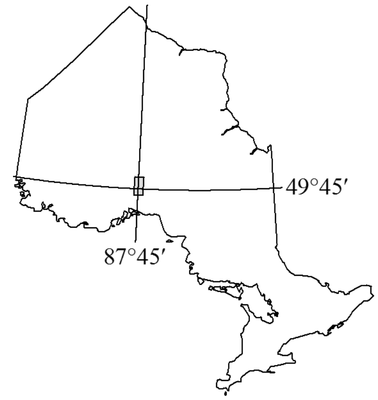
32. Preliminary Results from the Assessment of the Structural Evolution of the Southern Geraldton–Onaman Transect



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INTRODUCTION

The Geraldton–Onaman transect in the Archean Superior craton is one of 11 transects across the Abitibi and Wabigoon subprovinces undertaken as part of the Metal Earth program of the Mineral Exploration Research Centre at Laurentian University, Sudbury. The approximately 105 km long Geraldton–Onaman transect starts in the Onaman–Tashota greenstone belt (OTGB) of the granite-greenstone eastern Wabigoon Subprovince, crosses the Beardmore–Geraldton belt (BGB) along the southern margin of the subprovince, and ends in the metasedimentary Quetico Subprovince (Figure 32.1). The Geraldton–Onaman area hosts several mineral occurrences, but has an overall lower metal endowment than the Abitibi greenstone belt. The results of the geological mapping will be combined with seismic, magnetotelluric and gravity surveys to interpret the geology of the transect and compare it to that of other transects in the metal-endowed Abitibi greenstone belt. This report focusses on the structural evolution of the southern segments of the transect.

REGIONAL SETTING

The Wabigoon Subprovince was historically divided into eastern, central and western segments based purely on geographical location (Blackburn et al. 1991), but more recent studies suggest that 4 terranes can be defined, based on their neodymium model ages and hafnium–oxygen isotopic characteristics. This has implications for the crustal evolution and recycling (Tomlinson et al. 2004; Bjorkman 2017). The Winnipeg River terrane, which extends into the eastern part of the Wabigoon Subprovince, is intruded by predominantly Neoarchean granitoids, which formed by reworking and partial melting of the subprovince's Paleoarchean crust (*circa* 3400 Ma: Tomlinson et al. 2004). Similarly, the predominantly juvenile Marmion terrane (*circa* 3000 Ma) may extend into the eastern Wabigoon Subprovince, where it may have been reworked, partially melted and intruded by the Onaman pluton and other plutons of the Elmhirst–Rickaby assemblage (Tomlinson et al. 2004). The boundaries of the Winnipeg River and Marmion terranes are proposed to extend into the eastern Wabigoon Subprovince (Tomlinson et al. 2004; Stott et al. 2010; Lu et al. 2013; Bjorkman 2017), but their exact location needs to be defined.

The Onaman–Tashota greenstone belt comprises several Mesoarchean to Neoarchean supracrustal assemblages dominated by mafic to felsic metavolcanic rocks with tholeiitic and calc-alkalic geochemical affinity. The northern segment of the Geraldton–Onaman transect crosses the boundary between Mesoarchean intermediate to felsic volcanic rocks of the Tashota assemblage (*circa* 2960 Ma) and Neoarchean massive and pillowed mafic tholeiitic volcanic rocks of the Willett assemblage (*circa* 2740 Ma: Stott et al. 2002).

Summary of Field Work and Other Activities, 2018,
Ontario Geological Survey, Open File Report 6350, p.32-1 to 32-8.

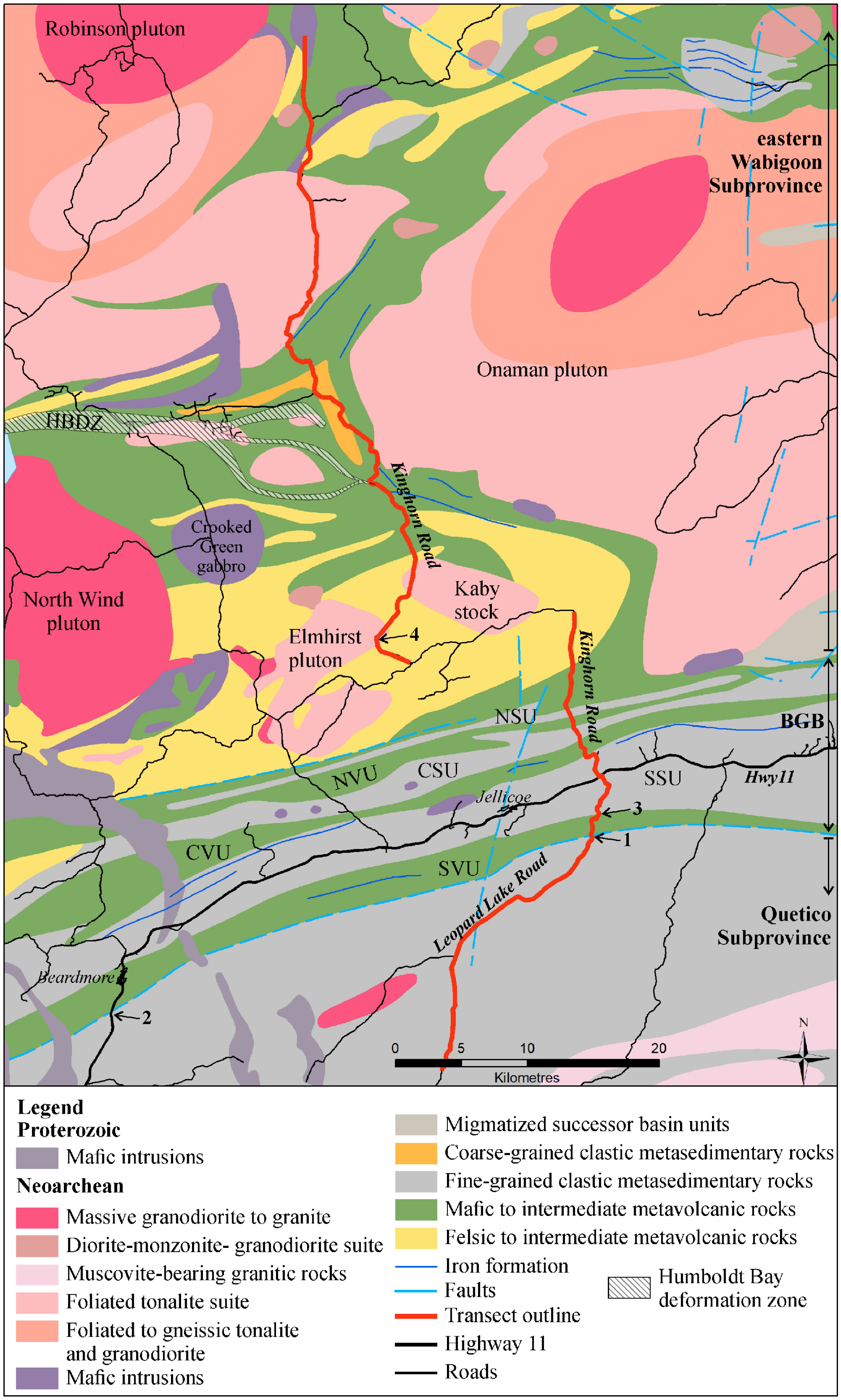

Figure 32.1. Geological map of the Geraldton–Onaman transect (*modified after* Ontario Geological Survey 2011). Abbreviations: BGB: Beardmore–Geraldton belt; HBDZ: Humboldt Bay deformation zone; NSU: northern sedimentary unit; CSU: central sedimentary unit; SSU: southern sedimentary unit; NVU: northern volcanic unit; CVU: central volcanic unit; SVU: southern volcanic unit.

The latter dominates in the northern OTGB and has geochemical affinities characteristic of a back-arc basin environment or a mixed oceanic floor–primitive island arc environment (Stott et al. 2002). The southern part of the OTGB is composed of calc-alkalic mafic to felsic igneous rocks of the Elmhirst–Rickaby assemblage (2735–2740 Ma). The latter was emplaced in a continental margin–arc environment and is in fault contact with the Beardmore–Geraldton belt to the south (Stott et al. 2002). The Beardmore–Geraldton belt is a greenstone belt that marks the transition between the dominantly igneous eastern Wabigoon Subprovince and the dominantly metasedimentary Quetico Subprovince. It consists of interleaved metavolcanic panels similar to the Onaman–Tashota greenstone belt, and metasedimentary rock panels similar to the metasedimentary Quetico Subprovince (Devaney and Williams 1989). It is bounded to the north by the Paint Lake deformation zone and to the south by the Bankfield–Tombill deformation zone. Both deformation zones are high-strain corridors several hundred metres wide, which were initiated as thrusts during D_1 accretion and were reactivated during D_2 sinistral and D_3 dextral transpression (Lafrance, DeWolfe and Stott 2004; Tóth 2018). Both deformation zones host significant gold mineralization (e.g., Hardrock and Brookbank deposits; Tóth 2018). To the south of the BGB, turbiditic sandstones of the Quetico Subprovince were deposited together with the metasedimentary panels of the BGB as a southward-prograding accretionary wedge above the metavolcanic substrate preserved in the volcanic panels of the BGB (Devaney and Williams 1989; Percival and Williams 1989; Tomlinson et al. 1996).

MAPPING IN THE QUETICO SUBPROVINCE

Mapping across the Quetico Subprovince was conducted to 1) identify possible stratigraphic marker units, 2) define how metamorphic grade varies along the transect, and 3) compare generations of structures in the Quetico Subprovince with similar structures in the BGB.

A traverse approximately 25 km long was completed through the Quetico Subprovince metasedimentary rocks along Leopard Lake Road south of Trans-Canada Highway 11. The rocks consist of finely laminated to thickly bedded, monotonous and massive, interlayered sandstones and siltstones, comprising southwest- to west-southwest–striking, alternating mafic- and felsic-rich layers varying in thickness from a few millimetres to several decametres. The mafic beds have biotite-chlorite compositions to the north, near the boundary between the Quetico Subprovince and the Beardmore–Geraldton belt, and amphibole–stilpnomelane compositions to the south. They typically dip moderately to steeply to the north-northwest, but become subvertical next to the greenstone belt–subprovince boundary. Small load structures, only a few centimetres in size, indicate that soft-sediment deformation occurred during or soon after deposition of the interlayered sandstones and siltstones (Photo 32.1A). A weak to strong, continuous foliation, striking parallel or slightly clockwise to bedding, is defined by mafic minerals (biotite – chlorite ± amphibole) and multi-grain aggregates. The foliation is likely axial planar to regional-scale folds defined by reversals in stratigraphic facing. The beds are folded by late, outcrop-scale, asymmetric Z-shaped folds with a southwest-striking axial plane (Photo 32.1B).

THE BOUNDARY BETWEEN THE QUETICO SUBPROVINCE AND THE BEARDMORE–GERALDTON BELT

The boundary between the Quetico Subprovince and the Beardmore–Geraldton belt ("Quetico–BGB boundary") is a major structural and lithological feature. Structures, alteration assemblages and rock units were mapped on both sides of the boundary to determine its stratigraphic and structural significance. These results will be compared to the well-endowed Larder–Cadillac deformation zone in the Abitibi greenstone belt, which occupies a similar position between a major metasedimentary subprovince to the south (Pontiac) and the Abitibi greenstone belt to the north.

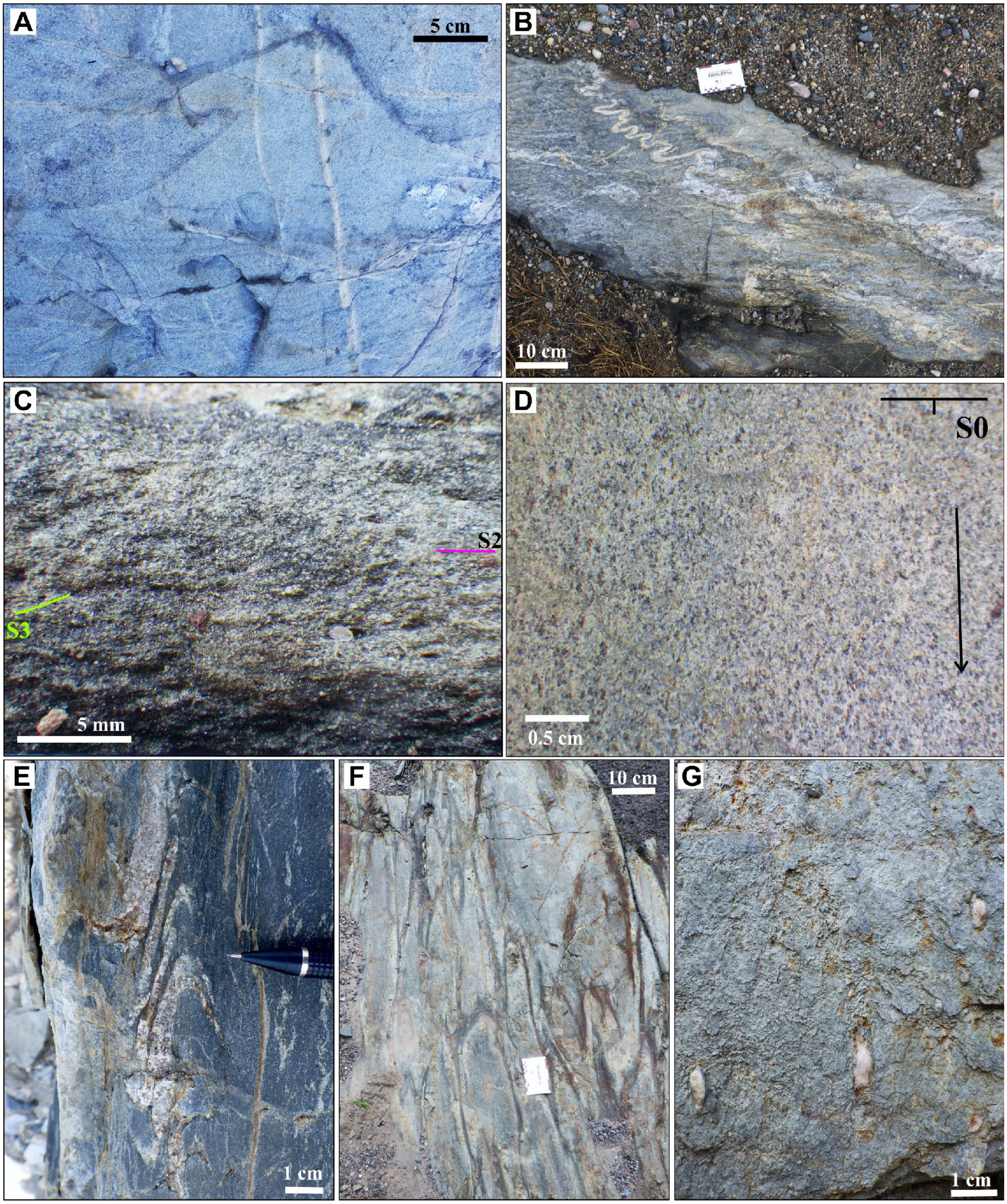

Photo 32.1. A to E: Field photographs from the Quetico Subprovince. **A**) Load structures indicating soft-sediment deformation in sandstone. **B**) Z-folded sandstone and siltstone. **C**) East-striking chloritic S_2 cleavage (purple line) overprinted by northeast-trending chloritic S_3 foliation (green line). **D**) Steeply plunging lineation along bed surface at the Quetico Subprovince–Beardmore–Geraldton belt boundary. **E**) Sigmoidal tension gashes in metasandstone. **F and G:** Field photographs from the southern volcanic unit. **F**) Flattened pillows near the subprovince boundary. **G**) Steeply plunging stretching lineation defined by elongated amygdules in mafic pillowed flow.

Along Leopard Lake Road (*see* Figure 32.1, location 1), the subprovince boundary is located within approximately 100 m of the southernmost exposure of dark green chlorite- and biotite-rich massive mafic volcanic rocks of the Beardmore–Geraldton belt. A spaced (2–3 mm spacing) chloritic foliation (S_2, *after* Lafrance, DeWolfe and Stott 2004) strikes easterly, dips steeply to the south (Photo 32.1C), and contains a shallowly east-plunging mineral lineation. This foliation is overgrown by biotite porphyroblasts. A spaced to continuous (~1 mm) chloritic cleavage (S_3, *after* Lafrance, DeWolfe and Stott 2004) is oriented approximately 15 to 20° anticlockwise to S_2 cleavage (*see* Photo 32.1C). The first outcrop of turbiditic sandstone of the Quetico Subprovince consists of east-northeast–striking, south-dipping and south-younging subvertical beds. An east-northeast–striking, steeply south-dipping continuous cleavage is oriented a few degrees clockwise to bedding (S_0). A second, weak cleavage is oriented approximately 10° anticlockwise to S_0.

Along Highway 11 south of Beardmore (*see* Figure 32.1, location 2), the Quetico Subprovince consists of southwest- to west-striking, subvertical, turbiditic sandstones and siltstones. Normal grading indicates younging to the north over a distance of at least 1 km south of the subprovince boundary. A weak to strong, continuous, chloritic S_2 foliation is oriented either parallel or up to 15° clockwise to bedding, which contains a weak, steeply northwest- to north-plunging chlorite mineral lineation (Photo 32.1D). Another weak to moderately intense, continuous, chloritic cleavage strikes southwest anticlockwise to bedding. Quartz-iron carbonate veins cut the S_2 cleavage in an anticlockwise manner and are overprinted by S-shaped folds. Their south-southwest strike and folding suggest that they were likely emplaced as tension gashes during sinistral shearing (Photo 32.1E). Iron-carbonate alteration is pervasive next to the subprovince boundary, but decreases in intensity southward. To the north of the subprovince boundary, pillowed and massive mafic flows of the southern volcanic unit are flattened and attenuated parallel to the S_2 cleavage (Photo 32.1F). The latter strikes southwest and dips steeply to the north. A steeply northwest-plunging lineation is defined by elongate amygdules and chlorite aggregates (Photo 32.1G). A second chloritic cleavage is oriented approximately 10 to 30° anticlockwise to S_2 cleavage, and is present only in higher strain zones within the mafic flows. The mafic flows are weakly iron-carbonate altered and silicified adjacent to the subprovince boundary.

THE SOUTHERN VOLCANIC UNIT–SOUTHERN SEDIMENTARY UNIT BOUNDARY OUTCROP

The contact between the southern volcanic and southern sedimentary units of the BGB is exposed in an aggregate pit along Leopard Lake Road (*see* Figure 32.1, location 3), where massive mafic metavolcanic rocks of the southern volcanic unit are in sheared and folded contact with oxide-facies banded iron formation of the southern sedimentary unit. The mafic volcanic rocks consist of chlorite and feldspar ± amphibole. The banded iron formation comprises interlayered magnetite-rich and cherty laminae and beds varying in thickness from a few millimetres to 5 cm. The contact is parallel to a penetrative, continuous, chloritic, west-southwest–striking S_2 cleavage, which is axial planar to an open, east-plunging, S-shaped F_2 fold (Photo 32.2A). Banded iron formation laminae are transposed parallel to S_2 foliation and are folded by open, steeply east-plunging Z-shaped F_3 folds with amplitudes of several centimetres. The folds have an axial planar S_3 cleavage oriented approximately 10° anticlockwise to S_2 foliation (Photo 32.2B). Adjacent to the contact, the F_3 folds are very tight, and their fold hinge is overprinted by another cleavage (S_3') oriented approximately 10° anticlockwise to S_3 cleavage (Photo 32.2C). A steeply east-plunging chloritic mineral lineation lies along the S_2 cleavage and is parallel to F_3 fold axes.

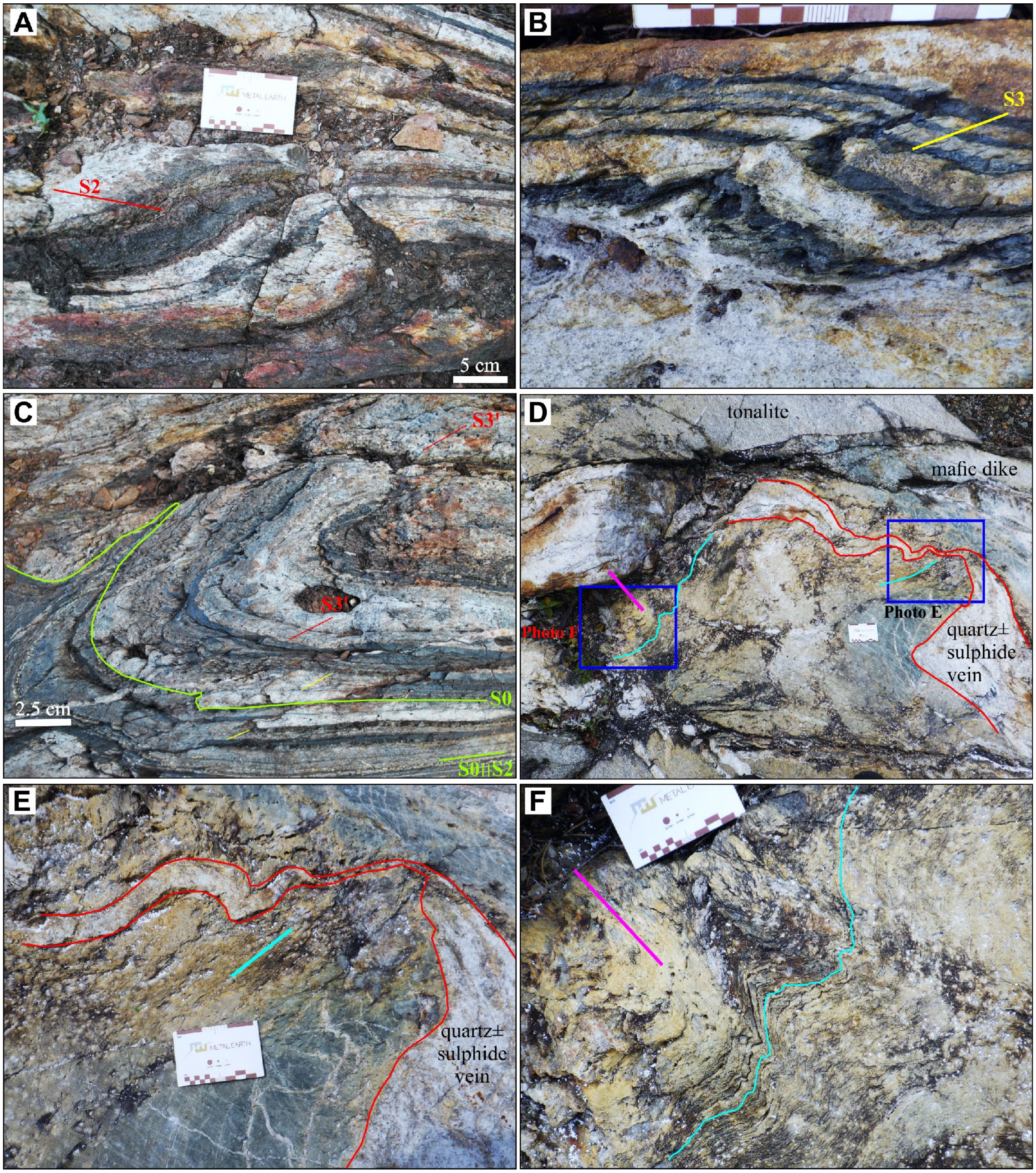

Photo 32.2. A to C: Field photographs from the banded iron formation outcrop along the boundary between the southern volcanic unit and the southern sedimentary unit. **A**) Banded iron formation folded by S-shaped F_2 fold with strong axial planar S_2 cleavage (orange-red line). **B**) Z-shaped F_3 fold with strong axial planar cleavage (S_3: yellow line). **C**) S_3' foliation (red lines) overprinting tight Z-shaped F_3 fold. **D to F:** Field photographs from the Golden Mile East extension outcrop. **D**) A foliation (blue lines) is axial planar to Z-folded quartz-chlorite-sulphide vein (outlined by orange-red lines). This first foliation is folded by S-shaped secondary folds with strong axial planar cleavage (purple line). **E**) Close-up of Z-folded quartz-sulphide vein (outlined by orange-red lines) with axial planar cleavage (blue line). **F**) Close-up of S-folded cleavage and axial planar foliation (purple).

THE GOLDEN MILE EAST EXTENSION

The Golden Mile East extension is a mechanically stripped outcrop (*see* Figure 32.1, location 4) within the Elmhirst pluton that provides an excellent opportunity to better understand the deformation history of the southern Onaman–Tashota greenstone belt. The outcrop consists of tonalite intruded by several chlorite-rich mafic dikes. Both lithologies are cut by multiple generations of quartz ± chlorite ± sulphide veins, striking northwest, north-northwest and northeast. A strong, spaced (2–6 mm spacing) foliation is defined by chlorite, sericite, and by trains of epidote (Photos 32.2D and 32.2E), and is axial planar to steeply southeast-plunging asymmetrical Z-shaped folds overprinting northeast-striking quartz veins. This foliation strikes east and dips subvertically to the south in the northwestern part of the outcrop, but strikes west-southwest and dips steeply to the north in the southern part of the outcrop, suggesting that it underwent anticlockwise rotation during a later deformation event. The foliation is folded by an open, steeply south-southwest–plunging, S-shaped asymmetrical secondary fold that has a strong, spaced (1–2 mm), southwest-striking cleavage defined by sericite-chlorite-iron carbonate (Photos 32.2D and 32.2F).

FUTURE WORK

The 2019 field season along the Geraldton–Onaman transect will focus on refining the stratigraphic and structural framework of the central and northern Onaman–Tashota greenstone belt. The remaining research objectives include a) the characterization of the contact between the Onaman assemblage (2775 Ma) and Elmhirst–Rickaby assemblage (2730–2740 Ma); b) review of the tectonic evolution of the Humboldt Bay deformation zone (*see* Figure 32.1, HBDZ); and c) description of the contact relationship between the Tashota assemblage (*circa* 2960 Ma) and the Willett assemblage (*circa* 2740 Ma).

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REFERENCES

Bjorkman, K.E. 2017. 4D Crust–mantle evolution of the western Superior Craton: Implications for Archaean granite–greenstone petrogenesis and geodynamics; unpublished PhD thesis, The University of Western Australia, Perth, Australia, 317p. doi:10.4225/23/5a39c88a2f559.

Blackburn, C.E., Johns, G.W., Ayer, J. and Davis, D.W. 1991. Wabigoon Subprovince; *in* Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 1, p.303-381.

Devaney, J.R. and Williams, H.R. 1989. Evolution of an Archean subprovince boundary: A sedimentological and structural study of part of the Wabigoon–Quetico boundary in northern Ontario; Canadian Journal of Earth Sciences, v.26, p.1013-1026.

Lafrance, B., DeWolfe, J.C. and Stott, G.M. 2004. A structural reappraisal of the Beardmore–Geraldton belt at the southern boundary of the Wabigoon Subprovince, Ontario, and implications for gold mineralization; Canadian Journal of Earth Sciences, v.41, p.217-235. https://doi.org/10.1139/E03-090.

Lu, Y., McCuaig, T.C., Hollings, P., Ketchum, K., Kerrich, R., Smyk, M., Cliff, J. and Bagas, L. 2013. Zircon multi-isotopic mapping in Wabigoon Subprovince, western Superior Craton: Implications for lithospheric architecture and controls on orogenic gold mineral systems; extended abstract *in* Society for Geology Applied to Ore Deposits (SGA), 12th Biennial Meeting, August 12–15, 2013, Uppsala, Sweden, Proceedings, v.3, p.7-11.

Ontario Geological Survey 2011. 1:250 000 Scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release–Data 126 – Revision 1.

Percival, J.A. and Williams, H.R. 1989. Late Archean Quetico accretionary complex, Superior Province, Canada; Geology, v.17, p.23-25.

Stott, G.M., Corkery, M.T., Percival, J.A., Simard, M. and Goutier, J. 2010. A revised terrane subdivision of the Superior Province; *in* Summary of Field Work and Other Activities, 2010, Ontario Geological Survey, Open File Report 6260, p.20-1 to 20-10.

Stott, G.M., Davis, D.W., Parker, J.R., Straub, K.J. and Tomlinson, K.Y. 2002. Geology and tectonostratigraphic assemblages, eastern Wabigoon Subprovince, Ontario; Ontario Geological Survey, Preliminary Map P.3449 (also Geological Survey of Canada, Open File 4285), scale 1:250 000.

Tomlinson, K.Y., Hall, R.P., Hughes, D.J. and Thurston, P.C. 1996. Geochemistry and assemblage accretion of metavolcanic rocks in the Beardmore–Geraldton greenstone belt, Superior Province; Canadian Journal of Earth Sciences, v.33, p.1520-1533.

Tomlinson, K.Y., Stott, G.M., Percival, J.A. and Stone, D. 2004. Basement terrane correlations and crustal recycling in the western Superior Province: Nd isotopic character of granitoid and felsic volcanic rocks in the Wabigoon subprovince, northern Ontario, Canada; Precambrian Research, v.132, p.245-274.

Tóth, Z. 2018. The geology of the Beardmore–Geraldton belt, Ontario, Canada: Geochronology, tectonic evolution and gold mineralization; unpublished PhD thesis, Laurentian University, Sudbury, Ontario, 300p.

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