GS-2 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)

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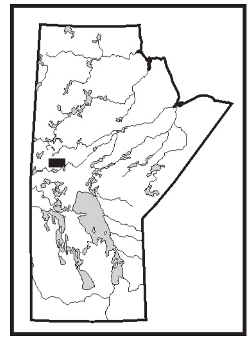

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Summary

The eastern portion of the Flin Flon–Snow Lake greenstone belt hosts a series of gold deposits that occur through a range of metamorphosed hostrocks. The hostrocks experienced metamorphic conditions from upper greenschist facies to upper amphibolite facies. Earlier observations and studies suggest that at least some of the deposits formed under early to syn–peak metamorphic conditions.

Preliminary data from the North Star gold deposit indicate that the quartz-vein–hosted gold mineralization formed early in the deformational history of the West Reed–North Star Shear Zone. Complex isoclinal folding, accompanied by hinge thickening and limb attenuation, was recognized from underground exposures of the North Star vein system. Visual examination of drillcore, combined with preliminary analysis of chemical data, allowed the distinction between a base-metal–rich and a base-metal–poor gold mineralization. Textural relationships from core examination also indicate that a late biotite alteration event overprints an earlier chloritization event. Observations on wasterock and core samples from Puffy Lake, Squall Lake and Nokomis Lake support the suggestion that mineralization and alteration were emplaced early to syn–peak metamorphic conditions in these deposits.

Introduction

Although best known for its volcanogenic massive sulphide (VMS) deposits, the eastern portion of the Flin Flon–Snow Lake greenstone belt (which includes the Snow Lake area and the southern flank of the Kisseynew Domain) also hosts numerous gold deposits, including the 1.5 million ounce New Britannia deposit, the largest Paleoproterozoic-hosted gold deposit in Canada. Previous studies and field observations suggest that at least some of these deposits formed just prior to, or synchronous with, the local metamorphic peak (e.g., Ostry and Halden, 1995; Fieldhouse, 1999). The timing of gold mineralization emplacement and its relationship to the metamorphic history, however, are generally poorly constrained. Similarly, the nature of the mineralizing fluid and the alteration paragenesis require further investigation. The Snow Lake area and the southern flank of the Kisseynew Domain contain a series of gold deposits that occur in hostrocks displaying a range of peak metamorphic conditions ranging from upper greenschist to upper amphibolite facies. The range in metamorphic grade and the suggestion that at least part of the gold mineralization is early to syn–peak metamorphic conditions makes the project area an ideal location to study the effects of metamorphism and deformation on gold mineralization.

A metallogenic, metamorphic and structural study of selected gold deposits (Figure GS-2-1) in the eastern portion of the Flin Flon–Snow Lake greenstone belt was initiated in June 2005. This project will include a detailed examination of six gold deposits (East Wekusko Lake, North Star Lake, New Britannia, Squall Lake, Puffy Lake and Nokomis Lake), whose hostrocks are representative of the range in metamorphic grade found in the study area. Aspects to be examined include the timing and style of gold mineralization emplacement and alteration events, the character of the mineralizing fluids and the metamorphic history of the deposits. The research will use detailed structural, geochemical and petrographic analysis of ore and altered wallrock to establish timing relationships. Geochronology and thermobarometry work will complement the study. Detailed field mapping and structural work will only be carried on at three of the locations (North Star Lake, Squall Lake and Puffy Lake). Investigation of the mineralization at the other three deposits will be completed mainly through the study of drillcore.

During the first field season, detailed work was carried out at the North Star gold deposit, and included underground sampling and mapping, surface mapping and core sampling. Sampling of mineralized trenches and reconnaissance traverses were completed at the Squall Lake deposit. A few days were also spent in the core-storage facilities in The Pas, looking at representative drillcore from Puffy Lake, Squall Lake and Nokomis Lake.

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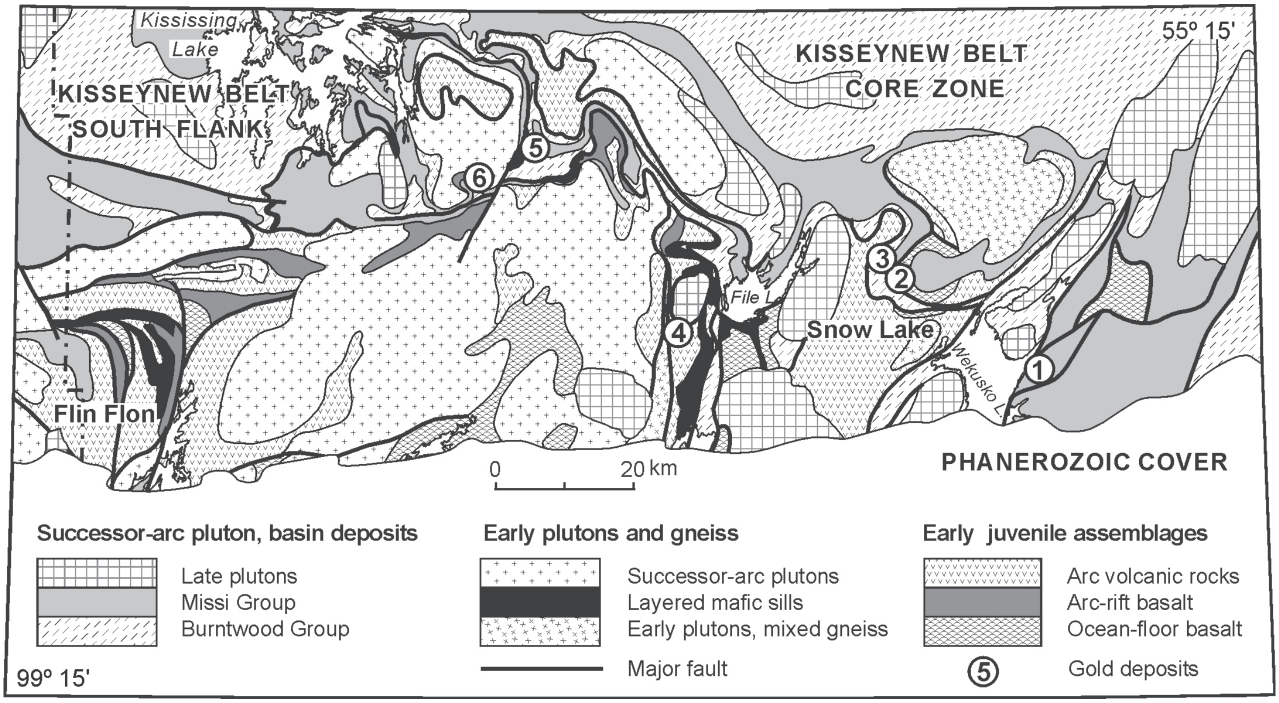


Figure GS-2- 1: *Generalized geology of the Snow Lake area, showing the location of the selected gold deposits: 1) East Wekusko Lake; 2) New Britannia mine; 3) Squall Lake; 4) North Star Lake; 5) Nokomis Lake; 6) Puffy Lake mine.*

Regional geology

The Flin Flon–Snow Lake greenstone belt in northwestern Manitoba is part of the internal or juvenile portion of the Trans-Hudson Orogen (THO). The greenstone belt trends east for more than 250 km and has a width of ~50 km from north to south. It is bounded to the north by the Kisseynew Domain, to the east by the reworked Archean rocks of the THO external zone (Superior Boundary Zone), and to the west by the Wollaston fold belt. Paleozoic platform sedimentary rocks unconformably overlie the greenstone belt to the south. Researchers (Lucas et al., 1996; Syme et al., 1996; Kraus, 1999) have recognized that the eastern and western portions of the belt have distinct tectonic histories.

The eastern segment of the Flin Flon–Snow Lake greenstone belt, the Snow Lake Allochthon of Syme et al. (1995), represents a tectonic collage comprising ocean-floor and island-arc assemblages (ca. 1.9 Ga) and younger (ca. 1.86–1.84 Ga) metasedimentary rocks of the Kisseynew Domain (Kraus and Williams, 1999). The Kisseynew Domain is a 240 km x 140 km east-trending belt of Paleoproterozoic paragneiss and related granitoid plutons, bounded to the north and south by the Lynn Lake and Flin Flon–Snow Lake greenstone belts, respectively. The Kisseynew Domain includes minor amounts of amphibolitic gneiss along the southern and northern flanks, which are interpreted to represent a former marginal basin metamorphosed under high-grade conditions and telescoped during continental collision (Kraus, 1999).

Metamorphic conditions and isograds

The metamorphic grade is highly variable in the Flin Flon–Snow Lake greenstone belt. Most of the western Flin Flon Domain experienced metamorphic conditions varying from lower to middle greenschist facies, with minor occurrences of sub-greenschist facies (prehnite-pumpellyite) rocks in the southwestern part of the area (Bailes and Syme, 1983). Metamorphic grade varies from lower to middle amphibolite facies in the eastern Flin Flon Domain (Snow Lake area), and the highest metamorphic grade, upper amphibolite facies, was reached in the centre of the Kisseynew gneiss belt, as indicated by the widespread development of garnet–cordierite–K-feldspar migmatite.

The Snow Lake area is characterized by a northward increase in peak metamorphic temperature from ~500°C to ~700°C, with only a minor corresponding increase in pressure from 4 to 6 kbar (Kraus and Menard, 1997). This northward increase is clearly indicated by metamorphic mineral assemblages, which progress from the chlorite zone in the south, through the staurolite zone (New Brittania mine), to the sillimanite zone near Squall Lake. In the Kisseynew Domain (Squall Lake, Puffy Lake and Nokomis Lake deposits), mineral assemblages vary from sillimanite-garnet-biotite along the margin to garnet–cordierite–K-feldspar migmatite in the central portion of the belt (Figure GS-2-2).

The gold deposits for this study were selected to provide representative examples from across the steep

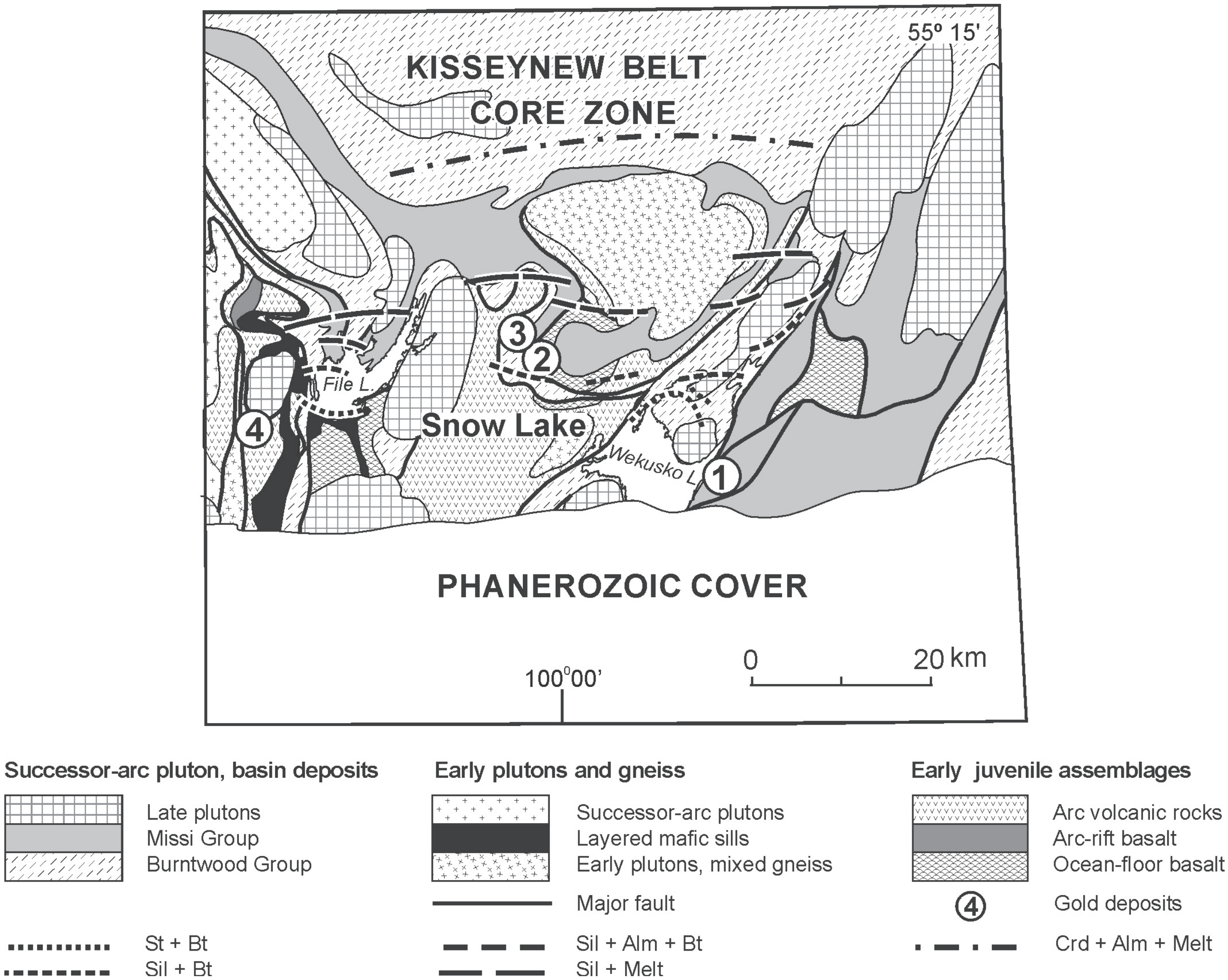


Figure GS-2-2: *Generalized geology in the immediate vicinity of Snow Lake, showing the locations of four of the selected gold deposits and the main regional mineral isograds. Gold deposits: 1) East Wekusko Lake; 2) New Britannia mine; 3) Squall Lake; 4) North Star Lake. Mineral abbreviations: Alm, almandine; Bt, biotite; Crd, cordierite; Sil, sillimanite; St, staurolite.*

south to north hostrock metamorphic gradient on the southern flank of the Kisseynew Domain. The Squall Lake, Puffy Lake and Nokomis Lake deposits represent mineralization in hostrock metamorphosed at middle to upper amphibolite facies. The New Britannia mine and the East Wekusko deposits are hosted by lower to middle amphibolite-grade rocks (Kraus, 1999). The North Star gold deposit is located in a major tectonite zone at the boundary between the two segments of the Flin Flon–Snow Lake greenstone belt. Rocks surrounding the deposit display mineral assemblages suggesting that metamorphic peak conditions reached upper greenschist to incipient amphibolite facies.

Previous work

The New Britannia gold mine (Galley et al., 1986; Bailes and Schledewitz, 1998; Fieldhouse, 1999) and the Puffy Lake gold deposit (Ostry and Trembath, 1992; Ostry and Halden, 1995) have been the subject of detailed study. Fieldhouse (1999) and Galley et al. (1986) proposed that the New Britannia gold deposit was emplaced along early structural breaks that predate the peak metamorphic conditions. Froese and Moore (1980) concluded that peak metamorphic conditions in the Snow Lake area were achieved late relative to the main deformation episodes, based on the absence of folding in the isograds. Similarly, Kraus and Menard (1997) demonstrated that the regional peak metamorphic conditions were reached during late east-west folding, corresponding to F_3 in this area, further suggesting that the New Britannia deposit was emplaced early relative to the metamorphic history of the region. In their study of the deposit at Puffy Lake, Ostry and Halden (1995) also concluded that the gold mineralization was initially emplaced prior to peak metamorphic conditions. Schledewitz (1997), in a regional study of the gold mineralization north of Snow Lake, concluded that the gold-arsenopyrite mineralization at Squall Lake was pre- to synmetamorphic in age. The other three deposits have only been described in the context of more regional metallogenic or mapping projects. There have not been any definitive studies regarding the timing of the gold mineralization in these deposits. A general descriptive review of the gold deposits selected for this study is available in Richardson and Ostry (1996).

Preliminary observations on the mineralization at Puffy Lake, Squall Lake and Nokomis Lake

Observations on wasterock and core samples from Puffy Lake, Squall Lake and Nokomis Lake suggest that mineralization and alteration were emplaced early to syn–peak metamorphic conditions. In trenches at Squall Lake, the authors identified some well-lineated arsenopyrite-rich zones in strongly foliated gabbro. A later, randomly distributed generation of arsenopyrite was also recognized. The presence of quartz-diopside veins, originally quartz-carbonate veins, associated with the mineralization further suggests that the gold-arsenopyrite mineralization was emplaced prior to peak metamorphic conditions. Similar observations of strongly lineated arsenopyrite associated with biotite and diopside alterations, in drillcore from the Puffy Lake and Nokomis Lake deposits, support the suggestion of a mineralization event that occurred just prior to or during peak metamorphic conditions. Further petrographic analysis will help establish the exact timing of the mineralization relative to peak metamorphic conditions.

Preliminary results from the North Star gold deposit

Part of the 2005 field season was dedicated to mapping and sampling at the North Star gold deposit. The deposit is located on the eastern margin of a major (kilometres wide), regionally extensive tectonite belt, the West Reed–North Star Shear Zone, which juxtaposes rocks of oceanic affinity (Reed Lake mafic-ultramafic complex) to the west with rocks of arc affinity (Fourmile Island assemblage) to the east (Syme et al., 1995). The deposit is hosted by the volcanic rocks of the Fourmile Island assemblage, which includes at least 5.5 km of subaqueous volcanic rocks dominated by thick mafic flows and synvolcanic dikes. The stratigraphic sequence also includes minor units of felsic-intermediate volcaniclastic rocks (~1500 m). In the vicinity of the deposit, the West Reed–North Star Shear Zone forms a broad zone of steeply west-dipping mafic mylonite and tectonite, protomylonitic basalt and gabbro, and minor felsic phyllonite. The hostrock at North Star consists dominantly of basalt and gabbro, which are typically highly sheared. As is typical with most shear zones, strain is heterogeneously distributed, and less deformed examples of basalt show a variety of primary volcanic textures and structures, including amygdaloidal pillows, massive flows and fragmental horizons. The North Star gold mineralization occurs in sphalerite-chalcopyrite-pyrite-gold–bearing shear-zone–hosted quartz veins, discontinuous lenses or stringers (Richardson and Ostry, 1996). Galena and carbonate are also common in the quartz veins. The dominant alterations found in the wallrock are biotitic alteration and chloritic alteration with minor silicification.

Earlier work by Syme et al. (1995) delineated five generations of structures in the Reed Lake–North Star Lake area. The earlier structures, D_1, mark the main period of activity of the West Reed–North Star Shear Zone, during which ductile deformation dominated. The D_2 deformation led to the formation of regionally north-trending isoclinal folds and is associated with the development of the Morton Lake Fault to the east of the West Reed–North Star Shear Zone. Peak metamorphic conditions, at upper greenschist–lower amphibolite facies, were reached near the end of D_2 deformation. The D_3 event is marked by regional folding, an east-northeast-trending foliation and the development of ductile shear zones. Local anisotropy of the West Reed–North Star Shear Zone favoured its reactivation during D_3. The D_4 event corresponds to the development of a northwest-trending crenulation cleavage, and D_5 was dominated by the development of brittle-ductile shear zones.

Results from fieldwork demonstrate overprinting relationships on surface, indicating that the West Reed–North Star Shear Zone has been overprinted by at least two generations of folds. The first overprinting event produced northeast-trending, moderately northeast-plunging, close to tight F_2 folds. An associated S_2 axial-planar fabric is rarely developed. The youngest deformation consists of northwest-trending F_3 chevron folds and associated differentiated S_3 crenulation cleavage. Shear-sense indicators indicate predominance of dextral movement along the shear zone (Figure GS-2-3), although there are many indications of later sinistral slip. As with the underground mapping, numerous mesoscopic sheath folds were observed. The sheath folds are characterized by steep, generally downdip axes that are subparallel to the stretching lineation developed in the more highly deformed tectonite units within the shear zone.

A preliminary analysis of drillcore samples obtained by Foran Mining Corporation indicates two types of gold mineralization. Type I mineralization is characterized by high gold values in association with high copper and zinc contents (Figure GS-2-4a). The Type I mineralization is commonly observed as disseminated or near-solid sulphide developed on one particular side of the main quartz vein (Figure GS-2-4b). Further work will determine if this characteristic can be used as a structural marker to help document the presence of complex isoclinal folds. Type II mineralization has low base-metal (copper and zinc) content, and is referred to as the 'zebra ore zone' by mine

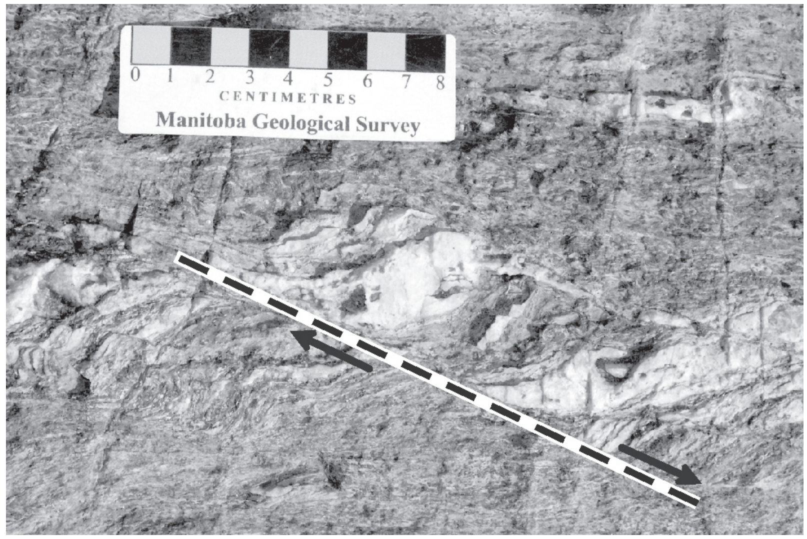
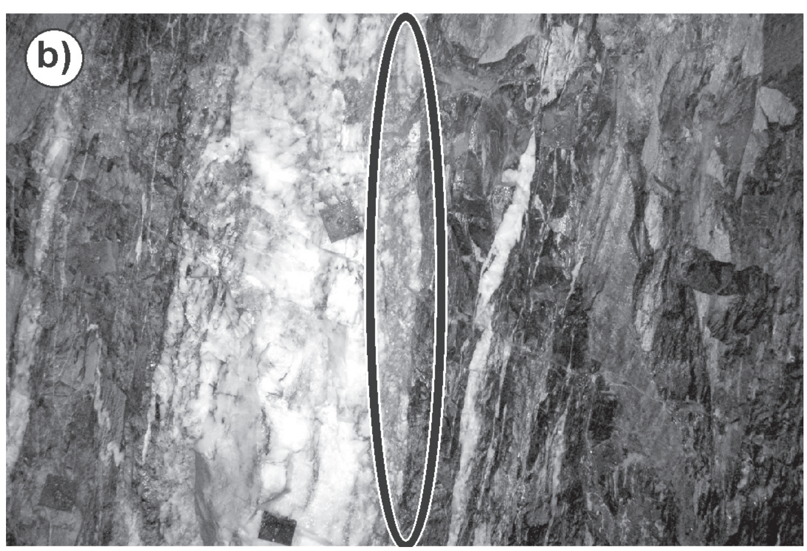


Figure GS-2-3: *Dextral shear band characterizing the West Reed–North Star Shear Zone; white is boudinaged quartz vein and grey matrix is a highly altered mafic rock; arrows indicate the dextral sense of shear.*

Figure GS-2-4: *Base-metal–associated gold mineralization:* ***a)*** *mineralized quartz vein from split drillcore, showing white vein quartz, light grey sulphide (mainly chalcopyrite and sphalerite) and a lens of dark grey, biotite-altered wallrock; sulphides are located along fractures in the quartz vein or along the margins of the vein;* ***b)*** *north end of the North Star drift, looking up at the back, with north toward the top of the picture; white material is quartz vein, which forms the main mineralized quartz vein in the North Star deposit, and dark material is sheared mafic hostrock; ellipse highlights sulphides, which are mainly located on the east side of the vein.*



geologists. It is possible that remobilization of quartz within late axial-planar quartz veins may have promoted development of the second type of mineralization. In this case, the gold values are not associated with high base-metal (copper and zinc) content. In fact, the rock hosting the type II mineralization, a mixture of small quartz veins (1–5 cm) with considerable proportions (40–60%) of altered wallrock lenses, contains little sulphide, with pyrite and pyrrhotite typically dominating the assemblage. An examination of drillcore from the mineralized zone allowed for the recognition of various types of wallrock alteration and two types of quartz vein–hosted gold mineralization. Some sections of drillcore clearly show a brown biotite halo developed along the vein margins, which replaces an early chloritic alteration. Quartz only and quartz-carbonate veins were identified.

Preliminary results from underground work demonstrate the structural complexity of the quartz-vein system. A photomosaic from the back of the underground drift was assembled in order to better describe and characterize the quartz-vein folding. A section of the photo mosaic (Figure GS-2-5) is included in this report. An unmarked copy of

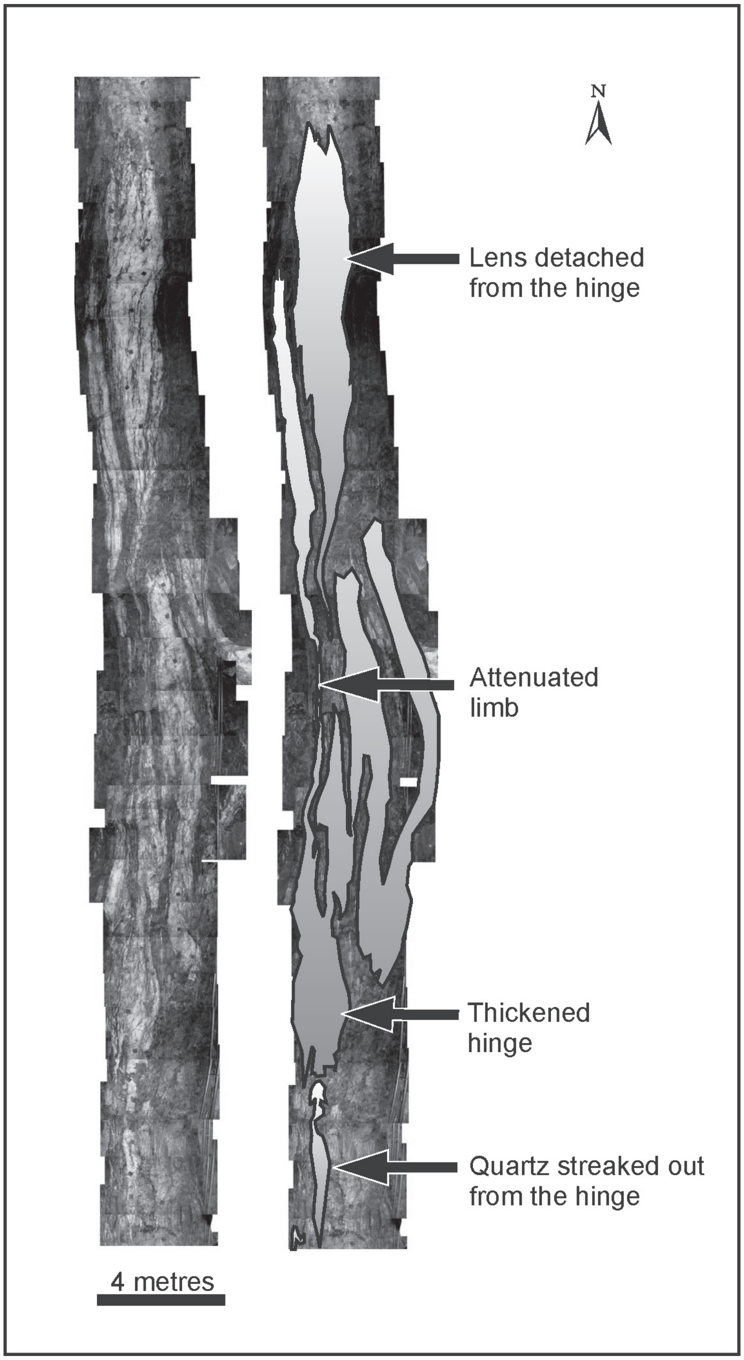


Figure GS-2-5: *Photomosaic of the back of the North Star drift from the north end, with a preliminary structural interpretation on the right.*

the quartz vein segment is presented on the left and the same segment is presented again on the right, overlain by a preliminary structural interpretation.

The photomosaic section (Figure GS-2-5) displays clear evidence for isoclinal folding accompanied by hinge thickening and limb attenuation of the mineralized quartz vein, indicating that it was emplaced relatively early in the history of the shear zone. The hinge of the fold is typically enriched in sulphides (mainly chalcopyrite and sphalerite) and is a good example of the base-metal–rich mineralization, in which high-grade gold mineralization is associated with high copper and zinc contents. The photomosaic also shows a later axial-planar quartz vein that extends out from the hinge and may have formed by remobilization of the main mineralized quartz vein (Figure GS-2-6a). The plunges of fold axes vary throughout the drift and, in the case of the main mineralized quartz vein, are tentatively interpreted to result from sheath folding. At least two clear examples of sheath folds were identified during underground mapping (Figure GS-2-6b). The variation in the plunge of fold axes of other minor quartz veins can also be explained by differences in the initial orientation of the quartz veins that resulted in differences in rotational path.

Economic considerations

New information obtained from the examination of selected gold deposits in the Snow Lake area and along the south flank of the Kisseynew Domain will provide a better understanding of the timing of gold emplacement, as well as the subsequent geological history. This information will, in turn, provide useful guidelines for explorationists to help in the selection of exploration targets.

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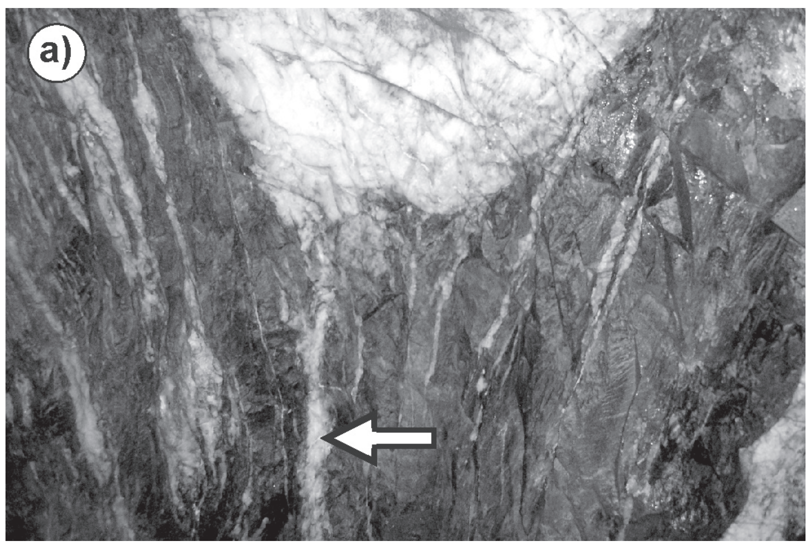
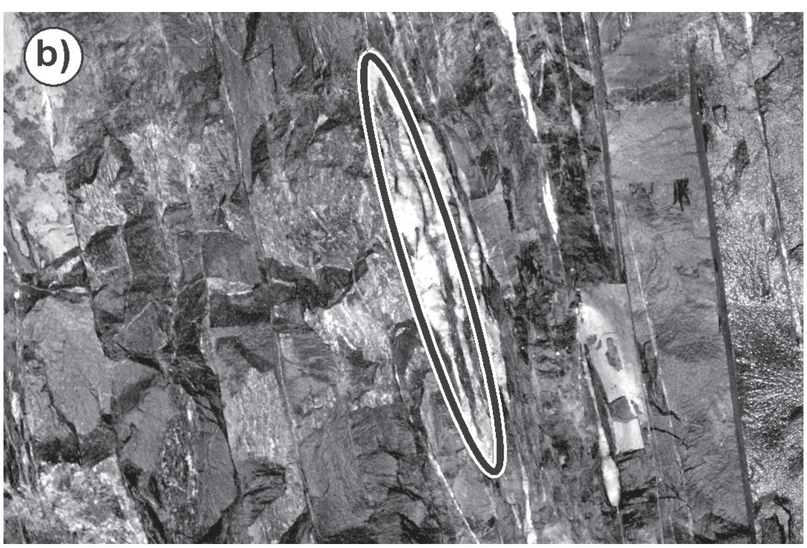


Figure GS-2-6: *Examples of fold development of the North Star vein:* ***a)*** *looking up at the back of the southern portion of the North Star drift, with north toward the top of the photo, illustrating an early quartz-fold hinge with later quartz vein that extends out from the hinge along the axial plane; arrow indicates a late axial-planar quartz vein;* ***b)*** *looking up at the back of the North Star drift, with north at the bottom of the photo, showing a sheath fold in a quartz vein highlighted by a red ellipse; ellipse is ~40 cm long.*



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