

Bedrock Geology of the Revell Batholith and Surrounding Greenstone Belts

NWMO-TR-2020-08

October 2020

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Nuclear Waste Management Organization

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ABSTRACT

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Abstract

This report presents a description of the bedrock geology of the ground surface in an area located to the northwest of the community of Ignace and to the southeast of Wabigoon Lake Ojibway Nation, in northwestern Ontario. This area is centred on the northern part of the Revell batholith, a body of plutonic rock that was previously identified by the Nuclear Waste Management Organization (NWMO) as being potentially suitable for hosting a Deep Geological Repository (DGR).

The objectives of this work were to: (1) describe the primary geological source datasets that were available for the Revell Regional Area, (2) where necessary, integrate geological datasets from multiple sources into single compilation datasets for the entire Revell Regional Area, and (3) present and describe the bedrock geology at the ground surface for the Revell Regional Area based on the available and recently-compiled information. The bedrock map, and integrated datasets, form a foundation for downstream users in safety assessment and repository engineering as well as providing input to the NWMO R&D programme.

Eleven bedrock units are defined and described in the study area. Five greenstone belt bedrock units are assigned to the Archean-aged supracrustal rock group. These include mafic metavolcanic rocks, intermediate to felsic metavolcanic rocks, metasedimentary rocks, including a distinct banded iron formation, and mafic intrusive rocks. Five additional bedrock units are assigned to the Archean-aged plutonic rock group. Four of these Archean-aged units occur within the Revell batholith, including biotite tonalite to granodiorite, hornblende tonalite to granodiorite, biotite granodiorite to granite, and feldspar-megacrystic granite suites. The fifth bedrock unit of the plutonic rock group, which is not identified as a phase of the Revell batholith, is an intermediate to felsic intrusive (sanukitoid) suite. Proterozoic-aged mafic dykes belonging to the Wabigoon dykes represent the youngest bedrock unit identified in this report.

The bedrock map presented in this report provides an updated representation of the surface distribution of the bedrock units across the area. Along with the surface location of bedrock units, the map presented here also displays the surface location of regional faults, interpreted lineaments, outcrop-scale structural measurements, the locations of NWMO's drilled and planned boreholes at the Revell Site, the distribution of areas with extensive Quaternary cover deposits, mineral occurrences, mineral exploration boreholes, the locations of abandoned mines, and sample locations for various types of complementary rock characterization analyses.

Six regional structural domains were defined for the Revell Regional Area, based on systematic variations in the orientation of mapped foliation within the supracrustal rocks, and on the distribution of supracrustal versus plutonic bedrock types identified within the Revell batholith. Regional-scale relationships between interpreted lineaments and mapped bedrock structures are examined. Findings and uncertainties are summarized at the end of the report.

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1. INTRODUCTION

This report presents a description of the bedrock geology of the ground surface in an area northwest of the community of Ignace and southeast of Wabigoon Lake Ojibway Nation, in northwestern Ontario (Figure 1). This area, referred to herein as the 'Revell Regional Area' is centred on the northern part of the Revell batholith, a body of plutonic rock that was previously identified by the Nuclear Waste Management Organization (NWMO) as being potentially suitable for hosting a deep geological repository (NWMO, 2013). The northern part of the Revell batholith was subsequently selected for further investigation (NWMO, 2015) and is currently in Phase 2 of NWMO's Adaptive Phased Management (APM) Site Selection Phase.

The bedrock map presented in this report provides an update of the distribution of bedrock units for the Revell Regional Area. Along with the surface location of bedrock units, the map presented here also displays the surface location of regional faults, interpreted lineaments, outcrop-scale structural measurements, the locations of NWMO's drilled and planned boreholes within the Revell batholith, the distribution of areas with extensive Quaternary cover deposits, mineral occurrences, mineral exploration boreholes, the locations of abandoned mines, and sample locations for various types of lithogeochemical analysis. Some of this information is included in the version of the bedrock map included in the main body of this report. A larger subset of the data are shown in the poster-sized version of the bedrock map that is included in Appendix A.

1.1 Objectives

The objectives of this work were to: (1) describe the primary geological source datasets that were available for the Revell Regional Area; (2) where necessary, integrate geological datasets from multiple sources into single compilation datasets for the entire Revell Regional Area; and (3) present and describe the bedrock geology at the ground surface for the Revell Regional Area based on available and recently-compiled information. This report does not include discussion of the relationship between findings from the surface characterization activities, presented herein, and findings from borehole drilling activities.

The bedrock map and integrated datasets form a foundation for downstream NWMO users in safety assessment and repository engineering as well as providing input to the research and development programme.

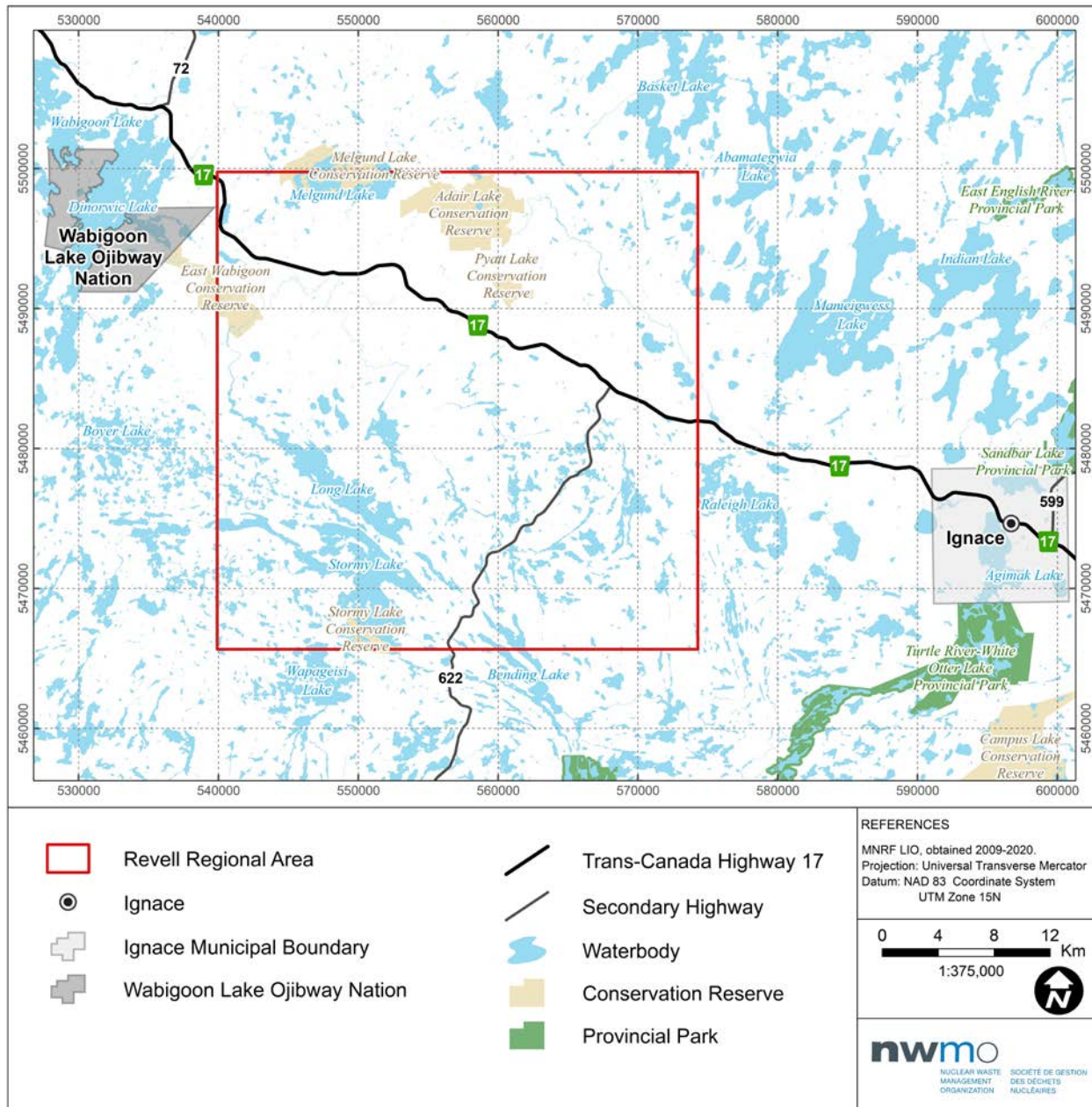


Figure 1: Area of study located northwest of the community of Ignace and southeast of Wabigoon Lake Ojibway Nation in northwestern Ontario. The Revell Regional Area is indicated by the red outline.

1.2 Report contents

Section 1 provides an introduction to the report and describes the study objectives and report contents. Section 2 provides a description of the regional geological setting and the structural and metamorphic history for the Revell Regional Area and surrounding area of northwestern Ontario. Section 3 summarizes the base data used to generate the updated bedrock and structure datasets that are presented on the bedrock map. Section 4 presents and describes the

updated bedrock map for the Revell Regional Area. Section 5 summarizes the main findings and uncertainties. Section 6 list the references cited in the report.

Appendix A presents a poster-sized version of the bedrock map (see back pocket). Appendix B presents the bedrock, structure and dyke datasets and describes the processes followed to create them. Appendix C presents a summary of the available historic mining information for the Revell Regional Area and a summary of additional complementary rock characterization analyses completed for the bedrock units within the Revell Regional Area.

2. REGIONAL GEOLOGICAL SETTING

The Revell Regional Area is situated in the northwestern part of the Superior Province of the Canadian Shield – a stable craton created from a collage of ancient plates and accreted juvenile arc terranes that were progressively amalgamated over a period of more than 2 billion years (Figure 2). The Canadian Shield forms the stable core of the North American continent. The Superior Province has historically been divided into various regionally extensive east-northeast-trending subprovinces based on rock type, age and metamorphism (Figure 2; Thurston, 1991). More recently, the Superior Province has been subdivided into lithotectonic terranes, defined as tectonically bounded regions with characteristics distinct from adjacent regions prior to their accretion into the Superior Province (Percival and Easton, 2007; Stott et al., 2010). The Revell Regional Area is situated in the south-central part of the Western Wabigoon terrane, adjacent to the boundary with the Marmion terrane (Figure 2).

A summary of the Archean and Proterozoic geological events that have shaped the bedrock in the Revell Regional Area is presented below and shown schematically in Figure 3. The western Wabigoon terrane, interpreted to represent a volcanic island arc, is predominantly composed of two main groups of rock. This includes ca. 2.745 to 2.711 Ga supracrustal rocks, comprising Archean mafic to intermediate to felsic metavolcanic rocks and subordinate sedimentary rocks distributed in greenstone belts, and, ca. 2.70 to 2.67 Ga rocks of granitoid affinity predominantly consisting of felsic plutonic rocks. These two major rock groups are a common characteristic of granite-greenstone belts, and granite-greenstone subprovinces, across the entire western Superior province.

The Archean supracrustal rocks in the Revell Regional Area wrap entirely around the northern margin of the Archean Revell batholith (Figure 2). The supracrustal rocks distributed to the southwest of the batholith belong to the Bending Lake greenstone belt and those distributed to the northeast of the batholith belong to the Raleigh Lake greenstone belt. Both of these greenstone belts, as well as the additional supracrustal rocks wrapping around the northern boundary of the batholith, represent contiguous parts of the Kakagi Lake-Savant Lake greenstone belt that underlies the entire western Wabigoon terrane.

The Revell batholith is roughly rectangular in shape, trends northwest, is approximately 40 km in length, and covers an area of approximately 455 km² (Figure 2). Szewczyk and West (1976) interpreted this batholith to be a sheet-like intrusion that is approximately 1.6 km thick. Recent 2.5D gravity modelling suggests that the batholith is on the order of 2 km to 3 km thick through the center of the northern part of the batholith (SGL, 2015).

The topography of the area around the Revell Regional Area is characterized by a broadly rolling surface of Canadian Shield bedrock (Thurston, 1991). Several regions in the northern and northwestern parts of the Revell Regional Area are covered by extensive overburden

(Figure 4). The remainder of the area is either exposed bedrock or covered by only a thin veneer of Quaternary cover.

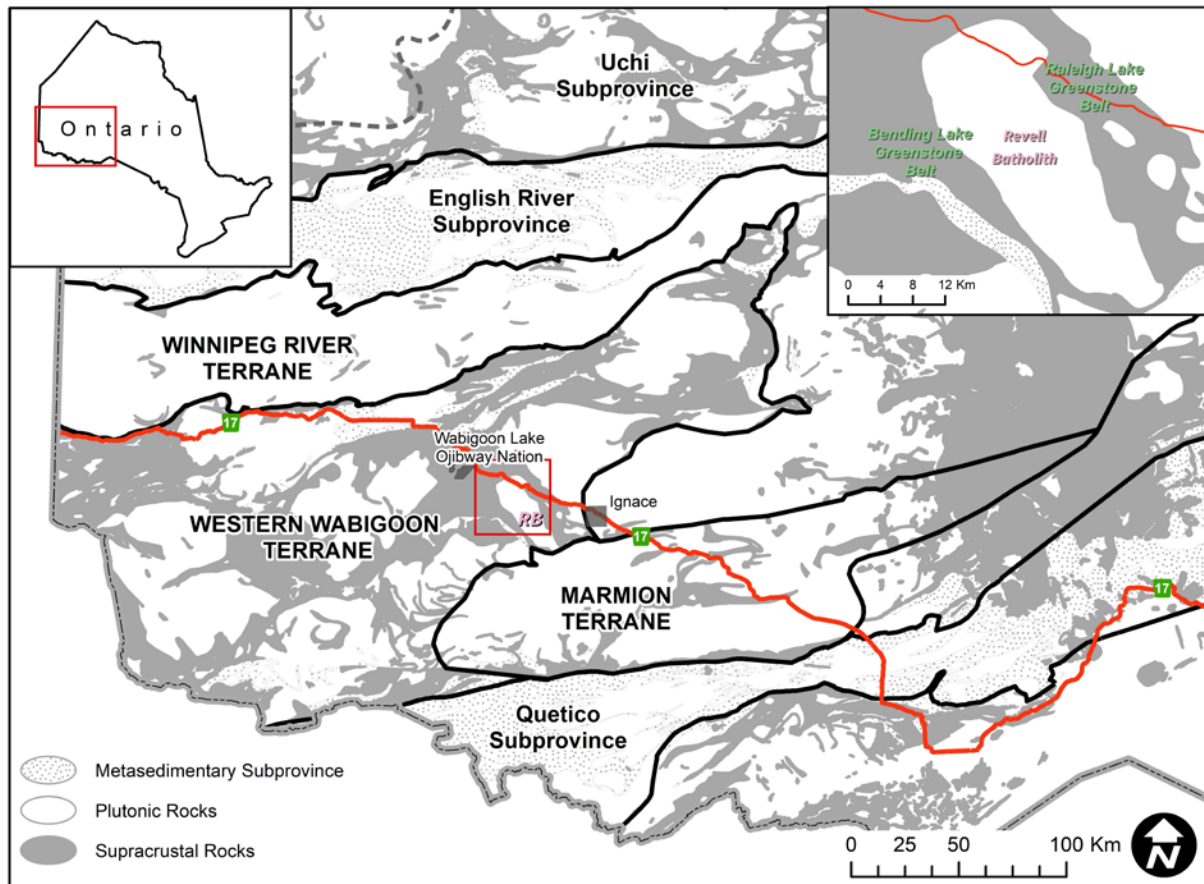


Figure 2: Geological setting of the Superior Province in Northwestern Ontario (after Thurston, 1991) around the Revell Regional Area (red outline on main map) and showing the outline of the Revell batholith (RB). Inset at top right shows the 1:250,000 scale outline of the Revell batholith and surrounding greenstone belts. The Winnipeg River, Marmion and Western Wabigoon terranes are part of the Wabigoon subprovince.

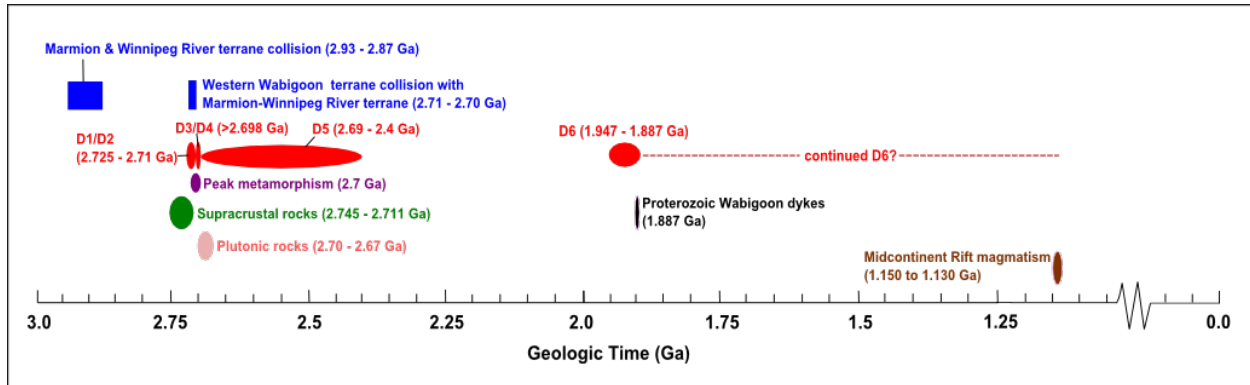


Figure 3: Summary of Archean and Proterozoic geological events for the Revell Regional Area.

2.1 Structural and Metamorphic History

The structural and metamorphic history of the Revell Regional Area is summarized below, and the documented sequence of deformation events is also shown in Figure 3. The information presented below is based on a synthesis of results from studies undertaken across the Wabigoon Subprovince (e.g., Percival et al., 2004; Bethune et al., 2006; Sanborn-Barrie and Skulski, 2006; Stone, 2010a). It is acknowledged that there is some uncertainty in applying the results from a regional synthesis to the Revell Regional Area. Additional discussion of the relationship between the rock units and structures in the Revell Regional Area and the documented stages in the regional structural history is included in Section 4.5.

In the earliest stage, the Marmion terrane underwent a complex history of magmatism, deformation and metamorphism ending with the collision of the Marmion and Winnipeg River terranes, between ca. 2.93 and ca. 2.87 Ga (Tomlinson et al., 2004). As a result of the collision, this part of the evolving Superior Province was amalgamated into the composite Winnipeg River-Marmion terrane (Tomlinson et al., 2004). The Western Wabigoon terrane is interpreted to have collided with this older terrane between ca. 2.71 and ca. 2.70 Ga (Sanborn-Barrie and Skulski, 2006). Subsequent plutonic activity took place throughout the Western Wabigoon terrane following this second collision event.

Pre-, syn-, and post-collisional tectonic events recorded in the Western Wabigoon terrane included five episodes of penetrative deformation (D1 to D5) and one prolonged episode of brittle deformation (D6). D1-D2 deformation occurred between ca. 2.725 and ca. 2.713 Ga. These two deformation events are recognized in gneissic rocks within the Western Wabigoon terrane. However, studies that were focused in the greenstone belts did not recognize any fabrics related to the D1-D2 event (e.g., Sanborn-Barrie and Skulski, 2006). Regional D3-D4 penetrative deformation (D1-D2 of Sanborn-Barrie and Skulski, 2006) finished prior to ca. 2.698 Ga and was characterised by the development of F3 northwest-trending folds and an associated S3 axial planar cleavage. D4 east- to northeast-striking structures locally overprint the northwest-striking S3 foliation. An S4 foliation occurs as a moderately- to strongly-developed, steeply-dipping, schistosity (Percival et al., 2004).

D5 deformation included events occurring between ca. 2.690 Ga (Davis, 1989) and ca. 2.678 Ga (Brown, 2002). D5 is characterized by the development of regional-scale conjugate shear zones in plutonic and gneissic rocks (Percival et al., 2004; Sanborn-Barrie and Skulski, 2006).

These shear zones are associated with significant sinistral strike-slip displacement along northeast-trending structures and dextral strike-slip motion along east- to east-southeast-trending structures (Bethune et al., 2006). The D5 event spanned the transition between ductile and brittle deformation into a poorly constrained and protracted series of episodic events that continued until ca. 2.4 Ga (Hanes and Archibald, 1998).

The D6 event is interpreted to have continued the episodic re-activation of pre-existing structures across the region (Kamineni et al., 1990). Evidence for D6 brittle deformation includes the presence of ca. 1.947 Ga pseudotachylite, a product of friction melting, observed along the northern boundary of the Quetico Subprovince, to the south of the Western Wabigoon and Marmion terranes (Figure 2; Peterman and Day, 1989). Both the supracrustal rocks and the plutonic rocks of the Western Wabigoon terrane are transected by north-west trending Proterozoic mafic dykes of the Wabigoon Swarm. The emplacement age of these mafic dykes is ca. 1.887 Ga, based on uranium-lead (U-Pb) geochronology (Stone et al., 2010), providing evidence of a younger Proterozoic brittle deformation event. Later rifting and intrusion associated with Midcontinent Rift magmatism, between ca. 1.150 and ca. 1.130 Ga (Heaman and Easton, 2006; Easton et al., 2007), may suggest a prolongation of the D6 event at a broader regional scale. It is unclear, however, to what extent this event contributed to the brittle deformation history in the Revell Regional Area.

The collision between terranes ca. 2.7 Ga years ago is interpreted to have coincided with the peak of regional metamorphism of the Western Wabigoon terrane (Easton, 2000). A greenschist to amphibolite facies metamorphic overprint is widespread in the Raleigh Lake greenstone belt with the highest grade metamorphic overprint indicated by numerous amphibolite and garnetiferous layers and clasts in the metavolcanic rocks (Blackburn and Hinz, 1996). In the Bending Lake greenstone belt, mineral assemblages are generally indicative of low to medium grade greenschist metamorphism. Kresz (1987) identified a thermal metamorphic overprint that extends up to 1.5 km away from the western contact between the Revell batholith and the adjacent supracrustal rocks. This contact metamorphism, caused by the emplacement of the batholith, caused recrystallization that destroyed earlier fabrics in the bedrock. The metamorphosed rocks are now, typically, massive hornfels. Distal to the pluton, albite-epidote hornfels is characteristic, whereas closer to the pluton contact, lower hornblende hornfels facies is suggested by the presence of hornblende (Kresz, 1987). Similar contact metamorphism was documented by Satterly (1960) and Stone (2010a) from other locations proximal to the margin of the Revell batholith.

3. BASE DATA INPUT

Historic and recent base data were used to develop three new geological datasets for the Revell Regional Area, including, a seamless compilation of bedrock units, an integrated compilation of Proterozoic diabase dykes of the Wabigoon swarm and a compilation of available structural measurements. The processes followed to compile these three datasets are presented in Appendix B. The base data that were used to develop these datasets are presented below, including:

- Historic publicly available geological maps, of various scales, and each covering some part of the Revell Regional Area (Figure 4 and Table 1). These maps include varying amount of detail on the locations and boundaries of distinct bedrock units, rock types, brittle and ductile structure, mineral resources information and Quaternary features, such as glacial striae orientations. The OGS digitized and compiled structural measurements from the historic maps listed in Table 1, where indicated, and included this information in

a GIS-based synthesis of geological information for the Wabigoon area (Beakhouse et al., 2011). Only the series of maps by Stone and others (i.e., Stone et al., 2007; Stone et al., 2011a; Stone et al., 2011b and Stone et al., 2011c) included digitized bedrock polygons. The older source maps were included in Beakhouse et al. (2011) as geo-referenced versions of the original paper maps without individually digitized bedrock polygons.

- The OGS compiled and released a digital dataset of the 1:250,000 scale bedrock geology of Ontario (Miscellaneous Release---Data 126-Revision 1; OGS, 2011a). This seamless GIS data set includes themes such as bedrock units, major faults, dike swarms and iron formations (Figure 4).
- More recent geological mapping was completed during two separate phases of fieldwork (SRK and Golder, 2015; Golder and PGW, 2017). In total, 256 bedrock stations were visited within the central and northern parts of the Revell Batholith during these two mapping campaigns (Figure 4). Major and minor bedrock units were mapped and described, brittle and ductile structures were catalogued where present, and field (hand-held device) magnetic susceptibility measurements were collected at all mapping stations. Field gamma ray spectrometer measurements were also collected at mapping stations by Golder and PGW (2017). Hand samples of representative bedrock units were collected. A subset of these samples were provided to the OGS for density analysis.
- Airborne magnetic data acquired by Sander Geophysics Ltd (SGL, 2015), along 100 m flight lines and 500 m perpendicular control lines at a nominal altitude of 100 m above ground surface, cover a large part of the Revell Regional Area (Figure 5). SGL also acquired airborne gravity data during the same survey (Figure 6). These gravity data were not utilized directly in updating the bedrock map. However, the gravity data do provide additional useful information on the character of the Revell batholith, and the additional information is included in the rock unit descriptions in Section 4.3 where applicable. Additional coverage of the Revell area is provided by airborne magnetic data gathered and processed during NWMO Phase 1 studies (OGS, 2011b; PGW 2013). These additional geophysical data were acquired along 200 m traverse lines, and 800 m perpendicular control lines at a nominal altitude of 73 m above ground surface.
- A digital elevation model (DEM) data generated following a Light Detection and Ranging (LiDAR) survey completed by ATLIS in the Fall of 2017 (ATLIS, 2018). LiDAR data were acquired using a Leica ALS70-HP sensor with a field of view of 40 degrees and a side lap of 50% in order to obtain a minimum spatial data point density of 8 points/m². The survey was flown at an altitude of 1500 m and has a final vertical accuracy of <15cm at 95% confidence. The LiDAR data were processed by ATLIS to obtain a DEM of the ground surface (trees removed) with a final ground resolution cell size of 1 m (Figure 7). Orthoimagery data (Red, Green, Blue and Infrared, RGB+IR) were acquired simultaneously during the LiDAR survey using a Leica RCD30 4-band sensor to capture images in true colour with an overall cell size of 15 cm. The LiDAR, airborne magnetic and orthoimagery datasets mentioned above were used to create an integrated lineament interpretation for the area within the LiDAR survey extent (DesRoches et al., 2018; Figure 8).

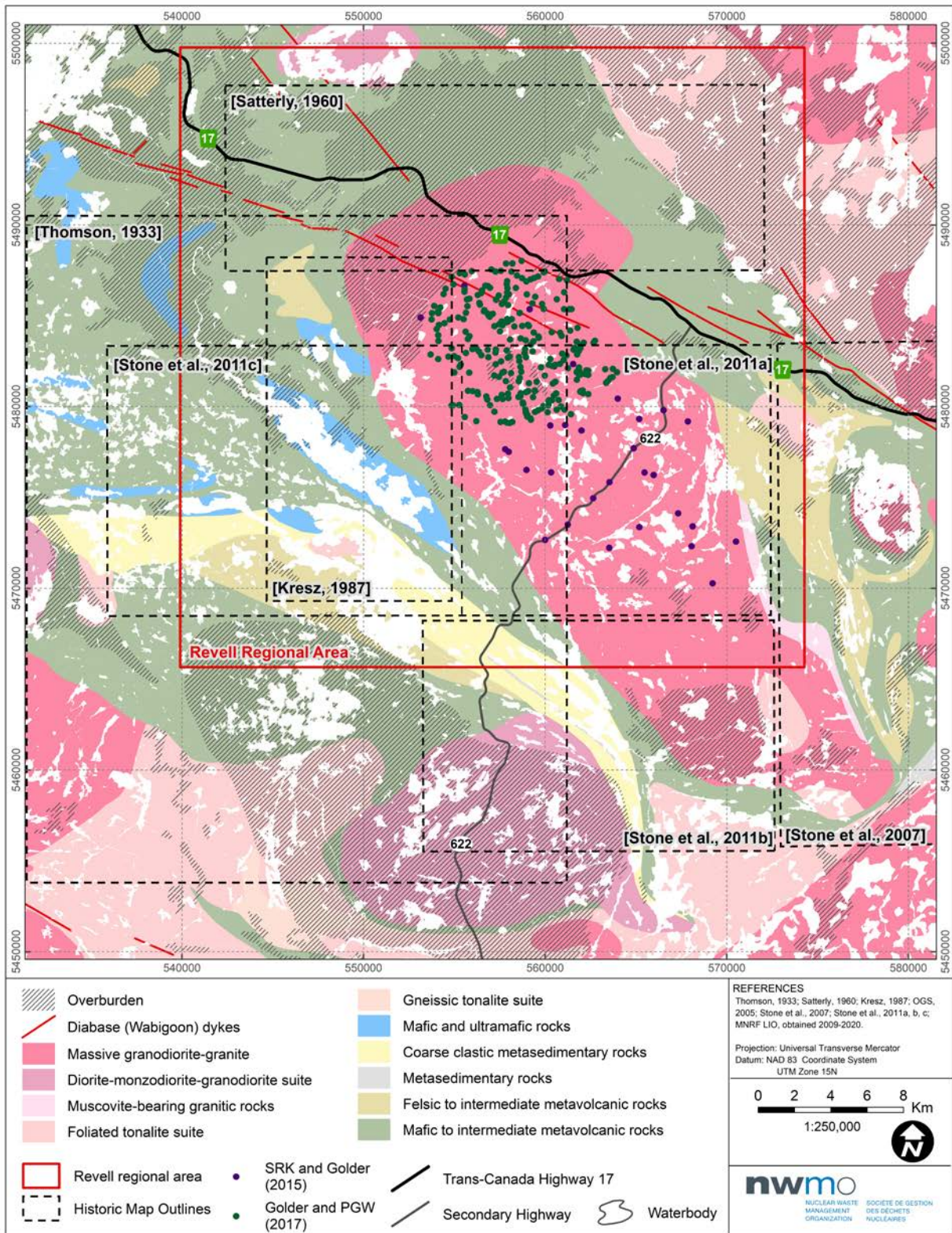


Figure 4: Historic map regions and recent geological mapping coverage for the Revell Regional Area. Hatched regions indicate areas of extensive overburden that masks the character of the bedrock. Underlying bedrock geology is from the 1:250,000 scale bedrock of Ontario compilation (OGS, 2011a).

Table 1: Summary of available historic maps and datasets

Map Title Map Number	Reference	Scale	Comments
Manitou-Stormy Lakes Area <i>Map 42c</i>	<i>Thomson, 1933</i>	<i>1:63,360</i>	Reconnaissance level map covers west part of area but with limited detail. This source was reviewed during compilation of the bedrock units. No outcrop measurements from this map were included in the structural data compilation.
Dryden- Wabigoon area, District of Kenora, Ontario Map Arm50e*	<i>Satterly, 1941</i>	<i>1:63,360</i>	Reconnaissance level map centred northwest and outside of the Revell Regional Area. The outline for this map area is not included in Figure 4. Outcrop measurements from this map were included in the structural data compilation. This source was not used in compilation of the bedrock units.
Geology of the Dymont Area <i>Map M1960h*</i>	<i>Satterly, 1960</i>	<i>1:31,180</i>	Map covers northern part of area and includes useful information on geological contacts, including well-constrained detail on the batholith-greenstone belt contact. This source was used in compiling the bedrock units. Outcrop measurements from this map were included in the structural data compilation.
Precambrian Geology of the Kawashagamuk Lake Area <i>Maps P2569*, P2570*</i>	<i>Kresz, 1987</i>	<i>1:15,840</i>	Maps cover western part of area and include useful information on geological contacts, including detail on the batholith-greenstone belt contact. This source was used in compiling the bedrock units. Outcrop measurements from these maps were included in the structural data compilation.
Precambrian geology, Melgund Lake area, MacFie and Avery townships Map 2529*	<i>Berger et al., 1989</i>	<i>1:20,000</i>	Map centred north of the northern boundary of the Revell Regional Area. The outline for this map area is not included in Figure 4. Outcrop measurements from this map were included in the structural data compilation. This source was not used in compilation of the bedrock units.
Precambrian Geology of the Butler Lake- Dinorwic Lake Area Map P3582*	<i>Beakhouse and Idziszek, 2006</i>	<i>1:20,000</i>	Map centred north of the northern boundary of the Revell Regional Area. Outcrop measurements from this map were included in the structural data compilation. This source was not used in compilation of the bedrock units.
Precambrian Geology, Ignace Area	<i>Stone et al., 2007</i>	<i>1:50,000</i>	Map covers the southeastern part of the batholith and includes coarse but useful information on geological contacts, including internal subdivisions of the Revell batholith, and the

<i>Map P3360</i>			batholith-greenstone belt contact. This source was used in compiling the bedrock units. Outcrop measurements from this map were included in the structural data compilation.
Precambrian geology of the Bending Lake area (north sheet) <i>Map P3623</i>	<i>Stone et al., 2011a</i>	<i>1:20,000</i>	Map covers the central part of area and includes useful information on geological contacts, including internal subdivisions of the batholith, and the batholith-greenstone belt contact. This source was used in compiling the bedrock units. Outcrop measurements from this map were included in the structural data compilation.
Precambrian geology of the Bending Lake area (south sheet) <i>Map P3624</i>	<i>Stone et al., 2011b</i>	<i>1:20,000</i>	Map covers the southern part of the batholith, slightly to the south of the study area and includes useful information on geological contacts, including internal subdivisions of the batholith, and the batholith-greenstone belt contact. This source was used in compiling the bedrock units. Outcrop measurements from this map were included in the structural data compilation.
Precambrian geology of the Stormy Lake area <i>Map P2515*</i>	<i>Stone et al., 2011c</i>	<i>1:20,000</i>	Map covers the southwestern part of area and includes useful information on geological contacts, including detail on the internal subdivisions of the batholith, and the batholith-greenstone belt contact. This source was used in compiling the bedrock units. Outcrop measurements from this map were included in the structural data compilation.
1:250 000 scale bedrock geology of Ontario MRD126-r1	<i>OGS, 2011a</i>	<i>1:250,000</i>	This seamless GIS product includes themes such as bedrock units, major faults, dike swarms and iron formations. This source was used in compiling the bedrock units. No outcrop measurements from this source were included in the structural data compilation.

**Included in the GIS-based synthesis of geological information for the Wabigoon area (Beakhouse et al., 2011)*

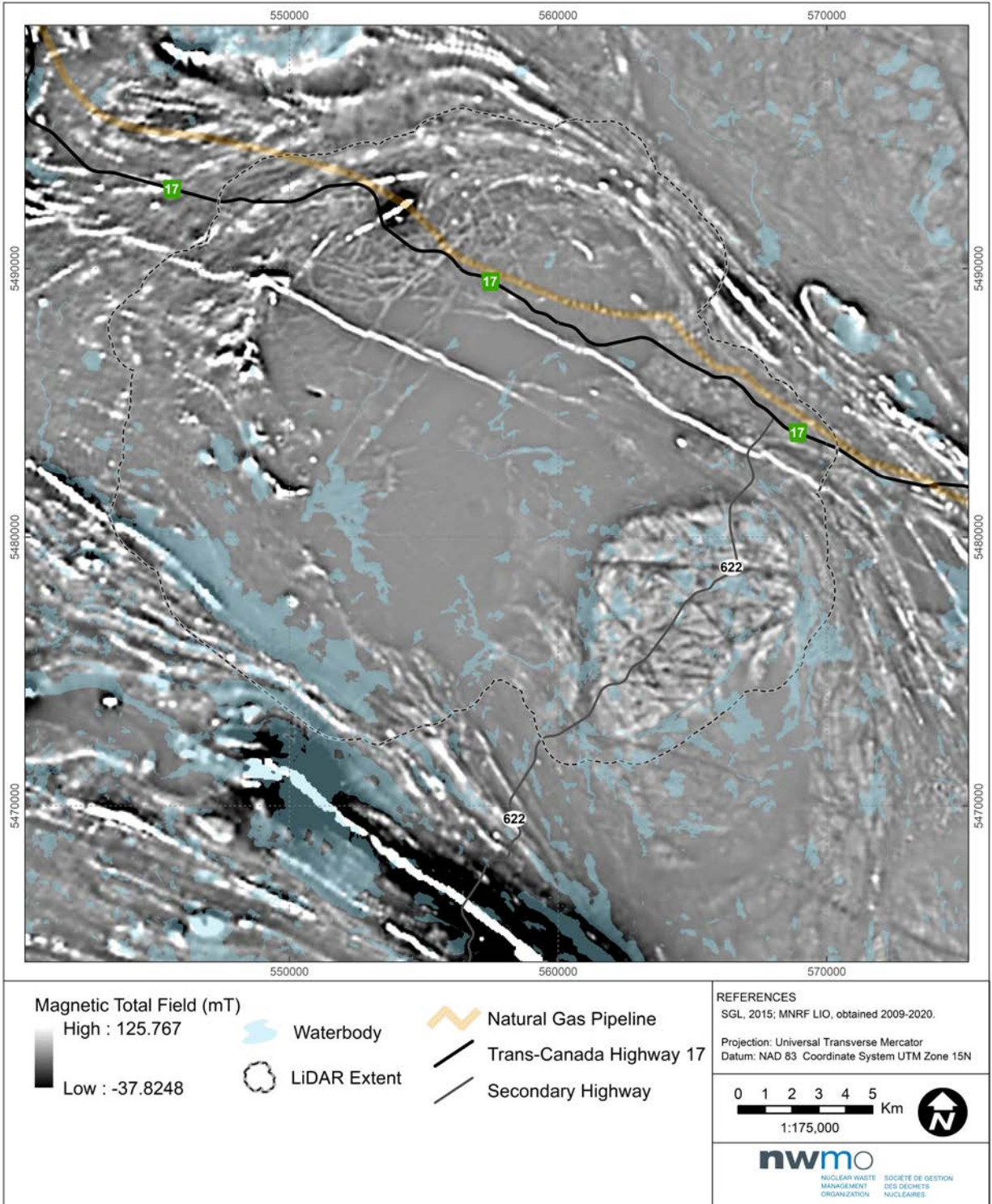


Figure 5: First vertical derivative of the total magnetic field data acquired by Sander Geophysics Limited (SGL, 2015), supplemented by magnetic data from OGS (2011b) in the western part of the area. Note that a natural gas pipeline (shown) defines a linear magnetic high in this dataset.

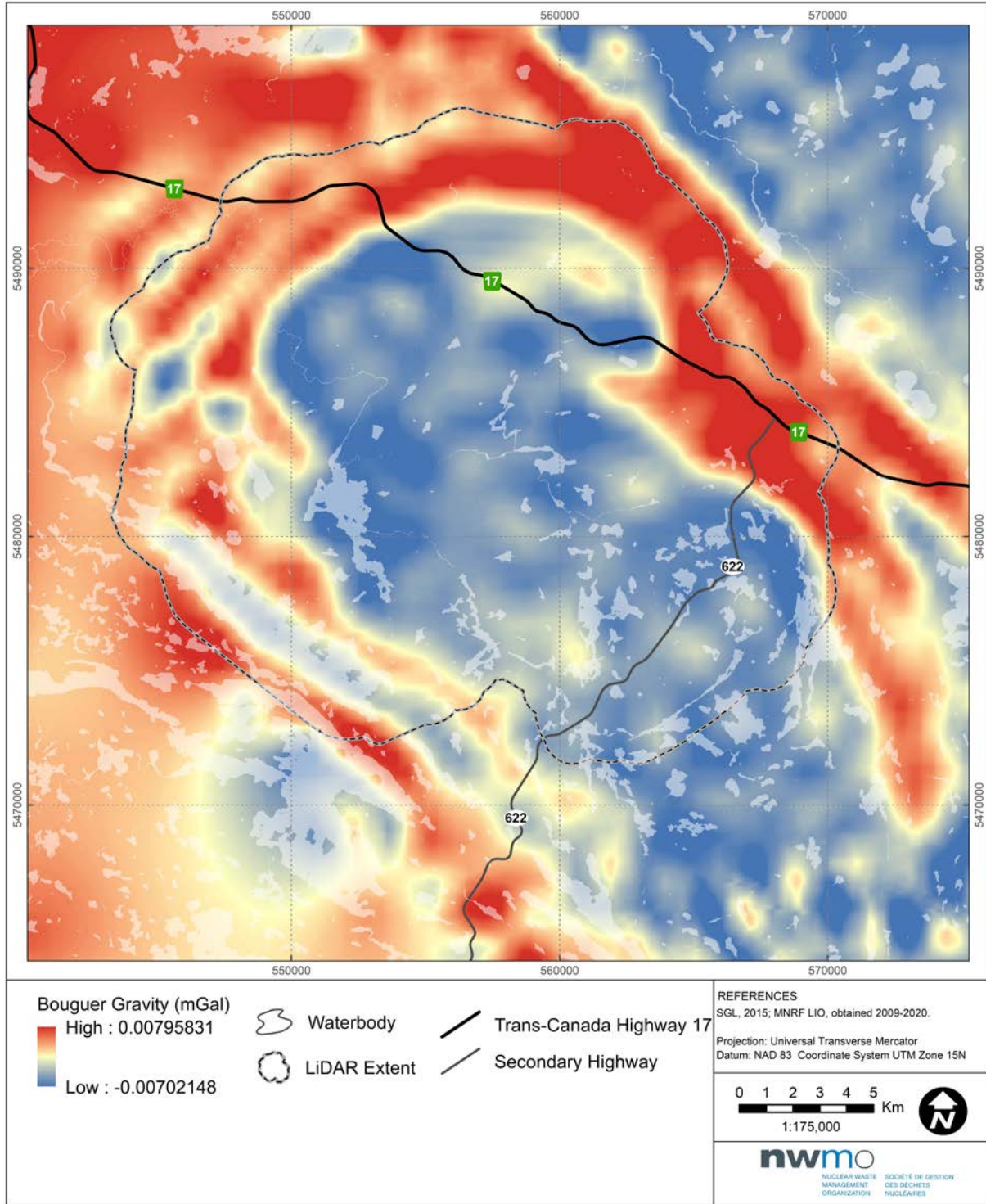


Figure 6: First vertical derivative of the Bouguer gravity data acquired by Sander Geophysics Limited (SGL, 2015), supplemented by gravity data from OGS (2011b) in the western part of the area.

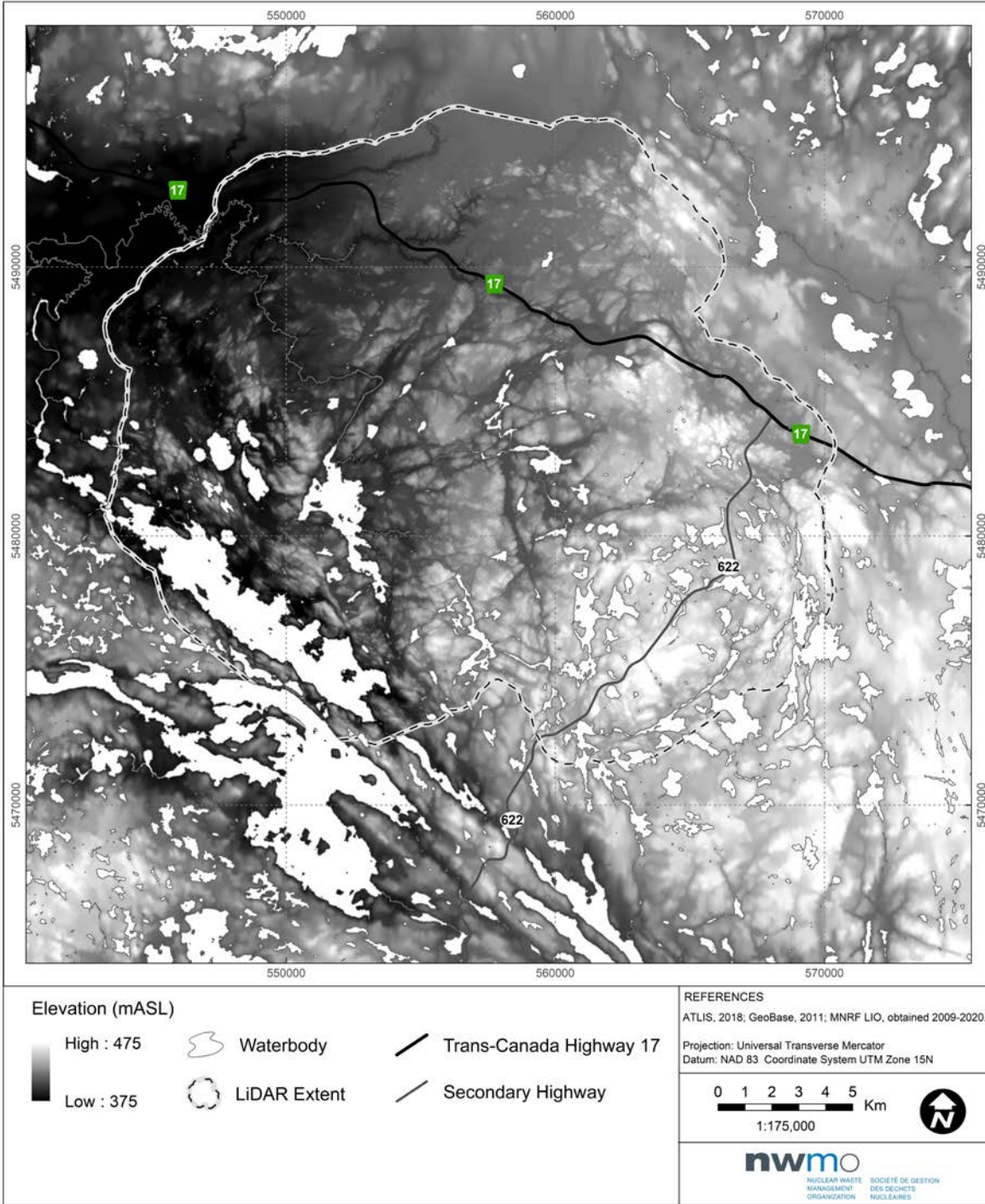


Figure 7: Digital elevation model (DEM) derived using the digital elevation data from aerial LiDAR survey acquired by ATLIS Geomatics (ATLIS, 2018), supplemented by topographic data from Geobase (2011) for the area outside of the LiDAR extent.

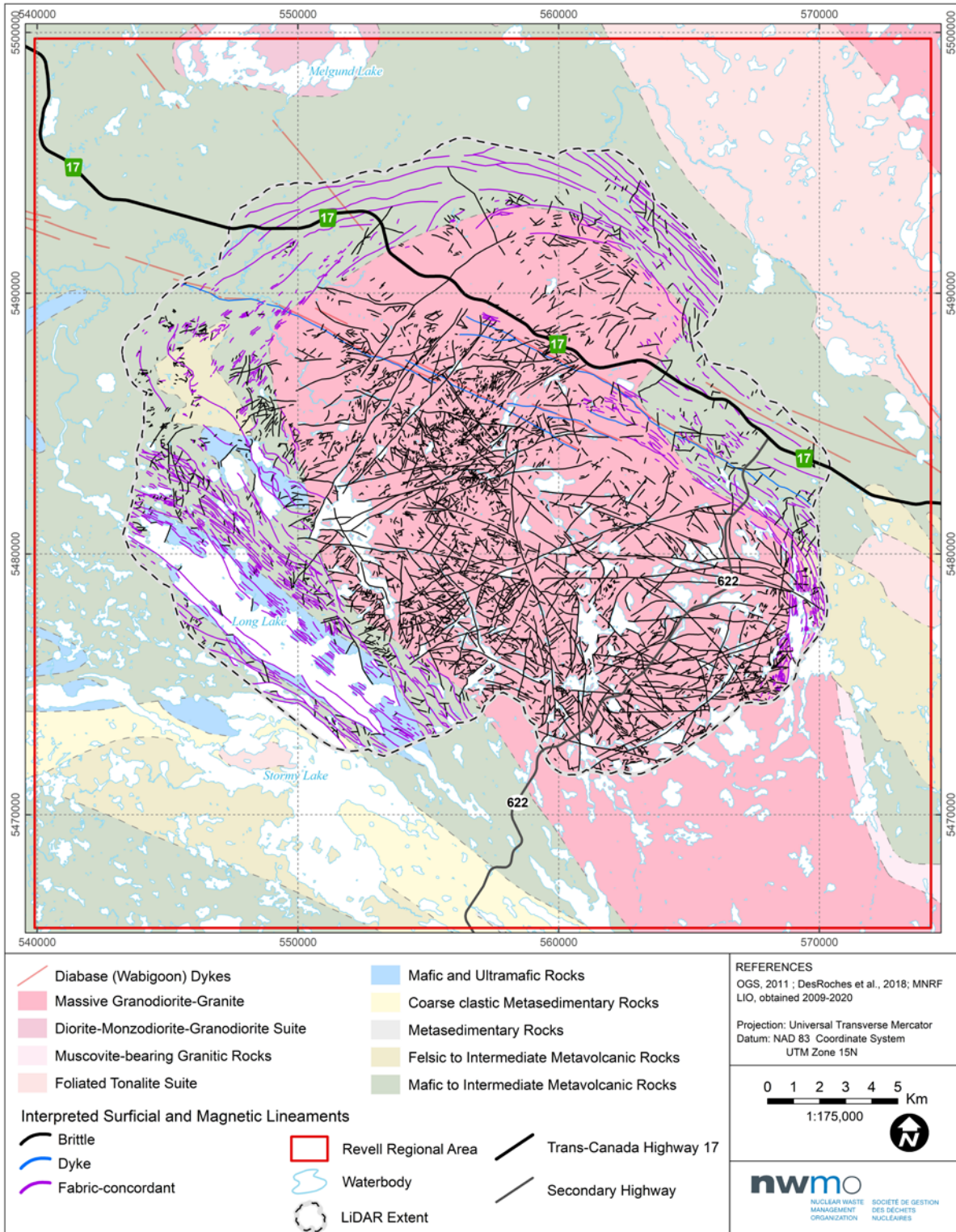


Figure 8: Integrated lineament interpretation showing the distribution of interpreted brittle, fabric-concordant and dyke lineaments (DesRoches et al., 2018). Underlying bedrock geology is from the 1:250,000 scale bedrock of Ontario compilation (OGS, 2011a).

4. PRESENTATION AND DESCRIPTION OF THE BEDROCK MAP

4.1 Map Components

A revised bedrock map compilation of the Revell Regional Area is presented in Figure 9. The map includes the updated compilation of 11 bedrock lithological units, including Proterozoic diabase dykes of the Wabigoon swarm (the “Wabigoon dykes”). The bedrock map also includes the surface traces of interpreted brittle and fabric-concordant lineaments greater than 500 m in length and the surface collar locations of drilled (IG_BH01, IG_BH02, IG_BH03, IG_BH04) and planned (IG_BH05, IG_BH06) NWMO boreholes. The surface location of the Washeibemaga Lake Fault, which is the only large-scale fault structure identified in the Revell Regional Area, is traced in the southwest corner of the map. The characteristics of this fault are described later in this section.

A poster-sized version of the bedrock map is also presented in Appendix B (Map C therein). The poster includes additional information not shown in Figure 9 such as the surface traces of lineaments < 500 m in length and a selection of structural data, including brittle and ductile features, from the structural measurement compilation. The poster also includes the locations of rock samples collected for previous geochronology and other laboratory analyses, and information on natural resources. This poster map also includes several additional inset images, including, the regional geological setting map (Map A, same as Figure 2), a seamless representation of the bedrock geology for the entire Revell batholith shown with areas of extensive Quaternary overburden (Map B) and a more detailed map of the area surrounding the NWMO boreholes (Map D).

The distinct character of the two main rock groups in the Revell Regional Area, namely the supracrustal rocks of the greenstone belts (units 5, 6 and 7 in Appendix B) and felsic plutonic rocks (units 12, 14, 15, 16 in Appendix B), including the granitoid phases of the Revell batholith, provides a natural way to subdivide the descriptions of the bedrock units presented below. The features of these two groups of rock are described in detail in the following subsections. Each subsection provides an overview of the geophysical signature of the rock group followed by a description of the rock types present. The main characteristics of the Wabigoon dykes are also described below after the rock group descriptions (unit 31 in Appendix B).

The terminology used to define each bedrock unit within the two rock groups is based on the map legend defined and used by Stone et al. (2011a, 2011b and 2011c). It should be noted that this legend, as shown in the poster-sized map (Map C) in Appendix B, is a modification of the legend used on the Geology of Ontario maps and on the Bedrock Geology Map of Ontario (OGS 2011a). As a consequence, not all of the units in the complete legend are present in the Revell Regional Area, nor is the number assigned to a map unit necessarily in chronological order.

Stone et al. (2010) reported absolute ages for some of the map units described below based on analysis of samples by laser ablation inductively coupled plasma mass spectroscopy (LA-ICP-MS) and chemical abrasion thermal ionization mass spectrometry (CA-TIMS). Where absolute age information is available from Stone et al. (2010) or from the Geochronology Inventory of Ontario (OGS, 2019), it is included in the descriptions below.

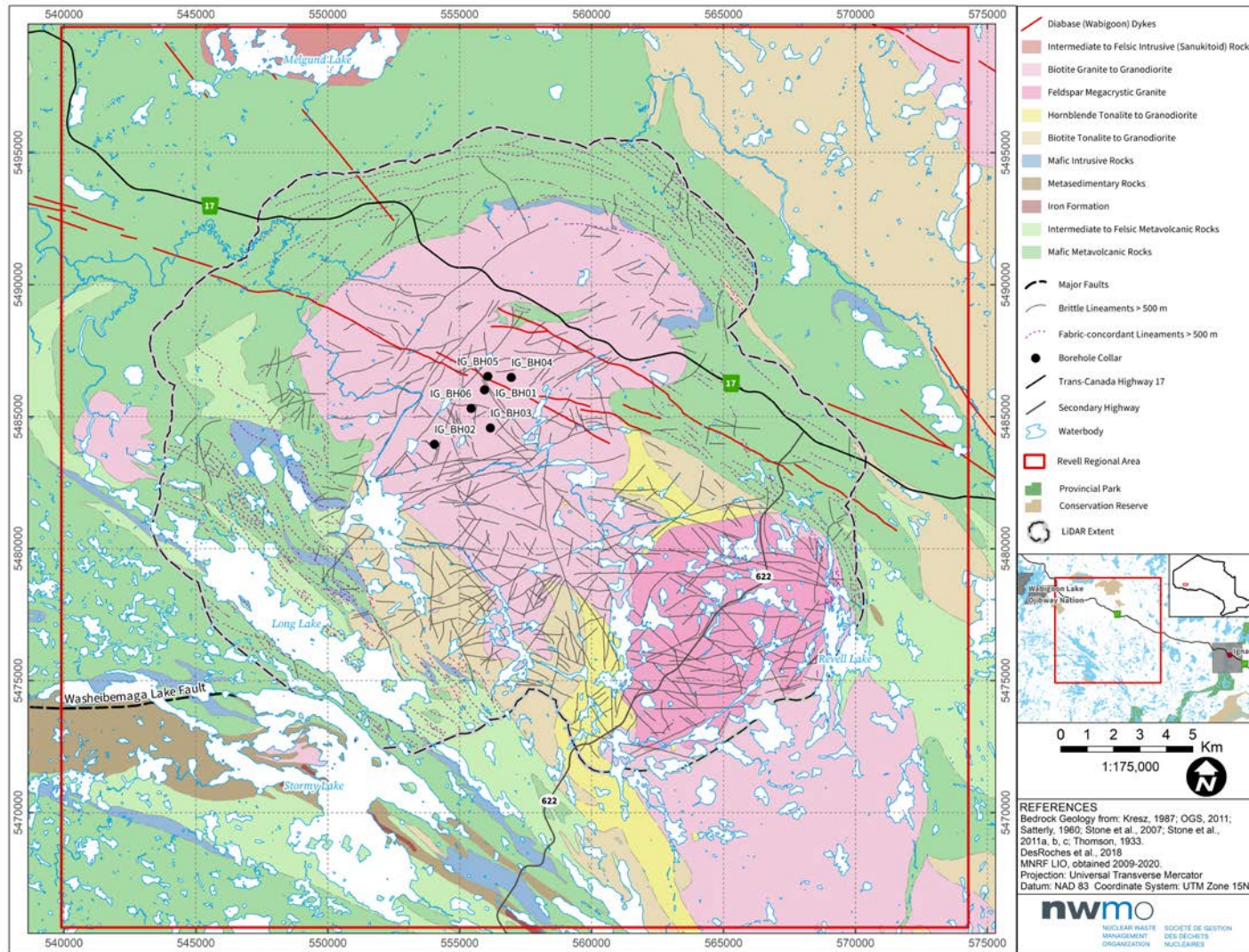


Figure 9: Bedrock map of the Revell Regional Area. Surface collar locations of drilled and planned NWMO boreholes are also shown.

4.2 Supracrustal Rock Group

Four main greenstone belt bedrock units are defined in the supracrustal rock group, including: mafic metavolcanic rocks; intermediate to felsic metavolcanic rocks; metasedimentary rocks; and mafic intrusive rocks. There is also a distinctive banded iron formation within the metasedimentary rock unit that will also be described separately below. All supracrustal rocks are affected, to varying degrees, by penetrative ductile to brittle-ductile deformation under greenschist- to amphibolite-facies metamorphic conditions. In some locations, primary features, such as pillow basalt or bedding in sedimentary rock units are preserved. In other locations, primary relationships are completely masked by penetrative deformation (e.g., Kresz, 1987; Blackburn and Hinz, 1996; Golder and PGW, 2017).

The first vertical derivative of the total magnetic field highlights a highly variable magnetic pattern that characterizes the supracrustal rock group. The magnetic pattern generally follows the arcuate shape of the supracrustal rocks wrapping around the margins of the Revell batholith (Figure 5). The magnetic data were the primary data source used to refine the location of the batholith margin. The contact between the supracrustal rocks and the batholith is also moderately well-defined in the first vertical derivative of the Bouguer gravity (Figure 6; SGL, 2015). This is primarily due to the contrast between the lower density plutonic rocks of the Revell batholith and the higher density supracrustal rocks surrounding the batholith.

4.2.1 Rock Types

Mafic Metavolcanic Rocks

Mafic metavolcanic rocks surround the northern part of the Revell batholith and are the most abundant supracrustal rock unit within the Revell Regional Area (Figure 9 and Figure 10A). Satterly (1960) also identified mafic metavolcanic rocks within the Revell batholith, including small inclusions along its northern margin and a larger km-scale body located in the centre of the northern part of the batholith. The smaller occurrences within the batholith are likely xenoliths entrained by the batholith during its emplacement. It is less certain whether the larger body is also a xenolith that was once completely enveloped by the batholith or if it rests upon the roof of the Revell batholith.

Mafic metavolcanic rocks are light to dark green colour with a fine to medium grain size. They are basaltic in composition and include pillow basalts, massive volcanic flows, flow breccias, and gabbro intrusions (Kresz, 1987; Stone, 2010a). The variable degree of bedrock exposure makes it difficult to determine if individual massive units represent centres of massive mafic volcanic flows or intrusions. The term amphibolite is also used to describe these metavolcanic rocks where primary features are partially or completely obscured (e.g., Satterly, 1960). The degree of foliation development varies markedly within the mafic metavolcanic rock unit, from relatively weak to areas with gneissic and schistose members present (Stone, 2011c). Typical mineral assemblages include albite, actinolite, chlorite and epidote (Kresz, 1987).

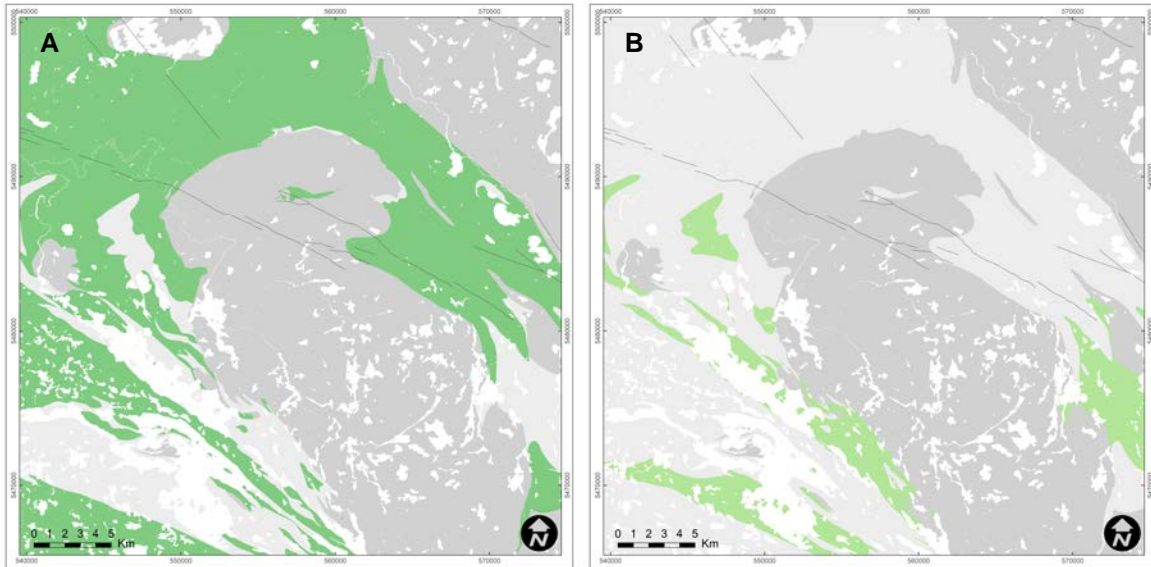


Figure 10: (A) Distribution of mafic metavolcanic rocks. (B) Distribution of intermediate to felsic metavolcanic rocks. Other supracrustal rock units are shaded light grey and plutonic rocks are shaded dark grey. Wabigoon dykes are identified by black lines.

Intermediate to Felsic Metavolcanic Rocks

Intermediate to felsic metavolcanic rocks are mapped in discontinuous regions to the southwest, west and east of the Revell batholith (Figure 9 and Figure 10B). Satterly (1960) also identified a few small occurrences of felsic metavolcanic rock throughout the mafic metavolcanic rocks to the north of the batholith. However, these are too small to be included on the bedrock map.

Intermediate to felsic metavolcanic rocks are calc-alkaline and rhyolitic in composition (Kresz, 1987; Stone, 2010a). They mainly occur as pale green volcanoclastic breccias characterized by subangular to subrounded felsic clasts (up to 30 cm) in a medium-grained matrix. Stone (2011c) identifies several types of intermediate to felsic metavolcanic rock occurrences, including, breccias and feldspar- and/or quartz-phyric flows or tuffs. Intermediate volcanic rocks are locally transitional to volcanoclastic sedimentary rocks, the latter containing numerous types of volcanic fragments distinguished by grain size, texture and composition. Two samples of intermediate volcanic breccia gave CA-TIMS ages of 2734.6 +/- 1.1 Ma and 2734.5 +/- 0.9 Ma, respectively (Stone et al., 2010).

Kresz (1987) and Stone (2011c) also identified subvolcanic felsic intrusions, occurring as dykes or small stocks, as components of the intermediate to felsic metavolcanic rock unit. These intrusions are grey in colour and characterized by a very fine-grained quartzofeldspathic matrix with varied amounts of potassium (K) feldspar phenocrysts, and sometimes biotite. Feldspar and feldspar-quartz porphyry variants are recognized. In thin section, these felsic intrusions are dominantly quartzofeldspathic with K-feldspar and varying amounts of chlorite, actinolite and iron oxides (Kresz, 1987). The main alteration products are albite, sericite and clinozoisite, epidote and quartz. Foliated versions are identified as sericite schists.

Metasedimentary Rocks

Metasedimentary rocks are primarily identified in the southwestern part of the Revell Regional Area (Figure 9 and Figure 11). There is also one additional small occurrence identified to the east of the Revell batholith.

Stone et al. (2011c) distinguish two distinct assemblages of metasedimentary rocks in the Revell Regional Area. One assemblage is characterized by varied amounts of bedded siltstone and sandstone, and the other assemblage comprises coarser-grained sandstone and polymictic, poorly sorted conglomerate (Stone, 2010b). However, this level of detail is not required and so these two assemblages are combined into one unit on the bedrock map presented here. Metasedimentary rocks are commonly observed to be intruded by felsic and mafic sills and are interlayered with mafic metavolcanic rocks (Stone, 2010b).

Iron Formation

One particularly distinct subunit of the metasedimentary rock unit is identified as an iron formation. This iron formation occurs as a narrow southeast-striking, discontinuous layer to the southwest of the Revell batholith (Figure 9 and Figure 11B).

The banded iron formation is blue-grey to black, fine-grained and hard (Fladgate, 2011). It is characterized by an argillaceous mixture of clastic and chemical sedimentary rocks composed of chert, magnetite, lesser hematite, and varying percentages of biotite, amphibole, chlorite, garnet, pyrite, and pyrrhotite (Stone, 2010b; Fladgate, 2011). Although this iron formation is only a very narrow unit in the metasedimentary rock, it is evident as a high magnetic response unit in the southeastern part of the Revell Regional Area (Figure 5).

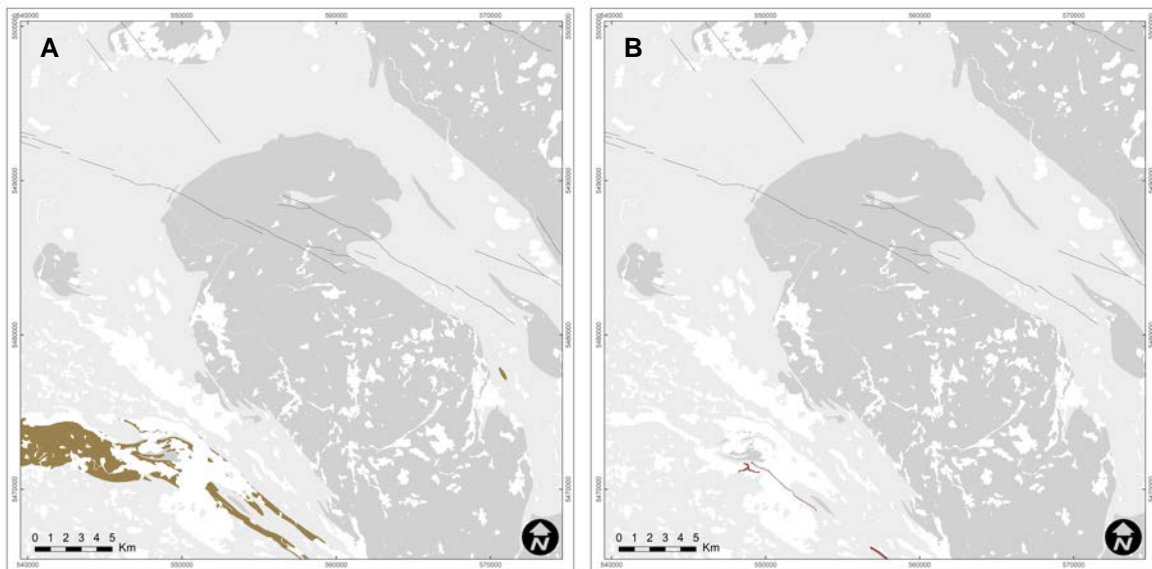


Figure 11: (A) Distribution of metasedimentary rocks, excluding iron formation. (B) Distribution of iron formation.

Mafic Intrusive Rocks

Mafic intrusive rocks, occurring as dykes and sills, are primarily distributed throughout the southwestern part of the Revell Regional Area and along the northern and southwestern margins of the Revell batholith (Figure 9 and Figure 12). One very small occurrence, mapped by Stone et al. (2011a), is located within the northern part of the Revell batholith, almost in the centre of the frame in Figure 12.

Mafic intrusive rocks include dark grey to black, fine- to medium-grained, foliated, amphibolite dykes, and massive, fine- to medium-grained hornblende metadiorite and metagabbro (Satterly, 1960; Stone, 2010a). Kresz (1987) described gabbro sills that cut pillow basalts of the mafic metavolcanic rock unit and that also contain felsic, rounded, xenoliths. One sill, identified by Kresz (1987), is 2.8 km long and has a maximum thickness of 600 m. A sample of medium- to coarse-grained gabbro from this mafic intrusive rock unit gave an LA-ICP-MS age of 2725 +/-5 Ma (Stone et al., 2010).

In thin section, mafic intrusive rocks comprise plagioclase and pale blue-green pleochroic ferro-actinolite, which is either fibrous or occurs as cm-scale long twinned, columnar crystals (Kresz, 1987). Minor ilmenite and magnetite are also sometimes present.

Sub-metre thick lamprophyre dykes were observed by Satterly (1960) to have intruded the plutonic rock in the northern part of the Revell batholith. The lamprophyre dykes are black in colour with a biotite-rich composition and plagioclase phenocrysts (Kresz, 1987). Lamprophyre dykes weather more easily than their surrounding rocks and some are weakly foliated. Altered lamprophyre dykes tend to contain chloritized biotite, carbonate, epidote, albite and quartz (Kresz, 1987). It remains uncertain whether or not these lamprophyre dykes should be included as part of the mafic intrusive rock unit or if they represent a separate intrusive event. The lamprophyre occurrences are too small to be shown on the bedrock map.

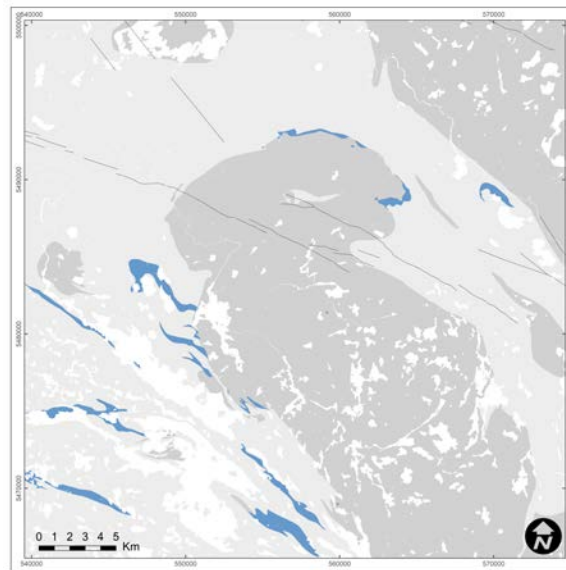


Figure 12: Distribution of mafic intrusive rocks.

4.2.2 Structure

The most commonly described structure overprinting the supracrustal rocks is a well-developed schistosity (e.g., Satterly, 1960; Kresz, 1987; Stone, 2010b). Figure 13 shows the trend of mapped foliations across the Revell Regional Area. This ductile fabric is generally parallel to layering in the supracrustal rocks and, in proximity to the Revell batholith, is sub-parallel to the batholith margin. Except near the northeastern margin of the batholith, the foliation dips away from the batholith (see below for more detail).

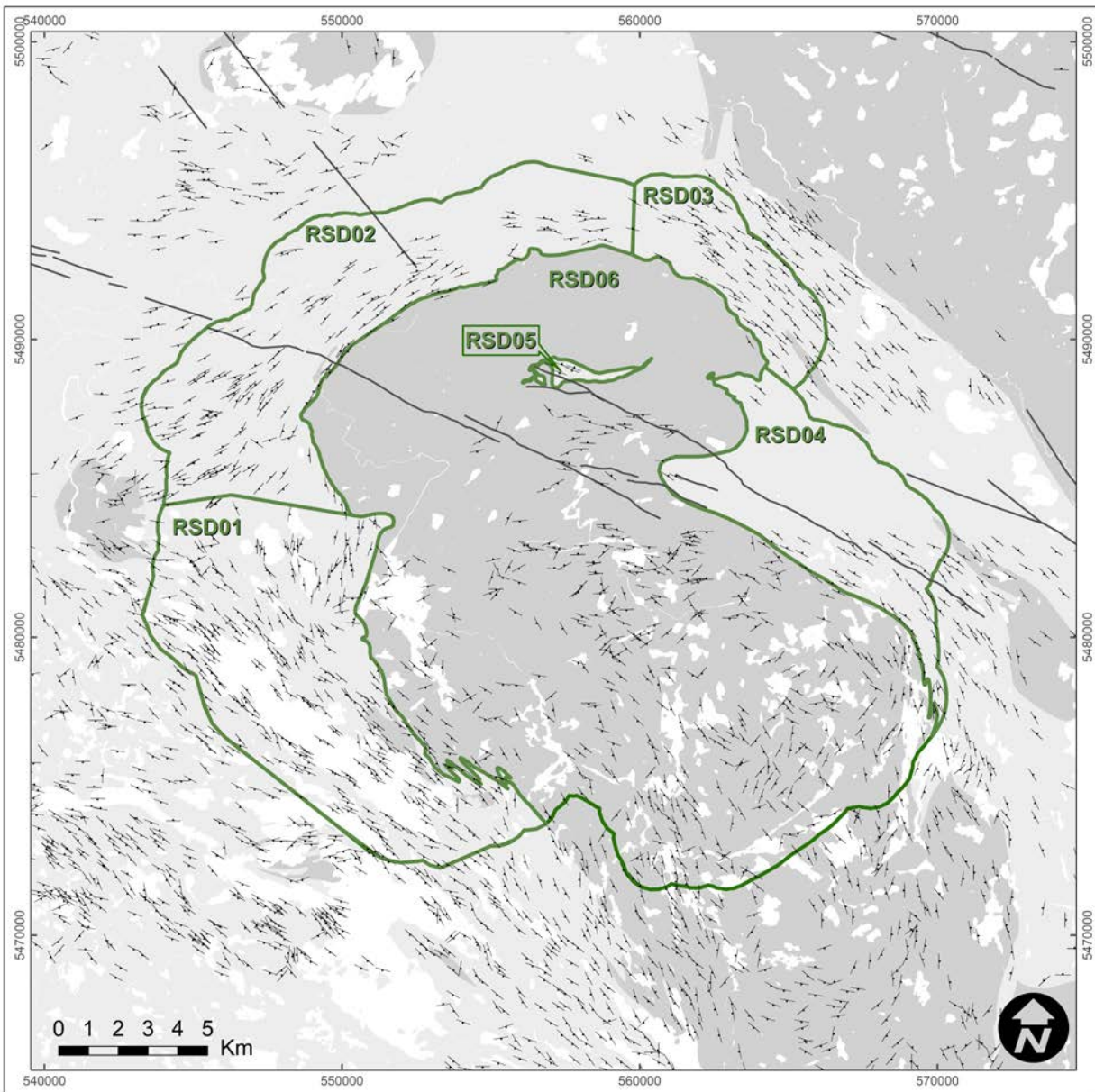


Figure 13: Trend of foliation from surface mapping and regional structural domains (RSD01 to RSD06) of the Revell Regional Area. The regional structural domains are identified inside the area where LiDAR data have been studied. Plutonic rocks are shown in dark grey and the supracrustal rocks are shown in light grey. Thick black lines represent the Wabigoon dykes.

Shear zones and major folds follow the same general trend as the foliation within the supracrustal rock group and kink bands are commonly observed in close proximity to the shear zones (Kresz, 1987). Where preserved, younging and facing indicators and steeply-dipping beds indicate a tight folding style (Kresz, 1987). The iron formation described above is preserved in an overturned, northeast-facing, fold limb (Fladgate, 2011).

Faults within the supracrustal rock group are both parallel and at a high angle to the batholith boundary (e.g. Kresz, 1987). One large mapped fault, the Washeibemaga Lake Fault, trends southeast to east near the western margin of the Revell Regional Area (Figure 9). Blackburn (1982) observed intense shearing in rocks along the presumed fault contact and interpreted the structure as a thrust fault. More recently, Stone (2010b) commented that the kinematics of the fault and the timing of movement are poorly understood and suggested that a component of south-side-down displacement on the fault would have created a basin for the deposition of the metasedimentary rock unit adjacent to the fault. Stone (2010b) also notes that the fault may have penetrated the crust, as it appears to have provided a conduit for mafic magmas to reach the surface.

4.2.2.1 Structural Domains

Five regional structural domains (RSD01 to RSD05) are defined for the areas underlain by supracrustal rocks (Figure 14). RSD01 to RSD04 are defined based on the systematic variation in the trend of the foliation as it wraps around the northern margin of the Revell batholith (Figure 13). RSD05 is defined by the extent of the body of mafic metavolcanic rock preserved within the northern part of the batholith rather than based on its unique foliation trend. One additional regional structural domain, RSD06, includes the area underlain by the Revell batholith within the Revell Regional Area. This domain will be discussed in Section 4.3.2. RSD01 to RSD04 are extended to cover the same area that is covered by the lineament interpretation of DesRoches et al. (2018). This was done in order to allow for a comparison between the orientations of interpreted lineaments and ductile and brittle structures within each domain. Figure 14 shows the structural domain boundaries and the interpreted fabric-concordant, brittle and dyke lineaments of DesRoches et al. (2018). The subset of lineaments that intersect the supracrustal rocks are emphasized.

Folding at several scales is evident in the supracrustal rock-batholith contact (Figure 13). For example, in the southeastern part of RSD01 the contact is defined by a series of adjacent tight folds. At a large scale, the trend in the foliation traces in the supracrustal rocks near the western margin of the batholith exhibit an inflection at the boundary between RSD01 and RSD02, defining a broad, open fold. Additionally, the northwestern boundary of RSD04 appears to be defined by two large, open to tight folds along the supracrustal rock-batholith margin (Figure 13).

Equal-area lower hemisphere stereographic projections showing the poles to measured foliations, and rose diagrams showing the trend of the fabric-concordant lineaments, are presented for each of RSD01 to RSD04, in Figure 15, Figure 16, Figure 17 and Figure 18, respectively. All rose diagrams presented below use a 10° bin size for the petals. Only five foliation measurements are available for RSD05, all striking east-southeast, and so this domain is not included in the comparison presented below.

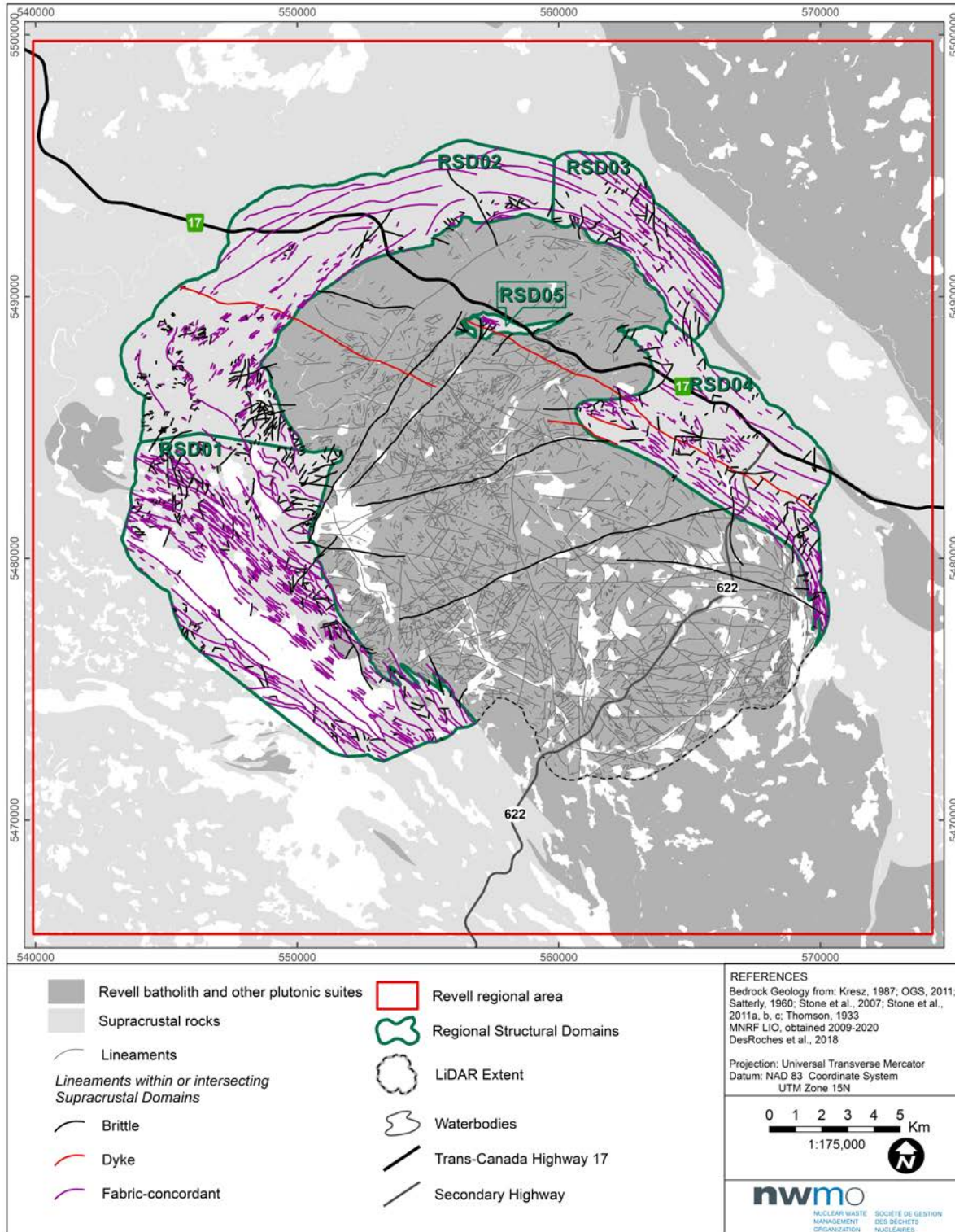


Figure 14: Regional structural domains (RSD01 to RSD05) and interpreted fabric-concordant, brittle and dyke lineaments. Those lineaments that fall within or intersect the area underlain by supracrustal rocks are emphasized.

The southwestern structural domain, RSD01, is characterized by a southeast-striking and southwest-dipping foliation with a mean strike and dip of 133° and 61° , respectively. Fabric-concordant lineaments in RSD01 exhibit a single dominant NW trend (Figure 15). The northwestern structural domain, RSD02, is characterized by northeast-striking and northwest-dipping foliation with a mean strike and dip of 225° and 65° , respectively. Fabric-concordant lineaments in RSD02 exhibit a single dominant NE trend (Figure 16). The northeastern structural domain, RSD03, is characterized by southeast-striking and southwest-dipping foliation with a mean strike and dip of 131° and 75° , respectively. Fabric-concordant lineaments in RSD03 exhibit a single dominant NW trend (Figure 17). The eastern structural domain, RSD04, is characterized by northwest-striking and northeast-dipping foliation with a mean strike and dip of 314° and 66° , respectively. Fabric-concordant lineaments in RSD04 exhibit a single dominant NW trend (Figure 18).

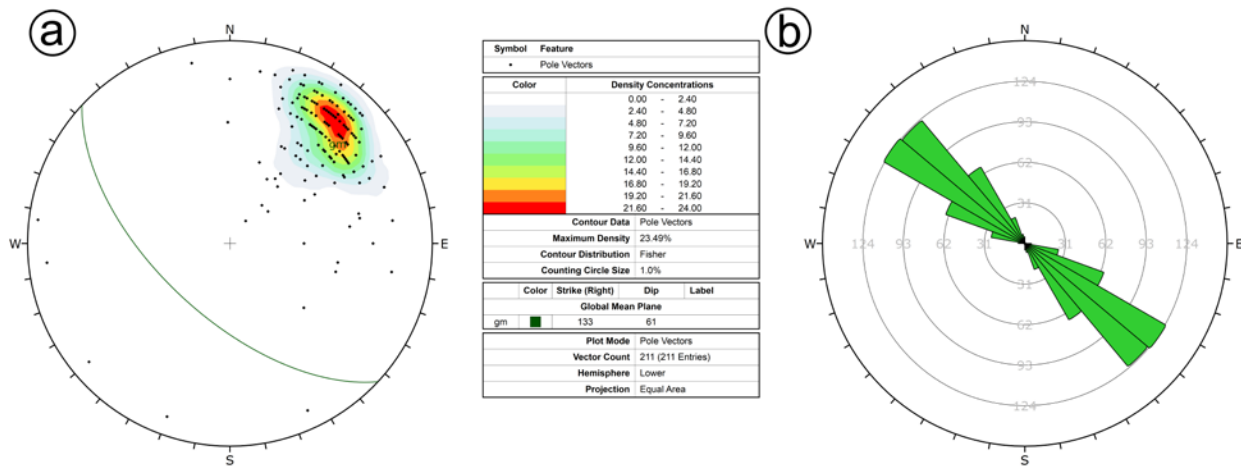


Figure 15: Summary of orientation information for RSD01. (a) Equal-area lower hemisphere stereographic projection showing poles to foliation planes (N = 211). Mean foliation strike = 133° and mean foliation dip = 61° . (b) Interpreted fabric-concordant lineaments with NW trend, plotted as an unweighted rose diagram (N = 444).

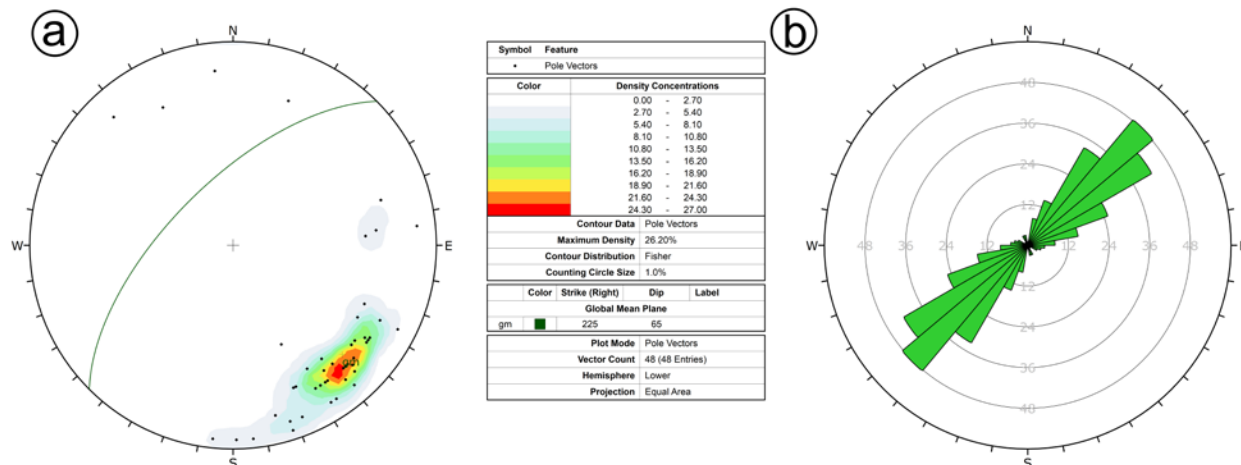


Figure 16: Summary of orientation information for RSD02. (a) Equal-area lower hemisphere stereographic projection showing poles to foliation planes (N = 48). Mean foliation strike = 225° and mean foliation dip = 65° . (b) Interpreted fabric-concordant lineaments with NE trend, plotted as an unweighted rose diagram (N = 216).

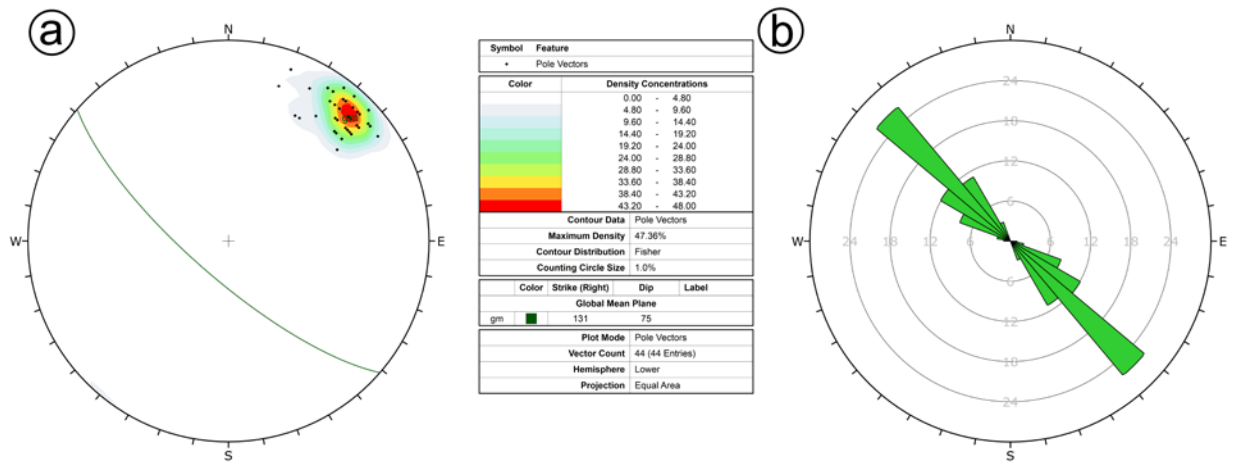


Figure 17: Summary of orientation information for RSD03. (a) Equal-area lower hemisphere stereographic projection showing poles to foliation planes (N = 44). Mean foliation strike = 131° and mean foliation dip = 75°. (b) Interpreted fabric-concordant lineaments with NW trend, plotted as an unweighted rose diagram (N = 53).

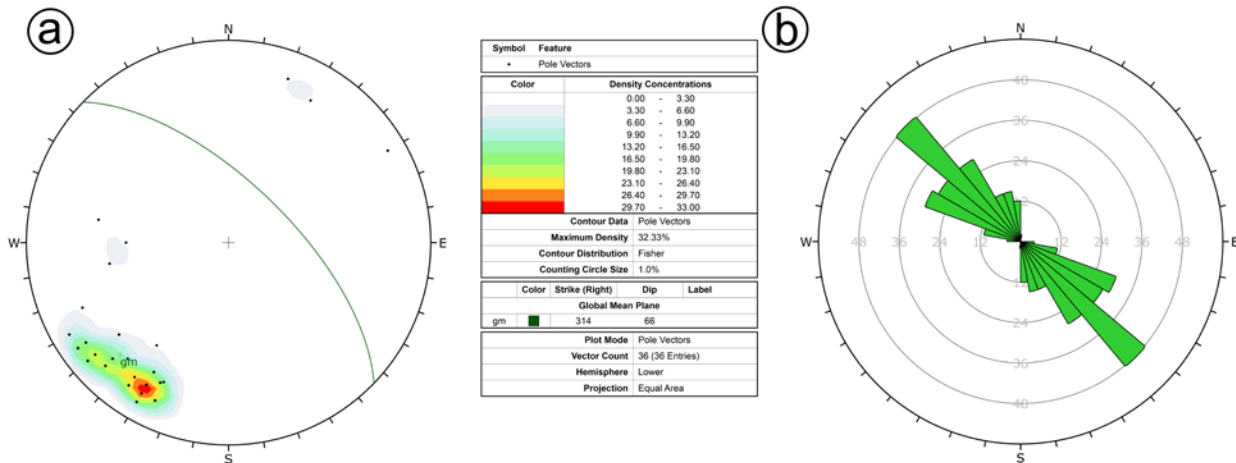


Figure 18: Summary of orientation information for RSD04. (a) Equal-area lower hemisphere stereographic projection showing poles to foliation planes (N = 36). Mean foliation strike = 314° and mean foliation dip = 66°. (b) Interpreted fabric-concordant lineaments with NW trend, plotted as an unweighted rose diagram (N = 193).

The mean foliation orientations and trends of the fabric-concordant lineaments are summarized for each structural domain in Table 2. Overall, there is a clear consistency in orientation between the average orientation of mapped foliations and the trend of fabric-concordant lineaments. This relationship was first described by DesRoches et al. (2018) and the analysis presented here further supports that initial interpretation. This result will be useful for guiding future discrete fracture network (DFN) modelling activities.

Table 2: Summary of mean foliation strike and dip, and mean fabric-concordant lineament trend, for structural domains RSD01 to RSD04.

Domain	Mean foliation strike (dip direction) in degrees	Mean foliation dip in degrees	Mean fabric-concordant lineament trend
RSD01	133 (223)	61	NW
RSD02	225 (315)	65	NE
RSD03	131 (221)	75	NW
RSD04	314 (044)	66	NW

A total of 30 fractures, all joints, were identified and measured in exposed bedrock within the entire area underlain by supracrustal rocks. Of these, only 10 measurements had a measured dip (Figure 19a). The poles to the planes of the fractures exhibit steep dips and strike in multiple directions, including northwest, north and east. Lineaments, primarily interpreted from the LiDAR DEM and orthoimagery to represent brittle structures, are predominantly short features within the supracrustal rocks (Figure 14). Several longer brittle lineaments also extend from the supracrustal rocks into the Revell batholith. A rose diagram of all brittle lineaments in the supracrustal rock domains highlights a dominant northeast trend, with subordinate north and east trends (Figure 19b). There are very few data available to draw any clear relationship between the interpreted brittle lineaments and surface-mapped fractures, except to state that the northeast trending brittle structures are poorly represented in the outcrop structure measurement dataset. However, Kresz (1987) described fractures interpreted from airphotos that exhibit a dominant northeast trend (see Figure G.2 in Kresz, 1987). These fractures are sub-parallel to the dominant brittle lineament trend in Figure 19b.

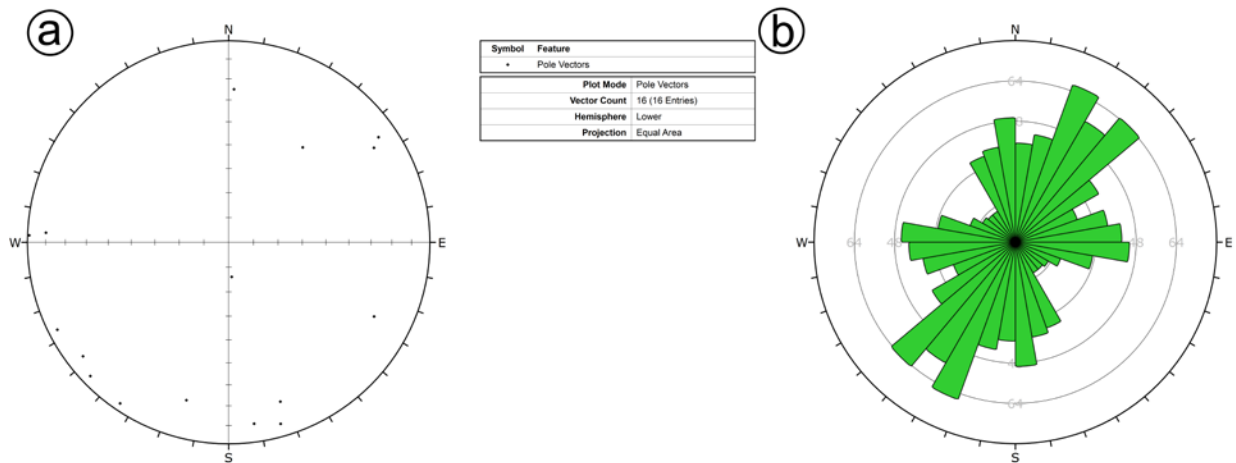


Figure 19: Summary of orientation information for brittle structures in the supracrustal rock group (unsubdivided). (a) equal-area lower hemisphere stereographic projection of poles to fracture planes, and (b) unweighted rose diagram of interpreted brittle lineaments.

4.3 Plutonic Rock Group

Five distinct suites of plutonic rocks are defined in the bedrock map, including: biotite tonalite to granodiorite, hornblende tonalite to granodiorite, biotite granite to granodiorite, a feldspar-megacrystic granite phase and an intermediate to felsic intrusive (sanukitoid) phase (Figure 9). The lithologic character of each of these distinct suites, primarily based on the summary descriptions in Stone (2010a), SRK and Golder (2015) and Golder and PGW (2017), are presented below. Following this, descriptions of the ductile and brittle structure for the Revell batholith are also presented.

Overall, the Revell batholith has a low and uniform magnetic character, with two distinct exceptions. One exception occurs in the northern part of the batholith, where two linear east-southeast trending magnetic highs are observed that are associated with the Wabigoon dykes. The other exception is an oval-shaped area of high magnetic intensity in the centre of the batholith, which is associated with the feldspar-megacrystic granite subunit of the biotite granite to granodiorite (Figure 5; SGL, 2015). The margin of the Revell batholith is very well-defined by the magnetic data. As noted above, the batholith margin is also moderately well-defined in the horizontal derivative of the Bouguer gravity (Figure 6; SGL, 2015).

SGL (2015) completed a forward 2.5D gravity model for the Revell batholith in order to provide constraints on its subsurface dimensions. Their modelling work suggested that the batholith is on the order of 2 km to 3 km thick through the center of the northern part of the batholith. Overall the depth of the batholith is relatively uniform, but it increases slightly towards the southeast (SGL, 2015). A simple conceptual cross-section is also presented and described in Section 4.6 herein.

4.3.1 Rock Types

Biotite Tonalite to Granodiorite

Rocks of the biotite tonalite to granodiorite suite occur along the southwestern and northeastern margins of the Revell batholith and in a large region in the northeastern corner of the Revell Regional Area (Figure 9 and Figure 20A).

The principal type of rock within the biotite tonalite to granodiorite suite is a white to grey, medium-grained and variably massive to foliated or weakly gneissic felsic plutonic rock. The biotite tonalite to granodiorite rock suite contains an average of 11% mafic minerals, including mainly biotite with accessory magnetite, titanite, ilmenite and zircon (Stone, 2010a). Amphibolite inclusions occur locally within this rock unit. Within local zones of alteration, the biotite is chloritized and feldspars are altered to epidote (Stone, 2010a). A sample of strongly foliated, medium-grained biotite tonalite from within this suite gave a CA-TIMS age of 2734.2 \pm 0.8 Ma (Stone et al., 2010), i.e. the same age as the intermediate to felsic metavolcanic rocks in the greenstone belt to the southwest of the Revell batholith.

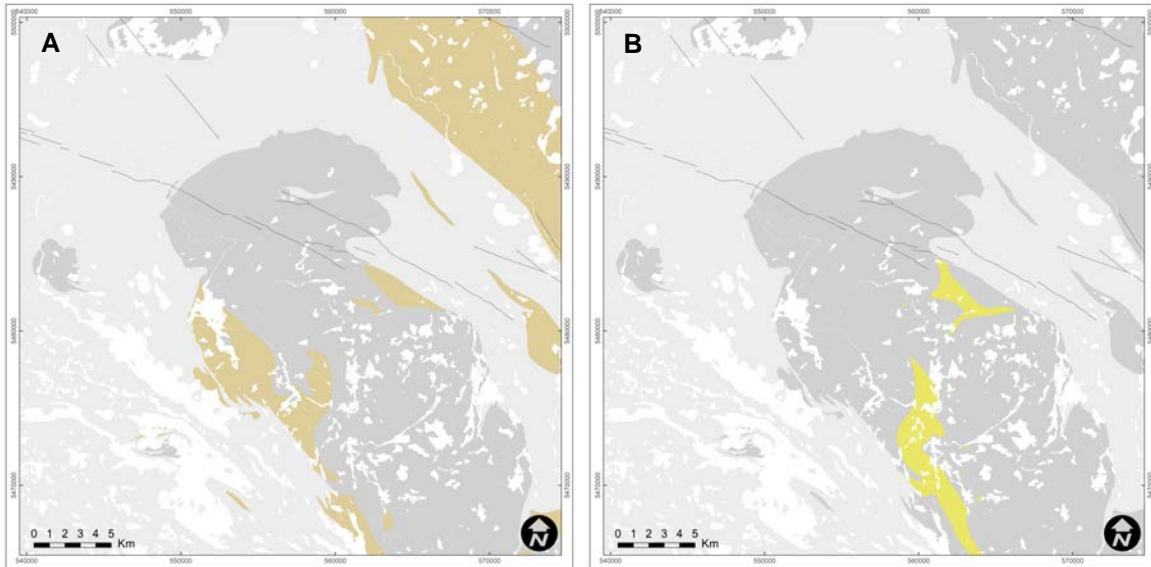


Figure 20: (A) Distribution of Biotite Tonalite to Granodiorite. (B) Distribution of Hornblende Tonalite to Granodiorite.

Hornblende Tonalite to Granodiorite

Rocks of the hornblende tonalite to granodiorite suite occur in two irregularly-shaped zones inside the southwestern and eastern marginal parts of the Revell batholith (Figure 9 and Figure 20B). The suite ranges compositionally from tonalite through granodiorite to granite and also includes significant proportions of quartz diorite and quartz monzodiorite (Stone, 2010a). It is typically grey to white in colour, massive to weakly foliated and coarse-grained, and exhibits a granular texture due to the presence of large blocky feldspars in a darker matrix of quartz and mafic minerals. It also has distinct lensoid dioritic inclusions.

The most common mafic minerals in the hornblende tonalite to granodiorite suite are amphibole and biotite, which comprise an average of 19% of the rock by volume (Stone, 2010a). Accessory minerals include magnetite, titanite, apatite, allanite, ilmenite and zircon. One sample of coarse-grained grey mesocratic hornblende tonalite gave a CA-TIMS age of 2732.3 \pm 0.8 Ma (Stone et al., 2010).

SRK and Golder (2015) identified several types of mafic rock that occur as m-scale, massive to foliated, xenoliths within the hornblende tonalite to granodiorite suite including: diorite, quartz diorite, gabbro, amphibolite and other undifferentiated, mafic metavolcanic rocks (Figure 21a, Figure 21b and Figure 21c). Xenolith contacts are sharp and intact, with no evidence of fault reactivation. In some occurrences, preserved primary features suggest these mafic rocks are xenoliths of the surrounding metavolcanic rocks (e.g., Figure 21c). In other occurrences where primary features are not evident they may represent deformed mafic dykes.



Figure 21: Examples of minor rock types identified within the Revell batholith. (a) to (c) represent examples of m-scale mafic xenoliths observed within the hornblende tonalite to granodiorite suite, including (a) quartz diorite, (b) foliated metavolcanic rock and (c) pillow basalt (pencil for scale). (d) Light pink aplite dykes in foreground of the image intrude the biotite granite to granodiorite suite with sharp and linear contacts. Dark grey irregularly-shaped tonalite inclusions are evident in the top centre of the image. Hammer for scale.

Biotite Granite to Granodiorite

The biotite granite to granodiorite suite has been mapped throughout the northern and southern parts of the Revell batholith (Figure 9 and Figure 22A). This rock type also occurs in the northeastern corner of the Revell Regional Area and as smaller intrusive bodies within the supracrustal rocks to the west and southwest of the batholith.

The biotite granite to granodiorite suite ranges compositionally from tonalite through granodiorite to granite (Stone, 2010a). The biotite granite to granodiorite suite is distinguished from the biotite tonalite to granodiorite suite by its massive character and overall homogeneity and distinguished from the hornblende tonalite to granodiorite by its colour, overall homogeneity and lack of matrix amphibole. Golder and PGW (2017) used a hand-held gamma ray spectrometer during mapping in this suite in order to determine the distribution of these three compositional phases. Using the potassium values as an indicator, the main rock types were tonalite (<1.7 % K), granodiorite (1.7 to 3.0 % K), or granite (>3.0 % K). Based on this analysis, Golder and PGW (2017) determined that granodiorite is the predominant phase based on number of occurrences, followed by tonalite and then granite. They observed no evidence of an intrusive

relationship between the granodiorite and tonalite phases and instead determined that they were in gradational contact and together represent a coherent intrusive complex. Furthermore, no boundary was defined for this granodiorite-tonalite complex inside the biotite granite to granodiorite suite. Core recovered during the initial stages of the borehole drilling campaign is also predominantly of granodiorite-tonalite composition, consistent with the surface mapping observations. Granite is observed to intrude the granodiorite-tonalite complex, providing evidence that it is a separate, younger, intrusive phase within the biotite granite to granodiorite suite (Golder and PGW, 2017). The surface extent of the younger granite, i.e., its boundary with the granodiorite-tonalite complex, has not been defined.

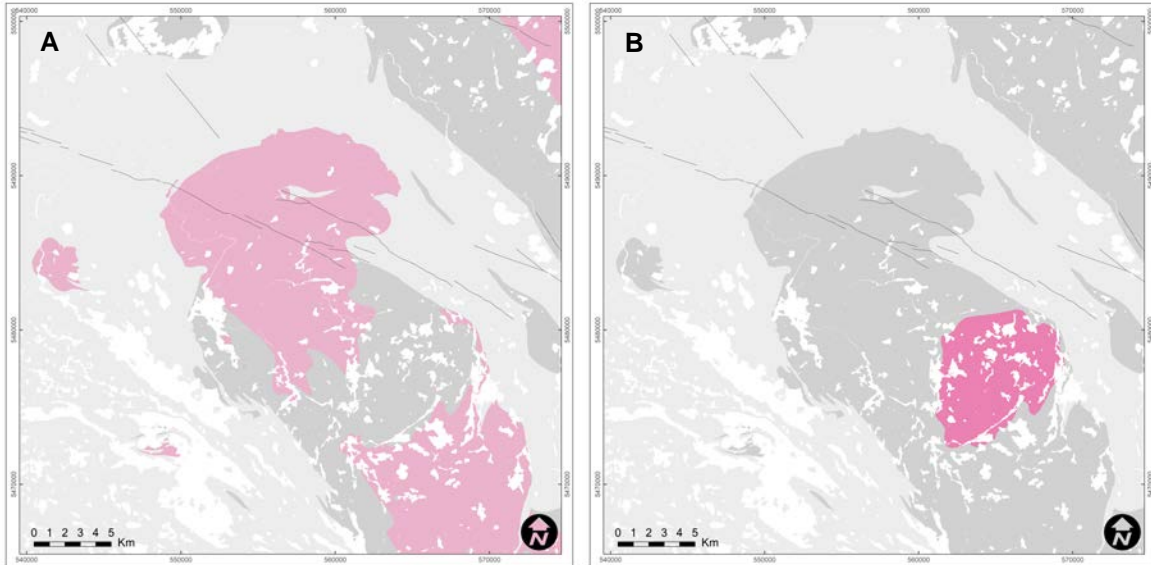


Figure 22: (A) Distribution of Biotite Granite to Granodiorite. (B) Distribution of Feldspar-Megacrystic Granite.

Detailed descriptions of the granodiorite, tonalite and granite phases distinguished within the biotite granite to granodiorite suite in the northern part of the Revell batholith are presented in Golder and PGW (2017). The granodiorite is predominantly white to light grey, pink or beige on fresh surfaces and light grey, white, brown or pink on weathered surfaces (Figure 23a and Figure 23b). The granodiorite matrix is most commonly medium-grained (1–5 mm), with some local fine-grained (0.5–1 mm) and coarse-grained (5–10 mm) variations. The main matrix minerals within the granodiorite are quartz, plagioclase, K-feldspar and biotite. The predominant phenocryst is medium to coarse-grained (10–50 mm) K-feldspar. The granodiorite is usually massive with an equigranular to inequigranular, occasionally porphyritic, texture. Locally, the granodiorite exhibits a weak foliation defined by aligned quartz, biotite and/or feldspar phenocrysts.

The tonalite is predominantly white to light grey or grey on fresh surfaces and most commonly light grey to grey or beige on weathered surfaces (Figure 23c). The tonalite matrix is most commonly medium-grained (1–5 mm), with some local variation to fine-grained (0.5–1 mm) and coarse-grained (5–10 mm). The main minerals within the tonalite matrix are quartz, plagioclase, biotite and hornblende. The predominant phenocryst phase is medium to coarse-grained (10–50 mm) plagioclase. The tonalite is either massive or weakly foliated in texture. Where foliated, the long axes of the phenocrysts and aligned quartz define a planar structure.

The granite is predominantly pink to off white or light grey on fresh surfaces and most commonly light grey to beige or pink on weathered surfaces (Figure 23d and Figure 23e). The granite matrix is fine-grained (0.5–1 mm) to medium-grained (1–5 mm). The main minerals within the granite are quartz, plagioclase, K-feldspar and biotite. Plagioclase, K-feldspar or quartz, phenocrysts commonly range from medium to coarse-grained (10–50 mm).



Figure 23: Field examples of the plutonic rocks of the Revell batholith. (a) Typical exposure of granodiorite at outcrop scale. Yellow notebook and gamma ray spectrometer for scale. (b) Close-up of granodiorite showing mineral composition and texture. (c) Close-up of tonalite showing mineral composition and texture. (d) Typical exposure of granite at outcrop scale. (e) Close-up of granite showing mineral composition and texture. (f) Close-up of feldspar-megacrystic granite showing mineral composition and texture.

Golder and PGW (2017) identified cm- to m-scale xenoliths of tonalite within the biotite granite to granodiorite suite (Figure 21d). These tonalite occurrences are distinguished by their sharp contacts with the surrounding biotite granite to granodiorite and by the presence of hornblende in their matrix. These xenoliths are interpreted to represent the remnants of a massive to gneissic tonalite suite that predated the intrusion of the biotite granite to granodiorite suite. It is possible, although not certain, that these xenoliths are equivalent to either or both of the hornblende tonalite to granodiorite and biotite tonalite to granodiorite suites described above.

Stone et al. (2011a) and Golder and PGW (2017) also identified cm- to m-scale pegmatite and aplite dykes throughout the biotite granite to granodiorite suite (Figure 21d). These dykes are often observed to be hosted by fractures that are parallel to unfilled joints. Felsic dykes are consistently cross-cut by quartz-filled shear zones and fractures. There is no evidence of brittle deformation localized along the felsic dyke contacts.

Larbi et al. (1995) reported a $^{207}\text{Pb}/^{206}\text{Pb}$ age of ca. 2.734 Ga for a sample described as foliated tonalite to granodiorite. The sample location is identified as being near to, but immediately outside of, the northern margin of the Revell batholith based on the position of the batholith contact on the updated bedrock map (Appendix A), possibly placing the sample within the biotite granite to granodiorite suite. The information about this sample, including its age, was included in OGS (2019) along with a note indicating that the precise co-ordinates of the sample collection location were not included in the original source. It remains uncertain if this age can be attributed to the biotite granite to granodiorite suite. Alternatively, it could represent a sample of the foliated tonalite that is present as xenoliths within the biotite granite to granodiorite suite. Two additional ages reported in OGS (2019), include a K-Ar (biotite) age of 2.584 +/- 0.125 Ga and an Rb-Sr (biotite) age of 2.515 +/- 0.125 Ga, originally reported by Peterman et al. (1972), for a tonalite sample collected from within the northern part of the Revell batholith. These younger ages may relate to stages of regional cooling of the Revell Regional Area. However, their true significance and importance for understanding the geological history of the Revell batholith remains uncertain.

Feldspar-Megacrystic Granite

A distinct feldspar-megacrystic granite underlies the centre of the Revell batholith (Figure 9 and Figure 22b). Two characteristic features of the feldspar-megacrystic granite are the presence of cm-scale K-feldspar megacrysts (e.g., Figure 23f) and its high intensity aeromagnetic response (Figure 5). Stone et al. (2011a) included this feldspar-megacrystic granite as a subunit of the biotite granite to granodiorite suite described above. Although Stone et al. (2011a) mapped outcrops uniquely as feldspar-megacrystic granite, he did not draw any boundary to define it. As part of the bedrock compilation presented here, the extent of this distinct unit was defined by tracing the outer boundary of the high magnetic response region within the centre of the batholith (Figure 5).

The feldspar-megacrystic granite is characterized by a pink to grey, inequigranular massive granite with 10-70 mm euhedral prismatic K-feldspar phenocrysts in medium grained (2-5 mm) groundmass of quartz, plagioclase and biotite (SRK and Golder, 2015). The phenocryst percentage in the groundmass varies from 20 to 50% and the phenocrysts occur in pods and layers (Stone, 2010a). In the core of this intrusive phase, the K-feldspar phenocrysts define a flat-lying igneous layering (SRK and Golder, 2015).

A single sample of coarse-grained, pink and massive K-feldspar-megacrystic granite gave a CA-TIMS age of 2694.0 \pm 0.9 Ma for this unit (Stone et al, 2010), i.e. distinctly younger than both the biotite tonalite and hornblende tonalite suites.

The relationship suggested by Stone et al. (2011a), that the feldspar-megacrystic granite is a subunit of the biotite granite to granodiorite suite, is hard to reconcile with the reported ca. 2.734 Ga age for this suite reported by Larbi et al. (1995). Two possibilities present themselves. First, given the uncertainty in the location of the Larbi et al. (1995) sample, and the fact that the Larbi et al. (1995) age is similar to that of the biotite tonalite and hornblende tonalite suites, it is possible that the Larbi et al. (1995) did not sample the biotite granite to granodiorite suite. Alternatively, the Larbi et al. (1995) does provide an age for the biotite granite to granodiorite suite, and that the feldspar-megacrystic granite is much younger than the other felsic intrusive rocks in the area, and possibly related to the sanukitoid suite of rocks.

Intermediate to Felsic Intrusive (Sanukitoid) rocks

One large body of intermediate to felsic intrusive (sanukitoid) rock occurs in the northern part of the Revell Regional Area (Figure 24). Intermediate to felsic intrusive (sanukitoid) rocks represent a range of quartz-undersaturated to saturated intermediate to felsic plutonic rocks with remarkable variation in composition (Stone, 2010a). These variations include, diorite to tonalite, monzodiorite to granodiorite and monzonite to granite, as well as syenite. The compositional heterogeneity is brought about by highly varied proportions of quartz, plagioclase and K-feldspar as well as mafic minerals including biotite, hornblende and clinopyroxene. Mafic minerals tend to be concentrated in quartz-undersaturated phases and comprise an average of 29% of the rock. Trace magnetite, titanite, apatite, epidote, ilmenite, pyrite and zircon are also present in the sanukitoid suite (Stone, 2010a).

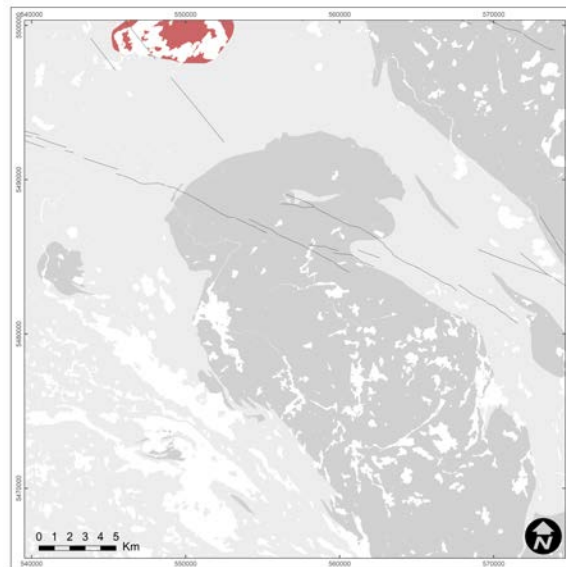


Figure 24: Distribution of Intermediate to Felsic Intrusive (Sanukitoid) rocks.

4.3.2 Structure

The structural description provided below for the plutonic rock group focuses on the part of the Revell batholith that is within the LiDAR boundary extent, which is defined as regional structure domain RSD06 (Figure 25). Both ductile and brittle structures have been mapped within the Revell batholith (e.g., SRK and Golder, 2015; Golder and PGW, 2017). Brittle structures, including mapped joints, veins and faults are more evident at the outcrop scale in the Revell batholith than ductile structures, which include a tectonic foliation and shear zones. Interpreted fabric-concordant, brittle and dyke lineaments within the Revell batholith, from DesRoches et al. (2018), are shown in Figure 25. Rose diagrams summarizing the orientations for these interpreted lineaments are shown in Figure 26. Equal-area lower hemisphere stereographic projections are presented for ductile structures (foliation and shear zones) in Figure 27 and for brittle structures (joints, veins, faults) in Figure 28.

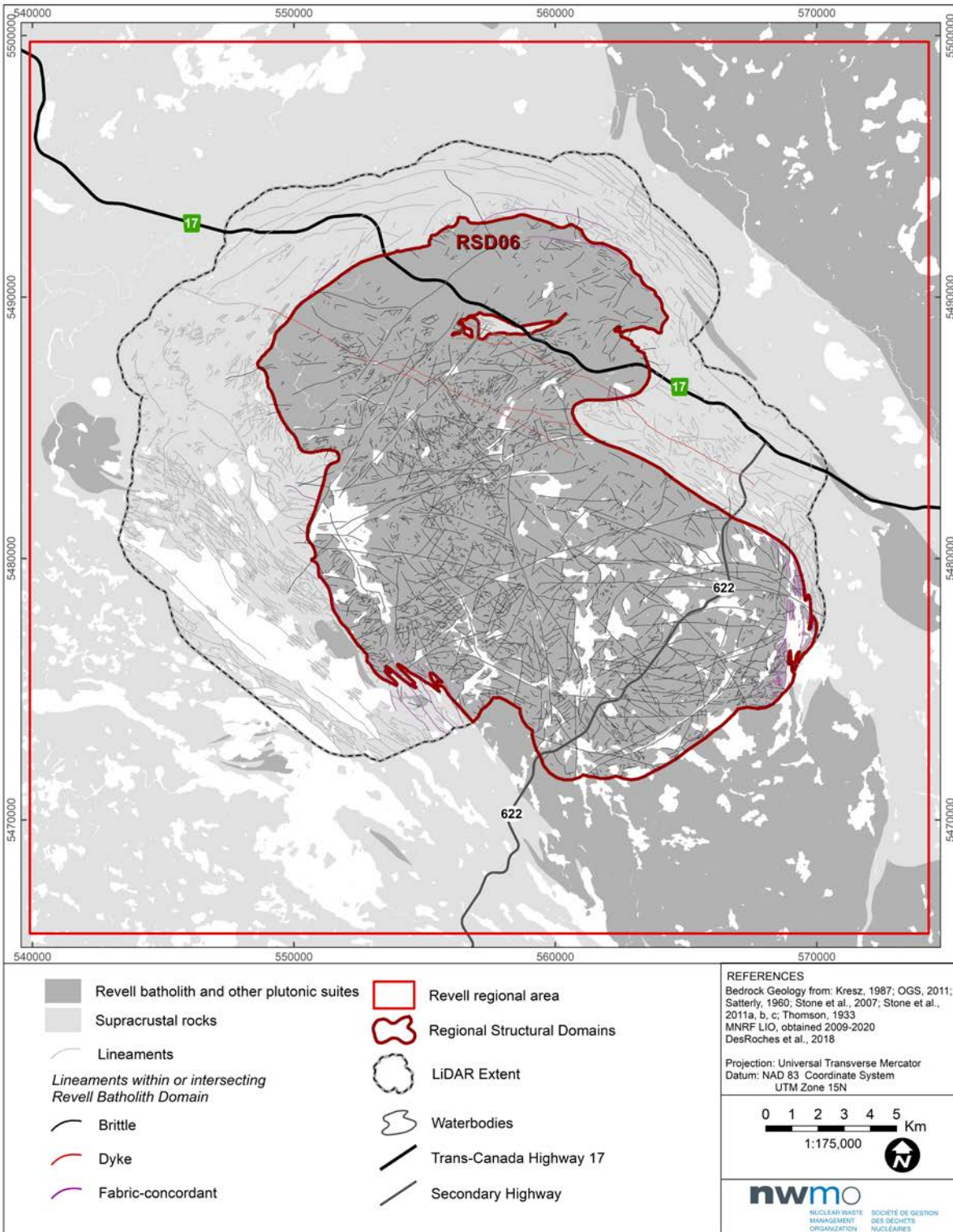


Figure 25: Regional structural domain, RSD06, defined for the northern part of the Revell batholith. Interpreted fabric-concordant, brittle and dyke lineaments within RSD06 are emphasized.

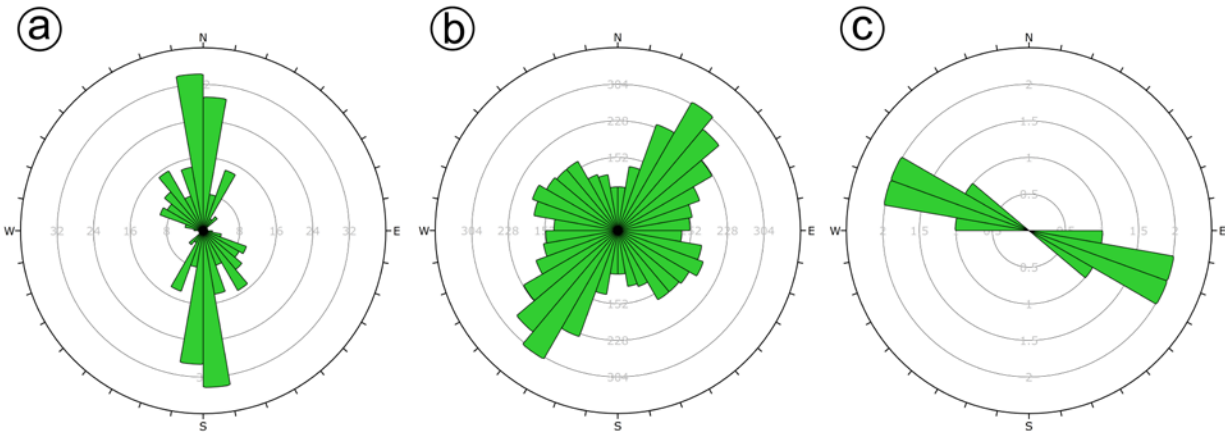


Figure 26: Rose diagrams showing the trend of interpreted lineaments within the Revell batholith, including, (a) fabric-concordant lineaments with a northerly trend (N = 167), (b) brittle lineaments with broad northeast and northwest trends (N = 3072), and (c) dyke lineaments with a broad west-northwest trend (N = 5).

The fabric-concordant lineaments exhibit a single dominant northerly trend (Figure 26a). However, this peak in the data is somewhat misleading as the fabric-concordant lineaments are identified only in a few specific locations within the Revell batholith. This includes occurrences of mainly north-trending fabric-concordant lineaments located around the southeastern boundary of the feldspar-megacrystic granite and mainly east-southeast-trending fabric-concordant lineaments in proximity to the mafic metavolcanic unit within the northern part of the batholith (Figure 25). Fabric-concordant lineaments are also present along the southwestern margin of the batholith, extending into the surrounding supracrustal rocks and within the batholith near its northern margin. In both of these latter instances, the fabric-concordant lineaments are generally parallel to the local trend of the batholith boundary. The brittle lineaments, which are identified throughout the batholith, exhibit northeast and northwest trends (Figure 26b). The dyke lineaments, which are present in the northern part of the batholith, exhibit a well-defined west-northwest trend (Figure 26c).

A weakly to moderately developed tectonic foliation, most commonly defined by aligned biotite or aligned quartz grains, is evident throughout the Revell batholith (Figure 13; Stone et al, 2011a, Golder and PGW, 2017). Poles to the planes of foliation within the Revell batholith are shown in Figure 27a. A major cluster of poles dips steeply and strikes west to west-northwest. A minor cluster of poles defines a southeast-striking foliation that dips moderately towards the southwest. There does not appear to be a direct relationship between the orientations of the foliation and the fabric-concordant lineaments within the batholith, in contrast to the relationship observed in the supracrustal rocks.

Ductile and brittle-ductile shear zones are characterized by a strong to intense planar fabric developed within mm- to cm-scale zones. In some cases, these shear zones include damage zones up to one metre in width. Shear zones are associated with quartz infilling and boudinaged quartz veins, and minor hematite and muscovite (Golder and PGW, 2017). One shear zone was observed to offset a felsic (aplitic) dyke. Poles to shear zones suggest that the majority of shear zones dip steeply and strike predominantly northeast, north and northwest (Figure 27b). Shear zones with interpreted sinistral offset strike northeast and northwest. Shear zones with interpreted dextral offset strike northwest, northeast and north suggesting the possibility of

multiple episodes of movement (Golder and PGW, 2017). The northwest and northeast trending orientations of mapped shear zones in the Revell batholith are similar to those of the brittle lineament dataset.

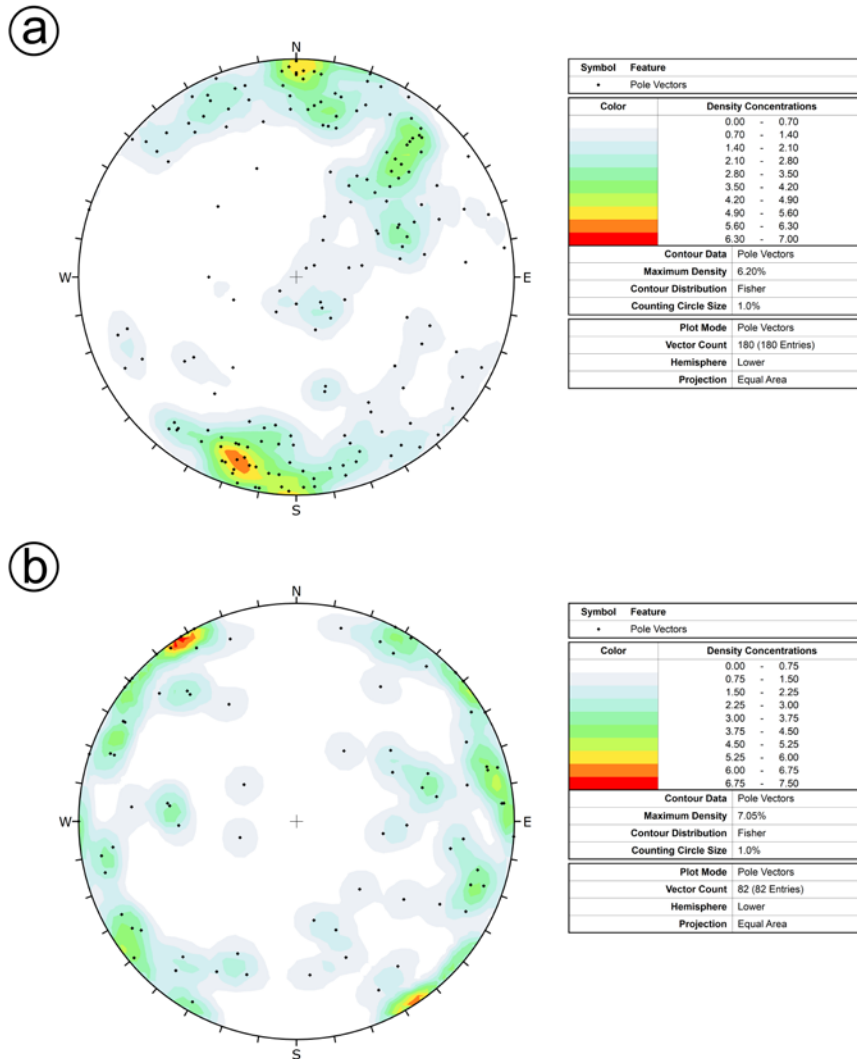


Figure 27: Equal-area lower hemisphere stereographic projections of poles to the planes, with density contours, for ductile structures identified in the Revell batholith. (a) Foliation (N = 180). (b) Shear zones (N = 82).

Fractures, including joints, veins and faults are the predominant brittle structures observed throughout the Revell batholith area (Golder and PGW, 2017). Fault damage zones range from thin, single slip surfaces to zones several metres wide. Secondary mineral infilling associated with faulting includes epidote, hematite, chlorite or breccia. Similar infilling mineral phases are identified in veins and as thin coatings on some joints. Slickenlines are observed on individual, isolated, fault planes and in fault zones characterized by multiple parallel surfaces. Slickenlines are consistently subhorizontal to moderately plunging suggesting primarily, or partly, strike-slip fault movement (Golder and PGW, 2017). The distribution of poles to all fracture planes from within the Revell batholith define both high and low density clusters (Figure 28). The high-

density pole clusters define steeply-dipping fracture sets that strike northwest and northeast. The low-density pole clusters define a steeply-dipping fracture set that strikes north and a subhorizontal fracture set. Dextral and sinistral faults exhibit some overlap in their trends, though one main peak in the dextral fault data set strikes southeast-northwest (Golder and PGW, 2017). The northeast and northwest strikes evident in the fracture dataset are also evident in the rose diagram of all brittle lineaments interpreted within the Revell batholith subarea (Figure 26b).

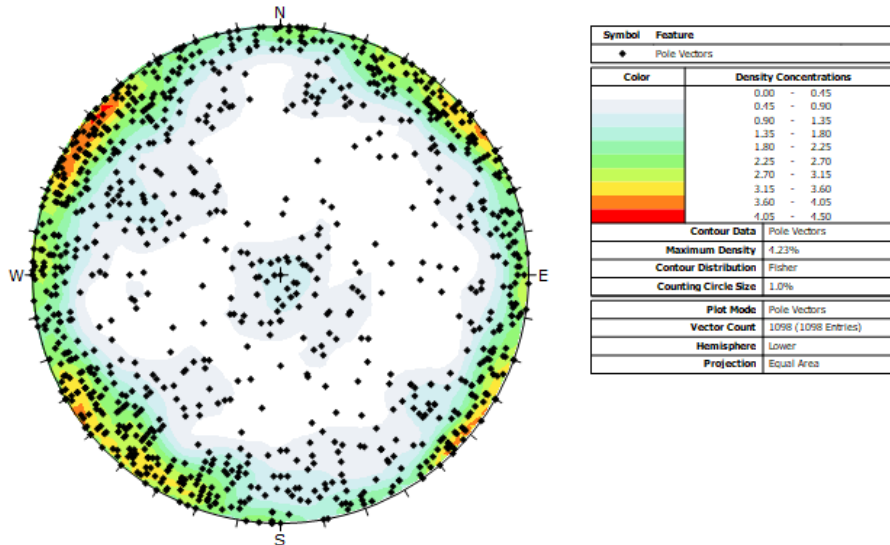


Figure 28: Equal-area lower hemisphere stereographic projections of poles to planes, with density contours, for fractures (N = 1098), including all joints, faults and veins, in the Revell batholith.

4.4 Wabigoon Dykes

The youngest Precambrian rocks in the Revell Regional Area are the west-northwest trending Wabigoon dykes (e.g., Figure 9). These dykes extend across the northern part of the Revell batholith and into the surrounding greenstone belts and are evident as high magnetic intensity lineaments that contrast with the low magnetic intensity response of the Revell Batholith (Figure 5; SGL, 2015). Regionally, Wabigoon dykes extend in a northwest direction for several tens of kilometres beyond the Revell Regional Area (OGS, 2011a).

The Wabigoon dykes are characteristically black to dark grey when fresh and brown to black when weathered (Figure 29a; Golder and PGW, 2017). They are massive in texture and generally vary from very fine- to medium-grained. The primary mineral phases observed within the mafic dykes include pyroxene, plagioclase, amphibole and magnetite with minor occurrences of pyrrhotite and biotite. Overall, the Wabigoon dykes exhibit the character typical of diabase dykes (Golder and PGW, 2017).

The Wabigoon dykes commonly exhibit a sharp and very fine-grained, mm- to cm-width, chilled margin which transitions to a coarser grainsize towards the dyke center (Satterly, 1960; Golder and PGW, 2017). Most observed dyke-host rock contacts are intact and exhibit no evidence of

brittle reactivation along their contacts. However, some Wabigoon dykes exhibit an increased density of jointing near their contacts with the surrounding bedrock (Figure 29b).

Wabigoon dykes range from less than 10 cm to approximately 30 m in width. Satterly (1960) traced the approximate locations of several of these dykes across the northern part of the Revell batholith. It is inferred, based on surface measurements across one 18 m wide dyke, that these late intrusions are sub-vertical (Golder and PGW, 2017).

A radiometric age of ca. 1.675 Ga reported by Wanless (1970) suggests a Proterozoic age for the Wabigoon dyke swarm. Subsequently, Fahrig and West (1986) reported a K/Ar age of ca. 1.9 Ga. More recently, a Wabigoon dyke sample gave a U-Pb age of ca. 1.887 Ga (Stone et al., 2010).

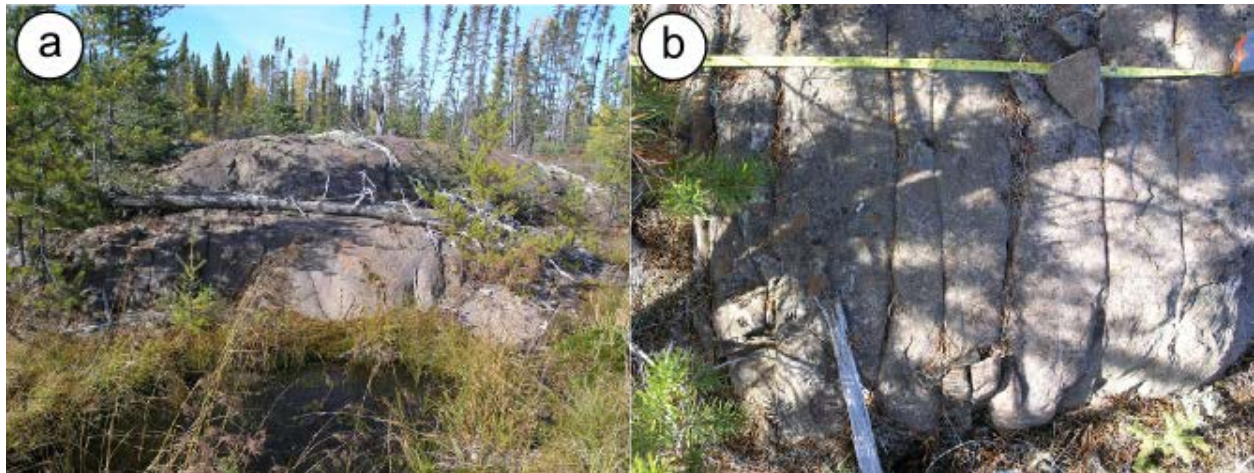


Figure 29: Field examples of Proterozoic Wabigoon dykes. (a) Typical exposure of a Wabigoon dyke. (b) Close-up of fractures developed at low angle to dyke contact near its margin.

4.5 Structural History of the Revell Regional Area

Golder and PGW (2017) provided a summary of the structural history of the Ignace area that includes the northern part of the Revell batholith. They describe an early tectonic foliation preserved in xenoliths of tonalitic gneiss found within the biotite granite to granodiorite suite, as described above. Golder and PGW (2017) also observed that aplite dykes fill an early set of steeply-dipping fractures. These fractures are interpreted to have initiated as cooling joints throughout the plutonic rocks. Ductile and brittle-ductile shearing and tectonic foliation development were synchronous with regional quartz mobilization into steeply-dipping shear zones, which in some cases re-activated these cooling joints. The history of movement along the shear zones remains uncertain, with more than one sense of slip identified on shear zones of the same or similar orientation (Golder and PGW, 2017). About half of the observed shear zones also exhibit a brittle component of deformation. Shear zones and faults are locally infilled with hydrothermal minerals such as quartz and epidote (Golder and PGW, 2017). Subsequently, brittle faults accommodated strike-slip motion on steeply-dipping fault planes. Dextral and sinistral horizontal offsets on similarly oriented structures, which are also in the same general orientation as the shear zones, suggests a complex history of ductile to brittle, episodic

movement. Overall, the full history of movement along the system of shear zones and faults identified throughout the Revell batholith remains poorly understood.

Some possible structural relationships can be drawn by relating the structures identified in the bedrock within the Revell batholith to the regional structural history described in Section 2.1. The gneissic fabric within tonalitic xenoliths in the Revell batholith are consistent with the older, D1-D2 fabric, which developed between ca. 2.725 and ca. 2.713 Ga. Based on the timing of regional D1-D2 deformation, it is reasonable to assume that the older biotite tonalite to granodiorite and hornblende tonalite to granodiorite suites of the Revell batholith were also overprinted by this event. The inferred episodic movement history and orientation of shear zones in the Revell batholith are consistent with their formation during the regional D3-D4 event which finished prior to ca. 2.698 Ga and coincided with peak regional metamorphism. The episodic movement history and orientation of brittle faults in the Revell batholith is consistent with their formation during the waning stages of D3-D4 and into D5, re-activating the same structural trends that define the shear zones. The occurrence of hydrothermal minerals on ductile to brittle structures suggest that at least some of these structures likely formed during on-going regional metamorphism. The emplacement of the west-northwest-trending Paleoproterozoic Wabigoon dykes has already been established regionally to represent one distinct temporal phase of D6 fault activation. The only structural overprint evident in these dykes are steeply- to shallowly-dipping non-mineralized joints. Non-mineralized steeply- and shallowly-dipping joints also overprint the older bedrock units. The precise timing of formation of these younger brittle structures remains uncertain. However, the shallowly-dipping fractures may have formed due to unloading, possibly in connection with post-glacial uplift (Golder and PGW, 2017).

4.6 Geological cross-section through the Revell Regional Area

A southwest-northeast oriented geological cross-section is presented in Figure 30 to illustrate a conceptual interpretations of the subsurface geometry of the rock units of the Revell batholith and surrounding supracrustal rocks. The section line location is shown in the inset map in Figure 30.

The orientation of the section line is perpendicular to the long axis of the batholith and also to the main fabric orientation in the surrounding greenstone belts. In the cross-section, the near-surface orientation of the southwest and northeast contacts between the supracrustal rocks and the batholith are taken from the average foliation orientation for RSD01 (mean strike/dip of 133°/61°) and RSD03 (mean strike/dip of 131°/75°), respectively, as presented in Table 2 in Section 4.2.2.1. These foliation orientations are honoured in the upper most part of the section. In the deeper subsurface, the batholith is given a generally tabular shape (e.g., Cruden, 1998). Recent gravity modelling aids in constraining the subsurface shape by suggesting that the batholith reaches a maximum depth of approximately 3 km adjacent to its southwest boundary and its base slopes gently upwards towards the northeast (SGL, 2015). The SGL (2015) interpretation also suggests the presence of a slight inflection in the slope of the base of the batholith towards its northeast margin, which has been reflected in the section shown here. The Wabigoon dykes are represented as vertical lines where crossed by the section.

Some uncertainty remains regarding the type the rock(s) that occur below the base of the batholith. The conceptual model presented here is consistent with the primary model presented by SGL (2015) whereby the dense supracrustal rocks that occur to the southwest and northeast of the batholith also extend below it. SGL (2015) also considered a basement model that includes a layer of lower density gneissic rock beneath the batholith. Importantly, both

alternative models suggest that the subsurface geometry of the Revell batholith is not very sensitive to varying the type of rock beneath it, though there is a slight increase in thickness of the batholith if lower density rock is included in the model (SGL, 2015).

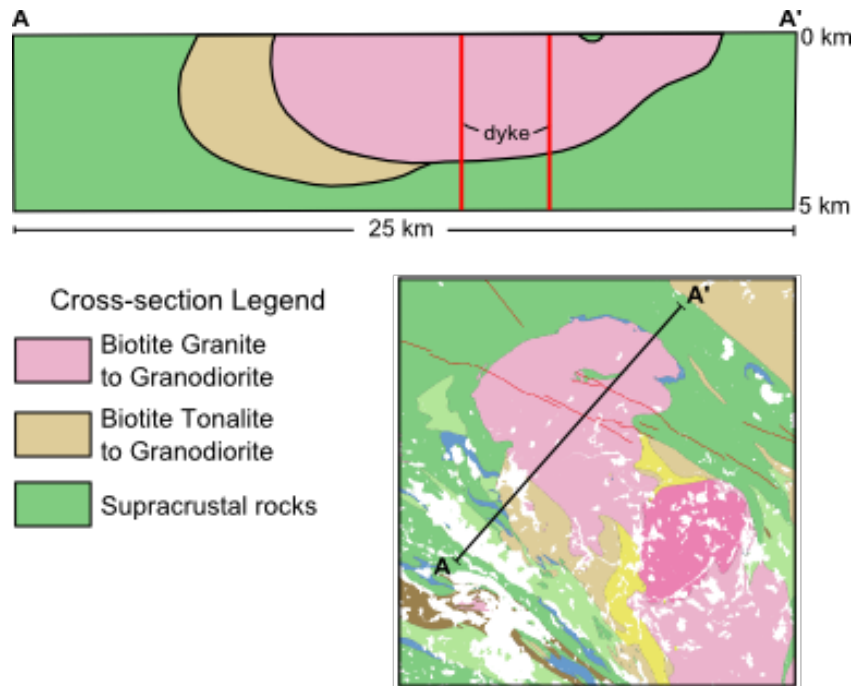


Figure 30: Simplified SW-NE oriented cross-section across the Revell Regional Area. Section line location is indicated on the inset map at bottom right. Refer to Figure 9 for legend to inset map.

5. Summary of Findings and Uncertainties

Findings and uncertainties are summarized below based on the information presented in this report.

Visual inspection of the airborne magnetic data indicated that it would be very useful for refining the location of the contact between the supracrustal rocks and the Revell batholith. However, several of the historic maps, including those produced by Satterly (1960) and Kresz (1987) were also extremely useful in this regard. Overall, 11 bedrock units, including the Proterozoic Wabigoon dykes, are identified for the Revell Regional Area. This includes five bedrock units in the supracrustal rock group and five bedrock units in the plutonic rock group. Two additional bedrock units were added within the Revell batholith that were not present on the existing 1:250,000 bedrock compilation or on detailed geological maps (e.g., Stone et al., 2011a). This includes a distinct body of mafic metavolcanic rock in the northern part of the Revell batholith, which is represented on the Satterly (1960) map, and a distinctive feldspar-megacrystic granite in the central part of the batholith.

The refined boundary between the supracrustal rocks and the Revell batholith, and the trend of the mapped foliation within the supracrustal rocks define large-scale folding of the boundary and

of the supracrustal rocks close to the boundary. Six regional structural domains were defined for the Revell Regional Area (RSD01 to RSD06). In several instances, i.e. for RSD01 to RSD04, the domains are defined by regions of similar foliation trend within the supracrustal rocks, the variation being related to the major folding. A comparison between the orientation of the foliation and the orientation of fabric-concordant lineaments, presented for each of these four domains, confirms that the fabric-concordant lineaments are generally parallel to the mapped foliation. Two regional structural domains are defined by the distribution of the body of supracrustal rocks within the northern part of the Revell batholith (RSD05) and by the extent of the plutonic rocks in the entire northern part of the Revell batholith (RSD06).

Similar orientations of ductile shear zones and faults indicates a complex history of movement on steeply-dipping structures within the Revell batholith. Pluton emplacement, ductile deformation and at least some amount of brittle deformation are well constrained to an Archean-Proterozoic timeframe based on the regional structural history of the Revell Regional Area. The predominantly steeply-dipping nature of shear zones and fault planes within the Revell batholith are consistent with horizontal shortening and strike-slip movement that occurred during the D3 to D5, and perhaps D6, deformation events. The youngest major deformation and emplacement event to occur in the Revell Regional Area was the intrusion of the west-northwest-trending Proterozoic Wabigoon dykes. It is also important to point out that the similarity in orientation of brittle lineaments, ductile shear zones and measured fractures supports the inference by DesRoches et al. (2018) that the lineaments are not simply surface features but they represent geologically significant structures.

There is some uncertainty remaining in the surface location of the geological contacts presented on the bedrock map. Multiple datasets were used to reduce this uncertainty as much as possible, including the airborne magnetic data and available historic map sources. While the airborne magnetic data are useful for defining the main supracrustal rock-batholith contact, the bedrock significance of slight differences in the magnetic character inside the batholith remain uncertain. Similarly, there is some uncertainty in the subsurface continuity of the rock units identified at the surface. To the extent possible, this uncertainty has been reduced by following the guidance provided by geophysical modelling results (SGL, 2015).

There is also uncertainty in the nature of the supracrustal rocks in the northern part of the Revell batholith where it is covered by overburden. The relatively uniform and homogeneous character of the northern part observed during recent mapping campaigns suggests that the unexposed part of the batholith is highly unlikely to host any major lithological variations. Notwithstanding the relative homogeneity of the Revell batholith, the distribution of the granodiorite, tonalite and granite phases within the biotite granite to granodiorite suite that underlies the northern part of the batholith remains uncertain. It is also uncertain if the subtle compositional differences between these phases of the bedrock are significant in terms of, for example, the thermal conductivity or geomechanical properties of this bedrock unit. It is not known if the reported radiometric age of ca. 2.734 Ga for the biotite granite to granodiorite suite represents the crystallization age of this unit or if the sample analyzed is actually from an older tonalitic phase, possibly from either of the hornblende tonalite to granodiorite or biotite tonalite to granodiorite suites, or another rock unit that is now only preserved in xenoliths within the batholith. Additional geochronological analyses will address this uncertainty.

There is some uncertainty in the true location and the documented orientation of mapped structures digitized from paper maps. However, the majority of the orientation information extracted from these older maps is for the supracrustal rocks and so the overall impact of this uncertainty is relatively low for the on-going investigation of the northern part of the Revell

batholith. The degree of uncertainty decreases for structural information collected during the more recent mapping campaigns (SRK and Golder, 2015; Golder and PGW, 2017), which are concentrated in and around the area of current investigation. There is also some uncertainty in assigning all >4000 structures to a short list of structure types. However, the source data are generally sufficient, including traceable structure codes, that this uncertainty is relatively low. These defined structure types are also consistent with terminology used in the borehole drilling program, which will simplify the integration of surface and borehole data.

Other uncertainties relate to the present understanding of the history of shear zone and fault movements. While it is reasonable to relate the regional deformation events to structures observed in the Revell Regional Area, it is less clear which structures accommodated the deformation. There is evidence at the outcrop scale for multiple stages of movement on shear zones and faults during both ductile and brittle phases of deformation (e.g., Golder and PGW, 2017). The similarity in interpreted lineament orientations and ductile and brittle structures across the Revell Regional Area also suggests that the movement history may have been accommodated on a large number of interconnected fractures that have not yet been fully investigated by surface mapping or subsurface investigations (e.g., targeted borehole drilling, seismic surveys). The internal structure and true width of interpreted lineaments remains an uncertainty that will be addressed by these on-going site characterization activities. In addition, the timing of the fracturing event(s) that produced the steeply- to shallowly-dipping, unfilled, joints that overprint the Revell batholith and the Wabigoon dykes is unclear. A subset of these fractures, in particular the shallowly-dipping structures, may have formed as a result of glacial unloading as recently as during the last period of deglaciation.

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APPENDIX A: Poster-sized bedrock geology map of the Revell Regional Area
(in pocket)

APPENDIX B: Compilation of bedrock units, Proterozoic dykes and structural measurements

Appendix B provides an overview of the processes involved in developing the three new datasets that were compiled for the Revell Regional Area, including:

- (1) a seamless compilation of bedrock units;
- (2) an integrated compilation of Proterozoic diabase dykes of the Wabigoon swarm; and,
- (3) a compilation of available structural measurements.

The base data inputs that were used to develop the datasets are presented in Section 3 above.

B.1 Bedrock

The updated seamless representation of the bedrock units for the Revell Regional Area is shown in Figure 31. A primary motivation for undertaking this activity was to enhance the understanding of the geological character of the northern part of the Revell batholith, which underlies the area of focus for NWMO's Phase 2 activities. It was deemed particularly important to refine the shape and location of the contact between the generally low magnetic response Revell batholith and the surrounding higher magnetic response greenstone belt units. For example, in comparing the location of this contact in the 1:250,000 scale representation of the bedrock units (OGS, 2011a; Figure 4) and the high-resolution airborne magnetic data (Figure 5), a discordance in its shape and location was evident. A detailed description of each bedrock unit included on the map is included in Section 4 above.

The airborne magnetic data were used as the primary dataset for retracing the location of the batholith-greenstone contact. Historic source maps were also studied, and contacts therein were also followed in some instances, throughout the retracing process. It was found that the early mapping work by Satterly (1960), in particular, included a very accurate representation of this contact along the northern margin of the batholith.

Key locations where the batholith-greenstone belt contact was refined, and the primary sources used in the refinement, include:

- the northeast, north and northwest batholith-greenstone belt boundaries, based on Satterly (1960) and the airborne magnetic data;
- the west batholith-greenstone belt boundary, based on the airborne magnetic data and Kresz (1987) and;
- the east batholith-greenstone belt boundary, based on detailed mapping work by Golder and PGW (2017) and the lineament interpretation of DesRoches et al. (2018).

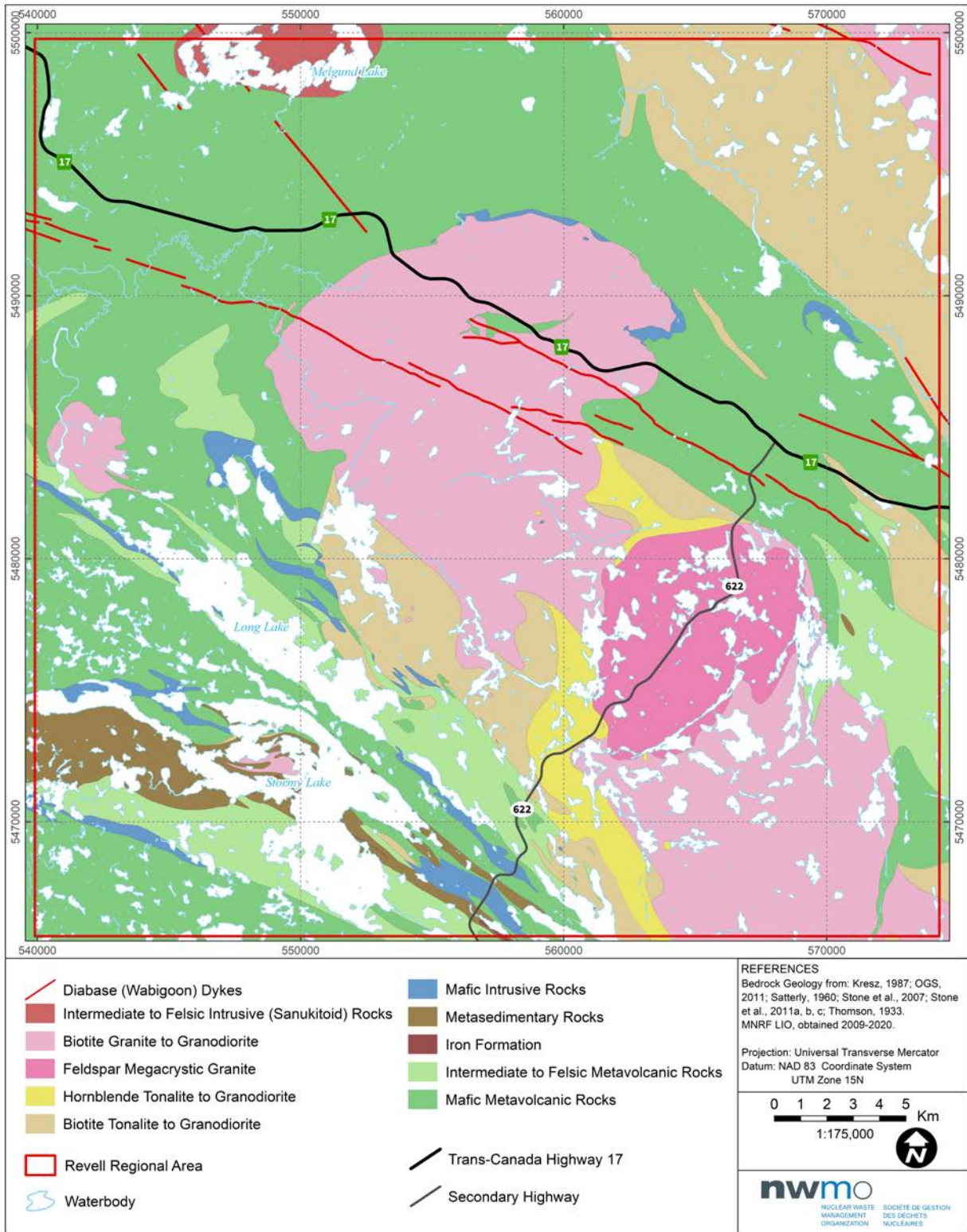


Figure 31: Compiled bedrock units and dyke lineaments for the Revell Regional Area. Legend for the bedrock units is from Stone et al. (2011a).

In addition, two bedrock units were defined within the Revell batholith, including, a distinct body of mafic metavolcanic rock in the northern part of the Revell batholith, originally identified by Satterly (1960), and the boundary of a distinctive feldspar-megacrystic granite suite in the central part of the batholith (Figure 31). Although Stone et al. (2011a) acknowledged this feldspar-megacrystic granite suite during mapping, its contact location with the surrounding bedrock within this part of the Revell batholith was not previously defined. The feldspar-megacrystic granite suite exhibits a high magnetic response on the magnetic data and its contact was traced along the outer boundary of this high magnetic response region (Figure 5). The LiDAR and ortho-imagery datasets were also reviewed periodically to aid in refining the shape and location of the batholith-greenstone contact, and as an additional constraint when smoothing geological contacts within the greenstone belt. Textural changes in the LiDAR topography and colour changes in the ortho-imagery were found to correlate well with the distinction between greenstone and granitoid bedrock.

As well as being used to refine the batholith-greenstone boundary, the airborne magnetic data were also useful for refining other geological contacts where there was a discordance in their continuity between adjacent map sheets. Kresz (1987) and Stone et al. (2011c) provided a relatively high level of detail regarding the distribution of greenstone belt units within their respective mapping areas. However, geological contacts were locally misaligned where their mapping areas overlapped. These discordances were smoothed by reviewing the magnetic data and applying expert judgement to best honour the underlying geology.

It was deemed less important to include a high level of detail within the region underlain by the supracrustal rocks. Overall, the level of detail in the bedrock units represented on the map decreases towards the outer edges of the Revell Regional Area, away from the Revell batholith, where the geological contacts of the 1:250,000 scale map (OGS, 2011a) were honoured.

B.2 Dykes

As described above, the youngest Precambrian rocks in the Revell Regional Area are a series of west-northwest trending mafic diabase dykes of the Wabigoon dyke swarm. These dykes stretch across the northern part of the Revell batholith and into the surrounding greenstone belts and are evident as highly magnetic lineaments that contrast with the low magnetic response of the Revell Batholith (Figure 5; SGL, 2015). Regionally, Wabigoon dykes extend in a west-northwest orientation for several tens of kilometres beyond the Revell Regional Area (OGS, 2011a). The compilation of Wabigoon dykes for the Revell Regional Area is shown in Figure 31.

Although well-represented on individual historic maps (e.g., Satterly, 1960; Stone et al. 2011a), and also included on the 1:250,000 scale bedrock compilation (Figure 4; OGS, 2011a), the interpreted surface locations of several Wabigoon dykes were traced with a higher degree of spatial accuracy and certainty across the Revell Regional Area using the recently acquired magnetic data with higher resolution (Figure 5; SRK, 2015; DesRoches et al., 2018). These higher certainty dykes are included in the updated dyke dataset. Wabigoon dyke occurrences located further to the west and east were carried forward from the 1:250,000 scale bedrock compilation (OGS, 2011a) and are also included in the updated dyke dataset, providing complete coverage of these dykes across the Revell Regional Area.

B.3 Structures

The objective of this effort was to compile together all available structural sample data (points) for the Revell Regional Area from the sources into a single integrated dataset. Figure 32 shows the distribution of the outcrop locations where structural measurements were made, and included in the compilation for the Revell Regional Area. A total of 4217 structural measurements were compiled for the Revell Regional area.

Structural data were compiled from several available sources (Table 3). This includes datasets from historic mapping campaigns that were previously compiled as part of the Western Wabigoon GIS Synthesis (Beakhouse et al., 2011) as well as data collected during more recent mapping campaigns, including Stone et al. (2011a), Stone et al. (2011b), Stone et al. (2011c), SRK and Golder (2015) and Golder and PGW (2017). All of these studies utilized the same OGS mapping nomenclature for structure types. The uniformity in nomenclature between all digital datasets included in the current compilation allowed for a relatively straightforward integration of these products and development of a suitable attribute table structure, which is shown in Table 4 below. The similarity in the underlying datasets also allowed for the development of a simple naming scheme for the structure types included in the source datasets. Table 5 describes the final assigned names for each structure type and this final assigned name is included in the field 'STRUCTURE_NAME' in the shapefile attribute table.

For the Beakhouse et al. (2011) compilation, the structural data were transferred to digital format by manually measuring strike/trend orientations in the historic maps. Data points that were not accurately described on the initial map or publication were excluded from this compilation. The location for the structural measurements was taken as that of the centre of the symbols on the initial map, which may have been offset from the actual point of measurement. The locations of these data points should therefore be regarded as approximate. No clear documentation of the uncertainty in location of the data included in the Stone et al. (2011a), Stone et al. (2011b) and Stone et al. (2011c) datasets is provided and so the locations of the structural measurements are also assumed to be approximate. All structural point data measurements by SRK and Golder (2015) were assigned to the location of the mapping station location and so again, their current position is considered approximate, though likely within metres, to at most tens of metres, from the station location. The data collection software used by Golder and PGW (2017) included the ability to locate each structural measurement at the location where the feature was identified. Therefore, this dataset provides the lowest degree of uncertainty in the location captured in the compilation dataset.

Comments are included in Table 3 that describe minor revisions made to the source data during the compilation process. Firstly, the Beakhouse et al. (2011) dataset included 14 out of 1380 features identified as 'Other' with the OGS symbol 'DHD' (diamond drill hole). These 14 entries were removed from the compilation as they are included with the historic mining information presented in Appendix C. Secondly, the original source file for some datasets did not include easting and northing UTM coordinates and so an automated ArcGIS function (Add X Y data) was applied, generating two additional fields into their attribute tables to include this information. Thirdly, it was noted that there were differences in how some dip magnitudes were documented in several different sources. This included occurrences with blank (no entry) dip magnitudes, dip magnitudes = '0' (though OGS feature codes suggested non-horizontal features), and dip magnitude = (-9999) or (99) in instances where this value could not be determined (e.g., on glacially-polished outcrops). In order to reduce uncertainty, including in future data analysis, a total of 818 dip magnitude entries were revised to blanks in the final structure compilation.

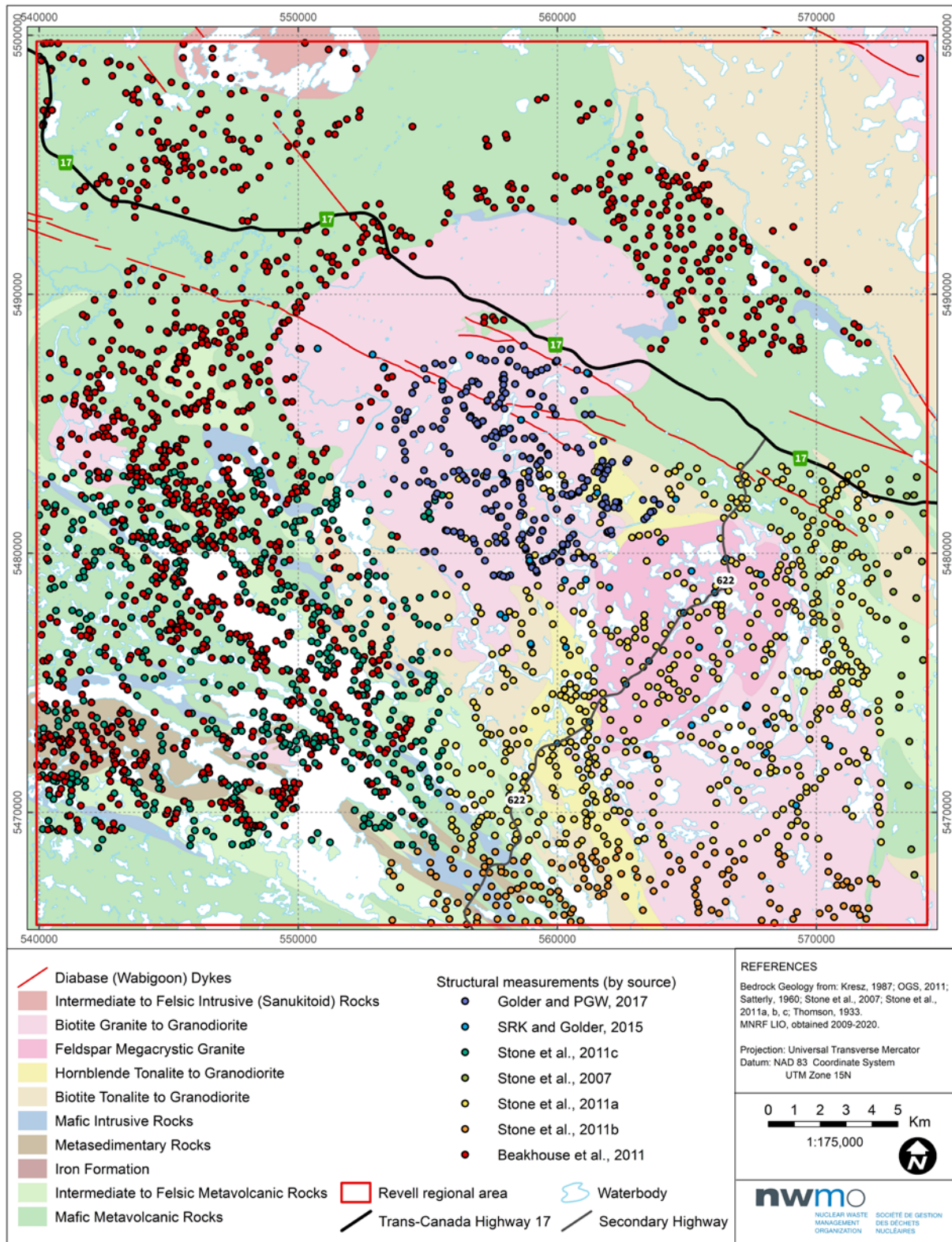


Figure 32: Outcrop locations of compiled structural measurements, identified by map source, for the Revell Regional Area.

Table 3: Available source datasets and summary of structure compilation results.

Source Dataset	# Features – Initial selection	# Features – export to .csv	# Features – Final compilation shapefile	Comments
Wabigoon GIS Synthesis; Beakhouse et. al., 2011	1380	1380	1366	14 features (DHD) removed; 780 Dip = 'blank' entries unchanged
SRK and Golder, 2015	281	281	281	X, Y coordinates added. One Dip = '99' entry changed to blank
Golder and PGW, 2017	1217	1217	1217	11 DIP = (-9999) entries changed to blanks
Stone et al., 2011a (P3623)	592	592	592	X, Y coordinates added. 425 Dip = '0' entries changed to blanks
Stone et al., 2011b (P3624)	154	154	154	X, Y coordinates added. 59 Dip = '0' entries changed to blanks
Stone et al., 2011c (P2515)	582	582	582	X, Y coordinates added. 322 Dip = '0' entries changed to blanks
Stone et al., 2007 (P3360)	25	25	25	10 Dip = 'blank' entries unchanged
Total	4231	4231	4217	

Table 4: List of attribute fields included in the structure compilation shapefile

Attribute Field Title	Description
FID	Field with unique identifier ID
SHAPE	Field indicating shapefile type = 'Point' added automatically in QGIS
EASTING	UTM Easting coordinate (in metres)
NORTHING	UTM Northing coordinate (in metres)
TYPE	Source dataset structure type
SUBTYPE	Source dataset structure subtype
OGS_CODE	Structure code from OGS symbol library (Jackson et al. 2010)
STRUCTURE_NAME	Final structure type
STRIKETREND	Planar strike/azimuth or linear trend
DIPPLUNGE	Planar dip or linear plunge
INTENSITY	Subjective visual assessment of degree of fabric development (e.g., foliation = moderate)
FABRIC	Prominence of planar vs. linear character (e.g., Linear(L)>Planar(S) fabric)

SOURCE_NOTES	Source notes
SOURCE	Map name/Source reference (see also Table 3)
COMPILATION_NOTES	Notes summarizing compilation edits
STATIONID	Unique Station Identification Number included from original source
LITHOID	Unique Station-Lithology Identification included from original source
STRUCID	Station-Lithology-Structure Identification included from original source
ROCKTYPE	Rock type associated with structural observation
SPACING	Across strike distance between features of same type (cm)
WIDTH	Structure (feature) width (cm)
STRUC_INFILL1	Secondary mineral infill
STRUC_INFILL2	Secondary mineral infill
STRUC_INFILL3	Secondary mineral infill
STRUC_INFILL4	Secondary mineral infill

Table 5: Summary of original structure types, subtypes or OGS code and assignment of final structure name in structure compilation dataset

OGS Code	Structure Type	Number	Final Structure Name
BED*	Bedding	180	Bedding
IGCAD*		29	Dyke (Contact)
FT*		104	Fault
CG*	Cleavage	4	
CLFA*	Compositional Layering and Parallel Foliation; Gneissose/Gneissic Layering	34	Foliation
FOL*	Foliation	2258	
SCH*	Schistosity	1	
STRD	Glacial Striae	140	Glacial Striae
IG*	Igneous Flow Foliation; Igneous Layering	35	Igneous Primary Layering
FR*	Joints/Fractures	55	Joint
JN*	Joint	925	
LIN*	Lineation	121	Lineation
BD*	Fault Brittle-Ductile	41	Shear Brittle-Ductile
SH*	Shear Zone	41	Shear Ductile
VN*	Vein	94	Vein
YN*	Younging	155	Younging
	Total	4217	

Note: *Code suffix varies by structure subtype.

APPENDIX C: Historic Mining Information and Complementary Datasets for the Revell Regional Area

C.1 Mineral Exploration Information

Publicly-available datasets from the Ontario Geological Survey provide information on the historic to recent exploration/mapping, sampling, and geophysical work completed in the Revell Regional Area. The available types of information are described below. Figure 33 shows spatially the available information on the mineral occurrences and mining activities for the Revell Regional Area.

- **Abandoned Mines Information System (AMIS):** a database containing information on known abandoned mine sites and mine hazard features located on both Crown and privately held lands within the province of Ontario. This includes sites that are abandoned, may possibly be in production or may be covered by a closure plan. It also includes sites under Mining Act, Aggregate Resources Act and Federal jurisdictions. The original AMIS database compiled in the late 1980's and early 1990's contained basic information on abandoned mine sites and mine hazard features. Abandoned Mines Rehabilitation Program staff maintains and updates the AMIS database. The database presented here is current to December, 2019.
- **Ontario Assessment File Database (OAFD):** released by the Ministry of Energy, Northern Development and Mines, Mines and Minerals Division. This database is an inventory of assessment files in the province of Ontario. The Ontario Assessment File Database is continuously updated, and this release includes assessment reports inputted by March 2, 2020. Assessment files are the technical results from exploration programs carried out on Crown Land in the Province of Ontario. Since the 1940s, the Government of Ontario has required those who perform exploration on claims staked over Crown Land to submit results of that work, including all reports and maps, in exchange for the right to retain the claims.
- **Ontario Drill Hole Database (ODHD):** released by the Ministry of Energy, Northern Development and Mines. This database is an inventory of drill holes in the province of Ontario compiled from assessment files and non-assessment exploration reports. This release includes drill holes for which information was input by February 3, 2020 and contains information for over 150 000 percussions, overburden, sonic and diamond-drill holes. Data include location, company name, company hole number, hole orientation, hole depth, and overburden depth if applicable. The presence of assay results with cutoff values for gold, silver, copper, zinc, lead, nickel and platinum group elements is noted. Source assessment file numbers are captured for cross referencing with the assessment file database.
- **Mineral Deposit Inventory (MDI):** released by the Ministry of Northern Development and Mines. This database is an inventory of mineral deposits in the province of Ontario and supersedes previous MDI releases. Originally compiled in the early 1970s by the Resident Geologist Program (RGP), the database is continually being reviewed and updated by RGP staff and is up to date as of March 2, 2020. The Mineral Deposit Inventory provides information on metallic, non-metallic, industrial and building stone occurrences/deposits across Ontario. Each MDI record provides all or some of the following information: deposit name(s), location, status (e.g., occurrence, prospect, producer, past producer), commodities, character/classification, geological structure,

lithology, minerals and mineral alteration, geochemistry, exploration history, and production and reserve data where available. Notes on deposit visits and references to additional publications related to the deposit are also included.

- **Mines Mining Lands Administration System (MLAS):** released by the Ministry of Northern Development and Mines. The database is designed to enhance client access to Ontario's mining lands data and improve their ability to manage their files, client profiles and perform all claim acquisition activities online. The data include operational data (claims and alienations, mining land tenure and non-mining land tenure), which is updated regularly, and administrative data (cell grids, lots and concessions, administrative boundaries, mining divisions, exploration regions, legacy claims and the provincial boundary). The database is current to March 31, 2020.

The supracrustal rocks surrounding the Revell batholith have been explored for their gold potential since the late nineteenth century, leading to the discovery of several precious metal occurrences, including quartz-vein hosted gold and silver (Kresz, 1987). There are past producing, now abandoned, mines of gold with minor silver that were in production until early in the twentieth century. All gold occurrences are confined to volcanic and sedimentary assemblages that have been affected by low grade metamorphism and the majority are associated with felsic volcanic rocks. Late-stage quartz veins are associated with the Revell batholith and are mineralized with molybdenite (Kresz, 1987).

Base metal exploration in the middle of the twentieth century led to the discovery of some copper mineralization in association with felsic volcanic rocks and small intrusions. More recently, a distinct hornblende metadiorite unit within the mafic intrusive rock unit that occurs around the margin of the batholith (Figure 12) has been explored for nickel, copper and platinum group elements. In addition, an open-pit iron ore mine has been proposed to extract the iron ore concentrated within the iron formation located in the southeastern part of the Revell Regional Area (Figure 11). The mining claims that extend across the southeastern part of the Revell Regional Area cover areas identified as possible waste-rock pile locations for this proposed open-pit operation (Figure 33).

The Revell batholith, with its characteristic massive, equigranular and exceedingly homogeneous character has been previously identified as favourable for the extraction of building stone (e.g., Storey, 1986).

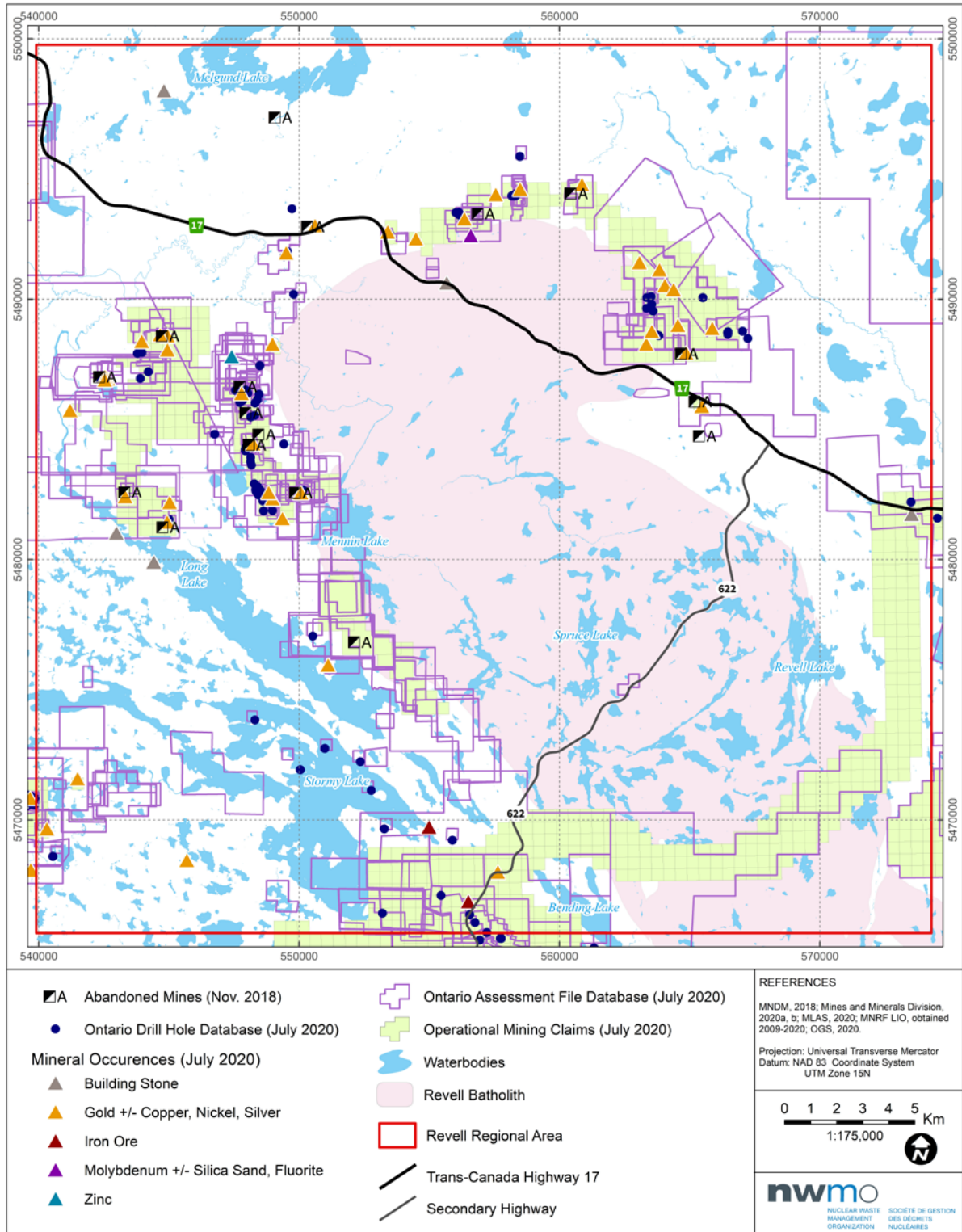


Figure 33: Historic mining information, mineral occurrences, exploration work, and current claims in the Revell Regional Area. The Revell batholith is shaded light pink.

C.2 Complementary Datasets

Additional complementary data are available for the bedrock units in the Revell Regional Area. The sources of this information are listed below and the distribution of the available information, by source, is shown in Figure 34.

- **PETROCH lithochemical database:** contains computerized information on rock samples collected by OGS staff geoscientists during field projects undertaken since the mid-1970s (Haus and Pauk, 2010). This database lists 27 476 samples for which chemical data were available as of August 1992. The database contains information on each sample such as the location where it was found, description of the sample, and the chemical analysis performed by the OGS Geoscience Laboratories. The PETROCH data underwent a data validation/verification process prior to the original release in 1993.
- **Geoscience Theses:** a collection of university theses held by the OGS's 8 district office libraries. The collection includes a wide variety of undergraduate and graduate theses on geoscience subjects relevant to the district. Data includes author, title and keywords. The theses are geospatially located based on subject matter. A total of eight theses are identified in the Revell Regional Area. The symbol furthest north on the map represents five theses and the symbol furthest south represents two theses, for a total of eight represented by the three symbols in Figure 34. Most of these theses were focused on petrologic, petrographic or geochemical studies of the supracrustal rocks.
- **Geochronology:** The Ontario Geological Survey has updated the geochronology inventory for Ontario (OGS, 2019). This database is an inventory of geochronological information in, and adjacent, to the province of Ontario and supersedes previous compilations of geochronological information. Originally compiled in the early 1980s by R.M. Easton and updated by him at various times since, the database is now continually being reviewed and updated by staff of the Earth Resources and Geoscience Mapping Section of the Ontario Geological Survey.
- **Specific Gravity:** The Ontario Geological Survey (OGS) has routinely measured the specific gravity of rock samples submitted to the OGS Geoscience Laboratories (Geo Labs) for chemical analysis. Specific gravity results, spanning nearly 5 decades, have been compiled into a single georeferenced database (Rainsford et al., 2018). The resulting specific gravity data set contains 26 079 geolocated records from rock samples collected across the province of Ontario between 1970 and 2014. The majority of the data were obtained from specific gravity measurements of Archean rocks, with smaller populations of data from Proterozoic and Paleozoic rocks.
- **Magnetic Susceptibility:** Magnetic susceptibility data were collected during recent field mapping campaigns (SRK and Golder, 2015; Golder and PGW, 2017).
- **Specific Gravity + XRD:** Samples collected by SRK and Golder (2015) and Golder and PGW (2017) were sent to the Ministry of Northern Development & Mines Geoscience Laboratory in Sudbury in 2018 for specific gravity and X-ray Diffraction (XRD) analysis. 117 samples were sent for specific gravity measurement, and 10 for XRD.

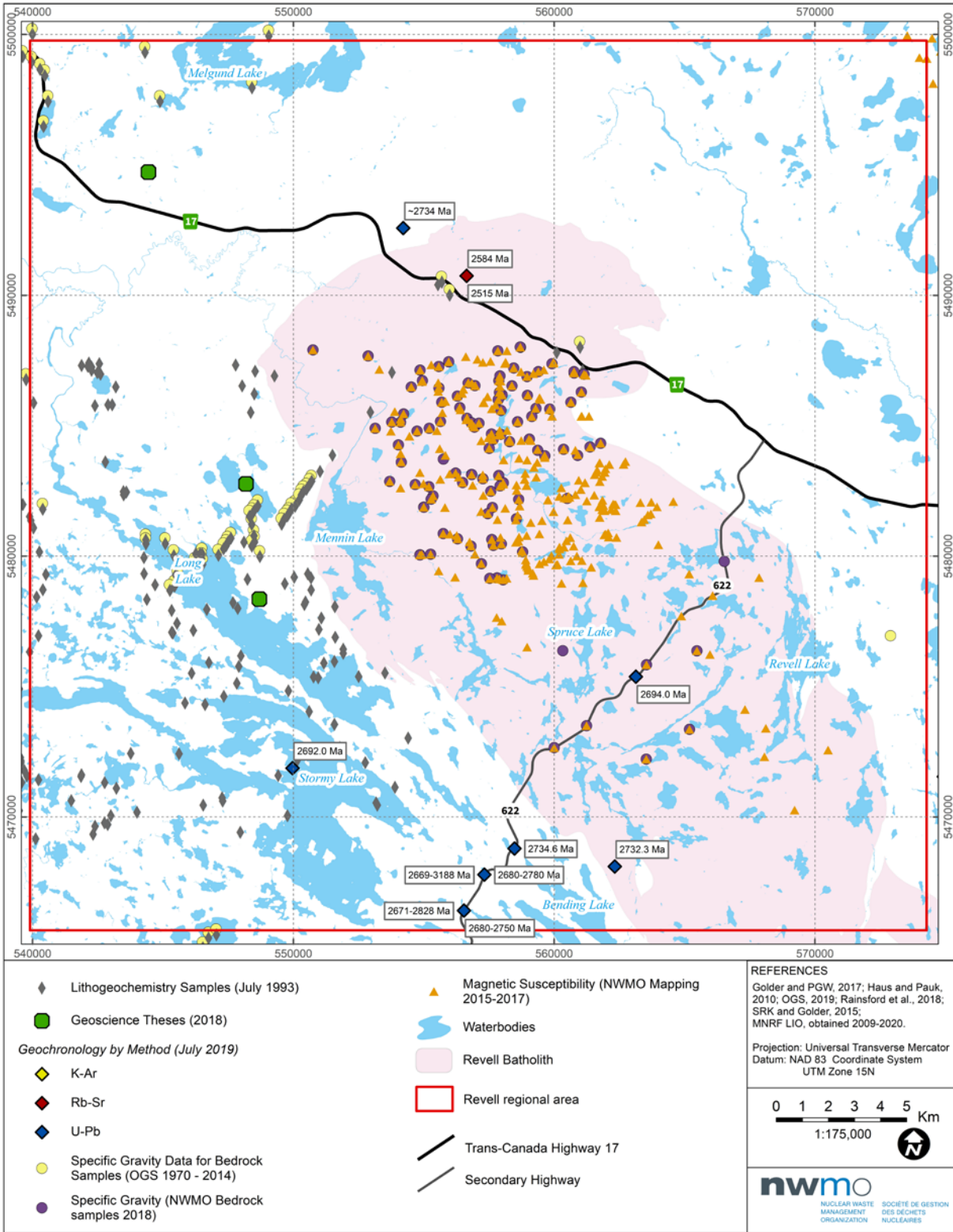


Figure 34: Complementary analytical data for the bedrock units in the Revell Regional Area. The Revell batholith is shaded light pink.

APPENDIX D: List of Abbreviations used

CA-TIMS	chemical abrasion thermal ionization mass spectrometry
DEM	digital elevation model
DFN	discrete fracture network
Ga	billion years before present (Giga-annum)
GIS	Geographic Information System
IG_BH	Ignace Borehole
K	potassium
Km	kilometre
K-Ar	potassium-argon
LA-ICP-MS	laser ablation inductively coupled plasma mass spectrometry
LiDAR	Light Detection and Ranging
m	metre
Ma	million years before present (Mega-annum)
mASL	metres above sea level
OGS	Ontario Geological Survey
RSD	regional structural domain
Rb-Sr	rubidium-strontium
U-Pb	uranium-lead