Introduction

The Rice Lake gold mine is located at Bissett, Manitoba, 150 km northeast of Winnipeg, in the central portion of the Archean Rice Lake greenstone belt.

Discovered in 1911, the Rice Lake deposit was in continuous production from 1932 to 1968, during which time it produced 1.31 million ounces of gold from 4.87 million tons of ore grading 0.27 oz. Au/ton. Including subsequent production in the periods 1980-1983, 1997-1998 and 1999-2001, the mine has produced a total of 1.44 million ounces of gold.

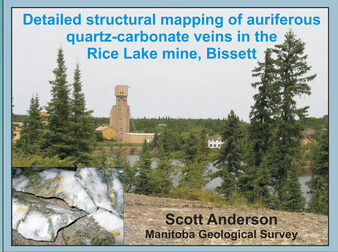
In 2006, San Gold Corporation reopened the Rice Lake mine and is currently working toward full production in fall 2007. Proven and probable reserves total 261,670 ounces within a total resource of 826,920 ounces. In terms of total gold endowment (past production, plus current reserves and resources), the Rice Lake deposit is the largest lode-gold deposit discovered to date in Manitoba.

This poster presents the results of detailed geological and structural mapping of auriferous quartz-carbonate vein arrays on the 30th level (1370 m below surface) of the Rice Lake mine. This work was undertaken by the MGS during the 2007 field season in order to gain a better understanding of the geology and structure of the deposit, and the mechanisms and relative structural timing of vein emplacement. Also included for reference is an overview of the structural geology of supracrustal rocks in the vicinity of the mine, based on MGS bedrock mapping in 2004.

This work forms part of the Rice Lake metallogeny project, which was initiated in 2002 with the objective of re-evaluating the stratigraphy, structure and tectonic evolution of the Rice Lake belt, using a combination of bedrock mapping, structural analysis, litho-geochemistry, Sm-Nd isotope geochemistry, U-Pb geochronology and mineral deposits studies.

Work completed to date, including the structural data presented in this poster, provides a significantly improved context for lode-gold exploration in the Rice Lake belt.

Detailed structural mapping of auriferous quartz-carbonate veins in the Rice Lake mine, Bissett



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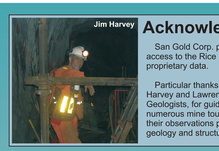
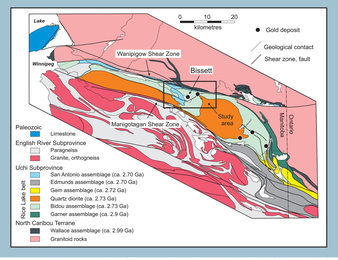
Manitoba Geological Survey

Acknowledgements

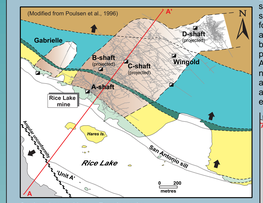
San Gold Corp. provided unfettered access to the Rice Lake gold mine and proprietary data.

Particular thanks are extended to Jim Harvey and Lawrence Norquay, Mine Geologists, for guiding the author on numerous mine tours and freely sharing their observations pertaining to the geology and structure of the deposit.

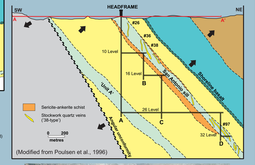


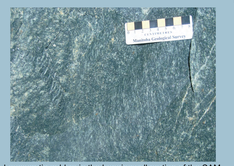


Geology of the Rice Lake deposit



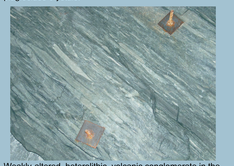
The Rice Lake deposit is hosted by a moderately northeast-dipping, weakly differentiated gabbro sill (the SAM sill) that intrudes ca. 2.72-2.73 Ga felsic epiclastic rocks of the Bidou assemblage. The gabbro is interpreted to be a subvolcanic equivalent to basaltic flows 300-400 m up-section, suggesting a very shallow emplacement depth. The sill ranges up to 190 m thick and has been traced down-dip for over 2.5 km. The deposit consists of a complex system of auriferous quartz-carbonate veins, which are mainly hosted by leucogabbro in the thickest portion of the sill. Sparsely porphyritic dacite dikes cut the sill prior to vein emplacement. Auriferous veins exhibit well-developed, though typically narrow, alteration haloes that grade outward from proximal ankerite-albite-sericite-pyrite to distal chlorite-calcite assemblages. Along the margins of the sill, the felsic epiclastic rocks contain intense ankerite-sericite alteration.





Leucocratic gabbro in the hangingwall portion of the SAM sill (3096E; wall exposure, facing southwest), showing penetrative L-fabric defined by altered and stretched plagioclase crystals.

Hangingwall contact of the SAM sill, showing sharp contact between variably-altered and quartz-veined gabbro (lower left) and felsic epiclastic rocks (upper right; 2998E; wall exposure, facing west).

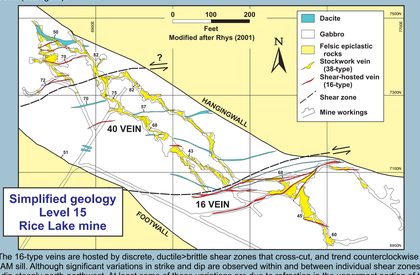


Weakly-altered, heterolithic, volcanic conglomerate in the footwall of the SAM sill (D-shaft access ramp, level 36; wall exposure, facing west). Rock-bolt plates are 15 cm square.

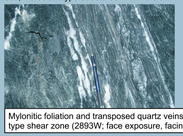
Intense ankerite-sericite alteration and L-S fabric in felsic epiclastic rocks in the immediate hangingwall of the SAM sill (2998E; wall exposure, facing north).

Structural geology of the Rice Lake deposit

Gold mineralization in the Rice Lake deposit is hosted by two distinct orientations of vein systems that are preferentially developed in the leucogabbroic portion of the SAM sill and are informally known as the '16-type' and '38-type' veins (see figure).



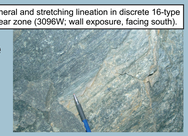
The 16-type veins are hosted by discrete, ductile>brittle shear zones that cross-cut, and trend counterclockwise to, the SAM sill. Although significant variations in strike and dip are observed within and between individual shear zones, most dip steeply north-northwest. At least some of these variations are due to refraction in the uppermost portion of the sill. Ductile asymmetrical fabrics and lineations indicate sinistral-reverse oblique-slip shear, consistent with the left-lateral offsets of felsic dikes and the hangingwall contact of the sill. Most shear zones appear to dissipate along strike to the southwest and do not displace the footwall contact of the sill, indicating that displacement was accommodated by more diffuse, 'horsetail'-type structures within the sill.



Mineral and stretching lineation in discrete 16-type shear zone (3096W; wall exposure, facing south).

16-type shear zones

Mylonitic foliation and transposed quartz veins in 16-type shear zone (2893W; face exposure, facing west).

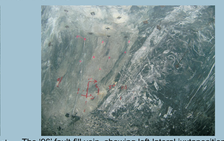


The 16-type veins are fault-fill veins that range up to 2.0 m thick and exhibit massive, laminated and breccia textures. Multiple generations of planar slip-surfaces, fault-fill quartz veins, quartz-filled extension fractures and stylolitic pressure solution seams indicate repeated cycles of fault slip, fault dilation, hydraulic extension fracturing, hydrothermal sealing and stress accumulation (i.e., fault-valve behaviour). Syndeformational arrays of en-echelon extension veins locally form complex peripheral stockwork systems. Shallow-dipping shear zone segments tend to host thicker, breccia-style veins, in contrast to the thinner, more strongly laminated veins in the steeply-dipping segments, consistent with hydrothermal infilling of extensional jogs (i.e., releasing bends) during sinistral-reverse shear.

The 38-type veins trend roughly parallel, or slightly clockwise, to the trend of the SAM sill. In the upper levels of the mine, subvertically-dipping 38-type veins are arranged en-echelon down the dip of the SAM sill, and are limited in dip-extent by the sill contacts. At depth however, some of these veins dip subparallel to the sill and thus extend for considerable distances down-dip. The 38-type veins range up to 10 m thick and comprise sinuous, irregular zones of intensely fractured and quartz-veined gabbro. Typically, the core is marked by quartz-matrix breccias and minor fault-fill veins, which grade outward into complex stockworks of quartz-filled extension fractures, and peripheral arrays of shallow-dipping extension veins. Hydraulic fracturing is indicated by in-situ fragmentation textures (i.e., jigsaw breccia) in the breccia veins. The geometry and internal structure of the peripheral vein arrays indicate that the near-field maximum principal stress was subhorizontal at the time of emplacement. Incipient 38-type vein-systems appear to be controlled by discrete brittle faults; however, felsic dikes cross-cut by these veins exhibit negligible to minor offsets. On this basis, the 38-type vein systems are interpreted to be controlled by brittle faults that accommodated minor back-rotation of fault-bounded blocks of the SAM sill, due to differential slip on the block-bounding 16-type shear zones.

16-type shear zones and veins

Shear-hosted, laminated fault-fill vein showing pinch and swell structure and flat, quartz-filled extension veins (3096E sub; face exposure, facing west)

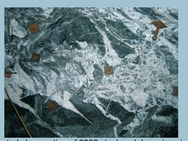


The '96' fault-fill vein, showing left-lateral juxtaposition of altered epiclastic rocks (left) and gabbro (right) (4650 drift; face exposure, facing east).

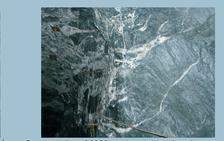
The '96' fault-fill vein showing laminated and breccia textures, and peripheral arrays of extension fractures (4650 drift; back exposure, facing south).

Laminated and brecciated domains in the 98 vein, separated pyritic slip-surface/pressure solution seam (2998W; back exposure, facing south).

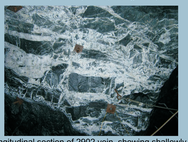
38-type veins



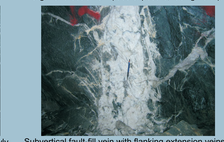
Inverted plan-section of 2902 stockwork-breccia vein, showing internal breccia flanked by wedge-shaped extension veins (back exposure, facing west).



Cross-section of 2902 stockwork-breccia vein, showing shallow-dipping extension veins on east margin of breccia vein (face exposure, facing north).



Longitudinal section of 2902 vein, showing shallowly south-plunging line of intersection between breccia vein and extension veins (wall exposure, facing east).



Subvertical fault-fill vein with flanking extension veins. Note discordant relationship to wall-rock G3 fabric (3098E; wall exposure, facing northwest).

Regional and local setting

The Rice Lake greenstone belt is situated in the western Uchi Subprovince of the Archean Superior Province, and is bound to the north and south, respectively, by the crustal-scale Wanipigow and Manigotagan shear zones. In Manitoba, the volcanoplutonic Uchi Subprovince is flanked to the north by the ca. 3.0 Ga North Caribou continental terrane and to the south by ca. 2.69 Ga metasedimentary rocks and granitoid plutons of the English River Subprovince.

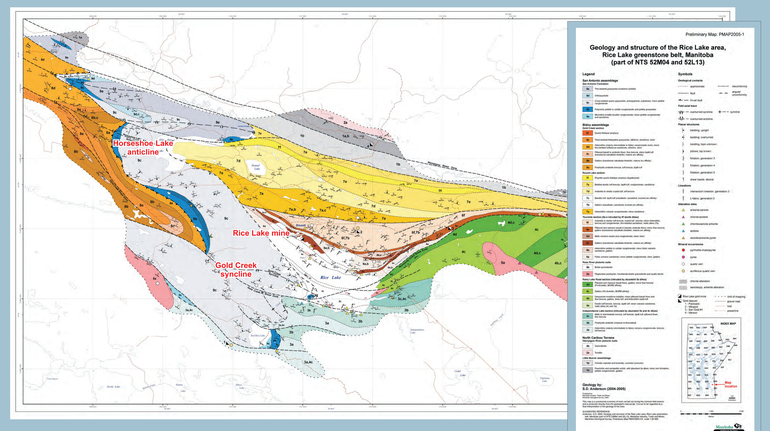
The Rice Lake belt consists of Meso- and Neoarchean mafic to intermediate volcanic and volcaniclastic rocks, intercalated with derived epiclastic rocks and intruded by synvolcanic mafic sills. In the eastern portion of the belt, these rocks are subdivided into distinct lithotectonic assemblages, which include the Mesoarchean Wallace (ca. 2.92-2.99 Ga) and Garner (ca. 2.87-2.90 Ga) assemblages, and the Neoarchean Bidou (ca. 2.72-2.73 Ga) and Gem (ca. 2.72 Ga) assemblages. The Bidou assemblage includes synvolcanic quartz diorite and granodiorite plutons, the most prominent of which is the ca. 2.73 Ga Ross River pluton in the central portion of the belt.

Fluvial and alluvial siliciclastic rocks of the ca. 2.70 Ga San Antonio assemblage unconformably overlie these rocks and likely represent the proximal equivalents to basinal turbidites of the ca. 2.70 Ga Edmunds assemblage, which overlaps the south margin of the belt.

Supracrustal rocks in the vicinity of the Rice Lake mine comprise the mainly metavolcanic Bidou assemblage and the metasedimentary San Antonio assemblage. At Rice Lake, the Bidou assemblage consists of an upright, homoclinal succession of intermediate to felsic volcaniclastic rocks that dips moderately north. These rocks are intruded by gabbro sills, which include the San Antonio Mine sill ('SAM sill') that hosts the Rice Lake deposit.

The Bidou assemblage is intruded in the southeast by porphyritic quartz diorite of the Ross River pluton and, to the west, is unconformably overlain by the San Antonio assemblage, which defines a 1.5-2.0 km thick, broadly S-shaped map unit that trends across the regional strike of the Rice Lake belt.

Metamorphic mineral assemblages throughout the Rice Lake area indicate regional metamorphism in the low to middle greenschist-facies.



Deformation history of the Rice Lake area

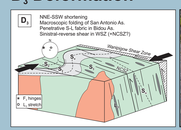
Ductile and ductile-brittle deformation structures in the Rice Lake area are subdivided into six generations (G1 to G6) on the basis of mesoscopic overprinting relationships and inferences drawn from macroscopic map patterns. These structures are interpreted to result from four distinct episodes of regional deformation (D1 to D4). Consistent overprinting relationships are observed between three generations of regionally-pervasive planar fabric (S3, S4 and S5), which provides a useful tool for structural correlation.

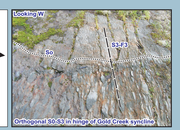
G3 structures are well developed in the San Antonio assemblage, indicating a ca. 2.70 Ga maximum age for penetrative regional deformation in the Rice Lake belt. As described below, the G3 fabrics are also well-developed in the SAM sill at depth in the Rice Lake mine. The implications of this new observation are described below.

Summary of ductile deformation in the Rice Lake area.

Generation	Shortening direction	Mesoscopic structure	Macroscopic structure	Tectonic significance
G_1	?	None observed	Pre-San Antonio tilting of the Bidou assemblage	D_1 accretion?
G_2	?	Local, weak, layer-parallel S2 foliation; narrow, bedding-parallel high-strain zones	Thrust fault at top of San Antonio assemblage	D_2 basin inversion; initial crustal thickening
G_3	NNE-SSW	Regional WNW-trending S3; steep L3 stretching lineation; upright F3 folds	Macroscopic folds; sinistral-reverse shear in Wanipigow Shear Zone	D_3 collisional tectonics; crustal thickening
G_4	NW-SE	Regional, WSW-trending, S4 crenulation cleavage, F4 Z-folds	Early dextral shear in Wanipigow Shear Zone	**Early-D_4**; onset of terminal collision
G_5	NNW-SSE	Regional S5 shear-band cleavage, mylonitic S5 in NW-trending high-strain zones; shallow L5 lineation; F5 Z-folds	Major dextral shear in Wanipigow Shear Zone and subsidiary zones	**Main-D_4**; terminal collision; dextral transcurrent shear
G_6	E-W	Open, north-trending F6 crenulations	Open fold in the Bidou assemblage at Rice Lake	**Late-D_4**; buttress effect on Ross River pluton; continued dextral shear

D_3 Deformation



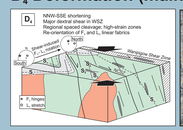


D3 deformation produced a regionally pervasive S3 flattening fabric and northeast-plunging L3 elongation lineation. Map patterns and bedding cleavage relationships define a macroscopic F3 fold-pair, the Horseshoe Lake anticline and Gold Creek syncline (see photo), which are tight, upright structures that are overturned to the southwest.

These G3 structures record NNE-SSW shortening (present coordinates) of the Rice Lake belt. Locally preserved sinistral kinematic indicators on the north margin of the Wanipigow Shear Zone are inferred to result from D3 shear deformation. G3 linear fabric elements adjacent to the south margin of the Wanipigow Shear Zone were significantly re-oriented during D4 deformation.

At depth in the Rice Lake mine, the SAM sill typically contains a penetrative L- or L-S fabric defined by foliated chlorite and actinolite, and elongate (stretched), altered, plagioclase crystals. The L-fabric plunges moderately northeast in the plane of the northeast dipping S-fabric. On the basis of style and orientation, these fabrics are correlated with the regional S3-L3 fabrics.

D_4 Deformation (main)

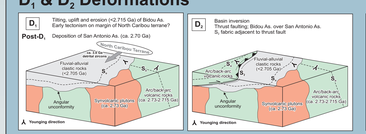


The main increment of D4 deformation produced a regionally pervasive fracture or shear-band cleavage (S5; see photo) that trends northwest and exhibits dextral offset or asymmetry. This cleavage locally intensifies into discrete, ductile-brittle, high-strain zones that contain mylonitic S5 foliations and shallowly-plunging L5 lineations. In these high-strain zones, packets of strongly Z-asymmetric, open to tight F5 folds exhibit variable plunges, from shallowly east to steeply north, and are associated with well-developed dextral kinematic indicators on horizontal out-crop surfaces.

In the Wanipigow Shear Zone, G5 mylonite contains conjugate (synthetic and antithetic) shear bands, indicating a significant component of zone-normal shortening. These G5 structures are interpreted to record NNW-SSE shortening of the Rice Lake belt during main-stage, orogen-scale dextral transcurrent shear in the Uchi Subprovince.

Auriferous vein systems at the Poundmaker and SG1 deposits are overprinted by penetrative dextral asymmetric fabrics that are correlated on the basis of style and orientation with the G5 deformation structures.

D_1 & D_2 Deformations

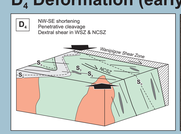


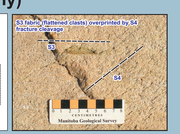
The existence and nature of two early deformation episodes (D1 and D2) are inferred from map patterns in the Horseshoe Lake area.

Field relationships indicate a pronounced angular unconformity at the base of the San Antonio assemblage, thereby requiring regional tilting of the underlying Bidou assemblage into a subvertical orientation prior to its deposition. This tilting is attributed to D1 deformation, and may record accretion-related tectonism along the North Caribou Terrane margin.

West of Horseshoe Lake, west-younging rocks of the San Antonio and Bidou assemblages exhibit an older-over-younger map pattern that is inferred to result from D2 thrusting during tectonic inversion of the San Antonio basin in the initial stages of crustal thickening within the Rice Lake belt. This deformation is evidenced by a locally preserved penetrative S2 foliation along the upper contact of the San Antonio assemblage.

D_4 Deformation (early)

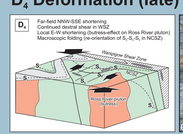


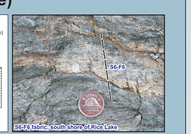


The initial stages of D4 deformation produced a penetrative to finely spaced crenulation cleavage (see photo) that transects the macroscopic F3 folds in the Rice Lake area. This cleavage is axial planar to minor Z-asymmetric F4 folds.

The G4 structures appear to have accommodated weak NW-SE shortening of the Rice Lake belt during the early increments of regional, late-orogenic, dextral transcurrent shear deformation along the Wanipigow Shear Zone. On a regional scale, this transcurrent shear deformation is interpreted to coincide with the terminal phase of the ca. 2.69 Ga Kenoran Orogeny.

D_4 Deformation (late)





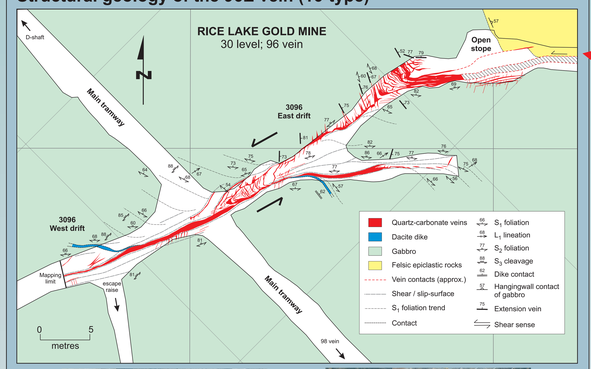
The latest increment of D4 deformation produced a macroscopic, north-trending, open fold of the Bidou assemblage in the Rice Lake area, which is associated with a north-trending, axial planar S6 crenulation cleavage (see photo) and mesoscopic open F6 folds. On the east limb of the macroscopic fold, S3-S4-S5 fabrics in the Normandy Creek Shear Zone trend southwes, and are thus markedly oblique to the regional foliation trends.

The tectonic significance of this deformation is uncertain, but may be related to a local strain perturbation in response to a buttressing effect along the northwest margin of the Ross River pluton during late increments of regional NNW-SSE shortening and dextral transcurrent shear deformation.

The fact that the Wanipigow Shear Zone is unaffected by the macroscopic F6 fold at Rice Lake suggests that late-stage transcurrent shear deformation likely continued subsequent to folding, and was strongly partitioned into the shear zone.

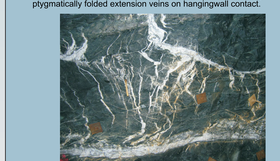
Manitoba

Structural geology of the 96E vein (16-type)

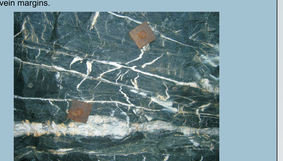


North-dipping fault-fill vein (96 vein; 3096E; wall/back exposure, facing west). Internal fabric defined by stylolitic pressure solution seams and tabular wall-rock inclusions. Note shallow-dipping and plygmatically folded extension veins on hangingwall contact.

Steeply north-dipping fault-fill vein (96 vein; 3096E; back exposure, facing south). Stylolitic pressure solution seams define a complex internal fabric that ranges from subparallel to markedly oblique to the vein margins.

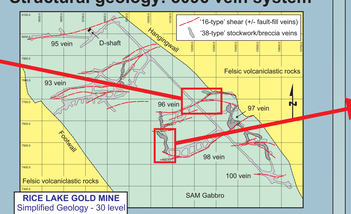


Extension-vein stockwork bound by the 96 vein (bottom) and a folded subsidiary fault-fill vein (top) (3096E; back exposure, facing south). The geometry and orientation of these structures indicate synkinematic vein emplacement in a sinistral kinematic frame.



Diffuse stockwork composed of subsidiary fault-fill veins and extension-vein arrays in the hangingwall of the 96 vein (3096E; back exposure, facing south). Note transposed felsic dike (emerald green) along the bottom edge of the photograph.

Structural geology: 3096 vein system



Detailed structural mapping has been completed along the entire length of the 96 vein system on the 30th level of the Rice Lake gold mine, with particular emphasis on the transitions from 16-type to 38-type veins at the NE and SW extents of the system. The map above shows the locations of the detailed maps presented on this poster.

Timing of vein emplacement

The present study provides important new constraints on the relative structural timing of vein emplacement, which can be summarized as follows:

1) At depth, the SAM sill contains a pervasive planar-linear (S-L) shape fabric that is correlated on the basis of style and orientation with the regional G3 fabric.
2) The G3 fabric is overprinted by 16-type shear zones and is cross-cut by peripheral, quartz-filled extension fractures associated with 16-type fault-fill veins and 38-type breccia veins.
3) The 16-type shear zones and 38-type veins exhibit mutual overprinting relationships, indicating that these structures are broadly coeval.

G3 shape fabric cross-cut by quartz-filled extension fractures (3096E sub; wall exposure, facing SE).

16-type shear zone cross-cut by 38-type breccia vein (3096W; floor/wall exposure, facing north).

Discrete 16-type shear zone cut by flat extension veins on the margin of 38-type breccia (3096W; wall exposure, facing W).

Implications

As is typical of Archean lode-gold deposits, the Rice Lake deposit is composed of complex arrays of synkinematic quartz veins in brittle-ductile fracture systems that formed under greenschist-facies metamorphic conditions in close proximity to crustal-scale, domain-bounding faults. Because the geometry and localization of lode-gold deposits is strongly influenced and controlled by structure, structural analysis is a critical tool for constraining metallogenic models and formulating exploration strategies.

The present study indicates that the auriferous 16-type and 38-type veins in the Rice Lake deposit were emplaced synchronously. Vein textures and structures, together with overprinting relationships, indicate that vein emplacement was intimately associated with late- to post-D3 faulting, and thus occurred subsequent to, or perhaps in the latest increments of, the regional D3 deformation. Vein orientations and textures indicate that the near-field maximum principal stress was subhorizontal (present coordinates) at the time of vein emplacement, in a direction that probably fluctuated from N-S to NE-SW (present coordinates) due to transient variations in the local boundary conditions.

These data, in conjunction with the results of the recent 1:20 000 scale bedrock mapping completed by the MGS, provide important new predictive parameters for lode-gold exploration in the central portion of the Rice Lake belt.

Structural geology of the 96W vein (38-type)

Thick, subvertical, hydraulic breccia vein (right) and relatively inclusion-poor, steeply northeast-dipping, fault-fill vein (left) at the northern extent of the 3096W vein (back exposure, facing N).

East margin of the 3096W vein shown to left, illustrating the gradation from hydraulic breccia (top) to peripheral arrays of shallowly dipping extension veins (wall exposure, facing NE).