Structural controls on gold mineralization, Magino gold mine, Wawa Subprovince, Northern Ontario

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ABSTRACT

The Magino gold mine is located approximately 40km northeast of the town of Wawa, within the Michipicoten greenstone belt of the Archean Wawa subprovince. It is a past-producing underground mine being redeveloped as a large tonnage open pit gold deposit with proven and probable reserves of 2.4 Moz of gold at a grade of 1.15 g/t Au. Gold mineralization at Magino is primarily hosted in the Webb Lake stock, a steeply-dipping ca. 2724 Ma[1] tabular multi-phase tonalitic intrusion. The Magino deposit underwent three episodes of ductile deformation (regional D_2, D_3, and D_4) and two pre- to syn-tectonic auriferous alteration events (Au_1 and Au_2; respectively). N-S-directed shortening during the D_2 event produced a steeply-dipping WSW-ENE striking flattening regional cleavage (S_2) which overprints the deposit. The D_3 event resulted in localized dextral shear zones and reactivation of D_2 fabrics, whereas the D_4 event produced recumbent F_4 folds and associated axial planar, flat-lying crenulation cleavage (S_4). The Au_1 event comprises early intrusion-related, disseminated phengite/muscovite-quartz-pyrite alteration and associated sheeted to stockwork-style, molybdenite-bearing sugary quartz (SQ) veins (pre-regional D_2 event). The intrusion-related SQ veins are cross-cut by inter-mineral quartz-feldspar-phyric (QFP) dikes, which are both transposed and boudinaged along S_2.The Au_2 event comprises N-S-trending orogenic quartz-carbonate-tourmaline (QTC) veins with albite-paragonite-ankerite-pyrite selvages (syn-regional D_2 event). The orogenic QTC veins cross-cut Au_1 veins and the S_2 foliation. QTC veins were emplaced syn- to late-D_2, and are deformed within D_2 high strain zones, D_3 dextral shear zones, and D_4 high strain zones. These structures are overprinted by metamorphic minerals, suggesting that alteration and mineralization formed prior to peak metamorphism. Late, sinistral E-side-up faulting along Matachewan(?) diabase dikes further modify and offset mineralization. Magino is an excellent example of a paragenetically complex Archean intrusion-related system which has been overprinted by multiple stages of deformation and orogenic-style mineralization.

REGIONAL AND DEPOSIT-SCALE GEOLOGY

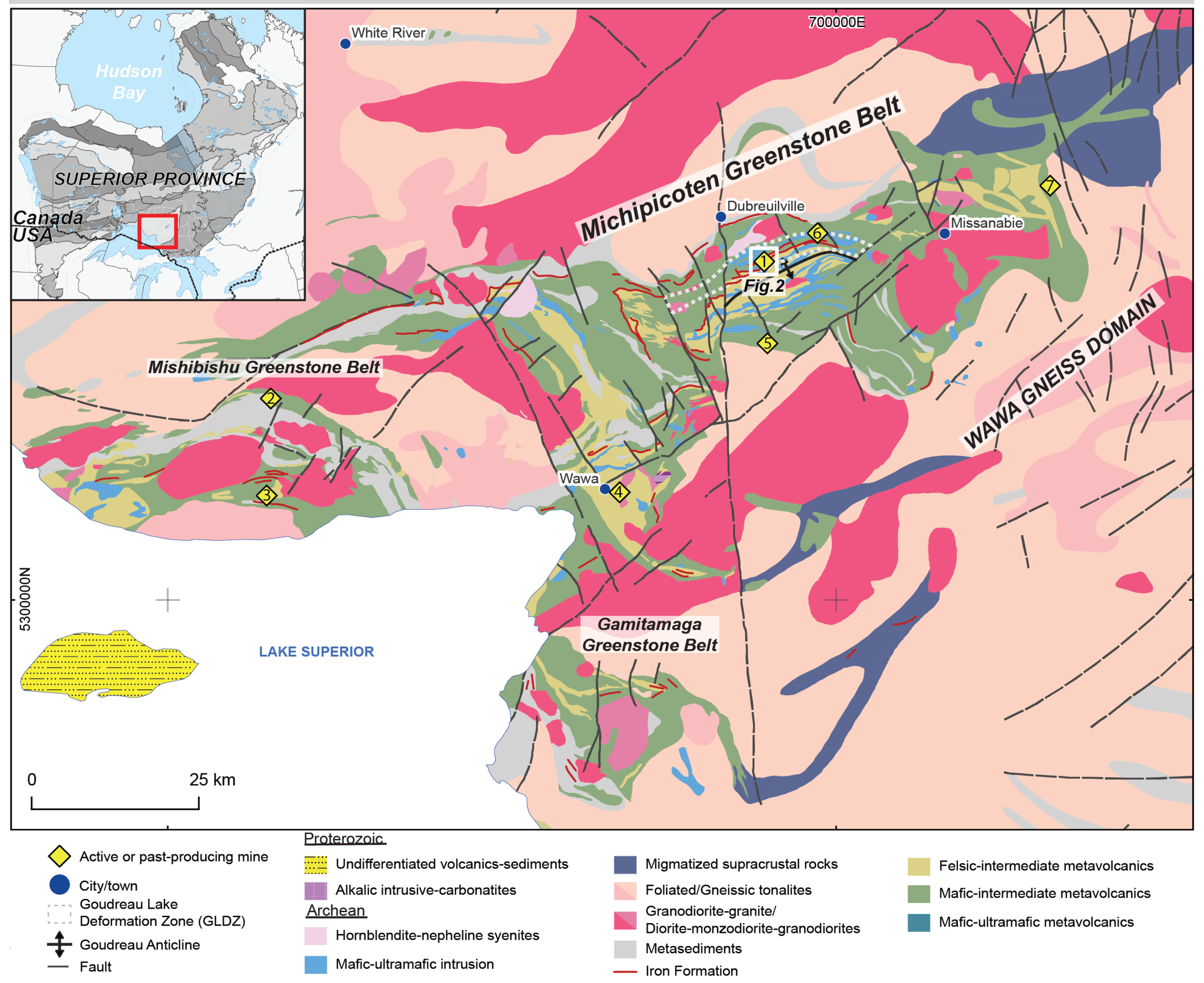

Figure 1. Simplified regional geological map of the Wawa subprovince, compiled after Sage, (1994), Stott et al., (2010), and Ontario Geological Survey, (2011). Inset map shows location within the Superior province, modified after Montsion et al. (2018). Keyed mines: 1) Magino, Island Gold; 2) Mishi, Magnacon; 3) Eagle River; 4) Wawa Gold Corridor; 5) Forge Lake; 6) Cline, Edwards; 7) Renabie.

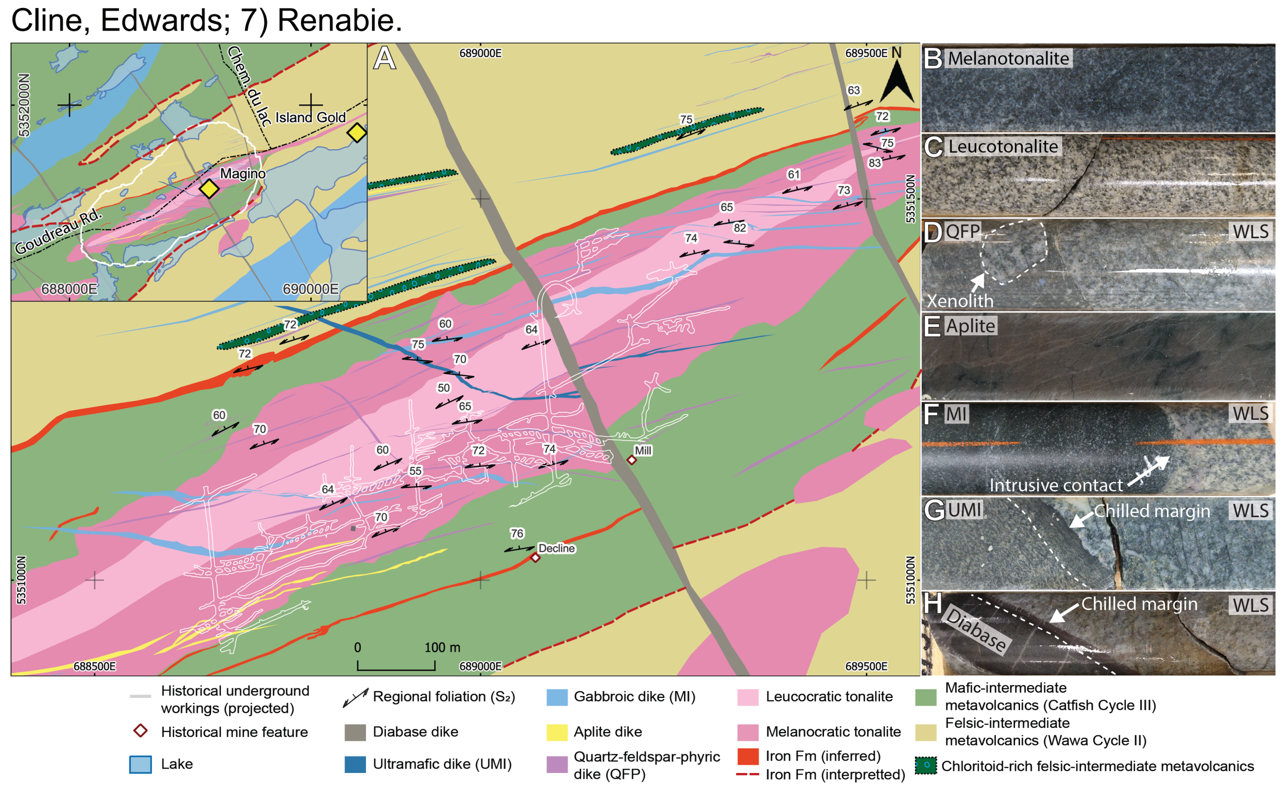

Figure 2. Magino deposit-scale geological map and units. (A) Geological map with historical underground mine features, compiled after Deevy (1993), Ontario Geological Survey (2011), and Argonaut Gold (unpublished). Inset map shows location of the Magino reserve pit outline and the Island Gold mine. (B) Melanotonalite. (C) Leucotonalite. (D) QFP dike. (E) Aplite dike. (F) Gabbroic dike (MI). (G) Ultramafic dike (UMI). (H) Diabase dike.

PRIMARY MINERALIZATION (Au_1)

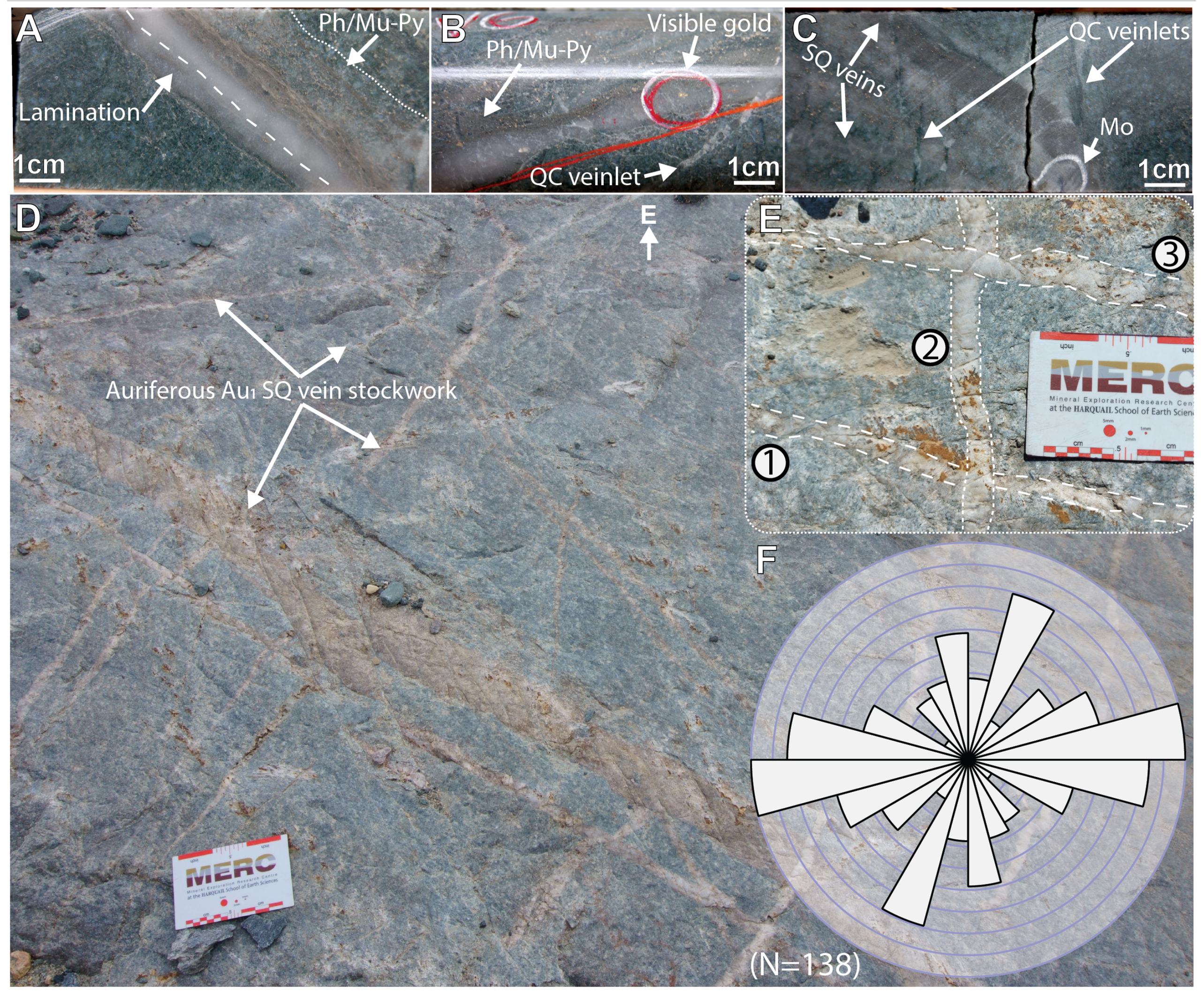

Figure 3. Au_1 sugary quartz (SQ) vein relationships and textures within the WLS. (A) SQ vein with phengite/muscovite-pyrite (Ph/Mu-Py) alteration selvage. (B) Boudinaged SQ vein containing visible gold. Note cross-cutting quartz-carbonate-chlorite (QC) veinlets. (C) Molybdenite (Mo)-bearing SQ veins cross-cut by QC veinlets. (D) SQ vein stock in undeformed tonalite. (E) Mutually-overprinting orthogonal SQ veins. (F) Rose diagram of measured SQ vein surface trends. N = number of measurements. Scale card is 10 cm wide.

D_2 DEFORMATION EVENT & SECONDARY MINERALIZATION (Au_2)

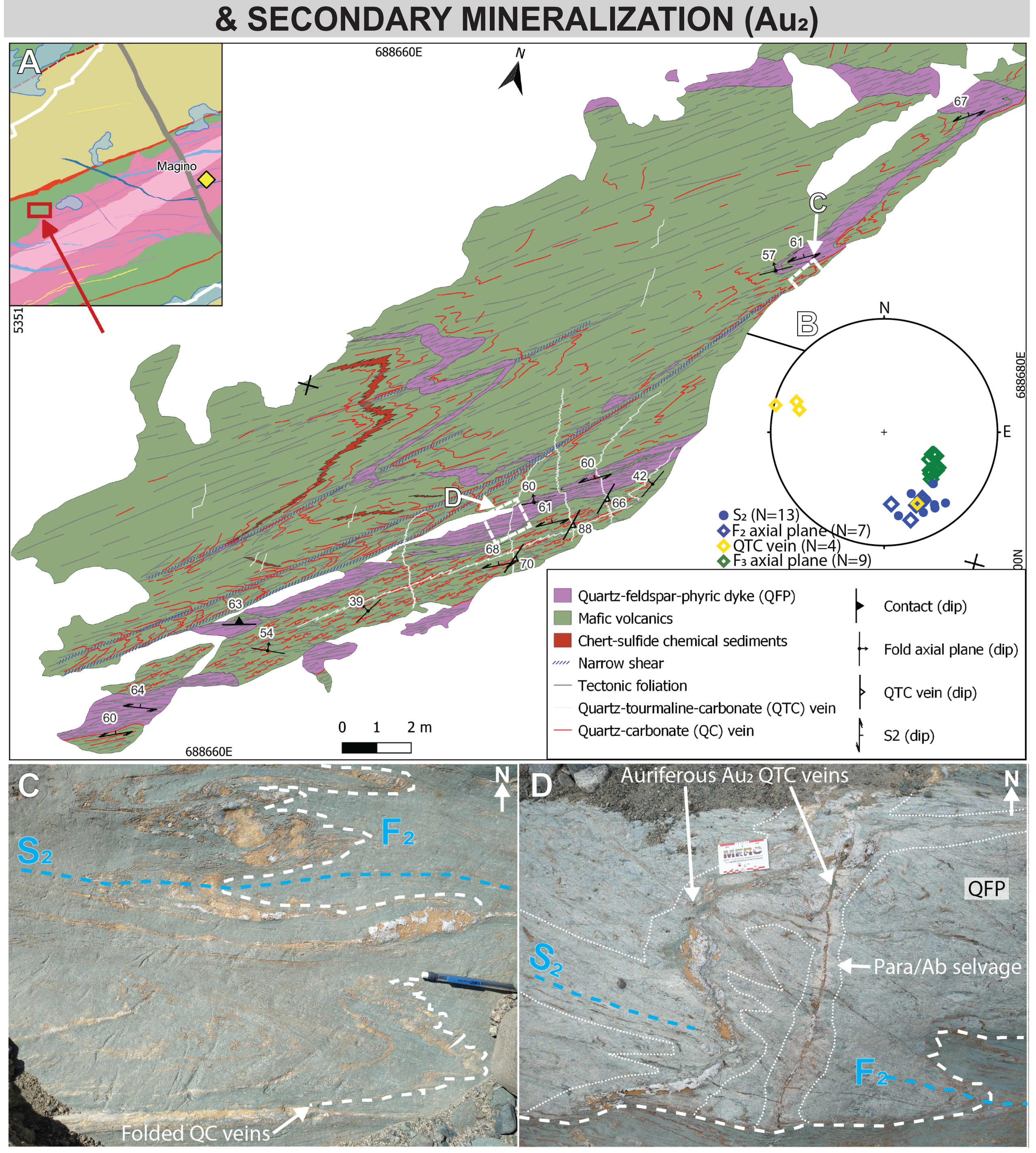

Figure 4. Field relationships of D_2 structures along northern flank of the WLS. (A) Detailed geological map. (B) Lower-hemisphere, equal-area stereographic plot of outcrop structures including, poles to S_2, F_2 axial planes, quartz-tourmaline-carbonate veins (QTC) veins, and F_3 axial planes. N = number of measurements. (C) Strongly folded and transposed quartz-carbonate (QC) veins with axial planar S_2 cleavage. (D) Gently F_2-folded auriferous Au_2 QTC vein with paragonite/albite (Para/Ab) selvages F_2-folded strata.

KEY OVERPRINTING RELATIONSHIPS – FELSIC DIKES, D_2, & D_3 DEFORMATION EVENT

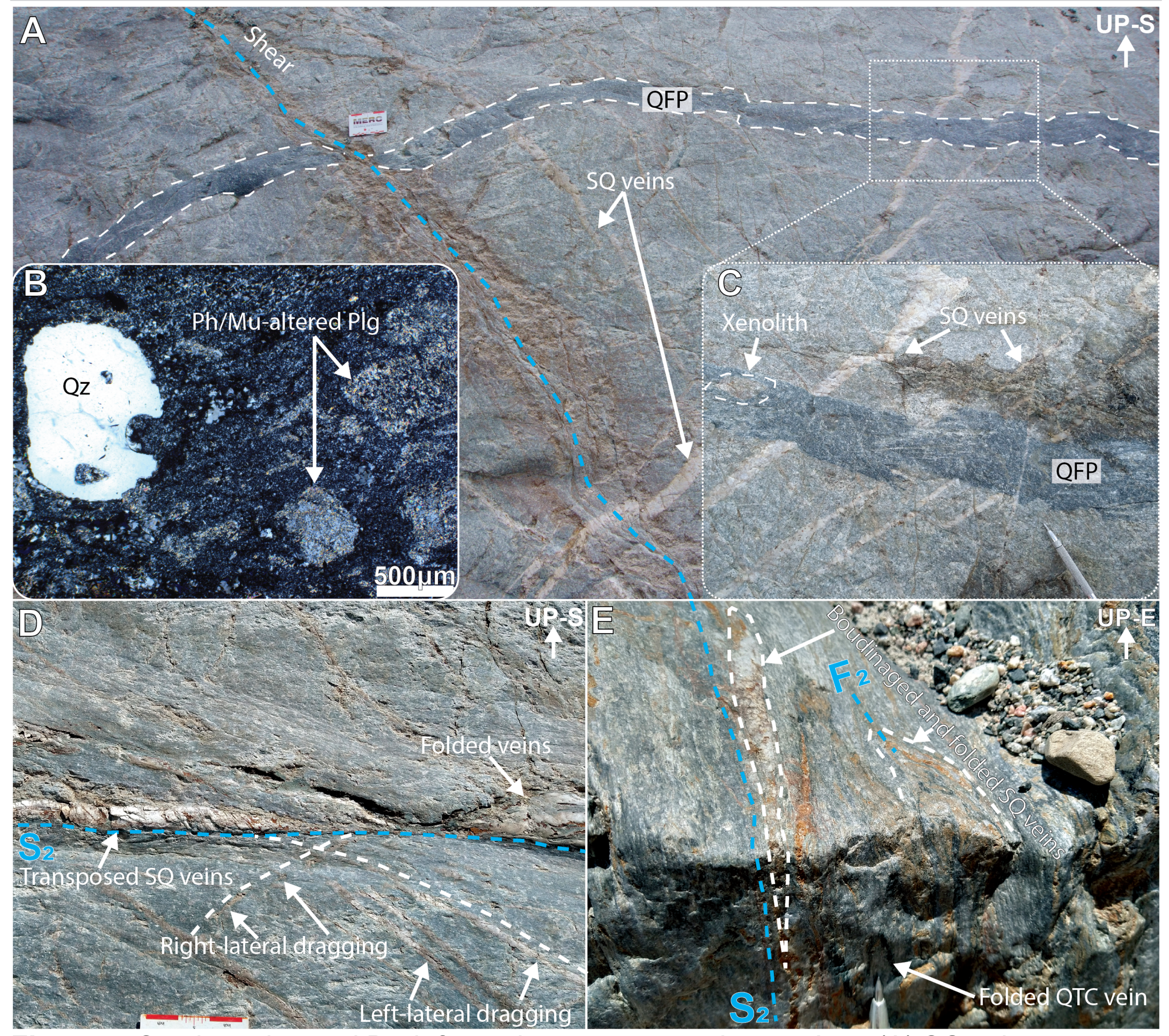

Figure 5. Syn-intrusion and D_2 deformation event contraints on Au_1 . (A) SQ veins cross-cut by a QFP dike, which are both overprinted by a narrow shear. (B) Photomicrograph of QFP shown under cross-polarized light (XPL) showing porphyritic texture, embayed quartz (Qz), and phengite/muscovite(Ph/Mu)-altered plagioclase (Plg). (C) Close view of QFP cross-cutting SQ veins. Note xenolith. (D) Doubly-dragged and transposed SQ veins along S_2 reflecting coaxial deformation. (E) Tightly upright-folded and boudinaged SQ and QTC veins along a D_2 high strain zone defined by the intensification of S_2 within the WLS.

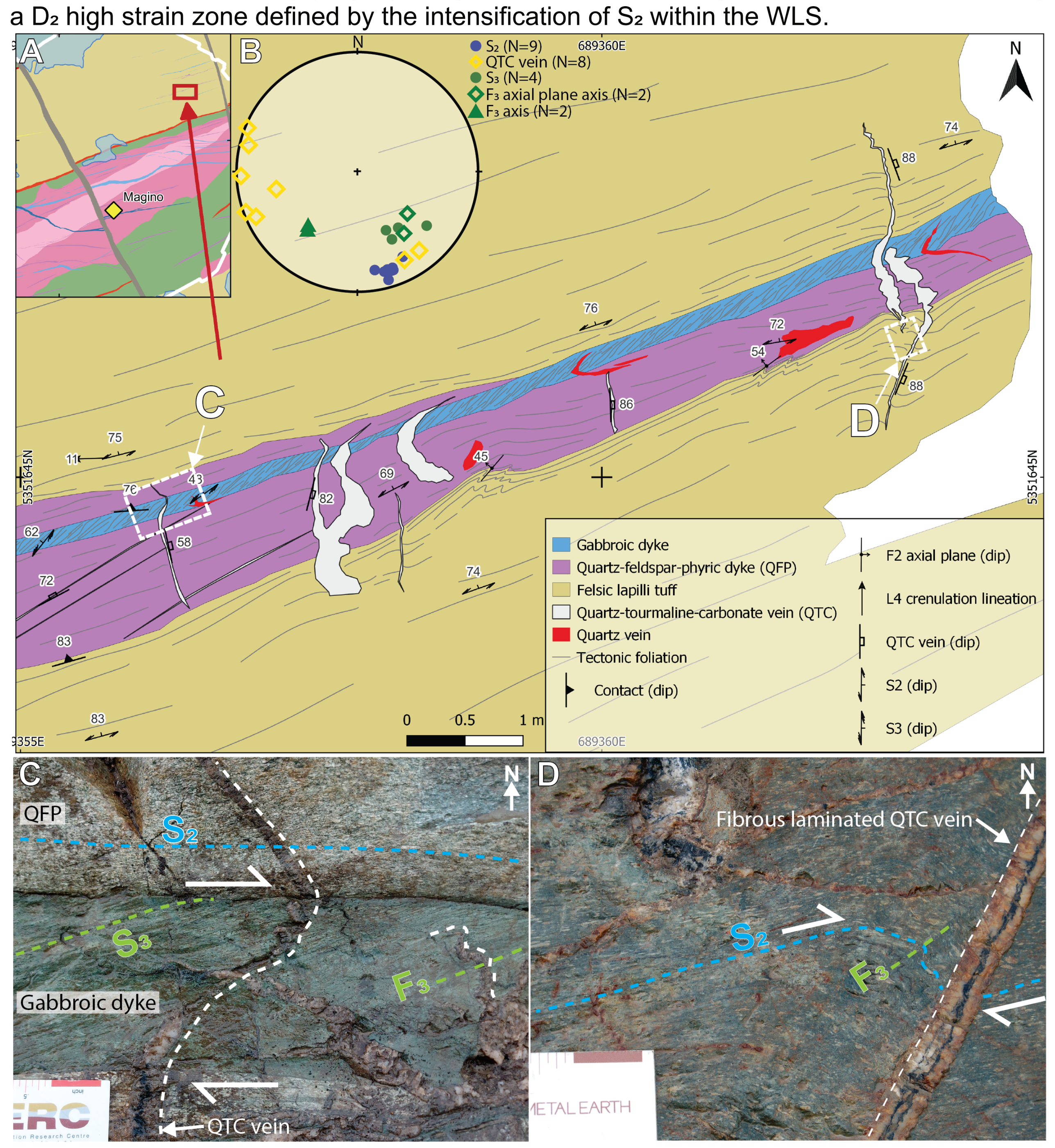

Figure 6. D_3 deformation event constraints on D_2 and Au_2. (A) Detailed geological map. (B) Lower-hemisphere, equal-area stereographic plot of outcrop structures, including poles to auriferous QTC veins, S_2, S_3, and F_3 axial planes. N = number of measurements. (C) F_3 micro-folds and S_3 foliation oriented anticlockwise to S_2 within gabbroic dike. Note apparent right-lateral offset of QTC vein. (D) QTC vein cross-cutting S_2 foliation and overprinted by D_3 flanking structure defined by asymmetric "Z"-shaped F_3 drag folds.

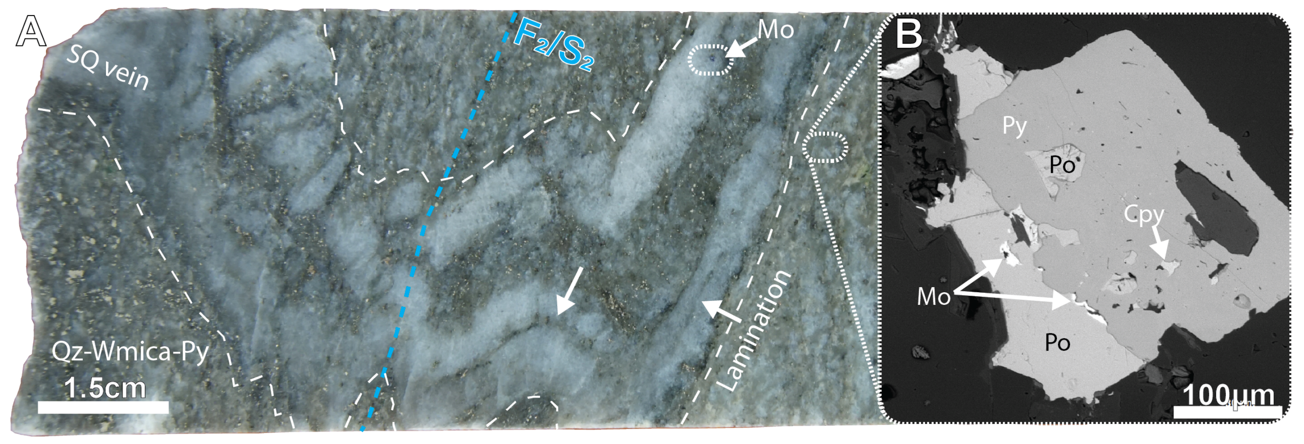

Figure 7. F_2 folding and transposition of SQ veins. (A) Folded laminated Mo-bearing SQ vein in quartz(Qz)-white mica(Wmica)-Py altered D_2 high strain zone. (B) Inset backscattered electron (BSE) photomicrograph showing intergrown disseminated Mo-pyrrhotite(Po)-chalcopyrite(Cpy)-Py.

D_4 DEFORMATION EVENT & METAMORPHISM

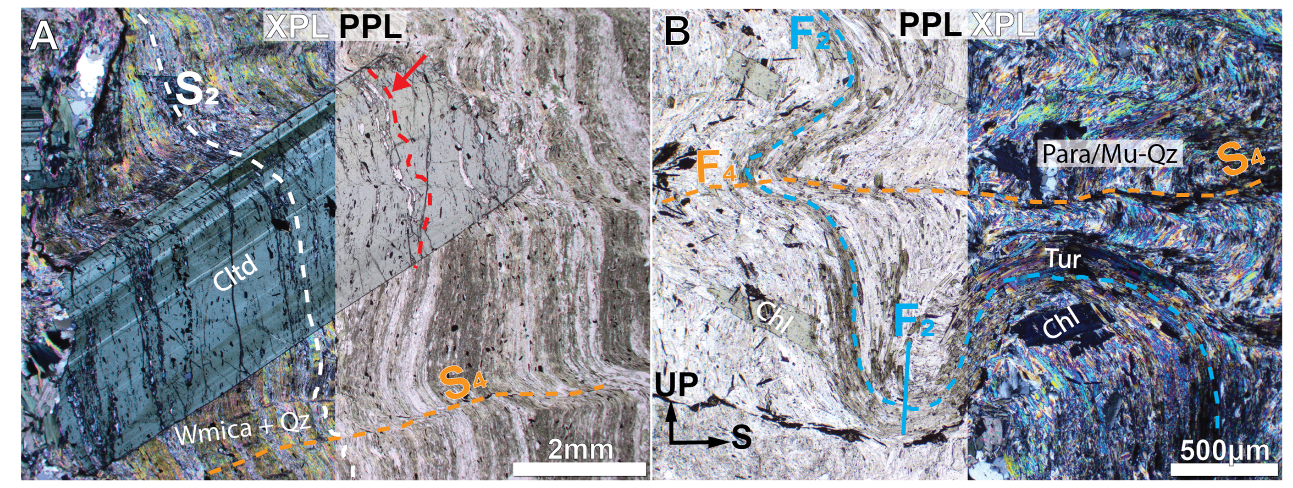

Figure 8. Metamorphic constraints on alteration and deformation. (A) Photomicrograph under cross-polarized light (XPL) and plane-polarized light (PPL) showing chloritoid (Cltd) porphyroblasts overgrowing F_4-crenulated S_2 foliation in white mica-quartz (Wmica-Qz) schist. (B) Photomicrograph under XPL and PPL showing F_2 folds defined by tourmaline (Tur; blue dashed line) refolded by F_4 folds axial planar to S_4 in paragonite/muscovite(Para/Mu)-Qz-Py schist. Note chlorite (Chl) porphyroblasts overgrowing F_4-folded S_2.

CONCLUSION

Using detailed structural mapping, field relationships, and relative timing criteria, we conclude that:

1) Primary gold mineralization (Au_1) at Magino is associated with disseminated syn-intrusion hydrothermal alteration and the emplacement of sheeted to stockwork sugary quartz (SQ) veins, which significantly pre-date the regional D_2 event constrained at ca. < 2680 Ma[2].

2) Secondary gold mineralization (Au_2) is associated with extensional quartz-carbonate-tourmaline (QTC) veins. These veins cross-cut both Au_1 veins and the S_2 foliation, and were emplaced syn- to late- D_2 parallel to the inferred D_2 N-S bulk shortening direction.

3) Later, D_3 dextral N-side-down shearing, D_4 recumbent folding, and late sinistral E-side-up faulting along diabase dikes modify earlier structures and mineralization.

4) Upper greenschist to amphibolite metamorphic minerals overgrow D_4 fabrics, which suggests that hydrothermal alteration at Magino occurred prior to peak metamorphism, contrary to late metamorphic devolatilization models.

Magino best represents an early intrusion-related gold system which was superimposed by deformation and a subordinate orogenic-style mineralization event to produce a complex overprinted ore deposit.

These findings have important implications for understanding the formation of polyphase ore deposits commonly found in ancient prospective metamorphic terranes by providing observational criteria which can be used to dicriminate between Archean intrusion-related and orogenic gold deposits.

Acknowledgements & References

Acknowledgments

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