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MANAGEMENT DES DÉCHETS  
ORGANIZATION NUCLÉAIRES

Phase 2 Geoscientific Preliminary Assessment  
Acquisition, Processing and Interpretation of  
High-Resolution Airborne Geophysical Data

TOWNSHIP OF MANITOUWADGE AND AREA, ONTARIO



**APM-REP- 1332-0213**

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## **PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT**

# **ACQUISITION, PROCESSING AND INTERPRETATION OF HIGH-RESOLUTION AIRBORNE GEOPHYSICAL DATA**

## **TOWNSHIP OF MANITOUWADGE AND AREA, ONTARIO**

**Prepared for:**

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## Executive Summary

This technical report documents the results of the acquisition, processing and interpretation of high-resolution airborne geophysical data conducted as part of the Phase 2 Geoscientific Preliminary Assessment, to further assess the suitability of the Manitouwadge area to safely host a deep geological repository (SRK, 2017b). This study followed the successful completion of a Phase 1 Geoscientific Desktop Preliminary Assessment (AECOM, 2014). The desktop study identified 4 potentially suitable areas warranting further studies such as high-resolution surveys and geological mapping; two located within the south central portion of the Black-Pic batholith, one in the Quetico metasedimentary rocks north of Manitouwadge, and one in the Fourbay Lake pluton in the southwest of the Manitouwadge area.

The purpose of the Phase 2 acquisition, processing and interpretation of geophysical data was to provide an updated interpretation of the geological characteristics of the potentially suitable bedrock unit identified in Phase 1 and to provide additional information to further assess the geology of the Manitouwadge area. Both magnetic and gravimetric data were acquired during the surveys in order to provide data to interpret the geometry and thickness of the potentially suitable bedrock units; the nature of geological contacts; bedrock lithologies; the degree of geological heterogeneities and the nature of intrusive phases within the plutons in the area; as well as the nature of structural features such as faults, shears zones, and alteration zones. The grids of the acquired magnetic and gravimetric data and associated processed grids (first, second and horizontal derivatives, total gradient amplitude, trend analysis solutions and tilt angle) were analyzed and interpreted together with the mapped bedrock geology and other available geological information (e.g. magnetic susceptibility and rock density).

The survey allowed for a characterization of the distinctive local gravity and magnetic signatures of the Black-Pic batholith and its encapsulated plutons and metavolcanic units, as well as the Quetico metasedimentary rocks north of the subprovince boundary. The Black-Pic batholith shows subtle internal variations in magnetic character with regions showing magnetic foliations and internal magnetic fabric highlighting either lithological heterogeneity or steeply dipping gneissic layering likely related to large-scale fold structures throughout the Black-Pic batholith. Three large gravity lows within the Black-Pic batholith have been interpreted to either represent the deepest portion of the batholith or local alternate phase of emplacement with a slightly lower density. The Fourbay Lake pluton is characterized as a prominent magnetic anomaly with a subtle gravity high. The Quetico metasedimentary rocks are weakly magnetic with an east-west trending magnetic fabric and a strong local gravity high anomaly both associated with the subprovince boundary. The Black-Pic batholith and the Quetico metasedimentary rocks have been cross-cut by at least three independent dyke swarms of both positive and negative magnetic polarity.

Preliminary forward modelling was completed on three profile lines covering the principle features of the Black-Pic batholith, Fourbay Lake pluton, and Quetico metasedimentary rocks and surrounding intrusions and greenstone belts within the study area. The Black-Pic batholith has been modelled as extending to a considerable depth with the encapsulated greenstone belts extending to 2.5 km and the Fourbay Lake pluton to 1 km. Rocks of the Quetico Subprovince have locally been modelled extending to depths typically greater than 6.5 km.

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# 1 Introduction

This technical report documents the results of the acquisition and interpretation of high-resolution airborne geophysical data (gravity and magnetic) conducted as part of the Phase 2 Geoscientific Preliminary Assessment, to further assess the suitability of the Manitouwadge area to safely host a deep geological repository (SRK, 2017b). This study followed the successful completion of a Phase 1 Geoscientific Desktop Preliminary Assessment (AECOM, 2014). The desktop Phase 1 study identified 4 potentially suitable areas warranting further studies such as high-resolution surveys and geological mapping; two located within the south central portion of the Black-Pic batholith, one in the Quetico metasedimentary rocks north of Manitouwadge, and one in the Fourbay Lake pluton in the southwest of the Manitouwadge area.

## 1.1 Study Objective

The main purposes of the acquisition and interpretation of high-resolution magnetic and gravity data are as follows:

- Acquire high-resolution airborne magnetic and gravimetric data within a geophysical survey area that encompasses the general potentially suitable areas of the Black-Pic batholith, Quetico metasedimentary rocks, and Fourbay Lake pluton identified in the Phase 1 Geoscientific Desktop Preliminary Assessment (AECOM, 2014).
- Characterize the geophysical response of the bedrock units (e.g. bedrock contacts, intrusive phases, potential natural resources, etc.).
- Characterize the extent of bedrock heterogeneity (e.g. ductile fabric, complexity, etc.).
- Interpret the geophysical character of potential structures (faults, dykes, joints, etc.).
- Develop initial models of bedrock units at depth (2.5D forward modeling).

## 1.2 Geophysical Survey Area

The Township of Manitouwadge is located in the Thunder Bay District, halfway between Thunder Bay and Sault Ste. Marie. The Town is at the terminus of Highway 614, about 55 km north of the Trans-Canada Highway 17. The geophysical survey consists of three survey blocks of high-resolution coverage: Manitouwadge North, Manitouwadge South, and Manitouwadge East. The Manitouwadge North survey block is located approximately 40 km north of the Township of Manitouwadge and covers an area of approximately 140 km<sup>2</sup>. The northern edge of the Manitouwadge South survey block is located directly over the Township of Manitouwadge and encompasses over 600 km<sup>2</sup> of land immediately to the south. The Manitouwadge East survey block is located approximately 25 km east of the Township of Manitouwadge and encompasses an area of nearly 300 km<sup>2</sup>. The location of the geophysical survey area is shown in Figure 1.1 overlying the bedrock geology, and the full set of survey lines are shown in Figure 1.2. The geophysical survey area is bounded by the coordinates presented in Table 1.1 (NAD-83 datum, UTM zone 16N).

Table 1.1: Coordinates of the survey area (NAD-83, UTM 16N)

Easting (m)	Northing (m)
<b>Manitouwadge North Block</b>	
585365	5478385
573046	5478385
573046	5489561
585365	5489561
<b>Manitouwadge South Block</b>	
566261	5419174
566261	5427635
572464	5427636
579000	5440785
599500	5440785
599500	5419174
<b>Manitouwadge East Block</b>	
622710	5450500
622710	5425000
611090	5425000
611090	5450500

## 2 Summary of Geology

The geology of the Manitouwadge area is described in detail in the Phase 1 Geoscientific Desktop Preliminary Assessment (AECOM, 2014). The following sections provide a brief description of the geologic setting, bedrock geology, structural history and mapped structures, metamorphism, and Quaternary geology of the Manitouwadge area. The focus of the following subsections are the bedrock units identified during Phase 1 as being potentially suitable to host a deep geological repository and the important structural features in proximity to these units.

### 2.1 Geological Setting

The Manitouwadge 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 Ga (e.g., Percival et al., 2006). The Superior Province covers an area of approximately 1,500,000 km<sup>2</sup> and is divided into east-trending subprovinces, including the Wawa and Quetico subprovinces. The Manitouwadge north survey block is located entirely within the Quetico Subprovince, whereas the south and the east survey blocks are located entirely within the Wawa Subprovince (Figure 1.1).

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).

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

Several generations of Paleoproterozoic diabase dyke swarms, ranging in age from ca. 2.473 to 2.101 Ga intrude all bedrock units in the Manitouwadge area (Hamilton et al., 2002; Buchan and Ernst, 2004; Halls et al., 2006).

### 2.2 Bedrock Geology

The main bedrock geology units present within the three Manitouwadge blocks include the metasedimentary rocks of the Quetico Subprovince (North survey block) and predominantly gneissic tonalite rocks of the Black-Pic batholith (south and east survey blocks) of the Wawa Subprovince. Additional relevant geological units include the Fourbay Lake pluton in the south survey block, and two gabbroic intrusions, a granite-granodiorite intrusion and a unit of mafic metavolcanic rocks, located within the east survey block (Figure 1.1). The southern boundary of a granite-granodiorite intrusion is located along the northern boundary of the northern survey block, but is not considered significant as only a minor amount of this intrusion is located within the interpretation area (see Section 2.3.5). The bedrock in the Manitouwadge area has experienced several generations of ductile and brittle deformation, and the individual rock units have been subjected to varying amounts of metamorphism. In addition, three generations of Proterozoic diabase dykes transect all bedrock units.

A detailed description of these bedrock units, and structural and metamorphic events, can be found in

the Phase 1 Geoscientific Desktop Preliminary Assessment (AECOM, 2014), and key points are summarized in the following subsections. A description of the bedrock geology units surrounding, but not included within the individual Phase 2 Manitouwadge lineament interpretation areas, can also be found in the aforementioned reference, and are not repeated here.

## **2.2.1 Quetico Subprovince**

### **2.2.1.1 Metasedimentary Rocks**

Metasedimentary rocks of the Quetico Subprovince occur in the northern portion of the Manitouwadge area, with the exception of the northernmost boundary, which is located along the contact of a granite-granodiorite intrusion (Figure 1.1).

Metasedimentary rocks of the Quetico Subprovince include wacke-pelite-arenite rocks, 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 includes 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 to 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).

### **2.2.1.2 Granite - Granodiorite Intrusion**

The southern boundary of a granite-granodiorite intrusion straddles the northern boundary of the Manitouwadge northern survey block (Figure 1.1). Similar intrusions have been mapped elsewhere in the region, and described as quartzofeldspathic 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 or age of these intrusions in the Manitouwadge area is not available.

## **2.2.2 Wawa Subprovince**

### **2.2.2.1 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<sup>2</sup>. With the exception of several relatively small intrusions (e.g., Fourbay Lake pluton, gabbroic intrusions), the bedrock underlying the south and east survey blocks is entirely contained within this batholith (Figure 1.1).

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 crosscutting 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 a structural dome with foliation dips that are shallow to moderate outward from the centre (Williams and Breaks, 1989; 1990). 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, 1998). A younger monzodioritic phase has also been dated at ca. 2.689 Ga (Zaleski et al., 1999). The thickness of the batholith in the Manitouwadge area is not known, but regional geologic models of the area (e.g., Lin and Beakhouse, 2013) suggest it may extend to a considerable depth.

#### **2.2.2.2 *Fourbay Lake Pluton***

The Fourbay Lake pluton is an approximately 64 km<sup>2</sup> elliptical-shaped intrusion located in the southwest corner of the Manitouwadge southern block (Figure 1.1). The pluton is mapped as a pyroxene-hornblende-biotite granodiorite (Milne, 1968), and as a hornblende–biotite ± clinopyroxene quartz monzodiorite (Beakhouse, 2001). The latter mapping also indicated the pluton exhibited a massive and medium-grained granular texture.

U-Pb (zircon) age dating of the Fourbay Lake pluton yielded an age of ca. 2.678 Ga (Beakhouse, 2001). The pluton has been interpreted as an intrusion in a series of late stage, likely post-tectonic plutons situated along the central axis of the Black-Pic batholith (Williams and Breaks, 1996). No information is available on the depth of the Fourbay Lake intrusion; however, it may be expected to extend to considerable depths based on the interpretation of regional gravity data (PGW, 2014) and the regional geological model for the area (Santaguida, 2001; Muir, 2003).

The Fourbay Lake pluton is evident in geophysical data, and clearly distinguished from the Black-Pic batholith by a prominent aeromagnetic anomaly with clearly defined boundaries (e.g., Milne, 1968 and PGW, 2014). The elevated magnetic signature relative to the surrounding Black-Pic batholith, may be due to the abundance Fe and Fe-Ti oxides (~1-2 percent) within the pluton (Williams and Breaks, 1996).

#### **2.2.2.3 *Granite-Granodiorite Intrusion***

An unnamed, northeast-trending granite-granodiorite pluton is depicted in the central portion of the eastern survey block (Figure 1.1). This geological unit is present in the compilation map of the area (Johns and McIlraith, 2003), and is based on previous geological maps (Giguere, 1972). No aeromagnetic anomaly is visible based on historic geophysical data (PGW, 2014; Figure 4).

#### **2.2.2.4 *Faries-Moshkinabi Intrusion***

The Faries-Moshkinabi intrusion is an east-northeast–trending linear intrusion located between the south and east survey blocks, and in the northern portion of the east survey block (Figure 1.1). The intrusion comprises a series of mafic rocks including websterite, hornblendite, metagabbro, gabbro, anorthositic gabbro, gabbroic anorthosite, and anorthosite (Giguere, 1972). The portion of the intrusion located in the east survey block is thought to have originally been connected to the gabbroic

intrusions immediately to the west (Williams and Breaks, 1996). Within this survey block, the Faries-Moshkinabi intrusion is in contact to the north with a relatively narrow unit of metavolcanic rocks of the Manitouwadge greenstone belt. The contact between the Faries-Moshkinabi intrusion and the Black-Pic batholith is a thrust-modified tectonic breccia, composed of centimetre- to metre-scale blocks of anorthosite, metawacke, and granitic rocks (Williams and Breaks, 1996).

Based on a previous interpretation of historic geophysical data the Faries-Moshkinabi intrusion is marked by a moderate magnetic intensity that strikes northeastward (PGW, 2014). No data are available on the thickness or age of this intrusion.

#### **2.2.2.5 Bulldozer Lake Intrusion**

The informally named Bulldozer Lake intrusion (AECOM, 2014) is an ellipsoid gabbroic intrusion, approximately 15 by 10 kilometres, in the southwest corner of the east survey block (Figure 1.1). The Bulldozer Lake intrusion is apparent in geophysical data, and can be differentiated from the surrounding Black-Pic batholith by an elevated magnetic signature (PGW, 2014). No additional information on this pluton, including its depth, was documented in the reviewed literature.

#### **2.2.2.6 Supracrustal Rocks**

Supracrustal rocks of the Wawa Subprovince, proximal to the Manitouwadge lineament assessment area, include the Manitouwadge and the Schreiber-Hemlo greenstone belts.

The Manitouwadge greenstone belt comprises a semi-continuous suite of metavolcanic and meta-sedimentary rocks and associated intrusions situated along the northern boundary of the Wawa Subprovince (Figure 1.1). A relatively narrow unit of mafic volcanic rocks of the Manitouwadge greenstone belt are located in the northern portion of the east survey block, whilst the remainder of the greenstone belt is located outside the Phase 2 lineament assessment areas, and is therefore only summarized briefly within this report.

The Manitouwadge greenstone belt comprises strongly metamorphosed wacke and siltstone metasedimentary rocks, mafic to felsic volcanic rocks, iron formations, and volcanogenic massive sulphide deposits. Locally, sedimentary and volcanic rocks are interwoven both along strike and down dip (Milne, 1969). Within the east survey block, the Faries-Moshkinabi gabbroic intrusion is in contact with the volcanic rocks of the Manitouwadge greenstone belt. Throughout the greenstone belt, bedding is rarely observed, and is typically transposed into planar fabrics due to extensive deformation (Zaleski et al., 1999).

The western part of the Schreiber-Hemlo greenstone belt occurs to the west of the Phase 2 lineament assessment area. The belt in this location comprises mafic metavolcanic rocks and associated intrusions of the Schreiber assemblage (Williams et al., 1991).

#### **2.2.3 Mafic Dykes**

Three diabase dyke swarms are known to crosscut the Manitouwadge area (Figure 1.1), 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 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-diorite 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.

The three dyke swarms in the Manitouwadge area are generally distinguishable by their unique strike directions, crosscutting relationships and, to a lesser extent, by magnetic amplitude.

### **2.3 Structural History**

Information on the structural history of the Manitouwadge area is based predominantly on structural investigations of the Manitouwadge 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 Manitouwadge area should be considered as a best-fit model that incorporates relevant findings from all studies. The structural history of the Manitouwadge area is described below and summarized in Table 2.1.

The Manitouwadge 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 Manitouwadge 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.

Table 1.1: Summary of the Geological and Structural History of the Manitowadge 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	<ul style="list-style-type: none"> <li>- ca. 2.720 Ga: Volcanism and subordinate sedimentation associated with the formation of the Manitowadge greenstone belt</li> <li>- ca. &lt;2.693: Deposition of sedimentary rocks in the Manitowadge greenstone belt and the Quetico Subprovince</li> <li>- ca. 2.720-2.678 Ga: Inferred emplacement of granitoid intrusions in the Manitowadge area. Emplacement of the Pukaskwa and Black-Pic gneissic complexes at ca. 2.72 Ga</li> <li>Emplacement of Loken Lake pluton (ca. 2.687 Ga), Nama Creek pluton (2.680 Ga), and Fourbay Lake pluton (ca. 2.678 Ga)</li> <li>- ca. 2.719 to 2.673 Ga: Four generations of ductile-brittle deformation (D<sub>1</sub>-D<sub>4</sub>)</li> <li>D1: ca. 2.719 – 2.691 Ga</li> <li>D2: ca. 2.691 – 2.683 Ga</li> <li>D3: ca. 2.682 – 2.679 Ga</li> <li>D4: ca. 2.679 – 2.673 Ga</li> </ul>
2.675 to 2.669 Ga	Peak metamorphism of the Manitowadge greenstone belt
2.666 to 2.650 Ga	Peak metamorphism of the Quetico Subprovince
2.5 to 2.100 Ga	<ul style="list-style-type: none"> <li>- ca. 2.5 Ga: Supercontinent fragmentation and rifting in Lake Superior area; development of the Southern Province</li> <li>- ca. 2.473 Ga: Emplacement of the Matachewan dyke swarm</li> <li>- ca. 2.167 Ga: Emplacement of Biscotasing dyke swarm</li> <li>- ca. 2.121 Ga: Emplacement of the Marathon dyke swarm</li> </ul>
1.9 to 1.7 Ga	Penokean Orogeny in Lake Superior and Lake Huron areas; possible deposition and subsequent erosion in the Manitowadge 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

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. 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 crosscutting 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) suggest that six deformation events occurred within the Manitowadge area. The first four deformation events (D<sub>1</sub>-D<sub>4</sub>) are associated with brittle-ductile deformation of the greenstone belts. D<sub>5</sub> and D<sub>6</sub> were associated with a combination of brittle deformation and fault propagation through all rock units in the Manitowadge area. The main characteristics of each deformation event are summarized below.

The earliest recognizable deformation phase ( $D_1$ ) is associated with rarely preserved small-scale isoclinal ( $F_1$ ) folds, ductile shear zones that truncate, and a general lack of penetrative foliation development. Peterson and Zaleski (1999) reported that an  $S_1$  foliation is only preserved locally in outcrop and in thin section.  $D_1$  deformation is poorly constrained to between ca. 2.719 and ca. 2.691 Ga (Muir, 2003).

$D_2$  structural elements include prevalent open to isoclinal  $F_2$  folds, an axial planar  $S_2$  foliation, and  $L_2$  mineral elongation lineations (Peterson and Zaleski, 1999). Muir (2003) interpreted  $D_2$  to have resulted from progressive north-northeast to northeast directed compression that was coincident with the intrusion of various plutons. The  $S_2$  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  $D_2$  deformation. This generation of deformation is constrained to between ca. 2.691 and ca. 2.683 Ga (Muir, 2003).

$D_3$  deformation was the result of northwest-southeast shortening during regional dextral transpression.  $D_3$  structural elements include macroscale  $F_3$  folds, including the regional scale isoclinal fold developed within the Manitouwadge greenstone belt, and local shear fabrics that exhibit a dextral sense of motion and overprint  $D_2$  structures (Peterson and Zaleski, 1999; Muir, 2003).  $D_3$  deformation did not develop an extensive penetrative axial planar and (or) crenulation cleavage.  $D_3$  deformation is constrained to between ca. 2.682 and ca. 2.679 Ga (Muir, 2003).

$D_4$  structural elements include isolated northeast-plunging  $F_4$  kink folds with a Z-asymmetry, and associated small-scale fractures and faults overprinting  $D_3$  structures.  $D_3$ - $D_4$  interference relationships are best developed in the Manitouwadge greenstone belt and in rocks of the Quetico Subprovince.  $D_4$  deformation is roughly constrained to between ca. 2.679 and ca. 2.673 Ga (Muir, 2003).

Details of structural features associated with the  $D_5$  and  $D_6$  deformation events are limited in the literature to brittle and brittle-ductile faults of various scales and orientations (Lin, 2001; Muir, 2003). Within the Hemlo greenstone belt, Muir (2003) suggested that local  $D_5$  and  $D_6$  faults offset the Marathon and Biscotasing dyke swarms (all ca. 2.2 Ga), and as such, suggested that in the Hemlo region  $D_5$  and  $D_6$  faults propagated after ca. 2.2 Ga. However, since there are no absolute age constraints on specific events, the entire  $D_5$ - $D_6$  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.

### **2.3.1 Mapped Structures and Named Faults**

In the Manitouwadge area, in both the Quetico and Wawa subprovinces, numerous faults are indicated on public domain geological maps (Figure 1.1). These faults display four dominant orientations: north, northeast, northwest, and east. Despite the interpretation of multiple mapped faults, few of these structures are named.

Surrounding the Manitouwadge lineament interpretation blocks, several named structures are present, including the north-trending Cadawaja, Slim Lake and Fox Creek faults, and the northwest-trending Mose Lake fault, all of which offset folded stratigraphy within the Manitouwadge greenstone belt (Chown, 1957; Peterson and Zaleski, 1999). The southern portions of the Cadawaja and Fox Creek faults extend into the northern portion of Manitouwadge Block B (Figure 1.1). Named east-trending structures are also present in the area surrounding the three blocks, including the Agam Lake, Rabbitskin Lake, and Little Nama Lake faults, which mimic the outline of the Manitouwadge greenstone belt and subprovince boundary, and are typically offset by north-trending faults. Mapping

and interpretation of aeromagnetic data (e.g., Miles, 1998), indicates that all mapped faults offset the regional fabric throughout the Manitouwadge area.

Of the aforementioned mapped structures, the north-trending Cadajwa, Slim Lake and Fox Creek faults were mapped as sinistral strike-slip faults (Miles, 1998). The Fox Creek fault exhibits a 60 metre sinistral strike-separation of the Geco VMS deposit combined with a minor east side up vertical displacement (Milnes, 1998). The Cadawaja fault offsets the stratigraphy on the southern edge of the Manitouwadge greenstone belt by 500 metres (Miles, 1998). The east-trending Agam Lake fault was mapped primarily as a brittle strike-slip fault (Chown, 1957). This structure in part follows the volcanic-sedimentary contact and locally may represent a reactivated ductile shear zone (Peterson and Zaleski, 1999).

The north-, northwest- and northeast-trending faults are subparallel and locally adjacent to Marathon, Matachewan, and Biscotasing dykes. Locally, these dykes are offset by younger generations of brittle faulting (e.g., Miles, 1998).

## **2.4 Metamorphism**

In the Manitouwadge area, the metamorphic grade of the exposed rocks of the Manitouwadge greenstone belt ranges from greenschist to upper amphibolite facies (James et al., 1978; Petersen, 1984; Pan and Fleet, 1992). To the north, 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, 1990; Zaleski and Peterson 1995; Pan et al., 1994). The area overprinted by granulite facies metamorphism is defined by an ortho-pyroxene isograd approximately 10 kilometres wide that extends from the western portion of the Manitouwadge area westward for over 100 kilometres (Pan et al., 1998). Outside the ortho-pyroxene isograd, the granulite facies grades into regional upper amphibolite facies metamorphic grade typical of this part of the Quetico Subprovince (Pan et al., 1998).

Geothermobarometric and geochronological calculations by Pan et al. (1994) and Pan et al. (1998) in the Manitouwadge area and surroundings, 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). In the Manitouwadge area, 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.

To the south of the greenstone belt, the Black-Pic batholith and other smaller plutons typically display greenschist facies metamorphism (AECOM, 2014). 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 Manitouwadge area may have been affected by thermotectonic overprints related to post-Archean events.

## 2.5 Quaternary Geology

Quaternary geology of the Manitowadge area is described in detail in the remote sensing and terrain evaluation completed as part of the Phase 1 Geoscientific Desktop Preliminary assessment (AECOM, 2014). An overview of the relevant Quaternary features is summarized below.

The Quaternary sediments in the Manitowadge 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 Manitowadge 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 bedrock are typically limited in thickness and the ground surface reflects the bedrock topography (Kristjansson and Geddes, 1986). Beyond bedrock-drift complexes, valleys and lowland areas are present, which typically exhibit extensive and thick surficial deposits, frequently in a linear geometry.

In Manitowadge north survey block, and to a limited extent within the other survey blocks, significant areas are covered by ground moraine (till). Two styles of till are documented: moderately loose, stony, sandy till of local derivation that forms a discontinuous veneer over the bedrock, and a calcareous, silt dominated till that contains abundant non-local pebble lithologies derived from the James Bay Lowland (Geddes and Kristjansson, 1984; Geddes et al., 1985). Till thickness in the Manitowadge area is variable and while depths of several metres are present locally; thicknesses are typically less than 3 metres (AECOM, 2014).

In Manitowadge south survey block, and to a limited extent within the other blocks, glaciolacustrine sediments cover significant areas and trend dominantly to the northeast. These sediments comprise stratified to laminated sand, silt and clay that were deposited during the incursion of glacial lakes into the Manitowadge area (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).

In Manitowadge east survey block, and to a limited extent within the other blocks, glaciofluvial outwash deposits cover significant areas. Deposits are generally well-sorted and consist predominantly of stratified sand (Kristjansson and Geddes, 1986). The thicknesses of the outwash deposits are anticipated to be variable.

Minor organic-rich alluvial deposits and eolian deposits are also locally present throughout the Manitowadge 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; Kristjansson and Geddes, 1986; Kettles and Way Nee, 1998).

Glacial striae in the Manitowadge area record that the last direction of glacial movement was toward the south-southwest (Kristjansson and Geddes, 1986)

### 3 Data Source Acquisition and Quality

Sander Geophysics Limited (SGL) completed a fixed-wing high-resolution airborne magnetic and gravity survey in the Manitouwadge area between July 23 and October 7, 2015. The survey area comprised three survey blocks surrounding the Township of Manitouwadge. The survey blocks were designed to cover the potentially suitable areas in the Black-Pic batholith, Quetico metasedimentary rocks, and Fourbay Lake pluton identified in the Phase 1 preliminary assessment and capture relevant geological features.

The survey included a total of 13,957 km flight lines covering a surface area of approximately 1,040 km<sup>2</sup>. Flight operations were conducted out of the Manitouwadge Municipal Airport, in Manitouwadge, Ontario using a Cessna 208B Grand Caravan. Data were acquired along traverse lines flown in a north-south direction spaced at 100 m, and control lines flown east-west spaced at 500 m. Five survey lines spaced 200 m apart were continued from the Manitouwadge South block to the Manitouwadge North block, effectively tying the two blocks together (Figure 1.2). Similarly, five survey lines spaced 200 m apart were also continued north and south 15 km beyond the edge of the Manitouwadge East block (Figure 1.2). The survey was flown at a nominal altitude of 80 m above ground level, with an average ground speed of 100 knots (approximately 185 km/h or 50 m/s). Airborne magnetic and gravity data were acquired using equipment with very high sensitivity and accuracy. The airborne magnetic data was recorded using a magnetometer sensor mounted in a fibreglass stinger extending from the tail of the aircraft. The airborne gravity data was recorded using a gravimeter, which includes three orthogonal accelerometers that are mounted on a stabilized platform inside the cabin of the aircraft. Table 3.1 gives a quick reference of the details of the survey.

*Table 3.1: Survey Details*

Survey Particulars	
Survey Start Date:	July 23, 2015
Survey End Date:	October 7, 2015
Field Office Location:	Manitouwadge
Airport Used:	Manitouwadge Municipal Airport (CYMG)
Aircraft Type:	Cessna 208B Grand Caravan (registration C-GSGL)
Total line kilometers:	13,957
Traverse Line numbers:	4001 – 4333, 5001 – 5124 (excluding lines 5070, 5072, 5074, 5076, 5078), 9001 – 9117
Traverse Line direction:	North-South
Traverse Line spacing:	100 m
Control Line numbers:	401 – 444, 501 – 523, 901 – 952
Control Line direction:	East – West
Control Line spacing:	500 m
Survey Altitude:	Smoothed drape with target height of 80 m above ground
Digital Terrain Source:	SRTM
Number of Flights (numbers):	26 (2001 – 2004, 2039, 2043, 2045 – 2064)
Aircraft Target Ground Speed:	100 knots
Magnetic Field Reference location	(NAD83 UTM 16N): 545,105 m E, 5,427,638 m N
Magnetic Field Inclination (+ve down):	74.3388°

Magnetic Field Declination (+ve east):	-6.9914°
Approximate total field value:	56,669.4 nT
Magnetic Reference Field Model:	World Magnetic Model (2015) interpolated to date and location of acquisition
Fundamental Gravity Network Ties:	Referenced to the local gravity value established by Sander Geophysics at the Ottawa Airport
Survey Base Gravity Value:	980854.00 mGal
Survey Base Parking Location (NAD83):	583,674.60 m E 5,437,649.6 m N Height: 331.306 m (above WGS-84 ellipsoid)
Base Station Locations (NAD83):	REF1: 587,100.5 m E, 5,442,586.9 m N Height: 290.93 m (above WGS-84 ellipsoid) REF2: 587,097.4 m E, 5,442,600.3 m N Height: 292.54 m (above WGS-84 ellipsoid) REF3: 584,501.4 m E, 5,441,099.0 m N Height: 307.26 m (above WGS-84 ellipsoid)
Field Acquisition Datum:	WGS-84
UTM Projection:	UTM 16N

### 3.1 Magnetic Data

Total magnetic field measurements were recorded with a single cesium magnetometer mounted in a fiberglass stinger extending from the tail of the survey aircraft. SGL's hardware and software system, AIRComp, was used to remove the effects of the aircraft and its manoeuvres from the recorded magnetic data. Coefficients to be used for compensation were derived by processing the calibration flight data, based on principles presented by Leliak (1961). The compensation coefficients were applied to data recorded during normal survey operations to produce compensated magnetic data.

Low-pass filtered reference station diurnal was subtracted from the airborne data on a reading by reading basis. As more than one reference station was used, the reference station value could be interpolated, based on the relative distance of the reading from each reference station.

Both the ground and airborne systems used the Geometrics G-822A cesium magnetic sensor. Total magnetic field measurements were recorded at 160 Hz in the aircraft, and then later down sampled to 10 Hz in the processing. A second order Butterworth 0.9 Hz low pass filter is utilised in the process for compensation and anti-aliasing. The ground systems recorded magnetic data at 11 Hz.

A pre-planned drape surface was prepared for the survey to guide the aircraft over the topography in a consistent manner, as close to the minimum clearance as possible. The drape surface was prepared with digital elevation model (DEM) data obtained from the Shuttle Radar Topography Mission (SRTM) (<http://srtm.usgs.gov/>) for the area. The DEM included an extension beyond the survey boundary to allow the aircraft to achieve the drape clearance before coming on line.

Details of the processing of the magnetic data are provided in Section 4.2 of this report.

## 3.2 Gravity Data

Gravity data were acquired with SGL's propriety AIRGrav (*Airborne Inertially Referenced Gravimeter*) system, which uses a Schuler tuned inertial platform supporting three orthogonal accelerometers, which remain fixed in inertial space, independent of the manoeuvres of the aircraft, allowing precise isolation from the effects of the movement of the aircraft. The gravity sensor used in AIRGrav is a very accurate accelerometer with a wide dynamic range. The system is not affected by the strong vertical motions of the aircraft, allowing the final gravity data to be almost completely unaffected by in-flight conditions classified as "moderate turbulence" or better. The instrument is also considered to be an inertial navigator and as such, the platform levelling was essentially unaffected by horizontal accelerations.

In typical survey flying, accelerations in an aircraft can reach 0.1 G, equivalent to 100,000 milligal. Data processing must extract gravity data from this very noisy environment. This was achieved by modelling the gravity due to movements of the aircraft in flight as measured by extremely accurate Global Positioning System (GPS) measurement. These measurements are affected by noisy conditions in the ionosphere, and by the variable conditions (e.g. temperature, pressure and humidity) within the troposphere. SGL has developed a full suite of programs to carry out all the necessary corrections.

The GPS data are extracted from the airborne and reference station acquisition system and reformatted. Differential corrections to correct the airborne ranges for variations calculated from the base station GPS data were performed. Each recorded position was recalculated based on these ranges. The original reference system for all GPS data was the WGS-84 datum. Positions were then converted to the local datum, reference system and desired projection. Each line was then checked for data continuity and quality.

An extremely accurate location of the base station GPS receiver is determined using an IGS permanent GPS Reference Station to apply differential corrections (<http://igs.org/network>). This technique provides a final base station receiver location with an accuracy of better than a few decimetres. The entire airborne data set is then reprocessed differentially using the recalculated base station location.

Gravity data were recorded at 128 Hz. Accelerations were filtered and resampled to 10 Hz to match the GPS, using specially designed filters to avoid biasing the data. Gravity was calculated by subtracting the GPS derived accelerations from the inertial accelerations. The calculated gravity was corrected for the Eötvös effect and latitude corrected (i.e. normal gravity), and the sample interval was then reduced to 2 Hz. These operations were all performed by SGL's proprietary GravGPS software. A detailed description of gravity processing is provided in Section 4.1 of this report.

## 3.3 Digital Elevation Data

Digital elevation data were collected during the survey using a laser altimeter (Riegl LD90-31K-HiP) mounted to the base of the aircraft. The elevation data were sampled at a rate of 3.3 Hz, which is consistent with a sample roughly every 16 m along the profile line. Even though the laser altimeter can record returns from more than 700 m above the ground with a high degree of certainty, some laser data dropouts occurred while flying over the areas of poor reflectivity. The laser data shows the effects of the dense tree cover; variable penetration of the canopy results in a high-frequency variation of recorded altitude. The raw laser data were processed with an iterative de-spiking routine designed to

remove many of the early laser returns from trees.

Digital elevation data were also collected using a King radar altimeter mounted to the base of the aircraft. Elevation data were sampled at a rate of 10 Hz, which is consistent with a sample roughly every 6m. The radar data penetrates the canopy less as it records the first return within the footprint of its signal. The radar altimeter data were filtered to remove high-frequency noise using a 67-point low pass filter.

A digital elevation model (DEM) was derived by subtracting the laser altimeter data from the differentially corrected DGPS altitude with respect to the Canadian Geodetic Vertical Datum 2013 (CGVD2013). Short sections of poor laser data due to locally weak reflectivity were replaced using King radar data. The DEM reflects the presence of vegetation (for example trees) and buildings and thus is not considered to be a digital terrain model (DTM).

The digital elevation data were gridded to form a DEM grid using a cell size of 25 m over the Manitouwadge survey area. The 25 m gridding cell was applied to present the highest resolution of the digital elevation model within the boundaries of the survey block comprising the principal survey area (Figure 3.1).

### **3.4 Additional Data Sources**

In addition to the acquired data, a number of other publically available data sources were used. These are detailed below.

#### **3.4.1 OGS Mapped Bedrock Geology**

The Precambrian Geoscience Section of the Ontario Geology Survey has compiled a 1:250,000 scale map of the bedrock geology of Ontario (OGS, 2011). These maps were recently revised and issued as 'Miscellaneous Release – Data 126 – Revision 1'. The data is publically available as a seamless GIS data set and includes such details as bedrock units, major faults, dyke swarms, iron formations and kimberlites. This resource was of fundamental importance in assisting with the geophysical interpretation of the acquired potential field data. The mapped bedrock geology was used for both qualitative and quantitative aspects of the interpretation. In the case of the qualitative interpretation, the mapped bedrock geology gave the overall context for the magnetic and gravity data. For the 2.5D modelling, the mapped bedrock geology provided initial surface constraints.

#### **3.4.2 Geological Base Maps**

Four additional geological maps (M2143, M2145, M2146, M2614 and M2219) are available at approximately 1:30,000, 1:50,000 and 1:60,000 scale of the bedrock geology covering the majority of the southern and eastern Manitouwadge survey areas (OGS, 1967a; 1967b; and 1967c; Giguere, 1972; OGS, 2000). The bedrock geologic maps were georeferenced and incorporated into the project geodatabase. Structural measurements including foliations, gneissic layering and bedding planes, folds and faults provided structural constraints and were incorporated into the qualitative and quantitative interpretations.

#### **3.4.3 OGS PETROCH Lithogeochemical Database**

The Ontario Geological Survey has a publicly available PETROCH Lithogeochemical Database (Haus and Pauk 2010). The database contains detailed rock chemical data collected by OGS geoscientists, which includes information about rock type, chemical composition, age, stratigraphy, major oxide values, sample location and specific gravity. Two data points are located above the large gabbroic

intrusion (Bulldozer Lake intrusion) located on the eastern side of the Manitouwadge area and 35 data points are located just to the south of the Manitouwadge area in the Schreiber-Hemlo greenstone belt. This information was used in the interpretation to: 1) obtain further information on the composition of major mapped rock units where samples have been taken; and 2) constrain the density of rock units used in the 2.5D modelling.

#### **3.4.4 Densities and Magnetic Susceptibilities**

Bedrock densities and magnetic susceptibilities in the Manitouwadge area were gathered from a database maintained by the Geological Survey of Canada (GSC, 2015). The database includes classification of rock type, and measured densities and magnetic susceptibilities. Seven data points occur within the survey area; within the Black-Pic batholith, Manitouwadge greenstone belt, and Fourbay Lake pluton in the Wawa Subprovince and the Quetico metasedimentary rocks and granite-granodiorite intrusions of the Quetico Subprovince. Magnetic susceptibility values were not available in the database for these rock units and only the density information was used in the modelling.

#### **3.4.5 Ontario Precambrian Bedrock Magnetic Susceptibility Geodatabase**

The Ontario Geological Survey has a publicly available Ontario Precambrian Bedrock Magnetic Susceptibility Geodatabase for 2001 to 2012 (Muir, 2013), which is known as Miscellaneous Release – Data 273 (MRD 273-Rev). This GIS database contains measurements of magnetic susceptibilities and rock classifications for points across Ontario. In the Manitouwadge survey area, the 61 data points locally present are limited to the western side of the Manitouwadge Synform.

#### **3.4.6 Other Magnetic Susceptibility Measurements**

Additional magnetic susceptibility data were obtained from Miles (1998) for several lithologies in the region of the Manitouwadge-Hornepayne greenstone belt. Statistics (minimum, maximum, mean, standard deviation) were presented. The lithologies and unit numbers/name were simplified from Zaleski and Peterson (1995).

## 4 Geophysical Data Processing Methods

### 4.1 Gravity Data Processing

Advanced gravity processing allows for the generation of high-resolution gravity data. These processes involve the use of GPS phase angle corrections, the integration of GPS processing with inertial data from the gravimeter and the advanced analysis of system states and uncertainties. This processing helps reduce system noise and allows for the generation of high quality, low noise raw gravity data through a wider range of survey conditions than was previously possible. The following standard corrections were applied to the gravity data (Telford et al. 1990; Blakely, 1996):

- a. Eötvös correction,

$$\delta g_{Eötvös} = -2 W_s v_x \cos \Phi - \frac{v_x^2}{\frac{r}{(1 - e^2 \sin^2 \Phi)^{1/2}} + h} - \frac{v_y^2}{\frac{r(1 - e_2)}{(1 - e^2 \sin^2 \Phi)^{3/2}} + h}$$

where  $\Phi$  is the latitude of the aircraft,  $v_x$  and  $v_y$  are the velocities of the aircraft in the  $x$  (east) and  $y$  (north) direction,  $r$  is the Earth's radius at the equator (6,378,137 m),  $e$  is a correction for Earth's flattening towards the poles (0.0818191908426),  $W_s$  is the angular velocity of Earth's rotation ( $7.2921158553 \times 10^{-5}$  rad/s), and  $h$  is the altitude of the plane above the ellipsoid;

- b. Normal gravity,

$$g_{Normal} = \frac{9.7803267715 (1 + 0.0019318513353 \sin^2 \Phi)}{\sqrt{1 - 0.0066943800229 \sin^2 \Phi}}$$

where  $\Phi$  is the latitude of the aircraft;

- c. Free air correction,

$$g_{fa} = - (0.3087691 - 0.0004398 \sin^2 \Phi) h + 7.2125 \times 10^{-8} h^2$$

where  $h$  is the height of the aircraft in metres above the ellipsoid;

- d. Full 3D Bouguer correction,  $g_b$ . See below for a description of the Bouguer correction technique;  
 e. Static correction,  $g_{sc}$ , based on static ground recordings and repeat lines;  
 f. Level correction,  $g_{lc}$ , based on line intersections.

Thus, the Bouguer anomaly in mGal is determined:

$$BouguerAnomaly = G - g_{fa} - g_b - g_{sc} - g_{lc}$$

where  $G$  is the calculated gravity in mGal adjusted for Eötvös effect and normal gravity.

#### **4.1.1 Bouguer Correction**

Shuttle Radar Topography Mission (SRTM) digital elevation model data were used to calculate the Bouguer corrections for gravity processing. The SRTM data contains information in a grid with a 3 arcsecond spacing, approximately equal to 100 m cell size, which has a higher density than the line spacing for this survey, and therefore provides terrain data at a better resolution between the survey lines than the SRTM data. Coverage up to 160 km from the survey block was kept for accurate regional corrections.

Terrain corrections were computed using software developed by SGL. The algorithm calculates the topographic attraction of the terrain using a mass prism model with a constant density. The difference between the topographic attraction and the simple Bouguer correction is the terrain correction. The terrain and Bouguer corrections were calculated for the bedrock at the height of the aircraft using a density of 2.67 g/cm<sup>3</sup>.

Terrain corrections were filtered to match the degree of filtering applied to the gravity data as described below.

#### **4.1.2 Static and Level Corrections**

The gravimetric data were levelled to compensate for instrument variations in two steps. A single constant shift determined from ground static recordings was applied on a flight-by-flight basis. The pre- and post-flight readings were averaged for each flight and the difference between the average value and the local gravity value was removed. This acts as a simple but effective coarse levelling of the data.

Intersection statistics were then used to adjust individual survey lines. Unlike magnetic levelling, individual intersections were not used to make corrections. Instead, intersection differences from whole lines were averaged and a single adjustment was applied to each survey line and each control line. Minor adjustments were calculated for sections of each line based on statistics from groups of intersections. The adjustments were smoothed and applied to line data that was filtered as described below. Grids of adjusted data were inspected to determine that the adjustments were appropriate.

#### **4.1.3 Gridding and Filtering**

Statistical noise in the data was reduced by applying a cosine tapered low-pass filter to the time series line data. For this survey, a 20 second (1000 m) half-wavelength filter was employed. The data were gridded using a minimum curvature algorithm that averages all values within any given grid cell and interpolates the data between survey lines to produce a smooth grid. The algorithm produces a smooth grid by iteratively solving a set of difference equations by minimizing the total second horizontal derivative while attempting to honour the input data (Briggs, 1974). Grids were generated using a 25 m grid cell size.

Low-pass spatial filtering is applied to the grid for noise reduction. Essentially, the survey area is over-sampled as the line spacing is smaller than the grid filter used. A range of grid filters were used and evaluated for noise levels and signal content. Final data for this survey was filtered with a 1.0 km half-wavelength grid filter.

The gravity data were gridded using a cell size of 25 m and 250 m over the Manitouwadge area. The 25 m gridding cell was applied to present the highest resolution of data within the boundary of the survey block, comprising the principal survey area. The 250 m gridding cell was applied to include the

extensions of the flight lines beyond the survey block, comprising the extended survey area. The Bouguer gravity with a terrain correction of 2.67 g/cm<sup>3</sup> is displayed in Figures 4.1 (principal survey area, grid cell size of 25 m) and Figure 4.2 (extended survey area, grid cell size of 250 m). The Free Air gravity is displayed in Figures 4.3 (principal survey area, grid cell size of 25 m) and Figure 4.4 (extended survey area, grid cell size of 250 m).

## 4.2 Magnetic Data Processing

The airborne magnetometer data were recorded at 160 Hz, and down sampled to 10 Hz for processing. A second order Butterworth 0.9 Hz low pass filter is utilized in the process for compensation and anti-aliasing. All magnetic data were plotted and checked for any spikes or noise. A 0.244 second static lag correction due to signal processing, plus a dynamic lag correction which varies between 0.04 s and 0.06 s, depending on the instantaneous velocity of the aircraft, was determined on a line-by-line basis using SGL's Dynlag software.

Ground magnetometer data were inspected for cultural interference and edited where necessary. All reference station magnetometer data were filtered using a 121-point low-pass filter to remove any high-frequency noise, but retain the low-frequency diurnal variations.

A correction for the International Geomagnetic Reference Field (IGRF) year 2015 model was applied to all ground magnetometer data using the fixed ground station location and the recorded date for each flight. The mean residual value of the reference station was calculated (173.141 nT) and subtracted to remove any bias when correcting the local anomalous field on the survey grid. Diurnal variations in the airborne magnetometer data were removed by subtracting the reference station data after subtraction of the mean residual.

The airborne magnetometer data were also corrected for the IGRF using the location, altitude, and date of each point. IGRF values were calculated using the year 2015 IGRF model. The altitude data used for the IGRF corrections are DGPS heights above the WGS84 datum.

### 4.2.1 Levelling

Intersections between control and traverse lines were determined by a program which extracts the magnetic, altitude, and x and y values of the traverse and control lines at each intersection point. Each control line was adjusted by a constant value to minimize the intersection differences, calculated as follows:

$\sum |i - a|$  summed over all traverse lines, where:

$i$  = (individual intersection difference)

$a$  = (average intersection difference for that traverse line)

Adjusted control lines were further corrected locally to minimize any residual differences. Traverse line levelling was carried out by a program called CLEVEL that interpolates and extrapolates levelling values for each point based on the two closest differences at intersections. After traverse lines were levelled, the control lines are matched to them. This ensured that all intersections tie very closely and permitted the use of all data in the final products.

CLEVEL provides a curved correction using a function similar to spline interpolation. A third degree polynomial was used to interpolate between two intersections. CLEVEL allows intersection points to be preserved with no mismatch and interpolation is smooth with the first derivative continuously

approaching the same value from both sides of the intersection points.

The levelling procedure was verified through inspection of the magnetic anomaly and vertical derivative grids, by plotting profiles of corrections along lines, and by examination of levelling statistics to check for steep correction gradients.

#### **4.2.2 Micro-Levelling**

Micro-levelling is occasionally applied to magnetic data to remove any residual diurnal effects by using directional filters to identify and remove artifacts that are long wavelengths parallel to survey lines and short wavelengths perpendicular to survey lines. A maximum 1 nT microlevel was only applied to hanging lines (i.e. survey lines not ending after an intersection) extending outside of the inner Manitouwadge survey area. A second, restricted instance of microlevel limited to 10 nT was also applied to remove corrugations caused by varying survey heights over the Township of Manitouwadge.

#### **4.2.3 Gridding**

The grid of the total magnetic intensity was made using a minimum curvature algorithm to create a two-dimensional grid equally sampled in the x and y directions following Briggs (1974). The final grids of the magnetic data were created with 25 m grid cell size appropriate for survey lines spaced at 100 m. Grids were also made that included the 1000 m spaced lines that extend out from the main block area. These were gridded with a cell size of 250 m. The magnetic data were gridded using a cell size of 25 m and 250 m over the Manitouwadge area. The 25 m gridding cell was applied to present the highest resolution of data within the boundary of the survey block, comprising the principal survey area. The 250 m gridding cell was applied to include the extensions of the flight lines beyond the survey block, comprising the extended survey area. The total magnetic intensity (or more correctly, the magnetic anomaly) is displayed in Figures 4.5 (principal survey area, grid cell size of 25 m) and Figure 4.6 (extended survey area, grid cell size of 250 m).

### **4.3 Gravity and Magnetic Derivative Products**

Filters may be applied to the data to enhance different wavelength information that arises from different sources. In many cases, filtering is best achieved by transforming the data from the space domain to the frequency domain by Fourier transform since frequency characteristics of the filter to be applied are more precisely defined in the frequency domain. The filtered derivatives created to assist with interpretation are described below.

### 4.3.1 Total Magnetic Intensity Reduced to Pole

Reduction to the pole (RTP) transforms anomalies as if they were at the north magnetic pole. The basic assumption is that magnetic anomalies arise from induced magnetization. This assumption may not always be true where significant magnetic remanence occurs. The method allows direct comparison of anomaly shapes from different magnetic latitudes, and if the assumptions hold true, the anomaly will be symmetrically disposed about the causative body. Reduction to pole is essentially a phase shift filter applied in the frequency domain, and is described by Baranov and Naudy (1964):

$$F(k_x, k_y) = \frac{1}{[\sin I + i \cos I \cos(D - \theta)]^2}$$

where

- $\theta$  is the angle in the  $k_x, k_y$  plane
- $I$  is the local magnetic inclination
- $D$  is the local magnetic declination

For ease of calculation, this transformation was performed through filtering in the frequency domain using a constant (average/central) inclination and declination which was considered valid throughout the entire grid. The inclination used was  $74.446^\circ$ , and the corresponding declination used was  $-7.836^\circ$  representing a station approximately at the centre of the survey. The total magnetic intensity reduced to the pole is shown in Figure 4.7 (principal survey area, grid cell size of 25 m) and Figure 4.8 (extended survey area, grid cell size of 250 m).

### 4.3.2 Vertical Derivatives of Total Magnetic Intensity and Bouguer Gravity

If  $k_x$  and  $k_y$  are the wave numbers of the potential field in the two-dimensional frequency domain, the  $n^{\text{th}}$  vertical derivative of a potential field is easily derived in the Fourier domain by applying the following filter:

$$F(k_x, k_y) = (-k)^n \quad \text{where } k = \sqrt{(k_x^2 + k_y^2)}$$

Vertical derivatives act as high-pass filters that enhance high-frequency data and suppress low-frequency data. The first vertical derivative ( $n=1$ ) enhances the rapid changes in gravity or magnetic field at the edges of anomalies and is therefore useful for delimiting the extents of causative bodies. The second vertical derivative ( $n=2$ ) enhances high-frequency signal variations even more, such that textural variations in the character of the potential field (especially for magnetic data) can be used to delimit domains of a specific geophysical response.

The first vertical derivative of the reduced to pole total magnetic intensity is shown in Figure 4.9 (principal survey area, grid cell size of 25 m) and Figure 4.10 (extended survey area, grid cell size of 250 m). The first vertical derivative of the Bouguer gravity with a terrain correction using a density of  $2.67 \text{ g/cm}^3$  is shown in Figure 4.11 (principal survey area, grid cell size of 25 m) and Figure 4.12 (extended survey area, grid cell size of 250 m). The first vertical derivative of the free air gravity is shown in Figure 4.13 (principal survey area, grid cell size of 25 m) and Figure 4.14 (extended survey area, grid cell size of 250 m). The second vertical derivative of the pole reduced total magnetic intensity is shown in Figure 4.15 (principal survey area, grid cell size of 25 m) and Figure 4.16 (extended survey area, grid cell size of 250 m). The gravity data do not contain high-frequency information to render its second vertical derivative useful for interpretation.

### 4.3.3 Total Horizontal Gradient of Total Magnetic Intensity and Bouguer Gravity

Horizontal gradients are most conveniently calculated in the space domain. Total horizontal gradient of a potential field ( $T$ ) is from the gradients in the horizontal  $x$  and  $y$  planes as follows (Nabighian, 1972):

$$\text{Total horizontal derivative} = \sqrt{(\partial T/\partial x)^2 + (\partial T/\partial y)^2}$$

Horizontal gradient grids are used primarily for edge detection of causative bodies (contacts, faults with large vertical displacement), and the data may also be employed for trend analysis and depth to source calculations.

Total horizontal derivatives of the pole reduced total magnetic intensity, Bouguer gravity (2.67g/cm<sup>3</sup> terrain corrections) and free air gravity are shown in Figures 4.17, 4.19, 4.21 (principal survey area, grid cell size of 25 m) and Figures 4.18, 4.20, 4.22 (extended survey area, grid cell size of 250 m).

### 4.3.4 Total Gradient Amplitude of Total Magnetic Intensity

The total gradient amplitude, otherwise known as the 3D analytic signal amplitude, of a potential field ( $T$ ) is defined as:

$$|A(x, y)| = \sqrt{(\partial T/\partial x)^2 + (\partial T/\partial y)^2 + (\partial T/\partial z)^2}$$

$|A(x, y)|$  is the amplitude of the analytic signal and  $T$  is the intensity at a point  $(x, y)$ . The horizontal derivatives are easily calculated in the space domain, whilst the vertical derivative is calculated in the frequency domain. The analytic signal is mostly independent of field direction and direction of magnetization, and is independent of the type of magnetization (induced or remanent). This means that all similar bodies have a similar analytic signal response, and that peaks in the analytic signal are symmetric and centred over the middle of narrow bodies and the edges of wide bodies. The amplitude however is affected by the strike of a body such that north-south oriented bodies at low latitudes are relatively weak for magnetic data. The analytic signal highlights areas where the field varies quickly in any direction, such as for contacts. The total gradient amplitude of the total magnetic intensity is shown in Figure 4.23 (principal survey area, grid cell size of 25 m) and Figure 4.24 (extended survey area, grid cell size of 250 m).

### 4.3.5 Tilt Angle

The tilt angle can be applied to the pole reduced total magnetic intensity to preferentially enhance the weaker magnetic signals. This is particularly useful for mapping texture, structure, and edge contacts of weakly magnetic sources. The arctan operator restricts the tilt angle to within the range of  $-90^\circ$  to  $+90^\circ$ , irrespective of the amplitude and wavelength of the field and enhances weak anomalies compared to the stronger anomalies. The tilt angle (Miller and Singh, 1994; Verduzco et al., 2004; Salem et al., 2007) is defined as:

$$\theta = \tan^{-1} \frac{\text{vertical component of gradient}}{\text{horizontal component of gradient}} = \tan^{-1} \left[ \frac{\partial T}{\partial z} \right] / \left[ \frac{\partial T}{\partial h} \right]$$

The vertical and horizontal gradients of the reduced to pole total magnetic intensity calculations are described above in subsections 4.3.2 and 4.3.3. The tilt angle grid for the reduced to pole total magnetic intensity is displayed in Figure 4.25 (principal survey area, grid cell size of 25 m) and Figure 4.26 (extended survey area, grid cell size of 250 m).

#### 4.3.6 Trend Analysis Method

Depth trend as implemented by Phillips (1997) can be utilized for the depth estimation using the horizontal gradient grid (HG). It uses the horizontal gradient of the reduced to pole total magnetic intensity and gravity grids to estimate strikes of and depths to thick and thin edges, respectively (Phillips, 2000). The method relies on the general principle that shallow sources produce anomalies with steep gradients, whereas deep sources produce anomalies with broad gradients. Depth estimates from the RTP magnetic and gravity data estimate the minimum and maximum depths to the top edge of the layer, respectively (Phillips, 2000).

The program uses a 5 by 5 window to both locate the crests of maxima and determine their strike direction. Once a crest is located and the strike direction is known, data within the window and within a belt perpendicular to the strike can be used to determine the depth of the contact by performing a least squares fit to the theoretical shape of the  $HG$  over a contact. If " $h$ " is the horizontal distance to the contact, " $d$ " is the depth to the top of the contact and " $K$ " is a constant, then the theoretical curve is given by (Roest and Pilkington, 1993):

$$HG(h) = K/(h^2 + d^2)$$

The least-squares fit gives an estimate of both the depth and its standard error, which can be expressed as a percentage of the depth. Typically only depth estimates with standard errors of 15% or better are retained in the final interpretation.

Due to the assumption of thick sources, the depth estimates obtained using the above procedure represent minimum depths. It is also possible to assume very thin sources and use a standard "pseudogravity" transformation instead of reduction to the pole (Roest and Pilkington, 1993). In this case the same analysis is done on the HG of the pseudogravity field, and the depth estimates represent maximum depths. Figures 4.27 and 4.28 show the depth results from the trend analysis solutions for the Bouguer gravity and the reduced to pole total magnetic intensity.

## 5 Geophysical Interpretation

The geophysical interpretation of the acquired gravity and magnetic data in the Manitouwadge area involved qualitative analysis of the various products derived from the magnetic and gravity grids (described in Section 4), and 2.5D forward modelling of the gravitational and magnetic data along three profile lines covering the principle features of the Black-Pic batholith, Fourbay Lake pluton, and Quetico metasedimentary rocks and surrounding intrusions and greenstone belts within the study area.

### 5.1 Results of Qualitative Analysis

Qualitative analysis of the gravity derivative products was used to provide general indications about: the location and general geometry of the Black-Pic batholith, Fourbay Lake pluton and Quetico metasedimentary rocks; variation in depth across the pluton and within the batholith and the metasediments; density variations within the rock units; and the presence of major or deep seated structures. Qualitative analysis of the magnetic derivative products was used to: identify the presence of potential features within the batholith, pluton, and metasedimentary rocks, such as faults and dykes (SRK, 2017a); and evaluate variation in the magnetic character of the batholith and metasedimentary rocks that may indicate changing composition of the rock or other potential heterogeneities.

For the qualitative geophysical interpretation, the Bouguer gravity (Figure 5.1), its first vertical derivative (Figure 5.2) and its total horizontal derivative (Figure 5.3), as well as the reduced to the pole total magnetic intensity (RTP) (Figure 5.4), its first vertical derivative (Figure 5.5), and its total horizontal derivative (Figure 5.6), were primarily utilized. In addition, the total gradient amplitude was used for interpretation of the magnetic data (Figure 4.23 and 4.24) because: (a) it has a maxima over vertical magnetic contacts regardless of the direction of magnetization; and (b) the magnetic intensity reduced to pole requires the assumption of only induced magnetization with the result that anomalies from remanently and anisotropically magnetized bodies can be severely distorted. Unlike the RTP, the total gradient amplitude will produce maxima over the edges of vertical magnetic contacts regardless of the presence of remanent magnetism (MacLeod, 1993).

The following subsections describe the qualitative observations made about the portions of the Black-Pic batholith, the Fourbay pluton and the Quetico metasedimentary rocks contained within the Manitouwadge survey area.

#### 5.1.1 *Black-Pic Batholith*

- Generally within the regionally extensive Black-Pic batholith, the Bouguer gravity data displays increasing values north towards the subprovince boundary (Figure 5.1). The most distinct local gravity highs correlate with mapped mafic volcanic rock units adjacent to the Black-Pic batholith, such as the Manitouwadge-Hornepayne greenstone belt, and intrusions contained within the Black-Pic batholith (e.g. Fourbay pluton and Bulldozer Lake gabbroic intrusion). The most prominent gravity lows occur centrally within the Black-Pic batholith away from greenstone belts and intrusions. The gravity data also shows a northeast trending short wavelength fabric within the Black-Pic batholith which matches the local topography and hydrology.

- The reduced to pole total magnetic intensity over the Black-Pic batholith generally shows a moderate magnetic response that diminishes towards the southern boundary of the survey area. Locally, higher magnetic intensities correlate to areas with a high density of lineament magnetic highs, interpreted as dykes. Interpreted dykes are evident within the batholith and surrounding area and show a prominent northwest trend (Matachewan dykes; Buchan and Ernst, 2004), and lesser north-northeast (Marathon dykes; Buchan et al., 1996; Hamilton et al., 2002) and northeast trends (Biscotasing dykes; Hamilton et al., 2002). Local magnetic highs within the Black-Pic batholith correlate well with mapped mafic metavolcanic units and granite-granodiorite and gabbroic intrusions.

Specific features identified in Figures 5.1-5.3 for the gravity data and Figures 5.4-5.6 for magnetic data are discussed below.

- The northern boundary of the Black-Pic batholith is defined by a high in the total horizontal derivative of the Bouguer gravity (labelled G-D1 in Figure 5.3). This curvilinear feature coincides well with the contact between the Manitouwadge-Hornepayne greenstone belt and the Black-Pic batholith, as mapped in MRD126-REV1 (OGS, 2011) and M2668 (Johns and McIlraith, 2003). Along G-D1, less dense tonalitic gneisses of the Black-Pic batholith are in contact with more dense mafic volcanic rocks of the Manitouwadge-Hornepayne greenstone belt and gabbroic rocks of the Rawluk Lake pluton and Faries-Moshkinabi intrusion. G-D2 is interpreted as the northern boundary of mafic volcanic and gabbroic rock packages of the Manitouwadge-Hornepayne greenstone belt in the Manitouwadge South and Manitouwadge East survey blocks. G-D2 was interpreted from the first vertical derivative of the Bouguer gravity (Figure 5.3) which also closely follows the mapped geology. Along G-D2, dense mafic volcanic rocks are in contact with less dense felsic volcanic rocks to the north (within the Manitouwadge Synform) and gneissic tonalitic rocks north of the Faries-Moshkinabi intrusion.
- A southern deflection in the Bouguer gravity derivatives (labelled G-D3; Figure 5.3) has been identified and may represent an extension of the mafic metavolcanics of the Manitouwadge-Hornepayne greenstone belt at depth. This interpretation is based on a geologic cross section across the Manitouwadge Synform presented in Zeleski and Peterson (2001) which shows the synform as a southward dipping fold. An alternative interpretation is that this interpreted boundary may be less continuous and may be defining a fragment of mafic metavolcanics hosted within the Black-Pic batholith adjacent to the Manitouwadge-Hornepayne greenstone belt.
- Another edge of a possible greenstone raft (labelled G-D4 in Figures 5.1 – 5.3) south of the Rawluk Lake pluton has been identified from the first vertical derivative of the Bouguer gravity (Figure 5.2). The anomaly occurs at the very eastern edge of the Manitouwadge South survey block and is only partly resolved. The anomaly correlates loosely to mapped mafic metavolcanics but also may be related to the gabbroic Rawluk intrusion. There is also a small magnetic anomaly (identified but not labelled in Figure 5.4) coincident with this gravity anomaly.
- A number of magnetic boundaries have been defined within the Manitouwadge-Hornepayne greenstone belt (labelled M-D1 to MD-4 in Figure 5.4). These boundaries generally match well with the mapped geology and define areas of alternating high and low magnetic intensities within the mafic metavolcanics and gneissic tonalite suite. The southern most of these lines

(labelled M-D1) correlates well with the mapped boundary between the greenstone belt and the tonalite suite of the Black-Pic batholith and is coincident with the gravity boundary G-D1. The first vertical derivative of the total magnetic intensity reduced to the pole (Figure 5.5) shows a marked change in the magnetic texture at this boundary and likely relates to deformation at the contact of the Manitouwadge Synform and the Black-Pic batholith. Eastwards, M-D1 defines the same textural change between the Faries-Moshkinabi intrusion and Black-Pic batholith, and seems to represent the southern extent of major deformation associated with the subprovince boundary.

- Lines M-D2 and M-D3 are most easily recognized in the total horizontal derivative of the total magnetic intensity reduced to the pole (Figure 5.6). These boundaries define the southern and northern limits of a zone of prominent linear magnetic anomalies within the mafic metavolcanic package. These anomalies are likely related to the Dead Lake Suite of the mafic volcanic package which can have very high magnetic susceptibilities in the Manitouwadge Synform area (Miles, 1998).
- East of the Manitouwadge Synform, M-D4 defines another textural change in the first vertical derivative of the reduced to pole total magnetic intensity (Figure 5.5). This boundary coincides with the mapped geologic contact between gneissic tonalities in the south and foliated tonalites with biotite and magnetite to the north (Zaleski and Peterson, 1995).
- Two magnetic anomalies correlating to mapped iron formations have been identified within the Manitouwadge Synform (both labelled M-A1 in Figure 5.4). These anomalies produce distinct magnetic highs, but are poorly resolved as they occur outside the area of high-resolution coverage.
- Another distinct magnetic high is produced in the area between the Manitouwadge South and East survey blocks (labelled M-A2 in Figure 5.4). This anomaly is coincident with the gabbroic Rawluk Lake intrusion.
- Along the western side of the Manitouwadge survey area, the total horizontal derivative of the Bouguer gravity (Figure 5.3) highlights a northeast trending boundary (labelled G-D5 in Figures 5.1 – 5.3) separating a denser unit to the west. This boundary is also defined by a more magnetic unit to the west in the reduced to pole magnetic intensity (labelled M-D5 in Figure 5.4). This boundary does not correlate to any mapped geologic structure but has a topographic expression in the digital elevation data (Figure 3.1). The feature may either represent lithological contact that has not been previously mapped within the Black-Pic batholith. The coupled response between the magnetic and gravity data potentially supports an interpretation of the Fourbay pluton extending to the north at depth.
- On the northeastern side of the Fourbay Lake pluton the magnetic data shows a broad fold pattern (labelled M-A3) in the first vertical derivative of the total magnetic field reduced to the pole (Figure 5.5). This broad pattern is consistent with an area of steeply dipping gneissic layering based on bedrock mapping within the Black-Pic batholith (OGS, 1967c). These structures may relate to deformation of the gneissic layering near the Fourbay Lake pluton.
- Three gravity lows have been identified in the southern portion of the Manitouwadge area (labelled G-A1, G-A2, and G-A3 in Figures 5.1 – 5.3). The gravity lows correlate to areas with no magnetic anomalies or magnetic textural variations. Two possible explanations for these gravity lows are: 1) they represent the thickest parts of the Black-Pic batholith; or 2) they

represent different intrusive, lower density phases within the Black-Pic batholith. The first scenario requires a relatively homogenous density throughout the Black-Pic batholith and thus the observed gravity is primarily controlled by thickness variations at the base of the Black-Pic batholith. Both of these scenarios are further explored in the quantitative modelling (Section 5.2). Some combination of both scenarios (i.e. structural relief or internal compositional variations) could also explain the observed gravity.

- Superimposed within the large gravity low labelled G-A1 exists a broad, linear gravity low labelled G-A4 in Figures 5.1 – 5.3. This anomaly has been interpreted from the total horizontal derivative and the first vertical derivative of the Bouguer gravity (Figures 5.2 and 5.3). Though the anomaly does not correlate to any mapped geologic structure, it does correlate well to the topography which is generally low and flat compared to the surrounding region (Figure 3.1). The edges of the gravity anomaly also generally follow the trend of the Black River valley along the northwestern side and an unnamed tributary on the southeastern side. A thick succession of low density, surficial alluvial sediments deposited in a structural low by the Black River could explain, or be a contributing factor, to the gravity low. The magnetic anomalies of several dykes are attenuated over within this region which supports a thicker cover of non-magnetic sediments. This interpretation is supported by the Trend analysis depth solutions of the magnetic data which show deeper solutions correlated to the Black River valley (Figure 4.28).
- Anomaly G-A5 represents a small northwest trending positive gravity ridge in Figure 5.1. The gravity anomaly does not show any relationship to the mapped geology, magnetic anomalies or topographic features. This anomaly may provide some indication of a rock density contrast in this area, however the limited geologic information makes the interpretation ambiguous.
- The Schreiber-Hemlo greenstone belt produces prominent positive magnetic and gravity anomalies at the south end and along the far western edge of the survey area. The positive gravity anomaly associated with the Schreiber-Hemlo greenstone belt has been labelled G-A6 in Figures 5.1 – 5.3 and the associate magnetic anomaly M-A4 in Figures 5.4 – 5.6. The Schreiber-Hemlo gravity anomaly is in general agreement with the mapped geology of the greenstone belt though the gravity defined boundary extends over 500 m further north. This may indicate some northerly dip of the greenstone belt geometry. The magnetic data shows a series of parallel linear anomalies of magnetic and non-magnetic lithology. This is probably the result of shearing and deformation within the greenstone belt, similar to the Manitouwadge-Hornepayne greenstone belt.
- The Bulldozer Lake intrusion (informal name) produces a distinct magnetic anomaly in the south-eastern corner of the Manitouwadge survey area (labelled M-A5 in Figures 5.4-5.6). The gabbroic intrusion has a sharp contact with the gneissic tonalities of the Black-Pic batholith and is intruded by northeast trending Biscotasing dykes and northwest trending Matachewan dykes. The intrusion has an irregular magnetic texture and is generally more magnetic along the outside perimeter of the body. The Bulldozer Lake intrusion also produces an associated gravity anomaly labelled G-A7 in Figures 5.1-5.3 which is most obvious in the first vertical derivative of the Bouguer gravity (Figure 5.2). The magnetic and gravity boundaries are relatively coincident, with the gravity showing a slight skew to the southeast possibly reflecting a southeasterly dip to the body, or a slight widening at depth.

- Two areas of unique magnetic texture have been labelled M-A6 and M-A7 in Figures 5.4-5.6. In the higher-order magnetic derivatives the textural patterns appear as alternating high-frequency but low amplitude signals that reflect a ductile fabric of the bedrock. Both areas occur entirely within the Black-Pic batholith. The M-A6 anomaly represents internal magnetic fabric which extends northerly from the anomaly associated with the Schreiber-Hemlo greenstone belt (M-A4 in Figures 5.4-5.6). This magnetic fabric may represent steeply dipping magmatic/tectonic foliation or layering with varying magnetic character (e.g. gneissic layering) within the Black-Pic batholith. This interpretation is consistent with steep gneissic layering mapped in the area by the Ontario Geological Survey (OGS 1967a; 1967b). The ability to recognize this anomaly may be a function of the layering having a relatively steep dip. A north-trending gravity anomaly, located between G-A1 and G-A2 in figure 5.1, is also coincident with the magnetic fabric, and may indicate either a thinning of the batholith in this location, or the presence of rocks with higher density. The western edge of M-A6 anomaly correlates to an apparent internal boundary in the batholith. Similarly, the M-A7 anomaly is shown as a zone of apparent magnetic fabric that extends in a northwesterly direction from the gabbroic Bulldozer Lake intrusion. This anomaly occurs within the region between the Manitouwadge South and Manitouwadge East survey blocks with coarse data coverage. Data provided from Phase 1 geophysical report (PGW, 2013) also highlights this anomaly. As both of these anomalies occur entirely within the Black-Pic batholith, it is difficult to discern their cause without further geologic information. There is potential for these anomalies to represent structural changes, or internal lithological heterogeneities.
- Throughout the Black-Pic batholith a number of small, circular magnetic anomalies have been identified in the Manitouwadge area (unlabelled in Figures 5.4-5.6). These anomalies appear to be restricted to the south of the Manitouwadge-Hornepayne greenstone belt and west of the Manitouwadge East survey block. These anomalies are typically several hundred meters wide and have positive magnetic anomalies with amplitudes greater than 100 nT. At least one of these anomalies in the Manitouwadge area produces a distinct low, suggesting remanent magnetization. Based on regional bedrock geology mapping (OGS, 2011, Johns and McIlraith, 2003, Sataguida, 2003), there is no apparent correlation between these anomalies and any mapped geological, topographic, or surficial feature. However, a number of these anomalies are coincident with mapped intrusions of amphibolitic metagabbro (OGS, 1967a). Alternatively, these anomalies may represent potential kimberlite pipes of economic interest, and would need to be investigated in the field.
- A number of short reversely magnetised, linear, northeast trending magnetic features have been identified and labelled M-L1 in Figures 5.4-5.6 within the Black-Pic batholith. The intensity of the magnetic lows that these lineations produce would suggest remanent magnetization. Similarly trending but less intense negatively magnetised lineations are seen elsewhere in the survey block but have not been marked. These lineations may be due to faults that cause a reduced magnetization or due to dykes with less significant reversed remanent magnetization. Other northeast trending, more prominent magnetic low lineations have been identified in the Quetico subprovince in the Manitouwadge North survey block.

### **5.1.2 Fourbay Lake Pluton**

- The Fourbay Lake pluton located on the western side of the Manitouwadge South survey block is characterized as a prominent magnetic anomaly with a more subtle gravity high. The magnetic boundary of the pluton is very well defined adjacent the gneissic tonalites of the Black-Pic batholith (labelled M-A8 in Figures 5.4-5.6), and correlates almost exactly with the mapped geologic boundary. The associated gravity anomaly (labelled G-A8 in Figures 5.1 – 5.3) is slightly broader than the magnetic boundary.
- At the north end of the pluton, both the magnetic and gravity data show an area of slightly elevated signal relative to the rest of the pluton (labelled M-A9 and G-A9 in Figures 5.1-5.3 and Figures 5.4-5.6, respectively). This could indicate some degree of physical property heterogeneity within the pluton. Based on field mapping, Milne (1967) observed that portions of the pluton contain higher amounts of mafic content, and significantly higher content of magnetite; in particular the northern and eastern portions. Milne (1967) also noted that these areas also correspond to highest magnetic responses over the pluton. The magnetic data also shows a number of well-defined faults and dykes that cross the Fourbay Lake pluton (SRK, 2017a). Within the pluton most of the dykes are characterized by magnetic lows as they are, relative to the pluton, less magnetic.
- The magnetic and gravity signatures of the Fourbay Lake pluton drastically differs from other mapped late granite-granodiorite type intrusions within the Black-Pic batholith. Although both the Fourbay pluton and a NE trending granite-granodiorite intrusion (unnamed) in the eastern survey block share the same lithology subtype based on historic mapping, they do not share the same magnetic and gravity characteristics. As previously noted, the Fourbay Lake pluton has a prominent magnetic anomaly with a subtle gravity high, whereas the unnamed intrusion further east is unrecognized in neither the magnetic or gravity data. This suggests that the two intrusions have drastically different mineralogy despite both being mapped within the same lithological class. Based on Giguere (1972), the dominant mineralogy of this granite-granodiorite unit is composed of quartz, microcline, plagioclase and hornblende or biotite, with minor amounts of magnetite, epidote and sericite. The Fourbay pluton consists of pyroxene-hornblende-biotite granodiorite with essential constituents of quartz, oligoclase, microcline, hornblende, biotite and augite with accessory magnetite, apatite and zircon (Milne, 1967).

### **5.1.3 Quetico Metasedimentary Rocks**

- The Quetico metasedimentary rocks in proximity to the Quetico-Wawa subprovince boundary show a broad and pronounced gravity high. The gravity increases gradationally immediately north of the subprovince boundary, peaks approximately 9 km into the Quetico Subprovince, and then decreases northwards (Figure 5.1). This high gravity anomaly is associated with the presence of rocks which have undergone high grade metamorphism (granulite facies) near the subprovince boundary (Williams and Breaks, 1996). Regionally, the Quetico Subprovince is typically dominated by low gravity away from the subprovince boundary (Percival, 1989).
- Magnetic data within the Quetico metasedimentary rocks shows intense east-west trending magnetic anomalies north of the subprovince boundary over a distance of approximately 15 km. Although this interval is only evident along a narrow band of flight lines, this is consistent with observations of the regional magnetic data (PGW, 2014). Similar to the gravity anomaly, this zone is associated with the presence of rocks which have undergone high grade

metamorphism (granulite facies) near the subprovince boundary (Williams and Breaks, 1996). North of these intense east-west trending magnetic anomalies, the intensity of the magnetic data diminishes and produces a more subtle pattern with a consistent east-west orientation. This pattern may reflect discrete zones of higher grade metamorphism or localized zones of shearing.

- A number of dykes trending north, northwest and northeast are visible. Overall the magnetic background within the Quetico Subprovince is lower than that of the Wawa Subprovince.

Specific features identified in Figures 5.1-5.3 for the gravity data and Figures 5.4-5.6 for magnetic data are discussed below.

- Along the very southern edge of the Manitowadge North survey block line M-D6 (Figures 5.4-5.6) has been interpreted to represent the northern limit of the regional magnetic high associated with the Quetico-Wawa subprovince boundary shear zone. North of this boundary, east-west magnetic lineations are still present, but significantly decrease in intensity past M-D7 and tend to occur on a non-magnetic background. Thus M-D6 or M-D7, may represent the northern limit of the zone that has undergone high grade metamorphism near the subprovince boundary (Williams and Breaks, 1996). Internal folding is also visible in the magnetic data through this area (labelled M-D8 in Figures 5.4 – 5.6) illustrating the highly deformed nature of these rocks.
- Three negative magnetic lineaments have been identified and are marked on the magnetic interpretation (labelled M-L2 in Figures 5.4 – 5.6). The negative intensity of these features, particularly in the less and non-magnetic areas would suggest that they are remanently magnetized dykes rather than faults causing demagnetization. The two more westerly anomalies have associated topographic low lineations with streams in parts.
- An area of unique magnetic texture has been identified on the magnetic interpretation (M-A10 in Figures 5.4-5.6). The magnetic fabric through this region is more chaotic than within the rest of the block, containing a large number of small scattered deformed lens-shaped anomalies. This fabric likely reflects some degree of heterogeneity or deformation.
- A single gravity boundary has been identified in the north of the Manitowadge North survey block interpreted from a textural change in the first vertical derivative of the Bouguer gravity (labelled G-D6 in Figures 5.1 – 5.3). North of this boundary the vertical derivative has a lower gradient than to the south and is less coherent in the total horizontal gradient of the Bouguer gravity. Although there is no clear correlation to any mapped geological boundary or structure, the orientation of the contact is consistent with the general east-west orientation of the magnetic fabric in this area.

## **5.2 Preliminary 2.5D Modelling**

The purpose of the 2.5D modelling is to develop an idea of the relatively deep and relatively shallow parts of the Black-Pic batholith, Fourbay Lake pluton, and Quetico metasedimentary rocks and obtain a rough approximation of the depth to the bottom of these bedrock units. The preliminary 2.5D modelling used the gravity, magnetic and digital elevation data sets, accompanied with constraints from the qualitative interpretation of the geophysical data and the mapped bedrock geology to provide a preliminary image of the subsurface along the three profile lines shown in Figures 5.7 and 5.8.

For the purpose of this initial modelling attempt, density and magnetic susceptibility values were assigned to the bedrock units mapped on the surface and to the bedrock units at depth based on readily available information (Figure 1.1). In the Manitowadge area, several surface bedrock density and magnetic susceptibility values have been compiled from available literature (data sources discussed in Section 3) and incorporated as constraints into the models. These assumed density and magnetic susceptibility values should be considered as approximate values.

In order to assess the sensitivity of the assigned density and magnetic susceptibilities on the modelled geometry and thickness of the bedrock units, a series of alternative models were also considered for some of the profile lines. The initial models assume a relatively horizontal contact with the undifferentiated basement bedrock, and therefore varied the rock density values within each mapped bedrock unit in order to fit the model to the observed data. On the contrary, the alternative models assumed uniform rock densities for each mapped bedrock units and varied the geometry of the basement contact to fit the model to the observed data. Both model approaches provide a good fit to the data. As we have an idea of the range of likely density values, the resulting 2.5D models can give an idea of the upper and lower bounds on total depth.

It is important to emphasize that the accuracy of these preliminary models is limited at this early stage of the assessment due to limited availability of bedrock densities and magnetic susceptibilities that are key for constraining the model. It is anticipated that the preliminary 2.5D models would be revised and refined if more field data is collected in the future.

### 5.2.1 Model Descriptions

The preliminary 2.5D forward modelling of gravity and magnetic data was carried out using GMSYS Software (copyright Northwest Geophysical Associates Inc. 2006) running under Geosoft Oasis Montaj (Geosoft, 2015). The modelling considered three profile lines. The locations of the profile lines are shown in Figure 5.7 superimposed on the total magnetic intensity reduced to the pole, and in Figure 5.8 superimposed on the Bouguer gravity. The coordinates of the start and end points for each of the profile lines are listed in Table 5.1

Table 5.1: Coordinates of 2.5D Model Profiles (UTM 16N, NAD83)

Profile Line	Start		End	
	UTM X	UTM Y	UTM X	UTM Y
1	580360	5411157	580360	5411157
2	615460	5406855	615460	5468555
3	561000	5425800	604800	5425800

The process for constructing the models was as follows:

- The location and extent of profile models was taken into consideration when the survey was originally planned. Traverse lines were flown connecting the Manitowadge North and south blocks to allow for a continuous regional profile to be constructed. Similarly, groups of traverse lines were extended past the northern and southern boundaries of the Manitowadge East block to capture the regional features outside of the area of high-resolution data.

- The profiles were modelled from Bouguer gravity and the total magnetic intensity data. It is possible to model either Free-Air or Bouguer gravity. Both approaches are valid, the difference is that topographic effects have been corrected in the Bouguer gravity, assuming a single density within the range of relief ( $2.67 \text{ g/cm}^3$  in this instance). Some terrain effects will still occur in the Bouguer gravity where density varies from the assumed value within the range of relief. The best choice depends on the degree to which the single density terrain corrections are applied and correctly handled. The model results should be essentially the same with either approach.
- Generally speaking, the gravity was modelled first to determine the broad large scale features and the magnetic data were used to refine the model and to help model the overall shape of smaller geological units. Long wavelength magnetic trends associated with large rock units were modelled as opposed to individual discrete anomalies and, as such, only the most prominent dykes and faults were included to fit the observed data.
- Densities for individual greenstone belts or plutons were assumed to be uniform throughout unless there were additional data that suggested the contrary (e.g. well logs, density measurements, etc.). This assumption was only violated if it was impossible to model the gravity using uniform densities. Thus the gravity anomalies were generally accounted for by varying the shapes of the rock units after initial density assumptions were made, rather than by varying the densities within the rock units.
- Depth trend, tilt angle and extended Euler solutions of the Bouguer gravity and magnetic data were used for determining locations and dips of faults and lithological contacts.
- Available geologic mapping (OGS, 2011) and qualitative interpretation of the geophysical data were used to determine the location of the points at which geological boundaries occurred along the surface of the models.
- Density information has been obtained and incorporated into the models from the OGS PETROCH database (Haus and Pauk, 2010) and the GSC rock property database (GSC, 2015), as discussed in Section 3. The density ranges used in the models are listed in Table 5.2.
- In determining the magnetic susceptibilities, measured values from the OGS Precambrian Bedrock Magnetic Susceptibility Geodatabase (Muir, 2013) and Miles (1998) were used as initial values for modelling, but were adjusted so as to (a) best match the amplitude of the magnetic variations that were obviously associated with terrain, (b) best reproduce the overall long wavelength trend associated with the larger rock units. This approach was employed due to the variability of the measured susceptibilities, in some cases over several orders of magnitude.
- In seeking to model magnetic variations within individual rock units, vertical boundaries were initially used in the absence of other indications. These boundaries were then adjusted to best fit the data. Where possible, trend analysis solutions for the magnetic field reduced to the pole were used to model the dip of magnetic contacts. Trend analysis solutions are shown in the 2.5D model figures which occur no more than 0.5 km away from the model line.
- The overburden has not been included in the modelling. It is deemed to be sufficiently thin that its effect on the gravity and magnetic anomalies is negligibly small for modelling purposes.

- Where the 2.5D model lines intersect, the geological boundaries, densities, and magnetic susceptibilities have been made to coincide at the model intersection points

Table 5.2: Densities and magnetic susceptibilities used in the 2.5D models

<b>Layer</b>	<b>Density (g/cm<sup>3</sup>)</b>	<b>Magnetic Susceptibility (S. I.)</b>
<i>Mafic metavolcanics (2)</i>	2.66-2.85	0-0.063
<i>Felsic volcanics (4)</i>	2.72	0.013
<i>Metasediments (5)</i>	2.72-2.75	0-0.055
<i>Gabbro (8)</i>	2.78	0-0.037
<i>Gneissic tonalite (9)</i>	2.64-2.75	0-0.065
<i>Foliated tonalite (10)</i>	2.70	0-0.029
<i>Granite-granodiorite (11)</i>	2.63	0-0.021
<i>Granite-granodiorite (13)</i>	2.66	0-0.042
<i>Dyke</i>	2.66	0.004-0.021
<i>Undifferentiated basement</i>	2.69	0

### 5.2.2 Model Results

This section discusses the results of the 2.5D modelling for the three profile lines considered. It is assumed in all models that the bedrock units (i.e. batholith, pluton, greenstone belt and metasedimentary rocks) are underlain by a uniformly dense unit (density of 2.69 g/cm<sup>3</sup>) defined as an undifferentiated basement. Where applicable, alternative models were developed to investigate different geological scenarios.

The 2.5D modeling results for the Manitouwadge area are shown on Figures 5.9 to 5.12. The figures show a plan view along the profile line (e.g. top panel Figure 5.9) in order to show the distribution of bedrock units that are included in the model calculations perpendicular to the strike of the profile line. The gravity view (e.g. second panel Figure 5.9) shows the observed gravity data along the profile line, as well as the calculated gravity data, the misfit and the RMS error (i.e. root mean square error). The RMS error is used as a measure of the difference between the observed gravity data and the modelled gravity results. The next gravity view (e.g. third panel Figure 5.9) shows the assignment of the rock density values to each of the bedrock units in the model. The magnetic view (e.g. fourth panel Figure 5.9) shows the observed and calculated magnetic data, as well as the misfit and RMS error between the two data sets. The next magnetic view (e.g. fifth panel Figure 5.9) shows the assignment of the magnetic susceptibility values to each of the bedrock units in the model. The structural view provides the overall interpretation of the modelled results, which are coloured based on geological unit (e.g. sixth panel on Figure 5.9). Each of these model views shows the depth on the y-axis in kilometers below mean sea level (MSL).

### 5.2.2.1 Initial Model Line 1 (Figure 5.9)

As shown in Figures 5.7 and 5.8, Line 1 runs from south to north, starting in the Schreiber-Hemlo greenstone belt, transecting the Black-Pic batholith, Manitouwadge Synform, and Quetico-Wawa subprovince boundary. The profile ends in the Quetico metasedimentary rocks.

- With a fixed rock density of  $2.69 \text{ g/cm}^3$  for the undifferentiated gneissic basement units, depths to bottom for the Black-Pic batholith and Quetico metasedimentary rocks of approximately 7.50 km were required for the model to fit the data. This model keeps the depth extent of the Black-Pic batholith and Quetico metasedimentary rocks relatively constant around 7.50 km and attempts to fit the observed gravity signal using variable density within the Black-Pic batholith and Quetico metasedimentary rocks. The assumption of this model is that different intrusive phases or rocks of different metamorphic grades have different density values.
- The observed gravity signal of Line 1 consists of a broad wavelength low response associated with the Black-Pic batholith. The gravity signal increases gradually approaching the Manitouwadge Synform, and reaches a maximum in the central region within the Quetico metasediments and then gradually decreasing farther north. A high amplitude anomaly is produced over the greenstone belt units of the Manitouwadge Synform. The magnetic profile on the other hand is highly variable and dominated by high amplitude, short wavelength anomalies over the Manitouwadge greenstone belt and the deformation zone at the Quetico-Wawa subprovince boundary. Elsewhere it shows a comparatively smooth magnetic anomaly associated with the Black-Pic batholith and the northernmost portion of the Quetico metasedimentary rocks, with several small amplitude short wavelength signals mostly associated with dykes.
- In the far south of the profile the Schreiber-Hemlo greenstone belt has been modelled with a relatively steep contact dipping towards the south with a depth extent of 1.2 km. The greenstone unit may extend deeper farther south beyond the limit of the survey. A portion of the greenstone belt was included just off-line approximately 1 km to the east for the first 2 kilometres of the line. This section of the line also requires an increase in the magnetic susceptibility in the gneissic tonalite suite located north of the greenstone belt defined in the qualitative interpretation.
- Generally, south of the Manitouwadge Synform, the gneissic tonalite suite of the Black-Pic batholith has an assigned density of  $2.66 \text{ g/cm}^3$ . The magnetic susceptibility of the batholith shows a gradual increase towards the Manitouwadge Synform, which may reflect a change in the magnetic character of the batholith, but is complicated by the profile line running parallel and adjacent to a north trending dyke for approximately 6 km. Where the gneissic tonalites of the Black-Pic batholith are modelled to underlie the Manitouwadge Synform, rock densities were increased ( $2.72$  to  $2.75 \text{ g/cm}^3$ ) in order to fit the model to the data. This increase in rock density of the gneissic tonalites is likely associated with the presence of rocks that have undergone higher grade metamorphism near the subprovince boundary (Williams and Breaks, 1996).
- Within the central portion of the Black-Pic batholith a small reduction in density ( $-0.02 \text{ g/cm}^3$ ) was required to fit the observed data over a distance of approximately 10 km. This area has been previously mapped as uniform lithology consisting of gneissic tonalite of the Black-Pic batholith (OGS, 2011). Reducing the rock density for this portion of the line has the effect of

producing the modelled gravity low and allowing for the base of the Black-Pic batholith to stay relatively flat. In the qualitative analysis this area has been interpreted as a broad area with a gravity low response (labelled as G-A1 in Figures 5.1-5.3).

- A noticeable gravity anomaly and short wavelength, high-amplitude magnetic anomalies are observed over the Manitouwadge Synform. The fold geometry incorporated into the model represents synform with a southward dipping axial plane whose maximum depth extends to approximately 2.5 km following information provided from Zaleski and Peterson (2001). Two bands of highly magnetic metavolcanics separated by a band of non-magnetic metavolcanics were required to fit the observed magnetic data. The model has the mafic metavolcanics wrapping underneath the fold and pinching out north of the hinge line. Mapped foliated tonalite is included within the core of the fold with small wedges of felsic volcanic and metasedimentary rocks extending to a depth around 300 m below MSL. On the northern side of the synform a thin granite-granodiorite unit dips under and pinches out to the south 2.4 km below MSL.
- North of the Manitouwadge Synform the gneissic tonalites of the Black-Pic batholith were modelled as a series of thin, steeply north dipping sheets up to and at the Quetico-Wawa subprovince boundary. These gneissic tonalite sheets have highly variable magnetic susceptibilities and increasing rock density towards the subprovince boundary (maximum of  $2.75 \text{ g/cm}^3$ ). The magnetic susceptibility changes and density increase could be explained by the inclusion of supracrustal rocks and granulite grade metamorphic rocks near the shear zone as suggested by Williams et al. (1991) and Zaleski and Peterson (1995).
- North of the subprovince boundary, in the Quetico metasedimentary rocks, the model consists of a series of steeply north dipping sheets with varying density and magnetic susceptibility. The increasing density assigned to the units along this boundary reflects the increased metamorphic grade (granulite facies) recognized in the bedrock near the subprovince boundary (Williams and Breaks, 1996). Immediately across the subprovince boundary the amplitude of the observed magnetic field decreases and the use of wider model blocks of constant magnetic susceptibility were able to approximate the trend in the observed data. However, these could be further subdivided to better represent the highly variable field. There is also a slight density decrease of  $-0.01 \text{ g/cm}^3$  in the metasedimentary rocks in a 2.5 km wide zone, relative to the gneissic tonalites immediately south of the subprovince boundary which have a density of  $2.75 \text{ g/cm}^3$ .
- About 10 km north of the subprovince boundary, the profile transects an area mapped as granite-granodiorite which extend much farther to the west than east. A very subtle gravity low is associated with this body with no detectable magnetic anomaly. A density value of  $2.63 \text{ g/cm}^3$  was chosen for granite-granodiorites as two density values measured on samples collected farther north had density values of  $2.66 \text{ g/cm}^3$  and  $2.57 \text{ g/cm}^3$ . The large density contrast between this body and the Quetico metasediments ( $2.75 \text{ g/cm}^3$  in this area) required it to be modelled as a thin synclinal shape with maximum depth of 0.23 km below MSL. Increasing the density of the granite-granodiorite body (thus decreasing the density contrast between it and the hosting metasediments) would effectively extend it deeper. Three other granite-granodiorite bodies profiled at the north end of the line defined from surface geology show no associated magnetic anomalies and no associated gravity anomalies. These were incorporated in the model as synclinal bodies to honour the bedrock mapping. The same density value was used for these granite-granodiorite bodies as the one to the south ( $2.63$

g/cm<sup>3</sup>) which produces a density contrast of 0.12 g/cm<sup>3</sup> between the granite-granodiorite rocks and metasedimentary rocks. No magnetic susceptibility was assigned to these bodies.

### 5.2.2.2 *Alternative Model Line 1 (Figure 5.10)*

Line 1 was also modelled using a constant density for the Black-Pic batholith south of the Manitouwadge Synform (Figure 5.10). The observed gravity signal in this model is primarily controlled by changing the depth to the base of the model where the Black-Pic batholith overlies undifferentiated basement.

- The magnetic contacts at the surface within this model are the same as those presented in Line 1, however in several places, notably within the Manitouwadge Synform and shear zone at the subprovince boundary, the magnetic susceptibilities of the magnetic blocks needed to be increased to account for the reduced total depth of the blocks.
- The density in the southern part of the Black-Pic batholith was set to 2.66 g/cm<sup>3</sup>, increasing to 2.73 g/cm<sup>3</sup> north of the Manitouwadge Synform, and 2.75 g/cm<sup>3</sup> at the subprovince boundary. The Quetico metasediments had density values set to 2.75 g/cm<sup>3</sup> north of the subprovince boundary, decreasing to 2.72 g/cm<sup>3</sup> at the north end of the profile. As previously mentioned, a density increase in both gneissic tonalites of the Wawa Subprovince and the metasedimentary rocks of the Quetico Subprovince is still required to match the observed gravity signal regardless of basement relief approaching the deformation zone and at the subprovince boundary.
- Based on the assumption of using a relatively constant density values for each of the mapped bedrock units, the contact between the Black-Pic batholith and undifferentiated basement shows considerable relief, especially south of the subprovince boundary. The broad gravity low associated with the central portion of the Black-Pic batholith results in a maximum thickness of the batholith of 13.6 km below MSL. Approaching the Manitouwadge Synform from the south, the gravity data gradually increases requiring the thickness of the batholith to decrease to approximately 3.3 km below MSL. North of the Manitouwadge Synform, the Black Pic batholith has a modelled thickness of approximately 3.8 km and then begins to thicken to 7.4 km at the boundary between the Quetico and Wawa subprovinces. The depth extent of the Quetico metasediments further increases to a maximum of 9.7 km below MSL at its maximum thickness. For the remainder of the profile the Quetico metasediments show a relatively uniform thickness of approximately 6 to 7 km below MSL.
- Within this model, the thickness of the Black-Pic batholith and Quetico metasediments is controlled primarily by the density contrast between the undifferentiated basement and the units above. As such, the density of the undifferentiated basement, Quetico metasedimentary rocks, and Black-Pic batholith are extremely important in controlling the thickness of the Black-Pic and Quetico metasedimentary rocks. A density of 2.66 g/cm<sup>3</sup> was used for the Black-Pic batholith in the south which was chosen from a measurement on a sample within the study area. If this value was reduced by -0.04 g/cm<sup>3</sup> to 2.62 g/cm<sup>3</sup> it would increase the density contrast with the undifferentiated basement which will have the effect of reducing the depth of the Black-Pic batholith from ~13.6 km below MSL to ~5 km below MSL. If the density of the undifferentiated basement was reduced from 2.69 g/cm<sup>3</sup> to 2.67 g/cm<sup>3</sup> it would have the opposite effect of thickening, or increasing the depth of the Black-Pic batholith contact. Increasing the density of the undifferentiated basement would conversely require a thinning in

the overlying units.

### 5.2.2.3 Initial Model Line 2 (Figure 5.11)

As shown in Figures 5.7 and 5.8, Line 2 runs south to north starting in the Black-Pic batholith, across the Bulldozer Lake (informal name) and the Faries-Moshkinabi intrusions, across the Quetico-Wawa subprovince boundary, and ending in the Quetico metasedimentary rocks (Figure 5.11).

- The gravity data shows a fairly smooth, broad signal increasing northwards into the metasedimentary rocks of the Quetico Subprovince. The magnetic data shows a number of short wavelength anomalies coincident with the Bulldozer Lake intrusion, numerous dykes, and anomalies in proximity to the Quetico-Wawa subprovince boundary.
- The southernmost portion of the profile lines presents a broad low gravity anomaly that is modelled assuming a density of 2.64 g/cm<sup>3</sup>. Based on the qualitative interpretation, this area could be related to an eastward extension of the gravity anomaly G-A2 (see Figure 5.1). The depth of the Black-Pic batholith in this area was modelled at approximately 7.25 km below MSL. Most of the remaining Black-Pic batholith is modelled with a bedrock density of 2.66 g/cm<sup>3</sup>, with the exception of near the subprovince boundary. Changing the rock density values within the mapped bedrock units allows for a relatively horizontal base at the contact with the undifferentiated basement.
- The gabbroic Bulldozer Lake intrusion produces a subtle gravity anomaly approximately 15 km from the southern end of the profile. Two density points were sampled above the pluton measuring 2.78 g/cm<sup>3</sup> and 2.88 g/cm<sup>3</sup> suggesting a higher density compared to the surrounding gneissic tonalites (Haus and Pauk, 2010). Initial modelling was carried out using a density of 2.78 g/cm<sup>3</sup>. With a density at the low end of the sampled densities, the structure of the pluton is shown to be shallow, extending to a maximum depth 0.46 km below MSL. In the center of the body, the pluton potentially thins to 0 MSL (approximately 300m below the topographic surface). If the density value assigned to this gabbroic unit were increased, the model result would have the effect of further reducing the thickness of the pluton.
- The magnetic anomaly associated with the Bulldozer Lake intrusion consists of multiple sharp magnetic highs on its south side and a broader magnetic high on its north side. The magnetic data characterizing the pluton was modelled as a series of vertical blocks with varying magnetic susceptibility, reflecting the chaotic magnetic signature of the pluton. Some of the magnetic highs within the pluton, primarily on the north side, are the result of interpreted dykes crossing the profile line. However, for simplicity they were not included in the model.
- Immediately north of the Bulldozer Lake intrusion, four discrete and strong magnetic anomalies have been incorporated into the model as vertical dykes. These dykes correlate to both Matachewan and Biscotasing swarms (SRK, 2017a). The largest of these anomalies is associated with a Biscotasing mafic dyke trending northeast from the Bulldozer Lake intrusion.
- In the central portion of the profile a granite-granodiorite intrusion has been incorporated into the model based on the bedrock geological map (Figure 1.1). This mapped unit is cut by several northeast trending dykes producing several small magnetic anomalies, but the unit itself produces no distinguishing signal. The intrusion also does not produce a detectable gravity anomaly, therefore was modelled with the same density as the encompassing Black-Pic batholith (2.66 g/cm<sup>3</sup>). The resulting geometry of this body is therefore unconstrained.

- The small gabbroic unit associated with the Faries-Moshkinabi intrusion, located ~39 km into the profile has been modelled to a depth of approximately 0.3 km below MSL. The anomaly occurs at the edge of a more regional increase in the gravity and only produces a very subtle local gravity anomaly. A thin mafic metavolcanic unit located on the northern side of the gabbroic unit is represented in the model as shallow with a high magnetic susceptibility.
- The bedrock unit mapped as foliated tonalite has been modelled as a series of moderately north dipping sheets, extending approximately 4.2 km which reflect variations in the magnetic susceptibility of the rocks, and possibly steepen towards the Quetico-Wawa subprovince boundary. Although these sheets do not produce a discernable gravity anomaly, they do produce variably strong magnetic anomalies.
- At and north of the subprovince boundary, the Quetico metasedimentary rocks were modelled as a series of steeply north dipping sheets with a highly variable magnetic susceptibility. The steeply dipping fabric is consistent with the geometry modelled at the subprovince boundary and is consistent with results from Model 1. The density of the metasedimentary rocks in the Quetico Subprovince increases from 2.72 g/cm<sup>3</sup> to 2.75 g/cm<sup>3</sup> from approximately 1 km north of the subprovince boundary for the remainder of the profile. Unlike in Model 1, the profile does not extend far enough north to encounter the decrease in the density.
- The base of the Black-Pic batholith and Quetico metasedimentary rocks in this model has been defined allowing both internal density variations and structural relief at their base. Overall the relief is small, reaching maximum depth of approximately 8.2 km below MSL, 40 km into the profile from the south. The portion of the batholith south of the Bulldozer Lake intrusion could be considerably deeper if a uniform rock density was assigned to the Black-Pic batholith. This scenario is explored in Section 5.2.2.4 “Alternative Model Line 2 (Figure 5.12)”. The Black-Pic batholith is also modelled as both thinning and increasing in density north towards the subprovince boundary reaching a minimum depth to base of ~7 km below MSL at the subprovince boundary. Past the subprovince boundary, the Quetico metasedimentary rocks have a fairly consistent depth to undifferentiated basement at ~7 km below MSL. There is a local decrease in density of these rocks immediately north of the subprovince boundary. If a density of 2.67 g/cm<sup>3</sup> is retained for the rest of the Quetico metasedimentary rocks, the anomaly can be modelled by raising the base of the metasedimentary rock by ~ 4 km.

#### **5.2.2.4 Alternative Model Line 2 (Figure 5.12)**

Line 2 was also modelled with a constant density for the Black-Pic batholith south of the Quetico-Wawa subprovince boundary. The observed gravity signal in this model is primarily controlled by changing the depth to the base of the model where the Black-Pic batholith overlies undifferentiated basement.

- A uniform density of 2.66 g/cm<sup>3</sup> was assigned to the southern half of the Black-Pic batholith. Bedrock geological contacts and magnetic susceptibility values assigned to the units in this model are identical to the initial model for profile line 2.
- South of the Bulldozer Lake intrusion, the base of the Black-Pic batholith is increased from approximately 7.3 km below MSL in “Initial Model Line 2” to approximately 17.5 km below MSL in this model.
- Immediately below and just north of the Bulldozer Lake intrusion the depth to base of the

Black-Pic batholith is raised by up to 3 km relative to “Initial Model Line 2.” Farther north, the base of the Black-Pic batholith levels at around 8 km below MSL which is fairly similar to the depth to the base of the Black-Pic batholith in “Initial Model Line 2.”

- At the north end of the profile, the depth to undifferentiated basement of the metasediments of the Quetico Subprovince increases northwards from 6.7 km up to 8.2 km in this model. This is in contrast to “Initial Model Line 2” where the basement is fairly flat in the same area.

#### **5.2.2.5 Initial Model Line 3 (Figure 5.13)**

As shown in Figures 5.7 and 5.8, Line 3 runs west to east across the Fourbay Lake pluton and the Black-Pic batholith. The profile transects two of the three gravity lows within the Black-Pic batholith identified during the qualitative interpretation (G-A1 and G-A2 in Figures 5.1-5.3). This profile also crosses Line 1.

- The gravity data is fairly smooth and broad along the length of the profile. There is a large regional gravity high on the western side of the profile (at least 5 mGal amplitude and 12 km wide anomaly). A small possible gravity anomaly coincides with the Fourbay Lake pluton. Another gravity anomaly within the Black-Pic batholith is located in the centre of the profile. The magnetic data shows an area of elevated magnetic intensity with short wavelength signal coincident with the Fourbay Lake pluton. The remainder of the profile shows numerous short wavelength, low amplitude (~100 nT) magnetic anomalies.
- The Fourbay Lake pluton was modelled with a constant density of 2.75 g/cm<sup>3</sup> extending to a maximum depth of ~ 1.1 km below MSL. It is entirely surrounded by gneissic tonalite of the Black-Pic batholith which have a density of 2.68 g/cm<sup>3</sup>. The pluton thins towards its center where it has been modelled with a minimum depth of ~0.4 km below MSL. However, it is acknowledged that this density value is anomalously high for a granite-granodiorite intrusion. A single density value of 2.98 g/cm<sup>3</sup> was measured on the western side of the pluton from a sample of diorite, but as noted in Beakhouse (2001), diorite is believed to represent <1% the total rock volume of the Fourbay Lake pluton. If the entire body was modelled with a density of 2.98 g/cm<sup>3</sup>, then the Fourbay Lake pluton would be considerably thinner, with a maximum thickness of about 150 m. The magnetic data however does not support an intrusive this thin.
- The Fourbay Lake pluton has been modelled with a high magnetic susceptibility which is variable across the body. Magnetic susceptibility increases in the Black-Pic batholith near its contact with the Fourbay Lake pluton, on the pluton’s western and eastern flanks; it was not possible to use a sharp magnetic susceptibility change between the Black-Pic batholith and Fourbay Lake pluton. Several dykes cut across the Fourbay Lake pluton in the plane of the profile. Typically the dykes produce a reduction in the magnetic intensity relative to the Fourbay Lake pluton. Two of these dykes were included in the model and are less magnetic than the surrounding rocks of the pluton.
- Encompassing the Fourbay Lake pluton, the Black-Pic batholith has been modelled with a density of 2.68 g/cm<sup>3</sup> extending to approximately 7 km below MSL, thickening eastwards. The magnetic susceptibility of the Black-Pic batholith in this area was also increased to better model the observed magnetic anomaly. East of 14 km the Black-Pic batholith has been modelled as essentially non-magnetic (SI = 0.01x10<sup>-3</sup>). The profile shows numerous short wavelength anomalies along its length which can all be correlated to dykes transecting it. For

simplicity, these dykes have not been included in the model

- On the western side of the profile, from approximately 1 km to 2.5 km, a thin zone of less dense Black-Pic batholith ( $2.62 \text{ g/cm}^3$ ) was used to model a thin gravity low. The block correlates to a northwest trending gravity low in-between the Fourbay Lake pluton and Schreiber-Hemlo greenstone belt. The anomaly does not correlate to any mapped geological structure.
- East of the Fourbay Lake pluton, the Black-Pic batholith has been modelled to a depth of approximately 7.6 km below MSL around the 20 km marker using a density of  $2.64 \text{ g/cm}^3$ . This area correlates to the gravity anomaly area G-A1 (Figures 5.1-5.3) identified in the qualitative analysis which was hypothesised as being either the deepest or least dense area of batholith. Both of these scenarios are included within the model (i.e. the Black-Pic batholith is thickest and less dense) but if only one is shown to be true, the model can be adapted accordingly. If density variations alone are the cause of the gravity anomaly, a density reduction would cause the depth to undifferentiated basement to also be reduced. If relief at the base of the batholith is determined to be the only factor, an increased density would require a proportionally thicker section of the Black-Pic batholith. This observation holds true also around the 39 km marker where the batholith also has a density of  $2.64 \text{ g/cm}^3$ , depth to undifferentiated basement of 7.6 km and correlates to the gravity anomaly G-A2 identified in the qualitative interpretation (Figures 5.1-5.3).
- At the centre of the profile a small gravity anomaly within the Black-Pic batholith was modelled as a block of higher density bedrock ( $+0.04 \text{ g/cm}^3$ ) in order to fit the observed data. The block has a wedge shape and dips moderately west on its western side, and steeply east on its eastern side. The thickness of the Black-Pic batholith is also reduced underneath the wedge. The body correlates to the gravity ridge running between the two gravity lows (G-A1 and G-A2; Figures 5.1-5.3) noted during the qualitative interpretation. Alternatively, the model results could have assumed a uniform rock density in this area, which would have resulted in the Black-Pic batholith thinning to zero (i.e undifferentiated basement coming to surface). It is geologically more reasonable to explain the cause of the observed anomaly by a change in rock density, rather than a drastic thinning of the batholith in this portion of the profile line.
- At the point where Line 1 and Line 3 intercept, the thickness and density of the batholith has been modelled to be consistent across both lines.

## 6 SUMMARY OF RESULTS

The following provides a summary of the qualitative observations and the preliminary 2.5D modelling of the geophysical data, focusing on the areas identified during Phase 1 as being potentially suitable within the Black-Pic batholith, Fourbay Lake pluton, and Quetico metasedimentary rocks. The survey allowed for a characterization of the distinctive local gravity and magnetic signatures of the Black-Pic batholith and its encapsulated plutons and metavolcanic units, as well as the Quetico metasedimentary rocks north of the subprovince boundary.

### ***Black-Pic Batholith***

- The Black-Pic batholith shows subtle internal variations in magnetic character with several regions showing magnetic foliations and internal magnetic fabric highlighting either some degree of lithological heterogeneity or steeply dipping gneissic layering. The steep gneissic fabric is suggested to relate to large-scale fold structures throughout the Black-Pic batholith.
- Three large gravity lows within the Black-Pic batholith have been shown to either represent the deepest portion of a uniformly dense batholith or a local alternate phase of emplacement with a slightly lower density. In both scenarios the batholith has been modelled as extending to a considerable depth.
- The gravity and magnetic signature of greenstone belts that flank the Black-Pic batholith are spatially restricted. Boundaries of the greenstone belt units generally match well with the mapped geology, although locally some improvements can be made. They have been modelled generally as tight synclines hosted entirely within the Black-Pic batholith and extend to depths less than 2.5 km below MSL. Greenstone belt units produce high amplitude, short wavelength magnetic anomalies and high amplitude gravity anomalies.
- Several small, circular magnetic anomalies have been identified within the Black-Pic Batholith, and appear to be restricted to the area south of the Manitouwadge-Hornepayne greenstone belt and west of the Manitouwadge East survey block. Based on geological mapping, these anomalies may be associated with amphibolitic metagabbroic intrusions (OGS, 1967a).
- The granite-granodiorite pluton mapped on the eastern portion of the Black-Pic batholith (north of the Bulldozer Lake intrusion) does not show a discernable magnetic or gravimetric signature.
- The Bulldozer Lake intrusion has been modelled as a thin sill-like body within the Black-Pic batholith no more than 700 m thick.
- The Black-Pic batholith, adjacent greenstone belt units and other intrusions are cross-cut by at least three independent dyke swarms of both positive and negative polarity.

### ***Fourbay Lake Pluton***

- The Fourbay Lake pluton is characterized as a prominent magnetic anomaly with a subtle gravity high. It is intruded by at least three differently oriented dyke swarms, and shows some degree of physical property heterogeneity. The boundary of the pluton adjacent to the gneissic tonalites of the Black-Pic batholith is very well defined and correlates almost exactly with the mapped geologic boundary.

- The north end of the pluton is slightly elevated in magnetic and gravity signal relative to the rest of the pluton, which may indicate some degree of physical property heterogeneity. This interpretation is consistent with field observations where portions of the pluton contain higher amounts of mafic content, and significantly higher content of magnetite; in particular the northern and eastern portions (Milne 1991).
- The pluton has been modelled extending to a depth of around 1 km, thinning in its center and being entirely surrounded by gneissic tonalites of the Black-Pic batholith.

### ***Quetico Metasedimentary Rock***

- The Quetico metasedimentary rocks are weakly magnetic and are locally overprinted by strong east-west trending magnetic fabric associated with the presence of rocks that have undergone metamorphism (granulite facies). The intensity of the magnetic fabric is strongest near the subprovince boundary and decreases dramatically at distance of approximately 15 km away.
- Some degree of lithological heterogeneity is apparent within the metasediments as zones of chaotic magnetic fabric, with a large number of small scattered deformed lens-shaped anomalies.
- Metasediments of the Quetico Subprovince are associated with a strong gravity anomaly that is attributed to the presence of higher grade metamorphic rocks (Williams and Breaks, 1996). Regionally, the Quetico Subprovince is typically dominated by low gravity away from the subprovince boundary (Percival, 1989).
- The Quetico metasedimentary rocks have been cross-cut by at least three independent dyke swarms of both positive and negative polarity.
- Rocks of the Quetico Subprovince have locally been modelled extending to depths typically >6.5 km. The depths shallow to a minimum of 4.5 km if density variations within the metasediments were limited.

The 2.5D models are viewed as preliminary primarily due to the limited availability of bedrock densities and magnetic susceptibilities that are key for constraining the model. More field data would allow for revision and refinement of the models.

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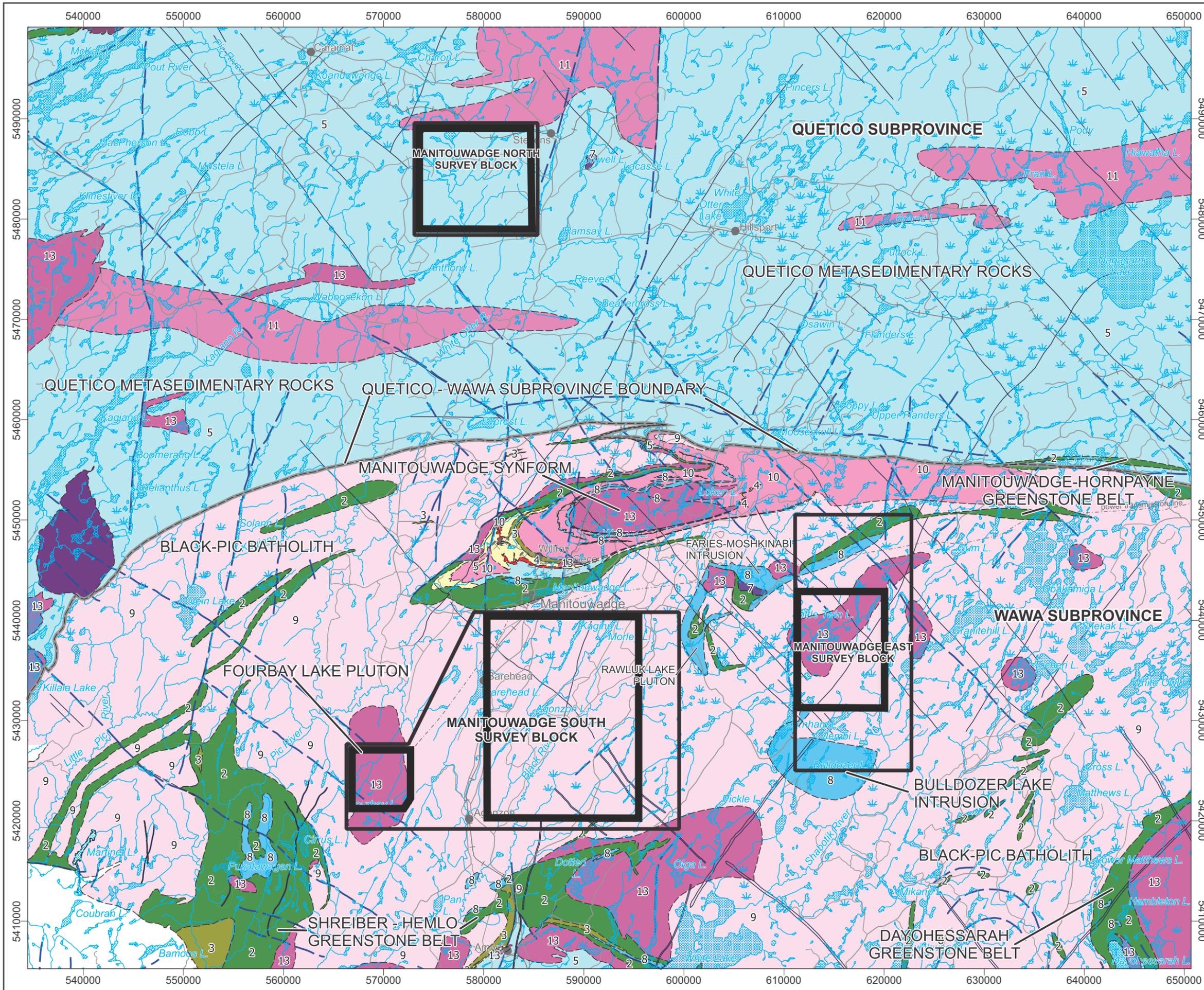
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## 8 FIGURES

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- 5.12 Forward Modeling Results: Line 2 – Alternative, Manitouwadge, Ontario
- 5.13 Forward Modeling Results: Line 3, Manitouwadge, Ontario

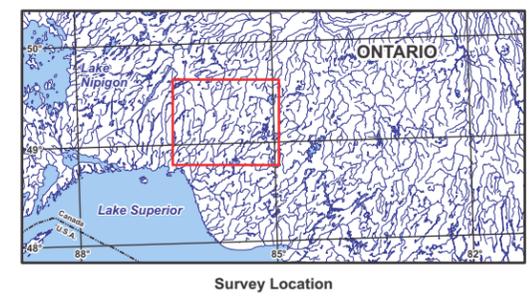


- Legend**
- Hydrography .....
  - Roads .....
  - Railway .....
  - Powerline .....
  - Mine .....

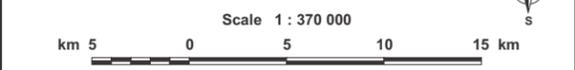
- Geology**
- Fault .....
  - Dyke .....
  - Subprovince Boundary .....

- 0: Iron formation
- 2: Mafic metavolcanics
- 3: Felsic and intermediate metavolcanics
- 4: Felsic volcanics
- 5: Metasedimentary rocks
- 7: Ultramafic plutonic rocks
- 8: Gabbroic rocks
- 9: Gneissic tonalite suite
- 10: Foliate tonalite suite
- 11: Granite-granodiorite, muscovite/biotite bearing rocks
- 13: Granite-granodiorite

- Survey Area .....
- Withdrawal Area .....



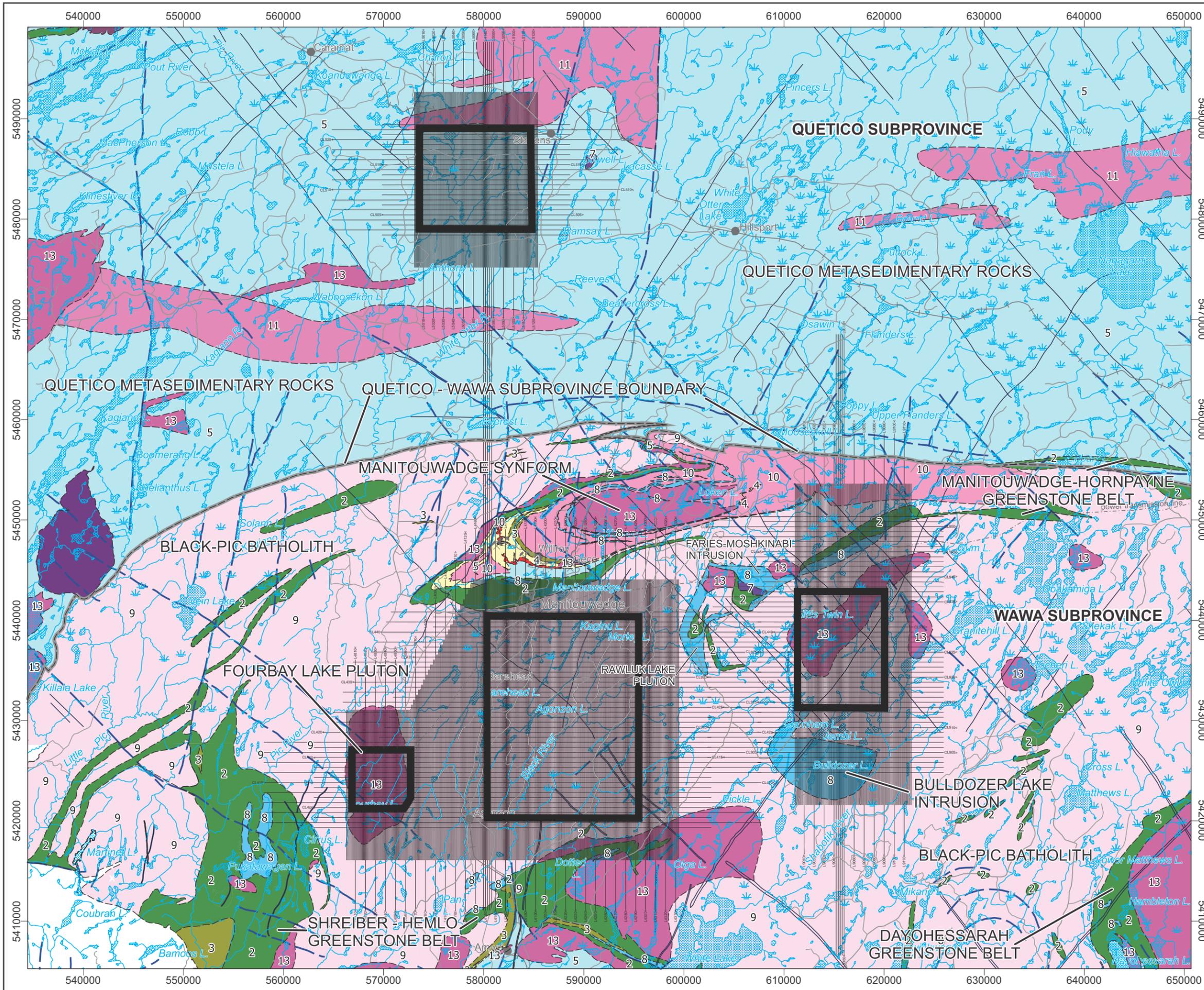
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 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)



**Airborne Geophysics  
 Acquisition and Interpretation**  
 Manitowadge Area, Ontario 2016

Survey Area

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	<b>FIGURE: 1.1</b>
	DATA	MP, PT, MM	13/07/2016	
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

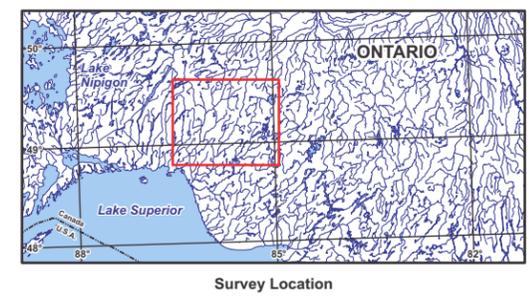
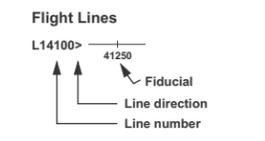
**Geology**

Fault .....

Dyke .....

Subprovince Boundary ...

- 0: Iron formation
- 2: Mafic metavolcanics
- 3: Felsic and intermediate metavolcanics
- 4: Felsic intermediate
- 5: Metasedimentary rocks
- 7: Ultramafic plutonic rocks
- 8: Gabbroic rocks
- 9: Gneissic tonalite suite
- 10: Foliate tonalite suite
- 11: Granite-granodiorite, muscovite/biotite bearing rocks
- 13: Granite-granodiorite



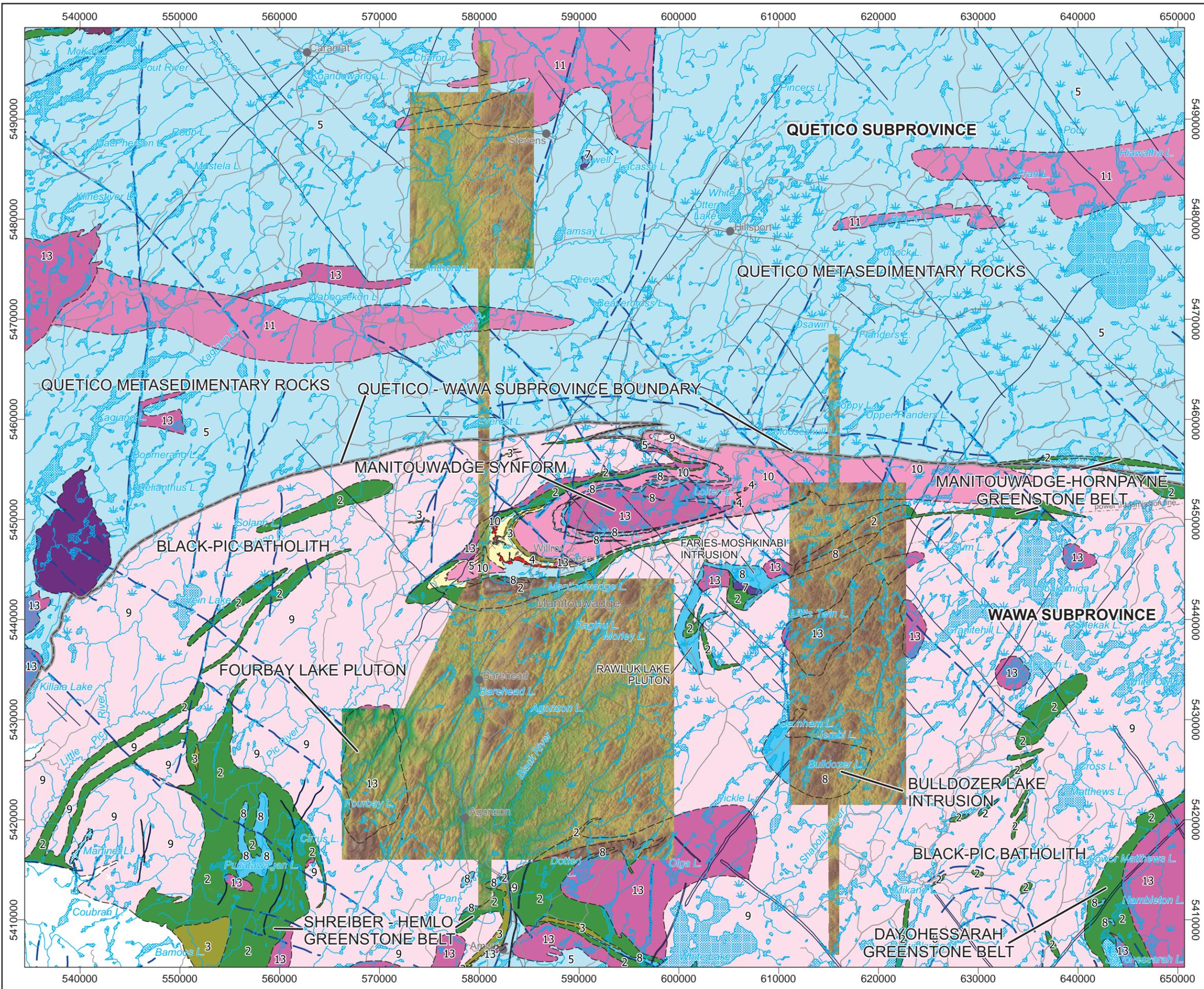
BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)



**Airborne Geophysics  
 Acquisition and Interpretation**  
 Manitowadge Area, Ontario 2016

**Flight Lines**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	<b>FIGURE: 1.2</b>
	DATA	MP, PT, MM	13/07/2016	
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

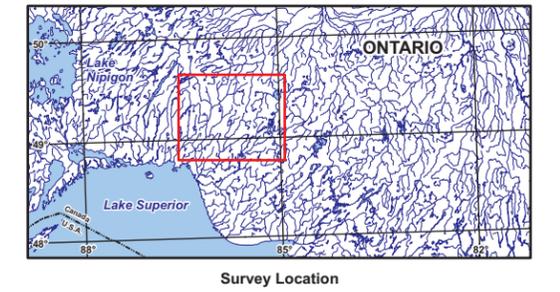
**Map Parameters**

Illumination: inclination 50°, declination 270°

Heights with respect to CGVD2013

Grid Cell Size: 25 m

m



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universe Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

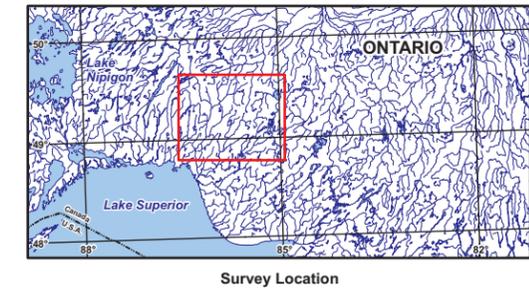
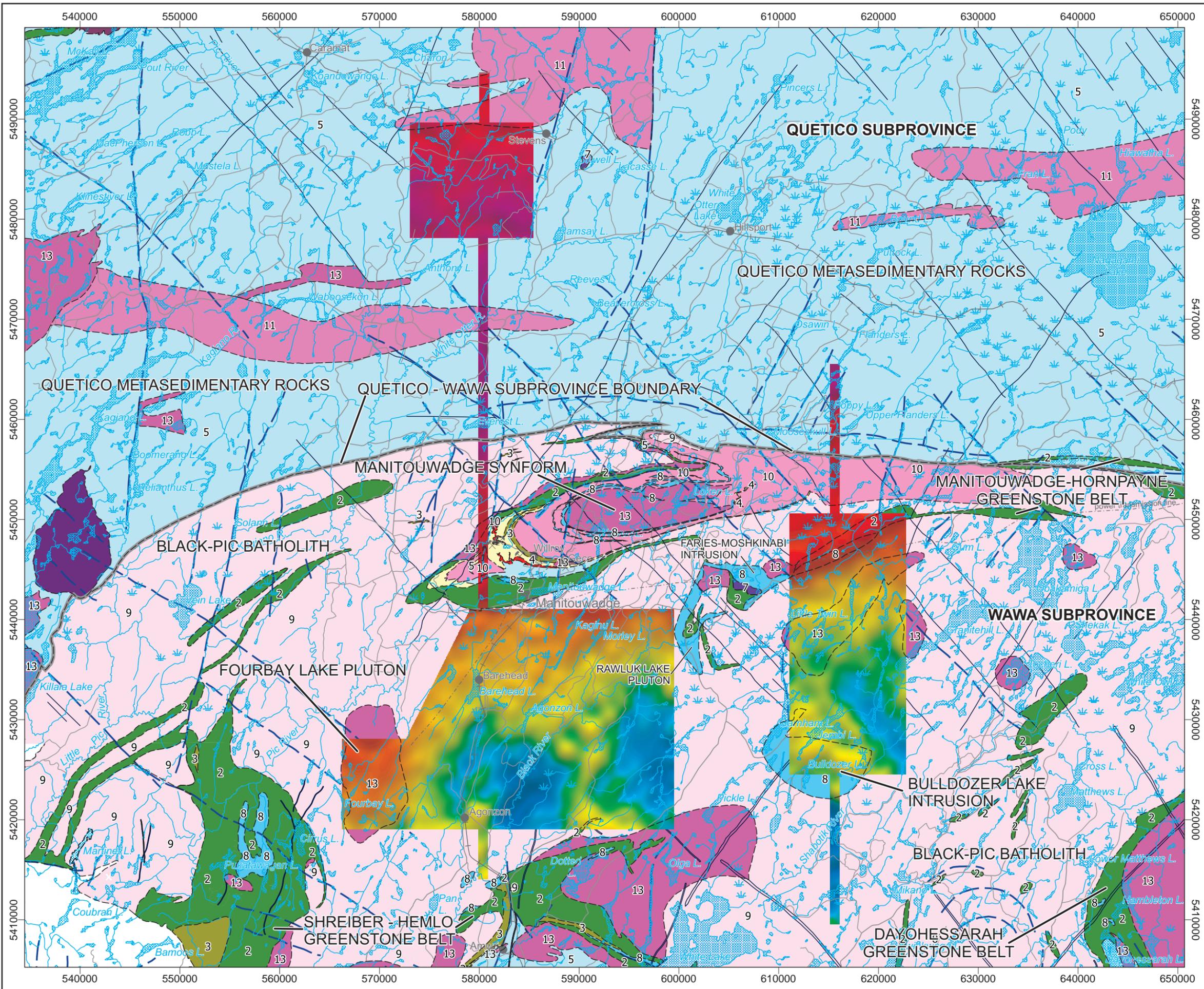
km 5 0 5 10 15 km

**Airborne Geophysics Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Digital Elevation Model**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	<b>FIGURE: 3.1</b>
	DATA	MP, PT, MM	13/07/2016	
	QC	MB	15/07/2016	



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

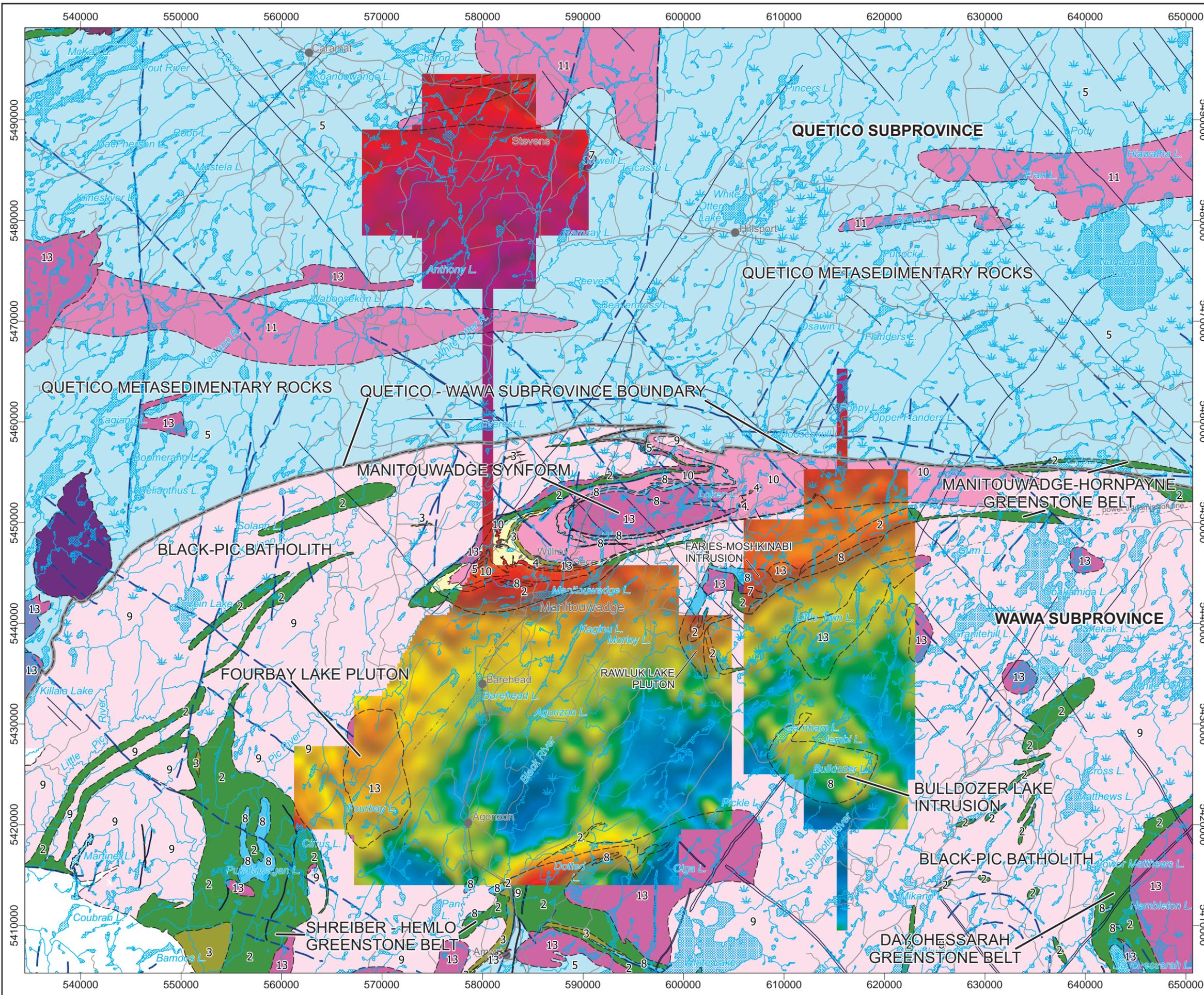
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Bouguer Gravity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	<b>FIGURE: 4.1</b>
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

**Map Parameters**

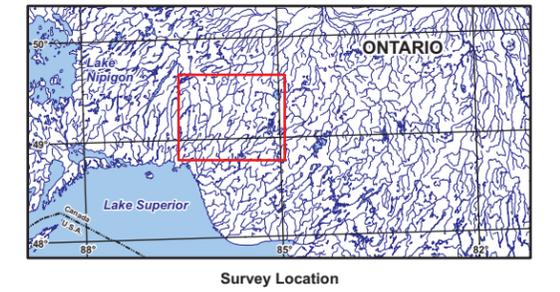
Illumination: inclination 50°, declination 270°

Spatial Filter (half-wavelength): 1000 m

Bouguer Density: 2.67 g/cm<sup>3</sup>

Grid Cell Size: 250 m

mGal



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universe Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

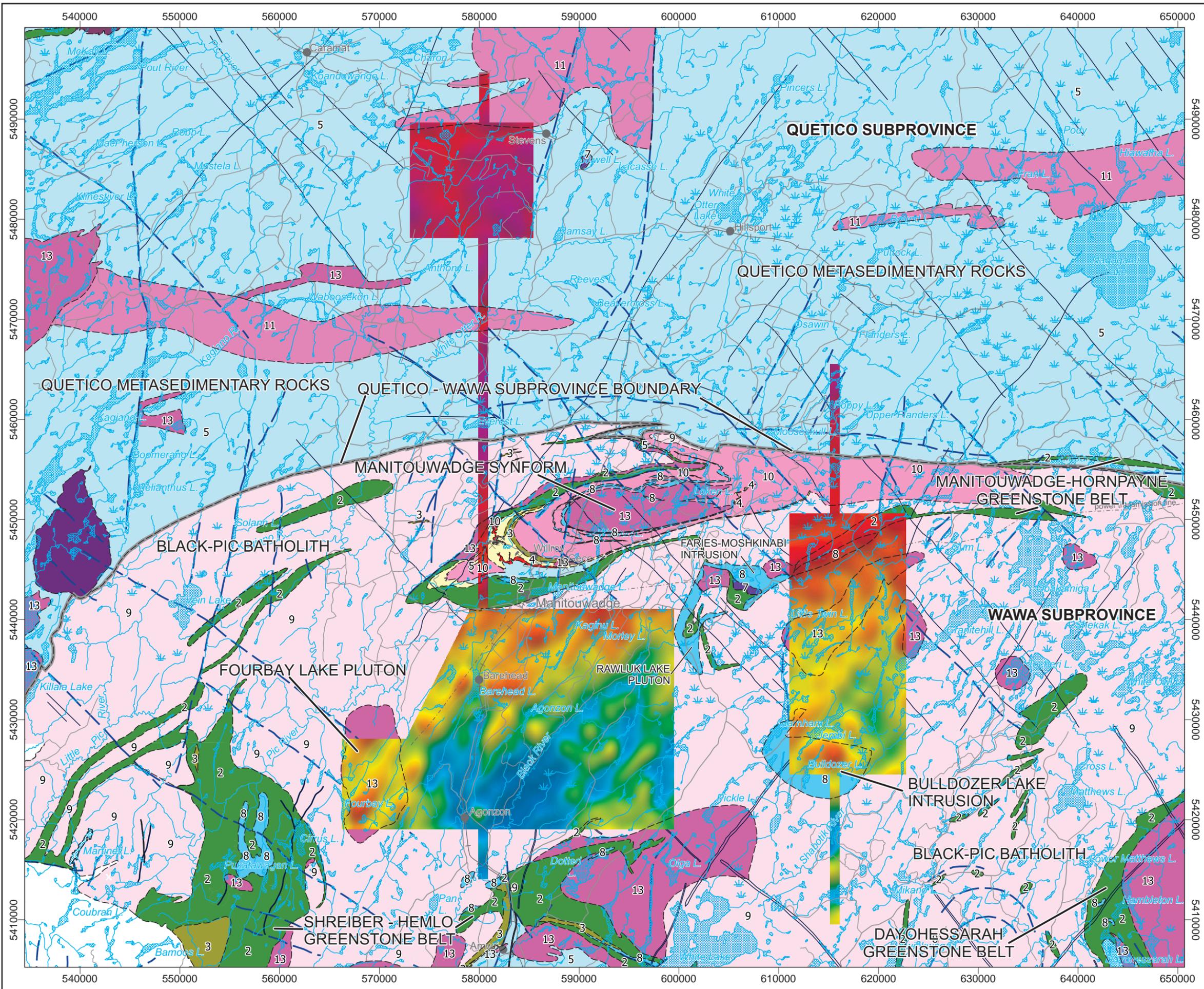
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Bouguer Gravity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	FIGURE: 4.2
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

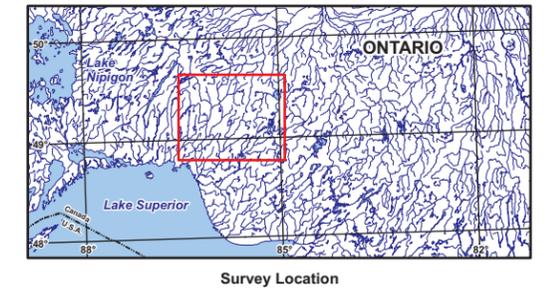
**Map Parameters**

Illumination: inclination 50°, declination 270°

Spatial Filter (half-wavelength): 1000 m

Grid Cell Size: 25 m

mGal



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

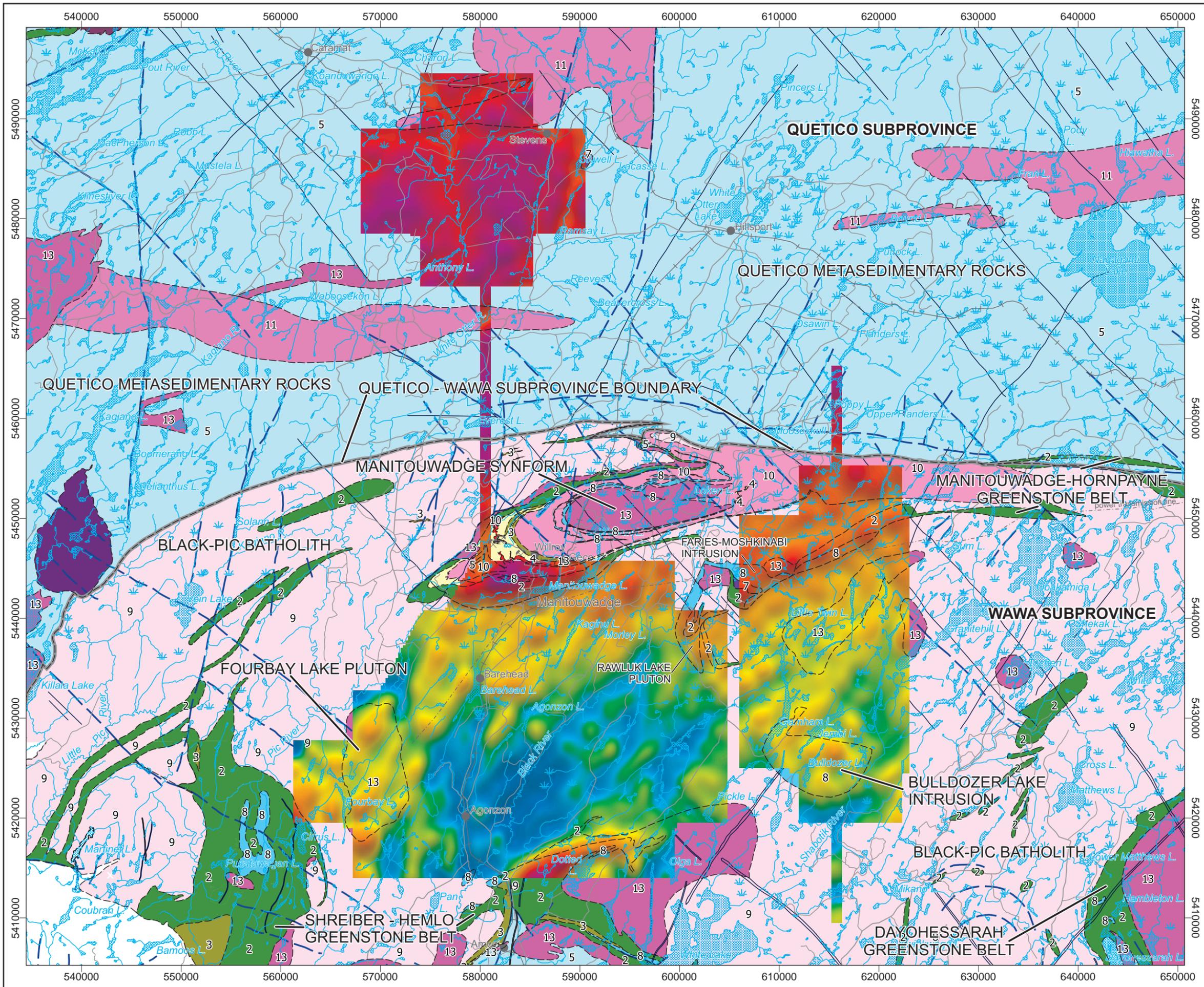
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Free Air Gravity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	FIGURE: 4.3
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

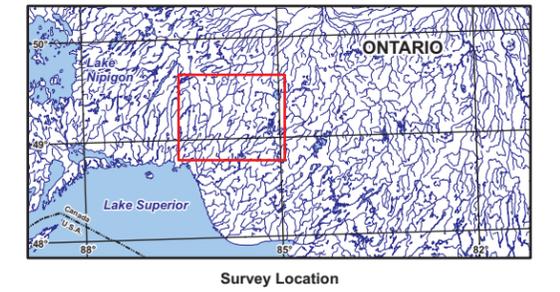
**Map Parameters**

Illumination: inclination 50°, declination 270°

Spatial Filter (half-wavelength): 1000 m

Grid Cell Size: 250 m

mGal



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

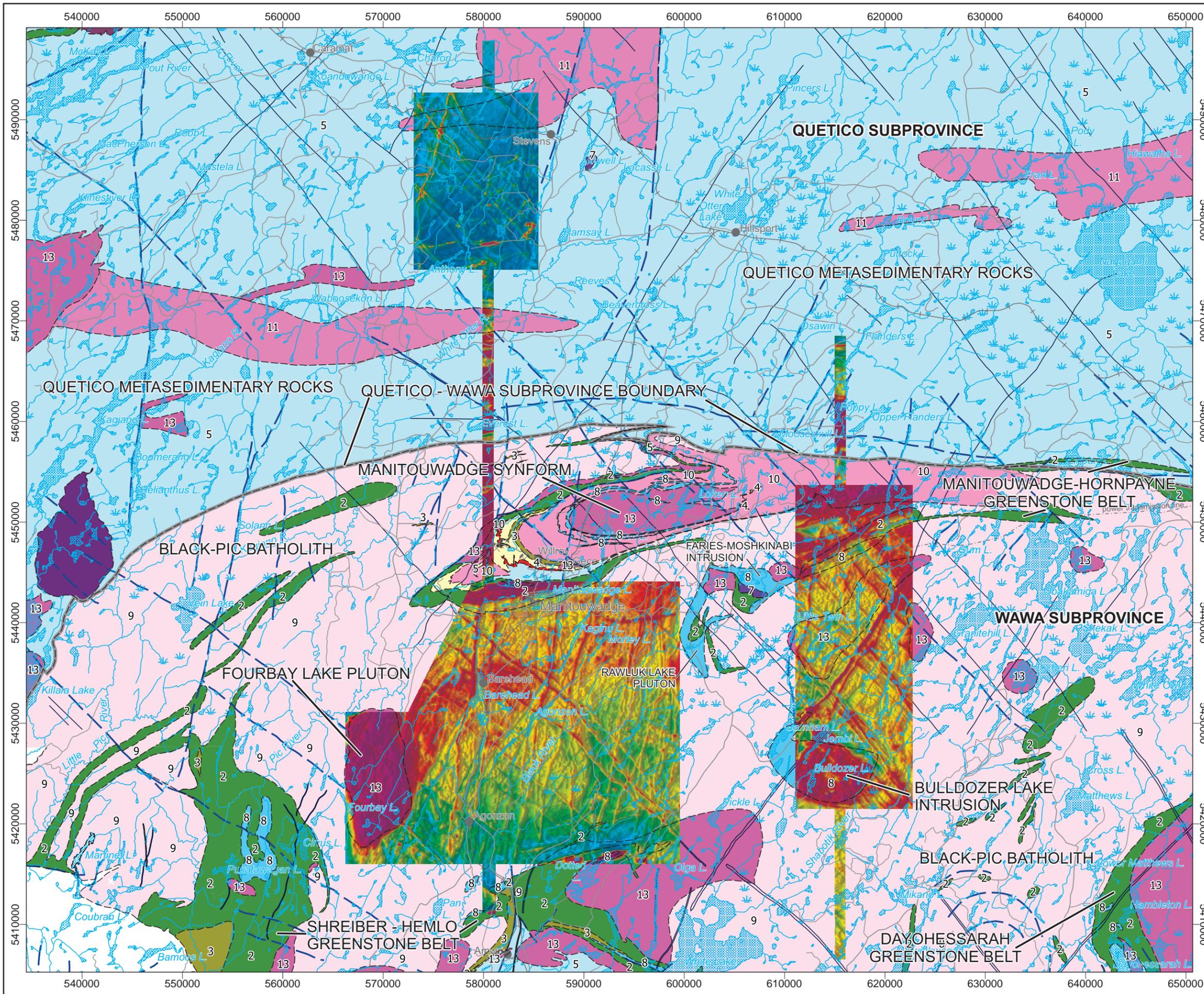
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Free Air Gravity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	<b>FIGURE: 4.4</b>
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

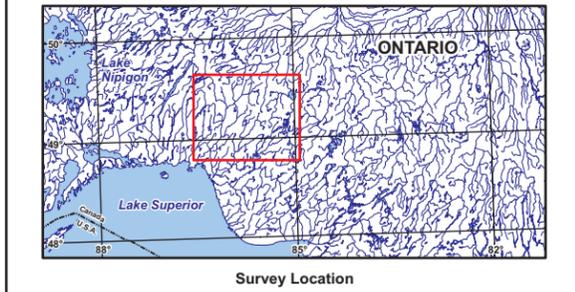
13: Granite-granodiorite

**Map Parameters**

Illumination: inclination 50°, declination 270°

Grid Cell Size: 25 m

nT



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

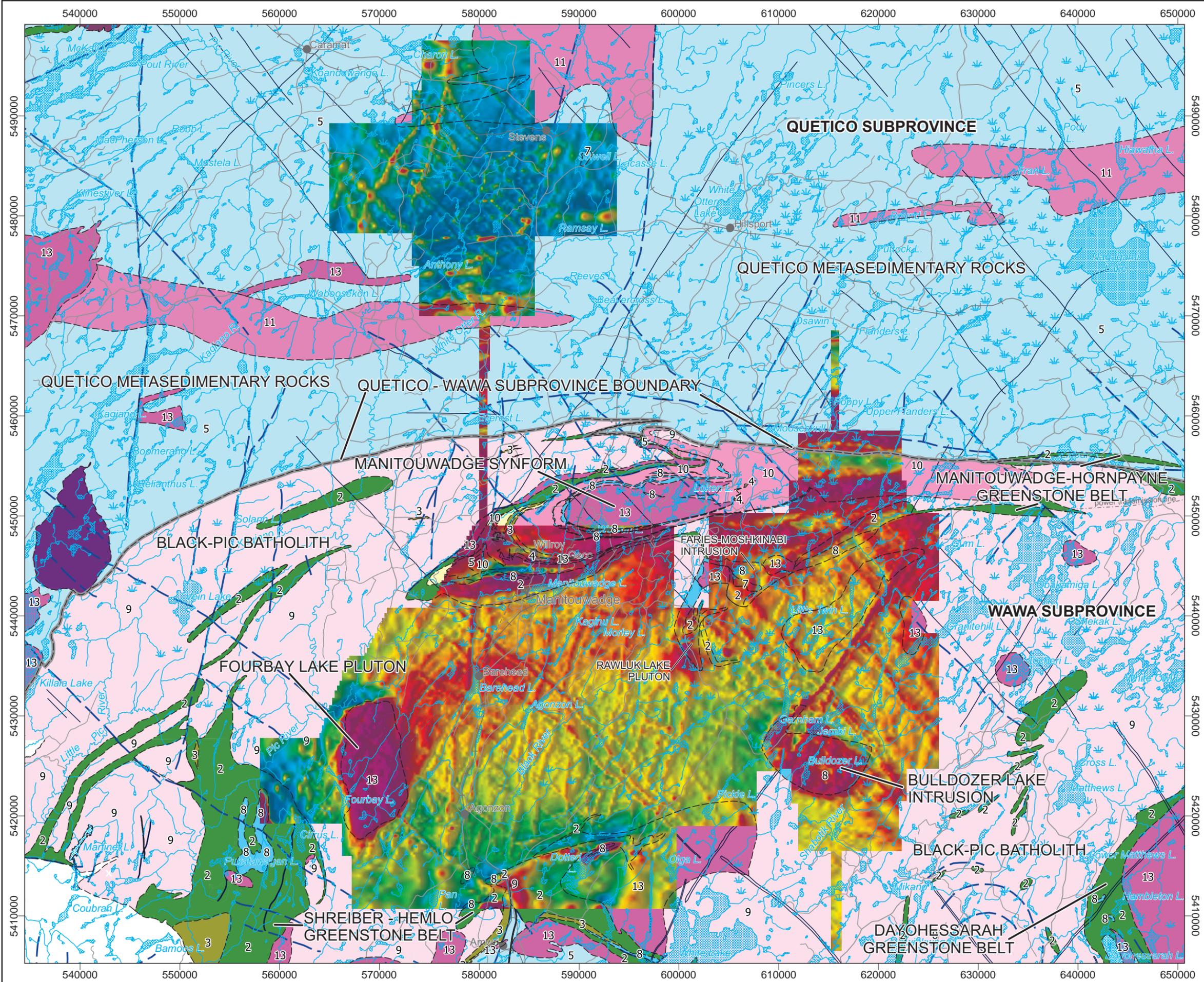
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Total Magnetic Intensity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	FIGURE: 4.5
	DATA	MP, PT, MM	13/07/2016	
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

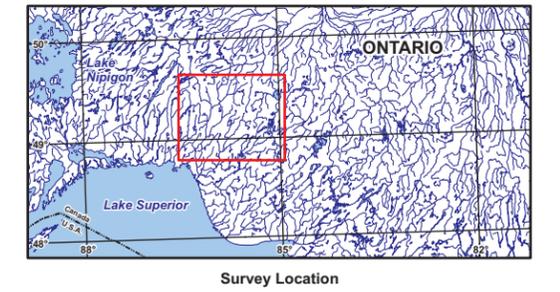
13: Granite-granodiorite

**Map Parameters**

Illumination: inclination 50°, declination 270°

Grid Cell Size: 250 m

nT



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

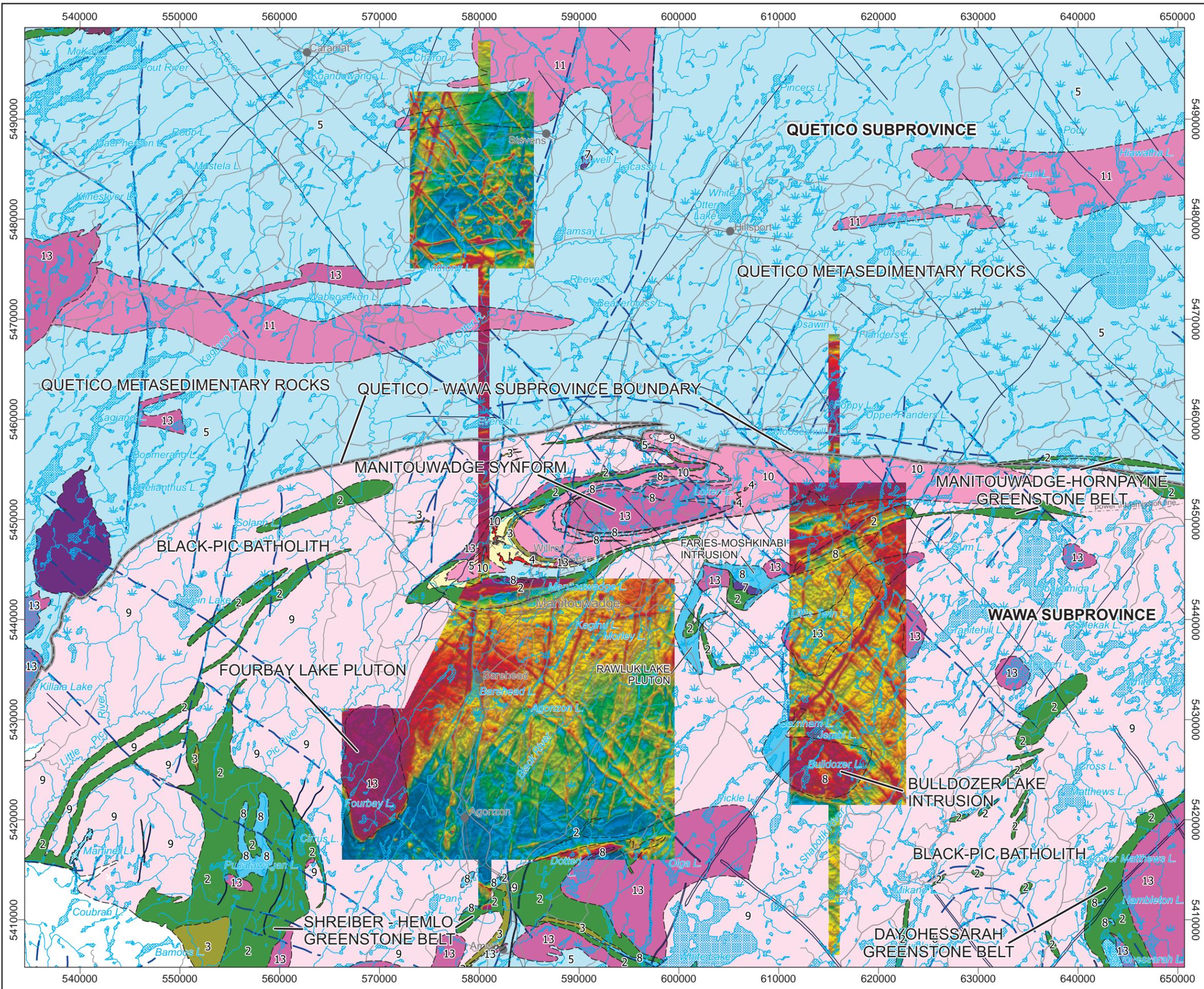
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Total Magnetic Intensity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	<b>FIGURE: 4.6</b>
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

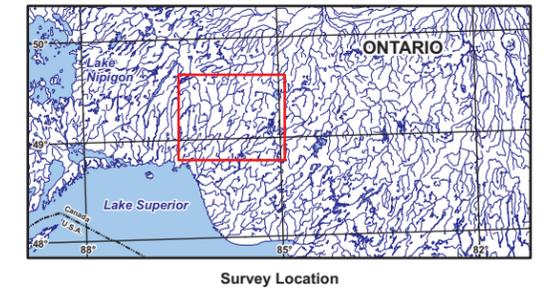
13: Granite-granodiorite

**Map Parameters**

Illumination: inclination 50°, declination 270°

Grid Cell Size: 25 m

nT



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

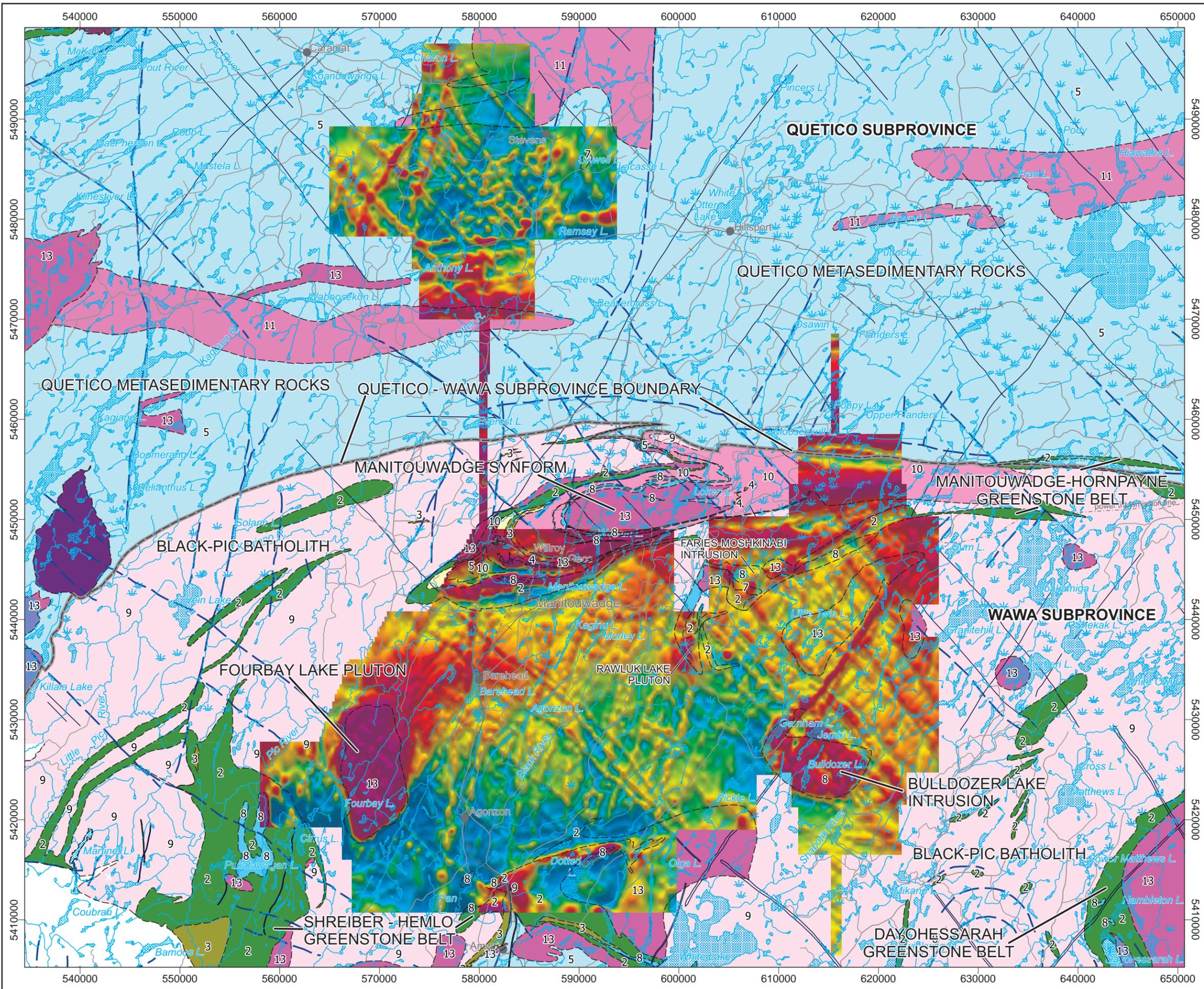
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Reduction to the Pole  
 of the Magnetic Field**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	FIGURE: 4.7
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

**Map Parameters**

Illumination: inclination 50°, declination 270°

Grid Cell Size: 250 m

nT

586.9

378.5

269.9

199.9

160.0

130.9

106.3

86.2

68.8

54.2

42.1

30.9

21.3

13.1

5.6

-1.7

-7.7

-13.9

-19.4

-25.0

-29.9

-34.7

-39.7

-44.7

-50.0

-55.0

-60.1

-65.3

-71.0

-76.4

-81.8

-87.1

-92.1

-97.2

-102.2

-107.2

-112.3

-117.0

-121.7

-126.2

-130.0

-136.5

-142.7

-149.2

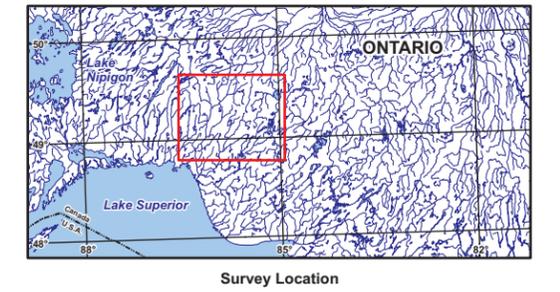
-156.4

-164.9

-175.6

-189.1

-212.4



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

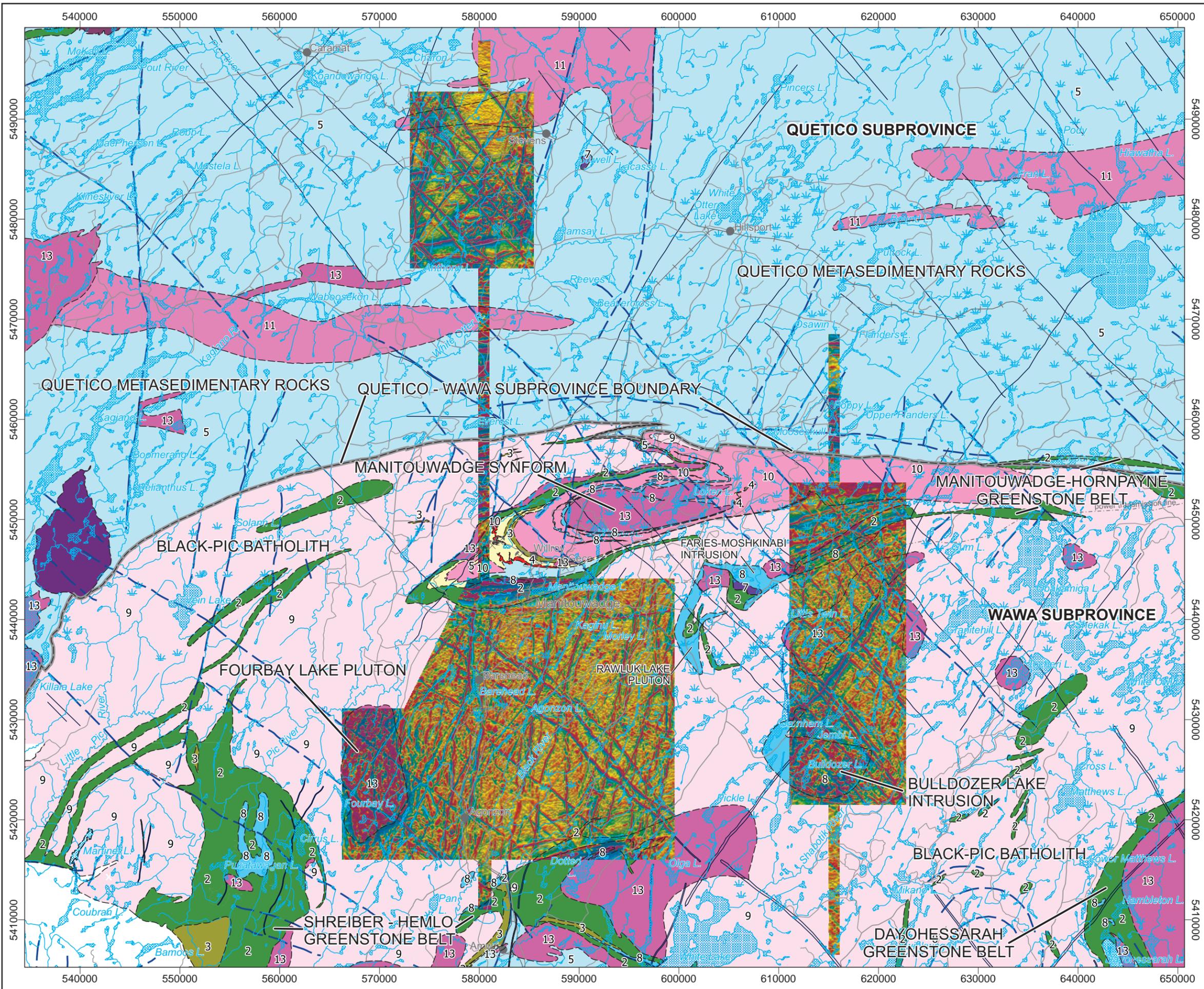
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

Manitowadge Area, Ontario 2016

**Reduction to the Pole  
 of the Magnetic Field**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	FIGURE: 4.8
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

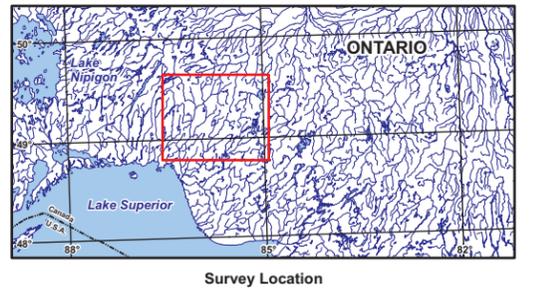
13: Granite-granodiorite

**Map Parameters**

Illumination: inclination 50°, declination 270°

Grid Cell Size: 25 m

nT/km



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

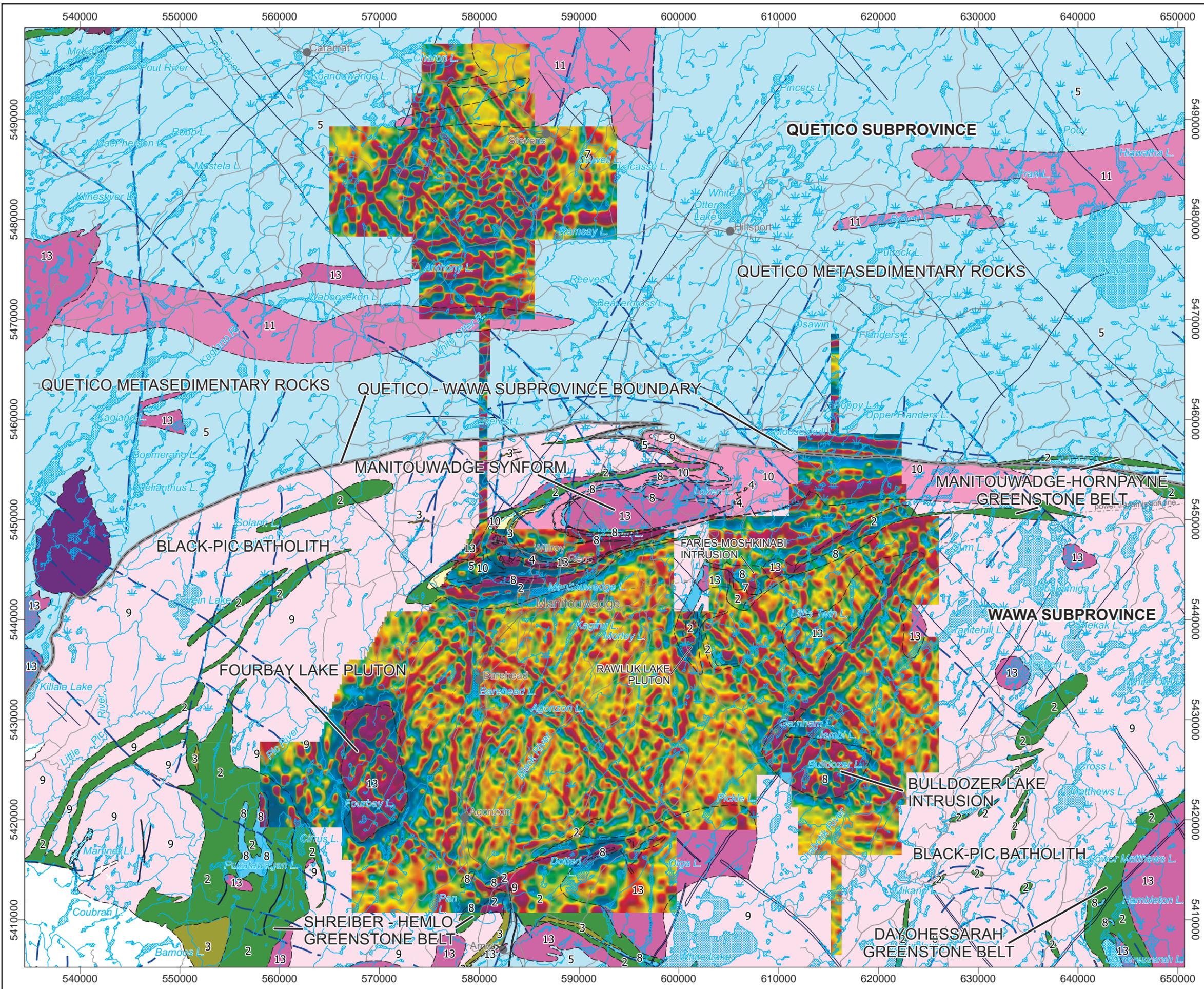
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**First Vertical Derivative of the  
 Reduction to the Pole of the Total Magnetic Intensity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	FIGURE: 4.9
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

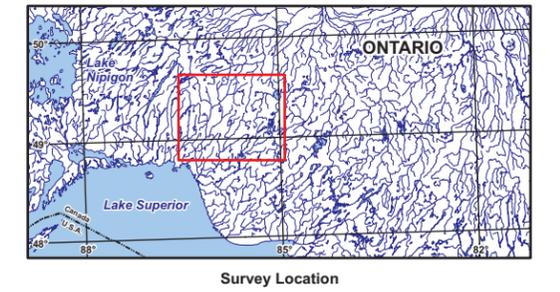
13: Granite-granodiorite

**Map Parameters**

Illumination: inclination 50°, declination 270°

Grid Cell Size: 250 m

nT/km



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

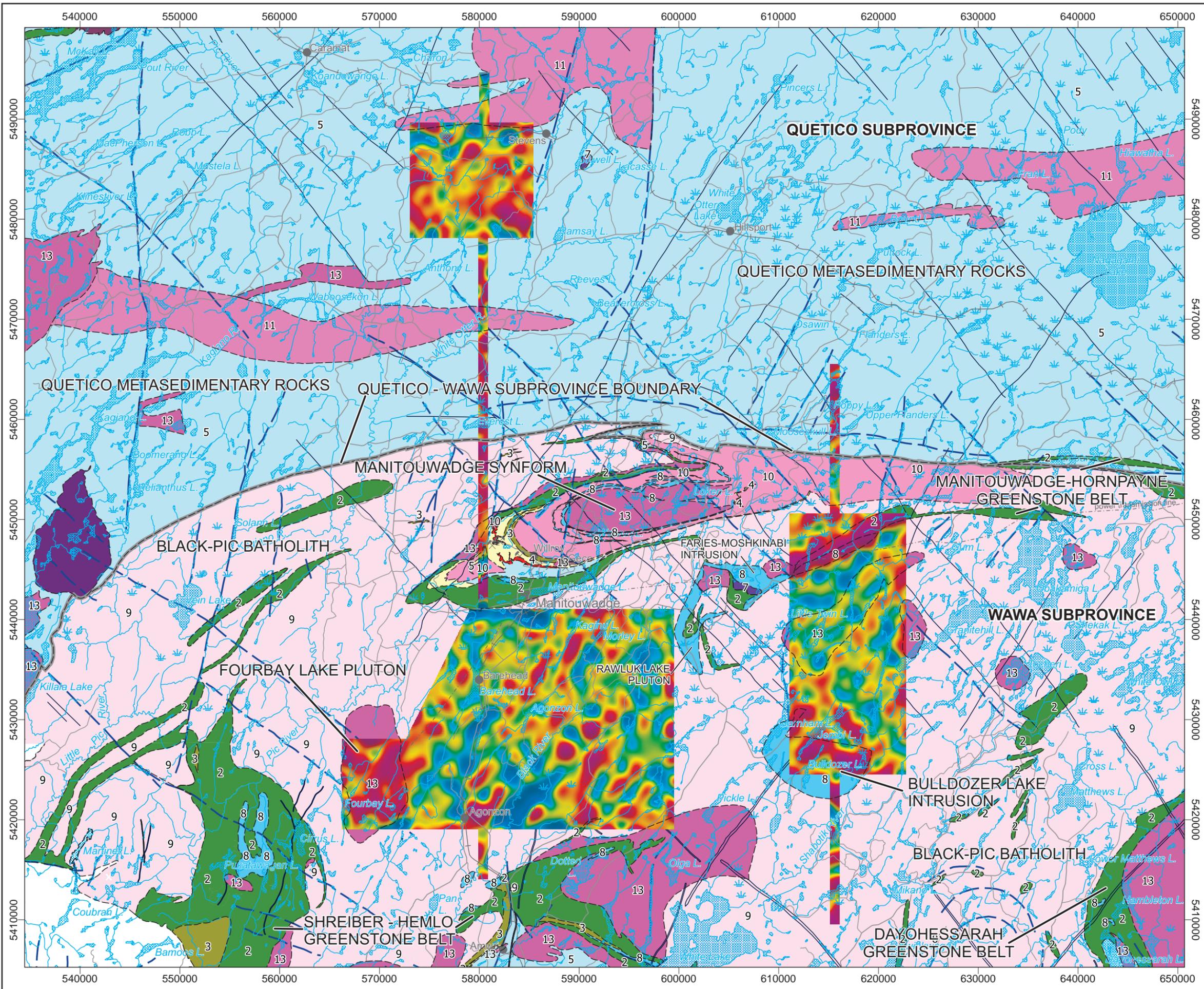
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**First Vertical Derivative of the  
 Reduction to the Pole of the Total Magnetic Intensity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	<b>FIGURE: 4.10</b>
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

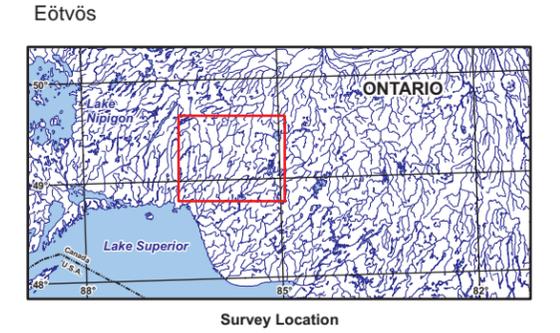
**Map Parameters**

Illumination: inclination 50°, declination 270°

Spatial Filter (half-wavelength): 1000 m

Bouguer Density: 2.67 g/cm<sup>3</sup>

Grid Cell Size: 25 m



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universe Transverse Mercator (UTM Zone 16N)

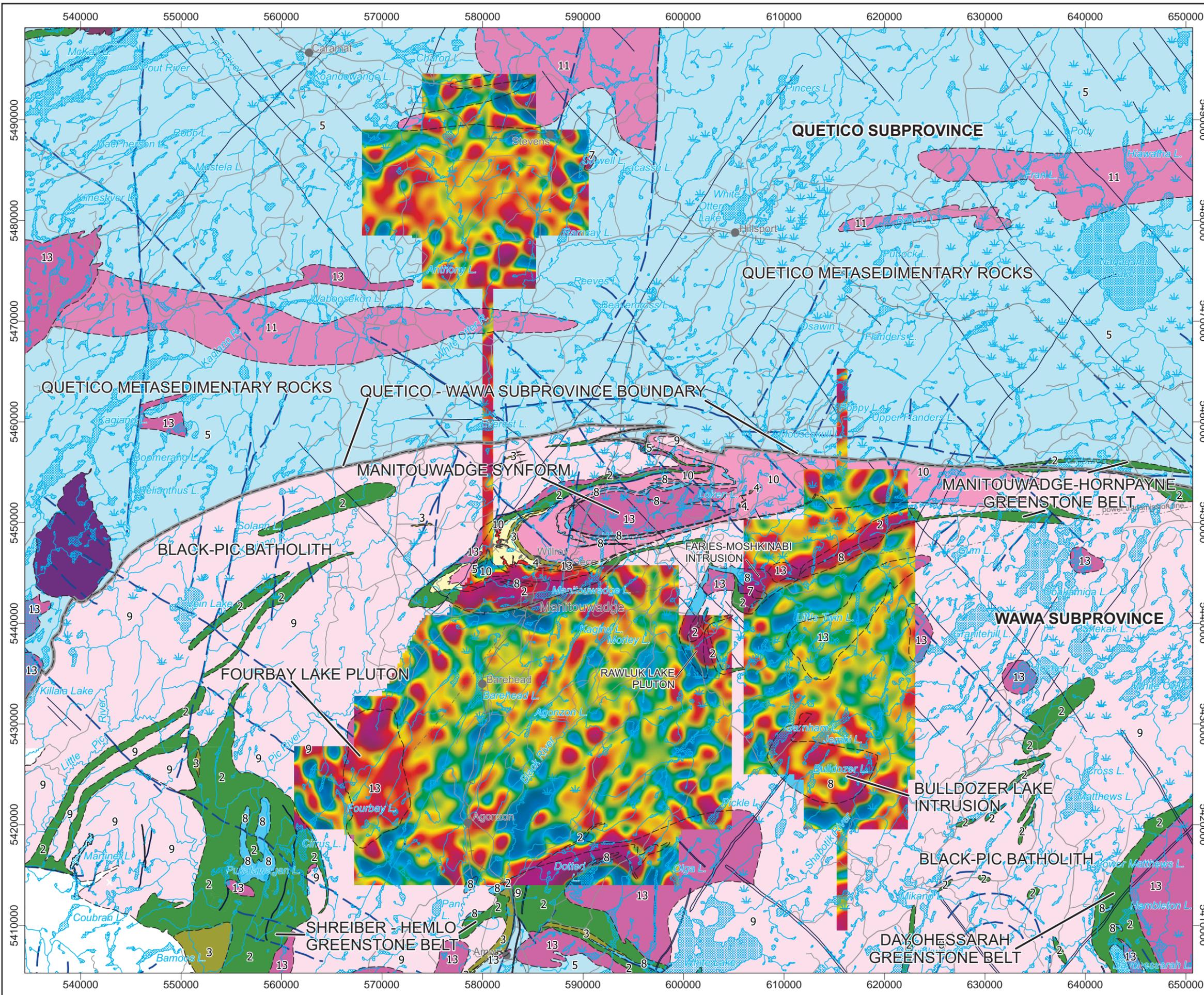
Scale 1 : 370 000

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**First Vertical Derivative  
 of the Bouguer Gravity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	<b>FIGURE: 4.11</b>
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

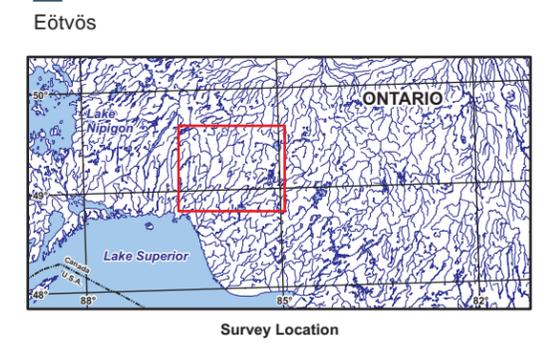
**Map Parameters**

Illumination: inclination 50°, declination 270°

Spatial Filter (half-wavelength): 1000 m

Bouguer Density: 2.67 g/cm<sup>3</sup>

Grid Cell Size: 250 m



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universe Transverse Mercator (UTM Zone 16N)

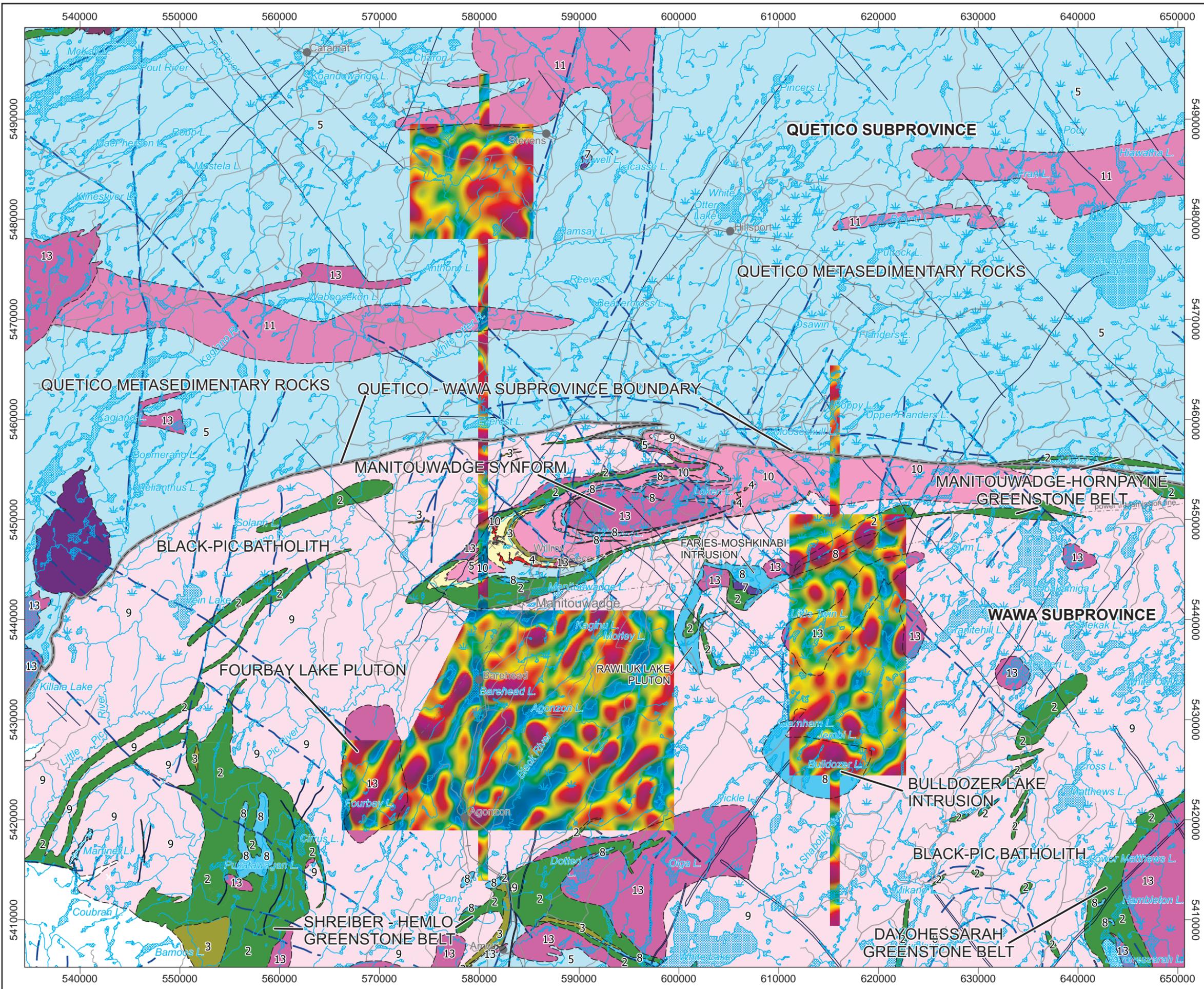
Scale 1 : 370 000

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitouwadge Area, Ontario 2016**

**First Vertical Derivative  
 of the Bouguer Gravity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	<b>FIGURE: 4.12</b>
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

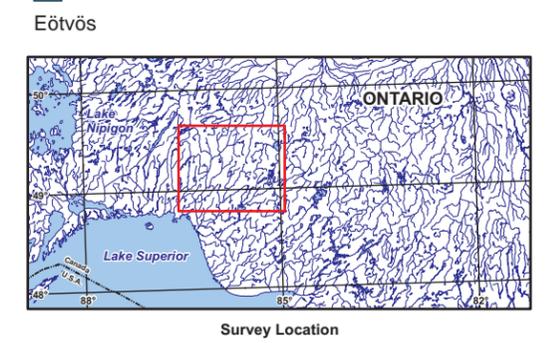
13: Granite-granodiorite

**Map Parameters**

Illumination: inclination 50°, declination 270°

Spatial Filter (half-wavelength): 1000 m

Grid Cell Size: 25 m



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universe Transverse Mercator (UTM Zone 16N)

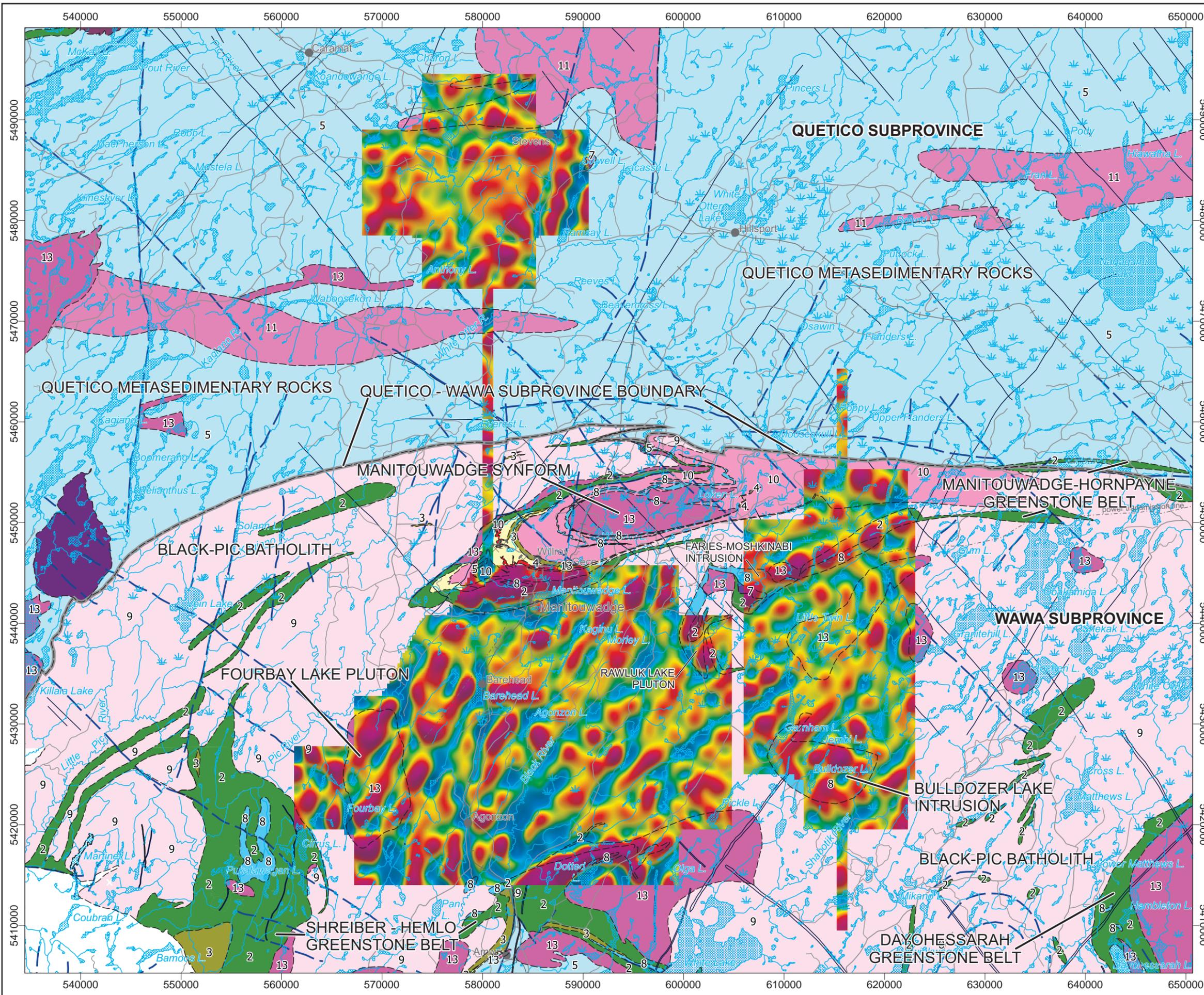
Scale 1 : 370 000

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**First Vertical Derivative of the Free Air Gravity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	FIGURE: 4.13
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

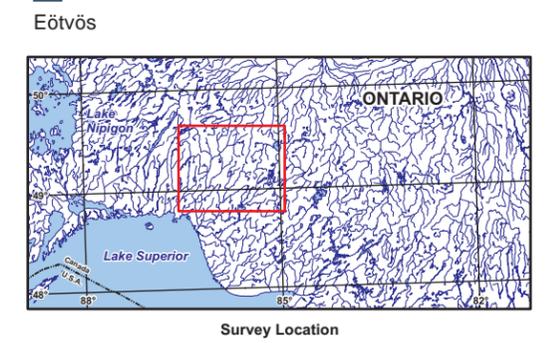
13: Granite-granodiorite

**Map Parameters**

Illumination: inclination 50°, declination 270°

Spatial Filter (half-wavelength): 1000 m

Grid Cell Size: 250 m



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

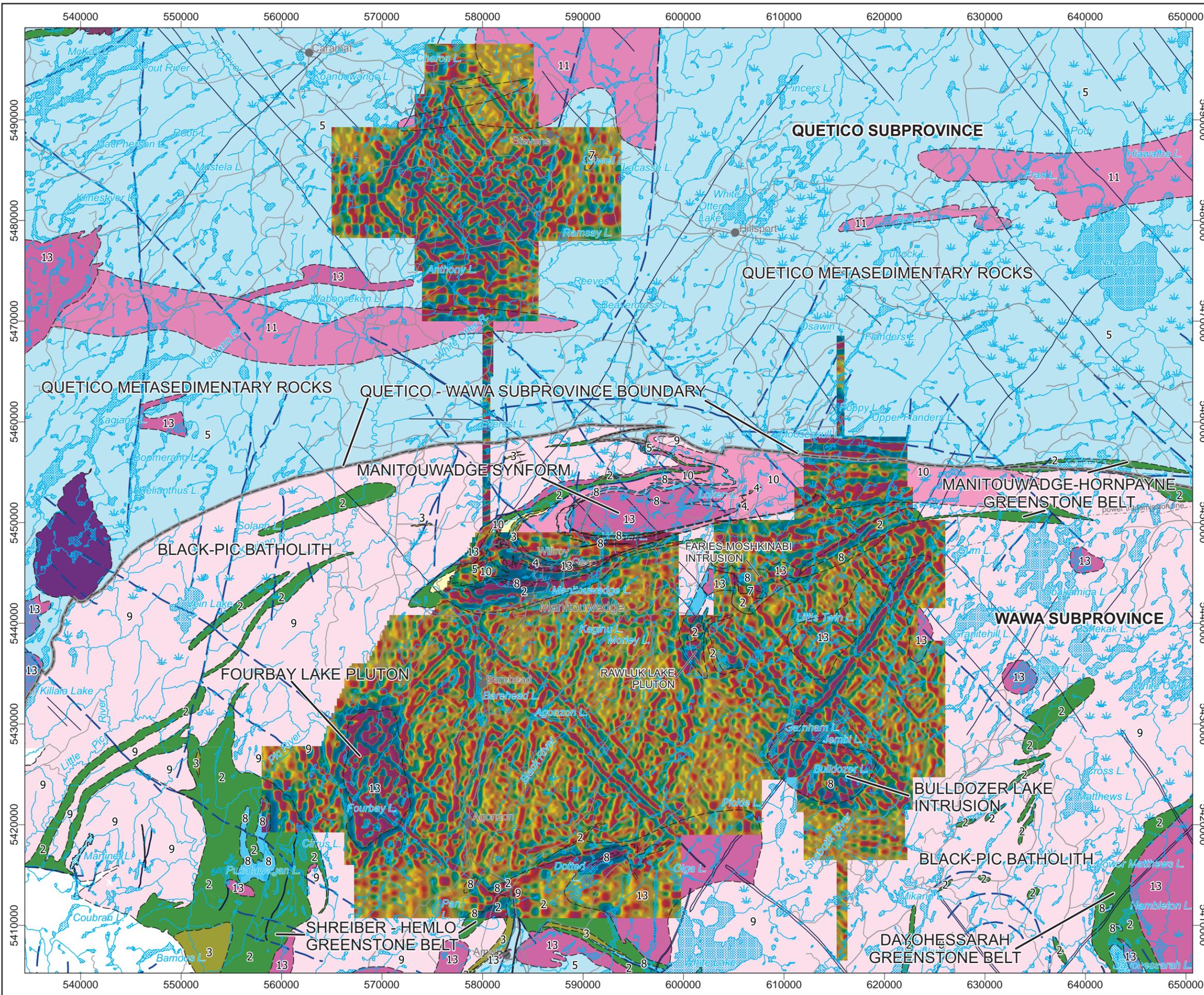
**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**First Vertical Derivative of the Free Air Gravity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	FIGURE: 4.14
	QC	MB	15/07/2016	





**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

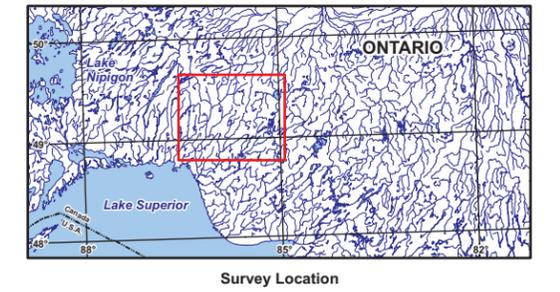
13: Granite-granodiorite

**Map Parameters**

Illumination: inclination 50°, declination 270°

Grid Cell Size: 250 m

nT/km<sup>2</sup>



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

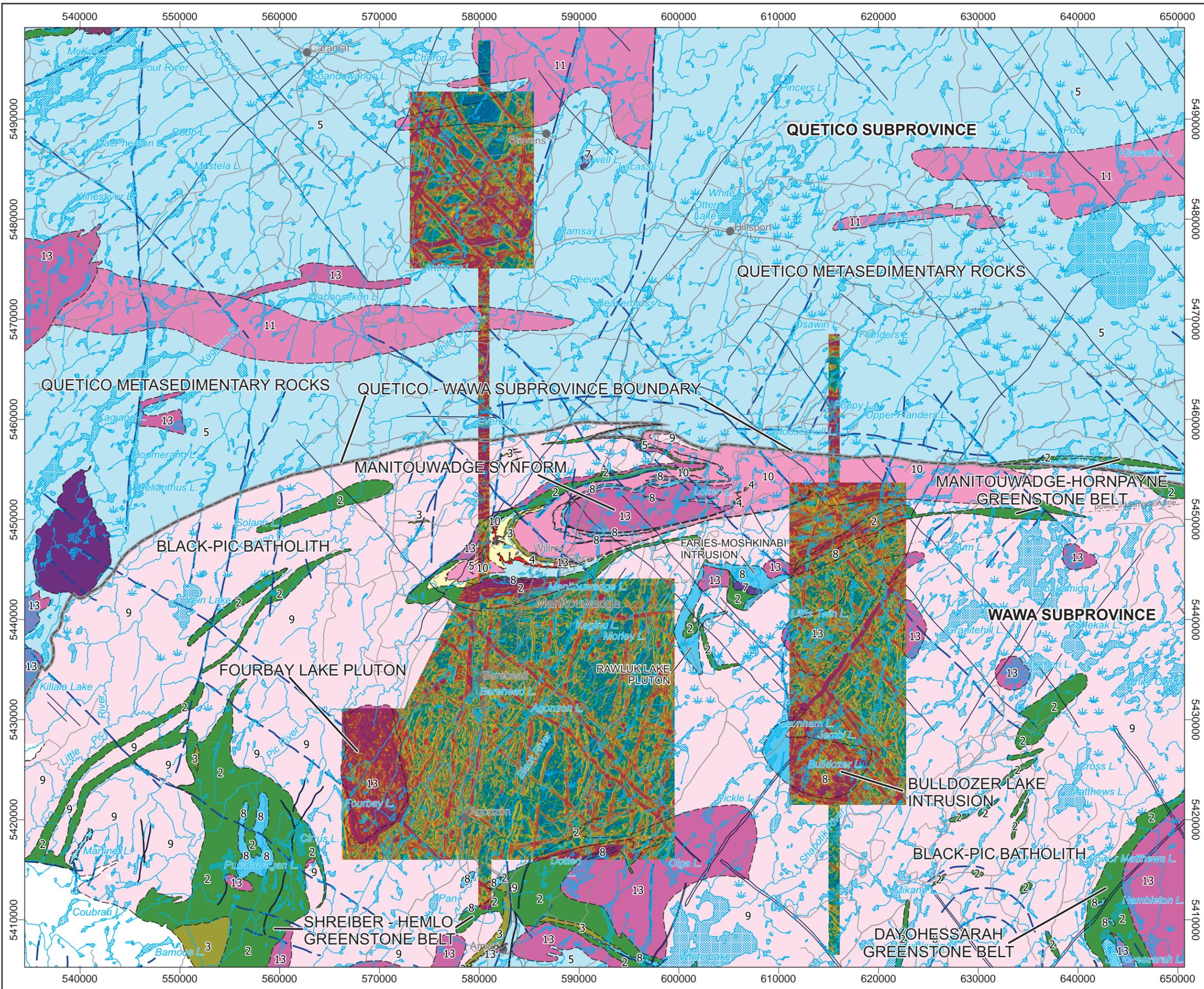
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Second Vertical Derivative of the  
 Reduction to the Pole of the Total Magnetic Intensity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	<b>FIGURE: 4.16</b>
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

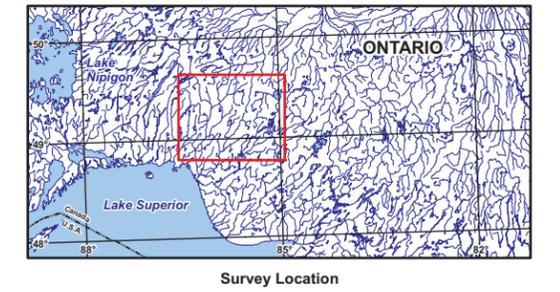
13: Granite-granodiorite

**Map Parameters**

Illumination: inclination 50°, declination 270°

Grid Cell Size: 25 m

nT/km



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

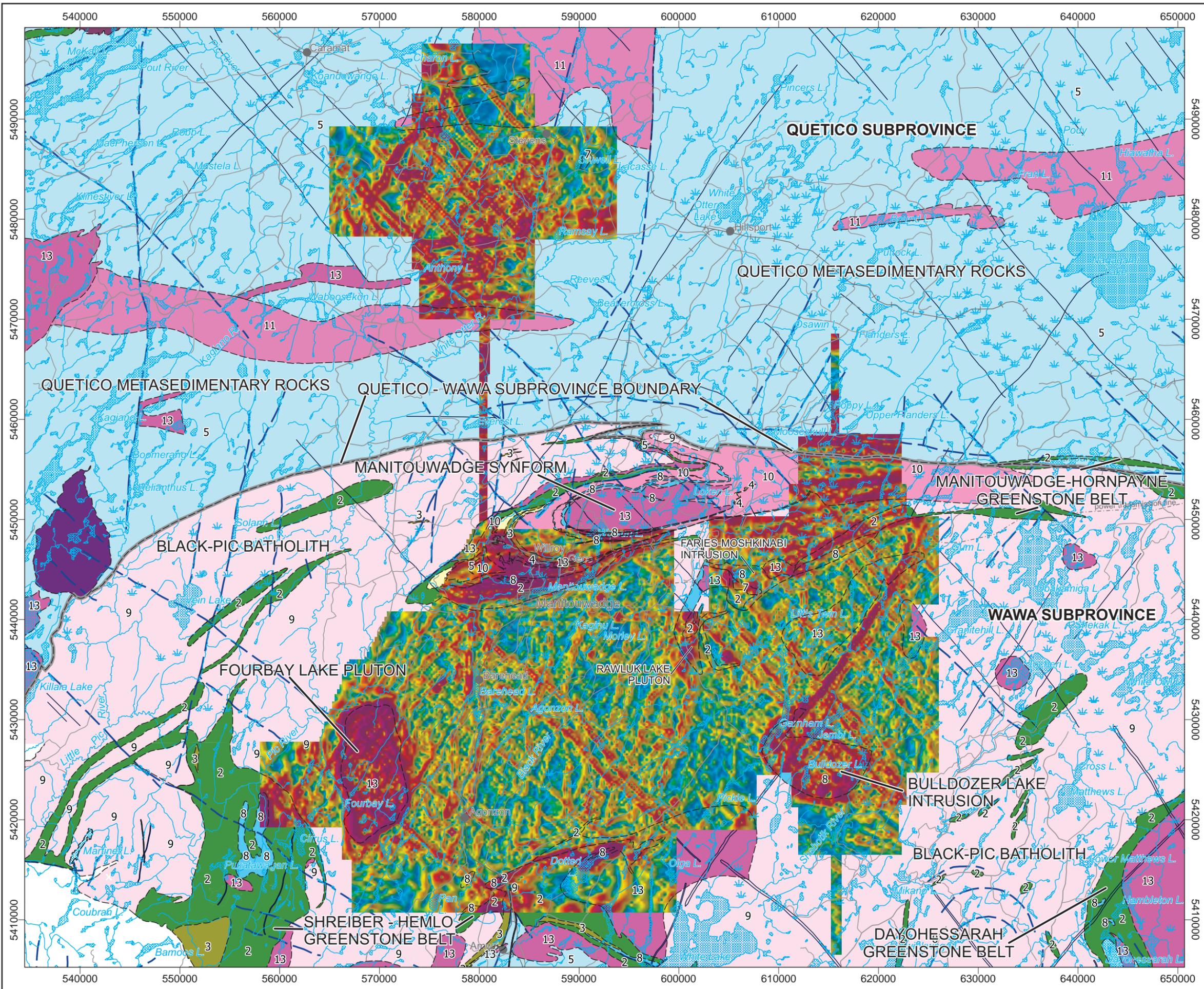
km 5 0 5 10 15 km

**Airborne Geophysics Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Total Horizontal Derivative of the Reduction to the Pole of the Total Magnetic Intensity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	FIGURE: 4.17
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

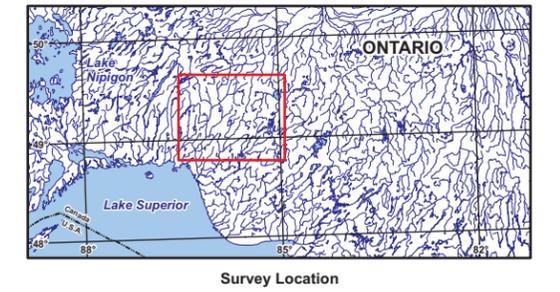
13: Granite-granodiorite

**Map Parameters**

Illumination: inclination 50°, declination 270°

Grid Cell Size: 250 m

nT/km



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

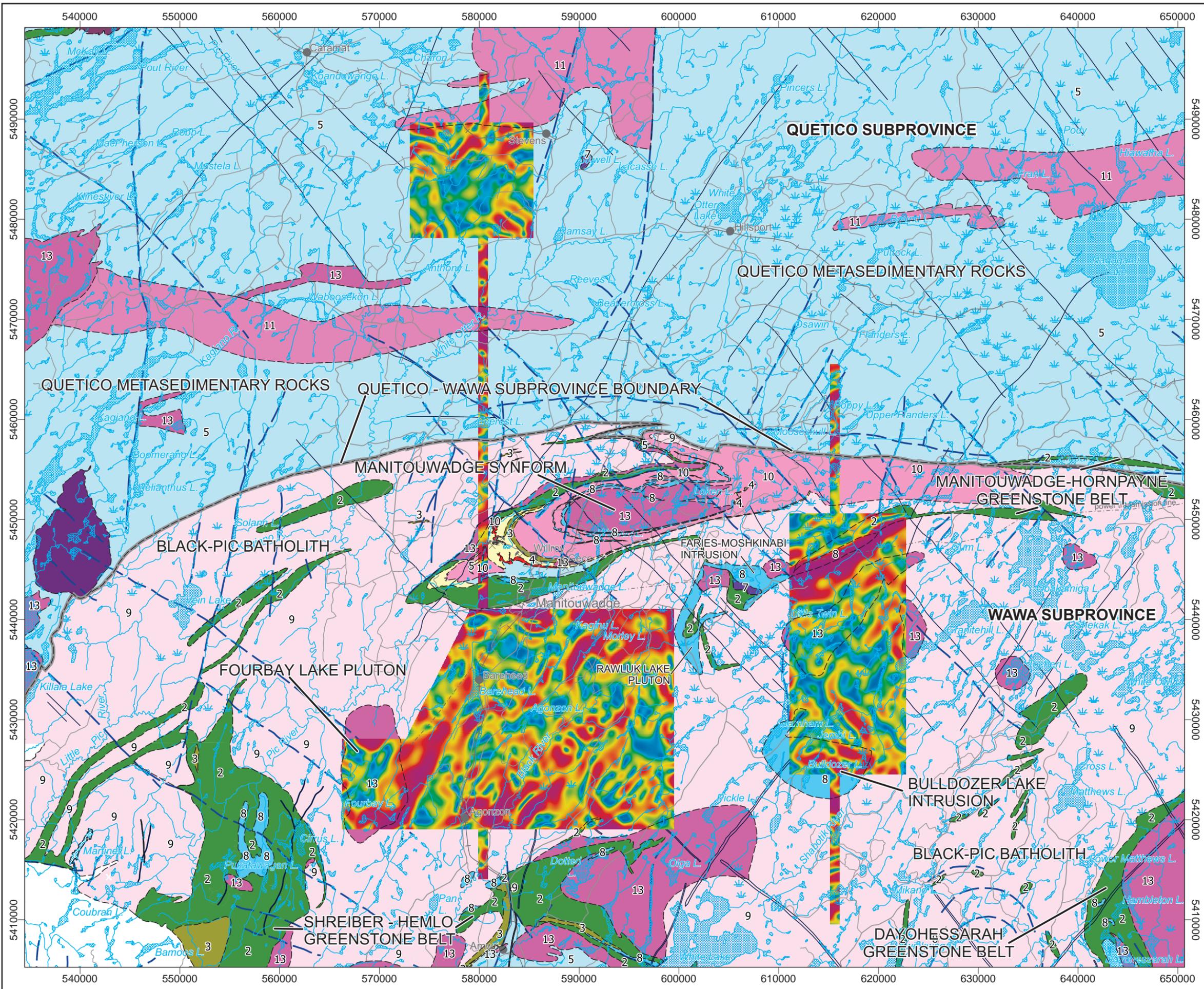
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Total Horizontal Derivative of the  
 Reduction to the Pole of the Total Magnetic Intensity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	<b>FIGURE: 4.18</b>
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

**Map Parameters**

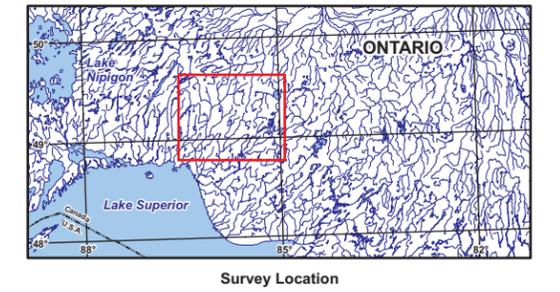
Illumination: inclination 50°, declination 270°

Spatial Filter (half-wavelength): 1000 m

Bouguer Density: 2.67 g/cm<sup>3</sup>

Grid Cell Size: 25 m

mGal/km



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

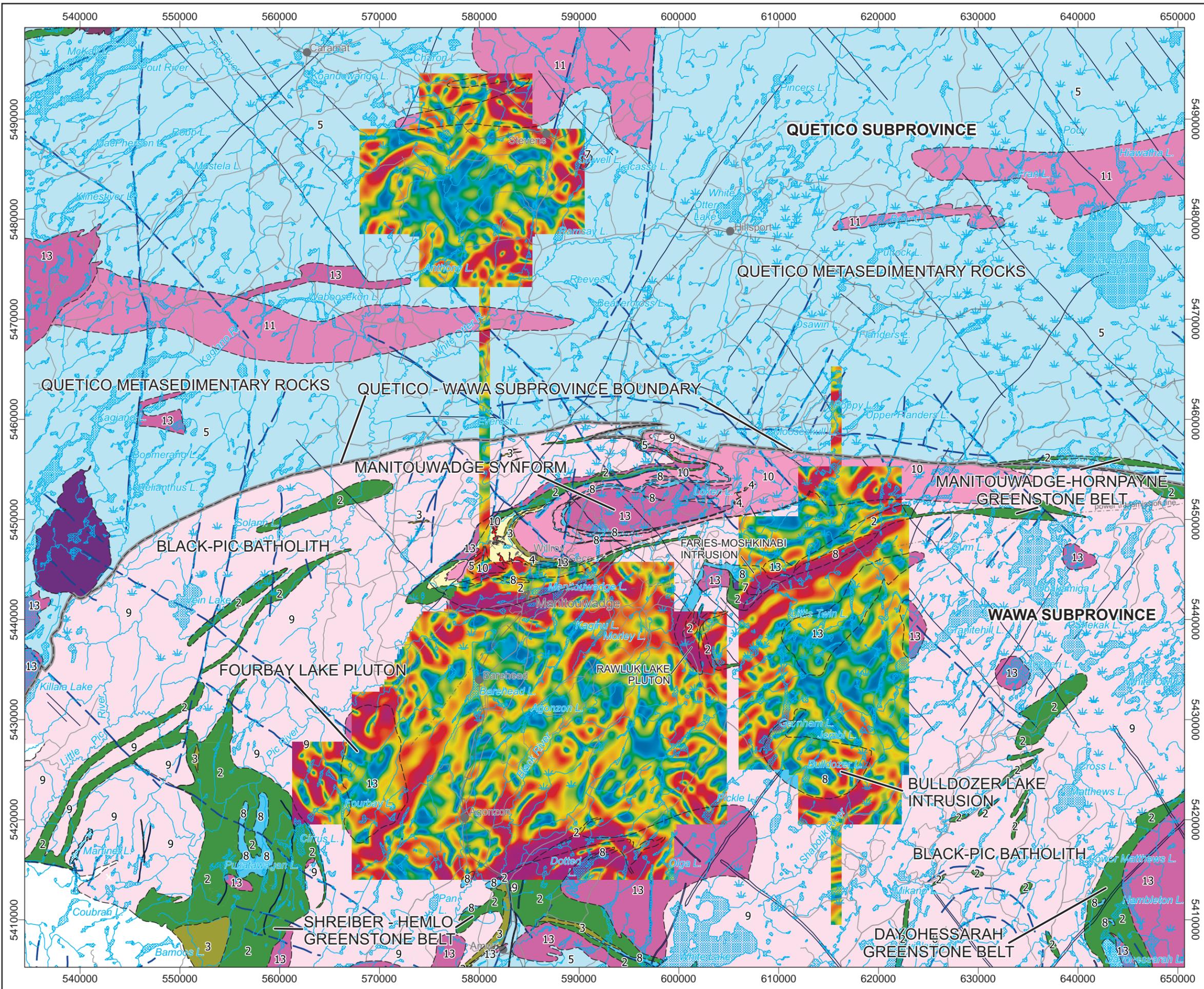
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Total Horizontal Derivative of the Bouguer Gravity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	FIGURE: 4.19
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

**Map Parameters**

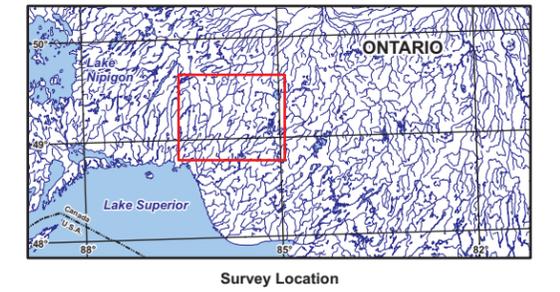
Illumination: inclination 50°, declination 270°

Spatial Filter (half-wavelength): 1000 m

Bouguer Density: 2.67 g/cm<sup>3</sup>

Grid Cell Size: 250 m

mGal/km



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

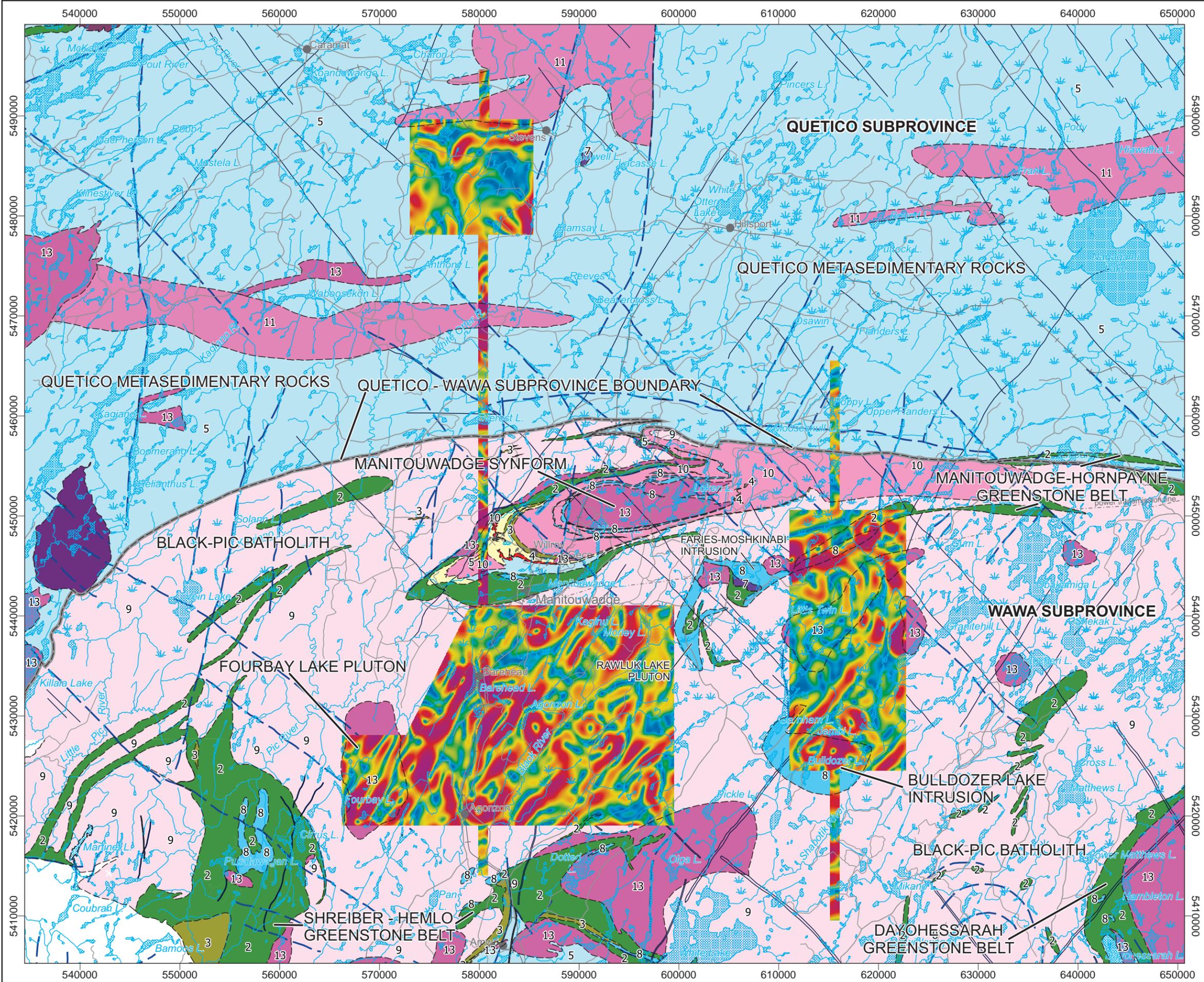
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Total Horizontal Derivative of the Bouguer Gravity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	<b>FIGURE: 4.20</b>
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

- 0: Iron formation
- 2: Mafic metavolcanics
- 3: Felsic and intermediate metavolcanics
- 4: Felsic volcanics
- 5: Metasedimentary rocks
- 7: Ultramafic plutonic rocks
- 8: Gabbroic rocks
- 9: Gneissic tonalite suite
- 10: Foliate tonalite suite
- 11: Granite-granodiorite, muscovite/biotite bearing rocks
- 13: Granite-granodiorite

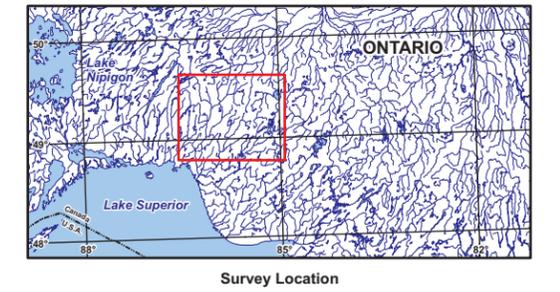
**Map Parameters**

Illumination: inclination 50°, declination 270°

Spatial Filter (half-wavelength): 1000 m

Grid Cell Size: 25 m

mGal/km



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

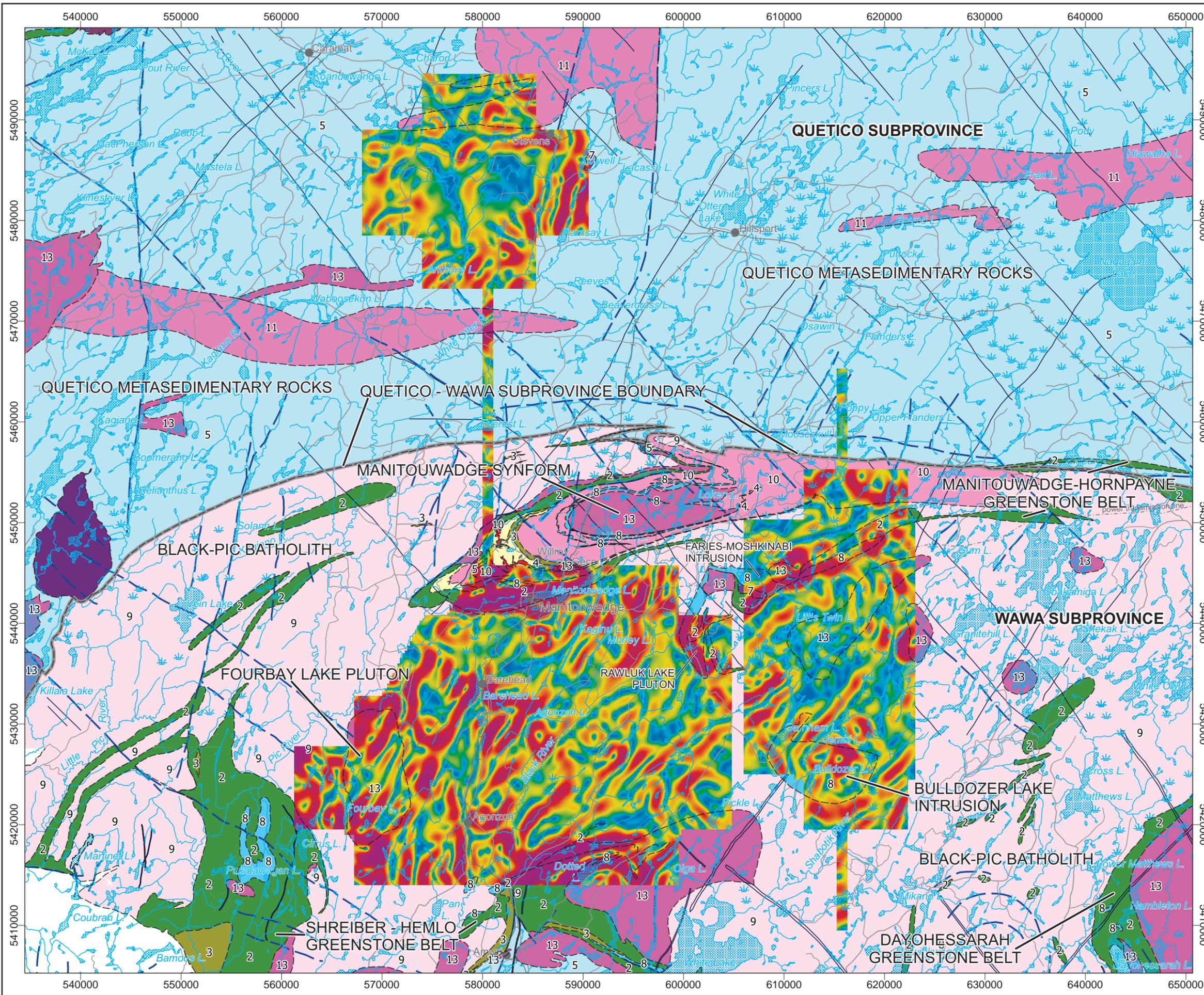
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Total Horizontal Derivative of the Free Air Gravity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	<b>FIGURE: 4.21</b>
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

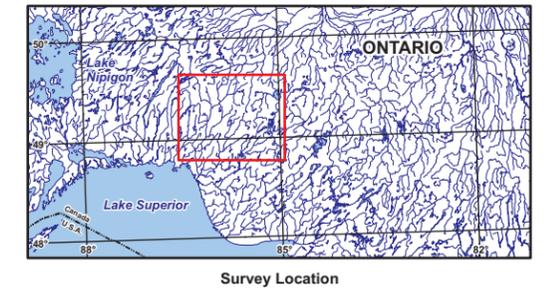
**Map Parameters**

Illumination: inclination 50°, declination 270°

Spatial Filter (half-wavelength): 1000 m

Grid Cell Size: 250 m

mGal/km



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universe Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

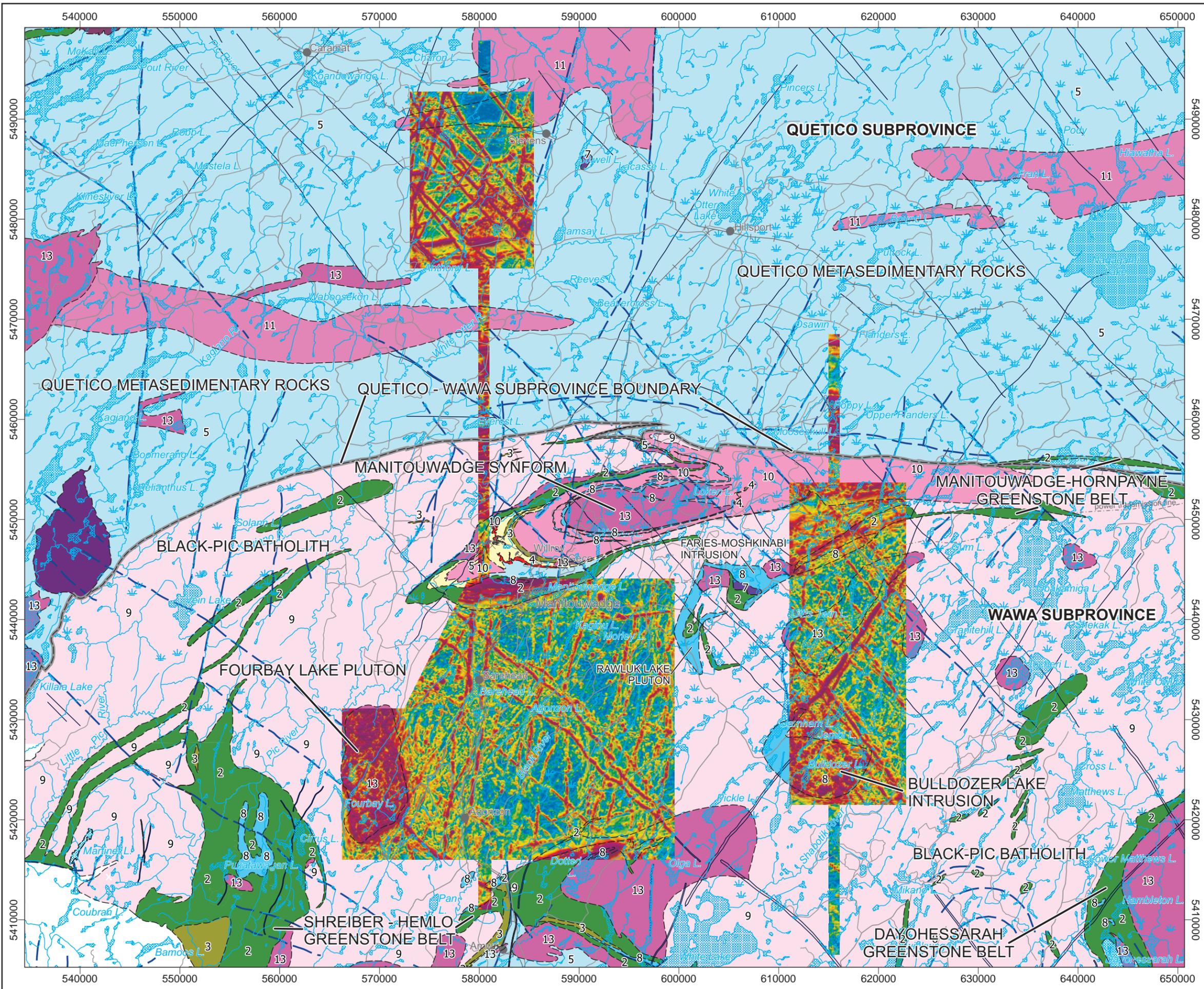
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Total Horizontal Derivative of the Free Air Gravity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	<b>FIGURE: 4.22</b>
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

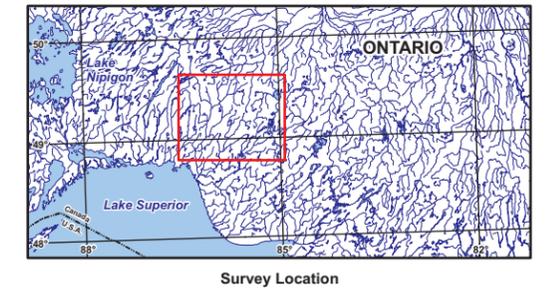
13: Granite-granodiorite

**Map Parameters**

Illumination: inclination 50°, declination 270°

Grid Cell Size: 25 m

nT/km



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

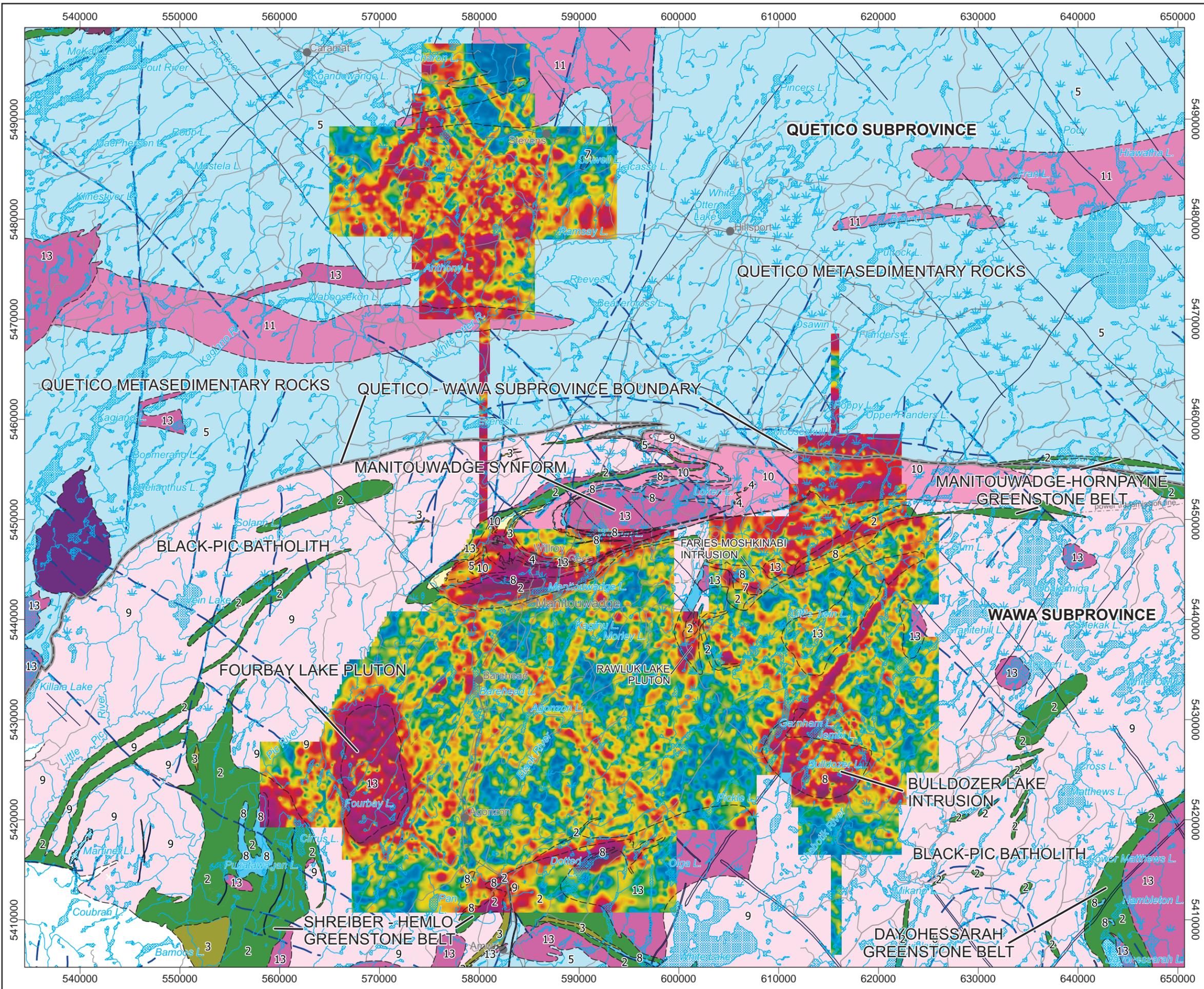
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Total Gradient Amplitude  
 of the Total Magnetic Intensity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	FIGURE: 4.23
	DATA	MP, PT, MM	13/07/2016	
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

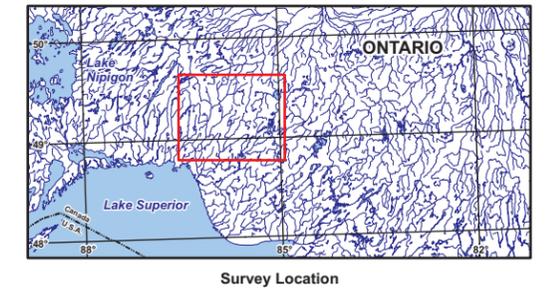
13: Granite-granodiorite

**Map Parameters**

Illumination: inclination 50°, declination 270°

Grid Cell Size: 250 m

nT/km



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

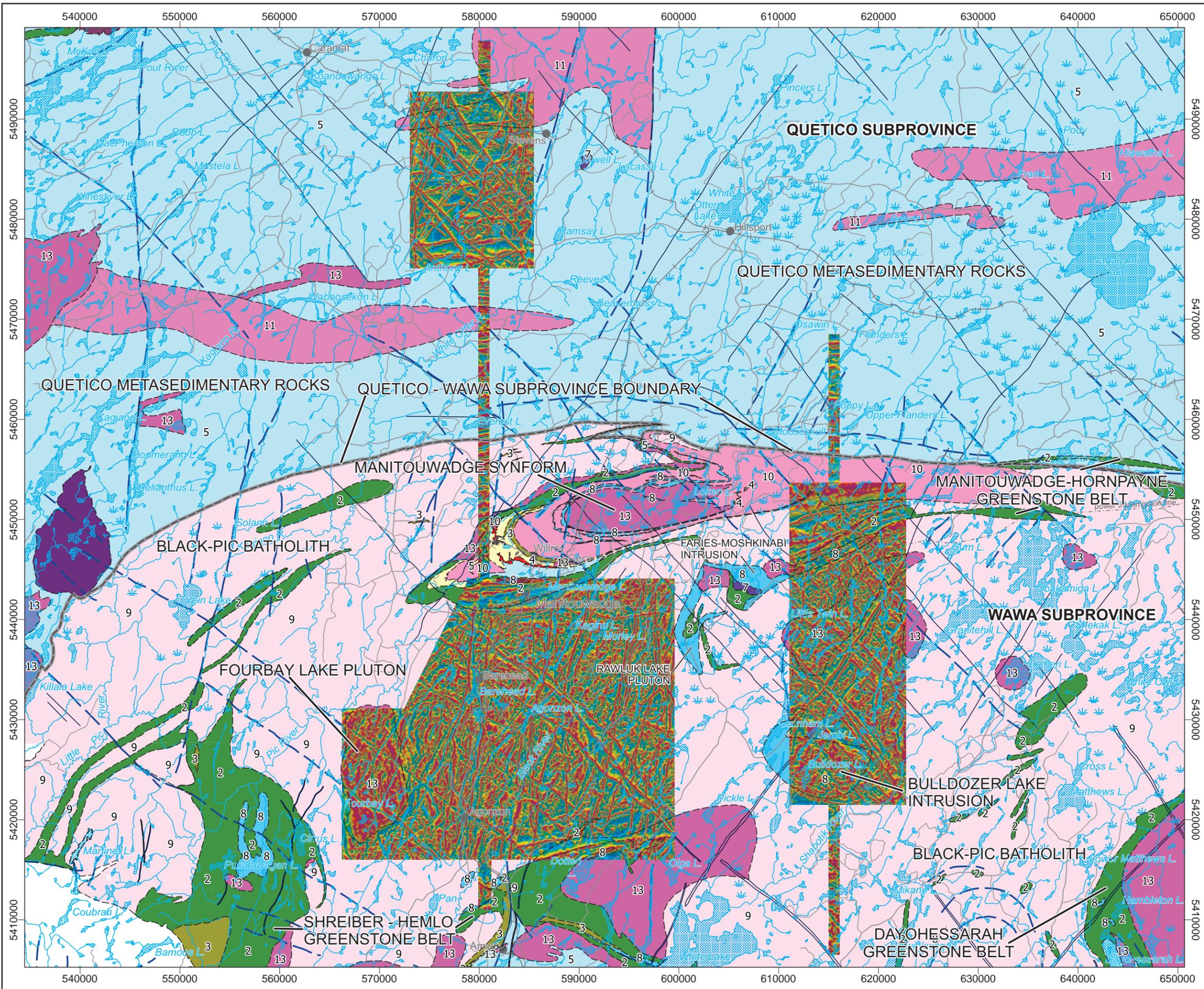
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

Manitowadge Area, Ontario 2016

**Total Gradient Amplitude  
 of the Total Magnetic Intensity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	<b>FIGURE: 4.24</b>
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

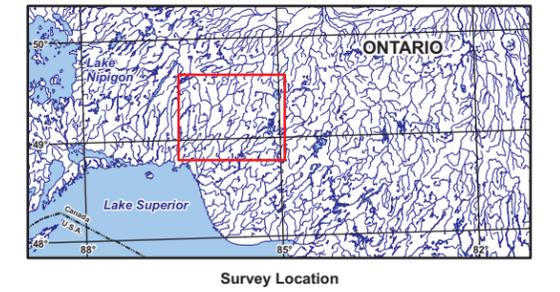
**Map Parameters**

Illumination: inclination 50°, declination 270°

Tilt Angle Grid: -45° to +45°

Grid Cell Size: 25 m

degrees



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

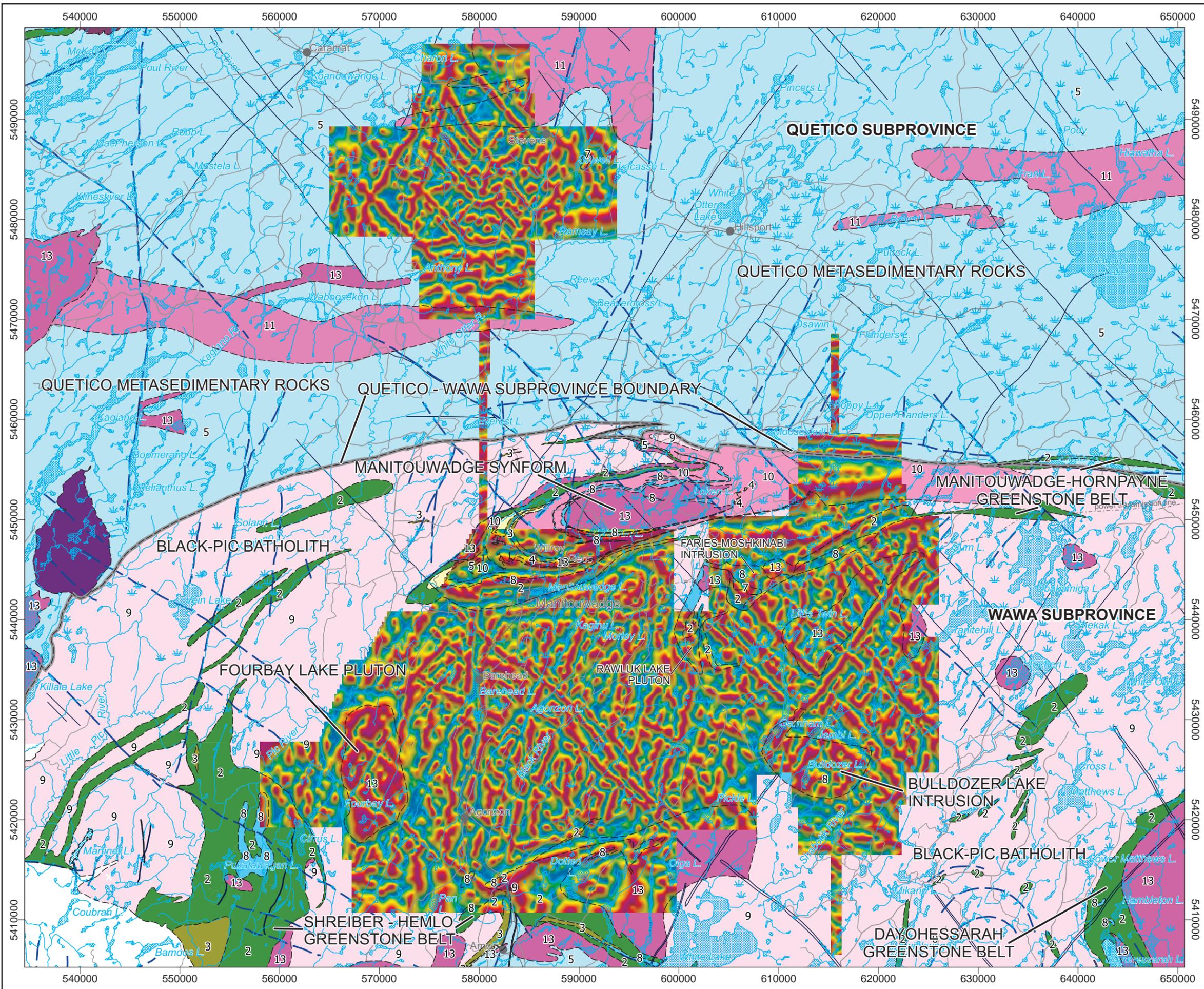
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Tilt Angle of the Reduction to the Pole  
 of the Total Magnetic Intensity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	FIGURE: 4.25
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

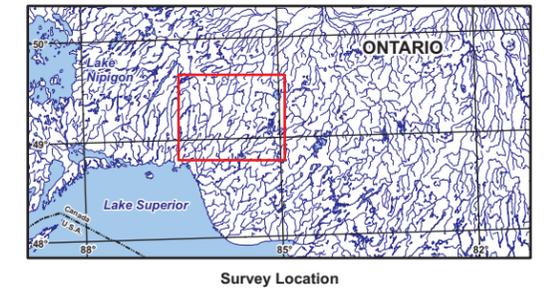
**Map Parameters**

Illumination: inclination 50°, declination 270°

Tilt Angle Grid: -45° to +45°

Grid Cell Size: 250 m

degrees



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

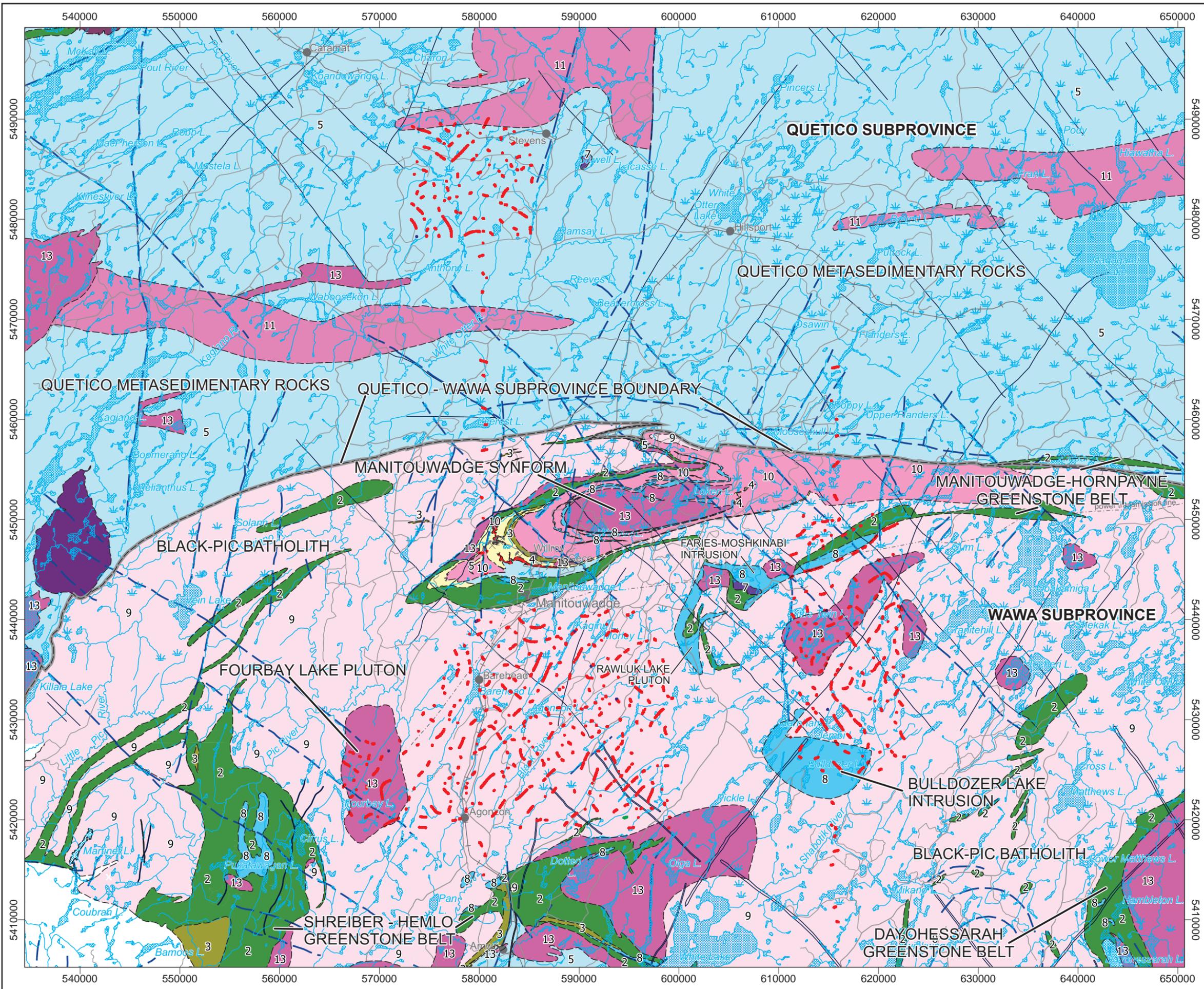
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

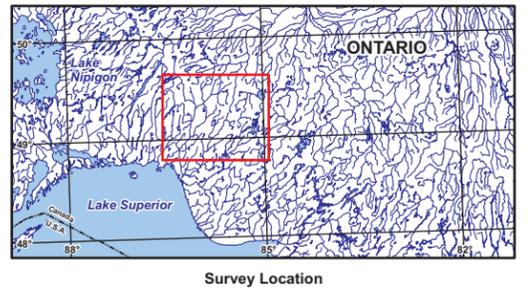
**Manitowadge Area, Ontario 2016**

**Tilt Angle of the Reduction to the Pole  
 of the Total Magnetic Intensity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	FIGURE: 4.26
	QC	MB	15/07/2016	



- Legend**
- Hydrography .....
  - Roads .....
  - Railway .....
  - Powerline .....
  - Mine .....
- Geology**
- Fault .....
  - Dyke .....
  - Subprovince Boundary .....
- Trend Analysis Solutions**
- Depth below surface
- 0 - 100 m
  - 101 - 200 m
  - > 200 m



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

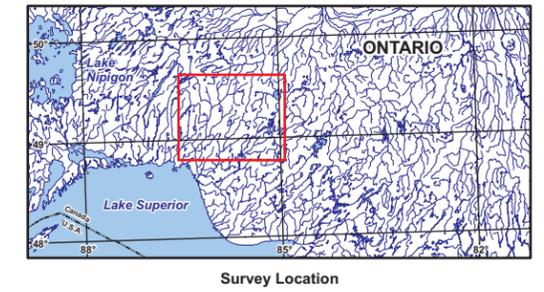
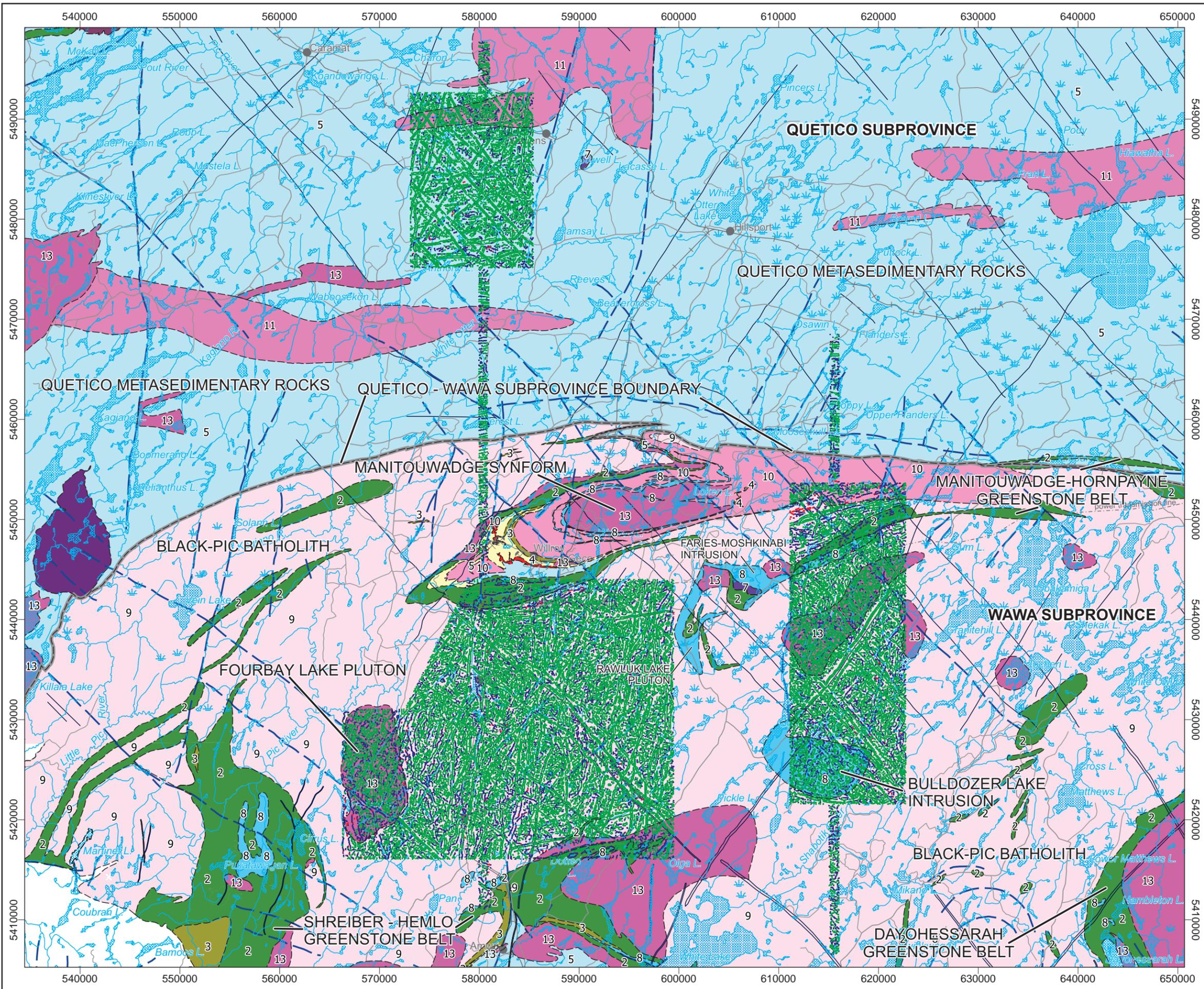
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Trend Analysis Solutions of Bouguer Gravity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	<b>FIGURE: 4.27</b>
	QC	MB	15/07/2016	



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

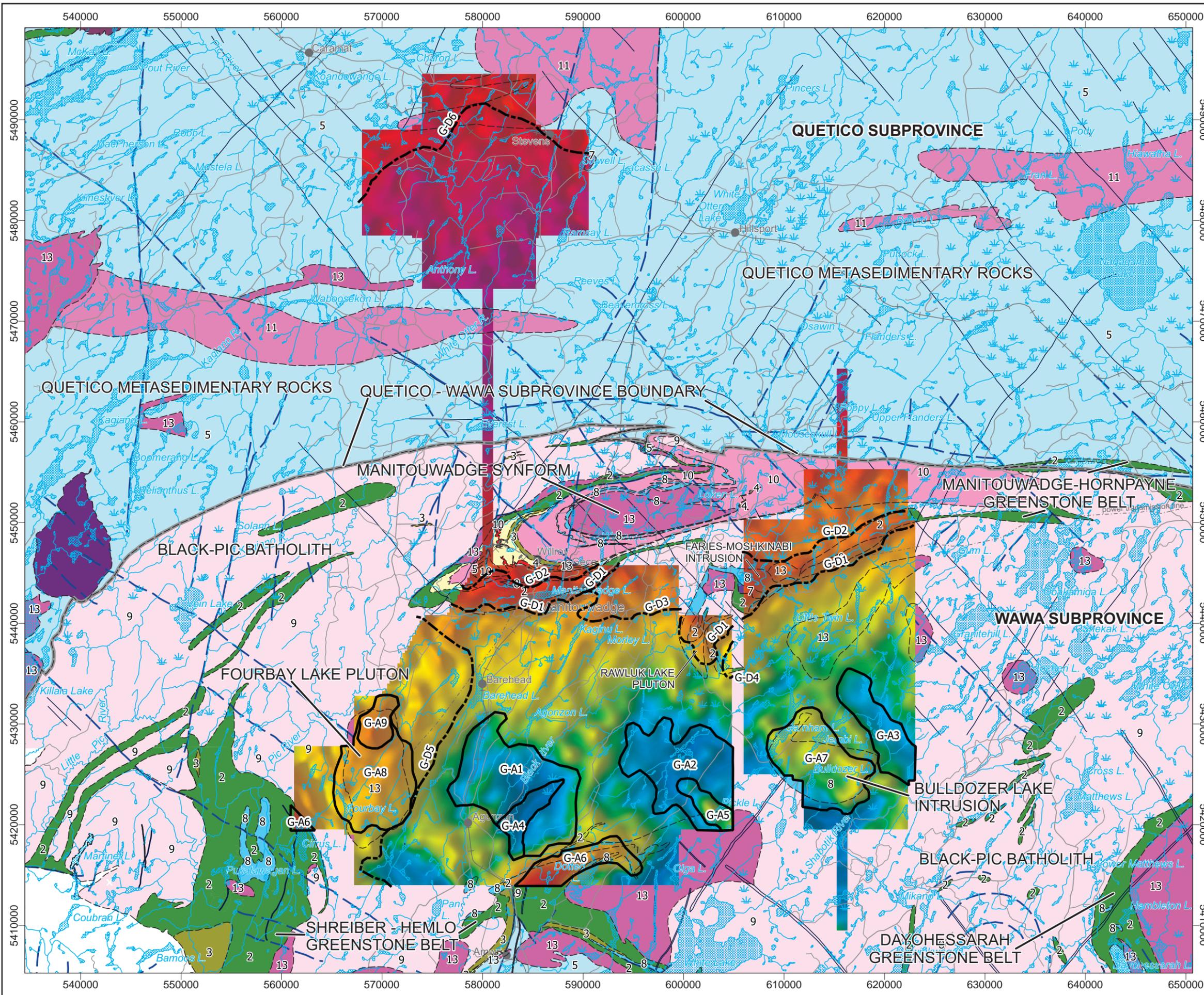
Scale 1 : 370 000

km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**  
 Manitowadge Area, Ontario 2016

**Trend Analysis Solutions of Reduction to the Pole  
 of the Total Magnetic Intensity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	<b>FIGURE: 4.28</b>
	DATA	MP, PT, MM	13/07/2016	
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

Gravity Anomaly .....

Gravity Domain Boundary .....

**Map Parameters**

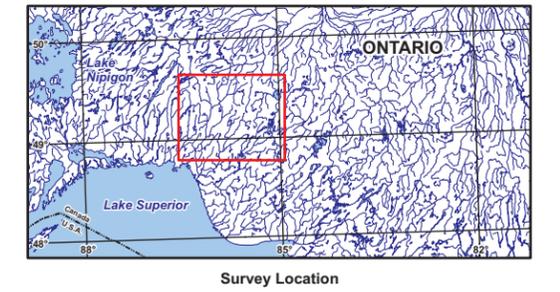
Illumination: inclination 50°, declination 270°

Spatial Filter (half-wavelength): 1000 m

Bouguer Density: 2.67 g/cm<sup>3</sup>

Grid Cell Size: 250 m

mGal



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universe Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

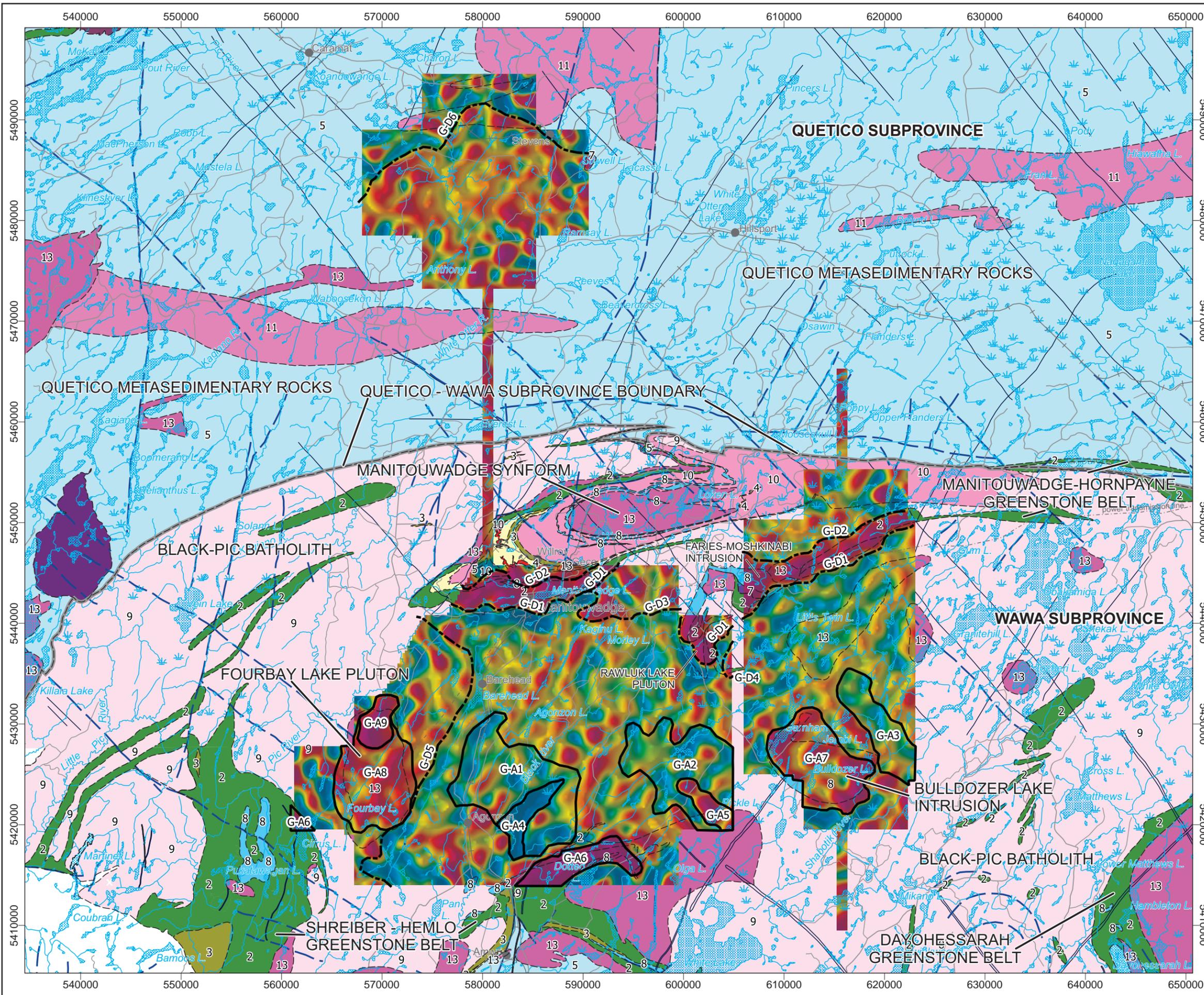
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Bouguer Gravity with Selected Interpreted Features**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	FIGURE: 5.1
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

**Gravity Anomaly** .....

**Gravity Domain Boundary** .....

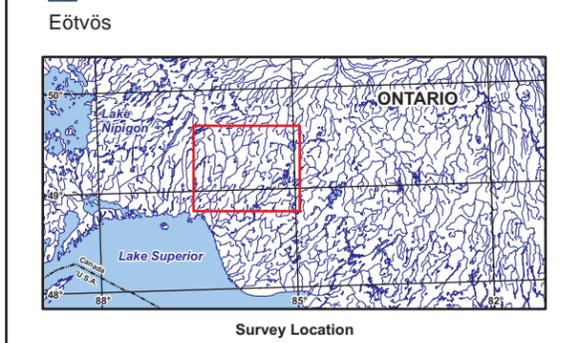
**Map Parameters**

Illumination: inclination 50°, declination 270°

Spatial Filter (half-wavelength): 1000 m

Bouguer Density: 2.67 g/cm<sup>3</sup>

Grid Cell Size: 250 m



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

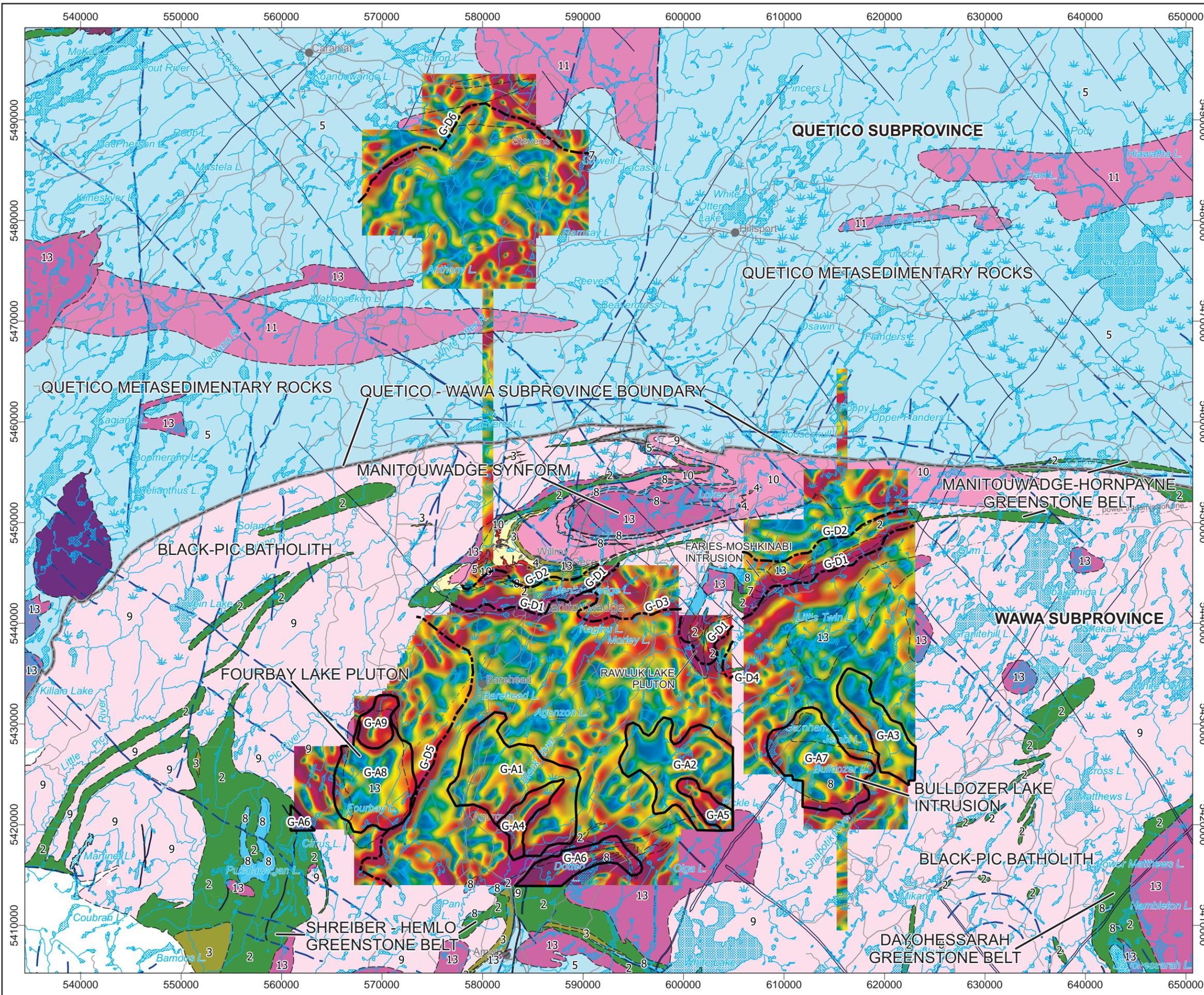
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**First Vertical Derivative of the Bouguer Gravity  
 with Selected Interpreted Features**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	FIGURE: 5.2
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

Gravity Anomaly .....

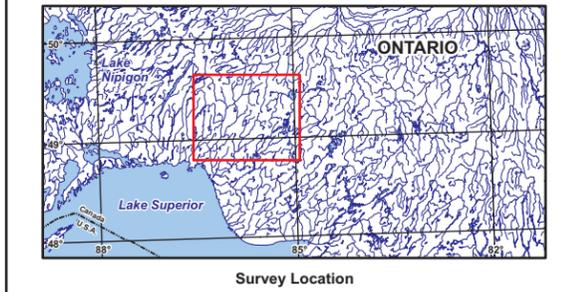
Gravity Domain Boundary .....

**Map Parameters**

Illumination: inclination 50°, declination 270°

Grid Cell Size: 250 m

mGal/km



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

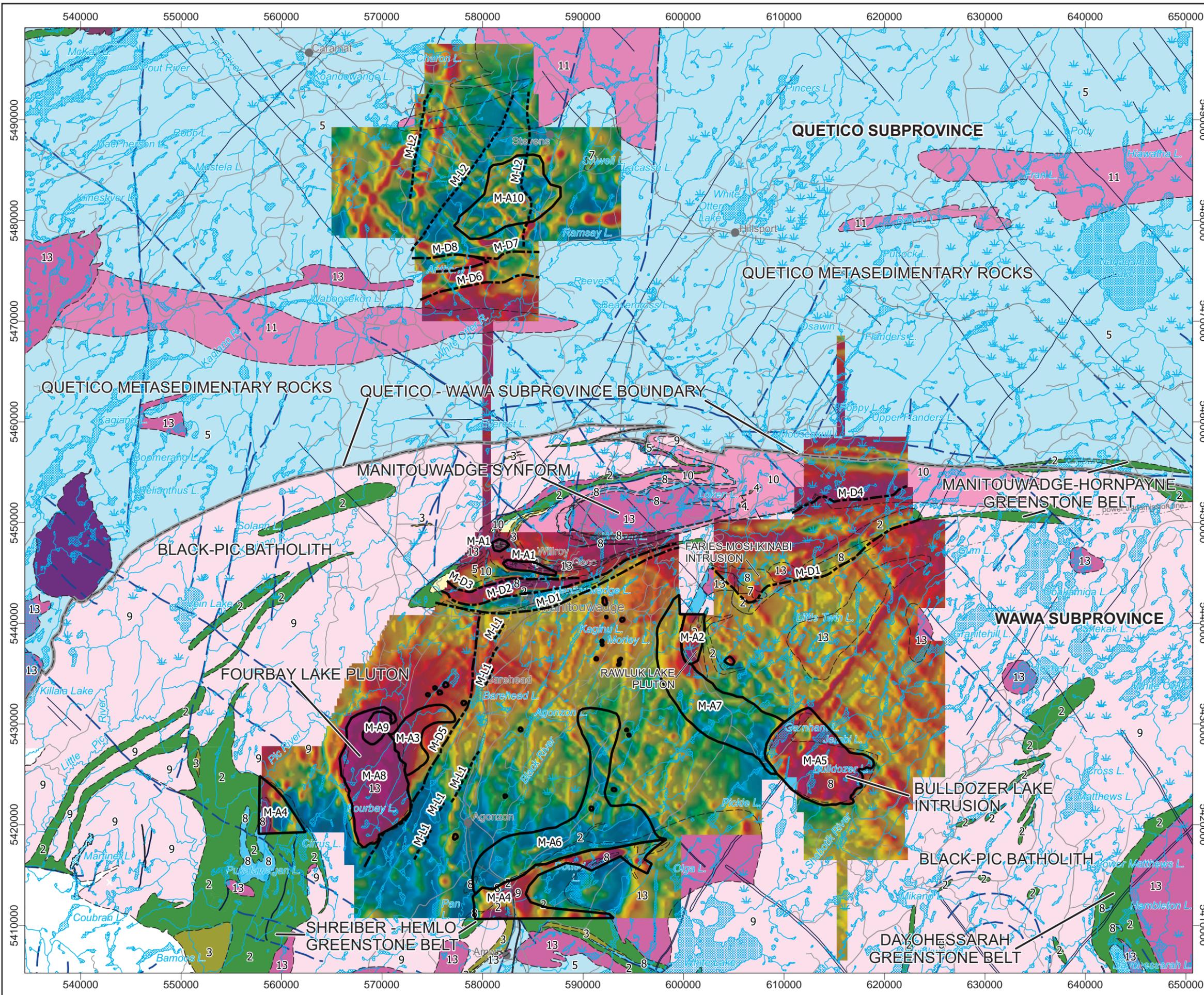
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Total Horizontal Derivative of the Bouguer Gravity  
 with Selected Interpreted Features**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	FIGURE: 5.3
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

**Magnetic Anomaly** .....

**Magnetic Domain Boundary** .....

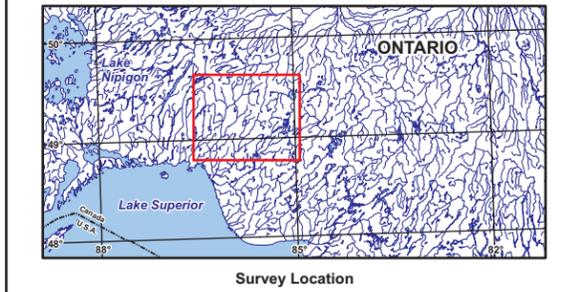
**Magnetic Lineament** .....

**Map Parameters**

Illumination: inclination 50°, declination 270°

Grid Cell Size: 250 m

nT



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

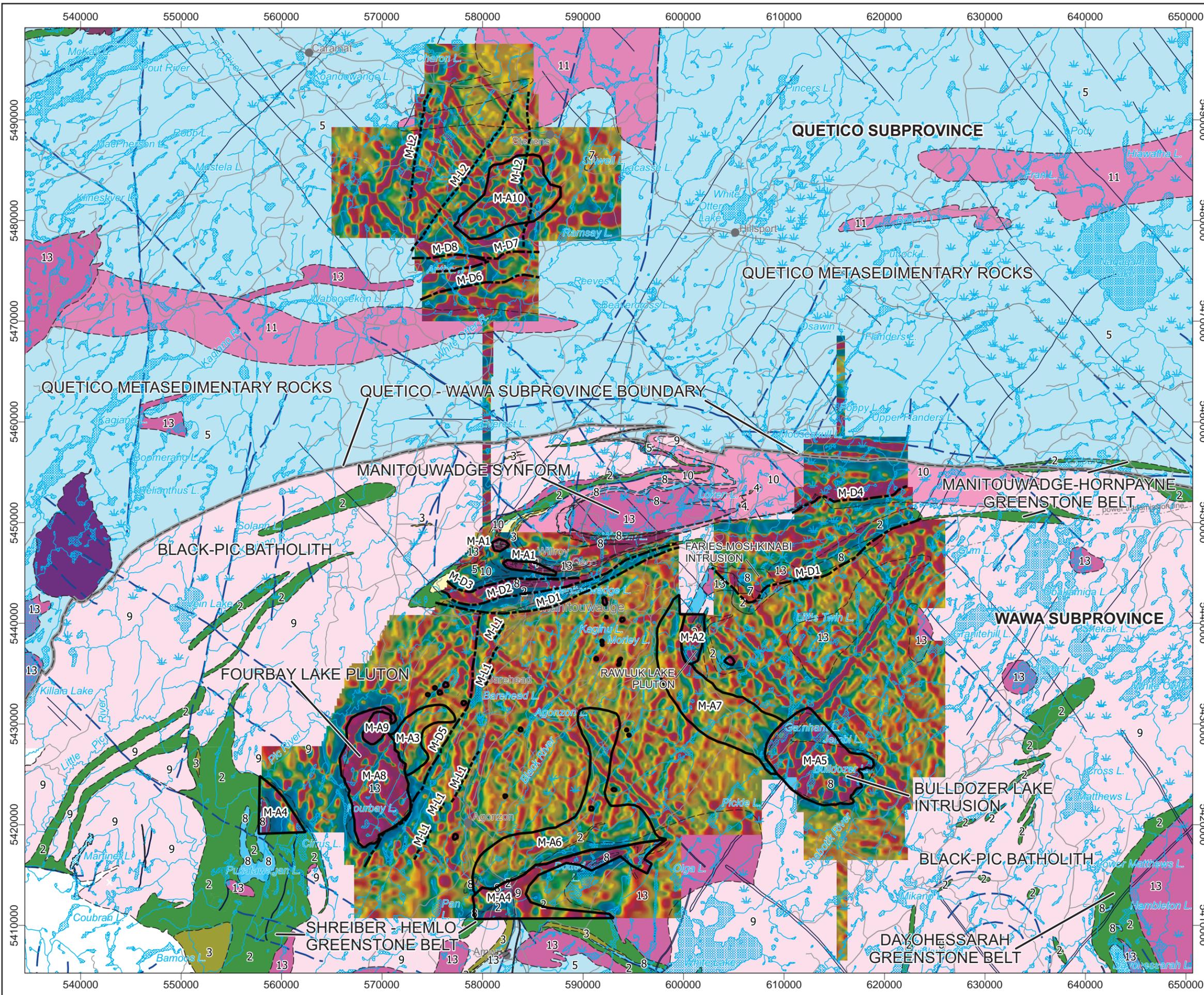
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Reduction to the Pole of the Total Magnetic Intensity  
 with Selected Interpreted Features**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	FIGURE: 5.4
	DATA	MP, PT, MM	13/07/2016	
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

**Magnetic Anomaly** .....

**Magnetic Domain Boundary** .....

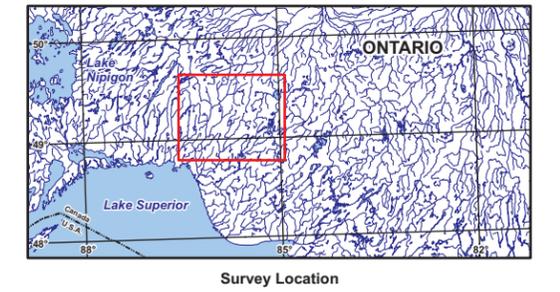
**Magnetic Lineament** .....

**Map Parameters**

Illumination: inclination 50°, declination 270°

Grid Cell Size: 250 m

nT/km



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

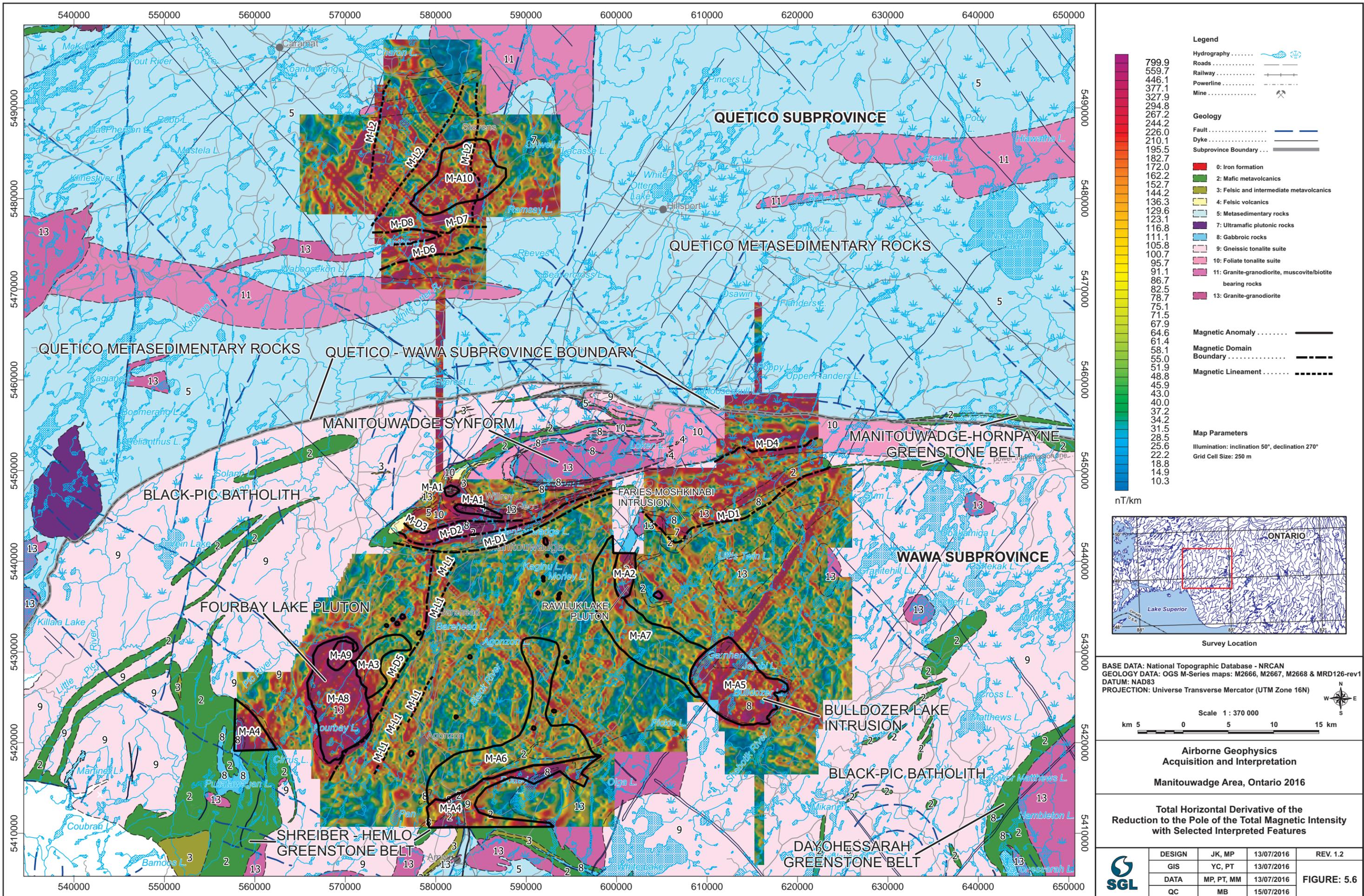
km 5 0 5 10 15 km

**Airborne Geophysics Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**First Vertical Derivative of the Reduction to the Pole of the Total Magnetic Intensity with Selected Interpreted Features**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	FIGURE: 5.5
	QC	MB	15/07/2016	



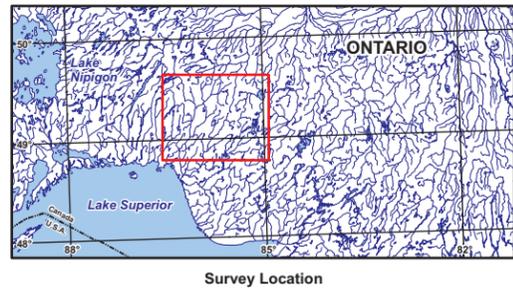
- Legend**
- Hydrography
  - Roads
  - Railway
  - Powerline
  - Mine

- Geology**
- Fault
  - Dyke
  - Subprovince Boundary

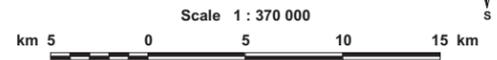
- 0: Iron formation
- 2: Mafic metavolcanics
- 3: Felsic and intermediate metavolcanics
- 4: Felsic volcanics
- 5: Metasedimentary rocks
- 7: Ultramafic plutonic rocks
- 8: Gabbroic rocks
- 9: Gneissic tonalite suite
- 10: Foliate tonalite suite
- 11: Granite-granodiorite, muscovite/biotite bearing rocks
- 13: Granite-granodiorite

- Magnetic Anomaly
- Magnetic Domain Boundary
- Magnetic Lineament

- Map Parameters**
- Illumination: inclination 50°, declination 270°
  - Grid Cell Size: 250 m



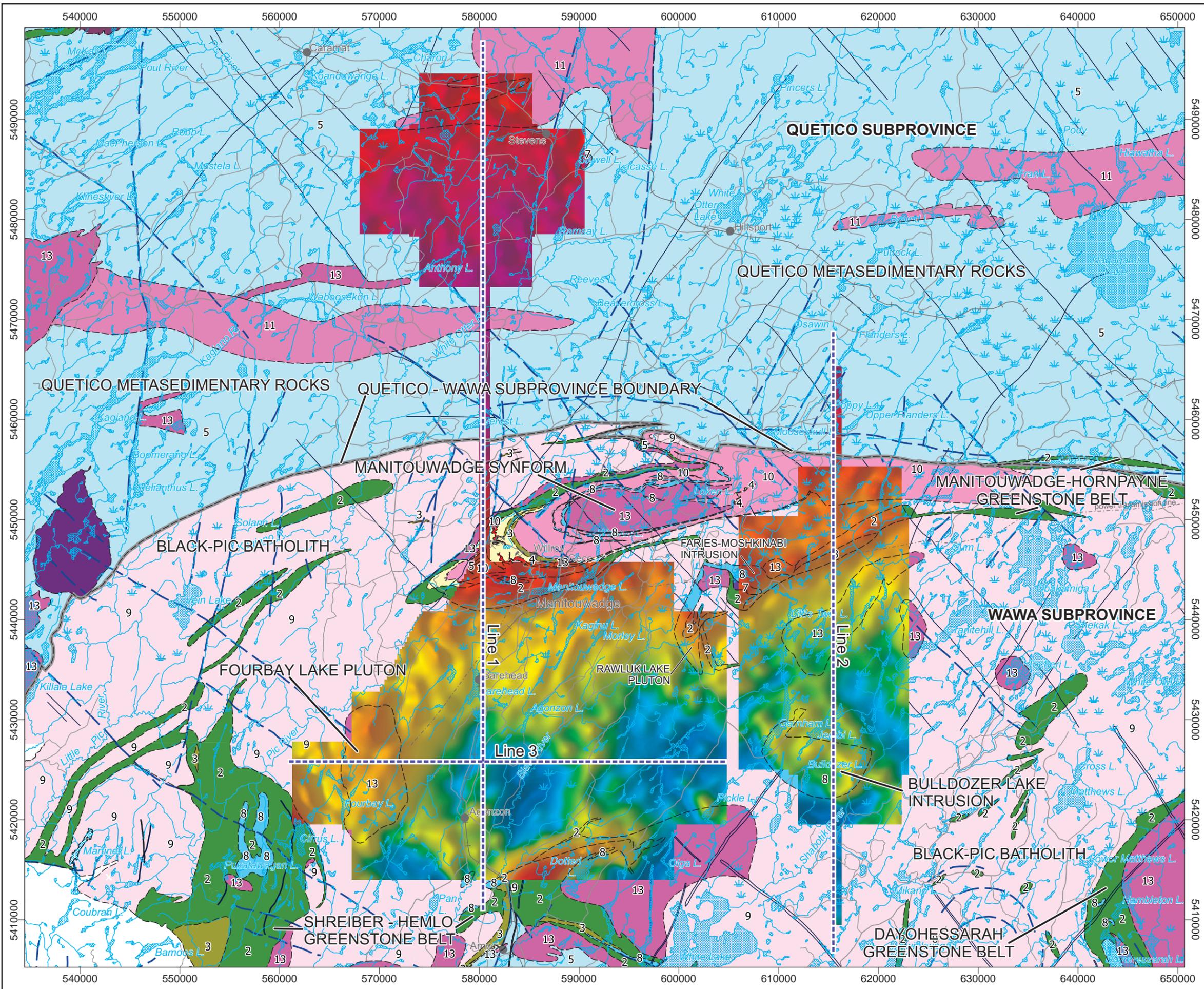
BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)



**Airborne Geophysics  
 Acquisition and Interpretation**  
 Manitowadge Area, Ontario 2016

**Total Horizontal Derivative of the  
 Reduction to the Pole of the Total Magnetic Intensity  
 with Selected Interpreted Features**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	FIGURE: 5.6
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

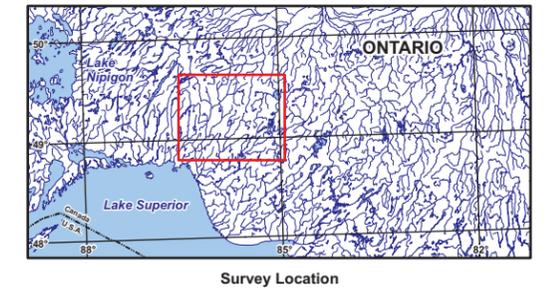
**Map Parameters**

Illumination: inclination 50°, declination 270°

Grid Cell Size: 250 m

2.5D model line .....

mGal



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universe Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

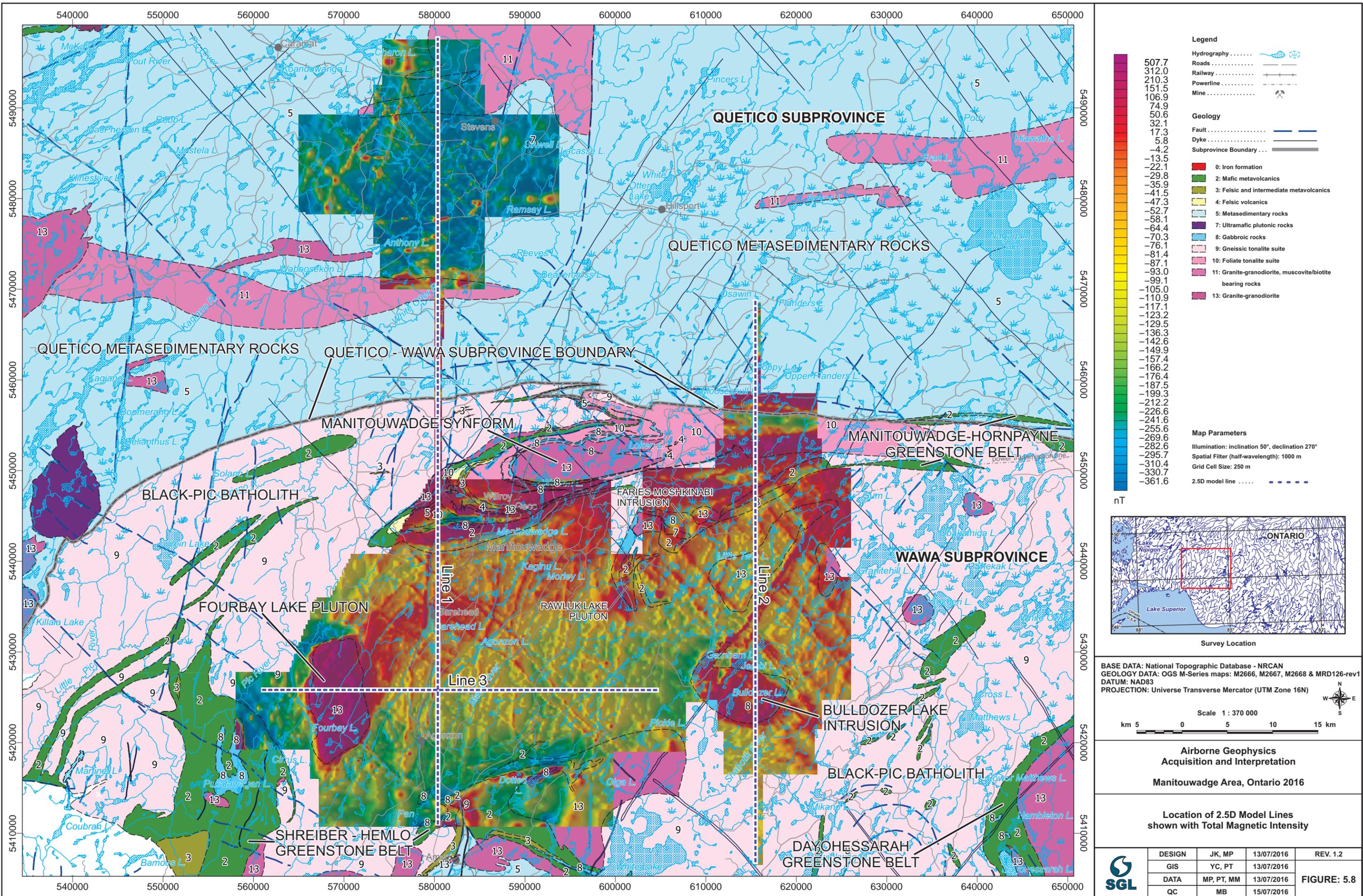
km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Location of 2.5D Model Lines  
 shown with Bouguer Gravity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	<b>FIGURE: 5.7</b>
	QC	MB	15/07/2016	



**Legend**

Hydrography .....

Roads .....

Railway .....

Powerline .....

Mine .....

**Geology**

Fault .....

Dyke .....

Subprovince Boundary .....

0: Iron formation

2: Mafic metavolcanics

3: Felsic and intermediate metavolcanics

4: Felsic volcanics

5: Metasedimentary rocks

7: Ultramafic plutonic rocks

8: Gabbroic rocks

9: Gneissic tonalite suite

10: Foliate tonalite suite

11: Granite-granodiorite, muscovite/biotite bearing rocks

13: Granite-granodiorite

**Map Parameters**

Illumination: inclination 50°, declination 270°

Spatial Filter (half-wavelength): 1000 m

Grid Cell Size: 250 m

2.5D model line .....

nT

507.7

312.0

210.3

151.5

106.9

74.9

50.6

32.1

17.3

5.8

-4.2

-13.5

-22.1

-29.8

-35.9

-41.5

-47.3

-52.7

-58.1

-64.4

-70.3

-76.1

-81.4

-87.1

-93.0

-99.1

-105.0

-110.9

-117.1

-123.2

-129.5

-136.3

-142.6

-149.9

-157.4

-166.2

-176.4

-187.5

-199.3

-212.2

-226.6

-241.6

-255.6

-269.6

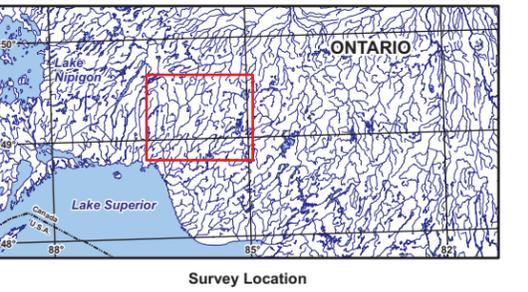
-282.6

-295.7

-310.4

-330.7

-361.6



BASE DATA: National Topographic Database - NRCAN  
 GEOLOGY DATA: OGS M-Series maps: M2666, M2667, M2668 & MRD126-rev1  
 DATUM: NAD83  
 PROJECTION: Universal Transverse Mercator (UTM Zone 16N)

Scale 1 : 370 000

km 5 0 5 10 15 km

**Airborne Geophysics  
 Acquisition and Interpretation**

**Manitowadge Area, Ontario 2016**

**Location of 2.5D Model Lines  
 shown with Total Magnetic Intensity**

	DESIGN	JK, MP	13/07/2016	REV. 1.2
	GIS	YC, PT	13/07/2016	
	DATA	MP, PT, MM	13/07/2016	FIGURE: 5.8
	QC	MB	15/07/2016	

Figure 5.9 - Forward Modeling Results: Line 1, Manitowadge, Ontario

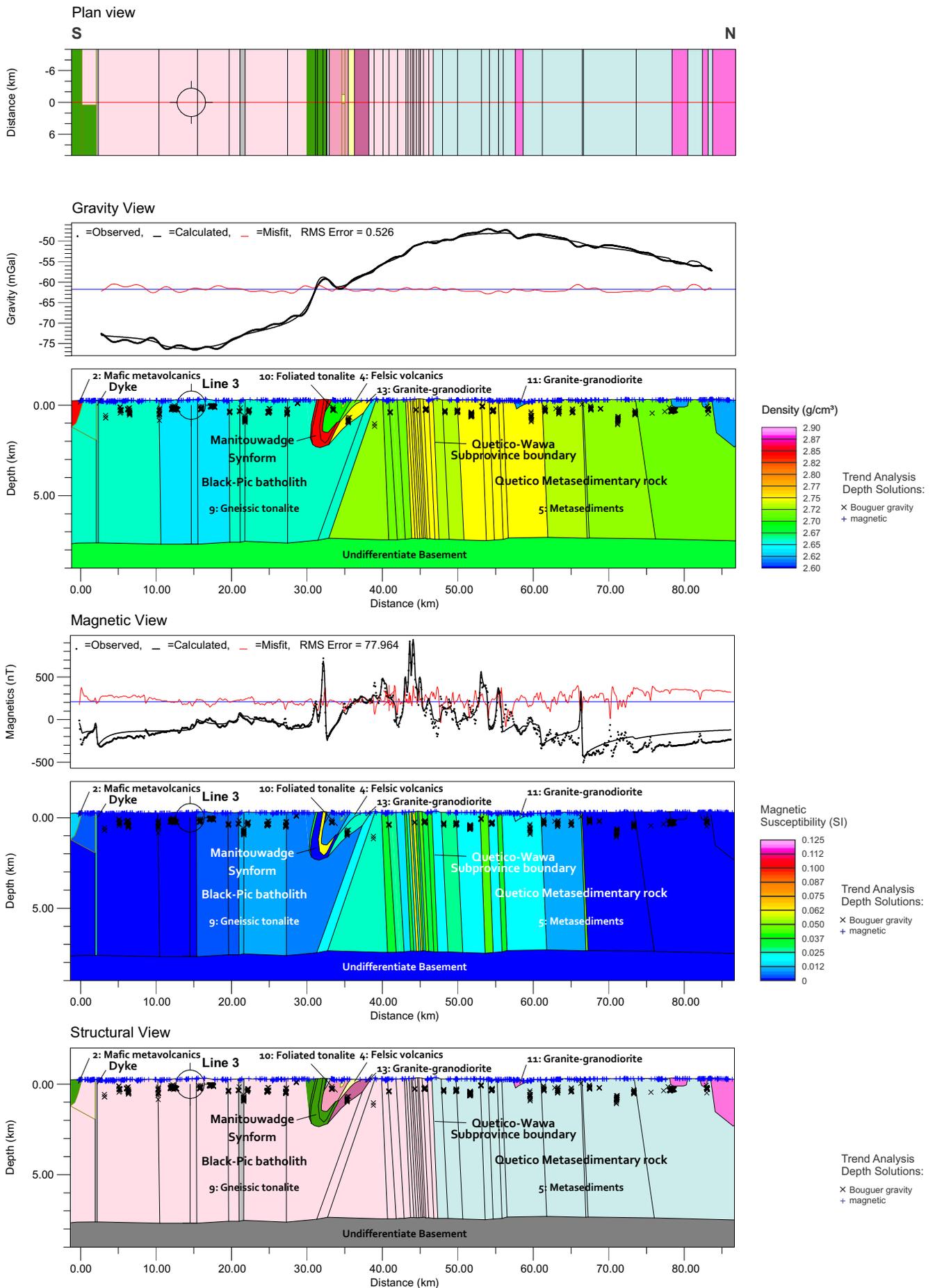


Figure 5.10 - Forward Modeling Results: Line 1-Alternative, Manitowadge, Ontario

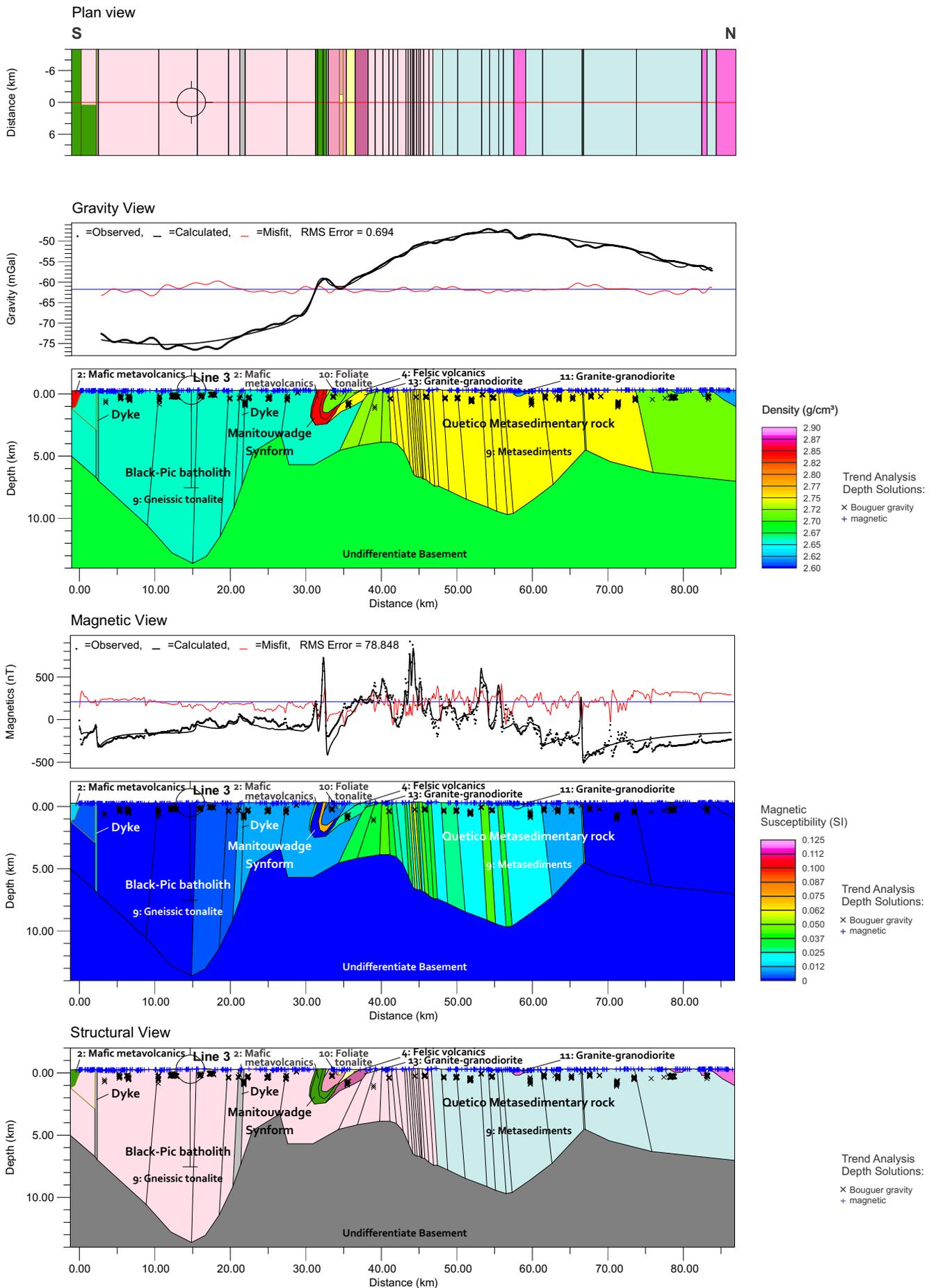


Figure 5.11 - Forward Modeling Results: Line 2, Manitouwadge, Ontario

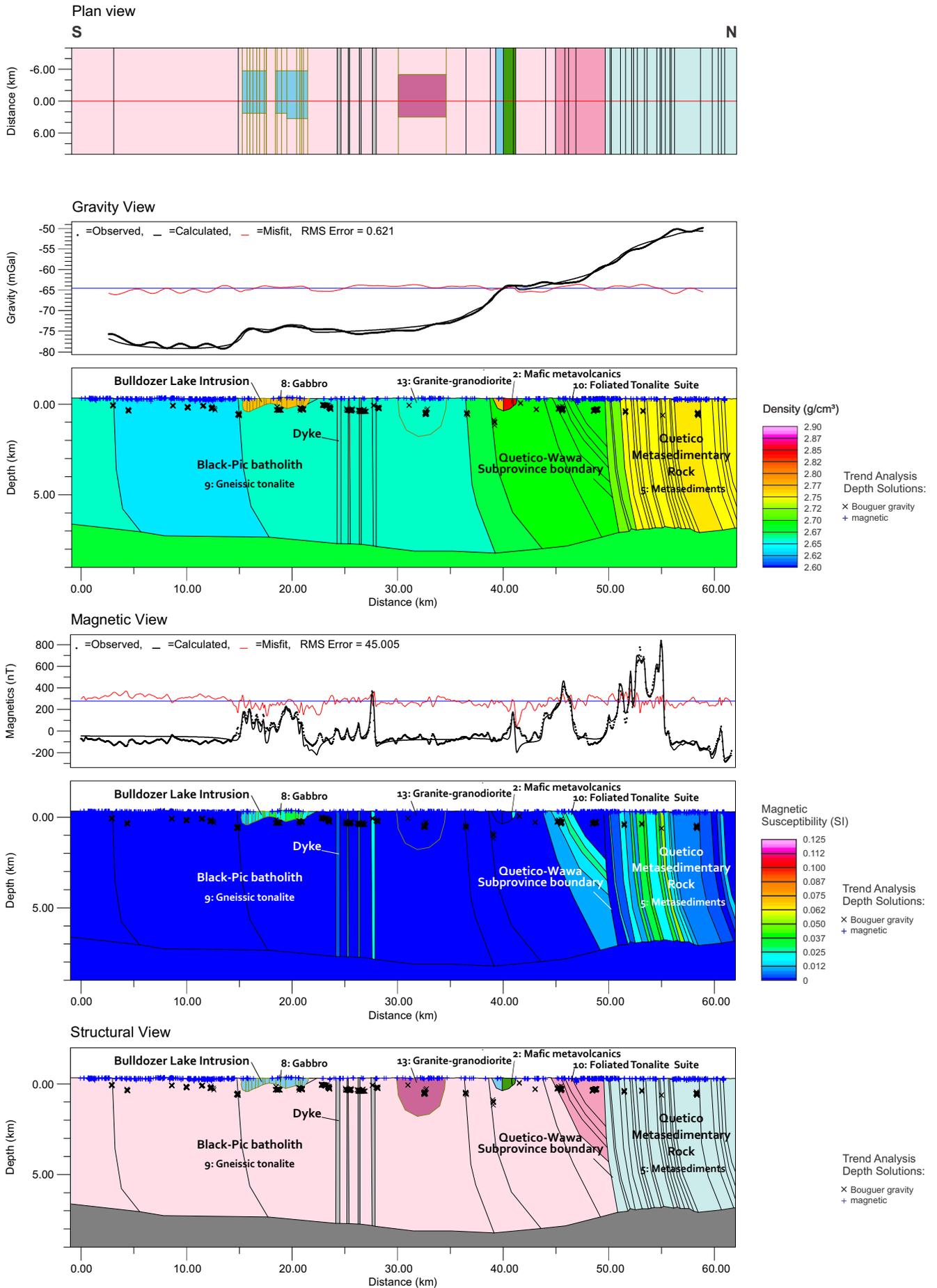


Figure 5.12 - Forward Modeling Results: Line 2-Alternative, Manitouwadge, Ontario

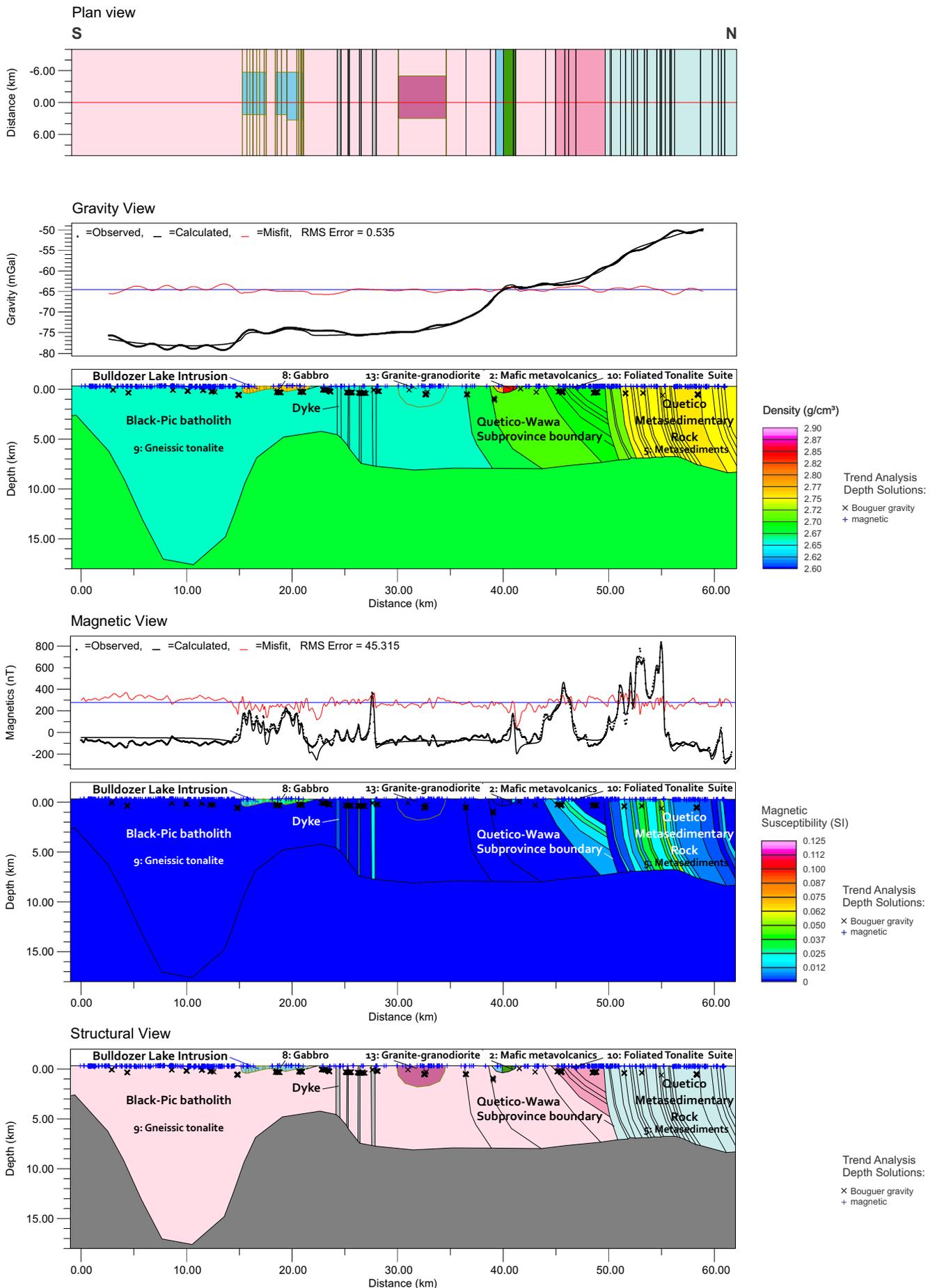


Figure 5.13 - Forward Modeling Results: Line 3, Manitouwadge, Ontario

