NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Phase 2 Geoscientific Preliminary Assessment

Geological Mapping

TOWNSHIP OF HORNEPAYNE AND AREA, ONTARIO

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Phase 2 Geoscientific Preliminary Assessment, Geological Mapping
Township of Hornepayne and Area, Ontario

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EXECUTIVE SUMMARY

This technical report documents the results of the Phase 2 Geological Mapping activity completed in 2016 as part of the Phase 2 Geoscientific Preliminary Assessment, to further assess the suitability of the Hornepayne area to safely host a deep geological repository. This study followed the successful completion of the Phase 1 Geoscientific Desktop Preliminary Assessment (Geofirma, 2013), which identified two withdrawal areas for further field studies. Geological mapping was completed within and around these two withdrawal areas.

The purpose of the Phase 2 Geological Mapping is to advance understanding of the bedrock geology of the withdrawal areas, with an emphasis on observation and analysis of bedrock structure and lithology. Information collected during Phase 2 Geological Mapping also helps to identify areas of exposed bedrock, assess overburden thickness, and identify surface constraints within and around the withdrawal areas, which might affect suitability.

Observations were conducted at select locations that were accessed using existing secondary roads, trail networks and waterbodies, as well as some off-trail hiking. The two areas were mapped over a total period of 48 days by four mapping teams using a consistent workflow and standardized digital data collection system. Observations were made at a total of 616 locations in and around the two withdrawal areas, including 308 locations in the Quetico area, 283 locations in the Black-Pic batholith area, and 25 stations in the Subprovince Boundary Zone, located between the two withdrawal areas.

A digital data collection protocol was applied and observations were compiled into a GIS-compatible database. This includes information on bedrock character (lithology, magnetic susceptibility, gamma ray spectrometry, structure, rock strength), fracture character, bedrock exposure and surface constraints. This report details the field observation for the withdrawal areas.

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1 INTRODUCTION

This technical report presents the results of Observing General Geological Features (OGGF) completed in 2014 and Detailed Geological Mapping completed in 2016 as part of the Phase 2 Geoscientific Preliminary Assessment, to further assess the suitability of the Hornepayne area (Figure 1.1) in northern Ontario, to safely host a deep geological repository. Phase 2 OGGF and Detailed Geological Mapping build on the results of the Initial Screening (Golder, 2011) and Phase 1 Geoscientific Desktop Preliminary Assessment (Geofirma, 2013). For the purpose of this report, OGGF and Detailed Geological Mapping will be collectively referred to as "Geological Mapping".

The Phase 1 Geoscientific Desktop Assessment identified three potentially suitable areas warranting further studies such as high-resolution geophysical surveys and geological mapping; one potentially suitable area is located in the metasedimentary rocks of the Quetico Subprovince and the other two in the Black-Pic batholith. Subsequent Phase 2 high-resolution geophysical surveys and interpretation (SGL, 2017), lineament interpretation (SRK, 2017) and geological mapping were conducted in two of the three potentially suitable areas identified in the Phase 1 Geoscientific Desktop Preliminary Assessment (Geofirma, 2013), in the Quetico Subprovince and the Black-Pic batholith

The objective of Phase 2 Geological Mapping is to advance understanding of the bedrock geology of the two potentially suitable areas assessed, with an emphasis on observation and analysis of bedrock structure and lithology, in the context of the results from the Phase 2 Airborne Geophysical assessment (SGL, 2017) and the Phase 2 Lineament Assessment (SRK, 2017). Information collected during Phase 2 Geological Mapping also helped identify areas of exposed bedrock, assess overburden thickness, and identify surface constraints affecting accessibility within the areas.

The Phase 2 Geological Mapping activity was completed by Geofirma Engineering Ltd. (Geofirma) and Fladgate Exploration Consulting Corporation (FECC). The observations were conducted at select locations that were accessed using existing secondary roads, trail networks and waterbodies, as well as some off-trail hiking (Figure 1.2).

1.1 Scope of Work

The Phase 2 Geological Mapping activity was carried out in two phases, including an initial Observing General Geological Features (OGGF) followed by Detailed Geological Mapping. During OGGF observations were made primarily along existing roads and trails, occasionally involving walking short distances off these trails. The findings from the OGGF results were assessed in conjunction with data collected from other field studies such as airborne geophysical surveys (SGL, 2017) and lineament interpretations (SRK, 2017) to help determine the focus of the Detail Geological Mapping phase, which involved investigating as many locations of exposed bedrock as possible within and around the potentially suitable areas.

The Phase 2 Geological Mapping work, including OGGF and Detailed Geological Mapping, was carried out in three stages (Section 4) as follows:

- Stage 1: Pre-mapping planning stage;
- Stage 2: Mapping stage; and

- Stage 3: Synthesis and reporting stage.

During the pre-mapping planning stage, a plan for the OGGF and Detailed Geological Mapping was developed for two of the general potentially suitable areas that were identified in the Phase 1 Geoscientific Desktop Preliminary Assessment (Geofirma, 2013). One of the areas mapped is within the Wawa Subprovince on the Black-Pic batholith, and one is within the metasedimentary rocks of the Quetico Subprovince (Figure 1.2).

During the geological mapping (Stage 2), geological information was collected in accordance with the work plans defined during Stage 1 (See Section 4 Methodology) and during Stage 3 the information was analysed, compiled and is documented in this report.

The two areas were mapped in the fall of 2014 (OGGF) and summer of 2016 (Detailed Geological Mapping) over a total period of 48 mapping days by four teams, each consisting of two geologists. A local guide also accompanied the field mapping crews occasionally. For the Detailed Geological Mapping phase several GIS datasets were used as base maps for planning and undertaking the work, including predictive outcrop mapping generated by NWMO using remote sensing data (See Section 4 Methodology), high-resolution satellite imagery, recently-acquired high-resolution geophysical data (SGL, 2017) and interpreted lineaments (SRK, 2017).

1.2 Qualifications of Team

The team that undertook OGGF and Detailed Geological Mapping, including field work and subsequent collation and reporting of data, was assembled by Geofirma and included subconsultants from Fladgate Exploration Consulting Corporation as well as Geofirma's staff, as follows:

- Sean Sterling — Project Manager
- Neil Pettigrew — Lead Mapper (OGGF)
- Mike Thompson — Lead Mapper (OGGF)
- Emily Kyte — Assistant Mapper (OGGF)
- Vanessa Scharf — Assistant Mapper (OGGF)
- Hubert Mvondo — Lead Mapper (Detailed Geological Mapping)
- Paul Gann — Lead Mapper (Detailed Geological Mapping)
- Robert Richard — Assistant Mapper (Detailed Geological Mapping)
- Ryan Shannon — Assistant Mapper (Detailed Geological Mapping)

A summary of the qualifications of the team is provided below.

Sean Sterling, M.Sc., P.Eng. (PEO #90503939), P.Geo (APGO #1678) - Senior Hydrogeologist/Engineer: Mr. Sterling has 22 years of specialized experience and expertise in site investigation and characterization, specializing in bedrock environments. He completed his Master of Earth Science from the University of Waterloo in 1999. Mr. Sterling is the project manager and geoscientific technical lead for all APM projects completed by Geofirma for NWMO, including four initial screening studies, crystalline and sedimentary rock feasibility studies, and two OGGF geological mapping studies for crystalline rock communities in Ontario.

Hubert Mvondo PhD., P.Geo. (APEGNB #M7409) - Senior Structural Geologist: Dr. Mvondo has over 20 years of research, teaching, and mineral exploration in various, low- to high-grade, Precambrian to Phanerozoic terranes including greenstone belts on different continents. He combines different data sets (structural, geophysical, drill core, petrological, and geochemical data) using various 2D GIS and 3D geological modelling programs to study the geometry and kinematics of rock masses at different scales and controls on fluid flow through time, with direct applications in mineral exploration and engineering design.

Paul Gann, BSc, P.Geo (APGO #1848) – Senior Field Geologist: Mr. Gann has 33 years of professional experience as project manager as well as undertaking regional and structural mapping in Northern Quebec, Ontario, Saskatchewan, British Columbia, Yukon, and Nunavut. He has worked in a consulting geologist role for many companies such as Skyonic Corporation, Tamerlane Ventures and Porpoise Bay Minerals.

Robert Richard, B.Sc., Assistant Field Geologist: Mr Richard has over 10 years in the mineral exploration business with a focus on structurally controlled gold deposits. He has spent most of his career with Rockport Mining Corp. / Portage Minerals Ltd, advancing grass root projects to advanced stage mineral deposits with NI 43-101 compliant gold resources. Highlight deposits include Devils Pike and Golden Ridge gold deposits in New Brunswick

Ryan Shannon, B. Eng., Assistant Field Geologist: Mr. Ryan Shannon is a recent graduate of the Geological Engineering program at Queen's University. During his undergrad Ryan gained course experience with geological mapping in the Grenville Province and the Eastern Townships of Quebec. Ryan gained additional field experience with his involvement in Society of Economic Geologist Queen's Student chapter including the trip to Sudbury where they spent the day with a regional geologist with the Ontario Geological Survey

Neil Pettigrew, M.Sc., P.Geo. (APGO #1462) - Senior Field Geologist (FECC): Mr. Pettigrew has over 10 years of professional experience with extensive experience in detailed grid and regional geological and structural mapping primarily in Northern Ontario, notably including 2 years with the Ontario Geological survey working as a senior Precambrian geoscientist.

Mike Thompson, B.Sc., P.Geo.(APGO #1521) - Senior Field Geologist (FECC): Mr. Thompson has over 10 years of professional experience with extensive experience in detailed grid and regional geological and structural mapping primarily in Northern Ontario. He has worked in a geologist role for a variety of mining clients including Teck Cominco Ltd. in Marathon and Placer Dome Ltd. in Thunder Bay.

Emily Kyte, B.Sc. - Assistant Field Geologist: Ms. Kyte is a Geoscientist with one year of consulting experience. She completed a B.Sc. undergraduate degree in Earth and Planetary Science (Geology) from McGill University in 2013. Since graduating, Ms. Kyte has worked as a Junior Geologist/Geotechnician to complete geological mapping in the Grenville Province of northern Quebec.

Vanessa Scharf, B.Sc. – Assistant Field Geologist: Ms. Scharf is a Geoscientist with three years of consulting experience. She completed a joint B.Sc. undergraduate degree in Geology and Physics from the University of Ottawa in 2011. Ms. Scharf has completed geological mapping and structural analysis of a region in the Appalachian belt.

1.3 Report Organization

A general description of the Hornepayne area, including location, physiography and access is provided in Section 2. Section 3 summarizes the regional and local geological setting for the Hornepayne area. The methodology employed to undertake the geological mapping activities is provided in Section 4. Field observations are described in Section 5. A brief summary of the report is included in Section 6, followed by references cited in Section 7 with a set of figures.

2 LOCAL AREA DESCRIPTION

2.1 Location

The Township of Hornepayne is situated in the District of Algoma 130 km north of the eastern end of Lake Superior and 340 km east of Thunder Bay, 260 km west of Timmins, and 300 km north of Sault Ste. Marie (Figure 1.1). Access to the Hornepayne area is via Highway 631 and a rail line operated by Canadian Pacific Railways. A network of secondary roads and forestry roads/trails accessed via Highway 631 provide the majority of access to mapping areas. Several hunting camps exist within the mapping areas with only light vehicle traffic along the secondary roads common (e.g. one to two cars a day).

2.2 Physiography

The Hornepayne area is located in the Abitibi Uplands, a broadly rolling surface of Canadian Shield bedrock that occupies most of north-central Ontario. Within the Abitibi Uplands, bedrock is typically either exposed at surface or shallowly covered with Quaternary glacial deposits or postglacial organic soils (Thurston, 1991).

The Hornepayne area contains a large number of lakes of various sizes; there are six lakes larger than 10 km^2, three of which (Nagagami Lake, Obakamiga Lake and Nagagamisis Lake) are larger than 20 km^2, with approximately 8.5% (404 km^2) of the entire area occupied by water bodies (JDMA, 2013). There is considerable relief between the lakes in most areas.

Topography in the Hornepayne area is somewhat variable with elevation exceeding 480 mASL on the north and west sides of Obakamiga Lake approximately 15 km west of the Township of Hornepayne. Lands further to the north and east are less rugged and lower in elevation (from 220 to 300 mASL) reflecting the continental drainage divide located to the southwest of Hornepayne in the vicinity of Granitehill Lake (JDMA, 2013). Topographic highs generally correspond to bedrock outcrops while topographic lows are generally associated with areas of thicker overburden in bedrock valleys. Bedrock terrain is mapped for roughly 43% of the Hornepayne area (JDMA, 2013). Bedrock terrain includes exposed bedrock and thin, discontinuous drift deposits generally less than one metre thick.

3 SUMMARY OF GEOLOGY

The detailed geology of the Hornepayne area was described in the Phase 1 Geoscientific Desktop Preliminary Assessment (Geofirma, 2013). The following subsections provide a brief description of the geologic setting, bedrock geology, structural history and mapped structures, metamorphism and Quaternary geology of the Hornepayne area.

3.1 Geological Setting

The Hornepayne area is located within the Superior Province of northern Ontario. The Superior Province is 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 (e.g., Percival et al., 2006). The Superior Province covers an area of approximately 1,500,000 km^2 and is divided into subprovinces, including the Wawa and Quetico Subprovinces. The Hornepayne south survey block is located entirely within the Wawa Subprovince, whereas the north survey block is located entirely within the Quetico Subprovince (Figure 1.2).

The Wawa Subprovince comprises multiple units of volcanic and associated metasedimentary rocks (greenstone belts) separated by extensive granitioid plutons and batholiths. These volcanic and metasedimentary units typically occur in elongate narrow geometries and represent volumetrically a relatively minor percentage of the rocks. The surrounding granitic bodies are composed primarily of tonalite to granodiorite, and represent the vast majority of the rock present throughout the area.

The Quetico Subprovince is an expansive geological domain comprised predominantly of metasedimentary rocks (Zaleski et al., 1995). Numerous granitic intrusions, and rare mafic to ultramafic intrusions are also located throughout the Quetico Subprovince (Williams, 1989; Sutcliffe, 1991).

Several generations of Proterozoic diabase dyke swarms, ranging in age from ca. 2.473 to 1.14 Ga intrude all bedrock units in the Hornepayne area (Hamilton et al., 2002; Buchan and Ernst, 2004; Halls et al., 2006).

3.2 Bedrock Geology

The main bedrock geology units present within the two Hornepayne survey blocks include the Black-Pic batholith of the Wawa Subprovince and the metasedimentary rocks of the Quetico Subprovince. Additionally, a sliver of the Strickland pluton occurs in the southeastern portion of the southern survey block, and the southern boundary of a granite-granodiorite intrusion is located along the northern boundary of the northern survey block (Figure 1.2). All bedrock units in the Hornepayne area are transected by three generations of diabase dykes. The bedrock in the Hornepayne area has experienced several generations of ductile and brittle deformation, and the individual rock units have been subjected to varying amounts of metamorphism.

A detailed description of these bedrock units, and structural and metamorphic events, can be found in the Phase 1 Geoscientific Desktop Preliminary Assessment (Geofirma, 2013), and are summarized in the following subsections. A description of the bedrock geology units surrounding, but not included within the individual Phase 2 Hornepayne interpretation areas, can also be found in the aforementioned reference, and are not repeated here.

3.2.1 Metasedimentary Rocks of the Quetico Subprovince

Metasedimentary rocks of the Quetico Subprovince occur in the northern portion of the Hornepayne assessment area and underlie the entire northern survey block, with the exception of the northernmost boundary, which is located along the contact of a granite-granodiorite intrusion (Figure 1.2).

Metasedimentary rocks of the Quetico Subprovince include wacke-pelite-arenite rocks of the Quetico belt, as well as varying amounts of ironstone, conglomerate, and siltstone (Williams and Breaks, 1996; Zaleski et al., 1999). Rocks within the Quetico Subprovince have experienced varying degrees of metamorphism and deformation, and commonly exhibit gneissic and migmatitic textures (Percival, 1989; Zaleski et al., 1999). Extensive deformation can be observed in numerous small-scale folds, shear zones, and boudinaged units (Williams and Breaks, 1996). Evidence of extensive metamorphism include significant volumes of leucosome, resulting from partial melting and segregation during high-grade metamorphism (Williams and Breaks, 1996).

The Quetico Subprovince has been interpreted to be an accretionary prism of an Archean volcanic island-arc system, which developed where the Wawa and Wabigoon belts formed converging arcs (Percival and Williams, 1989). The timing of the Quetico-Wawa belt accretion has been constrained between ca. 2.689 Ga and 2.684 Ga (Percival, 1989), and the metasedimentary rocks have been dated at 2.700 to 2.688 Ga (Percival, 1989; Zaleski et al., 1999).

3.2.2 Intrusive Rocks of the Quetico Subprovince

The southern boundary of a mapped granite-granodiorite intrusion straddles the northern boundary of the Hornepayne northern survey block (Figure 1.2). Similar intrusions have been mapped in the region, and described as quartzo-feldspathic gneisses (Coates, 1970) and biotite leucogranite (Percival, 1989). In general, granitic rocks in the Quetico Subprovince are typically medium- to coarse-grained and massive (Percival, 1989). Information on the depth of emplacement or age of these intrusions in the Hornepayne area is not available.

3.2.3 Intrusive Rocks of the Wawa Subprovince

Black-Pic Batholith

The Black-Pic batholith is a regionally-extensive intrusion located within the Wawa Subprovince, encompassing an area of approximately 3,000 km^2. With the exception of several relatively small granitic intrusions (e.g., Strickland pluton), the bedrock underlying the southern survey block is entirely contained within this batholith (Figure 1.2).

The Black-Pic batholith comprises a multi-phase suite of hornblende-biotite monzodiorite, foliated tonalite, and pegmatitic granite, with subordinate foliated diorite, granodiorite, granite and cross-cutting aplitic to pegmatitic dykes (Williams and Breaks, 1989; Zaleski and Peterson, 1993). Local lithological variations occur throughout the batholith, including upper levels of the tonalite, which are frequently cut by granitic sheets of pegmatite and aplite, and are generally more massive (Williams and Breaks, 1989). Also present throughout the batholith are zones of migmatized sedimentary rocks and massive granodiorite to granite. The contact between these rocks and the tonalitic rocks is gradational and associated with extensive sheeting of the tonalitic unit (Williams and Breaks, 1989; Williams et al., 1991).

The Black-Pic batholith is interpreted to be a domal structure with shallow dipping foliation radiating outward from its centre (Williams et al., 1991). Structurally deeper levels of the tonalite suite contain a strong sub-horizontal foliation and a weak north-trending mineral elongation lineation (Williams and Breaks, 1989).

The age of emplacement of the Black-Pic batholith has been constrained by U-Pb (zircon) dating of the oldest recognized phase of the tonalite at ca. 2.720 Ga (Jackson et al., 1998). A younger monzodioritic phase has also been dated at ca. 2.689 Ga (Zaleski et al., 1999). Regional geologic models of the area (e.g., Lin and Beakhouse, 2013) suggest that the Black Pic batholith may extend to a considerable depth. More recently, the Black-Pic batholith has been modelled using gravity and aeromagnetic data with modeled depths for the batholith ranging from 4 km to 7 km (SGL, 2017).

Strickland Pluton

Part of the Strickland pluton occurs in the southeast portion of the Hornepayne area bordering the Black-Pic batholith. The pluton occupies an area of approximately 600 km^2 and has maximum dimensions in the area of 34 km north-south and 55 km east-west (Figure 1.2). Stott (1999) described the Strickland pluton as a relatively homogeneous, quartz-porphyritic granodiorite. Although near the outer margin of the pluton, adjacent to greenstone belt rocks, granodiorite to tonalite and diorite are present. In the area west of the Kabinakagami greenstone belt, which occurs just south of the Black Pic batholith beyond the footprint of Figure 1.2, Siragusa (1977) noted that massive quartz monzonite (i.e., monzogranite in modern terminology) intrudes the granodioritic and trondhjemitic rocks in the form of medium-grained to pegmatitic dykes and small sills and irregular bodies.

Some degree of post-emplacement deformation and metamorphism of the Strickland pluton is indicated by the observed presence of fine- to medium-grained titanite and the widespread presence of hematite-filled fractures and weak alteration of silicate minerals (Stott, 1999). Stott (1999) noted that the pluton is petrographically similar to the ca. 2.697 Ga Dotted Lake batholith, located southwest of the Hornepayne area, and suggested that these plutons are members of an intrusive suite commonly found along the margins of greenstone belts in this part of the Wawa Subprovince.

The Strickland pluton has recently been modelled, using gravity and aeromagnetic data, with a roughly constant thickness slightly over 2 km with internal density variations or alternatively with a constant density and variable thickness with a maximum around 4 km in the central part of the pluton (SGL, 2017).

3.2.4 Mafic Dykes

Multiple diabase dyke swarms cross-cut the Hornepayne area (Figure 1.2), including:

- Northwest-trending Matachewan dykes (ca. 2.473 Ga; Buchan and Ernst, 2004). This dyke swarm is one of the largest in the Canadian Shield. Individual dykes are generally up to 10 metres wide, and have vertical to subvertical dips. Matachewan dykes are mainly quartz-diabase dominated by plagioclase, augite, and quartz (Osmani, 1991).

- North-northeast-trending-trending Marathon dykes (ca. 2.121 Ga; Buchan et al., 1996; Hamilton et al., 2002). These dykes form a fan-shaped distribution pattern around the northern, eastern, and western flanks of Lake Superior. The dykes vary in orientation from northwest to northeast, and occur as steep to subvertical sheets, typically a few metres to tens of metres thick, but occasionally up to 75 metres thick (Hamilton et al., 2002). The Marathon dykes are quartz-diabase dominated by equigranular to subophitic clinopyroxene and plagioclase (Osmani, 1991).

- Northeast-trending Biscotasing dykes (ca. 2.167 Ga; Hamilton et al., 2002). Locally, Marathon dykes also trend northeast and cannot be separated with confidence from the Biscotasing Suite dykes.

- Northeast-trending Abitibi dykes (ca. 1.14 Ga; Ernst and Buchan, 1993). These dykes occur locally in the Hornepayne area cross-cutting older dykes.

The four dyke swarms in the Hornepayne area are distinguishable, in some cases, by their unique strike directions, cross-cutting relationships and, to a lesser extent, by magnetic amplitude.

3.3 Structural History

Information on the structural history of the Hornepayne area is based predominantly on structural investigations of the Hornepayne and Dayohessarah greenstone belts (Polat, 1998; Peterson and Zaleski, 1999) and the Hemlo gold deposit and surrounding region (Muir, 2003). Additional studies by Lin (2001), Percival et al. (2006), and Williams and Breaks (1996) have also contributed to the structural understanding of the area. The aforementioned studies were performed at various scales and from various perspectives. Consequently, the following summary of the structural history of the Hornepayne area should be considered as a best-fit model that incorporates relevant findings from all studies. The structural history of the Hornepayne area is described below and summarized in Table 3.1.

The Hornepayne area straddles a structurally complex boundary between the metasedimentary-migmatitic Quetico Subprovince and the volcano-plutonic Wawa Subprovince within the Archean Superior Province.

The structural history of the Hornepayne and nearby Schreiber-Hemlo greenstone belts is generally well characterized and includes multiple phases of deformation (Polat et al., 1998; Peterson and Zaleski, 1999; Lin, 2001; and Muir, 2003). Polat et al. (1998) interpreted that the Schreiber-Hemlo and surrounding greenstone belts represent collages of oceanic plateaus, oceanic arcs, and subduction-accretion complexes amalgamated through subsequent episodes of compressional and transpressional collision.

On the basis of overprinting relationships between different structures, Polat et al. (1998) suggested that the Schreiber-Hemlo greenstone belt underwent at least two main episodes of deformation that also affected rocks of the Wawa Subprovince, including the Hornepayne area. These deformation events can be correlated with observations from Peterson and Zaleski (1999) and Muir (2003), who reported at least five and six generations of structural elements, respectively. Two of these generations of structures account for most of the ductile strain, and although others can be distinguished on the basis of cross-cutting relationships, they are likely the products of progressive strain events. Integration of the structural histories detailed in Williams and Breaks (1996), Polat et al. (1998), Peterson and Zaleski (1999), Lin (2001), and Muir (2003) suggests that six deformation events occurred within the Hornepayne area. The first four deformation events (D1-D4) are associated with brittle-ductile deformation of the greenstone belts. D5 and D6 were associated with a combination of brittle deformation and fault propagation through all rock units in the Hornepayne area. The main characteristics of each deformation event are summarized in Table 3.1.

Table 3.1 Summary of the Geological and Structural History of the Hornepayne Area (adapted from AECOM, 2014)

Approximate Time Period (years before present)	Geological Event
2.89 to 2.77 Ga	Progressive growth and early evolution of the Wawa-Abitibi terrane by collision, and ultimately accretion, of distinct geologic terranes
2.770 – 2.673 Ga	- ca. 2.720 Ga: Volcanism and subordinate sedimentation associated with the formation of the Manitouwadge-Hornepayne greenstone belt - ca. <2.693: Deposition of sedimentary rocks in the Hornepayne greenstone belt and the Quetico Subprovince - ca. 2.720-2.678 Ga: Inferred emplacement of granitoid intrusions in the Hornepayne area. Emplacement of the Pukaskwa and Black-Pic gneissic complexes at ca. 2.72 Ga Emplacement of Loken Lake pluton (ca. 2.687 Ga), Nama Creek pluton (2.680 Ga), and Fourbay Lake pluton (ca. 2.678 Ga) - ca. 2.719 to 2.673 Ga: Four generations of ductile-brittle deformation (D_1-D_4) D_1: ca. 2.719 – 2.691 Ga D_2: ca. 2.691 – 2.683 Ga D_3: ca. 2.682 – 2.679 Ga D_4: ca. 2.679 – 2.673 Ga
2.675 to 2.669 Ga	Peak metamorphism of the Hornepayne greenstone belt
2.666 to 2.650 Ga	Peak metamorphism of the Quetico Subprovince
2.5 to 2.100 Ga	- ca. 2.5 Ga: Supercontinent fragmentation and rifting in Lake Superior area; development of the Southern Province - ca. 2.473 Ga: Emplacement of the Matachewan dyke swarm - ca. 2.167 Ga: Emplacement of Biscotasing dyke swarm - ca. 2.121 Ga: Emplacement of the Marathon dyke swarm
1.9 to 1.7 Ga	Penokean Orogeny in Lake Superior and Lake Huron areas; possible deposition and subsequent erosion in the Hornepayne area
1.150 to 1.090 Ga	Rifting and formation of the Midcontinent Rift structure - ca. 1.1 Ga
540 to 355 Ma	Possible coverage of the area by marine seas and deposition of carbonate and clastic rocks subsequently removed by erosion
145 to 66 Ma	Possible deposition of marine and terrestrial sediments of Cretaceous age, subsequently removed by erosion
2.6 to 0.01 Ma	Periods of glaciation and deposition of glacial sediments

The earliest recognizable deformation phase (D1) is associated with rarely preserved small-scale isoclinal (F1) folds, ductile shear zones that truncate, and a general lack of penetrative foliation development. Peterson and Zaleski (1999) reported that an S1 foliation is only preserved locally in outcrop and in thin section. D1 deformation is poorly constrained between ca. 2.719 and ca. 2.691 Ga (Muir, 2003).

D2 structural elements include prevalent open to isoclinal F2 folds, an axial planar S2 foliation, and L2 mineral elongation lineations (Peterson and Zaleski, 1999). Muir (2003) interpreted D2 to have resulted from progressive north-northeast to northeast directed compression that was coincident with the intrusion of various plutons. The S2 foliation is the dominant meso- to macro-scale regional fabric evident across the study area. Ductile flow of volcano-sedimentary rocks between more competent batholiths may also have occurred during D2 deformation. This generation of deformation is constrained to between ca. 2.691 and ca. 2.683 Ga (Muir, 2003).

D3 deformation was the result of northwest-southeast shortening during regional dextral transpression. D3 structural elements include macroscale F3 folds, including the regional scale isoclinal fold developed within the Hornepayne greenstone belt (Figure 1.2), and local shear fabrics that exhibit a dextral sense of motion and overprint D2 structures (Peterson and Zaleski, 1999; Muir, 2003). D3 deformation did not develop an extensive penetrative axial planar and (or) crenulation cleavage. D3 deformation is constrained to between ca. 2.682 and ca. 2.679 Ga (Muir, 2003).

D4 structural elements include isolated northeast-plunging F4 kink folds with a Z-asymmetry, and associated small-scale fractures and faults overprinting D3 structures. D3-D4 interference relationships are best developed in the Hornepayne greenstone belt and in rocks of the Quetico Subprovince (Muir, 2003). D4 deformation is roughly constrained to between ca. 2.679 and ca. 2.673 Ga (Muir, 2003).

Details of structural features associated with the D5 and D6 deformation events are limited in the literature to brittle faults of various scales and orientations (Lin, 2001; Muir, 2003). Within the Hemlo greenstone belt, Muir (2003) suggested that local D5 and D6 faults offset the Marathon and Biscotasing dyke swarms (all ca. 2.2 Ga), and as such, suggested that in the Hemlo region D5 and D6 faults propagated after ca. 2.2 Ga. However, since there are no absolute age constraints on specific events, the entire D5-D6 interval of brittle deformation can only be constrained to a post-2.673 Ga timeframe that may include many periods of re-activation attributable to any of several post-Archean tectonic events.

3.3.1 Mapped Structures and Named Faults

In the Hornepayne area, in both the Quetico and Wawa Subprovinces, only three unnamed faults are indicated on public domain geological maps (Figure 1.2) within the northern and southern survey blocks. These faults display two dominant orientations: northeast and northwest.

Outside of the Hornepayne survey blocks, the east-northeast-trending Shekak River fault, which is mapped immediately east of the Hornepayne southern block affects granitic rocks of the Black-Pic batholith.

3.3.2 Metamorphism

Studies on metamorphism in Precambrian rocks across the Canadian Shield have been summarized in multiple publications (e.g., Fraser and Heywood, 1978; Kraus and Menard, 1997; Menard and Gordon, 1997; Berman et al., 2000; Easton, 2000a, 2000b; and Berman et al., 2005) and the thermochronological record for large parts of the Canadian Shield is documented in a number of studies (Berman et al., 2005; Bleeker and Hall, 2007; Corrigan et al., 2007; and Pease et al., 2008).

The Superior Province of the Canadian Shield largely preserves low pressure, high temperature Neoarchean (ca. 2.710-2.640 Ga) metamorphic rocks. The relative timing and grade of regional metamorphism in the Superior Province corresponds to the lithological composition of the subprovinces (Easton, 2000a; Percival et al., 2006). Subprovinces comprising volcano-sedimentary assemblages and synvolcanic to syntectonic plutons (i.e., granite-greenstone terranes) are affected by relatively early lower greenschist to amphibolite facies metamorphism. Subprovinces comprising both metasedimentary- and migmatite-dominated lithologies, such as the English River and Quetico, and dominantly plutonic and orthogneissic domains, such as the Winnipeg River, are affected by relatively late middle amphibolite to granulite facies metamorphism (Breaks and Bond, 1993; Corfu et al., 1995). Subgreenschist facies metamorphism in the Superior Province is restricted to limited areas, notably within the central Abitibi greenstone belt (e.g., Jolly, 1978; Powell et al., 1993).

In general, most of the Canadian Shield preserves a complex episodic history of Neoarchean metamorphism overprinted by Paleoproterozoic tectonothermal events culminating at the end of the Grenville orogeny ca. 950 Ma. The distribution of contrasting metamorphic domains in the Canadian Shield is a consequence of relative uplift, block rotation, and erosion resulting from Neoarchean orogenesis, subsequent local Proterozoic orogenic events and broader epeirogeny during later Proterozoic and Phanerozoic eons.

In the Hornepayne area, metasedimentary rocks of the Quetico Subprovince exhibit granulite facies metamorphic conditions close to the boundary between the Wawa and Quetico Subprovinces (Williams and Breaks, 1989, 1996; Zaleski and Peterson 1993; Pan et al., 1994).

Geothermobarometric and geochronological calculations by Pan et al. (1994) indicate that low pressure-high temperature, amphibolite facies metamorphism in metasedimentary rocks of the Quetico Subprovince had been in place before ca. 2.666 Ga, in agreement with the period ca. 2.671-2.665 Ga estimated by Percival and Sullivan (1988). This prograde amphibolite facies regional metamorphism would have been initiated ca. 2.675 Ga, increased after ca. 2.666 Ga and reached granulite facies under a thermal peak of 680-700 degrees Celsius (°C) and 4-6 Kbar perhaps ca. 2.658 Ga. Granulite facies metamorphism would have lasted until ca. 2.650 Ga, after which a retrograde event would have occurred at 550-660°C, 3-4 Kbar. After the retrogression, hydrothermal alteration occurred at 200-400°C, 1-2 Kbar.

Within the Black-Pic batholith and other smaller plutons greenschist facies metamorphism is typically observed (Geofirma, 2013). Locally, higher metamorphic grades up to upper amphibolite facies are recorded in rocks along the margins of plutons. No records exist that suggest that rocks in the Hornepayne area may have been affected by thermotectonic overprints related to post-Archean events.

3.4 Quaternary Geology

The Quaternary geology of the Hornepayne area is described in detail in the remote sensing and terrain evaluation completed as part of the Phase 1 Geoscientific Desktop Preliminary assessment (JDMA, 2013). An overview of the relevant Quaternary features are summarized below.

The Quaternary sediments in the Hornepayne area comprise glacial and post-glacial materials that overlie the bedrock. All glacial landforms and related materials are associated with the Wisconsinan glaciation, which began approximately 115,000 years ago (Barnett, 1992). Throughout the majority of the Hornepayne area, bedrock outcrops are common and the terrain is dominantly classified, for surficial purposes, as a bedrock-drift complex, i.e., thin drift cover that only locally achieves thicknesses that mask or subdue the bedrock topography. When present, drifts overlying the bedrock are typically limited in thickness and the ground surface reflects the bedrock topography. Beyond bedrock-drift complexes, valleys and lowland areas present, which typically exhibit extensive and thick surficial deposits, frequently have a linear geometry.

The main direction of the most recent glacial advance in the Hornepayne area was from the north-northeast (Gartner and McQuay, 1980). In the Hornepayne area, a common glacial deposit is stony, sandy till (ground moraine) which forms a veneer in rocky upland areas. The till composition is variable and two types are regionally recognizable (Geddes et al. 1985; Geddes and Kristjansson, 1986). A moderately loose, locally derived, very stony variety with a sandy texture dominates in areas of thin till cover in the western part of the area. A calcareous, silty till, rich in “exotic” carbonate lithologies derived from the James Bay Lowland (Geddes and Kristjansson, 1986) occurs in two facies, one of which is stone poor, massive, silty, and quite dense. The other more dominant facies is less compact and slightly sandier, and has a variable stone content. In some areas, the calcareous till is capped by coarser, locally derived till or till-like material. Geddes and Kristjansson (1986) noted that in areas where there is little relief on the land surface, the calcareous till is usually prominent, especially in areas on the leeside of significant topographic features. It is typical of the stony till to have a more hummocky or moranic surface expression.

The most significant Quaternary landforms occurring in the southern survey block of the Hornepayne area are two large northeast-trending esker complexes in the Bayfield Lake and West Larkin Lake-Shekak River areas. These esker complexes consist of sands and gravels and can exceed 15 metres in depth (Gartner and McQuay, 1980). The most significant Quaternary landforms occurring in the northern survey block are moraine in the southeastern part, and glaciolacustrine plains in the northwestern part.

Glaciolacustrine sediments cover the west-central portion and form a narrow northeastern belt that transects the southern survey block, and partly cover the northwest corner of the northern block. These sediments comprise stratified to laminated sand, silt, and clay that were deposited during the incursion of glacial lakes (Prest, 1970; Gartner and McQuay, 1980; Kettles and Way Nee, 1998). The thickness of glaciolacustrine deposits is variable, ranging from several tens of metres to a relative thin drape over bedrock (Kettles and Way Nee, 1998).

Minor organic-rich alluvial deposits and eolian deposits are also locally present throughout the Hornepayne area, and have limited extents. Alluvial deposits are organic-rich, consist of sand, silt and clay, and are typically present along water courses. Eolian deposits consist of sand and are present as dunes developed on certain glacial deposits (Gartner and McQuay, 1980; Geddes and Kristjansson, 1986; Kettles and Way Nee, 1998).

4 METHODOLOGY

The following sections provide an overview of the methods implemented in order to fulfill the requirements of the technical scope of work for the Phase 2 Geological Mapping completed by Geofirma and Fladgate for the Hornepayne area in Ontario. Phase 2 Geological Mapping in the Hornepayne area focused within and around the two withdrawal areas for mapping that were identified in the Phase 1 Geoscientific Desktop Preliminary Assessment (Geofirma, 2013), including the Quetico Area and the Black-Pic Batholith Area.

The OGGF component of the Phase 2 Geological Mapping was intended to acquire a reasonably-sized initial data set at easily accessible outcrops in order to define priority areas on which to concentrate during the subsequent Detailed Outcrop Mapping component. The methods described below include tasks associated with planning, implementation, and reporting of the Phase 2 Geological Mapping. Supporting information, as noted below, is also included in Appendix A and Appendix B.

4.1 Pre-Mapping Planning Stage

In order to optimize the time and resources available, a pre-mapping planning stage of the Phase 2 Geological Mapping activity was completed prior to mobilizing to the Hornepayne Area. This stage included the development of a list of available source data (Appendix A, Table A.1) and equipment requirements (Appendix A, Table A.2), for planning and implementing the OGGF and Detailed Mapping components of the Phase 2 Geological Mapping. This stage also included the development of a summary list of daily field tasks allocated to each mapping team member (Appendix A, Table A.3).

The key geological attributes to be investigated, along with the methods identified to observe and capture the relevant information at each bedrock outcrop location, were also outlined in the pre-mapping planning stage. This included the use of a digital data capturing method, which for this activity included an ArcGIS compatible data-logging instrument. The instrument consisted of a Trimble (T41 or equivalent) handheld computer that included a customized version of ArcPad data collection software (SRK, 2016) with a database specifically set-up to capture the attributes listed in Table A.4 (Appendix A). The database is consistent with a modified version of the GanFeld database used in previous OGGF mapping projects. The Ganfeld system is an Ontario Geological Survey (OGS) standard system for data collection which was originally provided in an open file format by the Geological Survey of Canada (Shimamura et al., 2008). Entry of geological information into the data collector followed a simple data collection protocol (SRK, 2016) which directed the observer to the appropriate digital form within the database system to capture the appropriate geological information for each geological characteristic being investigated. Additional guidance relevant to the documentation of the geological characteristics is provided in Table A.4 (Appendix A), and, specifically for geomechanical characterization, in Table A.5 (Appendix A).

Field and sample magnetic susceptibility measurements were obtained from fresh surfaces of outcrop or from the rock samples using a KT-10 or KT-20 magnetic susceptibility meter provided and calibrated by Terraplus Inc. of Richmond Hill, Ontario. The KT-10 and KT-20 meters are operated with a pin adaptor to improve reliability when used on rough surfaces. Field measurements were entered as the average of approximately five individual measurements taken over a representative portion of outcrop.

In addition, during Detailed Mapping field gamma ray measurements were obtained for each identified lithology at bedrock outcrops using an RS-125 or RS-230 gamma ray spectrometer provided and calibrated by Terraplus Inc.

4.1.1 Predicted Outcrop Filtering and Defining Daily Traverses

In the OGGF phase of geological mapping daily traverses were defined along the entire road network crossing each potentially suitable area to search for exposed bedrock outcrops for observation. Effort was made to investigate areas of high topography, where bedrock outcrop is most likely. Furthermore, in selected locations, additional off-road traverses were completed in areas of thin cover (as identified in Quaternary cover maps). Predicted outcrops were not available as an input dataset during the OGGF component of the Phase 2 Geological Mapping.

The results from a remote predictive bedrock mapping exercise, provided by the NWMO, show the distribution of predicted bedrock outcrop locations within and around the withdrawal areas (Figure 1.2). The process that was used to undertake the remote predictive bedrock mapping exercise is included in Appendix B below. These predicted outcrops serve as input for the task of defining traverses for the Detailed Mapping component of the Phase 2 Geological Mapping. The spatial distribution of predicted outcrop locations in relation to their distance to the existing road and trail network, and to the key geological features to be investigated during Phase 2 Geological Mapping, was assessed.

The predicted outcrops were individually assessed for proximity to the key geological features, including interpreted lineaments, interpreted geophysical anomalies and mapped geological bedrock units and their contacts. Outcrops that were coincident with, or near to, key geological features, and in close enough proximity that they could reasonably be examined during one day of mapping, were grouped together to form daily traverses for the Detailed Mapping component of Phase 2 Geological Mapping.

4.2 Mapping Stage

The information included in Section 4.1 describes the planning approach that was taken to meet the objectives of the Geological Mapping activity. Field mapping during both the Observing General Geological Features and Detailed Geological Mapping phases was conducted by two teams of two geologists. At each station visited, lithological and structural features were observed and were collected in accordance with Table A.4. Hand-sized rock samples, generally 1 kg in weight or larger, were collected to provide a representative example of the different rock types observed in the field.

Prior to starting Detailed Geological Mapping, a reconnaissance fly-over was completed to assess the results from the remote predicted outcrop activity and to verify accessibility constraints anticipated during the planning stages. Information from this reconnaissance fly-over was used to make minor adjustments to the daily mapping schedule. The plan for detailed mapping remained flexible to account for the progress and observations of the previous day, method of access and weather.

An important additional aspect of the Phase 2 Detailed Geological Mapping was the non-technical workflow that was followed on a daily basis to allow the technical work to be done to meet the required objectives. This included morning safety briefings, equipment calibration checks, data quality assurance checks, and planning for the next mapping day (Appendix A, Table A.3). A telephone conference was held with NWMO every evening during the course of the mapping campaign in order to discuss all aspects of the on-going work. This workflow provided the mechanism for communicating progress with the NWMO during mapping and for prioritizing traverses or making changes to planned traverses. The daily log documented the completion of the safety debriefing, calibration check and data back-up.

4.2.1 Proterozoic Mafic Dyke Scanline Fracture Mapping Exercise

Along with compiling observations on Proterozoic mafic dykes that were encountered on daily OGGF and Detailed Outcrop Mapping traverses, well-exposed examples of mafic dykes were identified as candidates for a scanline fracture mapping exercise, after the completion of the Detailed Outcrop Mapping. The emplacement of these Proterozoic mafic dykes, as outlined in Section 3, is understood to post-date the penetrative regional ductile deformation that is characteristic of the Superior Province. However, the relationship between dyke emplacement and the brittle deformation history of the Superior Province is less well constrained. The purpose of the scanline fracture mapping exercise is to assess both the nature and extent (if any) of the damage to the bedrock caused by dyke emplacement and the nature and extent of brittle deformation overprinting the dykes themselves. A summary of the method employed to complete each scanline fracture mapping exercise is described below.

Where a suitable target dyke is located, a scanline is laid out perpendicular to the strike of the dyke contact. One metre intervals were marked for reference along the strike direction, shifting the line to a parallel location where necessary (e.g. overburden cover). Observations of the type and distribution (spacing) of brittle deformation features (veins, faults, joints) were collected systematically within a 1 to 2 m wide swath parallel to the scanline line perpendicular to strike of dyke contact and extending as far as possible into the adjacent bedrock beyond the dyke contacts. Additional characteristics such as fracture infill, cross-cutting relationships and offsets were noted, if present. A sketch of the scanline was drawn, and photographs taken, to highlight key features (dyke contacts, prominent fractures, shifts in the scanline, overburden cover, etc.). Magnetic susceptibility readings were made at each 1 m interval, with five readings used to obtain an average for each measurement location. Host rock foliation on both sides of the dyke was also recorded, if present. The results from the scanline fracture mapping exercise of one Matachewan mafic dyke is included in Section 5.3.1 of this report. All exposures encountered of mafic dykes from the other Proterozoic swarms were relatively small and not suitable for undertaking a detailed scanline fracture mapping exercise.

Note also that due to the magnetic properties of the dykes, compass readings were significantly affected when placed close to the ground surface. In order to achieve the most accurate measurements for joints within the dyke, measurements were made approximately 1.5 m above the ground, and measuring the dip with the clinometer.

4.3 Synthesis and Reporting Stage

Following the completion of the Detailed Outcrop Mapping stage, this report was prepared describing the results from the OGGF and Detailed Outcrop Mapping components of the Phase 2 Geological Mapping. The report is focussed on the objective of increasing the overall understanding of the key geological attributes for the withdrawal areas and the identified withdrawal areas. This report includes the methodologies applied and an interpretation and analysis of the field observations in terms of an update on the new state of knowledge that the observations provide, specific to the withdrawal areas.

Shapefiles of the compiled mapping observations were delivered to NWMO are in accordance with the types of information entered into the observation database. The list of shapefiles delivered includes:

- Station.shp
- Lithology.shp
- Structure.shp
- Linework.shp
- Samples.shp
- Magnetic Susceptibility.shp
- Gamma Ray Spectrometry.shp
- Photographs.shp

All digital photographs were delivered in a zipped folder. Field notebooks were provided by means of a zipped folder of scanned pages. The data delivery also included a summary calibration report that includes copies of all calibration reports provided by third-party equipment providers and summary of results from all calibration activities undertaken during the mapping activities.

Metadata accompanying each shapefile and zipped folder, along with the calibration report, was prepared according to metadata guidelines provided by the NWMO. A summary of the mapping observations is presented in Section 5 of this report.

5 FINDINGS

This section summarizes the field observations made in the Hornepayne area based on two geological mapping initiatives, including:

- Phase 2 Observation of General Geological Features (OGGF) completed by Michael J. Thompson and Neil Pettigrew (FECC), assisted by Emily Kyte and Vanessa Scharf (Geofirma) between September 27 to October 5, 2014 during a single 9 day long field campaign; and,
- Phase 2 Detailed Geological Mapping completed by Dr. Hubert Mvondo and Paul Gann (FECC), assisted by Rob Richard (FECC) and Ryan Shannon (Geofirma), between July 2 to September 7, 2016 during three different field campaigns (July 2 to 19; Aug 4 to 20; and Sept 4 to 7) for a total of 39 mapping days.

Overall, a total of 616 locations were visited over 48 total mapping days. Field observations were made during OGGF mapping activities at a total of 160 readily-accessible locations using the existing road and trail networks in the Hornepayne area, primarily using either 4 x 4 trucks or ATV's. Field observations were made during detailed geological mapping activities in 2016 at a total of 456 additional locations. Again, 4 x 4 trucks were used when possible. However, difficult to access sites requiring ATV support or some degree of hiking were also visited during this phase.

Each mapping observation location has a unique station identification number made up of the two digit year (14 or 16 for 2014 and 2016, respectively), the lead geological mapper's initials (e.g. NP, MJT, HM, or PG), and a unique sequential number indicating the order in which the mapping teams visited each station during the field visit (Figures 5.1.1, 5.2.1 and 5.3.1).

As described in Section 1, Phase 2 Geological Mapping, including OGGF and Detailed Geological Mapping, focused in two of the general potentially suitable areas identified during Phase 1 Preliminary Assessment (Geofirma, 2013). The two areas where Geological Mapping was conducted are referred in this report as the Quetico Area (Quetico Subprovince), described below in Section 5.1, and the Black-Pic Batholith Area (Wawa Subprovince), described below in Section 5.2. In total, 308 locations were visited in the Quetico Area, and 283 locations were visited in the Black-Pic Batholith Area (Figure 1.2). During OGGF 25 stations were also visited in the area surrounding the mapped boundary between the two subprovinces to the north of the Black-Pic Batholith Area and to the southwest of the Quetico Area. This area is referred to in this report as the Subprovince Boundary Zone and a brief summary of observations in this area is included below in Section 5.3. Field observations from each of these three mapping areas is described separately in the following sub-sections. Note that field observations are described in less detail for the Subprovince Boundary Zone, since it lies outside of the potentially suitable areas.

Dykes, including Proterozoic mafic dykes and Archean felsic to intermediate dykes, are a prominent feature of the Hornepayne area and their characteristics are also described below in Section 5.4. The dyke discussion includes presentation of the results from scanline fracture mapping exercises undertaken on one well-exposed field example of each of the three Proterozoic mafic dyke swarms identified in the Hornepayne area. The results presented in Section 5 are summarized in Section 6.

5.1 Quetico Area

5.1.1 Accessibility and Surface Constraints

The Quetico Area is located between 6 and 24 km north of the town of Hornepayne and has relatively good road access. The area is accessed by several old and new logging roads that branch to the west and east off of Highway 631, north of the town of Hornepayne (Figures 1.2 and 5.1.1). The logging roads allowed access by four wheel drive pick-up truck to most planned traverses. As no active logging was ongoing, the use of two-way radios was not required. Field photos in Figure 5.1.2 show examples of accessibility and bedrock exposure conditions within the Quetico Area.

Kenogami Road is the main forestry road within this area, branching west off of Highway 631, approximately 4 km north of the town of Hornepayne. Kenogami Road provided access to the southwestern portion of the Quetico Area. Three other logging roads, Elgie Rd, Newlands Rd and West Elgie Rd (Figure 5.1.1) were used to access outcrops on the east and west side of Highway 631. All four of these secondary forestry roads provided access to all the traverses by either a 4 x 4 truck or ATVs. Most roads were in good condition with a sand and gravel base (Figure 5.1.2a).

Beaver dams, flooding and washouts were frequently encountered along the logging roads in the Quetico Area however most of these obstacles were easily overcome with the use of ATVs. Only wide lakes created due to beaver dams, and rare decommissioned bridges, prevented access to outcrops altogether (Figure 5.1.2b). Travel by ATV was the simplest and quickest way of accessing distant sites and targeted outcrops. Some traverses also involved hiking; however forest cover is locally quite dense and traverses through the bush were slow, limiting the amount of ground that could be covered. One cluster of predicted outcrops, located east of Station 14NP025 near the centre of the western boundary of the withdrawal area (Figure 5.1.1), was not investigated because access to the system of logging roads in this area was inhibited by a locked gate.

5.1.2 Bedrock Exposure and Overburden Thickness

In general, the Quetico Area has exposed bedrock at higher elevations intermixed with regions of overburden of significant (metre-scale or greater) thickness at low elevations or where eskers exist. Bedrock exposure in areas of topographic highs is moderate, with overburden cover generally 0 to 2 meters thick. A large percentage of outcrops within the Quetico Area were also heavily covered with moss. In areas of low topography, overburden cover is very thick, consisting of glaciofluvial sands and exposed bedrock is scarce.

Out of a total of 308 stations visited while mapping in the Quetico Area, 251 (81%) were stations of exposed bedrock and 57 (19%) were stations where overburden was encountered (Figure 5.1.1). Bedrock outcrops generally range in size from 10 to 50 m^2 in area (Figure 5.1.2.c). The majority of the overburden stations turned out to be open areas with sandy soil (Figure 5.1.2d). The northeastern corner of the Quetico Area shows a high concentration of overburden stations relative to bedrock stations, while additional overburden stations are scattered throughout the rest of the area. In addition, large portions of the Quetico Area in the vicinity of surface water features had little, if any, exposed bedrock. These locations correspond to areas of lowest topography and thickest forest cover where access is generally poor and overburden is thick and continuous.

5.1.3 Lithology and Physical Character

The descriptions below provide an overview of the main and minor bedrock lithological units observed in the Quetico Area, as well as their main physical characteristics. Lithological units described below as main units tend to occur as the predominant rock type covering at least 60% of the exposed bedrock, by area, at any individual bedrock station, and are observed at a high frequency of bedrock stations overall. Minor lithological units described below may occasionally occur as the main rock type at individual bedrock stations, but in general they occur infrequently, and represent only a small portion overall of the exposed bedrock in the Quetico Area. A summary of characteristics of the lithological units encountered in the Quetico Area is included in Table 5.1 below.

Two main Archean-aged bedrock units were identified for the Quetico Area, including migmatitic metasedimentary rock and granite. Field observations indicate that the concentration of granite relative to migmatitic metasedimentary rock is highly variable across the Quetico Area. There appears to be a continuum between low volumes of intrusive granite associated with high volumes of migmatitic metasedimentary rock grading into high volumes of granite associated with low volumes of migmatitic metasedimentary rock. In the latter case, the migmatitic metasedimentary rock persists only as xenoliths within the granite.

Additional minor Archean-aged lithological units include intrusive bodies of granodiorite and tonalite, as well as schist and amphibolite. Amphibolite is easily distinguished in the field from the much younger Proterozoic mafic dykes discussed later in the report by its occurrence as isolated boudins, xenoliths and highly attenuated and/or folded lenses of mafic composition exhibiting varying amounts of strain.

Table 5.1 Summary of Bedrock Characteristics by Lithology for the Quetico Area

Lithological Unit	# of Occurrences (% of bedrock stations)	Fabric	Magnetic Susceptibility (average S.I.)	Gamma Spectrometry (average)	Strength (range)
Migmatitic Metasedimentary Rock	233 (93%)	Foliated to gneissic	1.50×10^{-3}	K = 2.2% U = 1.7 ppm Th = 11.1 ppm	R5
Granite	173 (69%)	Massive to weakly foliated	1.90×10^{-3}	K = 4.0% U = 1.9 ppm Th = 23.2 ppm	R5
Granodiorite	49 (20%)	Massive to weakly foliated	2.07×10^{-3}	K = 2.3% U = 1.2 ppm Th = 13.6 ppm	R5
Tonalite	25 (10%)	Weakly to moderately foliated	3.09×10^{-3}	K = 1.3% U = 3.4 ppm Th = 7.5 ppm	R5
Schist	20 (8%)	Strongly foliated	1.39×10^{-3}	K = 2.1% U = 2.5 ppm Th = 10.1 ppm	R5
Amphibolite	11 (4%)	Moderately to strongly foliated	1.16×10^{-2}	K = 1.5% U = 2.0 ppm Th = 7.4 ppm	R5

5.1.3.1 Main Lithology 1 – Migmatitic Metasedimentary Rock

The most common lithology encountered in the Quetico Area is migmatitic metasedimentary rock, observed at 233 out of 251 (93%) bedrock outcrop locations in the Quetico Area (Figure 5.1.3.a). Migmatitic metasedimentary rock comprises two main components, metamorphosed sedimentary rocks and leucosome. The metasedimentary rock component includes a mixture of semi-pelitic and psammitic bedrock, suggesting protoliths with mudstone and sandstone composition, respectively. The leucosome is a light-coloured product of the partial melting of the metasedimentary rock. It is granodioritic in composition. Migmatitic metasedimentary rock occurrences are distributed relatively evenly across the entire Quetico Area, with only a slightly decrease in the concentration of this rock type in the central-eastern and extreme southwestern parts of the area. Figures 5.1.4a and 5.1.4b show field photos typical of the migmatitic metasedimentary rocks observed in the Quetico Area. A total of 41 migmatitic metasedimentary rock samples were collected from the Quetico Area.

The amount of leucosome component in the migmatitic metasedimentary rock at any individual bedrock observation location varied across the Quetico Area (Figure 5.1.3b). In 70 of the 233 (30%) migmatitic metasedimentary rock occurrences the leucosome component accounts for between 10 and 30% by area of the unit, indicating a low to moderate degree of partial melting. These occurrences were classified as metatexites. In 151 occurrences (65%), the migmatitic metasedimentary rock included greater than 30% leucosome by area and were classified as diatexites, indicating a higher degree of partial melting. In both the metatexites and the diatexites the metasedimentary rock component occurred as m-scale or greater thick panels with cm-to dm-scale leucosome layers. In general, both metatexite and diatexite are observed throughout the entire Quetico Area, although there is a tendency towards more diatexite in the central and eastern portions of the Quetico Area, while metatexites predominate in the southwestern portion. In the remaining 12 occurrences (5%) of migmatitic metasedimentary rock, less than 10% of the leucosome component was identified and psammitic rock with a protolith of sandstone composition was preserved. These occurrences are distributed broadly throughout the central to eastern portion of the Quetico Area. In nine of these 11 occurrences the migmatitic metasedimentary rock occurs as xenoliths up to one metre in diameter, within the younger granite unit described further below.

The metasedimentary component of the migmatitic metasedimentary rock is highly variable in appearance. It varies between pink, white and light to dark grey when fresh and light to dark grey or rusty brown when weathered. It is usually strongly foliated to gneissose, but locally exhibits a massive texture. The migmatitic metasedimentary rock exhibits both equigranular and inequigranular texture with grainsize varying from fine to coarse (0.5 to 10 mm). In occurrences with lesser leucosome the metasedimentary component is predominantly equigranular, varying in grain size between 1 - 5 mm (fine to medium grained).

The leucosome component of the migmatitic metasedimentary rock is primarily of granodioritic composition. Leucosome occurs as medium-grained bands or lenses that are generally a few centimeters to less than a meter wide and a few centimeters to several meters long, interlayered with the metasedimentary rock component and commonly stretched into parallelism with the regional foliation (Figure 5.1.4a). They are more resistant to weathering than the surrounding metasedimentary component. A dark-coloured, biotite-rich, mm-scale, seam was commonly developed along the contact between the leucosome and metasedimentary rock components. The migmatitic metasedimentary rock was observed to part along this seam. This characteristic was especially evident in vertical sections (Figure 5.1.4b).

A total of 170 rock hardness measurements were made on the migmatitic metasedimentary rocks in the Quetico Area, exhibiting a very strong (R5) character in all cases (100%).

Figures 5.1.4c and 5.1.4d show a histogram of magnetic susceptibility measurements and a ternary plot of gamma ray spectrometer measurements, respectively, collected from the migmatitic metasedimentary rocks within the Quetico Area. The migmatitic metasedimentary rocks yielded a relatively low magnetic susceptibility (average = 1.50 x10^{-3} SI, N = 102) ranging between 0.01 and 22.6 x10^{-3} SI. The gamma ray spectrometry readings (N=72) show the following characteristics:

- Total count is on average 82.6 cps and ranges between 6.1 and 270 cps.
- Potassium content is on average 2.2% and ranges between 0.9 and 5.3%.
- Uranium content is on average 1.7 ppm and ranges between 0.0 and 4.4 ppm.
- Thorium content is on average 11.1 ppm and ranges between 1.7 and 50.9 ppm.

5.1.3.2 Main Lithology 2 - Granite

Granite is the second most common lithological unit recognized in the Quetico Area, observed at 176 out of 251 (70%) bedrock outcrop locations (Figure 5.1.3.a). The granite is generally non-magnetic and appears to have intruded as a sill complex and to a lesser extent as dykes. Granite concentration at any individual outcrop is highly variable ranging from less than 10% to greater than 90%. At the lower end of concentration, granite occurs as small intrusions (dykes, sills) within the migmatitic metasedimentary rock. At the higher end of concentration, granite is the dominant phase and only xenoliths of migmatitic metasedimentary rock are preserved. Figures 5.1.5a and 5.1.5b show field photos typical of the granite observed in the Quetico Area. A total of 51 granite samples were collected from the Quetico area.

The granite is white to pink when fresh and grey to pink when weathered. It is predominantly equigranular, with an average grain size of 1 – 5 mm (medium grained). In some instances the granite is coarser grained and includes local pegmatitic patches. It also locally contains abundant pink potassium feldspar phenocrysts. No folds or lineations were observed within the granite.

The granite usually appears massive but a weak foliation was identified locally, primarily in the southern part of the Quetico Area. These fabric observations suggests that the granite intruded during the later stages of the regional deformation and associated migmatization event. However, it intruded while the surrounding rocks were still very hot as the granite does not possess any chilled margins with adjacent bedrock units. The granite locally forms the matrix of complex magmatic breccias with tonalite clasts.

A total of 148 rock hardness measurements were made on the granite in the Quetico Area and it exhibited a very strong (R5) character in all cases (100%).

Figures 5.1.5c and 5.1.5.d shows a histogram of magnetic susceptibility measurements and a ternary plot of gamma ray spectrometer measurements, respectively, collected from granite within the Quetico

Area. Granite has a relatively low but variable magnetic susceptibility (average = 1.90 x10^{-3} SI, N=137). Susceptibility values range between 0.0 and 24.5 x10^{-3} SI. The gamma ray spectrometry readings (N = 110) for granite in the Quetico Area show the following characteristics:

- Total count is on average 136.8 cps and ranges between 9.7 and 535.0 cps.
- Potassium content is on average 4.0% and ranges between 0.6 and 6.3%.
- Uranium content is on average 1.9 ppm and ranges between 0.0 and 8.5 ppm.
- Thorium content is on average 23.2 ppm and ranges between 0.0 and 79.8 ppm.

5.1.3.3 Minor Lithological Units

A total of four minor lithological units were identified within the Quetico Area, including granodiorite, tonalite, schist and amphibolite (Figure 5.1.6). Figures 5.1.7 and 5.1.8 shows some field examples of the minor lithologies within the Quetico Area.

Granodiorite

A suite of granodiorite intrusions are recognized at 49 out of 251 (20%) bedrock outcrop locations. The amount of intrusive granodiorite at any individual outcrop is variable and ranges between less than 10% and greater than 90%. Granodiorite is distributed throughout much of the Quetico Area except in the northeast corner. These intrusions of granodiorite are separate from the granodioritic leucosome component of the migmatitic metasedimentary rock, described above. Figure 5.1.7 shows two field photos typical of the granodiorite observed in the Quetico Area. A total of 10 granodiorite samples were collected from the Quetico Area.

This granodiorite phase intruded as one to greater than 10 metre wide dykes that cut the regional fabric in the migmatitic metasedimentary rocks. The granodiorite appears to have intruded while the migmatitic metasedimentary rocks were still fairly hot, or underwent post-emplacement recrystallization, as the granodiorite does not exhibit chilled margins against adjacent migmatitic metasedimentary rock. Granodiorite intrusions locally grade into intrusions closer to granite in composition suggesting a genetic relationship with the more voluminous granites mapped throughout the Quetico Area. In some locations granodiorite dykes cross-cut granite suggesting that the granodioritic intrusions post-date (or outlast) the intrusion of the granite.

The granodiorite is grey when fresh and also when weathered. It is predominantly equigranular, with an average grain size of 1 – 5 mm (fine - medium grained). The unit is typically homogenous in composition but is locally fairly magnetic with some coarse magnetite crystals.

Granodiorite varies between massive and weakly foliated in character. The foliated examples were identified primarily in the southern part of the area. Cuspate-lobate contacts in some occurrences indicate that some degree of deformation overprinted the granodiorite, and it was the weaker component relative to the surrounding migmatitic metasedimentary rock. No folds or lineations were observed within the granodiorite.

A total of 37 rock hardness measurements were made on the granodiorite in the Quetico Area and it exhibited a very strong (R5) character in all cases (100%).

Granodiorite has a relatively low but variable magnetic susceptibility (average = 2.03 x10^{-3} SI, N=49). Susceptibility values range between 0.02 and 18.5 x10^{-3} SI. The gamma ray spectrometry readings (N=28) for granodiorite in the Quetico Area show the following characteristics:

- Total count is on average 78.4 cps and ranges between 31.0 and 166.7 cps.
- Potassium content is on average 2.3% and ranges between 1.3 and 3.2%.
- Uranium content is on average 1.2 ppm and ranges between 0.0 and 8.6 ppm.
- Thorium content is on average 13.6 ppm and ranges between 1.0 and 42.0 ppm.

Tonalite

A suite of tonalitic intrusions, occurring as dykes and sills, is observed at 25 out of 251 (10%) outcrop locations, predominantly throughout the central portion of the Quetico Area. Similar to the distribution of the granodiorite dykes, the amount of intrusive tonalite at any individual outcrop is variable and ranges between less than 10% and greater than 90%. Tonalite is the earliest "exotic" intrusive phase, being cross-cut by the granite. Tonalite is locally gradational into intrusions that are more granodioritic in character suggesting a genetic association between these late felsic intrusions. Tonalite is also found as partially digested clasts within a magmatic breccia whose matrix is similar in composition to the intrusive granite, described above. A total of 4 tonalite samples were collected from the Quetico Area

Tonalite is white when fresh and grey to white when weathered. The tonalite is predominantly equigranular, and varies in grain size between 1- 10 mm (medium to coarse grained). Tonalite generally possesses a weakly to moderately well-developed foliation, though some more massive occurrences were observed (Figure 5.1.8a).

Seven rock hardness measurements were made on the tonalite in the Quetico Area and in all cases (100%) it exhibited a very strong (R5) character.

Tonalite has a relatively moderate magnetic susceptibility (average = 3.09 x10^{-3} SI, N=11). Susceptibility values range between 0.04 and 12.3 x10^{-3} SI. The gamma ray spectrometry readings (N=3) for tonalite in the Quetico Area show the following characteristics:

- Total count is on average 55.3 cps and ranges between 35.5 and 76.4 cps.
- Potassium content is on average 1.3% and ranges between 0.9 and 1.7%.
- Uranium content is on average 3.4 ppm and ranges between 0.5 and 7.0 ppm.
- Thorium content is on average 7.5 ppm and ranges between 1.7 and 15.1 ppm.

Schist

The term schist was used to describe occurrences of schistose rocks for which the protolith could not be easily identified. Schist was observed at 20 out of 251 (8%) outcrop locations, and generally covers 10 - 30% of any observed outcrop, by area. Schist occurrences are located in the southwestern and central-eastern parts of the Quetico Area, with additional clusters in the southeastern and northeastern corners of the area. A total of 5 schist samples were collected from the Quetico Area.

Schist is primarily grey to dark grey when fresh and also when weathered. It is predominantly equigranular, and varies in grain size between 1 and 5 mm (fine to medium grained) with quartz, k-feldspar and biotite, and locally hornblende, as the main mineral components. Schist was consistently observed to be strongly foliated (Figure 5.1.8b).

20 rock hardness measurements were made on the schist in the Quetico Area and in all cases (100%) it exhibited a very strong (R5) character.

Schist has a relatively low magnetic susceptibility (average = 1.39 $x10^{-3}$ SI, N=9). Susceptibility values range between 0.21 and 8.47 $x10^{-3}$ SI. The gamma ray spectrometry readings (N=8) for schist in the Quetico Area show the following characteristics:

- Total count is on average 67.7 cps and ranges between 44.0 and 136.4 cps.
- Potassium content is on average 2.1% and ranges between 1.3 and 3.6%.
- Uranium content is on average 2.5 ppm and ranges between 1.4 and 3.8 ppm.
- Thorium content is on average 10.1 ppm and ranges between 6.7 and 25.7 ppm.

Amphibolite

Amphibolite was observed at 10 out of 251 (4%) outcrop locations, covering less than 30% of any observed outcrop, by area. These few occurrences of amphibolite were observed in the central portion of the Quetico Area, and always in association with migmatitic metasedimentary rock (Figure 5.1.7). Amphibolite includes all undifferentiated occurrences of metamorphosed mafic rocks encountered during the mapping, including a coarse-grained gabbroic sub-unit, which was present in 7 of the 10 occurrences. As noted above, amphibolite is distinguished from the much younger Proterozoic mafic dykes by its occurrence as isolated boudins, xenoliths and highly attenuated and/or folded lenses exhibiting varying degrees of overprint by the regional penetrative fabric. No amphibolite samples were collected from the Quetico Area.

Amphibolite is light greenish-grey to dark green when fresh and light to dark greenish-grey when weathered. Amphibolite is predominantly equigranular, and varies in grain size between 1 and 10 mm (fine to coarse grained). In general, the amphibolite is moderately to strongly foliated (Figure 5.1.8c).

Three rock hardness measurements were made on amphibolite in the Quetico Area and it exhibited a very strong (R5) character in all cases (100%).

Amphibolite has a relatively high magnetic susceptibility (average = 11.64 $x10^{-3}$ SI, N=6). Susceptibility values range between 0.23 and 61.9 $x10^{-3}$ SI. The gamma ray spectrometry readings (N=3) for amphibolite in the Quetico Area show the following characteristics:

- Total count is on average 50.6 cps and ranges between 34.3 and 62.8 cps.
- Potassium content is on average 1.5% and ranges between 1.1 and 1.9%.
- Uranium content is on average 2.0 ppm and ranges between 1.0 and 3.0 ppm.
- Thorium content is on average 7.4 ppm and ranges between 5.3 and 9.9 ppm.

5.1.4 Structure

Structures observed in the Quetico Area, including products of both ductile and brittle deformation, are described below. Ductile structures are described in Section 5.1.4.1. Brittle structures are described in Section 5.1.4.2. Secondary mineral assemblages, in the form of fracture infilling mineral and alteration phases, are described in Section 5.1.4.3.

5.1.4.1 Ductile Structure

Ductile structural elements observed in the Quetico Area and documented below include various types of foliations, folds, shear zones and associated linear structures including fold hinges and mineral lineations. Table 5.2 provides a summary of orientation information for ductile structures in the Quetico Area. Figures 5.1.9 to 5.1.13 provide summary information on the distribution, orientation and field character of the ductile structures in the Quetico Area.

Table 5.2 Summary of Orientation Information for Ductile Structures in the Quetico Area

Structure Type	Orientation	Peak (°)	Frequency (%)	Range (°)	Confidence
Foliation and Lineation – All	ENE	060	12.8	054 - 065	High
	ENE-E	078	22.0	065 - 097	High
	ESE	103	8.2	097 - 109	Medium
Igneous Flow Foliation	NNE	022	18.7	006 – 034	Medium-High
	NE	044	11.8	034 - 071	Medium
	E-ESE	103	7.5	071 - 112	Low
	SE	143	10.7	134 – 150	Medium-Low
	SSE	160	7.4	150 – 166	Low
Tectonic Foliation	ENE	060	13.5	050 – 065	High
	ENE-E	078	24.0	065 – 098	High
	ESE	103	8.9	098 - 111	Medium
Shear Zones – All Ductile	NNE	026	11.3	020 – 034	Medium-Low
	ENE	063	20.3	058 – 068	Medium-High
	E	080 090 100	7.8 8.2 8.1	077 – 085 085 – 095 095 – 105	Low
	ESE	115	20.1	110 - 134	Medium-High

Foliation

Two main types of foliation are recognized in the Quetico Area, including a primary igneous flow foliation and a tectonic foliation characterized by the alignment of metamorphic minerals and formed during regional progressive deformation (Figures 5.1.9 and 5.1.10). The tectonic foliation includes gneissic layering and a local schistosity and is the most common ductile fabric element observed at the outcrop scale.

The total foliation population (N=258) is characterized by one dominant peak orientation of 077° with two subordinate peaks of 060° and 103° and a total range between 054° and 109° (Figures 5.1.10a and 5.1.10b). The east-northeast to east-southeast variation in trend of the foliation is consistent with the along-strike variation in orientation of the regional east-west oriented subprovince boundary. Foliation dip varies between vertical and horizontal with the majority of measurements indicating a steeply north-dipping geometry. Each foliation subtype is described below.

An igneous flow foliation is identified in the intrusive granodiorite and granite lithological units observed the Quetico Area. It is generally discontinuous and, where present, it is also generally subparallel to the tectonic foliation. It is defined by the alignment of feldspar. The igneous flow foliation population (N=18) is characterized by one dominant peak orientation of 022° within a total range between 006° and 034°, and with several statistically significant sub-peaks at 044°, 103°, 143° and 160°. Mean dip is approximately 65°, and ranges between 0° and 90° (Figure 5.1.10c).

The most common foliation type observed is a tectonic foliation (N=224). It was identified across the entire Quetico Area and is the predominant penetrative ductile structure at the outcrop scale (Figure 5.1.9). The tectonic foliation includes examples of gneissic layering and schistosity, and is well developed in the migmatitic metasedimentary rocks, schists and amphibolite (Figure 5.1.13). The tectonic foliation is commonly defined by the preferred alignment of biotite and / or amphibole, as well as stretched quartz, feldspar, and quartzo-feldspathic aggregates. It is generally weakly developed where observed in the tonalite, granite and granodiorite intrusions. Locally, in the hinge zone of small-scale folds two generations of tectonic foliation are recognized, one that defines the fold itself and one that is axial planar to it. In the migmatitic metasedimentary rock, primarily the diatexite end member, concordant leucosome transposed into parallelism with the metamorphic foliation resulted in the development of a gneissic layering. The gneissic layering is characterized by the cm-scale alternation of quartz-feldspar and biotite-rich bands.

The total tectonic foliation population is dominated by one dominant peak orientation of 078° with subordinate peaks of 060° and 103° and a total range between 050° and 111° (Figure 5.1.10d). In contrast to the rest of the Quetico area where the tectonic foliation is generally steeply north-dipping, the southeastern portion of the mapping area contains shallowly to moderately (< 45 ° dip) dipping tectonic foliation. Tectonic foliation is also quite variable locally, including where it wraps around earlier folds, as described above, or deflects around xenoliths, and in instances where the xenoliths with internal foliation are themselves rotated (see examples in Figure 5.1.13). Northeast striking tectonic foliation was observed in several corridors in the central and northeastern sections of the mapping area (Figure 5.1.9).

Ductile structures also included 11 observations of mineral lineations and 5 fold hinges were observed and measured. Mineral lineations show a range of trends between 46° to 270° with plunges ranging from 3° to 87°. Fold hinges also showed a similar and variable orientation between 53° to 272° with plunges ranging from 11° to 40°. A weakly developed mineral lineation, defined by quartz rods, was observed in four locations. It is developed on the tectonic foliation in the migmatitic metasedimentary rock and plunges shallowly to the west and northeast (≤ 35° plunge; Figure 5.1.10a). Boudinaged leucosome and quartz veins, formed parallel to and/or at acute angles to the metamorphic foliation, are also common (Figure 5.1.13).

Folds

Folds are common features at many observation locations across the Quetico Area. They are formed at all scales from mm-scale to greater than outcrop scale. They are most prominently seen in the migmatitic metasedimentary rock and amphibolite units (see examples in Figure 5.1.13). A total of 5 fold hinges were measured across the Quetico Area (Figure 5.1.10a). The measured fold hinges plunge between subhorizontal and subvertical and exhibit no distinct preferred orientation. Axial planes to the folds strike east to east-northeast, consistent with the overall trending of the tectonic foliation. Fold vergence is primarily towards the south.

In total, three generations of folding are distinguished based on variation in fold style and overprinting relationships observed. An early generation of folds (F1) are recognized and characterized by tight to isoclinal folding of the tectonic foliation and leucosome. These early folds are generally small, cm-scale structures in outcrop and their hinge lines are difficult to measure. Two additional folding phases (F2 and F3) were identifiable and represent the bulk of the measured fold structures. F2 folds were interpreted in instances where an early tectonic foliation was observed to be folded around younger tight folds and overprinted by an axial planar foliation. The F2 folds are predominantly inclined, plunge shallowly to the east or west, and exhibit a southward verging asymmetry. A later generation of open to tight, upright to inclined F3 folds warps the composite tectonic foliation, also about an approximately east-west axis, and also exhibits southward vergence.

Shear Zones

A total of 13 shear zones were documented in the Quetico Area (Figures 5.1.11 and 5.1.12) most commonly observed in the southwestern, northern and northeastern portions of the area. The shear zones were consistently observed to be less than one centimetre to several decimeters wide and a few centimeters to a few meters in length. They are generally characterized by a strong to intense planar fabric and, where hosted by migmatitic metasedimentary rock, they are associated with injected leucosome or rare quartz veins. There is no indication of a brittle component of deformation in the observed shear zones and so they are characterized as ductile structures.

Orientation information for the shear zones is shown in Figure 5.1.12. The total shear zone population (N=13) is characterized by two dominant peak orientations of 063° and 115°, with one subpeak at 026° and an additional tight cluster of three peaks within a range between 080° and 100° (Figure 5.1.12b). Shear zones predominantly dip at 70° or greater regardless of orientation. Both dextral and sinistral shear offsets were identified.

Dextral shear zones (N=8) are characterized by one dominant peak orientation of 115° and statistically significant sub-peaks at 065°, 080°, 090°, and 100° (Figure 5.1.12c). The total range in dextral shear zone orientation is between 058° and 105°. Sinistral shear zones (N=4) are characterized by two dominant peak orientations of 027° and 060° (Figure 5.1.12d). As these results show, dextral and sinistral shear zones exhibit some similarity in orientation suggesting that shear zones may have been active more than once. One, steeply south-dipping, normal-sense, shear zone was also identified in the Quetico Area.

5.1.4.2 Brittle Structure

Fractures, including joints and faults, and few veins, are the predominant brittle structures observed throughout the Quetico Area. A total of 888 fracture measurements were made across the 251 bedrock stations in the Quetico Area. This included 852 joints, 34 faults and 2 veins. Table 5.3 provides a summary of orientation information for brittle structures. Figures 5.1.14 to 5.1.21 provide summary information on the distribution, orientation and field character of the brittle structures. The secondary mineral infillings and alteration identified in association with the brittle structures are described in Section 5.1.4.3.

Table 5.3 Summary of Orientation Information for Brittle Structures in the Quetico Area

Structure Type	Orientation	Peak (°)	Frequency (%)	Range (°)	Confidence
Joints - All	NNE	007	9.3	347 - 016	Medium-Low
	NE	031 047 059	7.3 7.2 6.0	016 – 039 039 – 055 055 - 071	Medium-High
	SE	138 150	9.6 9.8	120 – 144 144 – 164	High
Joints – Subhorizontal	NNE	014	12.0	000 – 016	Medium
	NE	030	14.4	016 – 044	Medium – High
	E	091 100	8.6 7.6	077 – 096 096 – 110	Medium – Low
	SE	128	12.2	122 – 133	Medium
	SSE	148	8.2	144 – 157	Medium – Low
Joints – Intermediate	NNE	029	6.4	022 - 036	Medium – Low
	NE	050	14.6	040 – 064	Medium – High
	E	087	14.8	064 – 097	Medium – High
Joints - Subvertical	N	007	6.3	348 - 015	Medium – Low
	NE	032 046 059	7.1 7.1 6.0	015 – 037 037 – 055 055 - 077	Medium Medium Medium – Low
	SE	138 150	10.3 10.4	118 – 144 144 - 167	High High
Faults - All	NNE	013	5.7	000 - 024	Low
	NE	033	7.4	024 – 038	Medium-Low
	NE	048	10.7	038 - 068	Medium
	SE	135	19.4	116 – 153	High
	SSE	164	7.5	154 – 177	Low
Faults – Dextral	NE	052	8.3	046 – 067	Medium – Low
	SE	128	23.1	113 – 144	High
	SSE	168	10.6	144 – 172	Medium – Low

Faults - Sinistral	NNE	009	11.0	003 - 017	Medium – Low
	NE	045 060	19.2 10.9	039 – 053 053 - 064	Medium Medium - Low
	SE	120 133 148	11.5 16.7 11.1	116 – 125 125 – 141 141 – 156	Medium – Low Medium Medium - Low
	SSE	163	11.0	156 - 170	Medium - Low
Secondary Mineral Infill	NNE	010	10.0	356 - 020	Medium – High
	NE	028 047 060	6.1 6.2 6.4	020 – 036 036 – 055 055 – 070	Medium – Low Medium – Low Medium - Low
	SE	138 150	12.4 12.6	118 – 143 143 – 160	High High

Joints

A total of 852 joint measurements were recorded in the Quetico Area (Figures 5.1.14 and 5.1.15). As can be seen from Figure 5.1.14, only a small number of bedrock observation locations did not exhibit any joints and many locations exhibited several joint sets. The total joint population is dominated by two broad orientations, including one which ranges between 016° and 071° and includes peaks at 031°, 047° and 059°, and one which ranges between 120° and 164°, and includes peaks at 138° and 150°. One additional subordinate peaks, at 007°, was also evident. Figure 5.1.16 presents spacing information on Joints in the Quetico Area. Figure 5.1.17 provides field photos showing examples of the joints observed in the Quetico Area.

35 out of 852 joints (4%) dip between 0° and 30° and are classified as subhorizontal (Figure 5.1.15c). Several narrow orientation peaks are evident in the subhorizontal joint set spanning a broad range between west-southwest and west-northwest, including at 014°, 030°, 091°-100°, 128° and 148°. 52 out of 852 joints (6%) dip between 31° and 60° and are classified as intermediate (Figure 5.1.15d). Several orientation peaks are evident in the intermediate joint set spanning a broad range between west-southwest and west-northwest, including at 029°, 050° and 087°. 765 out of 852 joints (90%) have a dip of > 60° and are classified as subvertical (Figure 5.1.15e). Similar to the total dataset, two broad orientations are evident in this joint subset, including one which ranges between 118° and 167° and includes peaks at 138° and 150°, and one which ranges between 015° and 077°, and includes peaks at 032°, 046° and 059°. One additional subordinate peak at 007° is also evident in the subvertical joint subset.

Figure 5.1.16 presents information collected on joint spacing for the Quetico Area. Spacing ranged from <1 cm to >1000 cm for individual joint sets. Where the size of the outcrop made determination of average joint spacing difficult it was characterized as unknown. There is a clear predominance of joints with spacing between 30 and 500 cm, including a total of 675 out of 852 occurrences (79%).

Tightly spaced joints (<10–30 cm) occur throughout the mapping area, but there is a tendency for wider joint spacing (500–1000 cm) to be concentrated in the eastern portion of the Quetico Area.

Faults

A total of 34 fault measurements were obtained in the Quetico Area, with a cluster of observations made in the southwestern portion of the Quetico Area and the remainder mostly distributed within a broad zone through the middle of the central and eastern portions of the area (Figure 5.1.18). Figure 5.1.19 presents orientation information for faults observed in the Quetico Area. Figure 5.1.20 provides field photos showing examples of faults observed in the Quetico Area.

The total fault population is dominated by one narrow peak orientation at 135° with a range of 116° to 154° (15 of 35 fault measurements), and four additional subordinate peaks, at 013°, 033°, 048°, and 164°, each comprised of seven or fewer fault measurements (Figure 5.1.19). 29 out of the 34 faults (85%) dip at a magnitude of 70° or greater, the shallowest dip of any fault measured was 48°.

Fault damage zones range from mm-scale single slip surfaces to up to meter wide zones parallel to the fault plane, and slickenlines are sometimes present. Minor gouge was identified in only one observed fault. Where present, displaced markers suggest an offset of a few centimeters at most across any observed fault plane (Figure 5.1.20).

From the total fault set, field observations suggest that 17 (50%) are dextral faults, 9 (26%) are sinistral faults, 3 (9%) are normal faults and 5 (15%) faults display an unknown slip sense. Steps on fault planes and Riedel fractures are the main fault kinematic indicators. The dextral fault population is dominated by one narrow peak orientation at 128° and which ranges between 113° and 144°. The sinistral fault population is dominated by two well-defined peak orientations, one at 045° and which ranges between 039° and 053°, and another at 133° and which ranges between 125° and 141°. Three normal faults, orientated 020°, 138° and 175°, were observed. Overall, the similarity in orientation between faults interpreted to exhibit dextral, sinistral or normal movement may indicate multiple episodes of fault movement.

Three slickenline lineations were measured on fault surfaces in the Quetico Area (Figure 5.1.19f). They plunge between 45° and 60° and trend in a broad range of orientations from south to west-southwest, suggesting oblique-slip movement on the faults.

Veins

Only two veins were observed in the Quetico Area. Both were filled with quartz and observed within granite host rock. One vein was observed with a strike orientation of 077° and a dip of 50° and the other with a strike orientation of 258° and a dip of 68°.

5.1.4.3 Secondary Minerals/Alteration

Information on secondary minerals and alteration associated with fractures in the Quetico Area is described below and summarized in Tables 5.4 to 5.6 below. The results are presented based on assessment of all 888 fracture measurements, including 852 joints, 34 faults and 2 veins. The distribution of the secondary minerals and alteration in the Quetico Area is shown in Figure 5.1.21. Figure 5.1.22 provides a summary of the orientations of structures associated with the secondary minerals and alteration. Field examples of secondary minerals observed in the Quetico Area are shown in Figure 5.1.4b, Figure 5.1.17a and 5.17.1c (hematite staining on joint surfaces), as well as calcite mineralization defining slickenlines on a fault plane shown on Figure 5.1.20a.

Overall, five main secondary minerals, including epidote, chlorite, hematite, quartz and k-feldspar, are observed in fractures (joints, faults, veins) across the Quetico Area. In some instances, more than one infilling mineral was identified within a single fracture. Minor ‘other’ occurrences of infilling or alteration minerals observed in association with fractures include few examples each of albite, limonite, biotite, tourmaline, sericite and pyrite. Hematite occurrences are distributed mostly within an east- to northeast-trending band through the middle of the Quetico Area, with additional occurrences in the southeastern and southwestern corners (Figure 5.1.21). The distribution of chlorite and epidote are very similar to each other, though epidote has a broader spread across the area, and locally both are also spatially coincident with hematite occurrences. Quartz and k-feldspar exhibit very similar distributions, following a general northeasterly trend from southwest to northeast across the Quetico Area (Figure 5.1.21). Table 5.4 summarizes the number of occurrences of each mineral type for the total fracture set. The results indicate that the majority (83%) of all fractures are unfilled and that the majority (148/155; 95%) of filled fractures dip subvertically (61 – 90°).

Table 5.4 Secondary Minerals and Alteration Associated with Fractures in the Quetico Area

Mineral	Total Occurrences	% of total Fracture	Subvertical Dip (61-90°)	Intermediate Dip (31-60°)	Subhorizontal Dip (0-30°)
Hematite	60	7	57	2	1
Chlorite	43	5	43	0	0
Quartz	34	4	32	2	0
Epidote	33	4	32	1	0
K-feldspar	27	3	26	1	0
None	733	83	--	--	--

Orientation information for fractures associated with the secondary minerals and alteration in the Quetico Area is shown in Figure 5.1.22. The total population of secondary minerals and alteration is shown in Figures 5.1.22a and 5.1.22b. The rose diagram combining structural orientation information for the total secondary mineral population is dominated by a southeast trending peak, ranging from 119° to 170° with two peak orientations at 138° and 150° (Figure 5.1.22b). Several additional subordinate peaks, at 010°, 028°, 047°, and 060° are noted. The rose diagram for hematite is dominated by one narrow peak orientation at 145° and which ranges between 115° and 167° and several additional subordinate peaks, at 010°, 037°, and 062° (Figure 5.1.22c). The rose diagram for chlorite is dominated by one narrow peak orientation at 150° and which ranges between 125° and 163° and several additional subordinate peaks, at 010°, 025°, 043° and 060° (Figure 5.1.22d). The rose diagram for quartz is dominated by two narrow peak orientations at 132° and 171°, which range between 126° to 143° and 163° to 180°, respectively. Several additional subordinate peaks are identified, at 010°, 029°, 046° and 082° (Figure 5.1.22e). The rose diagram for epidote is dominated by one peak orientation at 138° and which ranges between 117° and 163° and additional subordinate peaks, at 007° and 051° (Figure 5.1.22f). The rose diagram for k-feldspar is dominated by one narrow peak orientation at 135° and which ranges between 127° and 142° and several additional subordinate peaks, at 010°, 048° and 169° (Figure 5.1.22g).

Secondary mineral infilling was identified on 137 out of 852 (16%) total documented joints, leaving the remaining 715 occurrences (84%) unfilled (Table 5.5). Filled examples include 53 instances of hematite (6%), 41 instances of chlorite (5%), 29 instances each of quartz (3%) and epidote (3%), and 20 instances of k-feldspar (2%). In some instances, more than one infilling mineral was identified within a single fracture. Epidote and chlorite were commonly observed together on joint surfaces, especially in instances where jointing occurs by parting on the regional foliation. Quartz was sometimes observed on joints in association with k-feldspar. A total of nine 'other' minor occurrences of infilling or alteration minerals observed in association with joints included albite, limonite, biotite, tourmaline, sericite and pyrite are not tabulated. When the dip of the observed joint plane is considered the majority of secondary minerals and alteration were associated with subvertically dipping joints.

Table 5.5 Secondary Minerals and Alteration Associated with Joints in the Quetico Area

Mineral	Total Occurrences	% of total Fracture	Subvertical Dip (61-90°)	Intermediate Dip (31-60°)	Subhorizontal Dip (0-30°)
Hematite	53	6	50	2	1
Chlorite	41	5	41	0	0
Quartz	29	3	27	2	0
Epidote	29	3	28	1	0
K-feldspar	24	3	23	1	0
None	715	84	--	--	--

A total of 16 out of 34 total documented faults (47%) were observed to be infilled with secondary minerals, leaving the remaining 18 occurrences (53%) unfilled (Table 5.6). This included 7 instances of hematite (21%), 5 instances of quartz (15%), 4 instances of epidote (12%), 3 instances of k-feldspar and 2 instances of chlorite (6%). Four additional faults (12%) were infilled with at least one of k-feldspar, plagioclase or biotite. Hematite and epidote were sometimes observed together on fault surfaces. Quartz was sometimes seen in association with plagioclase and/or k-feldspar. When the dip of the fault is considered, it is evident from Table 5.6 that all secondary minerals and alteration were associated with subvertical faults.

Table 5.6 Secondary Minerals and Alteration Associated with Faults in the Quetico Area

Mineral	Total Occurrences	% of total	Subvertical Dip (61-90°)	Intermediate Dip (31-60°)	Subhorizontal Dip (0-30°)
Hematite	7	21	7	0	0
Quartz	5	15	5	0	0
Epidote	4	12	4	0	0
K-feldspar	3	9	3	0	0
Chlorite	2	6	2	0	0
None	18	53	--	--	--

5.2 Black-Pic Batholith Area

5.2.1 Accessibility and Surface Constraints

The Black-Pic Batholith Area, located within the Wawa Subprovince, is located six to 10 km south of Hornepayne. Road access was generally good within and around Black-Pic Batholith Area with the majority of planned traverses accessible by four wheel drive pick-up truck along a network of gravel logging roads. These roads were routinely used by logging trucks and therefore two-way radios were required to facilitate communication with logging truck and ensure crew safety while driving. Figure 5.2.2 shows field photos of features of accessibility and bedrock exposure within the Back-Pic Batholith Area.

Highway 631 runs north-south along the easternmost boundary of the Black-Pic Batholith Area and three main secondary logging roads extending westward from the highway make up the main access to the mapping area. Hornepayne Creek Road runs east-west and has numerous tertiary roads and trails (Chelsea Loop/Jay Lake Road, East Buffalo Island Lake Road, Buffalo Island Road) that provide access to the northern part of Black-Pic Batholith Area. The White Owl Lake Road/South Bayfield Road network runs roughly northeast-southwest and, along with the associated tertiary logging roads/trails, provides access to the majority of Black-Pic Batholith Area. The southernmost part of Black-Pic Batholith Area is accessed via Road 300 and its associated network of tertiary roads and trails. A portion of the western central part of Black-Pic Batholith Area did not have a road network, and was covered by lakes, and as a result was inaccessible.

Road washouts, gravel piles, beaver dams, destroyed bridges, a meandering river and other impediments prevented the use of 4 x 4 trucks and necessitated the use of either ATVs or hiking in some instances. Several of the most northerly stations were accessed via Kenogami Road, situated north of Hornepayne. Also, several large swamps and north-northwest trending cliffs in the south-southwest corner of the Black-Pic Batholith Area made it difficult to reach predicted outcrops.

5.2.2 Bedrock Exposure and Overburden Thickness

The distribution of exposed bedrock in the Black-Pic Batholith Area is highly variable. Large parts of the west-central and east-central portions of the Black-Pic Batholith Area, covered by numerous lakes, did not have any predicted outcrops and were confirmed to the extent possible during mapping to be extensively overburden covered. Bedrock exposure is most commonly good in areas of topographic highs that do not correspond to eskers. Overburden thickness was visually estimated to be approximately 0 to 3 metres on average, but exposed gravel pits throughout the Black-Pic Batholith Area indicate that overburden thickness can be up to 15 metres locally. The locations of thickest overburden correspond to mapped eskers.

Out of a total of 283 predicted outcrop locations visited during the mapping in the Black-Pic Batholith Area, 194 (69%) were locations of exposed bedrock and 89 (31%) were locations where overburden was encountered. These overburden stations, which comprise primarily gravel pits and sand piles, are mostly located within a southwest to northeast trending broad topographic low band that extends across the Black-Pic Batholith Area (Figure 5.2.1). Several large outcrop areas consisted of steep rock cliffs while flat lying outcrops were typically covered with 10 to 15 cm of moss. Visual inspection suggested that in areas where outcrop was predicted more bedrock is actually exposed than is reflected in the remote sensing interpretation due to the thick forest and moss cover.

Overall, the observations on bedrock exposure and overburden are consistent with the existing Quaternary maps which indicated exposed or thinly covered bedrock across much of the northern section but large portions of the central, southwestern and southeastern parts of the area that were covered by sand.

5.2.3 Lithology and Physical Character

The descriptions below provide an overview of the main and minor Archean-aged bedrock lithological units observed in the Black-Pic Batholith Area, as well as their main physical characteristics. Lithological units described below as main units tend to occur as the predominant rock type covering at least 60% of the exposed bedrock, by area, at any individual bedrock station, and are observed at a high frequency of bedrock stations overall. Minor lithological units described below may occasionally occur as the main rock type at individual bedrock stations, but in general they occur infrequently, and represent only a small portion overall of the exposed bedrock in the Quetico Area.

Only tonalite, which underlies the majority of the Black-Pic Batholith Area, is considered a main lithological unit (Section 5.2.3.1). The remainder of the identified rock types are described below as minor lithological units (Section 5.2.3.2). These minor units, which include granite, granodiorite and amphibolite, may occasionally occur as the main rock type at individual bedrock outcrop locations but in general they represent a low percentage of the exposed bedrock in the Black-Pic Batholith Area. As noted previously, Archean amphibolite is easily distinguished in the field from the much younger Proterozoic mafic dykes discussed later in the report by its occurrence as isolated boudins, xenoliths and highly attenuated and/or folded lenses exhibiting varying degrees of overprint by the regional penetrative fabric.

A summary of characteristics of the lithological units encountered in the Black-Pic Batholith Area is included in Table 5.7 below.

Table 5.7 Summary of Bedrock Characteristics by Lithology for the Black-Pic Batholith Area

Lithological Unit	# of Occurrences (% of bedrock stations)	Fabric	Magnetic Susceptibility (average S.I.)	Gamma Spectrometry (average)	Strength (range)
Tonalite	183 (94%)	Gneissic	4.73×10^{-3}	K = 1.4% U = 0.8 ppm Th = 5.4 ppm	R4-R6
Granite	34 (18%)	Massive to weakly foliated	1.56×10^{-3}	K = 4.3% U = 1.6 ppm Th = 7.9 ppm	R5
Granodiorite	32 (16%)	Massive to weakly foliated	3.72×10^{-3}	K = 2.2% U = 1.0 ppm Th = 7.7 ppm	R4-R5
Amphibolite	11 (6%)	Moderately to strongly foliated	2.20×10^{-3}	K = 1.3% U = 1.2 ppm Th = 6.3 ppm	R4-R5

5.2.3.1 Main Lithology 1 - Tonalite

Tonalite is the main lithological unit across the Black-Pic Batholith Area, observed at 183 out of 194 (94%) bedrock outcrop locations (Figure 5.2.3). In 141 of these instances tonalite occupies at least 80% of an individual bedrock outcrop by area indicating that it underlies the majority of the Black-Pic

Batholith Area. Figure 5.2.4 shows field photos typical of the tonalite observed in the Black-Pic Batholith Area. A total of 63 tonalite samples were collected from the Black-Pic Batholith Area.

The tonalite is predominantly white when fresh and white to light grey when weathered. A distinctive black or grey and white banding is also typical of the tonalite exposures. The tonalite is typically composed of equigranular plagioclase and quartz with lesser hornblende, biotite and alkali feldspars, with average grain size of 1 – 10 mm (medium to coarse grained). Occasionally, cm-scale k-feldspar phenocrysts were observed within the tonalite. Overall, the mineral components within the tonalite produce the appearance of small-scale internal heterogeneity with exotic fragments and highly metamorphosed rafts including separation of mafic and felsic minerals into centimeter- to decimeter-scale bands, swirls and clots.

The tonalite predominantly varied from weakly to strongly gneissic. Four occurrences in the central northern part of the Black-Pic Batholith Area, did not clearly exhibit a gneissic fabric. The limited number of these occurrences did not provide justification to include a separate non-gneissic tonalite as a distinct lithological unit. The contact between tonalite and adjacent Archean lithological units is observed to be gradational. Cross-cutting Archean felsic dykes exhibit un-chilled and un-zoned, cuspate, margins. No brittle deformation is localized along any observed contacts.

A total of 175 rock hardness measurements were made on the tonalite in the Black-Pic Batholith Area and it exhibited a very strong (R5) character in 173 occurrences (99%). One measurement yielded an extremely strong (R6) character and another yielded a strong (R4) character.

Figures 5.2.4c and 5.2.4d show a histogram of magnetic susceptibility measurements and a ternary plot of gamma ray spectrometer measurements, respectively, collected from tonalite within the Black-Pic Batholith Area. Tonalite has a relatively high magnetic susceptibility (average = 4.73 x10^{-3} SI, N=145). Magnetic susceptibility values range between 0.04 and 13.4 x10^{-3} SI. The gamma ray spectrometry readings (N=87) for tonalite in the Black-Pic Batholith Area show the following characteristics:

- Total count is on average 91.3 cps and ranges between 15.5 and 302.0 cps.
- Potassium content is on average 1.4% and ranges between 0.7 and 4.0%.
- Uranium content is on average 0.8 ppm and ranges between 0.0 and 3.9 ppm.
- Thorium content is on average 5.4 ppm and ranges between 0.8 and 26.4 ppm.

5.2.3.2 Minor Lithological Units

Three minor lithological units were identified within the Black-Pic Batholith Area, including granite, granodiorite and amphibolite (Figure 5.2.5). Figure 5.2.6 shows field examples of the minor lithologies within the Black-Pic Batholith Area.

Granite

Granite was observed at 34 out of 195 (18%) outcrop locations. Its coverage ranged between less than 10% to greater than 90% at any observed outcrop, by area. Granite occurs both as homogeneous masses and as dykes. Granitic dykes tend to be small and rarely occupy more than

25% of any given outcrop. Granite occurrences are scattered relatively evenly throughout the entire mapped portion of the Black Pic Batholith Area (Figure 5.2.5). A total of 2 granite samples were collected from the Black Pic Batholith Area. The granite is white to grey when fresh and when weathered. It is predominantly equigranular, with an average grain size of 1 – 5 mm (fine - medium grained) and composed mainly of quartz, potassium feldspar, plagioclase and subordinate biotite. The granite usually exhibits a weak foliation defined by aligned biotite, but is also locally unfoliated (massive) in texture. The foliated examples are identified primarily in the southern part of the Black Pic Batholith Area. No folds or lineations were observed within the granite.

Granite often occurs as narrow (e.g. 5-15 cm wide), unfoliated, fine to medium-grained dykes. These granite dykes tend to be un-chilled and un-zoned and exhibit cuspate margins in gradational contact with surrounding bedrock, primarily the tonalite. Granitic dykes are typically dominated by alkali feldspar and quartz, with lesser plagioclase and biotite. Some granitic dykes include local, coarse-grained, pegmatitic patches.

A total of nine rock hardness measurements were made on the granite in the Black-Pic Batholith Area and in all nine instances (100%) it exhibited a very strong (R5) character.

The granite has a relatively low magnetic susceptibility (average = 1.56 x10^{-3} SI, N=8). Susceptibility values range between 0.12 and 4.94 x10^{-3} SI. The gamma ray spectrometry readings (N=6) for granite in the Black Pic Batholith Area show the following characteristics:

- Total count is on average 129 cps and ranges between 68.9 and 292.5 cps.
- Potassium content is on average 4.3% and ranges between 1.3 and 7.0%.
- Uranium content is on average 1.6 ppm and ranges between 0.0 and 3.5 ppm.
- Thorium content is on average 7.9 ppm and ranges between 2.9 and 16.3 ppm.

Granodiorite

Granodiorite was observed at 32 out of 195 (16%) outcrop locations (Figure 5.2.5). Its coverage ranged between less than 10% to greater than 90% of any observed outcrop, by area. It often forms homogeneous masses, but also occurs as dykes cross-cutting the tonalite. Compositionally the granodiorite and tonalite are quite similar, but the two rock types are clearly distinguished in outcrop by the lack of gneissic texture in the granodiorite. Where observed, the contact between granodiorite and surrounding bedrock is gradational. Granodiorite occurrences are scattered relatively evenly throughout the entire mapped portion of the Black-Pic Batholith Area. A total of 14 granodiorite samples were collected from the Black-Pic Batholith Area. The granodiorite is usually light grey or pink when fresh and has a mottled texture (light grey-white, black and pink) when weathered. The granodiorite is predominantly equigranular, with average grain size of 1 – 10 mm (medium - coarse grained). It is comprised primarily of quartz, plagioclase feldspar, potassium feldspar, biotite and/or lesser hornblende. Plagioclase phenocrysts (up to several centimetres in diameter) with corroded margins are occasionally observed. The granodiorite varied between massive and moderately foliated. The foliated examples were identified primarily in the northern part of the area. No folds or lineations were observed in the granodiorite.

In total, 25 rock hardness measurements were made on the granodiorite in the Black-Pic Batholith Area and exhibited a very strong (R5) character in 24 occurrences (96%). In one additional measurement the granodiorite yielded a strong (R4) character.

The granodiorite has a relatively moderate magnetic susceptibility (average = 3.72 x10^{-3} SI, N=23). Susceptibility values range between 0.11 and 8.4 x10^{-3} SI. The gamma ray spectrometry readings (N=20) for granodiorite in the Black Pic Batholith Area show the following characteristics:

- Total count is on average 76.0 cps and ranges between 33.2 and 158.8 cps.
- Potassium content is on average 2.2% and ranges between 1.4 and 2.8%.
- Uranium content is on average 1.0 ppm and ranges between 0.1 and 3.1 ppm.
- Thorium content is on average 7.7 ppm and ranges between 0.2 and 23.3 ppm.

Amphibolite

Amphibolite was observed at 11 out of 195 (6%) outcrop locations across the Black-Pic Batholith Area. Amphibolite includes all undifferentiated occurrences of metamorphosed mafic rocks encountered during the mapping, including a coarse-grained gabbroic sub-unit, which was present in 3 of the 11 occurrences. Amphibolite is distinguished from the much younger Proterozoic mafic dykes by its occurrence as isolated boudins, xenoliths and highly attenuated and/or folded lenses exhibiting varying degrees of overprint by the regional penetrative fabric. Amphibolite occurrences are also observed to be cut by felsic dykes genetically related to the granodiorite and granite units described above. Amphibolite occurrences are isolated and scattered widely across the southeastern half of the Black-Pic Batholith Area (Figure 5.2.5). Locally, amphibolite is the dominant lithology, comprising up to 90% of the exposed bedrock. However, its relative abundance ranges down to less than 1% by area of outcrop, and there is no indication that the amphibolite represents a continuous unit. One sample of amphibolite was collected from the Black-Pic Batholith Area.

The observed amphibolite is light to dark green when fresh and when weathered. It is predominantly equigranular in any single occurrence, and overall varied in grain size between 1 and 10 mm (fine to coarse grained). The dominant constituents were medium-grained hornblende with lesser plagioclase and occasionally garnet.

The amphibolite is weakly to strongly foliated and locally gneissic in texture. The contacts between the amphibolite and surrounding tonalite are usually sharply-defined, in part due to the clear colour contrast. Amphibolite occurs as attenuated lenses parallel to the regional gneissic fabric and as metre-scale xenoliths, within the tonalite. There is a lack of grain size differentiation at amphibolite contacts with the surrounding tonalite. Instead, both the amphibolite and the surrounding bedrock appear to be recrystallized.

A total of eight rock hardness measurements were made on the amphibolite unit in the Black-Pic Batholith Area. It exhibited a very strong (R5) character in seven cases (87%) and a strong character (R4) in one case (13%).

The amphibolite has a relatively low magnetic susceptibility (average = 2.2 $x10^{-3}$ SI, N=6). Susceptibility values range between 0.49 and 9.75 $x10^{-3}$ SI. The gamma ray spectrometry readings (N=4) for amphibolite in the Black Pic Batholith Area show the following characteristics:

- Total count is on average 92.3 cps and ranges between 29.1 and 160.0 cps.
- Potassium content is on average 1.3% and ranges between 1.0 and 1.6%.
- Uranium content is on average 1.2 ppm and ranges between 0.3 and 2.3 ppm.
- Thorium content is on average 6.3 ppm and ranges between 0.5 and 16.6 ppm.

5.2.4 Structure

Structures observed in the Black-Pic Batholith Area, including products of both ductile and brittle deformation, are described below. Ductile structures are described in Section 5.2.4.1, Brittle structures are described in Section 5.2.4.2. Secondary mineral assemblages, in the form of fracture infilling mineral and alteration phases, are described in Section 5.2.4.3.

5.2.4.1 Ductile Structure

Ductile structural elements observed in the Black-Pic Batholith Area and documented below include various types of foliation and shear zones. In addition, linear structures such as stretching lineations were documented and are also described below. Table 5.8 provides a summary of orientation information for ductile structures in the Black-Pic Batholith Area. Figures 5.2.7 to 5.2.9 provide summary information on the distribution, orientation and field character of the ductile structures in the Black-Pic Batholith Area.

Table 5.8 Summary of Orientation Information for Ductile Structures in the Black-Pic Batholith Area

Structure Type	Orientation	Peak (°)	Frequency (%)	Range (°)	Confidence
Foliation and Lineation - All	NE	050	10.0	037-055	Medium-High
	ENE	063 080	11.8 10.0	055-075 075-103	High Medium-High
Igneous Flow Foliation	NNE	020	16.4	015-027	Medium
	NE	050	16.5	045-057	Medium
	ENE	075	31.9	065-085	Medium
	ESE	112	16.0	104-118	Medium
Tectonic Foliation (Gneissic + metamorphic)	NNE	027	5.7	018-035	Medium-Low
	NE	050	9.7	035-055	Medium-Low
	ENE	063 080	12.5 9.3	055-075 077-100	Medium-High

Foliation

Two main types of foliation are recognized in the Black-Pic Batholith Area, including a primary igneous flow foliation and a tectonic foliation characterized by the alignment of metamorphic minerals and formed during regional progressive deformation (Figure 5.2.7). The tectonic foliation includes a gneissic layering which is common throughout the Black-Pic Batholith Area.

The total foliation population (N=176) is shown in Figures 5.2.8a and 5.2.8b. Foliation dip varies between vertical and horizontal with the majority of measurements indicating a subhorizontal orientation. The overall distribution of the foliation planes is consistent with folding about an east-northeast-trending axis. The total foliation population is characterized by one dominant, broad, peak orientation spanning 055° to 075° with two shoulder peaks at 050° and 080° and a total range between 037° and 103°. Each foliation subtype is described further below.

Igneous flow foliation is observed in 6 locations in the southern part of the Black-Pic Batholith Area (Figure 5.2.8c). This fabric is observed in the granite (4 locations), granodiorite (1 locations) and gabbronorite/other (1 location) and is defined by aligned quartz, potassium feldspar, plagioclase and subordinate biotite. The igneous flow foliation is dominated by one dominant peak orientation of 075° with subordinate peaks of 020°, 050° and 112° and a total range between 015° and 118°.

A moderately to strongly developed tectonic foliation is the dominant foliation type observed in the Black-Pic Batholith Area. The tectonic foliation is most commonly defined by aligned amphibole and biotite, as well as stretched quartz and quartzo-feldspathic aggregates. In few instances the tectonic foliation is only weakly-developed. The total tectonic foliation population includes eight occurrences of gneissic layering. The gneissic layering is moderately to strongly developed and defined by distinct alternating bands of aligned k-feldspar and biotite. This tectonic foliation is tentatively correlated with the composite tectonic foliation described above for the Quetico Area.

As the tectonic foliation population (N=165) accounts for approximately 89% of the total foliation population, it is not surprising that it generally shows the same peak orientations as the total foliation population with one broad dominant peak orientation at 063° with two shoulder peaks of 050° and 080° and a total range between 035° and 100°. A subordinate peak is oriented at 027°. In general, this foliation predominantly trends east-northeast to northeast and is subhorizontal to steeply dipping (Figure 5.2.8). There are several locations of subhorizontal foliation (≤ 30° dip), but this orientation is principally identified in the northwest and southeast corners of the Black-Pic Batholith Area (Figure 5.2.7).

In addition, two weak mineral lineations were observed, defined by stretched quartz and aligned epidote, and plunging 5° towards 359° and 0° towards 359°, respectively (Figure 5.2.8a).

Folds

Folds are a relatively uncommon structure at the outcrop scale in the Black-Pic Batholith Area, with only five occurrences mapped. These folds are distributed primarily in the northeastern part of the area and found within the tonalite. A total of three fold hinges were measured across the Black-Pic Batholith Area (Figure 5.2.8a). The measured fold hinges plunge 30° or less, with two plunging west and one plunging southwest. Two axial planes were measured; one striking southeast (134°) and one striking west (270°). Both planes were measured with relatively shallow dips of 27° and 26°, respectively. Overall the folds exhibit a broad range of orientations consistent with a radial lineation typical of non-cylindrical folding. These structures are interpreted as third-generation (F3) folds, and suggest north-northwest–south-southwest regional shortening.

Shear Zones

Two ductile shear zones were mapped in the Black-Pic Batholith Area, one in the centre and one in the southeastern corner of the area, nearly along strike with each other, and both within the tonalite (Figure 5.2.9). Both shear zone occurrences are a few centimeters wide and less than a meter long. They strike 036° and 038°, respectively and the dip is unknown. The former also exhibits evidence of dextral offset. There is no evidence of a brittle component to the shearing and so these are purely ductile structures.

5.2.4.2 Brittle Structures

Joints and faults are the main brittle structure types documented in the Black-Pic Batholith Area. Only one vein, filled with quartz and epidote, was observed and is not described further below. A total of 651 fracture orientation measurements were made in the Black-Pic Batholith Area, including measurement of 635 joints and 16 faults. The characteristics of each of these fracture types are described below. The secondary mineral infillings that accompanied some joints and faults are described in Section 5.2.4.3. Table 5.9 summarizes the orientation information for brittle structures.

Table 5.9 Summary of Orientation Information for Brittle Structures in the Black-Pic Batholith Area

Structure Type	Orientation	Peak (°)	Peak Frequency (%)	Range (°)	Confidence
Joints - All	NNE-NE	020	6.5	005-025	Medium-High
		037	7.6	025-045	Medium-High
		056	8.4	045-068	High
		071	5.7	068-079	Medium-Low
	SE	140	9.2	109-164	High
Joints - Subhorizontal	NNE-NE	013	7.0	007-023	Medium-Low
		033	7.9	023-040	Medium
		047	10.2	040-063	Medium
	E	083	11.0	063-098	Medium
	SSE-S	145	10.9	136-162	Medium
		175	8.2	162-181	Medium-Low
Joints - Intermediate	NNE-NE	019	7.3	012-025	Medium-Low
		035	13.0	025-045	Medium
		053	17.3	045-068	High
	SE-SSE	152	10.7	143-162	Medium
		169	7.2	162-181	Medium-Low

Joints - Subvertical	NNE-NE	020 040 058 071	6.6 7.4 8.1 6.1	002-025 025-045 045-068 068-085	Medium-Low Medium Medium-High Medium-Low
	SE-S	140 161	9.9 5.9	106-152 152-170	High Medium-Low
Faults - All	NNE	013 030	11.9 29.3	000-020 020-055	Medium High
	E	079 106	6.2 5.8	075-084 101-115	Low Low
	SE	130	12.0	123-145	Medium
Faults - Dextral	N-NE	008 033	8.3 31.9	001-015 015-055	Medium-Low High
	E	080 107	8.2 8.0	074-086 101-111	Low Low
	SE	129	15.8	122-150	Medium
Faults - Sinistral	N-NE	005 018 030	25.1 55.0 34.5	000-008 008-025 025-037	Medium High Medium
Secondary Mineral Infill	N-NE	011 030 054	8.1 12.8 9.6	353-021 021-043 043-066	Medium-Low High Medium
	SE	140 163	10.3 7.2	125-155 155-173	Medium-High Medium-Low

Joints

A total of 635 joint measurements were recorded in the Black-Pic Batholith Area (Figure 5.2.10). Joints are recognized at all outcrop locations in the Black-Pic Batholith Area. The total joint population is dominated by two broad orientations, including one which ranges between 005° and 079° and includes peaks at 020°, 037°, 056° and 071°, and one which ranges between 109° and 164°, and includes one broad peak at 140° (Figure 5.2.11). Figure 5.2.12 summarizes spacing information for all joints in the Black-Pic Batholith Area. Figure 5.2.13 provides field photos showing examples of the joints observed in the Black-Pic Batholith Area.

A total of 36 out of 635 joints (6%) dip between 0° and 30° and are classified as sub-horizontal (Figure 5.2.11c). Several narrow orientation peaks are evident in this sub-set of joints, including 013°, 033°, 047°, 083°, 145°, and 175° spanning a broad range of approximately 170° between north-northeast and south-southeast. 50 out of 635 joints (8%) dip between 31° and 60° and are classified as intermediate (Figure 5.2.11d). Two general peaks, trending northeast and south-southeast are evident, with narrow peaks at 019°, 035°, 053°, 152°, and 169°. 549 out of 635 joints (86%) dip between 61° and 90° and are classified as subvertical (Figure 5.2.11e). The pattern of orientations of this subset is very similar to that of the total joint set with a broad main peaks at 020° to 058° (range 355° to 093°) and another main peak at 140° (range 103° to 175°).

Figure 5.2.12 presents joint spacing data for the Black-Pic Batholith Area. All joint spacing bins are represented indicating that joints range in spacing from <1 cm to >1000 cm across the Black-Pic Batholith Area. There is a predominance of joints in the 30 – 100 cm and 100 to 500 cm spacing bins, which includes 453 out of 635 total joint occurrences (71%). The orientation pattern for both of these two spacing bins shows a similar distribution to those of the subvertical subset and total joint set. In general, tightly spaced (<10–30 cm), moderately spaced (30 – 500 cm) and widely spaced (500 cm or more) joints are distributed evenly throughout the entire Black-Pic Batholith Area. However, joints with spacing between the 500 – 1000 cm are absent in the northeastern corner and along the northern margin of the Black-Pic Batholith Area.

Faults

A total of 16 measurements of fault orientations were taken within the Black-Pic Batholith Area. Clusters of faults were observed in the northwestern, south-central and east-central parts of the area (Figure 5.2.14). Figure 5.2.15 presents orientation information for faults observed in the Black-Pic Batholith Area. Figure 5.2.16 provides field photos showing examples of faults observed in the Black-Pic Batholith Area.

The total fault population is dominated by one distinct orientation peak at 030°, and two additional subordinate peaks at 013° and 130° (Figures 5.2.15). Two additional minor peaks are evident at 079° and 106°. All of the faults dip 75° or greater, with 12 (75%) dipping at least 80° (Figure 5.2.15).

Steps on fault planes, and Riedel fractures, were identified in some instances as fault kinematic indicators. Based on the interpretation of these features, 12 faults (75%) were determined to be dextral and four faults (25%) were determined to be sinistral. The dextral subset of faults includes one main peak orientation at 030°, another peak at 130° and three additional subordinate peaks, one at 013°, one at 079° and one at 107°. The sinistral subset of faults includes one main peak orientation at 018° and shoulder peaks at 005° and 030° encompassing a total range of 25°. No slickenlines were identified on these faults. Figure 5.2.16 provides field examples of observed faulting.

Fault damage zones ranged in width from mm-scale single slip surfaces to metre-scale zones with multiple parallel fault planes and subordinate oblique fractures (Figure 5.2.16). Gouge was not found in association with any observed fault. Where observed, the fault offset was generally a few centimeters at the most, however one north-striking sinistral fault exhibited approximately one metre of offset.

5.2.4.3 Secondary Minerals/Alteration

Information on secondary minerals and alteration associated with fractures in the Black-Pic Batholith Area is described below and summarized in Tables 5.10 to 5.12 below. The results are presented based on assessment of all 652 fracture measurements, including 635 joints, 16 faults and 1 vein. Figure 5.2.17 shows the distribution of secondary minerals and alteration in fractures within the Black-Pic Batholith Area. Figure 5.2.18 shows orientation information for all structures associated with secondary minerals and alteration, and the most common occurrence types, including hematite, epidote, chlorite, quartz and K-feldspar. Figure 5.2.19 provides some field photos showing examples of secondary minerals or alteration observed in the Black-Pic Batholith Area, primarily hematite staining. Figure 5.2.16b shows an epidote filled fault in the tonalite host rock.

Overall, five main secondary minerals, including epidote, chlorite, hematite, quartz and k-feldspar, are observed in fractures (joints, faults, veins) across the Black-Pic Batholith Area. In some instances, more than one infilling mineral was identified within a single fracture. Minor 'other' occurrences of infilling or alteration minerals observed in association with fractures include one example each of plagioclase, biotite, muscovite, pyroxene and amphibole. Table 5.10 summarized the number of occurrences of each mineral type for the total fracture set. The results indicate that the majority (83%) of all fractures are unfilled and that the majority (148/155; 95%) of filled fractures dip subvertically (61 – 90°).

Table 5.10 Secondary Minerals and Alteration Associated with All Fractures in the Black-Pic Batholith Area

Mineral	Total Occurrences	% of total Fracture	Subvertical Dip (61-90°)	Intermediate Dip (31-60°)	Subhorizontal Dip (0-30°)
Hematite	54	8	51	3	0
Epidote	51	8	45	5	1
Chlorite	47	7	43	4	0
Quartz	13	2	11	0	2
K-feldspar	7	1	5	0	2
None	535	82	--	--	--

Orientation information for fractures associated with the secondary minerals and alteration in the Black-Pic Batholith Area is shown in Figure 5.2.18. The total population of secondary minerals and alteration is shown in Figures 5.1.18a and 5.1.18b. The rose diagram combining structural orientation information for the total secondary mineral population is dominated by one narrow peak orientation at 030° and which ranges between 021° and 043° and several additional subordinate peaks, at 011°, 054°, 140° and 163° (Figure 5.1.18b). The rose diagram for hematite is dominated by one narrow peak orientation at 030° and which ranges between 025° and 045° and several additional subordinate peaks, at 010°, 054°, 074°, 133° and 165° (Figure 5.1.18c). The rose diagram for chlorite is dominated by a broad twin peak orientation at 140° / 151° and which ranges between 134° and 167° and several additional subordinate peaks, at 011°, 030°, 051°, 077°, and 109° (Figure 5.1.18d). The rose diagram for epidote is dominated by one narrow peak orientation at 143° and which ranges between 134° and 154° and several additional subordinate peaks, at 007°, 029°, 053°, 099° and 165° (Figure 5.1.18d). The rose diagram for quartz and K-feldspar is combined as these two secondary minerals are consistently observed together (Figure 5.1.18f). This rose diagram is dominated by one narrow peak orientation at 038° and which ranges between 027° and 046° and several additional subordinate peaks, at 018°, 054°, 132° and 175°.

A total of 107 out of 635 total documented joints (17%) in the Black-Pic Batholith Area were observed to be infilled, leaving the remaining 528 joint occurrences (83%) unfilled (Table 5.11). The filled occurrences included 48 instances of hematite (8%), 48 instances of epidote (8%), 44 instances of chlorite (7%), 11 instances of quartz (2%), and 6 instances of K-feldspar (1%). Hematite and/or epidote and/or chlorite, either in solitary or in some combination, was the most prevalent occurrence type. Five (1%) of 'other' occurrences of infilling or alteration minerals included one instance each of plagioclase, biotite, muscovite, pyroxene and amphibole and are not tabulated. When the dip of the observed joint plane is considered the majority of secondary minerals and alteration were associated with subvertically-oriented joints (Table 5.11).

Table 5.11 Secondary Minerals and Alteration Associated with Joints in the Black-Pic Batholith Area

Mineral	Total Occurrences	% of total	Subvertical Dip (61-90°)	Intermediate Dip (31-60°)	Subhorizontal Dip (0-30°)
Hematite	48	8	45	3	0
Epidote	48	8	42	5	1
Chlorite	44	7	40	4	0
Quartz	11	2	9	0	2
K-feldspar	6	1	4	0	2
None	528	83	--	--	--

Nine out of 16 total documented faults (56%) were observed to be infilled with secondary minerals, leaving the remaining seven occurrences (44%) unfilled (Table 5.12). This included six instances of hematite (38%), three instances of chlorite (19%), two instances of epidote (13%) and one instance each of quartz and k-feldspar (6% each). Hematite was usually observed by itself and sometimes in association with either epidote or chlorite. Quartz was seen in association with K-feldspar and hematite. All secondary minerals and alteration were associated with steeply dipping (>65°) faults.

Table 5.12 Secondary Minerals and Alteration Associated with Faults in the Black-Pic Batholith Area

Mineral	Total Occurrences	% of total	Subvertical Dip (61-90°)	Intermediate Dip (31-60°)	Subhorizontal Dip (0-30°)
Hematite	6	38	6	0	0
Chlorite	3	19	3	0	0
Epidote	2	13	2	0	0
Quartz	1	6	1	0	0
K-feldspar	1	6	1	0	0
None	7	44	--	--	--

5.3 Subprovince Boundary Zone Area

During the Observing Geological Features phase (2014) of the geological mapping exercise, 25 stations were visited over a two day period north-northwest of the Black-Pic Batholith Area and west-southwest of the Quetico Area (Figure 5.3.1). These stations are grouped together into the Subprovince Boundary Zone Area which covers an approximately 25 km long section of the east-west trending Wawa-Quetico Subprovince boundary. This boundary extends beyond the Hornepayne Area both to the east and west. Stations are located in a zone that straddles both the Quetico Subprovince to the north and the Wawa Subprovince to the south. The following subsections provide a brief summary of the main observations made.

5.3.1 Accessibility, Bedrock Outcrop Exposure and Overburden Thickness

This area was easily accessible following a well-maintained system of secondary unpaved roads. The terrain is similar to that encountered in both the Quetico and Black-Pic Batholith Areas. It has a similar mixture of moderate to good bedrock outcrops in local topographic highs with thicker overburden deposits in local low areas.

5.3.2 Lithology and Physical Character

The Subprovince Boundary Zone is lithologically heterogeneous with slivers of amphibolitized mafic volcanic rocks in various states of partial to complete digestion by the surrounding granitoid rocks characteristic of the Black-Pic batholith. These slivers appear to represent the tightly folded and attenuated remnants of the Manitouwadge greenstone belt that continues along strike to the west. While not observed in the field by the authors, previous mapping by Johns and McIlraith (2003) suggest that mafic volcanic slivers also locally interfinger with Quetico metasedimentary rock adjacent to the Subprovince boundary fault.

Migmatitic metasedimentary rock is dominant to the north in the Quetico Subprovince and well-banded tonalite is dominant to the south in the Wawa Subprovince. Granite pegmatite is also generally more common close to the subprovince boundary, intruding both the migmatitic metasedimentary rocks and the tonalite.

5.3.3 Structure

Foliation in the Subprovince Boundary Zone Area is well developed and parallels the undulations of the subprovince boundary. Overall, 20 measurements of tectonic foliation, interpreted to correlate with the S2 foliation described above, were collected from 25 stations in the Subprovince Boundary Zone Area (Figures 5.3.2 and 5.3.3). The total tectonic foliation population is dominated by two peak orientations, including one at 078° and one at 093°. Two less prominent peaks occur at 044° and 109°.

A total of 36 joints were measured from the 25 stations within the Subprovince Boundary Zone Area. The total joint population is dominated by northeast and southeast peak orientations, including one at 038° and one at 131°. Two less prominent peaks occur at 055° and 170°. 11 of the 36 joints (31%) were observed to be infilled with secondary minerals including nine instances of quartz, four instances of feldspar, two instances of hematite and one instance of magnetite. No faults or veins were identified in the Subprovince Boundary Zone Area.

5.4 Dykes in the Hornepayne Mapping Area

Regional mapping suggests that as many as four Proterozoic mafic dyke swarms are present in the Hornepayne area, including northwest-striking Matachewan dykes (ca. 2.473 Ga), northeast-striking Biscotasing (ca. 2.167 Ga) and Abitibi (ca. 1.14 Ga) dykes, and north-northeast-striking Marathon dykes (ca. 2.121 Ga). The geological mapping activity in the Hornepayne area recognized all of these (Figure 5.4.1), except the Abitibi dykes), which were previously interpreted to be very sparsely distributed. The following sections discuss the character of these three main Proterozoic mafic dyke swarms, in order of their frequency of occurrence, in the Hornepayne area. Scanline fracture mapping exercises were completed across one well-exposed example from each of these three dyke swarms and those results are also presented below. No Proterozoic mafic dykes were identified at any of the few stations visited in the Subprovince Boundary Zone. All observations of Proterozoic dykes in the Hornepayne area are from the Quetico and Black-Pic Batholith areas.

Orientation measurements of three main sets of mafic dykes, including the regionally known Matachewan (Section 5.4.1), Biscotasing (Section 5.4.2), and Marathon (Section 5.4.3) mafic dykes, were made in the mapping area. Generally, the dykes are intensely jointed, with some joint sets continuous into the host rock. More detailed descriptions of the lithological and physical properties for each of these mafic dyke sets is provided below and summarized in Table 5.13.

Section 5.4.4 briefly discusses the character of the felsic dykes and sills that occur within the Hornepayne Area (Figure 5.4.4.1). The felsic dykes and sills all predate the Proterozoic mafic dykes and all exhibit welded contacts with the surrounding bedrock units.

Table 5.13 Proterozoic Mafic Dyke Summary Table

Dyke Swarm	Number of Bedrock Station Occurrences	Width (m)	Orientation	Peak (°)	Magnetic Susceptibility (average SI)	Gamma (average K, U, Th)	Strength (range)
Matachewan	22	0.01 - >10	NW	140	37.0×10^{-3}	K = 0.7% U = 0.8 ppm Th = 3.1 ppm	R5
Biscotasing	10	0.1 - >10	NE	035 057	15.8×10^{-3}	K = 1.2% U = 0.83 ppm Th = 3.4 ppm	R5
Marathon	8	0.01 - >10	NNE	015	23.6×10^{-3}	K = 1.8% U = 0.67 ppm Th = 5.6 ppm	R5

5.4.1 Matachewan Mafic Dykes

Mafic dykes of the Matachewan swarm are the most populous of the three Proterozoic dyke swarms encountered in the Hornepayne area. These dykes are easily distinguished as a distinct swarm by their consistent northwest strike. Summaries of the lithological and physical character of the Matachewan mafic dykes encountered, and the results from the scanline fracture mapping exercise undertaken across one well-exposed Matachewan mafic dyke, are presented below.

5.4.1.1 Lithology and Physical Characteristics

Matachewan mafic dykes were observed at a total of 22 locations in the Hornepayne Area, including 13 from within the Quetico Area and 9 from within the Black-Pic Batholith Area. Representative field photographs of Matachewan mafic dykes are shown in Figures 5.4.1.1a, 5.4.1.1b and 5.4.1.1c. A total of 19 Matachewan mafic dyke samples were collected in the Hornepayne area.

Matachewan mafic dykes are typically dark grey when fresh and brownish when weathered. They are generally massive, fine to medium grained, and exhibit an equigranular to porphyritic texture. The main mineral assemblage consists of pyroxene, plagioclase and olivine. Epidote and magnetite were common accessory minerals identified in both the Quetico and Black-Pic Batholith areas while chlorite and pyroxene were observed in the Black-Pic Batholith Area alone.

A total of 22 rock hardness measurements were made on the Matachewan mafic dykes and in all instances a value of R5 (Very Strong) was recorded.

A summary of 24 Matachewan mafic dyke width measurements is presented in Figure 5.4.1.1d. In many locations it was not possible to determine the true width of Matachewan mafic dykes encountered in the field due to insufficient exposure of both side of the contact, especially for the widest dykes. In these cases the reported width is a minimum value. Matachewan mafic dyke widths range from one to three centimetres for the thinnest examples, to greater than 10 metres for the widest examples. The majority (17/24 occurrences) of Matachewan mafic dykes are at least one metre wide, and more than a third (9/24) are at least five metres wide.

Matachewan mafic dykes have a high magnetic susceptibility (average = 37.0 x 10^{-3} SI, N = 36), and with a range of 52.6 X 10^{-3} SI and standard deviation of 11.6 x 10^{-3} SI (Figure 5.4.1.1e). Gamma ray spectrometry measurements (N = 27; Figure 5.4.1.1f) on Matachewan mafic dykes yielded the following characteristics:

- Total count is on average 33.5 cps with a range of 87.1 cps.
- Potassium content is on average 0.7% with a range of 0.7%.
- Uranium content is on average 0.8 ppm with a range of 2.6 ppm.
- Thorium content is on average 3.1 ppm with a range of 7.3 ppm.

5.4.1.2 Structure

The orientation of contact between Matachewan mafic dykes and the surrounding bedrock was measured in 24 instances (Figures 5.4.1.2a and 5.4.1.2b). Matachewan dykes generally dip subvertically, with the lowest dip magnitude recorded being 70°. They predominantly strike to the northwest, with one main orientation peak at 140° that ranges between 129° and 152°. One subordinate orientation peak is evident at 121°. A total range in orientations for Matachewan mafic dyke contacts extends between 113° and 152°.

Figure 5.4.1.3 shows three field examples of the contact between Matachewan mafic dykes and the adjacent bedrock. Where the contact is observed Matachewan mafic dykes exhibit a sharp contact with a well-developed, cm-scale, very fine-grained, chilled margin. No faults were identified parallel to the dyke-host contacts, however it was common for contact-parallel joints to develop in the bedrock within a zone extending up to 30 cm beyond the dyke contact. Dyke contacts are otherwise intact.

The only fractures identified within the Matachewan mafic dykes are joints (N = 71). The distribution of azimuth direction is variable, including a dominant, but poorly defined, north-northeast orientation at 013°. Several subordinate peaks are identified at 037°, 049°, 070°, 078°, 130° and 151°. The joints predominantly dip subvertically (Figures 5.4.1.2c and 5.4.1.2d). Subordinate joints with intermediate to subhorizontal dips exhibit variable strike orientations. Chlorite ± hematite is the main joint-infilling mineral, however most joints within the dyke show no infill.

Histograms of measured joint spacing within the Matachewan mafic dykes, and in the adjacent bedrock, are shown in Figures 5.4.1.2e and 5.4.1.2f, respectively. A peak spacing of 30 – 100 cm is evident for joints within the dykes, while the peak spacing for joints in the adjacent bedrock is 100 – 500 cm.

5.4.1.3 Matachewan Mafic Dyke Scanline Fracture Mapping Exercise

A scanline fracture mapping exercise was completed across two Matachewan mafic dykes of 6.1 m and 0.65 m width that intruded into the adjacent tonalite unit in the Black-Pic Batholith area (Station 16HM0054). Figure 5.4.1.4 summarizes the results from the scanline fracture mapping exercise and Figure 5.4.1.5 shows some field photographs from locations along the scanline. A detailed sketch of the scanline is provided as Figure 5.4.1.6. The rock exposure along the scanline was excellent and provided a clean area of investigation 19 m long and 2 m wide (Figure 5.4.1.4a and Figure 5.4.1.6). Based on the information collected during this scanline exercise, the following observations are made:

- The contacts between the dyke and the host rocks are sharp, chilled and intact.
- There is a dominant set of north-striking joints occurring with subordinate east and northeast-striking joint sets within the two dykes. Several northwest-striking joints occur within the smallest dyke (Figure 5.4.1.4b).
- The dykes are strongly fractured internally at a much greater frequency than that of the adjacent bedrock units (Figure 5.4.1.4c). The dominant joint spacing observed within the dykes is 10–50 cm.
- The host rock is very sparsely fractured with a few paired or isolated northwest to north-striking joints occurring throughout the entire map section (Figures 5.4.1.4b and 5.4.1.4c). The fracture density contrast between the dykes and the host rock along the scanline extent suggested no damage was caused as the result of emplacement of the former into the later.
- Chlorite is the main joint-infilling mineral, but joints with no infill are most common.
- Magnetic susceptibility measurements taken along the scanline are shown in Figure 5.4.1.4d. The measurements are consistent with the regional values for both Matachewan mafic dykes and the surrounding bedrock units.

5.4.2 Biscotasing Mafic Dykes

Mafic dykes of the Biscotasing dyke swarm are the second most populous of the three Proterozoic dyke swarms encountered in the Hornepayne area. These dykes are usually easily recognized, based on orientation and character in the field, as being part of the Biscotasing dyke swarm. However, in a few locations they were difficult to distinguish from Marathon mafic dykes as both locally have irregular contacts and their northeasterly orientations may overlap. A summary is given below of the lithological and physical character, and the main structural features, of the Biscotasing mafic dykes encountered in the Hornepayne area.

5.4.2.1 Lithology and Physical Characteristics

Biscotasing mafic dykes were observed at a total of ten locations in the Hornepayne Area, including three from within the Quetico Area and seven from within the Black-Pic Batholith Area. Representative field photographs of Biscotasing mafic dykes are shown in Figures 5.4.2.1a, 5.4.2.1b and 5.4.2.1c. A total of seven Biscotasing mafic dyke samples were collected from the Hornepayne Area.

Biscotasing mafic dykes are typically dark grey to black when fresh and dark grey or brown when weathered. The main mineral assemblage consist of plagioclase, olivine and magnetite with minor pyroxene. Generally, the rock is massive, fine grained, and texturally equigranular.

A total of 10 rock hardness measurements were made on the Biscotasing mafic dykes and in all instances a value of R5 (Very Strong) was recorded.

A summary of 11 Biscotasing mafic dyke width measurements is presented in Figure 5.4.2.1d. In many locations it was not possible to determine the true width of Biscotasing mafic dykes encountered in the field due to insufficient exposure of both side of the contact, especially for the widest dykes. In these cases the reported width is a minimum value. Biscotasing mafic dyke widths range from 10 - 30 centimetres for the thinnest examples, to greater than 10 metres for the widest examples. The majority (10/11 occurrences) of Biscotasing mafic dykes are at least one metre in width, and just over half (6/11) are at least five metres in width.

Biscotasing mafic dykes have a high magnetic susceptibility (average = 15.8 x 10^{-3} SI, N = 8), and with a range of 30.6 X 10^{-3} SI and standard deviation of 9.1 x 10^{-3} SI (Figure 5.4.2.1e). Seven gamma ray spectrometry measurements on Biscotasing mafic dykes, as shown in Figure 5.4.2.1f, yielded the following characteristics:

- Total count is on average 78.6 cps with a range of 115.6 cps.
- Potassium content is on average 1.2% with a range of 1.5%.
- Uranium content is on average 0.83 ppm with a range of 1.4 ppm.
- Thorium content is on average 3.4 ppm with a range of 5.2 ppm.

5.4.2.2 Structure

The orientation of the contact between Biscotasing mafic dykes and the surrounding bedrock was measured in 11 instances. Biscotasing mafic dykes consistently dip subvertically, with the shallowest dip magnitude recorded being 72°. Biscotasing dykes strike northeasterly, with two prominent orientation peaks at 035° and 057°. A total range for Biscotasing mafic dyke contact orientations extends between 024° and 065°.

Figure 5.4.2.3 shows two field examples of the contact between Biscotasing mafic dykes and the adjacent bedrock. Where the contact with the surrounding bedrock is observed it is consistently sharp, chilled, and intact. Tightly-spaced, contact-parallel joints developed along the contact between the dyke and surrounding bedrock host rock are observed locally within a zone that extends up to 30 cm into the adjacent bedrock. There was no evidence of fault re-activation along the dyke contact.

The only fractures identified within the Biscotasing mafic dykes are joints (N = 35). The dominant joints sets within the Biscotasing dykes are east-southeast-trending, with a central orientation peak at 100°, and southeast-trending, with an orientation peak at 143°. Two subordinate joint orientation peaks are also evident at 029° and 072°. The joints predominantly dip subvertically (Figures 5.4.2.2c and 5.4.2.2d). The majority of joints within the Biscotasing mafic dykes showed no infill.

Histograms of measured joint spacing within the Biscotasing mafic dykes, and in the adjacent bedrock, are shown in Figures 5.4.2.2e and 5.4.2.2f, respectively. A peak spacing of 30 – 100 cm is evident for joints both within the dykes and within the adjacent bedrock.

5.4.2.3 Biscotasing Mafic Dyke Scanline Fracture Mapping Exercise

A scanline fracture mapping exercise was completed across two Biscotasing mafic dykes of 0.8 m and 1.1 m wide within tonalite bedrock in the Black-Pic Batholith Area (Station 16HM0044). Figure 5.4.2.4 summarizes the results from the scanline fracture mapping exercise and Figure 5.4.2.5 shows some field photographs from locations along the scanline. The rock exposure along the scanline was excellent and provided a clean area of investigation 14 m long and 2 m wide (Figure 5.4.2.4a). A detailed sketch of the scanline is provided as Figure 5.4.2.6. Based on the information collected during this scanline exercise, the following observations are made:

- The dykes are massive and fine-grained intrusions with sharp, chilled and intact margins.
- The main joint sets occurring within the dykes along the scanline section strike east-northeast to southeast, with orientation peaks at 069°, 100°, 126°, and 145°, and north, with one orientation peak at 004°. These joints consistently dip subvertically (Figure 5.4.2.4b).
- The main joint sets occurring within the adjacent bedrock along the scanline section strike northeast, with an orientation peak at 040°, east-southeast, with an orientation peak at 100°, and south-southeast, with an orientation peak at 163° (Figure 5.4.2.4b).
- The southeasternmost dyke is fractured internally at a slightly higher frequency than that of the adjacent bedrock units and the other dyke (Figure 5.4.2.4c). The joints are tightly to moderately-spaced within both the dykes and host rock, with an average joint spacing 30 – 100 cm.
- Chlorite was identified in few of the east-southeast and northeast-trending joints within the host rock.
- Magnetic susceptibility measurements taken along the scanline are shown in Figure 5.4.2.4d. The measurements are consistent with the regional values for both Biscotasing mafic dykes and the surrounding bedrock units.

5.4.3 Marathon Mafic Dykes

Mafic dykes of the Marathon dyke swarm are the least populous of the three Proterozoic dyke swarms encountered in the Hornepayne area. These dykes are usually easily recognized, based on orientation and character in the field, as being part of the Marathon dyke swarm. However, in a few locations they were difficult to distinguish from Biscotasing mafic dykes as both locally have irregular contacts and their northeasterly orientations may overlap. A summary is given below of the lithological and physical character, and the main structural features, of the Marathon mafic dykes encountered in the Hornepayne area.

5.4.3.1 Lithology and Physical Characteristics

Marathon mafic dykes were observed at a total of eight locations in the Hornepayne Area, including six within the Quetico Area and two within the Black-Pic Batholith Area. Representative field photographs of Marathon mafic dykes are shown in Figures 5.4.3.3a, 5.4.3.3b and 5.4.3.3c. A total of four Marathon mafic dyke samples were collected from the Hornepayne Area.

Marathon dykes typically dark grey when fresh and brownish or sometimes rusty coloured when weathered. Generally, the rock is massive, fine to medium grained, and showed equigranular to porphyritic texture. The main mineral assemblage consist of amphibole, plagioclase, magnetite with minor observations of pyroxene.

A total of six rock hardness measurements were made on the Marathon mafic dykes and in all instances a value of R5 (Very Strong) was recorded.

A summary of eight Marathon mafic dyke width measurements is presented in Figure 5.4.3.1d. Most of the Marathon dykes are thin in nature and so, with the exception of one very wide example, the reported widths are true widths. Marathon mafic dyke widths range from 1 - 3 cm for the thinnest examples, to greater than 10 m in one instance. The majority (5/8 occurrences) of Marathon mafic dykes are one metre or less in width.

The Marathon dykes that were observed in the field often did not have a clear magnetic signature, likely due to their narrow width (generally less than 1 m), therefore only four measurements were collected at the six stations where Marathon dykes were observed. Based on the few reasonable measurements recorded Marathon mafic dykes have a high magnetic susceptibility (average = 23.6 x 10^{-3} SI, N = 4), and with a range of 24.7 x 10^{-3} SI and standard deviation of 9.8 x 10^{-3} SI (Figure 5.4.3.1e). Four gamma ray spectrometry measurements on Marathon mafic dykes, as shown in Figure 5.4.3.1f, yielded the following characteristics:

- Total count is on average 53.2 cps with a range of 82.3 cps.
- Potassium content is on average 1.8% with a range of 2.6%.
- Uranium content is on average 0.7 ppm with a range of 0.8 ppm.
- Thorium content is on average 5.6 ppm with a range of 4.3 ppm.

5.4.3.2 Structure

The orientation of the contact between Marathon mafic dykes and the surrounding bedrock was measured in eight instances. Marathon mafic dykes consistently dip subvertically, with the shallowest dip magnitude recorded being 70°. Marathon dykes predominantly strike north-northeasterly, with one main orientation peak at 015°. Two less prominent orientation peaks are evident at 056° and 174°. A total range for Marathon mafic dyke contact orientations extends between 005° and 180°.

Figure 5.4.3.3 shows three field examples of the contact between Marathon mafic dykes and the adjacent bedrock. Where the contact with the surrounding bedrock is observed it is consistently sharp, chilled, and intact. Tightly-spaced, contact-parallel joints developed along the contact between the dyke and surrounding bedrock host rock are observed locally within a zone that extends up to 30 cm into the adjacent bedrock. There was no evidence of fault re-activation along the dyke contact.

The only fractures identified within the Marathon mafic dykes are joints (N = 13) (Figures 5.4.3.2c and 5.4.3.2d). The dominant joints sets within the Marathon dykes are south-southeast to south-trending, with orientation peaks at 160° and 180°. Several additional, northeast to southeast-trending, minor orientation peaks are evident in the dataset. The joints predominantly dip subvertically. The majority of joints within the Marathon mafic dykes showed no infill.

Histograms of measured joint spacing within the Marathon mafic dykes, and in the adjacent bedrock, are shown in Figures 5.4.3.2e and 5.4.3.2f, respectively. A peak spacing of 10 – 30 cm is evident for joints within the dykes and a peak spacing of 30 – 100 cm is evident for joints within the adjacent bedrock.

5.4.3.3 Marathon Mafic Dyke Scanline Fracture Mapping Exercise

A scanline fracture mapping exercise was completed across a swarm of 7 Marathon mafic dykes within tonalite host rock in the Black-Pic Batholith Area (Station 16PG0058). Figure 5.4.3.4 summarizes the results from the scanline fracture mapping exercise and Figure 5.4.3.5 shows some field photographs from locations along the scanline. The rock exposure along the scanline was excellent and provided a clean area of investigation of 20 m long and 2 m wide (Figure 5.4.3.4a). A detailed sketch of the scanline is provided as Figure 5.4.3.6. Based on the information collected during this scanline exercise, the following observations are made:

- The dykes are massive and fine-grained intrusions with sharp and chilled margins. Sections of dyke-host contacts varied between intact and fractured.
- The main joint sets occurring within the dykes along the scanline section strike southeast to south-southeast, with orientation peaks at 135° and 150°. Several minor orientation peaks strike between north and east-southeast. These joints consistently dip subvertically (Figure 5.4.3.4b).
- The main joint sets occurring within the adjacent bedrock along the scanline section strike north-northeast, with an orientation peak at 015°, east-northeast, with an orientation peak at 071°, and southeast, with an orientation peak at 145° (Figure 5.4.3.4b).

- The Marathon dykes are consistently more fractured than the adjacent bedrock. Locally, the dyke-parallel fractures developed both with the dykes and in the adjacent host rocks, are tightly-spaced (≤ 2 cm) near to the contact between the two rock types.
- Most joints do not show any infill; but chlorite was observed at one station on two joints, striking at 320° and 022°.
- The Marathon dykes investigated in the scanline fracture mapping exercise are consistently too thin to provide an accurate magnetic susceptibility profile.

5.4.4 Felsic Dykes

Observations relating to the character and structure of felsic dykes observed in the Hornepayne area are summarized below and in Table 5.3.2. Overall, felsic dykes were observed at a total of ten bedrock stations (Figure 5.4.4.1). The majority of felsic dykes (nine) were observed in the Black-Pic Batholith area, and one felsic dyke was identified in the Quetico mapping area. One felsic dyke was noted in the Subprovince Boundary Zone. Felsic dykes observed in the Black Pic Batholith mapping area are interpreted to be associated with the Strickland pluton, given the proximity of the pluton to the observations.

Table 5.4.2 Felsic Dyke Summary Table

Dyke Swarm	Number of Bedrock Station Occurrences	Width (m)	Orientation	Peak (°)	Magnetic Susceptibility (average SI)	Gamma (average K, U, Th)	Strength (range)
Felsic Dykes	10	0.01 - 2	N E	003 092	3.7×10^{-3}	K = 2.0% U = 3.2 ppm Th = 13.2 ppm	R3 to R6

Local, decimeter to meter scale granite pegmatite dykes were observed, primarily in the Black-Pic Batholith area. The felsic dykes do not possess any strong preferred orientation but appear to intrude parallel to the subprovince boundary. Abundant granite pegmatite was also observed as foliation parallel bands. Cross-cutting Archean felsic dykes exhibit un-chilled and un-zoned, cuspate, margins. No brittle deformation is localized along any observed contacts. Representative field examples of felsic dykes in the Hornepayne area are presented in Figure 5.4.4.2a and 5.4.4.2b.

Within the Hornepayne area felsic dykes were observed to be relatively thin, with the majority less than 30 cm wide. Only three of 15 width measurements were greater than 30 cm and all were less than 100 cm. The orientation of contact between felsic dykes and the surrounding bedrock was measured in 15 instances (Figure 5.4.4.2c and 5.4.4.2d). Felsic dykes generally have two predominate peak orientations, north-south (003°) and east-west (092°), and four subordinate orientation peaks at 032°, 059°, 113° and 150° (Figure 5.4.4.2d). The majority of dykes are subvertical.

A total of 11 joint measurements were recorded in the felsic dykes. The primary joint set strikes northwest-southeast, with a second set striking east-west. Subordinate joint sets with peaks at 029°, 058°, and 108° were identified. Joints are sub-vertical, with a minimum dip of 72°. Mineral infilling was not observed to be associated with the felsic dykes.

6 SUMMARY OF FINDINGS

This report presents the results of the Phase 2 Geological Mapping completed in the Hornepayne area in 2016. Observations were made at outcrops along pre-defined traverse areas in and around the potentially suitable areas identified during Phase 1 Geoscientific Desktop Assessment in the Quetico Subprovince and the Black-Pic batholith. The geological mapping was completed to confirm and ground truth the presence and nature of key geological features, including: bedrock character (lithology, structure, magnetic susceptibility and geomechanical properties), fracture character, and bedrock exposure and surface constraints.

The following sections summarize the key findings of the geological mapping results presented in Section 5. The sections provide a discussion on how the geological data collected in 2014 and 2016 contributes to the understanding of the bedrock geology of the Hornepayne area, specifically the potentially suitable areas in the Quetico Subprovince and Black-Pic batholith, summarized in Section 6.1 and Section 6.2, respectively. Three major sets of mafic dykes have been mapped at the regional scale in the Hornepayne area and are discussed in Section 6.3.

6.1 Quetico Subprovince Area

The Quetico Area is located between 6 and 24 km north of the town of Hornepayne and has relatively good road access. The area is accessed by several old and new logging roads that branch to the west and east off of Highway 631, north of the town of Hornepayne.

Bedrock exposure within and around the Quetico Subprovince area is moderate, with overburden cover generally being up to 2 m thick in areas of topographic highs. Bedrock outcrops ranged in size from 10 to 50 m in diameter. In areas of low topography, overburden cover is very thick. Geological mapping confirmed that a large percentage of outcrops predicted by remote sensing data within the Quetico Subprovince area were actually sand (i.e., overburden) covered. A total of 308 stations were visited during mapping activities in the Quetico Subprovince area. Of these, 251 (81%) were locations of bedrock outcrop and 57 (19%) were mapped as overburden.

6.1.1 Lithology

Bedrock in the Quetico Subprovince is dominated by highly metamorphosed sedimentary rocks (i.e., migmatites). In the Hornepayne area, these rocks were previously described as showing a strong compositional layering and exhibiting small-scale folds, boudinage and shearing (Williams and Breaks, 1996). Sheeting of granitic material throughout the rocks is common (Williams, 1989). The migmatites of the Quetico Subprovince formed as a result of high-grade metamorphism of the original sedimentary rocks. The low-pressure, high temperature metamorphism that occurred in the area produced partial melting of the precursor sedimentary rocks, resulting in the formation of migmatites comprising two different lithological components: a metasedimentary protolith (i.e., paleosome) and a granitic component derived from the partial melting of the protolith (i.e., neosome).

Geological observations during Phase 2 Geological Mapping confirmed the heterogeneous distribution of bedrock lithologies within the Quetico Subprovince area. The two most common lithologies recorded in this area are migmatitic sedimentary rocks and granite. The sedimentary migmatites comprise two main components: metamorphosed sedimentary rocks and neosome resulting from partial melting, with the latter occurring as bands or lenses interlayered with the metasedimentary rock component. The degree of partial melting is variable across the area. Granite is also mapped throughout the Quetico Subprovince area and appears to have intruded as sills and to a lesser extent as dykes.

6.1.2 Structure

Ductile structures observed in the Quetico Subprovince area include various types of foliations, folds, and shear zones. The most common foliation type observed is a tectonic foliation identified across the entire area as the predominant penetrative ductile structure at the outcrop scale. Tectonic foliation is well developed in the migmatitic metasedimentary rocks, and generally weakly developed where observed in the tonalite, granite and granodiorite intrusions. In general, the foliation trends predominantly east-west subparallel to the subprovince boundary and is steeply dipping, with the exception of the south eastern portion of the Quetico Subprovince area where foliations are shallow to moderately dipping.

Folds are common features across the Quetico Subprovince area. They are formed at all scales from mm-scale to greater than outcrop scale. Interpretation of high-resolution magnetic data (SGL, 2017, in prep.) and interpreted unclassified lineaments (SRK, 2017) identify tight folds in the northwestern portion of the area, illustrating the presence of structural complexities within the metasedimentary rocks of the Quetico Subprovince. Field mapping recognized three generations of folding at the outcrop scale, which are most prominently seen in the migmatitic metasedimentary rocks. Shear zones observed in the Quetico Subprovince area are less that one centimeter to several decimetres wide, and up to several metres long. Where the shear zones are hosted by migmatitic metasedimentary rock, they are associated with injected neosome (i.e., material resulting from partial melting).

Joint measurements were recorded in most of the outcrop stations in the Quetico Subprovince area, with the majority being subvertical (i.e., 65 degrees dip or greater). Orientation of measured joints is variable, however dominant northwest- and northeast-trending sets were identified. Joint spacing is variable, with the majority of joints moderately spaced (i.e., 30 to 500 cm).

Faults in the Quetico Subprovince area were mainly recorded in the southeastern portion. Fault damage zones range from mm-scale single slip surfaces to up to meter wide zones parallel to the fault plane. Where it was possible to measure, offset was in the order of few centimeters at most across any observed fault plane. The majority of observed faults are steeply dipping, with two dominant orientations, to the northwest and the northeast.

6.2 Black-Pic Batholith Area

The Black-Pic batholith area, located within the Wawa Subprovince, is located six to 10 km south of Hornepayne. Road access is generally good within and around Black-Pic batholith area with the majority of traverses accessible by four wheel drive pick-up truck along a network of gravel logging roads. These roads were routinely used by logging trucks and therefore two-way radios were required to facilitate communication with logging truck and ensure crew safety while driving.

Bedrock exposure within and around the Black-Pic batholith area is variable, ranging from adequate to poor or non-existent, correlating extremely well to existing Quaternary mapping. Generally bedrock exposure is good in areas of topographic highs, such as in the northwestern and southeastern portions of the withdrawal area. Overburden cover is fairly extensive along a northeast-trending band that cross-cuts the withdrawal area, as shown in the Quaternary geology map and from geological mapping data.

6.2.1 Lithology

The Black-Pic batholith is a regionally extensive intrusion that encompasses an area of approximately 3000 km^2, covering the southern half of the Hornepayne area and extending west and south beyond it (Fenwick, 1967; Stott, 1999). Milne (1968) described the Black-Pic batholith as being mostly composed of well foliated to gneissic granodiorite to tonalite, with phases of hornblende-biotite, monzodiorite and pegmatite granite largely restricted to the margins of the batholith. Within the Hornepayne area, the Black-Pic batholith was previously mapped as a gneissic tonalite that locally includes biotite and/or amphibole-bearing tonalite (Williams and Breaks, 1996; Johns and McIlraith, 2003).

Geological observations during Phase 2 Geological Mapping indicate that the Black-Pic batholith area is dominated by very homogeneous crystalline bedrock consisting primarily of tonalite with minor amounts of granite, granodiorite, and amphibolite (metamorphic mafic rocks). The tonalite is typically composed of equigranular plagioclase and quartz with lesser hornblende, biotite and alkali feldspars, with average grain size of 1 – 10 mm (medium to coarse grained). Occasionally, coarse k-feldspar phenocrysts were observed. Granite and granodiorite occur as homogeneous masses and dykes, scattered relatively evenly throughout the area.

6.2.2 Structure

The most common ductile structure measured in the Black-Pic batholith area is moderate to strongly developed tectonic foliation, which predominantly trends east-northeast to northeast and is subhorizontal to steeply dipping. The assessment of measured foliations in conjunction with the magnetic fabric and interpreted unclassified lineaments suggests the presence of a regional, shallowly east-northeast-plunging vertical fold in the Black-Pic batholith area (SGL, 2017; SRK, 2017).

Folds are a relatively uncommon structure at the outcrop scale in the Black-Pic batholith area, with only five occurrences mapped. These folds are distributed primarily in the northeastern part of the area and exhibit a broad range of orientations. Shear zones are also uncommon in the Black-Pic batholith area, with only two occurrences mapped. Both shear zone occurrences are a few centimeters wide and less than a meter long, and are subhorizontal.

Joints and faults are the main brittle structure types documented in the Black-Pic batholith area during Phase 2 Geological Mapping. Most of the measured joints are subvertical, with dominant joint orientations north-northeast to east-northeast and northwest to north-northwest. Infilling was observed on approximately 20% of joint surfaces. Joint spacing is variable, ranging from <1 m to several hundreds of meters. Overall, widely spaced (500–1000 m) joints were observed in the eastern portion of the Black-Pic batholith area, while tightly to moderately spaced (1– < 500 m) joints were mostly observed in the western portion. Generally, subhorizontal joints sub-parallel to the overall trend of the foliations are tightly to moderately spaced (<10–100 m).

A total of 16 fault measurements were collected in the Black-Pic batholith area, with clusters of faults observed in the northwestern, south-central and east-central parts of the area. The majority of the measured faults were steeply dipping, with the dominant strike being northwest and north-northeast to northeast. Damage zones of faults range from thin, single slip surfaces to metre wide zones parallel to the fault plane. No fault gouge was observed, and faults are associated with hematite staining and localized epidote and chlorite infill.

Within the Black-Pic batholith area two magnetic lineaments were verified in the field as brittle structures; none of these were coincident with previously mapped faults. In station 14MJT016 field evidence of the verified lineament included a northeast striking brittle-ductile shear zone within the tonalite. Evidence of the second brittle lineament in the field included a set of two brittle faults observed striking northeast and steeply dipping.

6.3 Mafic Dykes

Three major sets of mafic dykes have been mapped at the regional scale in the Hornepayne area, Matachewan, Marathon and Biscotasing:

- The northwest trending Matachewan dyke swarm (ca. 2.473 Ga; Buchan and Ernst, 2004) is one of the largest in the Canadian Shield. Matachewan dykes are mainly quartz-diabase dominated by plagioclase, augite, and quartz (Osmani, 1991). Individual dykes are generally up to 10 metres wide, and have vertical to subvertical dips.
- The northeast-trending Biscotasing dykes (ca. 2.167 Ga; Hamilton et al., 2002) trend northeast and cannot be separated with confidence from the Marathon dykes that locally trend in the same direction.
- North-northeast-trending Marathon dykes (ca. 2.121 Ga; Buchan et al., 1996; Hamilton et al., 2002) form a fan-shaped distribution pattern around the northern, eastern, and western flanks of Lake Superior. The dykes vary in orientation from northwest to northeast, and occur as steep to subvertical sheets, typically a few metres to tens of metres thick, but occasionally up to 75 metres thick (Hamilton et al., 2002). The Marathon dykes are quartz-diabase dominated by equigranular to subophitic clinopyroxene and plagioclase (Osmani, 1991).

A fourth, sparsely distributed dyke set, Abitibi dykes, has been identified in regional mapping; however, this dyke family was not observed in the Phase 2 Geological Mapping.

The majority of dykes that were observed in the field in the Hornepayne area spatially coincide well with dyke lineaments interpreted from the high-resolution magnetic data (SRK, 2017). In only a few occurrences, dykes observed in the field were not interpreted from the magnetic data. In these cases, either the dykes were relatively thin or dyke lineaments had been interpreted in close proximity to the dykes mapped in the field. It is possible that thinner mafic dykes (e.g. <5 metres) may not be observable in the high-resolution magnetic data acquired at a nominal target altitude of 80 metres above ground surface; similarly, thinner dykes are less likely to be observed in the field compared to the widest dykes.

Dyke lineaments interpreted in the Hornepayne area are, for the most part, more than 5 km long (SRK, 2017). Based on the geological mapping data, Matachewan and Biscotasing dykes tend to be marginally thicker than the Marathon dyke swarm. The majority (55%) of Biscotasing dykes mapped in the field had a minimum thickness of 5 m, with 27% of the Biscotasing dykes observed to have a thickness greater than 10 m. 33% of the mapped Matachewan dykes had a measured thickness between 1-5 m, with 38% greater than 5 m. Three of eight (38%) mapped Marathon dykes had a thickness between 30 cm to 1 m, while only 13% (1 of 8) had a thickness of at least 5 m.

Overall, most of the contacts observed of Matachewan dykes were found to be sharp and intact and with no evidence of brittle re-activation. The two dominant joints sets within mapped Matachewan dykes are parallel and sub-perpendicular to the dyke contact, and subvertical. Subordinate joints of variable orientation were also present. No dyke-parallel faults were observed.

Within the Biscotasing dyke set, the main joint sets trend northwest, east, northeast (less common) striking. Tightly-spaced, contact-parallel joints within the dyke and host rock are local and formed a variably wide zone (≤ 30 cm) indicating some degree of dyke margin reactivation. Marathon dykes generally show sharp, chilled and intact contacts; however, dykes with jointed contacts are also locally present. The contact-parallel joints are tightly-spaced, and define a variably wide (≤ 30 cm) reactivation zone astride the contact to the dyke and host rock. The main joint sets within the dyke are north-northwest and northeast striking. Subordinate west to northwest striking joints were also present.

No apparent damage zone near dyke margins within the host rock was observed in the field that could be attributed to damage caused by the dyke intruding. Host rocks appeared to be no more or less fractured at the contacts with Matachewan mafic dykes than in areas away from mafic dykes.

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Appendix A

Methodology Section: Supporting Tables

Table A.1 Source Data Descriptions

Source Data	***File Name***	***Format***
Water bodies	Hornepayne_Water	geodatabase
Roads network	Hornepayne_FMURoadsHearst_r0.shp	shapefile
	Hornepayne_FMURoadsNagagami_r0.shp	shapefile
	White_River_FMURoadsMagpieandWhiteRiver_r0.shp	shapefile
Other base map data	Hornepayne_Base_Map	geodatabase
	Hornepayne_CandidateAreas_r1.shp	shapefile
Overburden	Hornepayne_Quaternary_Geology	geodatabase
Forest Resources Inventory (FRI) Imagery	48 different tiff files (ex. 2016670054600.tif)	tiff files
Geophysics	Hornepayne_Magnetic_Anomalies.shp	shapefile
Bedrock Geology	Hornepayne_Bedrock_Geology_v2	geodatabase
Predicted outcrop locations	Hornepayne_OutcropInterpreted_r1.shp	shapefile
Faults	Hornepayne_Local_Faults	feature class
Historical geological maps	Hornepayne_Bedrock_Geology_v2	geodatabase
Protected Areas	Hornepayne_Protected_Areas	geodatabase
Lineaments	Hornepayne_Phs2Ext_MAG_Lins_Final_20160616_r2.shp	shapefile
	Hornepayne_Phs2Ext_SURFICIAL_Lins_Final_20160602_r1.shp	shapefile

Table A.2 Equipment Requirements

Field Equipment	***Calibration Requirements***
Compass (Brunton Pocket Transit or similar)	Y – Check magnetic declination setting daily.
Digital camera	None
Trimble (or equivalent) field data collector w/GPS	Y – Check against hand held GPS
ArcPAD + modified GanFeld software	None
Magnetic susceptibility meter (KT-20 or equivalent)	Y – Calibrated by supplier before rental and upon return from rental period / daily check of reading at a reference rock outcrop. Certificate of Calibration to be provided by supplier and provided to NWMO.
Gamma Ray Spectrometer (RS-125 or equivalent)	Y – Calibrated by supplier before rental and upon return from rental period. Certificate of Calibration to be provided by supplier and provided to NWMO.
Notebook and pen	None
Handheld GPS	None
Geological hammer & rock chisel	None
Rock sample bags	None
Personal protective equipment (e.g., sturdy hiking boots, safety glasses, sunscreen, insect repellent, etc.)	None

Table A.3 Task Allocation

Task	*Responsibility*
Daily safety de-briefing	Assistant (Engineering) Geologist
Daily equipment calibration	Assistant (Engineering) Geologist
Host rock lithology characterization	Lead Geologist
Host rock structural characterization	Lead Geologist
Digital photographs	Lead Geologist
Fracture characterization	Lead/Assistant (Engineering) Geologist
Lineament observation/assessment	Lead Field Geologist
Data input into ArcPAD	Lead/Assistant (Engineering) Geologist
Manual (pencil and paper) note transcription	Lead/Assistant (Engineering) Geologist
Magnetic susceptibility measurements	Assistant (Engineering) Geologist
Rock strength assessment - Hammer test	Assistant (Engineering) Geologist
Bedrock overburden assessment	Assistant (Engineering) Geologist
Sample collection (if necessary)	Assistant (Engineering) Geologist
Surface constraint assessment	Lead/Assistant (Engineering) Geologist
Identification of potential detailed mapping areas	Lead Field Geologist
Daily QC verification of notebook with digital entry for two locations for each team	Lead/Assistant (Engineering) Geologist
Daily QC verification of instrument readings (KT-20, RS-125) with entries in notebook and digital database (GanFeld).	Lead/Assistant (Engineering) Geologist
Daily log write-up and transmittal	Assistant (Engineering) Geologist
Daily data back-up and back-up for the back-up	Lead/Assistant (Engineering) Geologist
Planning the next day traverse	Lead Field Geologist

Table A.4 Key General and Geological Attributes Characterized During Observing General Geological Features and Detailed Geological Mapping

		Characterization Method(s)
General Attributes	***Outcrop Location***	• Geo-locate exposed bedrock observation locations using GPS • Take representative digital photograph of outcrop area
	Bedrock exposure and overburden thickness	• Visually inspect the distribution and thickness of overburden vs. exposed bedrock during the daily traverse (in comparison to existing understanding)
	Surface Constraints	• Visually identify and geo-locate any surface constraints that would create challenges for further geological characterization activities (e.g., bridge wash-outs, poorly or unmaintained logging roads, beaver dams, steep and deep (impassable) valleys, etc.) • Visually identify access issues in areas without mapped roads or navigable waterways
Geological Attributes: Bedrock Characteristics	***Lithology***	• Visually inspect weathered and fresh rock surfaces for identification of major and minor lithological units and their constituent colour, primary minerals (e.g., granitic rocks have varying proportions of quartz, K-feldspar and plagioclase plus other minerals including micas, hornblende, etc.), grain size, texture, etc. • Name the lithological unit(s) in terms of relative abundance at the outcrop scale • Collect a representative sample(s) of the dominant lithological unit(s) at each outcrop (will require use of hammer and chisel only; fist-sized piece with both weathered and fresh surface) • Take digital photographs of representative lithological unit(s) across the area of interest [documentation will include (at a minimum), file name, scale, GPS coordinates, direction of view and description of the photo.]

	Primary and Ductile Structure	• Observe and document the bedrock structural features (e.g., bedding, foliations, lineations, folds and shear zones)
		• Take digital photographs/make field sketches of representative key structural features
		• Measure and document (by hand with compass-clinometer and subsequent digital and manual entry)
		  ◦ Strike and dip of planar structures
		  ◦ Trend and plunge of linear structures
		  ◦ Orientations of fold hinge lines and axial surfaces

	Geophysical and Geomechanical Character	• Record 5 magnetic susceptibility measurements for each identified lithological unit (will require use of magnetic susceptibility meter, e.g., KT10 or KT20) • Undertake gamma ray readings for each identified lithological unit using a gamma ray spectrometer (RS-125 or equivalent) • Undertake field rock strength test on representative lithologies at each station and in spatial relation to identified structural features (i.e. lineaments, fracture zones, dykes)

Geological Attributes: Fracture Characteristics		• Visually inspect the rock surface for identification of systematic fracture sets
		• Characterize fracture sets by type (joints, faults, veins, altered wall rock around fractures)
		• Measure and document (by hand with compass-clinometer and subsequent digital and manual entry)
		  ◦ Strike and dip of planar structures
		  ◦ Trend and plunge of linear structures on fracture planes
		• Document
		  ◦ Fracture mineral filling
		  ◦ Abutting, cross-cutting and intersection (relative age) relationships between fracture sets

		• Displacement (strike separations and dip separations if visible) • Fracture surface ornamentation • Fracture set spacing • Undertake block size analysis based on outcrop fracture geometry and spacing • Take representative digital photograph(s) as needed to show key fracture characteristics, for example cross-cutting relationships, damage zone width, alteration, mineral infill
Geological Attributes: Dyke Characteristics		• Visually inspect dyke for characteristic features (e.g., mineralogy, colour) • Collect a representative sample of each dyke type • Take representative digital photograph of dyke, including contact relationship with bedrock, if exposed • Document • Internal structure (fractures) • Width • Orientation (strike and dip along bedrock contact) • Nature of bedrock contact (e.g., welded, fractured, sheared, altered, extent of damage, etc.)
	Geophysical and Geomechanical Character	• Record 5 magnetic susceptibility measurements for each identified dyke • Undertake gamma ray readings for each identified dyke • Undertake field rock strength test on each dyke

Notes:

1. *All observations will be recorded in digital format with manual (pen and paper) backup for most pertinent field observations only, unless required due to digital device failure.*
2. *Samples will be stored in bags numbered in accordance with the sample number generated in the database.*
3. *Strike and dip measurements follow Canadian right-hand-rule notation.*
4. *Effort will be made to characterize fractures of all dip magnitudes (including horizontal to shallow dipping features)*

Table A.5 Field Estimates of Intact Rock Strength

Grade	*Description*	*Field identification*
R6	Extremely strong	Specimen can only be chipped with a geological hammer
R5	Very strong	Specimen requires many blows of a geological hammer to fracture it
R4	Strong	Specimen requires more than one blow of a geological hammer to fracture it
R3	Medium strong	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with a single blow from a geological hammer
R2	Weak	Can be peeled with a pocket knife with difficulty, shallow indentation made by firm blow with point of a geological hammer
R1	Very weak	Crumbles under firm blows with a geological hammer, can be peeled by a pocket knife
R0	Extremely weak	Indented by thumbnail

Note: Modified from Hoek (2007)

APPENDIX B

Remote Predictive Bedrock Analysis

Potential outcrop locations were identified through an automated object based image analysis (OBIA), filtered, and prioritized for use in planning and implementing the Phase 2 Geological Mapping in the Hornepayne area of Ontario. This work involved 2 main tasks: 1) automated OBIA and 2) manual filtering of OBIA results to produce an output of potential outcrop locations.

Object Based Image Analysis using eCognition

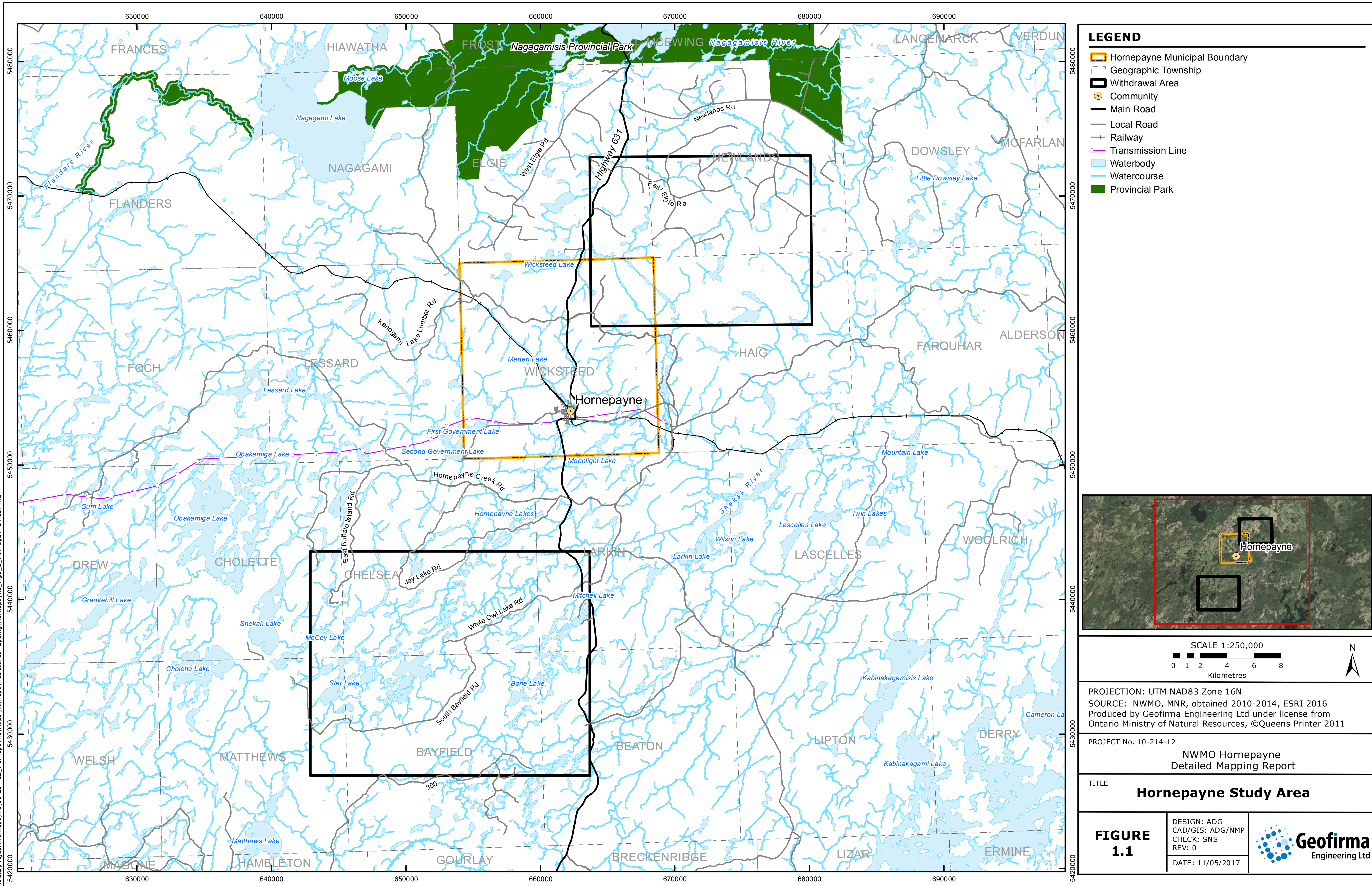
Automated OBIA was conducted using Trimble's eCognition 9.1 software for the two withdrawal areas identified for detailed mapping in the Hornepayne area. Forest Resource Inventory (FRI) orthoimagery of the Hornepayne area, from 2009, was the primary dataset used in the analysis. FRI imagery is 4-band (red, green, blue, near infra-red) multi-resolution, 40 cm airborne imagery collected and used for forest resource purposes by the Ministry of Natural Resources.

A ruleset was developed in eCognition which initially employed multi-resolution segmentation to develop small image objects of almost pixel size. Through a series of iterative steps, the ruleset was refined and the small image objects were merged into larger more identifiable objects of distinct classes. Areas of water were classified first, followed by those areas that are spatially and spectrally similar to exposed bedrock, such as unpaved road surfaces, sand covered areas and brightly reflecting bogs. The remaining image objects were considered to most likely represent exposed outcrop and output as a distinct data set. This raw eCognition output provided a framework for remotely interpreting the location of probable bedrock outcrops in the four potentially suitable areas.

Filtering of OBIA results

It is understood that similarities in spectral response of areas of ground cover versus areas of exposed bedrock in the Hornepayne area results in instances of false positive exposed bedrock classification when classifying by means of OBIA. In order to use the remotely predicted outcrop data set in a meaningful way for detailed outcrop mapping an additional step of manually comparing the raw output, against the FRI imagery, was required.

The process to undertake this filtering was straightforward and involved examining the FRI imagery in areas where the eCognition output showed clusters of pixels locating possible exposed bedrock. The cluster area was visually evaluated in the FRI imagery and a determination by consensus of two or more individual interpreters was made as to whether the location in question did or did not likely represent actual exposed bedrock. If it was determined likely, then the location was outlined and defined as a unique polygon. This analysis produced a set of shapefiles of polygons representing interpreted priority outcrop locations, for both withdrawal areas in the Hornepayne area (see Figure 1.2 from main body of this report). The planning for the Detailed Mapping component of the Phase 2 Geological Mapping activity in the Hornepayne Area is based upon these interpreted priority outcrop locations.



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Geographic Township
Withdrawal Area
Community
Main Road
Local Road
Railway
Transmission Line
Waterbody
Watercourse
Provincial Park
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Kilometres
N
PROJECTION: UTM NAD83 Zone 16N
SOURCE: NWMO, MNR, obtained 2010-2014, ESRI 2016
Produced by Geofirma Engineering Ltd under license from
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PROJECT No. 10-214-12
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Detailed Mapping Report
TITLE
Hornepayne Study Area
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Geofirma
Engineering Ltd
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650000
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670000
680000
690000
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5430000
5440000
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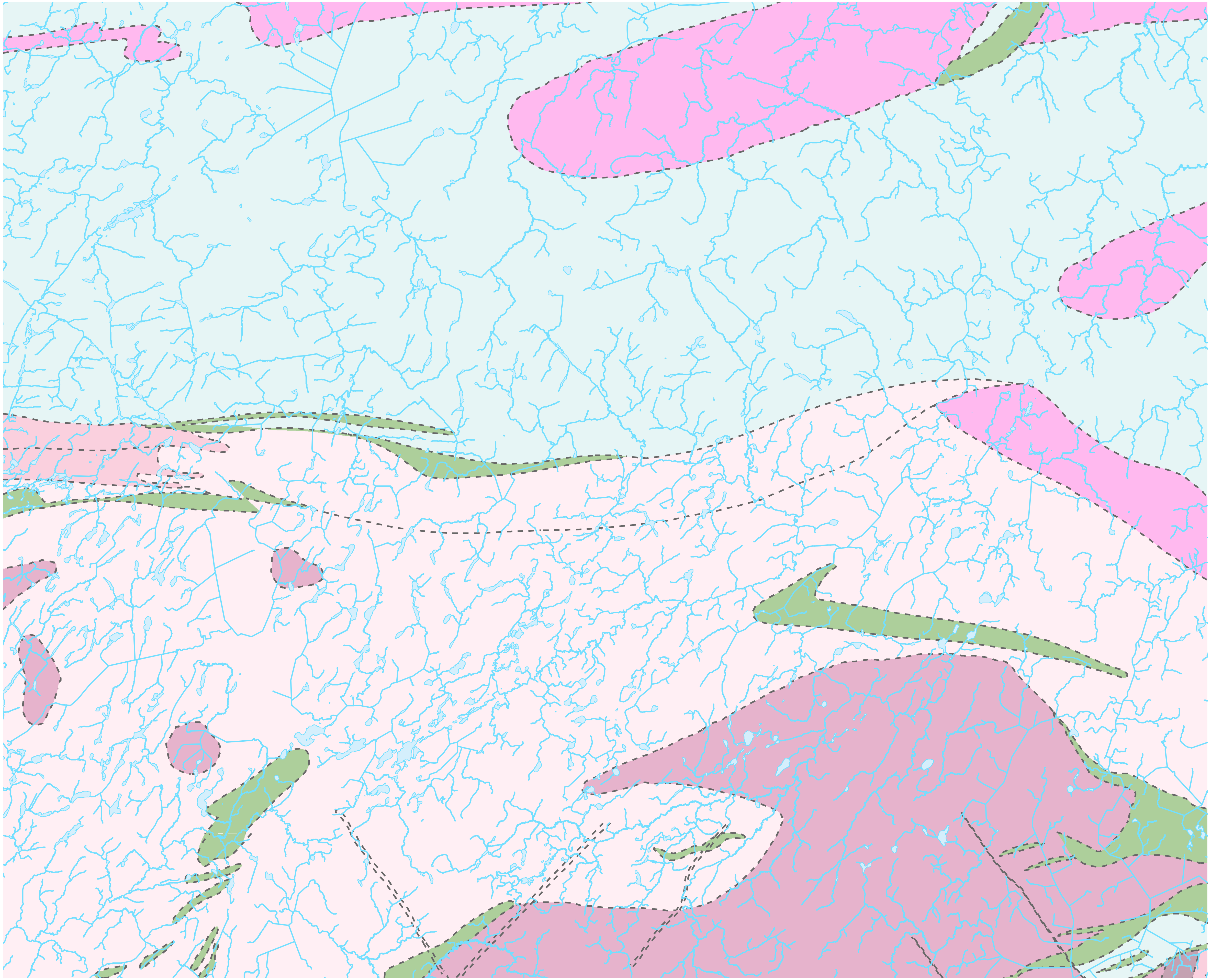
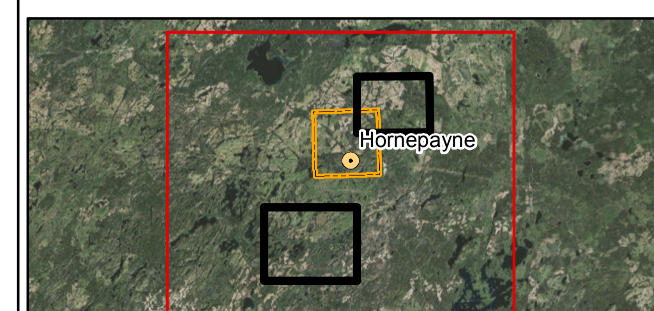
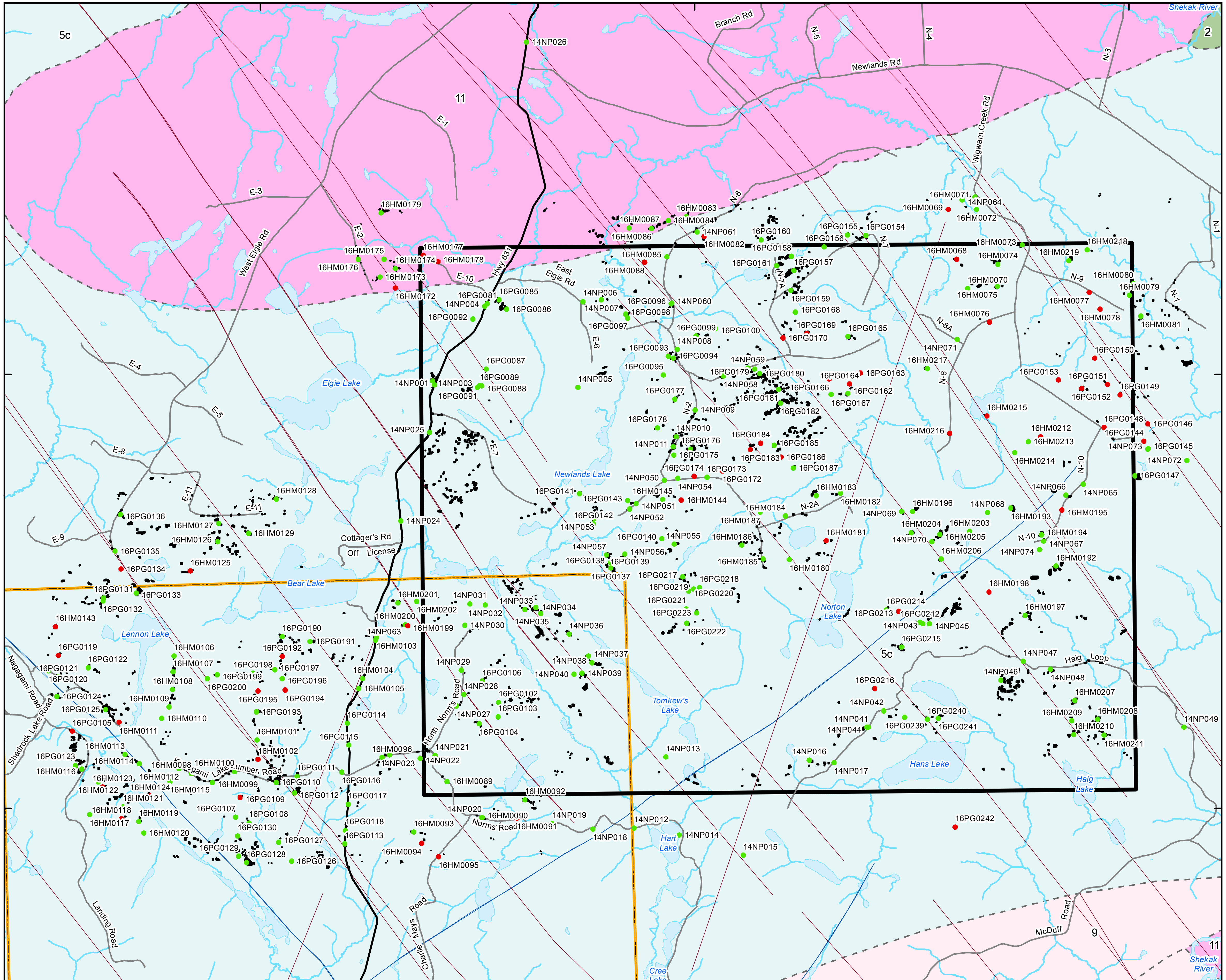
5460000
5470000
5480000
Hornepayne
Nagagamisis Provincial Park
Nagagamisis River
Flanders River
Shekak River
Highway 631
Newlands Rd
East Elgie Rd
West Elgie Rd
Kenogami Lake Lumber Rd
Hornepayne Creek Rd
East Buffalo Island Rd
Jay Lake Rd
White Owl Lake Rd
South Bayfield Rd
300
FRANCES
HIAWATHA
FROST
MCEWING
LANGEMARCK
VERDUN
NAGAGAMI
ELGIE
NEWLANDS
DOWSLEY
MCFARLAN
FLANDERS
FOCH
LESSARD
WICKSTEED
HAIG
FARQUHAR
ALDERSON
DREW
CHOLETTE
CHELSEA
LARKIN
LASCELLES
WOOLRICH
WELSH
MATTHEWS
BAYFIELD
BEATON
LIPTON
DERRY
MACGNE
HAMBLETON
GOURLAY
BRECKENRIDGE
LIZAR
ERMINE
Moose Lake
Nagagami Lake
Little Dowsley Lake
Wicksteed Lake
Marten Lake
Lessard Lake
First Government Lake
Second Government Lake
Obakamiga Lake
Moonlight Lake
Mountain Lake
Gum Lake
Hornepayne Lakes
Twin Lakes
Lascelles Lake
Wilson Lake
Larkin Lake
Granitehill Lake
Mitchell Lake
Shekak Lake
McCoy Lake
Cholette Lake
Star Lake
Bone Lake
Kabinakagamisis Lake
Cameron La
Kabinakagami Lake
Matthews Lake




Hornepayne

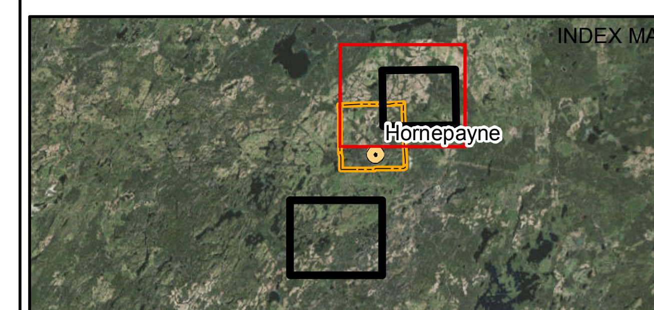


LEGEND

- Hornepayne Municipal Boundary
- Withdrawal Area
- Highway
- Local Road
- Waterbody
- Watercourse
- Mapped OGS Dykes
- Mapped OGS Faults
- Outcrop
- Overburden
- Predicted Outcrops (2221)

BEDROCK GEOLOGY

- 11: Granite-granodiorite
- 9: Gneissic tonalite suite
- 5: Metasedimentary rocks
- 2: Mafic metavolcanic Rocks
- Bedrock Geology Outline



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Kilometres

N

PROJECTION: UTM NAD83 Zone 16N

SOURCE: NWMO, MNR, obtained 2010-2016, ESRI 2016

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PROJECT No. 10-214-12

NWMO Hornepayne
Detailed Mapping Report

TITLE

Quetico Area -
Mapping Observation Locations

FIGURE 5.1.1

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CHECK: SNS
REV: 0

DATE: 11/05/2017

Geofirma Engineering Ltd

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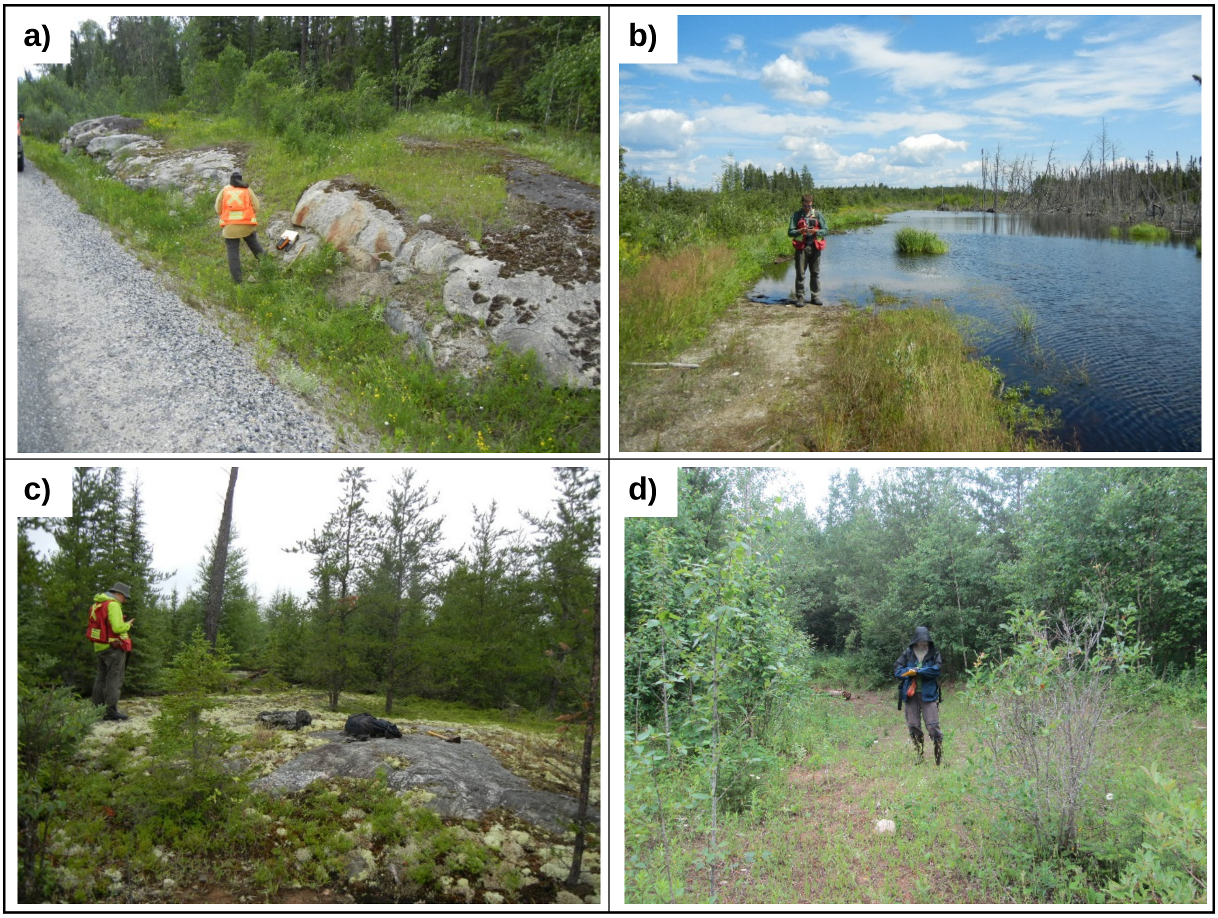
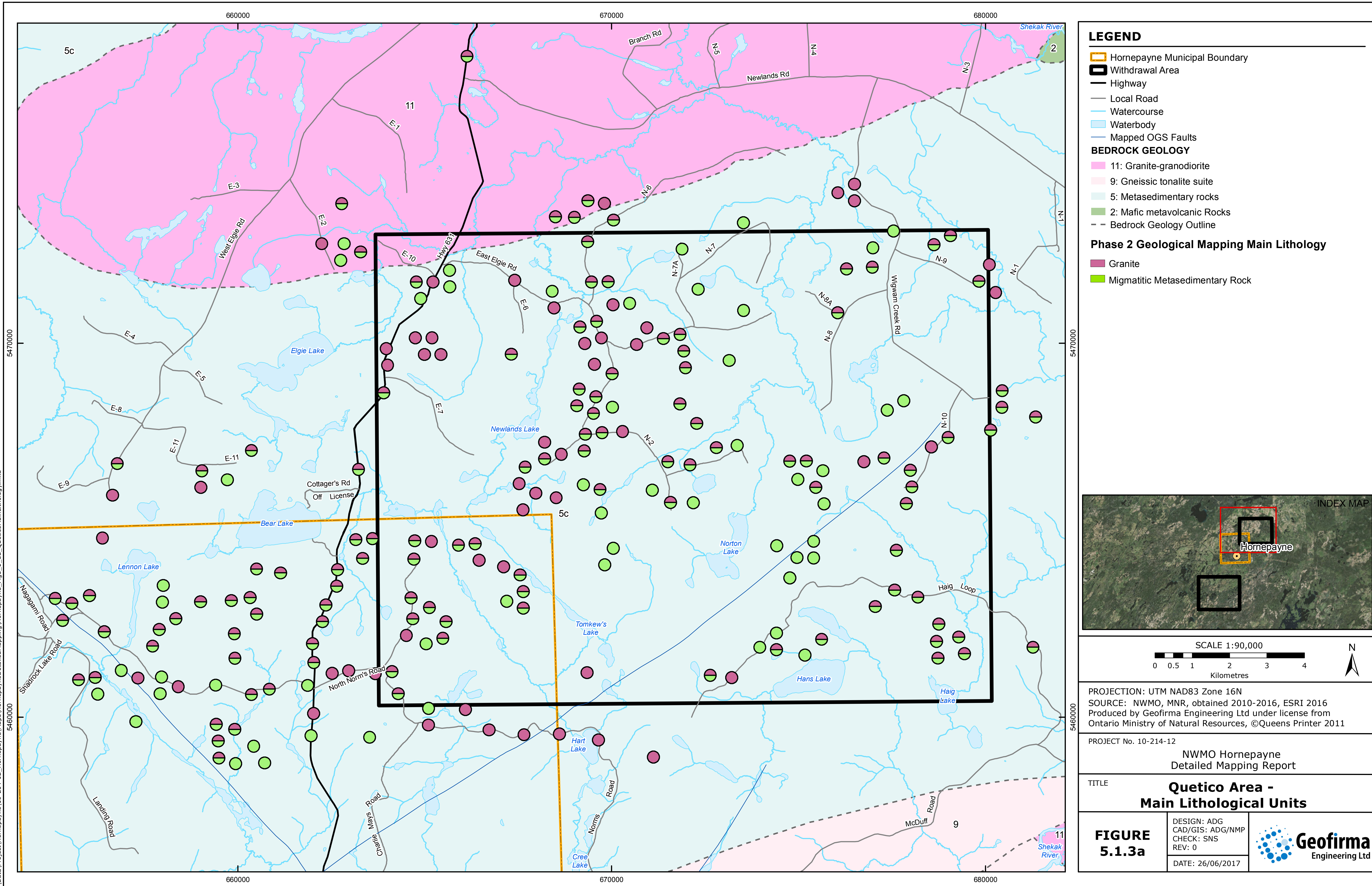


Figure 5.1.2: Quetico Area – Field Examples of Accessibility and Bedrock Exposure

a – Example photo showing outcrop along logging road used for access in the southwest portion of the Quetico mapping area. Person for scale. View to the southeast (Station 16PG0118).
b – Photo of flooding across access road in northern portion of the Quetico mapping area. View to the east, person for scale (Station 16PG0171).
c – Photo of typical outcrop exposure in the Quetico area. View to the north, person for scale (Station 16PG0138).
d – Photo of station predicted as outcrop during planning, but identified as overburden during mapping. Person for scale (Station 16HM0082).



LEGEND
Hornepayne Municipal Boundary
Withdrawal Area
Highway
Local Road
Watercourse
Waterbody
Mapped OGS Faults
BEDROCK GEOLOGY
11: Granite-granodiorite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
Bedrock Geology Outline
Phase 2 Geological Mapping Main Lithology
Granite
Migmatitic Metasedimentary Rock
INDEX MAP
Hornepayne
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Kilometres
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SOURCE: NWMO, MNR, obtained 2010-2016, ESRI 2016
Produced by Geofirma Engineering Ltd under license from
Ontario Ministry of Natural Resources, ©Queens Printer 2011
PROJECT No. 10-214-12
NWMO Hornepayne
Detailed Mapping Report
TITLE
Quetico Area -
Main Lithological Units
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REV: 0
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Geofirma
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Shekak River
Branch Rd
Newlands Rd
East Elgie Rd
West Elgie Rd
Hwy 631
Elgie Lake
Newlands Lake
Cottager's Rd
Off License
Bear Lake
Lennon Lake
Nagagami Road
Shadrock Lake Road
North Norm's Road
Tomkew's Lake
Norton Lake
Hans Lake
Haig Lake
Haig Loop
Hart Lake
Cree Lake
Norms Road
Charlie Mays Road
Landing Road
McDuff Road
Wigwam Creek Rd
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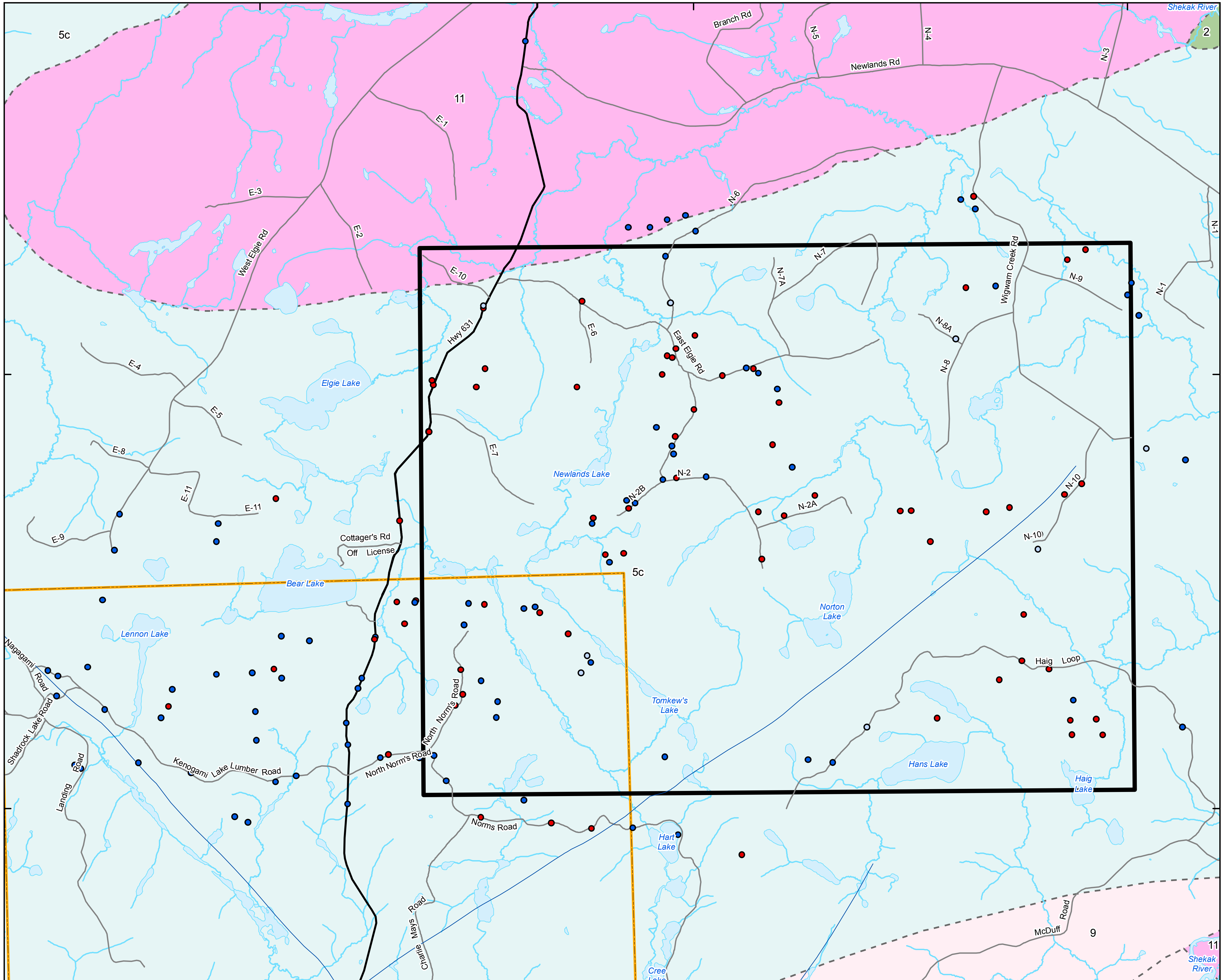
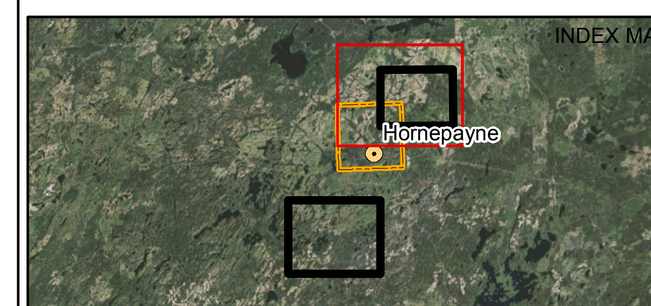


LEGEND

- Hornepayne Municipal Boundary
- Withdrawl Area
- Highway
- Local Road
- Watercourse
- Mapped OGS Faults
- Waterbody
- Diatexite (72)
- Metatexite (84)
- Sandstone (8)

BEDROCK GEOLOGY

- 11: Granite-granodiorite
- 9: Gneissic tonalite suite
- 5: Metasedimentary rocks
- 2: Mafic metavolcanic Rocks
- Bedrock Geology Outline



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Kilometres

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SOURCE: NWMO, MNR, obtained 2010-2016, ESRI 2016
Produced by Geofirma Engineering Ltd under license from Ontario Ministry of Natural Resources, ©Queens Printer 2011

PROJECT No. 10-214-12

NWMO Hornepayne
Detailed Mapping Report

TITLE

Quetico Area - Migmatite Classification

FIGURE 5.1.3b

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DATE: 26/06/2017

Geofirma Engineering Ltd

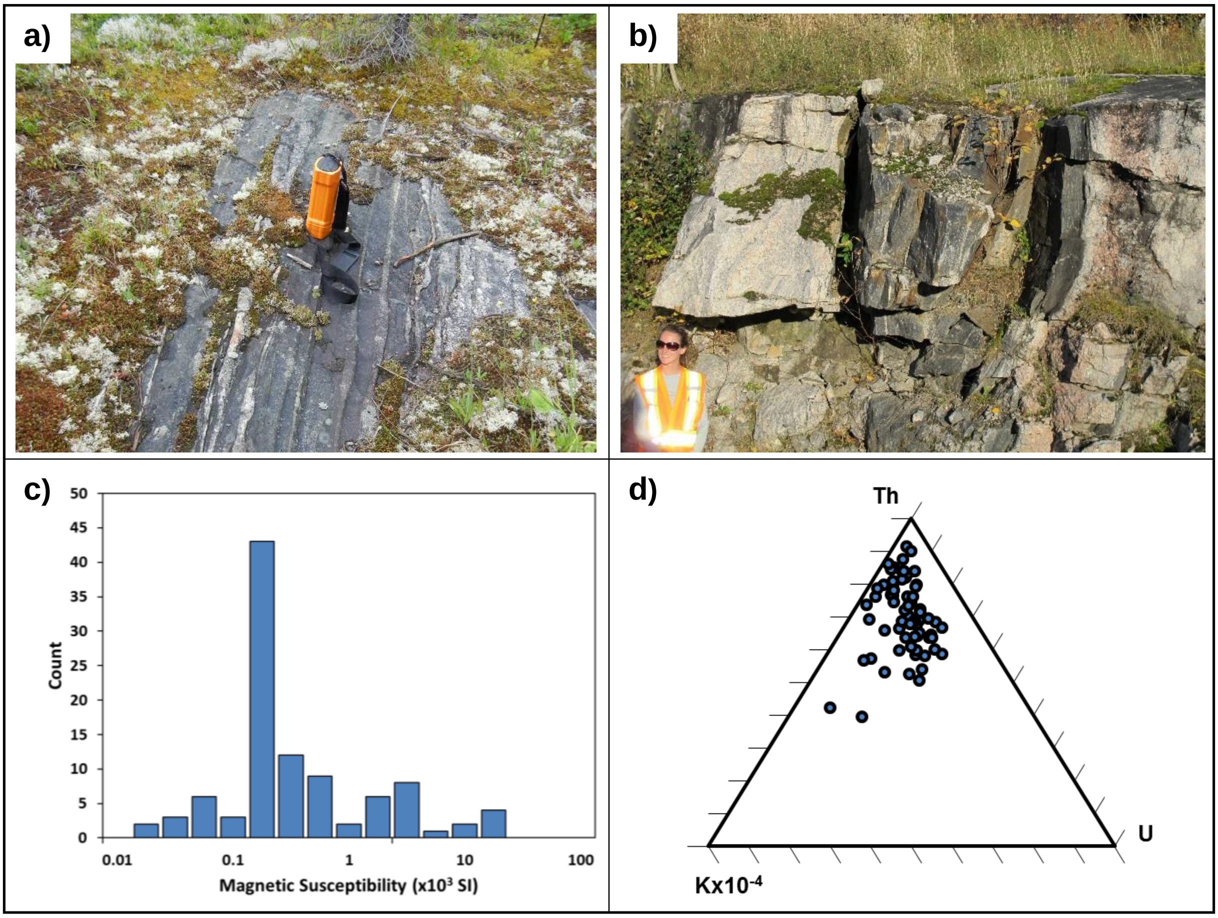


Figure 5.1.4: Quetico Area - Field Examples of Main Lithology: Migmatitic Metasedimentary Rocks

a – Photo of migmatitic metasedimentary rock with less than 30 % melt (metatexite), looking west with gamma spectrometer for scale. (Station 16PG0095)

b – Parting along contact between migmatitic metasedimentary rock and tonalite. Unknown orientation, person for scale (Station 14NP0025).

c – Logarithmic plot of magnetic susceptibility for migmatitic metasedimentary rock (N = 102) .

d – Ternary plot of gamma ray spectrometer data for migmatitic metasedimentary rock (N = 72) .

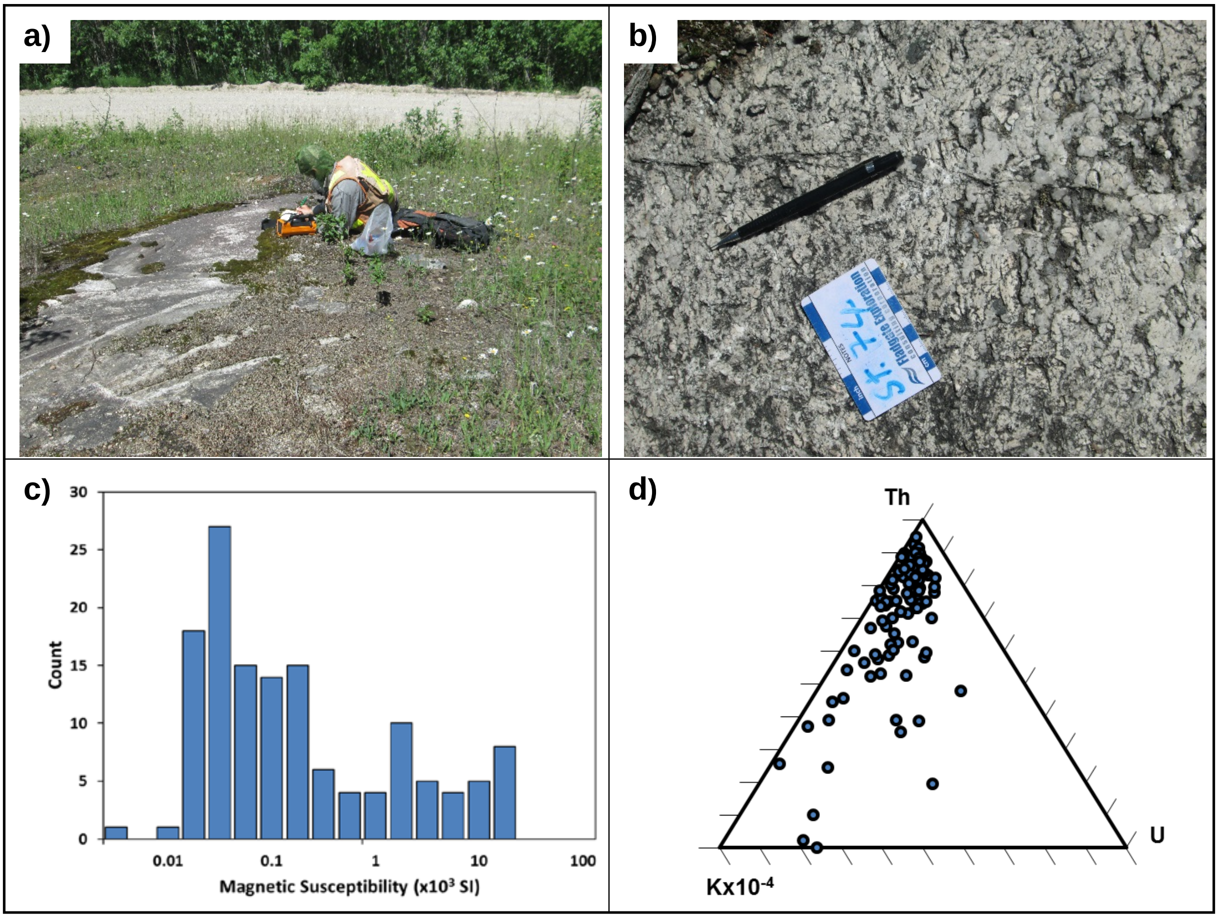
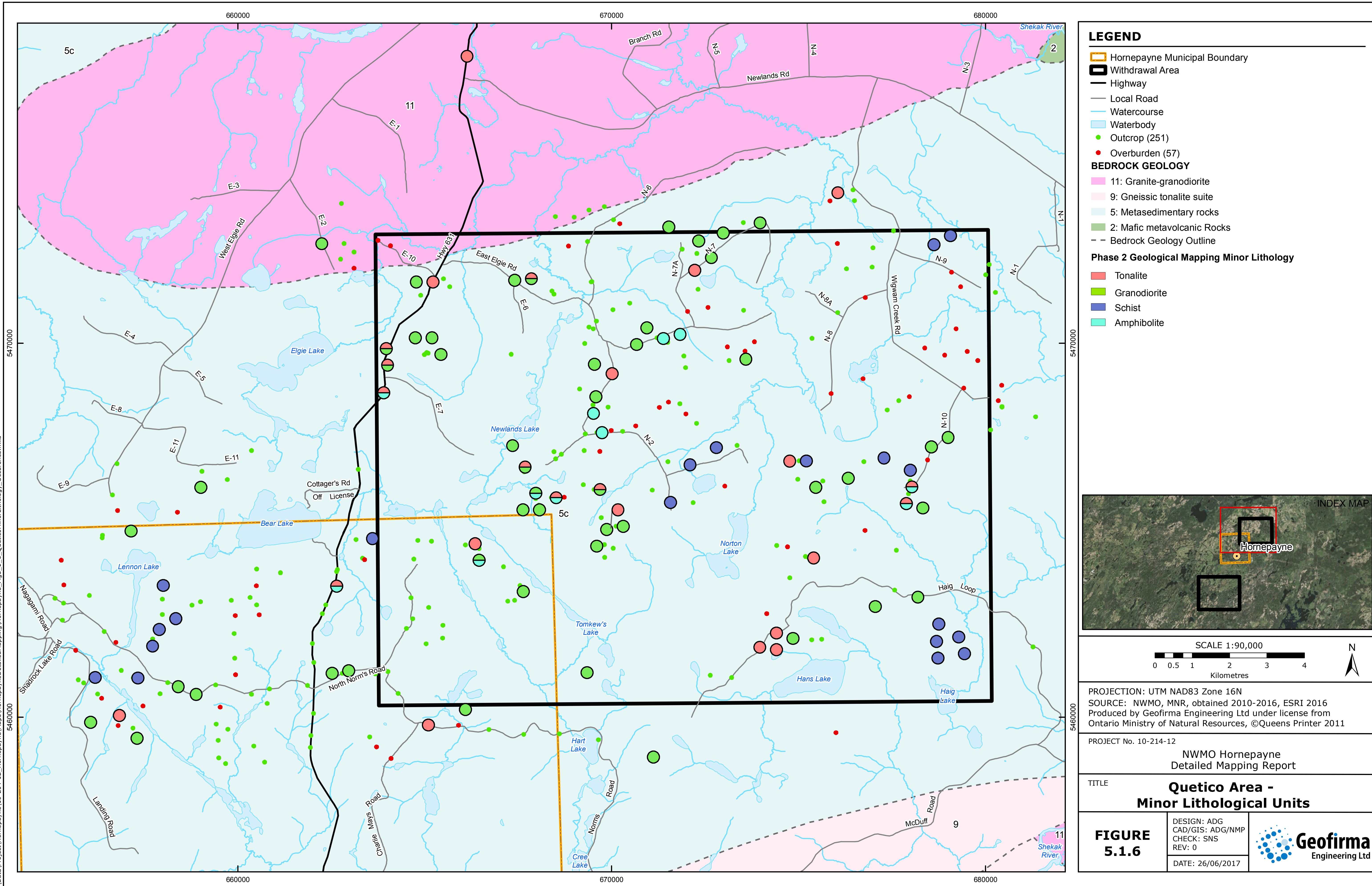


Figure 5.1.5: Quetico Area - Field Examples of Main Lithology: Granite

a – Photo of granite outcrop. View to the north, person for scale (Station 16HM0090)
b – Close-up photo of granite. Oriented in plan view, pen and scale card for scale (Station 16HM0074)
c – Logarithmic plot of magnetic susceptibility for granite (N = 137).
d – Ternary plot of gamma ray spectrometer data for granite (N = 110).


LEGEND
Hornepayne Municipal Boundary
Withdrawal Area
Highway
Local Road
Watercourse
Waterbody
Outcrop (251)
Overburden (57)
BEDROCK GEOLOGY
11: Granite-granodiorite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
Bedrock Geology Outline
Phase 2 Geological Mapping Minor Lithology
Tonalite
Granodiorite
Schist
Amphibolite
INDEX MAP
Hornepayne
SCALE 1:90,000
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Kilometres
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PROJECTION: UTM NAD83 Zone 16N
SOURCE: NWMO, MNR, obtained 2010-2016, ESRI 2016
Produced by Geofirma Engineering Ltd under license from
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PROJECT No. 10-214-12
NWMO Hornepayne
Detailed Mapping Report
TITLE
Quetico Area -
Minor Lithological Units
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REV: 0
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Newlands Rd
East Elgie Rd
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Cottager's Rd
Off License
North Norm's Road
Haig Loop
Nagagami Road
Shadrock Lake Road
Landing Road
Charlie Mays Road
Norms Road
McDuff Road
Elgie Lake
Newlands Lake
Bear Lake
Lennon Lake
Norton Lake
Tomkew's Lake
Hans Lake
Haig Lake
Hart Lake
Cree Lake
Shekak River
G:\Data\Project\Hornepayne\10-214-12_Hornepayne\Maps\HornepayneDetailedMapping\Hornepayne_Fig5_1_6_QueticoMinorLithology_Occurence.mxd

a)

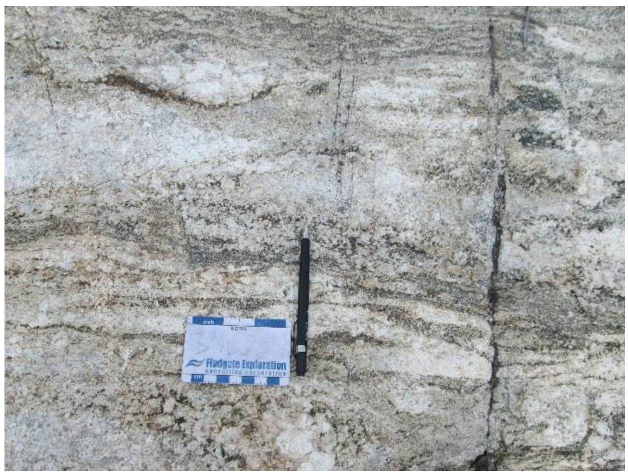
b)

<u>Figure 5.1.7: Quetico Area - Field Examples of Minor Lithology: Granodiorite</u>

a – Photo of moss covered granodiorite outcrop with person for scale. View to the southwest (Station 16HM0192)
b – Close-up photo of granodiorite. Unoriented photo, card and pen for scale (Station 16HM0092)

a)

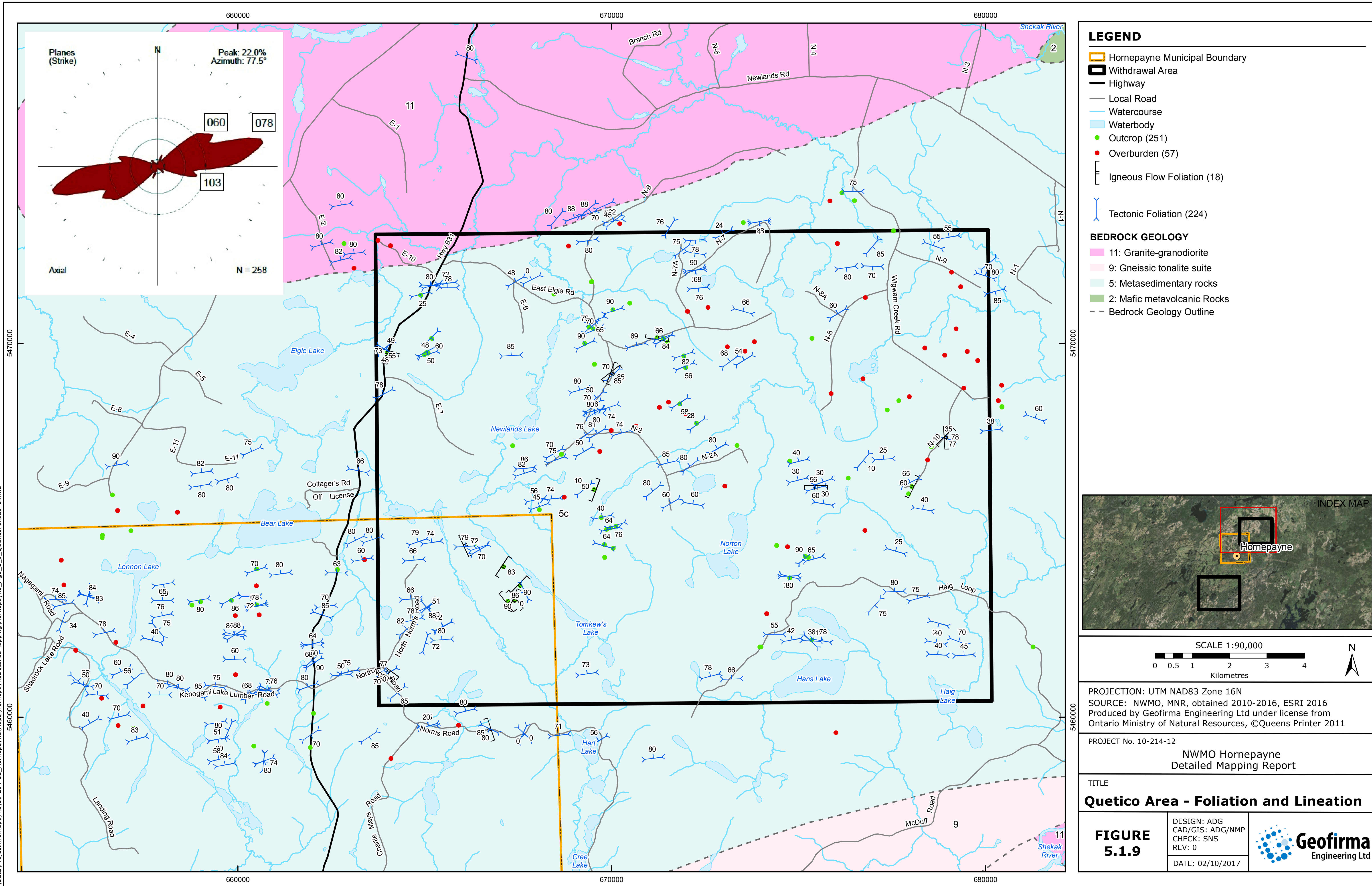
b)



c)

<u>Figure 5.1.8: Quetico Area – Field Examples of Minor Lithology: Tonalite, Schist and Amphibolite</u>

a – Micro-folding in tonalite outcrop. View to the northeast, card for scale (Station 16PG0081)
b – Close-up photo of schist showing rock fabric. Scale card and pen for scale (Station 16HM0194).
c – Photo of banding in amphibolite outcrop. Oriented east, hammer for scale (Station 16PG0175).



Planes (Strike)
Peak: 22.0%
Azimuth: 77.5°
N = 258
Axial
LEGEND
Hornepayne Municipal Boundary
Withdrawal Area
Highway
Local Road
Watercourse
Waterbody
Outcrop (251)
Overburden (57)
Igneous Flow Foliation (18)
Tectonic Foliation (224)
BEDROCK GEOLOGY
11: Granite-granodiorite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
Bedrock Geology Outline
INDEX MAP
Hornepayne
SCALE 1:90,000
Kilometres
PROJECTION: UTM NAD83 Zone 16N
SOURCE: NWMO, MNR, obtained 2010-2016, ESRI 2016
Produced by Geofirma Engineering Ltd under license from
Ontario Ministry of Natural Resources, ©Queens Printer 2011
PROJECT No. 10-214-12
NWMO Hornepayne
Detailed Mapping Report
TITLE
Quetico Area - Foliation and Lineation
FIGURE 5.1.9
DESIGN: ADG
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CHECK: SNS
REV: 0
DATE: 02/10/2017
Geofirma Engineering Ltd
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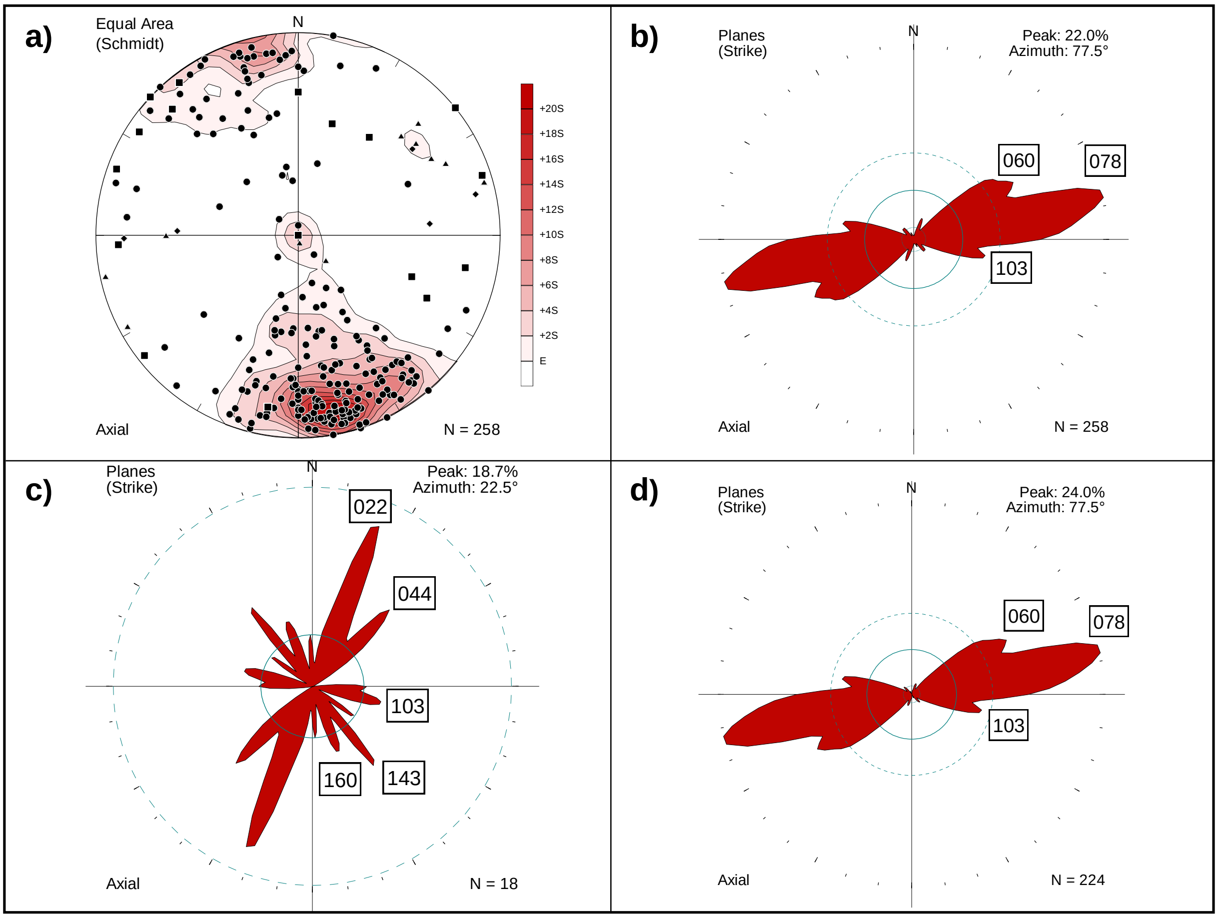
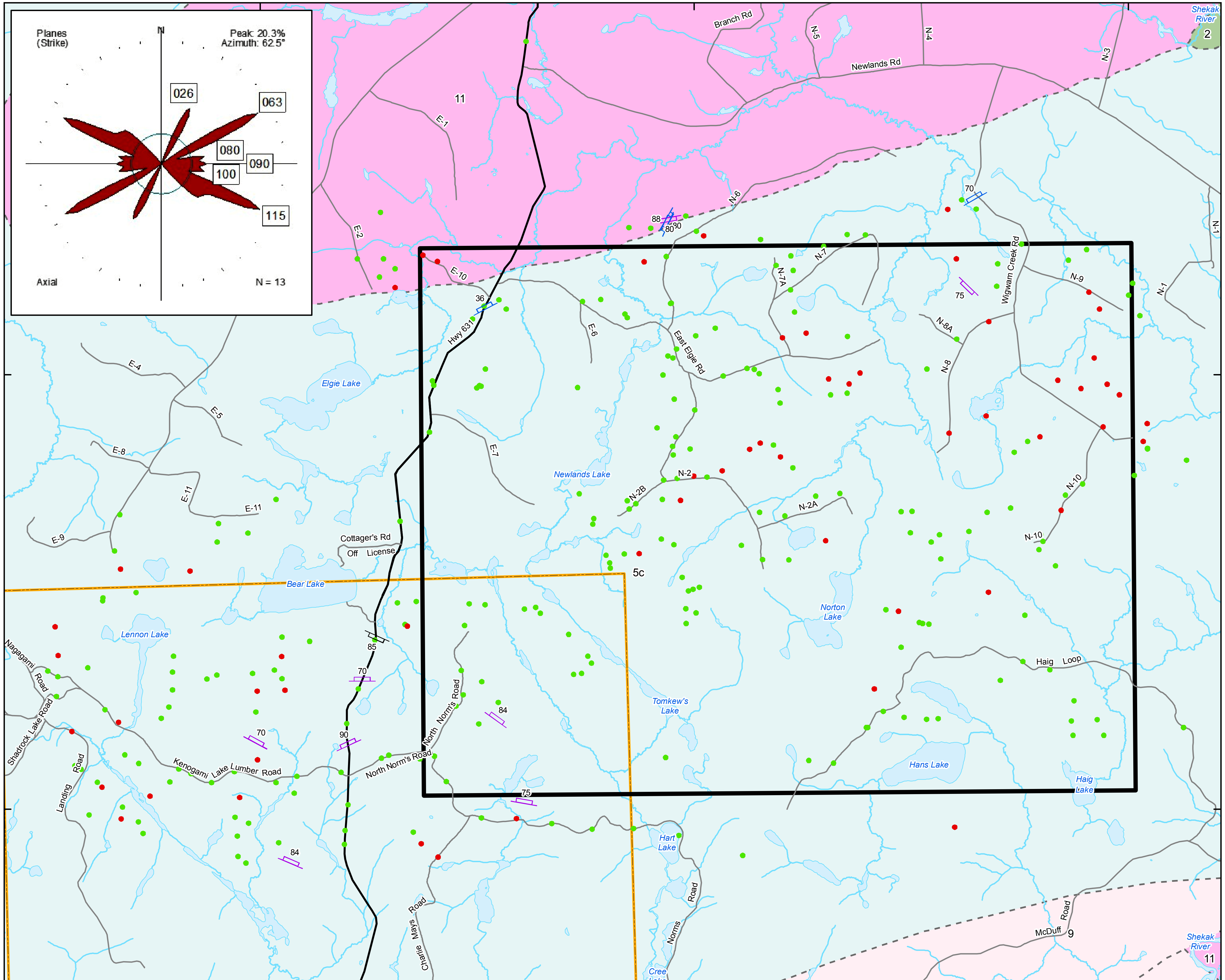


Figure 5.1.10: Quetico Area – Foliation and Lineation Orientation Data

a – All foliation data displayed as equal area lower hemisphere stereonet plot of poles to foliation planes. Tectonic foliation: circle (N=224); igneous flow foliation: square (N=18); lineation – mineral/unknown: triangle (N=11); lineation - fold hinge: diamond (N=5).
b – All foliation data displayed as rose diagram of trends of foliation planes (N=258)
c – Igneous flow foliation data displayed as rose diagram of trends of foliation planes (N=18)
d – Tectonic foliation displayed as rose diagram of trends of foliation planes (N=224)

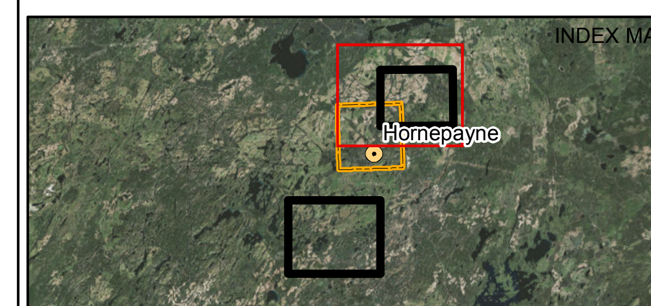


LEGEND

- Hornepayne Municipal Boundary
- Withdrawal Area
- Highway
- Local Road
- Watercourse
- Waterbody
- Outcrop (251)
- Overburden (57)
- Dextral Shear (8)
- Sinistral Shear (4)
- Normal Shear (1)

BEDROCK GEOLOGY

- 11: Granite-granodiorite
- 9: Gneissic tonalite suite
- 5: Metasedimentary rocks
- 2: Mafic metavolcanic Rocks
- Bedrock Geology Outline



SCALE 1:90,000

0 0.5 1 2 3 4
Kilometres

N

PROJECTION: UTM NAD83 Zone 16N
SOURCE: NWMO, MNR, obtained 2010-2016, ESRI 2016
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PROJECT No. 10-214-12

NWMO Hornepayne
Detailed Mapping Report

TITLE

Quetico Area - Ductile Shear Zones

FIGURE 5.1.11

DESIGN: ADG
CAD/GIS: ADG/NMP
CHECK: SNS
REV: 0

DATE: 01/06/2017

Geofirma Engineering Ltd

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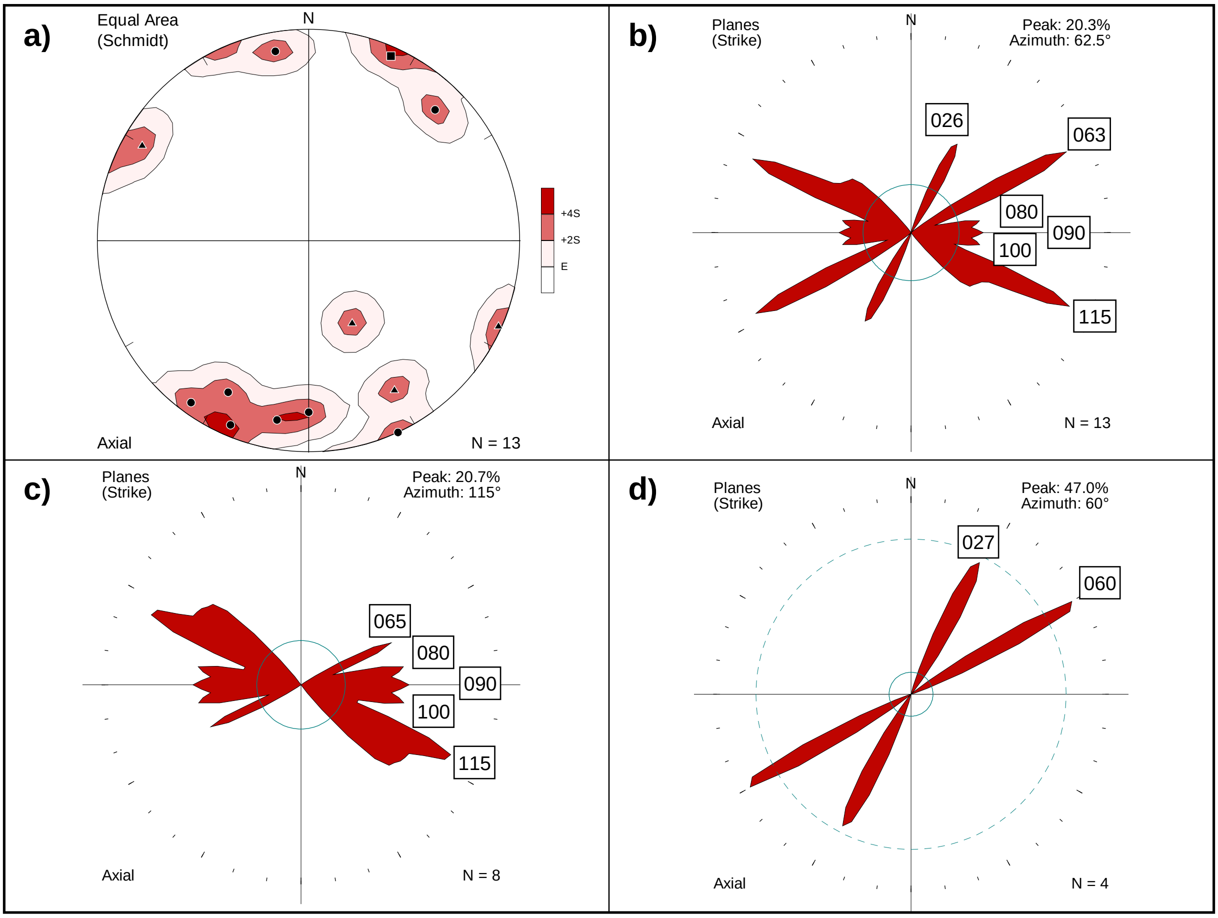
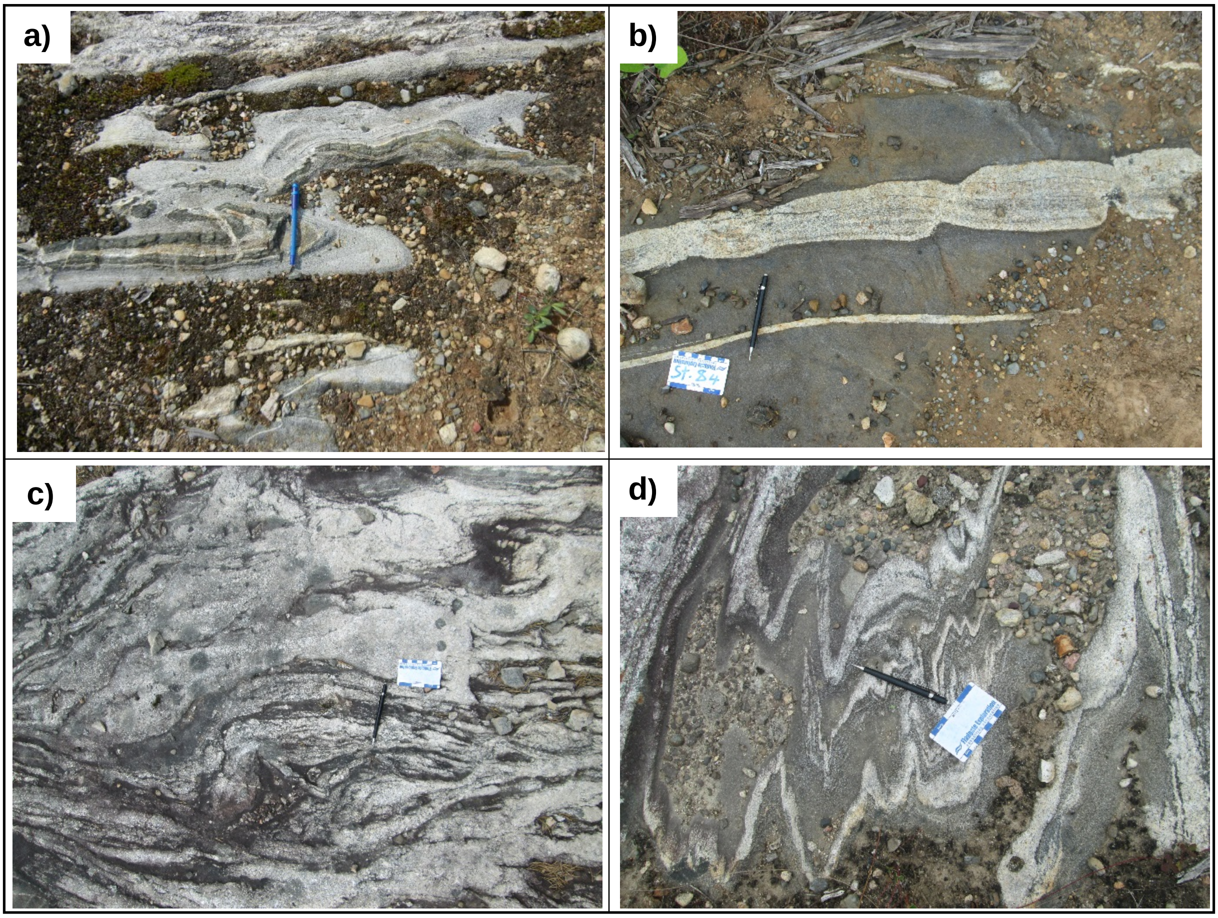


<u>Figure 5.1.12: Quetico Area – Ductile Shear Zone Orientation Data</u>

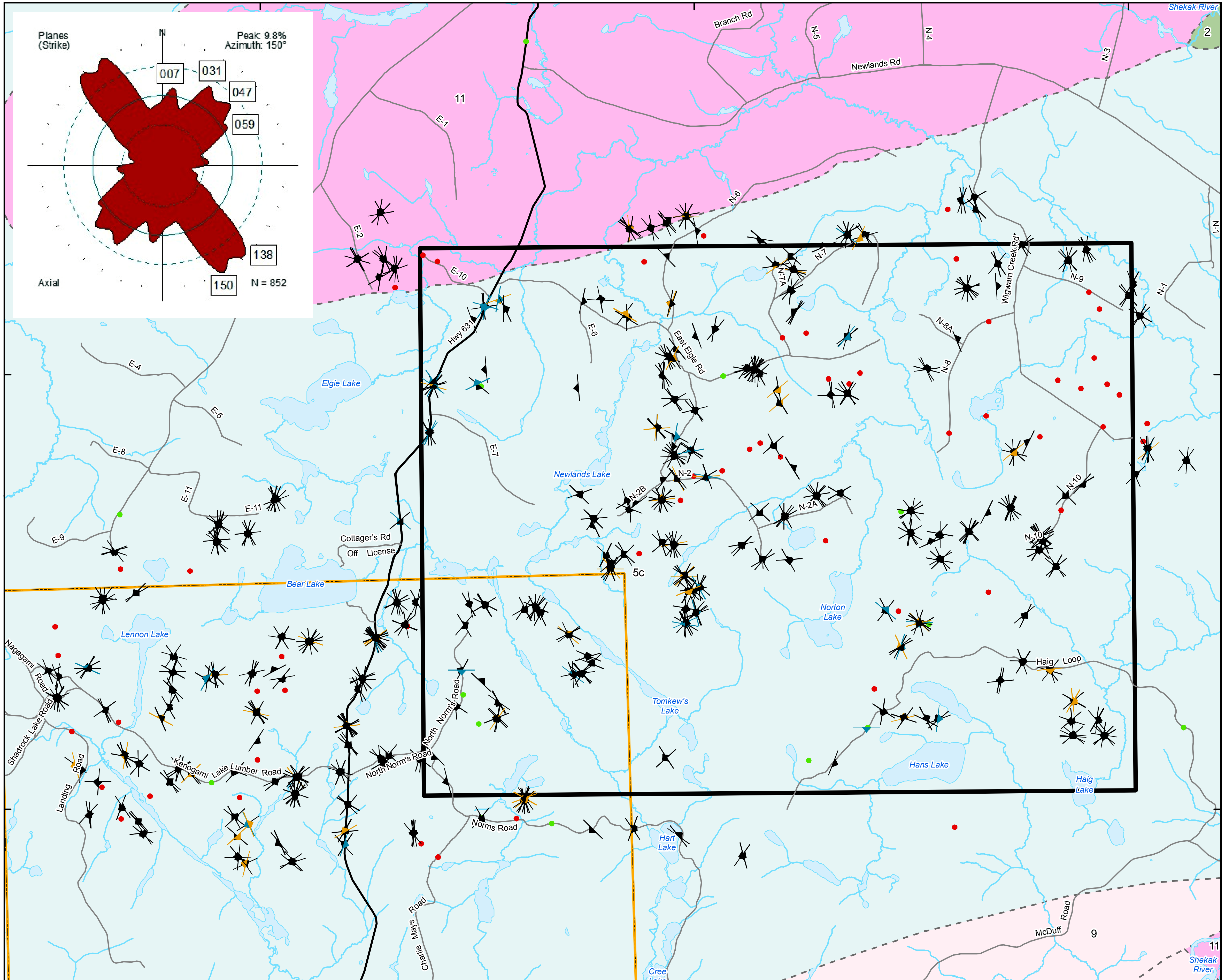
a – All shear zones displayed as equal area lower hemisphere stereonet plot of poles to shear planes. Dextral shear zones: circles (N = 8). Sinistral shear zones: triangles (N = 4). Normal shear zones: square (N=1).
b – All shear zone data displayed as rose diagram of trends of shear planes (N = 13)
c – Dextral shear zone data displayed as rose diagram of trends of shear planes (N=8).
d – Sinistral shear zone data displayed as rose diagram of trends of shear planes (N=4).



<u>**Figure 5.1.13: Quetico Area – Field Examples of Ductile Structure**</u>

a – Photo of tight F2 fold of S1 foliation in magmatitic metasedimentary rock outcrop. Plan view, pen for scale (Station 16PG0191).
b – Photo of stretched and sheared aplitic vein within the migmatitic metasediments. Plan view, scale card and pen for scale (Station 16HM0084).
c – 'S' shape open F2 fold of S1 in the migmatitic metasediments. Plan view, scale card and pen for scale (Station 16HM0126).
d – 'M' shape tight F2 fold of S1 in the migmatitic metasediments. Plan view, scale card and pen for scale (Station 16HM0126).

Note: pen oriented north in all photos



PROJECTION: UTM NAD83 Zone 16N
SOURCE: NWMO, MNR, obtained 2010-2016, ESRI 2016
Produced by Geofirma Engineering Ltd under license from Ontario Ministry of Natural Resources, ©Queens Printer 2011

PROJECT No. 10-214-12

NWMO Hornepayne
Detailed Mapping Report

TITLE
Quetico Area - Joints

FIGURE 5.1.14

DESIGN: ADG
CAD/GIS: ADG/NMP
CHECK: SNS
REV: 0
DATE: 01/06/2017

Geofirma Engineering Ltd

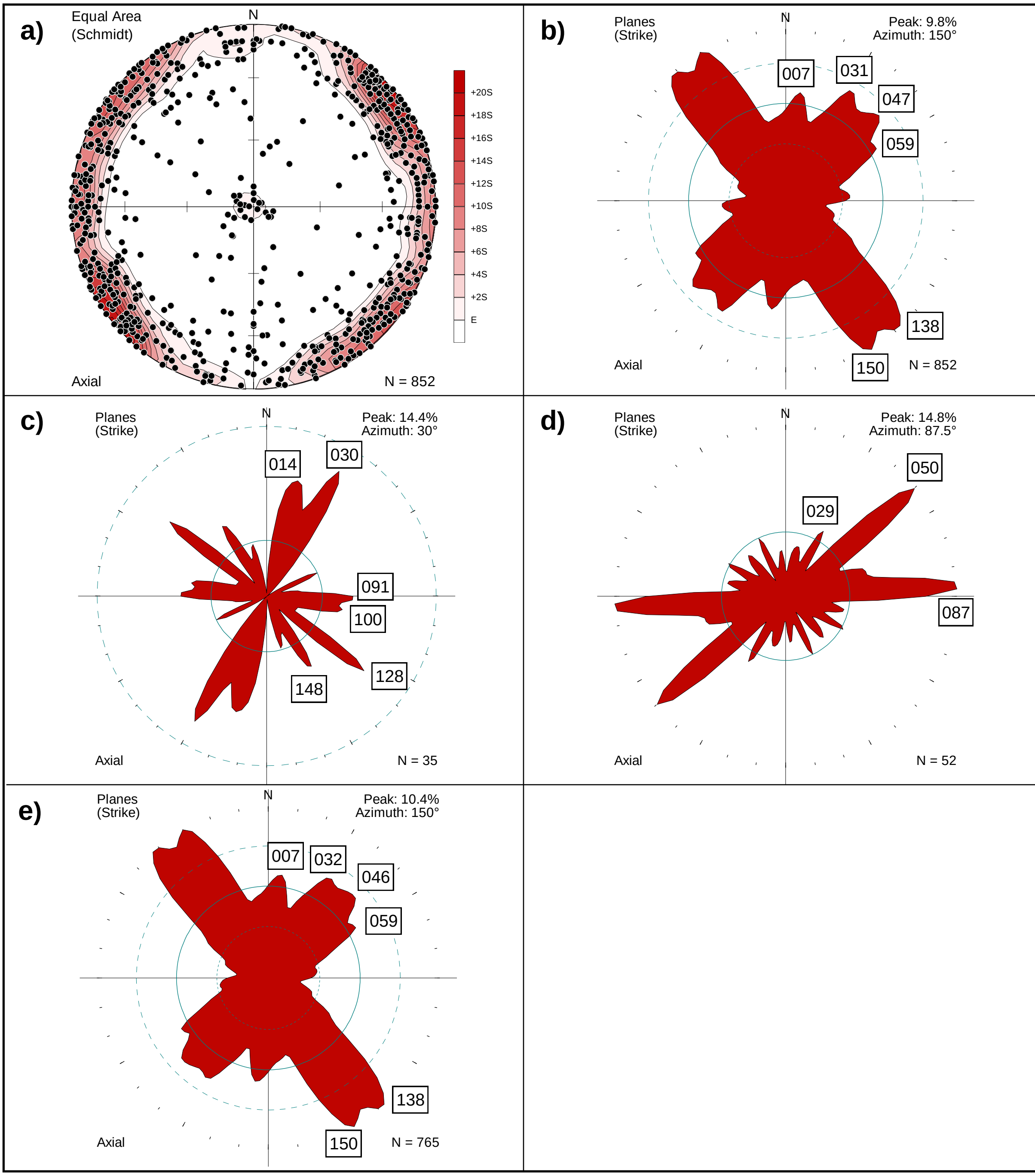


Figure 5.1.15: Quetico Area – Joint Orientation Data

a – All joint data displayed as equal area lower hemisphere stereonet plot of poles to joints (N = 852).
b – All joint data displayed as rose diagram of trends of joint planes (N = 852)
c – Subhorizontal joints (0 – 30 degree dip) displayed as rose diagram of trends of joint planes (N = 35)
d – Intermediate joints (31 – 60 degree dip) displayed as rose diagram of trends of joint planes (N = 52)
e – Subvertical joints (61 – 90 degree dip) displayed as rose diagram of trends of joint planes (N = 765)

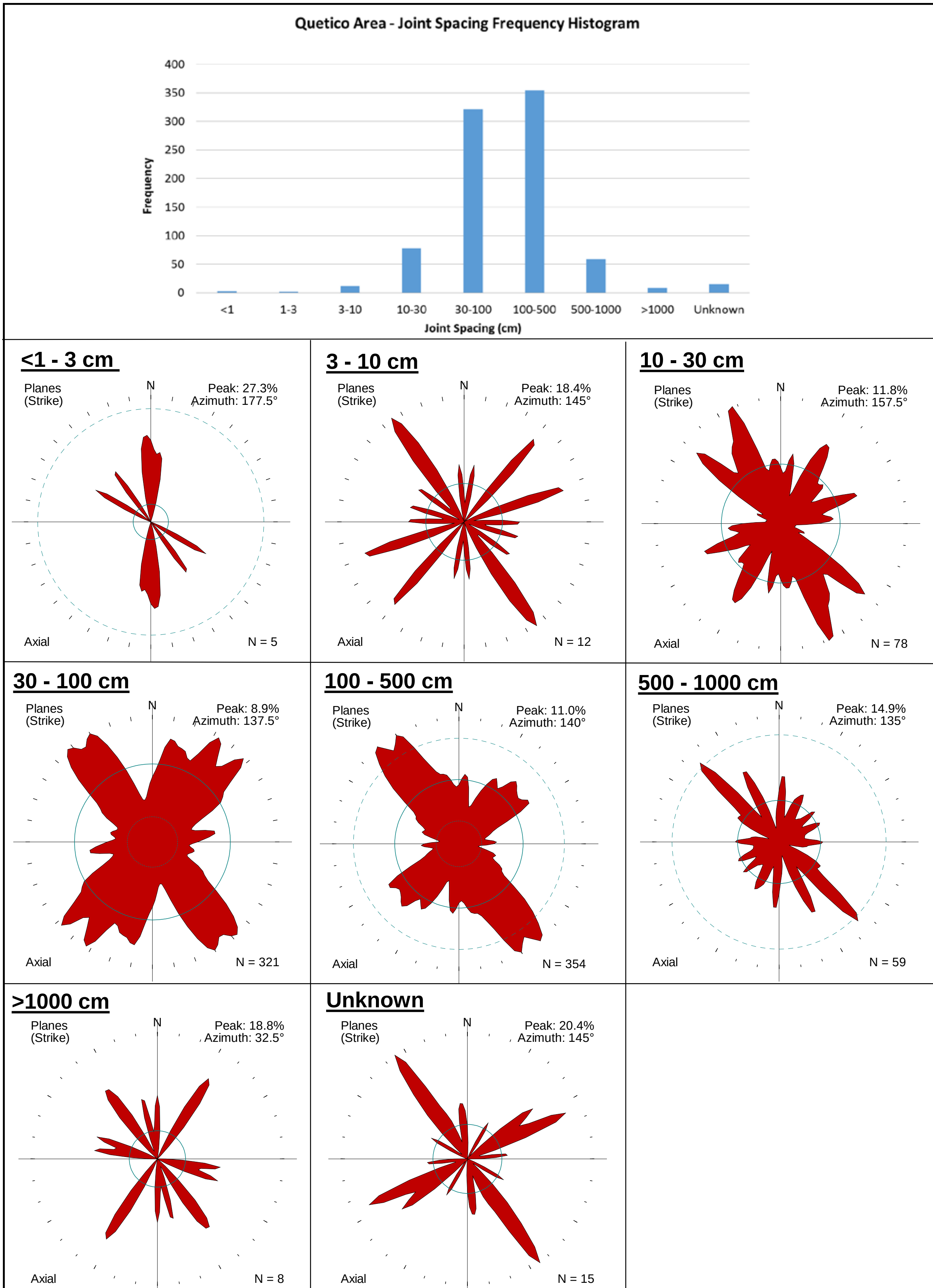


Figure 5.1.16: Quetico Area - Joint Spacing Summary

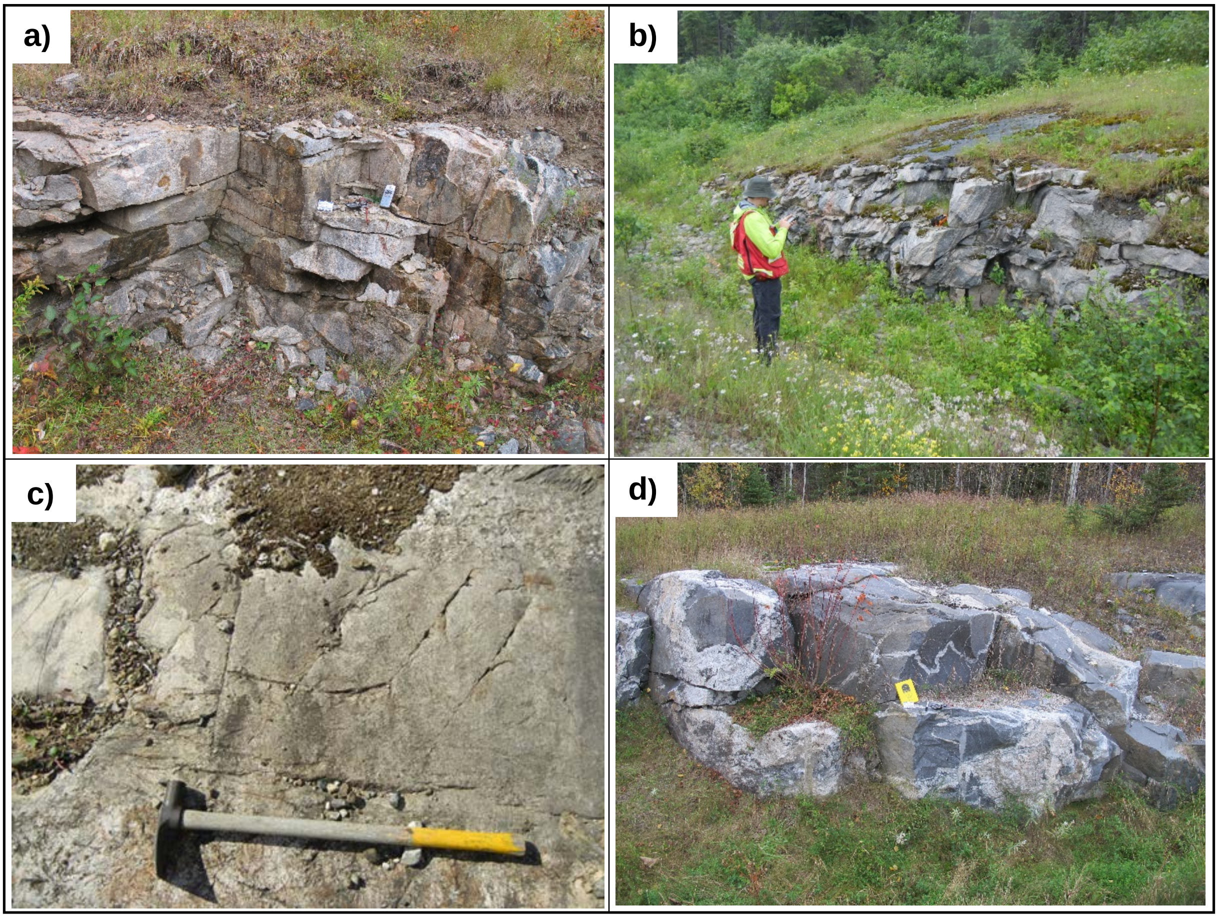
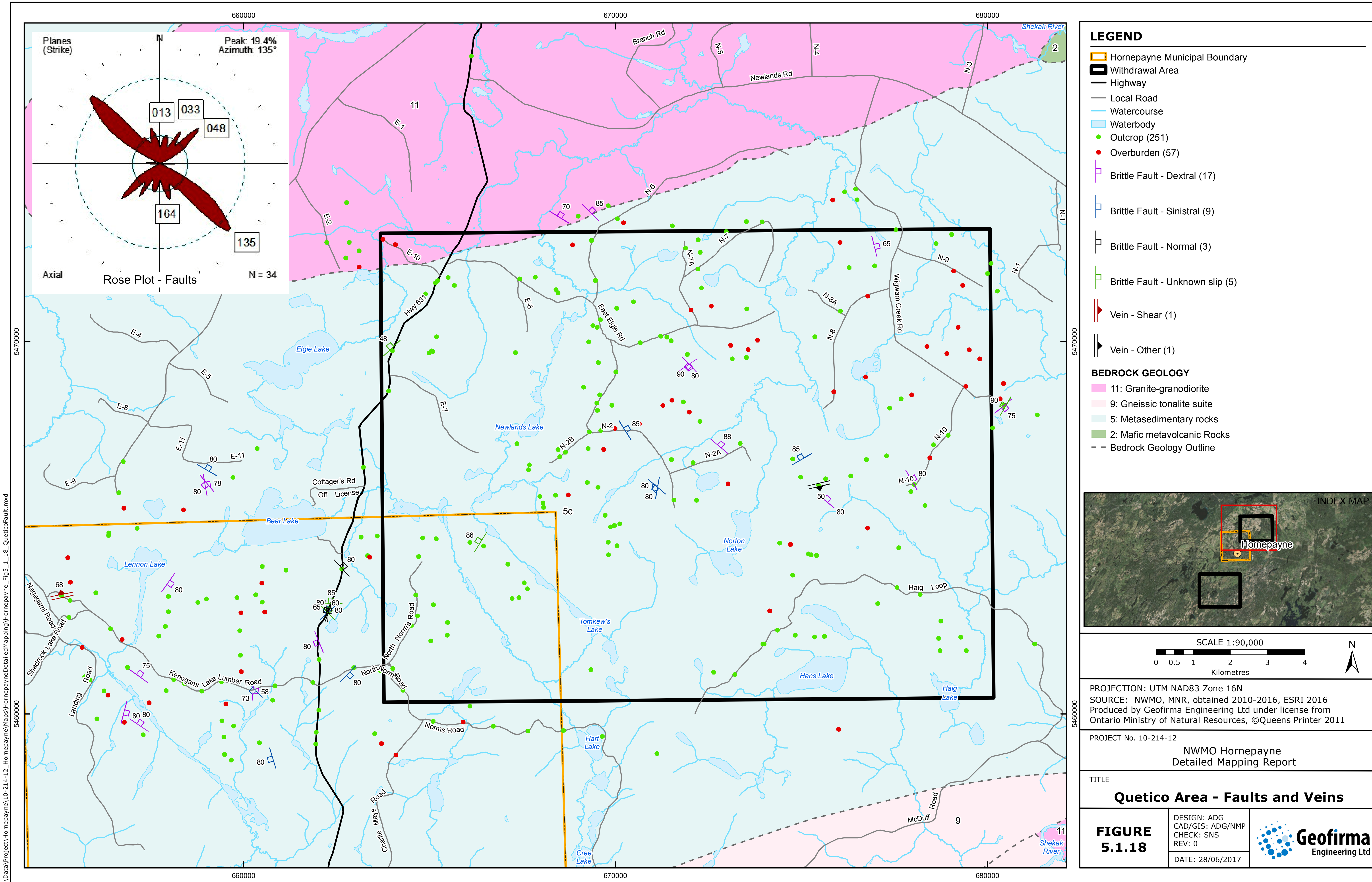


Figure 5.1.17: Quetico Area – Field Examples of Joints

a – Outcrop scale joint sets, grandodiorite. View toward northeast, person for scale (Station 14NP004).
b – Outcrop scale joint sets, tonalite (Station 16PG0081).
c – Photo of joint set in migmatitic metasedimentary rock outcrop. Plan view with hammer for scale (Station 16PG0179).
d – Photo of outcrop scale jointing in tonalite rich migmatitic metasedimentary rock cut. Unoriented photo, field book for scale (Station 14NP001).



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Azimuth: 135°
013
033
048
164
135
Axial
Rose Plot - Faults
N = 34
LEGEND
Hornepayne Municipal Boundary
Withdrawal Area
Highway
Local Road
Watercourse
Waterbody
Outcrop (251)
Overburden (57)
Brittle Fault - Dextral (17)
Brittle Fault - Sinistral (9)
Brittle Fault - Normal (3)
Brittle Fault - Unknown slip (5)
Vein - Shear (1)
Vein - Other (1)
BEDROCK GEOLOGY
11: Granite-granodiorite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
Bedrock Geology Outline
INDEX MAP
Hornepayne
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Kilometres
N
PROJECTION: UTM NAD83 Zone 16N
SOURCE: NWMO, MNR, obtained 2010-2016, ESRI 2016
Produced by Geofirma Engineering Ltd under license from
Ontario Ministry of Natural Resources, ©Queens Printer 2011
PROJECT No. 10-214-12
NWMO Hornepayne
Detailed Mapping Report
TITLE
Quetico Area - Faults and Veins
FIGURE
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CHECK: SNS
REV: 0
DATE: 28/06/2017
Geofirma Engineering Ltd
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Newlands Lake
Bear Lake
Lennon Lake
Norton Lake
Tomkew's Lake
Hans Lake
Haig Lake
Hart Lake
Cree Lake
Shekak River
Branch Rd
Newlands Rd
Hwy 631
East Elgie Rd
Wigwam Creek Rd
Cottager's Rd
Off License
Haig Loop
Kenogami Lake Lumber Road
Nagagami Road
Shadrock Lake Road
Landing Road
North Norm's Road
Norms Road
Charlie Mays Road
McDuff Road
660000
670000
680000
5470000
5460000
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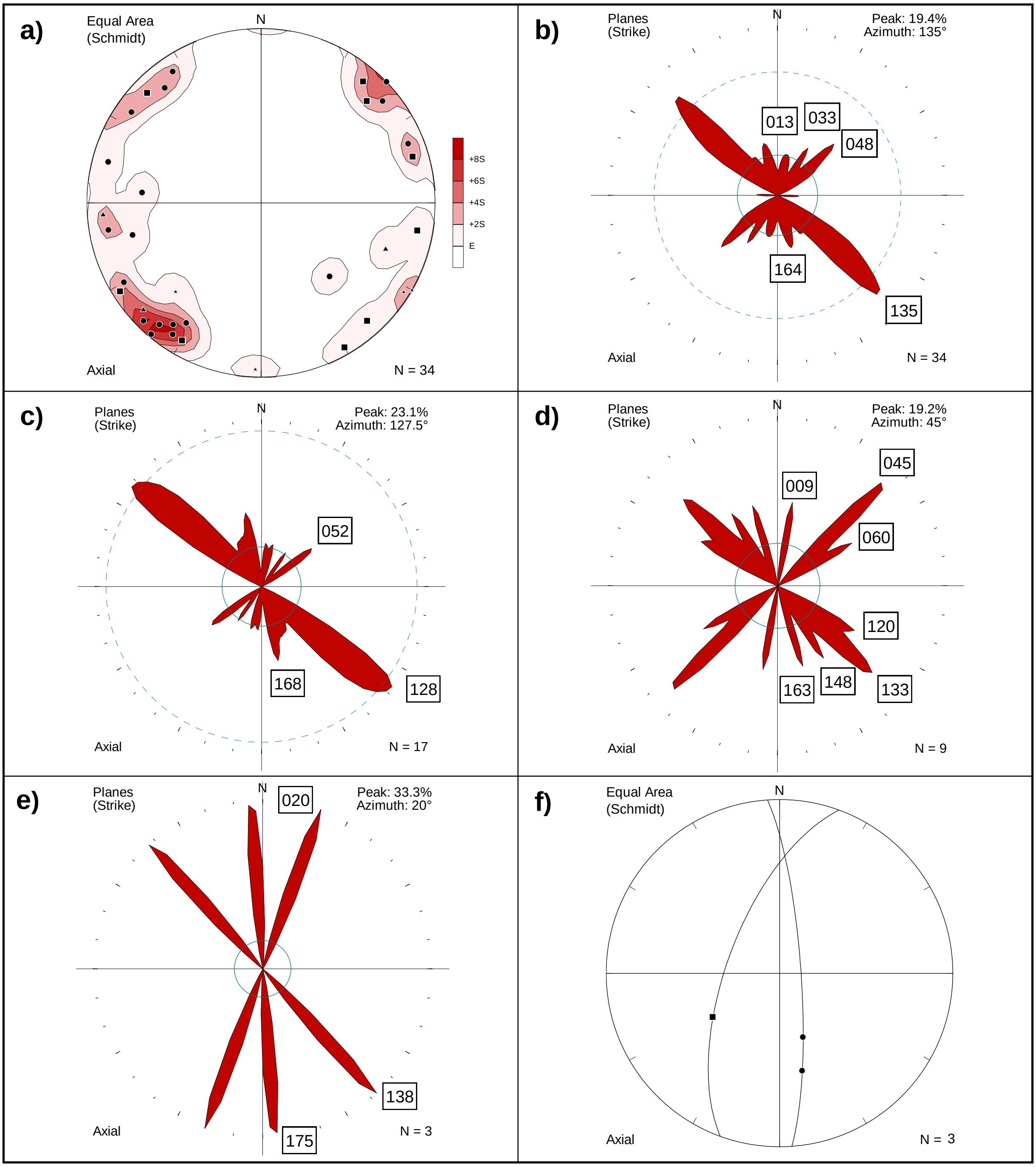


Figure 5.1.19: Quetico Area – Fault Orientation Data

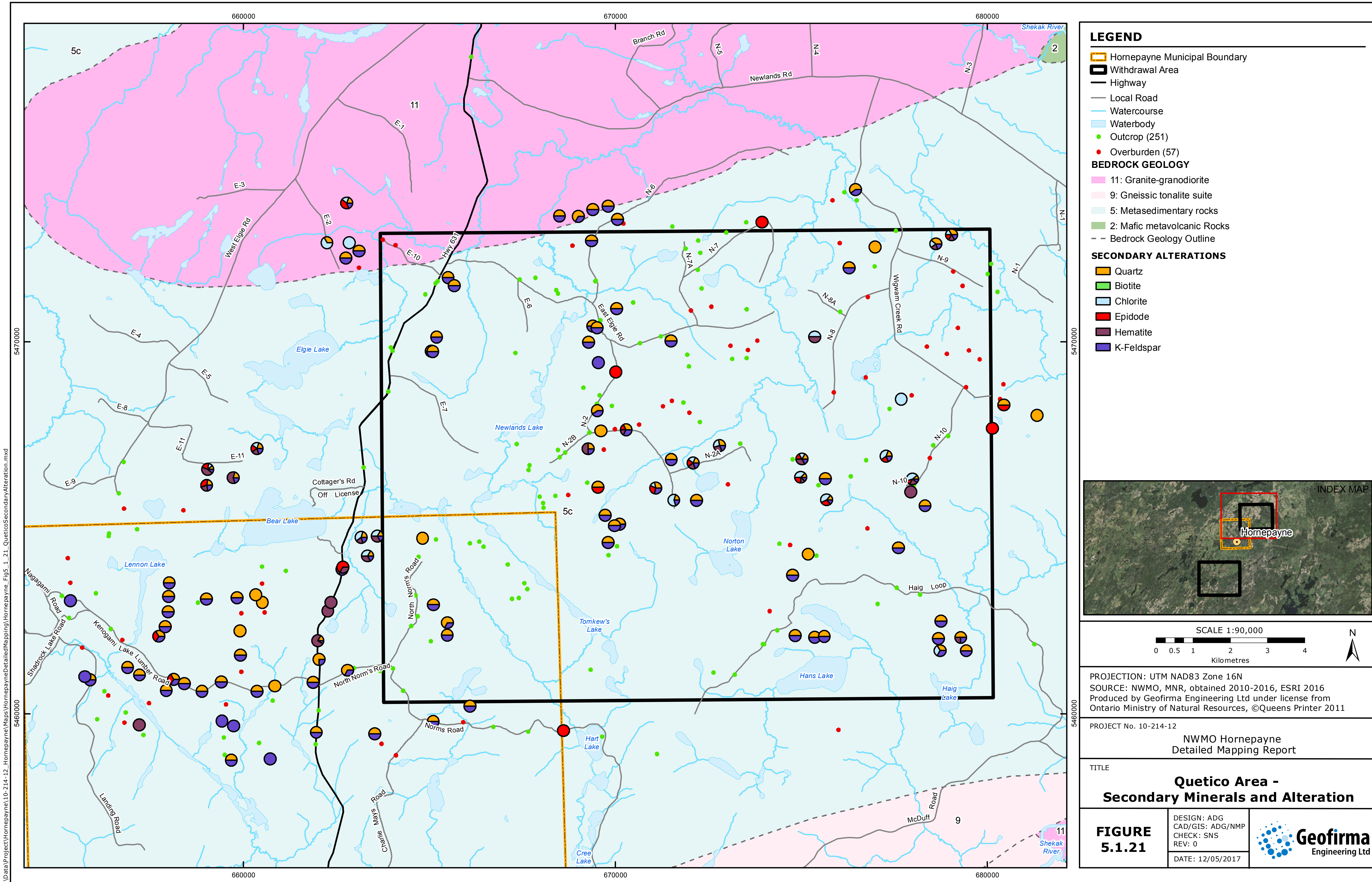
a – All fault data displayed as equal area lower hemisphere stereonet plot of poles to fault planes. Dextral faults: circles (N = 17). Sinistral faults: squares (N = 9). Normal faults: triangles (N = 3). Faults with unknown slip: stars (N = 5).
b – All fault data displayed as rose diagram of trends of joint planes (N = 34)
c – Dextral fault data displayed as rose diagram of trends of fault planes (N = 17)
d – Sinistral fault data displayed as rose diagram of trends of fault planes (N = 9)
e - Normal fault data displayed as rose diagram of trends of fault planes (N = 3).
f – Slickenline lineations plotted by their pitch on the fault plane on an equal area lower hemisphere stereonet plot (N = 3). Fault Plane 1 (200/65): square, Fault Plane 2 (356/80): circle.

a)

b)

<u>Figure 5.1.20: Quetico Area – Field Examples of Faults</u>

a - Fault plane with slickenline lineation. View toward north, scale card for scale (Station 16HM0105).
b – Small scale sinistral fault. Pencil oriented north (up), scale card for scale (Station 16HM0096).


660000
670000
680000
5470000
5460000
5c
11
9
2
Shekak River
Branch Rd
Newlands Rd
N-5
N-4
N-3
N-1
N-6
N-7
N-7A
N-8A
N-8
N-9
N-10
N-2
N-2A
N-2B
E-1
E-2
E-3
E-4
E-5
E-6
E-7
E-8
E-9
E-10
E-11
Hwy 631
West Elgie Rd
East Elgie Rd
Wigwam Creek Rd
Elgie Lake
Newlands Lake
Cottager's Rd
Off License
Bear Lake
Lennon Lake
Nagagami Road
Shadrock Lake Road
Kenogami Lake Lumber Road
North Norm's Road
Norms Road
Tomkew's Lake
Norton Lake
Haig Loop
Hans Lake
Haig Lake
Hart Lake
Cree Lake
Charlie Mays Road
Landing Road
McDuff Road
Shekak River
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LEGEND
Hornepayne Municipal Boundary
Withdrawal Area
Highway
Local Road
Watercourse
Waterbody
Outcrop (251)
Overburden (57)
BEDROCK GEOLOGY
11: Granite-granodiorite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
Bedrock Geology Outline
SECONDARY ALTERATIONS
Quartz
Biotite
Chlorite
Epidode
Hematite
K-Feldspar
INDEX MAP
Hornepayne
SCALE 1:90,000
0 0.5 1 2 3 4
Kilometres
N
PROJECTION: UTM NAD83 Zone 16N
SOURCE: NWMO, MNR, obtained 2010-2016, ESRI 2016
Produced by Geofirma Engineering Ltd under license from
Ontario Ministry of Natural Resources, ©Queens Printer 2011
PROJECT No. 10-214-12
NWMO Hornepayne
Detailed Mapping Report
TITLE
Quetico Area -
Secondary Minerals and Alteration
FIGURE
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REV: 0
DATE: 12/05/2017
Geofirma
Engineering Ltd

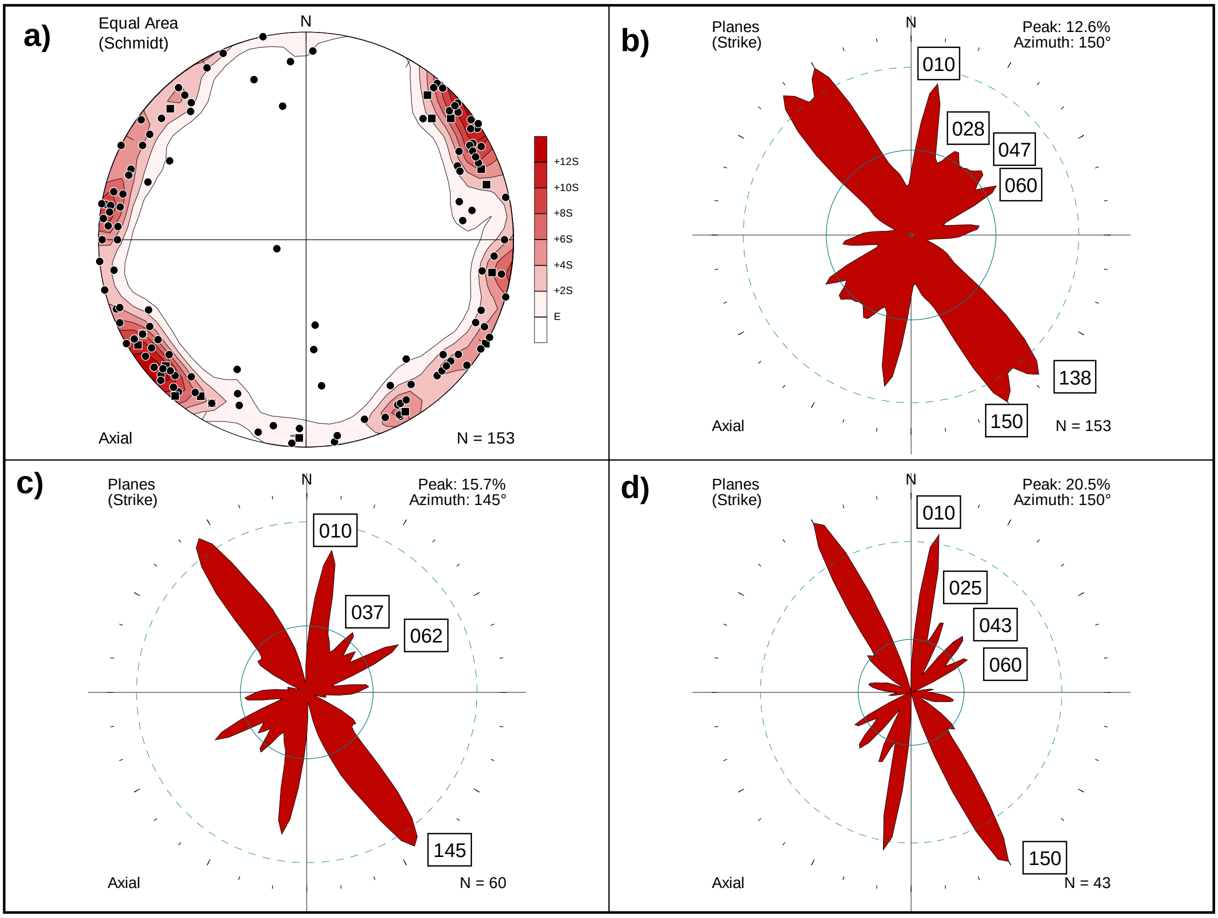


Figure 5.1.22: Quetico Area – Secondary Minerals and Alteration Data

a – All fractures with observed mineralization/alteration displayed as lower hemisphere stereonet plot of poles (N = 153). Poles to joint planes: circles (N = 137). Poles to fault planes: squares (N = 16).
b – All fractures with observed mineralization/alteration displayed as rose diagram of trends of joint/fault planes (N = 153).
c – Fractures with observed hematite mineralization/alteration displayed as rose diagram of trends of joint/fault planes (N = 60).
d – Fractures with observed chlorite mineralization/alteration displayed as rose diagram of trends of joint/fault planes (N = 43).

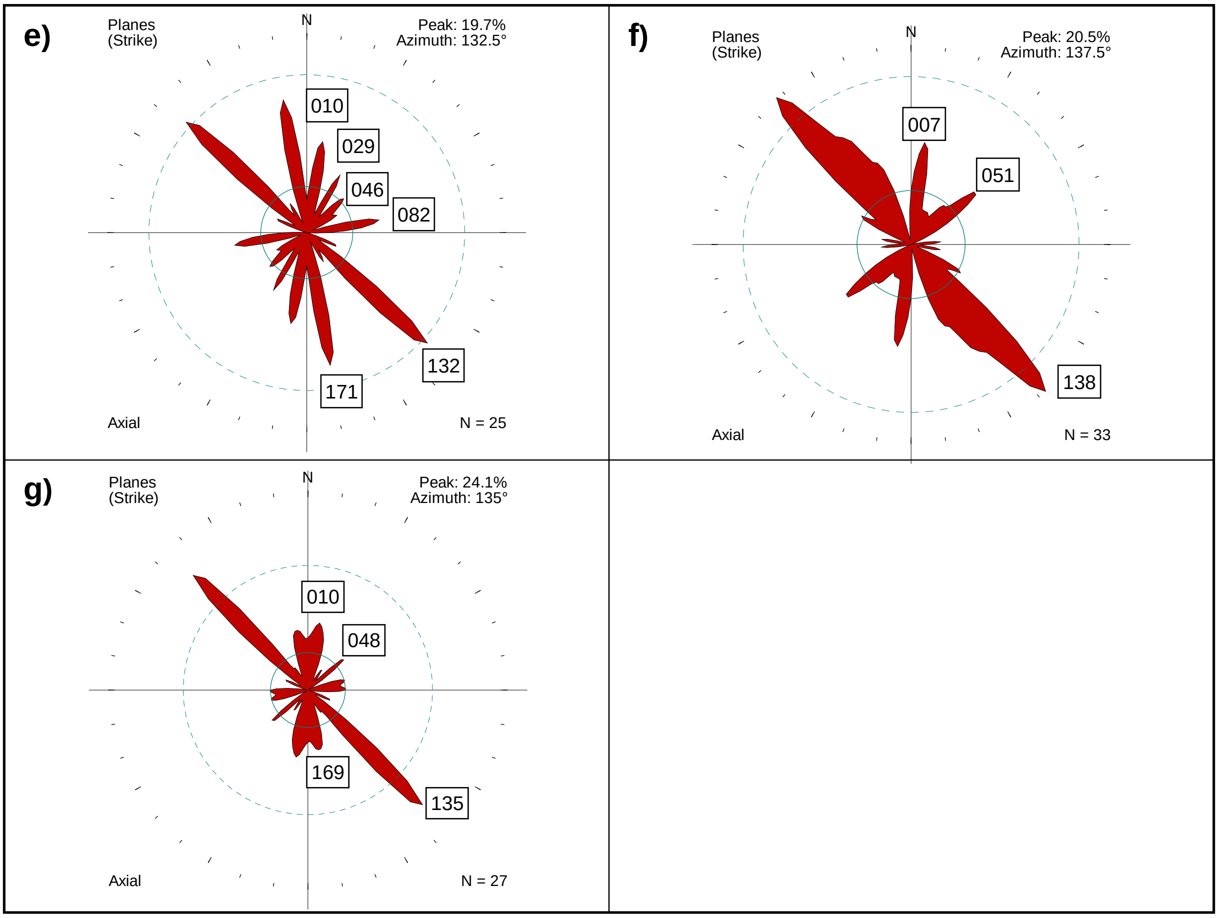


Figure 5.1.22: Quetico Area – Secondary Minerals and Alteration Data

e – Fractures with observed quartz mineralization/alteration displayed as rose diagram of trends of joint/fault planes (N = 25).
f – Fractures with observed epidote mineralization/alteration displayed as rose diagram of trends of joint/fault planes (N = 33).
g – Fractures with observed k-feldspar mineralization/alteration displayed as rose diagram of trends of joint/fault planes (N = 27).

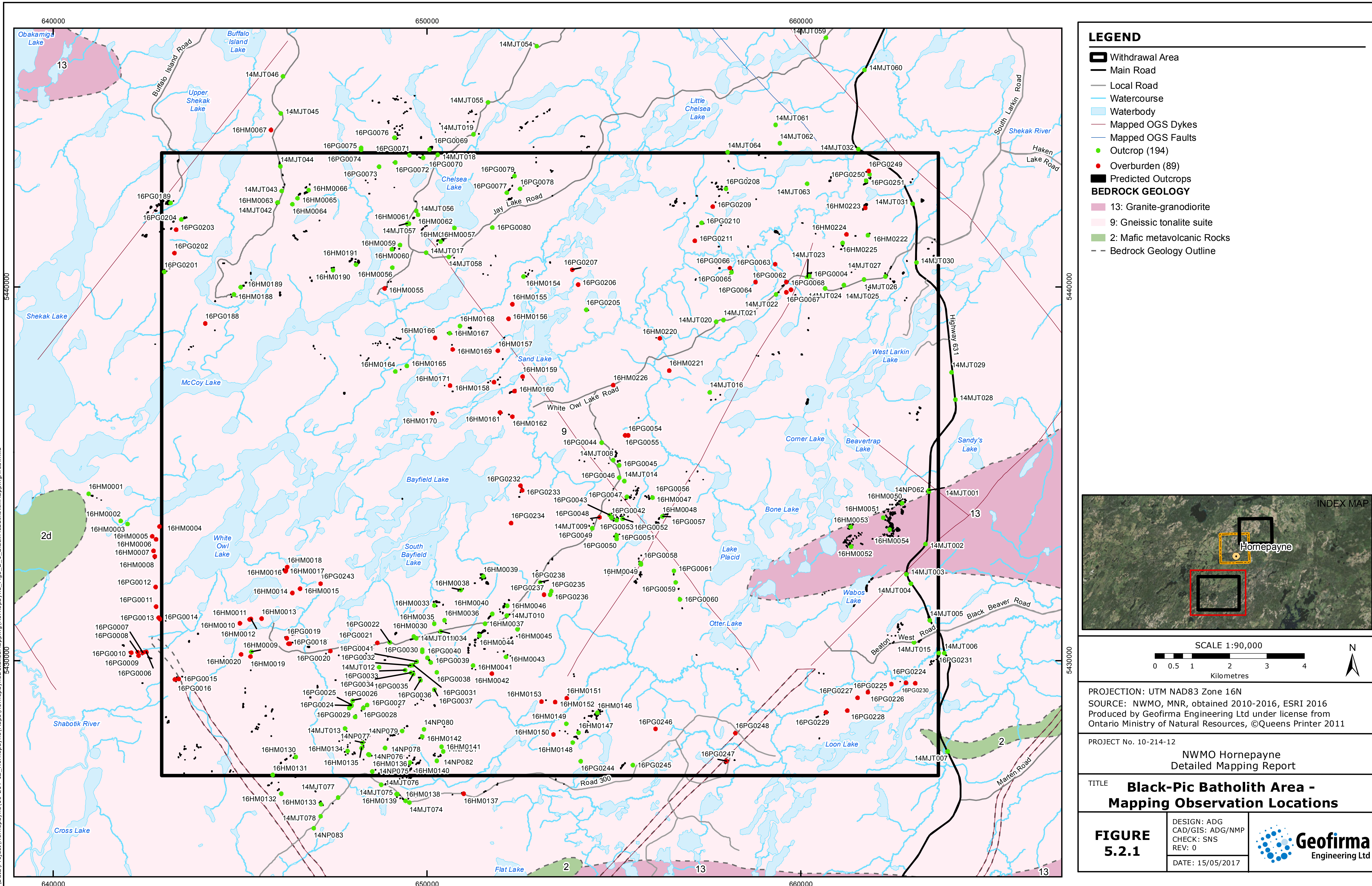
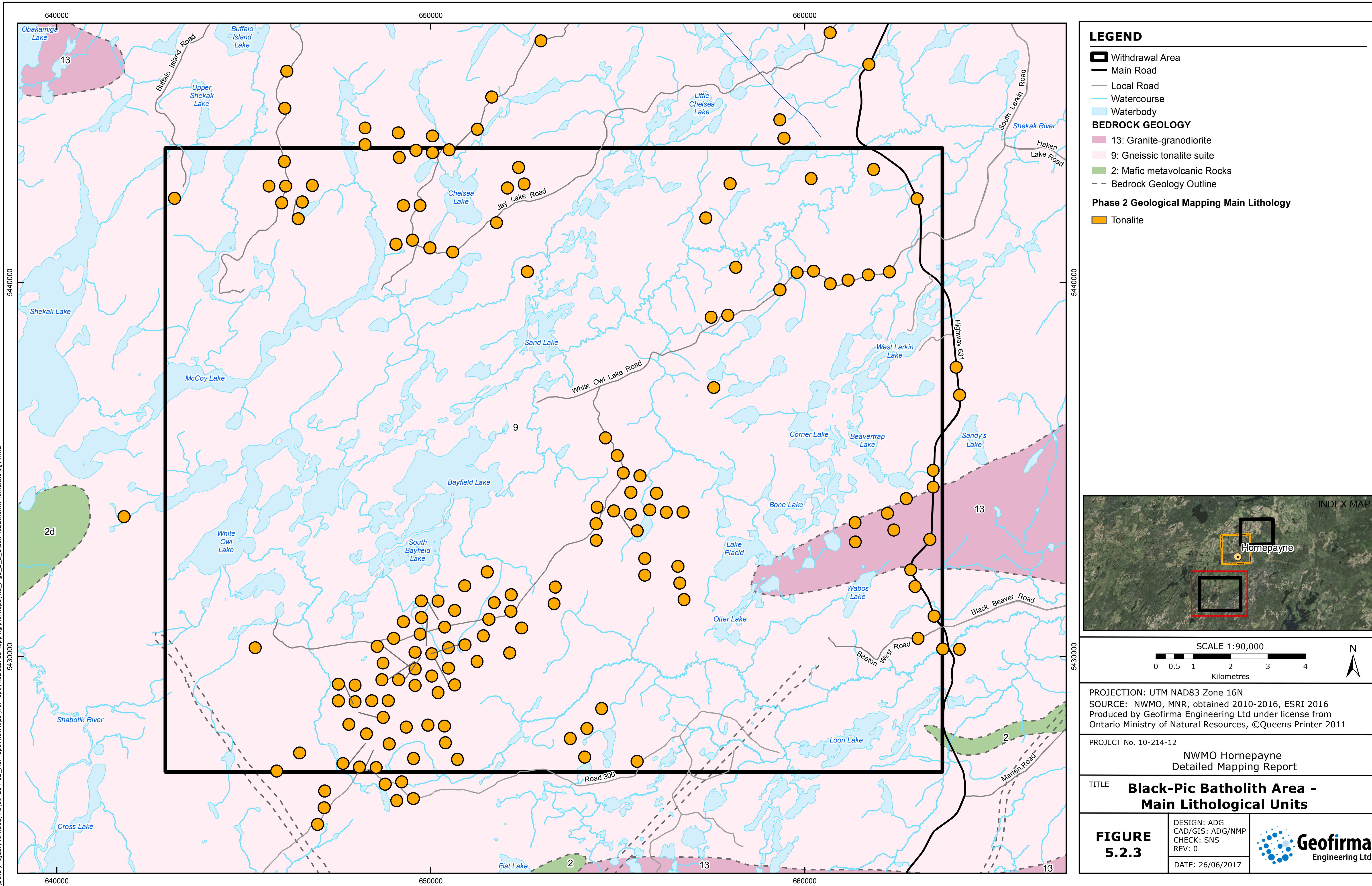


FIGURE 5.2.1

Black-Pic Batholith Area - Mapping Observation Locations

<u>Figure 5.2.2: Black-Pic Batholith Area - Field Examples of Accessibility and Bedrock Exposure</u>

a – Photo of typical outcrop exposure in the Black-Pic Batholith area. View to the west, pack and hammer for scale (Station 16PG0041).
b – Photo of outcrop exposure along edge of a wetland in the southern portion of the Black-Pic area. View to the north, person for scale (Station 16HM0165).
c –. Photo of typical overburden station. View to the north, person for scale (Station 16HM0137).
d –. Photo of overburden station with several metre thick sand pile. View to the northeast, person for scale (Station 16PG0226).


LEGEND
Withdrawal Area
Main Road
Local Road
Watercourse
Waterbody
BEDROCK GEOLOGY
13: Granite-granodiorite
9: Gneissic tonalite suite
2: Mafic metavolcanic Rocks
Bedrock Geology Outline
Phase 2 Geological Mapping Main Lithology
Tonalite
INDEX MAP
Hornepayne
SCALE 1:90,000
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Kilometres
N
PROJECTION: UTM NAD83 Zone 16N
SOURCE: NWMO, MNR, obtained 2010-2016, ESRI 2016
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PROJECT No. 10-214-12
NWMO Hornepayne
Detailed Mapping Report
TITLE
Black-Pic Batholith Area - Main Lithological Units
FIGURE 5.2.3
DESIGN: ADG
CAD/GIS: ADG/NMP
CHECK: SNS
REV: 0
DATE: 26/06/2017
Geofirma Engineering Ltd
640000
650000
660000
5440000
5430000
Obakamiga Lake
Buffalo Island Lake
Buffalo Island Road
Upper Shekak Lake
Little Chelsea Lake
Chelsea Lake
Jay Lake Road
South Larkin Road
Shekak River
Haken Lake Road
Shekak Lake
Sand Lake
White Owl Lake Road
McCoy Lake
West Larkin Lake
Highway 631
Corner Lake
Beavertrap Lake
Sandy's Lake
Bayfield Lake
Bone Lake
White Owl Lake
South Bayfield Lake
Lake Placid
Wabos Lake
Otter Lake
Black Beaver Road
Beaton West Road
Shabotik River
Loon Lake
Road 300
Marten Road
Cross Lake
Flat Lake
13
9
2d
2
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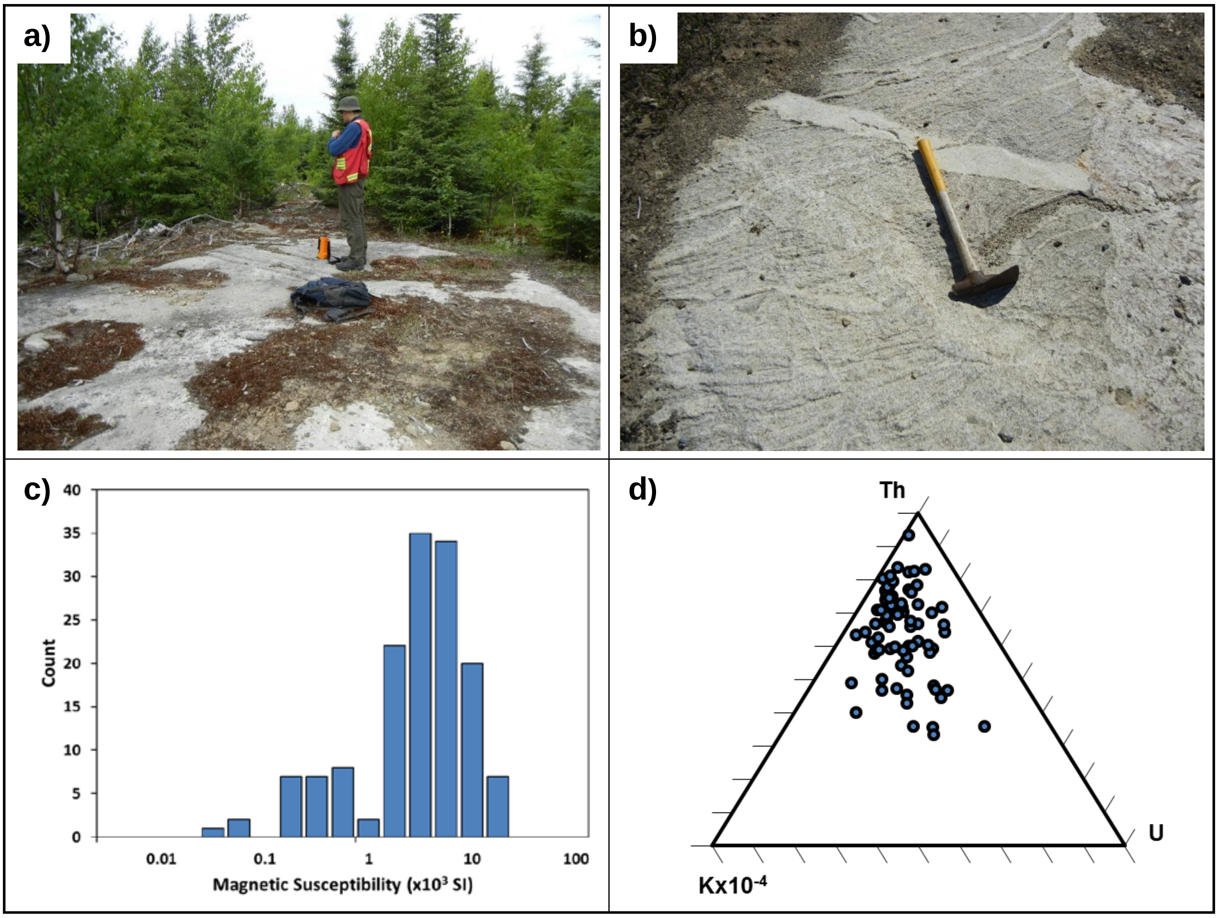


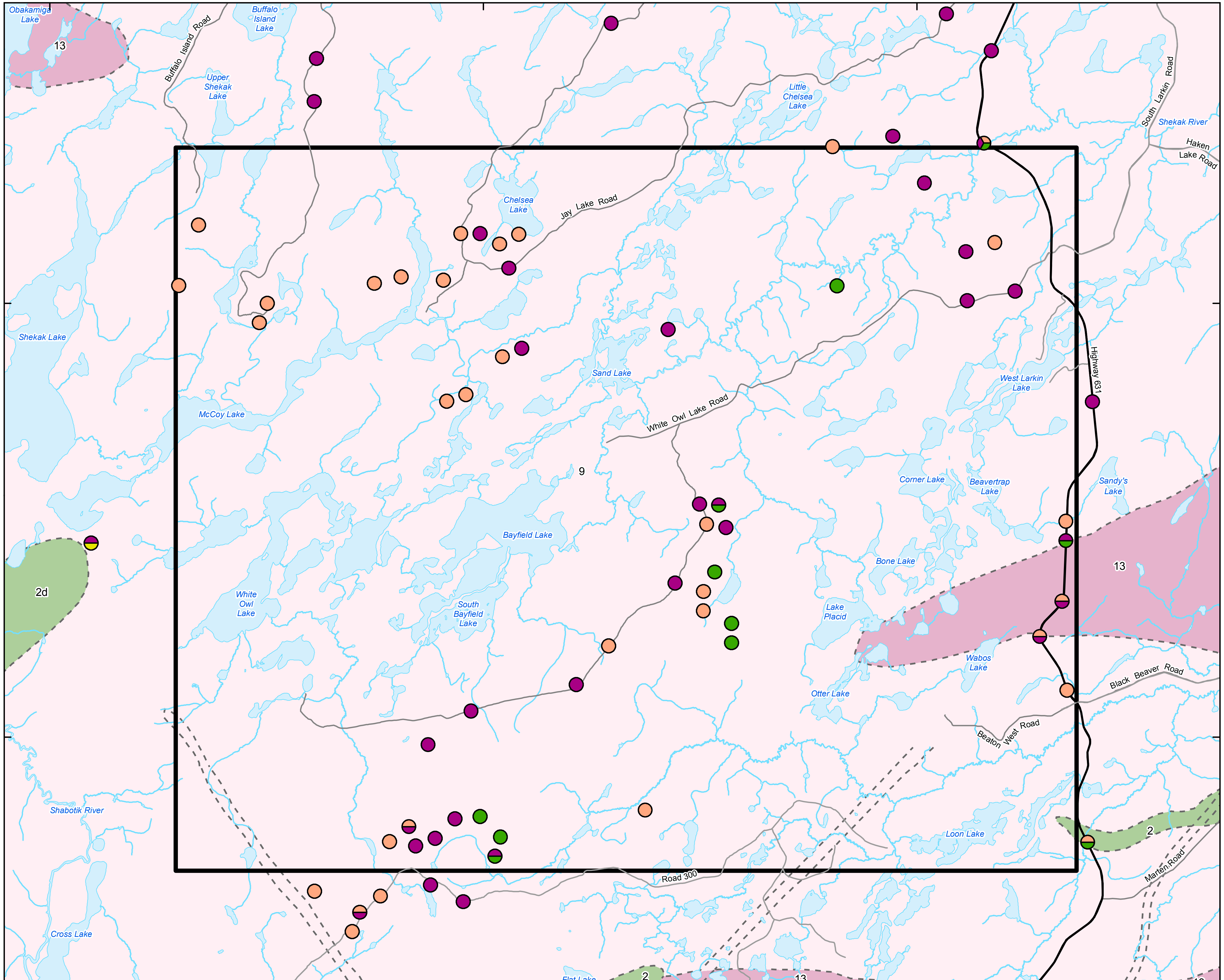
Figure 5.2.4: Black-Pic Batholith Area - Field Examples of Main Lithology: Tonalite

a – Photo of tonalite outcrop. View toward the north, person for scale (Station 16PG029).

b – Close-up photo of tonalite showing foliation and mineralogy. Oriented northeast, hammer for scale (Station 16PG036).

c – Logarithmic plot of magnetic susceptibility for tonalite (N = 145).

d – Ternary plot of gamma ray spectrometer data for tonalite (N = 87).



LEGEND

Withdrawal Area
Main Road
Local Road
Waterbody
Watercourse

BEDROCK GEOLOGY

13: Granite-granodiorite
9: Gneissic tonalite suite
2: Mafic metavolcanic Rocks
Bedrock Geology Outline

Phase 2 Geological Mapping Minor Lithology

Granodiorite
Granite
Amphibolite

INDEX MAP
Hornepayne

SCALE 1:90,000
0 0.5 1 2 3 4
Kilometres
N

PROJECTION: UTM NAD83 Zone 16N
SOURCE: NWMO, MNR, obtained 2010-2016, ESRI 2016
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PROJECT No. 10-214-12

NWMO Hornepayne
Detailed Mapping Report

TITLE

Black-Pic Batholith Area - Minor Lithological Units

FIGURE 5.2.5

DESIGN: ADG
CAD/GIS: ADG/NMP
CHECK: SNS
REV: 0
DATE: 26/06/2017

Geofirma Engineering Ltd

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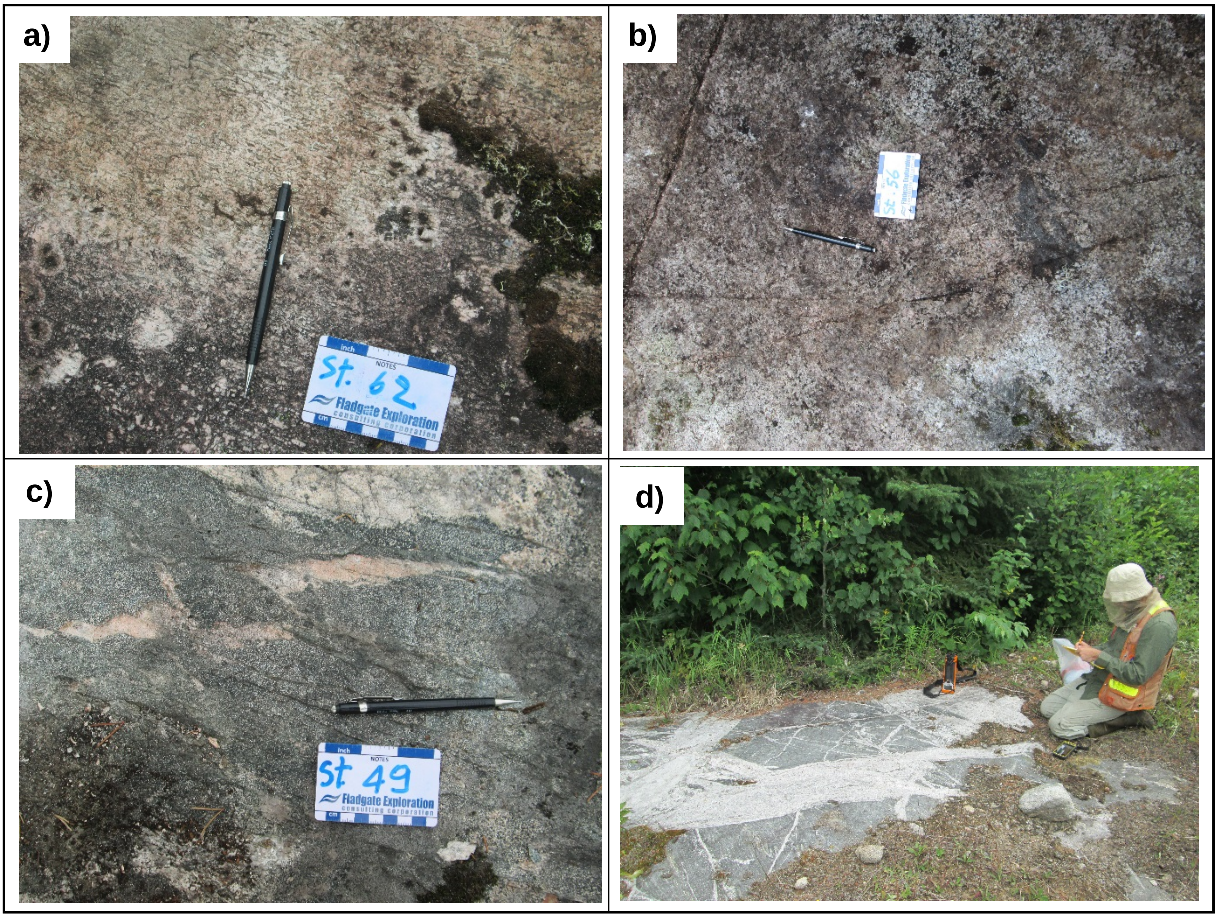
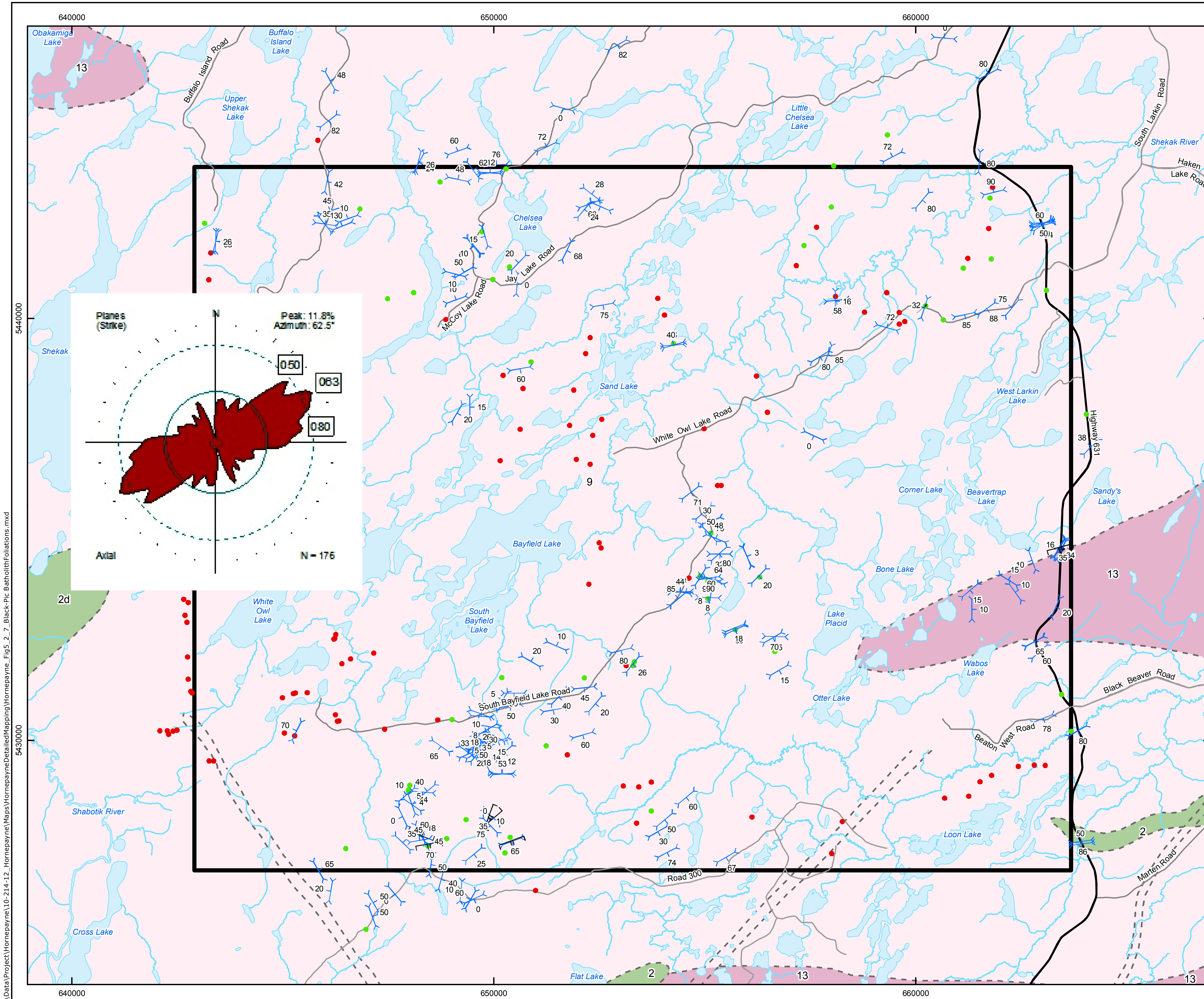


Figure 5.2.6: Black-Pic Batholith Area – Field Examples of Minor Lithological Units

a – Close-up photo of granite showing typical grainsize and mineralogy. Plan view, scale card for scale (Station 16HM0062)
b – Close-up photo of granodiorite showing typical grainsize and mineralogy. Plan view, scale card and pen for scale (Station 16HM0056)
c – Photo of amphibolite showing typical texture and mineralogy. Scale card and pen for scale (Station 16HM0049).
d – Photo of amphibolite outcrop. Person for scale, view to the west (Station 16HM0141).

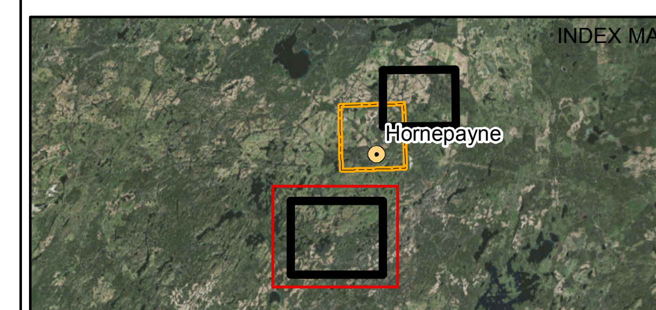


LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Watercourse
- Waterbody
- Outcrop (194)
- Overburden (89)
- Lineation (5)
- Igneous Flow Foliation (6)
- Tectonic Foliation (165)

BEDROCK GEOLOGY

- 13: Granite-granodiorite
- 9: Gneissic tonalite suite
- 2: Mafic metavolcanic Rocks
- Bedrock Geology Outline



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Kilometres

N

PROJECTION: UTM NAD83 Zone 16N
SOURCE: NWMO, MNR, obtained 2010-2016, ESRI 2016
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PROJECT No. 10-214-12

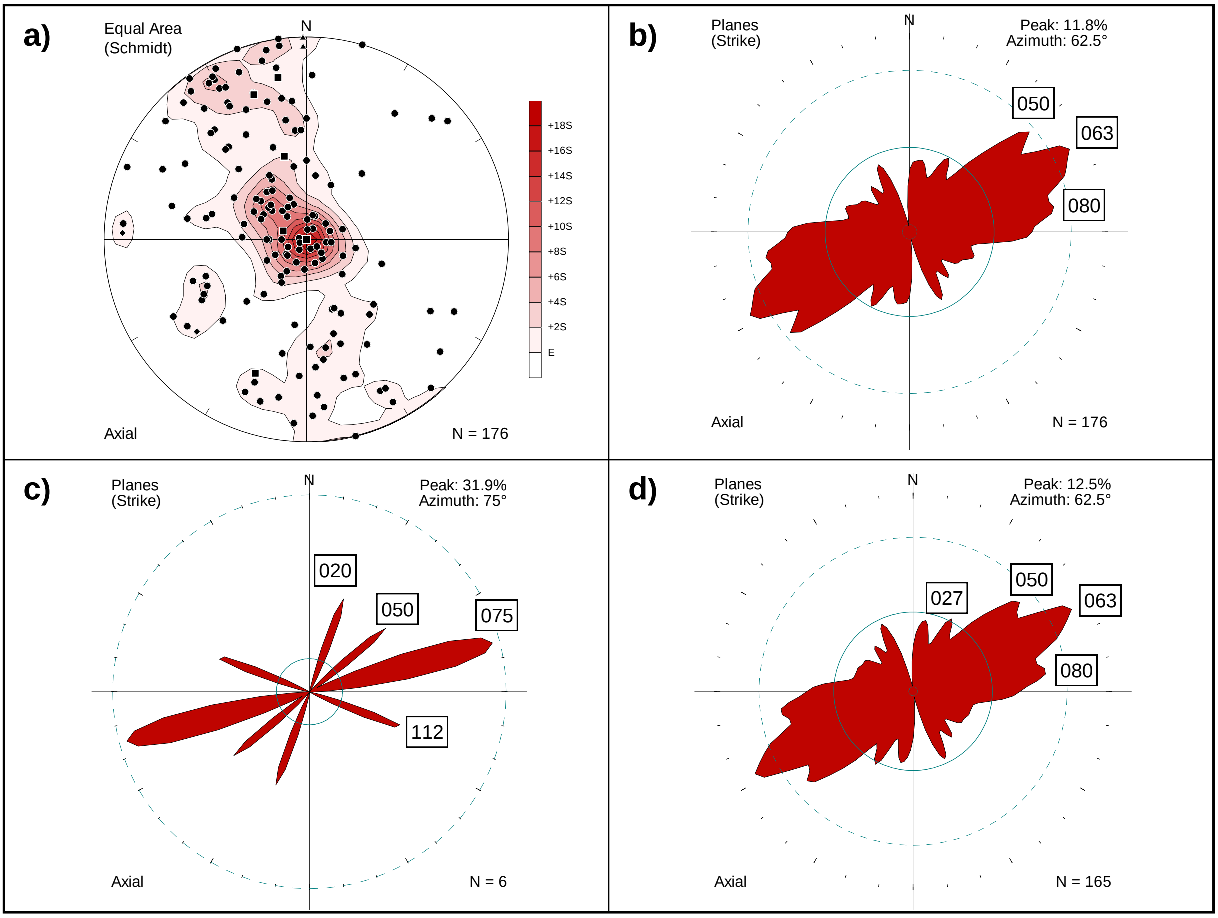
NWMO Hornepayne
Detailed Mapping Report

TITLE **Black-Pic Batholith Area - Foliation and Lineation**

FIGURE 5.2.7

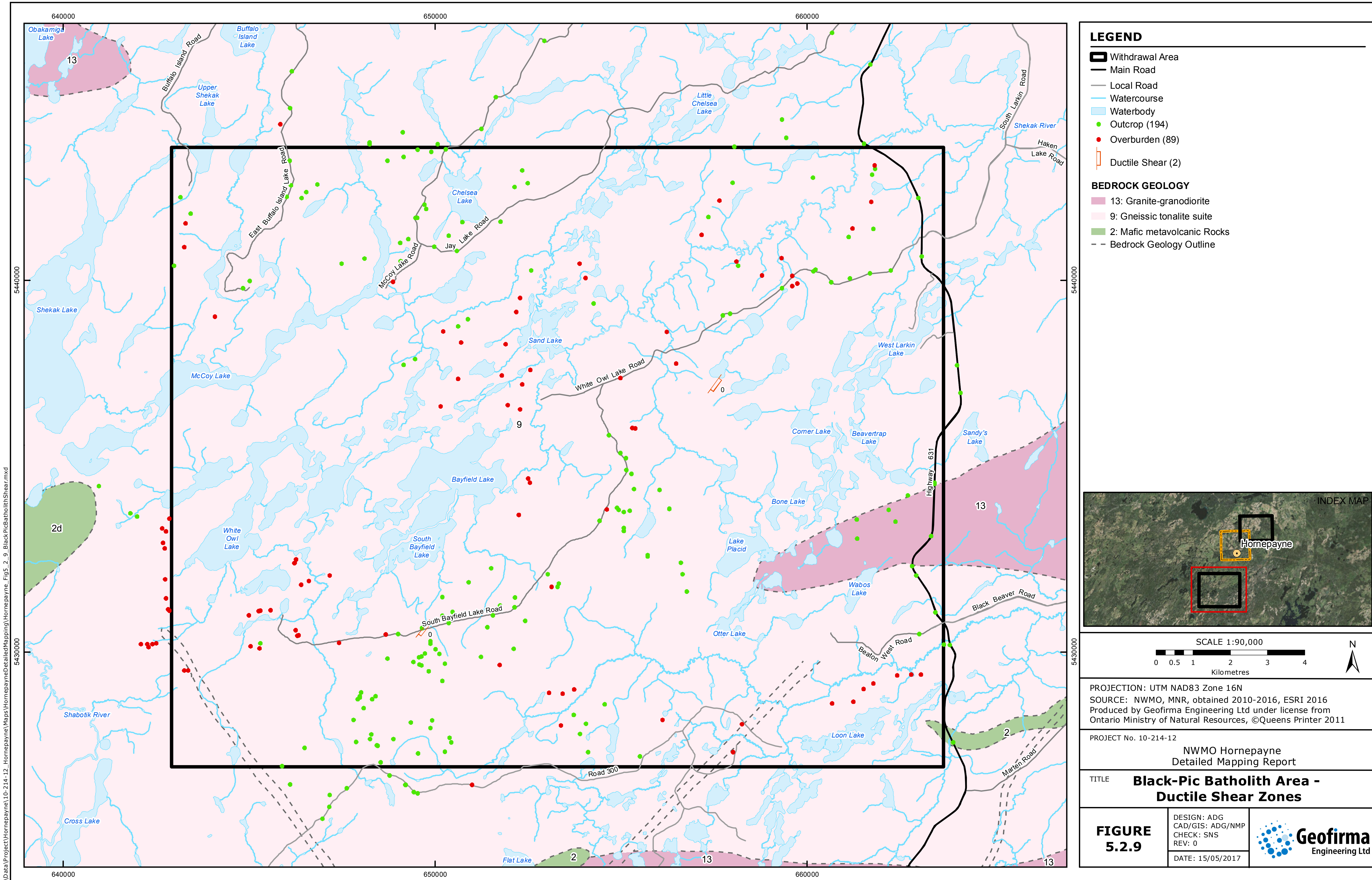
DESIGN: ADG
CAD/GIS: ADG/NMP
CHECK: SNS
REV: 0
DATE: 02/10/2017

Geofirma Engineering Ltd



<u>Figure 5.2.8: Black-Pic Batholith Area – Foliation and Lineation Orientation Data</u>

a – All foliation data displayed as equal area lower hemisphere stereonet plot of poles to foliation planes. Tectonic foliation: circle (N=165); igneous flow foliation: square (N=6); lineation – mineral/unknown: triangle (N=2); lineation - fold hinge: diamond (N=3).
b – All foliation data displayed as rose diagram of trends of foliation planes (N=178)
c – Igneous flow foliation data displayed as rose diagram of trends of foliation planes (N=6)
d – Tectonic foliation displayed as rose diagram of trends of foliation planes (N=165)



PROJECTION: UTM NAD83 Zone 16N
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PROJECT No. 10-214-12

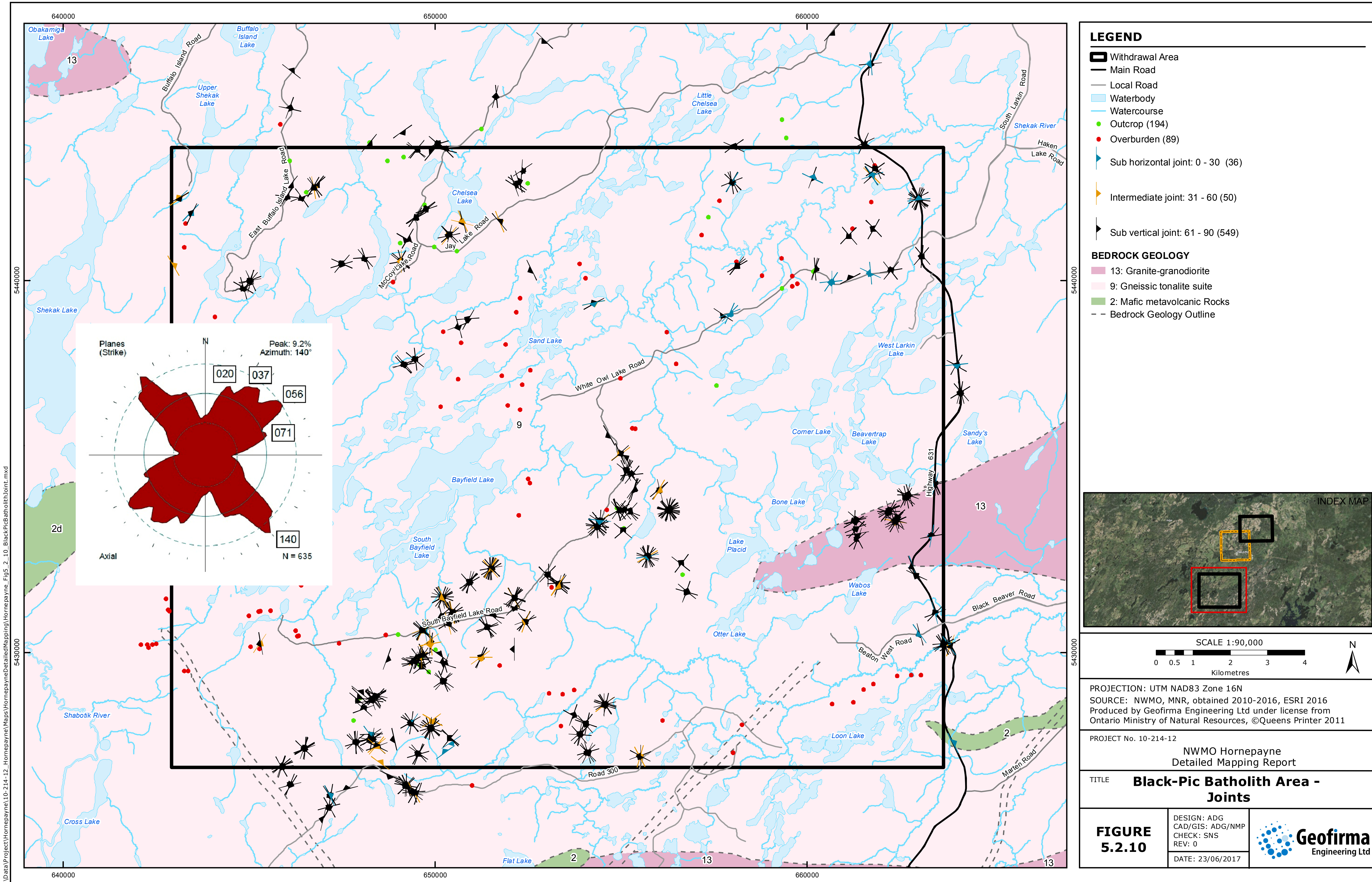
NWMO Hornepayne
Detailed Mapping Report

TITLE **Black-Pic Batholith Area - Ductile Shear Zones**

FIGURE 5.2.9

DESIGN: ADG
CAD/GIS: ADG/NMP
CHECK: SNS
REV: 0
DATE: 15/05/2017

Geofirma Engineering Ltd


LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Watercourse
Outcrop (194)
Overburden (89)
Sub horizontal joint: 0 - 30 (36)
Intermediate joint: 31 - 60 (50)
Sub vertical joint: 61 - 90 (549)
BEDROCK GEOLOGY
13: Granite-granodiorite
9: Gneissic tonalite suite
2: Mafic metavolcanic Rocks
Bedrock Geology Outline
Planes (Strike)
Peak: 9.2%
Azimuth: 140°
N
020
037
056
071
140
Axial
N = 635
INDEX MAP
SCALE 1:90,000
0 0.5 1 2 3 4
Kilometres
PROJECTION: UTM NAD83 Zone 16N
SOURCE: NWMO, MNR, obtained 2010-2016, ESRI 2016
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PROJECT No. 10-214-12
NWMO Hornepayne
Detailed Mapping Report
TITLE
Black-Pic Batholith Area - Joints
FIGURE 5.2.10
DESIGN: ADG
CAD/GIS: ADG/NMP
CHECK: SNS
REV: 0
DATE: 23/06/2017
Geofirma Engineering Ltd
640000
650000
660000
5440000
5430000
Obakamiga Lake
Buffalo Island Lake
Upper Shekak Lake
Little Chelsea Lake
Chelsea Lake
Shekak Lake
Shekak River
Sand Lake
West Larkin Lake
Corner Lake
Beavertrap Lake
Sandy's Lake
Bayfield Lake
Bone Lake
South Bayfield Lake
Lake Placid
Wabos Lake
Otter Lake
Loon Lake
Shabotik River
Cross Lake
Flat Lake
Buffalo Island Road
East Buffalo Island Lake Road
Jay Lake Road
McCoy Lake Road
White Owl Lake Road
South Larkin Road
Haken Lake Road
Highway 631
South Bayfield Lake Road
Black Beaver Road
Beaton West Road
Road 300
Marten Road
13
9
2
2d
G:\Data\Project\Hornepayne\10-214-12_Hornepayne\HornepayneDetailedMapping\Maps\Hornepayne_Fig5_2_10_BlackPicBatholithJoint.mxd

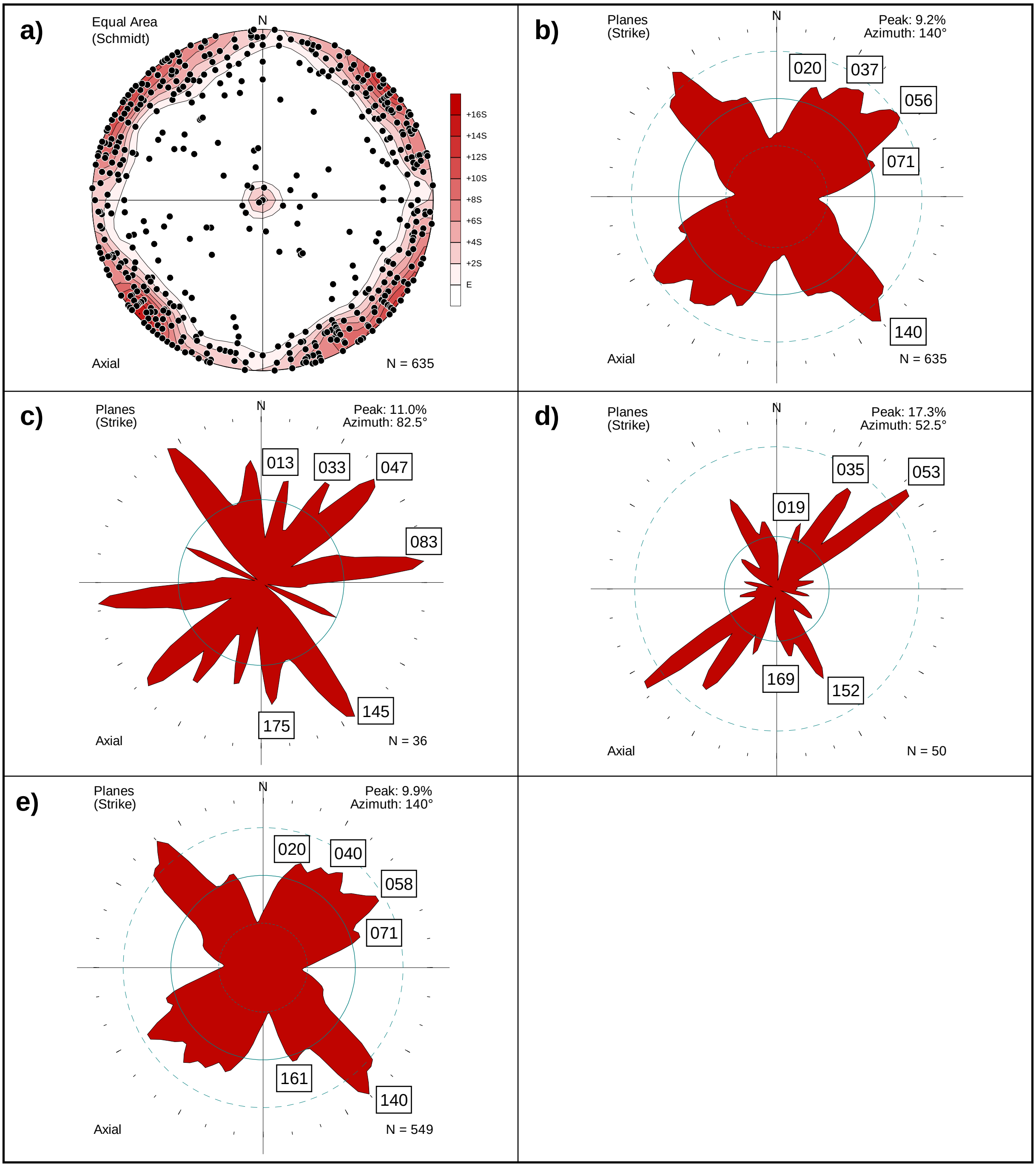


Figure 5.2.11: Black-Pic Batholith Area – Joint Orientation Data

a – All joint data displayed as equal area lower hemisphere stereonet plot of poles to joints (N = 635).
b – All joint data displayed as rose diagram of trends of joint planes (N = 635)
c – Subhorizontal joints (0 – 30 degree dip) displayed as rose diagram of trends of joint planes (N = 36)
d – Intermediate joints (31 – 60 degree dip) displayed as rose diagram of trends of joint planes (N = 50)
e – Subvertical joints (61 – 90 degree dip) displayed as rose diagram of trends of joint planes (N = 549)

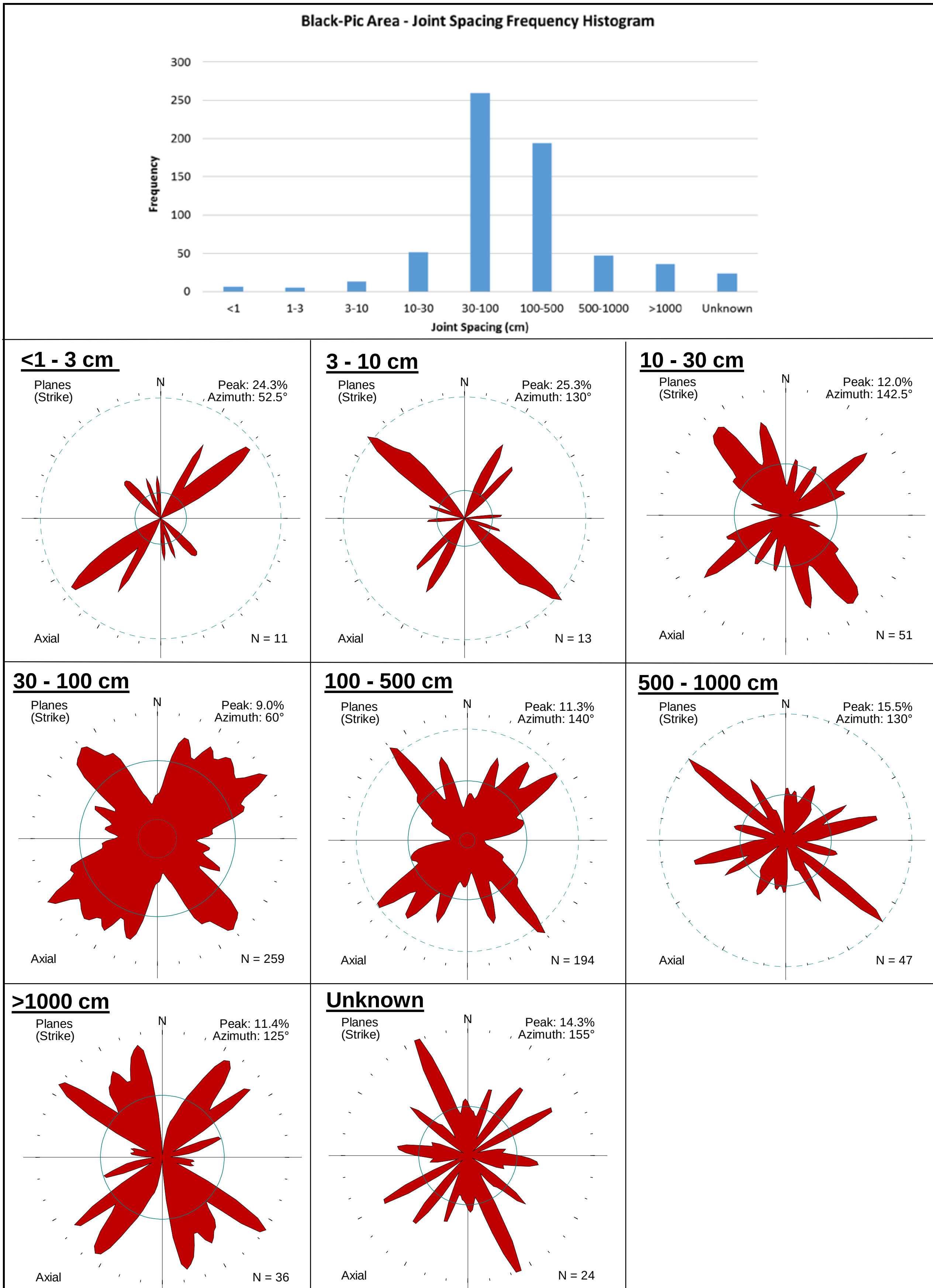


Figure 5.2.12 Black-Pic Batholith Area - Joint Spacing Summary

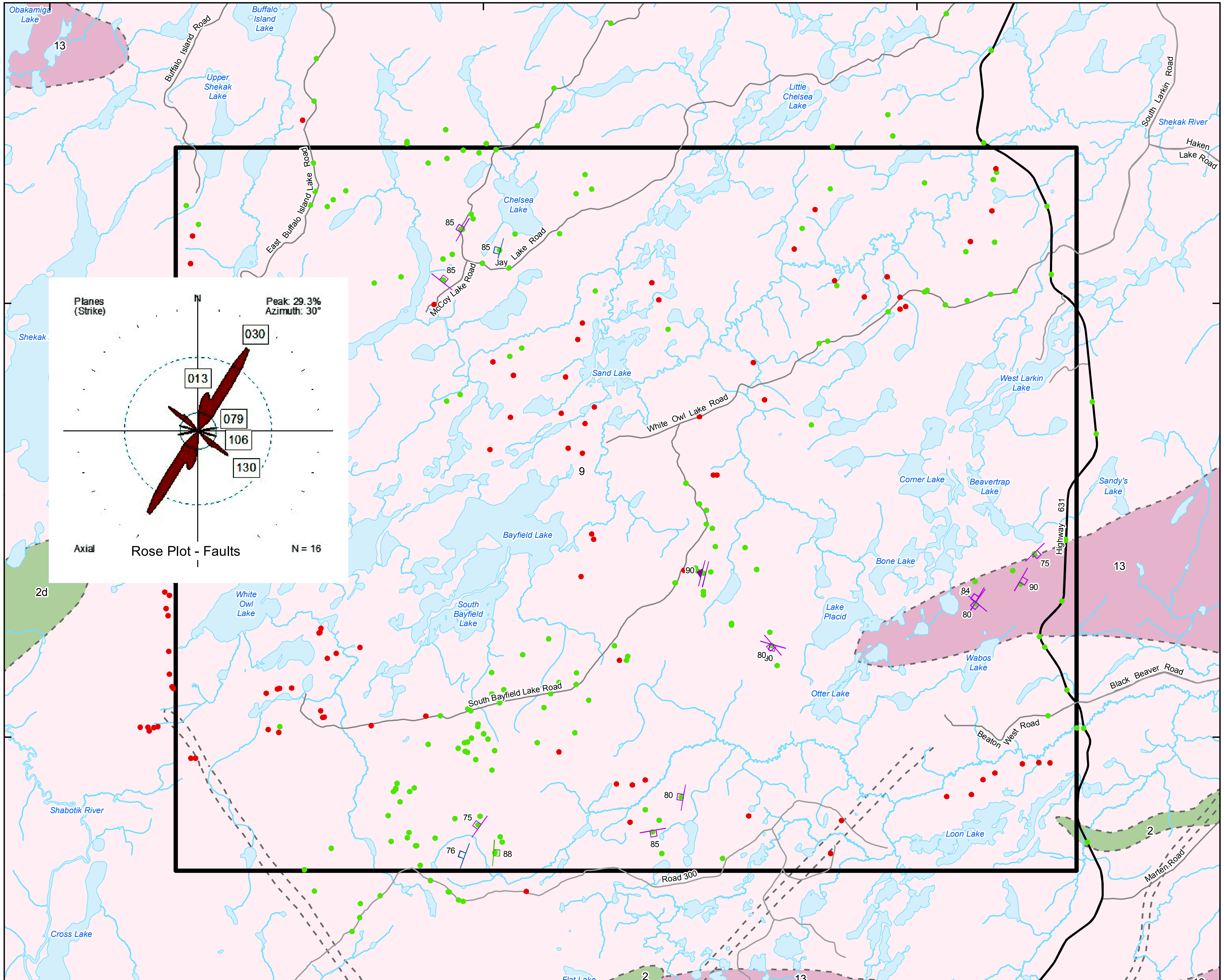
a)

b)

c)

<u>Figure 5.2.13: Black-Pic Batholith Area – Field Examples of Joints</u>

a – North and east trending, steeply dipping joints along with subhorizontal joints observed along road cut in tonalite-granodiorite. View to the southeast with scale card and GPS for scale (Station 14NP004).
b – Photo of jointing in tonalite with hammer for scale (Station 16HM0146)
c – Photo of single joint in tonalite. Plan view with book for scale (Station 16PG0060)



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PROJECT No. 10-214-12

NWMO Hornepayne Detailed Mapping Report

TITLE **Black-Pic Batholith Area - Faults and Veins**

FIGURE 5.2.14

DESIGN: ADG
CAD/GIS: ADG/NMP
CHECK: SNS
REV: 0
DATE: 27/06/2017

Geofirma Engineering Ltd

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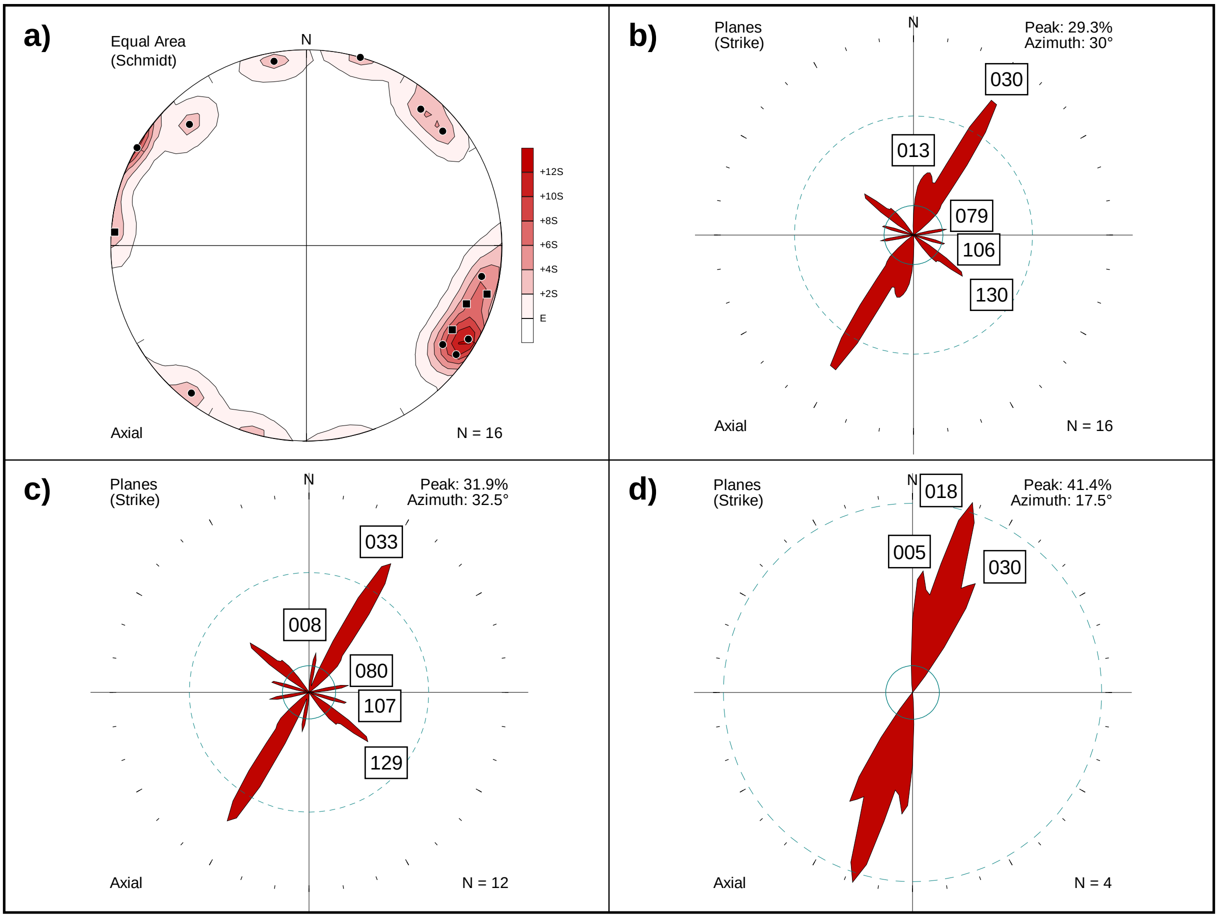


<u>Figure 5.2.15: Black-Pic Batholith Area – Fault Orientation Data</u>

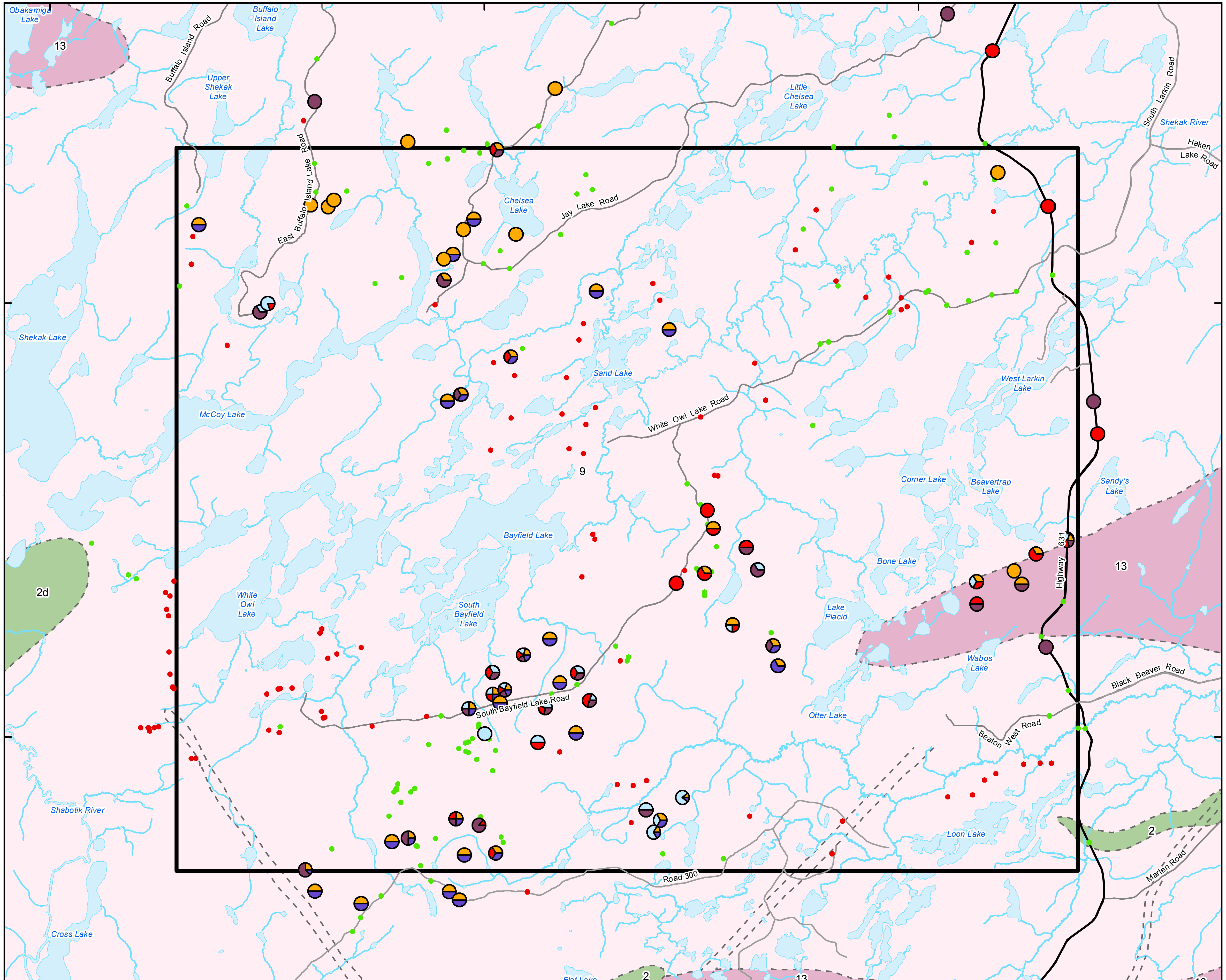
a – All fault data displayed as equal area lower hemisphere stereonet plot of poles to fault planes. Dextral faults: circles (N = 12). Sinistral faults: squares (N = 4).
b – All fault data displayed as rose diagram of trends of joint planes (N = 16)
c – Dextral fault data displayed as rose diagram of trends of fault planes (N = 12)
d – Sinistral fault data displayed as rose diagram of trends of fault planes (N = 4)

a)

b)

<u>Figure 5.2.16: Black-Pic Batholith Area – Field Examples of Faults</u>

a –. Photo showing decimetre scale offset of pegmatite dyke by sinistral fault. Plan view, scale card and compass for scale (Station 14NP080).
b – Epidote filled sinistral fault showing decimeter scale offset of pegmatite dyke in tonalite host rock. Scale card and GPS (Station 14NP082)



LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Watercourse
- Waterbody
- Outcrop (194)
- Overburden (89)

BEDROCK GEOLOGY

- 13: Granite-granodiorite
- 9: Gneissic tonalite suite
- 2: Mafic metavolcanic Rocks
- Bedrock Geology Outline

SECONDARY ALTERATIONS

- Quartz
- Chlorite
- Epidode
- Hematite
- K-Feldspar

INDEX MAP

Hornepayne

SCALE 1:90,000

0 0.5 1 2 3 4

Kilometres

N

PROJECTION: UTM NAD83 Zone 16N
SOURCE: NWMO, MNR, obtained 2010-2016, ESRI 2016
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PROJECT No. 10-214-12

NWMO Hornepayne
Detailed Mapping Report

TITLE

Black-Pic Batholith Area - Secondary Minerals and Alteration

FIGURE 5.2.17

DESIGN: ADG
CAD/GIS: ADG/NMP
CHECK: SNS
REV: 0
DATE: 15/05/2017

Geofirma Engineering Ltd

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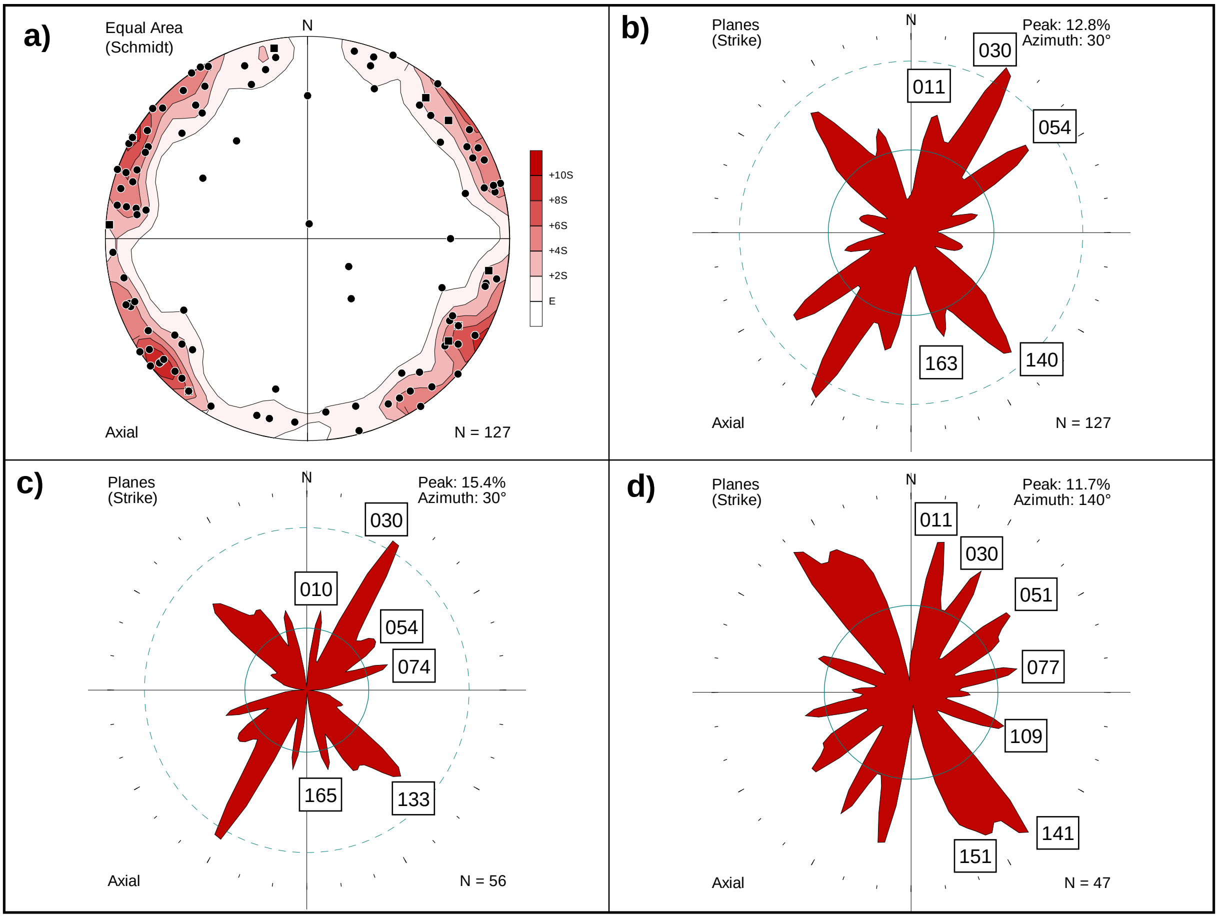


Figure 5.2.18: Black-Pic Batholith Area – Secondary Minerals and Alteration Data

a – All fractures with observed mineralization/alteration displayed as lower hemisphere stereonet plot of poles (N = 127). Poles to joint planes: circles (N = 118). Poles to fault planes: squares (N = 9).
b – All fractures with observed mineralization/alteration displayed as rose diagram of trends of joint/fault planes (N = 127).
c – Fractures with observed hematite mineralization/alteration displayed as rose diagram of trends of joint/fault planes (N = 56).
d – Fractures with observed chlorite mineralization/alteration displayed as rose diagram of trends of joint/fault planes (N = 44).

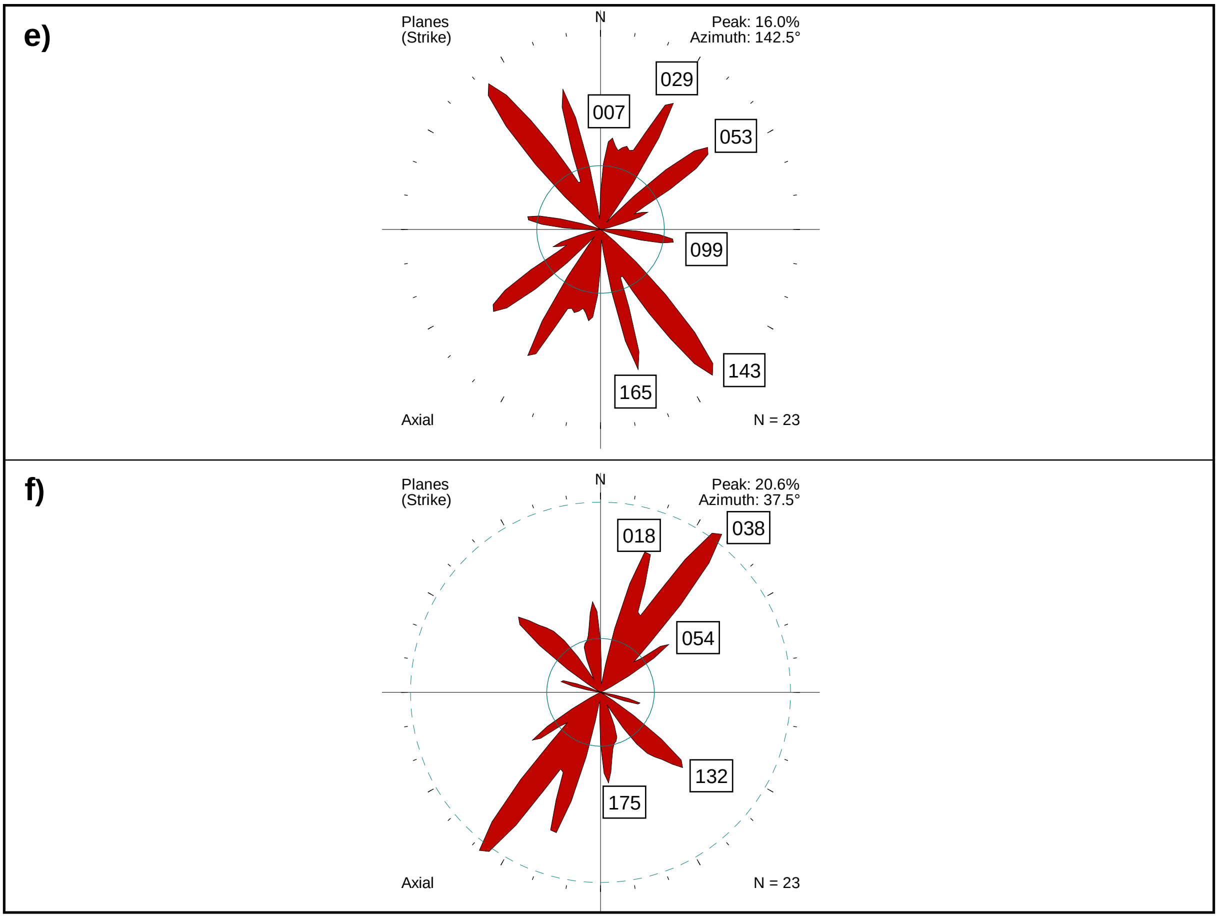


Figure 5.2.18: Black-Pic Batholith Area – Secondary Minerals and Alteration Data

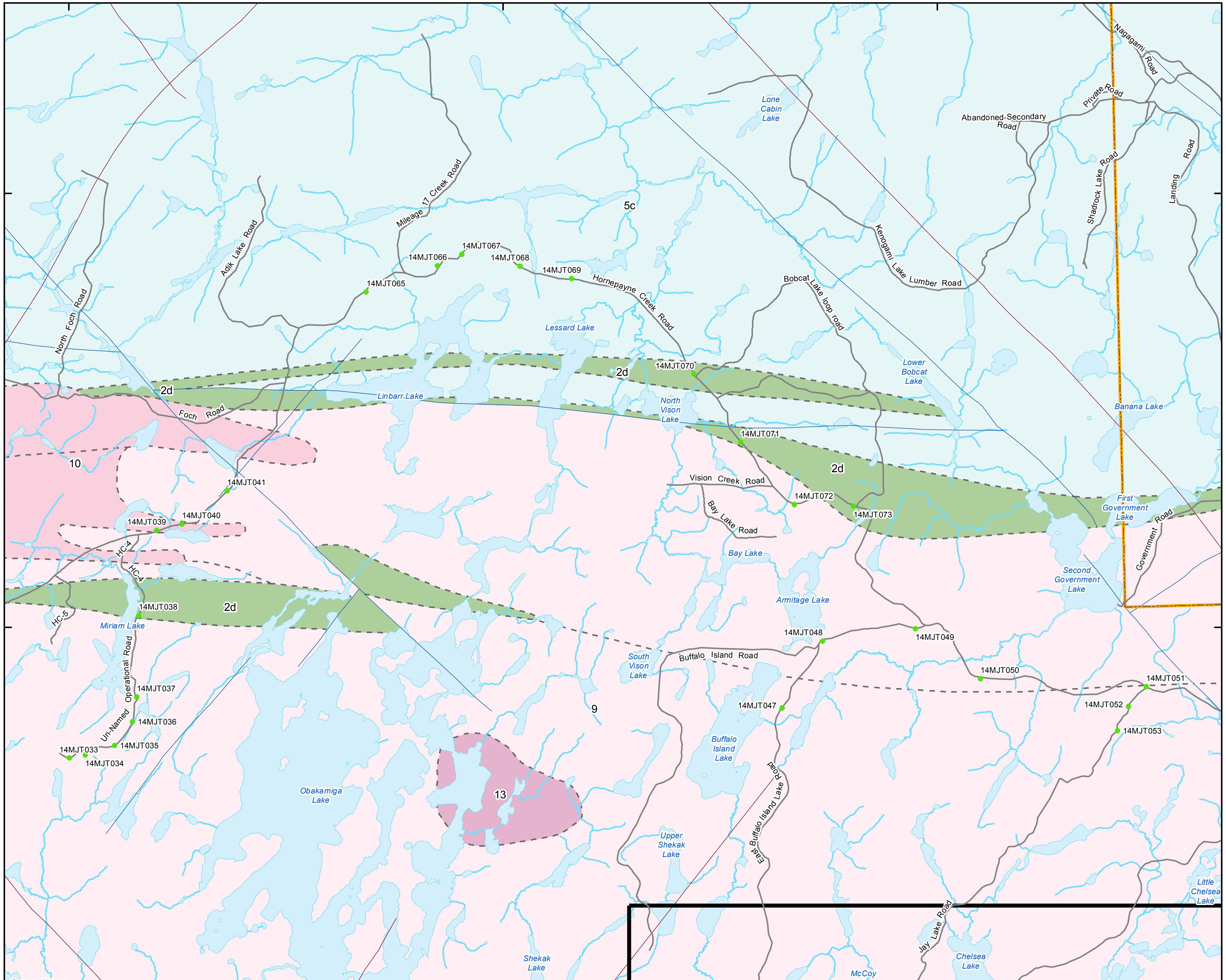
e – Fractures with observed epidote mineralization/alteration displayed as rose diagram of trends of joint/fault planes (N = 23).
f – Fractures with observed quartz and/or k-feldspar mineralization/alteration displayed as rose diagram of trends of joint/fault planes (N = 23).

a)

b)

Figure 5.2.19: Black-Pic Batholith Area – Field Examples Secondary Mineralization or Alteration

a – Photograph of hematite staining on mafic dyke. Plan view and field book for scale (Station 16PG0042).
b – Hematite and epidote staining on joint surfaces. Plan view with scale card for scale (Station 14NP079)



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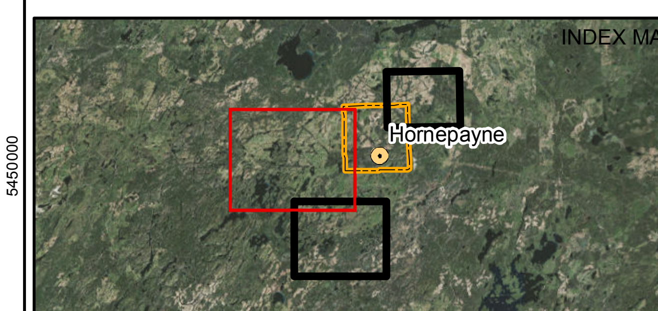
LEGEND

- Withdrawal Area
- Hornepayne Municipal Boundary
- Local Road
- Watercourse
- Waterbody
- Mapped OGS Dykes
- Mapped OGS Faults
- Outcrop (25)

BEDROCK GEOLOGY

- 13: Granite-granodiorite
- 10: Foliated tonalite suite
- 9: Gneissic tonalite suite
- 5: Metasedimentary rocks
- 2: Mafic metavolcanic Rocks
- Bedrock Geology Outline



SCALE 1:90,000

0 0.5 1 2 3 4
Kilometres

N

PROJECTION: UTM NAD83 Zone 16N
SOURCE: NWMO, MNR, obtained 2010-2016, ESRI 2016
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PROJECT No. 10-214-12

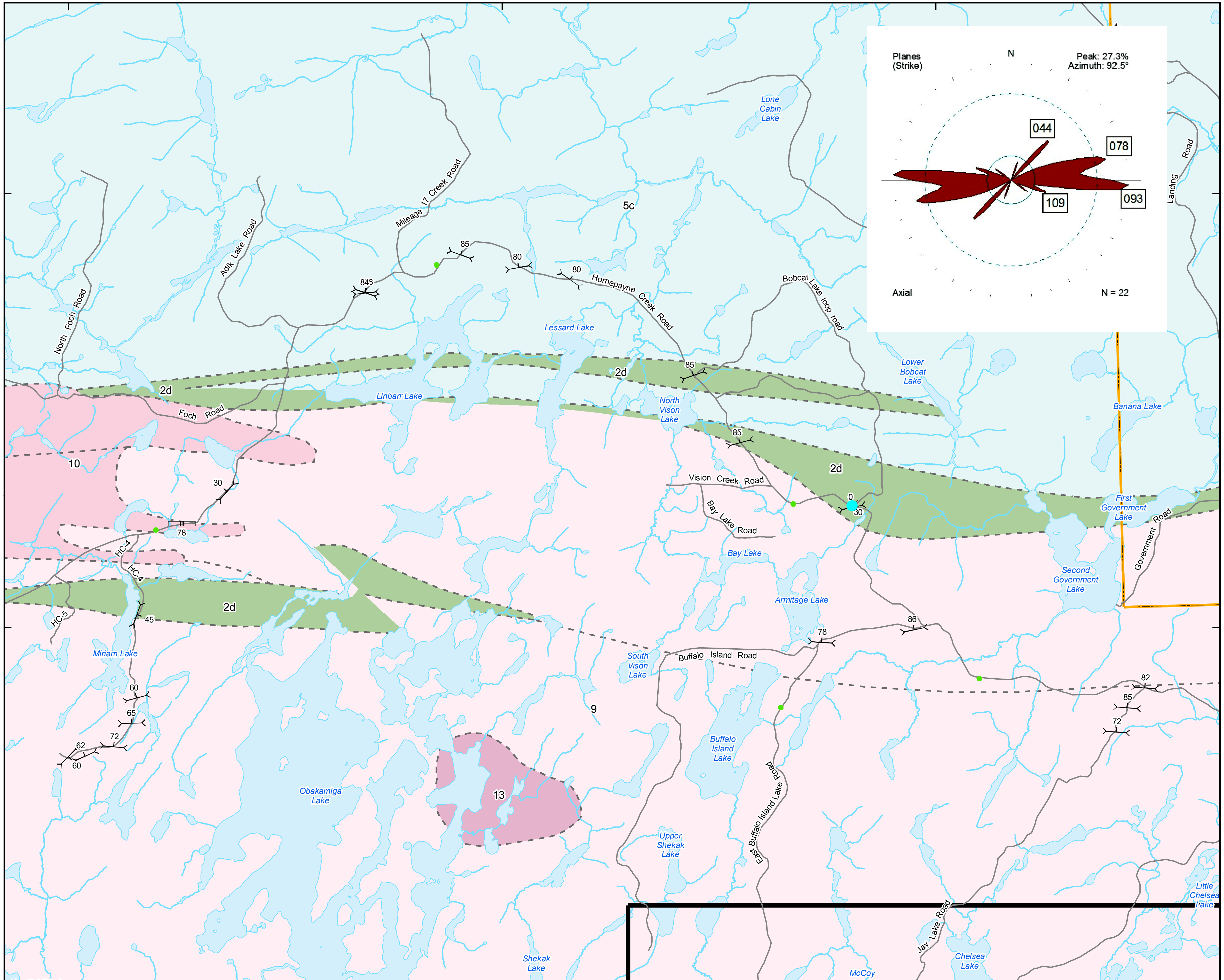
NWMO Hornepayne
Detailed Mapping Report

TITLE **Subprovince Boundary Zone - Mapping Observation Locations**

FIGURE 5.3.1

DESIGN: ADG
CAD/GIS: ADG/NMP
CHECK: SNS
REV: 0
DATE: 15/05/2017

Geofirma Engineering Ltd

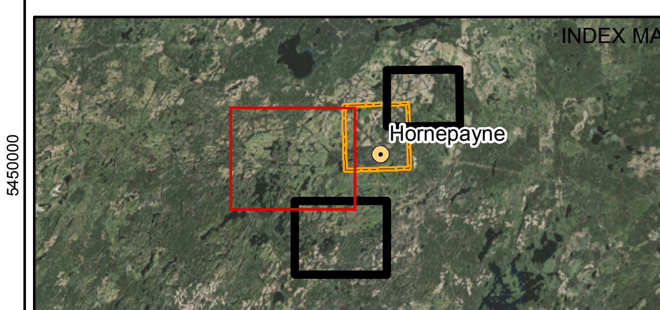


LEGEND

- Withdrawal Area
- Hornepayne Municipal Boundary
- Local Road
- Watercourse
- Waterbody
- Outcrop (25)
- Foliation (20)
- Igneous-Layering (1)
- Lineation (1)

BEDROCK GEOLOGY

- 13: Granite-granodiorite
- 10: Foliated tonalite suite
- 9: Gneissic tonalite suite
- 5: Metasedimentary rocks
- 2: Mafic metavolcanic Rocks
- Bedrock Geology Outline



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Kilometres

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PROJECTION: UTM NAD83 Zone 16N
SOURCE: NWMO, MNR, obtained 2010-2016, ESRI 2016
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PROJECT No. 10-214-12

NWMO Hornepayne
Detailed Mapping Report

TITLE **Subprovince Boundary Zone - Foliation**

FIGURE 5.3.2

DESIGN: ADG
CAD/GIS: ADG/NMP
CHECK: SNS
REV: 0
DATE: 26/06/2017

Geofirma Engineering Ltd

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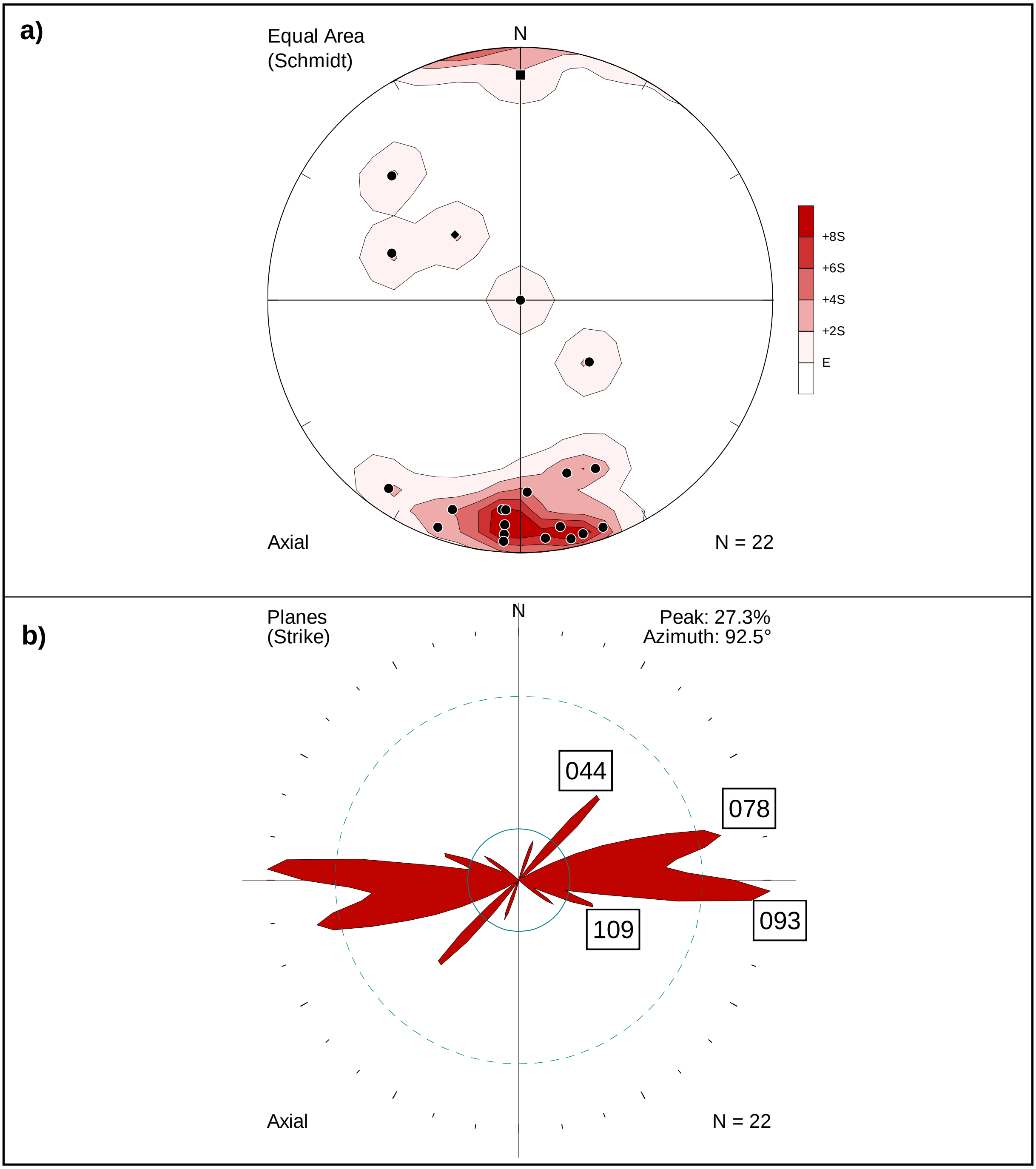
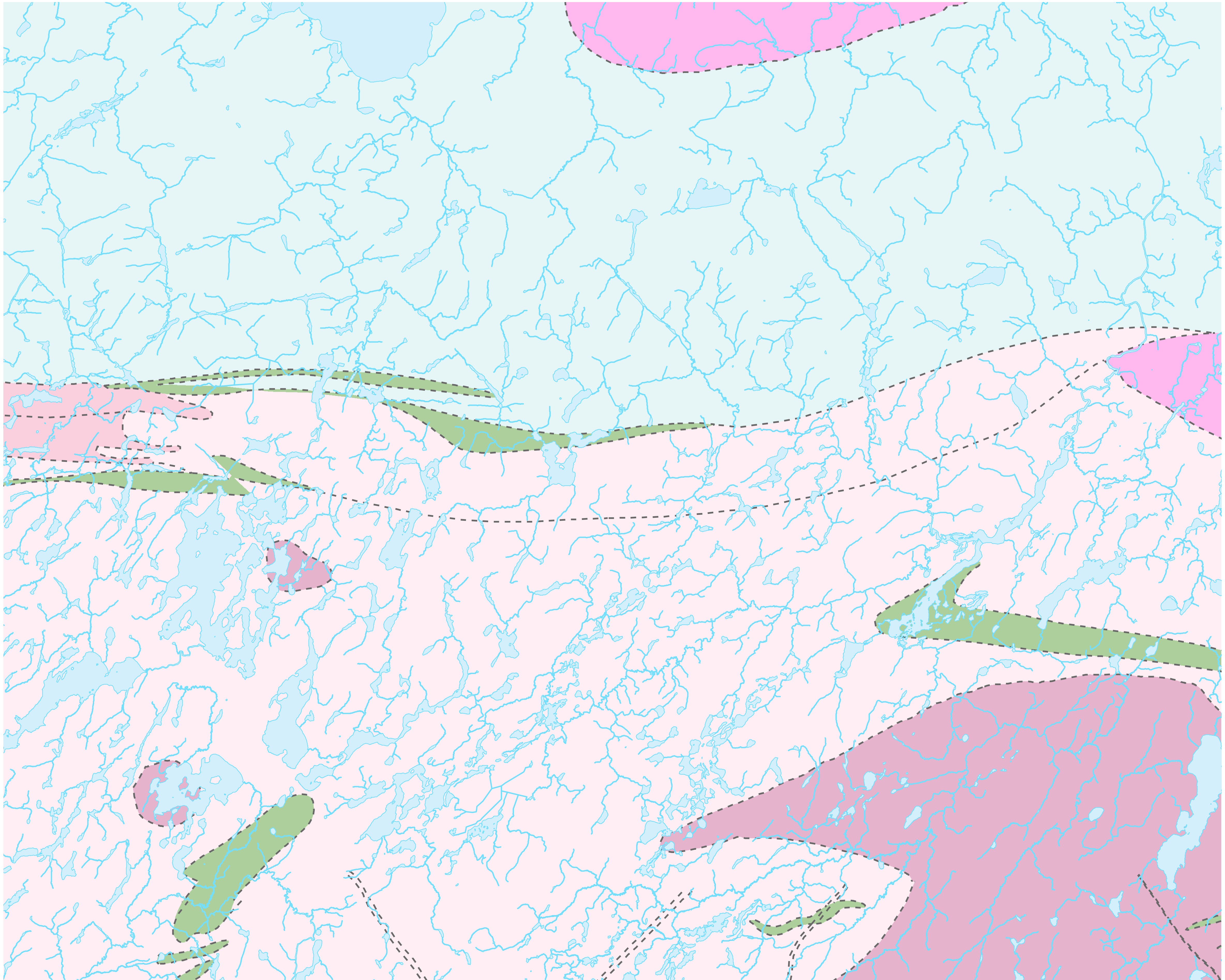
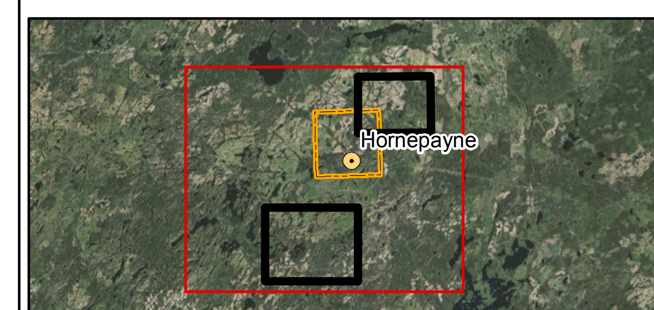


Figure 5.3.3: Subprovince Boundary Zone – Foliation Orientation Data

a – All foliation data displayed as equal area lower hemisphere stereonet plot of poles to foliation planes. Tectonic foliation: circle (N=20); igneous flow foliation: square (N=1); lineation - fold hinge: diamond (N=1).
b – All foliation data displayed as rose diagram of trends of foliation planes (N=22)




Hornepayne

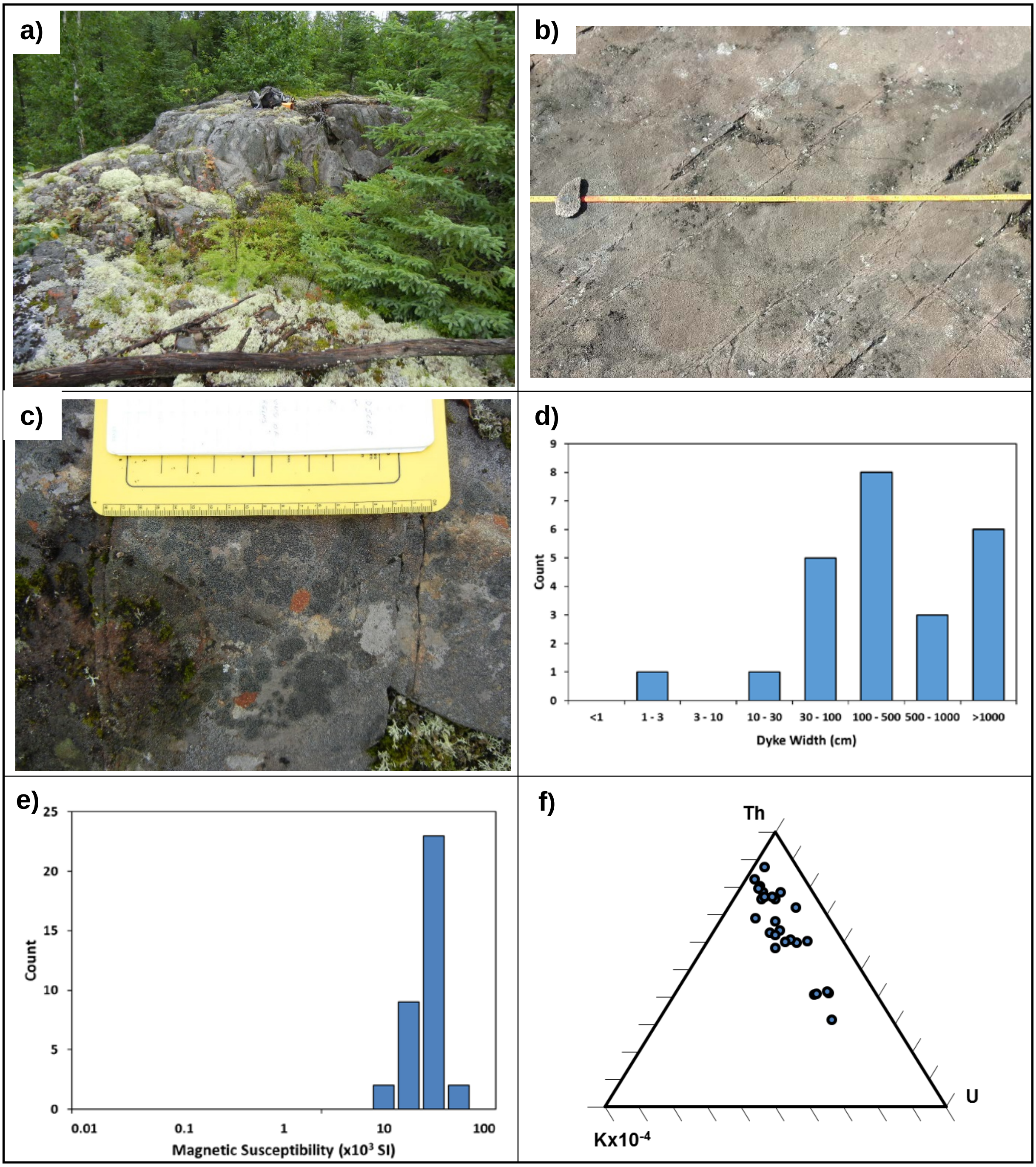


Figure 5.4.1.1: Matachewan Mafic Dykes – General Properties

a – Large outcrop exposure of Matachewan mafic dyke within granodiorite host rock. Station 16PG0137, looking north, gamma spectrometer for scale.
b – Representative texture and composition of the Matachewan mafic dyke set. Station 16HM054, plan view, tape for scale.
c – Close-up photo of mafic dyke surface, representing typical weathered surface texture. Station 16PG0137, looking northeast, field book for scale
d – Histogram showing frequency distribution of Matachewan mafic dyke width (N = 24)
e – Logarithmic histogram of magnetic susceptibility for Matachewan mafic dykes. (N = 36)
f – Ternary plot of gamma ray spectrometer data for Matachewan mafic dykes. (N = 27).

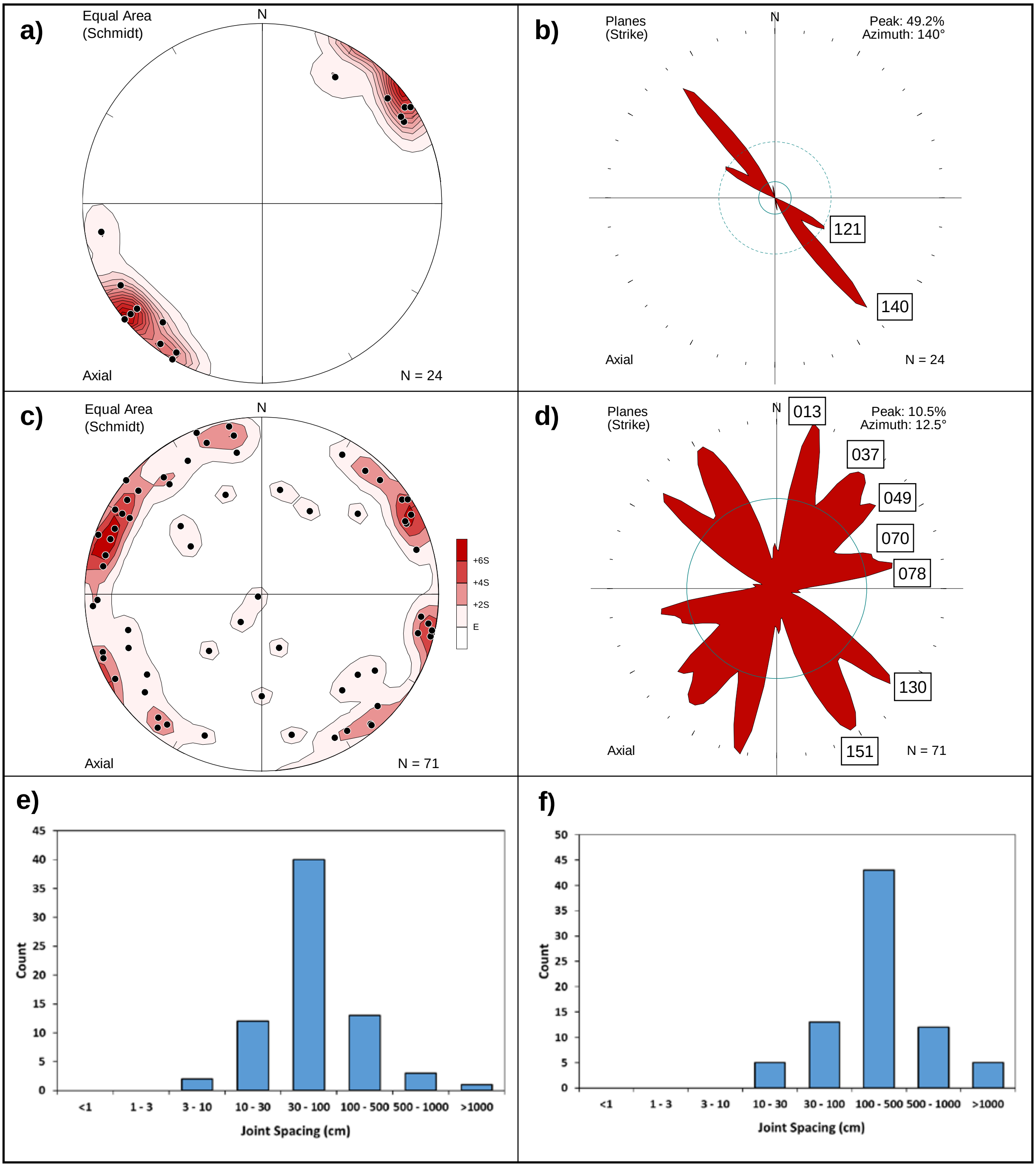


Figure 5.4.1.2: Matachewan Mafic Dykes – Structure

a – All mapped Matachewan mafic dyke contact orientations. Displayed as equal area lower hemisphere stereonet plot of poles to planes. (N = 24)
b – All mapped Matachewan mafic dyke contact orientations. Displayed as rose diagram of trends of planes. (N = 24)
c – All joints measured in Matachewan mafic dykes. Displayed as equal area lower hemisphere stereonet plot of poles to plans. (N = 71)
d – All joints measured in Matachewan mafic dykes. Displayed as rose diagram of trends of planes. (N = 71)
e – Histogram showing frequency distribution of joint spacing in Matachewan mafic dykes (N = 71)
f – Histogram showing frequency distribution of joint spacing in host rocks adjacent to Matachewan mafic dykes. (N = 78)

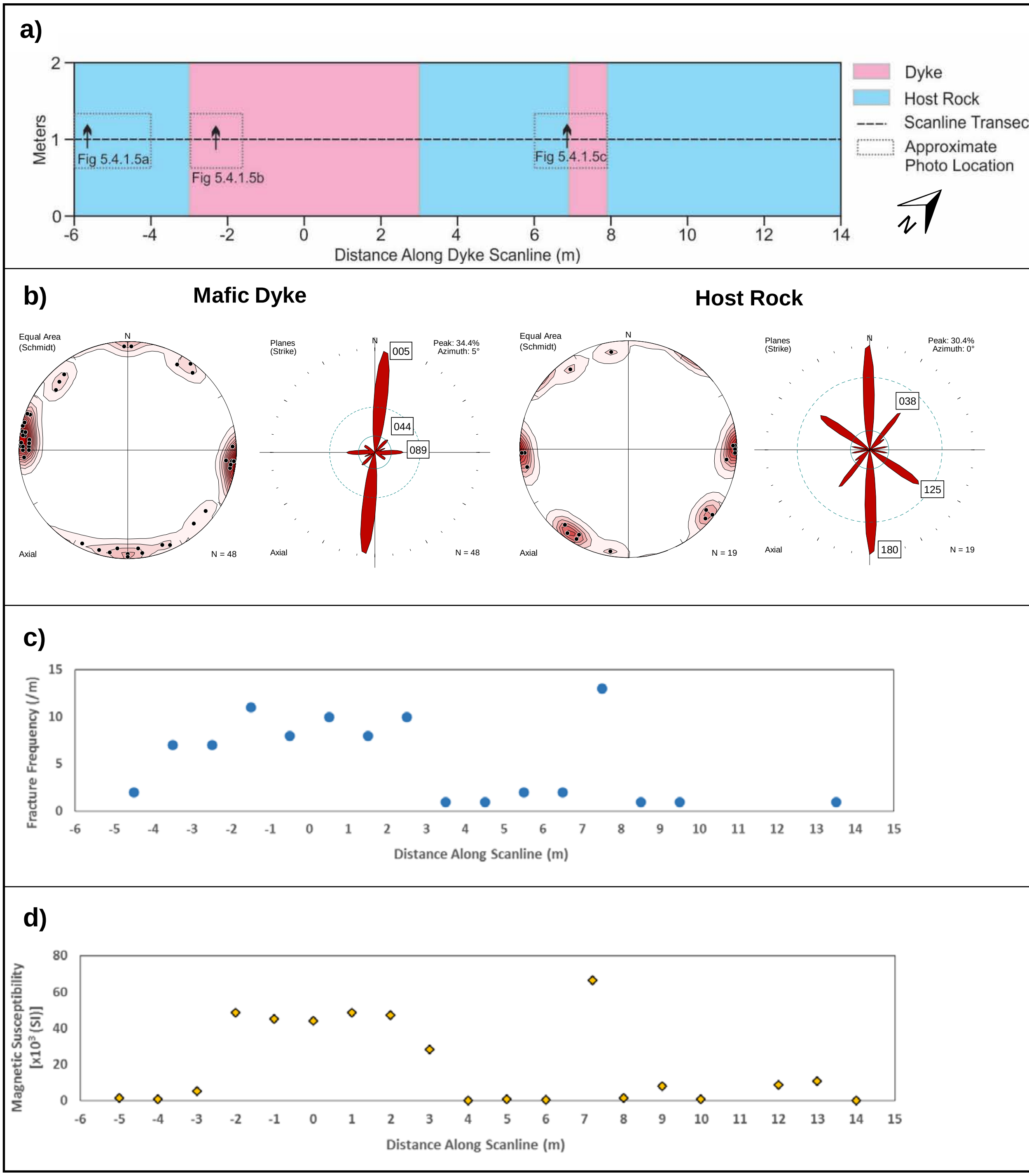
a)

b)

c)

<u>Figure 5.4.1.3: Matachewan Mafic Dykes – Field Examples of Structural Features</u>

a – Mafic dyke contact, cross-cutting granite. Station 16HM0046, looking north, card for scale.
b – Mafic dyke contact, cross-cutting granite displaying closely spaced jointing within the dyke. Station 16HM0054, plan view with pencil oriented north, card for scale.
c – Smaller mafic dyke cross-cutting migmatitic metasedimentary rock. Station 16PG0208, looking northwest, field book for scale.



<u>Figure 5.4.1.4: Matachewan Mafic Dykes – Composite Summary of Scanline Results</u>

a – Schematic drawing of Matachewan mafic dyke scanline transect.
b – All joints in Matachewan mafic dyke (N = 48) and adjacent host rock (N = 19) displayed as equal area lower hemisphere stereonet plot of poles to planes and rose diagrams of trends of planes.
c – Fracture frequency (joints) per metre interval in the mafic dyke scanline transect.
d – Magnetic susceptibility measurements along mafic dyke scanline transect.

a)

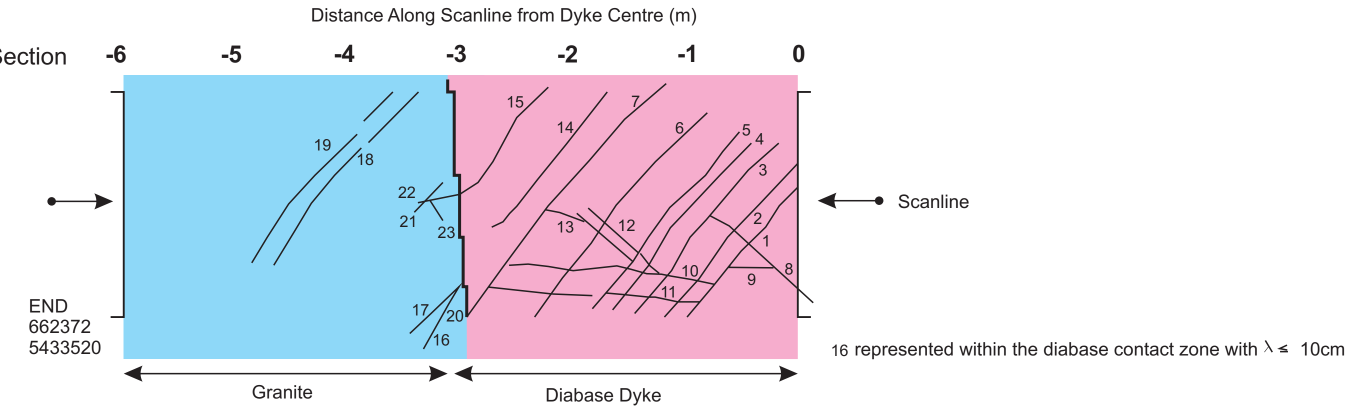
b)

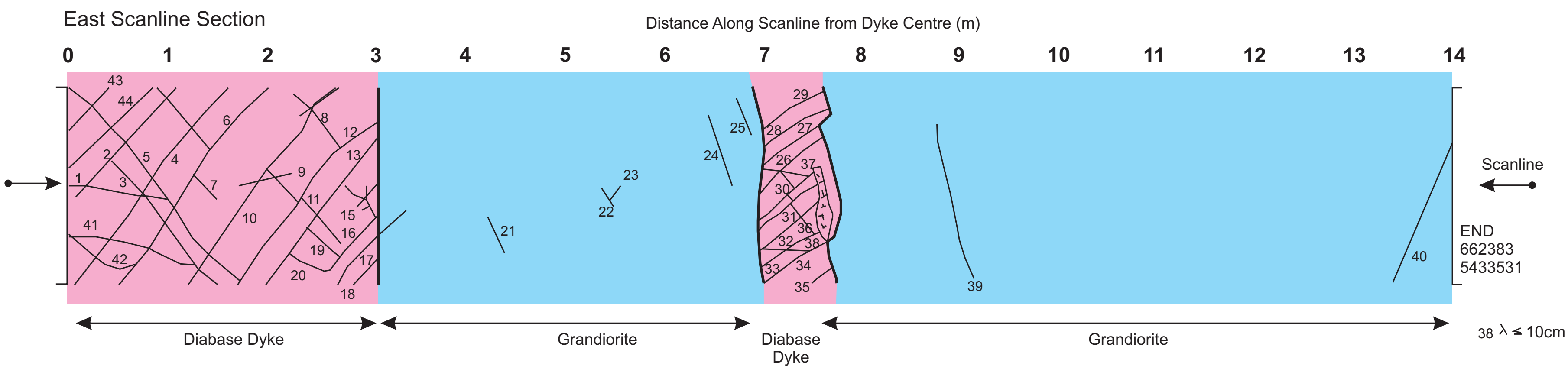
c)

Figure 5.4.1.5: Matachewan Mafic Dykes – Scanline Field Photos (Station 16HM0054)

a - Tonalite host rock, chainage -6 to -5 m.
b – Large mafic dyke hosted in in tonalite, chainage -3 to -2 m.
c - Small mafic dyke hosted in tonalite, chainage 6-7 m.

MATACHEWAN DYKE (Northwest Striking)
Daily Traverse #41 (Station 16HM0044) - September 4, 2016





Matachewan Mafic Dykes - Detailed Scanline Sketch NWMO Hornepayne Detailed Mapping Report		Prepared by: ADG Reviewed by: SNS Date: Feb 17, 2017
FIGURE 5.4.1.6	Doc. No.: "P:\Projects\2010\10-214 NWMO APM Site Screening\10-214-12 Hornepayne Detailed Mapping\30 Deliverables\30.10 Mapping Report\Figures\Working Figures\Hornepayne_Fig5_4_1_6_Matachewan_Scanlines.cdr"	

Scale: 1mm = 10cm

Geofirma Engineering Ltd

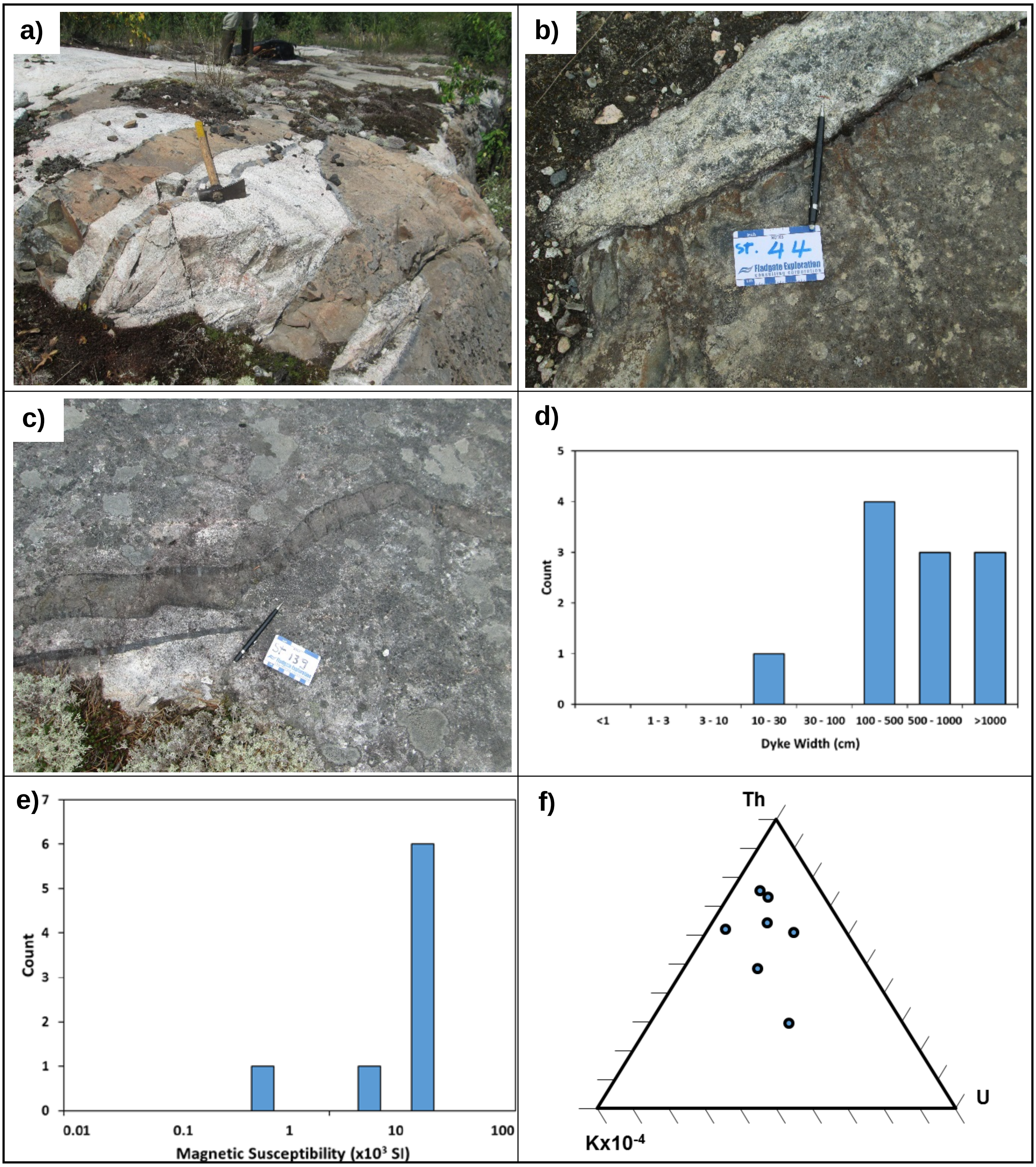


Figure 5.4.2.1: Biscotasing Mafic Dykes – General Properties

a –.Outcrop exposure of Biscotasing mafic dyke swarm cross cutting tonalite gneiss. Station 16HM0142, looking north, hammer for scale.
b – Representative texture and composition of the Biscotasing mafic dyke set, cross cutting tonalite. Station 16HM0044, looking north, card for scale
c – Photograph showing aphanitic Biscotasing mafic dykelet with chill margins cross cutting tonalite. Station 16HM0139, plan view with pencil and scale card for scale.
d – Histogram showing frequency distribution of Biscotasing mafic dyke width (N = 11)
e – Logarithmic histogram of magnetic susceptibility for Biscotasing mafic dykes (N = 8)
f – Ternary plot of gamma ray spectrometer data for Biscotasing mafic dykes (N = 7).

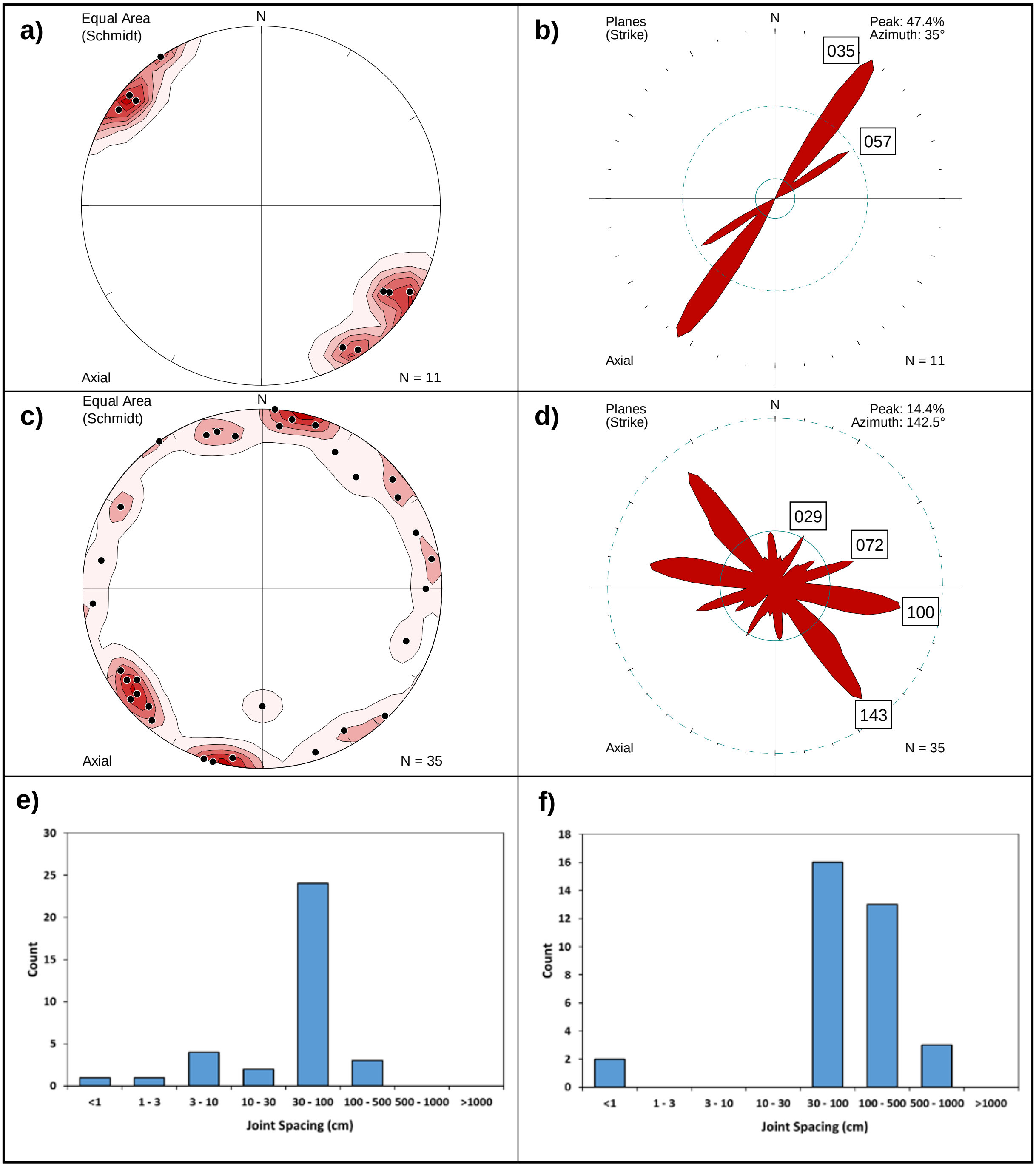


Figure 5.4.2.2: Biscotasing Mafic Dykes – Structure

a – All mapped Biscotasing mafic dyke contact orientations. Displayed as equal area lower hemisphere stereonet plot of poles to planes. (N = 11)
b – All mapped Biscotasing mafic dyke contact orientations. Displayed as rose diagram of trends of planes. (N = 11)
c – All joints measured in Biscotasing mafic dykes. Displayed as equal area lower hemisphere stereonet plot of poles to plans. (N=35)
d – All joints measured in Biscotasing mafic dykes. Displayed as rose diagram of trends of planes. (N = 35)
e – Histogram showing frequency distribution of joint spacing in Biscotasing mafic dykes (N = 35)
f – Histogram showing frequency distribution of joint spacing in host rocks adjacent to Biscotasing mafic dykes. (N = 34)

a)

b)

<u>Figure 5.4.2.3: Biscotasing Mafic Dykes – Field Examples of Structural Features</u>

a – Contact with tonalite host rock. Station 16PG0057, looking north, card for scale.
b – Thin, fine grained mafic dyke cross cutting strongly foliated migmatitic metasedimentary rock. Station 16PG0143, looking southwest, field book for scale.

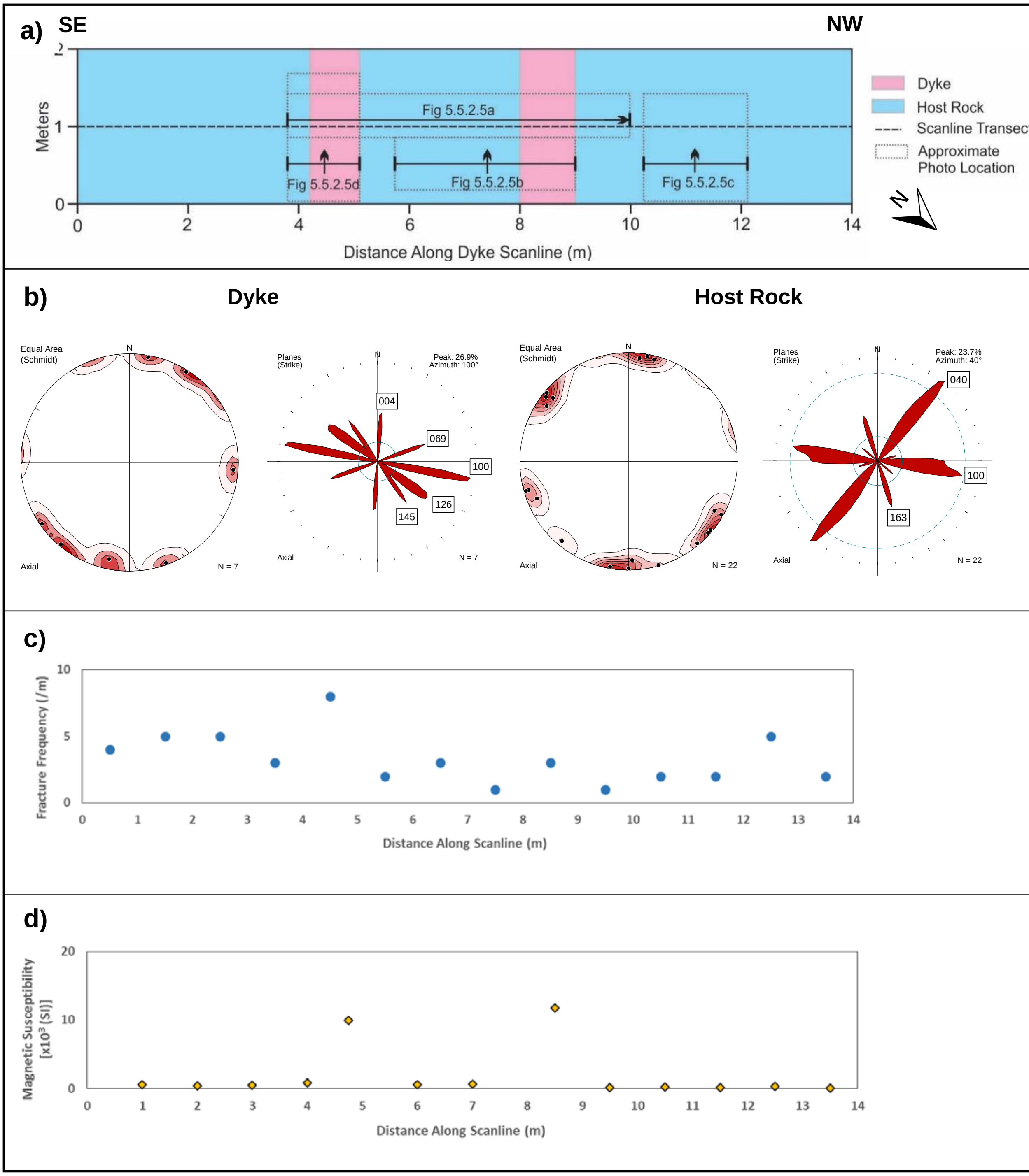


Figure 5.4.2.4: Biscotasing Mafic Dykes – Composite Summary of Scanline Results

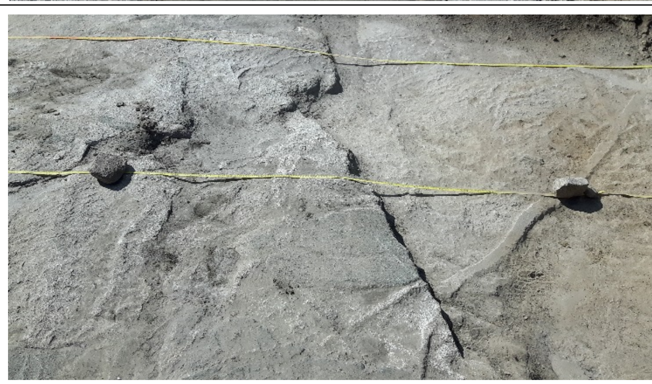
a – Schematic drawing of Biscotasing mafic dyke scanline transect.
b – All joints in Biscotasing mafic dyke and adjacent host rock displayed as equal area lower hemisphere stereonet plot of poles to planes and rose diagrams of trends of planes.
c – Fracture frequency (joints) per metre interval in the mafic dyke scanline transect.
d – Magnetic susceptibility measurements along mafic dyke scanline transect.

a)

b)

c)

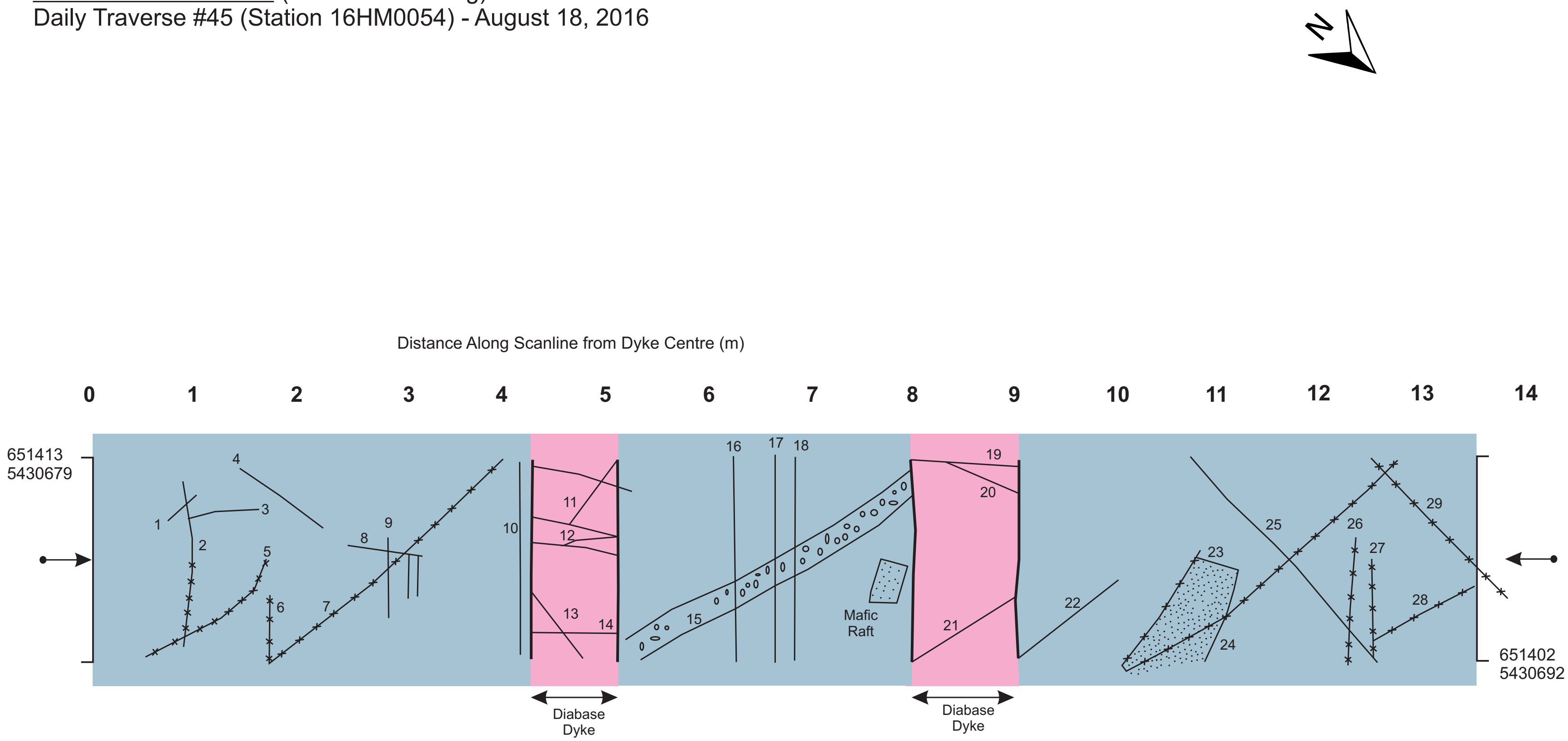
d)



<u>Figure 5.4.2.5: Biscotasing Mafic Dykes – Scanline Field Photos (Station 16HM044)</u>

a – Moderate size mafic dykes cross-cutting tonalite gneiss, chainage 4-10 m; long view of scanline outcrop, looking northwest.
b – Moderate size mafic dyke cross-cutting tonalite gneiss, chainage 9 - 6 m, long view of scanline outcrop, looking southeast.
c – Moderate size mafic dyke cross-cutting tonalite gneiss, chainage 4-5 m.
d – Larger mafic dyke cross-cutting tonalite gneiss, chainage 10-12 m.

BISCOTASING DYKE (Northeast Striking)
Daily Traverse #45 (Station 16HM0054) - August 18, 2016



Scale: 1mm = 10cm

Biscotasing Mafic Dykes - Detailed Scanline Sketch **NWMO Hornepayne Detailed Mapping Report**	Prepared by: ADG
FIGURE 5.4.2.6 Doc. No.: "P:\Projects\2010\10-214 NWMO APM Site Screening\10-214-12 Hornepayne Detailed Mapping\30 Deliverables\30.10 Mapping Report\Figures\Working Figures\Hornepayne_Fig5_4_2_6_Biscotasing_Scanlines.cdr"	Reviewed by: SNS Date: Feb 17, 2017

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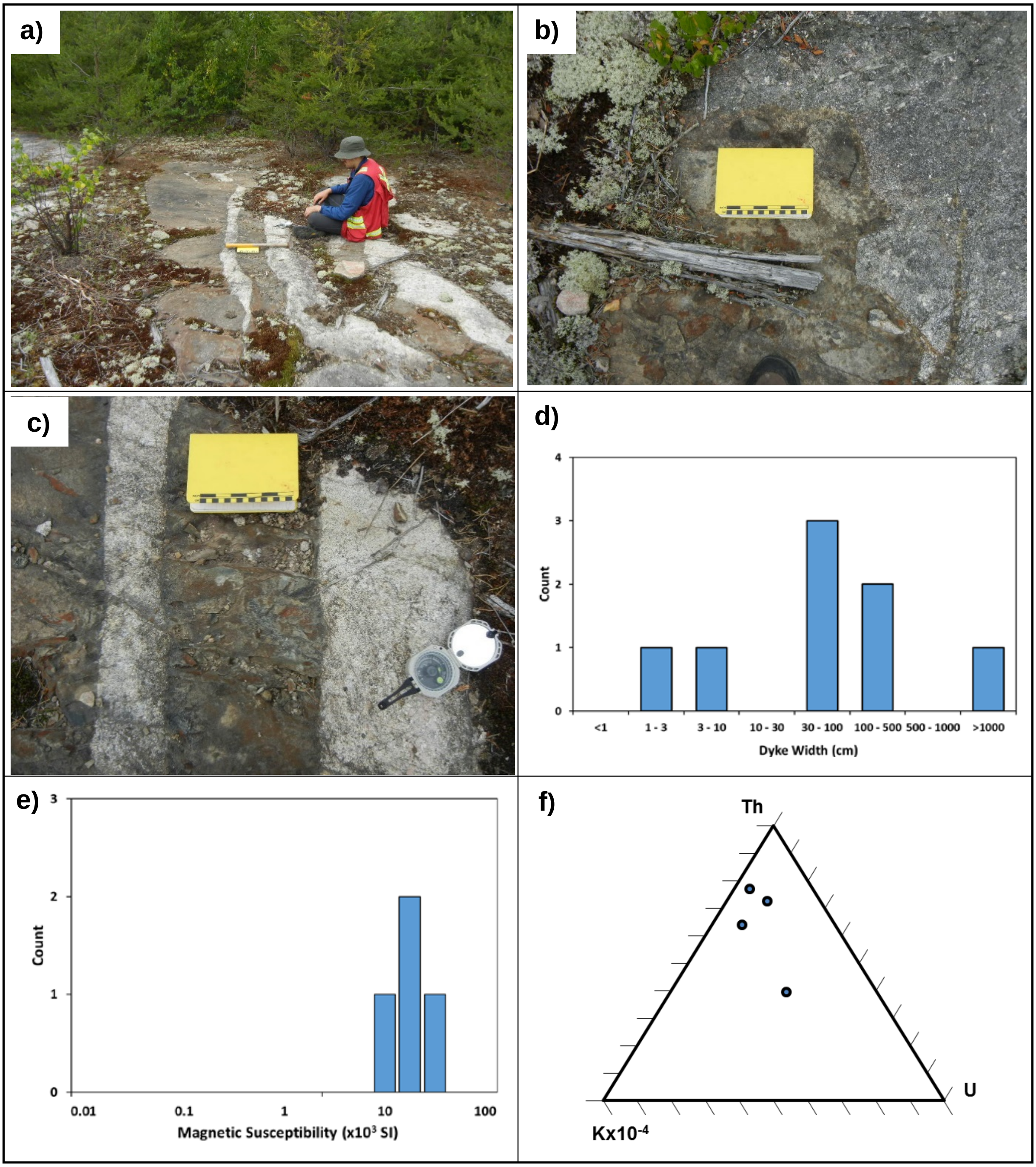
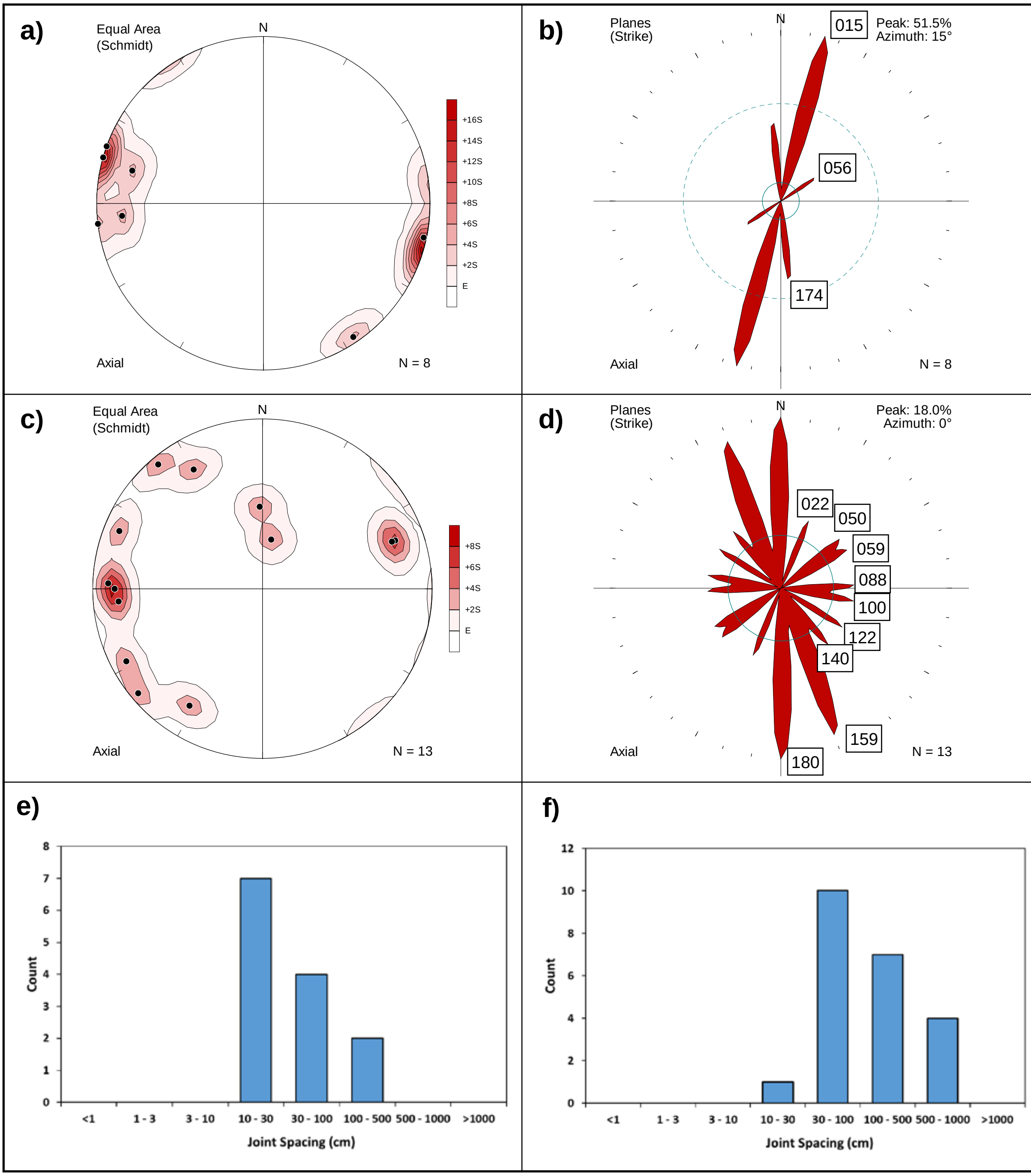


Figure 5.4.3.1: Marathon Mafic Dykes – General Properties

a – Typical outcrop exposure of Marathon mafic dyke, cross-cutting tonalite gneiss. Station 16PG0042, looking west, person for scale.
b – Representative texture and composition of larger Marathon mafic dykes. Station16PG0042, looking west, field book for scale.
c – Photo of weathered mafic dyke with hematite staining cross-cutting tonalite gneiss. Station 16PG0042, plan view with compass pointed north, field book for scale
d – Histogram showing frequency distribution of Marathon mafic dyke width (N = 8)
e – Logarithmic histogram of magnetic susceptibility for Marathon mafic dykes (N = 4)
f – Ternary plot of gamma ray spectrometer data for Marathon mafic dykes (N = 4).



<u>Figure 5.4.3.2: Marathon Mafic Dykes – Structure</u>

a – All mapped Marathon mafic dyke contact orientations. Displayed as equal area lower hemisphere stereonet plot of poles to planes. (N = 8)
b – All mapped Marathon mafic dyke contact orientations. Displayed as rose diagram of trends of planes. (N = 8)
c – All joints measured in Marathon mafic dykes. Displayed as equal area lower hemisphere stereonet plot of poles to plans. (N = 13)
d – All joints measured in Marathon mafic dykes. Displayed as rose diagram of trends of planes. (N = 13)
e – Histogram showing frequency distribution of joint spacing in Marathon mafic dykes (N = 13)
f – Histogram showing frequency distribution of joint spacing in host rocks adjacent to Marathon mafic dykes. (N = 22)

a)

b)

c)

Figure 5.4.3.3: Marathon Mafic Dykes – Field Examples of Structural Features

a – Lenses of tonalite incorporated into a large composite mafic dyke. Station 16PG0042, looking west, field book for scale.
b - Photo of mafic dyke chilled margin hosted in granodiorite. Station 16PG0097 – plan view, pencil pointed toward north (left), card for scale.
c – Aphanitic mafic dyklet cross-cutting migmatitic metasedimentary rock. Station 16PG0145

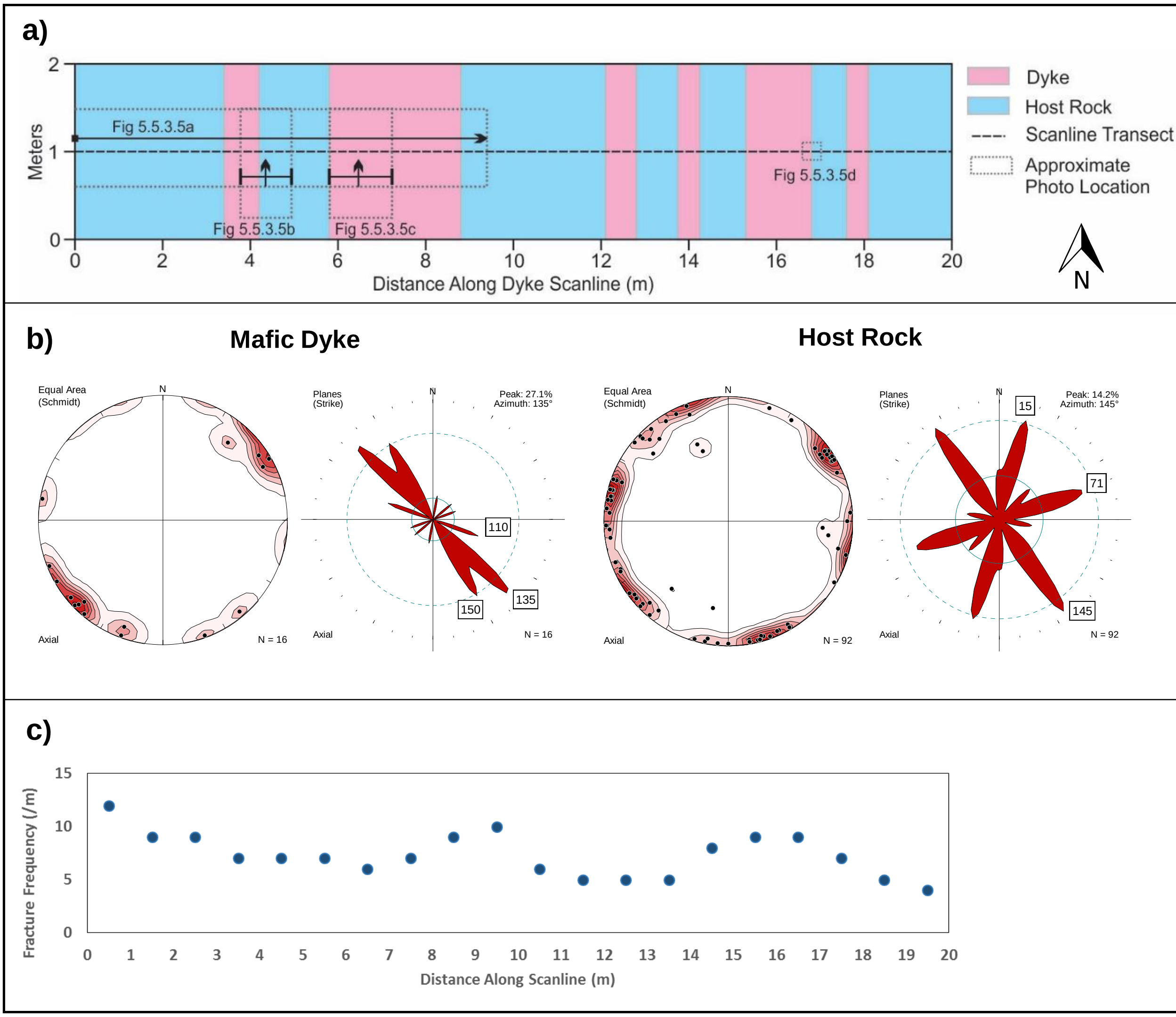


Figure 5.4.3.4: Marathon Mafic Dykes – Composite Summary of Scanline Results

a – Schematic drawing of Marathon dyke scanline transect.
b – All joints in Marathon dyke and adjacent host rock displayed as equal area lower hemisphere stereonet plot of poles to planes and rose diagrams of trends of planes.
c – Fracture frequency (joints) per metre interval in the dyke scanline transect.

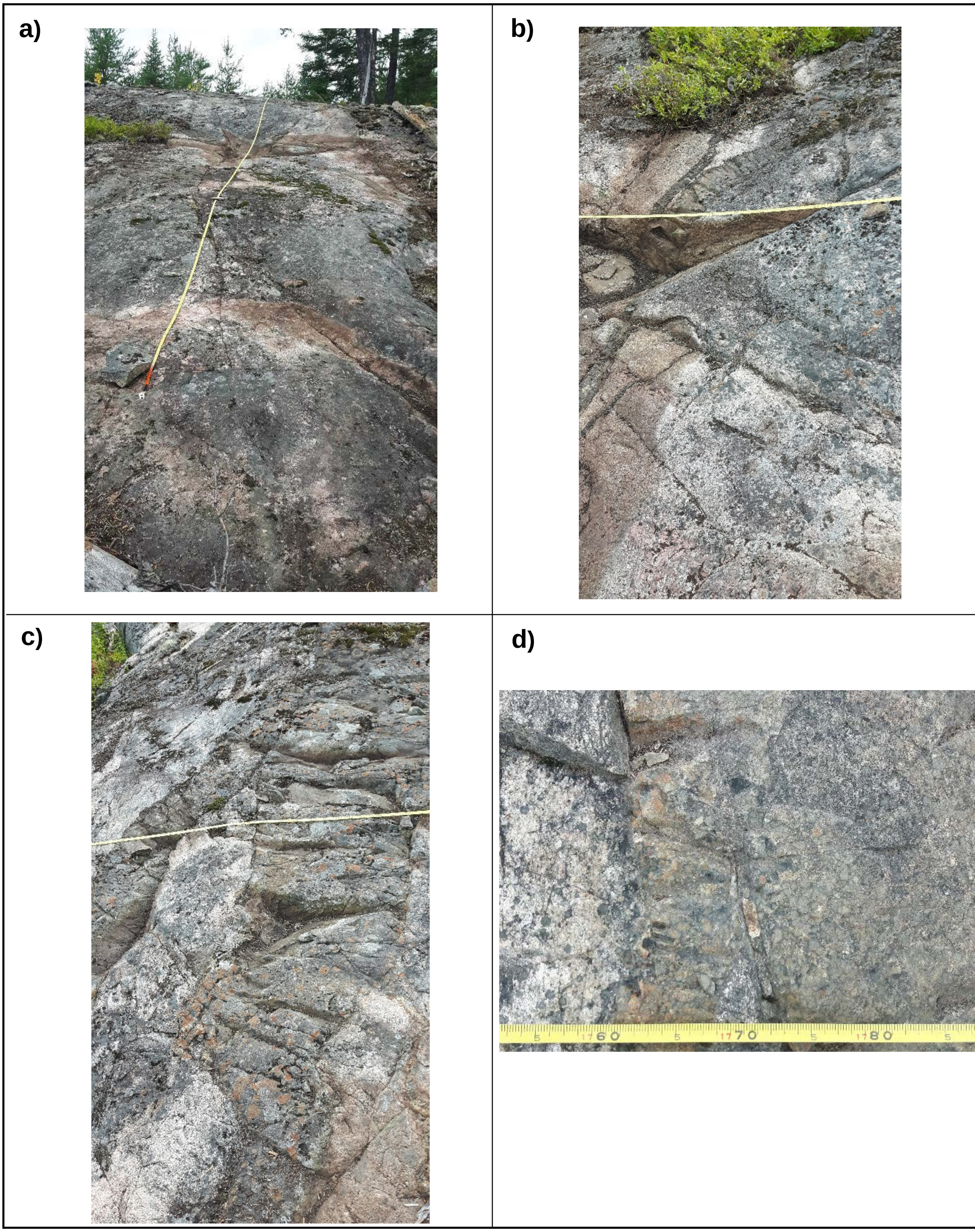
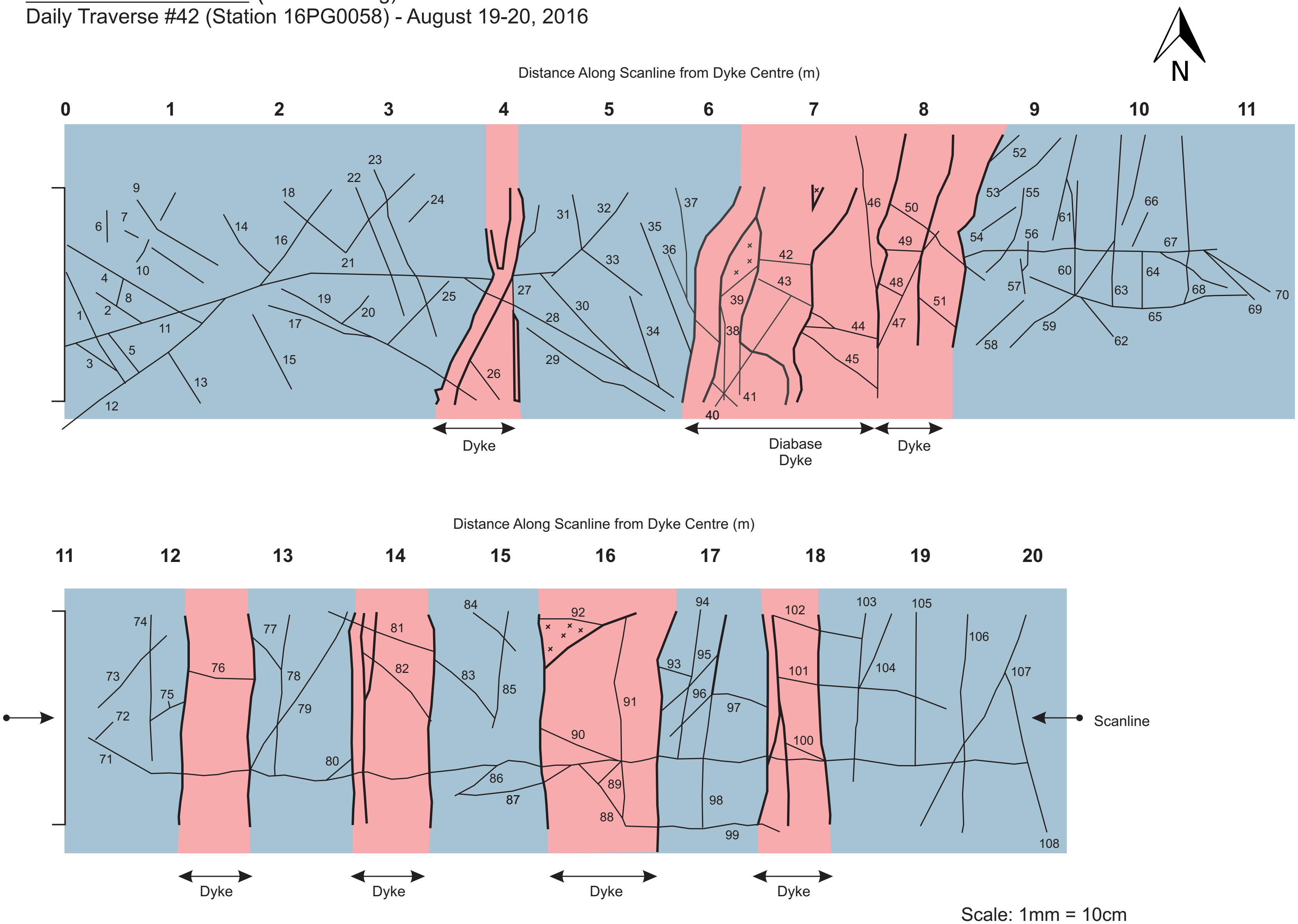


Figure 5.4.3.5: Marathon Mafic Dykes – Scanline Field Photos (Station 16PG0058)

a – Massive tonalite outcrop, long view of scanline outcrop.
b – Tonalite outcrop hosting thin mafic dykelet, chainage 4-5 m.
c – Tonalite outcrop hosting medium size bifurcating mafic dykes, chainage 6-7 m.
d – Chilled mafic dyke contact cross-cutting tonalite, chainage 17.5 to 17.9 m.

MARATHON DYKE (North Striking)
Daily Traverse #42 (Station 16PG0058) - August 19-20, 2016



Marathon Mafic Dykes - Detailed Scanline Sketch **NWMO Hornepayne Detailed Mapping Report**	Prepared by: ADG Reviewed by: SNS Date: Feb 17, 2017
FIGURE 5.4.3.6 — Doc. No.: "P:\Projects\2010\10-214 NWMO APM Site Screening\10-214-12 Hornepayne Detailed Mapping\30 Deliverables\30.10 Mapping Report\Figures\Working Figures\Hornepayne_Fig5_4_3_6_Marathon_Scanlines.cdr"	

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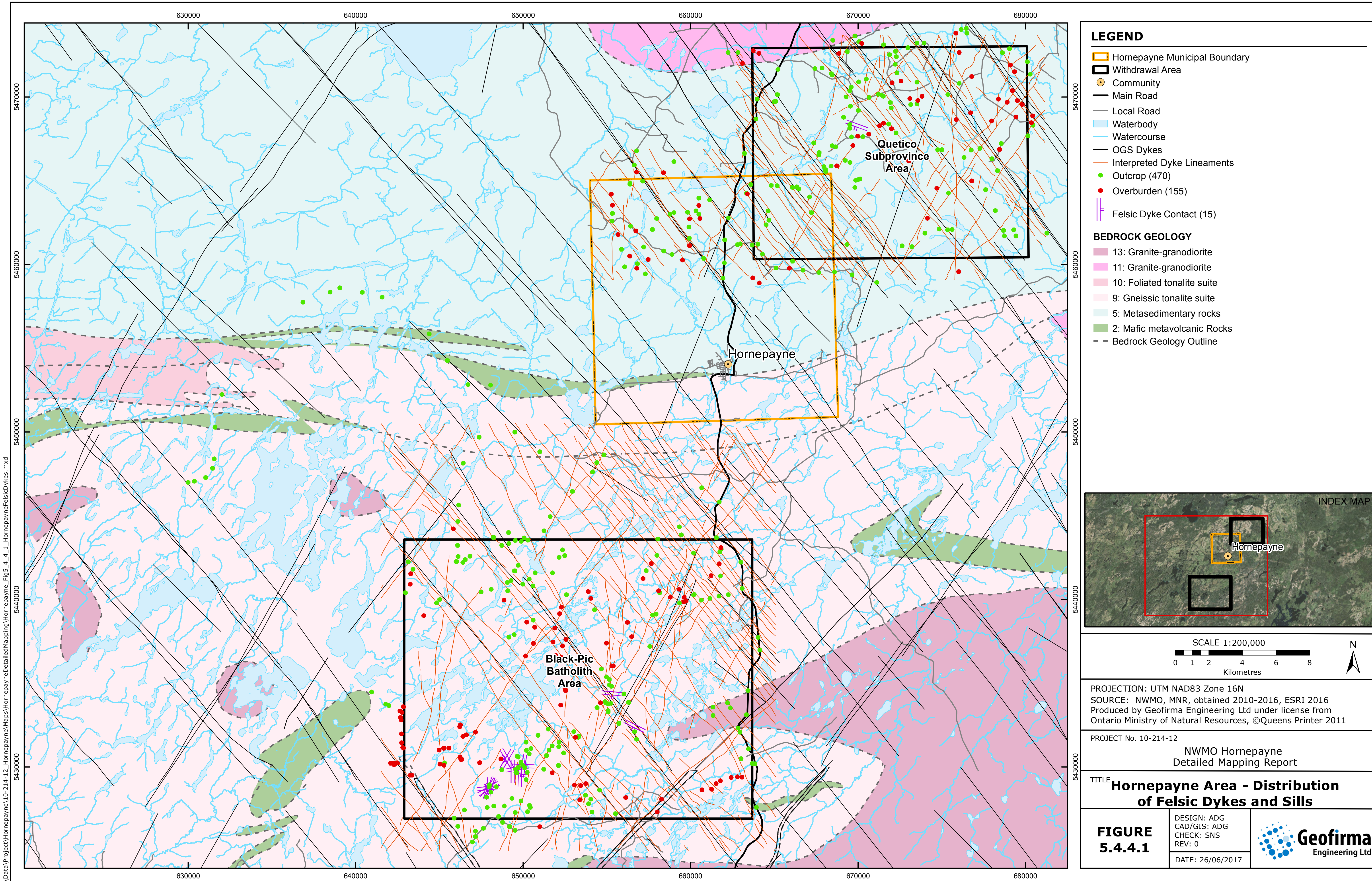

PROJECTION: UTM NAD83 Zone 16N
SOURCE: NWMO, MNR, obtained 2010-2016, ESRI 2016
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PROJECT No. 10-214-12

NWMO Hornepayne
Detailed Mapping Report

TITLE **Hornepayne Area - Distribution of Felsic Dykes and Sills**

FIGURE 5.4.4.1

DESIGN: ADG
CAD/GIS: ADG
CHECK: SNS
REV: 0
DATE: 26/06/2017

Geofirma Engineering Ltd

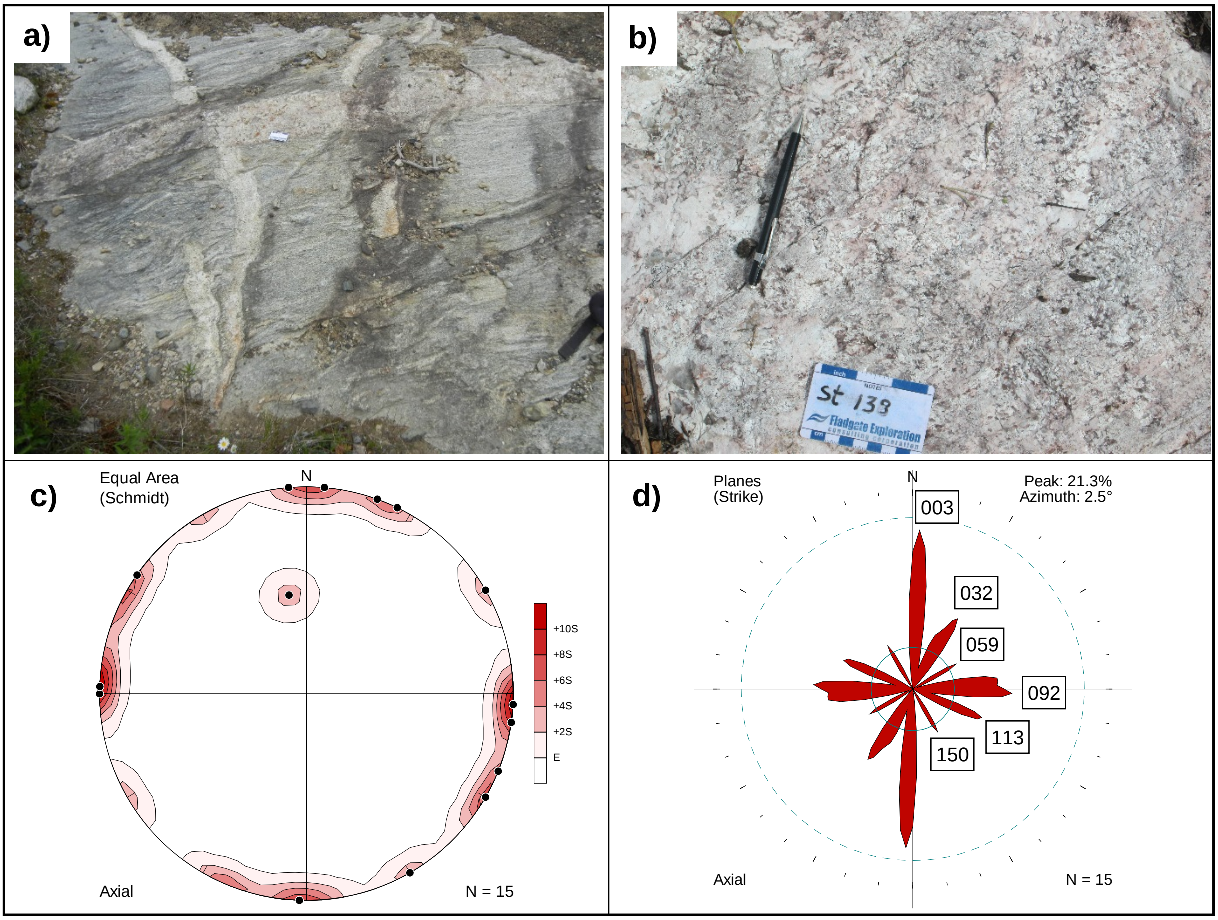

Figure 5.4.4.2: Felsic Dykes – Field Examples and Structure

a – Photo of pegmatite dyke cross-cutting tonalite host rock. View to the southwest, card for scale (Station PG0040).
b – Close-up photo of pegmatite dyke. Plan view with pencil oriented north, card for scale (Station HM0138).
c – All mapped felsic dyke contact orientations. Displayed as equal area lower hemisphere stereonet plot of poles to planes (N=15).
d – All mapped felsic dyke contact orientations. Displayed as rose diagram of trends of planes (N = 15).