GS2018-2

Documentation of the Ospwagan group stratigraphy at the Pipe II open-pit mine, Thompson nickel belt, central Manitoba (part of NTS 63O8)

by C.G. Couëslan

In Brief:

- Classic Ospwagan group outcrops are beginning to flood at the Pipe II open-pit mine
- A project has been initiated to photographically document details of the remaining outcrops, including the use of an unmanned aerial vehicle (drone)
- A digital Open File report integrating detailed geological maps, aerial imagery, and outcrop photographs will be available as a resource for geologists and researchers working in the Thompson nickel belt

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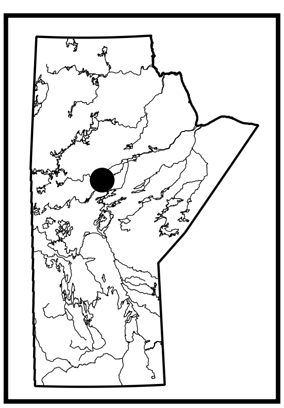

Summary

One of the few continuous exposures of Ospwagan group stratigraphy in the Thompson nickel belt, including the type section for the Pipe formation, is beginning to flood at the Pipe II open-pit mine. The classic outcrops are located along the east shoulder of the open pit, which has been flooding naturally since its closure in 1984. Detailed aerial images of the outcrops were collected by unmanned aerial vehicle (drone), and the available outcrops were photographed to document details of the stratigraphy, structure and metamorphic assemblages. The final output proposed for this project is a digital Open File report integrating detailed geological maps, aerial imagery and detailed outcrop photographs. The Open File will be available as a learning resource for geologists and researchers working in the Thompson nickel belt.

Introduction

Supracrustal rocks of the Ospwagan group are spatially associated with all of the economic nickel deposits in the Thompson nickel belt (TNB). Much of our understanding of the stratigraphy and structure of the TNB stems from the detailed mapping of Ospwagan group rocks at the Pipe II open-pit mine in the late 1980s (Bleeker and Macek, 1988a–i; Macek and Bleeker, 1989). Since that time, the outcrops at 'Pipe pit' have been the focus of geological studies (Bleeker, 1990; Couëslan et al., 2011; Scoates et al., 2017) and countless formal and informal field trips for industry, academic and government geologists (Galley et al., 1990; Bleeker and Macek, 1996). It is the type locality for the Pipe formation and where geologists come to be initiated into the geology of the TNB.

The Pipe II deposit was discovered in 1957 at Pipe Lake, and dredging of silt and clay overburden began in 1967. Production from the open pit began in 1969 and ceased in 1984 at a depth of 245 m after removal of approximately 18 million tonnes of Ni-Cu ore (Bleeker and Macek, 1996). Since the cessation of mining, the pit has been allowed to slowly fill with water, largely through surface drainage. Recent imagery from Google Earth™ (Google, 2018) revealed that the water had risen above the northeast rim of the open pit and was beginning to flood the adjacent outcrops, including some of the classic exposures of Ospwagan group rocks (Figure GS2018-2-1). In June 2018, a project was initiated to photographically document the outcrops along the east and northeast shoulders of the Pipe pit before they become inundated. As an additional component, a drone was loaned by the Department of Geological Sciences at the University of Manitoba to capture high-resolution aerial imagery of these important outcrops.

Ospwagan group

The following summary of the Ospwagan group is sourced largely from Bleeker (1990) and Zwanzig et al. (2007). The Paleoproterozoic Ospwagan group unconformably overlies Archean basement gneiss in the TNB (Figure GS2018-2-2). The lowermost unit of the Ospwagan group is the Manasan formation, a passive-margin, fining-upward siliciclastic sequence that consists of layered to laminated sandstone with local conglomerate layers near the base (M1 member) and overlying semipelitic rock (M2 member). This siliciclastic system grades into the overlying calcareous sedimentary rocks of the Thompson formation.

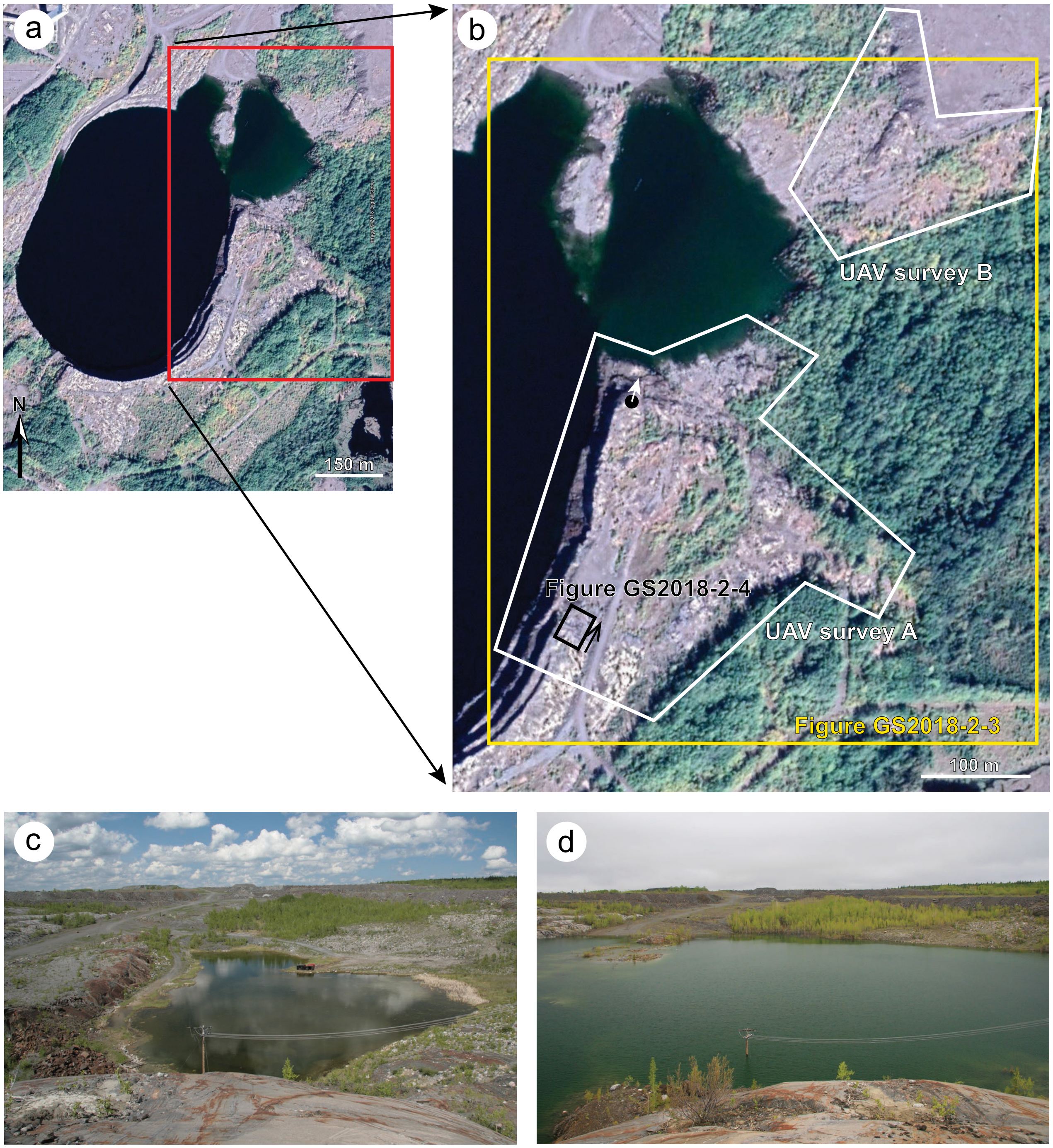

Figure GS2018-2-1: *Satellite imagery of the Pipe II open-pit mine* ***(a)*** *and outcrops along the east and northeast shoulders of the open pit (****b****; Google, 2018). The yellow outline indicates the approximate location of the geological map in Figure GS2018-2-3. The white outlines indicate the approximate locations of the two unmanned aerial vehicle (UAV) surveys. The black outline indicates the approximate location of the detailed aerial image in Figure GS2018-2-4 (the arrow indicates the top of the image). The black dot marks the vantage point of photos* ***(c)*** *and* ***(d)****, which were taken looking in the direction of the arrow. Photo* ***(c)*** *was taken during the summer of 2007 and photo* ***(d)*** *was taken in June 2018.*

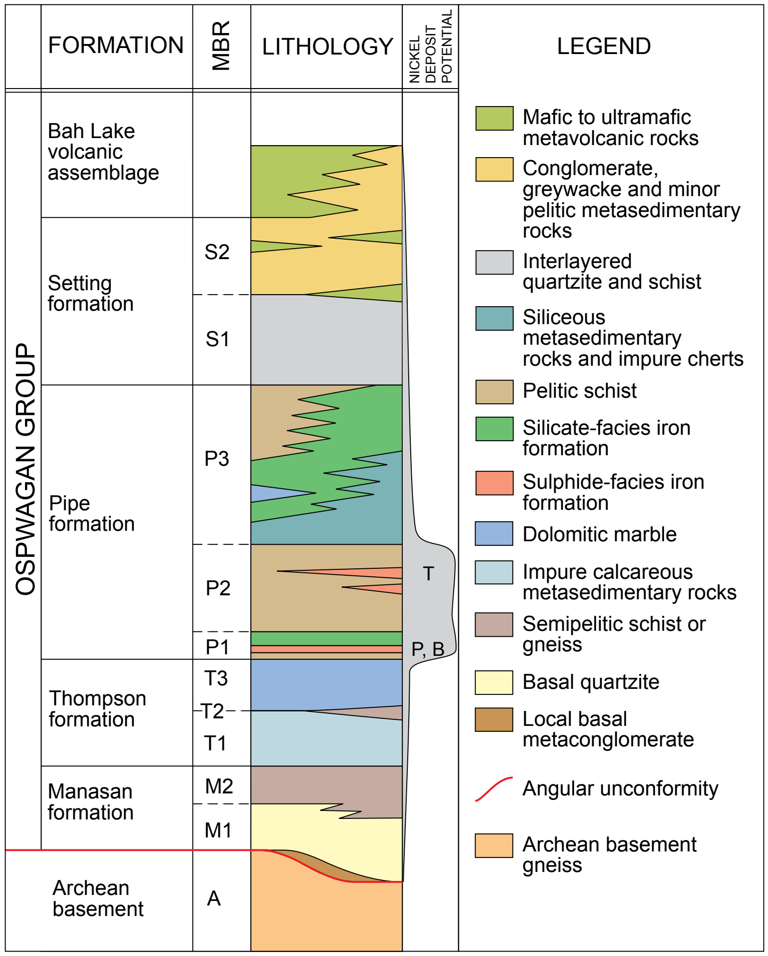

Figure GS2018-2-2: *Schematic lithostratigraphic section of the Ospwagan group (modified from Bleeker, 1990). Abbreviations: B, stratigraphic location of the Birchtree orebody; MBR, member; P, stratigraphic location of the Pipe II orebody; T, stratigraphic location of the Thompson orebody.*

The Thompson formation consists of a variety of calcareous–siliceous rocks, including chert, calcsilicate and impure marble (T1 member), and impure dolomitic marble with local horizons of calcsilicate (T3 member). The T2 member consists of a calcareous semipelitic rock that is rarely present. The Thompson formation represents a transition from a siliciclastic-dominated to a carbonate-dominated system.

The Pipe formation is subdivided into three members. The P1 member consists of a graphite-rich, sulphide-facies iron formation at the base (the locus of the Pipe II and Birchtree orebodies), overlain by a silicate-facies iron formation. The top of the P1 member consists of a reddish, laminated, siliceous rock. The P1 member grades into the overlying pelitic rocks of the P2 member, the top of which is marked by a sulphide-facies iron formation (the locus of the Thompson orebody). The overlying P3 member consists of a wide variety of rock types, including laminated, siliceous, sedimentary rocks; silicate-, carbonate- and local oxide-facies iron formations; and semipelitic rocks, calcsilicate and a local horizon of relatively pure dolomitic marble. The Pipe formation represents a mix of chemical sediments and fine to very fine siliciclastics that were deposited in either an open-marine environment (Zwanzig et al., 2007) or during the development of a foredeep basin (Bleeker, 1990).

The Setting formation is divided into two members and is defined to include all siliciclastic rocks above the uppermost iron formation of the P3 member. The S1 member consists of rhythmically interbedded quartzite and pelitic schist with local calcareous concretions, which are characteristic of the S1 member. The S2 member consists of thickly layered greywacke, with local horizons grading from conglomeratic at the base to pelitic at the top. The S2 member appears to be missing altogether in the area of the Pipe mine. The Setting formation is interpreted to have been deposited by turbidity currents in a relatively deep-marine environment, possibly a foredeep basin (Bleeker, 1990).

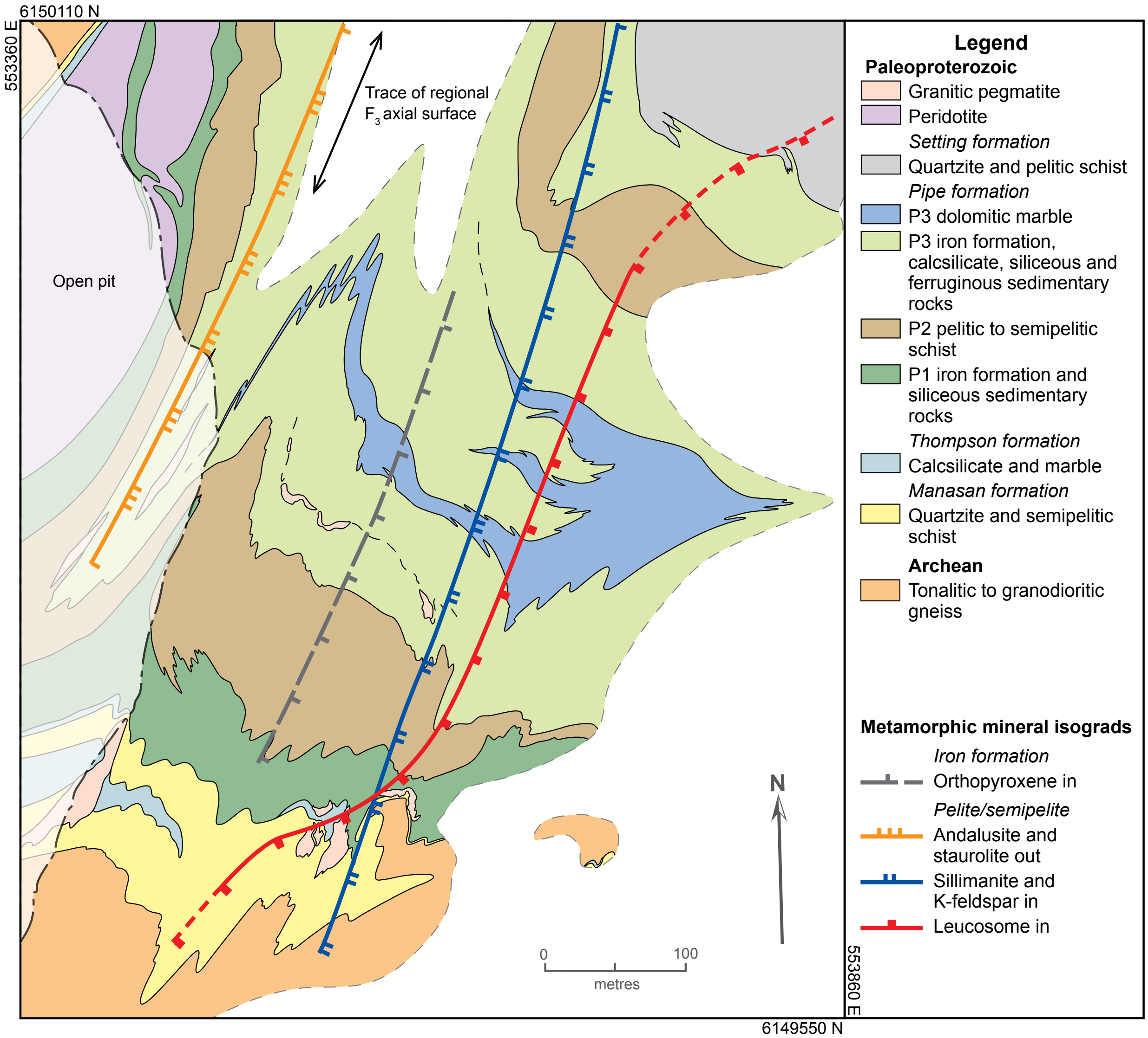

Figure GS2018-2-3: *Simplified geology of the east and northeast shoulders of the Pipe II open-pit mine (modified from Bleeker, 1990; Couëslan et al., 2011).*

At the top of the Ospwagan group is the Bah Lake assemblage, which consists of mafic to ultramafic volcanic rocks dominated by massive to pillowed basalt flows with local picrite and minor synvolcanic intrusions. Although present in the Pipe mine area, rocks of the Bah Lake assemblage are not present in the outcrops along the margin of the open pit. The Bah Lake assemblage may suggest the onset of active rifting in the TNB (Zwanzig, 2005; Zwanzig et al., 2007), or that the foredeep was magmatically active (Bleeker, 1990).

A maximum age for the Ospwagan group is provided by a ca. 1974 Ma zircon recovered from Setting formation greywacke (Bleeker and Hamilton, 2001). A minimum age for the Ospwagan group is provided by crosscutting amphibolitized dikes interpreted to be part of the Molson dike swarm, and the possibly comagmatic Ni-ore–bearing ultramafic sills that intruded the Ospwagan group at all stratigraphic levels ca. 1883 Ma (Bleeker, 1990; Zwanzig et al., 2007; Burnham et al., 2009; Heaman et al., 2009; Scoates et al., 2017). The interaction of these ultramafic intrusions with sulphide-rich horizons of the Pipe formation (Figure GS2018-2-2) led to sulphur saturation of the ultramafic magmas, and the precipitation and economic accumulation of Ni sulphides.

Geology of the Pipe II mine

The Pipe II mine is located approximately 35 km south of Thompson, Manitoba. Accessible outcrops along the east shoulder of the open pit provide one of the most complete successions of Ospwagan group

Figure GS2018-2-4: *Downsampled aerial image from the east shoulder of the Pipe II open-pit mine. Red rectangles mark the detailed outcrop images in Figure GS2018-2-5.*

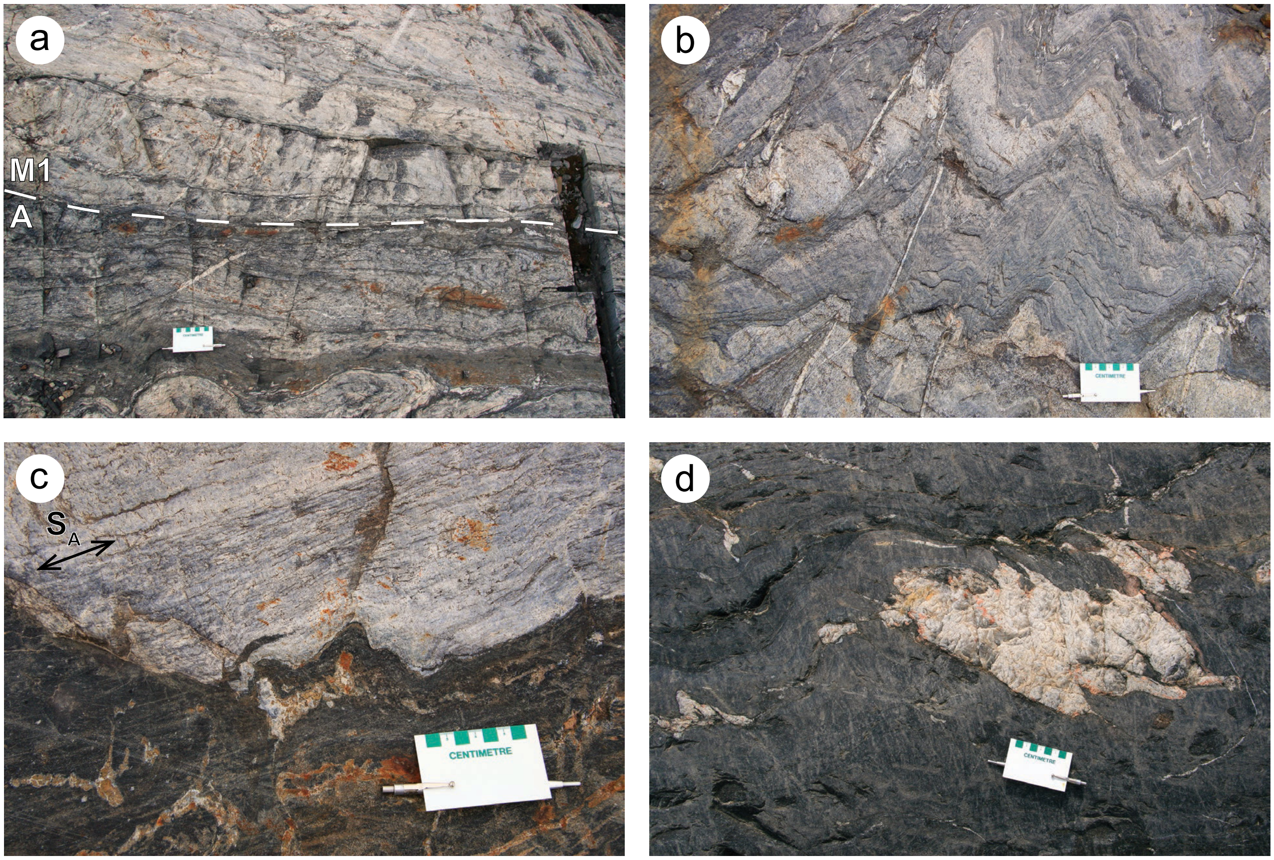

Figure GS2018-2-5: Detailed images from the outcrop shown in Figure GS2018-2-4: ***a)*** *unconformity between the Archean basement gneiss (A) and M1 member quartzite of the Manasan formation (M1);* ***b)*** *F_3 folds in graded beds of the M1 member;* ***c)*** *discordant relationship between Archean gneiss and a mafic dike, possibly related to the ca. 1883 Ma Molson swarm; S_A indicates the trace of the Archean gneissosity;* ***d)*** *a quartz-rich, likely subsolidus segregation in the M2 member semipelite of the Manasan formation.*

rocks in the TNB, and it is the type locality for the Pipe formation. The ore deposit is situated along the base of a serpentinized ultramafic body emplaced near the base of the Pipe formation (Bleeker, 1990). The ultramafic body is interpreted as a differentiated sill that comprises a base to top succession from dunite to peridotite to plagioclase-bearing orthopyroxenite. Intrusion of the ultramafic body occurred at 1880.2 ±1.4 Ma (Scoates et al., 2017). Simple quartz-feldspar pegmatite dikes up to tens of metres wide and hundreds of metres in length locally intrude both the Archean gneiss and Ospwagan group stratigraphy. Dikes of granitic pegmatite can be oriented subparallel to the stratigraphy or axial planar to F_3, or lack clear relationships to the stratigraphy or structures, and likely represent intrusions of various ages emplaced during metamorphism and deformation.

The rocks at the Pipe II mine are folded into a tight, northeast-trending F_3 synform that plunges steeply toward the east and has a steeply dipping axial plane (Figure GS2018-2-3; Fueten et al., 1986; Bleeker, 1990). The stratigraphy of the Ospwagan Group is upward facing and has been interpreted as the lower, upward-facing limb of an F_2 recumbent fold (Bleeker, 1990; Burnham et al., 2009). Metamorphic mineral assemblages in pelite and iron formation range from middle-amphibolite facies (585–600°C, 3.7–3.9 kbar) to upper-amphibolite facies (640–660°C, 3.0–3.6 kbar) and define a series of north-northeast-trending metamorphic mineral isograds subparallel to the trace of the F_3 axial surface. The mineral isograds suggest a metamorphic thermal gradient increasing toward the east-southeast across the Pipe mine area (Couëslan et al., 2011).

Methodology

Approximately 35 gigabytes of high-resolution aerial imagery was captured by unmanned aerial vehicle (UAV, drone; Figure GS2018-2-4). Individual images are approximately 24 megabytes each, with a resolution of 4000 by 3000 pixels, and were geospatially located with the onboard global positioning system (GPS). Surveys were flown over two separate areas as outlined in Figure

GS2018-2-1b. The surveys were flown at a height of 20 m above the approximate highest topographic point in each survey area. Attempts were made to get at least 80% overlap between adjacent images. Twelve control points were geospatially located with handheld GPS in the two survey areas (seven in area A and five in area B).

Approximately 200 detailed outcrop photographs were collected, each of which was spatially located by GPS. Attempts were made to document all of the units described in the preliminary maps of Bleeker and Macek (1988b–i), including representative images of the Archean basement, Ospwagan group and intrusive phases (Figure GS2018-2-5a–d). Images were also taken of structures, including the three main phases of folding, crosscutting relationships and late brittle faulting (Figure GS2018-2-5b, c); and of metamorphic mineral assemblages and features to document the west to east metamorphic field gradient (Figure GS2018-2-5d).

Planned outputs

The final output proposed for this project is a digital Open File report integrating a detailed geological map, high-resolution aerial imagery and detailed outcrop photographs in a geographic information system (GIS) format. The aerial imagery will be processed using structure-from-motion (SfM) photogrammetry to generate a 3-D point cloud and digital elevation model (DEM) based on the identification of matching features in multiple overlapping images (Turner et al., 2012; Westoby et al., 2012; Tavani et al., 2014). The UAV imagery and detailed geological map will then be overlain on the DEM. Detailed outcrop images of stratigraphy, structures and metamorphic assemblages will be linked to their locations projected on the map/aerial imagery surface. Processing of the UAV imagery is to begin in the autumn of 2018.

Economic considerations

A working knowledge of the Ospwagan group stratigraphy is key to successful exploration in the TNB. One must be able to recognize Ospwagan group stratigraphy in the drillcore, identify which part of the stratigraphy was intersected, and decide in which stratigraphic direction the most prospective horizons are located. In the mine environment, geologists must be able to recognize the stratigraphic and structural environment to vector-in on additional ore. The planned open file report will be available as a learning resource for geologists working in the TNB, as well as to researchers wishing to understand more about the belt.

Acknowledgments

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