NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Phase 1 Geoscientific Desktop Preliminary Assessment, Processing and Interpretation of Geophysical Data

TOWNSHIP OF HORNEPAYNE, ONTARIO

APM-REP-06144-0005

NOVEMBER 2013

For more information, please contact:
Nuclear Waste Management Organization
22 St. Clair Avenue East, Sixth Floor
Toronto, Ontario M4T 2S3 Canada
Tel 416.934.9814
Toll Free 1.866.249.6966
Email contactus@nwmo.ca
www.nwmo.ca

PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT

PROCESSING AND INTERPRETATION OF GEOPHYSICAL DATA

Township of Hornepayne, Ontario

Prepared for

Geofirma Engineering Ltd.
and
Nuclear Waste Management Organization (NWMO)

by

Paterson, Grant & Watson Limited
Consulting Geophysicists
www.pgw.on.ca

NWMO Report Number: APM-REP-06144-0005

Toronto, Canada **November, 2013**

EXECUTIVE SUMMARY

In December 2011, the the Township of Hornepayne, Ontario, expressed interest in continuing to learn more about the Nuclear Waste Management Organization nine-step site selection process (NWMO, 2010), and requested that a preliminary assessment be conducted to assess potential suitability of the Hornepayne area for safely hosting a deep geological repository (Step 3). This request followed the successful completion of an initial screening conducted during Step 2 of the site selection process.

The preliminary assessment is a multidisciplinary study integrating both technical and community well-being studies, including geoscientific suitability, engineering, transportation, environment and safety, as well as social, economic and cultural considerations. The findings of the overall preliminary assessment are reported in an integrated report (NWMO, 2013). The objective of the desktop geoscientific preliminary assessment is to determine whether the Township of Hornepayne and its periphery, referred to as the "Hornepayne area", contain general areas that have the potential to meet NWMO's geoscientific site evaluation factors.

This report presents the findings of a geophysical data interpretation assessment completed as part of the desktop geoscientific preliminary assessment of the Hornepayne area (Geofirma, 2013a). The purpose of this assessment was to perform a detailed interpretation of all available geophysical data (e.g., magnetic, electromagnetic, gravity and radiometric) for the Hornepayne area. The aim was to identify additional information that can be extracted from the data, in particular that relating to the coincidence of geophysical features with mapped lithology and structural features in the Hornepayne area.

The geophysical data covering the Hornepayne area show variability in dataset resolution. Low-resolution geophysical data, particularly the magnetic, gravity and radiometric data obtained from the Geological Survey of Canada (GSC), cover the entire Hornepayne area. Two additional magnetic/electromagnetic surveys obtained from the Ontario Geological Survey (OGS) provided higher resolution coverage over approximately 15% of the Hornepayne area, on its western portion and southeast corner.

The coincidence between the geophysical data and the mapped lithology and structural features was interpreted using all the available geophysical data sets (e.g., magnetic, electromagnetic, gravity and radiometric), with the aeromagnetic dataset being the most reliable for the interpretation. The boundaries of the geological units shown on the bedrock geology map are not always well-defined on the magnetic data due to the low data resolution over the majority of the Hornepayne area, and lack of magnetic contrast between the rock units mapped on the surface. However, a strong east-trending magnetic response characterized by subparallel lineations is evident in the magnetic dataset and interpreted as an approximately 15 km wide zone of deformation associated with the Wawa-Quetico subprovince boundary. Similarly, the aeromagnetic data shows a high density of northwest-trending linear anomalies, which coincide with dykes mapped in the Hornepayne area.

TABLE OF CONTENTS

EXECUTIVE SUMMARY i
1 INTRODUCTION 1
1.1 Objective of the Assessment 1
1.2 Hornepayne Area 2
1.3 Qualifications of the Geophysical Interpretation Team 2
2 SUMMARY OF PHYSICAL GEOGRAPHY AND GEOLOGY 3
2.1 Physical Geography 3
2.2 Bedrock Geology 4
2.2.1 Metasedimentary Rocks of the Quetico Subprovince 4
2.2.2 Granitic-Granodioritic Intrusions of the Quetico Subprovince 5
2.2.3 Black-Pic Batholith of the Wawa Subprovince 5
2.2.4 Mafic Dykes 6
2.2.5 Faults 6
2.2.6 Metamorphism 7
2.3 Geological and Structural History 8
2.4 Quaternary Geology 11
2.5 Land Use 12
3 GEOPHYSICAL DATA SOURCES AND QUALITY 13
3.1 Data Sources 13
3.1.1 Magnetic Data 13
3.1.2 Gravity Data 14
3.1.3 Radiometric Data 14
3.1.4 Electromagnetic Data 14
3.2 Data Limitations 15
4 GEOPHYSICAL DATA PROCESSING 17
4.1 Magnetic 17
4.2 Gravity 22
4.3 Radiometric 22
4.4 Electromagnetic 23
5 GEOPHYSICAL INTERPRETATION 24
5.1 Methodology 24

5.2 Results ... 25
5.2.1 Magnetic ... 25
5.2.2 Gravity ... 27
5.2.3 Radiometric ... 27
5.2.4 Electromagnetic ... 28
5.3. Geophysical Interpretation of the Quetico and Wawa Subprovince in the Hornepayne Area ... 29
5.3.1 Metasedimentary Rocks and Granitic-Granodioritic Intrusions of the Quetico Subprovince ... 29
5.3.2 Black-Pic Batholith of the Wawa Subprovince ... 30
6 SUMMARY OF RESULTS ... 32
7 REFERENCES ... 34

LIST OF FIGURES

Figure 1. Township of Hornepayne and surrounding area.
Figure 2. Bedrock geology of the Hornepayne area.
Figure 3. Surficial geology of the Hornepayne area.
Figure 4. Airborne geophysical coverage of the Hornepayne area.
Figure 5. Residual magnetic field reduced to pole.
Figure 6. First vertical derivative of the pole reduced magnetic field.
Figure 7. Second vertical derivative of the pole reduced magnetic field with foliation.
Figure 8. Tilt angle of the pole reduced magnetic field.
Figure 9. Analytic signal amplitude of the total magnetic field.
Figure 10. Depth to magnetic sources from source parameter imaging.
Figure 11. Bouguer gravity field with station locations.
Figure 12. First vertical derivative of the Bouguer gravity field with station locations.
Figure 13. Radiometric ternary image (RGB = K-eTh-eU).
Figure 14. EM conductors over apparent conductivity (GDS1024 and GDS 1205).
Figure 15. Geophysical interpretation showing distribution of bedrock units for the Hornepayne area.

LIST OF TABLES

Table 1. Summary of the regional geological and structural history of the Hornepayne area 9
Table 2. Summary of characteristics for the geophysical data in the Hornepayne area 16
Table 3. Radioelement response statistics for the Hornepayne area 28

1 INTRODUCTION

In December 2011, the Township of Hornepayne, Ontario expressed interest in continuing to learn more about the Nuclear Waste Management Organization nine-step site selection process (NWMO, 2010), and requested that a preliminary assessment be conducted to assess potential suitability of the Hornepayne area for safely hosting a deep geological repository (Step 3). The preliminary assessment is a multidisciplinary study integrating both technical and community well-being studies, including geoscientific suitability, engineering, transportation, environment and safety, as well as social, economic and cultural considerations (NWMO, 2013).

This report presents the findings of a geophysical data processing and interpretation assessment completed by Paterson, Grant & Watson Limited (PGW) as part of the desktop geoscientific preliminary assessment of the Hornepayne area (Geofirma, 2013a). The objective of the desktop geoscientific preliminary assessment is to determine whether the Hornepayne area contains general areas that have the potential to meet NWMO's geoscientific site evaluation factors. The assessment focused on the Township of Hornepayne and its periphery, referred to as the "Hornepayne area".

1.1 Objective of the Assessment

Geophysical data forms an important component of assessing a region for its potential suitability to host a deep geological repository, and to assist in the identification of potentially suitable areas.

The purpose of this assessment was to perform a review of available geophysical data for the Hornepayne area, followed by a detailed interpretation of all available geophysical data (e.g., magnetic, electromagnetic, gravity and radiometric) to identify additional information that could be extracted from the data, in particular regarding the coincidence of geophysical features with mapped lithology and structural features in the Hornepayne area.

The role of the geophysical interpretation is to extrapolate our current understanding of the mapped lithology and extent of overburden cover to assess how the distributions of rock units may change at depth. Drillholes, wells and other underground information may be available at individual points to supplement geological data acquired on surface. However, where these individual data points are limited (or non-existent), such as for the Hornepayne area, the critical advantage of airborne geophysical data is that it provides a basis for interpreting the subsurface physical properties across the area. This is particularly important in areas where bedrock exposure is limited by surface water bodies and/or overburden cover, such as in the Hornepayne area. A secondary role of geophysics is that it often elucidates certain characteristics of geological formations and structures that may not be easily discerned from surface mapping and analysis. Thirdly, it highlights tectonic and regional-scale features that may not be easily extracted from studies of a particular area on a more detailed scale.

1.2 Hornepayne Area

The Hornepayne area (4,800 km^2) incorporates the Township of Hornepayne (205 km^2) and surrounding area, located in north-central Ontario (Figure 1). The Township of Hornepayne is situated in the District of Algoma 130 km north of the eastern end of Lake Superior, 340 km east of Thunder Bay, 260 km west of Timmins, and 300 km north of Sault Ste. Marie. The closest settlements to the Township of Hornepayne are the Township of White River, approximately 100 km south and Township of Hearst, approximately 130 km northeast.

1.3 Qualifications of the Geophysical Interpretation Team

The team responsible for the geophysical review, processing and interpretation investigation component of the Phase 1 geoscientific desktop preliminary assessment for the Hornepayne area consisted of qualified experts from Paterson, Grant & Watson Limited (PGW). The personnel assigned to this assessment were as follows:

Stephen Reford, B.A.Sc., P.Eng. – project management, geophysical interpretation, report preparation

Mr. Reford is a senior consulting geophysicist and Vice-President of PGW. Mr. Reford has 31 years of experience in project management, acquisition and interpretation of airborne magnetic, electromagnetic, radiometric, gravity and digital terrain data for clients throughout Canada and around the world. Projects include management of the geophysical component of Operation Treasure Hunt for the Ontario Ministry of Northern Development and Mines as well as a similar role for the Far North Geoscience Mapping Initiative (2006-2009). Mr. Reford has served as a consultant to the International Atomic Energy Agency (IAEA) in gamma-ray spectrometry and is co-author of two books on radioelement mapping.

Edna Mueller, M.Sc. – data processing and map preparation

Ms. Mueller is a senior consulting geophysicist for PGW. She has 18 years of experience in project management, acquisition, processing and modelling of airborne magnetic, electromagnetic, radiometric, gravity and digital terrain data throughout and gamma-ray spectrometer surveys for clients throughout Canada and around the world. In recent years, she has provided management and quality control for a number of OGS magnetic, gravity and electromagnetic surveys, and has reprocessed numerous industry surveys published by OGS.

Winnie Pun, M.Sc. – data processing and map preparation

Ms. Pun will soon complete her first year as a consulting geophysicist for PGW after completing her M.Sc. in geophysics at the University of Toronto. She has prepared hundreds of geophysical maps for publication by government agencies in Nigeria and Botswana, and most recently has carried out several 2D/3D magnetic and gravity modelling studies on several iron ore projects.

Nikolay Paskalev, M.Sc. – GIS preparation

Mr. Paskalev has been the Manager, Geomatics and Cartography for Watts, Griffis and McOuat Limited (geological consultants) since 2006 and has been with the company since 2001. His work there has included a nationwide GIS of geology, ores and industrial minerals for Egypt, a GIS compilation of geological maps for a large part of Saudi Arabia and a Radarsat and DEM study for gold exploration in Sumatra. He has also worked part-time for PGW for the last 12 years, and most recently prepared a nationwide GIS for the geophysical interpretation of Nigeria. In 2011, he incorporated World GeoMaps Inc. for consulting in geomatics, cartography and GIS.

2 SUMMARY OF PHYSICAL GEOGRAPHY AND GEOLOGY

The Hornepayne area, shown in Figure 1, is underlain by a patchy to continuous cover of glacial soils and the approximately 3.0 to 2.6 billion year old bedrock of the Superior Province of the Canadian Shield – a stable craton that forms the core of the North American continent (Figure 2). The Canadian Shield is an assemblage of Archean-age plates and accreted juvenile arc terranes and sedimentary basins of Proterozoic age that were progressively amalgamated over geologic time scales.

The Hornepayne area straddles the boundary between the Quetico and Wawa subprovinces of the Superior Province. The Quetico Subprovince has mainly gneissic and migmatized metasedimentary rocks and the Wawa Subprovince is composed primarily of Archean greenstone belts and granitic intrusions, with smaller mafic intrusive rocks locally present. Diabase dykes, largely of Proterozoic age, occur in “swarms” in the entire Superior Province and in the Hornepayne area (Figure 2).

2.1 Physical Geography

A detailed discussion of the physical geography of the Hornepayne area is provided in a separate terrain analysis report (JDMA, 2013) and the following is a summary of that information.

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

Elevations within the Hornepayne area generally range from about 483 metres above sea level (mASL) near the southwest corner down to approximately 263 mASL in the northeast corner of the area. Topography in the Hornepayne area is generally rugged with elevation exceeding 480 mASL on the north and west sides of Obakamiga Lake approximately 15 km west of the Township of Hornepayne. Lands further to the north and east are less rugged and lower in elevation (from 220 to 300 mASL) reflecting the continental drainage divide located to the southwest of Hornepayne in the vicinity of Granitehill Lake (JDMA, 2013). Topographic highs generally correspond to bedrock outcrops while topographic lows are generally associated with areas of thicker overburden in bedrock valleys. Bedrock terrain is mapped for roughly 43% of the Hornepayne area (JDMA, 2013). Bedrock terrain includes exposed bedrock and thin, discontinuous drift deposits generally less than one metre thick.

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

2.2 Bedrock Geology

The bedrock geology of the Hornepayne area is described in detail in Geofirma (2013a) and the following is a summary of that information. Most of the Hornepayne area has only been subject to reconnaissance level bedrock geological mapping (Geofirma, 2013a).

The Superior Province has been divided into various subprovinces based on lithology, age, genesis and metamorphism (Thurston, 1991, Stott et al., 2010). The Hornepayne area straddles the boundary of the Quetico and the Wawa subprovinces, with the north half of the Hornepayne area being situated in the Quetico Subprovince (Figure 2). About 150 km to the east, the Quetico and Wawa subprovinces are truncated by the Kapuskasing structural zone that separates these subprovinces from the Abitibi Subprovince (and is sometimes referred to as the Abitibi-Wawa belt).

Figure 2 shows the general bedrock geology and main structural features of the Hornepayne area. The Wawa-Quetico subprovince boundary crosscuts the Hornepayne area and separates the metasedimentary and granitic rocks of the Quetico Subprovince to the north from the Black-Pic batholith of the Wawa Subprovince to the south. Thin slivers of metavolcanic rocks of the Manitouwadge-Hornepayne greenstone belt are mapped within the Black-Pic batholith and along the subprovince boundary. Paleoproterozoic diabase dykes are abundant in the Hornepayne area and include the dominant northwest-trending Matachewan swarm, and the subordinate northeast-trending dykes of Biscotasing and Marathon/Kapuskasing suites.

The initial screening report for the Hornepayne area (Golder, 2011), identified several potentially suitable geologic units within the Hornepayne area. These geologic units include the metasedimentary rocks and granitic-granodioritic intrusions of the Quetico Subprovince, and the Black-Pic batholith of the Wawa Subprovince. These potentially suitable geologic units are shown on Figure 2.

2.2.1 Metasedimentary Rocks of the Quetico Subprovince

Much of the bedrock of the Quetico Subprovince in the northern half of the Hornepayne area is variably exposed and has only been mapped at a reconnaissance level. In the Hornepayne area bedrock in the Quetico Subprovince is dominated by highly metamorphosed and migmatized clastic sedimentary rocks, including also tonalitic gneiss, slivers of mafic metavolcanic rock, granodiorite of uncertain origin, and granitic rocks derived from partial melting of the sedimentary rocks.

The precursor sedimentary rocks were typically composed of turbidite successions derived from the erosion of adjacent volcanic arcs (granite-greenstone terranes) either adjacent to the Quetico Subprovince or conceivably derived from other granite-greenstone terranes hundreds of kilometres away. The deposition of the original sedimentary rocks in the southern Quetico Subprovince was initiated approximately 2.698 billion years ago, and its termination is constrained to approximately 2.688 billion years ago (Zaleski et al., 1999).

The thickness of the Quetico Subprovince metasedimentary rocks is estimated to be at least 7.5 km (Percival, 1989), although the thickness is interpreted to decrease along the boundary between the Quetico and Wawa subprovinces, where the metasedimentary rocks are thought to be underlain by rocks of the Wawa Subprovince (Percival, 1989).

2.2.2 Granitic-Granodioritic Intrusions of the Quetico Subprovince

Approximately 10 and 20 km to the north of the Township of Hornepayne are two large east-trending, muscovite-bearing, granitic intrusions (Figure 2), each approximately 7 km by 30 km in size and likely derived from partial melting of the metasedimentary rocks (Percival, 1989; Williams et al.,1991). Similar, though smaller, bodies are mapped approximately 20 km to the east of the Township. No information regarding the thickness of these bodies was found in the available literature. There is some uncertainty whether these bodies are the end point of in situ migmitization of the metasedimentary rocks or true intrusions.

2.2.3 Black-Pic Batholith of the Wawa Subprovince

The Black-Pic batholith is a regionally-extensive intrusion that roughly encompasses an area of 3,000 km^2 covering the southern half of the Hornepayne area and extending west and south beyond the Hornepayne area (Figure 2; Fenwick, 1967; Stott, 1999). It is mostly composed of well foliated to gneissic granodiorite to tonalite (Milne, 1968), with phases of hornblende-biotite, monzodiorite and pegmatitic granite largely restricted to the margins of the batholith. Within the Hornepayne area, the Black-Pic batholith is described as a gneissic tonalite that locally includes biotite and/or amphibole-bearing tonalite (Williams and Breaks, 1996; Johns and McIlraith, 2003).

The age of emplacement of the Black-Pic batholith is poorly constrained. The oldest regional phase of this batholith has been dated at approximately 2.720 billion years old (Jackson et al., 1998), whereas the youngest phase is estimated to be approximately 2.689 billion years old (Zaleski et al., 1999). No information on the thickness of the batholith was found in available literature.

The Black-Pic batholith is interpreted to be a domal structure, with slightly dipping foliations radiating outwards from its center. Within the batholith, Williams and Breaks (1989) found that deeper levels of the tonalite suite are strongly foliated with a subhorizontal planar fabric. Upper levels of the tonalite are frequently cut by granitic sheets of pegmatite and aplite and are generally more massive (Williams and Breaks, 1989).

Zones of migmatized sedimentary rocks and zones of massive granodiorite to granite exist within the batholith. The contact between these rocks and the tonalitic rocks is relatively gradational with extensive sheeting of the tonalitic unit apparent (Williams and Breaks, 1989; Williams et al., 1991). Of note in the Black-Pic batholith is a massive to foliated granitic to granodioritic intrusion located in the southeastern part of the Hornepayne area.

2.2.4 Mafic Dykes

Paleoproterozoic diabase dykes are abundant across the Hornepayne area, dominated by the northwest-trending Matachewan swarm that was emplaced approximately 2.45 billion years ago (Heaman, 1997). The northeast-trending dykes comprise two suites: the approximately 2.17 billion year old Biscotasing suite and the approximately 2.11 billion year old Marathon/Kapuskasing suite (Halls et al., 2008). Both sets of diabase dykes cross-cut all other rock types in the Hornepayne area, including the metasedimentary rocks, greenstone belts, and granitoid plutons of the Quetico and Wawa subprovinces. The density of diabase dykes in this area tends to mask the magnetic signatures of the surrounding Archean bedrock lithologies. A further, more detailed subdivision of the dyke swarms north of 49° 30' was interpreted from aeromagnetic data by Stott and Josey (2009) based on orientation and previous work by Halls and others (Halls et al., 2008; Halls and Davis, 2004; Ernst and Halls, 1983). This dyke mapping was extended southwards for the revised Bedrock Geology of Ontario compilation map (OGS, 2011).

2.2.5 Faults

The east- west trending Quetico-Wawa subprovince boundary, which cross-cuts the Hornepayne area (Figure 2), is characterized as a major shear zone. Evidence for faulting along the subprovince boundary is generally not well documented. Inferred faults on the compilation map of Johns and McIlraith (2003) are based on earlier mapping, typically derived from air photo lineament interpretations. West of the Hornepayne area, mapping by Zaleski and Peterson (2001) has recorded no evidence of faulting along the subprovince boundary, either from lack of geophysical offsets or insufficient bedrock exposure. Similarly, other sections along the Quetico-Wawa boundary show little or no evidence of faulting (Williams et al., 1991).

There is one east-trending fault, and numerous northeast- and northwest-trending smaller-scale faults mapped (OGS, 1991) within the Hornepayne area (Figure 2). The east-trending fault runs along the Wawa-Quetico subprovince boundary in the western half of the Hornepayne area, extending well beyond it. The mapped northwest- and northeast-trending faults parallel Paleoproterozoic diabase dykes of the Matachewan swarm and the Biscotasing - Marathon/Kapuskasing suite.

2.2.6 Metamorphism

In general, there is limited local preservation of pre-Neoarchean metamorphism within the Canadian Shield (e.g., Breaks and Bartlett, 1991; Percival and Skulski, 2000). The Superior Province largely preserves low pressure – low to high temperature Neoarchean metamorphism, from ca. 2.710 to 2.640 billion years ago, but there is a widespread tectonothermal overprint of Archean crust by Paleoproterozoic deformation and typically amphibolite facies metamorphism across the Churchill Province through northernmost Ontario under the northern Hudson Bay lowland, western Manitoba, northern Saskatchewan and Nunavut (e.g., Skulski et al., 2002; Berman et al., 2005).

In the Archean Superior Province, the relative timing and grade of regional metamorphism corresponds to the lithologic composition of the subprovinces (Easton, 2000; Percival et al., 2006). Granite-greenstone subprovinces contain the oldest, Neoarchean metamorphism of lower greenschist to amphibolite facies in volcano-sedimentary assemblages and synvolcanic to syntectonic plutons. Both metasedimentary and associated migmatite-dominated subprovinces, such as the English River and Quetico subprovinces, and dominantly plutonic and orthogneissic subprovinces, such as the Winnipeg River Subprovince, display younger, syntectonic middle amphibolite to granulite facies metamorphism (Breaks and Bond, 1993; Corfu et al., 1995).

Sub-greenschist facies metamorphism in the Superior Province is restricted to limited areas, notably within the central Abitibi greenstone belt (e.g., Jolly, 1978; Powell et al., 1993). Most late orogenic shear zones in the Superior Province experienced lower to middle greenschist retrograde metamorphism. Post-metamorphic events along faults in the Abitibi greenstone belt show a drawn-out record through $^{40}Ar/^{39}Ar$ dating to ca. 2.5 billion years ago, the value of which remains unclear (Powell et al., 1995). The distribution of contrasting grades of metamorphism is a consequence of relative uplift, block rotation and erosion from Neoarchean orogenesis and subsequent local Proterozoic orogenic events and broader epeirogeny during Proterozoic and Phanerozoic eons. In northwestern Ontario, the concurrent post-Archean effects, are limited to poorly documented reactivation along faulted Archean terrane boundaries (e.g., Kamineni et al., 1990 and references therein).

In northeastern Ontario, the Kapuskasing structural zone, east of the Hornepayne area, documents a preservation of ca. 1.9 billion years ago thrust-uplifted, westward tilted Archean crust exposing greenschist facies rocks from <10 km depth in the west near the settlement area of Wawa to granulite facies metamorphism in the east side of the zone through erosion up to 30 km depth (Percival and West, 1994). Approximately 1 billion years ago far-field reactivation of faults by compression from the Grenville orogeny caused potential but poorly documented lower greenschist metamorphism along pre-existing faults are largely restricted to the vicinity of Lake Nipigon and near Lake Superior (Manson and Halls, 1994).

Overall, most of the Canadian Shield, outside of unmetamorphosed, late tectonic plutons, contains a complex episodic history of metamorphism largely of Neoarchean age with broad tectonothermal overprints of Paleoproterozoic age around the Superior Province and culminating at the end of the Grenville orogeny ca. 0.95 billion years ago.

2.3 Geological and Structural History

Direct information on the geological and structural history of the Hornepayne area is limited. The geological and structural history summarized below integrates the results from studies undertaken elsewhere throughout and proximal to the area shown in Figure 2, drawing particularly on information from the area around the Township of Manitouwadge, west of the Hornepayne area. It is understood that there are potential problems in applying a regional D_x numbering system into a local geological history. Nonetheless, the summary below represents an initial preliminary interpretation for the Hornepayne area, which may be modified after site-specific information has been collected.

Accordingly, the geological and structural history of the Hornepayne area described below can be summarized as a tectonic succession of events following one major episode of volcanism on the northern margin of the Wawa Subprovince, concurrent with and followed by clastic sedimentation and iron formation deposition dominantly within the Quetico Subprovince (Peterson and Zaleski, 1999; Zaleski et al., 1999; Zaleski and Peterson, 2001; Williams and Breaks, 1996).

Synvolcanic plutons are spatially associated with volcanic rocks and subsequently highly metamorphosed and deformed remnants of volcanic and metasedimentary host rocks (Zaleski et al., 1999; Zaleski and Peterson, 2001). Syn-orogenic activity included the exhumation and erosion of the Wawa Subprovince, deposition of sediments into the approximately 2.698 to 2.688 billion year ago Quetico basin (Zaleski et al., 1999), and emplacement of the approximately 2.689 billion year old Black-Pic batholith and granitic and gabbroic plutons and stocks (Zaleski et al., 1999). This later emplacement pre-dates and post-dates major collisional folding and refolding during transpressional deformation across the Wawa – Quetico subprovince-boundary.

Uplift and cooling of major plutonic bodies was followed by brittle fractures formed during residual late orogenic stress. Three and possibly four Proterozoic diabase dyke swarms intruded this region with the most prominent being the northwest-trending Paleoproterozoic Matachewan dykes (approximately 2.444 billion years ago) and the less frequent northeast-trending dykes of the approximately 2.17 billion year old Biscotasing suite and the approximately 2.11 billion year old Marathon/Kapuskasing suite (Halls et al., 2008; Stott and Josey, 2009). Proterozoic reactivation of Archean faults is suspected based on thermal resetting of biotite radiometric ages to Paleoproterozoic ages in this region (Manson and Halls, 1997), relatable to the uplift of the Kapuskasing structural zone to the east.

The relative sequence of Archean faulting across the Hornepayne area (Williams and Breaks, 1989; Peterman and Day, 1989; Percival and Peterman, 1994) indicates that the oldest faults tend to be more ductile and east-trending, concurrent with or followed by northwest- and northeast-trending ductile to brittle-ductile faults, followed by late, brittle north-trending faults. Subsequent brittle faulting of uncertain age occurs along each of these trends.

The structural style across the Quetico – Wawa Subprovince boundary is well characterized by structural mapping conducted over the years from Minnesota (Schultz-Ela and Hudleston, 1991) to the Shebandowan greenstone belt, west of Thunder Bay (Stott and Schwerdtner, 1981; Williams et al., 1991) and the Manitouwadge belt (Peterson and Zaleski, 1999; Zaleski et al., 1999; and Zaleski and Peterson, 2001). In general, two major penetrative deformation events are observed along the length of the Quetico Subprovince and the adjacent boundary with the Wawa Subprovince. The first deformation event is pre- to syn-metamorphic. The second penetrative deformation event either refolds or overprints structures formed during the first event and is responsible for the widespread upright to moderately inclined and east-plunging, folds defined by the lithologic layering at Manitouwadge and locally by iron-rich formations folded within the metasedimentary rocks of the Quetico Subprovince.

These large fold structures formed as a consequence of oblique, south-southeast directed collision between granite-greenstone subprovinces (terranes), following northward subduction of terranes evidenced from Lithoprobe studies in Ontario (e.g., Percival et al., 2006), during the final tectonic assembly of the Superior Province at around approximately 2.7 to 2.6 billion years ago. This collisional history is reflected in the production of granitic intrusions and injections of partial melts into the sedimentary successions that comprise the Quetico Subprovince, which served as a collisional buffer between more rigid granite-greenstone micro-continents to the north and south. Consequently, the more migmatitic matrix that dominates the Quetico Subprovince forms complex folds and refolds and some of the plutons appear to form metamorphosed, doubly-plunging domical structures (Peterson and Zaleski, 1999; Williams, 1991).

Table 1. Summary of the regional geological and structural history of the Hornepayne area

Time Period (billion years ago)	***Geological Event***
ca. 2.72	Oceanic arc to plume-generated volcanism and synvolcanic, trondhjemitic plutonism along the northern margin of the western Wawa-Abitibi terrane due to northward subduction of volcanic-dominated micro-continents (e.g., Wawa-Abitibi terrane) (White et al., 2003; Percival et al., 2006). Deposition of clastic sedimentary rocks in the Quetico basin. Emplacement of the oldest (tonalite) phase of the Black-Pic batholith (Jackson et al., 1998)
ca. 2.696 to 2.689	Commencement of the diachronous Shebandowanian orogeny (approximately 2.695 to 2.677 billion years ago) involving collision of the Wawa-Abitibi micro-continental terrane with terranes to the north. (Percival et al., 2006; Peterson and Zaleski, 1999).
ca. 2.689 to 2.687	Emplacement of the monzodiorite phase (2.689 billion years old) of the Black-Pic batholith (Zaleski et al., 1999),
ca. 2.687 to 2.680	Regional D_2 deformation coeval with the peak amphibolite facies regional metamorphism, and local granulite facies and partial melting of clastic sedimentary rocks in the Quetico basin.
ca. 2.680	Minimum age of regional D_2 deformation is defined by the 2.68 billion-year-old granite intrusion of the Loken Lake pluton in the Township of Manitouwadge. Maximum age of regional D_3 deformation is defined by folding of the 2.68 billion-year-old Nama Creek

Time Period (billion years ago)	***Geological Event***
	pluton, also in the Township of Manitouwadge.
ca. 2.679 to 2.677	Regional D_3 deformation that produced the major east-northeast-trending upright folds in response to northwestward directed collisional transpression recorded across the Wawa-Abitibi terrane boundary with the Quetico metasedimentary gneisses to the north. (Percival et al., 2006). Late D_3 ductile faults (D_4 of Williams and Breaks, 1989) and kink folds (D_4 of Peterson and Zaleski, 1999) occurred during cooling across the terrane boundary, notably in the Quetico metasedimentary migmatites.
ca. 2.679	The Everest Lake pluton, a sheet-like intrusion along the Quetico-Wawa contact near Manitouwadge, displays incipient migmatization and thereby constrains a period of metamorphism to be contemporaneous with D_3 deformation.
ca. 2.677	Regional D_4 deformation defined by antiform folding of the Banana pluton in Township of Manitouwadge and by local interference of D_3 structures preserved locally within the Quetico metasedimentary rocks.
ca. 2.673 to 2.671	Metamorphism (cooling?) of migmatized tonalite gneiss intruding migmatized Quetico metasedimentary basin north of Hornepayne, accompanied by muscovite-bearing granitic intrusions. Syn-orogenic granitic plutons and gabbroic intrusions occur across the Hornepayne area both in the Quetico basin and intruding the Black-Pic batholith. Late brittle (D_5) fault overprint.
ca. 2.45	Intrusion of the northwest-trending Matachewan diabase dyke swarm.
ca. 2.17	Intrusion of the northeast-trending Biscotasing diabase dyke swarm
ca. 2.126 to 2.101	Intrusion of the north- to northeast-trending Kapuskasing (Marathon) diabase dyke swarm (Halls et al., 2008).
ca. 1.947 to 1.9	Proterozoic brittle fault overprint and reactivation of regional-scale Archean faults (Peterman and Day, 1989; Percival and Peterman, 1994) collectively treated as D_6 events.
ca. 1.1 to 1.0	Onset of development of Mid-Continent Rift and emplacement of northeast-trending Abitibi dykes south and southeast of the Hornepayne area.

Six main regionally distinguishable deformation episodes (D_1-D_6) for the Manitouwadge area are inferred, based on the regional scale of the deformation, to have also overprinted the bedrock geological units of the Hornepayne area. The following sequence of tectonic deformation (D) events is based on detailed structural studies undertaken in the Manitouwadge area (Peterson and Zaleski, 1999; Zaleski et al., 1999; Zaleski and Peterson, 2001; Williams and Breaks, 1996) and is presented here as a general framework to understanding the likely tectonic history of the Hornepayne area.

- D_0 primary bedding and lithologic layering is locally preserved in strongly deformed sedimentary and volcaniclastic units.
- D_1 regional tectonic deformation is locally evident in Quetico metasedimentary rocks and as a ductile fault at Manitouwadge. S_1 foliations outline D_2 folds.
- D_2 defines the regional schistosity as an axial planar S_2 fabric within amphibolite grade volcanic and sedimentary rocks, migmatitic rocks and differentiated layering in tonalite. S_2 foliations dip northward and L_2 lineations plunge north to northeastward outside of the domain of D_3 deformation.
- D_3 deforms D_2 fabrics and produced major synform and antiform structures plunging shallowly westward or eastward, accompanied by late-stage east-trending

and northwest-trending dextral shear zones and faults, and northeast-trending sinistral shear zones in the Manitouwadge – Hornepayne region. Z asymmetry of F_3 folds is characteristic and reflects northwest-directed transpressive deformation.

- Late D_3 ductile faults (D_4 of Williams and Breaks, 1989) and kink folds (D_4 of Peterson and Zaleski, 1999) occurred during cooling across the terrane boundary, notably in the Quetico metasedimentary migmatites.
- D_4 local refolding of D_3 structures occurs most typically but very locally preserved within Quetico metasedimentary rocks.
- D_5 applies to later brittle faults and fractures trending northwest, northeast and northward. These brittle structures mark a period of crustal cooling under residual stress and affect rocks of the narrow, dominantly amphibolitic supracrustal belts as well as synvolcanic and synorogenic plutons, gneisses and the Black-Pic batholith. Some faults and fractures may have been reactivated during later D_6 Proterozoic events.
- D_6 events are collectively potential Early Proterozoic faults and reactivation on Archean faults. Reactivation of Archean faults, coincident with thermal resetting of biotite radiometric ages in the Hornepayne region, would have developed during far-distant collision of the Trans-Hudson Orogen with the Superior Province as well as related uplift of the Kapuskasing structural zone to the east.

Little information is available for the geological history of Hornepayne area for the period following the onset of development of Mid-Continent Rift approximately 1.1 billion years ago. During the Paleozoic, much of the Superior Province was inundated by shallow seas and Paleozoic strata dating from the Ordovician to Devonian are preserved within the Hudson Bay and Michigan basins. The presence of a small outlier of Paleozoic strata known as the Temiskaming outlier in the New Liskeard area indicates that Paleozoic cover was formerly much more extensive and much of the present surface of the Canadian Shield lies close to an exhumed paleoplain interpreted to be of Ordovician age (Brown et al., 1995).

While there is a restricted area of Mesozoic strata within the Moose River Basin and there is evidence of Mesozoic-age emplacement of kimberlitic pipes and dykes elsewhere in northern Ontario, no post-Precambrian to pre-Quaternary rocks are known within the Hornepayne area. The contact between bedrock and the overlying unconsolidated Quaternary sediments represents an unconformity exceeding one billion years.

2.4 Quaternary Geology

Information on Quaternary geology in the Hornepayne area is described in detail in the terrain report (JDMA, 2013) based on Northern Ontario Engineering Terrain Studies (NOEGTS) (Gartner and McQuay, 1980a; 1980b) and is summarized here.

The Quaternary cover in the Hornepayne area is dominated by glacial deposits that accumulated with the progressive retreat of the Laurentide Ice Sheet during the late Wisconsinan glaciation. Mapped glacial deposits include morainal (till), glaciofluvial and glaciolacustrine units (Figure 3). The most recent period of glaciation began approximately 115,000 years ago and reached its greatest extent 20,000 years before present, at which time the glacial ice front extended south of Ontario into what is now Ohio and Indiana (Barnett, 1992). The glacial retreat from the Hornepayne area is estimated at approximately 9,000 years ago (Barnett, 1992). Glacial erosion has generally removed any earlier deposits in the area.

The main direction of the most recent glacial advance in the Hornepayne area was from the north-northeast (Gartner and McQuay, 1980a). Ground moraine, glaciofluvial and glaciolacustrine deposits were laid down in the area east and north of the Township of Hornepayne as shown in Figure 3 (OGS Map 5085 - Gartner and McQuay, 1980a). These deposits combine to almost completely cover the bedrock in this part of the Hornepayne area.

An interlobate moraine (Arnott Moraine) was formed during a local re-advance of the ice sheet, which has been mapped as a series of kames in the vicinity of Nagagamisis Lake, in the northern part of the Hornepayne area. This moraine provides a potential source of sand and gravel. Quaternary deposits are more discontinuous in the western and southern parts of the Hornepayne area. The only significant Quaternary landforms within close proximity of the Township include two large esker complexes approximately 5 to 10 km to the south. These esker complexes consist of sands and gravels and can exceed 15 m in depth (Gartner and McQuay, 1980a).

Information on the thickness of Quaternary deposits in the Hornepayne area was obtained from water well records and the diamond drillhole database (JDMA, 2013) (see Figure 3). Overburden thicknesses within the Hornepayne area typically ranges from 0 to 15 m, with the greatest thickness encountered in a drilled well reported to be 38 m. Overburden is likely to be thickest in bedrock valleys and in the northern and eastern parts of the Hornepayne area where more extensive glaciofluvial and glaciolacustrine deposits are mapped.

The organic material is located in discontinuous areas throughout the Hornepayne area. The organic sediments vary considerably in thickness, and area associated with a high water table and extremely poor surface drainage.

2.5 Land Use

Land use within the 4,800 km^2 Hornepayne area outside of the Hornepayne settlement area is predominately unoccupied Crown land consisting of forest, wetland, lakes and exposed bedrock. There are no active mines in the Hornepayne area. There are linear infrastructure corridors such as roads, railways, and electrical transmission lines however these features do not adversely affect the geophysical interpretation.

3 GEOPHYSICAL DATA SOURCES AND QUALITY

For the Hornepayne area, geophysical data were obtained from available public-domain sources, particularly the Ontario Geological Survey (OGS) and the Geological Survey of Canada (GSC). To supplement these data, geophysical surveys performed in the Hornepayne area by the mining industry were reviewed as assessment files, but it was determined that none were available that would improve the geophysical coverage.

The quality of the available data was assessed to determine which data sets are suitable for inclusion in this assessment. The geophysical surveys covering the Hornepayne area show variability in data set resolution, whichis a function of the flight line spacing, the sensor height and equipment sensitivity. In particular, where more than one data set overlaps, the available data were assembled using the highest quality coverage. Various geophysical data processing techniques were applied to enhance components of the data most applicable to the current assessment. The integrity of the higher quality data was maintained throughout.

3.1 Data Sources

The geophysical data covering the Hornepayne area show variability in dataset resolution. Low-resolution geophysical data, particularly the magnetic, gravity and radiometric data obtained from the Geological Survey of Canada (GSC), cover the entire Hornepayne area. Two additional magnetic/electromagnetic surveys obtained from the Ontario Geological Survey (OGS) provided higher resolution coverage over approximately 15 percent of the Hornepayne area, on its western portion and southeast corner (Figure 4). These surveys focused on exploration in the greenstone belts, but also encompassed plutonic and metasedimentary rocks in the west of the Hornepayne area, particularly the Black-Pic batholith. The geophysical data sets are summarized in Table 2 and the characteristics of each of the data sources are discussed in detail below.

3.1.1 Magnetic Data

Magnetic data over the Hornepayne area were collected by various surveys using different survey parameters outlined in Table 2. Magnetic surveys help in the understanding of geological and structural variations caused by different rock types associated with their content of magnetic minerals, such as magnetite and pyrrhotite. Magnetic maps show the distribution of magnetic and non-magnetic geologic bodies within the subsurface, and are particularly useful for delineating spatial geometry of bodies of rock, and the presence of faults and folds.

The resolution of the retrieved magnetic datasets varies greatly within the Hornepayne area. Surveys were flown over a period of 27 years, over which time the quality and precision of the equipment as well as the quality of the processing has improved. Variability in the quality of the survey coverage also influenced the ability of the magnetic data to identify geological structures of interest relevant to this assessment.

Low-resolution magnetic data from the GSC (individual surveys include Ontario 3, 8, and 17) provides complete coverage of the entire Hornepayne area (GSC, 2012). Magnetic data from these surveys form part of the GSC Regional Magnetic Compilation data. These surveys were flown at a terrain clearance of 305 m and flight line spacing of 805 m, providing these surveys with a relatively low spatial resolution. Additional, high-resolution surveys from the OGS (Manitouwadge Survey, and Oba-Kapuskasing Survey) were flown at a lower terrain clearance (45 m) compared to the GSC surveys, and with tighter flight line spacing (200 m), providing these surveys with a relatively high spatial resolution (OGS, 2002; OGS, 2003). These surveys focused primarily on exploration in the greenstone belts, predominantly located outside of the Hornepayne area, although covering approximately 15 percent of the Quetico and Wawa subprovinces within the Hornepayne area.

3.1.2 Gravity Data

Gravity data provides complete coverage of the Hornepayne area (GSC, 2012), consisting of an irregular distribution of 35 station measurements, comprising roughly a station every 5 to 25 km.

The gravity measurements were retrieved as Bouguer corrected data. The Bouguer correction is applied to compensate for the gravity effect of the material between the measurement station and the datum elevation. However, the contribution to the measurement of the gravity effects of the surrounding topographic features (i.e. terrain correction) was not applied by the GSC.

Despite the fact that data are of good quality, the sparseness of the measurement locations in the Hornepayne area can only be used to provide information about large scale geologic features. The resolution of the acquired gridded data is 2 km by 2 km.

3.1.3 Radiometric Data

The GSC radiometric data provides complete coverage of the Hornepayne area (GSC, 2012). The data show the distribution of natural radioactive elements at surface: uranium (eU), thorium (eTh) and potassium (K), which can be interpreted to reflect the distribution of mineralogical and geochemical information in the area. The GSC radiometric data were flown at 5,000 m line spacing at a terrain clearance of 120 m above the surface.

Retrieved radiometric data consisted of measurements of four variables:

- Potassium, K (%),
- Equivalent uranium, eU (ppm),
- Equivalent thorium, eTh (ppm),
- Total Air Absorbed Dose Rate (nGy/h).

3.1.4 Electromagnetic Data

Two frequency domain electromagnetic (FDEM) surveys carried out by the OGS were retrieved from the Manitouwadge survey (OGS, 2002), and Oba-Kapuskasing survey (OGS, 2003). The FDEM system used for the OGS Manitouwadge survey used a DIGHEM IV system to measure the inphase and quadrature components of four different frequencies (four coil pairs) towed below a helicopter with the sensor at a nominal terrain clearance of 30 m. The survey was flown at 200 m flight line spacing providing a relatively high spatial resolution.

The FDEM system used for the Oba-Kapuskasing survey used an Aerodat system to measure the in-phase and quadrature components of three different frequencies (three coil pairs) towed below a helicopter with the sensor at a nominal terrain clearance of 30 m. The survey was flown at 200 m flight line spacing providing a relatively high spatial resolution.

The two EM surveys in the Hornepayne area overlay a small portion of granite to granodiorite rocks of the Wawa Subprovince, metasedimentary rocks of the Quetico Subprovince, as well as several small portions of greenstone units. The Manitouwadge survey (OGS, 2002) provides a broader coverage across the rocks of both subprovinces on the west side of the Hornepayne area.

3.2 Data Limitations

There is a fairly stark contrast between the high resolution of the magnetic surveys that cover the greenstone belts and the Black-Pic batholith and the older regional low resolution coverage elsewhere in the Hornepayne area. Nevertheless, the magnetic data reflect quite coherent responses that elucidate the mapped geology, particularly in areas of limited bedrock exposure. There is differentiation and stratigraphy within the volcanic and metamorphic rocks in the western part of the Hornepayne area where the high resolution magnetic data is available. Similarly, the main structural regimes are clearly delineated by the magnetic data, regardless of resolution, but at different levels of detail.

Table 2. Summary of characteristics for the geophysical data in the Hornepayne area

Product	Source	Type	Line Spacing/ Sensor Height	Line Direction	Coverage	Date	Additional Comments
Regional Magnetic Compilation Ontario #3	GSC, 2012	Fixed wing magnetic	805m/305m	0°	Covers northeast part of Hornepayne area	1968	Recorded on analog charts, navigation and flightpath based on photomosaics, digitized from the GSC contour maps, levelled to a nationwide magnetic datum.
Regional Magnetic Compilation Ontario #8	GSC, 2012	Fixed wing magnetic	805m/305m	0°	Covers west part of Hornepayne area	1962	Recorded on analog charts, navigation and flightpath based on photomosaics, digitized from the GSC contour maps, levelled to a nationwide magnetic datum.
Regional Magnetic Compilation Ontario #17	GSC, 2012	Fixed wing magnetic	805m/305m	0°	Covers most of Hornepayne area (east, south)	1963	Recorded on analog charts, navigation and flightpath based on photomosaics, digitized from the GSC contour maps, levelled to a nationwide magnetic datum.
GSC Gravity Coverage	GSC, 2012	Ground Gravity Measurements	5-25km/ surface		Entire Hornepayne area	1946-63	Bouguer gravity field, first vertical derivative, horizontal gradient and the isostatic residual gravity field were extracted from the GSC gravity compilation. Station locations were extracted from the point data.
GSC Radiometric Coverage	GSC, 2012	Fixed wing radiometric data	5000m/120m	0°	Entire Hornepayne area	1982	Grids of potassium, equivalent uranium, equivalent thorium, natural air absorbed dose rate, and ratios of eU/K, eTh/K and eU/eTh were extracted from the GSC's nationwide radiometric compilation.
Manitouwadge Survey (GDS1205)	OGS, 2002	Helicopter magnetic, FDEM (Dighem IV 4 frequency)	200m/ MAG 45m FDEM 30m	0° (north)/ 158° (south)	Covers 1,199 km^2 in west part of Hornepayne area	1989	The lower height, closer line spacing and vintage of this survey greatly improves standard GSC magnetic coverage, and provides electromagnetic coverage. The UHF navigation system was electronic but pre-dated GPS, so flightpath recovery was accurate but survey lines were not quite straight. The 1989 vintage of magnetic and electromagnetic equipment was relatively good compared to current FDEM systems. The data were reprocessed in 2002, which improved the quality.
Oba-Kapuskasing Survey (GDS1024)	OGS, 2003	Helicopter magnetic, FDEM (Aerodat 3 frequency)	200m/ MAG 45m FDEM 30m	176°	Covers 106 km^2 in southeast corner of Hornepayne area	1986	The lower height, closer line spacing and vintage of this survey greatly improves standard GSC magnetic coverage, and provides electromagnetic coverage. The radar navigation system was electronic but pre-dated GPS, so flightpath recovery was accurate but survey lines were not quite straight. The 1986 vintage of magnetic and electromagnetic equipment was relatively good compared to current FDEM systems. The data were reprocessed in 2003, which improved the quality.

GSC – Geological Survey of Canada
OGS – Ontario Geological Survey

All four data types considered, magnetic, gravity, radiometric and electromagnetic, contribute to the interpretation. The limitation in applying these data types to the Hornepayne area is governed mainly by the following factors:

- Coverage and quality of data – types available, density of the coverage, vintage and specifications of the instrumentation;
- Overburden – areal extent, thickness and physical properties; and
- Bedrock lithologies – physical properties and homogeneity.

The user of the geophysical information must bear in mind that each method relies on characterizing a certain physical property of the rocks. The degree to which these properties can be used to translate the geophysical responses to geological information depends mainly on the amount of contrast and variability in that property within a geological unit and between adjacent geological units. The usability of each data set also depends on its quality, especially resolution.

4 GEOPHYSICAL DATA PROCESSING

All data were processed and imaged using the Oasis montaj software package (Geosoft, 2012). Three additional magnetic grids were prepared using the Encom PA software package (Pitney Bowes, 2012). The grids that resulted from the various processing steps were also loaded in ArcMAP 10 (ESRI, 2012) using a Geosoft plug-in.

4.1 Magnetic

All surveys in the Hornepayne area where projected to the UTM16N/NAD83 coordinate system. Geophysical data from the surveys were upward or downward continued (if necessary) to a common flying height of 45 m, and regridded to a common grid cell size of 50 m. As a result, downward continuation of 260 m was only applied to the magnetic grids from the GSC regional compilation (Ontario 3, 8, and 17), which was followed by an 8^{th}-order 800 m low pass Butterworth filter in order to reduce noise associated with the application of downward continuation and coarseness of the data. The Butterworth filter is a type of signal processing filter designed to have as flat a frequency response as possible in the pass band. The 800 m wavelength did not reduce the geological signal due to the line spacing of 805 m and the coarse sampling of the digitized data long the flightlines. The two OGS surveys were at a flying height of 45 m so that they were not downward (or upward) continued. The GSC regional grid was regridded to a grid cell size of 50 m.

The surveys were merged together using Oasis montaj (Geosoft, 2012), where the suture path between the grids was along the edge of the grid with the original higher resolution grid cell size so that the most detailed data was retained in the final product. The resultant grid was the residual magnetic intensity grid (i.e. total magnetic field after IGRF correction) and the basis for preparing the enhanced magnetic grids.

Reduction to the Pole (RTP)

The direction (inclination and declination) of the geomagnetic field varies over the Earth and influences the shape of the magnetic responses over geological sources. At the North Magnetic Pole the inducing magnetic field is vertical (i.e. inclination of 90° and declination of 0°), which results in the magnetic response being a symmetric positive magnetic peak over a source, in the absence of dip and magnetic remanence. Transforming the measured magnetic field to a pole reduced magnetic field simplifies the interpretation, particularly to determine the location and geometry of the sources (Baranov, 1957). For the Hornepayne area, the residual magnetic intensity grid was reduced to the pole using a magnetic inclination of 77.9° N and magnetic declination of 5.3° W (Figure 5).

The RTP filter, computed from the residual magnetic field after it is transformed to the Fourier domain, is defined as follows:

$$L(\theta) = \frac{[\sin(I) - i \cdot \cos(I) \cdot \cos(D-\theta)]^2}{[sin^2(I_a) + cos^2(I_a) \cdot cos^2(D-\theta)] \cdot [sin^2(I) + cos^2(I) \cdot cos^2(D-\theta)]}$$

$$if\ (|I_a| < |I|), I_a = I \qquad \text{(eq. 4.1)}$$

Where:
L(θ) = pole-reduced magnetic field for wavenumber *θ*
I = geomagnetic inclination
I_a = inclination for amplitude correction (never less than *I*).
D = geomagnetic declination
i = imaginary number in the Fourier domain

First Vertical Derivative of the Pole Reduced Field (1VD)

The vertical derivative is commonly applied to the RTP magnetic field data in the Fourier domain to enhance shallower geologic sources in the data (Figure 6). This is particularly useful for locating contacts (e.g. the anomaly texture is revealed) and mapping structure (Telford et al., 1990). It is expressed as:

$$1VD = {}^{dRTP}/_{dZ} \qquad \text{(eq. 4.2)}$$

where *Z* is the vertical offset.

Second Vertical Derivative of the Pole Reduced Field (2VD)

The second vertical derivative is commonly applied to the RTP magnetic field data the Fourier domain to further enhance shallower geologic sources in the data (Figure 7). This is particularly useful for locating contacts (e.g. the anomaly texture is revealed) and mapping structure close to surface (Telford et al., 1990). It is expressed as:

$$2VD = {d^2RTP}/{dZ^2} \qquad \text{(eq. 4.3)}$$

where *Z* is the vertical offset.

One limitation of this filter is that the higher order derivatives tend to also enhance the high frequency noise in the data set. To reduce noise that resulted from aliasing during the minimum curvature gridding process, an 8th-order 200 m low- pass Butterworth filter was also applied.

Tilt Angle of the Pole Reduced Field

The tilt angle (Miller and Singh, 1994) has been applied to the RTP magnetic field data to preferentially enhance the weaker magnetic signals (Figure 8). This is particularly useful for mapping texture, structure, and edge contacts of weakly magnetic sources. It is expressed as:

$$TILT = \tan^{-1}\left\{\frac{\frac{dRTP}{dZ}}{\sqrt{\left([\frac{dRTP}{dX}]^2+[\frac{dRTP}{dY}]^2\right)}}\right\} \qquad \text{(eq. 4.4)}$$

where *X* and *Y* are the horizontal offsets in the east and north directions. The first vertical derivative is computed in the Fourier domain whereas the horizontal derivatives in *X* and *Y* are computed in the space domain.

Analytic Signal Amplitude

The amplitude of the analytic signal (AS) (Figure 9) is the square root of the sum of the squares of the derivatives in the horizontal (*X* and *Y*), and vertical (*Z*) directions (i.e. the Fourier domain first vertical derivative and the space domain horizontal derivatives in the *X* and *Y* directions), computed from the total magnetic field (Nabighian, 1972):

$$AS = \sqrt{\left([\frac{dT}{dX}]^2 + [\frac{dT}{dY}]^2 + [\frac{dT}{dZ}]^2\right)} \qquad \text{(eq. 4.5)}$$

The analytic signal is useful in locating the edges of magnetic source bodies, particularly where remanence complicates interpretation. It is particularly useful to interpret the contacts of intrusions.

Depth to Magnetic Sources Using Source Parameter Imaging (SPI™)

The SPI method locates the depths of edges in the gridded magnetic data (Thurston and Smith, 1997). It assumes a 2D sloping contact or 2D dipping thin sheet model. The SPI solutions extracted from the pole reduced magnetic field grid are stored in a database. The SPI values calculated are depths between the magnetic source and the instrument height. If the survey was flown at a constant terrain clearance, then the drape height could be subtracted from the SPI value to result in a depth below surface. For the GSC surveys and Oba-Kapuskasing survey, only the average flying height was known. For the Manitouwadge survey, the radar altimeter data were included in the survey database and were consequently used to more accurately determine the distance between the magnetic sensor and the computed depth to the magnetic source. The radar altimeter channel was gridded at the original grid cell size and sampled back to the SPI database. If the value of the depth to source is < 0, i.e. above ground, it is set to a value of zero. Thus, the SPI depth with respect to the ground surface is calculated as:

- SPI_depth = SPI_value – average flying height, if no radar data is available, or
- SPI_depth = SPI_value – radar value, if available.

The SPI depths were calculated for each individual data set in the Hornepayne area (Figure 10) taking into account the elevation of the magnetic sensor. Low resolution grids are biased with deeper basement depths due to the lack of high frequency content. Thus, where a high resolution survey overlaps with a low resolution regional survey, the SPI depths from the low resolution grid were excluded. The final SPI depth grid was calculated with a grid cell size of 200 m.

Encom Magnetic Grids

A series of grids were created to highlight the edges of both shallow and deep sources and to categorize anomalous zones into different areas (Shi and Butt, 2004). These grids are:

- rtpzsedge – gradient filters applied to the pole reduced magnetic field to emphasize edges
- rtpzsedgezone – gradient filters and amplitude equalization filters applied to the pole reduced magnetic field to emphasize edges
- rtpzsplateau – gradient filters and amplitude equalization filters applied to the pole reduced magnetic field to emphasize homogeneous blocks bounded by edges.

Magnetic Peaks, Troughs and Edges

The semi-automated extraction of magnetic anomaly peaks, troughs and edges is useful for delineating structure, foliation, texture and contacts. Anomaly peaks typically trace the center of a source or the more magnetic horizons within a larger source. Anomaly troughs often complement the peaks, indicating a less magnetic horizon. They also may map a remanent (i.e. reversely) magnetized source, or magnetite depletions (e.g. along a fault) which are a less magnetic source in a more magnetic host rock. Anomaly edges mark geological contacts or the boundaries of horizons within a geological unit. Offsets and orientation changes in the peaks, troughs and edges are useful for mapping faults and shears. Detection for peaks, troughs and edges was performed based on the CET (Centre for Exploration Targeting) Grid Analysis package in Oasis montaj (Geosoft, 2012).

The phase symmetry method, a frequency-domain approach based on axes of symmetry, is used to identify arbitrarily oriented line features. The 2D image is analyzed with 1D profiles in multiple orientations and varying scales. A line feature exhibits strong symmetry responses from profiles in all orientations not parallel to the line itself. Symmetry is closely related to periodicity: the symmetry point in the spatial domain corresponds to either a minimum or maximum of its local Fourier components. Thus the detection is carried out by frequency analysis.

The frequency analysis is performed by wavelet transform, which estimates local frequency using complex valued log-Gabor filters. The filters are comprised of an even symmetric (cosine) wavelet and an odd symmetric (sine) wavelet, each modulated by a Gaussian. These filters at different scales respond to particular bands of frequencies. The local frequency information is obtained from the convolution of the wavelet filters with the 2D data. An array of filter response vectors are generated for each point in the signal for each scale. Localized frequency representation is produced from these vectors. The frequency component is represented as a complex number; its real and imaginary parts are the outputs from the even and odd symmetry filter responses, respectively. At the point of symmetry, frequency components are at their amplitude extrema. This corresponds to where the absolute values of the outputs are high from even symmetry filter and low from odd symmetry filter, for all frequencies. This 1D analysis is performed in multiple orientations to extend to 2D analysis (Holden et al., 2008).

An amplitude threshold is then applied to the output symmetry grid, to distinguish cells that contain signal of interest from the background. A lower threshold value leads to the detection of more features, but may also introduce noise in the data. The resulting grid is binary: 1 for regions of interest and dummies for background. The grid is then skeletonized to trendlines. This process also sets the minimum valid line length.

The smallest filter wavelength used in this analysis for the Hornepayne area was four cells (equivalent to 200 m), over five scales. The filter sizes were therefore 200 m, 400 m, 800 m, 1600 m and 3200 m. All orientations were considered in the search for symmetry. A threshold value of 0.1 was applied, and a minimum line length of three cells (150 m) was set.

Edges were enhanced by computing the balanced horizontal gradient magnitude (TDX) (Cooper and Cowan, 2006) from the RTP grid, as modified by Fairhead and Williams (2006):

$$TDX = \tan^{-1}\left\{\frac{\sqrt{\left([\frac{dRTP}{dX}]^2+[\frac{dRTP}{dY}]^2\right)}}{\frac{dRTP}{dZ}}\right\} \qquad \text{(eq. 4.6)}$$

The first vertical derivative is computed in the Fourier domain whereas the horizontal derivatives in *X* and *Y* are computed in the space domain.

The TDX of the pole-reduced magnetic field is a more accurate locator of source edges and less susceptible to noise in the data than other forms of edge detectors. Pilkington and Keating (2009) confirmed that TDX and its analog, "theta mapping", produce identical results and are the most robust of the edge detection techniques applicable to potential field data.

The positive peak values are extracted by applying an amplitude threshold to the TDX grid to identify cells of interest. The resulting grid is binary and is skeletonized to locate the source edges. In this project, a threshold value of 0.9 was used.

The peaks, troughs and edges generated using the CET methods were not submitted directly for further lineament analysis. The ENCOM grids and TDX images are not presented in this report. However, all of these maps and images were used as guides during the manual interpretation process. The accuracy and reliability of these products were greatly influenced by the resolution of the original magnetic data.

4.2 Gravity

The following four gravity grids and their gravity station locations (35 gravity measurements) were downloaded for the Hornepayne area from the GSC gravity compilation (GSC, 2012) at 2000 m grid cell size:

- Bouguer gravity field (Figure 11)
- First vertical derivative of the Bouguer gravity field (Figure 12)
- Total horizontal gradient of the Bouguer gravity field
- Isostatic residual gravity field.

All grids were reprojected to the Hornepayne area's coordinate system, UTM16N/NAD83. The first vertical derivative was computed by the GSC using the same methodology applied to the pole reduced magnetic field, as described in Section 2.1. The total horizontal gradient of the Bouguer gravity provided similar results as the first vertical derivative, and therefore was not presented in this report. The isostatic residual compensates for mass deficiencies at depth predicted from topography, preserving the shorter wavelength components of the field due to nearer surface sources. In the Hornepayne area, the isostatic residual field closely resembles the Bouguer gravity field due to the relatively gentle topography, and therefore was not presented in this report. The GSC applied standard gravity reduction methods to compute the free air and Bouguer gravity fields. A Bouguer correction density of 2.67 g/cm^3 was applied, the typical value for the Canadian Shield. As the data for the Hornepayne area were collected in 1963 and earlier, station elevations were likely determined using barometric altimeters (much less accurate than GPS) and terrain corrections were not applied.

4.3 Radiometric

The following seven radiometric grids (radioelement concentrations and ratios) were downloaded for the Hornepayne area from the GSC radiometric compilation (GSC, 2012) at 1,000 m grid cell size:

- Potassium (K %)
- Thorium (eTh ppm)
- Uranium (eU ppm)
- Total air absorbed dose rate (nGy/h)
- Thorium over potassium ratio (eTh/K)
- Uranium over potassium ratio (eU/K)
- Uranium over thorium ratio (eU/eTh).

The grids were already a merge of high and low resolution data prepared by the GSC. The determination of the radioelement concentrations, dose rate and ratios followed the methods and standards published by the International Atomic Energy Agency (IAEA, 2003), many of which were developed at the GSC. All grids were reprojected to the Hornepayne area's coordinate system, UTM16N/NAD83. The dose rate is a calibrated version of the measured "total count", and reflects the total radioactivity from natural and man-made sources. The radiometric data are presented in Figure 13 as a ternary RGB image of the three radioelements, with the intensity of potassium (%) displayed in red, equivalent thorium (ppm) in green and equivalent uranium (ppm) in blue. Areas of highest intensity of all three radioelements show light colours and trend towards white. Areas of lowest intensity of all three radioelements are dark colours and trend towards black.

4.4 Electromagnetic

The EM surveys flown by the Ontario Geological Survey were invariably at 200 m line spacing, which provides good resolution for mapping. These surveys typically focus on the greenstone belts, extending into the edges of neighbouring granites and sometimes encompassing smaller plutons where the greenstones wrap around them. Certain intrusions that have known mineral potential have also been flown (e.g. in the Abitibi Subprovince). Helicopter surveys typically have better signal/noise than fixed wing surveys due to closer proximity of the EM transmitter, EM receiver and magnetometer to the ground.

FDEM surveys typically include a grid of apparent resistivity (conductivity is simply the inverse). Newer surveys have an apparent resistivity for three frequencies reflecting shallower (highest frequency) to deeper (lowest frequency) responses – this helps in discriminating between overburden and bedrock responses. Coplanar coils are more responsive to mapping subhorizontal horizons, whereas coaxial coils are better suited to map subvertical conductors.

All surveys are delivered with an EM anomaly database, where individual anomalies have been picked along flightlines and then classified as bedrock source, surficial source (e.g. overburden) or cultural (e.g. hydro line). Bedrock anomalies usually incorporate a vertical plate or similar model to provide an estimate of depth-to-top and conductivity. The depth values give an indication of overburden thickness, assuming the conductor subcrops.

The analysis of the EM data herein consisted mainly of plotting the EM anomalies over the gridded images provided by OGS and joining bedrock anomalies into quasi-linear conductors, where the character of the EM response remained consistent along strike. Typically, these conductors follow the stratigraphy evident in the mapped geology and magnetic data.

For the electromagnetic surveys in the Hornepayne area, the following data products were available:

- Oba-Kapuskasing (GDS1024) – Apparent resistivity grid (4,186 Hz coplanar) and EM anomaly database.

- Manitouwadge (GDS1205) – Apparent resistivity grids (900 Hz, 7,200 Hz, 56,000 Hz coplanar) and EM anomaly database. The 56,000 Hz apparent resistivity grid (and profile data) was incomplete, including most of the coverage within the Hornepayne area.

5 GEOPHYSICAL INTERPRETATION

5.1 Methodology

The coincidence of geophysical features with mapped lithology and structural features were identified and interpreted for the Hornepayne area using all available geophysical data sets. In particular, the pole reduced magnetic field and its first vertical derivative were the most reliable for mapping variations in geological contacts, identifying heterogeneity, and delineation and classification of structural lineaments (faults, dykes). The results from the structural lineament interpretations are presented in the lineament report for the Hornepayne area (Geofirma, 2013b). The first and second vertical derivatives were used to trace quasilinear magnetic anomaly peaks (magnetic foliation) to emphasize the ductile structure. These ductile structures are interpreted as being associated with the internal fabric to the rock units and may include in places sedimentary or volcanic layering, tectonic foliation or gneissosity, and magmatic foliation. Enhanced grids of the magnetic field data were used to assist in the interpretation:

- Pole-reduced magnetic field – magnetic units (Figure 5)
- Pole-reduced first and second vertical derivatives – lineaments, boundaries, texture, foliation (Figure 6 and Figure 7)
- Tilt angle – subtle magnetic responses (Figure 8)
- Analytic signal – anomaly character, texture, boundaries (Figure 9)

Gravity data were of insufficient resolution to be used for interpretation of geological units and boundaries. However, some general characterizations of the regional scale units were possible (Figure 11). Similar comments apply to the radiometric data. The electromagnetic data were not used for interpreting lithologies as the magnetic data proved greatly superior from a mapping perspective in the Hornepayne area. However, certain geological features were evident in the electromagnetic data and are discussed below in the results.

The coincidence of the lithological units with the geophysical data was mainly recognized in the magnetic images from their anomaly amplitude, texture, width, and orientation characteristics. The automated peaks, troughs and edges generated from the magnetic data assisted in more accurate identification of geological contacts. The magnetic anomaly characteristics and geophysical contacts were compared to the current bedrock geological maps in order to identify similarities and/or changes in the lithological contact locations. In some cases, difference in the boundaries determined from the magnetic data and the mapped boundaries may reflect a subsurface response which may not match the mapped surface contacts (e.g. dipping unit) and/or a contact extended through locations with limited outcrop exposure (e.g. under overburden and drainage cover). Results of the coincidence between the geophysical interpretation and the bedrock geological maps are presented in Figure 15.

The geophysical data were evaluated against the following two published regional scale geological maps:

- Johns, G.W. and McIlraith, S., 2003, Precambrian geological compilation series – Hornepayne sheet, Ontario Geological Survey, Map 2668, scale 1:250 000.
- Ontario Geological Survey, 2011, 1:250 000 scale bedrock geology of Ontario, Miscellaneous Release Data 126-Revision 1 (OGS, 2011) (Figure 2).

The mapping by Johns and McIlraith (2003) more accurately delineates the boundary between the Quetico and Wawa subprovinces and the greenstone belts in the area compared to the OGS Bedrock Geology of Ontario (MRD 126) (OGS, 2011) mapping. In addition, Milne (1964), Fenwick (1965), Giguere (1972), and Siragusa (1976) provided additional information with finer scale mapping programs in the Hornepayne area

5.2 Results

The following section presents a regional-scale description and interpretation of each geophysical data set in the Hornepayne area, followed by detailed interpretations of geophysical responses within the metasedimentary rocks and granitic-granodioritic intrusions of the Quetico Subprovince and Black-Pic batholith of the Wawa Subprovince. Using the published regional bedrock geology maps as a starting point, the integration of all suitable geophysical information provides a preliminary interpretation of a subsurface distribution of geological units for the Hornepayne area presented in Figure 15.

5.2.1 Magnetic

The magnetic data over the Hornepayne area exhibits a strong variability in the magnetic response associated with the rock units of the Quetico and Wawa subprovinces. Although a portion of the Hornepayne area is covered by high resolution magnetic data, the boundaries of the geological units shown on the bedrock geology map are not always well-defined due to the low data quality over the majority of the Hornepayne area, and lack of magnetic contrast between the rock units mapped on the surface.

The central portion of the Hornepayne area shows a strong east-trending magnetic response in the reduced to pole magnetic field (Figure 5), as well as the first (Figure 6) and second vertical (Figure 7) derivative grids. This response is characterized by several subparallel lineations that are each on the order of several hundred metres width and oriented in an east-west direction (Figure 15; units A1). The lineations are more numerous north of the subprovince boundary and tend to dissipate towards the south slightly into the Wawa Subprovince forming a 15 km wide anomalous zone. The boundaries of the highly magnetic zone are well-delineated by the analytic signal grid (Figure 9). This zone largely extends across the entire Hornepayne area, whereby the strength of the linear anomalies diminishes towards the east (Figure 15; unit G). This anomaly corresponds to a high magnetic response in the reduced to pole magnetic grid, but its response is indistinguishable in the derivative grids. The high magnetic intensity in the Quetico portion of the boundary zone may reflect the occurrence of granulite grade metamorphism in the metasedimentary rocks (Williams, 1991). Further to the east, the reduction in the intensity of this anomaly may result from more weakly magnetized rocks adjacent to the subprovince boundary which may not have undergone the same degree of metamorphism. Alternatively, these rocks may reflect similar magnetization but either plunge or are displaced towards the east.

The strong east-trending magnetic response quickly diminishes north of the subprovince boundary associated with metasedimentary rocks, lesser amounts of granite to granodiorite intrusive and minor mafic volcanics of the Quetico Subprovince (Figure 15). These rock units show a weak magnetic background, predominantly composed of metasedimentary rocks with a low magnetic mineral content (Figure 15; unit A). Granitic to granodiorite intrusive units shown on the bedrock geology maps hosted within the metasedimentary rocks tend to display similar magnetic responses as the adjacent host rocks. Although subtle differences in the magnetic response are visible, the lack of magnetic contrast between the two geological units hinders the ability to accurately trace the geological contacts. Locally, a few small magnetic high anomalies occur within the mapped granite to granodiorite unit, particularly along the southern edge of the Nagagamisis Lake (Figure 15; unit B).

South of the subprovince boundary the magnetic response grades from moderate to high across the area, particularly in the southeastern portion of the Hornepayne area. The magnetic results reflect mapped bedrock units that are dominated by large areas of gneissic tonalitic suite forming the Black-Pic batholith, foliated tonalites and granite to granodiorite rocks, as well as lesser amounts of mafic volcanics of the Wawa Subprovince. In this area the identification of geological boundaries in the magnetic data sets are largely hindered by the presence of low resolution magnetic data, and are masked by the abundance of northwest trending magnetic lineaments, although subtle lithological variation may be evident.

Much of the observed anomalous response reflects a high density of northwest-trending linear anomalies, which are mapped as diabase dykes of the Matachewan swarm. The Matachewan dyke swarm shows clear linear magnetic highs across the entire Hornepayne area, generally spaced at roughly 2 km intervals. Much of their signal is lost across the subprovince boundary, with some apparent offsets (both dextral and sinistral) observed along the east-west trending ductile structure. Elsewhere, there are faults of the same orientation that are characterized by magnetic lows (low magnetite content). Both the faults and Matachewan dykes show dextral offsets of the younger northeast trending Biscotasing dykes, indicating reactivation of northwest-trending faults after approximately 2.17 billion years ago. The Biscotasing dyke swarm also shows clear linear magnetic highs across much of the Hornepayne area. They are less prevalent and variable in their spacing compared to the Matachewan dyke swarm, and are slightly more magnetic overall. Their presence in the Quetico Subprovince is mainly restricted to the west side of the Hornepayne area whereas they are more widespread in the Wawa Subprovince.

5.2.2 Gravity

The Bouguer gravity data and gravity station locations across the Hornepayne area are presented in Figure 11, and its first vertical derivative in Figure 12. Although the gravity data were insufficient resolution to be used for interpretation of geological units and boundaries, some general characterizations of the regional scale units were possible. There is a higher gravity response (-40 mGal) located immediately north of the subprovince boundary that is roughly 10 – 15 km wide associated with the metasedimentary rocks of the Quetico Subprovince (Figure 15; unit A1). This response correlates well with an anomaly interpreted from the magnetic data, which strikes east-northeast along the northwest margin of the Hornepayne area, extending for tens of kilometres. The high gravity anomaly in this area may reflect the presence of higher density rock units adjacent to the subprovince boundary. In the area around Little Dowsley Lake the magnitude of the gravity anomaly diminishes and perhaps continues again approximately 20 km to the north.

In the Wawa Subprovince, the large granite to granodiorite unit correlates well with a gravity low response. Locally, gravity measurements over minor amounts of greenstone units may have resulted in weak gravity highs, particularly in the area around Wilson Lake and north of Obakamiga Lake. The broader gravity low to the southwest may reflect a thicker portion of the Black-Pic batholith.

5.2.3 Radiometric

Radiometric data in the Hornepayne area were of insufficient resolution to be used for interpretation of geological units and boundaries (Figure 13). In the case where the overburden material is locally derived from the underlying bedrock, it may serve as a proxy when interpreting the radiometric data.

The radiometric data show areas of low radioelement response associated with the location of lakes and surrounding wetlands. In general, the radiometric response does not correlate particularly well with geological boundaries shown on the bedrock geological maps or anomalies interpreted from the magnetic data. Although there is no sharp response associated with the subprovince boundary, a subtle response elevated in thorium exists which may correlate with the east-west trending anomalies observed in both the gravity and magnetic data sets (Figure 15; unit A1). Rock units of the Wawa Subprovince tend to be slightly elevated in potassium to the south, whereas the rocks of the Quetico Subprovince tends to be slightly elevated in uranium.

For the GSC radiometric compilation within the Hornepayne area, the radioelement responses are as follows:

Table 3. Radioelement response statistics for the Hornepayne area

Radioelement	Minimum	Maximum	Mean
Potassium (%)	0.05	1.20	0.62
Uranium (ppm)	0.00	1.10	0.35
Thorium (ppm)	0.14	4.13	1.83
Natural air absorbed dose rate (nGy/h)	1.24	30.79	14.60

These levels are towards the low end for intermediate to mafic volcanics, mafic intrusions and metamorphic rocks (IAEA, 2003) and well below those of felsic volcanics and felsic (alkalic) intrusions.

The low uranium levels suggest low radon risk. However, radon risk is also quite dependent on soil permeability and should be verified by soil gas measurements (IAEA, 2003). The highest uranium response in the area is located within the metasedimentary rocks towards the north, centered on Highway 17.

5.2.4 Electromagnetic

The apparent conductivity grids derived from the electromagnetic data are shown together with the EM anomaly responses provided with the OGS databases to highlight the conductive responses (Figure 14). The EM anomaly databases includes a mixture of electrically conductive sources from cultural (e.g. power lines), surficial (e.g. clays and lake-bottom sediments) and bedrock units (e.g. conductive horizons, sulphide minerals). The interpretation focused on using the EM anomaly response to delineate bedrock sources into linear conductors which traverse a few to several flightlines (i.e. 200 m to 1000 m or more).

In the Hornepayne area, few bedrock conductors have been interpreted from the Manitouwadge survey (OGS, 2002), and are predominantly located in the metasedimentary rocks towards the northern end of the survey block. The bulk of the apparent conductivity grids show a low conductivity response over most of the surveyed areas, punctuated by broader conductive zones that tend to correlate well with electrically conductive minerals (typically clays) within the Quaternary deposits and lake-bottom sediments. In particular, a significant amount of the high apparent conductivity response located in the area around Granitehill Lake, Obakamiga Lake and Cholette Lake presumably correspond to the lake-bottom sediments, as well as large glaciolacustrine deposits that are assumed to comprise high clay content. A similar high apparent conductivity response is also coincident with the Nagagami Lake sediments, and the

Quaternary deposits to the west. In addition, several linear conductive features are observed to be coincident with the interpretation of dyke lineaments trending in a west to northwest direction (Geofirma, 2013b).

Overall, the EM coverage over the geological formations of interest in the Hornepayne area is rather limited. In general, the EM has reduced application for bedrock mapping in the Hornepayne area, as most of the units are electrically resistive.

5.3 Geophysical Interpretation of the Quetico and Wawa Subprovince in the Hornepayne Area

The following section provides more detailed interpretations with a focus on the potentially suitable geology in the Quetico Subprovince (metasedimentary rocks and granitic-granodioritic intrusions) and Wawa Subprovince (Black-Pic batholith) within the Hornepayne area. These interpretations include a description of the geophysical characteristics of each unit, as well as a refinement of geologic contacts, where possible, and the identification of internal heterogeneities within the structures where present. These interpreted features are presented alongside the current bedrock geology mapping on Figure 15, noting that the interpretations are preliminary and require future geologic validation.

5.3.1 Metasedimentary Rocks and Granitic-Granodioritic Intrusions of the Quetico Subprovince

The magnetic responses within the Quetico Subprovince are associated with the metasedimentary rocks, and lesser amounts of granite to granodiorite intrusive and mafic volcanics. These rock units predominantly show a weak magnetic background, likely reflecting lithologies composed of low magnetic mineral content. Predominantly, through the entire Quetico Subprovince, the magnetic response tends to reflect the presence of northwest trending Matachewan dyke swarm, with an approximate spacing of 2 km between dykes. Adjacent to the subprovince boundary, magnetic data shows an east-west trending high response that extends several kilometres to the north into the metasedimentary rocks, and is characterized by numerous subparallel lineations (Figure 15; unit A1). Based on the OGS bedrock geology map this unit is mapped as undifferentiated metasedimentary rocks. However, the higher magnetic response suggests that these bedrock units located adjacent to the subprovince boundary contain a higher concentration of magnetic minerals, and may reflect a change in the bedrock lithology and higher degree of heterogeneity within the subsurface. The high abundance of subparallel lineations evident in the metasedimentary rocks are most likely associated with a deformation zone extending north and south of the subprovince boundary (Figure 15; unit A1). The high magnetic intensity in the Quetico portion of the boundary zone may reflect the occurrence of granulite grade metamorphism in the metasedimentary rocks (Williams, 1991). This area north of the subprovince boundary is also coincident with an east – west trending linear gravity anomaly that is well-defined, despite the wide distribution of gravity stations. Both the magnetic and gravity responses diminish to the east, which may suggest that the rock unit may either terminate or extend to depth. The more regional gravity response in the northern part of the Hornepayne area may reflect slightly lower densities of the metasedimentary rocks combined with the granitic to granodioritic unit compared to the rock units adjacent to the subprovince boundary.

The geological boundaries of the granite to granodiorite unit are not very well delineated in any of the geophysical data sets. Within the magnetic data subtle anomalies are present that show a slightly elevated response compared to the background with an east-northeast orientation (Figure 15; unit B in the Quetico Subprovince and unit B1 in the Wawa Subprovince). These identified responses are poorly coincident with the distribution of granite to granodiorite intrusive units, where magnetic responses tend to be reduced in areal extent compared to the boundaries presented in the bedrock geology map. Reasons for this may reflect the lack of magnetic contrast between the two geological units identified on the bedrock geology map; as well these rock units occur within the lower resolution magnetic survey area, resulting in the poorly delineated contacts between the two rock units. These results suggest that the uniform distribution of granite to granodiorite units, as shown on the bedrock geology map, may reflect a more complicated lithological heterogeneity in the area.

The radiometric data in the Quetico Subprovince displays a very regional anomaly that is elevated in eTh and eU, compared to the Wawa Subprovince. The eTh anomaly tends to show an eastern trend which is largely coincident with the gravity anomaly, as well as the high magnetic anomaly crossing the Hornepayne area adjacent to the subprovince boundary. Due to the poor data resolution, the radiometric anomaly responses do not correspond well with individual mapped bedrock units.

Electromagnetic coverage in the Quetico Subprovince area is limited, reflecting a generally low apparent conductivity of the metasedimentary rock units. Observed high conductivity anomalies tend to reflect the distribution of Quaternary deposits and lake-bottom sediments within the Quetico Subprovince. Few linear conductivity high responses observed crossing the subprovince boundary into the Quetico Subprovince correspond well with the locations and orientation of dykes identified in the magnetic data trending in a northwestern direction. In addition, a small number of linear conductivity high anomalies were also identified corresponding to the east trending magnetic high anomalies along the subprovince boundary.

5.3.2 Black-Pic Batholith of the Wawa Subprovince

The magnetic responses within the Wawa Subprovince are associated with rock units dominated by the gneissic tonalitic suite, foliated tonalites and granite to granodiorite rocks forming the Black-Pic batholith, as well as lesser amounts of mafic volcanics. In contrast to the metasedimentary rocks of the Quetico Subprovince, magnetic data over the Black-Pic batholith are slightly elevated and tend to display more variability between different lithologies. However, interpreted contacts are largely hindered by the presence of low resolution data, and are also masked by the abundance of northwest trending dykes. The gneissic tonalite suite displays a fairly uniform magnetic background (Figure 15; unit C) that gradually increases toward the granite to granodiorite rocks to the east (Figure 15; unit D). This gradual increase towards the east may reflect a gradational change in the lithology corresponding to higher magnetic mineral content, or alternatively, may be associated with the overshadow effect of the interpreted dykes observed within the poor resolution magnetic data. Although these dykes may dominate the amplitude of the response in the lower resolution magnetic data, there appears to be greater number of dykes to the west observed within the higher resolution magnetic data available in that area. However, despite the abundance of interpreted dykes, large areas appear to be magnetically quiescent and relatively homogeneous. These areas correspond to intact blocks which are devoid of the northwest trending dykes in the high resolution data near Obakamiga Lake, as well as low resolution data underlying the McCoy and Star Lakes (Figure 15; unit E). In addition, several northeast trending foliations are interpreted in the magnetic data, particularly within the high-resolution data to the southwest, which to some degree can be interpreted through into the lower resolution magnetic data. Elsewhere in the Wawa Subprovince the identified magnetic foliations tend to trend from east to east-northeast, in particular the foliated tonalite suite located at the subprovince boundary on the west side of the Hornepayne area.

Adjacent to the subprovince boundary, the magnetic data display a sharp magnetic contact that is characterized by numerous subparallel high amplitude lineations (Figure 15; unit F). Although the response is similar north of the subprovince boundary, bedrock units mapped adjacent and south of the boundary comprise foliated tonalite, gneissic tonalite and a number of thin east trending mafic volcanic units. The high magnetic response along the boundary implies a change in the bedrock lithology reflected by a higher concentration of magnetic minerals, and potentially a higher degree of lithological heterogeneity, and the high abundance of subparallel lineations immediately south of the subprovince boundary are most likely associated with the deformation zone extending north and south on the bedrock geology map (Figure 15; unit F). Based on high magnetic response and the dominance of east trending lineations, this area may comprise more mafic volcanic rocks at depth compared to what has been mapped. The area mapped as foliated tonalite suite shows strong evidence of subparallel horizons with a strong magnetic response, many of which are truncated against the subprovince boundary to the north. Identification of these truncated horizons is predominantly interpreted from the high resolution magnetic data covering the foliated tonalite suite, where such details are lost in the lower resolution data.

The large granite-granodiorite correlates quite well with a gravity low response. Locally, minor amounts of mafic volcanic units correlate fairly well with weak gravity highs, particularly in the area around Wilson Lake and north of Obakamiga Lake. The broader gravity low in the southwest of the Hornepayne area may reflect a thickening of the gneissic tonalite suite of the Black-Pic batholith.

The radiometric data display a very broad anomaly that is elevated in potassium throughout the Wawa Subprovince reflecting the predominance of potassium-rich intrusive rocks particularly corresponding to the gneissic tonalite suite. In addition, the radiometric data suggest a slight depletion in thorium relative to the portion near the subprovince boundary, perhaps reflecting one of the compositional variations within the batholith towards the southwest. Due to the poor data resolution the anomaly responses do not correspond well with individual mapped bedrock units.

Electromagnetic data in the Black-Pic batholith shows a generally low apparent conductivity of the gneissic-tonalite rock units. The majority of the high conductivity anomalies are associated with the distribution of Quaternary deposits and lake-bottom sediments. Few linear conductivity high responses observed Wawa Subprovince correspond well with the locations and orientation of dykes identified in the magnetic data trending in a northwestern direction.

6 SUMMARY OF RESULTS

The purpose of this assessment was to identify and obtain the available geophysical data for the Hornepayne area, followed by a detailed interpretation of all available geophysical data (e.g., magnetic, electromagnetic, gravity and radiometric) to identify additional information that could be extracted from the data, in particular regarding the coincidence of geophysical features with mapped lithology and structural features in the Hornepayne area.

The geophysical data covering the Hornepayne area show variability in data set resolution. Low-resolution geophysical data, particularly the magnetic, gravity and radiometric data obtained from the Geological Survey of Canada (GSC), cover the entire Hornepayne area. Two additional magnetic/electromagnetic surveys obtained from the Ontario Geological Survey (OGS) provided higher resolution coverage over approximately 15% of the Hornepayne area to the southwest, and for a small part of the southeast corner. These surveys focused primarily on mineral exploration in the greenstone belts, but also encompassed granitic, gneissic and sedimentary rocks across the Quetico-Wawa Subprovince boundary in the west of the Hornepayne area.

The coincidence between the geophysical data and the mapped lithology and structural faults were interpreted using all available geophysical data sets (e.g., magnetic, electromagnetic, gravity and radiometric). In particular, the pole reduced magnetic field (RTP) and its first vertical derivative (1VD) were the most reliable for mapping variations in geological contacts and identifying lithological heterogeneity. The boundaries of the geological units shown on the bedrock geology map are not always well-defined on the magnetic data due to the low data resolution over the majority of the Hornepayne area, and lack of magnetic contrast between the rock units mapped on the surface. In particular, the granite-granodiorite units in the Wawa Subprovince and Quetico Subprovince do not show strong contrasts with adjacent in the regional magnetic data so the interpretation of the extent of contacts is tentative.

The strongest responses in the Hornepayne area are characterized as subparallel lineations evident in the magnetic dataset and interpreted as an approximately 15 km wide zone of deformation associated with the Wawa-Quetico subprovince boundary. Magnetic interpretation within the Black-Pic batholith is hampered by low-resolution data over all but the west side, and the overprint of signal from the magnetic dykes. Nevertheless, it has been subdivided into three units. Unit C within gneissic tonalite shows internal fabric. Unit D displays a slightly elevated magnetic response associated with granite-granodiorite. Unit E is less disturbed by dykes and folding, and appears more homogeneous.

The northwest-striking Matachewan dyke swarm and the northeast-striking Biscotasing dyke swarm cut all of the geological units throughout the Hornepayne area. There is a greater density of Matachewan dykes. The number of Biscotasing dykes is reduced north of the subprovince boundary.

The resolution of the gravity data was insufficient to be used for interpretation of geological units and boundaries. However, some general characterizations of the regional scale geological units were possible. The Bouguer gravity field shows a regional-scale gravity high that correlates with the more magnetic portion of the Quetico Subprovince metasedimentary rocks (unit A1) along the north edge of the subprovince boundary. The gravity low in the Wawa Subprovince reflects the granitic rocks (units B and E). The strongest gravity low to the southwest may reflect the thickening of the Black-Pic batholith and/or variation in its internal composition (unit C).

Radiometric responses due to the presence of potassium, uranium and thorium related minerals are typically elevated in granitic rocks compared to volcanic rocks, and this relationship is seen to some extent in the Hornepayne area. The regional nature of the radiometric data, presence of numerous lakes and limited greenstone exposure makes differentiation difficult. Rock units of the Wawa Subprovince tend to be slightly elevated in potassium to the south, whereas the rocks of the Quetico Subprovince tend to be slightly elevated in uranium.

Electromagnetic surveys show a mixture of sources, including cultural (*e.g.* power lines), surficial (*e.g.* clays and lake-bottom sediments) and bedrock (*e.g.* conductive horizons, sulphide minerals) over the greenstone belts. The bedrock responses are concentrated mainly in the greenstone belt in the southeast corner of the Hornepayne area, where conductive horizons parallel the magnetic foliation. The Manitouwadge survey to the west indicates that most of the rocks are resistive in that region, bedrock units to the north of the subprovince boundary being slightly more conductive. Most of the electromagnetic responses in the area reflect drainage-related sediments.

Respectfully Submitted,

PATERSON, GRANT & WATSON LIMITED

Stephen W. Reford, B.A.Sc., P.Eng.
Vice-President

7 REFERENCES

ArcMAP mapping and GIS system, v. 10.0 SP4, ESRI Inc.

Baranov, V., 1957. A new method for interpretation of aeromagnetic maps: pseudo-gravimetric anomalies. Geophysics, vol. 22 (2), pp. 359–383.

Baird, A., and S. D. McKinnon, 2007. Linking stress field deflection to basement structures in southern Ontario: results from numerical modeling, Tectonophysics, Vol. 432, pp. 89-100.

Barnett, P.J., 1992. Quaternary Geology of Ontario in Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 2, 1010-1088.

Berman, R.G., M. Sanborn-Barrie, R.A. Stern and C.J. Carson, 2005. Tectonometamorphism at ca. 2.35 and 1.85 Ga in the Rae Domain, western Churchill Province, Nunavut, Canada: Insights from structural, metamorphic and IN SITU geochronological analysis of the southwestern Committee Bay Belt, The Canadian Mineralogist, Vol. 43, pp. 409-442.

Breaks, F.W., and J.R. Bartlett, 1991. Geology of the Eyapamikama Lake Area; Ontario Geological Survey, Open File Report 5792, 132p.

Breaks, F.W., and W.D. Bond, 1993. The English River Subprovince-An Archean Gneiss Belt: Geology, Geochemistry and associated mineralization; Ontario Geological Survey, Open File Report 5846, Vol.1, pp.1-483, 884p.

Brown, A., R.A. Everitt, C. D. Martin and C.C. Davison 1995. Past and Future Fracturing In AECL Research Areas in the Superior Province of the Canadian Precambrian Shield, with Emphasis on the Lac Du Bonnet Batholith, Atomic Energy of Canada Ltd. Report, AECL-11214, COG-94-528, 138 p.

Cooper, G.R.J., and Cowan, D.R. 2006. Enhancing potential field data using filters based on the local phase, Computers and Geosciences, v. 32, 1585-1591.

Corfu, F., G.M. Stott and F.W. Breaks, 1995. U-Pb geochronology and evolution of the English River Subprovince, an Archean low P – high T metasedimentary belt in the Superior Province, Tectonics, Vol.14, pp.1220-1233.

Easton, R.M., 2000. Metamorphism of the Canadian Shield, Ontario, Canada. I. The Superior Province, The Canadian Mineralogist, Vol. 38, pp. 287-317.

Ernst, R. E. and H.C. Halls, 1983. Structural variation of Proterozoic dikes in the Central Superior Province-a possible reflection of post-Archean shield deformation, In: Workshop on a cross-section of the Archean crust. Edited by L. D. Ashwal and K. D. Card. Lunar and Planetary Institute, Houston, TX, LPI Technical Report 83-03, pp. 42-46.

Fairhead, J.D. and Williams, S.E. 2006. Evaluating normalized magnetic derivatives for structural mapping, Society of Exploration Geophysicists Expanded Abstracts, v. 26, 845-849.

Fenwick, K.G. 1967. Geology of the Dayohessarah Lake Area; Ontario Department of Mines, Geological Report 49, 16p. Accompanied by Map 2129, Dayohessarah Lake area, District of Algoma, scale 1 inch to 2 miles.

Fenwick, K.G., 1965. Dayohessarah Lake area, District of Algoma, Ontario, Ontario Geological Survey, Preliminary Map P.0288, scale 1:63660.

Gartner, J.F. and D.F. McQuay, 1980a. Hornepayne Area (NTS 42F/SE), Districts of Algoma and Cochrane. Ontario Geological Survey, Northern Ontario Engineering Terrain Study 46.

Gartner, J.F. and D.F. McQuay, 1980b. Obakamiga Lake Area (NTS 42F/SW), Districts of Algoma and Thunder Bay. Ontario Geological Survey, Northern Ontario Engineering Terrain Study 45.

Geofirma (Geofirma Engineering Ltd.), 2013a. Phase 1 Geoscientific Desktop Preliminary Assessment of Potential Suitability for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel, Township of Hornepayne, Ontario. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report Number: APM-REP-06144-0003

Geofirma (Geofirma Engineering Ltd.), 2013b. Phase 1 Geoscientific Desktop Preliminary Assessment, Lineament Interpretation, Township of Hornepayne, Ontario. Prepared for Nuclear Waste Management Organization (NWMO). NWMO Report Number: APM-REP-06144-0006

Geosoft, 2012. Oasis montaj geophysical processing system, v 7.5, Geosoft Inc.

Giguere, J.F., 1972. Granitehill Lake area, Thunder Bay and Algoma districts, Ontario Geological Survey, Map 2219, scale 1:63660.

Golder (Golder Associates Ltd.), 2011. Initial Screening for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel, Township of Hornepayne, Ontario, Final Report prepared for Nuclear Waste Management Organization, June.

GSC (Geological Survey of Canada), 2012. Geoscience Data Repository for Geophysical and Geochemical Data, gdr.nrcan.gc.ca.(data accessed 2012)

Halls, H.C., Davis, D.W., Stott, G.M., Ernst, R.E. and Hamilton, M.A., 2008. The Paleoproterozoic Marathon Large Igneous Province: New evidence for a 2.1 Ga long-lived mantle plume event along the southern margin of the North American Superior Province, Precambrian Research, v. 162, 327-353.

Halls, H.C. and D.W. Davis, 2004. Paleomagnetism and U-Pb geochronology of the 2.17 Ga Biscotasing dyke swarm, Ontario, Canada: evidence for vertical-axis crustal rotation across the Kapuskasing Zone, Canadian Journal of Earth Sciences, 41: 255-269.

Heaman, L.M., 1997. Global mafic magmatism at 2.45 Ga: Remnants of an ancient, large igneous province? EOLOGY, Vol. 25, pp. 299-302.

Holden, E. J., Dentith, M. and Kovesi, P. 2008. Towards the automated analysis of regional aeromagnetic data to identify regions prospective for gold deposits, Computers & Geosciences, v. 34, 1505-1513.

IAEA (International Atomic Energy Agency), 2003. Guidelines for radioelement mapping using gamma ray spectrometry data, IAEA-TECDOC-1363.

Jackson, S.L., G.P. Beakhouse and D.W. Davis. 1998. Regional geological setting of the Hemlo gold deposit; an interim progress report, Ontario Geological Survey, Open File Report 5977.

JDMA (J.D. Mollard and Associates Ltd.), 2013. Phase 1 Geoscientific Desktop Preliminary Assessment, Terrain and Remote Sensing Study, Township of Hornepayne, Ontario. Prepared for Geofirma Engineering Ltd. and Nuclear Waste Management Organization (NWMO). NWMO Report Number: APM-REP-06144-0004

Johns, G.W. and McIlraith, S., 2003. Precambrian geology compilation series – Hornepayne sheet. Ontario Geological Survey, Map 2668, scale 1:250,000.

Jolly, W.T., 1978. Metamorphic history of the Archean Abitibi Belt, In: Metamorphism in the Canadian Shield; Geological Survey of Canada, Paper 78-10, pp.63-78.

Kamineni, D.C., D. Stone and Z. E. Peterman, 1990. Early Proterozoic deformation in the western Superior province, Canadian Shield, Geological Society of America Bulletin. Vol.102, pp.1623-1634.

Karrow, P.F. and O.L. White. 2002. A history of neotectonic studies in Ontario, Tectonophysics, Vol. 353, pp.3-15.

Manson, M.L. and H.C. Halls, 1997. Proterozoic reactivation of the southern Superior Province and its role in the evolution of the Midcontinent Rift, Canadian Journal of Earth Sciences, Vol. 34, pp. 562-575.

Manson, M.L., and H.C. Halls, 1994. Post-Keweenawan compressional faults in the eastern Lake Superior region and their tectonic significance, Canadian Journal of Earth Sciences, Vol.31, pp. 640-651.

McFall, G. H., 1993. Structural elements and neotectonics of Prince Edward County, Southern Ontario, Géographie physique et Quaternaire, Vol. 47, No. 3, pp. 303-312.

McMurry, J., D.A. Dixon, J.D. Garroni, B.M. Ikeda. S. Stroes-Gascoyne, P. Baumgartner, and T.W. Melnyk, 2003. Evolution of a Canadian Deep Geologic Repository: Base Scenario, Ontario Power Generation, Nuclear Waste Management Division Report 06819-REP-01200-10092-R00. Toronto, Canada.

Miller, H.G. and Singh, V., 1994. Potential field tilt - a new concept for location of potential field sources, Journal of Applied Geophysics, v. 32, 213-217.

Milne, V.G., 1968. Geology of the Black River Area, District of Thunder Bay, Ontario Department of Mines, Geological Report 72, 68p., accompanied by Maps 2143 and 2144, scale 1:31 680 (1 inch to ½ mile).

Milne, V.G., 1964. Geology of the Flanders Lake area; Ontario Department of Mines, Geological Report 21, 18p. Accompanied by Map 2047, scale 1 inch to 1 mile.

Nabighian, M.N. 1972. The analytic signal of two-dimensional magnetic bodies with polygonal cross-section: Its properties and use for automated anomaly interpretation. Geophysics, vol. 37, pp. 507-517.

NWMO, 2010. Moving forward together: Process for selecting a site for Canada's deep geological repository for used nuclear fuel, May 2010.

NWMO, 2013. Preliminary Assessment for Siting a Deep Geological Repository for Canada's Used Nuclear Fuel – Township of Hornepayne, Ontario – Findings from Phase One Studies. NWMO Report Number: APM-REP-06144-0001.

OGS (Ontario Geological Survey), 1991. Bedrock geology of Ontario, east-central sheet; Ontario Geological Survey, Map 2543, scale 1:1,000,000.

OGS (Ontario Geological Survey), 2002. Ontario airborne geophysical surveys, magnetic and electromagnetic data, Manitouwadge area, Geophysical Data Set 1205 - Revised.

OGS (Ontario Geological Survey), 2003. Ontario airborne geophysical surveys, magnetic and electromagnetic data, Oba-Kapuskasing area, Geophysical Data Set 1024 - Revised.

OGS (Ontario Geological Survey), 2011. 1:250 000 scale bedrock geology of Ontario, Miscellaneous Release Data 126 - Revision 1.

Peltier, W.,R., 2002. On eustatic sea level history: last glacial maximum to Holocene, Quaternary Science Reviews Vol. 21, pp. 377–396.

Percival, J.A. 1989. A regional perspective of the Quetico metasedimentary belt, Superior Province, Canada, Canadian Journal of Earth Sciences, v. 26, 677-693.

Percival, J.A. and Z.E. Peterman, 1994. Rb-Sr biotite and whole-rock data from the Kapuskasing uplift and their bearing on the cooling and exhumation history, Canadian Journal of Earth Sciences, Vol.31, pp.1172-1181.

Percival, J.A., Sanborn-Barrie, M., Skulski, T., Stott, G.M., Helmstaedt, H. and White, D.J., 2006. Tectonic evolution of the western Superior Province from NATMAP and Lithoprobe studies, Canadian Journal of Earth Sciences, v. 43, 1985-1117.

Percival, J.A., and T. Skulski, 2000. Tectonothermal evolution of the northern Minto block, Superior Province, Québec, Canada, The Canadian Mineralogist, Vol. 38, pp. 345-378.

Percival, J.A., and G.F. West, 1994. The Kapuskasing uplift: A geological and geophysical synthesis, Canadian Journal of Earth Sciences, Vol. 31, pp. 1256–1286.

Peterman, Z.E. and W. Day, 1989. Early Proterozoic activity on faults in the western Superior - evidence from pseudotachylite, Geology, Vol.17, p.1089-1092.

Peterson, V.L. and Zaleski, E., 1999. Structural history of the Manitouwadge greenstone belt and its volcanogenic Cu-Zn massive sulphide deposits, Wawa subprovince, south-central Superior Province, Canadian Journal of Earth Sciences, v. 36, 605-625.

Pilkington, M. and Keating, P.B., 2009. The utility of potential field enhancements for remote predictive mapping, Canadian Journal of Remote Sensing, v. 35:(S1), S1-S11.

Pitney Bowes, 2012. Encom PA (Profile Analyst) geophysical processing system, v 12.0, Pitney Bowes Software.

Powell, W.G., D.M. Carmichael and C.J. Hodgson, 1993. Thermobarometry in a subgreenschist to greenschist transition in metabasites of the Abitibi greenstone belt, Superior Province, Canada, J. Metamorphic Geology, Vol.11, pp.165-178.

Powell, W.G., C.J. Hodgson, J.A. Hanes, D.M. Carmichael, S. McBride and E. Farrar, 1995. 40Ar/39Ar geochronological evidence for multiple postmetamorphic hydrothermal events focused along faults in the southern Abitibi greenstone belt, Canadian Journal of Earth Sciences, Vol.32, pp. 768-786.

Sbar. M. L., and L. R. Sykes, 1973. Contemporary compressive stress and seismicity in eastern North America: An example of intra-plate tectonics, Geol. Soc. America Bull., Vol. 84, pp. 1861-1882.

Schultz-Ela, D. and Hudleston, P.J., 1991. Strain in an Archean greenstone belt of Minnesota, Tectonophysics, v.190, 233-268.

Shackleton, N.J., A. Berger and W.R. Peltier, 1990. An alternative astronomical calibration of the lower Pleistocene timescale based on ODP Site 677, Transactions of the Royal Society of Edinburgh, Earth Sciences, Vol. 81, pp. 251-261.

Shi, Z. and Butt, G. 2004. New enhancement filters for geological mapping, Extended Abstracts, Australian Society of Exploration Geophysicists, 5p.

Siragusa, G.M., 1976. Kabinakagami Lake, Algoma District, Ontario Geological Survey, Map 2355, scale 1:63,360.

Skulski, T., H. Sandeman, M. Sanborn-Barrie, T. MacHattie, D. Hyde, S. Johnstone, D. Panagapko and D. Byrne, 2002. Contrasting crustal domains in the Committee Bay belt, Walker Lake – Arrowsmith River area, central Nunavut; Geological Survey of Canada, Current Research 2002-C11, 11p.

Stott, G.M., Corkery, M.T., Percival, J.A., Simard M. and Goutier, J., 2010. A revised terrane subdivision of the Superior Province, In: Summary of Field Work and Other Activities 2010, Ontario Geological Survey, Open File Report 6260, 20-1 - 20-10.

Stott, G.M. and Josey, S.D., 2009. Proterozoic mafic (diabase) dikes and other post-Archean intrusions of northwestern Ontario, north of latitude 49° 30', Ontario Geological Survey, Preliminary Map P.3606, scale 1:1 000 000.

Stott, G.M. 1999. Precambrian Geology of the Dayohessarah Lake Area, White River, Ontario, Ontario Geological Survey, Open File Report 5984, 59p.

Stott, G.M. and Corfu, F., 1991. Uchi Subprovince, In: Geology of Ontario, Special Volume 4, Part 1, 145-236.

Stott, G.M. and Schwerdtner, W.M., 1981. Structural analysis of the central part of the Shebandowan metavolcanic-metasedimentary belt, In Ontario Geoscience Research Grant Program, Final Research Reports, 1980, Ontario Geological Survey, Open File Report 5349, 44p.

Telford, W. M., Geldart, L. P., Sheriff, R. E., 1990. Applied Geophysics Second Edition. Cambridge University Press, 1990-10-26, p.792

Thurston, J.B. and Smith, R.S., 1997. Automatic conversion of magnetic data to depth, dip, and susceptibility contrast using the SPI™ method, Geophysics, v. 62, 807-813.

Thurston, P.C., 1991. Geology of Ontario: Introduction, In Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 1, 3-25.

White, D.J., G. Musacchio, H.H. Helmstaedt, R.M. Harrap, P.C. Thurston, A. van der Velden and K. Hall, 2003. Images of a lower crustal oceanic slab: Direct evidence for tectonic accretion in the Archean western Superior Province; Geology, Vol.31, pp.997-1000.

Williams, H.R. and Breaks, F.R., 1996. Geology of the Manitouwadge-Hornepayne region, Ontario, Ontario Geological Survey, Open File Report 5953, 138p.

Williams, H.R., 1991. Quetico Subprovince; In Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 1, pp. 383-403.

Williams, H.R., Stott, G.M., Heather, K.B., Muir T.L. and Sage, R.P., 1991. Wawa Subprovince, In: Geology of Ontario, Special Volume 4, Part 1, 485-546.

Williams, H.R. and Breaks, F.R., 1989. Project Unit 89-13. Geological studies in the Manitouwadge-Hornepayne region. In: Summary of Field Work and Other Activities 1989, Ontario Geological Survey Miscellaneous Paper 146, 79-91.

Zaleski, E. and Peterson, V.L., 2001. Geology of the Manitouwadge greenstone belt and the Wawa-Quetico subprovince boundary, Ontario, Geological Survey of Canada, Map 1917A, scale 1:25 000.

Zaleski, E., van Breemen, O. and Peterson, V.L., 1999. Geological evolution of the Manitouwadge greenstone belt and the Wawa-Quetico subprovince boundary, Superior Province, Ontario, constrained by U-Pb zircon dates of supracrustal and plutonic rocks. Canadian Journal of Earth Sciences, v. 36, 945-966.

Zoback, M.L. 1992. First- and second-order patterns of stress in the lithosphere: the world stress map project, Journal of Geophysical. Research, Vol. 97, pp. 11,703-11,728.

FIGURES

Figure 1. Township of Hornepayne and surrounding area.

Figure 2. Bedrock geology of the Hornepayne area.

Figure 3. Surficial geology of the Hornepayne area.

Figure 4. Airborne geophysical coverage of the Hornepayne area.

Figure 5. Residual magnetic field reduced to pole.
(with mapped geological contacts and geophysical survey outlines)

Figure 6. First vertical derivative of the pole reduced magnetic field.
(with mapped geological contacts and geophysical survey outlines)

Figure 7. Second vertical derivative of the pole reduced magnetic field with foliation.
(with mapped geological contacts and geophysical survey outlines)

Figure 8. Tilt angle of the pole reduced magnetic field.
(with mapped geological contacts and geophysical survey outlines)

Figure 9. Analytic signal amplitude of the total magnetic field.
(with mapped geological contacts and geophysical survey outlines)

Figure 10. Depth to magnetic sources from source parameter imaging.
(with mapped geological contacts and geophysical survey outlines)

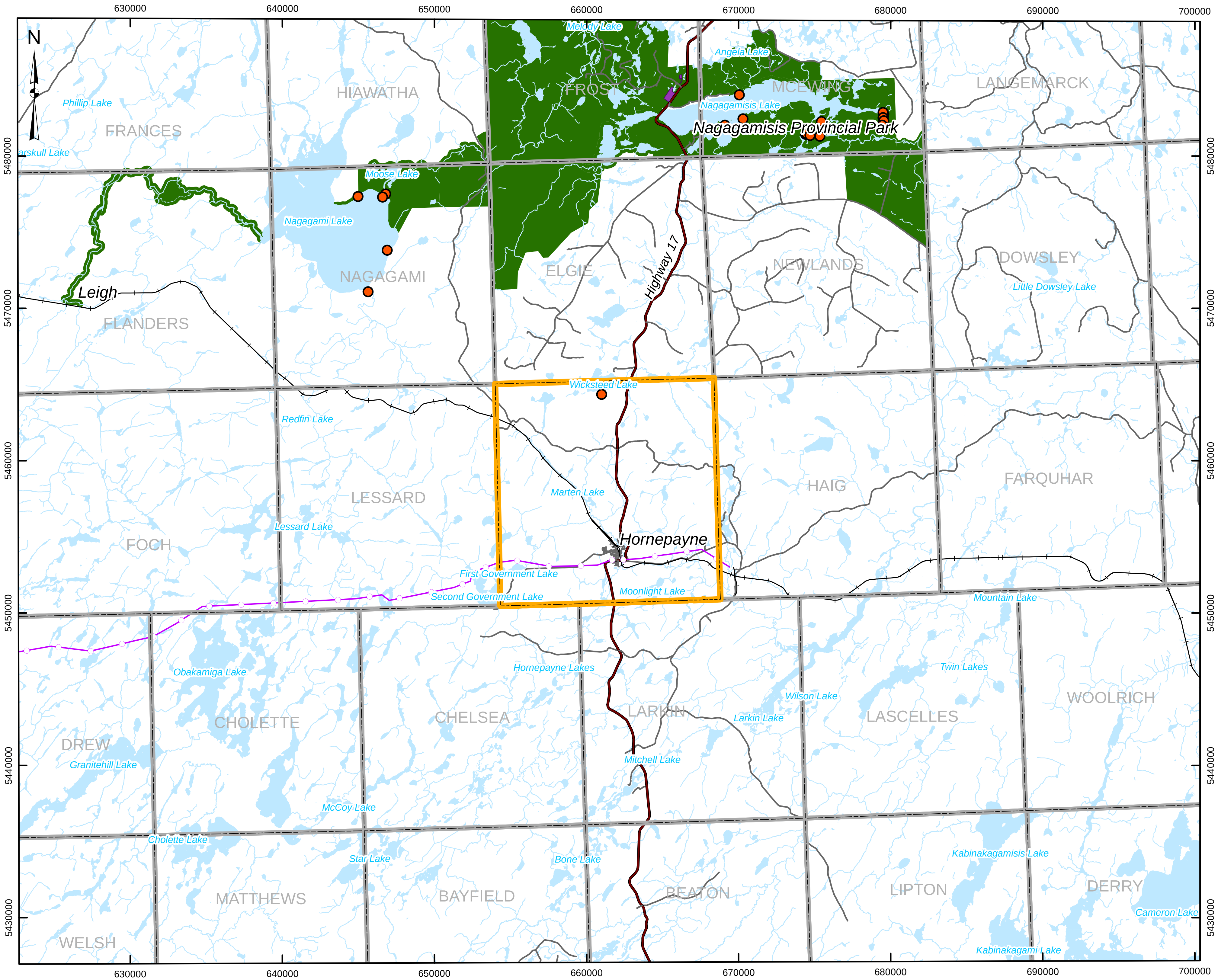
Figure 11. Bouguer gravity field with station locations.
(with mapped geological contacts)

Figure 12. First vertical derivative of the Bouguer gravity field with station locations.
(with mapped geological contacts)

Figure 13. Radiometric ternary image (RGB = K-eTh-eU).
(with mapped geological contacts)

Figure 14. EM conductors over apparent conductivity (GDS1024 and GDS 1205).
(with mapped geological contacts and geophysical survey outlines)

Figure 15. Geophysical interpretation showing distribution of bedrock units for the Hornepayne area.
(with geophysical survey outlines)



LEGEND

- Township of Hornepayne
- Geographic Township
- Forest Reserve
- Provincial Park
- Registered Archaeological Site
- Highway
- Local Road
- Railway
- Utility Line
- Water Area, Permanent
- Watercourse, Permanent
- Watercourse, Intermittent

Geofirma Engineering Ltd

SCALE 1:300,000

0 2.5 5 10 15 20

Kilometres

PROJECTION: UTM NAD83 Zone 16N
SOURCE: MNR, Geobase, Ministry of Tourism and Culture
Produced by Geofirma Engineering Ltd under license from
Ontario Ministry of Natural Resourses, ©Queens Printer 2011

PROJECT No. 10-214-4
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT,
GEOPHYSICAL STUDY, HORNEPAYNE AREA, ONTARIO

TITLE **Location and Overview of the Hornepayne area**

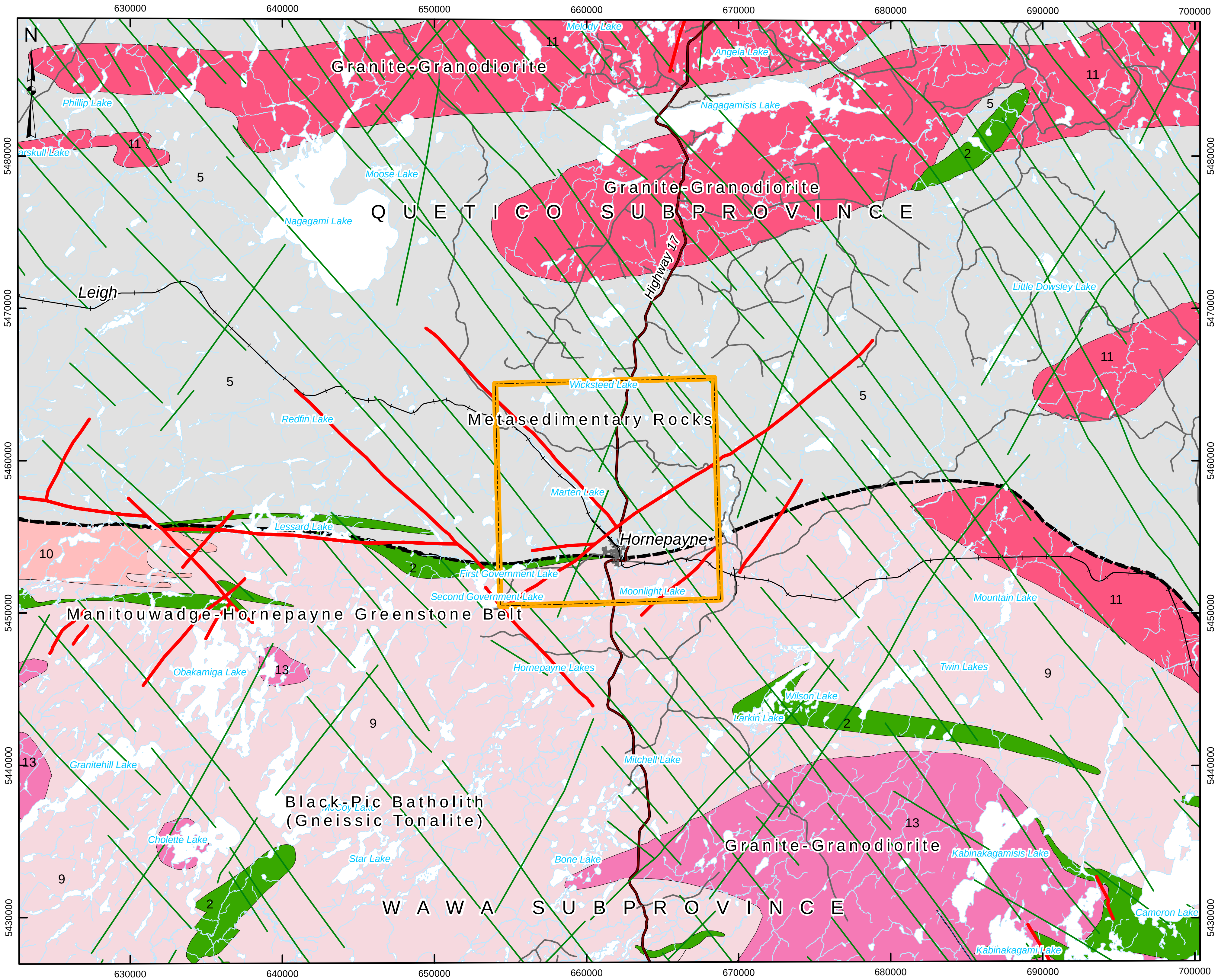
FIGURE 1

DESIGN: NMP
CAD/GIS: NMP
CHECK: KGR/SNS
REV: 0A

DATE: 16/10/2013

Paterson, Grant & Watson Limited
Consulting Geophysicists
www.pgw.on.ca

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Hornepayne\Oct_2013\Fig1_PGW_Hornepayne_Area.mxd



C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Hornepayne\Oct_2013\Fig2_PGW_Hornepayne_Bedrock_Geology.mxd

LEGEND

- Township of Hornepayne
- Highway
- Local Road
- Railway
- Water Area, Permanent
- Watercourse, Permanent
- Watercourse, Intermittent
- Geological Fault
- Dyke
- Subprovince Boundary

Bedrock Geology

- 13 Granite-granodiorite
- 11 Granite-granodiorite
- 10 Foliated tonalite suite
- 9 Gneissic tonalite suite
- 5 Metasedimentary rocks
- 2 Mafic volcanic rocks

Geofirma Engineering Ltd

SCALE 1:300,000

0 2.5 5 10 15 20

Kilometres

PROJECTION: UTM NAD83 Zone 16N
SOURCE: MNR, Geobase
Geology: MRD126-REV1 Bedrock Geology of Ontario, 2011
NWMO, Johns, G.W. and McIlraith, S. 2003.
Precambrian bedrock geology compilation series. Ontario Geological Survey, Map 2668, scale 1:250,000, Santaguida, F. 2002.
Precambrian geology compilation series – White River sheet. Ontario Geological Survey, Map 2668, scale 1:250,000
Produced by Geofirma Engineering Ltd under license from Ontario Ministry of Natural Resourses, ©Queens Printer 2011

PROJECT No. 10-214-4

PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, HORNEPAYNE AREA, ONTARIO

TITLE

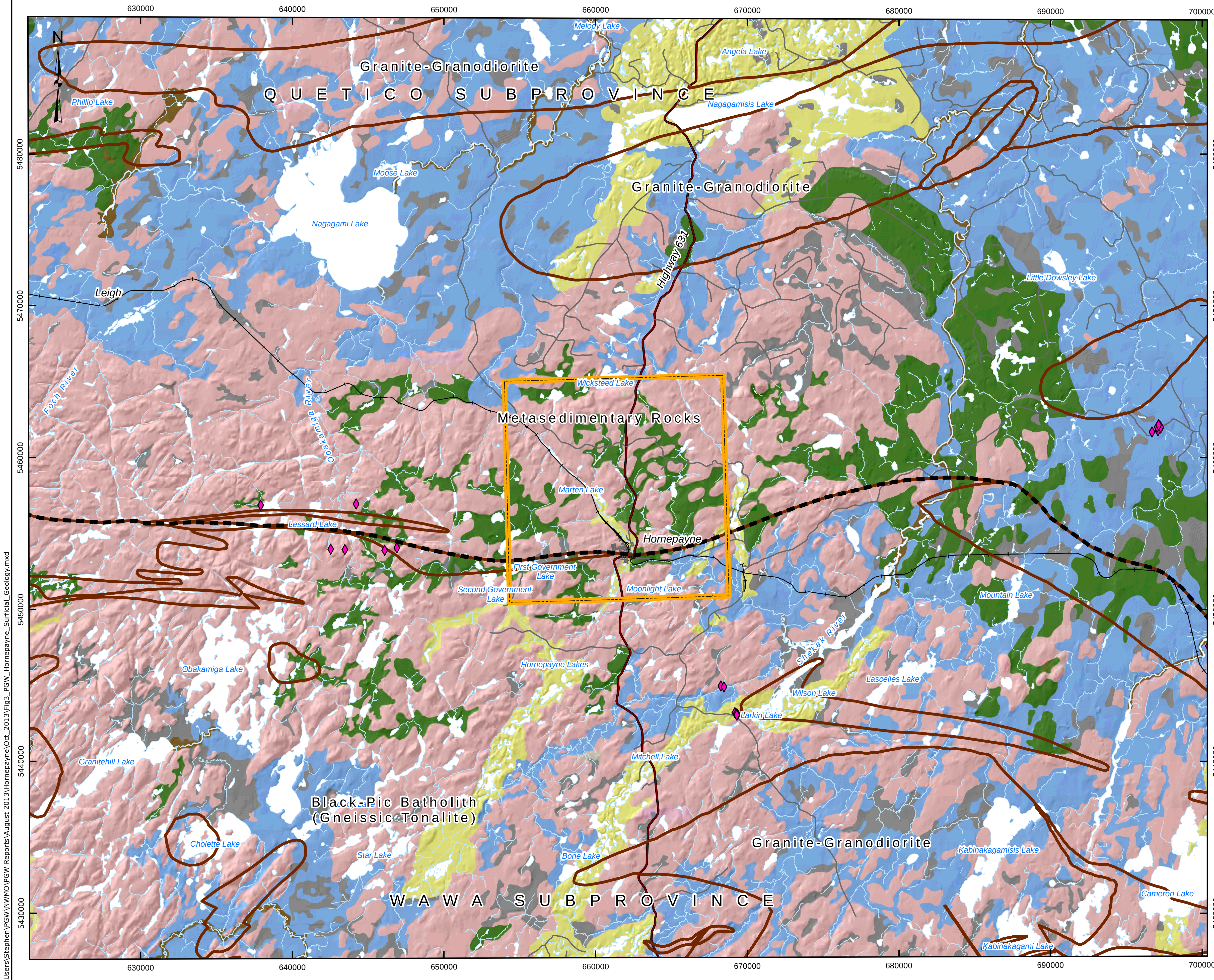
Bedrock Geology of the Hornepayne Area

FIGURE 2

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

DATE: 16/10/2013

Paterson, Grant & Watson Limited
Consulting Geophysicists
www.pgw.on.ca



LEGEND

- Township of Hornepayne
- Highway
- Local Road
- Railway
- Water Area, Permanent
- Subprovince Boundary
- Outline of Geologic Unit
- Diamond Drill Hole

Quaternary Geology

- Moraine
- Sand and gravel
- Glaciolacustrine
- Alluvial
- Organics
- Bedrock

Geofirma Engineering Ltd

SCALE 1:250,000

0 2.5 5 10 15 20

Kilometres

PROJECTION: UTM NAD83 Zone 16N
SOURCE: MNR, obtained 2010-2012
NOEGTS: OGS MRD-160 (scale 1:100,000)
Geology: MRD126-REV1-Bedrock Geology of Ontario, 2011
MOE Wells: Ministry of Environment, 2011
Diamond Drill Holes: OGS MRD 126-Bedrock Geology, 2007
Produced by Geofirma Engineering Ltd under license from
Ontario Ministry of Natural Resources, ©Queens Printer 2011

PROJECT No. 10-214-4

PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, HORNEPAYNE AREA, ONTARIO

TITLE

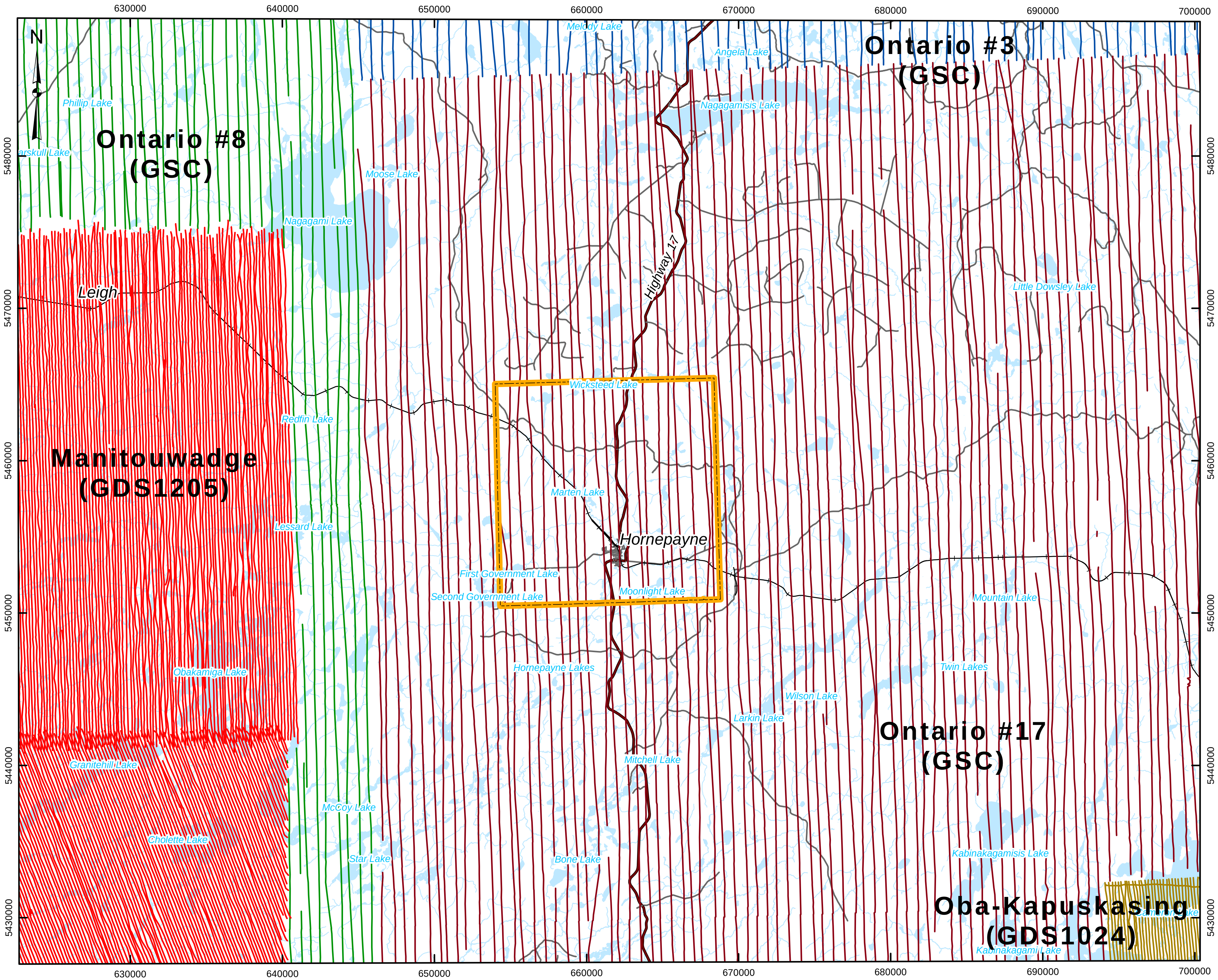
Surficial Geology of the Hornepayne Area

FIGURE 3

DESIGN: NMP
CAD/GIS: NMP/VMS
CHECK: KGR/SNS
REV: 0

DATE: 05/11/2013

Paterson, Grant & Watson Limited
Consulting Geophysicists
www.pgw.on.ca



LEGEND

- Township of Hornepayne
- Highway
- Local Road
- Railway
- Water Area, Permanent
- Watercourse, Permanent
- Watercourse, Intermittent
- Flightpath OGS Manitouwadge
- Flightpath OGS Oba-Kapuskasing
- Flightpath GSC Ontario #3
- Flightpath GSC Ontario #8
- Flightpath GSC Ontario #17

Geofirma Engineering Ltd

SCALE 1:300,000

0 2.5 5 10 15 20

Kilometres

PROJECTION: UTM NAD83 Zone 16N

SOURCE: MNR, Geobase

FLIGHTPATH: OGS GDS1024, GDS 1205
GSC nationwide compilation

PROJECT No. 10-214-4

PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, HORNEPAYNE AREA, ONTARIO

TITLE **Airborne geophysical coverage of the Hornepayne area**

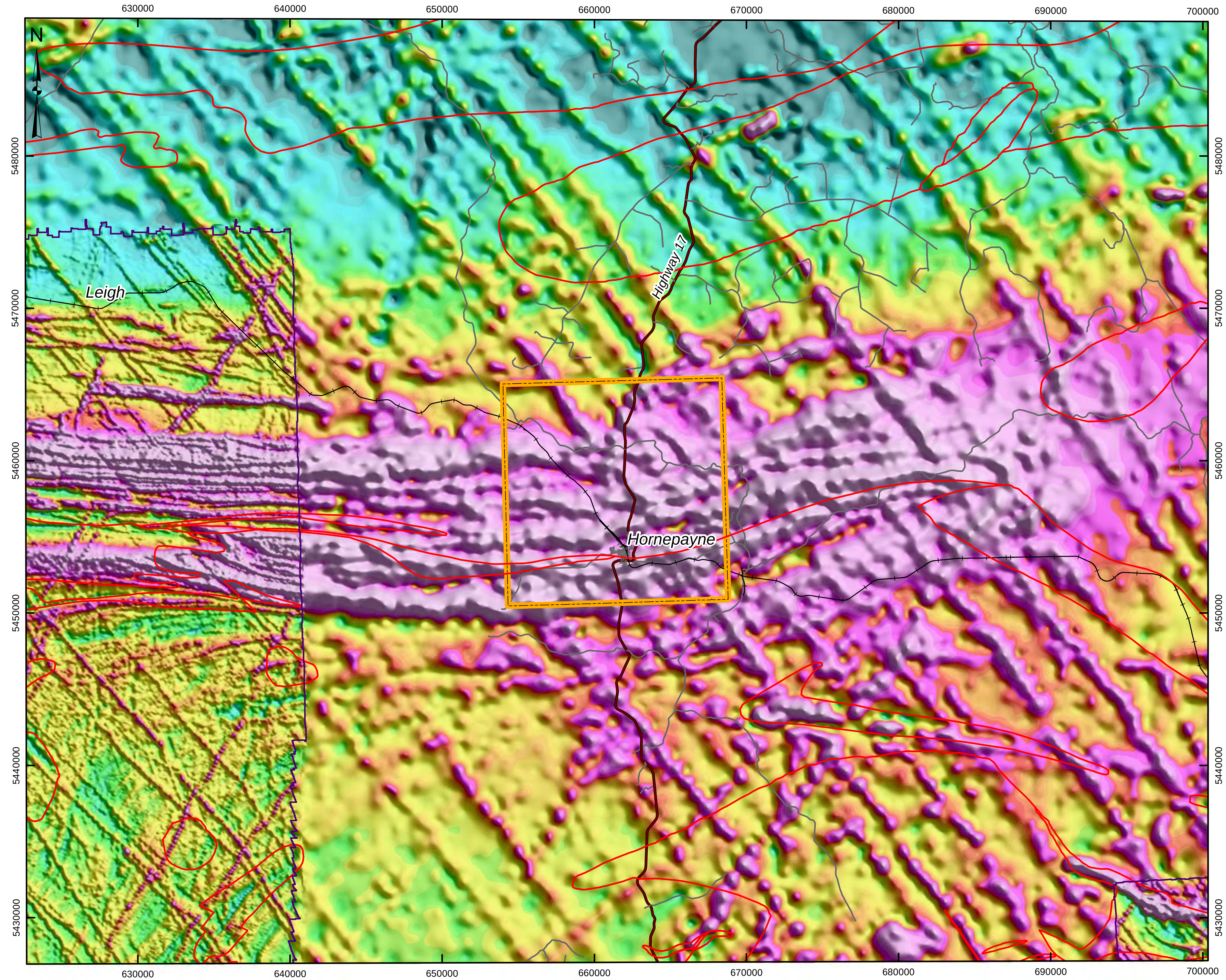
FIGURE 4

DESIGN: SWR
CAD/GIS: SWR
CHECK:ELM/SNS
REV: 0B

DATE: 24/09/2013

Paterson, Grant & Watson Limited
Consulting Geophysicists
www.pgw.on.ca

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Hornepayne\Fig4_PGW_Hornepayne_Flightpath.mxd



LEGEND

- Township of Hornepayne
- Highway
- Local Road
- Railway
- Geophysical Survey Outlines
- Bedrock Geology Contacts

RTP (nT): 2548, 440, 280, 200, 140, 100, 80, 60, 40, 20, 0, -20, -40, -60, -80, -100, -120, -140, -160, -180, -200, -240, -260, -280, -300, -320, -545

Geofirma Engineering Ltd

SCALE 1:300,000

0 2.5 5 10 15 20
Kilometres

PROJECTION: UTM NAD83 Zone 16N
SOURCE: MNR, Geobase
Geology: MRD126-REV1 Bedrock Geology of Ontario, 2011
High-resolution magnetics: OGS GDS1024, GDS 1205
Regional magnetics: GSC nationwide compilation

PROJECT No. 10-214-4

PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, HORNEPAYNE AREA, ONTARIO

TITLE

Residual magnetic field reduced to pole

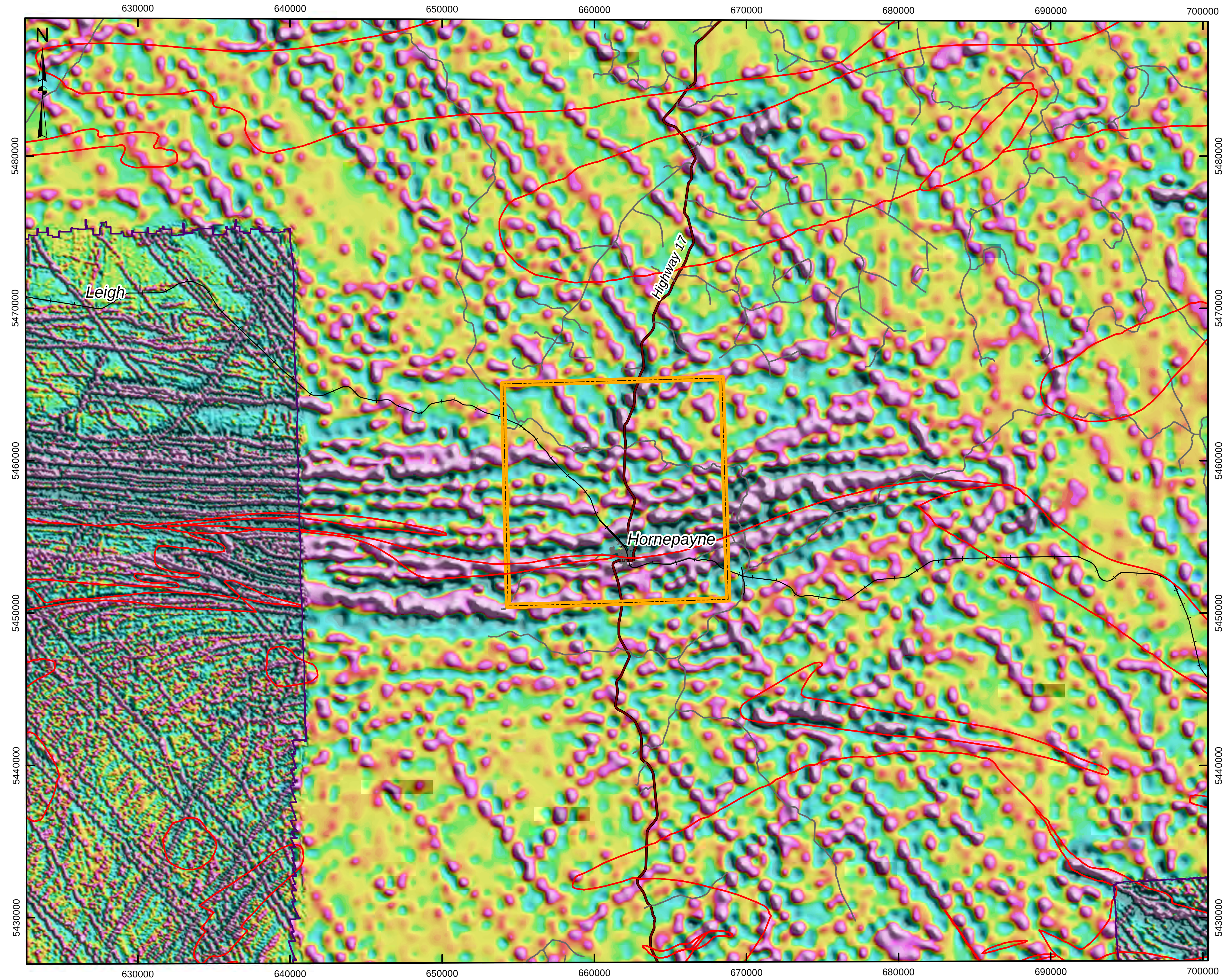
FIGURE 5

DESIGN: SWR
CAD/GIS: SWR
CHECK:ELM/SNS
REV: 0B

DATE: 24/09/2013

Paterson, Grant & Watson Limited
Consulting Geophysicists
www.pgw.on.ca

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Hornepayne\Fig5_PGW_Hornepayne_Mag_RTP.mxd



LEGEND

- Township of Hornepayne
- Highway
- Local Road
- Railway
- Geophysical Survey Outlines
- Bedrock Geology Contacts

35.16
0.64
0.39
0.28
0.21
0.16
0.12
0.09
0.07
0.05
0.03
0.01
0.00
-0.01
-0.02
-0.03
-0.05
-0.06
-0.07
-0.08
-0.10
-0.11
-0.13
-0.16
-0.18
-0.22
-0.27
-0.34
-0.52
-10.85

1VD of RTP
(nT/m)

Geofirma Engineering Ltd

SCALE 1:300,000

0 2.5 5 10 15 20
Kilometres

PROJECTION: UTM NAD83 Zone 16N
SOURCE: MNR, Geobase
Geology: MRD126-REV1 Bedrock Geology of Ontario, 2011
High-resolution magnetics: OGS GDS1024, GDS 1205
Regional magnetics: GSC nationwide compilation

PROJECT No. 10-214-4

PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, HORNEPAYNE AREA, ONTARIO

TITLE

First vertical derivative of the pole reduced magnetic field

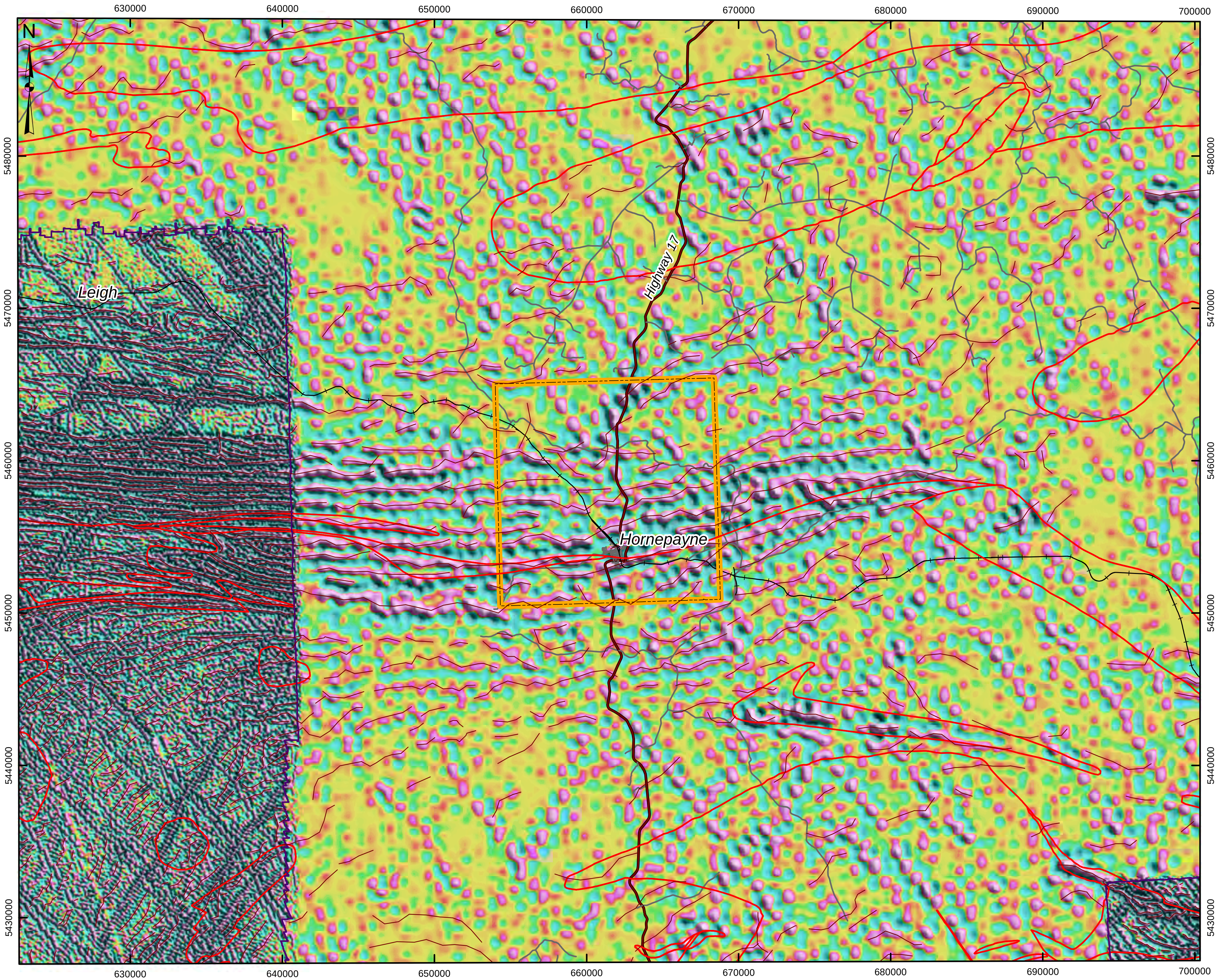
FIGURE 6

DESIGN: SWR
CAD/GIS: SWR
CHECK: ELM/SNS
REV: 0B

DATE: 24/09/2013

Paterson, Grant & Watson Limited
Consulting Geophysicists
www.pgw.on.ca

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Hornepayne\Fig6_PGW_Hornepayne_Mag_RTP_1VD.mxd



LEGEND

- Township of Hornepayne
- Highway
- Local Road
- Railway
- Geophysical Survey Outlines
- Bedrock Geology Contacts
- Magnetic Foliation

0.49134
0.00398
0.00202
0.00132
0.00092
0.00068
0.00050
0.00038
0.00026
0.00018
0.00012
0.00008
0.00002
0.00000
-0.00002
-0.00006
-0.00010
-0.00014
-0.00018
-0.00024
-0.00030
-0.00038
-0.00048
-0.00062
-0.00078
-0.00102
-0.00140
-0.00216
-0.00442
-0.24205

2VD of RTP
(nT/m2)

Geofirma Engineering Ltd

SCALE 1:300,000

0 2.5 5 10 15 20
Kilometres

PROJECTION: UTM NAD83 Zone 16N
SOURCE: MNR, Geobase
Geology: MRD126-REV1 Bedrock Geology of Ontario, 2011
High-resolution magnetics: OGS GDS1024, GDS 1205
Regional magnetics: GSC nationwide compilation

PROJECT No. 10-214-4

PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, HORNEPAYNE AREA, ONTARIO

TITLE **Second vertical derivative of the pole reduced magnetic field with foliation**

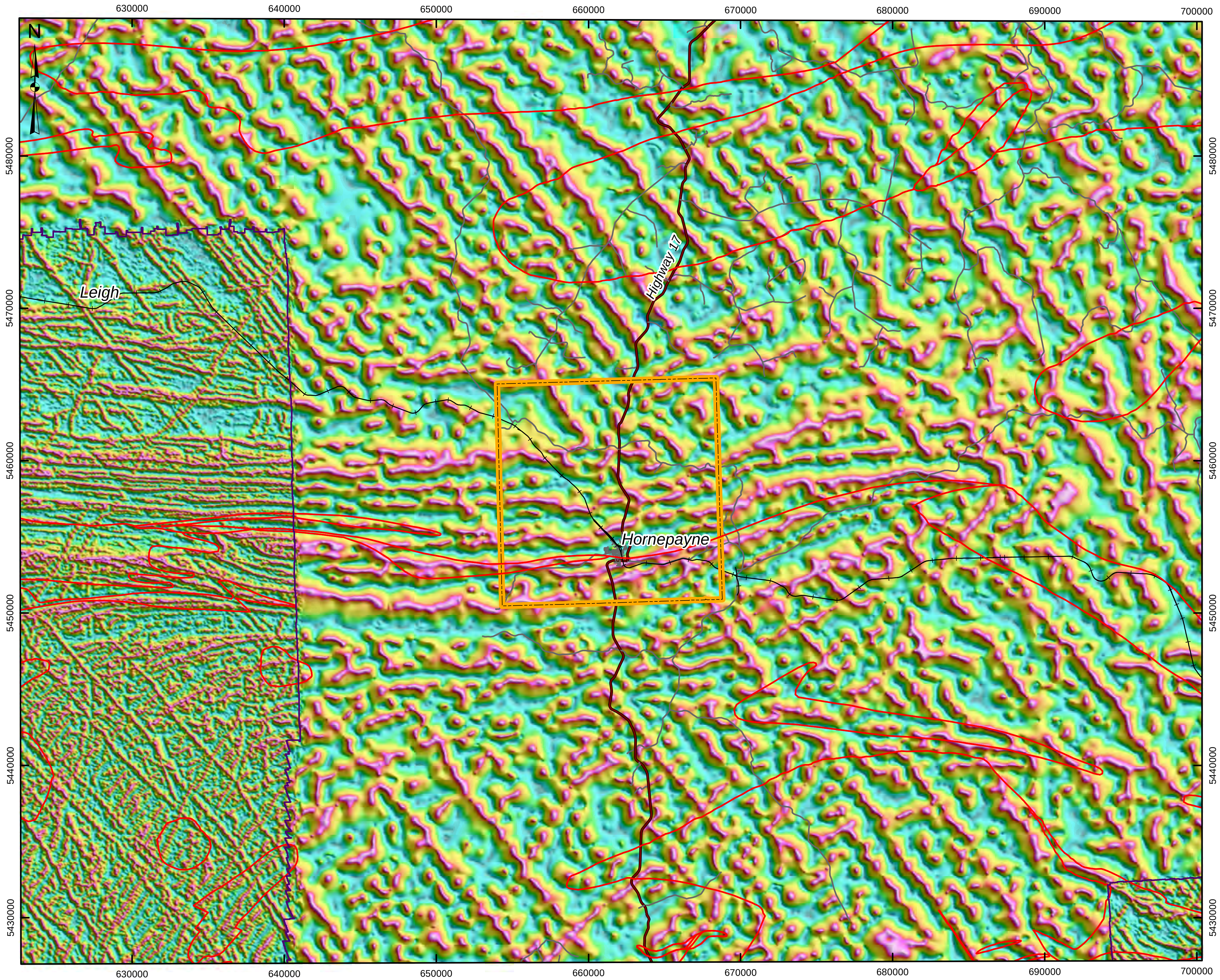
FIGURE 7

DESIGN: SWR
CAD/GIS: SWR
CHECK:ELM/SNS
REV: 0B

DATE: 24/09/2013

Paterson, Grant & Watson Limited
Consulting Geophysicists
www.pgw.on.ca

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Hornepayne\Fig7_PGW_Hornepayne_Mag_RTP_2VD.mxd



LEGEND

- Township of Hornepayne
- Highway
- Local Road
- Railway
- Geophysical Survey Outlines
- Bedrock Geology Contacts

Tilt Angle (radians)

1.57, 1.46, 1.35, 1.25, 1.14, 1.03, 0.92, 0.81, 0.70, 0.60, 0.49, 0.38, 0.27, 0.16, 0.05, -0.05, -0.16, -0.27, -0.38, -0.49, -0.60, -0.70, -0.81, -0.92, -1.03, -1.14, -1.25, -1.35, -1.46, -1.57

Geofirma Engineering Ltd

SCALE 1:300,000

0 2.5 5 10 15 20

Kilometres

PROJECTION: UTM NAD83 Zone 16N
SOURCE: MNR, Geobase
Geology: MRD126-REV1 Bedrock Geology of Ontario, 2011
High-resolution magnetics: OGS GDS1024, GDS 1205
Regional magnetics: GSC nationwide compilation

PROJECT No. 10-214-4

PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, HORNEPAYNE AREA, ONTARIO

TITLE

Tilt angle of the pole reduced magnetic field

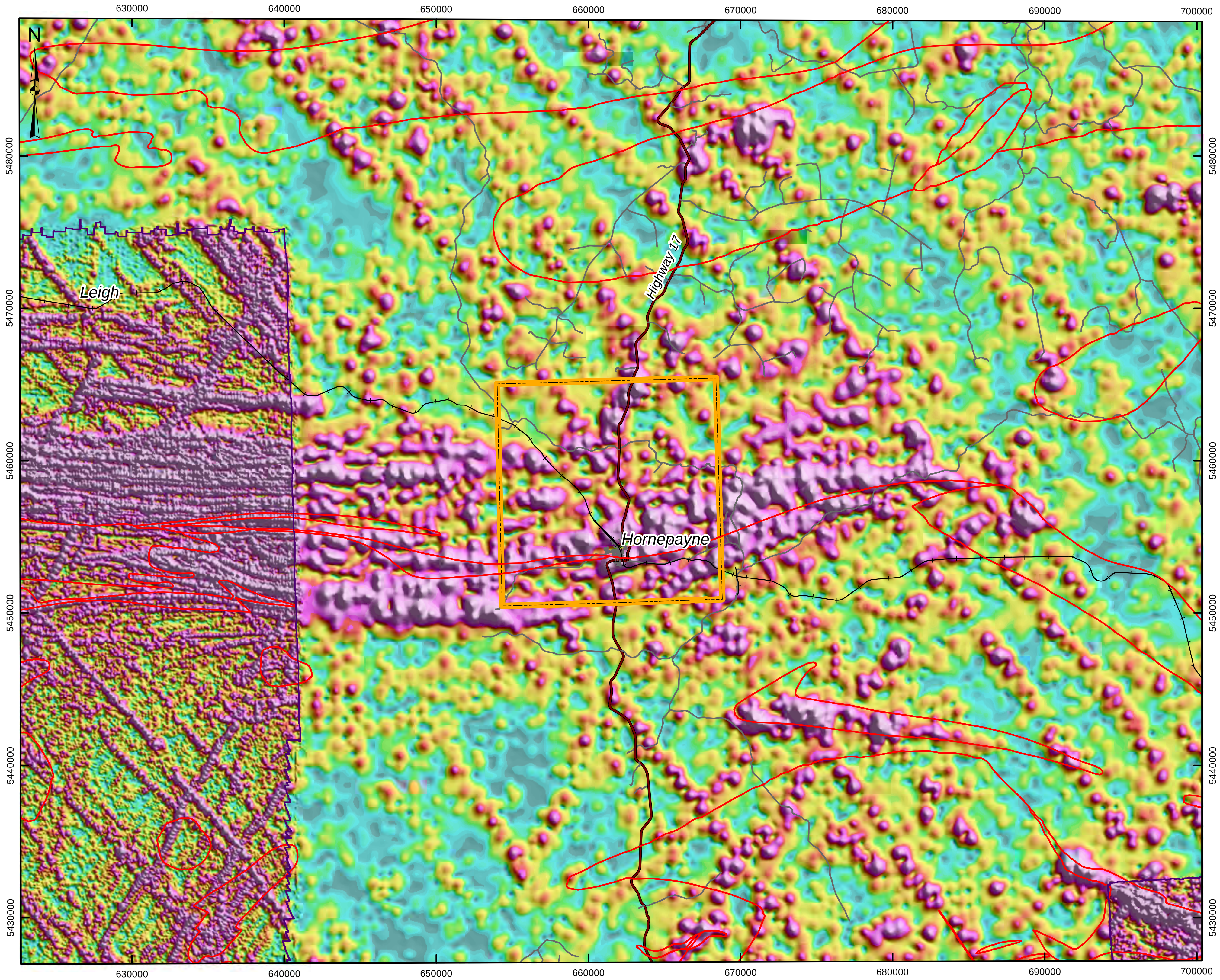
FIGURE 8

DESIGN: SWR
CAD/GIS: SWR
CHECK:ELM/SNS
REV: 0B

DATE: 24/09/2013

Paterson, Grant & Watson Limited
Consulting Geophysicists
www.pgw.on.ca

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Hornepayne\Fig8_PGW_Hornepayne_Mag_RTP_Tilt.mxd



LEGEND

- Township of Hornepayne
- Highway
- Local Road
- Railway
- Geophysical Survey Outlines
- Bedrock Geology Contacts

Analytic Signal (nT/m)
36.13
1.22
0.83
0.65
0.54
0.47
0.41
0.37
0.34
0.31
0.28
0.26
0.24
0.23
0.21
0.20
0.18
0.17
0.16
0.15
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.04
0.00

Geofirma Engineering Ltd

SCALE 1:300,000

0 2.5 5 10 15 20
Kilometres

PROJECTION: UTM NAD83 Zone 16N
SOURCE: MNR, Geobase
Geology: MRD126-REV1 Bedrock Geology of Ontario, 2011
High-resolution magnetics: OGS GDS1024, GDS 1205
Regional magnetics: GSC nationwide compilation

PROJECT No. 10-214-4

PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, HORNEPAYNE AREA, ONTARIO

TITLE
Analytic signal amplitude of the total magnetic field

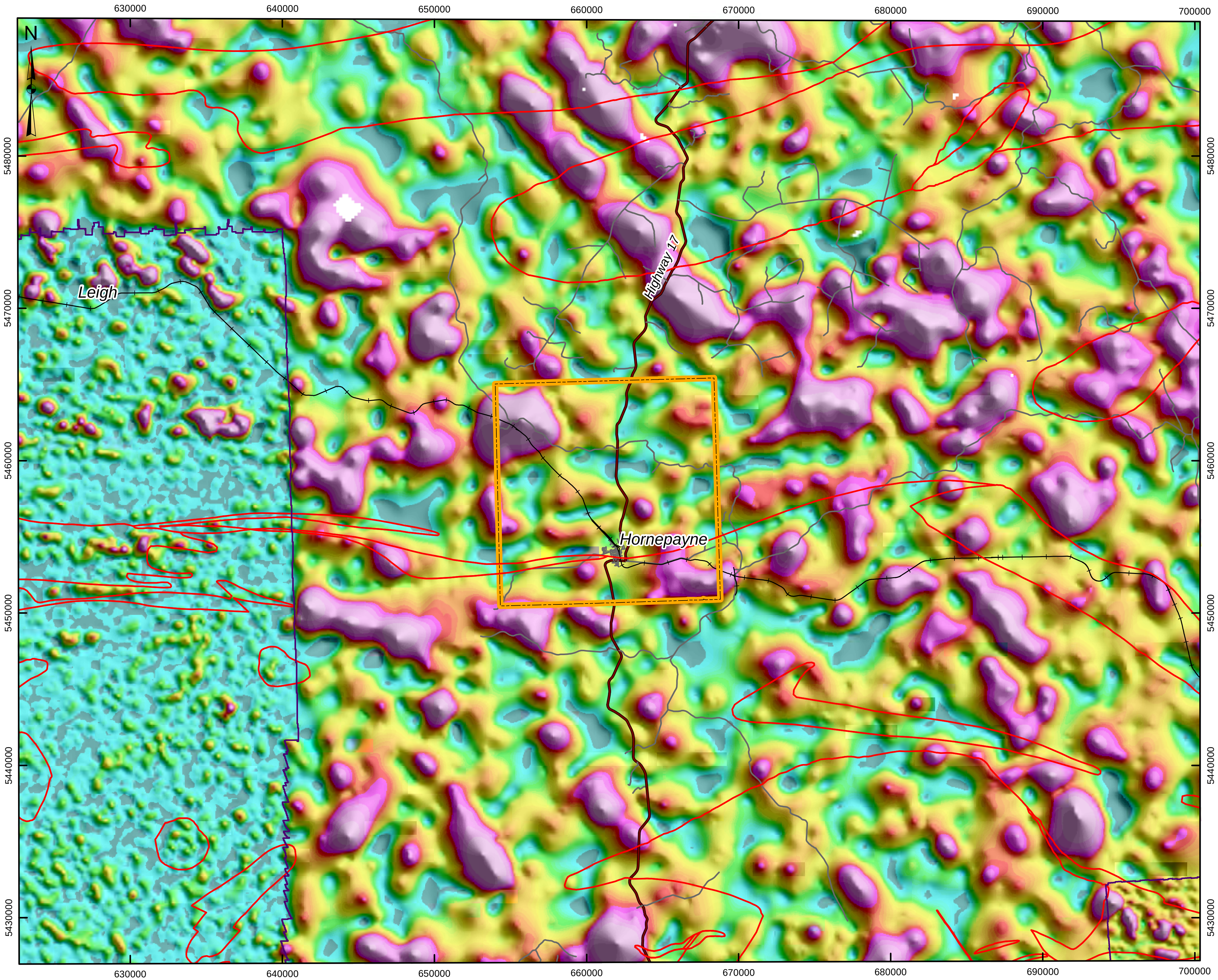
FIGURE 9

DESIGN: SWR
CAD/GIS: SWR
CHECK:ELM/SNS
REV: 0B

DATE: 24/09/2013

Paterson, Grant & Watson Limited
Consulting Geophysicists
www.pgw.on.ca

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Hornepayne\Fig9_PGW_Hornepayne_Mag_ASIG.mxd



LEGEND

- Township of Hornepayne
- Highway
- Local Road
- Railway
- Geophysical Survey Outlines
- Bedrock Geology Contacts

1667
370
270
220
185
165
145
135
120
110
100
90
85
75
70
65
55
50
45
40
35
25
20
15
10
5
0
-232

Depth to Basement
(m below surface)

Geofirma Engineering Ltd

SCALE 1:300,000

0 2.5 5 10 15 20
Kilometres

PROJECTION: UTM NAD83 Zone 16N
SOURCE: MNR, Geobase
Geology: MRD126-REV1 Bedrock Geology of Ontario, 2011
High-resolution magnetics: OGS GDS1024, GDS 1205
Regional magnetics: GSC nationwide compilation

PROJECT No. 10-214-4

PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, HORNEPAYNE AREA, ONTARIO

TITLE

Depth to magnetic sources from source parameter imaging

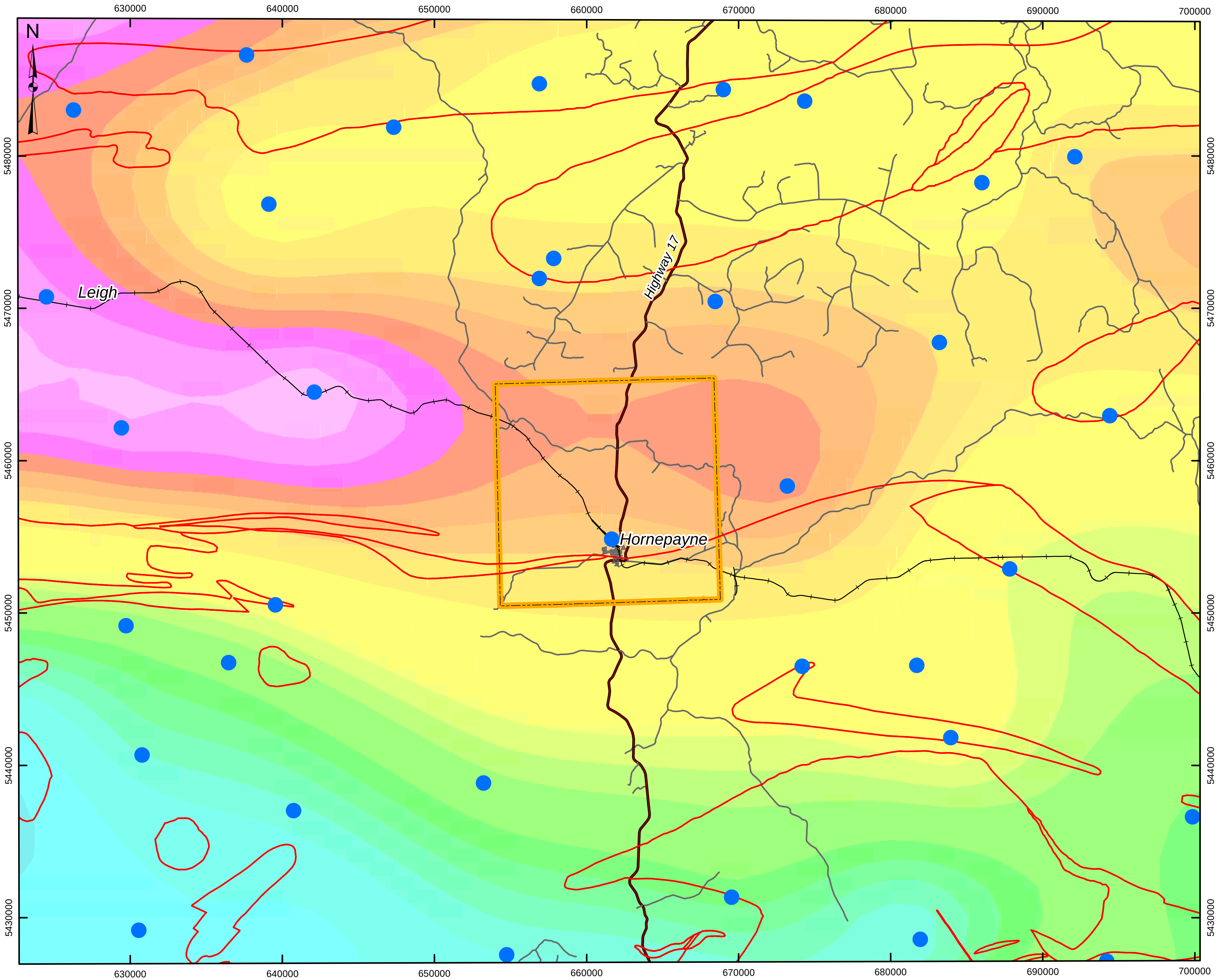
FIGURE 10

DESIGN: SWR
CAD/GIS: SWR
CHECK: ELM/SNS
REV: 0B

DATE: 24/09/2013

Paterson, Grant & Watson Limited
Consulting Geophysicists
www.pgw.on.ca

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Hornepayne\Fig10_PGW_Hornepayne_Mag_SPIDepth.mxd



LEGEND

- Township of Hornepayne
- Highway
- Local Road
- Railway
- Bedrock Geology Contacts
- Gravity Stations

Bouguer Gravity (mGal)

-38, -40, -42, -43, -44, -45, -46, -47, -48, -49, -50, -51, -52, -53, -54, -55, -56, -58, -59, -60, -61, -62, -64, -66, -68, -70, -74

Geofirma Engineering Ltd

SCALE 1:300,000

0 2.5 5 10 15 20

Kilometres

PROJECTION: UTM NAD83 Zone 16N

SOURCE: MNR, Geobase
Geology: MRD126-REV1 Bedrock Geology of Ontario, 2011
Gravity: Geological Survey of Canada nationwide compilation

PROJECT No. 10-214-4

PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, HORNEPAYNE AREA, ONTARIO

TITLE

Bouguer gravity field with station locations

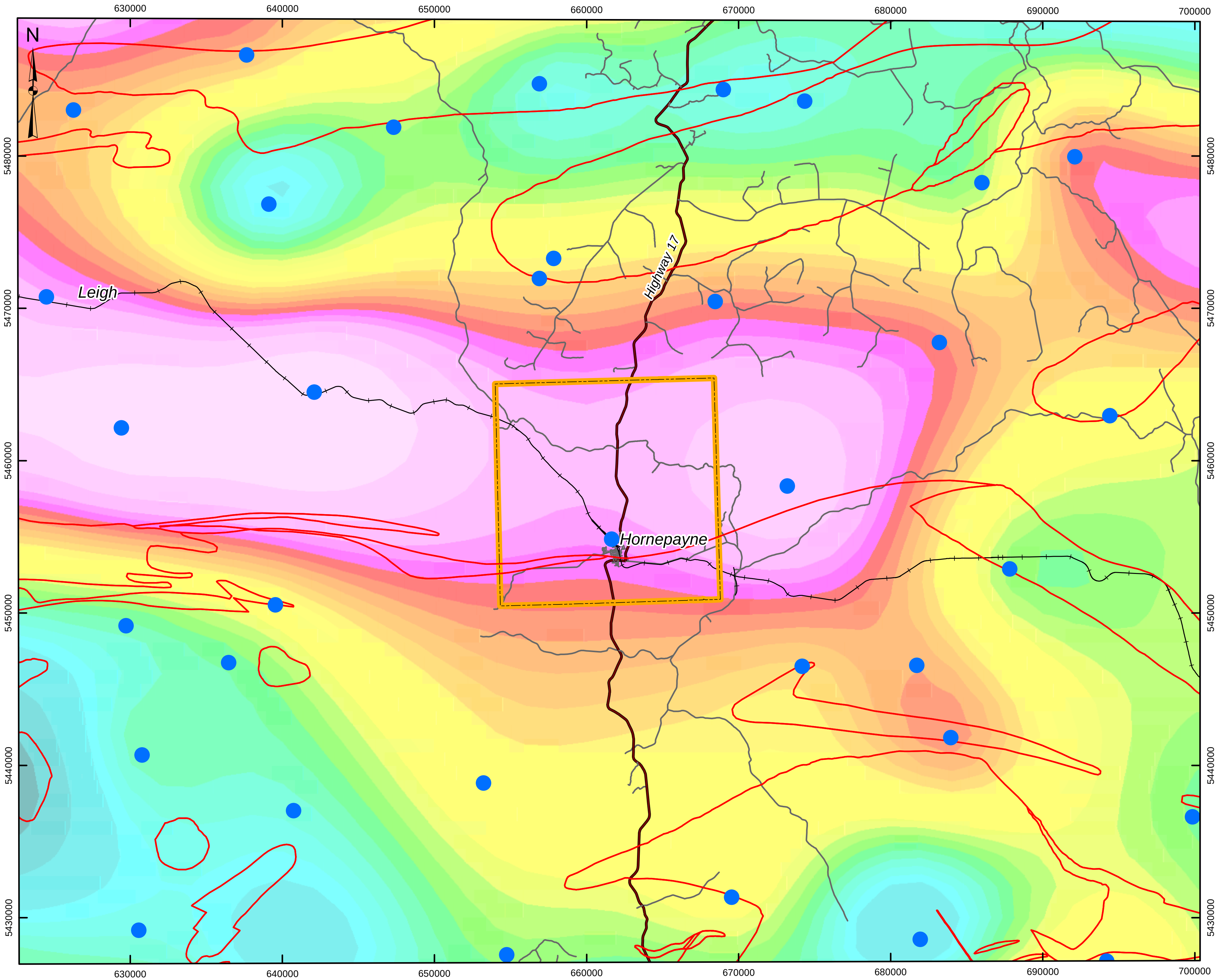
FIGURE 11

DESIGN: SWR
CAD/GIS: SWR
CHECK:ELM/SNS
REV: 0B

DATE: 24/09/2013

Paterson, Grant & Watson Limited
Consulting Geophysicists
www.pgw.on.ca

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Hornepayne\Fig11_PGW_Hornepayne_Grav_Boug.mxd



LEGEND

- Township of Hornepayne
- Highway
- Local Road
- Railway
- Bedrock Geology Contacts
- Gravity Stations

0.00183
0.00060
0.00045
0.00035
0.00030
0.00025
0.00020
0.00015
0.00010
0.00005
0.00000
-0.00005
-0.00010
-0.00015
-0.00020
-0.00025
-0.00030
-0.00035
-0.00040
-0.00045
-0.00050
-0.00055
-0.00060
-0.00075
-0.00090
-0.00147

1VD of BG
(mGal/m)

Geofirma Engineering Ltd

SCALE 1:300,000

0 2.5 5 10 15 20

Kilometres

PROJECTION: UTM NAD83 Zone 16N

SOURCE: MNR, Geobase
Geology: MRD126-REV1 Bedrock Geology of Ontario, 2011
Gravity: Geological Survey of Canada nationwide compilation

PROJECT No. 10-214-4

PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, HORNEPAYNE AREA, ONTARIO

TITLE **First vertical derivative of the Bouguer gravity field with station locations**

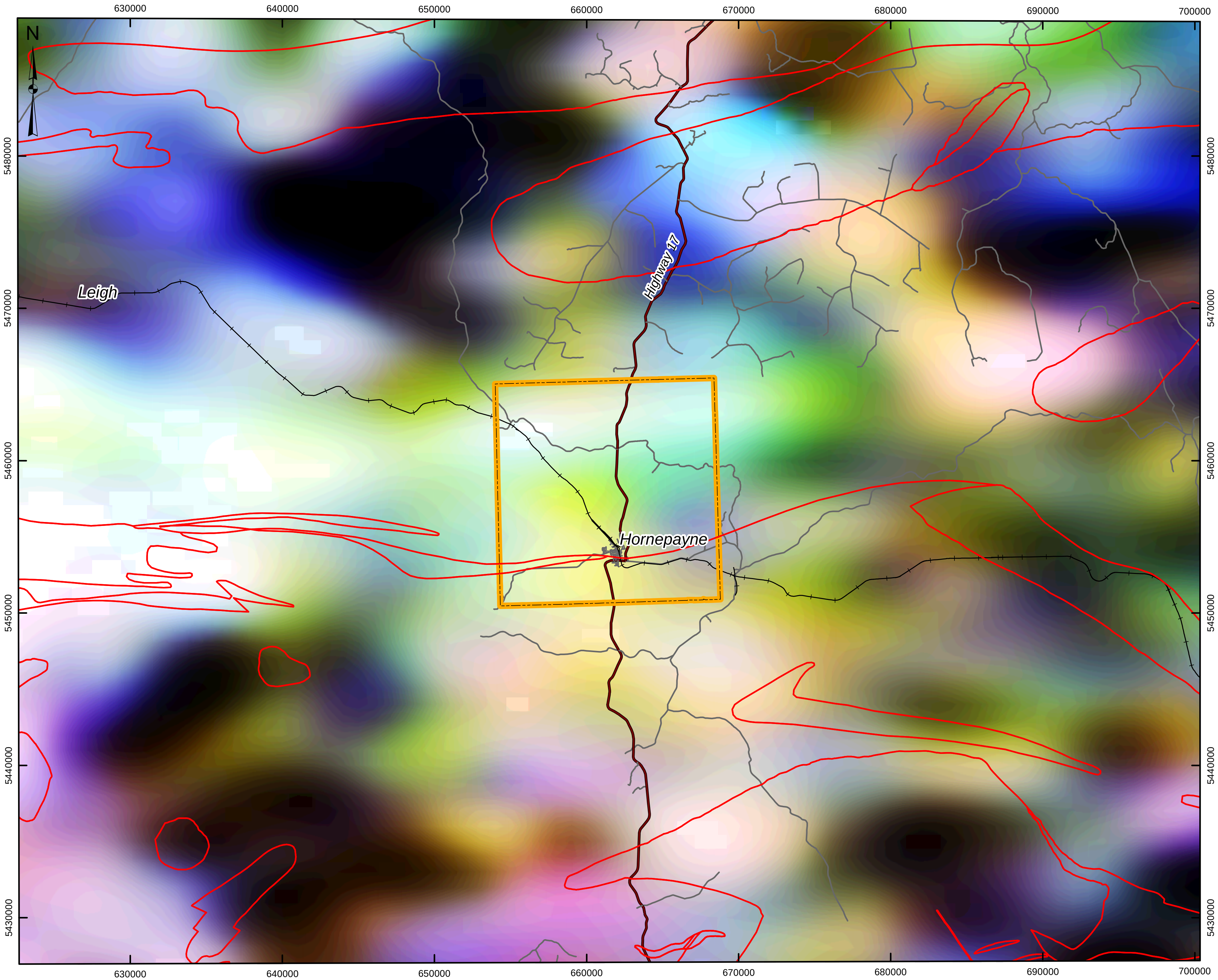
FIGURE 12

DESIGN: SWR
CAD/GIS: SWR
CHECK:ELM/SNS
REV: 0B

DATE: 24/09/2013

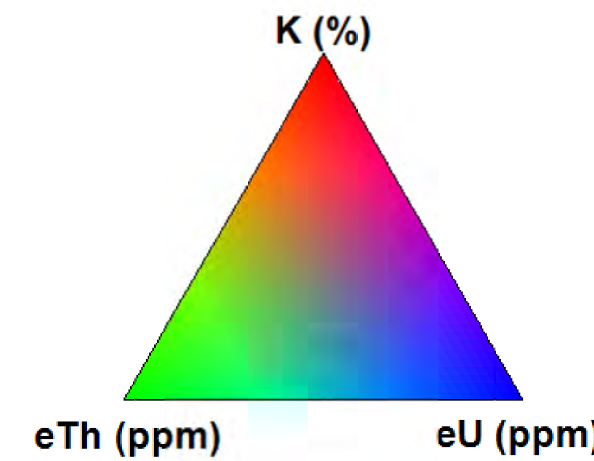
Paterson, Grant & Watson Limited
Consulting Geophysicists
www.pgw.on.ca

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Hornepayne\Fig12_PGW_Hornepayne_Grav_Boug_1VD.mxd



LEGEND

- Township of Hornepayne
- Highway
- Local Road
- Railway
- Bedrock Geology Contacts



Geofirma Engineering Ltd

SCALE 1:300,000

0 2.5 5 10 15 20

Kilometres

PROJECTION: UTM NAD83 Zone 16N

SOURCE: MNR, Geobase
Geology: MRD126-REV1 Bedrock Geology of Ontario, 2011
Radiometrics: Geological Survey of Canada nationwide compilation

PROJECT No. 10-214-4

PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, HORNEPAYNE AREA, ONTARIO

TITLE

Radiometric ternary image (RGB = K-eTh-eU)

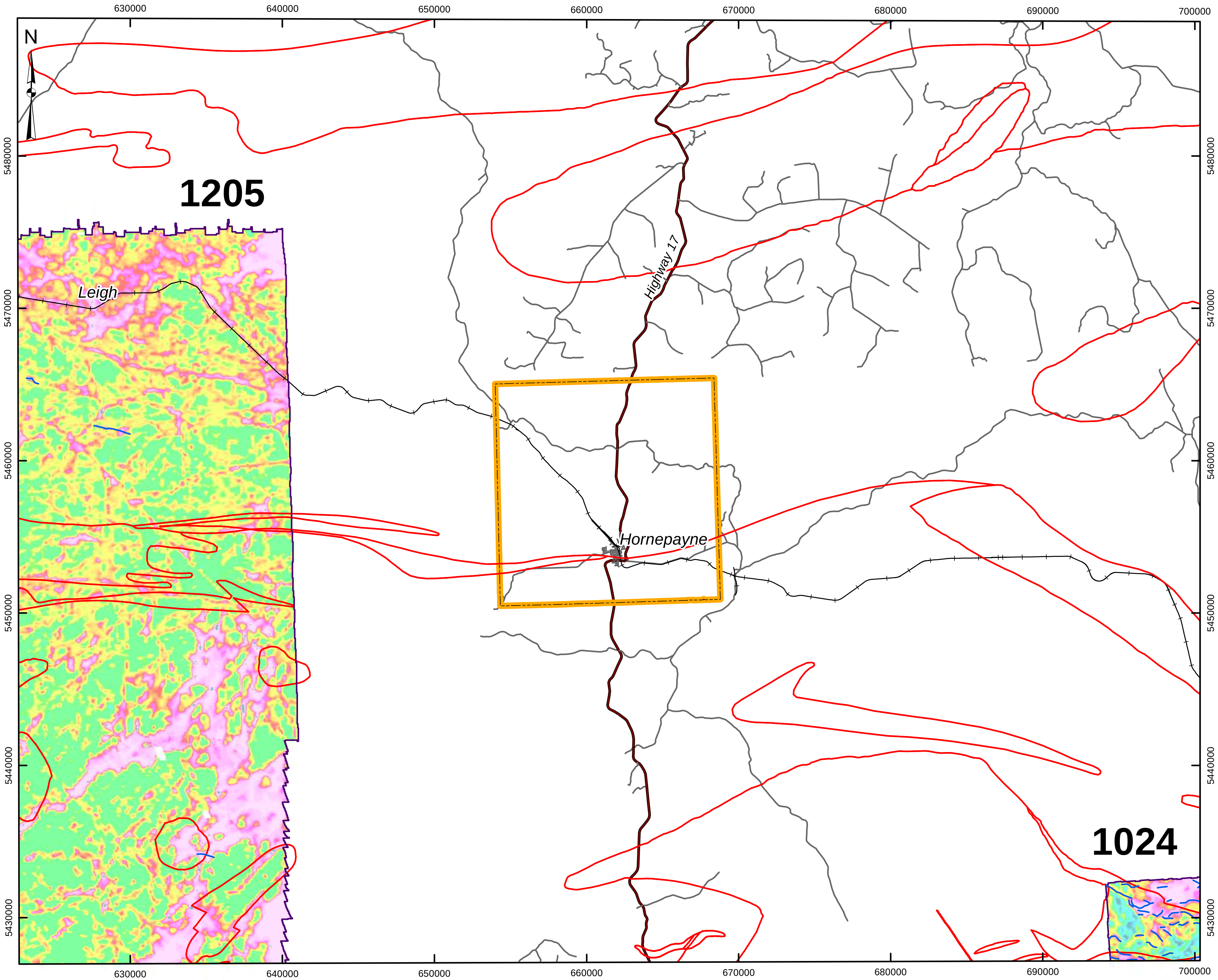
FIGURE 13

DESIGN: SWR
CAD/GIS: SWR
CHECK: ELM/SNS
REV: 0B

DATE: 24/09/2013

Paterson, Grant & Watson Limited
Consulting Geophysicists
www.pgw.on.ca

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Hornepayne\Fig13_PGW_Hornepayne_Rad_Ternary.mxd



LEGEND

- Township of Hornepayne
- Highway
- Local Road
- Railway
- Bedrock Geology Contacts
- Geophysical Survey Outlines
- EM Conductors

1205 - Conductivity (S/m)	1024 - Conductivity (S/m)
27.32478	0.04955
0.00317	0.00726
0.00176	0.00590
0.00106	0.00506
0.00074	0.00442
0.00060	0.00394
0.00050	0.00352
0.00044	0.00316
0.00039	0.00286
0.00036	0.00258
0.00032	0.00232
0.00029	0.00210
0.00027	0.00188
0.00025	0.00170
0.00023	0.00154
0.00021	0.00138
0.00019	0.00124
0.00017	0.00110
0.00016	0.00098
0.00015	0.00088
0.00014	0.00078
0.00013	0.00068
0.00012	0.00058
0.00011	0.00048
0.00010	0.00040
0.00009	0.00032
0.00008	0.00026
0.00007	0.00020
0.00006	0.00018
-49.94486	0.00017

Geofirma Engineering Ltd

SCALE 1:300,000

0 2.5 5 10 15 20

Kilometres

PROJECTION: UTM NAD83 Zone 16N

SOURCE: MNR, Geobase
Geology: MRD126-REV1 Bedrock Geology of Ontario, 2011
Electromagnetics: : OGS GDS1024, GDS 1205

PROJECT No. 10-214-4

PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, HORNEPAYNE AREA, ONTARIO

TITLE **EM conductors over apparent conductivity (GDS1024 and GDS 1205)**

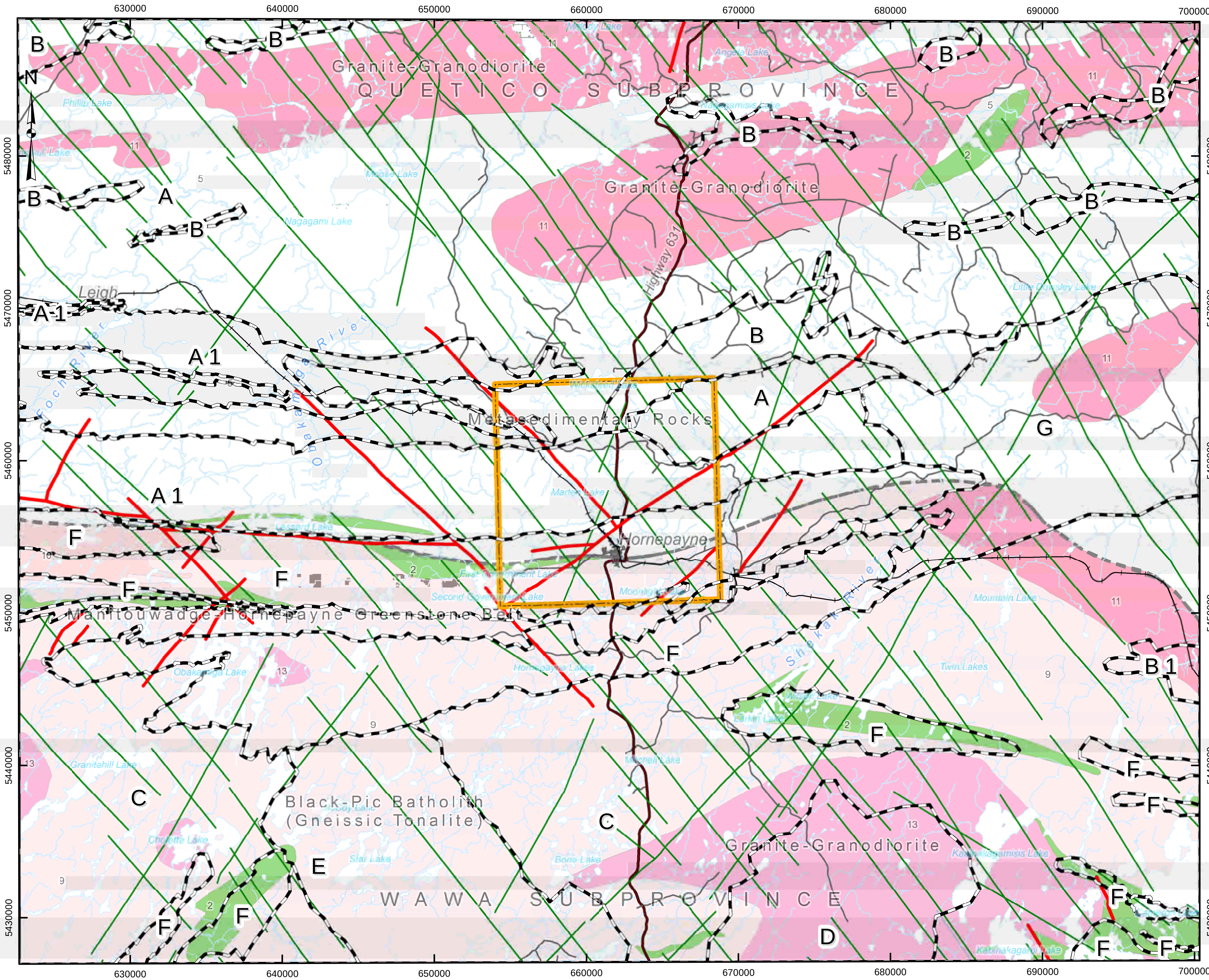
FIGURE 14

DESIGN: SWR
CAD/GIS: SWR
CHECK:ELM/SNS
REV: 0B

DATE: 24/09/2013

Paterson, Grant & Watson Limited
Consulting Geophysicists
www.pgw.on.ca

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Hornepayne\Fig14_PGW_Hornepayne_EM_Cond.mxd



LEGEND

- Township of Hornepayne
- Highway
- Local Road
- Railway
- Water Area, Permanent
- Watercourse, Permanent
- Watercourse, Intermittent
- Mapped Geological Fault
- Mapped Dyke
- Subprovince Boundary

Bedrock Geology

- 13 Granite-granodiorite, massive to foliated
- 11 Granite-granodiorite, muscovite/biotite bearing
- 10 Foliated tonalite suite
- 9 Gneissic tonalite suite
- 5 Metasedimentary rocks
- 2 Mafic volcanic rocks
- Geologic units interpreted from geophysics

Geofirma Engineering Ltd

SCALE 1:300,000

0 2.5 5 10 15 20
Kilometres

PROJECTION: UTM NAD83 Zone 16N
SOURCE: MNR, Geobase
Geology: MRD126-REV1 Bedrock Geology of Ontario, 2011
Johns, G.W. and McIlraith, S. 2003.
Precambrian bedrock geology compilation series. Ontario Geological Survey, Map 2668, scale 1:250,000, Santaguida, F. 2002.
Precambrian geology compilation series – White River sheet. Ontario Geological Survey, Map 2668, scale 1:250,000
Produced by Geofirma Engineering Ltd under license from Ontario Ministry of Natural Resources, ©Queens Printer 2011

PROJECT No. 10-214-4

PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, HORNEPAYNE AREA, ONTARIO

TITLE

Geophysical interpretation showing distribution of bedrock units for the Hornepayne Area

FIGURE 15

DESIGN: NMP
CAD/GIS: SWR
CHECK: DJM
REV: 0B

DATE: 16/10/2013

Paterson, Grant & Watson Limited
Consulting Geophysicists
www.pgw.on.ca

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Hornepayne\Oct_2013\Fig15_PGW_Hornepayne_Interpretation.mxd