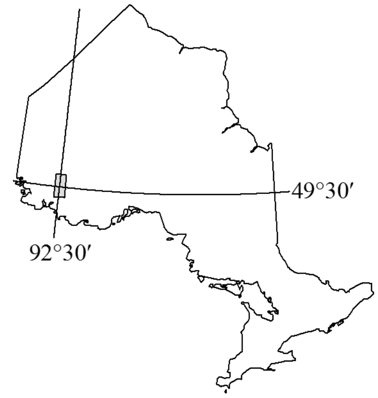
36. Preliminary Structural and Stratigraphic Investigations Along the Metal Earth Dryden–Stormy Lake Transect



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INTRODUCTION

Archean greenstone belts in the Superior Province are variably endowed with base and precious metal resources despite similarities in rock types, ages and tectonic settings. For example, both the Abitibi and western Wabigoon subprovinces formed during a similar time frame in the Neoarchean (~2750–2700 Ma) and comprise mainly juvenile mafic volcanic successions that were emplaced in a subaqueous environment. However, whereas the Abitibi Subprovince contains numerous base and precious metal deposits (e.g., >150 million ounces of gold), the western Wabigoon Subprovince contains only a few deposits (e.g., <10 million ounces of gold). Identifying the factors contributing to variable metal endowment in greenstone belts represents one of the primary goals of the Metal Earth Research Program, which is funded by the Canada First Research Excellence Fund that is being led by Laurentian University. This report summarizes preliminary field observations in the western Wabigoon Subprovince that coincide with geophysical surveys (seismic and magnetotellurics; Figure 36.1). This work will be used to constrain potential factors that contributed to the lesser base and precious metal endowment of the western Wabigoon Subprovince relative to other greenstone belts of the Superior Province. Ultimately, this work will be used to resynthesize the geodynamic evolution of and metallogenesis in the western Wabigoon Subprovince in order to compare to better mineralized belts of the Superior Province.

REGIONAL SETTING

The western Wabigoon Subprovince comprises mafic volcanic successions (2750–2715 Ma), Porcupine-like turbiditic rocks (~2715–2710 Ma), and Timiskaming-like alluvial–fluvial rocks (~2703–2696 Ma) in successor basins (Beakhouse et al. 1995; Beakhouse 2000, 2001; Dostal, Mueller and Murphy 2004; Corcoran and Mueller 2007). These supracrustal packages largely display greenschist-facies metamorphic assemblages (protolith names are being used for simplicity) and were variably intruded by granodioritic to tonalitic plutonic rocks that are ~2750–2680 Ma in age. The western Wabigoon Subprovince is juxtaposed between Meso- to Neoarchean gneissic-plutonic rocks of the Winnipeg River and Marmion terranes to the north and south, respectively (*see* Figure 36.1). These rocks record several major phases of deformation that resulted in widespread folding and thrusting of the supracrustal successions, and progressive localization of strain along regional deformation zones.

New regional mapping and outcrop-scale observations that provide preliminary constraints on the stratigraphic and structural evolution of the Dryden–Stormy Lake transect area are discussed below. In particular, this report discusses domains adjacent to the Wabigoon (WDZ), Manitou–Dinorwic (MDDZ), and Mosher Bay–Washeibemaga (MBWDZ) deformation zones. These deformation zones represent

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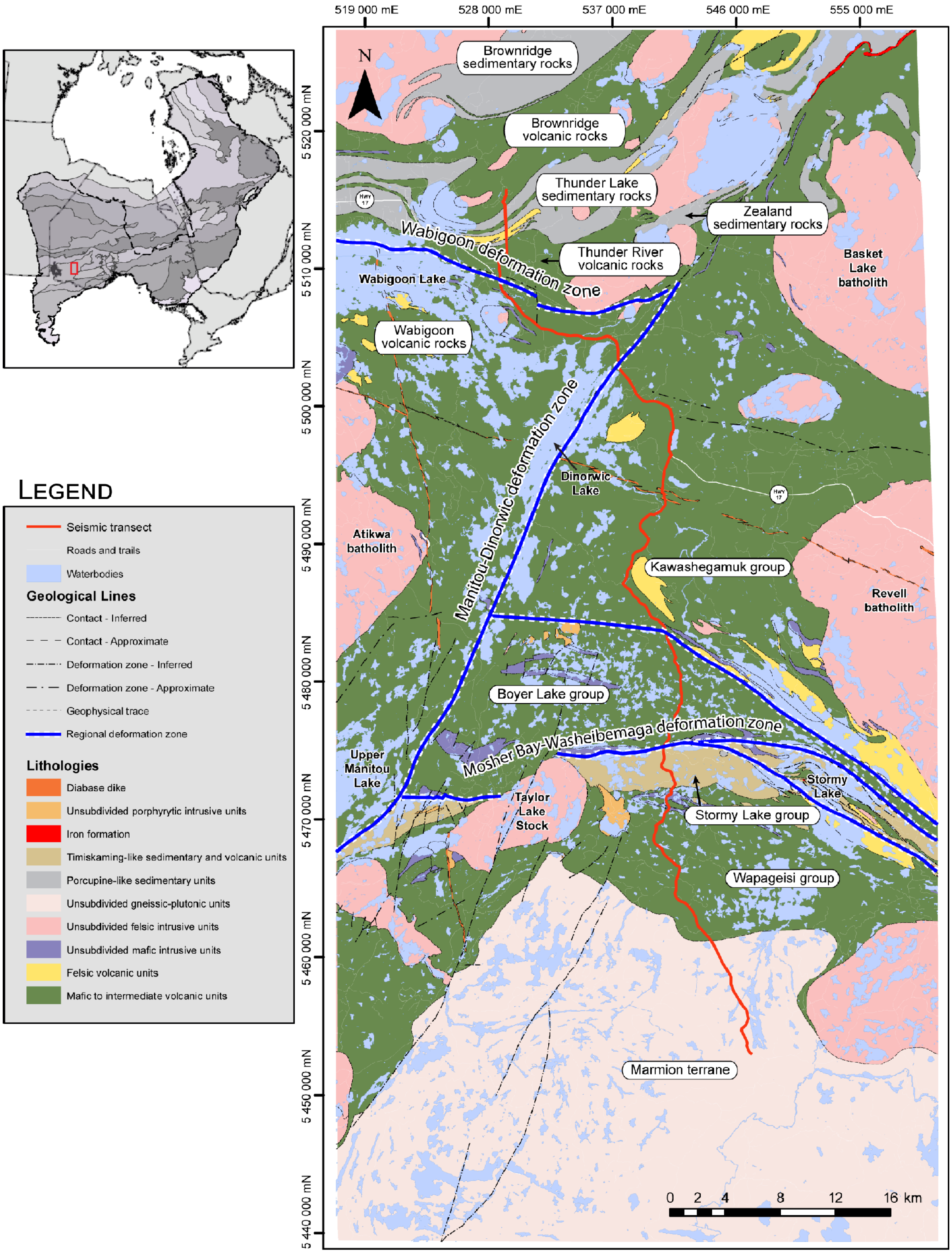

Figure 36.1. Geologic map of the Dryden–Stormy Lake area highlighting the major lithological units and regional deformation zones. Inset map displays the location of the study area in the Superior Province. Geology *modified from* Blackburn (1978). Universal Transverse Mercator (UTM) co-ordinates provided in North American Datum 1983 (NAD83), Zone 15N.

crustal-scale structures that accommodated deformation and acted as possible fluid conduits and, thus, are potential hosts to structurally controlled gold occurrences. Furthermore, these structures are likely to be imaged by the Metal Earth seismic and magnetotelluric (MT) surveys, providing the potential to constrain mid-crustal structure and related processes. In addition, initial field investigations have revealed several exceptionally well-preserved outcrop areas within the Timiskaming-like, Stormy Lake group sedimentary and volcanic rocks. Understanding the significance of these Timiskaming-like sedimentary rocks is important, because they represent a critical temporal marker unit for the geodynamic setting of late deformation and are a common host to orogenic gold deposits in many greenstone belts throughout the Superior Province.

The Wabigoon Deformation Zone and Northern Domains

The Wabigoon deformation zone (WDZ) and areas to the north have previously been referred to by Beakhouse et al. (1995) as the Sioux Lookout domain. The Sioux Lookout domain includes mafic volcanic rocks (2735–2730 Ma: Davis and Trowell 1982; Davis, Blackburn and Krogh 1982) referred to as the Brownridge and Thunder River volcanic rocks (Beakhouse 2000) and Porcupine-like turbiditic rocks that include the Brownridge, Thunder Lake and Zealand sedimentary rocks (*see* Figure 36.1; Beakhouse 2000). These are juxtaposed with the Wabigoon volcanic rocks (2745–2735 Ma: Davis, Blackburn and Krogh 1982) that occur to the south of the WDZ. The Sioux Lookout domain displays a different metamorphic grade (upper greenschist to lower amphibolite facies) from areas to the south of the WDZ, suggesting that they represent a deeper crustal level. The reason for this apparent differential exposure is unclear, but, perhaps relates to thrust exhumation of the northern domains by displacement along the WDZ (Beakhouse et al. 1995). The contact between these successions has been interpreted to be conformable (Beakhouse 2000), although the youngest detrital zircon grains in the Thunder Lake and Brownridge sedimentary rocks have yielded U/Pb ages of 2715–2710 Ma (Davis, Sutcliffe and Trowell 1988), suggesting that their contact may be disconformable. Regardless, all of the volcanic and sedimentary successions north of the WDZ record a shared structural history. They are complexly folded and faulted, forming a broad, kilometre-scale zone of ductile deformation features along the WDZ. Structural relationships indicate that 2 main deformation events affected these northern domains, including an early phase of shortening (D_1) and a later phase of dextral strike-slip and/or transpression (D_2). Early shortening resulted in isoclinal F_1 folds with steeply plunging fold axes that are widely preserved in outcrop exposures throughout the northern domains. This deformation event resulted in the dominant foliation (S_1) preserved in these areas. The S_1 foliation is an east-trending, subvertical foliation that is defined by aligned grains of chlorite or biotite. Progressive deformation (D_2) was characterized by a transition to dextral shear. The D_2 shear resulted in re-folding of F_1 folds, forming asymmetric F_2 Z-folds, and boudinage of quartz veins, forming σ-clasts. Asymmetric F_2 Z-folds display an axial planar S_2 crenulation cleavage that is northeast trending and moderately dipping toward the northwest. New investigations on the distribution and timing of deformation events in the northern domain relative to regions to the south are being conducted by Metal Earth investigators (Zammit, Frieman and Perrouty, this volume, Article 34).

The Mosher Bay–Washeibemaga Deformation Zone

The Mosher Bay–Washeibemaga deformation zone (MBWDZ) is a major east-trending deformation zone that occurs in the central portion of the study area (*see* Figure 36.1). It juxtaposes older mafic volcanic rocks of the Boyer Lake group to the north with younger sedimentary and volcanic rocks of the Stormy Lake group to the south and has been inferred to be a crustal-scale structure (Dostal, Mueller and Murphy 2004). Approximately 1 km to the north of the MBWDZ, pillowed volcanic rocks of the Boyer Lake group are essentially unstrained, steeply dipping and north facing, forming the south limb of a kilometre-scale syncline (Photo 36.1A). In contrast, within several hundred metres of the MBWDZ, the Boyer Lake group rocks display penetrative fabrics defining the high-strain zone associated with the deformation zone (Photo 36.1B). Within this high-strain zone, pillow basalts are still facing to the north, but are flattened into parallelism with a north-dipping foliation (~284°/67°). Based on these observations, it is inferred that the MBWDZ involved an early history of north-over-south thrust kinematics. Progressive deformation along the MBWDZ is characterized by a transition to dextral strike-slip and/or transpressional strain. Kinematic indicators are poorly preserved within mafic volcanic rocks to the north of the MBWDZ, but are more easily recognized within sedimentary rocks of the Stormy Lake group to the south. Vein-type mineralization is rare along the MBWDZ. Commonly, narrow (<5 cm) shears contain foliation-parallel quartz-carbonate veins and weak disseminated sulphide mineralization. Although several gold occurrences have been documented along the MBWDZ (Parker 1989), no significant deposit has been discovered. Further research as part of the Metal Earth initiative will investigate the structural setting and potential for gold mineralization in more detail. In part, this work will a focus on mapping of the MBWDZ along and across strike on Washeibemaga Lake and Stormy Lake.

The Manitou–Dinorwic Deformation Zone

The MDDZ is a major, regional, northeast-trending deformation zone that extends across the study area from Upper Manitou Lake in the southwest through Dinorwic Lake in the northeast where it is exposed along Highway 17 (*see* Figure 36.1). The MDDZ primarily affects mafic supracrustal rocks (2745–2720 Ma) of the Wabigoon volcanic rocks and the Kawashegamuk, Boyer Lake and Wapageisi groups. The MDDZ hosts a number of orogenic gold occurrences, mainly in the southwest near Upper Manitou Lake where a series of early twentieth century mines collectively produced approximately 20 000 ounces of gold (Parker 1989). Along its length, the MDDZ is marked by intense fabric development, heterogeneous alteration, silicification and structurally controlled quartz-carbonate veins. The age of deformation along the MDDZ relative to other regional structures is poorly constrained.

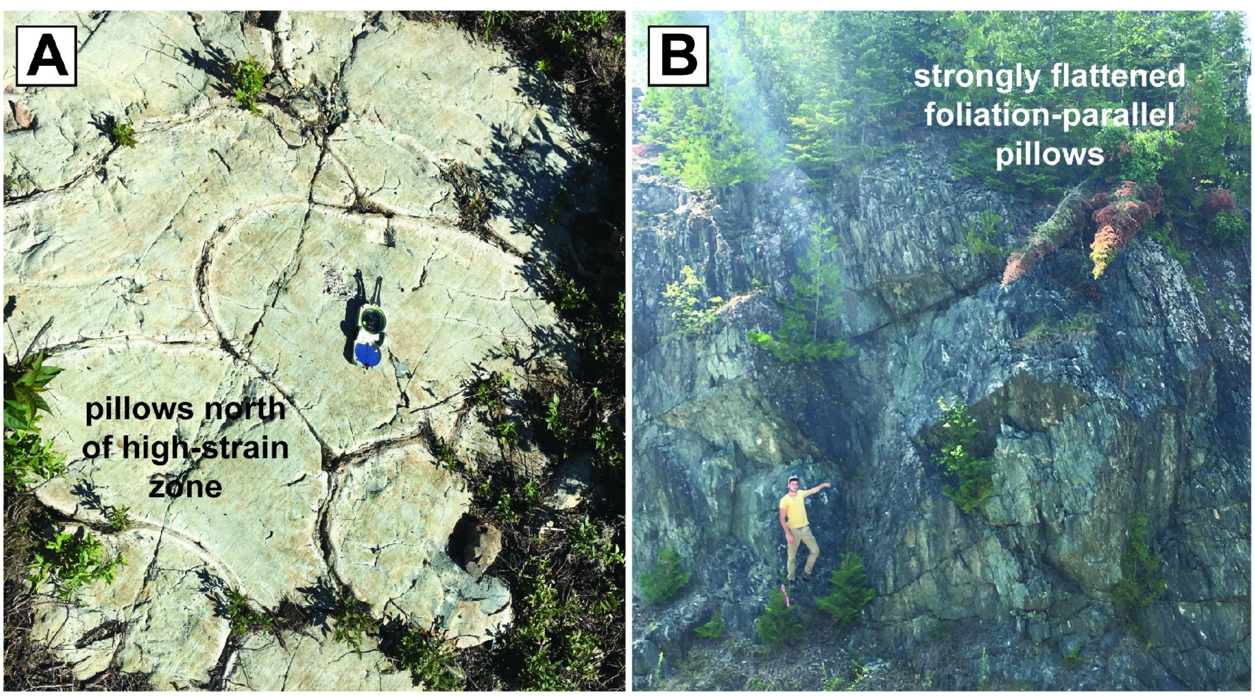

Photo 36.1. Features observed in the Boyer Lake group volcanic rocks to the north of the Mosher Bay–Washeibemaga deformation zone (MBWDZ). **A**) Unstrained pillows that occur outside of the high-strain zone associated with the MBWDZ. **B**) Foliated and flattened pillow basalt at the margin of the high-strain zone associated with the MBWDZ.

Deformation features characteristic of the MDDZ are well exposed along the Metal Earth transect line along Highway 17 (*see* Figure 36.1; UTM 556780E 5501875N, NAD83, Zone 15U). At this locality, deformed basaltic rocks display a subvertical foliation that strikes toward the northeast (~045°/88°). Aligned grains of chlorite on these foliation surfaces plunge steeply to the south (82°/180°). These fabric relationships are interpreted to reflect a transpressional strain regime. In several locations at this outcrop area, the dominant northeast-trending foliation can be observed to overprint an earlier, roughly east-trending fabric that is interpreted to relate to deformation associated with the WDZ. This suggests that peak deformation along the MDDZ postdates D_1 shortening and, potentially, D_2 shear along the WDZ.

Several generations of veins can be observed at this locality. Early formed composite quartz-carbonate veins are irregularly folded and are roughly foliation parallel (Photo 36.2). Banded vein structures suggest cyclic emplacement. These veins are texturally related to a younger generation of shallowly to moderately dipping vein sets, consistent with broadly coeval emplacement. Both of these vein generations are locally associated with narrow zones of disseminated sulphide minerals and iron-carbonate alteration halos (*see* Photo 36.2). In contrast, a late generation of veins are represented by discontinuous, moderately to shallowly dipping arrays of tension gashes. These are not associated with wall rock alteration and are mainly filled with calcite. The calcite-filled tension gashes crosscut the foliation and all earlier generations of veins, and form prominent erosional surfaces, particularly in the southern portion of the outcrop.

Ongoing work along the MDDZ will seek to constrain the kinematic history, timing of deformation to other regional deformation zones (e.g., the WDZ and MBWDZ), and potential relationships to orogenic gold mineralization. To establish these relationships, detailed structural mapping, geochemical and paragenetic studies are being conducted by Metal Earth researchers (Zammit, Frieman and Perrouty, this volume, Article 34).

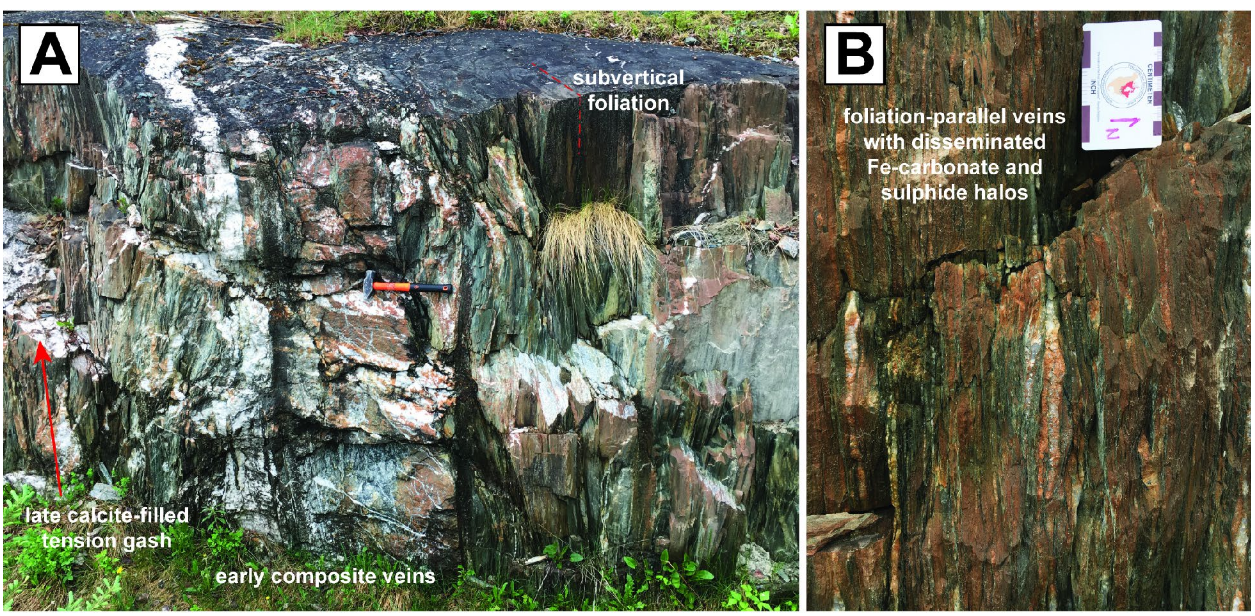

Photo 36.2. Features associated with the Manitou–Dinorwic deformation zone along Highway 17. **A**) Strongly foliated basalt with composite, early formed quartz-carbonate veins and late calcite-filled tension gashes (hammer is 42 cm in length). **B**) Steeply dipping veins with associated sulphide and iron-carbonate alteration of the host rock.

The Stormy Lake Group

The Stormy Lake group (~2703–2696 Ma) is a synorogenic, Timiskaming-like sedimentary and volcanic succession that is structurally bound by the MBWDZ in the north and is in unconformable contact with Wapageisi group mafic volcanic rocks to the south (*see* Figure 36.1; Corcoran and Mueller 2007; Dostal, Mueller and Murphy 2004). Field investigations during the summer of 2018 revealed exceptionally well-preserved exposures of the Stormy Lake group along a newly constructed logging access road (Figure 36.2). These exposures display low-strain intensity, preserve approximately 1 km of internally conformable stratigraphy, and contain a basal unconformity with the older volcanic rocks. Thus, mapping along these exposures provides new constraints on the sedimentary and volcanic environment associated with deposition of the Stormy Lake group during the late phases of regional construction and deformation. These observations will be placed into the regional structural context in order to assess the geodynamic processes recorded in the western Wabigoon Subprovince.

Near the end of the logging road, the base of the Stormy Lake group is characterized by extensive outcrops of conglomerate and sandstone. These outcrops are separated from the basal unconformity of the Stormy Lake group by approximately 30 m where a shear zone occurs within a bog. Within the bog, several small outcrops of sheared conglomerate and sandstone occur. These display a steeply dipping, northeast-trending foliation (302°/86°) and sinistral S-C fabrics indicative of simple shear kinematics. To the south of the bog, a small area of the basal conglomerate is preserved along its contact with mafic

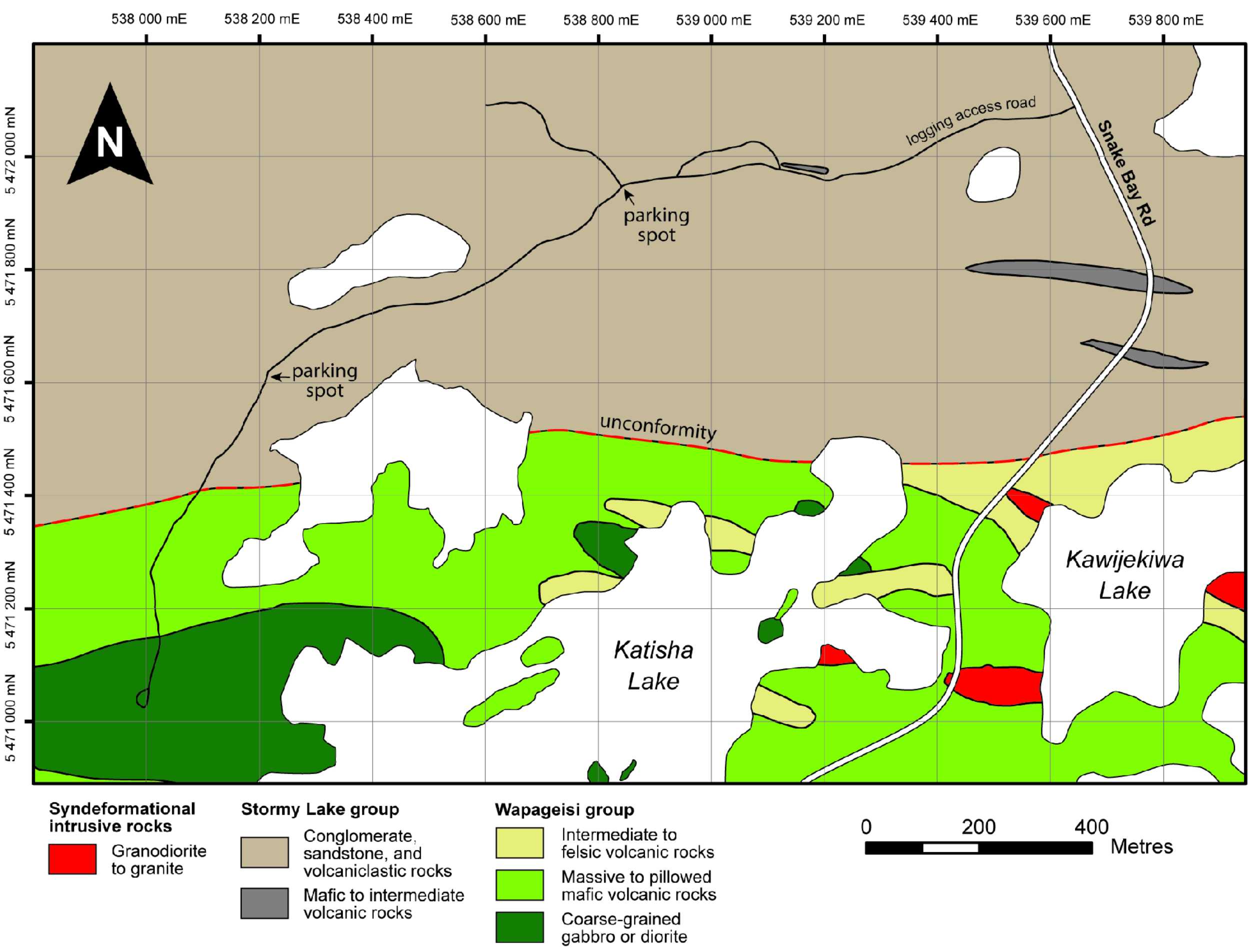

Figure 36.2. Geologic map of the southern margin of the Stormy Lake group showing the extent of the logging access road (geology *modified from* Stone, Paju and Smyk 2011).

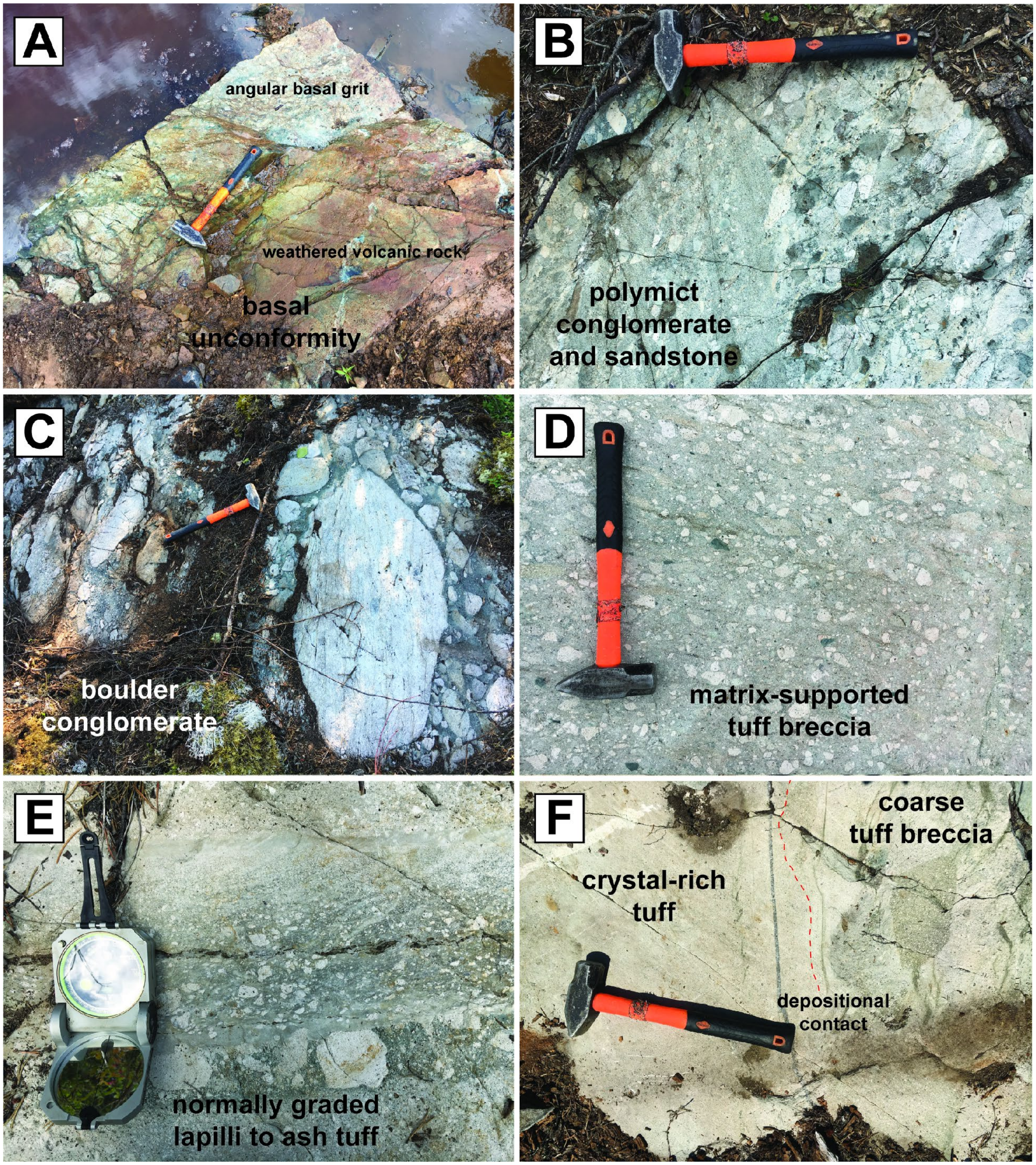

Photo 36.3. Representative sedimentary and volcaniclastic textures observed in the Stormy Lake group along the logging access road (Figure 36.2). **A**) The basal unconformity of the Stormy Lake group with mafic volcanic rocks of the Wapageisi group volcanic rocks. **B**) Conglomerate-sandstone facies that comprises much of the lower stratigraphic section of the Stormy Lake group. **C**) Boulder conglomerate that stratigraphically overlies volcaniclastic deposits. **D**) Ungraded, matrix-supported tuff breccia in the central portion of the Stormy Lake group. **E**) A thin, normally graded pyroclastic unit. **F**) A depositional contact between crystal-rich tuff and tuff breccia. Hammer is 42 cm in length.

volcanic rocks. There, irregularly weathered talus material occurs that may represent an *in situ* weathering profile (Photo 36.3A). The contact is irregular and moderately to steeply dipping to the north. Above the blocky talus, locally derived, angular, matrix-supported gravel-sized clasts dominate. The basal unconformity can be traced to the west for several hundred metres to where conglomerate units form a similar unconformity with felsic intrusive rocks of the Thunder Cloud porphyry (Corcoran and Mueller 2007).

Across the bog, to the north, alternating beds of conglomerate and sandstone from an approximately 300 m thick succession of north-facing and moderately dipping (~50°–60°) units (Photo 36.3B). The conglomeratic units are polymictic, with clast sizes ranging from gravel to cobble. The clasts are well rounded and, in part, comprise felsic volcanic, mafic volcanic, jasperoid and banded iron formation (BIF) compositions. Conglomerates occur as thick, metre-scale amalgamated beds, as well as in association with sandstones as thinner (<10 cm) normally graded units (*see* Photo 36.3B). Sandstone units range from coarse sandstone to fine-grained greywacke, and locally planar and trough cross-beds can be observed. Sedimentary structures, such as grading, pebble channel lags and cross-beds, consistently indicate younging toward the north. These observed primary sedimentary features are interpreted to reflect deposition in a subaerial alluvial–fluvial environment similar to the Timiskaming assemblage in the Abitibi Subprovince (e.g., Hyde 1980).

Along the central portion of the logging road, felsic volcaniclastic rocks dominate and form an approximately 150 m thick succession (Photos 36.3D to 36.3F). Although mafic to felsic volcanic flows are well documented in the Stormy Lake group (Corcoran and Mueller 2007; Dostal, Mueller and Murphy 2004), volcaniclastic facies are poorly described. Thus, exposures on this newly constructed logging road provide a unique opportunity to better describe the volcanic setting of the basin. Volcaniclastic rocks include ash, crystal-rich, lapilli and breccia tuffs (*see* Photos 36.3D to 36.3F) that conformably overlie the conglomerate-sandstone facies that occur in a lower portion of the stratigraphy described above (Photos 36.3A and 36.3B). In general, the volcaniclastic rocks are ungraded, forming metres-thick units that, locally, display sharp depositional contacts (*see* Photo 36.3F). Crystal-rich tuffs are abundant in the central portion of the volcaniclastic section. These contain millimetre-scale phenocrysts of quartz and feldspar within a fine-grained matrix. Lapilli to tuff breccia dominate the northern portion of the preserved section. In general, these are matrix supported, and contain abundant angular clasts consisting of felsic volcanic, porphyritic, and more rare mafic volcanic rocks (*see* Photo 36.3D). Locally, thin (<10 cm) beds of graded lapilli to ash tuffs can be observed that may represent pyroclastic flow deposits (*see* Photo 36.3E). Volcaniclastic units can be observed for approximately 175 m along the northern extension of the road (*see* Figure 36.2). Near the stratigraphic top of the volcaniclastic succession, a thick (~20 m) unit of clast-supported tuff breccia can be observed. Imbricated clasts and additional clast compositions observed relative to lower in the stratigraphy are interpreted to reflect some degree of re-sedimentation. Stratigraphically above this unit, to the north at the end of the road, boulder conglomerate units were observed (Photo 36.3C). These boulder conglomerates contain abundant felsic volcanic and intrusive material that is well rounded. This unit indicates that high relief and/or high energy environments existed in the western Wabigoon Subprovince during the Neoarchean.

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