New Airborne Geophysical Surveys in the Creighton–Flin Flon Area

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Abstract

The Saskatchewan Geological Survey initiated a multiyear geoscience project in the Creighton–Flin Flon area, near the Saskatchewan–Manitoba border, as part of the Government of Saskatchewan's Mineral Development Strategy, a program aimed at supporting diversification of the province's mineral industry. This project, launched in 2018, is focused on understanding the economic potential of the sub-Phanerozoic basement rocks in the western Flin Flon Domain, and is centred on an area of new airborne geophysical surveys completed in areas between Deschambault, Amisk and Tobin lakes. These surveys comprised helicopter-borne electromagnetic/magnetic surveys funded as part of the Mineral Development Strategy, and fixed-wing gravity gradiometer surveys funded by Natural Resources Canada. The surveys were designed to help understand the basement geology, in particular, the distribution of volcanic sequences that might host volcanogenic massive sulfide deposits and the expressions of ore-forming systems to depth, as well as to provide guidance for exploration. The locations of the airborne surveys were selected to cover areas lacking geophysical data or to provide higher-quality data for areas covered by previous surveys. In this first year of the project, three surveys were conducted using CGG's (Compagnie Générale de Géophysique) HeliTEM EM/magnetic system, and two surveys were conducted using CGG's Falcon gravity gradiometer system. Each survey used a line spacing of 200 m with 1200 m tie-lines. In order to provide value-added products to the new surveys, physical rock properties, including specific gravity, magnetic susceptibility and conductivity, were measured during the summer of 2018 on core samples from drillholes collared in the survey areas. In total, core from 18 boreholes was examined and more than 3000 measurements were collected, to better understand the link between geological and geophysical features in the area. Conductivity measurements clearly defined sulfide mineralization zones in drillcore. Specific gravity and magnetic susceptibility measurements could not only indicate the mineralized zones, but could also differentiate between some lithological units, based on their physical characteristics.

Keywords: *sub-Phanerozoic, Flin Flon belt, VMS deposit, geophysical survey, physical property measurement*

1. Introduction

The Flin Flon Domain in Saskatchewan is within the Reindeer Zone (Figure 1A), in the internal portion of the Paleoproterozoic Trans-Hudson Orogen (Stauffer, 1984). The Flin Flon Domain (or Flin Flon 'belt') is well known for its base metal and gold deposits, with volcanogenic massive sulfide (VMS) deposits being considered the primary base metal exploration targets in the area (Morelli, 2010a). Mining in the Flin Flon district of Saskatchewan and Manitoba began in the late 1920s and has continued to the present day, making it the most productive Paleoproterozoic VMS district in the world (Syme and Bailes, 1993). The revenue generated from base- and precious-metal production has been pivotal in developing the region; however, the only remaining mine in the immediate Flin Flon area (Mine 777) is scheduled to close by 2020, which will negatively impact the region's economy. To help stimulate exploration in and around this area, the Saskatchewan Geological Survey recently initiated a multiyear geoscience project as part of the Saskatchewan Mineral Development Strategy to support and diversify the province's mineral industry. Launched in the spring of 2018, the project focuses on rocks with gold and

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base metal potential below the Phanerozoic cover of the western Flin Flon Domain. Some components of the project are being carried out in collaboration with the Geological Survey of Canada.

Due to the overlying Phanerozoic and Quaternary sequences, understanding the geology of the Precambrian basement rocks is challenging. Geophysical techniques are therefore of critical importance in characterization of subsurface geology and target identification (McLean *et al.*, 2009; Isles and Rankin, 2013). In 2018, new airborne geophysical surveys were flown over three areas between the Saskatchewan–Manitoba border and Deschambault Lake (Figure 2A), either because the area lacked geophysical data or to provide higher quality, more enhanced data for areas covered by previous surveys.

Three areas (Block 1A, Block 1B, and Block 2; Figure 2A) were covered by a helicopter-borne EM/magnetic survey as part of the Saskatchewan Mineral Development Strategy. Two of these areas (blocks 1A and 1B) were also covered by a fixed-wing gravity gradiometer survey funded by Natural Resources Canada.

Physical rock property measurements can help in understanding the geophysical characteristics of geological features. During the summer of 2018, magnetic susceptibility, specific gravity and conductivity measurements were undertaken on core from 18 drillholes in the Bigstone Lake area, just east of Deschambault Lake (Figure 2B), stored at Foran Mining Corp.'s McIlvenna Bay exploration camp.

2. Geological Setting

The Flin Flon Domain comprises several individual juvenile arc assemblages separated by younger plutonic rocks, sedimentary rocks, and faults (NATMAP Shield Margin Project Working Group, 1998). Lucas *et al.* (1996) divided the Flin Flon Domain into three lithotectonic subgroups: island arc/backarc and ocean floor magmatic assemblages (1.9 to 1.87 Ga); successor arc magmatism generated by later intra-oceanic subduction (1.87 to 1.83 Ga); and structurally and stratigraphically overlying Burntwood and Missi groups that represent remnants of a sedimentary basin (1.85 to 1.84 Ga). During an early orogenic phase, the intra-oceanic volcanic-plutonic-sedimentary complex started to thrust over the Archean Sask craton at 1845 Ma (Lewry, 1981; Ashton *et al.*, 1997). There are today only a few exposures of the Sask craton, as tectonic windows (Figure 1A) bounded by mylonitic zones developed at the base of the intra-oceanic rock collage. Due to collisional shortening and crustal thickening involving the Paleoproterozoic sequences, peak metamorphic mineral assemblages in the Sask, Hearne and Superior cratons (Figure 1B) were generated between 1815 to 1810 Ma (Syme *et al.*, 1998; Ashton *et al.*, 2005). The Precambrian rocks are overlain by rocks of the Western Canada Sedimentary Basin, including Ordovician Winnipeg Formation sandstone and Red River Formation dolostone. The transition from Precambrian to Phanerozoic rocks is marked by an angular unconformity surface with a well-developed paleoregolith that is typically several metres thick. The Phanerozoic cover thickens from the edge of the Precambrian Shield to the south (Morelli, 2012). Quaternary till covers much of the area (Fenton *et al.*, 1994).

3. Survey Objectives

In recent years there have been several interpretive maps of the sub-Phanerozoic basement geology completed in the area (Macdonald and Leclair, 1994; Morelli, 2010a, 2010b; Morelli and Corrigan, 2011). Although these maps have contributed significantly towards an understanding of the general geology, the scale and resolution of the maps, which were created mainly based on regional geophysical data, are not suitable for the definition of rock units and structures that are potential hosts to base metal and gold deposits or spatially associated with kimberlite bodies. The purpose of this new multidisciplinary, multi-agency initiative (see also Maxeiner *et al.*, 2018) is to foster collaborative efforts in support of understanding the host volcanic sequences, as well as the expressions of ore-forming systems to depth, structural pathways hosting gold deposits, and structures associated with kimberlite bodies, thereby providing guidance for exploration. To achieve this goal, new geophysical surveys were needed to provide high-resolution data for detailed characterization of the basement geology and structural features.

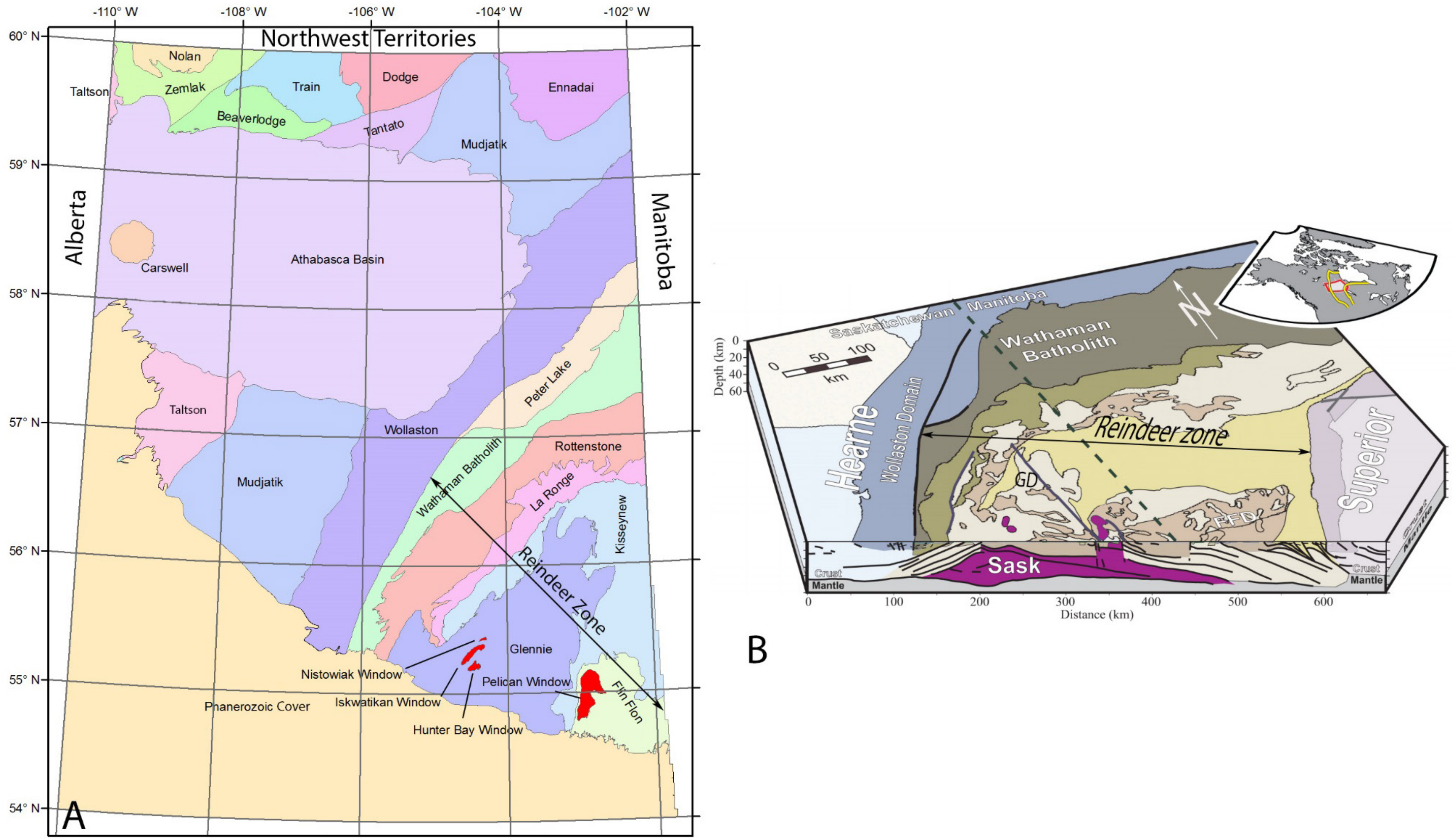

Figure 1 – A) *Lithostructural domain map of Saskatchewan, showing the location of the Flin Flon Domain within the Reindeer Zone. Four Archean tectonic windows, remnants of the Sask craton, are shown as red polygons.* ***B)*** *A 3-D schematic block (*after Hammer et al., *2010) revealing the arc and backarc domains (FFD—Flin Flon Domain; GD—Glennie Domain) formed as a result of collision between the Hearne, Superior and Sask cratons. The successor sedimentary sequences formed in the backarc basin are shown in yellow. Inset location map includes yellow lines that outline the bounds of the Trans-Hudson Orogen.*

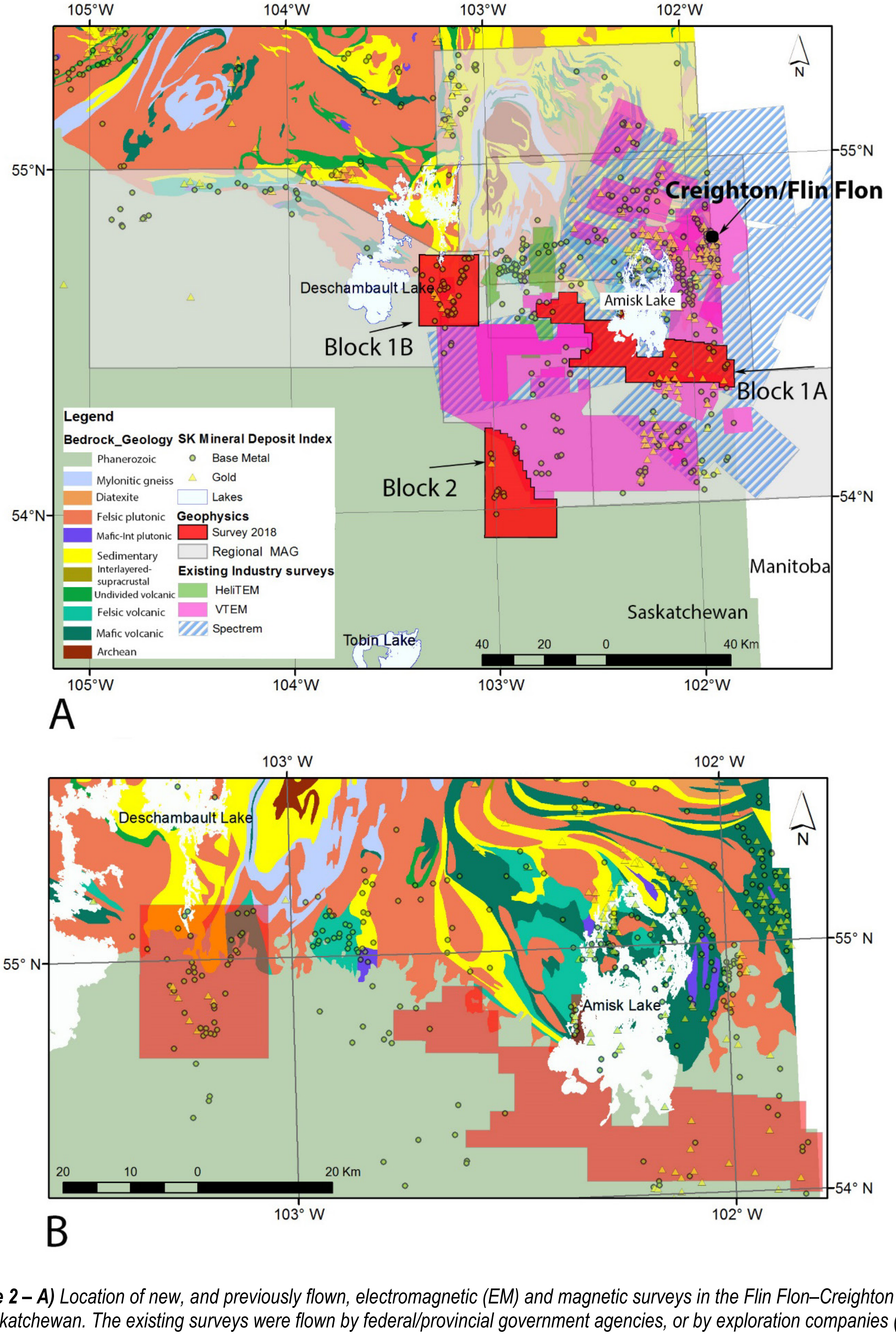

Figure 2 – A) *Location of new, and previously flown, electromagnetic (EM) and magnetic surveys in the Flin Flon–Creighton area of Saskatchewan. The existing surveys were flown by federal/provincial government agencies, or by exploration companies (data were submitted to the Saskatchewan Geological Survey as assessment files).* ***B)*** *Close-up view of the new survey areas covering ground presumably containing prospective rock packages.*

4. Survey Location

Several factors were considered during the planning process for the new geophysical surveys, including available knowledge of the basement geology, coverage of existing industry data, thickness of Phanerozoic cover, and the physical characteristics of targeted deposit types, among others. Some of the salient aspects of these parameters are described below.

a) Geology

Knowledge of basement geology was one of the more important factors in determining survey location. Surveys were planned for regions deemed favourable to contain volcanic sequences, which are considered one of the more favourable rock types to host VMS deposits, and structures associated with orogenic gold deposits and kimberlite bodies (*e.g.*, Syme *et al.*, 1998). The surveys are focused on the sub-Phanerozoic components of the western Flin Flon Domain and southeastern Glennie Domain, which, based on previous interpretations (Macdonald and Leclair, 1994; Morelli, 2010a; Figure 2), are thought to contain higher proportions of volcanic rocks.

b) Existing Geophysical Surveys

A number of geophysical surveys have been previously flown in the area, the majority of which are Versatile Time-Domain Electromagnetic (VTEM) and Spectrem EM surveys with concurrent magnetic surveys. The new survey outlines were designed to avoid overlap with these existing geophysical surveys as much as possible, with the exception of Spectrem EM surveys. Much of the Spectrem EM data were collected in the early 1990s and had a limited depth of investigation of ~300 m (Zang, 2001). The new surveys did overlap some of these older Spectrem EM surveys because a greater depth of investigation was desired.

c) Depth of Phanerozoic Cover

The capability of electromagnetic systems to detect features within buried Precambrian rocks dwindles with thicker sedimentary cover. Therefore, planning of the new surveys excluded areas in which the thickness of Phanerozoic cover was greater than 200 m. Two survey areas, blocks 1A and 1B, were located near the Precambrian Shield margin in order to facilitate extrapolation of geological characteristics from exposed areas to covered areas. The third survey, Block 2, is in an area with thicker cover rocks and was partly selected to evaluate the effectiveness of geophysical surveys in characterizing sub-Phanerozoic geology under a relatively thicker cover.

d) Flight Line Distance

The minimum length of survey lines (commonly 3 km for helicopter and 5 km for fixed-wing aircraft) was also considered during planning of the surveys, and resulted in the removal of narrow sleeves and small corners, and the filling of small gaps in the middle of survey polygons. Thus, the survey polygons were designed to minimize the number of vertices and remove odd-shaped segments. After the core survey was designed, an additional area of ~10% (of the core survey area) was added around the survey perimeter to facilitate delineation of features near the survey boundary, as well as to aid in correlating the data with adjacent surveys (Isles and Rankin, 2013; Dentith and Mudge, 2014).

e) Physical Characteristics

Magnetic, electromagnetic and gravity surveys have been very effective in targeting VMS deposits (Dentith and Mudge, 2014) due to strongly contrasting magnetic susceptibility, conductivity and density properties of the sulfide deposits relative to their host rocks. These types of geophysical survey can also be used to target late faults that might be spatially related to orogenic gold deposits, as well as favourable structures and geophysical anomalies associated with kimberlite bodies (Isles and Rankin, 2013; Dentith and Mudge, 2014). Subsurface conductivity maps can be derived from EM surveys; gravity surveys provide information about the densities of subsurface rocks; and magnetic surveys reveal magnetic susceptibility information about the subsurface rocks. Therefore, two types of geophysical survey were used during this project: EM surveys with concurrent magnetic data acquisition, and gravity gradiometer surveys with concurrent magnetic data acquisition.

5. Survey Specifications

All of the new airborne surveys were flown along east-west–oriented lines because the dominant geological domains and structures in the area have mainly northerly strikes. East-west–oriented lines also facilitated gridding and processing of the data, because surveys flown in orientations other than north-south or east-west are usually rotated to create standardized ‘north-up’ grids.

To determine the optimal parameters of the survey, and to test the capability of the EM system to detect a simulated buried VMS deposit, EM responses for a dipping tabular model were calculated (Figure 3A). These calculations were done at various depths, hosted by rocks of 0.001 siemens per metre (S/m), by CGG (Compagnie Générale de Géophysique) using the forward modelling tool of the Maxwell software developed by EMIT (ElectroMagnetic Imaging Technology). The geometry of CGG’s HeliTEM system used in forward modelling is represented in Figure 3B. The graphs shown in Figure 3C indicate that the EM response of the specified conductive target at a depth of 500 m can be detected by several time channels above the HeliTEM system’s noise level, which provides adequate information to characterize the target.

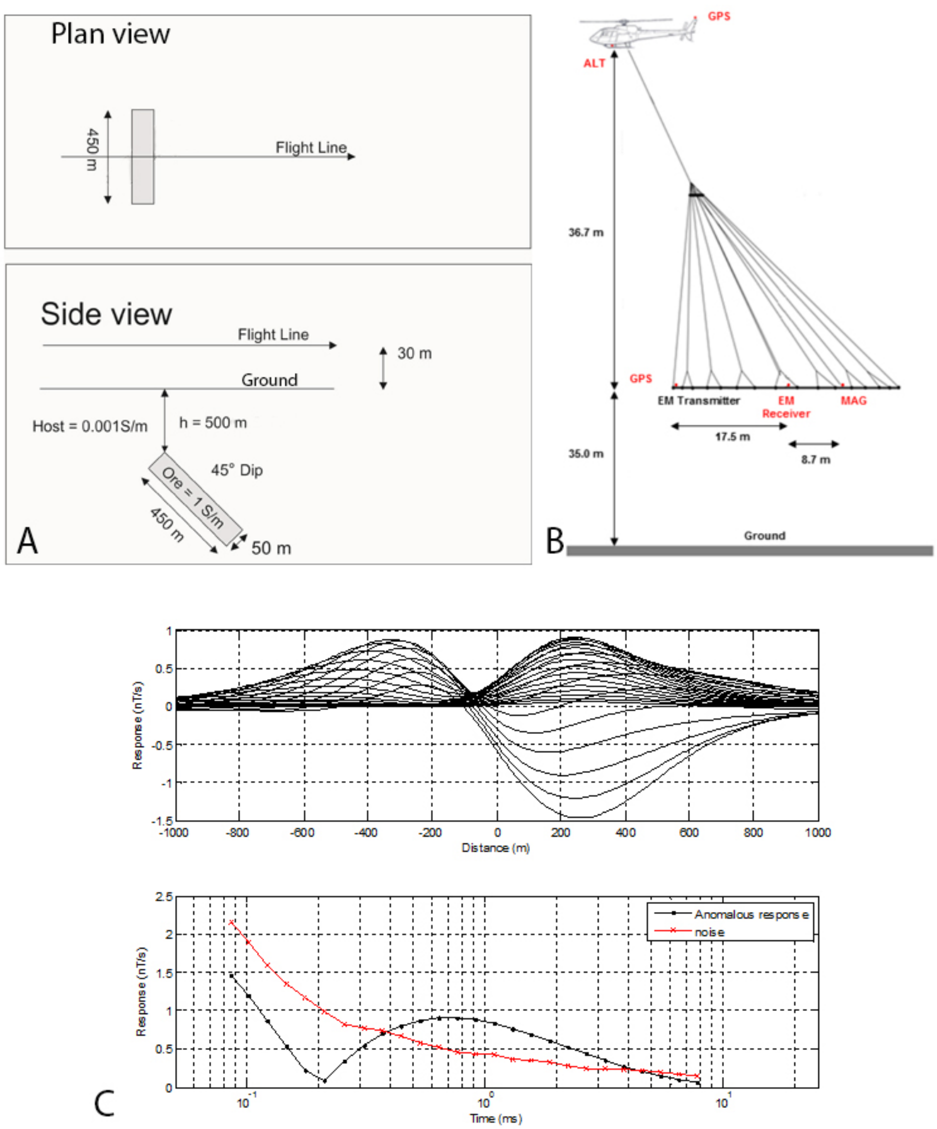

***Figure 3 – A)** Plan view and side view of a conductive target showing parameters used for forward modelling. **B)** Geometry of CGG’s HeliTEM system. **C)** EM response of the conductive target at 500 m depth using CGG’s HeliTEM system (figure provided by CGG).*

The EM surveys were flown at 45 m nominal terrain clearance using a 200 m line spacing (and 1200 m tie-line spacing) to suit regional geological interpretation at detailed scales down to 1:20 000 (*i.e.*, the scale to which the data can validly be enlarged, where one flight line spacing represents 1 cm on the map). In practice, a line spacing to flying height ratio of 4:1 or 5:1 is commonly used to collect data, although it results in some degree of line-perpendicular artifacts in the gridded data due to 'across line under-sampling' (Isles and Rankin, 2013). A flight drape (predetermined flight height) with average terrain clearance of 35 m was provided by the Geological Survey of Canada geophysics team to ensure proper resolution of the collected data and equal flying height at the intersections of traverse lines and tie-lines. Minimum flying heights were determined based on the safety of the air crew and inhabitants of the survey area, and also to minimize unwanted noise from superficial sources such as cultural features (*e.g.*, farm sheds, roads, wire fences, *etc.*; Isles and Rankin, 2013). CGG's helicopter-borne HeliTEM system was used to collect time-domain electromagnetic and magnetic data. The gravity gradiometer survey using CGG's fixed-wing Falcon system was also flown along the specified survey lines with 200 m line spacing and 95 m nominal terrain clearance, to co-locate the EM, magnetic, and gravity gradiometer data.

6. Products

The new airborne surveys were completed in the spring and summer of 2018. Pre-processing and processing of the data were carried out by CGG, and PDF files of the geophysical maps, databases and grid data were released in late September, 2018. All maps are publicly available through the Geoscience Data Repository for Geophysical Data section at the Natural Resources Canada website (Gravity Gradient: http://bit.ly/GGsept2018; Electromagnetic: http://bit.ly/EMsept2018).

As two examples of the survey products, the residual magnetic map and the apparent conductivity map of Block 1B are shown in Figures 4A and 4B, respectively. A compilation of these new data and existing data from adjacent surveys is in progress and will be published at a later date.

7. Physical Property Measurements from Block 1B (Bigstone Lake Area)

Physical properties were measured on drillcore samples from the Bigstone Lake area, from core stored at Foran Mining Corp.'s McIlvenna Bay exploration camp, to better understand the link between geological and geophysical features in the area. Core from a total of 18 drillholes from the Bigstone Lake area was selected to log lithological features (Maxeiner *et al.*, 2018), and to collect specific gravity, magnetic susceptibility and conductivity measurements. Seven of the 18 boreholes were drilled at the Bigstone Lake deposit (BS-035, -039, -042 and -117, and BS-15-241, -242 and -243), whereas the others were regional boreholes (Figure 5).

Felsic to mafic volcanic rocks, clastic sedimentary rocks, and exhalative sedimentary rocks are the most common rock types in the Bigstone Lake area boreholes, whereas subvolcanic and plutonic rocks are less abundant (Maxeiner *et al.*, 2018). The Bigstone Lake VMS deposit is hosted by a series of steeply dipping felsic and lesser intermediate volcaniclastic rocks that are locally interlayered with iron formation, graphitic argillites, and zinc-rich lenses. Mineralization at the Bigstone Lake VMS deposit is characterized by zinc-rich massive sulfide lenses that are closely associated with occurrences of iron formation and syngenetic copper stockwork mineralization. Chalcopyrite and pyrrhotite (±magnetite) stockwork mineralization is interpreted to be associated with chlorite-garnet– and quartz-sericite–rich alteration zones (Adamson, 1988; Maxeiner *et al.*, 2018) that overprint the felsic to intermediate volcanic host rocks. According to Maxeiner *et al.* (2018), the sulfides might have been remobilized by fluids along late faults or by late feldspar porphyry intrusions. This could create anomalous zones on measured physical logs.

Magnetic susceptibility and conductivity measurements were collected at a one-metre interval using a handheld tool manufactured by GDD Instrumentation, which provides measurements with resolution of 0.1 S/m for conductivity and 0.01 SI*10^{-3} for magnetic susceptibility. Specific gravity was measured at three-metre intervals by calculating the ratio of sample weight in air and water. Two weeks of fieldwork resulted in 2764 measurements for both magnetic susceptibility and conductivity, and 927 measurements of specific gravity. The selected boreholes were re-logged and studied during the summer field program by Maxeiner *et al.* (2018). Preliminary analysis was performed on the measured physical properties and logged lithological information to investigate any link between geological and geophysical features.

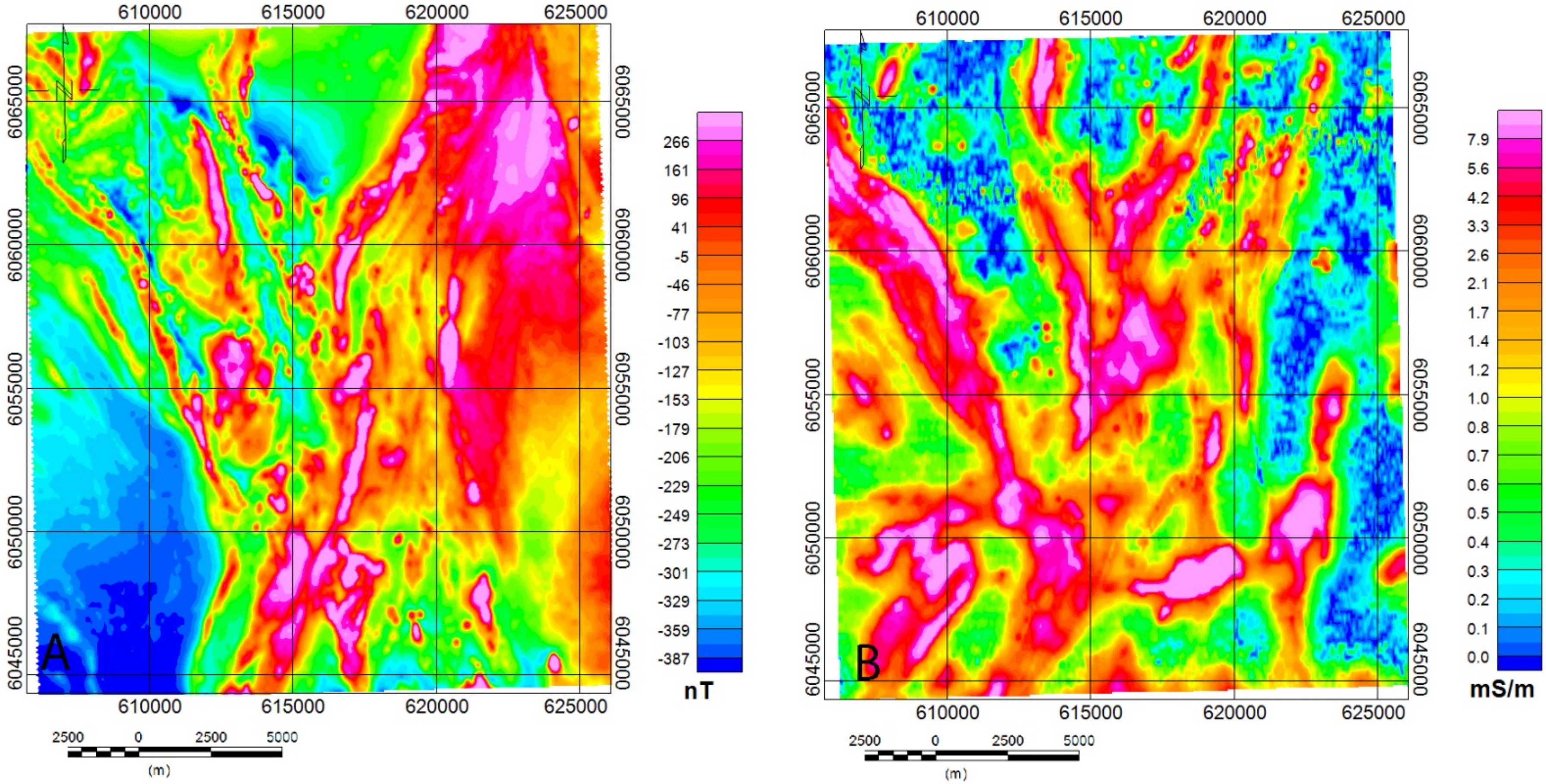

Figure 4 – A) *Residual magnetic field map of Block 1B (nT: nanotesla).* ***B)*** *Apparent conductivity early-time map of Block 1B (mS/m: millisiemens per metre). (All UTM coordinates in this document are in North American Datum 1983 (NAD83), Zone 13.)*

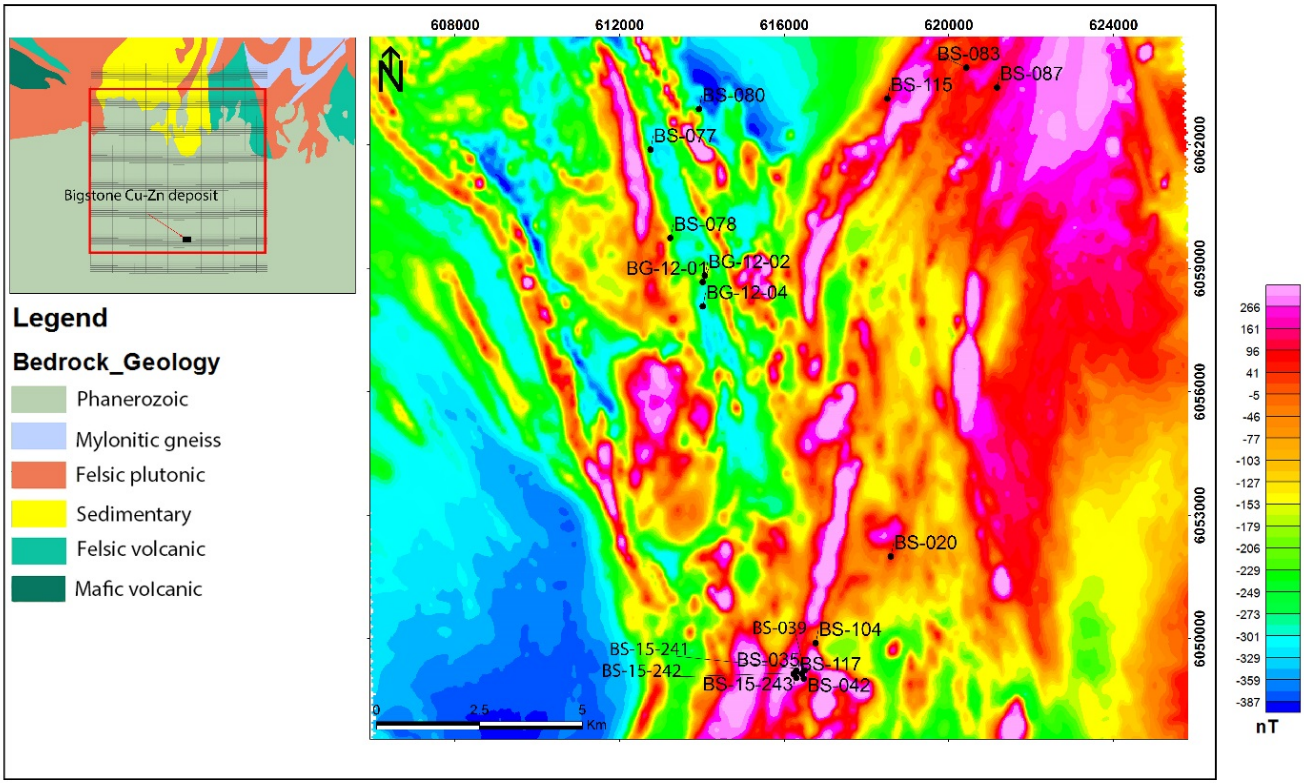

Figure 5 – *Location of boreholes selected for physical property measurements, overlying the residual magnetic map (nT = nanotesla). Small map on left shows the location of the magnetic survey within the 1:250 000 scale geology map from the Saskatchewan Mining and Petroleum GeoAtlas (olive colour represents Phanerozoic cover; other colours represent exposed Precambrian rocks).*

8. Discussion

Borehole BS-15-243 was collared in Quaternary till, underlain by Phanerozoic sedimentary rocks. Inspection of the core from this drillhole reveals a thick succession of felsic volcanic rocks that is intercalated with subordinate units of metre-scale graphitic argillite, mafic dykes, iron formation and faulted rocks, from ~60 m to ~190 m drilled depth (Figure 6). This is followed by a ~100 m thick sulfide-rich rock. Felsic volcanic rocks are present again at ~300 m and continue until the end-of-hole (346 m; Figure 6). Measured physical properties for borehole BS-15-243 start at 60 m depth (Figure 6), because the portion of the drillcore containing the Phanerozoic cover was not available. The felsic volcanic rocks (Figure 7A) are characterized by relatively low specific gravity of ~2.7; however, this increases to ~2.9 between 81 m and 102 m depth (Figure 6) where the felsic rock unit is crosscut by mafic dykes (Figure 7B). Local slight increases in the specific gravity and magnetic susceptibility of the felsic volcanic rock unit (*e.g.*, 88 m depth) might correspond to remobilized sulfide minerals along fractures (Figure 7C).

For the sulfide-rich unit, the physical characteristics of the host rock are masked by chalcopyrite and pyrrhotite (±magnetite) stockwork mineralization and associated chlorite-garnet and quartz-sericite alteration. The elevated specific gravity of the sulfide-rich rocks (>3.1; Figure 6) is due to high and variable concentrations of chalcopyrite, pyrrhotite, magnetite and, in some cases, sphalerite (Figure 7D). Magnetite and pyrrhotite also cause high magnetic susceptibility for this unit. The variation of physical property measurements within the sulfide-rich rock is due to variable concentrations of the various sulfide minerals (and oxide minerals).

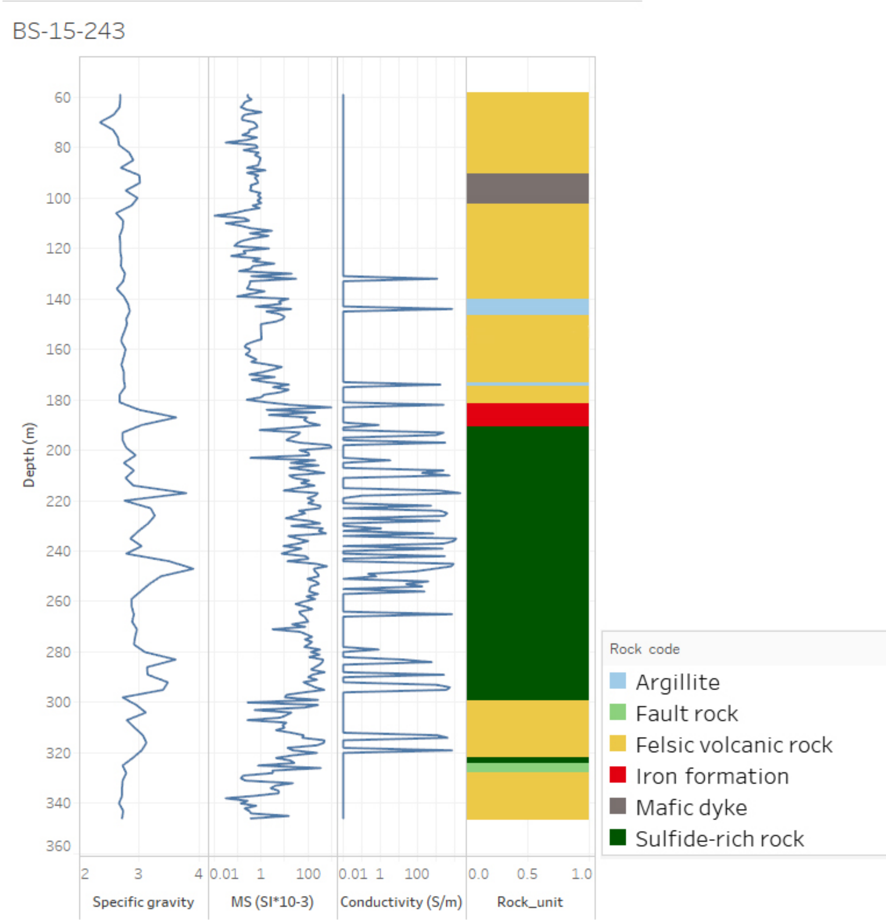

Figure 6 – *Measurements of specific gravity, magnetic susceptibility (MS) and conductivity, as well as the interpreted geological rock units in borehole BS-15-243.*

The iron formation is characterized by high specific gravity (>3.1; Figure 6) due to the high concentrations of magnetite, pyrrhotite, and to some extent sphalerite (within the oxide-sulfide facies), as well as garnet (within the silicate facies) (Figure 7E). Again, magnetite and pyrrhotite contribute to the elevated magnetic susceptibility of this unit.

The graphitic argillite, which occurs as intercalations within the felsic volcanic rocks (Figure 7F), is characterized by high specific gravity and magnetic susceptibility (Figure 6) caused by sulfide minerals (mostly pyrrhotite and chalcopyrite) redistributed/remobilized by later fluids. The introduced sulfides were emplaced along and crosscutting the foliation plane and in late carbonate veins within brittle fault zones (Figure 7G).

Considering the range of conductivities detectable by the GDD instrument (0.1 to 40,000,000 S/m), conductivity measurements do not allow differentiation between the various lithological units, unless they contain appreciable amounts of interconnected networks of sulfide minerals (pyrrhotite and chalcopyrite). High concentrations of these minerals are shown by high conductivity values within the sulfide-rich rock, graphitic argillite (at 144 m depth), and felsic rock (at 315 m depth; Figure 6).

Primary statistical analysis was applied to the measured data from all drillcore, to further understand the physical characteristics of the rock units in the Bigstone Lake area. Figure 8 shows the abundance of each rock type observed within the 18 boreholes. The number of measurements of any particular rock type is directly correlative to its abundance in the drillcores that were investigated. Therefore, the least abundant rock types (*e.g.*, psammite and massive sulfide) may not have a statistically representative measurement for their physical characteristics.

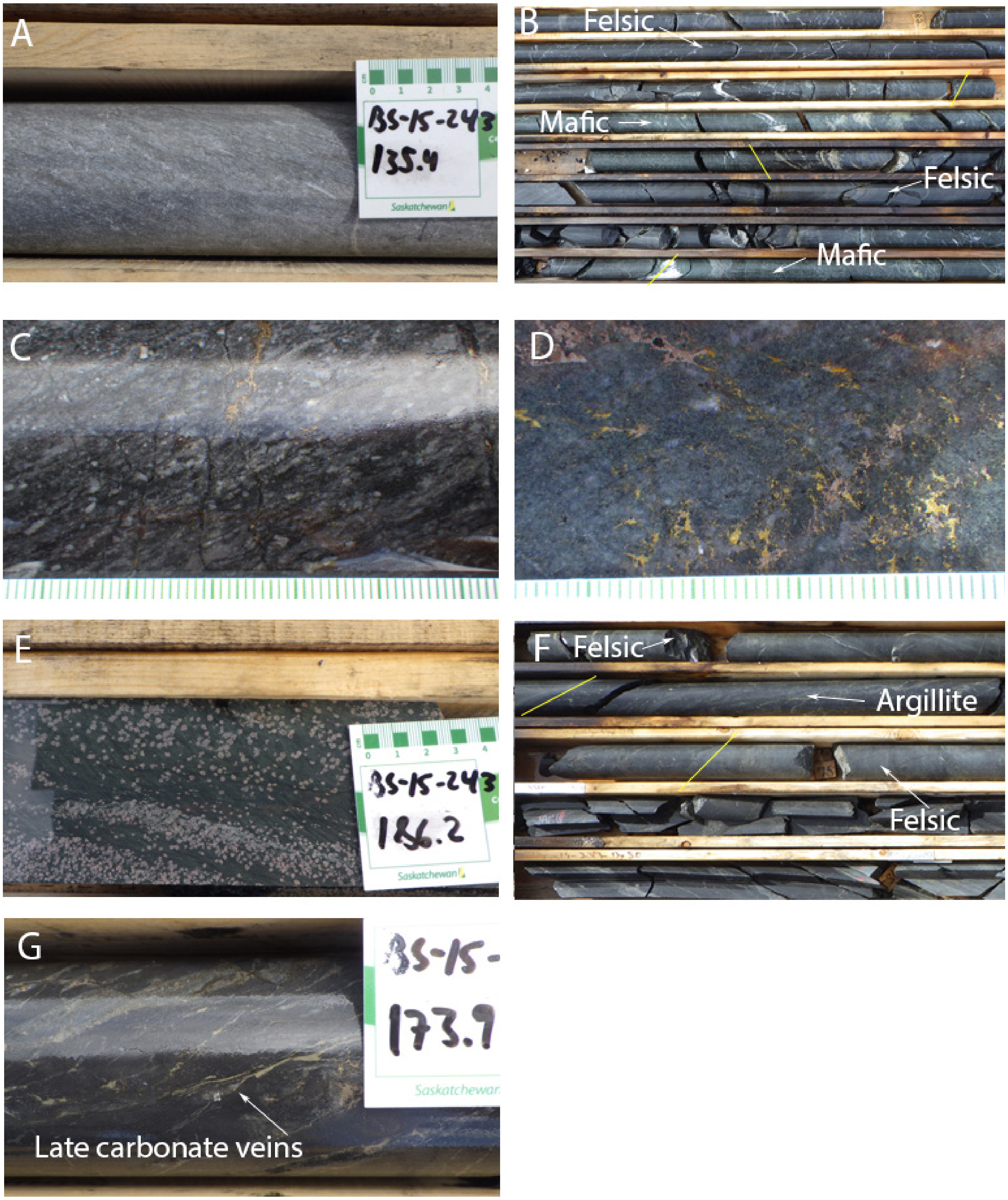

Figure 7 – *Core photos from borehole BS-15-243 (all core photographs are of HQ core).* ***A)*** *Felsic lapilli tuff at 135.4 m depth.* ***B)*** *Contacts between felsic volcanic rock and mafic dykes are marked by yellow lines between 81 and 92.3 m.* ***C)*** *Redistributed/ mobilized sulfide minerals along fractures in felsic volcanic rocks at 88 m depth.* ***D)*** *Pyrrhotite-chalcopyrite stringer zone in altered felsic volcanic rocks at 223 m depth.* ***E)*** *Garnet-rich, silicate-oxide–facies iron formation at 186.2 m depth.* ***F)*** *Contacts between felsic volcanic rock and intercalated graphitic argillite are marked by yellow lines between 173.3 and 174.8 m.* ***G)*** *Sulfide minerals redistributed/remobilized along and crosscutting the foliation plane and in late carbonate veins at 174 m depth.*

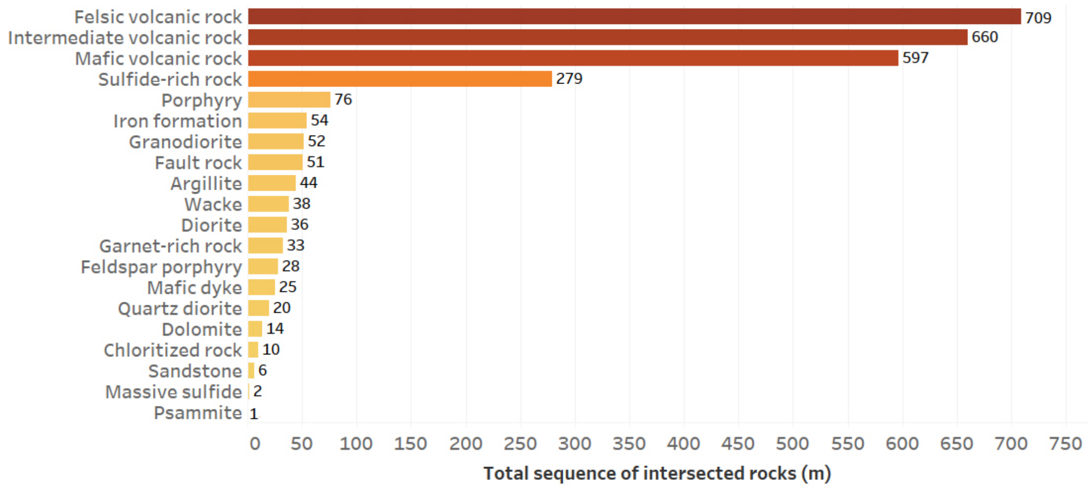

***Figure 8 –** Histogram of total length, in metres, of rock types intersected in the boreholes studied (number at the end of each bar is the exact total length for each rock type).*

The variation in the three physical properties for each rock unit, from all boreholes, is shown in Figure 9 by a series of box-and-whisker plots. Boxes indicate the middle 50 percent of the data (the middle two quartiles of the data's distribution, excluding outlier data), and lines—called whiskers—display all points within 1.5 times of each of the two interquartile ranges. The rock units containing sulfide mineralization (felsic to intermediate volcanic rocks, graphitic argillite, iron formation and sulfide-rich rocks) can clearly be identified by high conductivity values on this diagram.

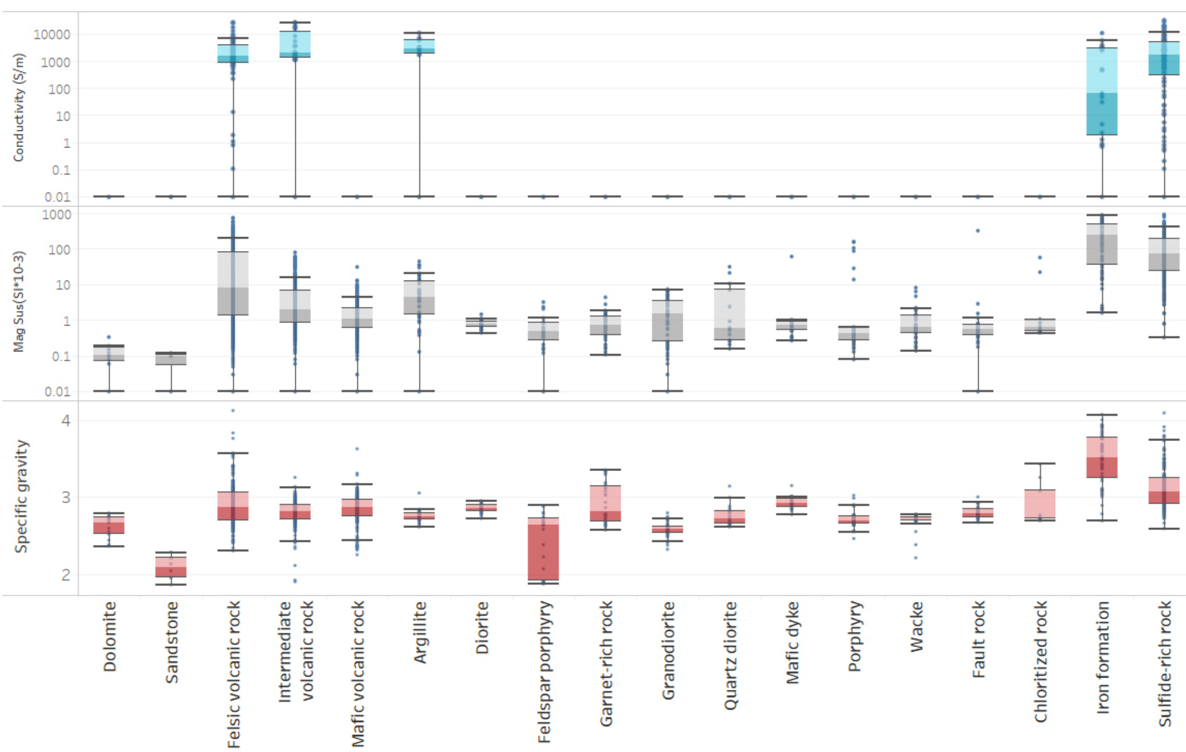

***Figure 9 –** Box-and-whisker plots of physical property measurements (specific gravity, magnetic susceptibility and conductivity) for each rock unit intersected in the studied core. The contact between the light and dark boxes in the middle of the box represents the median. The light- and dark-coloured boxes represent the middle two quartiles of the data's distribution. The horizontal lines above and below the box show all points within 1.5 times of each of the two interquartile ranges. Outlier data, which deviate markedly from other data, are represented by dots above or below the whiskers.*

The Phanerozoic rocks (dolomite and sandstone) are represented by low magnetic susceptibility and low specific gravity. The felsic volcanic rocks show moderately high magnetic susceptibility, which might be related to mineralization and overprinting alteration. Unmineralized mafic volcanic rocks have higher specific gravity measurements compared to felsic and intermediate rocks, but this is not reflected in the box-and-whisker plots, since a large percentage of the felsic volcanic rocks in this drillhole were mineralized, which becomes apparent when comparing the three rows of plots in Figure 9. Expectedly, a high concentration of garnet causes high specific gravity in the garnet-rich rocks. Iron formation and sulfide-rich rocks are characterized by high magnetic susceptibility due to high concentrations of magnetite and pyrrhotite. The feldspar porphyry dykes, quartz diorite and granodiorite are depleted in sulfide mineralization, so are mostly characterized by low specific gravity and magnetic susceptibility. Some of these rocks intruded the older volcanic rocks and crosscut the stockwork mineralization zone, which resulted in local remobilization of chalcopyrite and pyrrhotite along the contact margins, whereas they themselves remained unmineralized (Maxeiner *et al.*, 2018).

A cross-plot of magnetic susceptibility and specific gravity measurements for the major rock types identified in this study is shown in Figure 10. At low magnetic susceptibility values, below $1*10^{-3}$ SI (which correspond to the east side of the deposit, where felsic, intermediate and mafic volcanic rocks are mainly unaltered and unmineralized), the specific gravity changes from relatively high values of ~2.7 to 3.1 for mafic volcanic rocks to somewhat lower values of ~2.75 to 2.95 for intermediate volcanic rocks, and ~2.65 to 2.85 for felsic volcanic rocks. At higher magnetic susceptibility, above ~$5*10^{-3}$ SI (corresponding to rocks with high magnetite and sulfide mineral content), higher specific gravity values (up to >3.1) are observed for the felsic volcanic rocks.

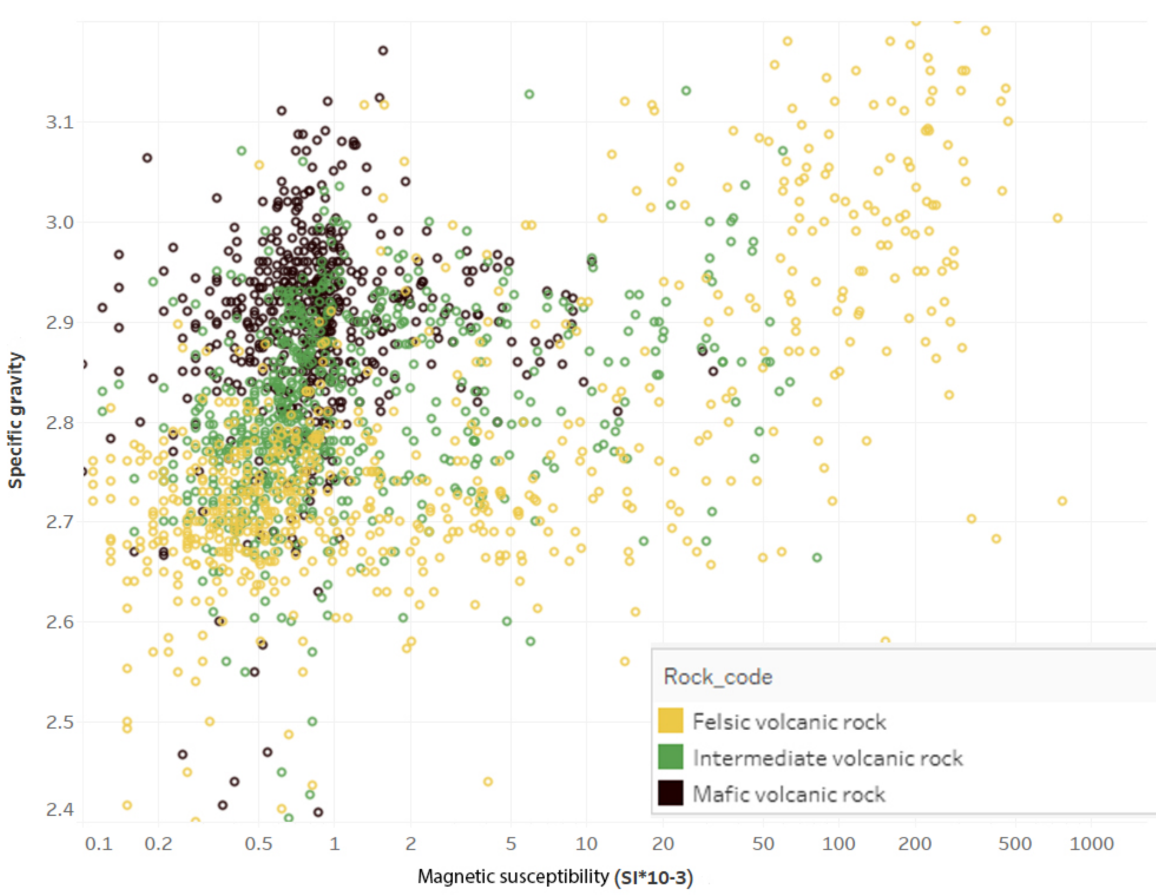

Figure 10 – *Cross-plot of magnetic susceptibility and specific gravity measurements for some major rock types in the Bigstone Lake area. (The samples with magnetic susceptibility values below 1*10*$^{-3}$ *SI correspond to samples from the east side of the Bigstone deposit, where the volcanic rocks are mainly unaltered and unmineralized.)*

9. Plans for Future Studies

The present study is the first part of a multiyear research project initiated to understand the sub-Phanerozoic Precambrian basement rocks in the western Flin Flon Domain. Future work will include further physical property measurements from areas covered by new geophysical surveys (*i.e.*, Blocks 1A, 1B, and 2) and statistical analyses of these data to obtain a better understanding of the physical characteristics of geological features and of the variation of physical properties in the area. Furthermore, airborne magnetic, electromagnetic and gravity data will be interpreted to create two-dimensional (2-D) interpretative maps. The 2-D maps will then be used to facilitate the creation of cross-sections and 3-D geophysical/geological models, which will be enhanced through geophysical data inversions.

10. Acknowledgments

We would like to thank Foran Mining Corp. for providing access to drillcore and hosting us at the McIlvenna Bay camp during the fieldwork. Thanks to Matthew Holden, the Manager, Geophysics, at HudBay Minerals for providing insightful discussions on planning geophysical surveys. Summer student Keegan Arnyek is gratefully thanked for his assistance during the summer. We would also like to thank CGG and their staff operating the HeliTEM system for logistical support and for making arrangements for a two-day site visit.

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