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Ministry of Energy, Mines & Petroleum Resources
Mining & Minerals Division
BC Geological Survey

BC Geological Survey
Assessment Report
39069

Assessment Report
Title Page and Summary

TYPE OF REPORT [type of survey(s)]: Analyses of digitized airborne magnetic data Down Dip p **TOTAL COST:** $5,899.20

AUTHOR(S): Frederick A. Cook **SIGNATURE(S):** Frederick A. Cook Digitally signed by Frederick A. Cook DN: cn=Frederick A. Cook, o, ou, email=fcook@ucalgary.ca, c=CA Date: 2020.05.08 08:01:27 -07'00'

NOTICE OF WORK PERMIT NUMBER(S)/DATE(S): **YEAR OF WORK:** 2020

STATEMENT OF WORK - CASH PAYMENTS EVENT NUMBER(S)/DATE(S): Event 5773853, Dates: January 13-20, 2020

PROPERTY NAME: Down Dip

CLAIM NAME(S) (on which the work was done): Down Dip 01-19 (Title No. 1066460), Down Dip 02-19 (Title No. 1068446)

COMMODITIES SOUGHT: massive sulphides

MINERAL INVENTORY MINFILE NUMBER(S), IF KNOWN:

MINING DIVISION: Ft. Steele **NTS/BCGS:** 082F

LATITUDE: 49 ° 05 ' 09.6 " **LONGITUDE:** 115 ° 53 ' 55.2 " **(at centre of work)**

OWNER(S):
1) D. E. LaVoie
2)

MAILING ADDRESS:
2290 DeWolfe Ave.
Kimberley, BC V1A1P5

OPERATOR(S) [who paid for the work]:
1)
2)

MAILING ADDRESS:

PROPERTY GEOLOGY KEYWORDS (lithology, age, stratigraphy, structure, alteration, mineralization, size and attitude):

Metasedimentary rock; Proterozoic; Middle Aldridge Formation, sedex deposits

REFERENCES TO PREVIOUS ASSESSMENT WORK AND ASSESSMENT REPORT NUMBERS: Woodfill (24652); Gal and Weidner (26121); Kennedy (36299)

Next Page

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	1066460, 1068446	2400.00
Airborne	Digitization		499.20
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)/trail			
Trench (metres)			
Underground dev. (metres)			
Other	Report		$3,000.00
		TOTAL COST:	$5,899.20

Assessment Report:

Analyses of Digitized Airborne Magnetic Data on the Down Dip Property, Southeastern British Columbia

MTO event 5773853

North 49° 05' 09.6"; West 115° 53' 52.2"

UTM Zone 11: 580475E, 5437600N, WGS84

NTS map sheet 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:

Darlene Lavoie
2290 DeWolfe Ave.
Kimberley, B.C. V1A1P5

May, 2020

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1.0 Summary

Application of modern data processing techniques to existing geophysical data on the Down Dip property in southeastern British Columbia has provided new insights into structures delineated on aeromagnetic. The results include identification and delineation of prominent magnetic features and truncations in anomaly trends that may be related to structures. In some cases these structures may have been used as fluid pathways for movement and deposition of metals.

2.0 Introduction

The purpose of this report is to describe the advanced processing and analysis of airborne magnetic data that were recorded 25 years ago and that were digitized to allow applications of digital filtering techniques. The objectives are to use these techniques to enhance our understanding of the geologic structure and distribution of metals in the near subsurface of the Down Dip 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. Units used in this report are metric.

3.0 Property Description and Location

The Down Dip Property (‘the property’) is located approximately 20-25 kilometres south of Moyie in the Fort Steele Mining Division of southeastern British Columbia (Figure 1). The two tenures (1066460 and 1068446; Table 1) cover an area of 1586.7 hectares and is centred at approximate UTM coordinates 580475E, 5437600N, zone 11N WGS84, or 49° 5' 9.6” North Latitude; 115° 53’ 52.2” West Longitude within map sheet 082G. Access to the property is via Highway 3 southwest of Moyie and then via the Hawkins Creek forest service road east of Yahk. At a distance of about 12 km, the Cold Creek forest service road intersects the Hawkins Creek road. At about 6 km from the intersection, an all terrane vehicle road that can be followed into the property branches to the east. Mineral cell titles were acquired online, and as such, there are no posts or lines marking the location of the property on the ground.

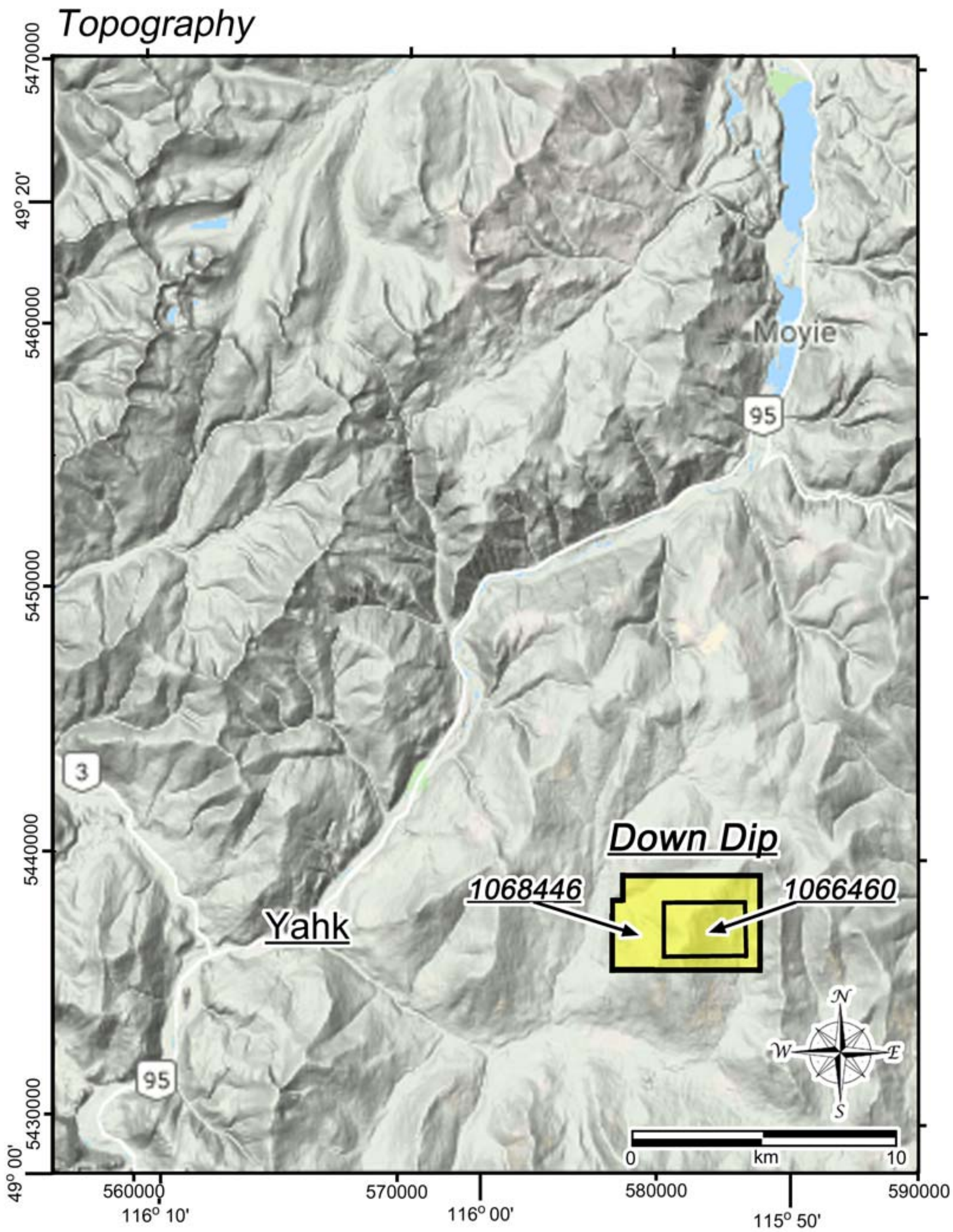

Figure 1. Shaded relief elevation map of the area near Moyie, British Columbia with the Down Dip property indicated in yellow.

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
1066460	DOWN DIP 01-19	2019/FEB/12	2020/FEB/12	2021/Jan/06	329	507.76	$ 2282.15	$ 0.00
1068446	DOWN DIP 02-19	2019/MAY/09	2020/MAY/09	2021/Jan/06	242	1078.94	$ 3576.75	$ 0.00

Table 1. Description of Down Dip property mineral titles.

4.0 Geological Setting

The geology in the vicinity of the Down Dip property (Figure 2) consists primarily of the Mesoproterozoic (ca. 1.47 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 north-northeast and plunge northward in Canada. The location of the property with respect to the geologic structure is in the foot wall of the Moyie thrust fault, an east-northeast directed oblique thrust fault that was active into the late Cretaceous.

Uplift of the anticlinorium probably began in the Mesoproterozoic, but the latest movement on the Moyie thrust was at least as late as the Cretaceous (Yin, 1995) and that is likely when the final uplift of the Moyie anticline occurred as well. Uplift of the Moyie anticline as it is visible today was caused when the thick basinal sedimentary strata encroached upon and were thrust over a prominent west-facing ramp in the pre-Purcell basement. The property is situated in the vicinity of some of the stratigraphically deepest rocks of the Aldridge Formation that host the Sullivan deposit approximately 55 km to the north.

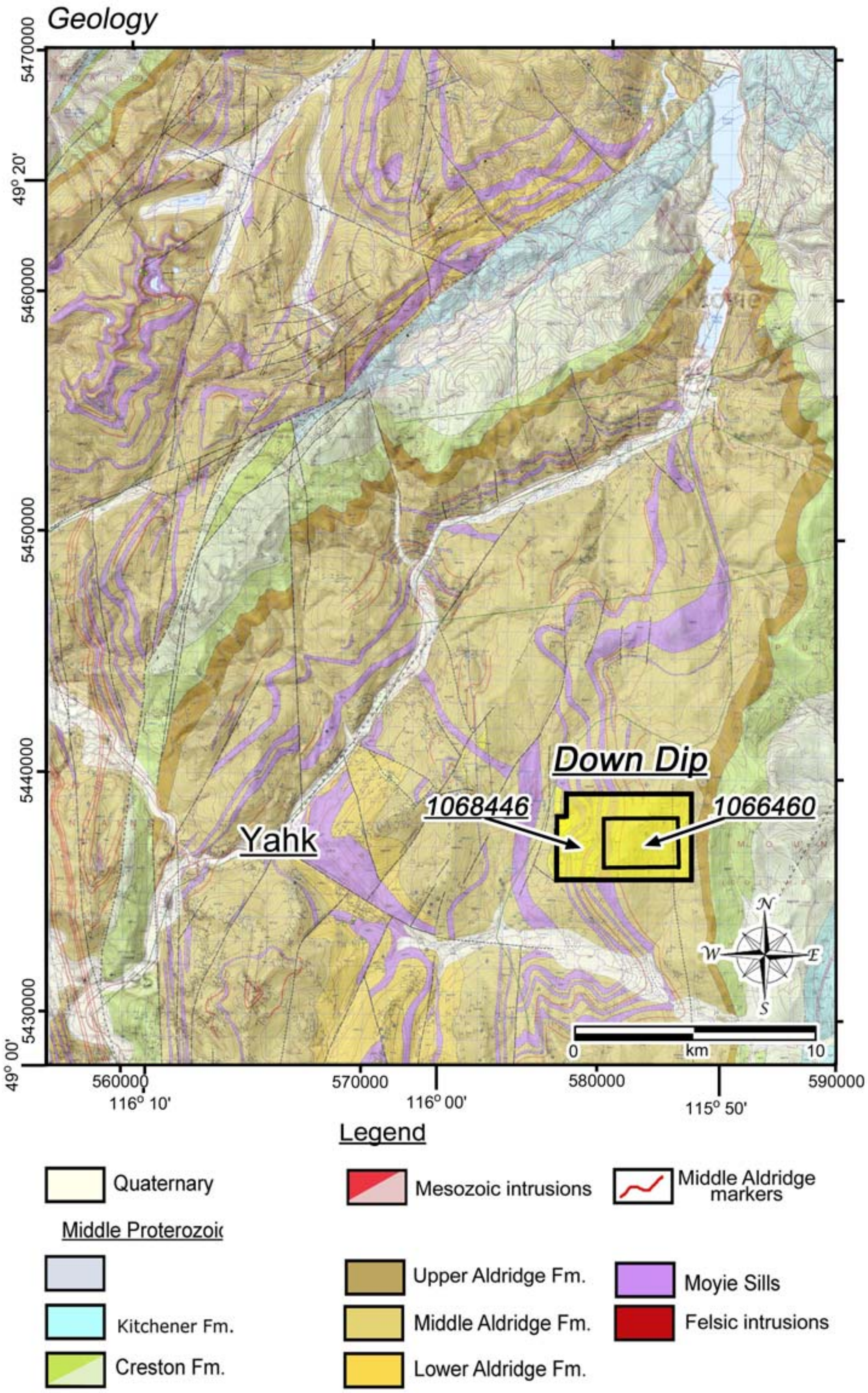

Figure 2. Geological map in the vicinity of the Down Dip property (modified from Brown et al., 1998). The property area is outlined by the black rectangle surrounding the yellow shading.

5.0 Historical Development

Although the area of the Down Dip property has been part of large-scale claim blocks, there is no record of detailed geochemical or geophysical work done in the immediate area of the property. However, a number of studies focused on Mt. Mahon have provided a significant amount of data. For example in Assessment Report #26121, Gal and Weidner (1999) described a deep drill hole (YK 99-01, 883.2m) that intersected anomalous copper and nickel in the Lower Aldridge below about 750m depth. Minnova undertook gravity, soil sampling and drilling in the area east of the property. Chevron held claims southeast of the property on Mount Mahon and undertook mapping, soil sampling and several drill holes. Woodfill (1996) described an airborne magnetic survey of a large area that included about 50% of the Down Dip property. Analyses of these data provide a large part of the present study. Kennedy (2016) provided the most recent work on the property with the discovery of several rock samples that are anomalous in Pb and Zn.

6.0 Work Done in 2019

Work completed on the Down Dip property in 2019 consisted of the analysis of digitized airborne magnetic data in an effort to delineate key structures that may be associated with metal deposits. The magnetic data were acquired in 1996 and reported in Woodfill (1996) in the form of scaled maps. As a result, the Total Field Magnetics, also known as the TMI (Total Magnetic Intensity) map, could be digitized and then processed with additional methods that help to delineate structure.

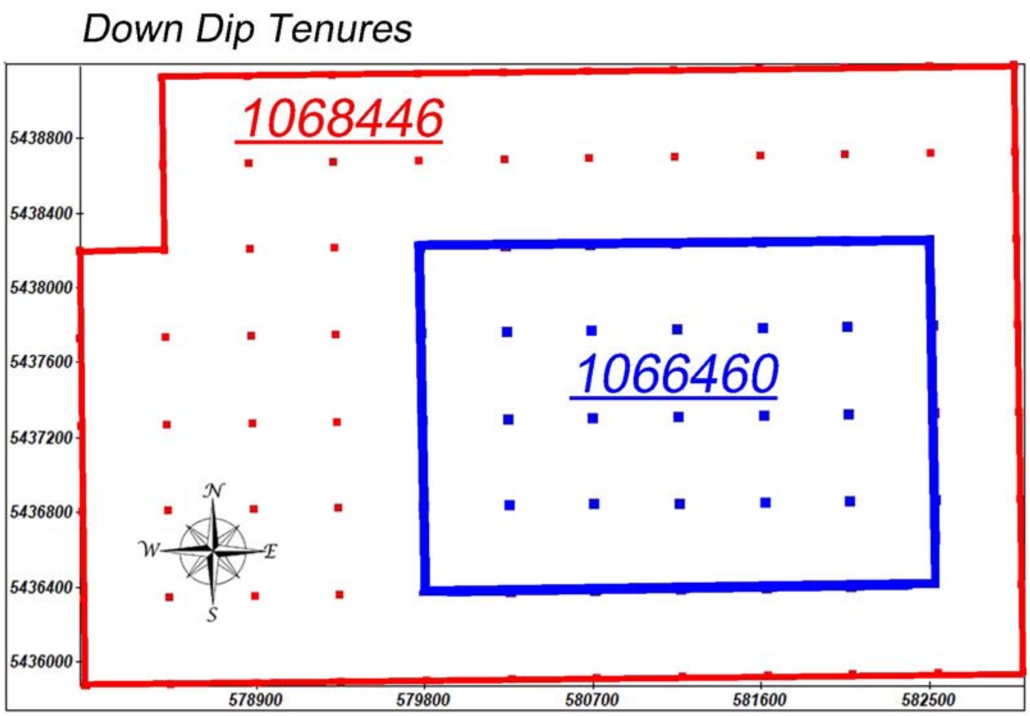

Figure 3. Map of the two Down Dip tenures with the corners of each claim block indicated by dots.

7.0 Data

7.1 General

The magnetic data were presented as a large-scale map in Woodfill (1996) such that it could be digitized and regridded. The results of these efforts are the basis for further analyses of the data, including:

1. Removal of the IGRF (International Geomagnetic Reference Field);
2. Application of derivative – based analyses such as the tilt derivative and normalized standard deviation to delineate structure.

7.2 Magnetic Data

The magnetic data utilized here were recorded by High Sense Geophysics with much higher resolution (50m grid spacing; Woodfill, 1996) than the regional magnetic data from Natural Resources Canada (~200m grid spacing). The line spacing of 200m in the High Sense survey allowed for a grid spacing of 50m and contour maps are available in Woodfill (1996). In order to utilize these data for studies such as this one, and because the digital data were not available, the Total Field Magnetics (also known as the Total Magnetic Intensity, or TMI) 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.

Figure 4 shows the regional magnetic data from the area of the Down Dip property. Figure 4a displays the regional magnetic data from Natural Resources Canada (http://gdr.agg.nrcan.gc.ca/gdrdap/dap/search-eng.php) with 250m grid spacing. After digitization of the map in Woodfill (1996), Figure 4b is the same map as in Figure 4a with the high-resolution data superimposed. The results of the high resolution data analysis shown in Figure 4b includes corrections for diurnal variations and the IGRF (International Geomagnetic Reference Field) and reduction to the North Pole (RTP). Corrections for the IGRF were made by taking the IGRF value for the central time of the survey (August 24 through September 1, 1996) at a number of points, contouring the values, and then subtracting from the measured values. Although not as accurate as calculating for each point during data acquisition, this approach does allow a regional trend of the IGRF to be removed.

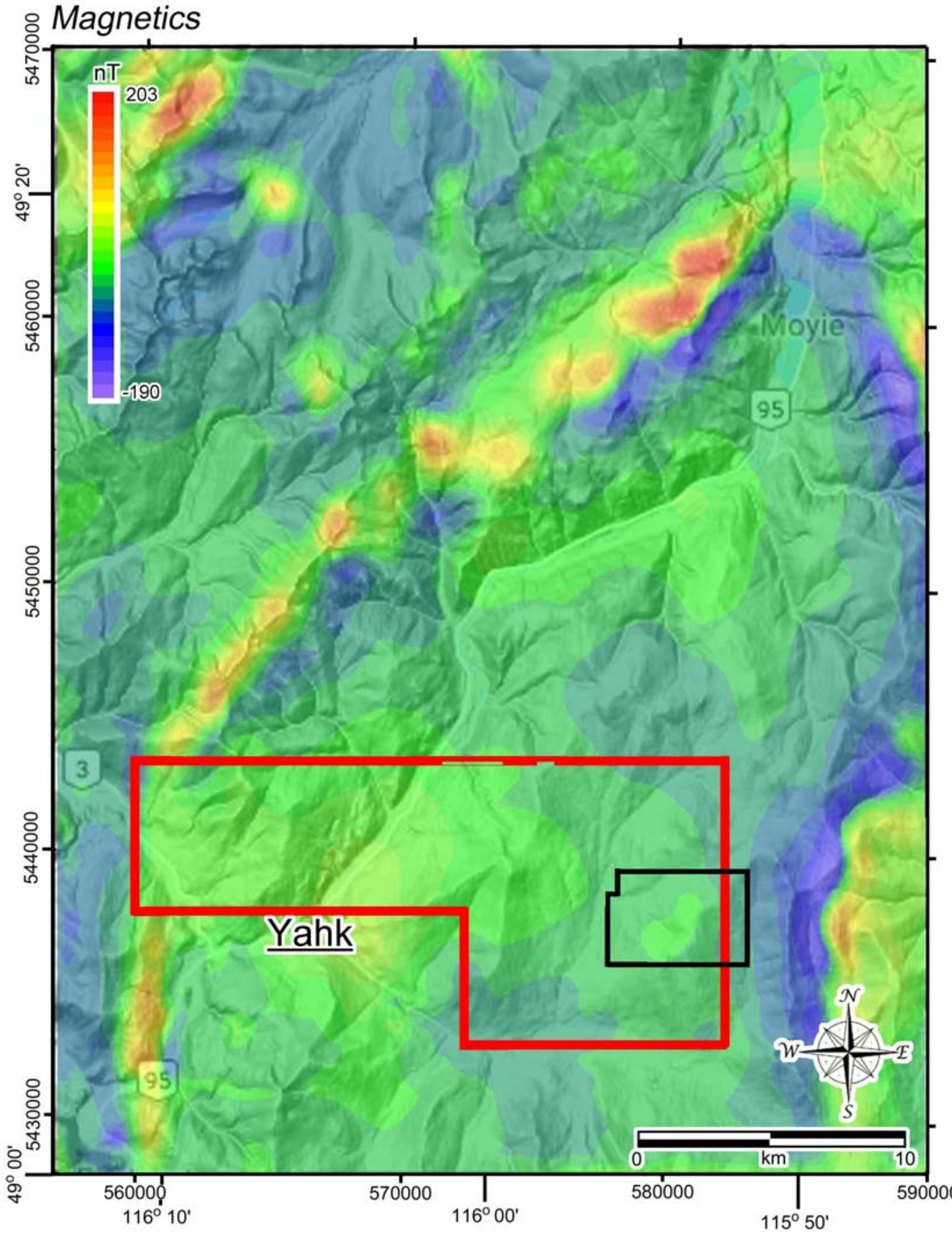

Figure 4a. Regional aeromagnetic map (200m grid spacing) from Natural Resources Canada (data available from http://gdr.agg.nrcan.gc.ca/gdrdap/dap/search-eng.php). The black rectangle outlines the Down Dip property and the red outlines the area of the digitized magnetic data from Woodfill (1996).

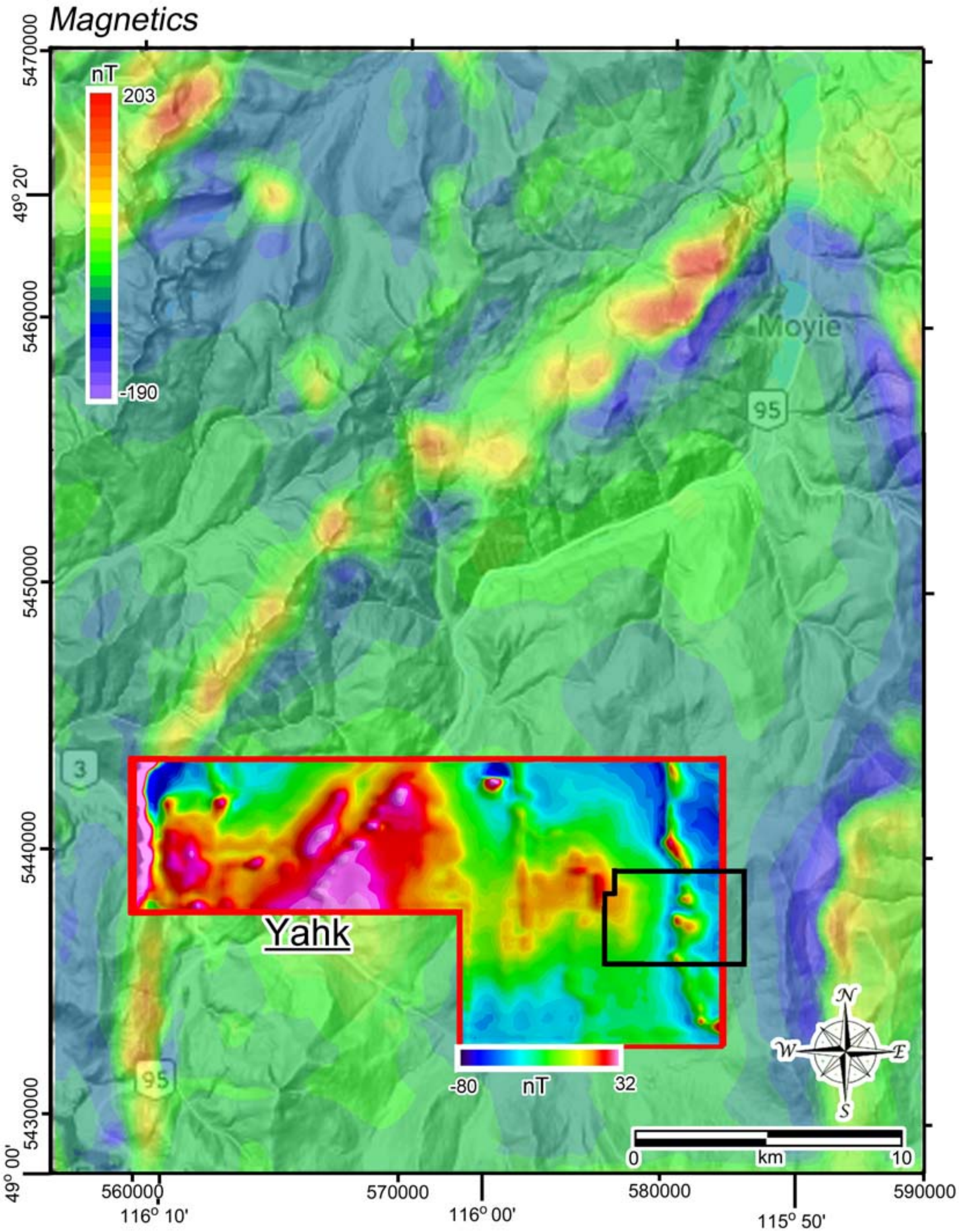

Figure 4b. Regional aeromagnetic map from Figure 4a with the newly digitized data within the red outline. Note that the colour scales are different between the regional and the local data sets.

8.0 Results: Magnetic Data

8.1 Magnetic Data: General

Analyses of the magnetic data were undertaken to delineate two types of characteristics in the magnetic data. First, the data were analysed for structural variations that could be related to the known geology in order to identify and map features that may not be visible in the geological mapping. Second, individual anomalies were analysed for depth and structural information. To accomplish these objectives, following reduction of the magnetic data by removing the IGRF signal and reduction to the North Pole, a series of gradient-based filters (e.g., tilt angle, Generalized Derivative Operator, etc.) were applied and the results were compared with the geological mapping.

8.2 Magnetic Data: Regional Filter Results

Filtering is the process of modifying the data set to either enhance desirable signal, or to attenuate undesirable noise. For these data, several different approaches were taken in order to obtain as much information as possible. These include the tilt angle (Miller and Singh, 1994), the Generalized Derivative Operator (GDO; Cooper and Cowan, 2011) and the Normalized Standard Deviation (Cooper and Cowan, 2008).

Figure 5a shows the digitized data after gridding (50m), removal of the (approximate) IGRF, and reduction to the North Pole. This is the same result as displayed in the inset in Figure 4b and it is clear the digitized map provides significantly higher resolution results than the regional NRCan data set (~200m grid spacing). Application of the tilt angle (Figure 5b) provides a first look at geometry. The tilt angle tends to equalize amplitudes such that low-amplitude anomalies on the reduced-to-pole version appear as anomalies that are nearly equivalent (in amplitude) to those of the prominent anomalies because calculation of the tilt angle depends on the gradients of the anomalies, rather than the amplitudes.

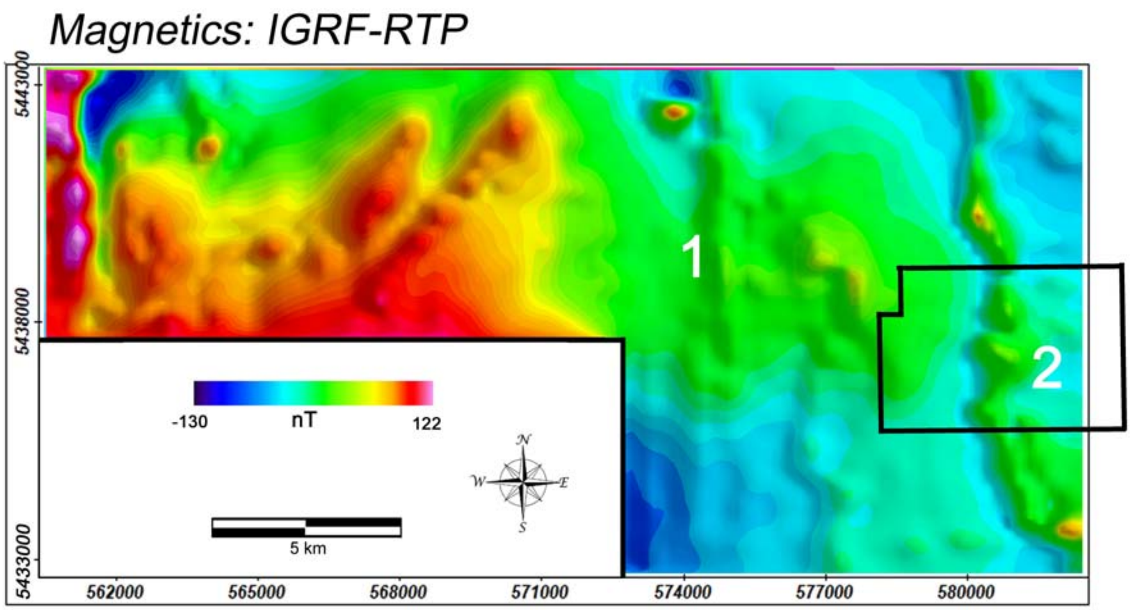

Figure 5a. Map of digitized magnetic data after removal of the (approximated) IGRF and reduction to the pole. The locations of the Down Dip tenures are shown by the outlines. This map forms the basis for the structural analyses as well as the anomaly-based analyses.

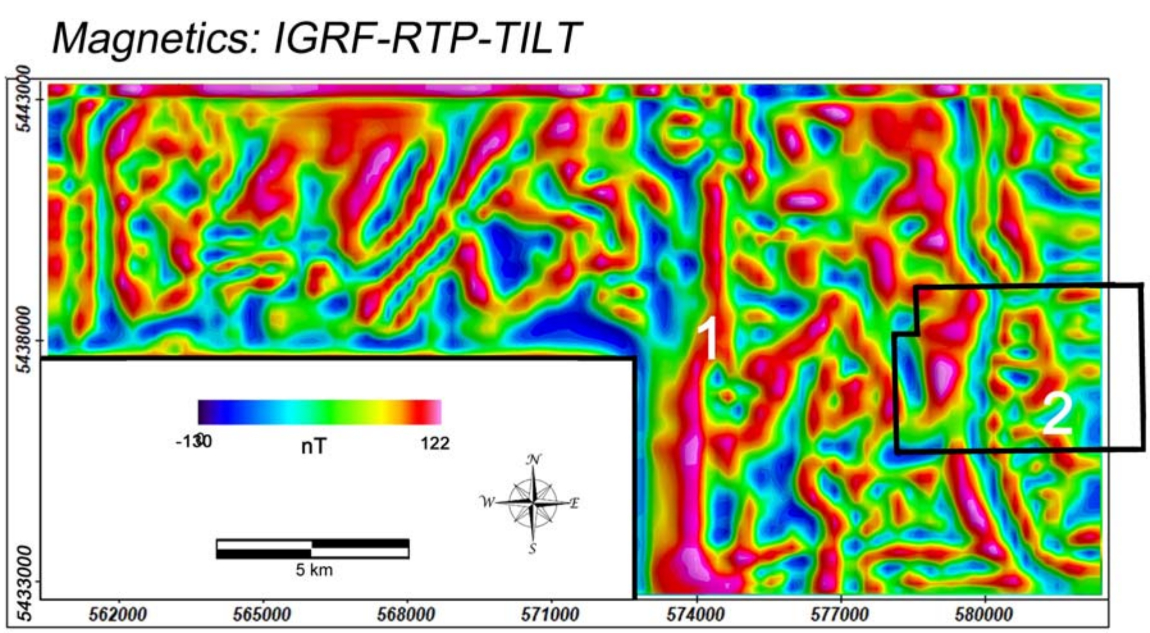

Figure 5b. Same map as in Figure 6a after application of the tilt angle. The N-S linear anomaly (1) is from a dyke; location 2 is an indication of discontinuous anomalies.

The effect of applying gradient-based filters is to minimize the significance of amplitude variations and to enhance the variations in geometry (structure). In Figure 7, for example, anomaly 1 is a long (7-8 km) north-south anomaly that is barely visible on the reduced-to-pole version (Figure 7). This anomaly corresponds to a north-south mafic dyke that may be associated with the ca. 1468 Ma Moyie intrusions. Perhaps significantly, there appears to be another, similar north-south linear anomaly about 1 km west of the southern part of anomaly 1. This may be another dyke that has not been seen in outcrop. Elsewhere in the tilt angle image (Figure 8), location 2 appears to be either a structural disruption in the N-S linear anomaly (fault?), or a discontinuous anomaly caused by variations in magnetization.

8.3 Magnetic Anomaly Data: Property Scale Results

In order to assess the magnetic anomalies and their relationship(s) to the known geology, a map of the geology area in the vicinity of the Down Dip property is enlarged in Figure 6. In this area near the axis of the Moyie anticline, there is a series of sills that trend north south. They are spatially associated with large areas of fragmental deposits (yellow colour on Figure 6).

Application of the filtering techniques at the property-scale produced two significant results. First, anomaly 1 is barely visible on the reduced to pole data (Figure 7) but is clearly visible as a straight, north-south anomaly on the tilt angle version of the data that is centered over a known dyke (Figure 8). In addition, however, a second north-south linear anomaly ('2' on Figure 8) is parallel to anomaly 1 and is also centred over a second dyke. Note, however, that the second dyke ('2') is not visible on the reduced-to-pole data (Figure 7). This observation illustrates one of the most useful characteristics of the tilt angle in that it can be effective at delineating the geometry of magnetic sources. Note also that, even though these dykes are not on the Down Dip property, the spatial correlation of the dykes with the prominent magnetic anomalies provides strong evidence that the tilt angle is effective for delineating some geometrical features.

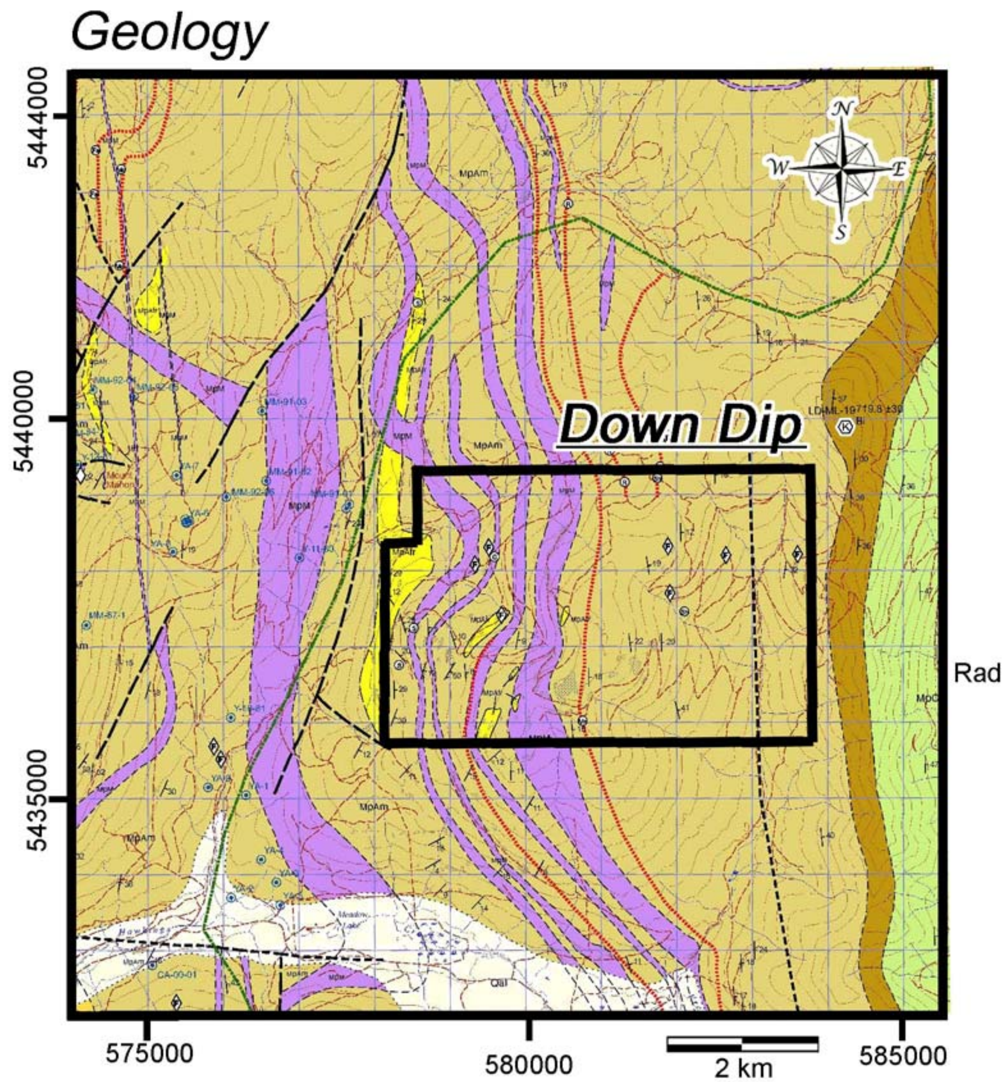

Figure 6. Map of geology in the vicinity of the Down Dip property with the location of the property outlined.

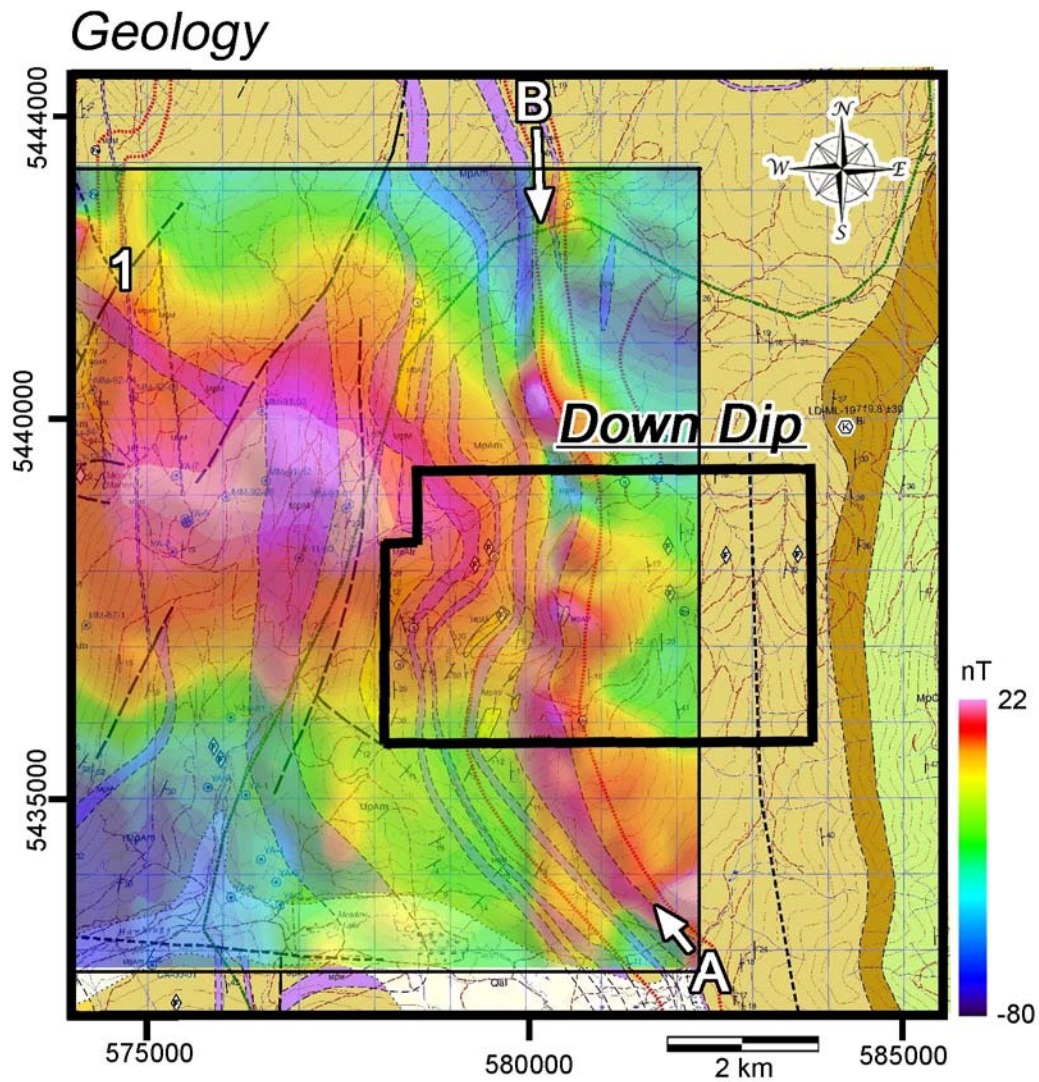

Figure 7. Enlargement of magnetic data near the Down Dip property after removal of the (approximate) IGRF and reduction to the North Pole (RTP).

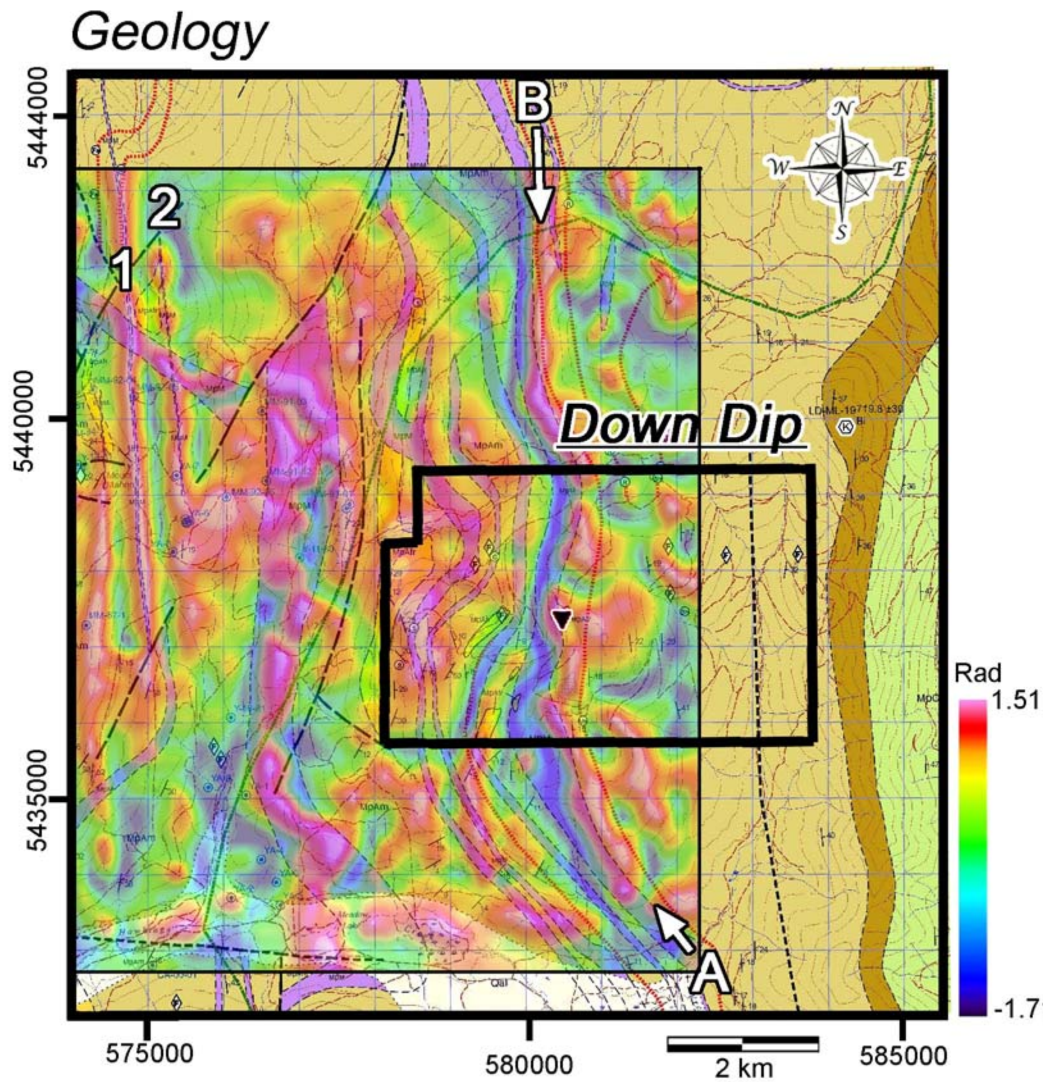

Figure 8. Map of the data in Figure 7 after application of the tilt angle. Note that the sinuous series of anomalies along A-B are located at the eastern margin of a long sill. The inverted triangle within the property is the location where Kennedy (2016) found rock samples with anomalous Pb and Zn.

This last point is important for interpreting the magnetic anomaly pattern along the sinuous trend labelled A-B on Figures 7 and 8 that does indeed cross the property. The A-B anomaly trend appears to comprise a series of distinct anomalies that line up along the trend. It is indeed possible that such separate anomalies could have been caused by variations in either magnetic susceptibility only, or in structure (i.e., separate magnetic sources). However, the most important characteristic of the A-B trend is that it is located at the margin of a sill (Figure 8). This is important for two reasons:

1. The sill itself does not produce a magnetic anomaly and is thus not magnetic, and,
2. The A-B magnetic anomalies are located at the margin of the sill where the sill is in contact with the metasedimentary rocks (primarily quartzites).

The observation of the magnetic anomalies at the sill margin can be explained in a number of possible ways. These include:

1. The sill could vary in magnetic susceptibility due to magmatic separation during cooling and solidification,
2. The sill may be non-magnetic, but may have intruded into a magnetic country rock, and,
3. Fluids could have migrated along the sill-metasedimentary rock contact some time after intrusion. Such migration could enhance oxidation of Fe-bearing minerals and deposition along permeability barriers, such as sills.

Fluid flow may cause significant oxidation of sulphide minerals, including Fe-sulphides. Hence, where fluids may be channelled, for example along permeability contrasts (e.g. sills to quartzites), it is likely that changing conditions (temperature, pressure) could have encouraged the precipitation of iron oxides, which in turn are often magnetic. In short, the simple observation that the A-B magnetic anomaly is located along the margin of the sill, rather than the sill proper, may be evidence of significant fluid flow and associated oxidation some time after the sill was intruded.

An approach that is similar to the tilt gradient in a more generally applicable technique is the Generalized Derivative Operator (GDO; Cooper and Cowan, 2011). The GDO can be considered the tilt angle with an azimuthal component. Thus, to present the results of the GDO, maps of the GDO for a series of azimuths are shown in Figure 9. In a manner similar to directional filtering, the illumination is controlled by two parameters, the azimuth, or angle from north, and the elevation, or inclination. For each of the azimuths shown in Figure 7 (0^o, 45^o, 90^o, 135^o, …, 315^o), the inclination of the illuminating source was taken to be 20^o. Thus, for the map in the top centre of Figure 9, the azimuth was 0^o (north) and the illumination inclination was 30^o from horizontal.

This approach can enhance features by both the gradient amplitudes as well as illumination inclination. For example, when the illumination is from the north with a low inclination angle, features that are oriented east-west will tend to be enhanced. Similarly, a feature that is oriented northwest-southeast will tend to be enhanced when the illumination direction is from the northeast.

When the illuminating azimuth is from the east (90^o) the prominent north-south dyke anomaly (anomaly 1 in Figure 7) is enhanced. Note that it is even more evident when illumination is from the west (270^o).

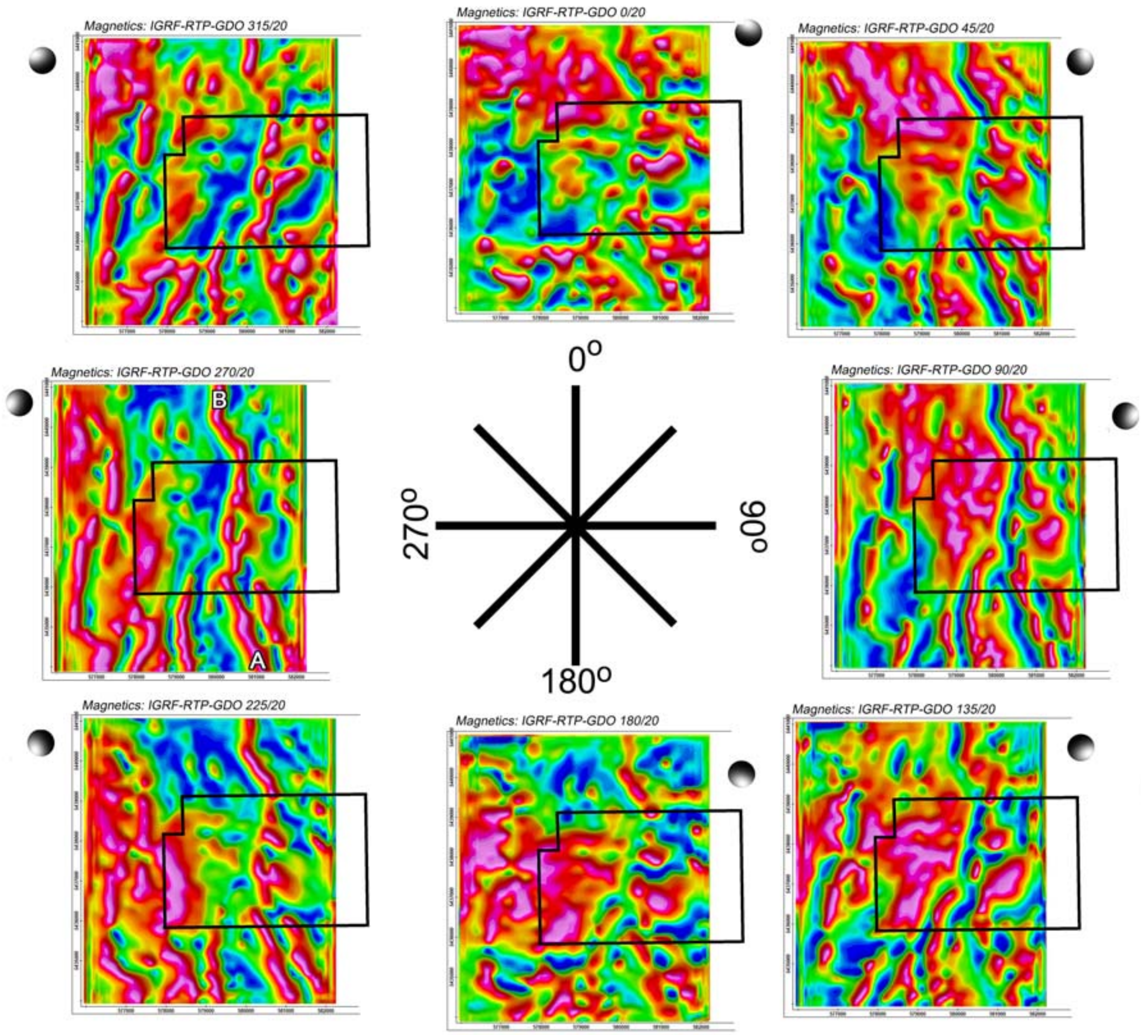

Figure 9. Eight Generalized Derivative Operator (GDO) maps for eight different azimuths. For each map the illumination inclination is 30°.

9.0 Conclusions

Analyses of the digitized magnetic data from the Down Dip property has lead to the following findings:

1. Linear north-south dykes produce prominent magnetic anomalies that are most visible on the tilt angle version of the data;
2. A sinuous north-south anomaly trend that follows a Moyie sill is located along the east margin of the sill, rather than the sill itself;
3. This geometry may be indicative of fluid flow along the margin of the sill that may have caused oxidation of the iron.

10.0 References

Brown, D. A. and Macleod, R. F. 2011. Geology, Yahk River, British Columbia, Geological Survey of Canada, Open File 6304, scale 1:50,000.

Cooper, G. R. J., and Cowan, D. R. 2008. Edge enhancement of potential field data using normalized statistics, Geophyeics, v. 73, p. 111-114.

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Woodfill, R., 1996. Assessment Report on Geophysics. Yak, Tour and Cold Claims, Yahk area, British Columbia Ministry of Energy and Mines, Assessment Report 24652, 97pp.

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

11.0 Statement of Costs

Property: Down Dip

Date		Amount (days)	Rate	Total	Notes	Totals
3. Airborne Magnetic Data Reprocessing - Digitize TMI Map from AR 26452					(1)	
13-Jan-2020	Fred	1	800	124.80	(2)	
13-Jan-2020	Fred	1	800	124.80	(2)	
13-Jan-2020	Fred	1	800	124.80	(2)	
13-Jan-2020	Fred	1	800	124.80	(2)	
				499.20		$499.20
4. Airborne Magnetic Data Reprocessing - Gradient Analyses/Structure (1)						
22-Jan-20	Fred	1	800	800.00	(1)	
22-Jan-20	Fred	1	800	800.00	(1)	
22-Jan-20	Fred	1	800	800.00	(1)	
				2400.00		$2,400.00
5. Report						$3,000.00
		TOTAL				$5,899.20

Note (1): Work done on tenures 1068446 and 1066460
Note (2) Amount prorated (15.6%) to Down Dip area

12.0 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 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 22nd day of April, 2020
Registration License No. 34585
Association of Professional Engineers and Geoscientists of British Columbia

Appendix 1: Magnetic Anomaly Map RTP
Scale 1:20000

Magnetics: IGRF-RTP