NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

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

TOWNSHIP OF IGNACE, ONTARIO

APM-REP-06144-0013

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PHASE 1 - DESKTOP GEOSCIENTIFIC PRELIMINARY ASSESSMENT

PROCESSING AND INTERPRETATION OF GEOPHYSICAL DATA

Township of Ignace, Ontario

Prepared for

Golder Associates
and
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by

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EXECUTIVE SUMMARY

In November 2011, the Township of Ignace, 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 Ignace 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 Ignace and its periphery, referred to as the "Ignace 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 Ignace area (Golder, 2013). 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 Ignace area, Ontario. The aim is 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 Ignace area.

The geophysical data covering the Ignace area show variability in resolution. Low-resolution magnetic, gravity and radiometric data obtained from the Geological Survey of Canada (GSC) cover the entire Ignace area. Three higher resolution magnetic/electromagnetic surveys were obtained from the Ontario Geological Survey (OGS) covering approximately one third of the Ignace area (northwest and small parts of the northeast and southeast corners of the Ignace area). A fourth high-resolution survey (magnetic and radiometric data) covering a small portion in the north part of the Ignace area, was obtained from an assessment file provided by the OGS.

The coincidence between the geophysical data and the mapped lithology and structural features was interpreted using all available geophysical data sets (e.g., magnetic, electromagnetic, gravity and radiometric). In general the coincidence between the interpretation of aeromagnetic data and the published geological maps is in good agreement. In the Revell batholith, where higher resolution data is available, the interpretation of aeromagnetic data allowed to identify internal intrusive phases, most of which are in good agreement with the available detailed geological mapping. The interpretation of gravity data identified large negative gravity anomalies in the Basket Lake and White Otter Lake batholiths, which may be indicative of significant thicknesses for these units. The northern portion of the Basket Lake batholith has been estimated to be at least 8 km thick (Szewczyk and West 1976).

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1 INTRODUCTION

In November 2011, the Township of Ignace, 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 Ignace 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 interpretation assessment completed as part of the desktop geoscientific preliminary assessment of the Ignace area (Golder, 2013). The objective of the desktop geoscientific preliminary assessment is to determine whether the Ignace area contains general areas that have the potential to meet NWMO's geoscientific site evaluation factors. The assessment focused on the Township of Ignace and its periphery, referred to as the "Ignace area".

1.1 Objective

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 general potentially suitable areas.

The purpose of this assessment was to perform a review of available geophysical data for the Ignace 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 Ignace 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 Ignace 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 glacial sediments, such as in the Ignace 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 Ignace Area

The Ignace area (6,200 km^2) incorporates the Township of Ignace (100 km^2) and surrounding areas as shown on Figure 1. It is situated in the District of Kenora in northwestern Ontario. The settlement area of Ignace is situated on the north shore of Lake Agimak, approximately 250 km northwest of Thunder Bay and 110 km southeast of Dryden.

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 of potential suitability for the Ignace area consisted of qualified experts from Paterson, Grant & Watson Limited (PGW). The personnel assigned to this assessment were as follows:

Dr. D. James Misener, Ph.D., P.Eng. – geophysical interpretation, report preparation

Dr. Misener is President of PGW and a senior geophysicist with 37 years of experience in all aspects of geophysics and geophysics software applications. Dr. Misener founded Geosoft Inc. and led its development of world-leading geosciences software applications until he succeeded Dr. Paterson as President of PGW. He has directed implementation of geophysical data processing systems; initiated and managed major continental scale compilations of aeromagnetic/marine magnetic data in North America and worldwide including interpretation of aeromagnetic, radiometric, gravity and electromagnetic surveys in; Algeria, Brazil, Cameroon, Niger, Ivory Coast, Zimbabwe, Malawi, Kenya, China, Suriname, and Ireland.

Stephen Reford, B.A.Sc., P.Eng. – project management, EM 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-Markham, M.Sc. – data processing and map preparation

Ms. Mueller-Markham 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

A detailed discussion of the geological setting of the Ignace area, including bedrock geology and structural history, is provided in a separate report (Golder, 2013), and a summary is presented below.

The Ignace area is underlain by Archean bedrock of the Superior Province of the Canadian Shield – a tectonically stable craton created from a collage of ancient plates and accreted juvenile arc terranes (Card and Ciesielski, 1986; Percival and Easton, 2007). The Superior Province covers an area of approximately 1,500,000 km^2 stretching from the Ungava region of northern Québec through the northern part of Ontario and the eastern portion of Manitoba, and extending south through to Minnesota and the northeastern part of South Dakota. The Superior Province has been divided into various regionally extensive east-northeast-trending subprovinces based on lithology, age and metamorphism. The Superior Province has also been subdivided in recent years into lithotectonic terranes and domains (Percival and Easton, 2007; Stott et al., 2010). Terranes are defined as tectonically bounded regions with characteristics distinct from adjacent regions prior to their accretion into the Superior Province, while domains refer to lithologically distinct portions within a terrane (Stott et al., 2010).

The Ignace area is situated in the central portion of the Wabigoon Subprovince, which is characterized by thin, bifurcated and anastomosing greenstone belts separated by large, commonly oval-shaped masses of felsic plutonic rocks (Figures 2 and 3). The Wabigoon Subprovince is about 900 km long and 150 km wide and bounded by the Winnipeg River Subprovince to the northwest, the English River Subprovince to the northeast, and the Quetico Subprovince to the south (Blackburn et al., 1991). The Wabigoon Subprovince is further subdivided into three lithotectonic terranes: the granitoid Marmion terrane, the predominantly volcanic Western Wabigoon terrane, and the plutonic Winnipeg River terrane. The Ignace area includes portions of all three terranes. The boundaries between lithotectonic terranes are not sharply defined due to the emplacement of younger plutonic rocks at places along the inferred terrane boundaries (Stone, 2010a).

The following sections on Physical Geography, Bedrock Geology, Structural History, Quaternary Geology and Land Use, present summaries of the information presented in Golder (2013) and JDMA (2013a,b) where applicable, in order to provide the necessary context for discussion of the results of this geophysical interpretation).

2.1 Physical Geography

A detailed discussion of the physical geography of the Ignace area is provided in a separate terrain analysis report (JDMA, 2013a), and the following is a summary of that information. The Ignace area exhibits topographic and drainage features that are characteristic of the Canadian Shield physiographic region, a low-relief, dome-like, gently undulating land surface. Topography in the Ignace area is generally subdued due to infilling with unconsolidated deposits and prolonged erosion but portions are rugged and hilly with roughly 192 m of relief variation (from the SRTM digital elevation model), ranging from a minimum elevation of 368 m to a maximum elevation of 554 m across the Ignace area. Topographic highs generally correspond to bedrock outcrops, while topographic lows are generally areas of thicker overburden. Exposed bedrock covers roughly 2,340 km^2 (38%) of the Ignace area (Figure 4).

The Ignace area contains a large number of lakes of various sizes, twenty-seven of which are larger than 10 km^2 and ten of which are larger than 20 km^2, with approximately 18% (1,115 km^2) of the entire area occupied by water bodies (JDMA, 2013a). The large lakes are sufficiently large to conceal geological structures up to about ten kilometres in length, and nests of lakes have additional potential to conceal structures, especially when the lakes are located in areas where lineaments are obscured by overburden deposits (see also Section 2.4). There is considerable relief between the lakes in most areas.

2.2 Bedrock Geology

The bedrock geology of the Ignace area is described in detail in Golder (2013), and the following is a summary of that information. The bedrock geology of the Ignace area is dominated by a number of granitic to granodioritic batholiths (Stone, 2010a). These large rock masses intruded into the metavolcanic and metasedimentary supracrustal rocks of the Raleigh Lake and Bending Lake greenstone belts, and to a lesser extent the Phyllis

Lake greenstone belt, as well as an older assemblage of foliated and/or gneissic tonalites. The regional-scale distribution of the geological units (1:250,000) mapped by the OGS are shown in Figure 2. Six additional detailed geological map tiles (1:50,000) have been superimposed on the OGS regional bedrock geology map and are presented in Figure 3. The initial screening report for the Ignace area (Golder, 2011) identified a number of geological units with geoscientific characteristics that are potentially suitable for hosting a deep geological repository within the Ignace area. These units include the Indian Lake batholith, as well as the White Otter Lake and Revell batholiths. The bedrock of the Ignace area exhibits evidence of both ductile and brittle deformation and is transected by at least two suites of undeformed diabase dykes.

2.2.1 Intrusive Rocks

The Indian Lake batholith (approximately 2.671 billion years old; Tomlinson et al., 2004) is composed of medium- to coarse-grained, massive to weakly foliated, light grey-white to pale pink biotite granite. Available detailed geological mapping of the Indian Lake batholith suggests that the majority of this body is compositionally uniform (Stone et al., 2007b). The batholith measures approximately 55 km in length from west to east and 25 km from north to south within the Ignace area. It underlies the Township of Ignace and extends beyond the township boundaries for a considerable distance to the east, covering a total surface area of approximately 1,600 km^2 (Figures 2 and 3). The Indian Lake batholith is bounded by the Raleigh Lake greenstone belt along its southwestern and southernmost margins and elsewhere by gneissic tonalite (Figure 3).

The White Otter Lake batholith (approximately 2.685 billion years old; Davis, 1993) is composed of medium- to coarse-grained, light grey-white to pink biotite granite. Available detailed geological mapping of the White Otter Lake batholith suggests that the majority of this body is compositionally uniform (Stone et al., 2007a). The batholith measures approximately 65 km in length from west to east and 20 km from north to south within the Ignace area. The batholith continues for a considerable distance to the south beyond the Ignace area boundary. The White Otter Lake batholith is bounded by the Raleigh Lake and Bending Lake greenstone belts as well as gneissic tonalite along its northwestern and northern margins and elsewhere primarily by gneissic tonalite (Figure 3).

The Revell batholith is an elongate northwest trending pluton extending 40 km in length and 10 to 15 km in width. The Revell batholith is a compositionally heterogeneous igneous body with distinct and internally mappable early, intermediate and late phases (Stone et al., 2007a; Stone et al., 2011a; 2011b). The earliest phase of the Revell batholith is an oval-shaped body of biotite tonalite (approximately 2.734 billion years old; Stone et al., 2011b) exposed primarily in the southeastern corner and along the western margin of the batholith (Figure 3). An intermediate phase identified as hornblende tonalite (approximately 2.732 billion years old; Stone et al., 2011a; 2011b) is mapped along its southwestern and northeastern margins. The late phase of the Revell batholith is characterized generally as a biotite granodiorite to granite and also includes potassium-feldspar megacrystic biotite granite. A sample of the megacrystic facies, from the centre of the Revell batholith, yielded an age of approximately 2.694 billion years old (Buse et al., 2010; Stone et al., 2011a). The Revell batholith is surrounded by the Raleigh Lake and Bending Lake greenstone belts.

An additional large igneous body, the Basket Lake batholith, is exposed in the northwestern corner of the Ignace area (Figure 3). The Basket Lake batholith measures approximately 10 to 15 km in width from southwest to northeast and 35 km in length from northwest to southeast. Almost half of this batholith extends beyond the Ignace area to the northwest. The Basket Lake batholith has a granodioritic to quartz-monzonitic composition (Stott, 1973; Sage et al., 1974). Although no direct age determination is available for this batholith, Szewczyk and West (1976) interpret the existence of a weak foliation defined by aligned biotite and a fine- to medium-grained character to suggest that it experienced some degree of ductile deformation. This suggests that the Basket Lake batholith pre-dates the intrusion of the White Otter Lake and Indian Lake batholiths, as well as the late phase of the Revell batholith.

The Ignace area hosts a number of additional, smaller felsic to intermediate plutons such as the Islet and Paddy Lake plutons in the southwestern corner of the Ignace area, the Adele Lake and Norway plutons in the southeastern corner of the Ignace area, the Melgund Lake stock in the northwest corner of the Ignace area, and the Raleigh Lake intrusions in the center of the Ignace area (Figure 3). The Islet pluton is compositionally heterogeneous, predominated by coarse-grained, grey to pink, and massive diorite to monzonite with local mafic phases as well as granitic units around its margins. It is considered to be a member of the sanukitoid suite of late intrusive rocks, and has a potential association with gold and platinum group metal mineralization (Stone, 2009a). No direct age determinations have been documented for the Islet pluton, however sanukitoid plutons cross-cut most other lithologies and show a narrow range of ages from approximately 2.697 to 2.684 billion years old (Stone, 2010a). The Paddy Lake pluton is composed of coarse-grained and strongly banded biotite tonalite. A high degree of strain within the pluton fabric precludes a precise interpretation of its origin as either a product of magmatic processes or a strongly deformed arkosic sedimentary rock (Stone, 2009b). No direct age determinations have been documented for the Paddy Lake pluton. The Adele Lake pluton is a compositionally heterogeneous rock mass with distinct, and internally mappable, phases (Stone et al., 2007a and 2007b). The predominant phase is biotite tonalite to granodiorite, which is locally gneissic (approximately 2.989 billion years old; Tomlinson et al., 2001). Additional phases include tonalite to granodiorite gneiss and hornblende tonalite (approximately 2.721 billion years old; Tomlinson et al., 2001). The Norway pluton (approximately 2.690 billion years old; Stone, 2010a) and the Melgund Lake stock are additional examples of the compositionally heterogeneous sanukitoid suite described above. The Raleigh Lake intrusions comprise three epizonal granitic stocks enclosed within the metavolcanic rocks of the Raleigh Lake greenstone belt (Figure 3). These small bodies are compositionally similar to the large granodioritic to granitic batholiths that dominate the Ignace area.

The majority of the region in the northeastern portion of the Ignace area surrounding the Basket Lake and Indian Lake batholiths has been mapped as compositionally heterogeneous tonalitic gneiss and foliated tonalite (Figure 3). Throughout the Wabigoon Subprovince these gneisses yield a broad range of ages (approximately 3.009 to 2.673 billion years old) and appear to exhibit an episodic history of development. The tonalitic gneisses show a wide variety of textures, folding and strongly foliated to mylonitized zones. Locally, tonalite gneiss is gradational in composition to amphibolite gneiss of volcanic or migmatized sedimentary rock origin. More felsic phases are gradational to biotite tonalite and are cut by felsic dykes of the younger plutonic suites (Stone, 2010a). Although mapped as distinct plutonic units (Figure 3), the Paddy Lake and Adele Lake plutons described above are a subset of this complexly deformed and poorly defined suite of crystalline rocks.

2.2.2 Mafic Dykes

Mafic dykes are widespread throughout the Superior Province (Figure 2) including multiple generations (the Kenora-Fort Frances, Wabigoon, and Eye-Dashwa swarms) of dyke emplacement between approximately 2.5 and 1.0 billion years ago (Osmani, 1991). Within the Ignace area, early dyke emplacement, typically in a northwesterly orientation, occurred between approximately 2.20 and 1.96 billion years ago, represented by the Kenora-Fort Frances and Wabigoon dyke swarms, and a late stage of emplacement represented by the Eye-Dashwa dyke swarm. The most prominent are the Wabigoon dykes which extend in a northwest orientation for at least 70 km from Ignace to Lac des Mille Lacs and are not offset along any terrane boundaries. Within the Ignace area, the Wabigoon dykes are typically 100 to 200 m in width. Fahrig and West (1986) give a K/Ar age of approximately 1.900 billion years old for the Wabigoon dykes.

The northwest-trending Kenora-Fort Frances dyke swarm contains hundreds of dykes up to 100 km long and 120 m wide, covering an area of approximately 90,000 km^2 (Osmani, 1991). Within the Ignace area, Kenora-Fort Frances dykes occur in clusters in the Melgund lake area to the northwest of the Revell batholith, and in the Mameigwess Lake area between the Basket and Indian Lake batholiths (Figure 2). The Kenora-Fort Frances dykes are composed of variable amounts of plagioclase, pyroxene, quartz, hornblende with varying degrees of alteration. Southwick and Halls (1987) report a Rb-Sr age of approximately 2.120 billion years old.

The emplacement of the Kenora-Fort Frances and Wabigoon dykes was followed by pulses of brittle deformation and fault reactivation, concurrent with the Penokean Orogeny. Following these deformation stages, late dyke emplacement and presumably fault-joint reactivation associated with Midcontinent Rift magmatism occurred at approximately 1.150 to 1.130 billion years ago (Easton et al., 2007). Kamineni and Stone (1983) give K/Ar ages of approximately 1.132 and approximately 1.143 billion years old for dykes of the Eye–Dashwa swarm, which are considered by Stone (2010a) to pre-date the main phase of rifting and intrusion associated with Midcontinent Rift magmatism (Heaman and Easton, 2006; Easton et al., 2007). Though Eye-Dashwa swarm dykes are mapped by the OGS in the surrounding region, none are identified in the Ignace area.

2.2.3 Greenstone Belts

Metavolcanic/metasedimentary rocks occur in the western portion of the Ignace area within the Bending Lake and Raleigh Lake greenstone belts, and to a lesser extent in the eastern portion of the area within the Phyllis Lake greenstone belt (Figure 3). Together these greenstone belts cover approximately 458 km^2 within the Ignace area. The metavolcanic and metasedimentary supracrustal rocks in the greenstone belts show intense planar fabrics of tectonic origin with complex curved trajectories that parallel geologic contacts (Stone et al., 1998; Stone, 2010a).

The Bending Lake greenstone belt occurs south of the Revell batholith and trends northwesterly. It is mostly composed of mafic metavolcanic rocks, gabbro, intermediate metavolcanic rocks, and clastic metasedimentary rocks (wacke and argillite; Stone, 2010a). The Raleigh Lake greenstone belt occurs north of the Revell batholith and also trends northwesterly. Although dominated by mafic metavolcanic rocks, the Raleigh Lake greenstone belt contains about thirty percent intermediate to felsic fragmental metavolcanic rocks (Stone, 2010a). These two greenstone belts coalesce and extend for a considerable distance beyond the northern and western boundaries of the Ignace area as part of the approximately 2.745 to 2.712 billion years old Kakagi Lake-Savant Lake volcanic belt (Stone, 2010a). The northeasterly-striking Phyllis Lake greenstone belt is preserved as a sliver of supracrustal rocks between the Adele Lake pluton and the White Otter Lake batholith. The belt has a maximum width of a few kilometres and extends for about 30 km in length towards the edge of the Ignace area. A felsic tuff (approximately 2.955 billion years old; Tomlinson et al., 2003) and a conglomeratic unit with detrital zircon ages of between 2.718 and 2.700 billion years old (Tomlinson et al., 2001) provide bounding constraints on the age of the Phyllis Lake greenstone belt.

2.2.4 Faults

The geological structure in the Ignace area and surrounding region generally follows an easterly to northeasterly trend parallel to the boundary between the Wabigoon, Quetico and Winnipeg River subprovinces. Ductile deformation in the Wabigoon Subprovince is evidenced by the sinuous and anastomosing nature of the greenstone belts, at both the regional and local scale, which are now preserved in synforms and homoclinal panels between the voluminous masses of plutonic rock. Greenstone belts in the Wabigoon Subprovince often contain long, subconcordant, sinuous shear zones that exhibit complex histories of ductile and brittle deformation. In the Ignace area, the metavolcanic rocks of the greenstone belts show intense planar fabrics of tectonic origin with complex curved trajectories that parallel geologic contacts (Stone et al., 1998; Stone, 2010a).

The only regional-scale faults that have been mapped within the Ignace area are the northeast-trending Finlayson-Marmion fault zone located approximately 35 km southeast of the Township of Ignace and the east-trending Washeibemaga Lake fault (referred to as the "Bending Lake fault" by Stone, 2009b), located approximately 28 km west of the Township of Ignace (Figure 3). These two fault orientations, trending northeast and east, are considered to be consistent with the orientation of known fault structures at the regional scale. For example, larger subprovince-bounding faults, such as the east-trending Quetico fault to the south of the Ignace area, which is characterized as a dextral-sense strike-slip fault structure (e.g., Kamineni et al., 1990).

The northeast-trending Finlayson-Marmion fault zone occurs as a broad zone of strike-slip ductile to brittle-ductile deformation (Stone and Halle, 1999). It is one of several splayed, northeast-trending, structural features evident at the regional scale (Figure 2). The fault is a complex braided structure with strong aeromagnetic contrast showing bifurcations and splays occurring in both the horizontal and vertical planes. The fault zone exhibits shallow to moderately plunging south-southwesterly oriented slickenside lineations, but the overall movement history is poorly constrained (Stone, 2010a). Woolverton (1960) reports near-vertically dipping schists and between 100 m and 1 km of dextral offset at Lumby Lake, in the southeastern part of the Ignace area (Figure 3). Stone (2010a) reports that the Finlayson-Marmion fault zone does not cut the Steep Rock Lake greenstone belt to the south of the Ignace area, and therefore may have ceased to move by approximately 2.780 billion years ago, although the cross-cutting relationship between the fault and the approximately 2.671 billion year old Indian Lake batholith (Figure 2) indicates that the temporal constraints of the Finlayson-Marmion fault zone are poorly defined.

The Washeibemaga Lake fault is described by Stone (2009b) as a deep-seated structure curving from an easterly to southeasterly trend through the Bending Lake greenstone belt in the Stormy Lake Area (Figure 3). The fault is inferred to follow the axis of the Bending Lake greenstone belt south of the Revell batholith (Stone, 2009b). One published account suggests that movement across the Washeibemaga Lake fault involved south-directed thrusting, and that the western extension of the fault is offset sinistrally by a northeast-trending fault (Beakhouse et al., 1996).

No evidence of post-Archean ductile shear-type deformation along the Finlayson-Marmion fault zone and the Washeibemaga Lake fault has been reported in the available literature, although there is evidence suggesting that brittle reactivation took place during the Proterozoic (Kamineni et al., 1990; Stone, 2009a).

2.2.5 Metamorphism

Metamorphism in the Central Wabigoon region, where the Ignace area is located, occurred in late Neoarchean time, from approximately 2.722 to 2.657 billion years ago (Stone, 2010a), and it peaked approximately 2.701 billion years ago (Easton, 2000). The collision of the Western Wabigoon terrane with the Winnipeg River-Marmion terrane approximately 2.70 billion years ago (Percival et al., 2006) may have been the cause of the peak regional metamorphism. Older, pre-NeoArchean metamorphic events may have also affected the region, but evidence of their occurrence has been obscured by the later metamorphic stages (Stone, 2010a). Metamorphism in the Central Wabigoon region is generally restricted to greenschist facies, and increases locally to middle-amphibolite facies in some rocks of the greenstone belts (Sage et al., 1974; Blackburn et al., 1991; Easton, 2000; Sanborn-Barrie and Skulski, 2006). Very high-grade (i.e. granulite facies) or very low-grade (eg. zeolite facies) metamorphism is largely absent from the central Wabigoon (Stone, 2010a).

A low to medium grade metamorphic overprint is recognized within the rocks of the Ignace area, mainly within the rocks of the Raleigh Lake and Bending Lake greenstone belts and within marginal zones of the Revell batholith. High metamorphic grade in the Ignace area is found in tonalite rocks surrounding plutons and greenstone belts, where there is widespread migmatization of rocks. In the Raleigh Lake greenstone belt, greenschist facies metamorphic grade varies to amphibolite facies. Presence of the mineral assemblage of garnet+amphibole+feldspar+biotite is widespread in the rocks of the greenstone belt (Stone et al., 1998) and numerous amphibolite and garnetiferous layers and clasts are found in rocks of the belt (Blackburn and Hinz, 1996). In the Balmoral Lake area, southwest of the Township of Ignace, metasedimentary sequences are extensively migmatized (Blackburn and Hinz, 1996; Stone et al., 1998), possibly due to contact metamorphism with the White Otter Lake batholith. In the Bending Lake greenstone belt, mineral assemblages are indicative of variable metamorphic grade, up to amphibolite facies. Rocks at the margins and in thin extensions of the belt exhibit higher metamorphic grade than rocks in the core of the belt, implying a degree of contact metamorphism adjacent to the surrounding intrusive bodies (Stone, 2009a). Satterly (1960) identified greenschist facies metamorphism within the metavolcanic rocks bordering the northwest part of the Revell batholith in Melgund and Revell townships, which grade to amphibolite facies near the contact with the Revell batholith. These observations imply a contact metamorphic aureole associated with the emplacement of the batholith. Stone (2010a) used aluminum in hornblende geobarometry to determine that the approximately 3.0 to 2.72 billion year old phases yielded average crystallization pressures of approximately 6 kilobars, while the approximately 2.690 billion year old and younger plutonic intrusions (such as the Indian lake, Revell, and Indian Lake batholiths) crystallized at approximately 4 kilobars.

2.3 Structural History

Direct information on the geological and structural history of the Ignace area is limited. The geological and structural history summarized below integrates the results from studies undertaken elsewhere throughout and proximal to the regional area shown in Figure 2. It is understood that there are potential problems in regional correlation of specific structural events within a D_x numbering system and in the application of such a system to the local geological history. Nonetheless, this summary represents an initial preliminary interpretation for the Ignace area, which may be modified after site-specific information has been collected.

The description provided here is based primarily on available structural syntheses of portions of the Western Superior Province (Kamineni et al. 1990; Percival, 2004; Bethune et al., 2006; Sanborn-Barrie and Skulski, 2006; Stone, 2010a) and is a summary of the detailed history documented in Golder (2013). Five episodes of penetrative strain (D_1 to D_5) have affected the central Wabigoon Subprovince (Kamineni et al, 1990; Percival, 2004). The D_5 event may have spanned the transition between ductile and brittle deformation. D_5 was followed by a poorly constrained D_6 episode of localized brittle deformation (e.g. Peterman and Day, 1989).

The first two episodes of deformation, D_1-D_2, produced and subsequently modified an S_1 gneissic layering through the progressive development and overprinting of this foliation by tight to isoclinals F_2 folds. The geometric and kinematic character of D_1-D_2 is cryptic as a result of the subsequent stages of magmatic and structural overprinting. D_1-D_2 structures are primarily confined to the gneissic tonalites throughout the central Wabigoon Subprovince. The D_1-D_2 episode is estimated to have occurred between approximately 2.725 and 2.713 billion years ago (Percival, 2004).

The D_3 episode produced northwest-trending F_3 folds and an associated northwest-striking axial planar cleavage (S3) that affected the gneissic tonalites and the supracrustal assemblages. The D_4 episode is characterized by the development of a moderately to well-developed, steeply-dipping, schistosity (S_4) that is axial planar to 050°-070° trending, steeply-plunging, F_4 folds. It should be noted that, locally, the D_3 and D_4 events are interpreted as D_1 and D_2 where the earlier episodes are not recognized (e.g., Sanborn-Barrie and Skulski, 2006). The D_3 and D_4 events are interpreted to have occurred prior to approximately 2.698 billion years ago (Percival, 2004).

The D_5 episode is characterized by the activation of major ductile-brittle shear zones across the central Wabigoon Subprovince (Percival, 2004). The D_5 shear zones are interpreted to have undergone significant sinistral strike-slip displacement along northeast-trending structures, and dextral strike-slip displacement along easterly-trending structures (Bethune et al., 2006). D_5 is interpreted to have overprinted all main bedrock lithologies in the Ignace area, including the large batholiths. Regionally, the timing of D_5 shear movement has been constrained to between 2.690 and 2.687 billion years ago (Davis, 1989; Brown, 2002). One example of a possible D_5 structure is the Finlayson-Marmion fault zone, which trends northeasterly and transects the southeastern corner of the Ignace area. As noted above, the recognition that this fault cuts the eastern extension of the approximately 2.671 billion years old Indian Lake batholith suggests that D_5 continued longer than has been documented. This is also consistent with the interpretation by Kamineni et al. (1990) that suggests regional east-oriented dextral transpression occurred along major terrane bounding shear zones between approximately 2.685 and 2.500 billion years ago, including the regional-scale Quetico fault. In addition, Hanes and Archibald (1998) suggest that approximately 2.400 billion years ago regional differential uplift was associated with movement along major fault zones throughout the Superior Province. Therefore the D_5 episode is considered to have been a protracted event of shear zone activation and re-activation that occurred between approximately 2.690 and 2.400 billion years ago.

A D_6 episode of deformation is inferred to have potentially re-activated pre-existing faults in the Ignace area. Evidence for this reactivation is based on the occurrence of approximately 1.947 billion year old pseudotachylite, a product of friction melting, observed along the Quetico Fault (Peterman and Day, 1989). The approximately 1.900 billion years old Wabigoon dykes are straight and continuous across the Ignace area

(Figure 3), and one dyke cuts across the Finlayson-Marmion fault zone without apparent offset. This relationship suggests that only limited fault movement, if any, has occurred along this fault since the emplacement of the Wabigoon dykes approximately 1.900 billion years ago.

A simplified geological history for the Ignace area and surrounding region is provided below.

Table 1. Summary of the geological and structural history of the Ignace area

Time Period (billion years ago)	**Geological Event**
ca. 3.0	Assemblage of the oldest rocks in the Ignace area comprising the Marmion terrane – essentially a micro-continent comprising tonalite basement rocks dominated by the Marmion batholith which occurs immediately south of the Ignace area.
ca. 3.0 to 2.74	Progressive growth of the Marmion terrane through the additions of magmatic and crustal material in continental arcs and through accretion of allochthonous crustal fragments. This growth included the emplacement of the Phyllis Lake gneisses and tonalites approximately 2.989 to 2.955 billion years ago and amalgamation of the Winnipeg River and Marmion terranes by approximately 2.93 to 2.87 billion years ago (Tomlinson et al., 2004; Percival and Easton, 2007).
ca. 2.745 to 2.711	A major period of volcanism, derived from subduction, occurred in the Winnipeg River-Marmion terrane (Blackburn et al., 1991). The result of this volcanic period is the Raleigh Lake and Bending Lake greenstone belts (Stone, 2010a). Sedimentation within the greenstone belts was largely synvolcanic, although sediment deposition in the Bending Lake area may have continued past the volcanic period (Stone, 2009b; Stone, 2010b). Synvolcanic to post-volcanic plutonism in the Ignace area included minor mafic intrusions (possibly flow centres) of gabbroic composition and the intrusion of tonalitic phases of the Revell batholith, approximately 2.737 to 2.732 billion years ago (Larbi et al., 1999; Buse et al., 2010). D_1-D_2 (Percival, 2004).
ca. 2.71	Collision of the Winnipeg River-Marmion terrane and a northern superterrane (Uchian Orogeny) (Corfu et al., 1995).
ca. 2.70 to 2.67	Collision of the volcanic island arc (Western Wabigoon terrane) against the superterrane (Central Superior Orogeny) (Percival et al., 2006; Stone, 2010a). The central Superior Orogeny was accompanied by widespread regional plutonism. In the Ignace area, this resulted in emplacement of intrusive rocks including the major batholiths of interest in this assessment. Specific dates include: ▪ Ca. 2.694 billion years ago: Crystallization age of the youngest phase of the Revell batholith; ▪ Ca. 2.685 billion years ago: Crystallization age of the White Otter Lake batholith; ▪ Ca. 2.671 billion years ago: Crystallization age of the Indian Lake batholith; and ▪ Ca. 2.697 to 2.684 billion years ago: an interval of sanukitoid magmatism (Stone, 2010a), which is expressed in the Ignace area by the emplacement of small plutons, such as the Islet pluton (Stone, 2009a) D_3 and D_4 (Percival, 2004).

ca. 2.6 to 2.4	Regional faulting and brittle fracturing (Kamineni et al., 1990).
ca. 2.12	Emplacement of the northwest trending Kenora-Fort Frances dyke swarm (Southwick and Halls, 1987).
ca. 1.947	Brittle reactivation of regional-scale faults (Peterman and Day, 1989).
ca. 1.900	Emplacement of the west-northwest trending Wabigoon dyke swarm (Fahrig and West, 1986; Osmani, 1991).
ca. 1.13 to 1.14	Emplacement of the northwest trending dykes of Eye–Dashwa swarm (Kamineni and Stone, 1983).

2.4 Quaternary Geology

Information on Quaternary geology in the Ignace area is described in detail in the terrain report (JDMA, 2013a) and is summarized here. The Quaternary deposits in the Ignace area accumulated during and after the last glacial maximum, known as the Late Wisconsinan Glaciation, with a significant amount of the material deposited during the progressive retreat of the Laurentide Ice Sheet (Figure 4). Advancement of the Laurentide Ice Sheet from the northeast across the area deposited a veneer of till throughout the areas mapped as bedrock terrain on Figure 4, with thicker accumulations of till mapped as morainal terrain. During the retreat of the Laurentide Ice Sheet, significant deposition of glaciofluvial outwash and glaciolacustrine plains occurred, with the three major end moraines (Lac Seul, Hartman, Eagle-Finlayson moraines) extending through the Ignace area recording the progressive retreat of the ice sheet (Figure 4).

The Hartman moraine is a significant Quaternary landform in the Ignace area that divides the area into distinct zones based on the thickness of Quaternary deposits. Thicker till, glaciofluvial outwash, and deep-water glaciolacustrine deposits occur north of this moraine, whereas surficial deposits are generally thinner to the south (Figure 4). Areas mapped as bedrock terrain to the north of the Harman moraine represent a spattering of islands within a proglacial lake known as Glacial Lake Agassiz that subsequently contracted into a set of large modern lakes.

Information on the thickness of Quaternary deposits within the Ignace area has been largely derived from terrain evaluation, and is described in detail in JDMA (2013a). Measured thicknesses are limited to a small number of water well records for rural residential properties, typically along the TransCanada highway, and to diamond drill holes concentrated in the greenstone belts. Recorded depths to bedrock in the Ignace area range from 0 to 80 m, with an average of about 7 to 10 m. The thickness of the Quaternary deposits southwest of the highway in the periphery of the Township of Ignace is typically less than 5 m. The thickest overburden is inferred to occur along the axes of the Eagle-Finlayson, Hartman, and Lac Seul moraines.

2.5 Land Use

Land use within the Ignace area is limited mostly to forestry and to linear infrastructure corridors like roads, railways, pipelines and electrical transmission lines. These features do not negatively impact on the geophysical interpretation.

3 GEOPHYSICAL DATA SOURCES AND QUALITY

For the Ignace 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 Ignace area by the mining industry were reviewed as assessment files, and mining companies were contacted in an effort to acquire the original digital data sources.

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 Ignace area show variability in data set resolution, which is 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 Ignace 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 Ignace area. Three additional magnetic/electromagnetic surveys obtained from the Ontario Geological Survey (OGS) provided higher resolution coverage over approximately 40 percent of the Ignace area to the northwest, and small parts of the northeast and southeast corners (Figure 5). These surveys focused primarily on exploration in the greenstone belts, but also encompassed plutonic rocks in the northwest of the Ignace area, particularly the Revell 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 Ignace 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 Ignace area. Surveys were flown over a period of 44 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 (Ontario #7) provides complete coverage of the entire Ignace area (GSC, 2012). Magnetic data from this survey forms part of the GSC Regional Magnetic Compilation data. The survey was flown at a terrain clearance of 305 m and flight line spacing of 805 m, providing it with a relatively low spatial resolution. Additional, high-resolution surveys from the OGS (Sturgeon-Savant Lake Survey, Stormy Lake Survey and Lumby-Finlayson Lakes Survey) were flown at a lower terrain clearance (45 – 81 m) compared to the GSC surveys, and with tighter flight line spacing (200 m), providing these surveys with a relatively high spatial resolution (OGS, 2003; OGS, 2009, OGS, 2011a). These surveys focused primarily on exploration in the greenstone belts. In addition, the Stormy Lake Survey covered the Revell batholith, the Paddy Lake pluton, most of the Islet pluton and smaller intrusions. The high-resolution coverage amounts to approximately 40 percent of the Ignace area.

Assessment files archived at the OGS were reviewed for the Ignace area, and consist of three airborne geophysical surveys, and some ground geophysical follow-up, that focused on relatively small areas within the greenstone belts. One assessment file of particular interest (AFRI number 20000003895, AFRO number 2.40559) extends the high resolution coverage of the Stormy Lake survey (GDS1107) with a high-resolution magnetic survey flown in 2008 for Takara Resources over a block measuring roughly 20 km by 15 km, focused on the southeastern part of the Basket Lake batholith (Evans, 2008). The magnetic survey was flown with 100 m line spacing at 60 m terrain clearance. Although the digital geophysical data were not available for the Takara Resources surveys, the magnetic were incorporated into this assessment in the form of raster maps that were extracted from the report and georeferenced.The assessment report included the survey reports provided by the airborne survey contractors, including several geophysical maps. The results are incorporated in the interpretation section of this report.

3.1.2 Gravity Data

Gravity data provides complete coverage of the Ignace area (GSC, 2012), consisting of an irregular distribution of 53 station measurements within the Ignace area, comprising roughly a station every 5 to 15 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 Ignace 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.

Szewczyk (1974) collected 410 gravity stations over the Basket Lake batholith, northern part of the Indian Lake batholith and neighbouring rocks. This data has been incorporated into this assessment. Within the Ignace area, a total of 226 gravity measurements were recorded, with the remaining stations located outside the Ignace area to the north and northwest (Figure 12). The gravity data were collected primarily along roads and lakeshores at approximately 1.5 km intervals, with gaps of 5 to 10 km between lakes.

3.1.3 Radiometric Data

The GSC radiometric data provides complete coverage of the Ignace area (GSC, 2012). The acquired 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); and
- Total Air Absorbed Dose Rate (nGy/h).

A small area of the Basket Lake batholith contains a high-resolution radiometric survey flown in 2008 for Takara Resources (AFRI number 20000003895, AFRO number 2.40559), providing coverage over an area measuring roughly 20 km by 15 km (Pelletier, 2008). The radiometric survey was flown with 100 m line spacing at 80 m terrain clearance. Although the digital geophysical data were not available for the Takara Resources surveys, the radiometric data were incorporated into this assessment in the form of raster maps that were extracted from the report and georeferenced. The assessment report included the survey reports provided by the airborne survey contractors, including several geophysical maps. The results are incorporated in the interpretation section of this report.

3.1.4 Electromagnetic Data

One frequency-domain electromagnetic (FDEM) survey carried out by the OGS was retrieved from the Sturgeon-Savant Lake survey (GDS1033; OGS, 2003) (Figure 5). This survey acquired FDEM data using an Aerodat system to measure the inphase and quadrature components of four different frequencies (two coaxial and two coplanar 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.

Two time-domain electromagnetic (TDEM) surveys carried out by the OGS were retrieved from the Stormy Lake survey (GDS1107; OGS, 2011a) and from the Lumby-Finlayson Lakes survey (GDS1060; OGS, 2009) (Figure 5). The TDEM systems were designed to locate moderate to highly conductive ore deposits with a reduced sensitivity to conductive overburden, and can penetrate to depths of several hundred metres, depending on transmitter power and geology.

The TDEM system used for the Stormy Lake survey was a Geotem III system to measure the on-time (2040 µs period, 5 channels) and off-time (3415 µs period, 15 channels) X, Y and Z component responses. The transmitter was attached to a fixed wing platform flown at a nominal height of 120 m above terrain, with the receiver mounted in a towed bird 50 m below and 131 m behind the aircraft. The survey was flown at 200 m flight line spacing providing a relatively high spatial resolution.

The TDEM system used for the Lumby-Finlayson Lakes survey was an Aeroquest III system to measure the on-time (523 µs period, 16 channels) and off-time (3382 µs period, 17 channels) X and Z component responses. The transmitter and receiver were mounted on a bird flown at a nominal height of 45 m above terrain and towed beneath a helicopter. The survey was flown at 200 m flight line spacing providing a relatively high spatial resolution.

The Sturgeon-Savant Lake and Lumby-Finlayson Lakes EM surveys provide a small amount of coverage in the northeast and southeast corners of the Ignace area, focused on greenstone belts. The Stormy Lake survey provides broader coverage across the west side of the Ignace area, covering the Bending Lake and Raleigh Lake greenstone belts, the Revell Batholith, the Paddy Lake pluton and a large portion of the Islet pluton.

Three older surveys flown by the OGS overlap the Ignace area, but are superseded by the more recent surveys, which were flown with similar specifications but are superior in terms of the equipment, navigation and data compilation. As a result, the data from the following three surveys were not incorporated in the assessment:

- Manitou-Stormy Lakes (GDS1019), 1979, fixed wing FDEM (Scintrex Tridem) – replaced by Stormy Lake (GDS1107)

- Dryden (GDS1016), 1986, fixed wing TDEM (Geotem I) – replaced by Stormy Lake (GDS1107)

- Atikokan Mine Centre (GDS1029), 1980, fixed wing TDEM (INPUT Mk VI) – replaced by Lumby-Finlayson Lakes (GDS1060).

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

Product	Source	Type	Line Spacing/ Sensor Height	Line Direction	Coverage	Date	Additional Comments
Ontario #7	GSC, 2012	Fixed wing magnetic	805m/305m	0°	Entire Ignace area	1965	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	5-15km/ surface		Entire Ignace area	1946-74	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.
Detailed Gravity Coverage	Szewczyk, 1974	Ground Gravity Measurements	1.5 km intervals along roads and lakeshores		Basket Lake intrusion, northern part of Indian Lake intrusion	1974	410 gravity stations were collected and listed in an M.Sc. thesis, and results described in Szewczyk and West (1976). A total of 226 gravity stations are located within the Ignace area.
GSC Radiometric Coverage	GSC, 2012	Fixed wing radiometric data	5000m/120m	0°	Entire Ignace area	1975 1979 1996	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.
Sturgeon-Savant Lake Survey (GDS1033)	OGS, 2003	Helicopter magnetic, FDEM (Aerodat 4 frequency)	200m/45m	0°	Covers 48.1 km^2 in northeast corner of Ignace area	1990	The lower height, closer line spacing and vintage of this survey greatly improves standard GSC magnetic coverage, and provides electromagnetic coverage.
Lumby-Finlayson Lakes Survey (GDS1060)	OGS, 2009	Helicopter magnetic, TDEM (Aerotem III)	200m/81m	0°	Covers 40.3 km^2 in southeast corner of Ignace area	2009	The lower height, closer line spacing and vintage of this survey greatly improves standard GSC magnetic coverage, and provides electromagnetic coverage.
Stormy Lake Survey (GDS1107)	OGS, 2011a	Fixed wing magnetic, TDEM (Geotem III)	200m/73m	36° (east block) 74° (west block)	Covers 2,050.7 km^2 in western part of Ignace area	2001	The lower height, closer line spacing and vintage of this survey greatly improves standard GSC magnetic coverage, and provides electromagnetic coverage. Covers the entire Revell batholith
Takara Resources Survey (AFRI 20000003895)	Evans, 2008; Pelletier, 2008	Fixed wing magnetic, radiometric	100m/60m	0°	Covers 300 km^2 in northwestern corner of Ignace area	2008	Magnetic and radiometric surveys flown in 2008 for Takara Resources over a block measuring roughly 20 km by 15 km, focused on the southeastern part of the Basket Lake batholith.

GSC – Geological Survey of Canada
OGS – Ontario Geological Survey

3.2 Data Limitations

There is a fairly stark contrast between the high resolution of the magnetic surveys that cover the greenstone belts, the southeastern part of the Basket Lake batholith and the Revell batholith and the older regional low resolution coverage elsewhere in the Ignace 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 zonation within the plutonic rocks in the western part of the Ignace area where the high resolution magnetic data is available (and for the limited radiometric coverage), and it is likely that new, unmapped intrusions and/or intrusive phases have been identified by the geophysical interpretation. Similarly, the main structural regimes are clearly delineated by the magnetic data, regardless of resolution, but at different levels of detail.

All four data types considered, magnetic, gravity, radiometric and electromagnetic, contribute to the interpretation. The limitation in applying these data types to the Ignace 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 (e.g. batholith contacts can be easily mapped but batholiths themselves are sometimes quite homogeneous, making geophysical characterization of internal structure difficult).

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.

The Takara Resources magnetic and radiometric survey data in the Basket Lake batholith area (Figures 17 and 18) were incorporated after the other surveys were compiled and interpreted. The 20 km x 15 km Takara magnetic survey (100 m line spacing, 60 m terrain clearance) was of much higher resolution than the GSC magnetic survey (805 m line spacing, 305 m terrain clearance) that it mainly overlapped. This provided a good opportunity to compare the interpretations of the regional data that covers 2/3 of the Ignace area to a survey of typical specifications for characterizing a general potentially suitable area. The regional and high resolution radiometric data were also compared. The main improvements to the interpretation by incorporating the data to delineate subtle intrusion signature not evident in the regional magnetic data, and confirmed by the radiometric data

This indicates that the batholiths that are only covered by the GSC geophysical data (encompassing the footprint of a repository several times over) may host more extensive and complex structure, and have more lithological variation, than is currently evident, especially where overburden obscures the bedrock geology.

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 Ignace area where projected to the UTM15N/NAD83 coordinate system. Magnetic data from the surveys were upward or downward continued (if necessary) to a common flying height of 80 m, and regridded to a common grid cell size of 40 m. As a result, downward continuation of 225 m was only applied to the GSC regional compilation, 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 along the flightlines. The remaining surveys were similar in flying height so that they were not downward (or upward) continued. The Sturgeon Lake-Savant Lake grid was not upward continued to 80 m from 45 m, to preserve the original data resolution. The GSC regional grid was regridded to a grid cell size of 40 m.

The surveys were knitted 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.

<u>Reduction to the Pole (RTP)</u>

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 Ignace area, the residual magnetic intensity grid was reduced to the pole using a magnetic inclination of 77.6° N and magnetic declination of 3.7° E (Figure 6).

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 7). 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 in the Fourier domain to further enhance shallower geologic sources in the data (Figure 8). 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 = vertical distance upwards

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 9). 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 **10**) 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 X and Y), 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, only the average flying height was known. For the remaining surveys (Sturgeon Lake-Savant Lake, Stormy Lake and Lumby-Finlayson Lakes), 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 Ignace area, taking into account that the elevation of the magnetic sensor (Figure 11). 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 Ignace area was four cells (equivalent to 160 m), over five scales. The filter sizes were therefore 160 m, 320 m, 640 m, 1280 m and 2560 m. All orientations were considered in the search for symmetry. A threshold value of 0.1 was applied, and a minimum line length of 3 cells (120 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 (53 gravity measurements) were downloaded for the Ignace area from the GSC gravity compilation (GSC, 2012) at 2000 m grid cell size:

- Bouguer gravity field (Figure 12)
- First vertical derivative of the Bouguer gravity field (Figure 13)
- Total horizontal gradient of the Bouguer gravity field
- Isostatic residual gravity field.

All grids were reprojected to the Ignace area's coordinate system, UTM15N/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 Ignace 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 Ignace area were collected in 1974 and earlier, station elevations were likely determined using barometric altimeters (much less accurate than GPS) and terrain corrections were not applied.

Subsequent incorporation of the gravity data from Szewczyk (1974) improved the resolution of the gravity coverage in the northern part of the Ignace area. The Bouguer gravity values and station locations for the entire Szewczyk dataset were recovered and directly compared to the GSC gravity data. Several gravity stations were coincident within a few hundred meters, mainly north of the Ignace area. A constant value of 7.1 mGal was removed from the Szewczyk data to match the GSC data and the two were combined in a single database. These data were then gridded at a 500 m interval using the minimum curvature algorithm and windowed to the Ignace area and buffer (Figure 12). The first vertical derivative (Figure 13) was computed using the same methodology applied to the magnetic data as described in Section 4.1.

4.3 Radiometric

The following seven radiometric grids (radioelement concentrations and ratios) were downloaded for the Ignace area from the GSC radiometric compilation (GSC, 2012) at 250 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 Ignace area's coordinate system, UTM15N/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 14 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 in 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 (Figures 15 and 16). Certain intrusions that have known mineral potential have also been flown (e.g. in the Abitibi Subprovince). Helicopter surveys generally 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.

TDEM surveys typically include a grid of decay constant, which is used to discriminate bedrock conductors, and a grid of conductance or conductivity, which is oriented towards mapping conductive horizons. Newer systems measure three components: Z-component that best couples with subhorizontal conductors, X-component with subvertical conductors and sometimes Y-component with lateral (offline) 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 Ignace area, the following data products were available:

- Sturgeon Lake-Savant Lake (GDS1033) – Apparent resistivity grid (4175 Hz coplanar) and EM anomaly database.

- Lumby-Finlayson Lakes (GDS1060) – Apparent resistivity grid (Z-component), decay constant grid (Z-component) and EM anomaly database.

- Stormy Lake (GDS1107) – Apparent conductance grid (combined X and Z-components, decay constant grids (X and Z-components) and EM anomaly database. Both original and de-herringboned grids were provided, the latter to remove lineations that result from the asymmetry of the Geotem configuration.

5 GEOPHYSICAL INTERPRETATION

5.1 Methodology

The coincidence of geophysical units with mapped lithology and structural features were identified and interpreted for the Ignace 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 Ignace area (JDMA, 2013b). The first and second vertical derivatives were used to trace quasilinear magnetic anomaly peaks to emphasize the ductile features. These ductile features 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 (shown on Figure 8). Enhanced grids of the magnetic field data were used to assist in the interpretation:

- Pole-reduced magnetic field – magnetic units (Figure 6)
- Pole-reduced first and second vertical derivatives – lineaments, boundaries, texture, foliation (Figures 7 and 8)
- Analytic signal – anomaly character, texture, boundaries (Figure 9)
- Tilt angle – subtle magnetic responses (Figure 10)

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 12). Similar comments apply to the radiometric data, except where the high resolution maps from the Takara Resources survey were available. The electromagnetic data were not used for interpreting lithologies as the magnetic data proved greatly superior from a mapping perspective in the Ignace 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 location of contacts. The magnetic anomaly characteristics and geophysical contacts were compared to the current bedrock geologic map 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 geologic map are presented in Figure 19. The geophysical data were evaluated against the following published geological maps:

- Ontario Geological Survey, 2011, 1:250 000 scale bedrock geology of Ontario, Miscellaneous Release Data 126-Revision 1 (OGS, 2011b) (Figure 2)
- OGS Map P.2515 Precambrian Geology - Stormy Lake Area (Stone et al., 2011c) (Figure 3)
- OGS Map P.3623 Precambrian Geology - Bending Lake Area - North Sheet (Stone et al., 2011a) (Figure 3)
- OGS Map P.3624 Precambrian Geology - Bending Lake Area - South Sheet (Stone et al., 2011b) (Figure 3).

In addition, Stone (2010b), Stone (2011) and Beakhouse et al. (2011) provided additional information with finer scale mapping programs in the Ignace area.

5.2 Results

The following section presents a regional-scale description and interpretation of each geophysical data set in the Ignace area, followed by detailed interpretations of geophysical responses within the four major batholiths (Revell, White Otter Lake, Indian Lake and Basket Lake batholiths) as well as the minor plutons (Islet, Paddy Lake, Norway, Melgund Lake, Raleigh Lake series plutons) in the Ignace area. Using the published regional bedrock geology maps as a starting point, the detailed geophysical interpretation leads to the development of an updated geological map for the Ignace area presented in Figure 19. The geophysical units referred to in this section generally match those of the published regional (OGS, 2011b) and detailed bedrock geology (Stone et al., 2011a; 2011b; 2011c) quite well.

5.2.1 Magnetic

The magnetic data over the Ignace area exhibits a strong regional magnetic high associated with the Indian Lake (unit A) and White Otter Lake batholiths (unit B), and the Norway pluton (unit C), which crosses the Ignace area from the southwest to the east and northeast (Figure 6). The boundaries of these intrusive units are not always well-defined, largely due to the low resolution data, and the resulting relatively subdued texture exhibited in the magnetic image. The western portion of the Ignace area displays a relatively low magnetic response, which is associated with the Revell batholith and portions of the greenstone belts. The high-resolution survey over the Raleigh Lake and Bending Lake greenstone belts has enhanced the geological contacts within the volcano-sedimentary packages in the western part of the Ignace area (Figure 6), particularly within the first and second vertical derivative grids (Figure 7 and Figure 8). Subparallel horizons that vary from weakly to strongly magnetic provide a good definition of both the geometry and relative composition of the ductile fabric within the greenstone belts. They clearly show the dominant northwest strike of the ductile fabric, in the greenstone belts, as well as the structure wrapping around the margins of the younger batholiths and plutons. The magnetic responses grade from strong over the mafic volcanic and intrusive rocks to weak over the felsic and metasedimentary rocks, with the exception of the iron formation along the spine of the Bending Lake greenstone belt, which naturally produces a very strong magnetic response due to its high magnetite content (Figure 6). Incidentally, this magnetic anomaly skews the statistics of the data for imaging so care must be applied to imaging the weaker responses elsewhere in the Ignace area.

The interpretation of the local-scale compositional/phase changes and inclusions of remnant volcanics, and the occurrence of later-stage Wabigoon dykes within the major batholiths in the Ignace area (Basket Lake, Indian Lake, White Otter Lake), have been hampered by the overall low resolution of the regional aeromagnetic data (800 m line spacing). In contrast, the Revell batholith and the Paddy Lake and Islet plutons have been covered at 200 m line spacing and more detailed interpretations have been carried out for these areas. The Revell batholith and smaller intrusions within and adjacent to the greenstone belts comprise a relatively low magnetic response and well-defined contacts. Furthermore, several subdivisions within the Revell batholith are apparent. In contrast to the quasi-linear ductile fabric of the greenstone belts, the various intrusions exhibit different foliation patterns (often concentric), anomaly wavelengths and amplitudes (weak to moderate). The magnetic characteristics of each batholith are discussed in section 5.2.5.

5.2.2 Gravity

The Bouguer gravity data and gravity station locations across the Ignace area are presented in Figure 12. The results show a series of regional-scale gravity lows that correspond to the locations of the Indian Lake (unit A), Basket Lake (unit D) and White Otter Lake (unit B) batholiths, which extend across the Ignace area from the southwest to the east and northeast. Gravity variations tend to be low through these intrusive rock units, and transition into a pronounced gravity high with steep gravity gradients towards the Bending Lake and Raleigh Lake greenstone belts located to the west of the Township of Ignace. The Revell batholith is evident as a gravity low response, which is bounded to the north and south by high gravity response of the greenstone belts. Although the density of gravity stations in the Ignace area is generally poor, the northwest-southeast trend of the gravity high anomalies associated with the greenstone belts is consistent with the dominant trend of the magnetic response.

5.2.3 Radiometric

Radiometric data in the Ignace area were of insufficient resolution to be used for interpretation of geological units and boundaries (Figure 14). 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 White Otter Lake (unit B) and Indian Lake (unit A) batholiths show elevated responses in all three radioelements (Figure 14). This response extends northwest from the Indian Lake batholith to the intrusion interpreted from the magnetic data in the Basket Lake area (unit E). The high-resolution radiometric data in this area (Figure 18) reflect this same response, despite the numerous lakes and drainage that limit bedrock exposure. The latter data also display moderate, somewhat potassium-rich responses over the foliated tonalite to the west (unit F) and diminished responses over the Raleigh Lake greenstone belt to the southwest. Similar responses for the foliated tonalites and greenstone belts are observed in the regional data. The Revell batholith does not display a distinct signature, although the variability in responses hints at zonation.

For the GSC radiometric compilation within the Ignace area, and the Takara Resources maps, the radioelement responses are summarized in Table 3.

Table 3. Radioelement responses of the Ignace area

Radioelement	Minimum	Maximum	Mean	Takara Maximum
Potassium (%)	0.22	2.18	0.93	2.03
Uranium (ppm)	0.03	2.05	0.61	3.35
Thorium (ppm)	0.42	13.90	3.67	10.96
Natural air absorbed dose rate (nGy/h)	4.14	70.09	25.19	68.40

These levels are typical of 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 at the south end of the Basket Lake batholith (unit E) and was the focus of the radiometric survey by Takara Resources. Although uraniferous pegmatites were targeted, the measured uranium concentrations were quite low. The highest dose rates occur in the White Otter Lake batholith south of the Paddy Lake pluton (unit G).

5.2.4 Electromagnetic

The electromagnetic surveys in the Ignace area were focused on the greenstone belts (Figure 15 and Figure 16), although the Stormy Lake survey (GDS1107) does provide complete coverage of the Revell batholith (OGS, 2011a). The results from the electromagnetic surveys correspond to 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). The following interpretation focused on delineating bedrock sources into conductors that traverse a few to several flight lines (i.e. 200 m to 1000 m or more).

The apparent conductivity results (4175 Hz coplanar) from the Sturgeon Lake-Savant Lake survey (GDS1033; OGS, 2003) show several conductive responses (Figure 16) that are typical of lake-bottom sediments in northern Ontario. The electromagnetic anomaly database provided by the OGS show some bedrock conductors that are interpreted in the greenstone belt and the foliated tonalite to the south (units H and I), following the west to southwest-striking local foliations of these two units.

The decay constant (Z-component), and apparent conductivity grids from the Lumby-Finlayson Lakes survey (GDS1060; OGS, 2009), and the results from the OGS electromagnetic anomaly database suggest that the identified conductors predominantly correspond to horizons within the metavolcanic-metasedimentary rocks, which follow the structural trends (Figure 15). Other portions of these rocks and the Norway pluton (diorite-monzodiorite-granodiorite, unit C) are quite resistive.

The decay constant (X-Component and Z-component) and apparent conductance grids from the Stormy Lake survey (GDS1107; OGS, 2011a), and the results from the OGS electromagnetic anomaly database suggest that the main conductive units reflect two broad swaths of northwest-striking greenstone belts located near the Revell batholith, with certain horizons within the Raleigh Lake and Bending Lake greenstone belts (mainly mafic portions), and some conductive zones within the foliated tonalite (units F and J) south of the Basket Lake batholith (Figure 15). The bedrock conductors are concentrated in the Bending Lake greenstone belt and the southern end of the Raleigh Lake greenstone belt, manifested as closely spaced subparallel conductors that follow the same ductile fabric evidence in the magnetic data. The majority of conductors occur in the mafic metavolcanic and intrusive rocks, but some are found in the felsic metavolcanics. Further north, they are mainly restricted to the mafic metavolcanics. Some conductors extend southeast of the greenstone belts into the neighbouring Indian Lake batholith (unit A), White Otter Lake batholith (unit B) and metasediments. These batholiths are electrically resistive for the most part, which is typical of granitic rocks. There are some conductive patterns within the batholiths which may reflect lake-bottom sediments where these intrusions have been preferentially eroded (e.g. unit K at Raleigh Lake). There are some circular conductive patterns within the intrusive stock at Melgund Lake (unit L) that correlate with the similar magnetic patterns within the pluton. There are several power lines that run northwest, subparallel to the greenstone belts. Their responses have been screened out of the interpretation.

Overall, the EM coverage over the geological formations of interest in the Ignace area is rather limited. In general, the EM has proven to be a useful mapping tool, and is particularly applicable to characterizing overburden responses associated with drainage. Where it does cover metavolcanics and metasediments, it typically reflects stratigraphy and structure that is evident in the magnetic data. To a small extent, structure that occurs within the granitic rocks also generates an EM response.

5.3 Geophysical Interpretation of the Batholiths and Plutons in the Ignace Area

The following section provides more detailed interpretations with a focus on identifying internal heterogeneity associated with lithology contrasts within the four major batholiths (Revell, White Otter Lake, Indian Lake and Basket Lake) as well as the minor plutons (Islet, Paddy Lake, Norway, Melgund Lake, Raleigh Lake series) in the Ignace area. Tonalite units located adjacent to the major batholiths are also discussed. Some inferences are also made from recently acquired magnetic and radiometric images (Evans, 2008; Pelletier, 2008) over the southeastern part of the Basket Lake batholith.

5.3.1 Revell Batholith

The Revell batholith has been mapped by OGS as relatively uniform at the regional scale (Figure 2). Recent mapping by Stone et al. (2011a; 2011b; 2011c) at the detailed scale of 1:20,000 shows new subdivisions in the southeastern part of the Revell batholith that span approximately 40 Ma of magmatism (Stone et al., 2010) (Figure 3).

Based on the current interpretation of the processed magnetics presented in Figure 19, the overall outline of the Revell batholith is consistent with the detailed mapping. However, the western contact with the greenstone belts appears as a transitional zone of foliated tonalite suite (unit M) in the magnetic data, and is characterized by weakly magnetic foliations oriented subparallel to the adjacent volcanic stratigraphy. At the northern end of the batholith, north of the TransCanada Highway, the magnetic response is typically low and homogeneous across the batholith, with the exception of linear, magnetic high responses, associated with the presence of remnant mafic to intermediate metavolcanics intermixed with the foliated tonalite suite (unit N).

South of this transition zone (unit N) between the Raleigh Lake greenstone belt and the Revell batholith, the granodiorite to granite (unit O) is marked by a very quiescent magnetic pattern (Figure 7). This zone is characterized by a reduced density of geophysical lineaments, presented in the lineament investigation (JDMA, 2013b). The Wabigoon dykes oriented west-northwest-east-southeast and dated 1.887 billion years old (Stone et al., 2010) cut this unit. The second vertical derivative shows weak responses with no discernible internal foliation (Figure 8). Several magnetic lineaments that traverse other portions of the batholith, and the adjacent greenstones, do not appear to extend into this portion (JDMA, 2013b).

Slightly more magnetic phases of the batholith (units P and Q) are evident in the northwest and central portions and correlate with the mapped hornblende tonalite to granite (Figure 7). Within this unit, magnetic horizons reflect curvilinear foliation patterns of various orientations.

The most significant change in magnetic character within the Revell batholith occurs nears its center (Figure 7). Within this region, the magnetic pattern is much more anomalous, exhibiting an increase in frequency and magnitude. The recent mapping of Stone et al. (2011a) shows numerous traverses across this unit and a strong correlation with the exposures mapped as a feldspar megacrystic component (unit R) of the biotite-granite to granodiorite.

The southern half of the Revell batholith exhibits a slightly more active magnetic pattern, possibly indicating varying degrees of remnant metavolcanic overprinting. The southern contact is marked by a thin east-striking band of mafic to intermediate metavolcanics in the west and by a direct contact with a northern extension of the Paddy Lake pluton foliated tonalite suite (unit S) (Figure 7). Both are interpreted from the magnetic data, where they reflect magnetic signatures similar to the corresponding mapped units further southwest. Units T and U show a more active magnetic response, comparable to unit N to the north whereas as unit V is more quiescent, similar to unit O.

The Revell batholith produces a pronounced gravity low in between the two greenstone belts. Although this anomaly is defined by a small number of gravity stations, the amplitude of the gravity low is greater towards the northwest and west, indicating a lower density for the subdivisions in that part of the batholith and/or a thickening or root of the batholith (Figure 13). Szewczyk and West (1976) interpret the Revell batholith (referred to as the Hodgson intrusion by the authors) to be a sheet-like intrusion approximately 1.6 km in thickness, which was modeled based on an average density of 2.60 g/cm^3 determined from five tested rock samples.

The two greenstone belts bounding the Revell batholith exhibit northwest-southeast striking regional gravity highs that appear to coalesce across a major north-striking structure along the eastern shore of Raleigh Lake and then continue in a subdued manner east to the Bonheur River greenstone belt. This suggests that the two greenstone belts may form part of a larger single unit on a tectonic scale.

5.3.2 White Otter Lake Batholith

The White Otter Lake batholith has been mapped as a regional granodiorite-to-granite intrusion (unit B) that extends east-west for 60 km, from Pekagoning Lake in the west to Gulliver River in the east. The magnetic data reveals little detail within the batholith, other than the continuation of major faults noted to the north. In contrast to the Revell batholith to the north, the White Otter Lake batholith exhibits a well-defined magnetic high in the pole reduced magnetic field and an overall increase in anomaly frequency and magnitude (Figure 6). The magnetic pattern appears to be severely distorted and possesses a general east-northeast orientation, subparallel to the regional strike, and is cross-cut by west-northwest trending lineaments that are interpreted as faults and dykes. The northwest margin is sharply defined against the greenstone belts, whereas to the northeast it appears more gradational into the foliated tonalite suite of the Adele Lake pluton (unit W) and the gneissic tonalite suite (unit X). Discrete intrusions within the batholith are not apparent, likely due to the limited resolution of the gridded data.

The foliated tonalite suite of the Adele Lake pluton (unit W) to the northeast exhibits an east to east-northeast anomaly trend, and has a lower regional background base level. The same change in anomaly strike direction and lowering of base level is also evident along the northern contact with the gneissic-tonalite suite (unit X).

The gravity response over the White Otter Lake batholith (unit B), particularly to the east of Half Moon Lake, exhibits a marked gravity low of over 20 mGal amplitude, compared to the local gravity field measurements. This gravity response trends in an easterly direction and extends into the foliated tonalite suite (unit X). The gravity low response is similar in amplitude to the Basket Lake batholith, which is interpreted by Szewczyk and West (1976) to be at least 8 km thick. The similar gravity response over the White Otter Lake batholith suggests that it may also extend to a comparable depth.

5.3.3 Indian Lake Batholith

The Indian Lake batholith (unit A) covers the majority of the northern half of the Ignace area. In general, the regional aeromagnetic data reveals a quite similar magnetic pattern to that observed over the White Otter Lake batholith (unit B), both internally (vertical derivative images) (Figures 7 to 9) and as a whole (pole reduced magnetic field) (Figure 6). The southern contact of the Indian Lake batholith (unit A) appears as a transitional change into the foliated tonalite suite of the Adele Lake Pluton (unit W). The magnetic response shows a gradual fall-off to the north and northwest, perhaps indicating that the batholith thins or extends to depth beneath the bounding gneissic (unit Y) and foliated tonalites (unit Z). The reduced response on the west side of the batholith (Figure 6) and slightly longer anomaly wavelengths (Figure 7) could reflect a compositional change, elongated to the northwest towards the Basket Lake batholith.

The northern portion of the Indian Lake batholith (unit A) possesses a more subdued gravity anomaly, possibly indicating a more limited depth extent to this granodiorite-to-granite intrusion (Figure 12). Szewczyk and West (1976) estimated the thickness of the Indian Lake batholith to be about 2 km ± 0.5 km based on gravity data, and forward modeling using an average density of 2.68 g/cm^3 or greater. The authors noted the absence of a strong gravity response beneath the western margin of the batholith in the Ignace area, evident as a response that is 5 mGal higher northwest of Highway 599 than elsewhere within the batholith. They infer either the presence of a denser rock mass beneath the batholith (2.73 g/cm^3) or the thinning of the intrusion in this area. Szewczyk and West (1976) provide a possible explanation for denser rock unit as the presence of mixed greenstone belts incorporated into the gneiss formation, which is consistent with the northern gneiss terrane south of Sturgeon Lake. Other studies (Everitt, 1999) interpret the Indian Lake batholith to be a sheet-like intrusion less than 2 km thick.

5.3.4 Basket Lake Batholith

In the northwest corner of the Ignace area, the granodiorite to granite compositional bedrock (unit D) corresponds to the Basket Lake batholith. Its magnetic response is less intense and smoother than that of the Indian Lake batholith (unit A), and appears to contain fewer lineaments (JDMA, 2013b) and the batholith contacts are typically poorly defined by the low resolution magnetic data.

The Takara Resources high resolution magnetic data (Evans, 2008) over the southeastern part of the Basket Lake batholith shows an oval-shaped magnetic anomaly measuring 11 km by 9 km and centered near 579500 E, 5493500 N (
Figure 17: unit E). Its response differs from the Basket Lake batholith to the northwest and the Indian Lake batholith to the southeast due to its somewhat higher amplitude and spotty texture. It is located within an area mapped as foliated tonalite but is interpreted to reflect a separate intrusion, termed pegmatitic granite (unit E) based on Takara Resources exploring for uranium associated with pegmatite in this area (Evans, 2008).

The gravity data over the Basket Lake batholith (unit D) exhibits a large negative gravity anomaly, compared to the local gravity field measurements, of over 20 mGal amplitude. This gravity response suggests that it may be the thickest of the batholiths in the Ignace area (Figure 12). Szewczyk and West (1976) estimated the thickness of the northern side of the Basket Lake batholith to be at least 8 km located near the Wabigoon metavolcanics, based on the forward modeling of the gravity data, which progressively thins to the southeast to 0.5 km, forming a tongue-like extension of the main batholith body. They found an average density of 2.61 g/cm^3 based on 10 tested rock samples.

5.3.5 Minor Plutons

In addition to the major plutonic bodies described, the Ignace area contains a number of smaller felsic to intermediate intrusions including the Raleigh Lake intrusions (units K, AA, BB, CC and DD), the Paddy Lake (unit G), Norway Lake (unit C) and Islet plutons (unit EE), and the Melgund Lake stock (unit L). All are clearly defined in the magnetic data (Figure 7), typically by the following:

- Moderate to highly increased amplitude in the pole-reduced magnetic field relative to surrounding rocks (mainly mafic to intermediate metavolcanics and/or foliated tonalite)
- Concentric pattern of magnetic highs visible in the various derivative maps (less developed over the Norway Lake pluton)
- Contrast in magnetic texture visible in the various derivative maps e.g. less linear than the metavolcanics.

These plutons have been assigned to the following units based on the mapped geology and their magnetic responses:

- Paddy Lake pluton (unit G) and northernmost Raleigh Lake intrusion (unit AA) – foliated tonalite suite. As described above in the discussion on the Revell batholith, a second part of the Paddy Lake pluton has been interpreted northeast of the mapped pluton. These exhibit moderate magnetic responses.
- Norway Lake pluton, Islet pluton (unit C), Melgund Lake stock (unit L) and southernmost Raleigh Lake intrusion – diorite-monzodiorite-granodiorite suite (unit DD). These exhibit the strongest magnetic responses of the group.
- Central Raleigh Lake intrusions (units K, BB and CC) – massive granodiorite to granite. These exhibit the most subdued magnetic responses of the group.

The gravity coverage over these intrusions is generally sparse to non-existent. The intrusion (unit K) at Raleigh Lake does appear to show a discrete gravity low in contrast to the surrounding metavolcanics (Figure 13).

6 SUMMARY OF RESULTS

The purpose of this assessment was to identify and obtain the available geophysical data for the Ignace 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 units with mapped lithology and structural features in the Ignace area.

The geophysical data covering the Ignace 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 Ignace area. Three additional magnetic/electromagnetic surveys obtained from the Ontario Geological Survey (OGS) provided higher resolution coverage over approximately 40 percent of the Ignace area to the northwest, and for small parts of the northeast and southeast corners. These surveys focused primarily on mineral exploration in the greenstone belts, but also encompassed plutonic rocks in the northwest of the Ignace area, particularly the Revell batholith.

The Stormy Lake survey flown in 2001 shows the value of acquiring high-resolution magnetic data over granitic terrain (OGS, 2011a). It covers several batholiths and plutons, each of which display unique magnetic character in terms of the anomaly amplitudes, geometry, texture, patterns and intersecting structure. Internal heterogeneities are apparent (e.g. Revell batholith), some of which were confirmed by subsequent geological mapping (Stone at al., 2011a; 2011b, 2011c).

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 heterogeneity. In general the coincidence between the geophysical interpretations and the published geological maps is in good agreement, but in some locations the geophysical data provided new interpretations.

A strong regional magnetic high is present in the data associated with the Indian Lake and White Otter Lake batholiths, and the Norway pluton, which crosses the Ignace area from the southwest to the east and northeast. The geological boundaries of these intrusive units were not always well-defined, largely due to the low resolution data, and the resulting relatively subdued texture exhibited in the magnetic image. The western portion of the Ignace area displays a relatively low magnetic response, which is associated with the Revell batholith and the greenstone belts. The Revell batholith and smaller intrusions within and adjacent to the greenstone belts comprise a relatively low magnetic response and possess well-defined contacts, where several subdivisions within the Revell batholith are apparent. The southern contact of the Indian Lake batholith appears as a transitional zone which changes from granitic rocks into the foliated tonalite suite, which shows a magnetic response that dissipates to the northeast. This response perhaps indicates a thinning or extension of the batholith to depth beneath the bounding gneissic and foliated tonalites.

Magnetic data over the White Otter Lake batholith indicate a relatively consistent magnetic response characterized by a well-defined magnetic high in the pole-reduced magnetic field and an overall increase in anomaly frequency and magnitude. The northwest margin is sharply defined against the greenstone belts, whereas to the northeast it appears more gradational into the foliated and gneissic tonalite suites.

The Basket Lake batholith has a relatively consistent magnetic response, which is less intense and smoother than that of the Indian Lake batholith. The contacts are typically poorly defined by the low resolution aeromagnetic data.

Resolution of the gravity data were 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 series of regional-scale gravity lows that correspond to the locations of the Indian Lake, Basket Lake and White Otter Lake batholiths, which extend across the Ignace area from the southwest to the east and northeast. Gravity variations tend to be low through these intrusive rock units, and transition into a pronounced gravity high with steep gradients towards the Bending Lake and Raleigh Lake greenstone belts located to the west of the Township of Ignace.

The Revell batholith is evident as a gravity low response, which is bounded to the north and south by high gravity response of the greenstone belts. Although this anomaly is defined by a small number of gravity stations, the amplitude of the gravity low is greater towards the northwest, indicating a lower density for the subdivisions in that part of the batholith and/or a thickening or root of the batholith. Szewczyk and West (1976) interpret the Revell batholith (referred to as the Hodgson intrusion by the authors) to be a sheet-like intrusion approximately 1.6 km in thickness.

The gravity data over the Basket Lake batholith exhibits a large negative gravity anomaly, compared to the local gravity field measurements, of over 20 mGal amplitude. Szewczyk and West (1976) estimated the thickness of the northern side of the Basket Lake batholith to be at least 8 km located near the Wabigoon metavolcanics, based on the forward modeling of the gravity data, which progressively thins to the southeast to 0.5 km, forming a tongue-like extension of the main batholith body. They found an average density of 2.61 g/cm^3 based on 10 tested rock samples.

Similarly, the gravity response over the White Otter Lake batholith, particularly to the east of Half Moon Lake, exhibits a marked gravity low of roughly 20 mGal amplitude. This gravity response trends in an easterly direction and extends into the Kay Lake foliated tonalite suite. The similar gravity response suggests that the depth extent of the White Otter Lake batholith may be comparable the Basket Lake batholith.

The northern portion of the Indian Lake batholith possesses a more subdued negative gravity anomaly, possibly indicating a more limited depth extent to this granodiorite-to-granite intrusion. Szewczyk and West (1976) estimated the thickness of the Indian Lake batholith to be about 2 km ± 0.5 km based on gravity data, and forward modeling using an average density of 2.68 g/cm^3 or greater. The authors noted the absence of a strong gravity response beneath the western margin of the batholith in the Ignace area, and infer either the presence of a denser rock mass beneath the batholith (2.73 g/cm^3) or the thinning of the intrusion in this area. More recent studies (Everitt, 1999) interpret the Indian Lake batholith as a sheet-like intrusion less than 2 km thick.

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 in the Ignace area. The White Otter Lake and Indian Lake batholiths show elevated responses in all three radioelements. This response extends northwest from the Indian Lake batholith to the Basket Lake area. The high resolution radiometric data in the Basket Lake area reflect this same response, despite the numerous lakes and drainage that limit bedrock exposure. The latter data also display moderate, somewhat potassium-rich responses over the foliated tonalite to the west and diminished responses over the Raleigh Lake greenstone belt to the southwest. Similar responses for the foliated tonalites and greenstone belts are observed in the regional data. The Revell batholith does not display a distinct signature, although the variability in responses hints at zonation.

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 and the Revell batholith in the Stormy Lake area. The surveys in the Stormy Lake area suggest that the main conductive units reflect two broad swaths of east-northeast-striking greenstones located northwest of the Revell batholith, certain horizons within the southwest-striking Raleigh Lake and Bending Lake greenstone belts (mainly mafic portions), and some zones within the foliated tonalite south of the Basket Lake batholith. The electromagnetic response in the Revell batholith is relatively limited due to granitic rocks typically being electrically resistive for the most part.

Respectfully Submitted,

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Figure 1. Township of Ignace and surrounding area

Figure 2. Bedrock geology of the Ignace area

Figure 3. Bedrock geology of the Ignace area with detailed mapping

Figure 4. Surficial geology of the Ignace area

Figure 5. Airborne geophysical coverage of the Ignace area

Figure 6. Residual magnetic field reduced to pole

Figure 7. First vertical derivative of the pole reduced magnetic field

Figure 8. Second vertical derivative of the pole reduced magnetic field

Figure 9. Tilt angle of the pole reduced magnetic field

Figure 10. Analytic signal amplitude of the total magnetic field

Figure 11. Depth to magnetic sources from source parameter imaging

Figure 12. Bouguer gravity field with station locations

Figure 13. First vertical derivative of the Bouguer gravity field with station locations

Figure 14. Radiometric ternary image (RGB = K-eTh-eU)

Figure 15. EM conductors over apparent conductivity (GDS1033) and decay constant (GDS1060 and GDS1107)

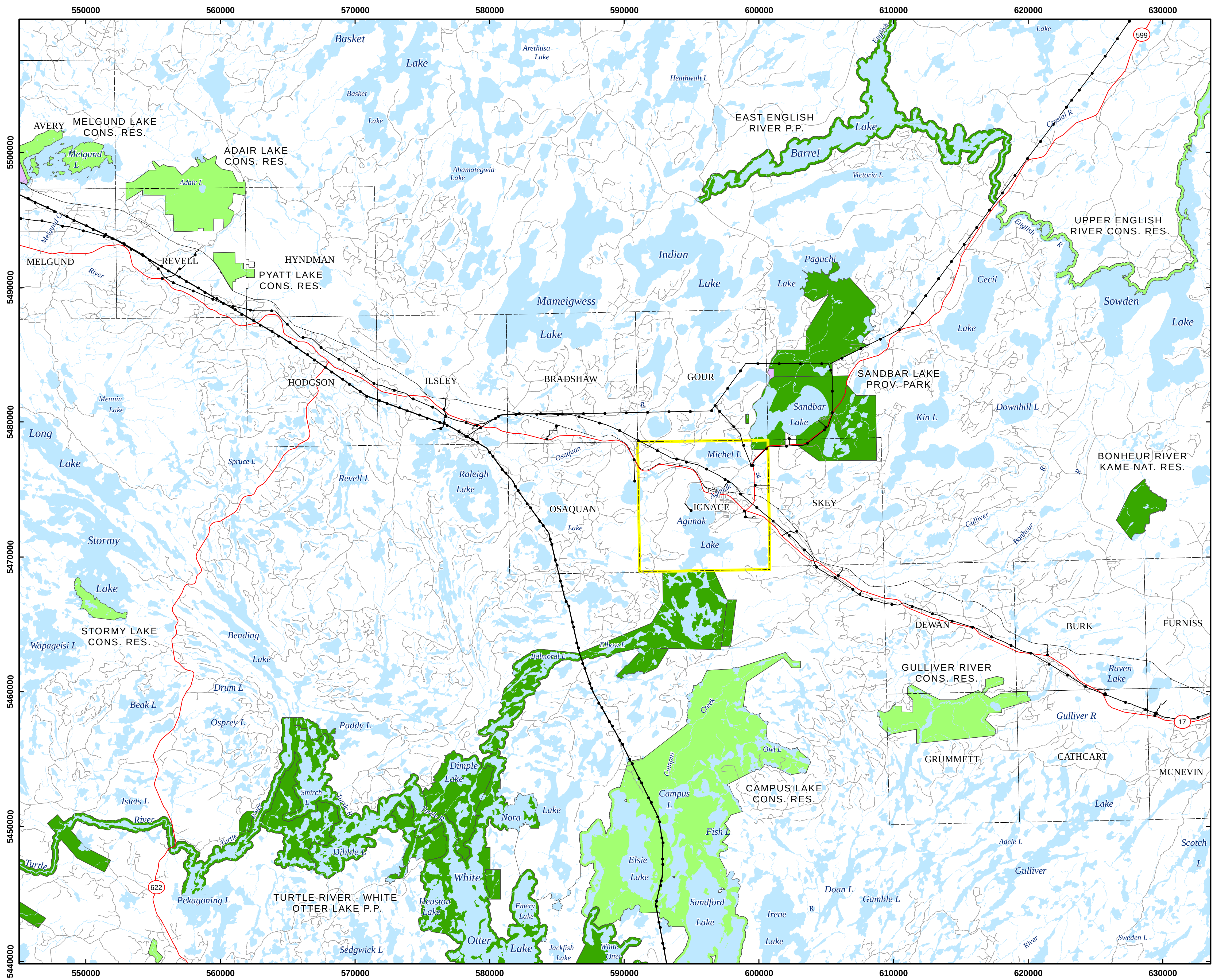
Figure 16. Apparent conductivity (GDS1033 and GDS 1060) and apparent conductance (GDS1107)

Figure 17. First vertical derivative of the total magnetic field, Basket Lake area, Takara Resources Inc. (Evans, 2008)

Figure 18. Ternary radiometric image (RGB = K-eTh-eU), Basket Lake area, Takara Resources Inc. (Pelletier, 2008)

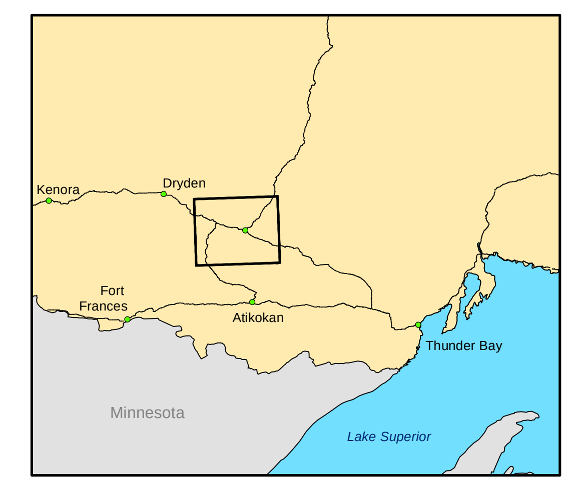
Figure 19. Geophysical interpretation showing distribution of bedrock units for the Ignace area

FIGURES



LEGEND

- Township of Ignace
- Geographic township
- Main road
- Local road
- Rail
- Utility
- Waterbody
- Watercourse
- Forest Reserve
- Conservation Reserve
- Provincial Park



Data sources:
Parks: LIO CLUPA designation
Rail: LIO Railway
Road: Selected roads from LIO MNR Road Segment
Township: "ADMIN" file from MNDM Claimap data
Utility: LIO Utility Line
Waterbody: LIO OHN Waterbody
Watercourse: LIO OHN Watercourse

NORTH
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J.D. MOLLARD

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, IGNACE AREA, ONTARIO

TITLE
Township of Ignace and surrounding area

DESIGN	DVZ	25 JUN 2012	FIGURE 1	REVISION 2
GIS	DVZ	30 AUG 2013		UTM ZONE 15
CHECK	SWR	15 OCT 2013		NAD 1983
REVIEW	GS	16 OCT 2013		1:300,000

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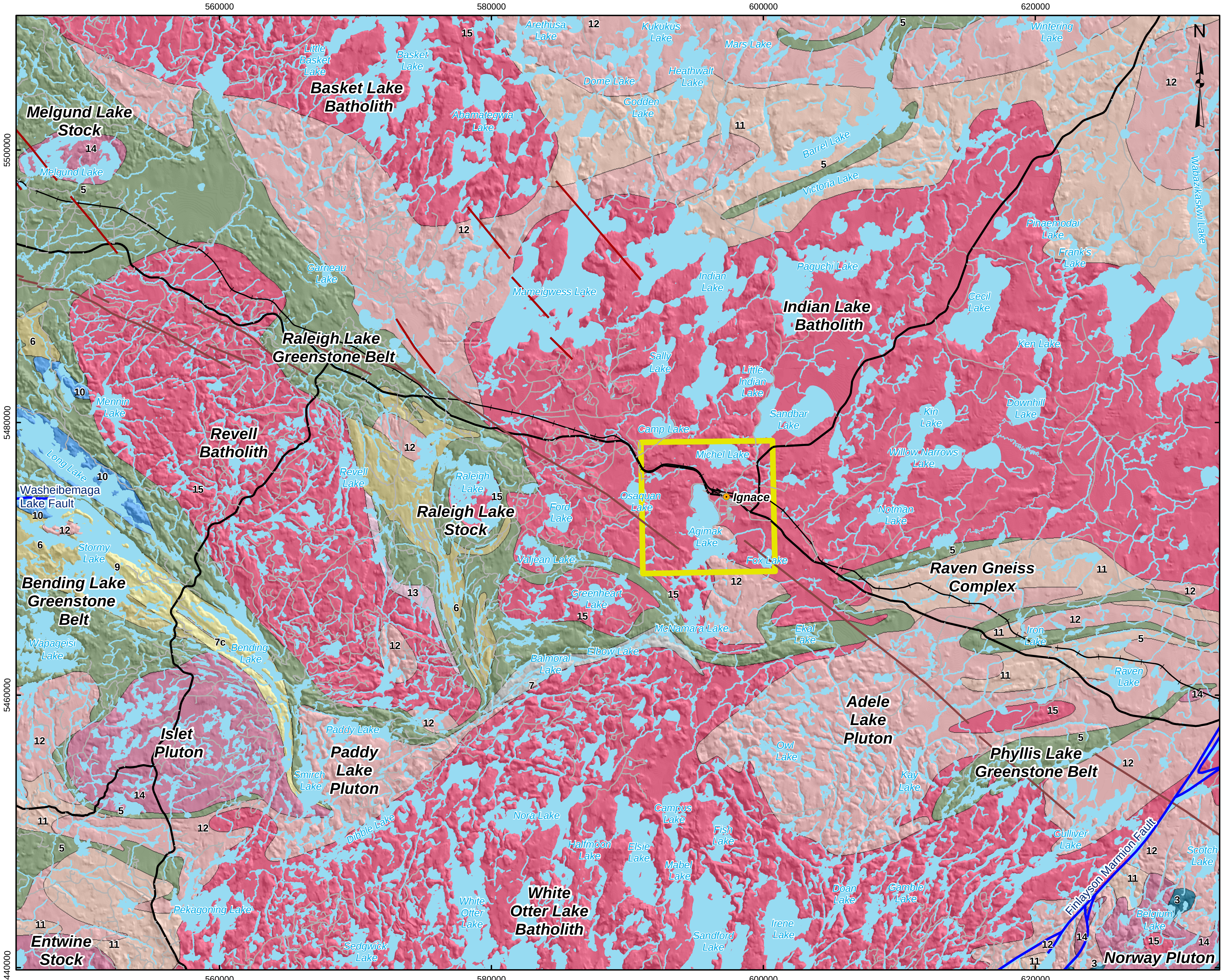

LEGEND

- Municipal Boundary (Township of Ignace)
- Ignace
- Main Road
- Local Road
- Railway
- Watercourse, Permanent
- Watercourse, Intermittent
- Water Area, Permanent
- Mapped Fault

Mapped Dyke

- Kenora-Fort Frances Dyke
- Wabigoon Dyke

Bedrock Geology

- 23 Mafic and related intrusive rocks
- 16 Hornblendite - nepheline syenite suite
- 15 Massive granodiorite to granite
- 14-Diorite-monzodiorite-granodiorite suite
- 13 Muscovite-bearing granitic rock
- 12 Foliated tonalite suite
- 11 Gneissic tonalite suite
- 10 Mafic and ultramafic rocks
- 9 Coarse clastic metasedimentary rocks
- 7 Metasedimentary rocks
- 7c Marble, chert, iron formation, minor metavolcanic rocks
- 6 Felsic to intermediate metavolcanic rocks
- 5 Mafic to intermediate metavolcanic rocks
- 4 Mafic to ultramafic metavolcanic rocks
- 3 Mafic metavolcanic and metasedimentary rocks

REFERENCE

Base Data - MNR LIO, obtained 2009-2012
Geology - MRD126-Bedrock Geology of Ontario, 2011
Hillshade - CDED slope raster: Geobase.ca (1:50,000)
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2012
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15N

5 2.5 0 5 10 15
SCALE 1:300,000 KILOMETRES

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, IGNACE AREA, ONTARIO

TITLE
Bedrock geology of the Ignace area

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

Golder Associates
Mississauga, Ontario

PROJECT NO. 12-1152-0026			SCALE AS SHOWN	REV. 0.0
DESIGN	PM	17 MAY 2012	FIGURE 2	
GIS	PMJB	27 AUG 2013		
CHECK	SWR	15 OCT 2013		
REVIEW	GWS	16 OCT 2013		

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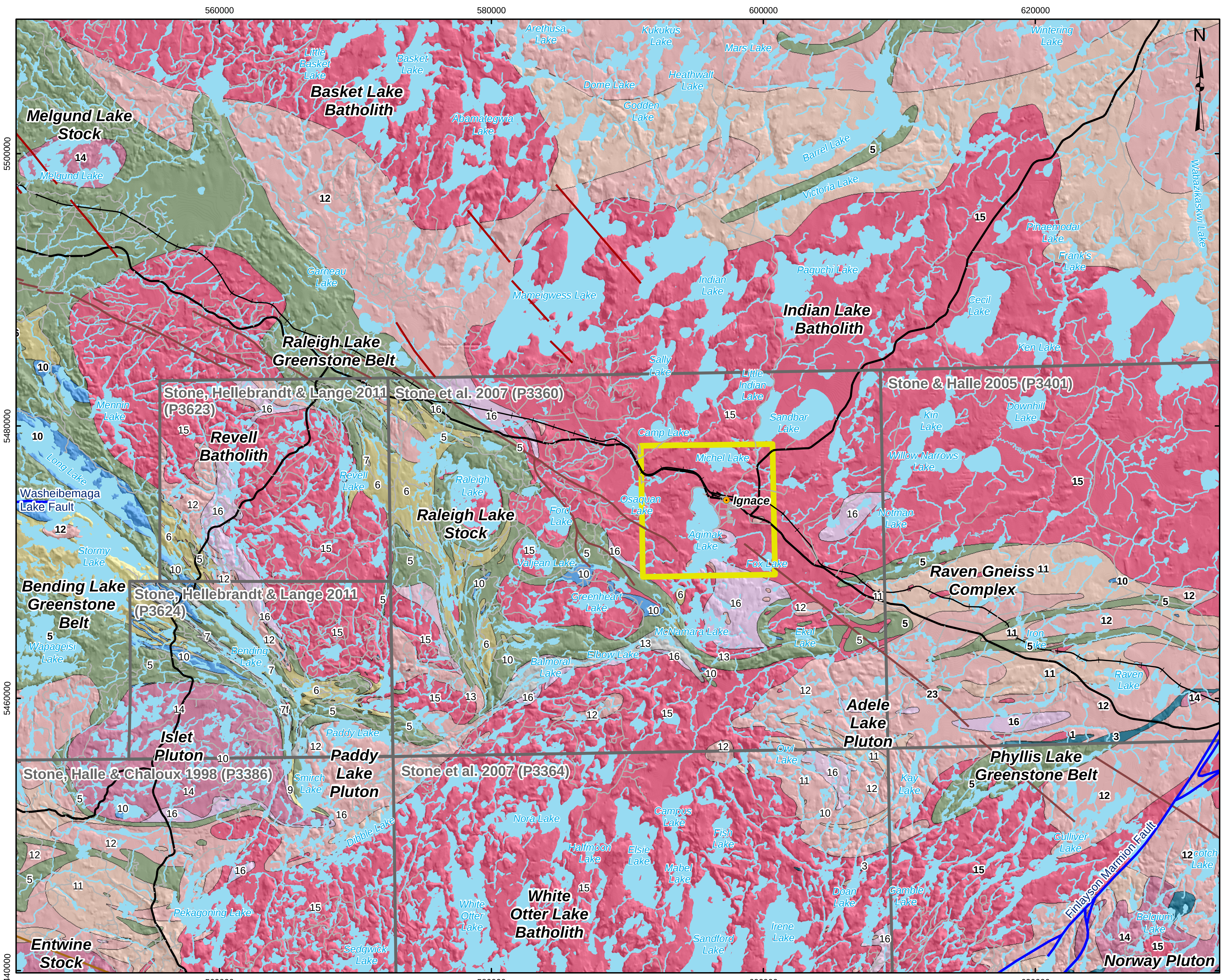


LEGEND

Municipal Boundary (Township of Ignace)
Ignace
Main Road
Local Road
Railway
Watercourse, Permanent
Watercourse, Intermittent
Water Area, Permanent
Mapped Fault

Mapped Dyke

Kenora-Fort Frances Dyke
Wabigoon Dyke
Dyke (Other)
Detailed Geology Extent

Bedrock Geology

23 Mafic and related intrusive rocks
16 Hornblendite - nepheline syenite suite
15 Massive granodiorite to granite
14-Diorite-monzodiorite-granodiorite suite
13 Muscovite-bearing granitic rock
12 Foliated tonalite suite
11 Gneissic tonalite suite
10 Mafic and ultramafic rocks
9 Coarse clastic metasedimentary rocks
7 Metasedimentary rocks
7c Marble, chert, iron formation, minor metavolcanic rocks
6 Felsic to intermediate metavolcanic rocks
5 Mafic to intermediate metavolcanic rocks
4 Mafic to ultramafic metavolcanic rocks
3 Mafic metavolcanic and metasedimentary rocks

Stone et al. 2007 (P3360)
Stone et al. 2007 (P3364)
Stone, Halle & Chaloux 1998 (P3386)
Stone, Hellebrandt & Lange 2011 (P3623)
Stone, Hellebrandt & Lange 2011 (P3624)
Stone & Halle 2005 (P3401)

REFERENCE

Base Data - MNR LIO, obtained 2009-2012
Geology - MRD126-Bedrock Geology of Ontario, 2011
Hillshade - CDED slope raster: Geobase.ca (1:50,000)
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2012
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15N

5 2.5 0 5 10 15
SCALE 1:300,000 KILOMETRES

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

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, IGNACE AREA, ONTARIO

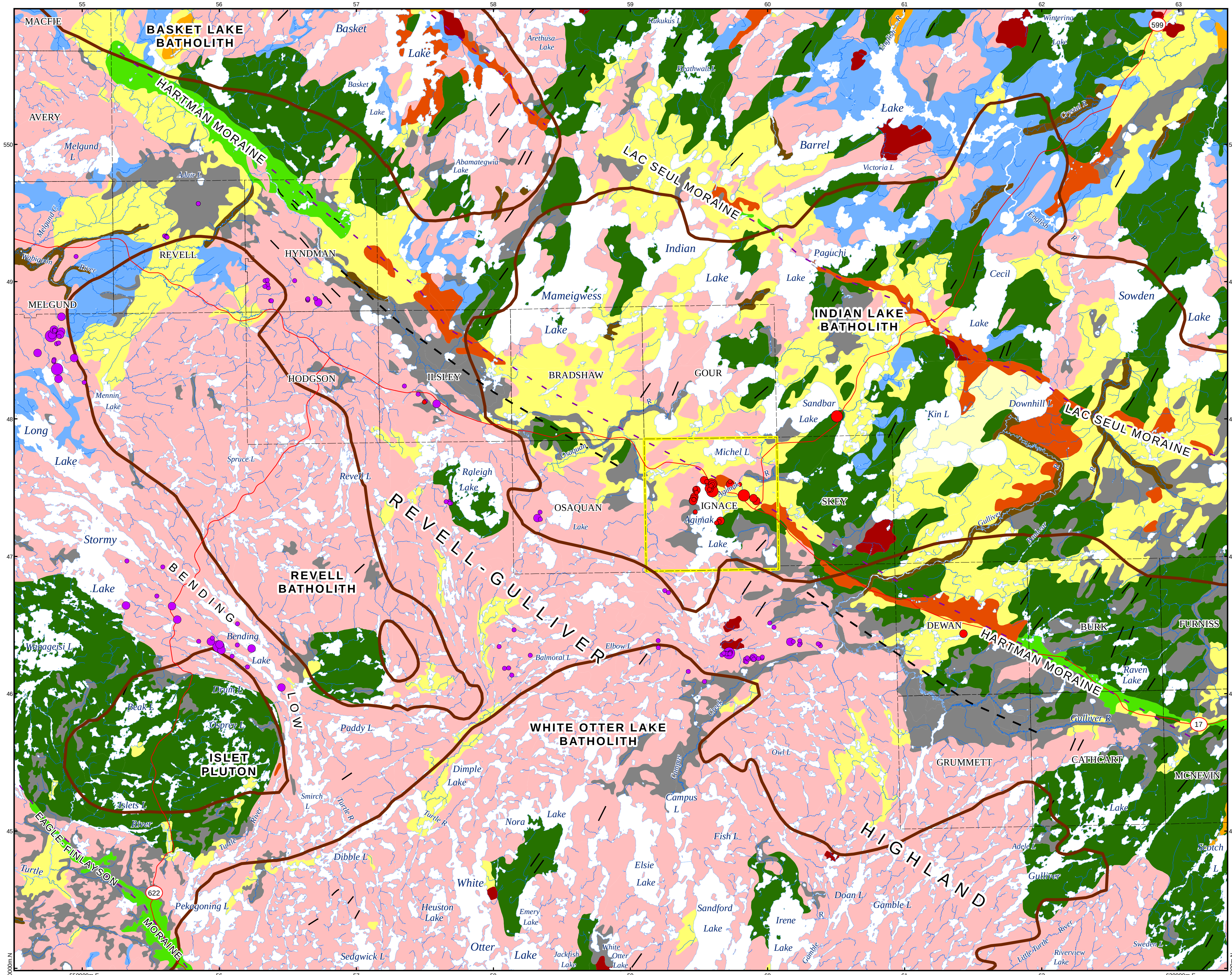
TITLE
Bedrock geology of the Ignace area with detailed mapping

Golder Associates
Mississauga, Ontario

PROJECT NO. 12-1152-0026		SCALE AS SHOWN	REV. 0.0
DESIGN	PM	17 MAY 2012	
GIS	PMUB	27 AUG 2013	
CHECK	SWR	15 OCT 2013	
REVIEW	GWS	16 OCT 2013	

FIGURE 3

G:\Projects\2012\12-1152-0026_NWMO_Phase1_Feasibility\GIS\MXDs\Reporting\Ignace\Draft_Integrated_Report\LocalBedrockGeologyIgnaceArea.mxd



LEGEND

	Township of Ignace
	Geographic township
	Main road
	Waterbody
	Watercourse
	Ice-flow (NOEGTS)
	Ilsley-Gulliver trough (JDMA)
	End moraine (JDMA)
	Batholith\pluton

Surficial geology (NOEGTS)

- Ground moraine
- End moraine
- Outwash
- Glaciolacustrine esker
- Kame
- Ice-contact delta
- Glaciolacustrine plain
- Alluvial plain
- Aeolian dune
- Organic terrain
- Bedrock terrain

Water well (MOE)

DP2BR_m

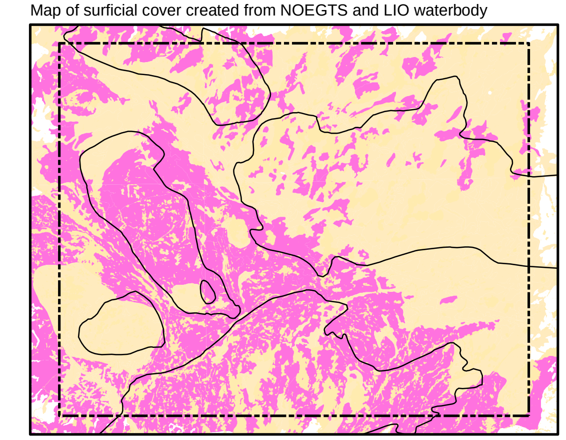
- 0.9 - 5.0
- 5.1 - 15.0
- 15.1 - 80.5

Drill hole (OGS)

DRIFT_m

- 0.2 - 5.0
- 5.1 - 15.0
- 15.1 - 31.7

Map of surficial cover created from NOEGTS and LIO waterbody



- Surficial/water (62%)
- Bedrock terrain (38%)

Data sources:
Batholiths: Generalized after OGS MRD 126-REV1
NOEGTS: OGS MRD 160 (scale 1:100,000)
Road: Selected roads from LIO MNR Road Segment
Township: "ADMIN" file from MNDM Claimap data
Waterbody: LIO OHN Waterbody
Watercourse: LIO OHN Watercourse
Water well: MOE Water Well Information System
Drill hole: OGS Drill Hole Database (selected)

NORTH

5 km

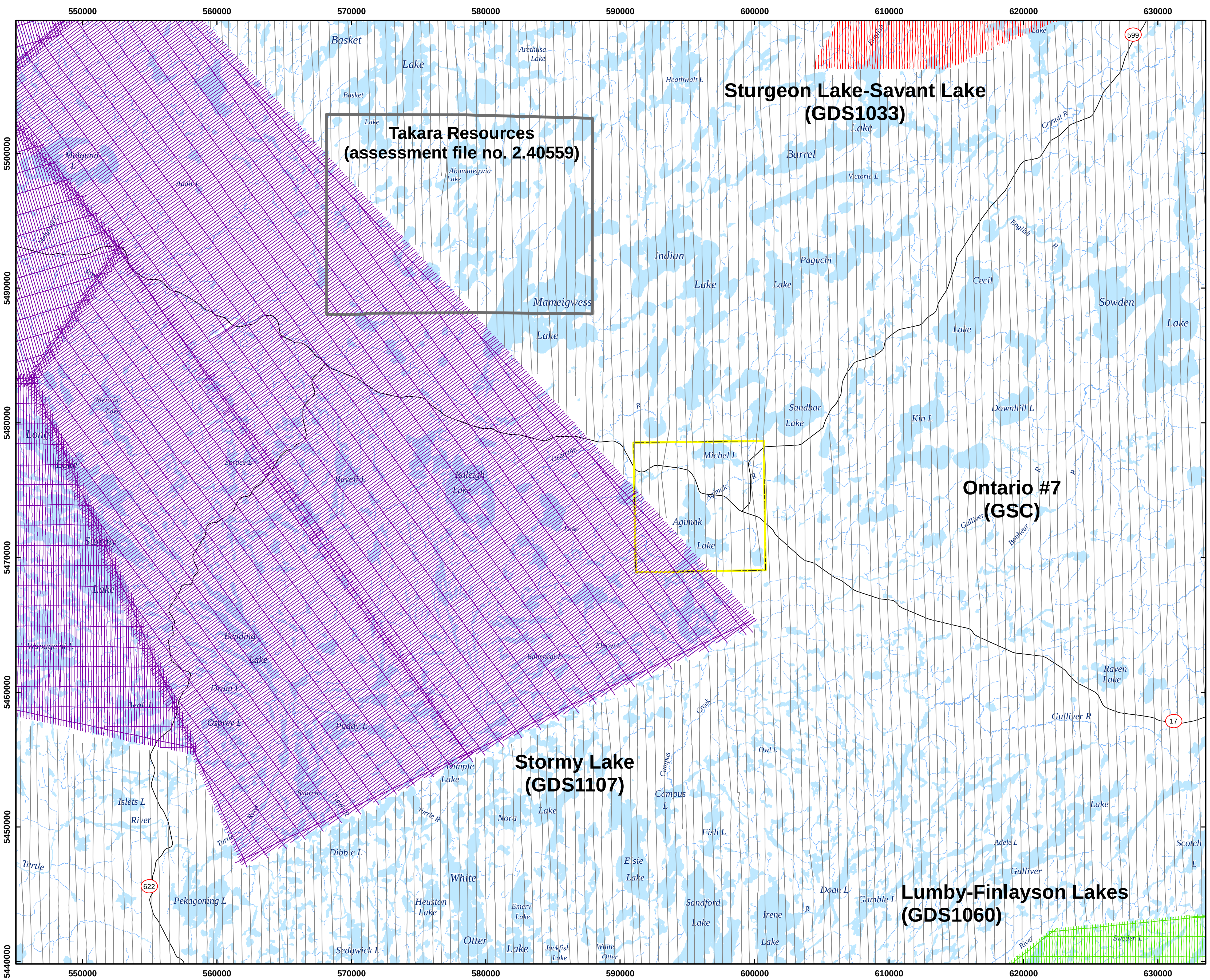
Paterson, Grant & Watson Limited
Consulting Geophysicists
www.pgw.on.ca

J D MOLLARD

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, IGNACE AREA, ONTARIO

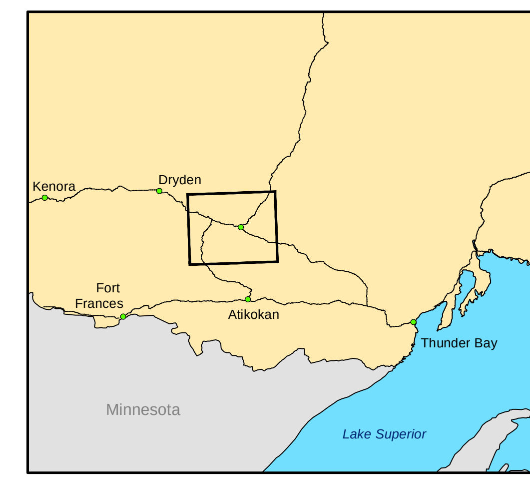
TITLE
Surficial geology of the Ignace area

DESIGN	DVZ	25 JUN 2012	FIGURE 4	REVISION 5
GIS	DVZ	01 AUG 2013		UTM ZONE 15
CHECK	SWR	15 OCT 2013		NAD 1983
REVIEW	GS	16 OCT 2013		1:300,000



LEGEND

- Township of Ignace
- Main road
- Waterbody (permanent)
- Watercourse
- Flightpath OGS 1033
- Flightpath OGS 1060
- Flightpath OGS 1107
- Flightpath GSC Ontario #7
- Takara Resources survey



Data sources:
Flightpath: OGS GDS1033, GDS1060, GDS1107
Road: Selected roads from LIO MNR Road Segment
Township: "ADMIN" file from MNDM Claimap data
Waterbody: LIO OHN Waterbody
Watercourse: LIO OHN Watercourse

NORTH
5 km

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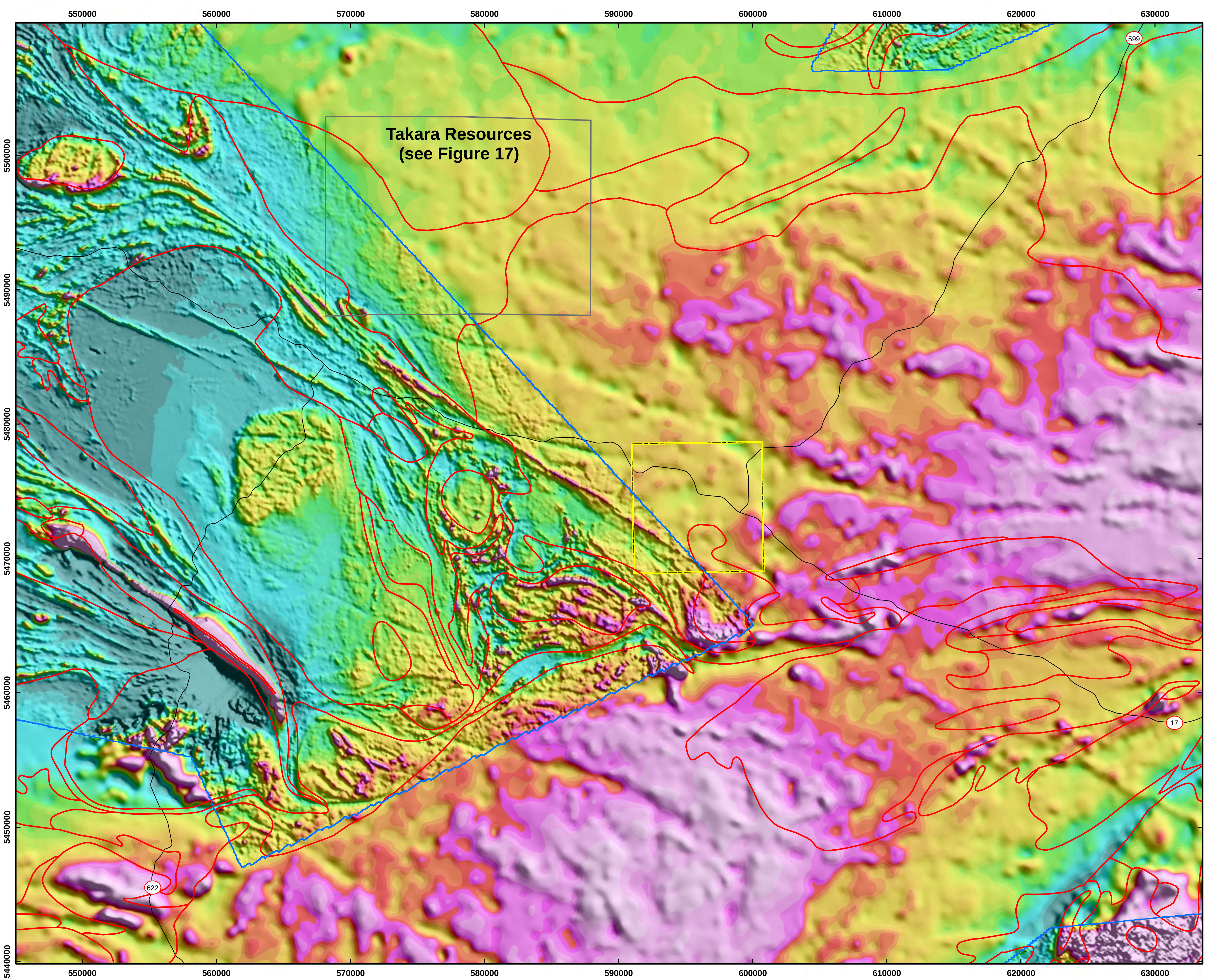
Consulting Geophysicists

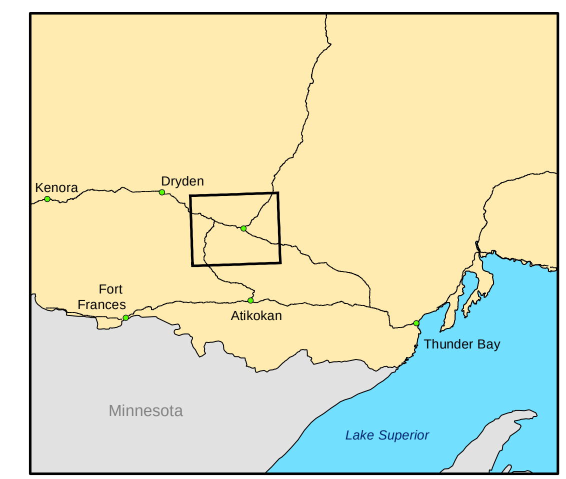
PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, IGNACE AREA, ONTARIO

TITLE
Airborne geophysical coverage of the Ignace area

DESIGN	SWR	20 JUL 2012	FIGURE 5	REVISION 2
GIS	SWR	30 AUG 2013		UTM ZONE 15
CHECK	ELM	30 AUG 2013		NAD 1983
REVIEW	GS	30 AUG 2013		1:300,000

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Ignace\Fig5_PGW_Flightpath.mxd





LEGEND

- Township of Ignace
- Main road
- Bedrock geology contacts
- Geophysical survey outlines
- Takara Resources survey

RTP (nT): 300, 240, 200, 160, 140, 120, 100, 80, 60, 40, 20, 0, -20, -40, -60, -80, -100, -120, -140, -160, -180, -220, -240, -280

Data sources:
High-resolution Magnetics: OGS GDS1033, GDS1060, GDS1107
Regional Magnetics: GSC nationwide compilation
Bedrock Geology Contacts: OGS MRD 126_REV1 (1:250,000)
Road: Selected roads from LIO MNR Road Segment
Township: "ADMIN" file from MNDM Claimap data

NORTH

5 km

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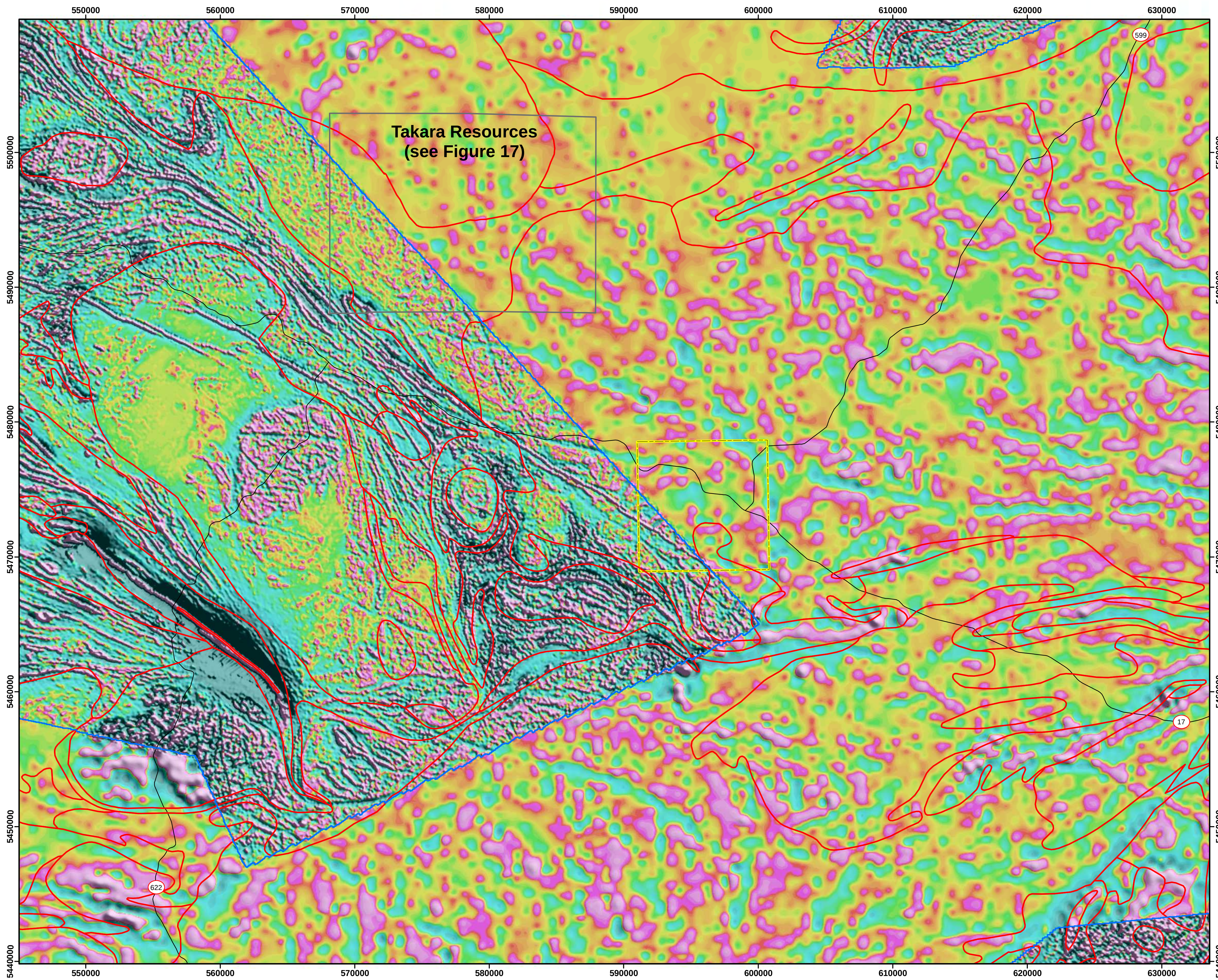
Consulting Geophysicists

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, IGNACE AREA, ONTARIO

TITLE
Residual magnetic field reduced to pole

DESIGN	SWR	20 JUL 2012	FIGURE 6	REVISION 2
GIS	SWR	30 AUG 2013		UTM ZONE 15
CHECK	ELM	30 AUG 2013		NAD 1983
REVIEW	GS	30 AUG 2013		1:300,000

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Ignace\Fig6_PGW_Mag_RTP.mxd

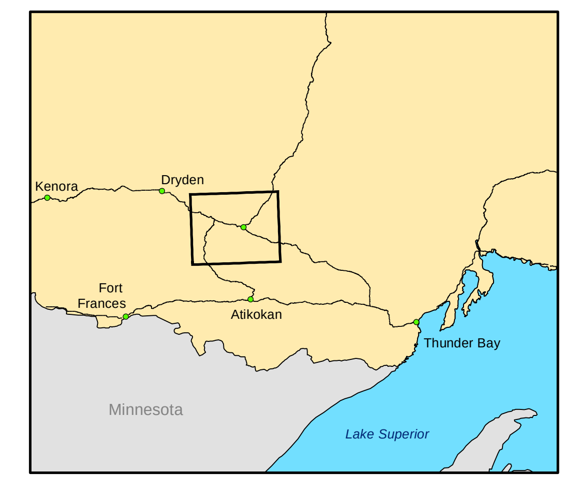


LEGEND

- Township of Ignace
- Main road
- Geophysical survey outlines
- Takara Resources survey
- Bedrock geology contacts

0.37
0.19
0.13
0.10
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.09
-0.11
-0.15
-0.20
-0.28
-0.47

1VD of RTP
(nT/m)



Data sources:
High-resolution Magnetics: OGS GDS1033, GDS1060, GDS1107
Regional Magnetics: GSC nationwide compilation
Bedrock Geology Contacts: OGS MRD 126_REV1 (1:250,000)
Road: Selected roads from LIO MNR Road Segment
Township: "ADMIN" file from MNDM Claimap data

NORTH
5 km

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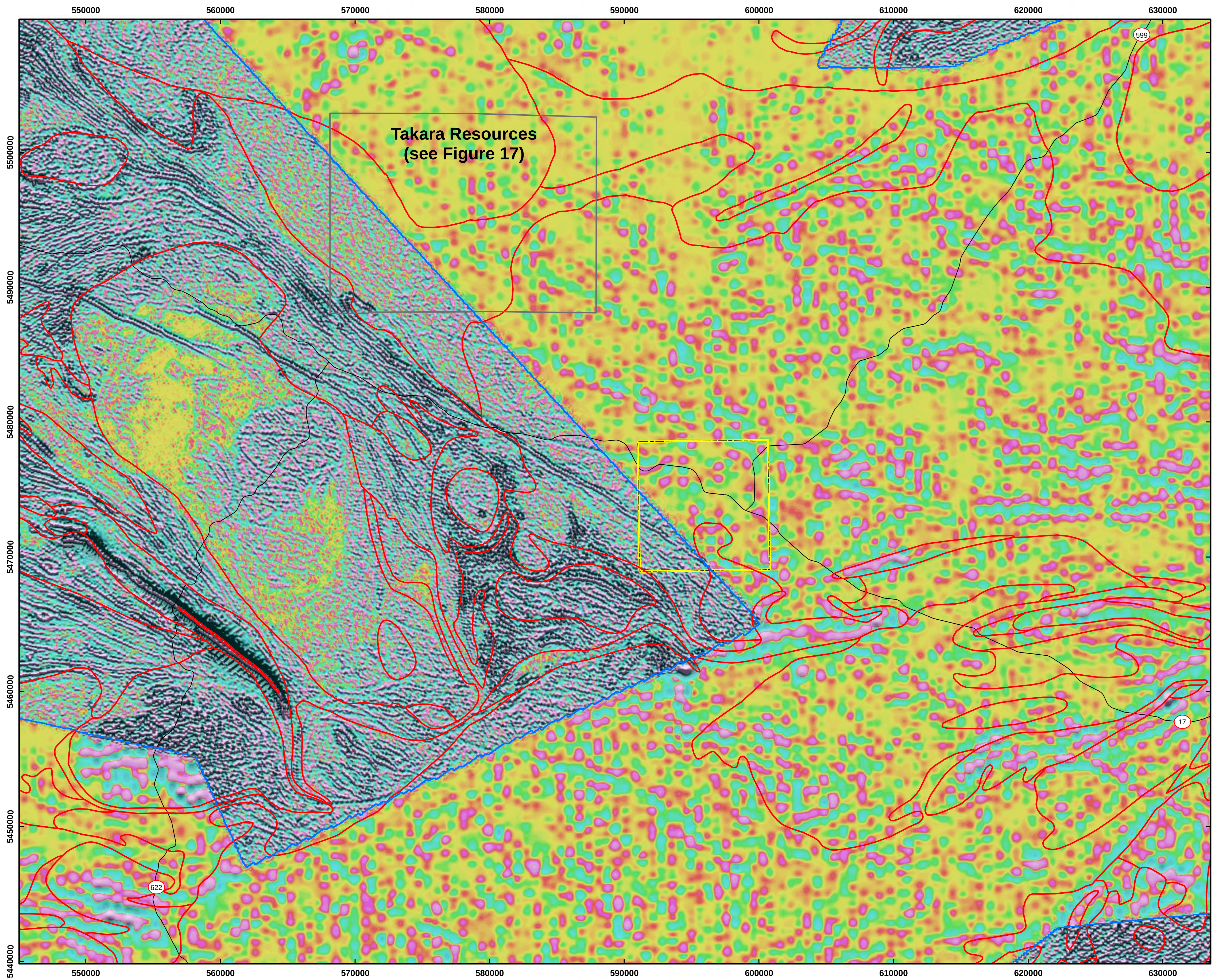
PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT,
GEOPHYSICAL STUDY, IGNACE AREA, ONTARIO

TITLE
First vertical derivative of the pole reduced magnetic field

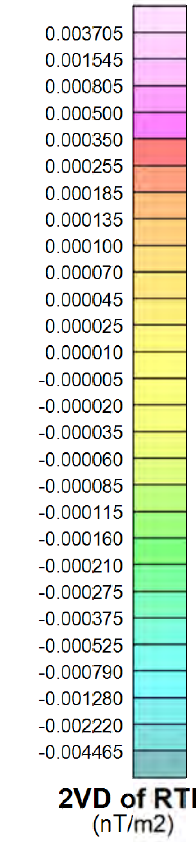
DESIGN	SWR	20 JUL 2012	FIGURE 7	REVISION 2
GIS	SWR	30 AUG 2013		UTM ZONE 15
CHECK	ELM	30 AUG 2013		NAD 1983
REVIEW	GS	30 AUG 2013		1:300,000

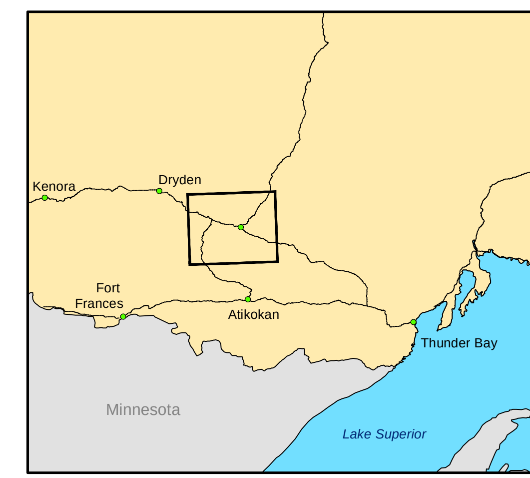
C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Ignace\Fig7_PGW_Mag_RTP_1VD.mxd



LEGEND

- Township of Ignace
- Main road
- Geophysical survey outlines
- Takara Resources survey
- Bedrock geology contacts





Data sources:
High-resolution Magnetics: OGS GDS1033, GDS1060, GDS1107
Regional Magnetics: GSC nationwide compilation
Bedrock Geology Contacts: OGS MRD 126_REV1 (1:250,000)
Road: Selected roads from LIO MNR Road Segment
Township: "ADMIN" file from MNDM Claimap data

NORTH
5 km

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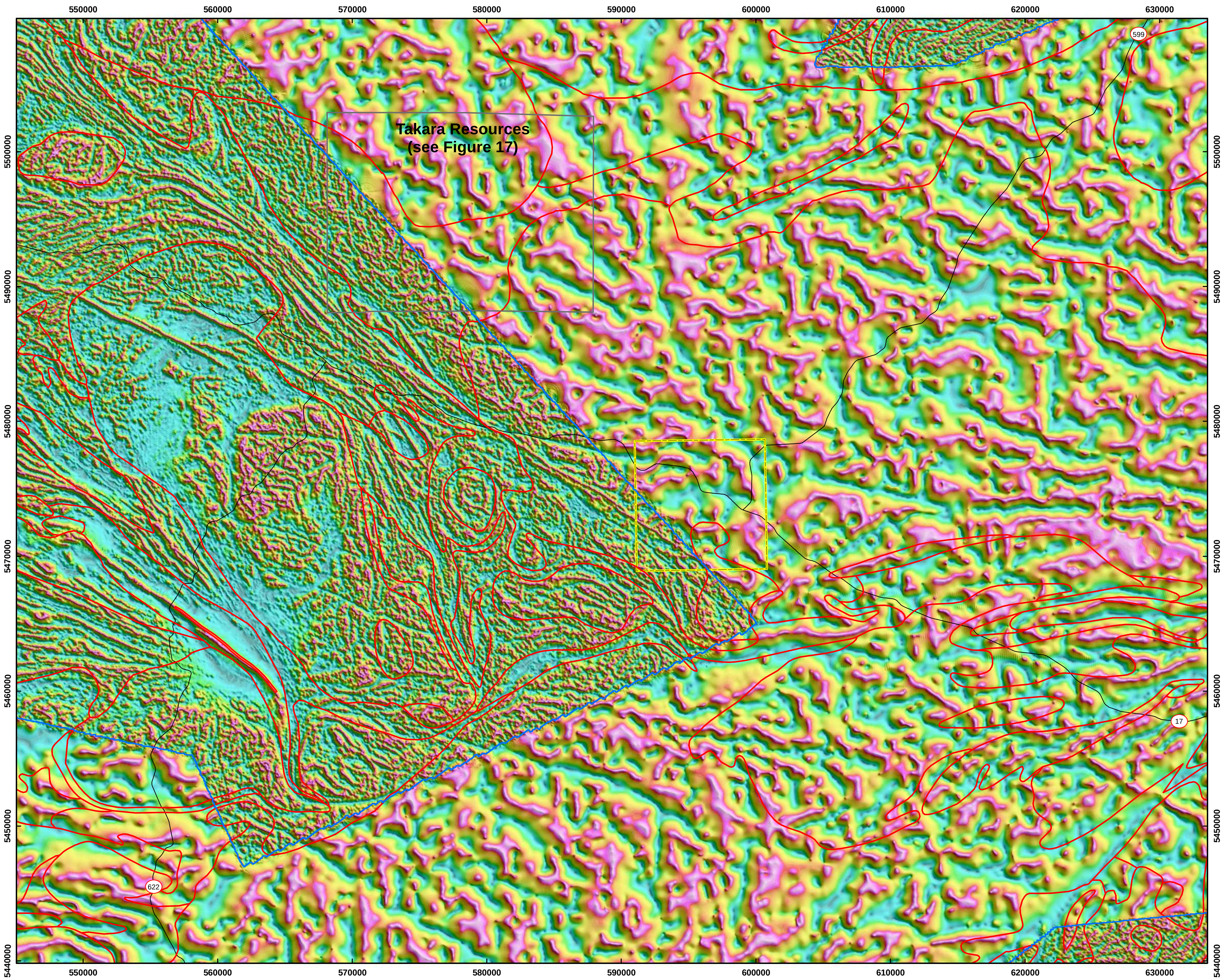
PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT,
GEOPHYSICAL STUDY, IGNACE AREA, ONTARIO

TITLE
Second vertical derivative of the pole reduced magnetic field
(with mapped geological contacts and geophysical survey outlines)

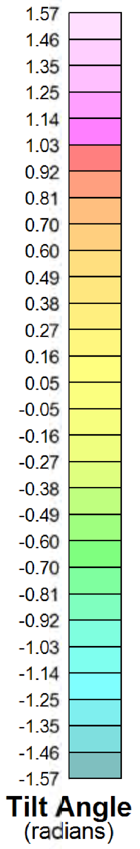
DESIGN	SWR	20 JUL 2012	FIGURE 8	REVISION 3
GIS	SWR	15 OCT 2013		UTM ZONE 15
CHECK	ELM	15 OCT 2013		NAD 1983
REVIEW	GS	16 OCT 2013		1:300,000

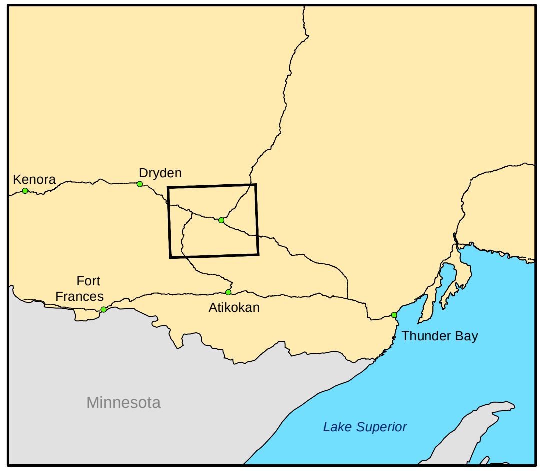
C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Ignace\Oct 2013\Fig8_PGW_Mag_RTP_2VD.mxd



LEGEND

- Township of Ignace
- Main road
- Geophysical survey outlines
- Takara Resources survey
- Bedrock geology contacts





Data sources:
High-resolution Magnetics: OGS GDS1033, GDS1060, GDS1107
Regional Magnetics: GSC nationwide compilation
Bedrock Geology Contacts: OGS MRD 126_REV1 (1:250,000)
Road: Selected roads from LIO MNR Road Segment
Township: "ADMIN" file from MNDM Claimap data

NORTH
5 km

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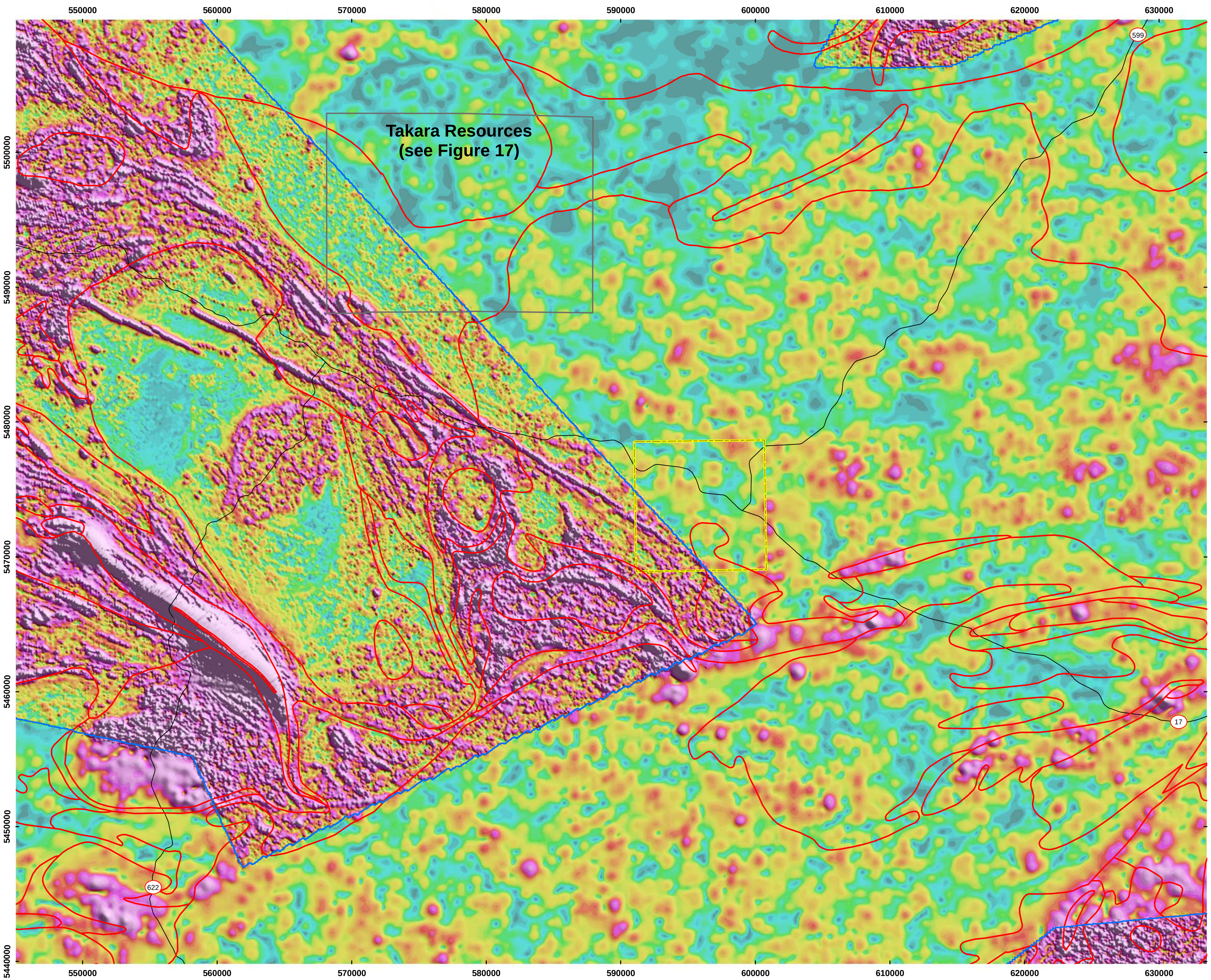
PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, IGNACE AREA, ONTARIO

TITLE
Tilt angle of the pole reduced magnetic field

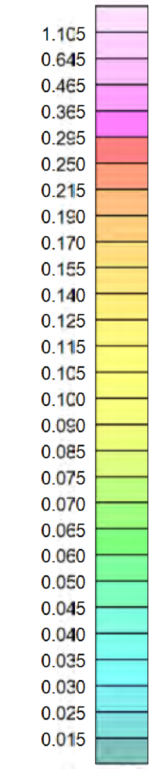
DESIGN	SWR	20 JUL 2012	FIGURE 9	REVISION 2
GIS	SWR	30 AUG 2013		UTM ZONE 15
CHECK	ELM	30 AUG 2013		NAD 1983
REVIEW	GS	30 AUG 2013		1:300,000

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Ignace\Fig9_PGW_Mag_RTP_Tilt.mxd

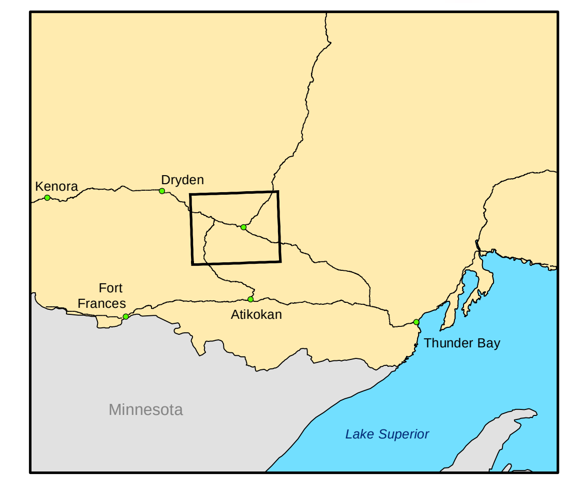


LEGEND

- Township of Ignace
- Main road
- Geophysical survey outlines
- Takara Resources survey
- Bedrock geology contacts



Analytic Signal
(nT/m)



Data sources:
High-resolution Magnetics: OGS GDS1033, GDS1060, GDS1107
Regional Magnetics: GSC nationwide compilation
Bedrock Geology Contacts: OGS MRD 126_REV1 (1:250,000)
Road: Selected roads from LIO MNR Road Segment
Township: "ADMIN" file from MNDM Claimap data

NORTH
5 km

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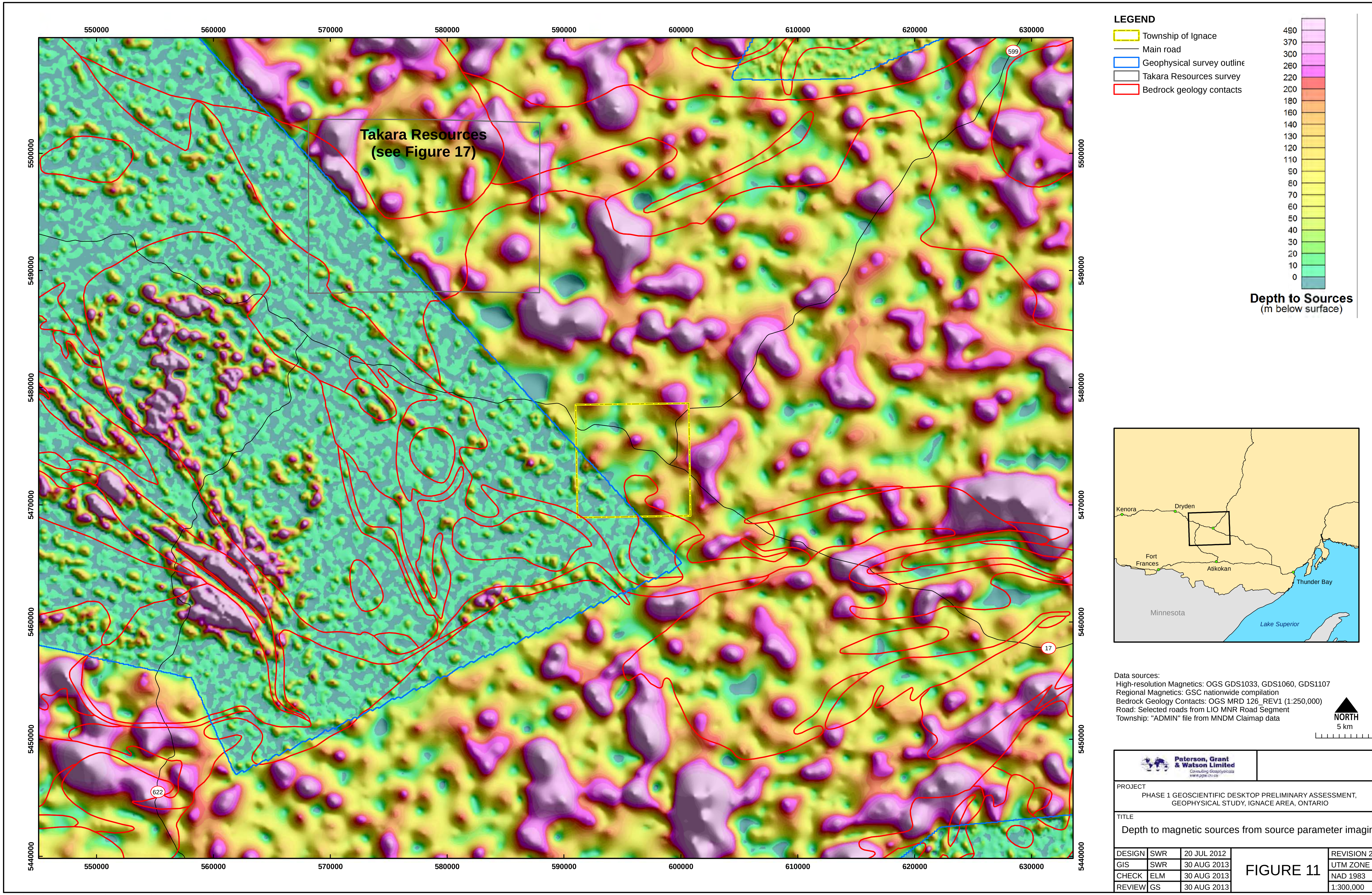
PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, IGNACE AREA, ONTARIO

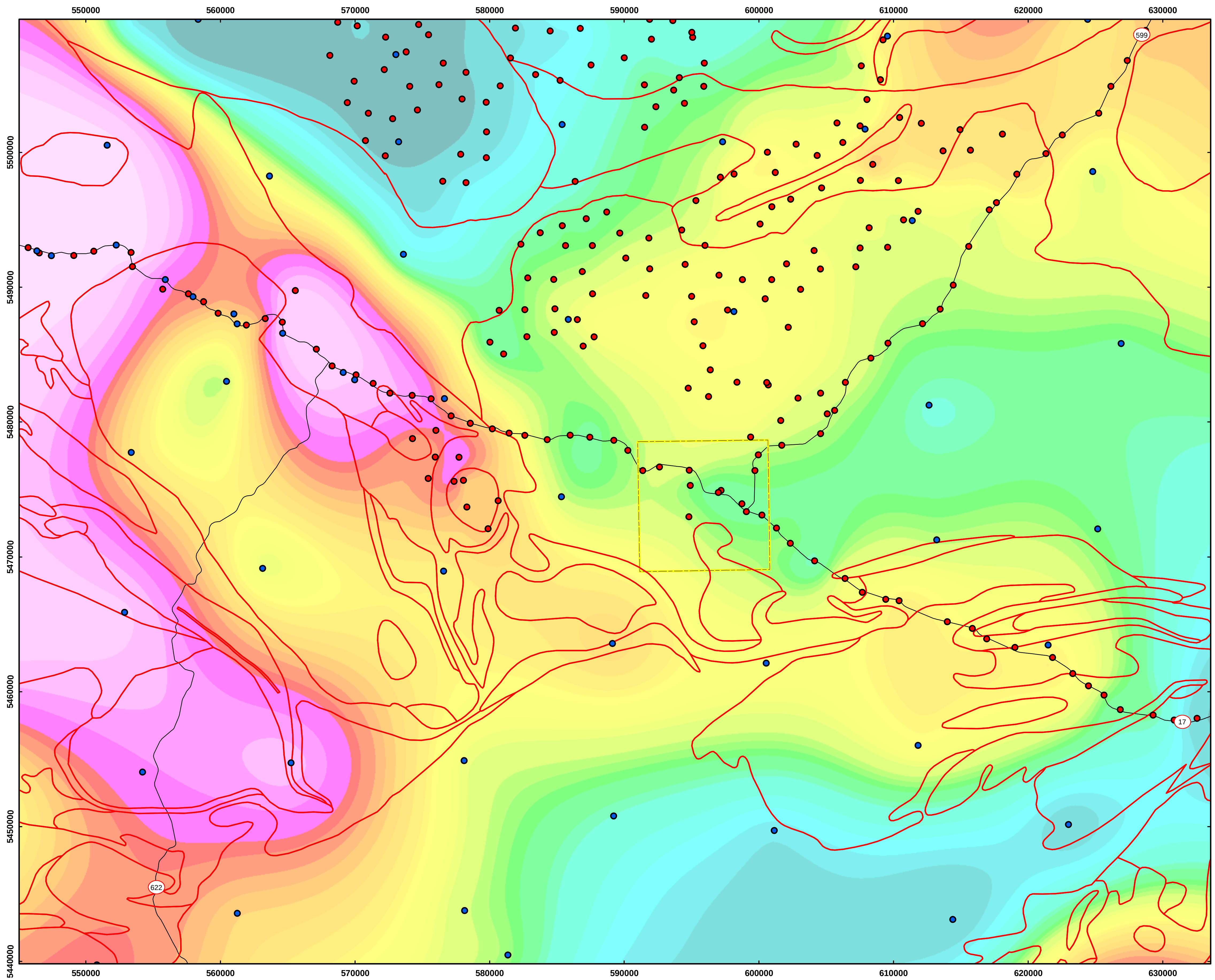
TITLE
Analytic signal amplitude of the total magnetic field

DESIGN	SWR	20 JUL 2012	FIGURE 10	REVISION 2
GIS	SWR	30 AUG 2013		UTM ZONE 15
CHECK	ELM	30 AUG 2013		NAD 1983
REVIEW	GS	30 AUG 2013		1:300,000

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Ignace\Fig10_PGW_Mag_ASIG.mxd



Takara Resources
(see Figure 17)
550000
560000
570000
580000
590000
600000
610000
620000
630000
5500000
5490000
5480000
5470000
5460000
5450000
5440000
599
17
622
LEGEND
Township of Ignace
Main road
Geophysical survey outline
Takara Resources survey
Bedrock geology contacts
490
370
300
260
220
200
180
160
140
130
120
110
90
80
70
60
50
40
30
20
10
0
Depth to Sources
(m below surface)
Kenora
Dryden
Fort Frances
Atikokan
Thunder Bay
Minnesota
Lake Superior
Data sources:
High-resolution Magnetics: OGS GDS1033, GDS1060, GDS1107
Regional Magnetics: GSC nationwide compilation
Bedrock Geology Contacts: OGS MRD 126_REV1 (1:250,000)
Road: Selected roads from LIO MNR Road Segment
Township: "ADMIN" file from MNDM Claimap data
NORTH
5 km
Paterson, Grant & Watson Limited
Consulting Geophysicists
PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, IGNACE AREA, ONTARIO
TITLE
Depth to magnetic sources from source parameter imaging
DESIGN SWR 20 JUL 2012
GIS SWR 30 AUG 2013
CHECK ELM 30 AUG 2013
REVIEW GS 30 AUG 2013
FIGURE 11
REVISION 2
UTM ZONE 15
NAD 1983
1:300,000
C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Ignace\Fig11_PGW_SPIDepth.mxd

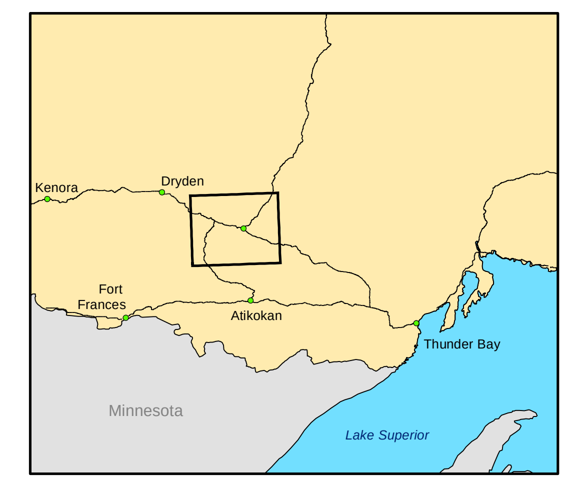


LEGEND

- Township of Ignace
- Main road
- Bedrock geology contacts
- GSC Gravity Stations
- Szewczyk Gravity Stations

Bouguer Gravity (mGals)

-24.3
-43.0
-48.5
-51.5
-53.5
-56.0
-57.0
-58.5
-59.5
-60.5
-61.5
-62.5
-63.5
-64.0
-64.5
-65.5
-66.0
-66.5
-67.5
-68.0
-68.5
-69.0
-70.0
-70.5
-72.0
-73.0
-74.0
-75.0
-77.0
-82.1



Data sources:
Regional Gravity: GSC nationwide compilation
Detailed Gravity: Szewczyk (1974)
Bedrock Geology Contacts: OGS MRD 126_REV1 (1:250,000)
Road: Selected roads from LIO MNR Road Segment
Township: "ADMIN" file from MNDM Claimap data

NORTH
5 km

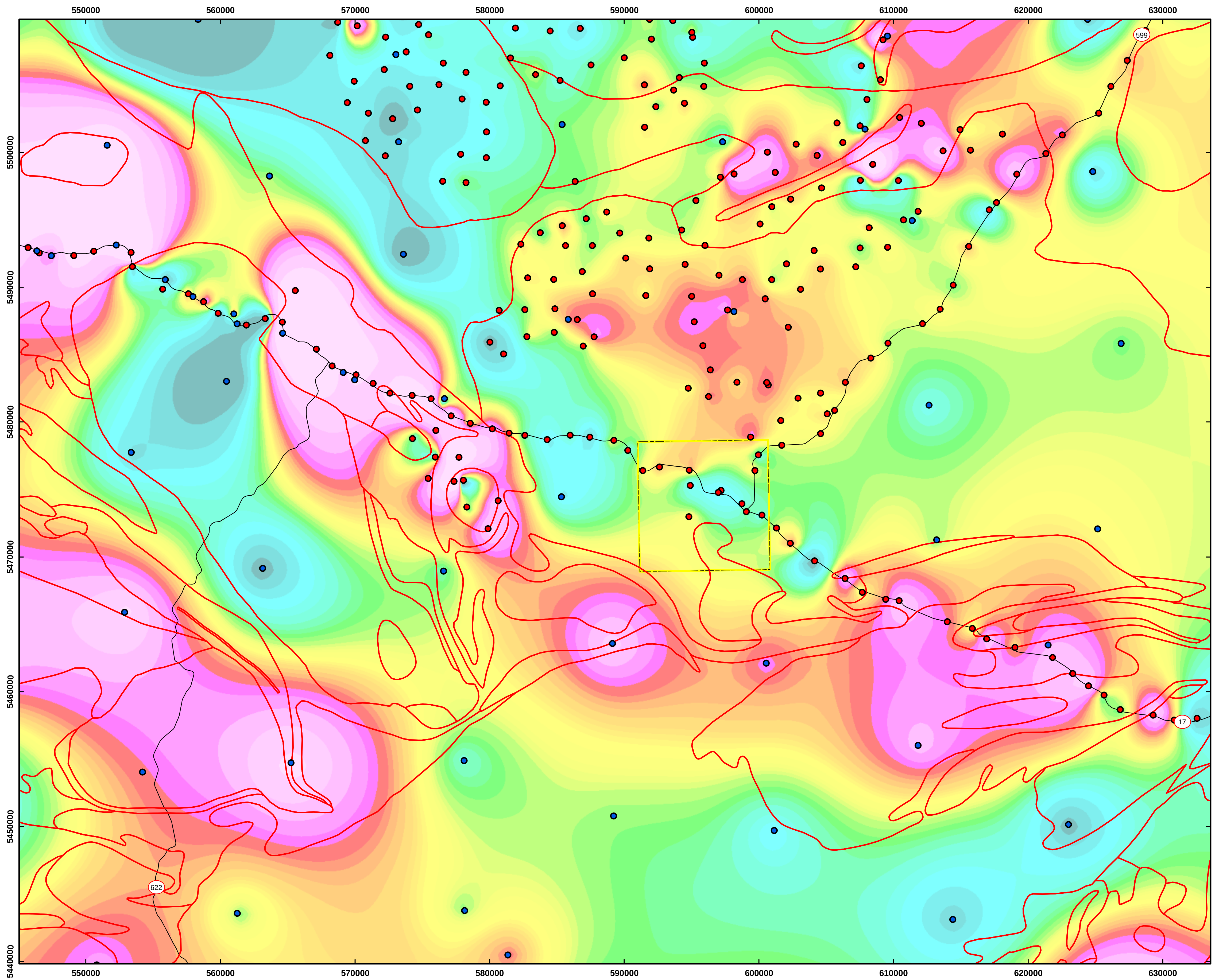
Paterson, Grant & Watson Limited
Consulting Geophysicists

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, IGNACE AREA, ONTARIO

TITLE
Bouguer gravity field with station locations

DESIGN	SWR	20 JUL 2012	FIGURE 12	REVISION 3
GIS	SWR	30 AUG 2013		UTM ZONE 15
CHECK	ELM	30 AUG 2013		NAD 1983
REVIEW	GS	30 AUG 2013		1:300,000

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Ignace\Fig12_PGW_Grav_Boug.mxd

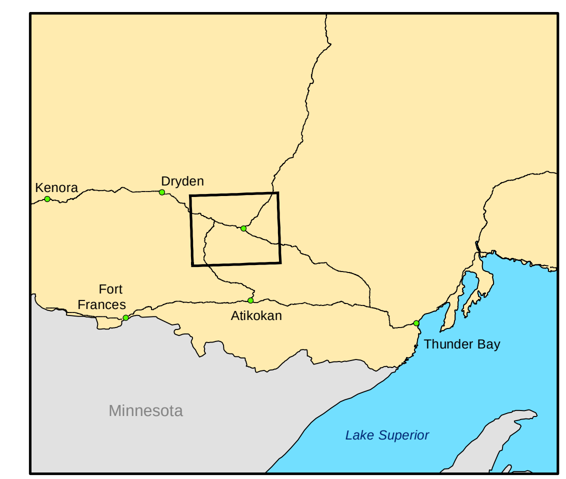


LEGEND

- Township of Ignace
- Main road
- Bedrock geology contacts
- GSC Gravity Stations
- Szewczyk Gravity Stations

1VD of Bouguer Gravity (mGal/m)

0.01093
0.00270
0.00170
0.00120
0.00085
0.00065
0.00045
0.00035
0.00025
0.00015
0.00005
0.00000
-0.00005
-0.00010
-0.00020
-0.00030
-0.00035
-0.00040
-0.00045
-0.00055
-0.00065
-0.00075
-0.00085
-0.00100
-0.00120
-0.00140
-0.00175
-0.00215
-0.00270
-0.00974



Data sources:
Regional Gravity: GSC nationwide compilation
Detailed Gravity: Szewczyk (1974)
Bedrock Geology Contacts: OGS MRD 126_REV1 (1:250,000)
Road: Selected roads from LIO MNR Road Segment
Township: "ADMIN" file from MNDM Claimap data

NORTH
5 km

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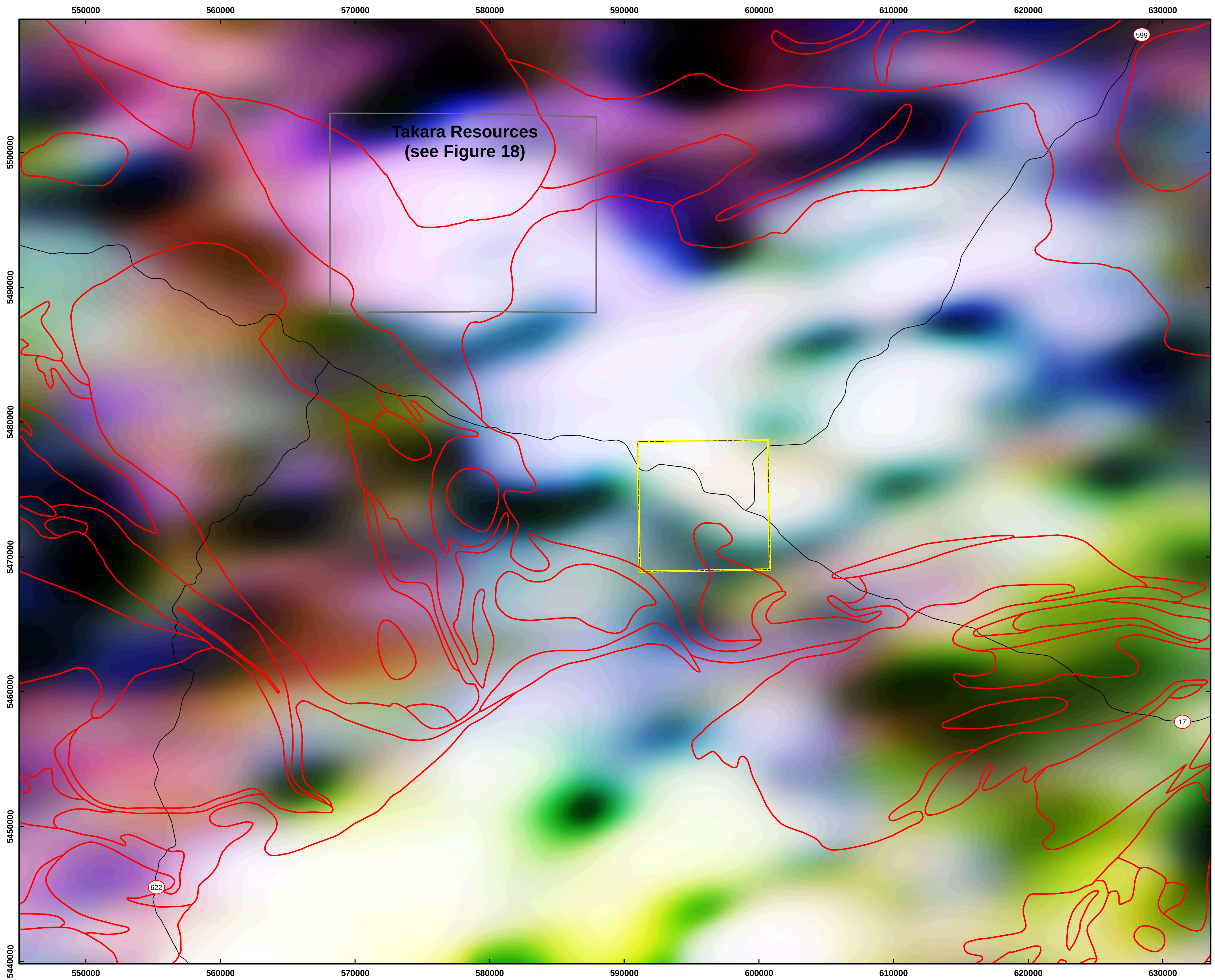
www.pgw.on.ca

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, IGNACE AREA, ONTARIO

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

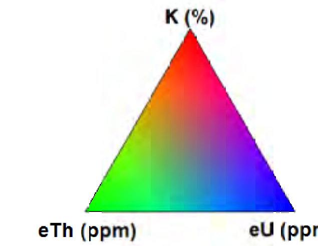
DESIGN	SWR	20 JUL 2012	FIGURE 13	REVISION 3
GIS	SWR	30 AUG 2013		UTM ZONE 15
CHECK	ELM	30 AUG 2013		NAD 1983
REVIEW	GS	30 AUG 2013		1:300,000

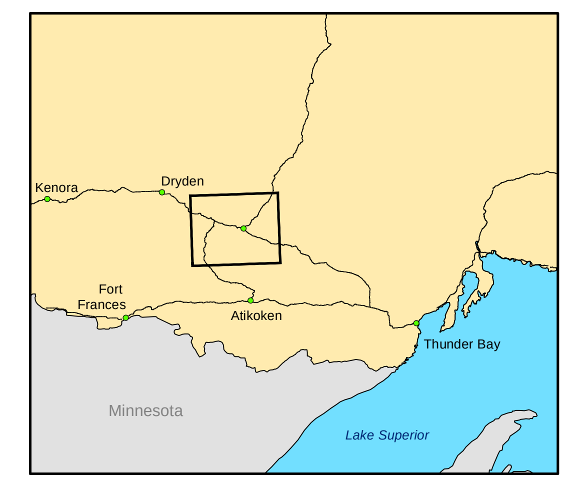
C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Ignace\Fig13_PGW_Grav_Boug_1VD.mxd



LEGEND

Township of Ignace
Main road
Takara Resources survey
Bedrock geology contacts





Data sources:
Regional Radiometrics: GSC nationwide compilation
Bedrock Geology Contacts: OGS MRD 126_REV1 (1:250,000)
Road: Selected roads from LIO MNR Road Segment
Township: "ADMIN" file from MNDM Claimap data

NORTH
5 km

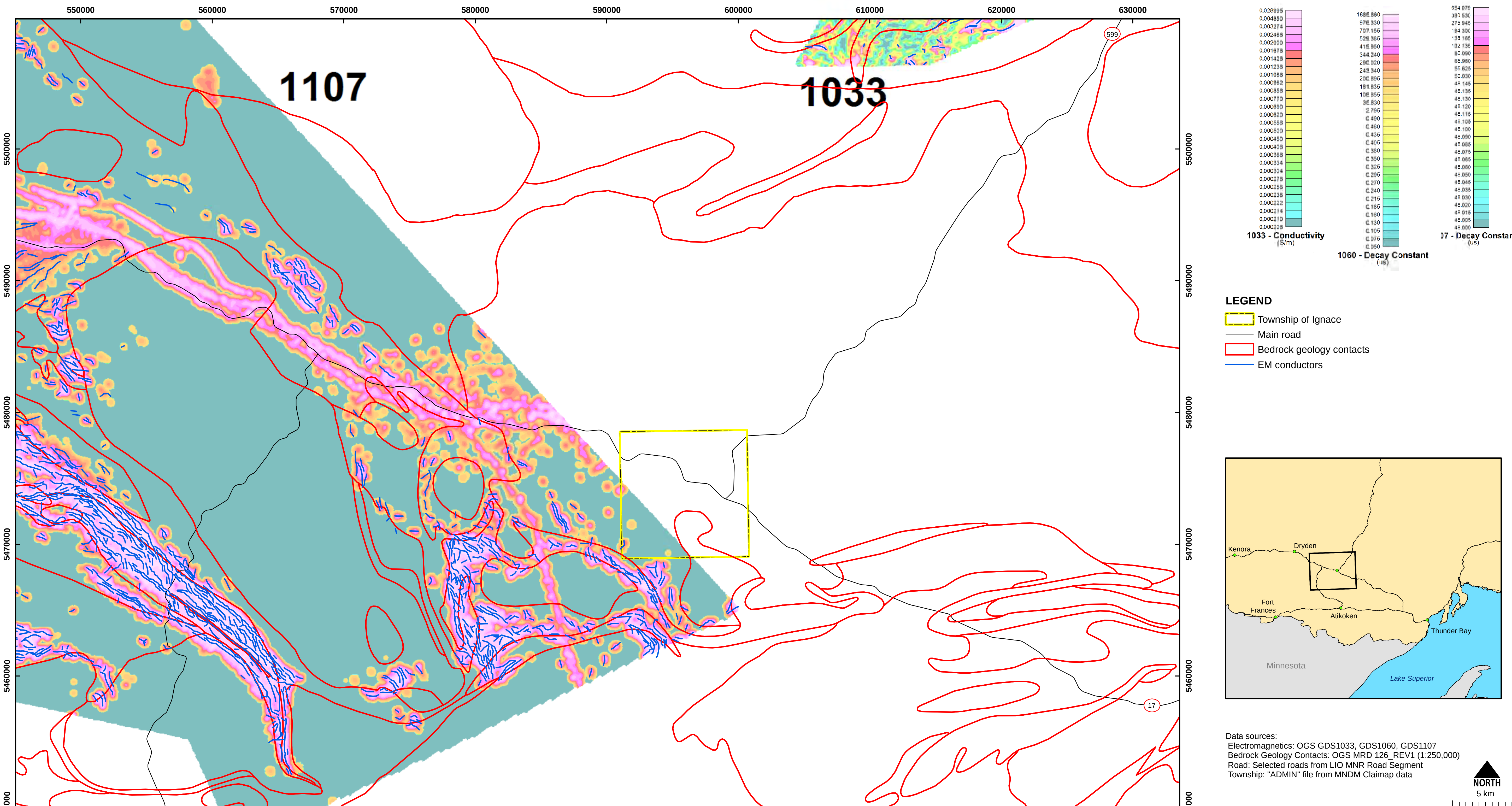
Paterson, Grant & Watson Limited
Consulting Geophysicists

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, TERRAIN AND REMOTE SENSING STUDY, IGNACE AREA, ONTARIO

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

DESIGN	SWR	20 JUL 2012	FIGURE 14	REVISION 1
GIS	SWR	15 OCT 2013		UTM ZONE 15
CHECK	ELM	15 OCT 2013		NAD 1983
REVIEW	GS	16 OCT 2013		1:300,000

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Ignace\Oct 2013\Fig14_PGW_Rad_Ternary.mxd



Data sources:
Electromagnetics: OGS GDS1033, GDS1060, GDS1107
Bedrock Geology Contacts: OGS MRD 126_REV1 (1:250,000)
Road: Selected roads from LIO MNR Road Segment
Township: "ADMIN" file from MNDM Claimap data

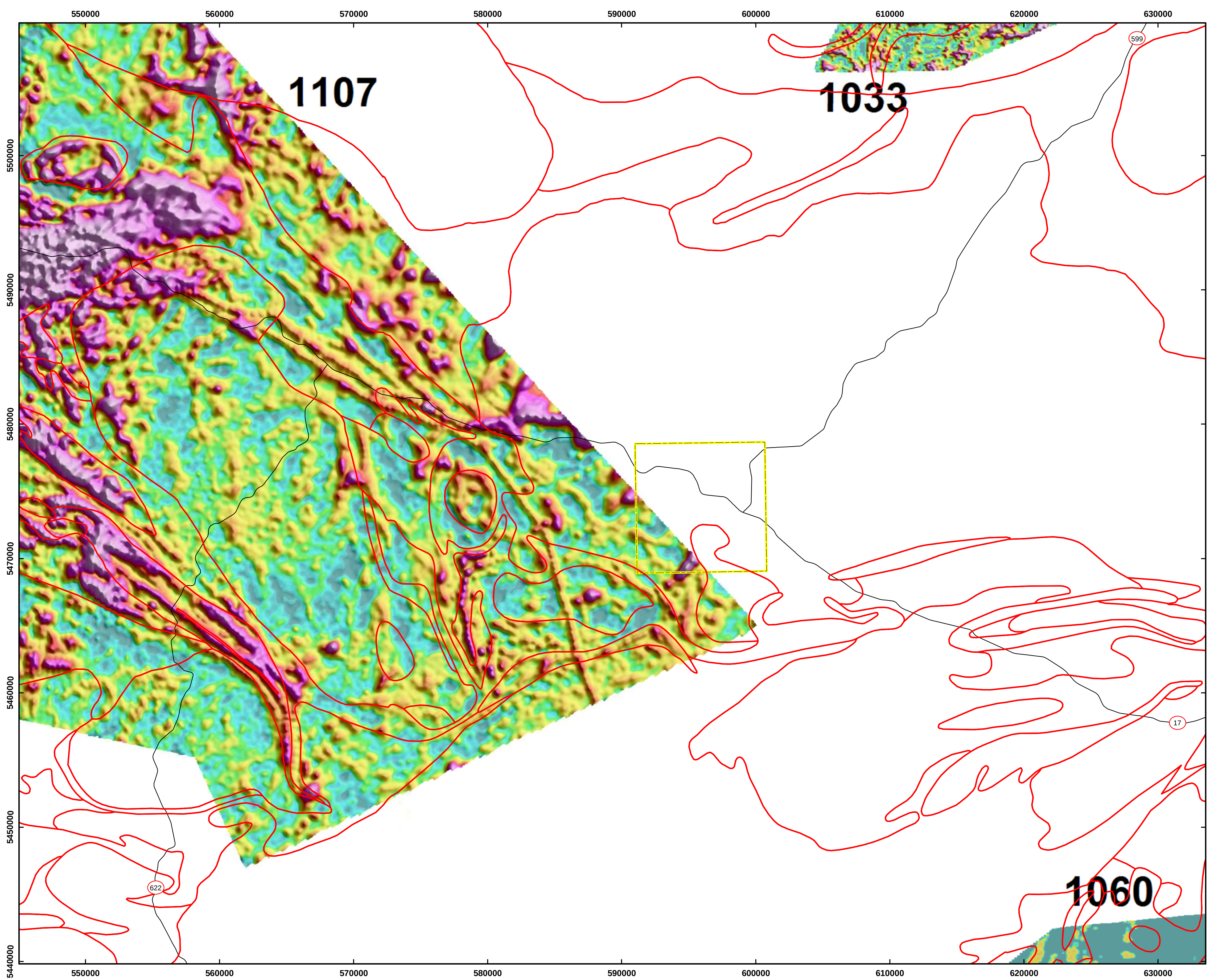
Paterson, Grant & Watson Limited

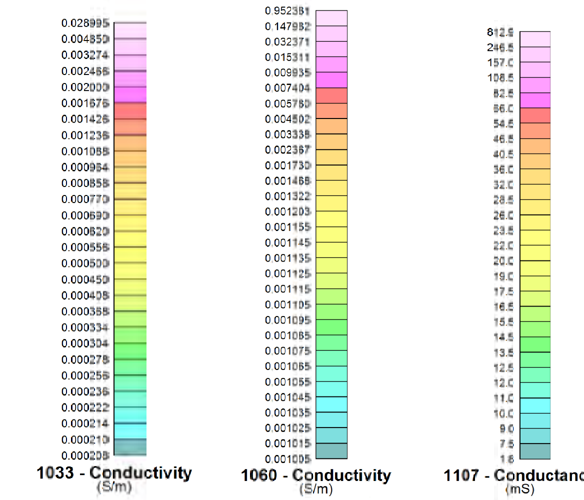
PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, TERRAIN AND REMOTE SENSING STUDY, IGNACE AREA, ONTARIO

TITLE
EM conductors over apparent conductivity (GDS1033) and decay constant (GDS1060 and GDS1107)

DESIGN	SWR	20 JUL 2012	FIGURE 15	REVISION 1
GIS	SWR	30 AUG 2013		UTM ZONE 15
CHECK	ELM	30 AUG 2013		NAD 1983
REVIEW	GS	30 AUG 2013		1:300,000

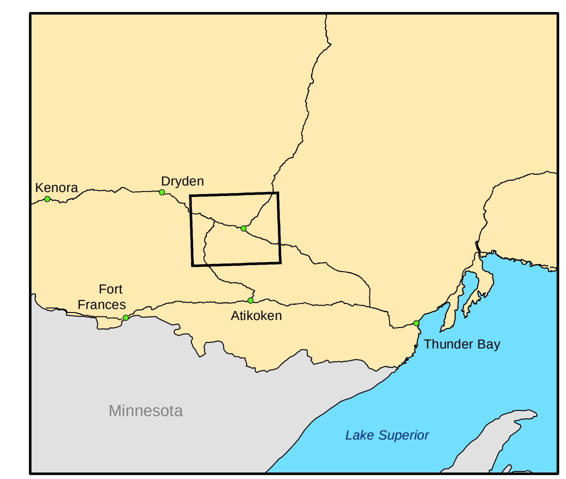
C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Ignace\Fig15_PGW_EM_Decay.mxd





LEGEND

- Township of Ignace
- Main road
- Bedrock geology contacts



Data sources:
Electromagnetics: OGS GDS1033, GDS1060, GDS1107
Bedrock Geology Contacts: OGS MRD 126_REV1 (1:250,000)
Road: Selected roads from LIO MNR Road Segment
Township: "ADMIN" file from MNDM Claimap data

NORTH
5 km

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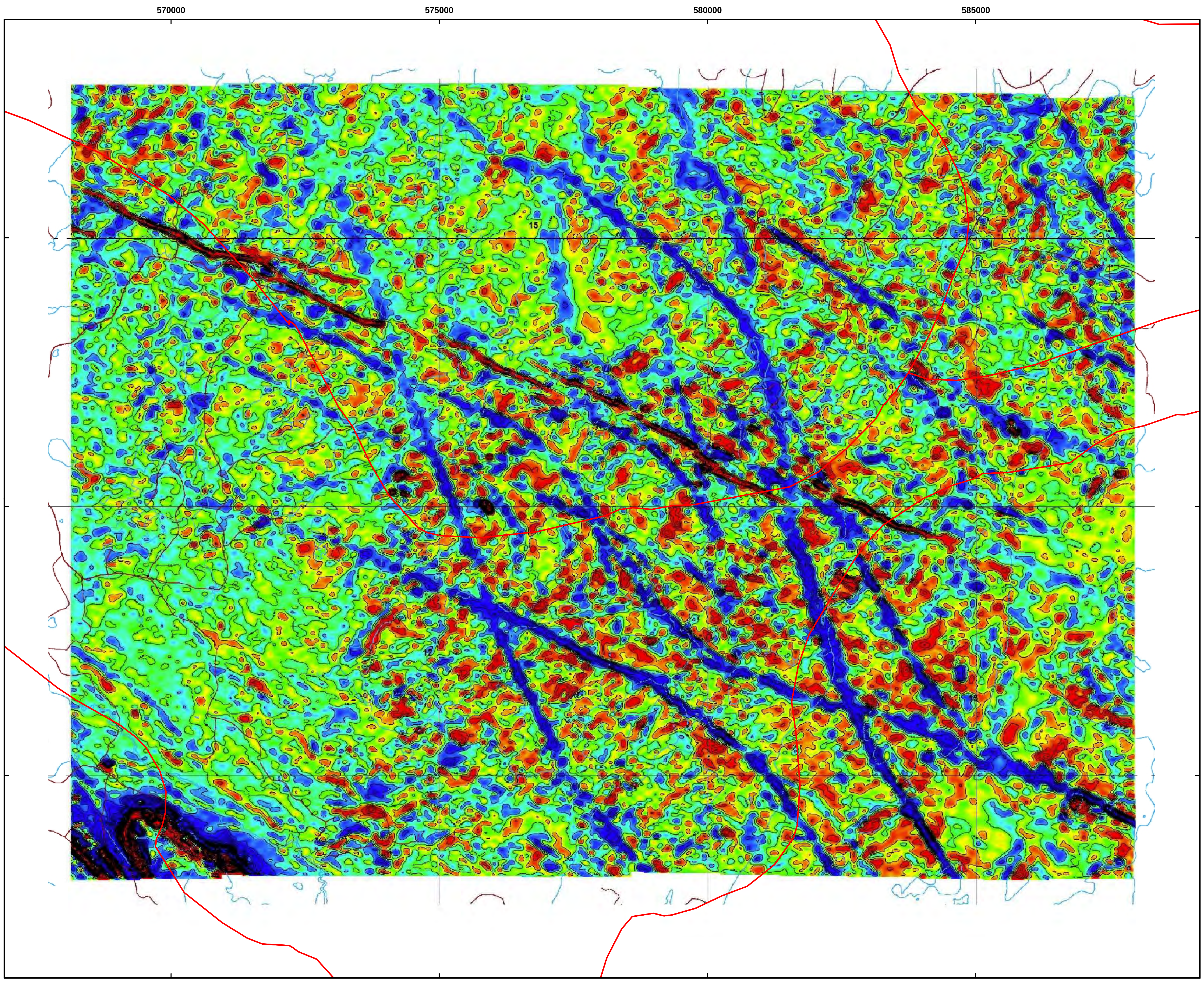
www.pgw.on.ca

PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, IGNACE AREA, ONTARIO

TITLE
Apparent conductivity (GDS1033 and GDS1060) and apparent conductance (GDS1107)

DESIGN	SWR	20 JUL 2012	FIGURE 16	REVISION 1
GIS	SWR	15 OCT 2013		UTM ZONE 15
CHECK	ELM	15 OCT 2013		NAD 1983
REVIEW	GS	16 OCT 2013		1:300,000

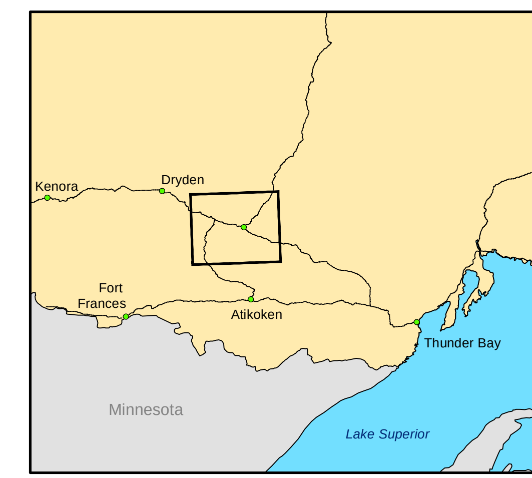
C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Ignace\Oct 2013\Fig16_PGW_EM_Cond.mxd



LEGEND

Bedrock geology contacts

nT/m
8.8803
0.1649
0.1046
0.0659
0.0252
0.0014
-0.0189
-0.0582
-0.0969
-0.1634
-3.9331



Data sources:
High-resolution Magnetics: Takara Resources Inc.
(assessment file no. 2.40559)
Bedrock Geology Contacts: OGS MRD 126_REV1 (1:250,000)

NORTH
5 km

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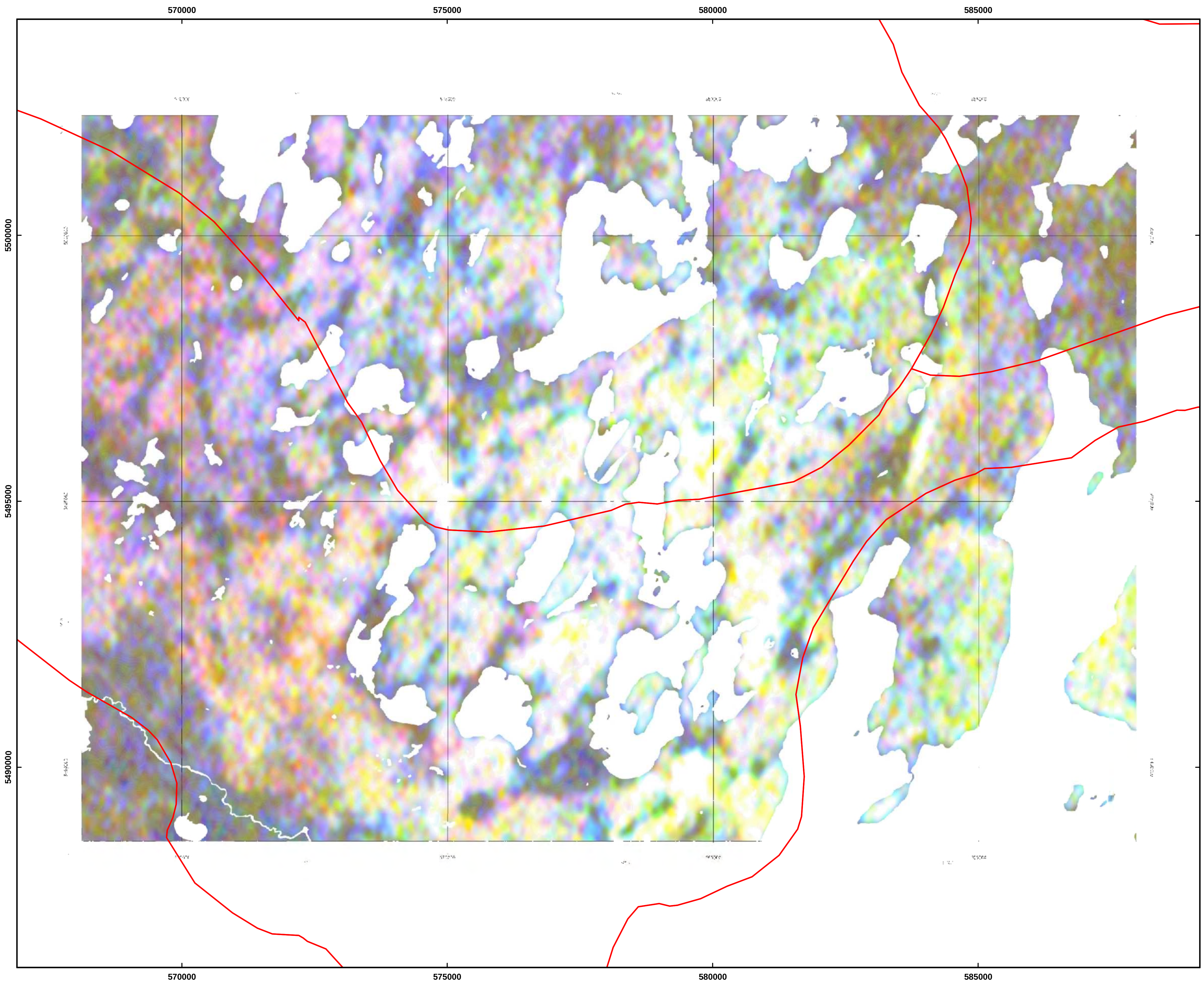
PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, IGNACE AREA, ONTARIO

TITLE
First vertical derivative of the total magnetic field, Basket Lake area, Takara Resources Inc. (Evans, 2008)

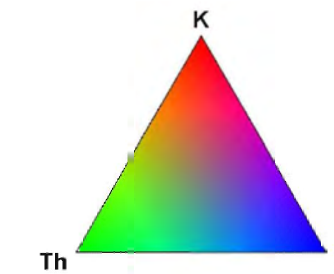
DESIGN	SWR	20 JUL 2012	FIGURE 17	REVISION 1
GIS	SWR	30 AUG 2013		UTM ZONE 15
CHECK	ELM	30 AUG 2013		NAD 1983
REVIEW	GS	30 AUG 2013		1:75,000

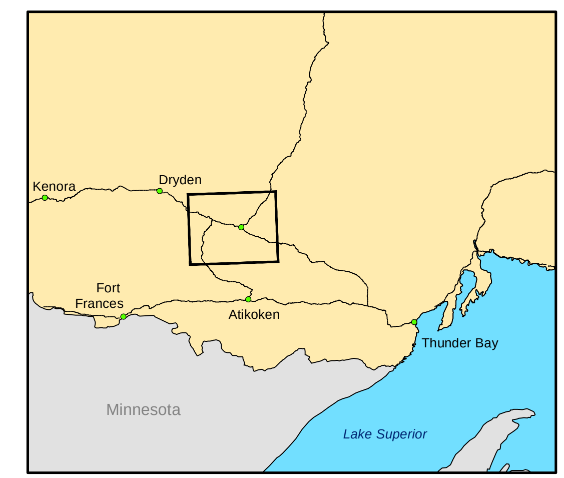
C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Ignace\Fig17_PGW_Mag_Takara_TMI_1VD.mxd



LEGEND

Bedrock geology contacts





Data sources:
High-resolution Radiometrics: Takara Resources Inc. (assessment file no. 2.40559)
Bedrock Geology Contacts: OGS MRD 126_REV1 (1:250,000)

NORTH

5 km

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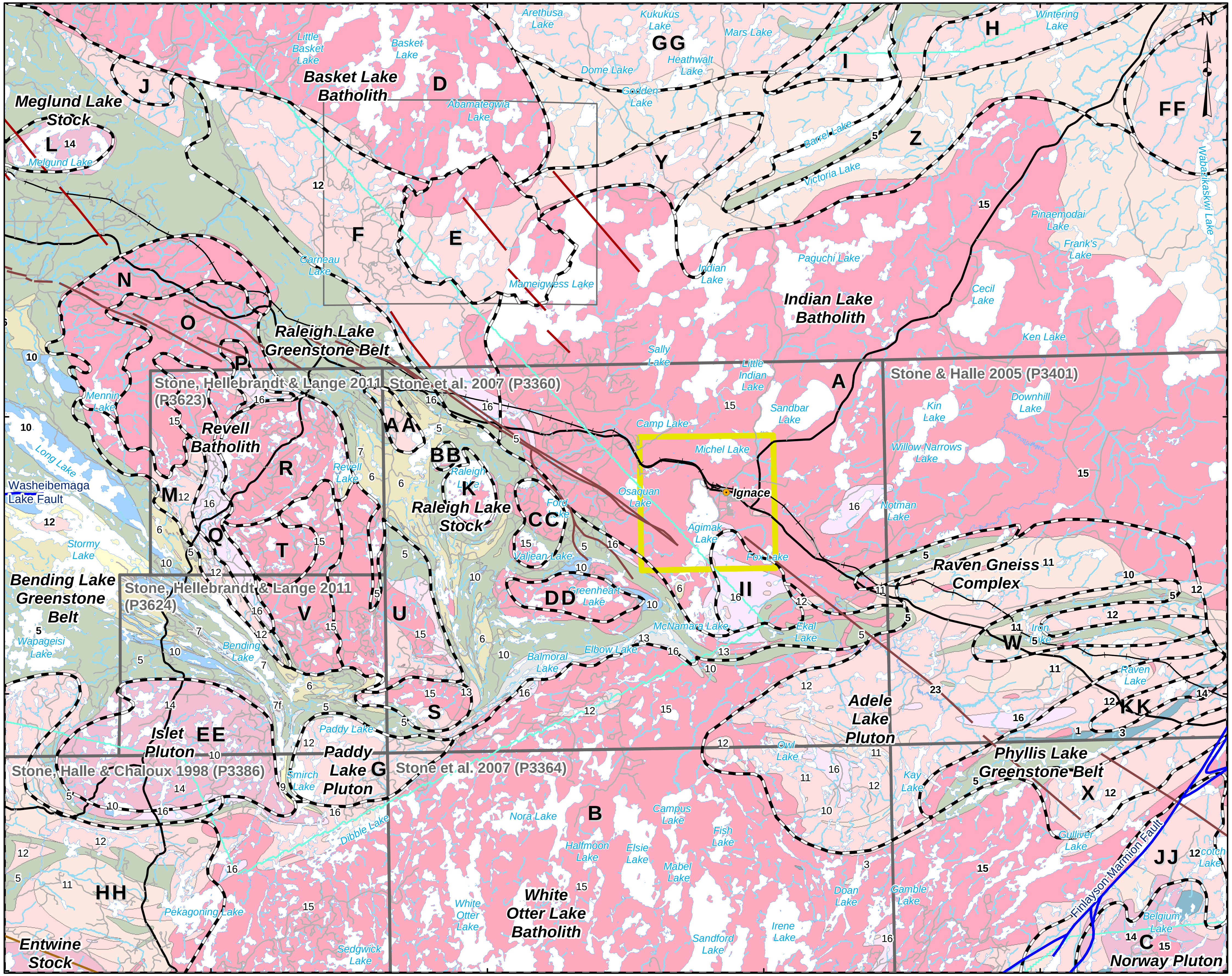
PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, IGNACE AREA, ONTARIO

TITLE
Ternary radiometric image (RGB = K-eTh-eU), Basket Lake area, Takara Resources Inc. (Pelletier, 2008)

DESIGN	SWR	20 JUL 2012	FIGURE 18	REVISION 1
GIS	SWR	30 AUG 2013		UTM ZONE 15
CHECK	ELM	30 AUG 2013		NAD 1983
REVIEW	GS	30 AUG 2013		1:75,000

C:\Users\Stephen\PGW\NWMO\PGW Reports\August 2013\Ignace\Fig18_PGW_Rad_Takara_Ternary.mxd



LEGEND

- Municipal Boundary (Township of Ignace)
- Ignace
- Main Road
- Local Road
- Railway
- Watercourse, Permanent
- Watercourse, Intermittent
- Water Area, Permanent
- Mapped Fault

Mapped Dyke

- Kenora-Fort Frances Dyke
- Wabigoon Dyke
- Dyke (Other)
- Detailed Geology Extent

Bedrock Geology

- 23 Mafic and related intrusive rocks
- 16 Hornblendite - nepheline syenite suite
- 15 Massive granodiorite to granite
- 14-Diorite-monzodiorite-granodiorite suite
- 13 Muscovite-bearing granitic rock
- 12 Foliated tonalite suite
- 11 Gneissic tonalite suite
- 10 Mafic and ultramafic rocks
- 9 Coarse clastic metasedimentary rocks
- 7 Metasedimentary rocks
- 7c Marble, chert, iron formation, minor metavolcanic rocks
- 6 Felsic to intermediate metavolcanic rocks
- 5 Mafic to intermediate metavolcanic rocks
- 4 Mafic to ultramafic metavolcanic rocks
- 3 Mafic metavolcanic and metasedimentary rocks
- Geophysical survey outlines
- Takara Resources survey
- Geological units interpreted from geophysics

Stone et al. 2007 (P3360)
Stone et al. 2007 (P3364)
Stone, Halle & Chaloux 1998 (P3386)
Stone, Hellebrandt & Lange 2011 (P3623)
Stone, Hellebrandt & Lange 2011 (P3624)
Stone & Halle 2005 (P3401)

REFERENCE

Base Data - MNR LIO, obtained 2009-2012
Geology - MRD126-Bedrock Geology of Ontario, 2011
Hillshade - CDED slope raster: Geobase.ca (1:50,000)
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2012
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15N

5 2.5 0 5 10 15
SCALE 1:300,000 KILOMETRES

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PROJECT
PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT, GEOPHYSICAL STUDY, IGNACE AREA, ONTARIO

TITLE
Geophysical interpretation showing distribution of bedrock units for the Ignace area

Golder Associates
Mississauga, Ontario

PROJECT NO. 12-1152-0026			SCALE AS SHOWN	REV. 0.0
DESIGN	PM	17 MAY 2012		
GIS	PMJB	27 AUG 2013		
CHECK	SWR	15 OCT 2013		
REVIEW	GWS	16 OCT 2013		

FIGURE 19

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