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RioTinto

Rio Tinto Exploration Canada Inc.

2022 UAV Magnetic Survey
on the McCoig Property

McCoig Township
NTS 42F/15
Porcupine Mining Division
Ontario, Canada

Lindsay McClenaghan
January 10th, 2023

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Summary

This report presents the results of a UAV magnetic survey conducted by MWH Geo-Surveys on the McCoig property in September 2022. The survey was commissioned by Rio Tinto Exploration Canada Inc. to get higher resolution magnetic data over anomalies interpreted to represent MCR rift related Proterozoic intrusions. The objective was to better define the size and morphology of the magnetic body and allow for higher resolution modelling in 3D of the interpreted intrusion.

The work was performed between September 16th and 30th, 2022. The MWH Geo-Surveys crew was onsite for four days with a stand-by day due to poor weather conditions.

The lack of mafic-ultramafic outcrop and the irregular morphology of the magnetic feature led to the conclusion that there are no immediate drill targets of interest. Gravity surveys could be performed to located higher density prospective portions of the interpreted intrusion.

All coordinates are UTM projection, zone 16N, in WGS84 Datum.

Introduction

In early 2021, Rio Tinto Exploration Canada Inc. (RTECI) acquired mineral rights over the McCoig claims in McCoig Township, to explore for Ni-Cu-PGE mineralization. The magnetic feature that underlies the property may represent a mafic-ultramafic intrusion interpreted to be related to the Proterozoic Mid Continent Rift System. In the fall of 2022 RTECI completed a magnetic survey over the McCoig project. The work presented in this report includes this UAV magnetic survey, completed by MWH Geo-Surveys, for RTECI. Christophe Hyde and Steve Pham are thanked for their contribution to this report.

Location and Access

The McCoig property is located approximately 76km west northwest of Hearst, north of Highway 11 (Figure 1). The survey area is accessible by light truck during the summertime off the Hwy going north on Pitopiko Road then northwest on Rail Road then south on Stanley Road into Mulloy Lake forestry block.

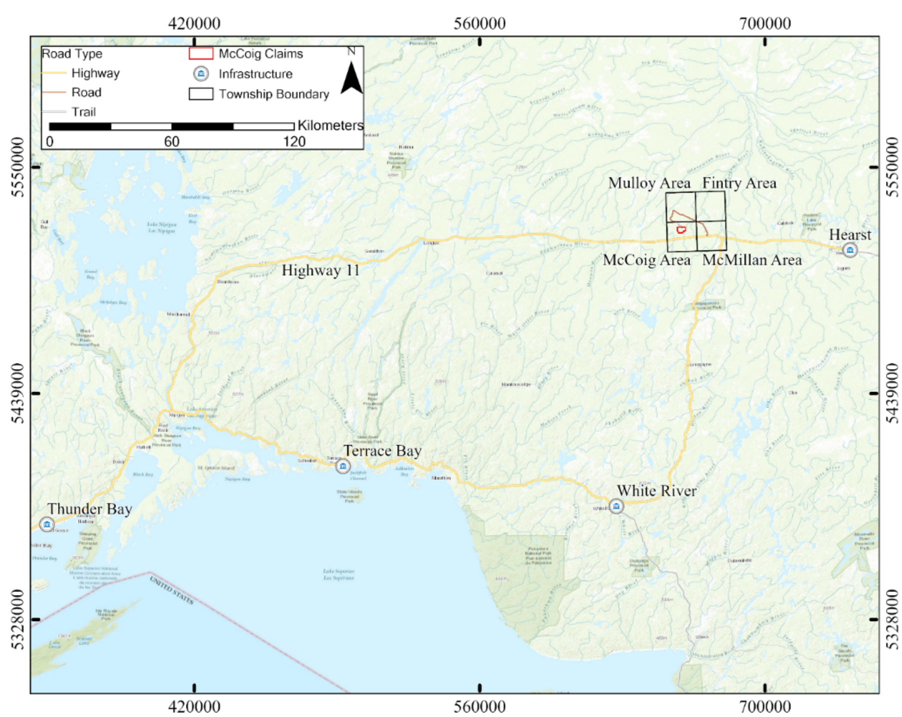


Figure 1: Project area map showing regional location to nearest towns.

Property Status

The McCoig property currently consists of 47 contiguous claims totalling 980 Ha. These claims are shown in plan map in Figure 2 and further described in Table 1. These claims are all located on Crown Land.

Work included in this assessment report is not subject to an Exploration Plan.

Table 1: List of claims on which the magnetic survey was completed

Claim Number	Provincial Grid Cell Number	Type	Holder	Township	2022 Work Performed	Ha.
630201	42F15C191	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630191	42F15C192	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630163	42F15C193	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630169	42F15C194	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630199	42F15C195	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630196	42F15C171	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630174	42F15C172	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630186	42F15C173	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630192	42F15C174	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630200	42F15C175	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630172	42F15C176	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630202	42F15C150	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630161	42F15C151	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630205	42F15C152	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630206	42F15C153	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630182	42F15C154	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630193	42F15C155	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630183	42F15C156	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630165	42F15C157	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630177	42F15C158	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630203	42F15C130	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630204	42F15C131	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630168	42F15C132	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630187	42F15C133	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630175	42F15C134	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630170	42F15C135	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630184	42F15C136	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630176	42F15C137	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630167	42F15C138	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630190	42F15C110	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21

630197	42F15C111	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630179	42F15C112	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630188	42F15C113	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630198	42F15C114	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630171	42F15C115	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630195	42F15C116	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630207	42F15C117	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630185	42F15C118	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630178	42F15C090	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630162	42F15C091	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630180	42F15C092	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey	21
630181	42F15C093	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630189	42F15C094	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630194	42F15C095	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630164	42F15C096	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630166	42F15C097	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21
630173	42F15C098	Single Cell Mining Claim	RTECI	McCoig	Geophysical Survey, Field Mapping	21

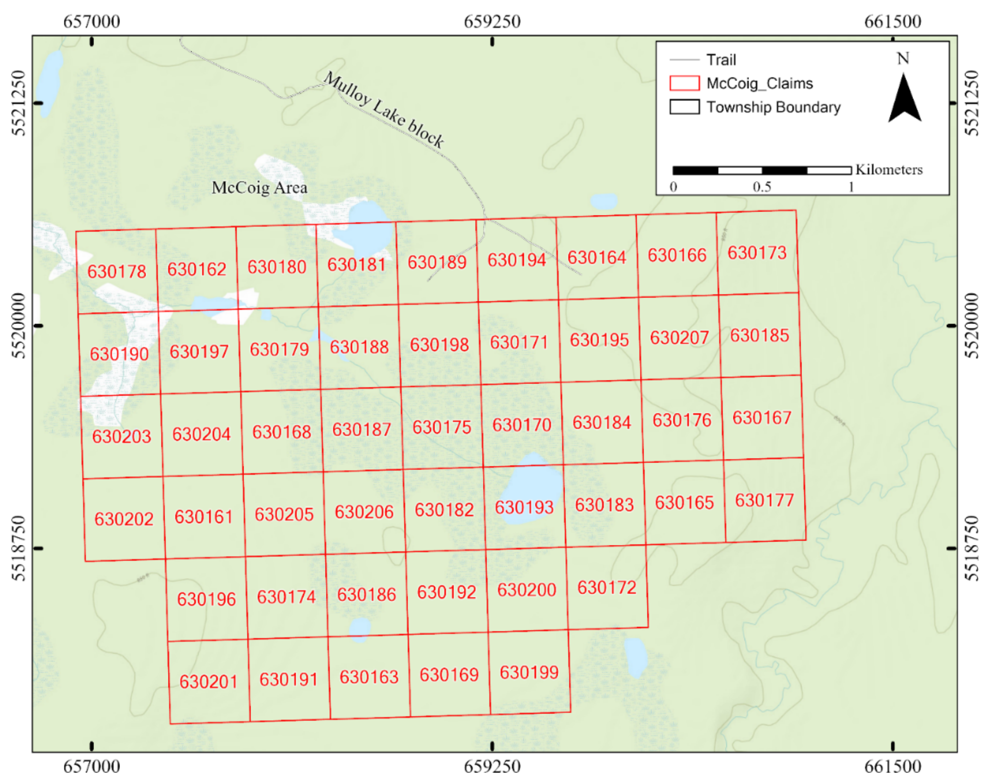


Figure 2: Map of the McCoig property claims and the local forestry access road.

Previous Work

In July 2001 Valerie Gold Resources Ltd. of Vancouver, BC, completed 28.625km of line cutting, and along those lines conducted magnetics and time domain induced polarization surveys over the property. Their work program covered a larger area which included ground further to the west. No further work was recommended over the area reported on in this document (AFRI_FID 42F15SW2001).

In March 2010 Zenyatta Ventures Ltd. contracted Geotech Ltd. to conduct an airborne magnetic and electromagnetic geophysical survey over a historical claim block that covered the current McCoig claims and extended further west. Results of the airborne survey generated several magnetic and electromagnetic geophysical targets that prompted a 2011 diamond drilling program 5kms west of the current McCoig property. The 2010 VTEM survey was flown over the current McCoig property area at a 150m line spacing with a N-S line orientation (AFRI_FID 20000009244).

Regional and Property Geology

The McCoig property is located within the Quetico Subprovince, an Archean meta-sedimentary belt that has been intruded by multiphase granitoids. The Quetico Subprovince is fault bounded to the north and south by metavolcanic greenstone belts: the Wabigoon Subprovince and the Wawa Subprovince respectively (Figure 3). The Quetico belt rocks consist mainly of migmatite and biotite-quartz-feldspar paragneiss and granite-granodiorite intrusions. A Keweenawan age (~1100Ma) ultramafic-gabbroic and granophyric intrusions is mapped on the property (1:250,000 OGS Geology Map, 2011). Several other Keweenawan age intrusions are mapped to the northeast, and all coincide with magnetic features. These intrusions have the potential to host Cu-Ni-PGE sulphide mineralization. Two Paleoproterozoic dike sets crosscut the property: a northwest southeast trending Matachewan-Hearst Swarm (2450Ma) and the northeast southwest Marathon Mafic swam (2150Ma). From previous prospecting on this property, the bedrock exposure is limited with evidence of only two lithologies: a massive equigranular, coarse grained syenite and a massive dark grey, fine-grained metasediment with thin granitic bands.

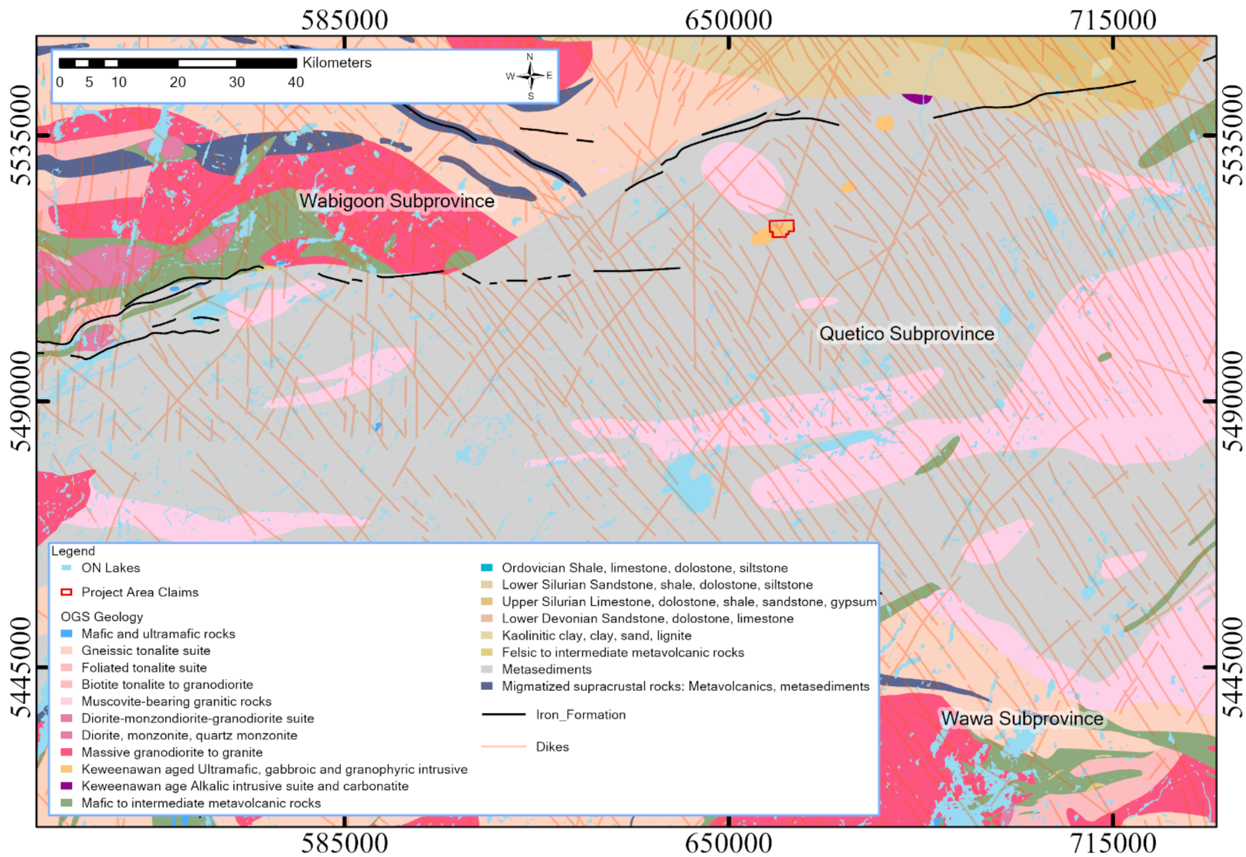


Figure 3: Geological map showing the RTECI project area in red (from the 1:250k OGS digital map, 2011).

Field Reconnaissance

RTECI completed two short field mapping visits to the property on October 1st, 2021, and from September 29th to October 3rd, 2022, covering an area of 23 claim cells. The initial property visit highlighted the challenges of the landscape and vegetation with poor access from the south. Two outcrops were found on the magnetic anomaly coming in from the south: a large outcrop of syenite and a magnetic Archean metasediment (Figure 4). The syenite is massive equigranular, coarse grained, contained 10% hornblende and was found in the magnetic low of the anomaly. The second outcrop was found on the magnetic high and is interpreted as a dark grey, fine grained Archean meta-sedimentary rock, it appears foliated, with thin bands of granitic material. It was strongly magnetic which may be due to proximity to an intrusion. During the second property visit, the property was accessed from the north utilizing the existing forestry roads. Similarly, prospecting was challenging with few outcrop exposures due to wetlands and dense vegetation. A 50m massive outcrop of equigranular amphibole bearing syenite with no mineralization was found on the boundary of the magnetic high of the anomaly (Figure 4). Detailed sample descriptions can be found below in Table 2.

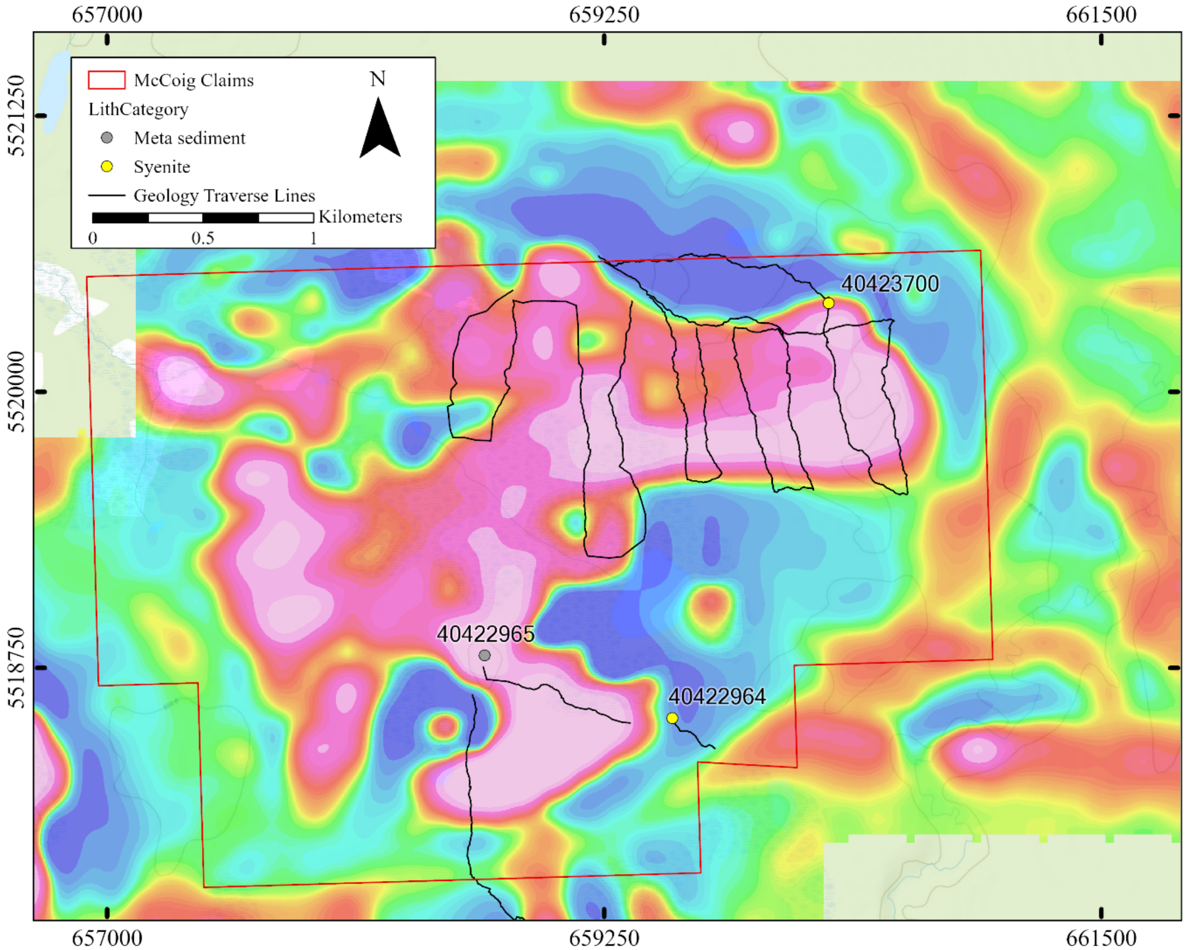


Figure 4: A map of the McCoig property showing the lithology points and traverse lines underlain by the magnetic first vertical derivative from the 2010 VTEM survey.

Table 2: Outcrop grab samples collected on the property.

Sample ID	Easting	Northing	Lithology	MagSus (10^{-3} SI)	Comment
40422964	659557.76	5518521.35	Syenite	1.07	Massive mg-cg equigranular amphibole syenite. Localized hematitic staining. Barren of sulphides.
40422965	658708.66	5518806.91	Metasediment	43.3	Difficult to identify, massive fine grained grey intrusive or metasediment? Red feldspathic bands. Barren of sulphides.
40423700	660265.47	5520401.23	Syenite	5.1	50m outcrop. Massive red equigranular amphibole bearing syenite. Coarse grain euhedral Kspar with 30% medium grained euhedral black amphibole. Barren of sulphides. Magnetic susceptibility ranges 1-5x10^{-3} SI.

UAV Magnetic and Orthophoto Survey

An unmanned airborne survey (UAV) magnetic and orthophoto survey was completed by MWH on the following dates: September 16th -19th and September 30th, 2022. Line spacing was 50m and 223 line-kms were flown. The magnetic sensor is the Geometrics MagArrow with noise levels specified as

<0.02nT/sqrt(Hz). Noise levels assessed visually appear to be less than 0.01 nT. The biggest jumps in magnetic field appear where lines have been spliced and are on the order of 4 nT (Figure 5).

The orthophoto survey was conducted with a Wingtra One PPK VTOL mapping drone. Ground control targets were laid out and the positions surveyed before the photo mapping. The ground control targets were post processed to the HRST UFCORS control site in Hearst, ON (see Appendix B: MWH Geo-Surveys Report for details). The resulting digital surface model (DSM) was processed with a 3cm resolution (Figure 6).

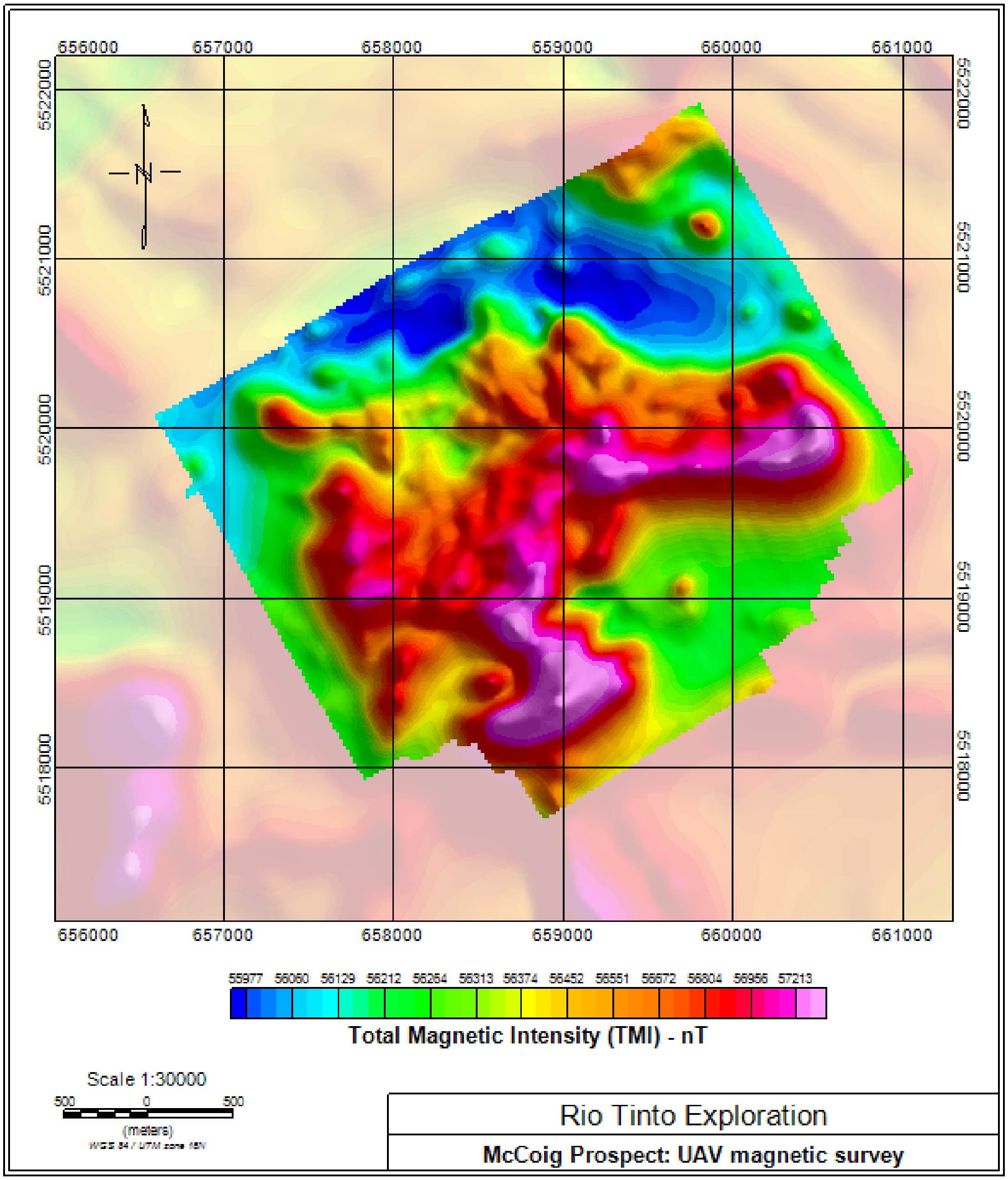


Figure 5: Total Magnetic Intensity (TMI) from UAV magnetic survey over McCoig Prospect.

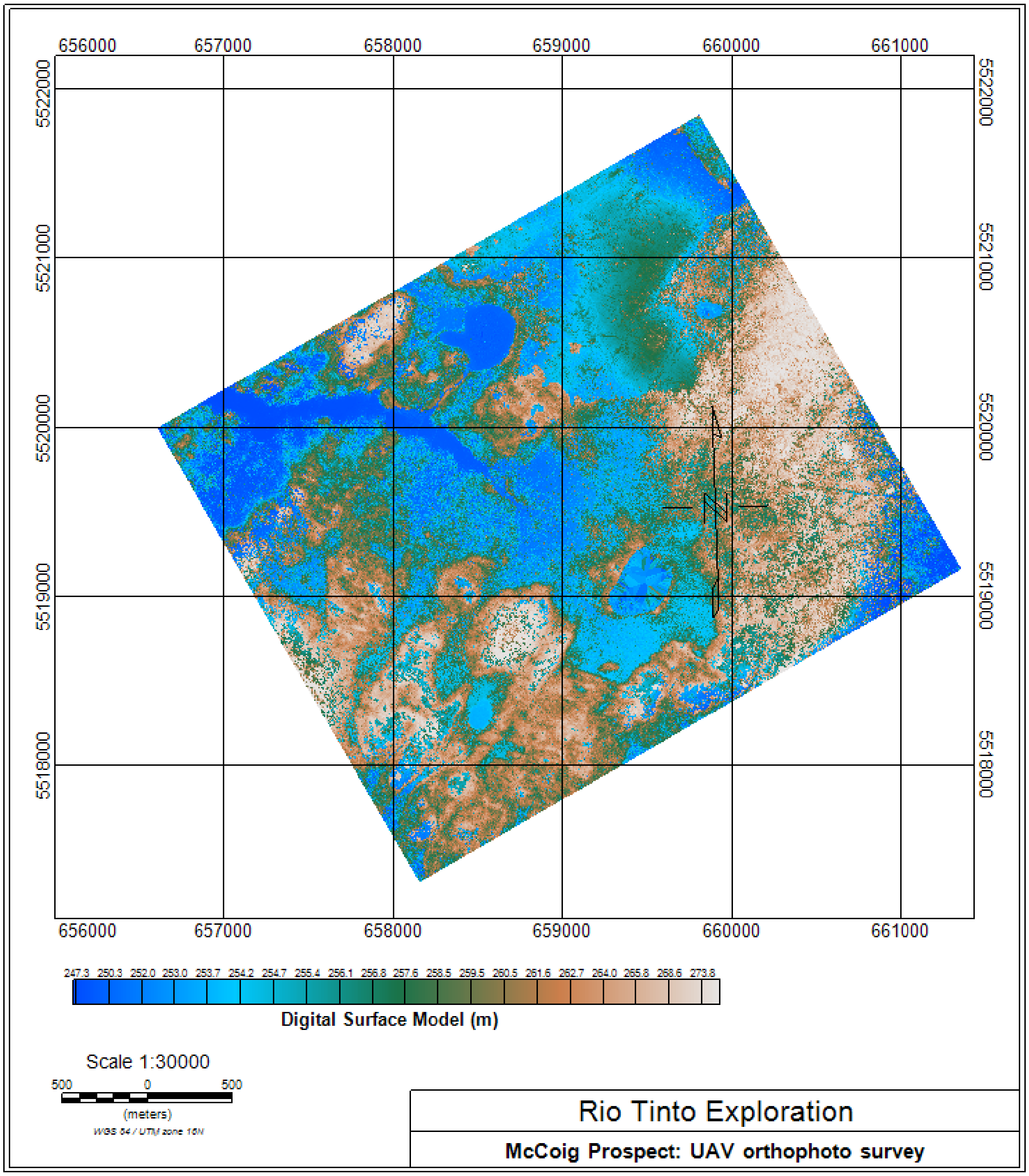


Figure 6: Digital Surface Model (DSM) from UAV orthophoto survey over McCoig Prospect.

Interpretation of the Magnetic data

The claims cover part of a magnetic anomaly on the public regional magnetic data (Figure 7), mapped by the Ontario Geological Survey as Proterozoic "Ultramafic, gabbroic and granophyric intrusions" within Archean meta-sediments. There are no mineral occurrences reported on the property and no previous drilling. The claims were acquired to prospect over the eastern side of the mapped intrusion. Field visits in 2021 and 2022 found three outcrops: two non-magnetic syenite outcrops (magnetic susceptibility of 1×10^{-3} SI) and one magnetic outcrop interpreted to be Archean age (magnetic susceptibility of 43×10^{-3} SI). The exact lithology is uncertain but believed to be magnetite bearing paragneiss or a fine-grained Archean intrusion. The magnetic anomaly may be explained by the interpreted Archean outcrop and there appears to be no direct evidence that the magnetic anomaly is caused by Proterozoic ultramafic or gabbroic intrusions. In addition, the folded appearance of the magnetic signal further supports the hypothesis that it is caused, at least in part by near-surface folded Archean rock unit and if there is some portion that is caused by a more homogeneous Proterozoic intrusion, it is likely at depth. Finally, the regional magnetic data (Mille Lacs- Nagagami Survey – OGS) suggests that the McCoig magnetic feature cuts the north-west/south-east trending linear magnetic features, presumably caused by Paleoproterozoic dikes, and therefore may have a younger intrusive explanation.

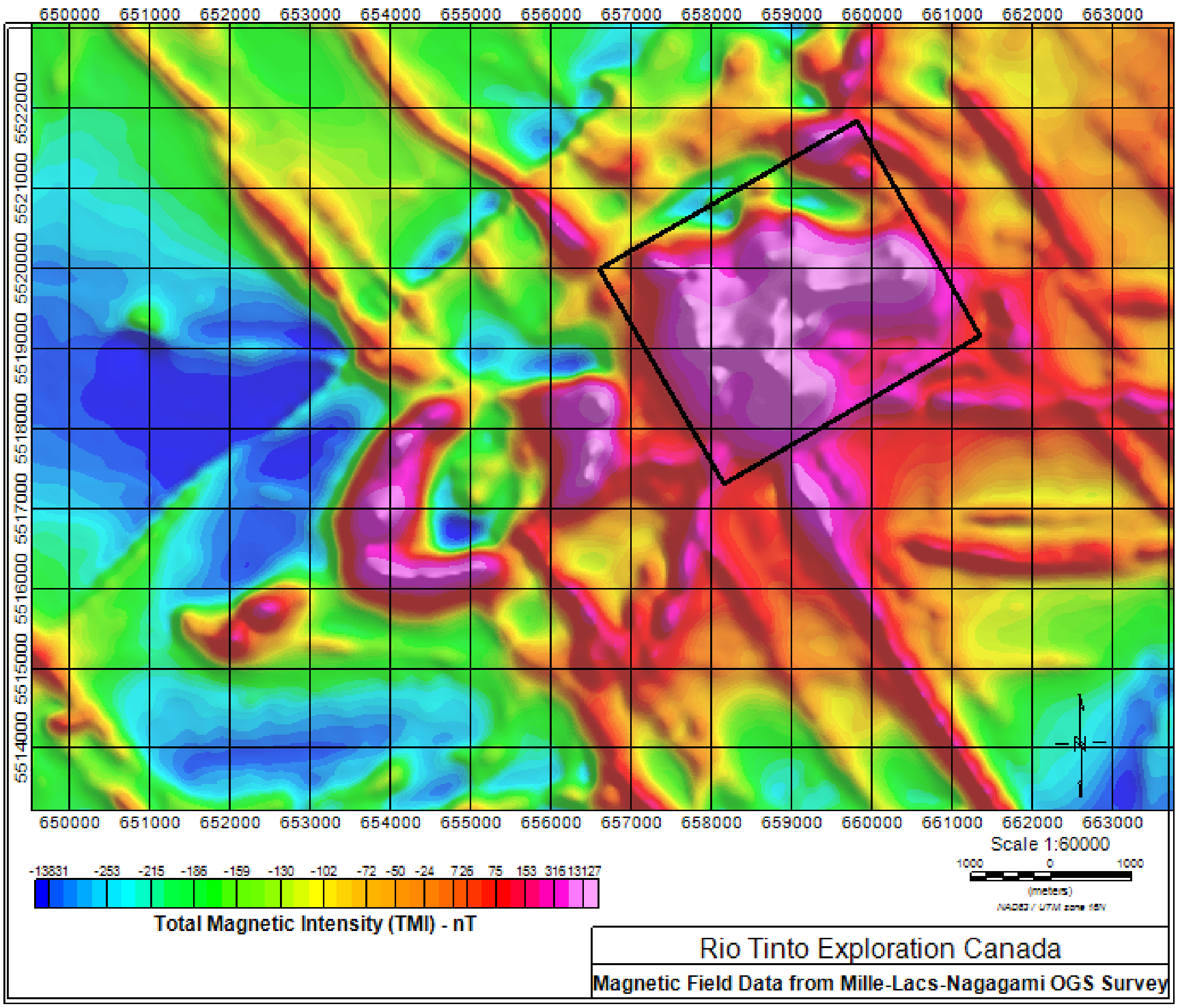


Figure 7: Residual Total Magnetic Intensity (TMI) from Mille Lacs – Nagagami airborne magnetic survey over the greater McCoig prospect. Black polygon represents planned outline of UAV magnetic survey.

Recommendation for Further Work

Historical VTEM data does not show any conductors. There is a lack of outcrop exposure due to dense forest and wetland cover. What little outcrop was found, gave no evidence for mafic or ultramafic rocks which are the target host rocks for potential Ni-Cu-PGE mineralization. For these reasons this does not present a strong drill target. The uppermost level of the intrusion comes to surface as syenite which would place targets at the base of the intrusion at significant depths. If a mafic/ultramafic intrusion is the explanation for the magnetic feature, a gravity survey could be completed to distinguish this potential. However, drilling the magnetic feature to depth would provide a more definitive test.

References

Ontario Geological Survey 2015. Ontario Airborne Geophysical Surveys, magnetic and gamma-ray spectrometric data, grid and profile data (ASCII format) and vector data, Lac des Mille Lacs–Nagagami Lake area; Ontario Geological Survey, Geophysical Data Set 1078.

Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release–Data 126

Statement of Qualifications

I, Lindsay McClenaghan certify that:

I am a full-time employee of Rio Tinto Exploration Canada Inc.

I graduated with Bachelor of Science Honours Specialization in Geology degree from the University of Western, Ontario, in 2008, and Master of Science degree in Geological Sciences from the University of British Columbia, BC, in 2013.

I am a registered Professional Geoscientist in the province of Ontario and have 13 years of experience working in mineral exploration. I authored this assessment report entitled; 2022 UAV Magnetic Survey on the McCoig Property and managed the activities on the project.

To the best of my knowledge, all costs reported in this Assessment Report were incurred by Rio Tinto Exploration Canada in the 2022 UAV McCoig survey program.

Signed,

L. McClenaghan

Dated this 10th of January 2023

Lindsay McClenaghan
Principal Geoscientist
Rio Tinto Exploration Canada Inc.

Appendix A: Exploration Costs

Table A 1:UAV Geophysics Survey Assessment Costs

Cost Type	Service Provider	Actual Cost
Magnetic Survey	MWH Geo-Surveys Ltd.	$28,377

Table A 2: Claim units and associated cost

Claim Number	Area of Mag Survey (km^2)	Percentage of Survey	Total
630161	0.2	2%	$691
630162	0.2	2%	$691
630163	0.11	1%	$380
630164	0.2	2%	$691
630165	0.18	2%	$622
630166	0.2	2%	$691
630167	0.1	1%	$346
630168	0.2	2%	$691
630169	0.2	2%	$691
630170	0.2	2%	$691
630171	0.2	2%	$691
630172	0.19	2%	$657
630173	0.08	1%	$277
630174	0.2	2%	$691
630175	0.2	2%	$691
630176	0.2	2%	$691
630177	0	0%	$0
630178	0.13	1%	$449
630179	0.2	2%	$691
630180	0.2	2%	$691
630181	0.2	2%	$691
630182	0.2	2%	$691
630183	0.2	2%	$691
630184	0.2	2%	$691
630185	0.18	2%	$622
630186	0.2	2%	$691
630187	0.2	2%	$691
630188	0.2	2%	$691
630189	0.2	2%	$691
630190	0.2	2%	$691
630191	0.1	1%	$346

630192	0.2	2%	$691
630193	0.2	2%	$691
630194	0.2	2%	$691
630195	0.2	2%	$691
630196	0.17	2%	$588
630197	0.2	2%	$691
630198	0.2	2%	$691
630199	0.11	1%	$380
630200	0.2	2%	$691
630201	0.05	0%	$173
630202	0.08	1%	$277
630203	0.13	1%	$449
630204	0.2	2%	$691
630205	0.2	2%	$691
630206	0.2	2%	$691
630207	0.2	2%	$691
Outside of Property	1.87	19%	$6,464
Total	**10**	**100%**	**$34,841**
Total Assessment Value			**$28,377**

Appendix B: MWH Geo-Surveys Report

MWH Geo-Surveys Ltd.

Logistical Summary
McCoig Project, ON, Canada

For Rio Tinto Exploration Company

MWH Geo-Surveys Ltd.
Sept-Oct 2022

Contents

Magnetic Survey

Beginning Sept 16 and Sept 30, 2022 MWH Geo-Surveys Ltd. carried out a UAV Magnetic and UAV Orthophoto survey located approximately 18 km west of Palmquist, ON at the request of for Rio Tinto Exploration.

OPERATIONS and SCHEDULING:

Survey Personnel: The personnel involved on this project were:

- Mark Bedford
- Kaolin Pickett
- Marshall MacNabb

- Remote Pilot in Command
- UAV flight crew
- Data Processing

The following is the project timeline:

Date	Status	Kms Flown	Flights	Flight Hours
16-Sept-22	Orthophoto/Mag Production	81	15	7.8
17-Sept-22	Standby/Weather	-	-	-
18-Sept-22	Mag Production	56	13	5.9
19-Sept-22	Mag Production	61	13	5.8
30-Sept-22	Orthophoto/Mag Production	23	4	2.9
Total		**223**	**45**	**22.5**

UAV ORTHOPHOTO FIELD PROCEDURES

The orthophoto survey was conducted with a Wingtra One PPK VTOL mapping drone. Ground control targets were laid out and the positions surveyed before the photo mapping. The ground control targets were post processed to the HRST UFCORS control site in Hearst, ON. The positional information for HRST is noted below:

CORS_ID	HRST
PID	DF5364
STATE/COUNTY	ON/COCHRANE
COUNTRY	CANADA
NTS MAPSHEET	HEARST (2020)
NAD 83(2011) POSITION	49 40 02.76888(N) 083 30 39.73555(W)
NAD 83(2011) ELLIP HT	229.404 (meters)

Prior to take off and during the entire duration of every flight a static GNSS base station was recording data to enable precise post processing of the UAV camera location. The combination of surveyed ground targets and the PPK positioning of the mapping drone and camera yields a high-

MWH Geo-Surveys International Inc. 50 W. Liberty Street, Suite 800, Reno, NV, USA 89501

resolution digital surface model. Photos were collected using the 42 mega-pixel WingtraOne Sony RX1R II camera. Images were processed in Pix4D software and the resultant surface models and orthophotos were produced and exported at various resolutions. Absolute accuracy is projected to be better than 5cm.

UAV MAGNETIC FIELD PROCEDURES:

A total of approximately 222.5 line kilometers of UAV magnetics were flown bearing either southeast or northwest at a spacing of approximately 50 meters; northeast-southwest tielines were flown at a spacing of approximately 1000 meters. All acquisition was flown at an elevation of approximately 49 meters above ground level (AGL) with a tolerance of +/- 3 meters.

Access to all flight staging sites was by truck. A portable generator was used to run the navigational planning and control software on a field PC and to charge the flight batteries.

Our UAV mag system uses a Geometrics MagArrow Cesium Magnetometer flown under a Watts Innovation Prism X8 axial quadcopter. The MagArrow sensor takes 1000 readings per second and is flown at a maximum speed of 8m/second. The sensor is suspended on a 2.5m lanyard to remove it from the electromagnetic noise of the UAV. Data is down sampled after collection to 10Hz. Technical information on the airborne sensor is attached as an appendix. The MagArrow readings are diurnally corrected via a Geometrics G858 base mag, cycling at 10 readings per second.

DATA REDUCTION and MAPPING:

Base and aerial magnetic data was downloaded and diurnally corrected each day. Geophysics-Minerals (GM) received and processed a combined total of 222.5 Line-Kilometers of data, after final edits, approximately 217.6 Line-Kilometers of data were delivered. The processing results were used to map the Total Magnetic Intensity (TMI) field and calculate the Reduced to Pole (RTP). All data points are shown in Figure 2. Magenta points resulted from the editing and are used for final mapping. Green points were removed from the received dataset and not used for final mapping.

MWH Geo-Surveys International Inc. 50 W. Liberty Street, Suite 800, Reno, NV, USA 89501

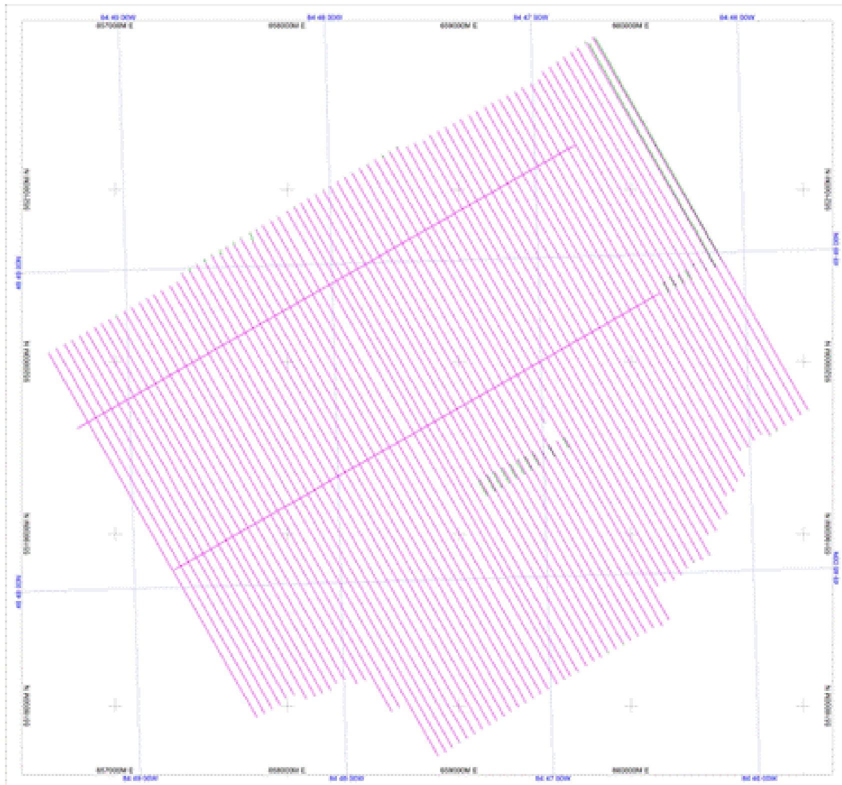


Figure 2 - Rio Tinto Exploration, McCoig Survey - Ontario, Canada UAV Aeromagnetic data acquisition. Magenta points used for final mapping; Green points removed from survey dataset.

DATA EDITING:

Flightlines were flown bearing either east or west. The purpose of the editing was to isolate the points along flightlines and remove points associated with five occurrences:

1. "Transit" lines which connect the ends of flightlines with takeoff and landing locations.
2. "Loops" which connect ends of adjacent flightlines.
3. "Hovers" which occur at takeoff and landing where there is little or no lateral travel.
4. "Re-flights" when a line is reflown and duplication is acquired; only one flight must be selected.
5. "Spikes" when a single reading is anomalously much greater or lower than adjacent points. A point was rejected if its value was 5 nT greater or less than the average value of its four adjacent points; that is the two points recorded approximately 0.2 seconds (approximately 1.4 meters) before and after it

International Geomagnetic Reference Field (IGRF) Correction:

The IGRF is a mathematical representation of the smoothly varying earth's magnetic field. The aeromagnetic acquisition records a magnetic value which is the sum of the IGRF and the magnetic anomalies caused by the local geology. Therefore, to isolate the anomalies, the IGRF must be calculated for each acquired data point and subtracted from it. The value of the IGRF for a point depends on the time and location of acquisition: date, time of day, latitude, longitude and elevation (above sea level).

Using the 13th generation IGRF adopted in December 2019 by IAGA Working Group, the method used here calculates the IGRF value for each data point at its time and location of acquisition. This value of the IGRF for the particular point is then subtracted from the Diurnally Corrected Magnetic Value producing the IGRF correction, sometimes called the IGRF anomaly. The Final TMI was calculated by then adding a constant to the IGRF correction of 56,180 nanoTesla. This is the approximate average value of the IGRF for the entire survey.

Total Magnetic Intensity (TMI):

The final TMI values were gridded at a grid interval of 40 meters. Data were of high quality and so contoured at a 25 nT increment. Data resolution is considered to be 2 nT.

Reduction-to-Pole (RTP):

The TMI grid was then used to calculate the RTP grid using an Inclination= 74.2° and Declination= -7.8°. The RTP was applied then 56,300 nT were added; this value is the approximate average difference between the TMI and calculated RTP grids. Contouring was at 25 nT as with the TMI map.

The RTP data enhancement map results from a mathematical operator which corrects for position offset of the skewing of an induced magnetic anomaly due to the earth's magnetic field's inclination and declination. The reduction-to-pole mathematically transforms the total magnetic intensity (TMI) field at its observed inclination (I) and declination (D) to that of the north magnetic pole (i.e., I=90°, D=0°); thereby centering the magnetic anomaly directly over the causative body and so assisting the interpretation process. For example, the anomaly signature for a body located in an area of high (steep) magnetic inclination such as central Ontario (I ≈ 74°N) is illustrated in Figure 3.

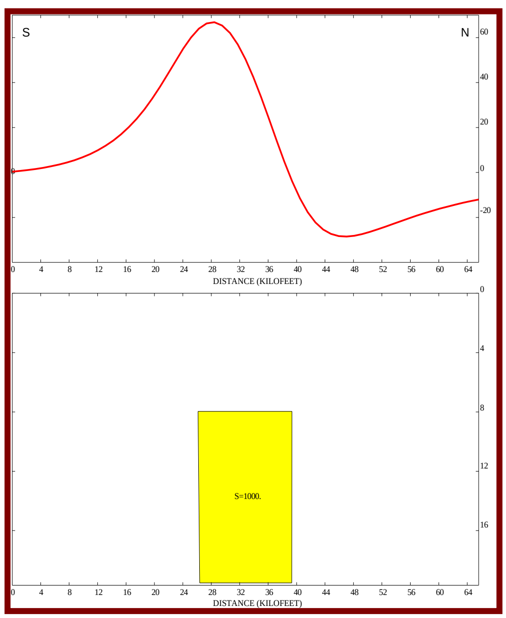


Figure 3 Magnetic inclination effect due to a body located at 74° Inclination along a 0° azimuth south-north traverse.

The RTP operator is applied to the TMI grid to adjust the steeply dipping inclination effect to the vertical 90° inclination angle of the magnetic north pole as illustrated in Figure 4. The asymmetry of the anomaly signature shown in Figure 3. has been exaggerated to highlight the effect of the correction.

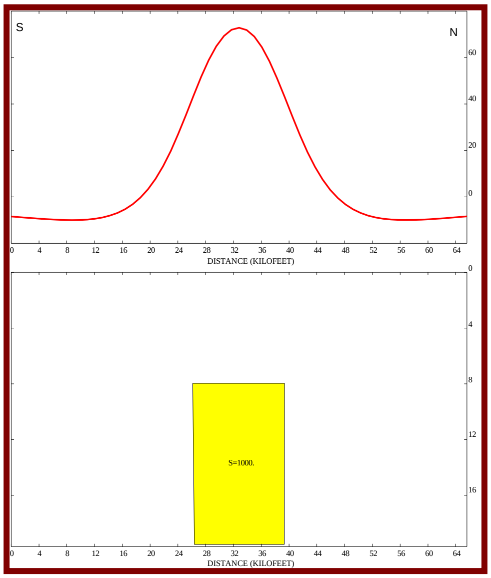


Figure 4 Magnetic inclination effect due to a body located at the magnetic north pole along a 0° azimuth south-north traverse.

First Vertical Derivative (1VD) of Reduction-to-Pole (RTP)

The 1VD data enhancement map results from a mathematical operator which calculates the rate of change in magnetic intensity in the vertical direction, ($\partial M / \partial z$). This process produces a residual map where longer wavelength anomalies have been removed thus accentuating short wavelength anomalies. These shorter wavelength anomalies result from relatively shallow geologic structures and bodies. Additionally, the mapped zero (0) contour can be indicative of vertical or near vertical geologic boundaries or contacts. Contour interval is 0.5 nT/m.

The 1VD data enhancement map and grid delivered are the result of a standard vertical derivative calculation with a limited amplitude display range. The areas where the 1VD values lie within the range of -1.0 and 1.0 nT/m were set to null. This very low amplitude data range is considered data noise hampering interpretation. However, a zero (0) contour may be reasonably interpreted where the amplitudes are higher and the distance between the -1.0 and 1.0 nT/m contours is narrow.

Mapping Parameters:

Full maps are in Adobe PDF format
Geotiff images are in GCP format
Grid files for the 3 maps are provided in Geosoft Binary format (grd) and in ASCII format: Row-Major (rmg) and projection information (prj)

Scale: 1 : 5,000
Projection: UTM zone 16N (EPSG 32616)
Datum: WGS84
Magnetic Field Units: nanoTesla or nanoTesla/meter
Distance Units: meters
Geographic Units: degrees north and east
Contour increment: 25.0 nanoTesla or 0.5 nT/m
Grid increment: 40 meters
Null value: 99999

DATA DELIVERABLES:

Note on filename abbreviations:

TMI – Total Magnetic Intensity
RTP – Reduced to Pole
1VD – First Vertical Derivative
Limited – An interval of the values has been nulled

Note on images:

The following images were produced from the grid files. The grids were created from the survey data delivered herein using an optimum grid increment. It is not recommended to regird because loss of resolution will occur. If a finer grid increment is sought, it is recommended to grid the delivered data.

Maps:

GM_MWH_RTX_MCCOIG_ON_UAV_Mag_TMI_20221007.pdf
GM_MWH_RTX_MCCOIG_ON_UAV_Mag_RTP_20221007.pdf
GM_MWH_RTX_MCCOIG_ON_UAV_Mag_RTP_1VD_Limited_20221007.pdf

Geotiffs:

GM_MWH_RTX_MCCOIG_ON_UAV_Mag_TMI_20221007.tif
GM_MWH_RTX_MCCOIG_ON_UAV_Mag_RTP_20221007.tif
GM_MWH_RTX_MCCOIG_ON_UAV_Mag_RTP_1VD_Limited_20221007.tif

Grids: Geosoft binary (grd), row-major (rmg) formats & projection information (prj)

GM_MWH_RTX_MCCOIG_ON_UAV_Mag_TMI_20221007.grd
GM_MWH_RTX_MCCOIG_ON_UAV_Mag_TMI_20221007.prj
GM_MWH_RTX_MCCOIG_ON_UAV_Mag_TMI_20221007_rmg.asc
GM_MWH_RTX_MCCOIG_ON_UAV_Mag_RTP_20221007.grd
GM_MWH_RTX_MCCOIG_ON_UAV_Mag_RTP_20221007.prj
GM_MWH_RTX_MCCOIG_ON_UAV_Mag_RTP_20221007_rmg.asc
GM_MWH_RTX_MCCOIG_ON_UAV_Mag_RTP_1VD_Limited_20221007.grd
GM_MWH_RTX_MCCOIG_ON_UAV_Mag_RTP_1VD_Limited_20221007.prj
GM_MWH_RTX_MCCOIG_ON_UAV_Mag_RTP_1VD_Limited_20221007_rmg.asc

Note on data files:

Data are being delivered in a generic format (ASCII) generally considered compatible with mapping software.

Data:

GM_MWH_RTX_MCCOIG_ON_UAV_Mag_Data_20221007_csv.zip
GM_MWH_RTX_MCCOIG_ON_UAV_Mag_delivery_comments_20221007.txt

In the ASCII comma separated value (csv) formatted files of the edited data, the Line numbers begin with 1 then increment by 1 from east to west; the TieLine numbers begin with 101 then increment by 1 from north to south. The Lines are sorted by line Number then by Northing, north to south for each line. The Tielines are sorted by line Number then by Easting, west to east for each line.

Additionally, file header records define the following:

Projection: UTM zone 16N (EPSG 32616)
Datum: WGS84
Magnetic Field Units: nanoTesla
Distance Units: meters
Geographic Units: degrees north and east
Directional Units: degrees east of north
Date Units: day-month-year
Time Units: hour,minute,second hhmmss.sss

Note: Date and Time are Local
Note: The Final TMI was calculated by subtracting the IGRF value from the diurnally corrected magnetics then adding a constant of 56,180 nT, the approximate average IGRF value for the survey.

The first 3 records of the csv portion of the Data file are:

Line,X,Y,Lat,Long,Date,Time,Alt,AGL,Adjusted Diurnally Corrected Mag,IGRF value,
IGRF correction,Final Total Magnetic Intensity (TMI),LineDirection,Mag,FiltMag,
BaseDatum,BaseVal,FiltBaseVal,DiurnalCorrection,DiurnallyCorrectedMag,
UTMZone,GroundHt,Flight,Segment,Counter,Track,TrackAdj

1,659776.723,5521886.672,49.8281076,-84.7783878,30-Sep-22,153526.8,302.16,53.2,
56238.4797,56182.8523,55.6274,56235.6274,330,56267.8292,56268.4366,56000,56031.13,
56031.0718,31.0718,56237.3647,16N,249,4,96,378362,332.5,183

1,659776.958,5521886.267,49.8281039,-84.7783847,30-Sep-22,153526.7,302.15,53.1,
56238.6499,56182.8512,55.7987,56235.7987,330,56268.009,56268.6067,56000,56031.13,
56031.0718,31.0718,56237.5349,16N,249,4,96,378361,332.2,182

Appendix

- Data Heading Index
- Magnetometer Specifications

Core Data Delivery	Line #	Line number. May contain multiple segments to build a complete line across the survey area
	UAVgpsX	UTM Easting WGS84 from UAV GPS
	UAVgpsY	UTM Northing WGS84 from UAV GPS
	UAVgpsLng	Latitude in Decimal Degrees from UAV GPS
	UAVgpsLat	Longitude in Decimal Degrees from UAV GPS
	Date	Data collection date in local time zone (dd-MMM-yy)
	Time	Data collection time in local time zone (hhmmss.s)
	UAVgpsAlt	Sensor Altitude based on UAV GPS
	AGL	Sensor Height above ground based on UAV GPS
	AdjustedDiurnallyCorrectedMag	Rover data after application of Diurnal correction and Heading Error Calculation
	IGRF Value	IGRF calculated by IGC
	IGRF_Correction	IGRF correction calculated by IGC
	Final Total Magnetic Intensity (TMI)	Calculated by subtracting the IGRF value from the Adjusted Magnetics field, then adding a constant of 48,958, the approximate average IGRF value for the survey
Data Calculation Steps	LineDirection	Direction of flight rounded to near degree
	Mag	Raw magnetometer reading off Mag Arrow
	FiltMag	Rover data after filtering to remove EM noise of UAV and downsampling from 1000Hz to 10Hz
	Base Datum	Base Datum
	Base Val	Base magnetometer value after interpolation to match rover time sampling
	Filt Base Val	Base magnetometer with a Savitzky-Golay Filter to remove any significant data spikes
Extra Internal Information	DiurnalCorrection	Calculated diurnal correction
	DiurnallyCorrectedMag	Rover data after application of Diurnal correction
	UTMZone	WGS84 UTM zone
	GroundHt	Ground height from DSM at the sensor XY coordinates
	Flight	Flight Number per day
	Segment	Number to track line segments
	Counter	Index number for data orginazation
	Track	Compass direction of sensor
	TrackAdj	Compass direction of sensor adjusted to orient with line direction

MagArrow

UAS Deployable Magnetometer

GEOMETRICS
Simplify your search

Survey large areas of inaccessible terrain 10x faster than a typical magnetic survey

The MagArrow by Geometrics is our first ever UAS deployable magnetometer, and it sets a new standard for UAS magnetic surveys. The MagArrow is engineered to address the limitations of both large manned and small helicopter surveys. To meet these special survey conditions, the MagArrow was built with reliability, efficiency, and ease of use in mind.

The vessel is made of an aerodynamic, light-weight carbon fiber shell. Internally the system contains an MFAM miniature magnetometer, GPS, IMU sensors, an SD card, and battery connectors. The MFAM sensors in the MagArrow are our most groundbreaking sensors yet, capable of highly precise measurements in an extremely lightweight and tiny package. Our system ships complete with a full featured data logger.

The MagArrow can be attached easily to a wide variety of enterprise UAS. The 1000 Hz sample rate synchronized to the on-board GPS allows the system to function independently of the UAS and the UAS software. With such a fast sample rate, surveys can be completed at speeds up to 10 m/s with samples collected every 1 cm.

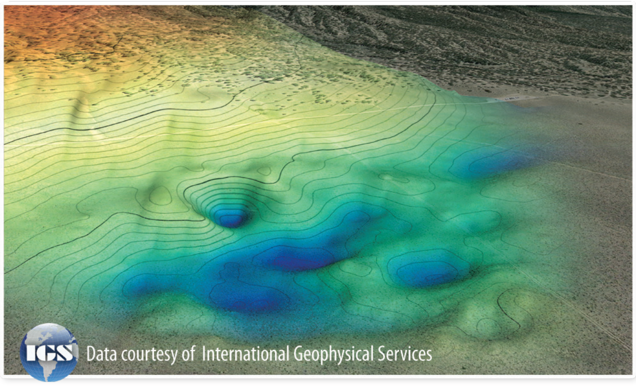
Operation in the field is simple. Survey details are programmed into the user's UAS software of choice. The MagArrow is turned on, and once airborne, preprogrammed GPS waypoints carry the MagArrow in altitude stable survey lines. Once work is completed, data from the MagArrow can be wirelessly downloaded to a computer.

The MagArrow is a robust yet flexible system that can adapt to changing field conditions and new user workflows. How will you use the MagArrow?

FEATURES & BENEFITS

- **Lightweight** – Weighs only 1 kg, allowing a flight time 20% longer* than a 2.5 kg-payload UAS.
- **UAV Agnostic** – Can be easily attached to your existing enterprise UAS.
- **Self-Contained** – GPS, storage, and WiFi on board. No connection to UAS needed.
- **Super-Fast Sampling Rate** – Fly faster, up to 10 m/s with samples every 1 cm. Filter out UAS motor noise.
- **Long Battery Life** – 2 hours of battery life will outlast multiple UAS flights. Hot swappable.
- **High Quality Data** – Peace of mind.

*DJI Matrice 600 Pro



"The UAS-enabled MagArrow also fills the gap between pilot-on-board aeromagnetic surveys and ground magnetic surveys where the areal size of the survey is too small to justify a pilot-on-board aeromagnetic survey, or the need for low altitude flight operations makes a pilot-on-board survey too risky or too costly."

— Ron Bell of International Geophysical Services, MagArrow user.

POWERFULLY BUILT, SIMPLY EXECUTED

For simplicity in the field, the MagArrow has no external connections, instead containing the GPS, WiFi, and memory on board. Battery packs are hot swappable. All operations are accessed through the web-browser interface. Internal IMU sensors allow for a complete suite of data compensation algorithms to be applied, if desired, to remove platform-induced field variations.

Operating Principle: Laser pumped cesium vapor (Cs133 non-radioactive) total field scalar magnetometer.

Operating Range: 20,000 to 100,000 nT.

Gradient Tolerance: 10,000nT/m.

Operating Zones: Configured for operation anywhere in the world without dead zones.

Dead Zone: None.

Noise/Sensitivity: 0.005nT/ $\sqrt{Hz}_{rms}$ typical; (SX (export) version: <0.02 nT/$\sqrt{Hz}_{rms}$)

Sample Rate: 1000 Hz. synchronized to GPS 1PPS.

Bandwidth: 400Hz.

Heading Error: ± 5 nT over entire 360° equatorial and polar spins typical.

Output: WiFi data download over 2.4GHz WiFi access point.

GPS: Commercial grade with typical 1 m accuracy.

USB Port: Port for USB flash drive. Used for field upgrades.

Data Logger: Built in Data Logger.

Data Storage: 32 Gbyte Micro SD card, U3 speed class. Not field-accessible. Contact sales for higher capacities.

Data Download: Over WiFi 2.4GHz using user-supplied browser-capable device. 10 minutes of data requires 1 minute to download.

IMU: Bosch BMI160 Accel/Gyro - 200 Hz sample rate. Insentek Compass - 100 Hz Sample rate.

Total Weight: 1 kg without batteries.

Length: 1 m.

BATTERY

Battery Connection: 2x XT60 connectors for 206 type batteries.

Battery Recommendations: Non-magnetic 1800 mAh or 2200 mAh lithium polymer, 3cell, 11.1v. Hot swappable.

ENVIRONMENTAL

Operating Temperature: -10°C to +40°C (+14°F to +104°F).

Humidity: Non-condensing.

ACCESSORIES

Standard: Carrying case, AC power adapter and USB drive containing operation manual and software.

Warranty: 1 year.

Specifications subject to change without notice. MagArrow_v2 (1019)

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