Ministry of Energy, Mines & Petroleum Resources Mining & Minerals Division BC Geological Survey	BC Geological Survey Assessment Report 38865 Assessment Report Title Page and Summary
TYPE OF REPORT [type of survey(s)]: Analysis of Airborne Magnetic Dat	a Coupled With VLF-
AUTHOR(S): Frederick A. Cook	SIGNATURE(S): Frederick A. Cook DN: cn=Frederick A. Cook DN: cn=Frederick A. Cook, o, ou, email=fook@ucajary.ca, c=CA Date: 2020.02.05 12:13:46 -08'00'
	YEAR OF WORK: 2019
STATEMENT OF WORK - CASH PAYMENTS EVENT NUMBER(S)/DATE(S): $Even$	
PROPERTY NAME: Mac Attack	
CLAIM NAME(S) (on which the work was done): 1064522 Mac Attack	
COMMODITIES SOUGHT:       Precious metals, massive sulphides         MINERAL INVENTORY MINFILE NUMBER(S), IF KNOWN:	_ NTS/BCGS: 082F
OWNER(S):         1)         Sean Kennedy         2)	<u>59</u> <u>29</u> (at centre of work)
MAILING ADDRESS: 2290 DeWolfe Ave.	
Kimberley, B. C. V1A1P5	
OPERATOR(S) [who paid for the work]:       2)         1) Sean Kennedy       2)	
MAILING ADDRESS: 2290 DeWolfe Ave.	
Kimberley, B. C. V1A1P5	
PROPERTY GEOLOGY KEYWORDS (lithology, age, stratigraphy, structure, alte	eration, mineralization, size and attitude):
Metasedimentary rock; Proterozoic; Middle Aldridge Formation, silic	a veins

REFERENCES TO PREVIOUS ASSESSMENT WORK AND ASSESSMENT REPORT NUMBERS: 19277, 35499, 35430, 19965, 24786

TYPE OF WORK IN THIS REPORT	EXTENT OF WORK (IN METRIC UNITS)	ON WHICH CLAIMS	PROJECT COSTS APPORTIONED (incl. support)
GEOLOGICAL (scale, area)			
Ground, mapping			
Photo interpretation			
GEOPHYSICAL (line-kilometres)			
Ground			
Magnetic		-	
Electromagnetic		-	
Induced Polarization		_	
Radiometric			
Seismic			
Other Data Processing a	and analysis		\$ 3,200.00
Airborne			
GEOCHEMICAL (number of samples analysed for)			
Soil		_	
Silt			
Rock			
Other			
DRILLING (total metres; number of holes, size)			
Core			
Non-core			
RELATED TECHNICAL			
Sampling/assaying		-	
Petrographic		-	
Mineralographic		_	
Metallurgic			
PROSPECTING (scale, area)			
PREPARATORY / PHYSICAL			
Line/grid (kilometres)			
Topographic/Photogrammetric (scale, area)			
Legal surveys (scale, area)			
Road, local access (kilometres)/			
Trench (metres)			
Other Report (\$3000)			\$3,000.00
		TOTAL COST:	\$ 6,200.00
			φ 0,200.00

Assessment Report:

# Analysis of Airborne Magnetic Data Coupled With VLF-EM

# Data on the Mac Attack Property,

Southeastern British Columbia

MTO event 5763536

North 49° 21' 8"; West 115° 59' 29"

UTM Zone 11 573250E, 5467100N

NTS map sheets 082F and 82G

**Fort Steele Mining Division** 

by

F. A. Cook, Ph.D., P.Geo. Salt Spring Imaging, Ltd. 128 Trincomali Heights Salt Spring Island, B.C for

**Property Owner/Operator:** 

Sean Kennedy 2290 DeWolfe Ave. Kimberley, B.C. V1A1P5

February, 2020

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# Appendices

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Appendix 1	Magnetic Anomaly maps
Appendix 2	Maps of Conductivity 'Slices"

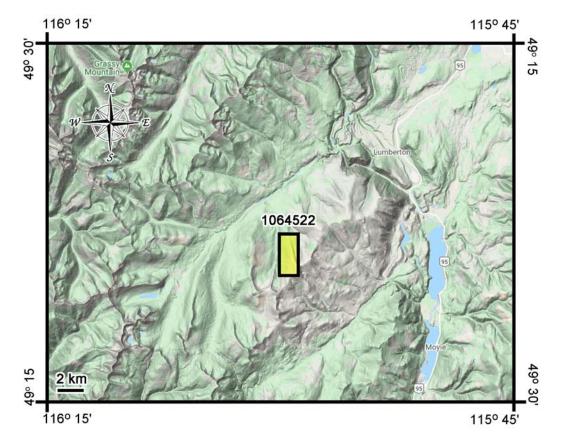
#### **1.0 Summary**

Application of modern data processing techniques to existing geophysical data on the Mac Attack property in southeastern British Columbia has provided new insights into structures delineated on aeromagnetic data as well as on subsurface variations of electrical conductivity determined from digitized VLF-EM data. The results include identification and delineation of a prominent and extensive zone of elevated conductivity and magnetic susceptibility in the near subsurface that has not been tested by drilling.

## **2.0 Introduction**

The purpose of this report is to describe the advanced processing and analysis of airborne magnetic data and ground-based VLF-EM data in an effort to use these techniques to enhance our understanding of the geologic structure and distribution of metals in the near subsurface of the Mac Attack property in the Purcell anticlinorium of southeastern British Columbia (Figure 1). The approach here will be to outline the geological setting, and then to focus on the results from the geophysical data sets.

All units used in this report are metric.



**Figure 1.** Shaded relief elevation map of the area near Moyie, British Columbia with the Mac Attack property indicated in yellow.

# **3.0 Property Description and Location**

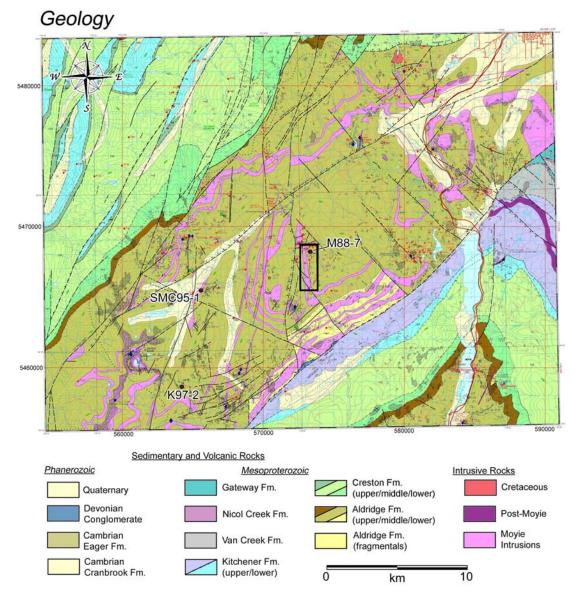
The Mac Attack Property ('the property') is located approximately 15-20 kilometres west-southwest of Cranbrook in the Fort Steele Mining Division of southeastern British Columbia (Figure 1). The single tenure (1064522; Table 1) covers an area of 441.93 hectares and is centred at approximate UTM coordinates 573250E, 54671000N, zone 11N WGS84, or 49° 21' 8" North Latitude; 115° 59' 29" West Longitude within map sheet 082G. Access to the property is via the Lumberton Forest Service road southwest of Cranbrook and then onto the McNeill Creek forest service road. Much of the area, including the old roads, is be overgrown with brush making travel along the roads by all-terrain vehicles necessary. Mineral cell titles were acquired online and as such there are no posts or lines marking the location of the property on the ground.

Title Number	Claim Name/Property	Issue Date	Good To Date	New Good To Date	# of Days For- ward	Area in Ha	Applied Work Value	Sub- mission Fee
1064522	MAC ATTACK	2018/NOV/16	2019/NOV/16	2022/jun/20	947	441.93	\$ 7034.54	\$ 0.00

**Table 1.** Description of Mac Attack property mineral title.

## 4.0 Geological Setting

The geology in the vicinity of the Mac Attack property (Figure 2) consists primarily of the Mesoproterozoic (ca. 1.55 Ga) Aldridge Formation metasedimentary rocks and associated mafic sills (Moyie sills). These rocks were deposited in an extensional basin (Belt-Purcell basin) that was subsequently uplifted and arched into the Purcell anticlinorium. The anticlinorium consists of thrust sheets that produced uplift and deformation of the strata into regional anticlines (e.g., Moyie anticline) that strike northnortheast and plunge northward in Canada. The location of the property with respect to the geologic structure is in the hanging wall of the Moyie fault, an east-northeast directed oblique thrust fault that was active into the late Cretaceous, and in the footwall of the St. Mary fault, an east-southeast directed thrust fault.



**Figure 2**. Geological map in the vicinity of the Mac Attack property (modified from Brown, 1998). The property area is outlined by the black rectangle. M88-7 is the location of a key drill hole.

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#### **5.0 Historical Development**

Lead and zinc mineralization were found in veins on the property in 1979 (O'Grady, 1987). This work was followed up by mapping and trenching (e.g., O'Grady, 1987), ground-based geophysical data acquisition (Bapty and Klewchuk, 1989; Ryley et al. 1990), part of a large-scale airborne magnetic survey (Woodfill, 1997), and drilling (Bapty and Klewchuk, 1989; Ryley et al. 1990; Hoy and Pighin, 2002). In 2016, Cook (2016) reprocessed the VLF data that were reported in Bapty and Klewchuk (1989) to produce cross-sectional images of the near-surface electrical conductivity structure.

#### 6.0 Work Done in 2019

Work completed on the Mac Attack property in 2019 consisted of the analysis of recently digitized airborne magnetic data (Cook, 2015). The data were acquired in 1996 and reported in Woodfill (1997) in the form of scaled maps. As a result, the TMI (Total Magnetic Intensity) map could be digitized and then processed with additional methods that help to delineate structure. Following this, the results could be compared and integrated with the conductivity variations detected in the VLF data.

A grid of VLF-EM lines was described in Bapty and Klewchuk (1990). These data were reprocessed in Cook (2016) and a portion of them is reviewed, reprocessed as necessary, and re-analysed here to correlate with the results of the magnetic data.

#### 7.0 Data

#### 7.1 General

Two data sets were used in this study. They are:

- 1. A grid of aeromagnetic data that were acquired by High Sense Geophysics in 1996 (Woodfill, 1997), and,
- 2. A grid of VLF-EM data that is localized to the vicinity of the Mac Attack property (Bapty and Klewchuk. 1989; Cook, 2015).

The magnetic data were presented as a large-scale map in Woodfill (1997) such that it could be digitized and regridded (Cook, 2015). The results of these efforts are the basis for further analyses of the data, including:

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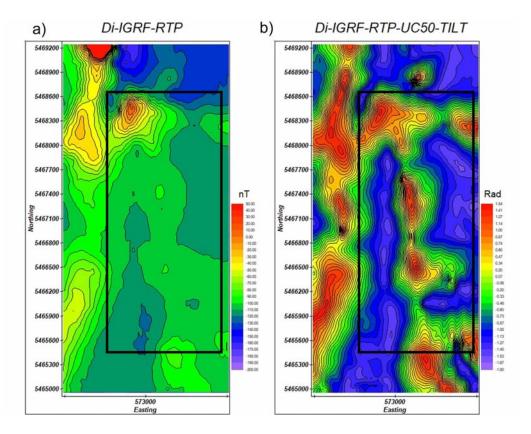
- 1. Removal of the IGRF;
- 2. Application of derivative based analyses such as the tilt derivative and normalized standard deviation to delineate structure.

The VLF-EM data were presented in Bapty and Klewchuk (1989) as a series of scaled profiles. Cook (2015) digitized these such that they could be inverted in order to detect zones of anomalous electrical conductivity and to present the conductivity variations in cross sections. These inversions were updated for this project in order to integrate them with the magnetics and geology.

#### 7.2 Magnetic Data

The magnetic data utilized here were recorded by High Sense Geophysics with much higher resolution (50m grid spacing; Woodfill, 1997) than the regional magnetic data from Natural Resources Canada (200m grid spacing). The line spacing of 200m allowed for a grid spacing of 50m and contour maps are available in Woodfill (1997). In order to utilize these data for studies such as this one, and because the digital data were not available, the TMI (Total Magnetic Intensity) map was hand digitized and re-gridded (50m grid spacing). Once the digitized data were obtained, the regional International Geomagnetic Reference Field (IGRF) was approximated and removed from the signal at each grid point (Cook, 2015).

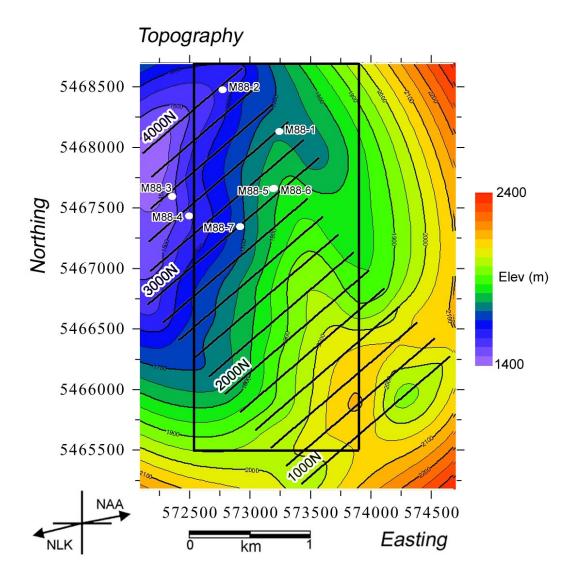
Figure 3 shows the magnetic data from the area of the Mac Attack property. Figure 3a displays the magnetic data after digitization, corrections for diurnal variations and the IGRF and reduction to the North Pole (RTP). Figure 3b shows the same data after application of the tilt angle. The results are similar to Figure 3a except that the amplitudes have been (nearly) equalized. Advanced analyses of the magnetic data will be shown in Section 8.0, "Correlations with the Geology".



**Figure 3**. Magnetic maps from the Mac Attack property. a) Magnetic anomalies after corrections for diurnal variations, the IGRF, and reduction to the North Pole; b) The same data after application of the tilt angle.

#### 7.3 VLF-EM Data

The VLF-EM data were acquired along a series of parallel lines that are oriented northeast-southwest (Figure 4). These data were reprocessed in Cook (2015) in an effort to apply new inversion methods that could provide subsurface targets with elevated conductivity. They were re-examined here to include some long-wavelength signals that may be relevant for the deep structure. An example is shown in Figure 4 for line 2000N, NLK transmitter. In previous work, (e.g., Cook, 2015) the very long wavelength signals were usually filtered out. However, the long wavelengths may be important for deep conductivity.



**Figure 4.** Topographic map of the vicinity of the Mac Attack property with the VLF lines shown. Lines 1000, 2000, 3000 and 4000 are labelled.

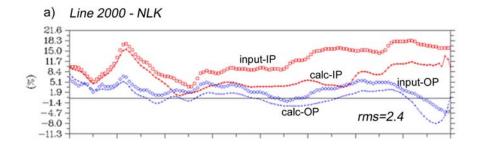
Consider Figure 5a. In this image, the recorded data are shown at the top after applying only a smoothing (running average) filter, but not removing any long wavelength components. After the inversion, the calculated curves (solid red and blue lines) match the overall shapes of the in-phase (IP) and out-of-phase (OP) but are displaced significantly from the input curves. This result produces an rms misfit of 2.4%.

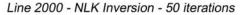
A second version is shown in Figure 5b. In this case, the inversion was run for 217 iterations in an attempt to more closely produce the IP and OP curve. After the many

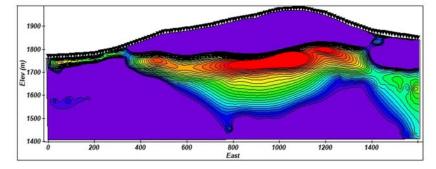
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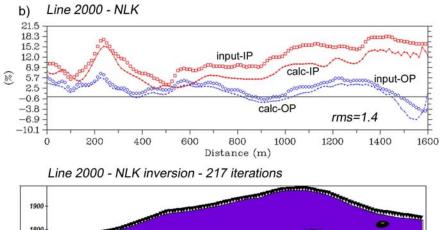
iterations, the result shows that the curves do indeed provide better approximation to the input signals. In addition, the inversion cross section has significantly larger and higher conductivity for the conductive zone beneath the hill.

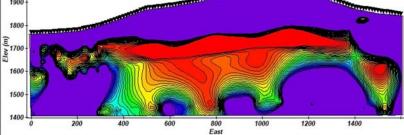
The resulting inversions for each of the lines and for each of the two transmitters (NLK, Seattle and NAA, Cutler, Maine) are shown in Figure 6 (modified from Cook, 2015). Three key observations result from these images. First, there appears to be an electrically conductive zone beneath the northwest-trending topographic ridge in the southeastern area of the Property. Second, the conductive zone appears to intersect the surface in the vicinity of exposed veins (e.g., Figure 5 at about 250m distance). Third, in many cases the major conductive zone appears to connect to narrow zones of elevated conductivity that dip deep below the sections (e.g., Figure 5 at about 1300m to 1500m distance and Figure 6b, lines 1000, 1200, 1600, 1800, 2000, 2200, and 2400). Although these features have the appearance of conduits, whether they are indeed conduits that allowed for fluid migration is not clear at this time.











**Figure 5.** a) Inversion of the data from Line 2000 (NLK). The curves at the top are the inphase (red dots) and out-of-phase (blue dots) that were input for inversion. The red and blue lines are the calculated curves from the inversion model below. b) Same as (a) for 217 iterations in an effort to improve the curve fit. Note that the red and blue lines are closer to the input curves than in (a).

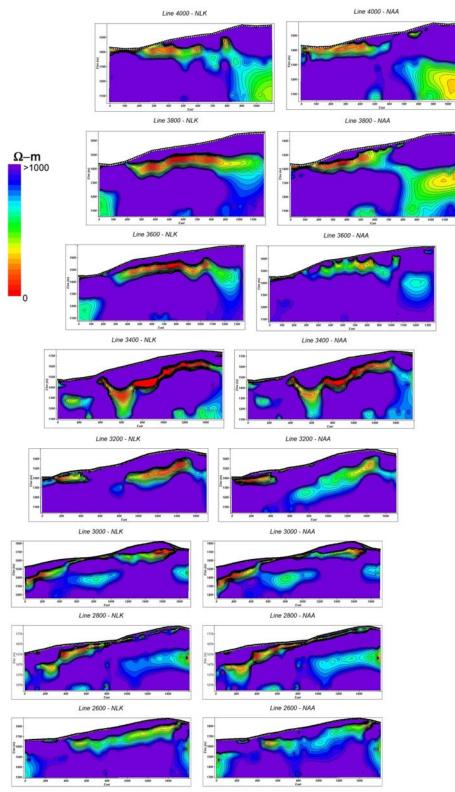


Figure 6a. Inversions for lines 2600 to 4000; modified from Cook (2016).

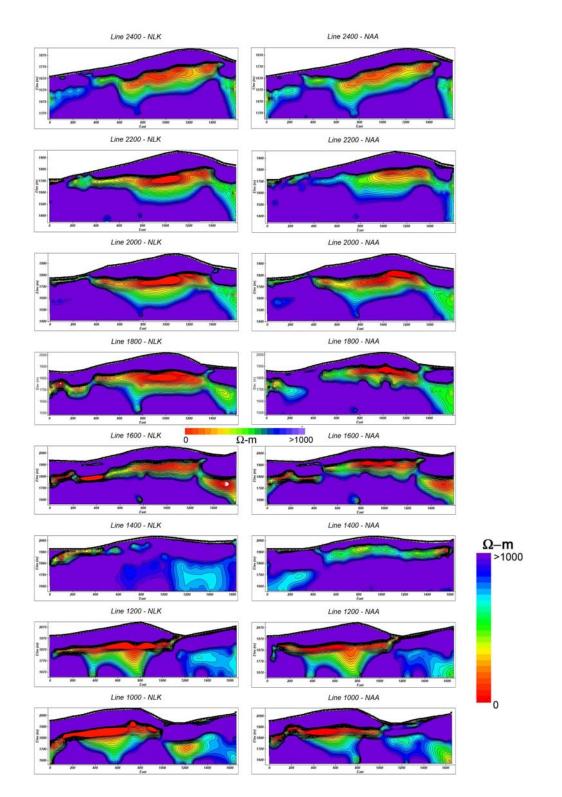


Figure 6b. Inversions for lines 1000 to 2500; modified from Cook (2016).

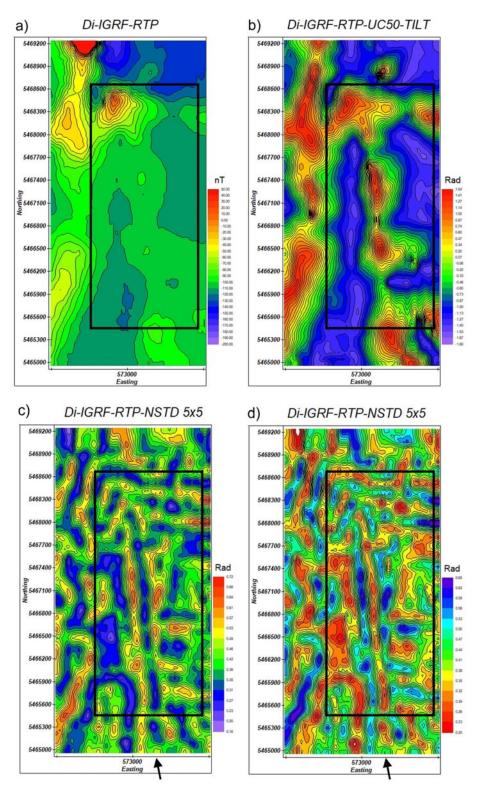
#### 8.0 Correlations With the Geology

#### 8.1 Magnetic Data Results

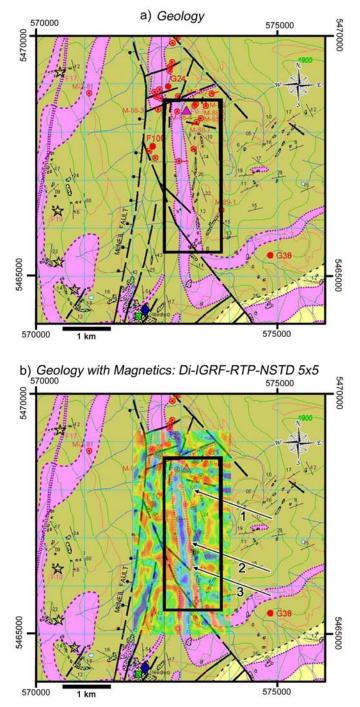
A relatively new approach to analysing gridded magnetic data was proposed by Cooper and Cowan (2008) as the Normalized Standard Deviation (abbreviated NSTD). This technique is very effective for delineating the edges of anomalies and thus the general structure. Figures 6a and 6b are the magnetic anomaly maps from Figure 3. Figure 7c shows the result of applying NSTD using a window of 5 x 5 grid points. Because the NSTD is effective at delineating the edges of anomalies (and possibly sources), Figure 7d shows the same result in reversed colours in order to approximate the locations of the sources as highs (red), rather than the edges of the sources. Figure 8 shows the local geology (Figure 8a) and Figure 8b shows the map from Figure 7d overlain on the geology with 50% transparency.

Although all of these images (Figures 7 and 8) show dominant north-northwest oriented anomalies, the NSTD versions of the map display a prominent double linear feature (arrows in Figures 7c and 7d). These anomalies correlate with the margins of the Hiawatha sill (Figures 7d and 8b). Additional observations include: 1) the linear anomalies (Figure 7d and 8b) appear to be disrupted in the northern part of the property, near UTMeast =573000, UTMnorth =5468300; 2) near the southern end of the map in Figure 6d, the linear anomalies also appear to be disrupted in the vicinity of a mapped fault where the sill bifurcates and is re-oriented to a more easterly direction (Figure 8); 3) third, the western portion of the linear anomalies appears to widen westward near UTMe=572900, UTMn=546620. This geometry coincides with a mapped widening of the sill (Figure 7a) at this location. The observation that the linear anomalies are located on the eastern and western edges of the sill can be interpreted to indicate that the magnetic source is either within the sill at its edge, or in the meta-sedimentary rocks at its margin. In the Duncan Moyie drill hole, the sills were generally found to be non-magnetic, but the adjacent sedimentary rocks often include magnetic minerals such as pyrrhotite and magnetite (e.g., Cook and Jones, 1995).

In addition to the long linear anomalies, there appear to be a number of short eastwest anomalies that terminate at the north-south anomaly (Figure 7d). Some of these linear anomalies and intersections correlate with the locations of veins. For example, in Figure 7d, there are a number of linear anomalies that are oriented about 110-120° and that terminate against the north-south linear (sill) anomaly. As noted by Bapty and Klewchuk (1989), these veins appear to haved a similar orientation to the St. Eugene veins (about 120°), and the results here indicate that magnetic anomalies associated with some of the veins may be visible in Figure 7d.



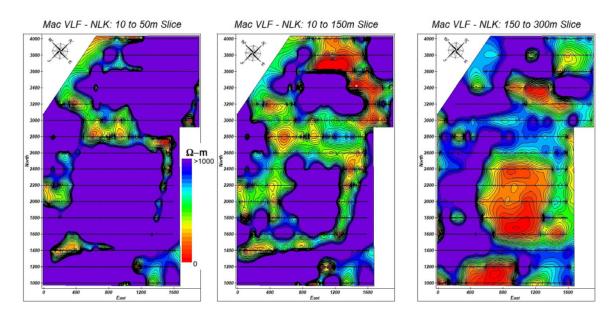
**Figure 7.** a) and b) are the same maps as in Figure 3; c) is the result of applying the NSTD procedure and d) is the same as c) with reversed colors.



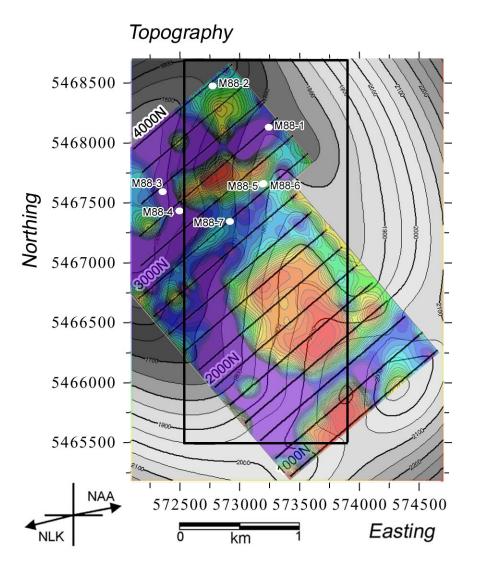
**Figure 8.** a) Geologic map in the vicinity of the Mac Attack property (rectangular outline); b) Same area as in (a) with the map from Figure 7d overlain with transparency and no contour lines. Note that the linear north south anomalies clearly, and in detail, delineate the edges of the sill. Arrows 1, 2 and 3 are displayed at an azimuth of about 300° (120°), approximately the same as the St. Eugene-Aurora-Guindon shear zone. Each arrow points to a short linear anomaly that terminates against the north-south Hiawatha sill anomaly.

#### 8.2 VLF-EM Results

Results of the VLF analysis indicate that there is a prominent highly conductive zone that is more-or-less horizontal beneath the hill in the southeast corner of the property. This is displayed clearly by mapping 'slices' with different depth intervals (=slice thickness; Figure 9). In Figure 9, three depth intervals are included: 10-50m (Figure 9a), 10-150m (Figure 7b), and Figure 9c (150-300m). In Figure 10, the 100-300m 'slice' is shown overlain on the topography. Clearly, the major high conductivity zone is concentrated beneath the northwest-oriented hill.



**Figure 9.** 'Slices' for three depth intervals: a) 10-50m, b) 10-150m, and c) 100-300m. Note that in (a) and (b), elevated conductivity appears to outline a nearly rectangular area. This outline represents conductive zones that are approaching, or at, the surface. In c), however, the dominant feature is a nearly rectangular zone of very high conductivity that correlates with the prominent conductive zone on the inversion cross sections in Figure 6.



**Figure 10.** Superposition of the 150-300m 'slice' from Figure 9c onto the topography in greyscale. Note that the dominant conductor is located beneath the northwest oriented hill

#### 8.3 Combined Results

The magnetic, VLF and geological results can be combined in cross sections to illustrate the spatial relationships of these methods. This is perhaps best shown in a 2D cross section as illustrated in Figure 11. Figure 10a shows the inversion section from line 2000 (NLK transmitter); Figure 11b shows the magnetic data profile along the same line and Figure 11c shows the tilt angle version of the same data as in Figure 11b. Figure 11d is

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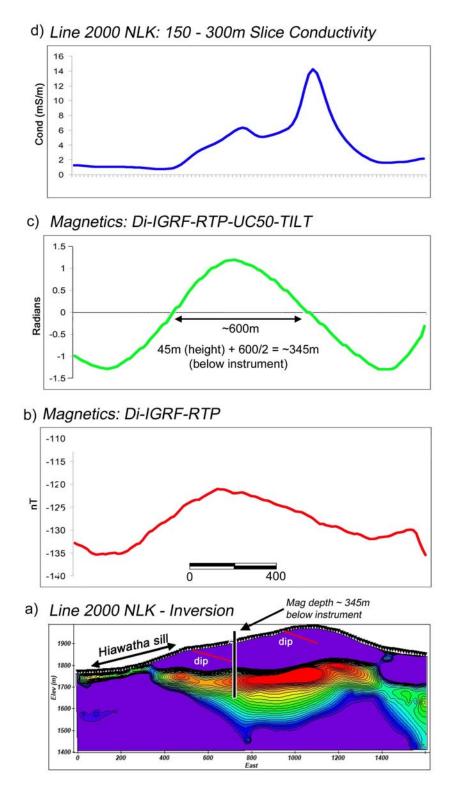
a profile of the conductivity values along line 2000 from the map in Figure 7c. Following are several observations that are significant:

- 1. The region of the prominent conductivity high is also characterised by high magnetic values (about 10-14 nT above background);
- 2. The magnetic high is slightly skewed toward the west side of the conductive zone;
- 3. The elevated conductivity appears highest on the east side of the anomalous area.

In addition, the tilt angle result can be used to estimate depth of the magnetic source in the following way. Salem et al (2007) describe a simple method to estimate depth by measuring the width of the zero-crossings of the tilt angle. In Figure 11c, this distance is ~600m. As Salem et al (2007) describe, the depth estimate would then be  $\frac{1}{2}$  of this distance (~300m) plus the height of the magnetometer (about 45 m; Woodfill, 1997). Thus, the estimate of depth to the magnetic source is ~345m below the instrument. This distance is shown by a vertical black line in Figure 11a. Note that the estimated depth of the source is very close to the location of the conductive zone.

Also shown on Figure 11a are the surface exposed position of the Hiawatha sill and two examples (red lines) of the stratigraphic dip (about 18-20° east). The significance of this information is that if the dip remain constant at depth, then the conductive zone would cross-cut the stratigraphy (including the sill). Alternatively, the strata (and sill) may flatten such that the conductive zone is more-or-less parallel to the stratigraphy.

While either of these interpretations is consistent with these data, the latter interpretation would appear to be more consistent with the fact that the Hiawatha sill (and associated stratigraphy) outline a syncline whose axial surface is oriented northeast (Figure 8).



**Figure 11.** a) VLF inversion cross section along line 2000; b) profile of the magnetic anomaly data along the same line; c) tilt angle version of the magnetic data along line 2000 and d) is a profile of the VLF conductivity results along line 2000.

# 9.0 Conclusions

Analyses of the digitized magnetic data and VLF-EM data from the Mac Attack property has lead to the following findings:

- 1. Application of the tilt derivative and normalized standard deviation has led to the discovery of linear north-northwest anomalies at the margins of the Hiawatha sill.
- 2. Although it is not clear whether the magnetic anomalies are due to magnetic rocks within the sill, or in the meta-sedimentary rocks adjacent to the sill, this appears to be the first time that a sill in the Aldridge Formation has been delineated in detail with magnetic data;
- 3. In addition to the sill magnetic anomalies, there appear to be a number of northwest-southeast magnetic anomalies that merge with, or are truncated at, the east side of the sill. At least two of these features abut the sill anomaly where veins are found at the surface. This may be the first time in this area that veins appear to have been visible with magnetic data;
  - 4. Re-analysis of the VLF data has identified a large conductivity high beneath a topographic ridge in the southeastern portion of the property;
  - 5. It is not clear at this time whether the conductive zone is parallel to the stratigraphy or whether it cross-cuts stratigraphy.

# **10.0 References**

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- Brown, D.A. 1998. Geological Compilation of Grassy Mountain (East Half) and Moyie Lake (West Half) Map Areas, Southeastern British Columbia (82F/8E, 82G/5W); B.C. Ministry of Energy and Mines, Geoscience Map 1998-3, 1:50 000 scale map
- Cook, F., 2015. Analyses of VLF Geophysical Data: Big Kahuna-STA (east) Property, Southeastern British Columbia, British Columbia Ministry of Energy and Mines, Assessment Report 35499, 25pp.
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- Cook, F. and Jones, A. 1995. Seismic reflections and electrical conductivity: A case of Holmes' curious dog? Geology, v. 23, p. 141-144.

- Ryley, J., Klewchuk, P., and Bapty, M., 1990. Property development report: Gold Creek NTS 82/G3, British Columbia Ministry of Energy and Mines, Assessment Report 19965, 163pp
- Woodfill, R., 1997. Assessment Report on Geology, Geophysics and Geochemistry: Part 1, Introduction and Airborne Magnetic Survey, British Columbia Ministry of Energy and Mines, Assessment Report 24786, 190pp.

# **11.0 Statement of Costs**

Property:	Mac Attack	
Event #	5763536	
Start - End Date:	September 18, 2019 – September 23, 2019	
Tenure work done on:	1064522	
Type of work done:	Geophysical – VLF/Magnetics	
Fred Cook	Data processing	\$ 3,200.00
(Salt Spring Imaging, Ltd.)	September 18-23, 2019	
	Assessment Report	\$ 3,000.00
Subtotal		\$ 6,200.00
Total		\$ 6,200.00

# **15.0 Statements of Qualifications**

I, Frederick A. Cook do hereby certify that:

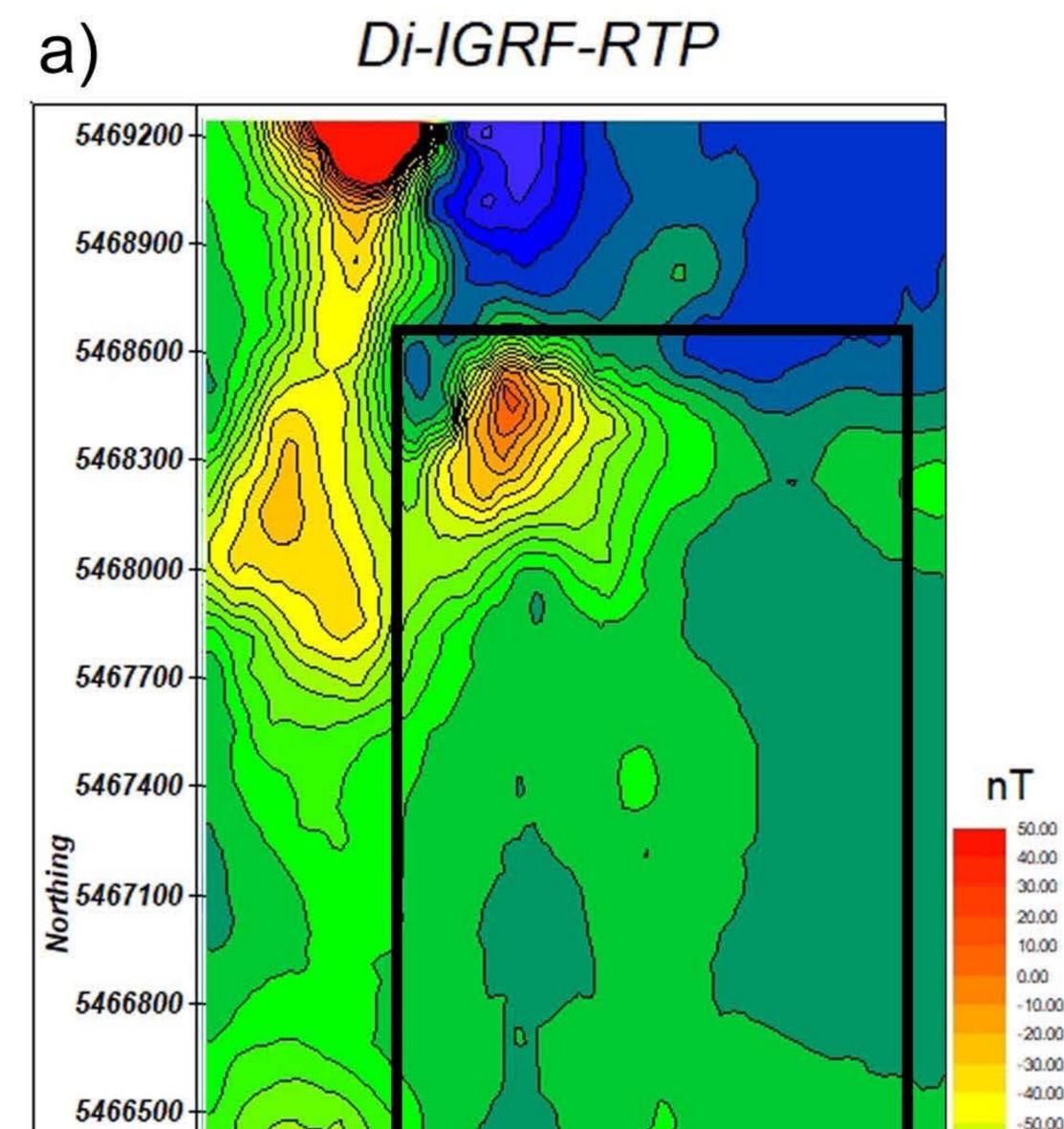
- 1) I attained the degree of Doctor of Philosophy (Ph.D.) in geophysics from Cornell University in Ithaca, New York in 1981.
- 2) I have a B.Sc. in geology (1973) and an MSc. in Geophysics (1975) from the University of Wyoming in Laramie, Wyoming.
- 3) I am a registered member of the Association of Professional Engineers and Geoscientists of British Columbia (P. Geo. 2009). Previously, from 1984-2009, I was registered with the Association of Professional Engineers, Geologists and Geophysicists of Alberta as both a P. Geol. and a P. Goph.
- 4) I am a member of the American Geophysical Union and the Geological Society of America.
- 5) I have worked as a geophysicist/geologist for a total of 38 years since my graduation from university.
- 6) I have worked for the Continental Oil Company (1975-1977) and the University of Calgary (1982-2010).
- 7) I was the Director of the Lithoprobe Seismic Processing Facility at the University of Calgary from 1987-2003.
- 8) I have recently (2011) been appointed an International Consultant for the Chinese SinoProbe project.
- 9) I have a thorough knowledge of the geology of southern British Columbia based on extensive geological and geophysical field work since 1980.
- 10) I have authored more than 125 scholarly publications in peer-reviewed journals and books.
- 11) I was retained to undertake analyses of the geophysical data in the vicinity of the Gold Shear property.
- 12) I am the author of this report.
- 13) I am not aware of any material fact or material change with respect to the subject matter of this report, which is not reflected in this report.

"signed and sealed" at Salt Spring Island, B.C.

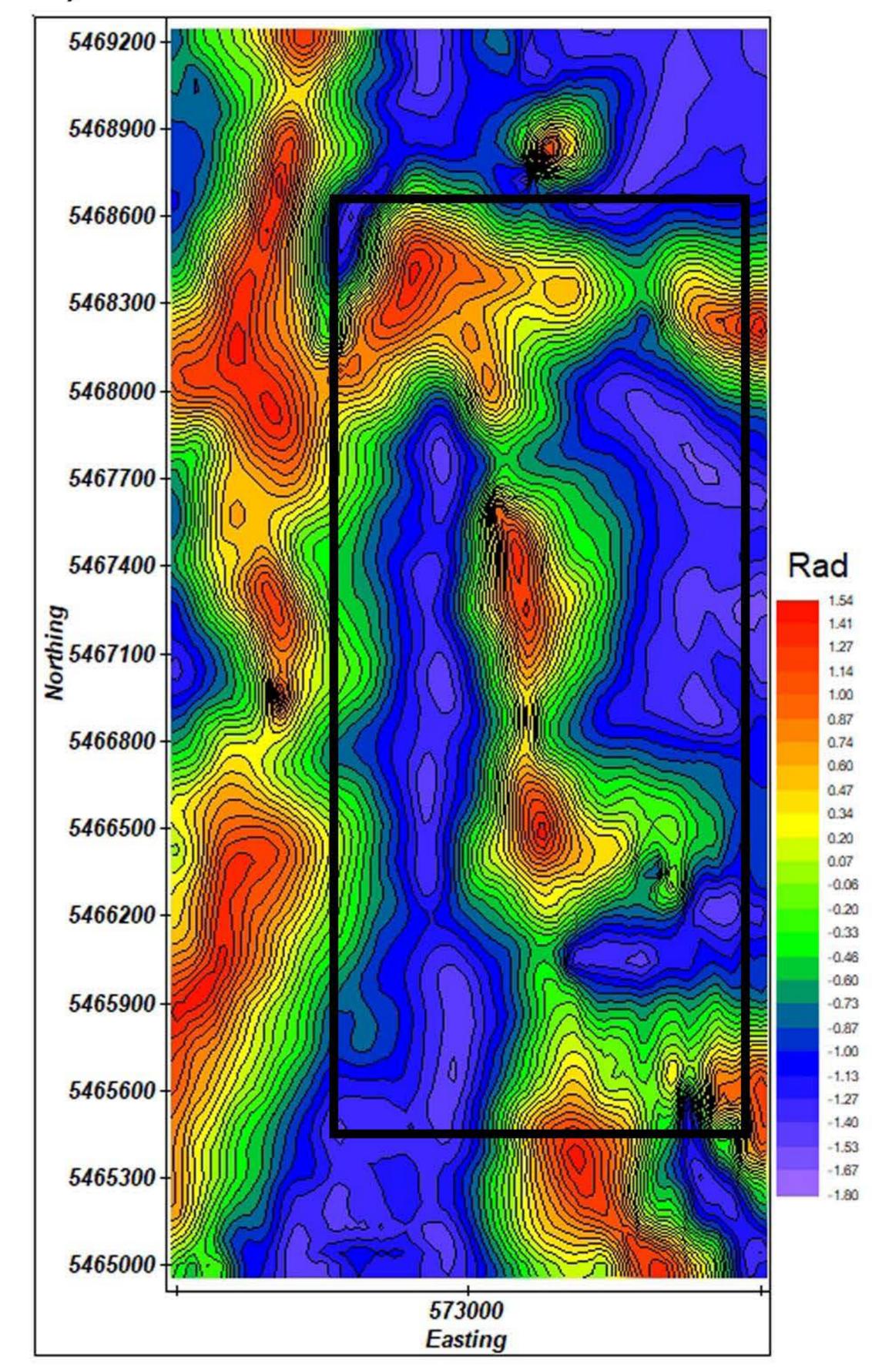
**Frederick A. Cook**, P. Geo. Salt Spring Imaging, Ltd 128 Trincomali Heights Salt Spring Island, B.C.

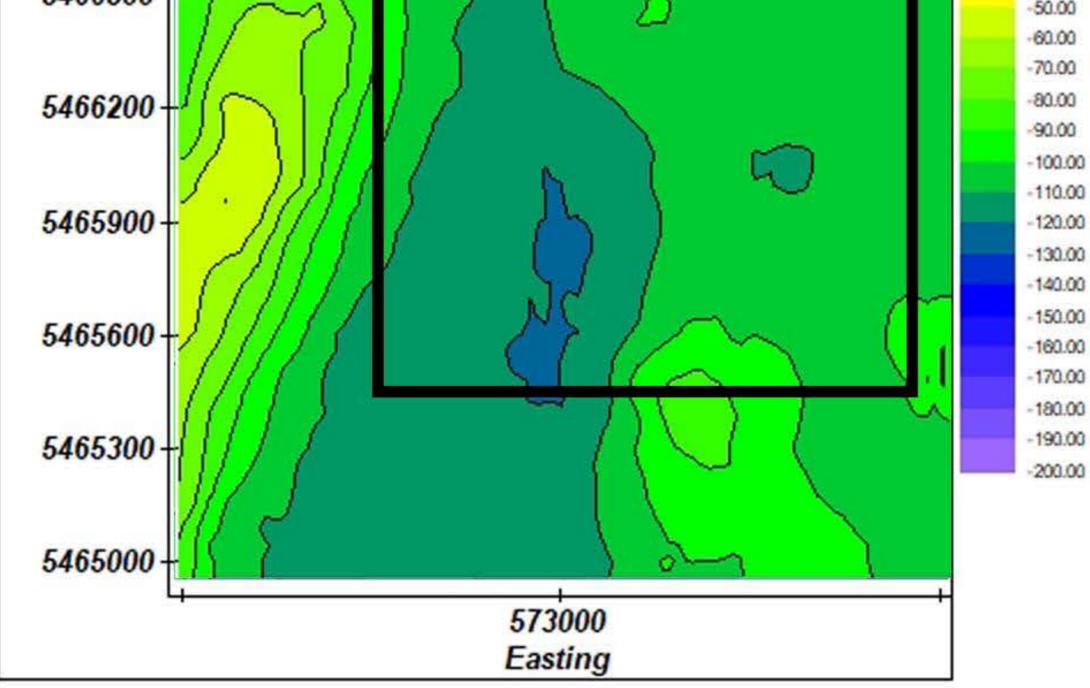
Dated at Salt Spring Island, B.C. this 1<sup>st</sup> day of February, 2020 Registration License No. 34585 Association of Professional Engineers and Geoscientists of British Columbia

# Appendix 1: Magnetic Anomaly Maps Scale 1:10000



# Di-IGRF-RTP-UC50-TILT b)



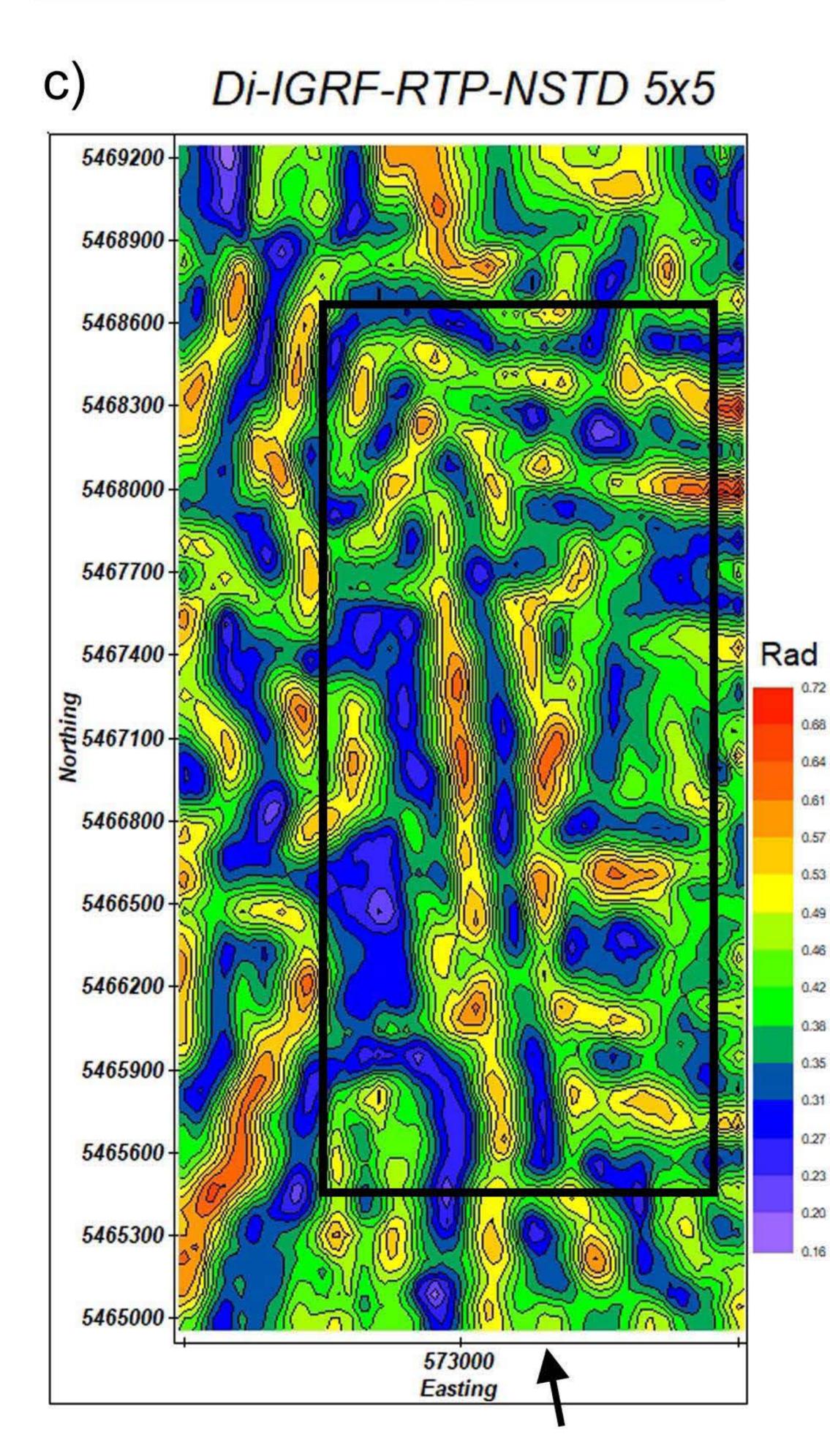


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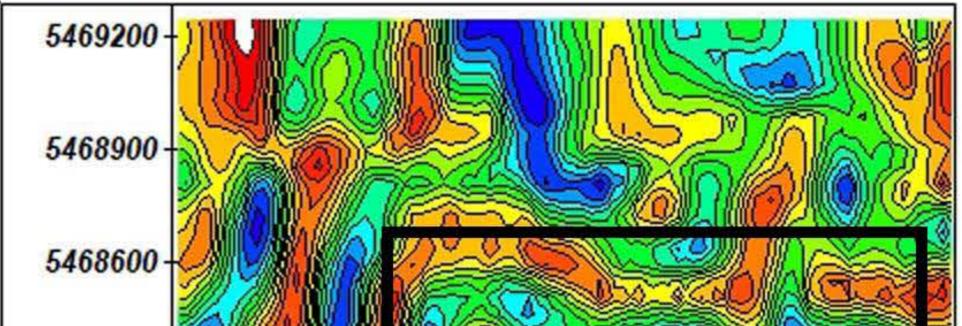
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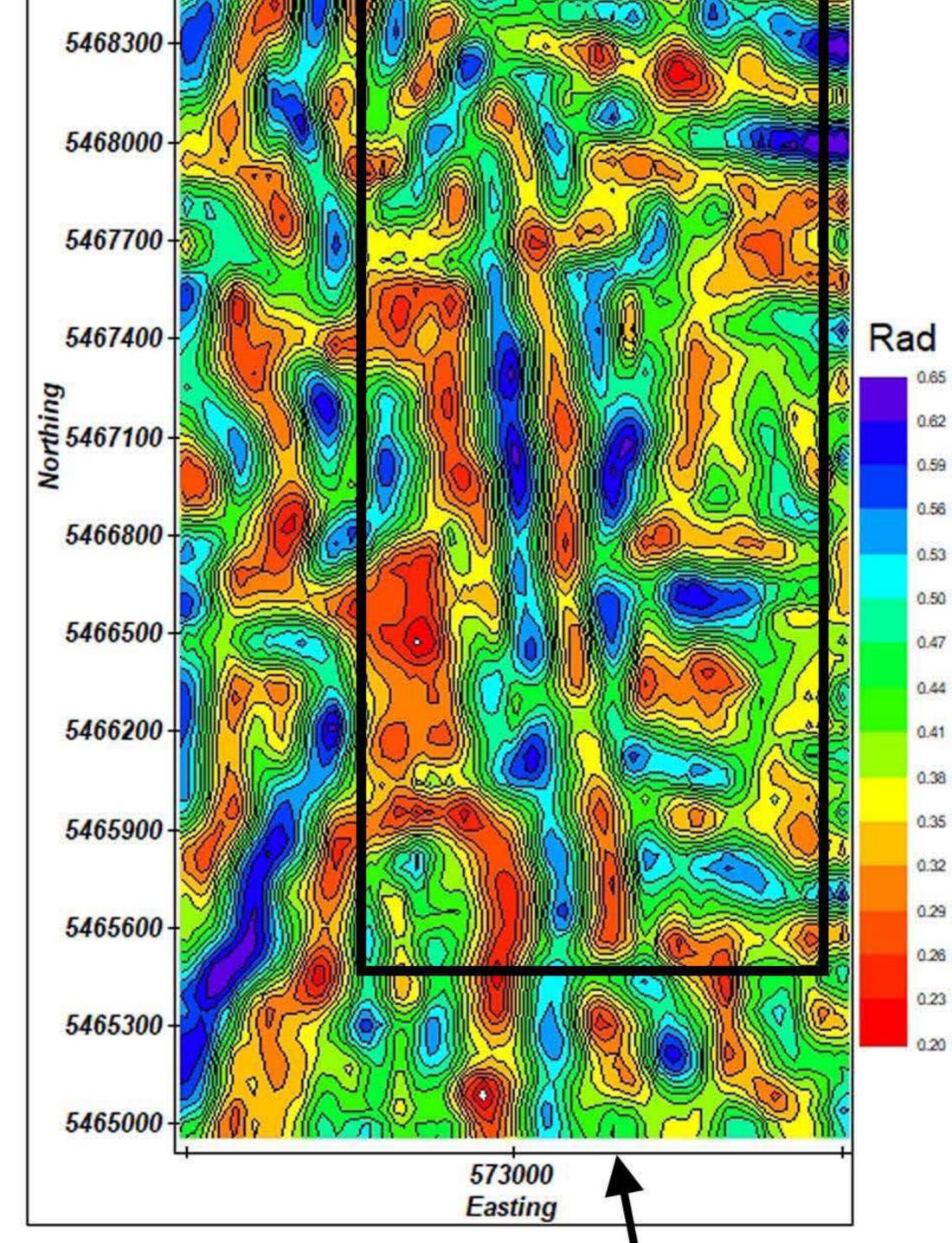
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-40.00



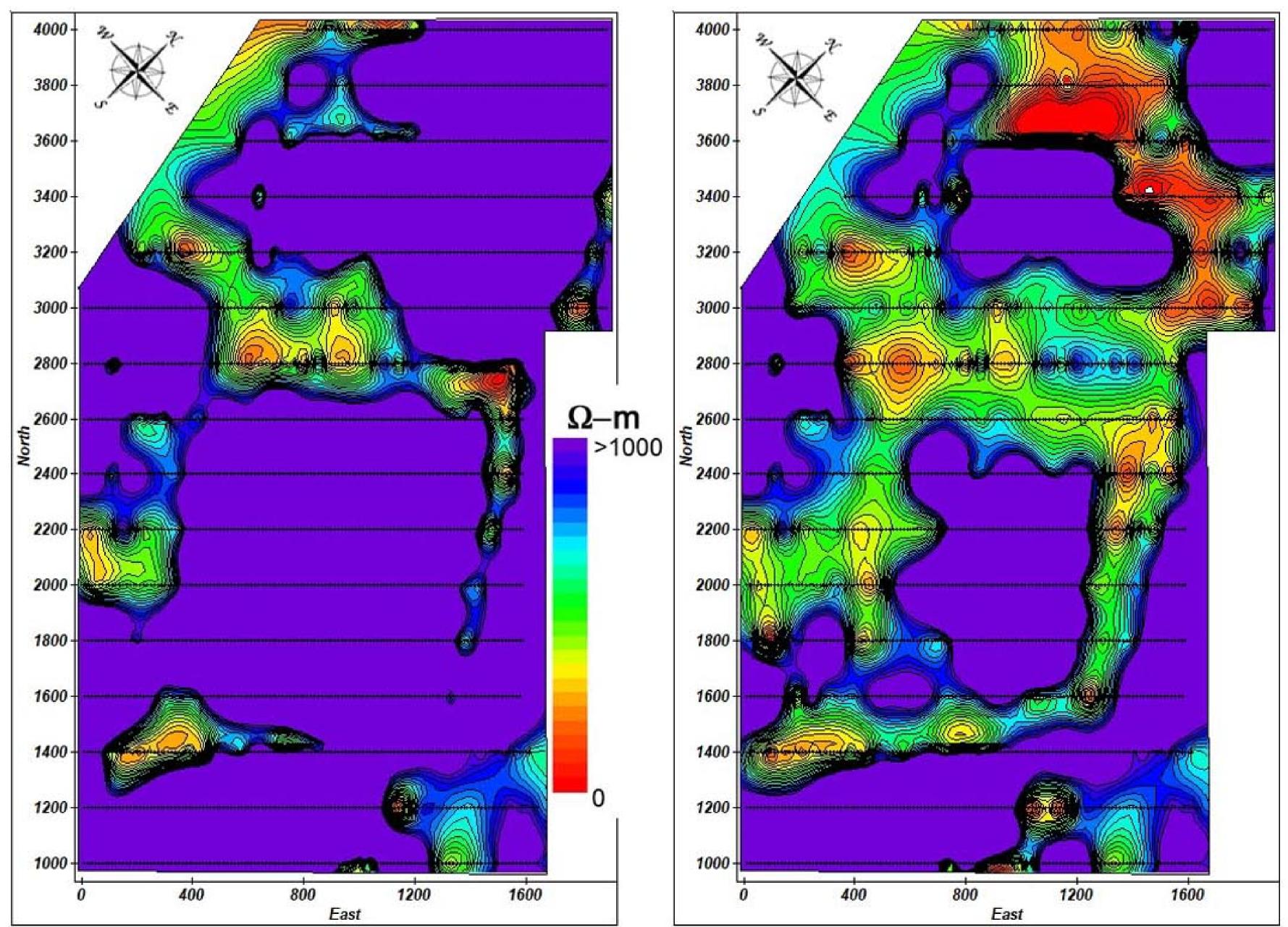






# Appendix 2: Maps of Conductivity 'Slices' Scale 1:10000

Mac VLF - NLK: 10 to 50m Slice



# Mac VLF - NLK: 10 to 150m Slice

# Mac VLF - NLK: 150 to 300m Slice

