ERRATUM
Report of Activities 2014

Manitoba Mineral Resources
Manitoba Geological Survey

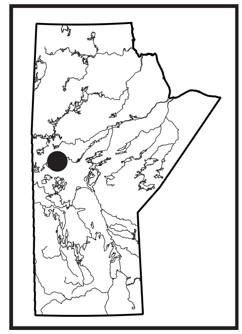
GS-8
Structural controls on geometry and ore distribution in the Lalor auriferous VMS deposit, Snow Lake, west-central Manitoba (part of NTS 63K16): preliminary results from underground mapping
by A. Caté, P. Mercier-Langevin, P.-S. Ross and D. Simms
Reprinted with revisions, January 2015

The following figures have been revised:

Figure GS-8-3: *Geological maps (at 1:250 scale) of the vertical walls of underground workings (maps rotated to horizontal) in: a) drift mL 865 10 HW; b) drift mL 865 North Access.* (page 108)

Figure GS-8-5: *Geological maps (at 1:250 scale) of the vertical walls of underground workings (maps rotated to horizontal) in: a) drift mL 865 20 North (with map of the back); b) drift mL 815 West Haulage.* (page 110)

GS-8 Structural controls on geometry and ore distribution in the Lalor auriferous VMS deposit, Snow Lake, west-central Manitoba (part of NTS 63K16): preliminary results from underground mapping



by A. Caté[1], P. Mercier-Langevin[2], P.-S. Ross[1] and D. Simms[3]

Caté, A., Mercier-Langevin, P., Ross, P.-S. and Simms, D. 2014: Structural controls on geometry and ore distribution in the Lalor auriferous VMS deposit, Snow Lake, west-central Manitoba (part of NTS 63K16): preliminary results from underground mapping; *in* Report of Activities 2014, Manitoba Mineral Resources, Manitoba Geological Survey, p. 104–115.

Summary

The Lalor volcanogenic massive-sulphide deposit is the largest deposit in the Snow Lake mining camp and is also the richest in terms of total contained Au. The deposit is affected by polyphase deformation that has strongly influenced the geometry of the ore zones and the distribution of metals. Underground mapping has been completed at several selected locations in the mine to document the effects of deformation on the geometry of the deposit. Two regional deformation events (D_2 and D_3) strongly influenced the macroscopic geometry of the deposit, whereas early (D_1) deformation features have been obliterated by later events and their importance is still not clear. Local remobilization of some base- and precious-metal sulphide minerals out of the primary massive-sulphide lenses occurred during deformation and led to epigenetic reconcentration of ore. These observations will assist in characterizing the structural setting and geometry of the Lalor deposit.

Introduction

The Lalor volcanogenic massive-sulphide (VMS) deposit has combined reserves and resources estimated at 25.3 Mt averaging 5% Zn, 0.79% Cu, 2.9 g/t Au and 25.04 g/t Ag (as of January 2014; HudBay Minerals Inc., 2014), potentially containing more than 70 t Au, making it the largest and best VMS deposit in the Snow Lake camp in terms of Au endowment. These features, as well as the location of the deposit in an already well-studied camp (Galley et al., 2007 and references therein), make the Lalor deposit an ideal study area to improve our understanding of precious metals–enrichment processes in VMS systems. The Geological Survey of Canada, through the VMS project of the Targeted Geoscience Initiative 4 program and in collaboration with the Manitoba Geological Survey, HudBay Minerals Inc., the Institut national de la recherche scientifique and the University of Ottawa, initiated a research project at Lalor in 2011, which includes two graduate thesis projects (Ph.D. and M.Sc.). The Ph.D. study (this report) involves extensive drillcore logging, underground mapping, petrography, whole-rock geochemistry and oxygen-isotope analysis (Mercier-Langevin et al., GS-7, this volume). In 2013 and 2014, underground mapping was completed to improve our knowledge of the geological and structural setting of the deposit and the effects of deformation on the ore, with a focus on the Zn-rich massive-sulphide zones, Au-rich sulphide-poor zones and main structural contacts. Preliminary results and their implications for the structural setting of the deposit are presented here.

Previous and ongoing work

The Snow Lake camp hosts eight past-producing VMS mines and a past-producing orogenic Au mine (Galley et al., 2007). Previous studies have documented the regional geodynamic, structural and metallogenic context (Stern et al., 1995; Bailes and Galley, 1996; David et al., 1996; Lucas et al., 1996; Bailes and Galley, 1999; Kraus and Williams, 1999; Gagné et al., 2006; Galley et al., 2007; Rubingh et al., 2013), the hydrothermal alteration associated with VMS deposits (Galley et al., 1993; Hodges and Manojlovic, 1993; Skirrow and Franklin, 1994; Bailes and Galley, 1996) and the regional metamorphic history (Froese and Gasparrini, 1975; Gordon, 1989; Zaleski et al., 1991; Kraus and Menard, 1997; Menard and Gordon, 1997; Kraus and Williams, 1998; Gagné et al., 2005).

Ongoing research in the Snow Lake camp is concentrated on the volcanic stratigraphy and geometry of the Chisel sequence (see below) and its ore deposits (Bailes, unpublished reports for HudBay Minerals Inc., 2008, 2009, 2011; Engelbert et al., 2014; Gibson et al., 2014). The Lalor deposit is also the focus of geological investigations (Bailes, unpublished reports for HudBay Minerals Inc., 2008, 2009, 2011) and several projects to study specific aspects of the deposit: volcanic stratigraphy, alteration and structure (Caté et al., 2013a, b, 2014, in press); three-dimensional (3-D) modelling of the deposit and its hostrocks using geophysical, geochemical and rock-physical properties (E. Schetselaar, P. Shamsipour, K. Miah, G. Bellefleur, S. Cheraghi, J. Craven, A. Caté,

[1] Institut national de la recherche scientifique–Centre Eau Terre Environnement, 490 rue de la Couronne, Québec, QC G1K 9A9
[2] Natural Resources Canada, Geological Survey of Canada, 490 rue de la Couronne, Québec, QC G1K 9A9
[3] Geology Department, Lalor Mine, P.O. Box 130, Snow Lake, MB R0B 1M0

P. Mercier-Langevin, N. El Goumi, R. Enkin and M. Salisbury, work in progress); ore mineralogy and chemistry (Duff et al., 2013); and metamorphism (Lam et al., 2013, 2014; Tinkham, 2013).

Geological and structural setting

The Lalor deposit is part of the Paleoproterozoic Snow Lake arc assemblage (SLA), which has been described in detail in the literature (e.g., Bailes and Galley, 1996; David et al., 1996); only a summary of its main features relevant to this study are presented here. The SLA is located in the eastern part of the Paleoproterozoic Flin Flon greenstone belt in the Trans-Hudson orogen (Figure GS-8-1). The SLA is bounded to the north by the Snow Lake fault, to the east by the Berry Creek fault and to the west by the Ham Lake pluton. Volcanogenic massive-sulphide deposits in the SLA are present in the Anderson primitive-arc sequence and in the overlying Chisel mature-arc sequence (Bailes and Galley, 1999; Figure GS-8-1). The Lalor deposit is located in the Chisel sequence, along with other Zn-rich VMS deposits (Chisel, Chisel North, Ghost and Lost) and one Au-rich VMS deposit (Photo Lake; Galley et al., 2007; Figure GS-8-1). Most of these deposits, including the Lalor deposit, are thought to be located at the same time/stratigraphic level (Bailes et al.,

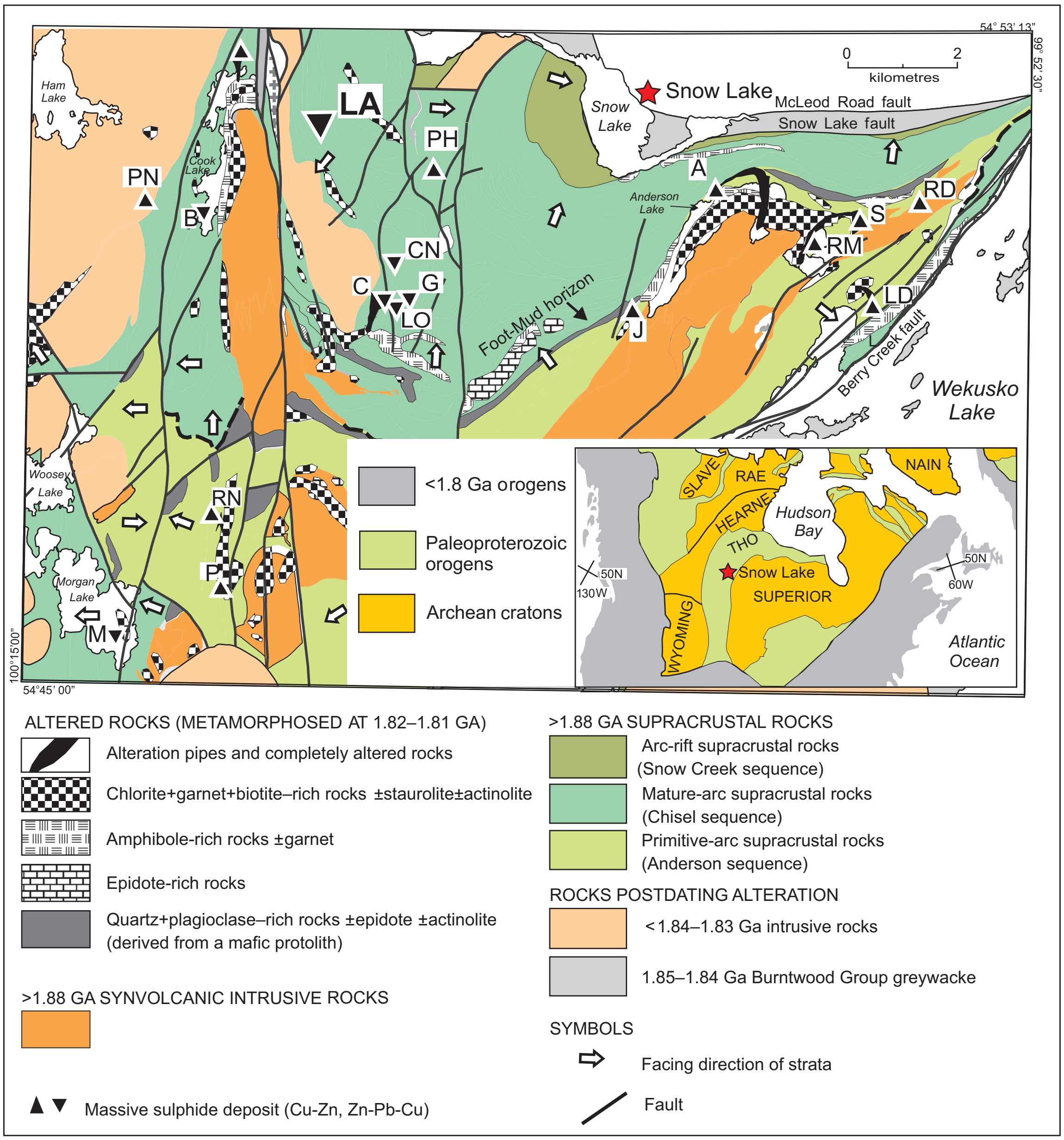


Figure GS-8-1: *Simplified geology of the Snow Lake area (from Galley et al., 2007), showing major alteration zones and VMS deposits, including the Lalor deposit (LA). Other deposits: A, Anderson; B, Bomber zone; C, Chisel Lake; CN, Chisel North; G, Ghost; J, Joannie zone; LO, Lost; LD, Linda zone; M, Morgan Lake zone; P, Pot Lake zone; PH, Photo Lake; PN, Pen zone; RD, Rod; RM, Ram zone; RN, Raindrop zone; S, Stall Lake.*

2013; Engelbert et al., 2014; Caté et al., in press), defined as the contact between the Lower Chisel and Upper Chisel subsequences and marking a transition from dominantly calcalkaline to more tholeiitic volcanism. This contact, referred to as the Lalor-Chisel contact in this report, has been described as a stratigraphic contact in the Chisel area (Engelbert et al., 2014) but has been interpreted as structural in other locations (Bailes, unpublished reports for HudBay Minerals Inc., 2008, 2009, 2011; Bailes et al., 2013), and its nature in the hangingwall of the Lalor deposit is still debated.

The Snow Lake area records polyphase deformation (D_1 to D_4) related to its accretion to the Amisk collage (Lucas et al., 1996) and its subsequent modification during the Trans-Hudson orogeny (Kraus and Williams, 1999). The D_1 structural features have generally been obliterated by later events, but S_0 parallel foliation (S_1), tight isoclinal folds and early thrusts are locally preserved. In most cases, the S_1 foliation is parallel to the main regional foliation (S_2), which is attributed to D_2 and is associated with the stretching of primary volcanic features (including clasts in volcaniclastic rocks). The S_2 foliation generally dips moderately (30–40°) to the north or northeast, but is commonly affected by later deformation. The F_2 southerly-verging folds are tight and isoclinal with S_2-parallel axial planes. The D_3 deformation is manifested as broad, open to locally tight, northeast-trending upright folds. An S_3 crenulation cleavage is locally present. Structures associated with D_4 deformation are very subtle and have not been observed in the Lalor deposit. Polyphase metamorphism (Menard and Gordon, 1997) affected the SLA and mineral assemblages indicate peak amphibolite-facies metamorphism. Late north-south brittle faults overprint features of the previous deformations (Figure GS-8-1).

Lalor deposit

The Lalor deposit is hosted in a distinct volcanic succession (herein referred to as the Lalor volcanic succession; Figure GS-8-2) overprinted by intense hydrothermal alteration (Caté et al., 2014) and amphibolite-grade metamorphism. However, the prefix 'meta' will not be used here in naming rock units to simplify the text. Least-altered rocks are tholeiitic to calcalkaline

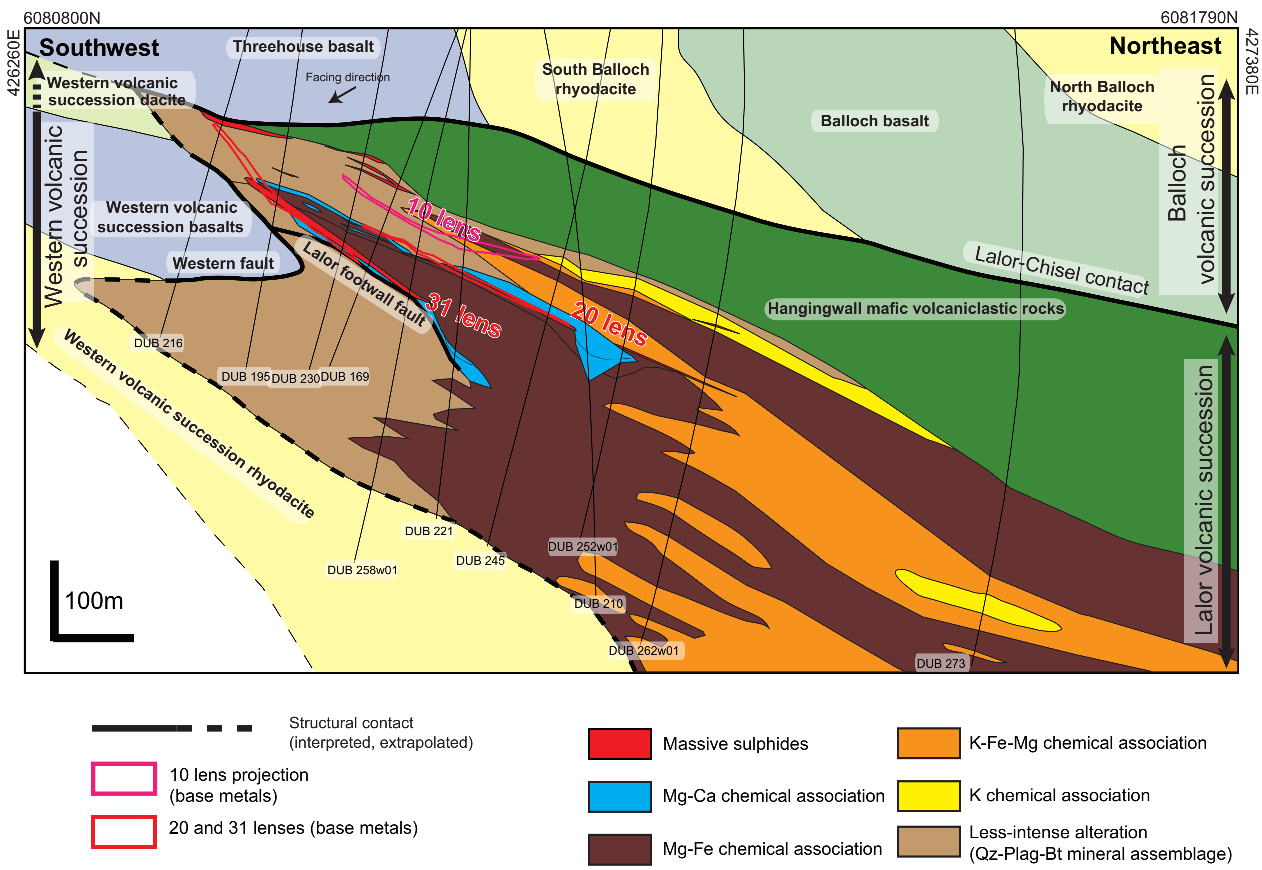


Figure GS-8-2: *Simplified geological cross-section 5600N (looking northwest) of the Lalor deposit. The Balloch and Western volcanic successions are in washed-out colours and the Lalor volcanic succession is in brighter colours. Ore zone outlines were determined from HudBay Minerals Inc.; the 10 lens is projected from section 5500N. Unit names in the Balloch volcanic succession are from Bailes (2008). Traces of drillholes used to interpret this section are indicated. See Caté et al. (in press) for more information on the protoliths of altered rocks in the Lalor volcanic succession.*

volcaniclastic rocks, lava flows and subvolcanic intrusions of mafic, intermediate and felsic composition. Individual volcanic units dip 20–30° to the northeast. Extensive alteration in the Lalor volcanic succession is marked by diverse metamorphic mineral assemblages, including quartz, muscovite, biotite, chlorite, Mg-Fe–amphiboles, cordierite, garnet, staurolite, kyanite, sillimanite, Ca-amphiboles, diopside, carbonates, anhydrite, gahnite, sulphides and other minerals. Mineral assemblages have been divided into five groups (or chemical associations) using geochemical characteristics (Caté et al., 2014; Figure GS-8-2): 1) the K chemical association, 2) the K-Mg-Fe chemical association, 3) the Mg-Fe chemical association, 4) the Mg-Ca chemical association, and 5) the Ca chemical association. The mineralization is hosted in the most intensely altered rocks as stratigraphically and structurally stacked, variably elongated lenses. Individual mineralized lenses dip 20–30° to the northeast. Zinc-rich, massive- to semi massive-sulphide lenses are located in the uppermost part of the host succession. They are underlain by, or are mixed with, Au-rich sulphide-poor ore lenses. Semimassive to disseminated Cu-Au sulphide mineralization is located north of the Zn-rich massive-sulphide lenses, at depth in the footwall.

Least-altered mafic volcaniclastic rocks stratigraphically overlie the Lalor deposit (Figure GS-8-2). They are truncated by the Lalor-Chisel contact and juxtaposed with steeply dipping, overturned, mafic to felsic volcanic units (Bailes, 2008), herein informally referred to as the 'Balloch volcanic succession' (Figure GS-8-2). Relatively fresh volcanic units (informally grouped here in the Western volcanic succession; Figure GS-8-2) located west of the deposit are in contact with the intensely altered rocks of the Lalor volcanic succession. The contact between these two volcanic successions is defined here as the 'Western fault'.

Underground mapping

Detailed mapping (1:250 scale) of drift walls at selected locations in underground workings, and localized observations elsewhere in the mine, have been completed to date.

Drift mL 865 10 HW

The 865 10 HW drift follows the strike of the 10 lens, which consists of massive sulphide. The mapped area is located at the northwest end of the 10 lens on the southeast-dipping limb of an F_3 fold. The massive-sulphide lens is hosted in quartz-muscovite-pyrite-biotite schist; a boudinaged mafic dike (or sill) crosscuts mineralization and altered wallrocks (Figures GS-8-3a, -4a). Intense D_2 deformation produced isoclinal folds in the sequence and resulted in boudinage of the dike (Figure GS-8-3a). More-ductile sulphide minerals (sphalerite, chalcopyrite and pyrrhotite) were remobilized into the necks of boudins, and locally constitute remobilized Zn-rich ore (Figures GS-8-3a, -4a). The dike was locally affected by Ca-rich metasomatism characterized by diopside, grossular, epidote, actinolite, carbonates and anhydrite (Figure GS-8-4b). Veins of grossular, calcite, actinolite, anhydrite, chalcopyrite, galena and sulphosalts are associated with this Ca-rich metasomatism (Figure GS-8-4c). Similar Cu-Pb–bearing, sulphosalt- and Ca-rich assemblages are also present in weakly altered, competent dikes that crosscut the mineralization in drillcore. These dikes are commonly associated with anomalous Au grades at the intersection with massive-sulphide lenses. Such association has not been observed in strongly altered, ductile, quartz-muscovite-pyrite-biotite schist. The Ca-rich metasomatism in the 865 10 HW drift overprints the S_2 foliation (Figure GS-8-4b).

Drift mL 865 North Access

The 865 North Access drift intersects the contact between altered rocks of the Lalor volcanic succession and least-altered rocks of the Western volcanic succession, close to the contact with massive sulphide of the 20 lens (Figure GS-8-3b). A repetition of the S_{1-2}-subparallel contact occurs in the drift, with the least-altered rocks of the Western volcanic succession in contact with altered rocks of the 10 lens footwall (quartz-biotite-pyrite with lesser kyanite and muscovite) to the northeast and rocks of the 20 lens hangingwall (quartz-muscovite-pyrite with lesser biotite and kyanite) to the southwest. Evidence of reverse shearing (southwestern contact; Figure GS-8-4d) and an intensification of the deformation are observed close to the contact. Least-altered rocks of the Western volcanic succession consist of massive, biotitized mafic rocks with bands of epidote and lesser grossular pervasive alteration. Some of these bands are affected by the main foliation and folded by F_2 folds (Figure GS-8-4e), but many bands clearly crosscut the S_2 foliation, suggesting a protracted, syn- to post-D_2 history of Ca metasomatism (Figure GS-8-4f).

Drift mL 865 20 North

The 865 20 North drift follows the strike of the 20 lens. Altered hostrocks are chlorite schist, quartz-muscovite-pyrite schist and quartz-biotite-pyrite schist (Figure GS-8-5a). Isoclinal F_2 folds are overprinted by open F_3 folds with steeply dipping axial planes (Figure GS-8-6a). Hinges of F_3 folds can be traced using variations in the strike of the S_{1-2} foliation (Figure GS-8-5a). The strike of the 20 lens is affected by both F_2 and F_3 folds, which results in a complex ore envelope (Figure GS-8-5a).

Drift mL 815 West Haulage

The West Haulage on level 815 exposes the 20 and 31 massive-sulphide lenses separated by an interval of intensely chlorite-altered rocks (Figure GS-8-5b) that show

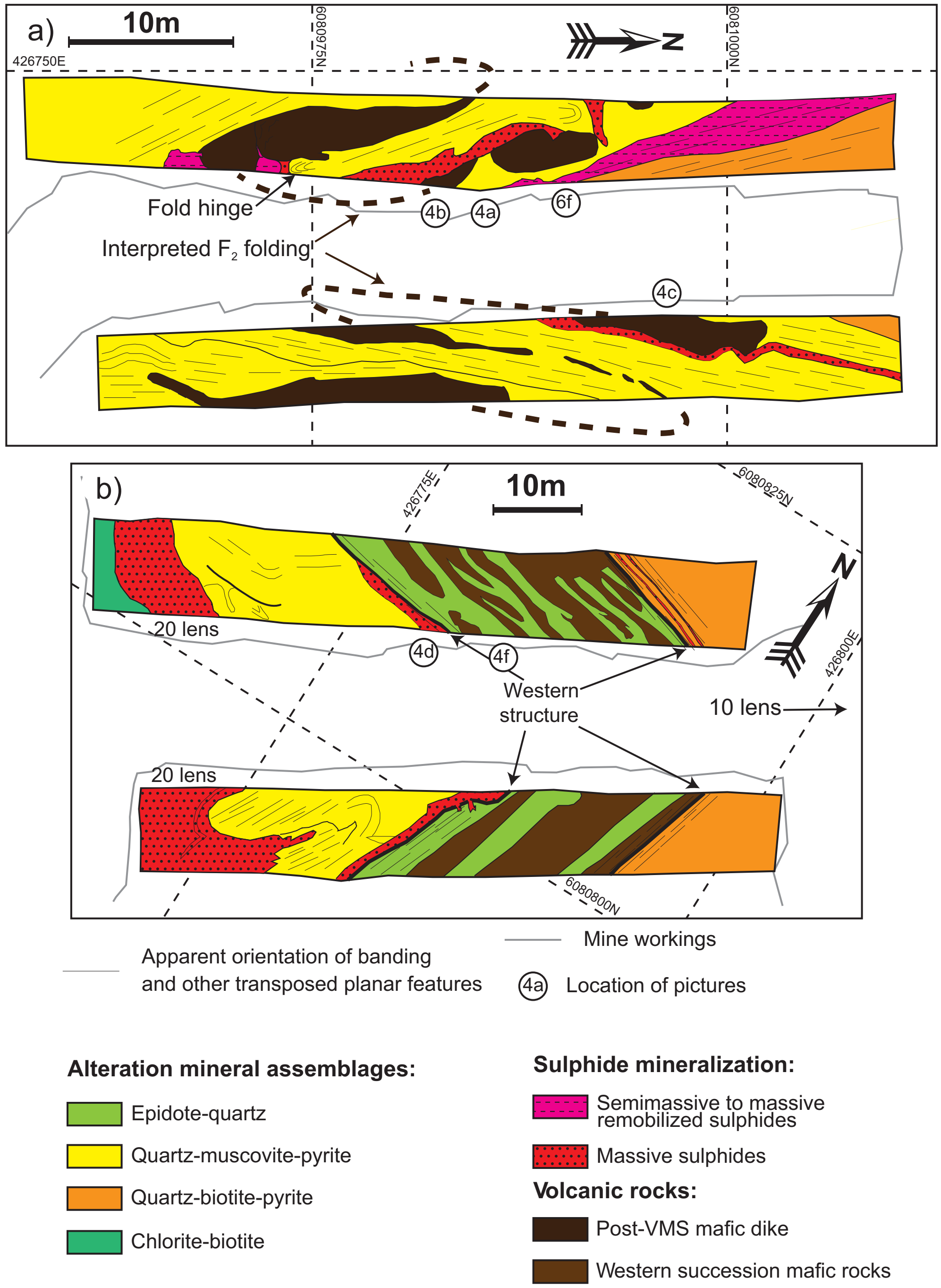


***Figure GS-8-3:** Geological maps (at 1:250 scale) of the vertical walls of underground workings (maps rotated to horizontal) in: **a)** drift mL 865 10 HW; **b)** drift mL 865 North Access.*

variable deformation intensity. Rocks in the hangingwall of the 20 lens are weakly altered. Intense deformation is focused along the 31 lens, with both C-S kinematic indicators and drag folds suggesting a component of apparent normal movement (Figure GS-8-6b). This shear zone corresponds to the Lalor footwall fault shown in Figure GS-8-2. The footwall of the 31 lens is in contact with intensely foliated and moderately altered felsic rocks (Figure GS-8-6c) that also show non-coaxial shear indicators close to the contact. Least-altered massive mafic rocks of the Western volcanic succession are in discordant contact with the 31 lens and the moderately altered felsic rocks (Figure GS-8-6c). No evidence of shearing is present at the contact, which is subparallel to the S_2 foliation. Intense deformation is apparent in the mafic rocks, but there is no clear evidence of non-coaxial shear. Mafic rocks contain bands of epidote alteration similar to that present in the mL 865 North Access drift

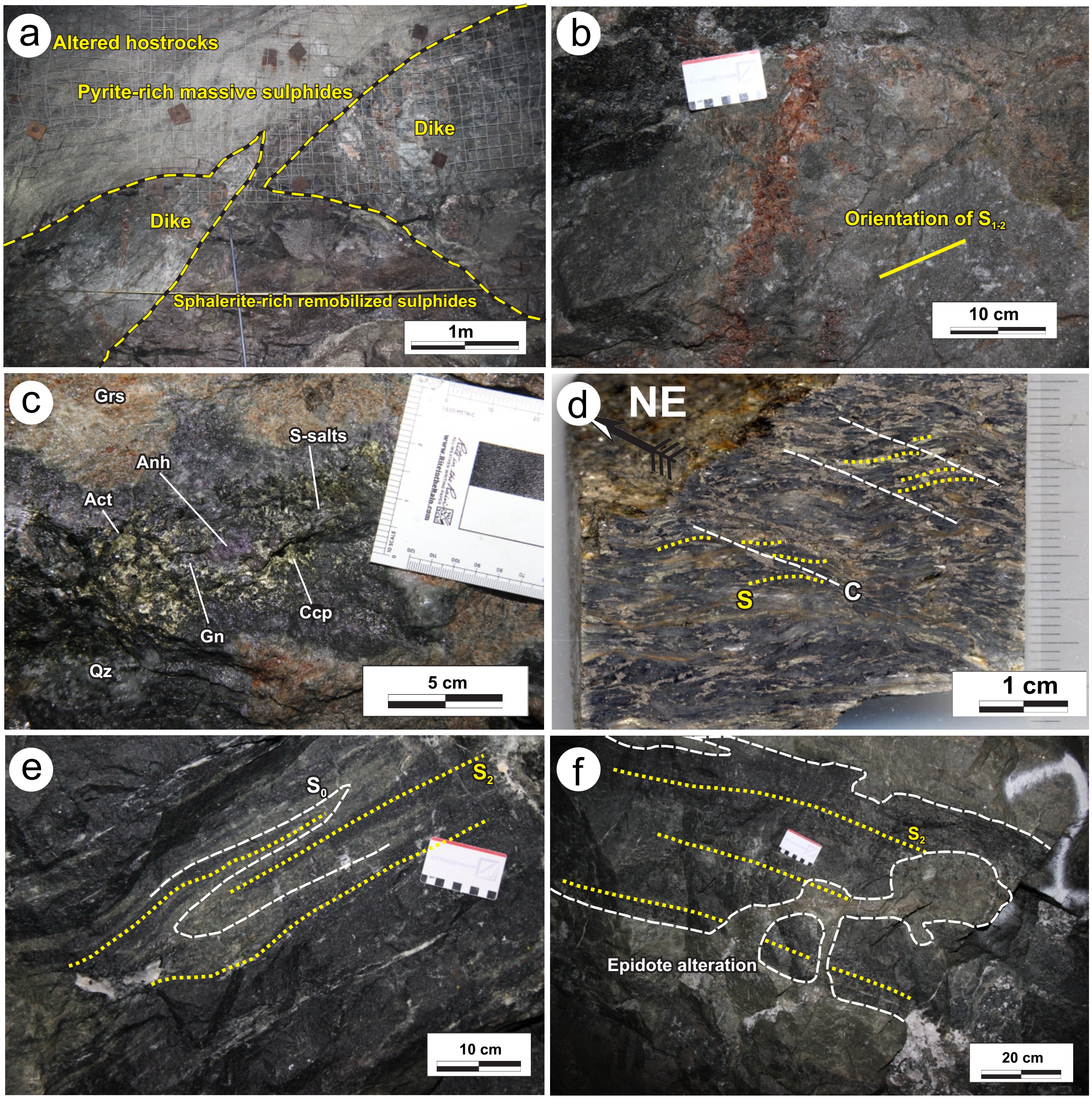


Figure GS-8-4: *Structural features and relationships in the Lalor deposit:* ***a)*** *remobilized sulphides in the neck of a boudinaged dike, drift mL 865 10 HW;* ***b)*** *late- to post-D_2 grossular-rich vein, drift mL 865 10 HW;* ***c)*** *chalcopyrite (Ccp), galena (Gn), and sulphosalt (S-salts) mineralization in a post-VMS dike with actinolite (Act), quartz (Qz), grossular (Grs) and anhydrite (Anh), drift mL 865 10 HW;* ***d)*** *S-C fabric developed in altered rocks near the western fault, drift mL 865 North Access;* ***e)*** *F_2-folded band of epidote (Ca-rich alteration), drift mL 815 West Haulage;* ***f)*** *late- to post-D_2 bands of epidote (Ca-rich alteration) that crosscut the S_2 foliation, drift mL 865 North Access.*

and variably intense quartz-calcite veining, both of which are affected by D_2 deformation structures. The exact nature of the felsic over mafic contact is still not clear. The altered felsic rocks structurally overlying the mafic rocks exposed on the southeast wall of the drift are not present on the northwest wall, suggesting that the contact is structural and/or intrusive in nature. Similar contacts might be present elsewhere in the deposit.

Lalor-Chisel contact

As presented above, the nature of the Lalor-Chisel contact in the hangingwall of the Lalor deposit is still debated. The Lalor-Chisel contact has only been observed in drillcore, as it is not currently exposed underground. The contact between units of the Balloch volcanic succession (hangingwall) and the Lalor volcanic succession (footwall) was intersected by Hudson Bay Exploration and

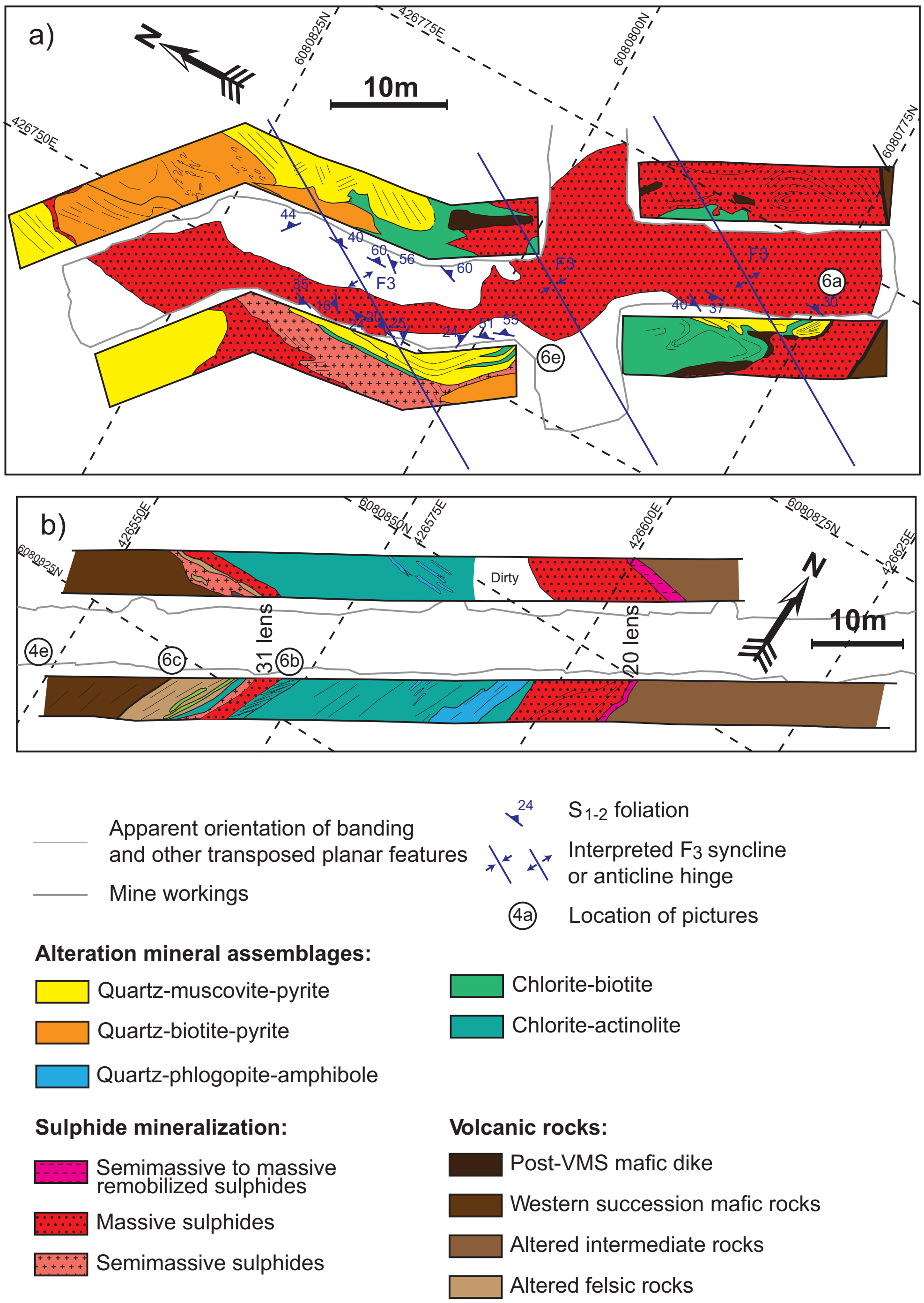


Figure GS-8-5: *Geological maps (at 1:250 scale) of the vertical walls of underground workings (maps rotated to horizontal) in:* ***a)*** *drift mL 865 20 North (with map of the back);* ***b)*** *drift mL 815 West Haulage.*

Development Co. Ltd. drillholes DUB211, DUB223 and DUB241. In the first two holes, the contact is overprinted by strong amphibolitization, which prevented detailed structural observations. In DUB241, a rhyodacitic unit of the Balloch volcanic succession is in contact with the mafic volcaniclastic rocks that conformably overlie the Lalor deposit. The contact is sharp, wavy and cut by the S_2 foliation (Figure GS-8-6d). No major increase in the strain intensity is apparent at or near the contact. The mafic volcaniclastic rocks are affected by a strong amphibolitization.

Structural observations

Numerous structural measurements were collected in several locations in the mine. The S_1 and S_2 foliations

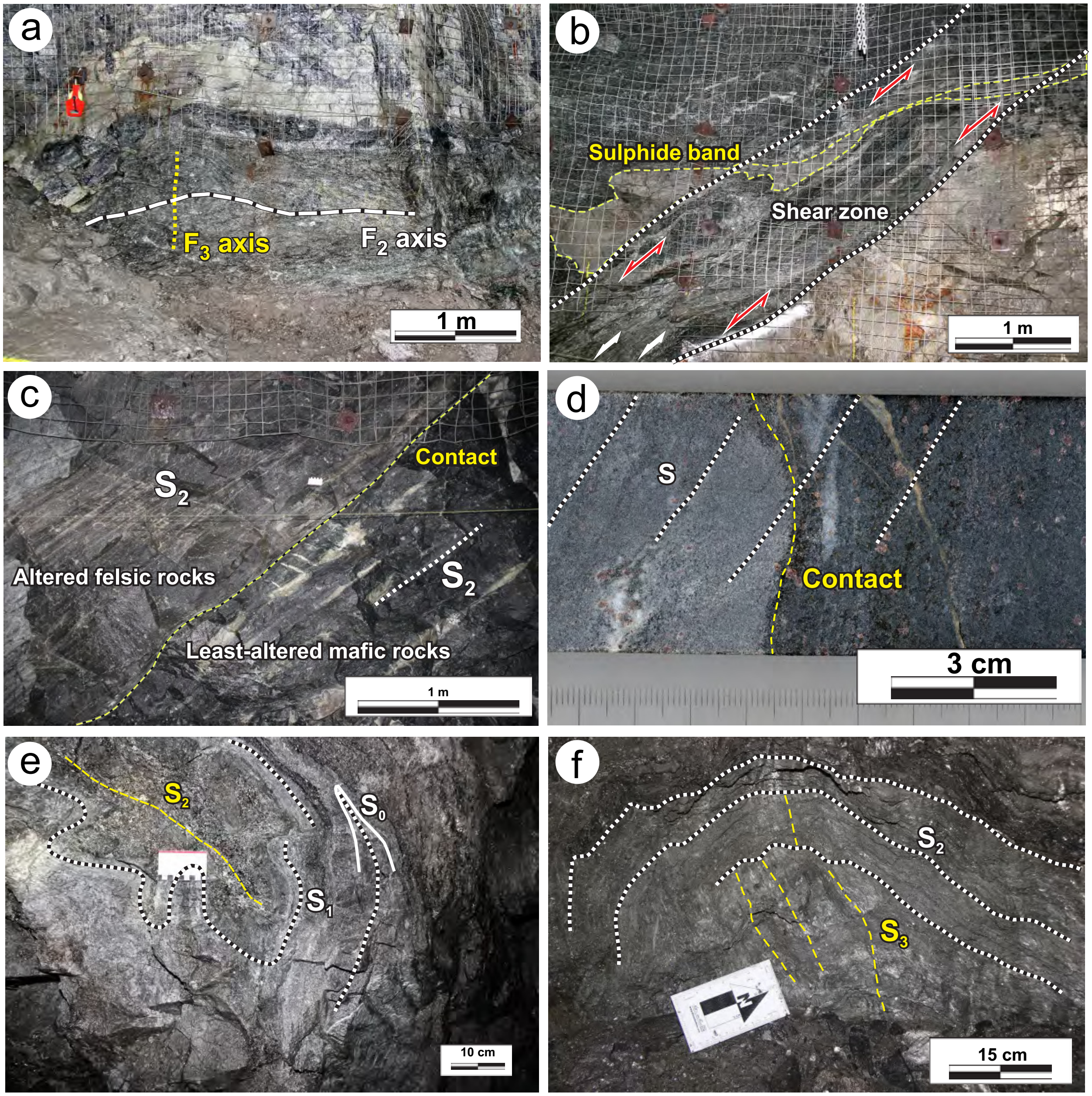


Figure GS-8-6: *Structural features and relationships in the Lalor deposit:* ***a)*** *F_2 and F_3 folds in altered rocks in the structural footwall of the 20 lens massive sulphides, drift mL 865 20 North;* ***b)*** *shear zone in the structural hangingwall of the 31 lens (massive sulphide) with a sheared sulphide band, drift mL 815 West Haulage;* ***c)*** *contact between altered felsic rocks and least-altered massive mafic rocks, drift mL 815 West Haulage;* ***d)*** *contact between felsic rocks of the Balloch volcanic succession and mafic rocks of the Lalor volcanic succession, drillhole DUB 241;* ***e)*** *relationships between S_0, S_1 and S_2 in the hinge zone of an isoclinal F_2 fold in altered rocks, drift mL 865 20 North;* ***f)*** *relationship between S_2 and S_3 in an open S_3 fold in altered rocks, drift mL 865 10 HW.*

can be distinguished in F_2 fold hinges (Figure GS-8-6e), but they are usually parallel to each other elsewhere. The F_2 folds are present in all rock types and affect S_1, early veins, alteration textures and contacts. An S_3 crenulation cleavage is present in phyllosilicate-rich rocks (Figure GS-8-6f) and, in rare cases, obliterates the S_{1-2} foliation. Poles to the composite S_1-$_2$ foliation define a partial girdle on a stereogram, perhaps due to noncylindrical F_2 folding inherited from D_1 structures, but possibly also due to the presence of cylindrical F_3 folds (Figure GS-8-7). The F_3 folds at the Chisel mine (Martin, 1966) are concentric and moderately plunging folds. Calculated fold axis (030°/26°) and fold-axial plane (214°/82°N) orientations fit with the measured orientation of the S_2-S_3 crenulation lineation and S_3 crenulation foliation, respectively (Figure GS-8-7).

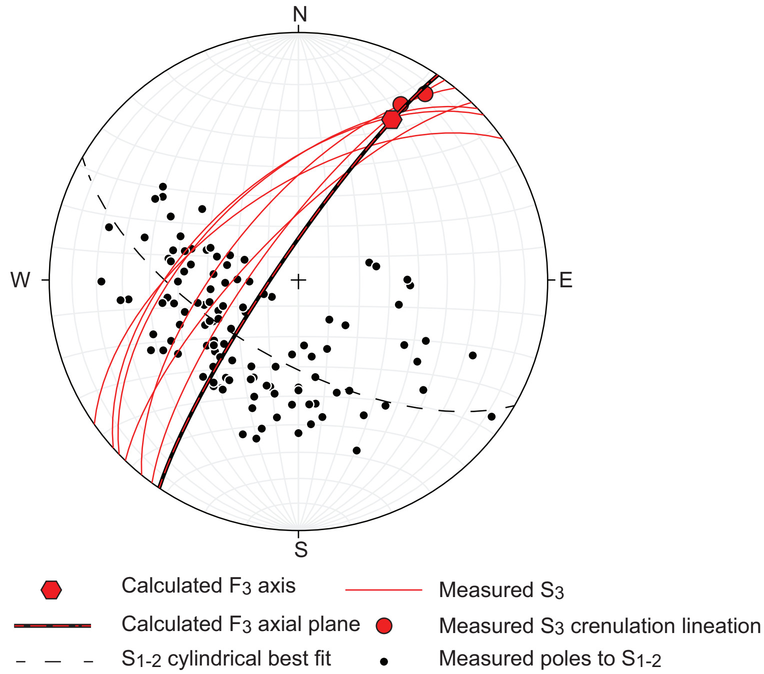


Figure GS-8-7: *Wulff stereographic projection (lower hemisphere) of measured and calculated structural features in the Lalor mine.*

Preliminary interpretations

Structural features associated with the regional D_1, D_2 and D_3 deformation events have been observed in the Lalor mine. However, no clear evidence of the regional D_4 deformation is observed. The effect of D_1 deformation is cryptic due to the overprinting by later deformation events. The main foliation is S_2, and older structures (including S_1) and contacts are highly transposed into parallelism with S_2. The F_2 folds are ubiquitous, but their isoclinal nature often makes them difficult to map and interpret at the scale of a mine stope. Importantly, F_2 folds are responsible for structural repetitions of units and ore lenses at various scales (Figure GS-8-3a). The D_3 deformation event produced large open folds that locally affect the orientation of older features without having a major effect on deposit-scale trends. The presence of a shear zone affecting the 31 lens suggests that structural repetition of ore lenses (Caté et al., 2014) is, in part, due to structural breaks.

The Lalor-Chisel contact and the Western fault are pre-D_2 features. Despite clear evidence of a structural contact at the cross-section scale (Bailes, unpublished report for HudBay Minerals Inc., 2009; Figure GS-8-2), the Lalor-Chisel contact is wavy, sharp and overprinted by the S_2 foliation where observed at Lalor. Based on our preliminary observations and available data, the Lalor-Chisel contact can be interpreted as an unconformity or an early brittle fault. The Western fault sharply cuts VMS-related alteration, and it also cuts the Lalor volcanic succession (Caté et al., in press). At stope scale, the contact is transposed subparallel to the S_2 foliation and its repetition indicates tight D_2 folding±transposition (Figures GS-8-2, -3b). The Western fault could be an early intrusive contact that has been passively folded during D_2, or an early fault that has been folded during D_2. Evidence of shearing indicates reactivation of this contact during D_2 (e.g., transposition).

Mechanical (i.e., solid-state) remobilization of less-competent sulphide minerals into boudin necks represents a significant, but most probably local, means for remobilizing Zn- and Cu-rich sulphides, whereas Au and Ag are associated with sulphosalt-rich veins and Ca-rich metasomatism, indicating hydrothermal (i.e., fluid-state) remobilization and concentration, plausibly along high-strain zones in the host sequence. Overprinting relationships indicate that these remobilizations occurred in various stages (syn- to late- or post-D_2 deformation), but mechanical remobilization apparently also occurred earlier in the deformation, as the earliest of such features were reworked during D_2 and D_3.

Economic considerations

The general shape and orientation of massive-sulphide lenses in the Lalor deposit is largely controlled by an intense flattening and stretching±transposition subparallel to S_2 foliation. Attenuation due to D_2 flattening, as well as thickening due to F_2 folding, both clearly affect the geometry of the ore zones and their hostrocks. The D_3

deformation does not seem to have had a major impact on the general shapes of ore lenses, but both F_2 and F_3 folds locally affect their strike.

Mechanical remobilization of ductile sulphides probably also occurred in the hinges of F_3 folds and at the contacts of massive-sulphide lenses with more competent and/or least-altered rocks. This remobilization is local and may cause reconcentration of some metals in ore shoots that have a geometry controlled by the structure responsible for their development.

Remobilization of Au and Ag is apparent only local, generally very close to massive-sulphide lenses, and is associated with various stages (syn- to late- or post-D_2) of Ca-rich metasomatism. Galena-chalcopyrite-sulphosalt–rich bands and veins preferentially occur in competent rocks such as dikes or least altered rocks, and rarely in strongly altered, more ductile rocks such as muscovite-rich schist. This remobilization seems to reconcentrate part of the Au and Ag outside of the primary ore gangue (base-metal–rich sulphide lenses).

Future work

The current report presents preliminary observations and interpretations on the various structural features present in the Lalor deposit. More work will be conducted in 2014–2015 to further constrain the relative timing and effects of the different deformation events recorded by the deposit and its hostrocks. Future work on the structural setting of the Lalor deposit will focus on 1) the nature of the Lalor-Chisel contact and the Western fault, in order to understand the distribution of the Lalor volcanic succession outside the mine area; 2) F_2-F_3 fold interference and its influence on the geometry of the massive-sulphide lenses; 3) the macroscale deposit geometry; 4) the relative timing and significance of the remobilization of base and precious metals at the scale of stopes or the entire deposit. This work will involve additional underground mapping, thin-section petrography, structural analysis, and 3-D geophysical, geological, geochemical and structural modelling of the host successions, ore lenses and distribution of metals.

Acknowledgments

The authors thank HudBay Minerals Inc. for authorization to publish this report. Our research at Lalor is funded by the Geological Survey of Canada (GSC) through the Targeted Geoscience Initiative 4 program (TGI-4) and by HudBay Minerals Inc. S. Duff, M. Hannington, B. Dubé, S. Gagné, D. Tinkham, H. Gibson, B. Lafrance, M. Engelbert, J. Lam and V. Friesen are thanked for their constant and essential help and support, and for sharing their knowledge of the Snow Lake camp. The authors most sincerely thank M. Moher for her work as field assistant, Hudbay geologists for their support and help, and A. Bailes for his precious advice. C. Taylor is gratefully acknowledged for his constructive comments on an earlier version of this report. Reviews by N. Pinet, S. Gagné and S. Anderson greatly helped improve the content of this report.

Natural Resources Canada, Earth Sciences Sector contribution 20140263

References

Bailes, A. and Galley, A. 1996: Setting of Paleoproterozoic volcanic-hosted massive base metal sulphide deposits, Snow Lake; *in* EXTECH 1: A Multidisciplinary Approach to Massive Sulphide Research in the Rusty Lake–Snow Lake Greenstone Belts, Manitoba; G. Bonham-Carter, A.G. Galley and G.E.M. Hall (ed.), Geological Survey of Canada, Bulletin 426, p. 105–138.

Bailes, A.H. and Galley, A.G. 1999: Evolution of the Paleoproterozoic Snow Lake arc assemblage and geodynamic setting for associated volcanic-hosted massive sulphide deposits, Flin Flon Belt, Manitoba, Canada; Canadian Journal of Earth Sciences, v. 36, no. 11, p. 1789–1805, doi:10.1139/e98-111.

Bailes, A.H., Rubingh, K., Gagné, S., Taylor, C., Galley, A., Bernauer, 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, Winnipeg, Manitoba, May 22–24, 2013, Field Trip Guidebook; Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, Open File OF2013-3, 63 p.

Caté, A., Mercier-Langevin, P., Ross, P.-S., Duff, S., Hannington, M., Dubé, B., and Gagné, S. 2013a. The Paleoproterozoic Lalor VMS deposit, Snow Lake, Manitoba: preliminary observations on the nature and architecture of the gold- and base metal-rich ore and alteration zones; Geological Survey of Canada, Open File 7483, 19 p.

Caté, A., Mercier-Langevin, P., Ross, P.-S., Duff, S., Hannington, M., Dubé, B. and Gagné, S. 2013b. Preliminary observations on the geological environment of the Paleoproterozoic auriferous volcanogenic massive sulphide deposit of Lalor, Snow Lake, Manitoba; Geological Survey of Canada, Open File 7372, 13 p.

Caté, A., Mercier-Langevin, P., Ross, P.-S., Duff, S., Hannington, M., Dubé, B., and Gagné, S. 2014: Deciphering the multiple hydrothermal, metasomatic and structural events responsible for the formation and post-depositional evolution of the Paleoproterozoic Lalor auriferous VMS deposit, Snow Lake, Manitoba; Geological Association of Canada–Mineralogical Association of Canada, Joint Annual Meeting, Fredericton, May 20–22, 2014, Program with Abstracts, p. 52–53.

Caté, A., Mercier-Langevin, P., Ross, P.-S., Duff, S., Hannington, M., Gagné, S., and Dubé, B. in press: Insight on the chemostratigraphy of the volcanic and intrusive rocks of the Lalor auriferous volcanogenic massive sulphide deposit host succession, Snow Lake, Manitoba; Geological Survey of Canada, Current Research 2014-6, doi:10.4095/295080.

David, J., Bailes, A.H., and Machado, N. 1996: Evolution of the Snow Lake portion of the Palaeoproterozoic Flin Flon and Kisseynew belts, Trans-Hudson Orogen, Manitoba, Canada; Precambrian Research, v. 80, no. 1–2, p. 107–124.

Duff, S., Caté, A., Hannington, M., Mercier-Langevin, P. and Ross, P.-S. 2013: Major ore types of the Lalor deposit, Snow Lake, Manitoba; Geological Society of America Meeting, Program with Abstracts, v. 45, no. 7, p. 806.

Engelbert, M.S., Friesen, V., Gibson, H. and Lafrance, B. 2014: Volcanic reconstruction of the productive VMS ore interval in the Paleoproterozoic Chisel sequence, Snow Lake, Manitoba; Geological Association of Canada–Mineralogical Association of Canada, Joint Annual Meeting, Fredericton, May 20–22, 2014, Program with Abstracts, p. 83–84.

Froese, E., and Gasparrini, E. 1975: Metamorphic zones in the Snow Lake area, Manitoba; Canadian Mineralogist, v. 13, no. 2, p. 162–167.

Gagné, S., Beaumont-Smith, C.J., Hynes, A. and Williams-Jones, A.E. 2005: Gold metallogenesis and tectonometamorphic history of selected deposits from the Snow Lake area and the southern flank of the Kisseynew Domain, west-central Manitoba (NTS 63J13, 63K10, 63K16 and 63N2); *in* Report of Activities 2005, Manitoba Industry, Economic Development and Mines, Manitoba Geological Survey, p. 20–27.

Gagné, S., Beaumont-Smith, C.J., Williams-Jones, A.E. and Hynes, A. 2006: Metallogenic and metamorphic study of selected deposits from the Snow Lake area and the southern flank of the Kisseynew Domain, Manitoba (NTS 63K16 and 63N2); *in* Report of Activities 2006, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 42–48.

Galley, A.G., Bailes, A. H. and Kitzler, G. 1993: Geological setting and hydrothermal evolution of the Chisel Lake and North Chisel Zn-Pb-Cu-Ag-Au massive sulfide deposits, Snow Lake, Manitoba; Exploration and Mining Geology, v. 2, no. 4, p. 271–295.

Galley, A.G., Syme, R., and Bailes, A.H. 2007: Metallogeny of the Paleoproterozoic Flin Flon Belt, Manitoba and Saskatchewan; *in* Mineral Deposits of Canada: A Synthesis of Major Deposit Types, District Metallogeny, The Evolution of Geological Provinces, and Exploration Methods, W.D. Goodfellow (ed.), Geological Association of Canada, Mineral Deposits Division, Special Publication 5, p. 509–531.

Gibson, H., Engelbert, M.S., Lafrance, B., Friesen, V., DeWolfe, M., Tinkham, D.K. and Bailes, A.H. 2014: Reconstruction of the ore interval and environment for the Paleoproterozoic, Lost and Ghost Lake VMS deposits, Snow Lake, Manitoba; Geological Association of Canada–Mineralogical Association of Canada, Joint Annual Meeting, Fredericton, May 20–22, 2014, Program with Abstracts, p. 102.

Gordon, T. 1989: Thermal evolution of the Kisseynew sedimentary gneiss belt, Manitoba: metamorphism at an early Proterozoic accretionary margin; *in* Evolution of Metamorphic Belts, J.S. Daly, R.A. Cliff and B.W.D. Yardley (ed.), The Geological Society of London, Special Publications, v. 43, p. 233–243.

Hodges, D.J., and Manojlovic, P.M. 1993: Application of lithogeochemistry to exploration for deep VMS deposits in high grade metamorphic rocks, Snow Lake, Manitoba; Journal of Geochemical Exploration, v. 48, no. 2, p. 201–224.

HudBay Minerals Inc. 2014: Hudbay provides annual reserve and resource update; HudBay Minerals Inc., news release, March 26, 2014, URL <http://www.hudbayminerals.com/English/Media-Centre/News-Releases/News-Release-Details/2014/Hudbay-Provides-Annual-Reserve-and-Resource-Update/default.aspx> [October 2014].

Kraus, J. and Menard, T. 1997: A thermal gradient at constant pressure: implications for low- to medium-pressure metamorphism in a compressional tectonic setting, Flin Flon and Kisseynew domains, Trans-Hudson orogen, central Canada; Canadian Mineralogist, v. 35, no. 5, p. 1117–1136.

Kraus, J. and Williams, P.F. 1998: Relationships between foliation development, porphyroblast growth and large-scale folding in a metaturbidite suite, Snow Lake, Canada; Journal of Structural Geology, v. 20, no. 1, p. 61–76.

Kraus, J. and Williams, P.F. 1999: Structural development of the Snow Lake Allochthon and its role in the evolution of the southeastern Trans-Hudson Orogen in Manitoba, central Canada; Canadian Journal of Earth Sciences, v. 36, no. 11, p. 1881–1899.

Lam, J., Tinkham, D.K. and Gibson, H. 2013: Identification of metamorphic assemblages and textures associated with gold mineralization at the Lalor deposit, Snow Lake, Manitoba; Geological Association of Canada–Mineralogical Association of Canada, Joint Annual Meeting, Winnipeg, May 22–24, 2013, Program with Abstracts, p. 127.

Lam, J., Tinkham, D.K. and Gibson, H. 2014: Characterization of gold occurrences with respect to metamorphism at the Lalor deposit, Snow Lake, Manitoba; Geological Association of Canada–Mineralogical Association of Canada, Joint Annual Meeting, Fredericton, May 20–22, 2014, Program with Abstracts, p. 150–151.

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, no. 5, p. 602–629, doi:10.1130/0016-7606(1996)108<0602:itatdo>2.3.co;2.

Martin, P. 1966: Structural analysis of Chisel Lake orebody; Canadian Mining and Metallurgical Bulletin, v. 69, p. 208–214.

Menard, T. and Gordon, T.M. 1997: Metamorphic P-T paths from the eastern Flin Flon Belt and Kisseynew Domain, Snow Lake, Manitoba; Canadian Mineralogist, v. 35, no. 5, p. 1093–1115.

Rubingh, K., Lafrance, B. and Gibson, H. 2013: Structural analysis of the McLeod Road–Birch Lake thrust panel, Snow Lake, west-central Manitoba (parts of NTS 63K16, 63J13); *in* Report of Activities 2013, Manitoba Mineral Resources, Manitoba Geological Survey, p. 106–113.

Skirrow, R.G. and Franklin, J.M. 1994: Silicification and metal leaching in semiconformable alteration beneath the Chisel Lake massive sulfide deposit, Snow Lake, Manitoba; Economic Geology, v. 89, no. 1, p. 31–50, doi:10.2113/gsecongeo.89.1.31.

Stern, R.A., Syme, E.C., Bailes, A.H., and Lucas, S.B. 1995: Paleoproterozoic (1.90–1.86 Ga) arc volcanism in the Flin Flon Belt, Trans-Hudson Orogen, Canada; Contributions to Mineralogy and Petrology, v. 119, no. 2–3, p. 117–141.

Tinkham, D.K. 2013: A model for metamorphic devolatilization in the Lalor deposit alteration system, Snow Lake, MB; Geological Association of Canada–Mineralogical Association of Canada Annual Meeting, Winnipeg, May 22–24, 2013, Program with Abstracts, p. 187.

Zaleski, E., Froese, E., and Gordon, T. M. 1991: Metamorphic petrology of Fe-Zn-Mg-Al alteration at the Linda volcanogenic massive sulfide deposit, Snow Lake, Manitoba; Canadian Mineralogist, v. 29, no. 4, p. 995–1017.