GS-9 Structural analysis of the McLeod Road–Birch Lake thrust panel, Snow Lake, west-central Manitoba (parts of NTS 63K16, 63J13)

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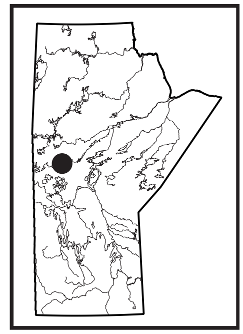

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Summary

The McLeod Road–Birch Lake thrust panel[2], comprising mafic and felsic volcanic and volcaniclastic rocks in the hangingwall of the McLeod Road thrust, is host to a series of structurally controlled gold deposits. Detailed structural analysis was performed at two sites along this thrust fault, where fabrics in the Burntwood group (1.84 Ga) could be compared with those in the overlying volcanic rocks of the McLeod Road–Birch Lake thrust panel (1.89 Ga). At least two generations of fabric have been recognized from overprinting relationships in the field, and are provisionally interpreted to represent increments of a single progressive deformation, which likely corresponds to the regional D_1 deformation event. These newly recognized deformation increments will assist in redefining the sequence of deformation in the thrust panel and will lead to an improved understanding of the relative timing of gold mineralization.

Introduction

The McLeod Road–Birch Lake thrust panel (MBTP) hosts four gold deposits, which are situated along stratigraphic contacts at the intersection of a fault and fold hinge in the hangingwall of the McLeod Road thrust (MRT). The largest deposit is the Nor-Acme of the New Britannia mine[3], which produced 1,404,950 oz. (43 699 kg) gold and is associated with the Howe Sound fault. There have been many authors who have either mapped the regional geology and/or investigated gold mineralization at the New Britannia mine (Hogg, 1957; Galley et al., 1988; Galley et al., 1991; Bailes and Schledewitz, 1998; Kraus et al., 1998; Fieldhouse, 1999; Fulton, 1999; Gale, 2002; Beaumont-Smith and Gagné, 2008; Beaumont-Smith and Lavigne, 2008); however, the structural history of the MBTP and the controls on gold mineralization remain poorly understood.

On the basis of lithostratigraphic mapping in 2011 and 2012 (Rubingh et al., 2012a, b), and follow-up chemostratigraphy, the MBTP is subdivided into different stratigraphic units. Internal repetition of these units along bedding-parallel contacts has been interpreted to result from thrust faulting. In order to establish the structural controls on gold mineralization and the timing of mineralization, it is therefore important to understand the structural history of the MBTP, including the postulated thrust faults and how they relate to the regional geology. One of the main objectives of fieldwork in 2013 was to resolve the deformational history of the MBTP using additional knowledge from field and drill-core analysis, and relate it to the regional structural framework as defined by previous workers (e.g., Connors et al., 1996; Kraus, 1998; Beaumont-Smith and Lavigne, 2008; Gagné, 2009).

Structural setting

The Flin Flon–Snow Lake greenstone belt (Figure GS-9-1) is located in the internides of the Trans-Hudson orogen. The belt is an amalgamation of tectonostratigraphic assemblages that differ in geochemistry, metamorphic grade and structural history (Lucas et al., 1996; Syme et al., 1996). The Snow Lake arc assemblage (SLA) is located within a north-dipping panel and is successively overlain from south to north by thrust-bounded panels of Burntwood group turbidites, the MBTP (see below) and Missi group arkosic sandstone. The SLA in the Snow Lake area consists of three separate sequences that reflect an evolution from a primitive arc (Anderson sequence) to a mature arc (Chisel sequence) to an evolved arc-rift environment (Snow Creek sequence; Bailes and Schledewitz, 1999). Based on both volcanological characteristics and geochemistry, the volcanic units within the MBTP are considered to be correlative with those of the SLA (Bailes and Schledewitz, 1998; Rubingh et al., 2012a, b).

The MBTP is a north-dipping homoclinal sequence of mafic and felsic volcanic and volcaniclastic rocks (Bailes and Schledewitz, 1998; Rubingh et al., 2012a, b). It is bounded to the south by the MRT and to the north by the Birch Lake fault. Imbrication of the panels occurred during south-directed transport and resulted in the formation of a strong regional northeast-plunging stretching lineation, a regional foliation and the Nor-Acme anticline in the MBTP. These structures and panels were subsequently folded around the northeast-trending Threehouse

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[2] For the sake of consistency, the Manitoba Geological Survey has opted to make a universal change from capitalized to noncapitalized for the generic part of lithostructural feature names (formal stratigraphic and biostratigraphic nomenclature being the exceptions).

[3] To maintain consistency with previous publications, this report will continue to use 'New Britannia mine' despite it being renamed 'the Snow Lake mine' by QMX Gold Corporation in 2012.

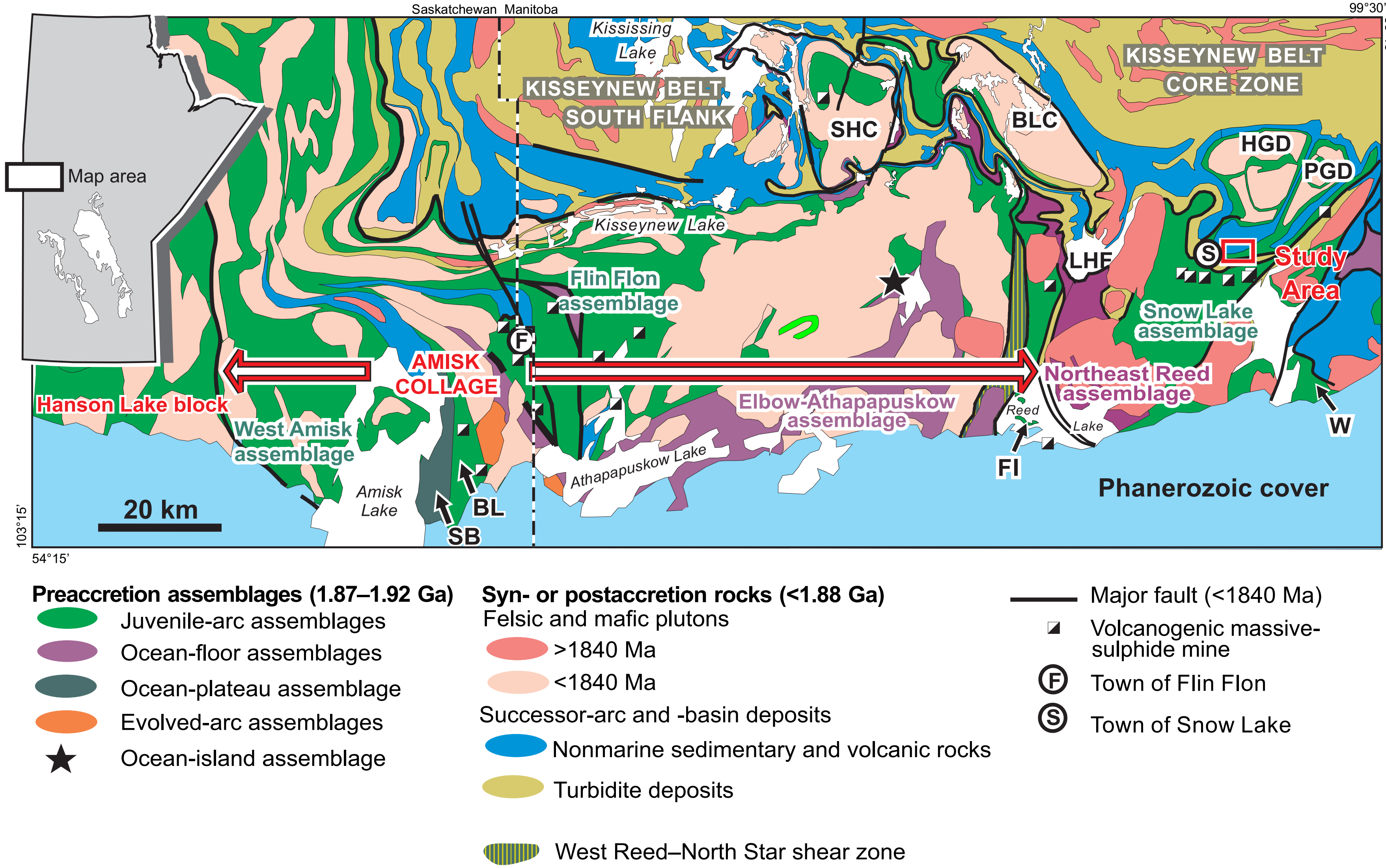

Figure GS-9-1: *Regional geology of the Flin Flon–Snow Lake belt, west-central Manitoba (after Syme et al., 1998). Abbreviations: BL, Birch Lake; BLC, Batty Lake complex; FI, Fourmile Island; HGD, Herblet gneiss dome; LHF, Loonhead Lake fault; PGD, Pulver gneiss dome; SB, Sandy Bay; SHC, Sherridon–Hutchinson Lake complex; W, Schist-Wekusko assemblage.*

synform (Figure GS-9-2; Beaumont-Smith and Lavigne, 2008; Gagné, 2009).

Structure of the MBTP

The lithostratigraphy of the MBTP has been presented and described by Rubingh et al. (2012a, b) and Rubingh (2011), and is shown in Figure GS-9-2. The stratigraphic column for the MBTP (Bailes et al., 2013) highlights the locations of bedding-parallel thrusts, which have been interpreted as a mechanism to repeat stratigraphic units within the MBTP (Rubingh et al., 2012a, b). The following section provides a brief description of each deformational event from oldest to youngest, followed by additional field observations from the 2013 field season, which included detailed mapping at specific sites along the MRT (Figure GS-9-2). As shown in Figure GS-9-2, the map area is separated for descriptive purposes into three structural domains (A, B and C).

The bedding-parallel thrusts described by Rubingh et al. (2012a, b) are the earliest deformation structures preserved within the MBTP and are assigned to an 'early D_1' deformational event, which appears to precede the MRT because the thrusts are cut by the MRT. The bedding-parallel thrust faults are identified solely on the basis of apparent repetitions of stratigraphic units. An attempt to identify the thrusts in drillcore during the 2013 field season was unsuccessful; they are apparently obscured by dikes, later deformation and/or alteration.

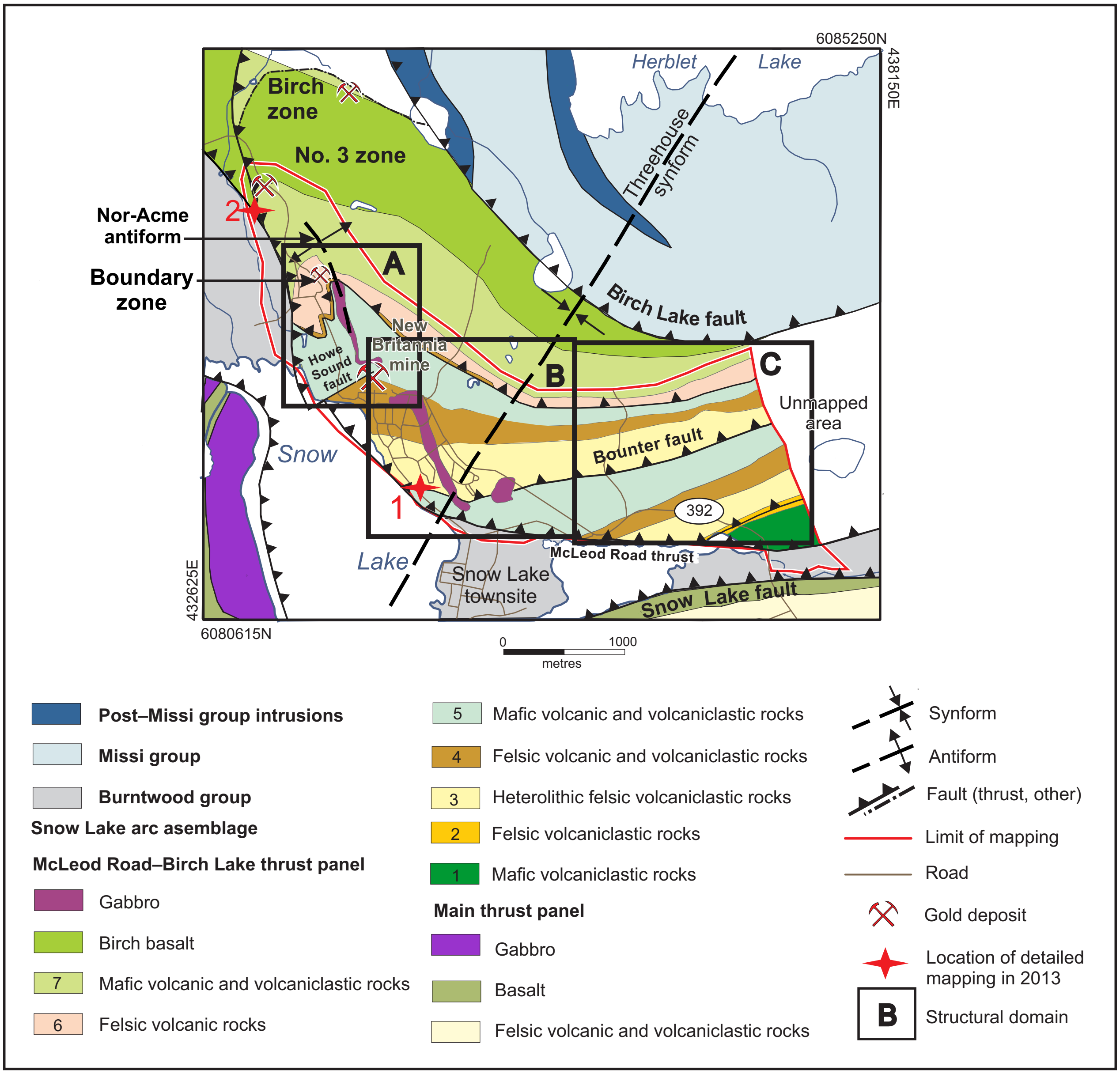

Figure GS-9-2: *Simplified lithostratigraphy and structural geology of the McLeod Road–Birch Lake thrust panel, Snow Lake area, west-central Manitoba, showing structural domains A, B and C (after Rubingh et al., 2012a, b) and the detailed mapping sites.*

In the MBTP, S_1 is a moderate to strong foliation defined by the flattened clasts in the volcaniclastic rocks and aligned biotite in volcanic flows (Rubingh et al., 2012a, b). It is also locally expressed as a strong biotite foliation that wraps around flattened clasts. The S_1 fabric changes orientation along the MRT: it is parallel or at a small angle to the MRT in the Town of Snow Lake, where data are available close to the MRT; farther away from the MRT, S_1 is at an angle to the MRT and is parallel to stratigraphic contacts and bedding parallel thrusts. The S_1 fabric is also parallel to the axial plane of the Nor-Acme anticline, a tight to isoclinal fold defined by folded bedding and lithological contacts. The Nor-Acme anticline plunges moderately to the northeast, parallel to the L_1 stretching lineation defined by elongated clasts.

The Howe Sound fault (HSF), which is associated with the Nor-Acme deposit, consists of a segment that trends east-northeast (HSF proper), and a segment that trends east-southeast and is bedding parallel. The S-asymmetric drag folds of the S_1 fabric (defined by flattened clasts) along the bedding-parallel segment of the HSF are interpreted to be due to drag folding in an anticlockwise sense. Coupled with a near-horizontal mineral lineation, these folds indicate sinistral strike-slip movement along the fault.

The S_2 fabric in the volcanic rocks of the MBTP is a penetrative spaced cleavage that is best preserved in the hinge of the Nor-Acme anticline, where it is locally observed at a small angle (5–8°) to the S_1 axial-planar fabric. The S_2 cleavage is defined by the alignment of hornblende in mafic rocks and biotite in felsic rocks, and it trends northwest to north-northeast and dips moderately northeast to east. Along the MRT (site 1; Figure GS-9-2), the S_2 cleavage in the Burntwood group is folded by F_3 Z-folds (Figure GS-9-3a) that lack an axial-planar cleavage. The asymmetry and orientation of the folds suggest that they are related to the regional Threehouse syncline, which folds the S_2 cleavage in domains B and C (Figure GS-9-2) and is therefore attributed to D_3 deformation. At the No. 3 zone (Figure GS-9-2), S_2 is folded by small-amplitude symmetric F_3 folds, which are associated with a steeply dipping, north-northeast- to east-northeast-trending axial-planar S_3 cleavage. At the HSF, the S_3 fracture cleavage overprints the S_1-S_2 fabrics and appears to be axial planar to the Threehouse synform.

Results of the 2013 field season

In order to understand how the sequence of deformational events in the MBTP relates to fabrics identified in the Burntwood group, two specific sites (sites 1 and 2; Figure GS-9 -2) were chosen for detailed study. At both sites, the relationships between fabrics in both the volcanic rocks of the MBTP and the turbidites of the underlying Burntwood group at the MRT can be observed. Site 1 is located in the immediate hangingwall of the MRT, where a wedge of Burntwood group turbidites has been imbricated within the MBTP, whereas site 2 is located along the trace of the MRT. The structural framework of Kraus (1998) is used to compare the S_1 and S_2 fabrics at these two sites based on recent field observations. The S_1 fabric in the Burntwood group is defined by inclusion trails in garnet porphyroblasts and a rare axial-planar cleavage to F_1 isoclinal folds, whereas S_2 is the main macroscopic fabric in the Burntwood group and is defined by aligned staurolite porphyroblasts and biotite (Kraus, 1998).

Site 1

At the first site (Figure GS-9-2, -4), the fabric relationships were investigated at the contact between the Burntwood group and pillowed mafic volcanic rocks of the MBTP, along an interpreted imbricate fault in the hangingwall of the MRT (unit 1; Rubingh et al., 2012a, b). The volcanic rocks contain an S_1 fabric that is oriented approximately parallel to the contact. Close to the contact, a second-generation cleavage is also observed, and is oriented clockwise of S_1. The contact and the S_1 and S_2 fabrics are folded by open F_3 folds.

In the Burntwood group, bedding and a bedding-parallel fabric (S_0-S_{1a}) are oriented clockwise to the contact (Figure GS-9-3b). This fabric is designated S_0-S_{1a} because its relationship to S_1 in the volcanic rocks is uncertain. The S_0-S_{1a} fabric is overprinted by a spaced S_2 cleavage, which is dragged in a sinistral manner parallel to S_0-S_{1a} and is also oriented clockwise to the turbidite-volcanic contact (Figure GS-9-3c, -4).

The S_1 fabric in the volcanic rocks can be traced across the contact into the Burntwood group. At this site, it is parallel to the S_0-S_{1a} fabric in the Burntwood group; more typically, it is oriented at an angle to the contact. The volcanic rocks were thrust on top of the Burntwood group; however, it is inferred that this imbricate of the MRT was at an oblique angle to the contact in the volcanic rocks and was rotated into parallelism with the contact during continued deformation. This fabric is provisionally attributed to a D_{1a} increment of progressive D_1 deformation.

Site 2

At the second site (Figure GS-9-2, -5), the fabric relationships in the Burntwood group and in the sheared volcanic rocks at the base of the MRT were investigated. The shear foliation in the volcanic rocks is folded by F_2 S-folds with an axial-planar S_2 cleavage (Figure GS-9-3d). The transposed S_1 fabric is parallel to the MRT, and sinistral shear-sense indicators (shear bands; Figure GS-9-3e) are observed; in conjunction with a biotite mineral lineation that plunges shallowly northeast, these fabrics imply top to the southwest movement.

Mesoscopic isoclinal F_2 folds (Figure GS-9-3f, -5) are also identified within the Burntwood group. Folded

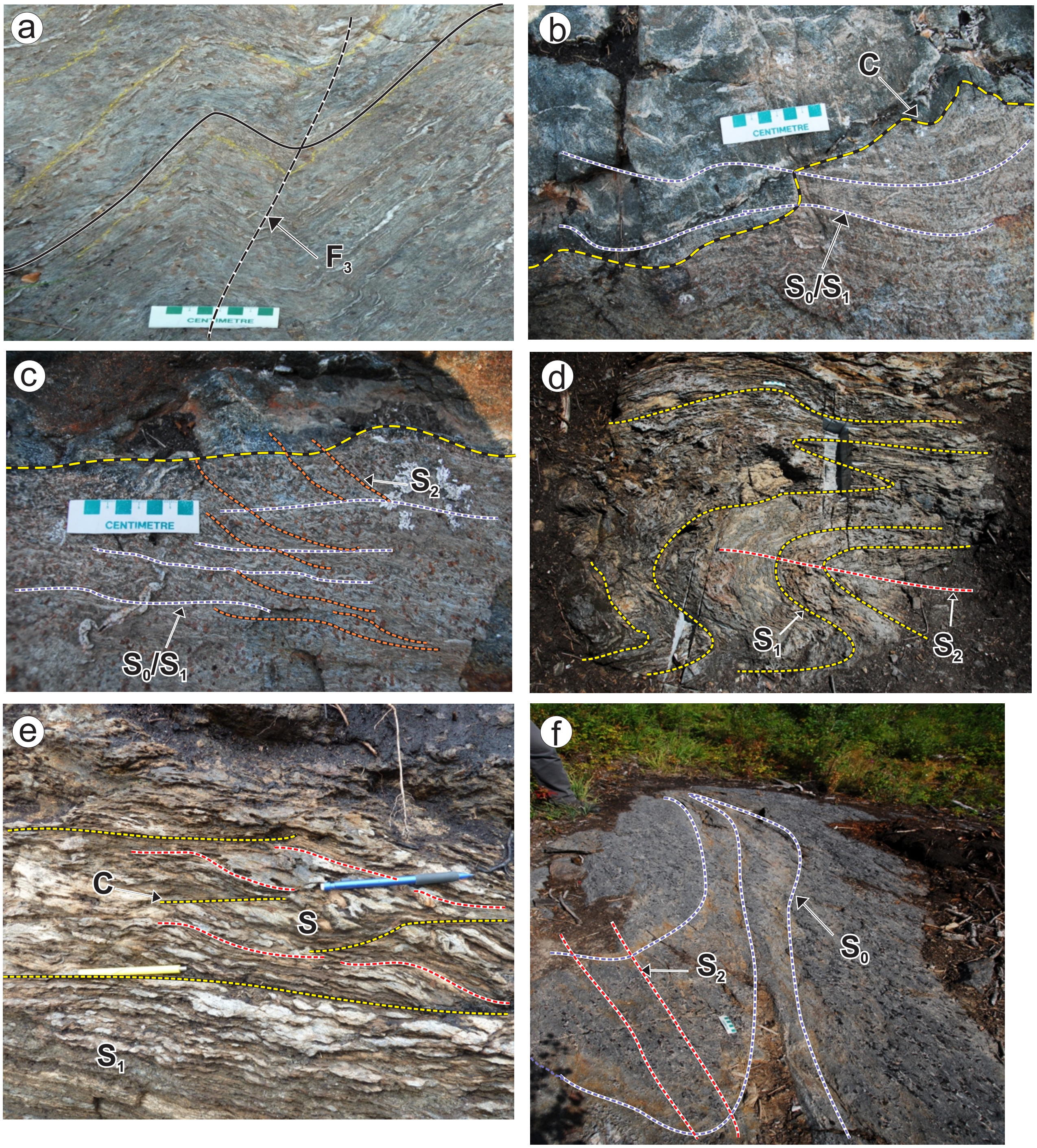

Figure GS-9-3: *Structural features and fabrics in the immediate hangingwall of the McLeod Road thrust (site 1; photos a–c) and along the trace of the thrust (site 2; photos d–f):* ***a)*** *S_2 fabric (solid line) folded by F_3 Z-fold;* ***b)*** *bedding and S_0-S_1 truncated along the MRT; 'C' marks contact;* ***c)*** *S_2 fabric overprinting S_0-S_1 fabrics, close to the MRT;* ***d)*** *F_2 S-folds overprinting the S_1 foliation;* ***e)*** *shear bands (C) and shape-fabric (S) defining the shear foliation in the MRT;* ***f)*** *outcrop-scale F_2 folds (defined by bedding) and the axial-planar S_2 fabric. Site locations are shown in Figure GS-9-2.*

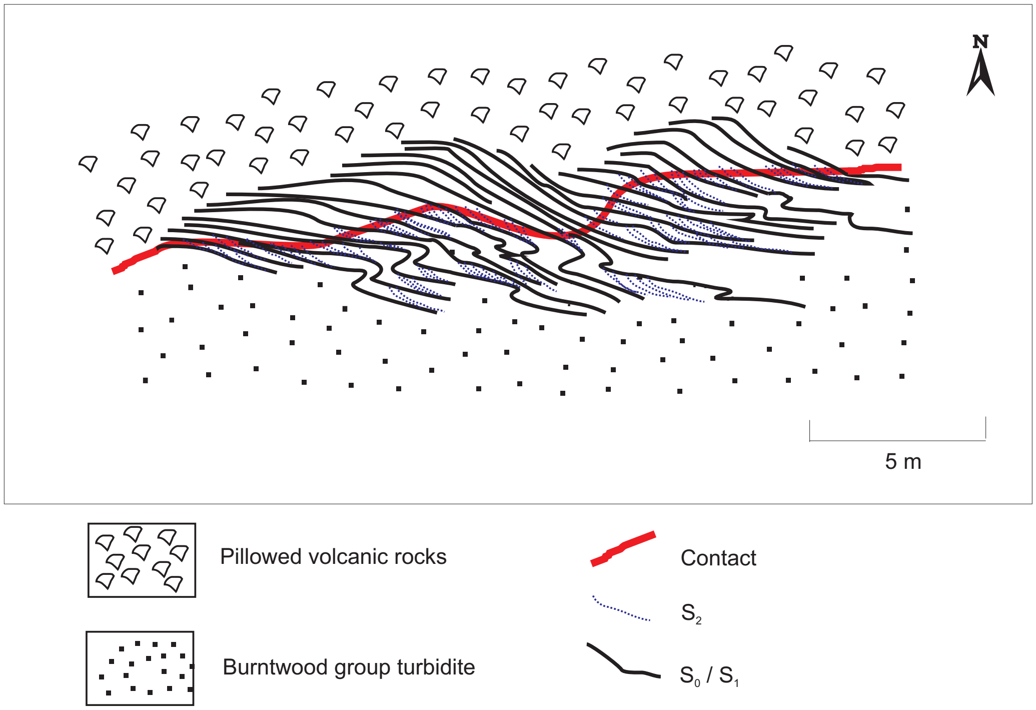

Figure GS-9-4: *Sketch map (1:100 scale) of fabric relationships at site 1, showing pillowed mafic volcanic rocks of the MBTP in contact with Burntwood group turbidites.*

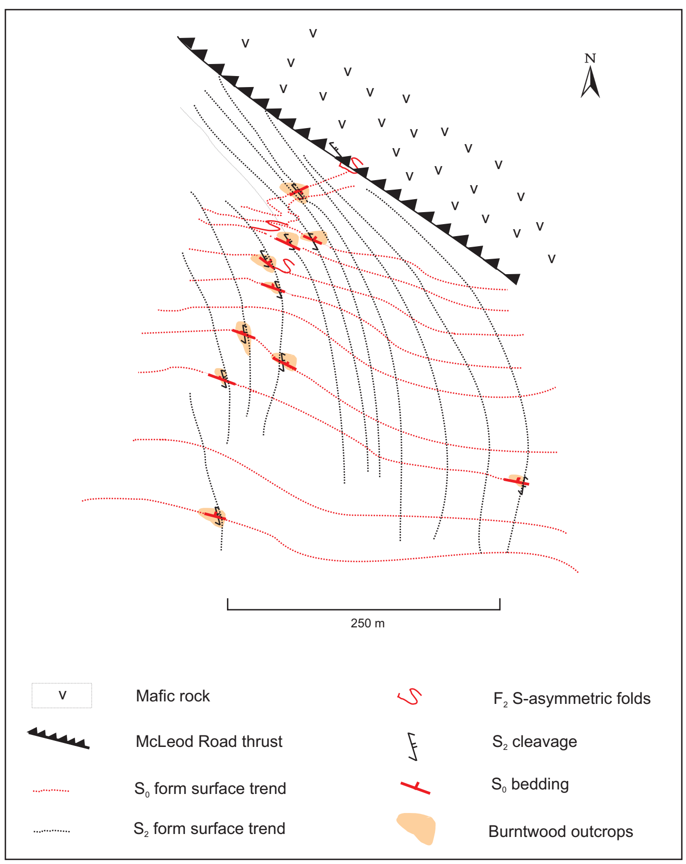

Figure GS-9-5: *Sketch map of structural relationships at site 2. The F_2 folds are defined by folded bedding and are associated with an axial-planar S_2 cleavage. The S_1 fabric is a shear foliation that is only developed at the MRT.*

bedding is observed with an axial-planar S_2 cleavage defined by biotite wrapping around aligned staurolite porphyroblasts, implying that bedding and the S_1 foliation are folded in the Burntwood group. The S_2 axial-planar cleavage observed in the Burntwood group is parallel to the S_2 axial-planar cleavage at the base of the MRT, in the shear foliation in the volcanic rocks. Therefore these fabrics are considered part of the same deformational event and likely formed in the same kinematic frame.

Preliminary interpretation of results

There are knowledge gaps in the structural framework that must be resolved before the fabrics in the Burntwood group can be compared directly with those of the MBTP. However the preliminary interpretation, based on analysis of field data prior to petrographic work, has identified at least two additional fabrics: S_{1a} and S_{1b}.

At site 1, the regional S_1 fabric, which is well constrained for the MBTP, is observed in the volcanic rocks. The regional S_1 fabric formed parallel to lithological contacts during bedding-parallel thrusting and is interpreted to have rotated into parallelism with the MRT during continued deformation. The S_1 fabric is older than the MRT, and the fabric observed here at the contact is thought to be the S_1 fabric that has been dragged into parallelism with the contact (S_{1a}). It is traceable across the contact from volcanic rocks directly into sedimentary rocks. This fabric is also overprinted by F_3 folds.

At site 2, the MRT contains a shear foliation that is inferred to represent a transposition fabric after the S_1 foliation, and is thus designated as S_{1b}. At this site, the relationship of the mesoscopic F_2 folds to the regional-scale F_2 folds (McLeod Lake synform and Whitefish bay synform; Kraus, 1998; Gagné, 2009) is uncertain and remains to be resolved. For consistency, therefore, the S_2 axial-planar fabric here is denoted S_{1b}, as it is considered to be a later increment of D_1 deformation. Further analytical work using polished thin sections from samples collected in 2013 will examine the nature of the S_1 fabric at each site to constrain these deformational events.

Economic considerations

Gold mineralization in the Snow Lake area occurs within the MBTP, in the hangingwall of the MRT; therefore, an improved understanding of the structural framework of the MBTP will aid in understanding the structural controls and timing of gold mineralization. This study has indicated a more detailed internal geometry for the panel, and the 2013 mapping has indicated potential for at least two additional fabrics within the MBTP, possibly associated with an additional generation of folds. Further work using petrography and historical sections will help establish the sequence of deformations and the implications for ongoing gold exploration.

Acknowledgments

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References

Bailes, A.H. and Schledewitz, D.C.P. 1998: Geology and geochemistry of the Paleoproterozoic volcanic rocks between the McLeod Road and Birch Lake faults, Snow Lake area, Flin Flon belt (parts of NTS 63K/16 and 63J/13); *in* Report of Activities 1998, Manitoba Energy and Mines, Geological Services, p. 4–13.

Bailes, A., Rubingh, K., Gagné, S., Taylor, C., Galley, A., Bernaeur, S. and Simms, D. 2013: Volcanological and structural setting of Paleoproterozoic VMS and gold deposits at Snow Lake, Manitoba; Geological Association of Canada–Mineralogical Association of Canada, Joint Annual Meeting, Field Trip Guidebook FT-A2, Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, Open File OF2013-3, 63 p., URL <http://www.manitoba.ca/iem/mrd/info/libmin/gacmac/OF2013-3_FT-A2.pdf> [accessed October 2013]

Beaumont-Smith, C.J. and Gagné, S. 2008: Structural geology of the Snow Lake–Squall Lake area, Manitoba (parts of NTS 63K16, 63J13); Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Preliminary Map PMAP2008-1, scale 1:20 000.

Beaumont-Smith, C.J. and Lavigne, J. 2008: Structural geology and gold metallogenesis of the New Britannia mine area, Snow Lake, Manitoba (NTS 63K16); *in* Report of Activities 2008, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 7–17.

Connors, K.A., Ansdell, K.M. and Lucas, S.B. 1996: Coeval sedimentation, magmatism, and fold-thrust development in the Trans-Hudson orogen: propagation of deformation into an active continental arc setting, Wekusko Lake area, Manitoba; Canadian Journal of Earth Sciences, v. 36, p. 275–291.

Fieldhouse, I. 1999: Geological setting of gold mineralization in the vicinity of the New Britannia mine, Snow Lake, Manitoba; M.Sc. thesis, University of Manitoba, Winnipeg, Manitoba, 136 p.

Fulton, P.J. 1999: Distribution of gold mineralization at the New Britannia mine in Snow Lake, Manitoba: implications for exploration and processing; M.Sc. thesis, University of Manitoba, Winnipeg, Manitoba, 207 p.

Gagné, S. 2009: Geological investigation of the McLeod Road–Birch Lake allochthon east of Snow Lake, Manitoba (part of NTS 63J13); *in* Report of Activities 2009, Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, p. 58–68.

Gale, G.H. 2002: Geology of the New Britannia mine, Snow Lake (NTS 63K16), Manitoba; *in* Report of Activities 2002, Manitoba Industry, Economic Development and Mines, Manitoba Geological Survey, p. 83–86.

Galley, A.G., Bailes, A.H., Syme, E.C., Bleeker, W., Macek, J.J. and Gordon, T.M. 1991: Geology and mineral deposits of the Flin Flon and Thompson belts, Manitoba (Field Trip 10); Geological Survey of Canada, Open File 2165, 136 p. doi:10.4095/132363

Galley, A.G., Franklin, J.M. and Ames, D.E. 1988: Geological setting of gold mineralization, Snow Lake, Manitoba; Geological Survey of Canada, Open File 1700, scale 1:50 000.

Hogg, N. 1957: Nor-Acme mine; *in* Structural Geology of Canadian Ore Deposits, Volume II; Canadian Institute of Mining and Metallurgy, 6th Commonwealth Mining and Metallurgical Congress, p. 262–275.

Kraus, J. 1998: Structural and metamorphic studies in the Snow Lake area, Trans-Hudson orogen, Manitoba, central Canada; Ph.D. thesis, University of New Brunswick, Fredericton, New Brunswick, 229 p.

Lucas, S.B., Stern, R.A., Syme, E.C., Reilly, B.A. and Thomas, D.J. 1996: Intraoceanic tectonics and the development of continental crust: 1.92–1.84 Ga evolution of the Flin Flon belt, Canada; Geological Society of America Bulletin, v. 108, p. 602–629.

Rubingh, K.E 2011: Stratigraphy of the McLeod Road–Birch Lake thrust panel, Snow Lake, west-central Manitoba (parts of NTS 63K16 and 63J13); *in* Report of Activities 2011, Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, p. 68–78.

Rubingh, K.E., Lafrance, B., Gibson, H.L. and Gagné, S. 2012: Preliminary lithostratigraphic map of the McLeod Road–Birch Lake thrust panel, Snow Lake, west-central Manitoba (parts of NTS 63K16, 63J13); Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, Preliminary Map PMAP2012-7, 1:5000 scale.

Rubingh, K.E., Lafrance, B. and Gibson, H.L. 2012: Lithostratigraphy and structural geology of the McLeod Road–Birch Lake thrust panel, Snow Lake, west-central Manitoba (parts of NTS 63K16, 63J13); *in* Report of Activities 2012, Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, p. 104–114.

Syme, E.C., Bailes, A.H. and Lucas, S.B. 1996: Tectonic assembly of the Paleoproterozoic Flin Flon belt and setting of VMS deposits; Geological Association of Canada–Mineralogical Association of Canada, Joint Annual Meeting, Field Trip Guidebook B1, 130 p.

Syme, E.C., Lucas, S.B., Zwanzig, H.V., Bailes, A H., Ashton, K.E. and Haidl, F.M. 1998: Geology, NATMAP Shield Margin Project area (Flin Flon belt), Manitoba-Saskatchewan; Geological Survey of Canada, Map 1968A, Manitoba Energy and Mines, Map A-98-2, Saskatchewan Energy and Mines, Map 258A, 54 p., scale 1:100 000.