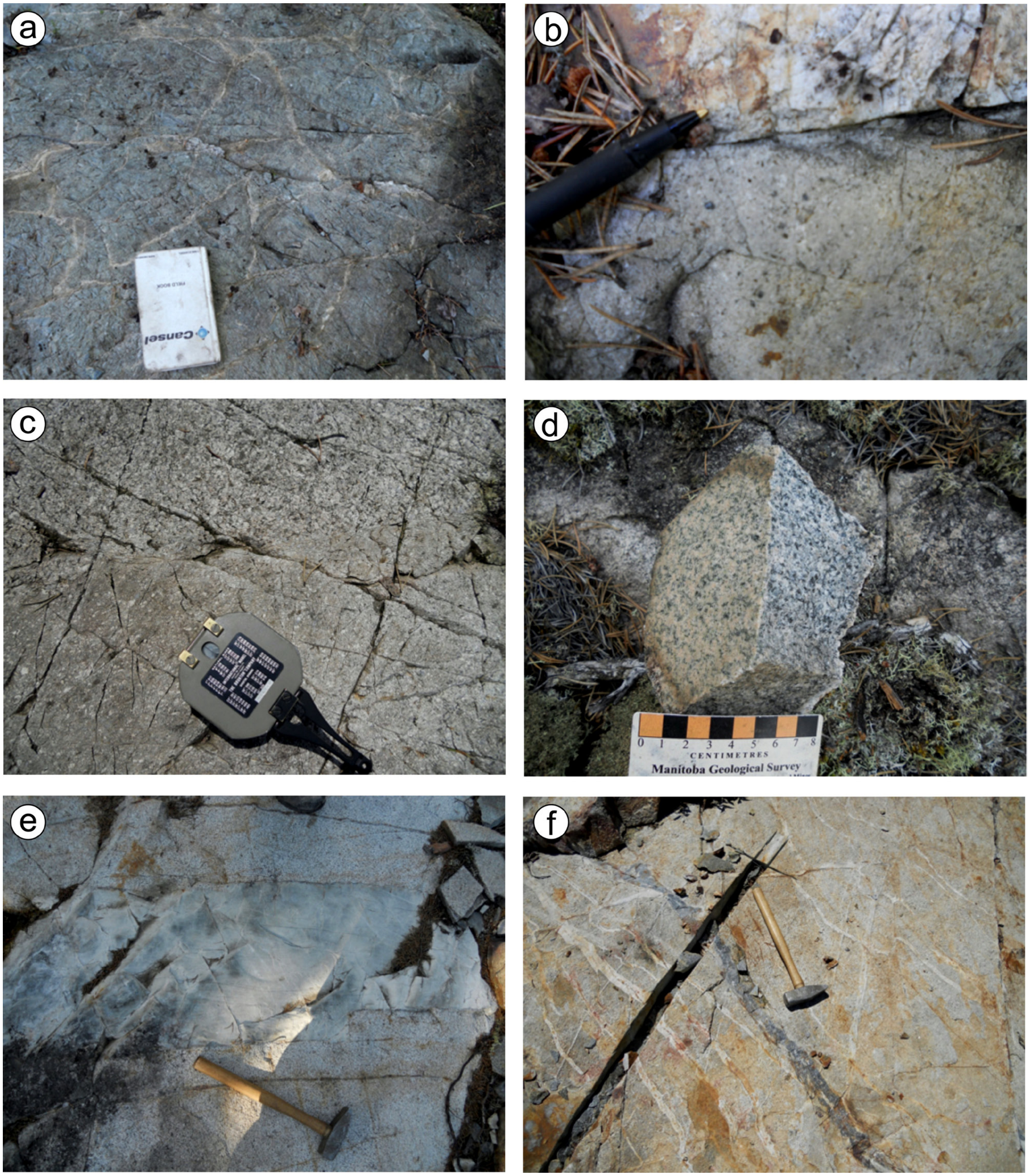

Figure GS-5-2: *Outcrop and hand-sample photographs of rock types in the Ogama-Rockland gold deposit area:* ***a)*** *basalt showing vague pillow structure;* ***b)*** *round quartz amygdules in basalt (bottom) in sharp contact with fine-grained tonalite (top); the chilled margin on the tonalite and the dark metamorphic aureole in the basalt indicate an intrusive contact relationship;* ***c)*** *sharp contact between medium-grained equigranular tonalite (subunit 2a; top) and fine- to medium-grained plagioclase-phyric tonalite (subunit 2b; bottom);* ***d)*** *hand sample of K-feldspar–phyric granodiorite showing weathered and fresh surfaces;* ***e)*** *quartz-feldspar porphyry dike (light grey) intruding equigranular tonalite;* ***f)*** *subparallel aplite dikes and quartz veins in plagioclase-phyric tonalite.*

In places, the basalt flows contain numerous vaguely bounded blocks of pale green epidote mixed with quartz and feldspar, which may represent epidosite formed during seafloor hydrothermal alteration.

Ross River pluton

The southeastern margin of the Ross River pluton is well exposed in the study area. Several different intrusive phases were identified in the field on the basis of mineral modes and textures. The pluton is composed mainly of equigranular to plagioclase-phyric tonalite and equigranular to K-feldspar–phyric granodiorite. The pluton also includes minor plagioclase-phyric quartz diorite, K-feldspar–phyric biotite monzogranite and equigranular alkali-feldspar granite. These various intrusive phases are intruded by numerous discordant quartz-feldspar porphyry and aplite dikes.

Hornblende-biotite tonalite (unit 2)

Hornblende-biotite tonalite often weathers yellowish grey but is greyish white on fresh surfaces, with a medium-grained hypidiomorphic-granular texture. Fine-grained and coarse-grained textures were also identified in some places. The principal minerals are plagioclase (45–75%), quartz (20–30%), hornblende (15–25%), biotite (~5%) and K-feldspar (<5%). Plagioclase forms euhedral to subhedral crystals that range from 2 to 5 mm. No preferred orientation has been identified for plagioclase. Quartz is typically anhedral and interstitial, and ranges in size from 1 to 3 mm, up to a maximum of 5 mm. At several outcrops, quartz grains have an ellipsoid shape and define a weak foliation and grain lineation that trends 230–240° on horizontal outcrop surfaces. It is difficult, in most places, to identify the dip of this early foliation or plunge of the quartz-grain lineation due to the typical two-dimensional plane of observation. The hornblende crystals are euhedral to subhedral, ranging from 3 to 6 mm, and also define a weak and moderate foliation striking 230–240°.

This unit can be subdivided into two subunits: equigranular hornblende-biotite tonalite (subunit 2a) and plagioclase-phyric hornblende-biotite tonalite (subunit 2b; Figure GS-5-2c). The latter tonalite shows a porphyritic texture with plagioclase phenocrysts ranging from 5 to 7 mm, and accounting for 10–15% of the total modal volume. The matrix is composed of fine- to medium-grained plagioclase, quartz, hornblende and biotite. In contrast, equigranular tonalite has no obvious phenocrysts and grain size is broadly uniform, ranging from 2 to 4 mm.

Biotite-hornblende tonalite (unit 3)

Biotite-hornblende tonalite weathers yellowish grey and is greyish white on fresh surfaces. In most places, this tonalite is massive and homogeneous with a medium-grained equigranular texture (subunit 3a). The principal minerals are plagioclase (55–65%), quartz (20–25%), biotite (5–15%), hornblende (<5%) and K-feldspar (<5%). Plagioclase is euhedral to subhedral, ranging from 3 to 5 mm. Quartz and K-feldspar are subhedral to anhedral, ranging from 2 to 4 mm. Biotite is euhedral to subhedral, ranging from 3 to 5 mm. Some samples contain biotite aggregates up to 10 mm across. Hornblende crystals range in size from 3 to 5 mm and are euhedral to subhedral. In some outcrops, biotite-hornblende tonalite shows a plagioclase-phyric texture (subunit 3b), of which plagioclase phenocrysts account for 5–15% of modal volume and range in size from 6 to 8 mm.

Equigranular and K-feldspar–phyric biotite granodiorite (unit 4)

This unit is located mainly in the northwestern and southeastern parts of the map area. Equigranular granodiorite (subunit 4a) consists of K-feldspar (10–15%), plagioclase (40–45%), quartz (20–25%) and biotite (15%). Plagioclase is often euhedral to subhedral, ranging up to 4 mm in size. The K-feldspar and quartz are subhedral to anhedral and interstitial, ranging from 2 to 4 mm. Biotite is euhedral to subhedral and ranges up to 8 mm in places.

The K-feldspar–phyric biotite granodiorite (subunit 4b) has a composition similar to that of equigranular biotite granodiorite, except that K-feldspar phenocrysts (5–6 mm) account for 10–15% of the mode and the matrix consists of medium-grained (2–4 mm) K-feldspar (5%), plagioclase (40–45%), quartz (20–25%) and biotite (15%).This rock has a light pink fresh surface and pale green to greyish-pink weathered surface (Figure GS-5-2d). The plagioclase is locally altered to epidote.

Plagioclase-phyric quartz diorite (unit 5)

This unit occurs in several small outcrops, including an outcrop at the Rockland shaft. This rock is dark grey and fine to medium grained (1–3 mm) with a porphyritic texture. Phenocrysts are chiefly euhedral plagioclase (5–7 mm) and account for 5% of the modal volume. The fine- to medium-grained matrix consists of plagioclase (30%), hornblende (45%), quartz (10%) and K-feldspar (5%). Hornblende and plagioclase are euhedral to subhedral, whereas quartz and K-feldspar are subhedral to anhedral.

K-feldspar–phyric monzogranite (unit 6)

This unit consists of pink to grey, medium-grained (2–4 mm) monzogranite that contains 25–30% K-feldspar phenocrysts. The matrix is composed of euhedral plagioclase (30%), subhedral biotite (15%) and anhedral quartz (25%).

Alkali feldspar granite (unit 7)

This unit only occurs in the northwestern portion of the map area. It consists of pink granite that contains

70–80% euhedral to subhedral K-feldspar (3–5 mm), 20–25% anhedral quartz (2–4 mm), and 10–15% subhedral biotite (3–4 mm).

Dikes

Quartz-feldspar porphyry dikes (unit 8)

This unit crosscuts the above intrusive phases and usually has a greyish-white weathered surface with a dark grey fresh surface. It consists of quartz-feldspar porphyry dikes less than half a metre in thickness that have sharp and planar contacts with country rocks (Figure GS-5-2e). Most of these dikes show a strong foliation, especially near the margins. Some of them have irregular shapes on horizontal outcrop surfaces, which make it easy to mistake them as inclusions. They consist of feldspar (15–30%) and quartz aggregates (1–5%), with 65% matrix consisting of aphanitic to very fine grained quartz and feldspar. The quartz-feldspar porphyry dikes generally trend east-northeast or east-southeast and are steeply dipping. These dikes are often associated with, and concordant with, shear zones.

Aplite dikes (unit 9)

This unit is abundant across the map area and crosscuts various intrusive phases of the Ross River pluton (Figure GS-5-2f). It consists of very fine grained feldspar (~70%) and quartz (~30%), with minor biotite (<5%). Some of these dikes contain a central quartz vein. Most are oblique or orthogonal to adjacent shear zones or brittle shear fractures. They are commonly offset by apparent dextral brittle shear fractures. Some aplite dikes are folded, possibly due to shearing (Figure GS-5-3e).

Structural geology

Shear zones and faults

Shear zones are an important structural feature of the Rice Lake gold district in that they are spatially and genetically associated with all the major gold deposits. They provide critical information on the structural setting and controls of gold mineralization. Both the basaltic country rock and the southeastern margin of the Ross River pluton host numerous discrete brittle-ductile shear zones associated with auriferous quartz (-carbonate) veins. Most of the shear zones are west-northwest to northwest striking and subvertical to steeply north or south dipping, with apparent dextral displacements. A small number of shear zones are subvertical and north trending, showing sinistral offsets. The basaltic country rocks contain one west-trending, steeply north-dipping shear zone that appears to be a high-angle reverse fault and is described separately below.

Various orientations of brittle shear fractures have also been identified in the field, mostly based on the sharp offset of passive markers (e.g., aplite dikes). Most of these fractures show apparent dextral offset. In cases where they are parallel or subparallel to an adjacent brittle-ductile shear zone and have the same sense of shear, they are assumed to have formed in the same generation of deformation. However, an overprinting relationship has also been discovered between two oblique brittle shear fractures, one of which parallels the associated shear zone and the other of which is oblique to and crosscut by the shear zone; this indicates that the shear zones may have been preceded by at least one increment of brittle deformation.

West-trending reverse shear zone

Near the contact with the Ross River pluton, the basalt (unit 1) is intensely deformed and metamorphosed, and is overprinted by an approximately 5–10 m wide, west-striking, steeply north-dipping ductile shear zone. The rocks in this high-strain zone are dark green, strongly foliated chloritic mylonite. Subvertical ridge-in-groove slickenside striations are well developed on the surface of the mylonitic foliation (Figure GS-5-3a) and plunge steeply. Vertical outcrop surfaces oriented perpendicular to the mylonitic foliation and parallel to the slickenside striation contain prominent asymmetric fabrics, including S-C fabrics and shear bands (Figure GS-5-3b). Here, the mylonitic foliation is defined by curviplanar C-foliations, which are parallel to the boundary of the shear zone. The C-foliations typically contain rheologically weak phyllosilicate minerals, which are chiefly chlorite with minor sericite. They typically show relatively high strain compared to S-domains. The S-domains are mainly composed of less-deformed felsic materials like quartz and feldspar, and typically display a fabric (S-foliations) that curves smoothly into C-foliations. There are also concordant fault-fill quartz veins and lenses within the shear zone (Figure GS-5-3b).The S-C fabric, shear bands, ridge-in-groove slickenside striations and steps on the C surface indicate that this shear zone is a top-to-the-south, high-angle, reverse ductile fault.

In the eastern extension of this shear zone, the slickenside striations plunge shallowly to the east, and the deflection of pre-existing foliations along the shear zone boundary indicates an apparent dextral offset on the horizontal surface. The apparent change in kinematics of this shear zone may record two different increments of a single progressive deformation event, or may indicate two distinct phases of deformation.

West-northwest- to northwest-trending strike-slip shear zones

The Ross River pluton and basaltic country rocks contain numerous west-northwest- to northwest-trending, mostly subvertical to steeply north-dipping, dextral brittle-ductile shear zones and associated fault-fill quartz veins. Various types of shear-sense indicators are

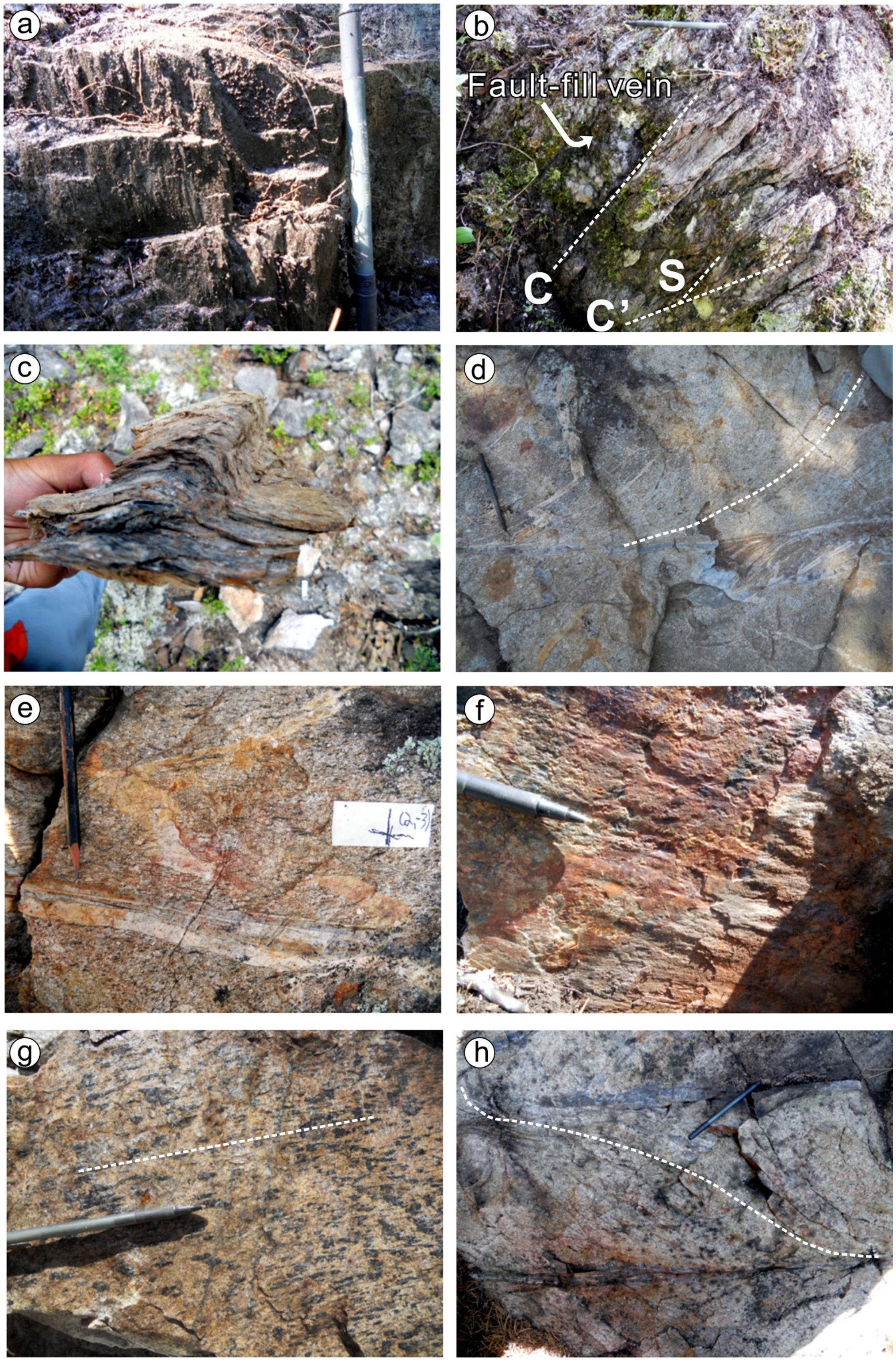

Figure GS-5-3: *Outcrop photographs of shear-zone–related structural features in the area of the Ogama-Rockland gold deposit:* ***a)*** *subvertical ridge-in-groove slickenside striations on stepped C-surfaces (facing south);* ***b)*** *steeply north-dipping reverse shear zone showing S-C fabric and shear bands (north is to the left; indicated by pen);* ***c)*** *example of an S-asymmetric fold in ductile mylonite (the hand sample was overturned to expose the clean underside and therefore shows the opposite sense of fold asymmetry); fold asymmetry indicates sinistral sense of shear;* ***d)*** *deflection of pre-existing foliation along a discrete shear zone, indicating dextral sense of shear;* ***e)*** *folded aplite dike near a shear zone (the pen points north);* ***f)*** *slickenfibres and steps on the margin of a fault-fill quartz vein within a shear zone (corresponds to C-surface);* ***g)*** *tourmaline striae on a brittle shear fracture;* ***h)*** *shear-band cleavage indicating sinistral sense of shear (pen points north).*

developed in these shear zones, including S-C fabrics, shear bands, asymmetric folds (Figure GS-5-3c), deflections of older foliations (Figure GS-5-3d), offsets or drag of passive markers (e.g., aplite dikes; Figure GS-5-3e) and steps on C-surfaces (Figure GS-5-3f).

Two types of striation have been identified: discontinuous tourmaline striations (Figure GS-5-3g) on fault surfaces or joints and quartz slickenfibres (Figure GS-5-3f) on the boundaries between massive quartz veins and quartz-mica mylonite or granitic mylonite. Most of these striations plunge at a shallow or moderate angle (mostly less than 25° to a maximum of 45°) to the east, with a few plunging shallowly to the west. This suggests that shearing is oblique-slip, with a dominant dextral strike-slip component and minor dip-slip component.

North- to north-northeast-trending strike-slip shear zones

Several north- to north-northeast-trending, subvertical, sinistral shear zones have been investigated in the field. They are relatively rare compared to the dextral shear zones and contain fewer fault-fill quartz veins. The kinematics of these shear zones are indicated by shear bands and deflections of pre-existing foliations (Figure GS-5-3h). Both of these features indicate sinistral shear. Few examples of quartz slickenfibres or slickenside striations were observed in the field; therefore, the slip history of this set of shear zones is not well constrained.

Folds and cleavages

Minor folds of quartz veins and associated axial-plane cleavages are locally developed within 3 m of the dextral shear zones (Figure GS-5-4a), and their geometry and orientation indicate that they likely formed during one progressive dextral shear event. However, some folded quartz veins have no corresponding axial-plane cleavage (Figure GS-5-4b) or have a geometry that indicates a far-field stress regime similar to that of the west-striking reverse shear zone, perhaps indicating that more than one generation of folds exist in the study area.

Auriferous vein systems

Auriferous quartz (-carbonate) veins in the study area can be classified into three main groups based on their orientation and geometry with respect to the associated shear zones: fault-fill veins, extensional veins and stockwork veins.

Fault-fill veins

Fault-fill veins are the most common vein type in the study area. They are typically less than half a metre thick, may extend continuously along strike for tens of metres and can locally be traced intermittently for up to 100 m. They are usually grey to milky white and tabular or lenticular, and have mainly a massive internal texture. They are bound on one or both sides by strongly foliated mylonite. Shallowly to moderately plunging ridge-in-groove slickenside striations are typically well developed on the vein margins.

Close to the Rockland shaft, quartz in some of the fault-fill veins is dark grey to smoky or locally blue grey. Some of these veins are laminated or banded and also show evidence of ductile deformation (Figure GS-5-5a); asymmetric fabrics in the veins typically show the same sense of shear as host shear zones. Some fault-fill veins split into two branches with opposing sense of shear, suggestive of a conjugate set (Figure GS-5-5b).

The above observations, including the spatial association of the quartz veins with shear zones, indicate that the veins were most likely emplaced along the shear zones late during shearing.

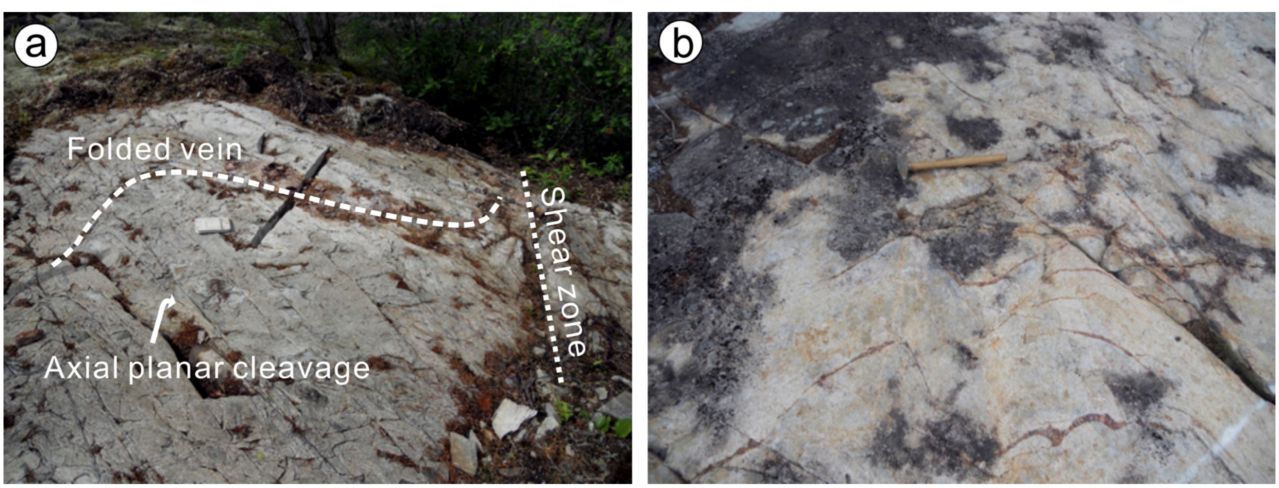

***Figure GS-5-4:** Outcrop photographs of folded quartz veins in the area of the Ogama-Rockland gold deposit: **a)** folded quartz veins and associated axial-plane cleavage along the margin of a west-northwest-trending, subvertical, dextral shear zone; north is to the right of the picture; **b)** example of an array of folded quartz veins; north is to the left of the picture.*

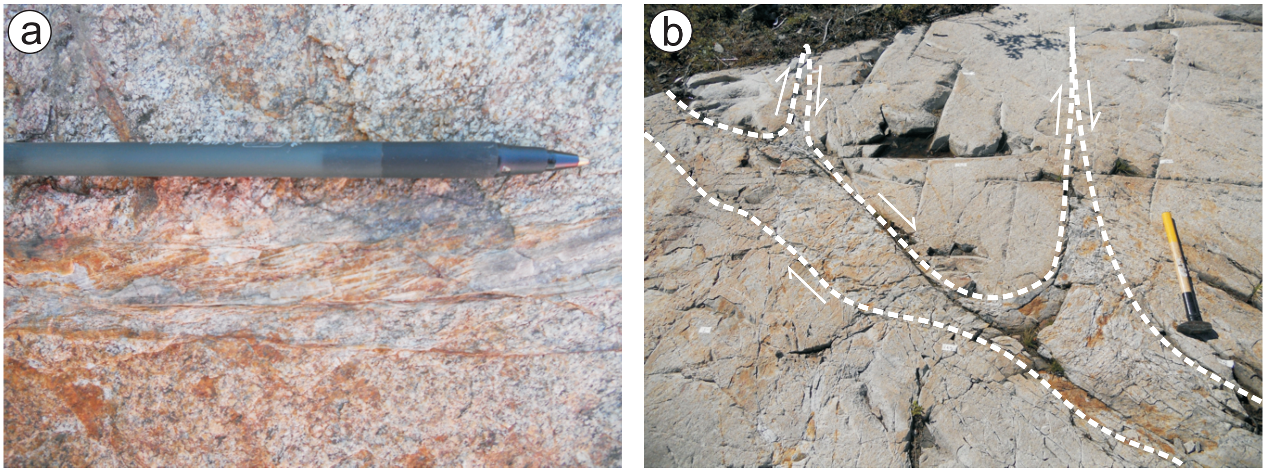

Figure GS-5-5: *Outcrop photographs of fault-fill veins in the area of Ogama-Rockland gold deposit:* ***a)*** *thin, laminated quartz vein in a discrete ductile shear zone;* ***b)*** *example of a possible conjugate shear zone and fault-fill vein system.*

Extension veins

Extension veins are typically 1–10 cm thick and smoky grey to milky white. They are usually oriented at a moderate to high angle to adjacent shear zones. Some outcrops contain parallel arrays of extension veins. Typically, wallrocks adjacent to extension veins show no evidence of shearing. Several thick extension veins strike north, and one of these clearly truncates a northwest-trending fault-fill vein, indicating that it formed relatively late.

Stockwork veins

Stockwork veins contain two or more oblique or perpendicular sets of veins. In some locations, one set consistently cuts across the other, indicating two distinct stages of emplacement. However, most stockworks consist of two sets of veins with mutual crosscutting relationships, indicating broadly coeval emplacement.

Economic considerations

As indicated above, the Ogama-Rockland gold deposit is hosted by quartz (-carbonate) veins associated with brittle-ductile shear zones in felsic granitoid rocks at the southeastern margin of the Ross River Pluton. Auriferous quartz (-carbonate) veins show a close spatial relationship with northwest-trending, dominantly dextral shear zones and are mainly of the fault-fill type. Some north-trending extensional veins might also have a temporal and genetic relationship with this deformational event. A west-trending reverse shear zone along the southern margin of the pluton may be related to an earlier shearing event. The auriferous veins contain cubes or disseminated grains of pyrite, with disseminated chalcopyrite, sericite and carbonate, and minor sphalerite, molybdenite and possible orpiment. Most of these veins are massive. However, some of them exhibit laminated or banded internal textures and contain asymmetric fabrics that indicate the same sense of shear as the northwest-trending, dominantly dextral shear zones. The veins were most likely emplaced late during shearing. In this regard, the ongoing detailed structural analysis of these veins will provide important new information to constrain exploration models, and will help draw attention to intrusion-hosted, shear-related, vein-type gold mineralization in the Rice Lake belt.

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