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New High Resolution Aeromagnetic Data: A New Perspective on Geology of the Bonaparte Lake Map Area, British Columbia

Thomas, M.D. and Pilkington, M.
Geological Survey of Canada

GEOLOGICAL SURVEY OF CANADA   COMMISSION GÉOLOGIQUE DU CANADA

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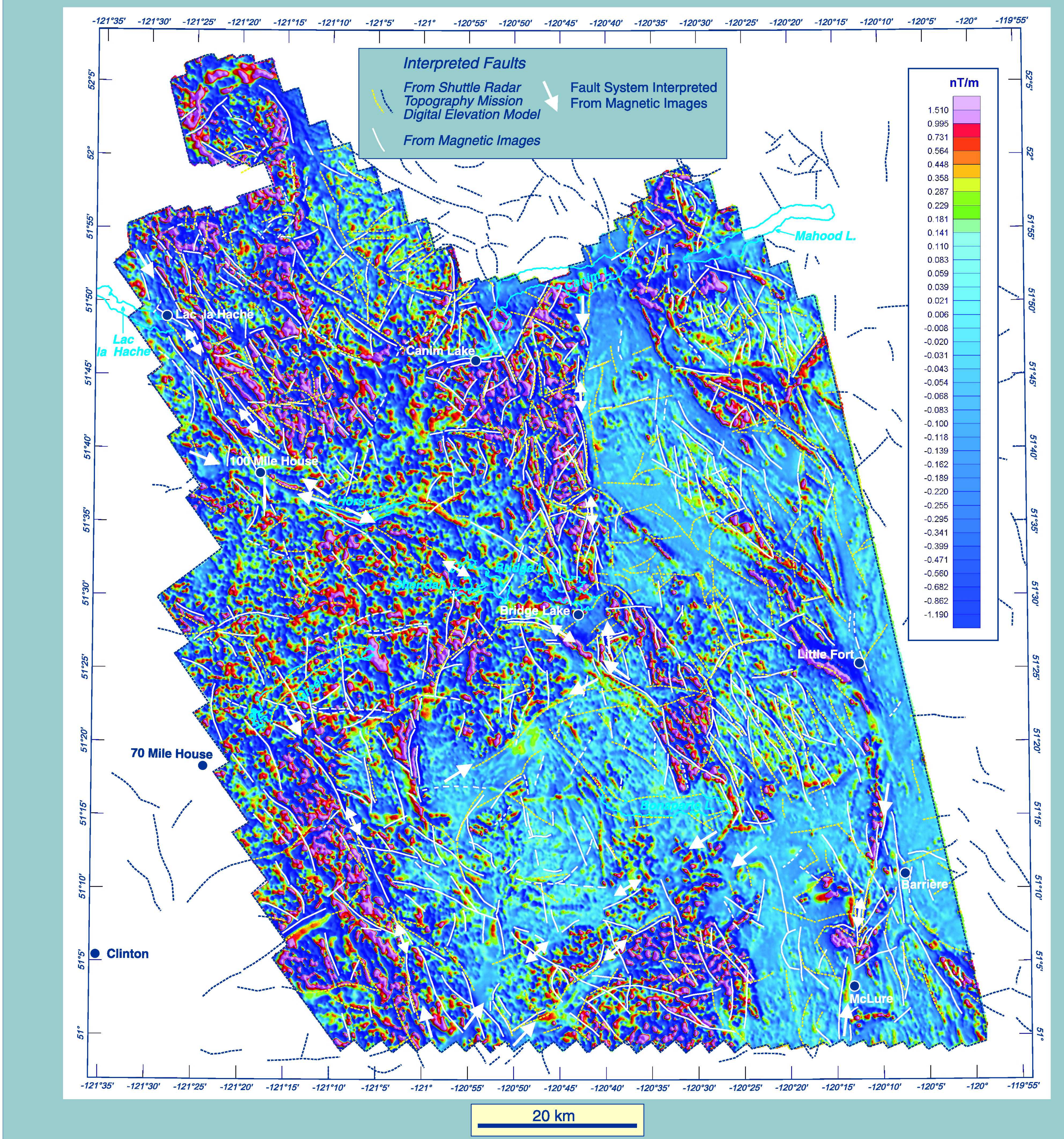
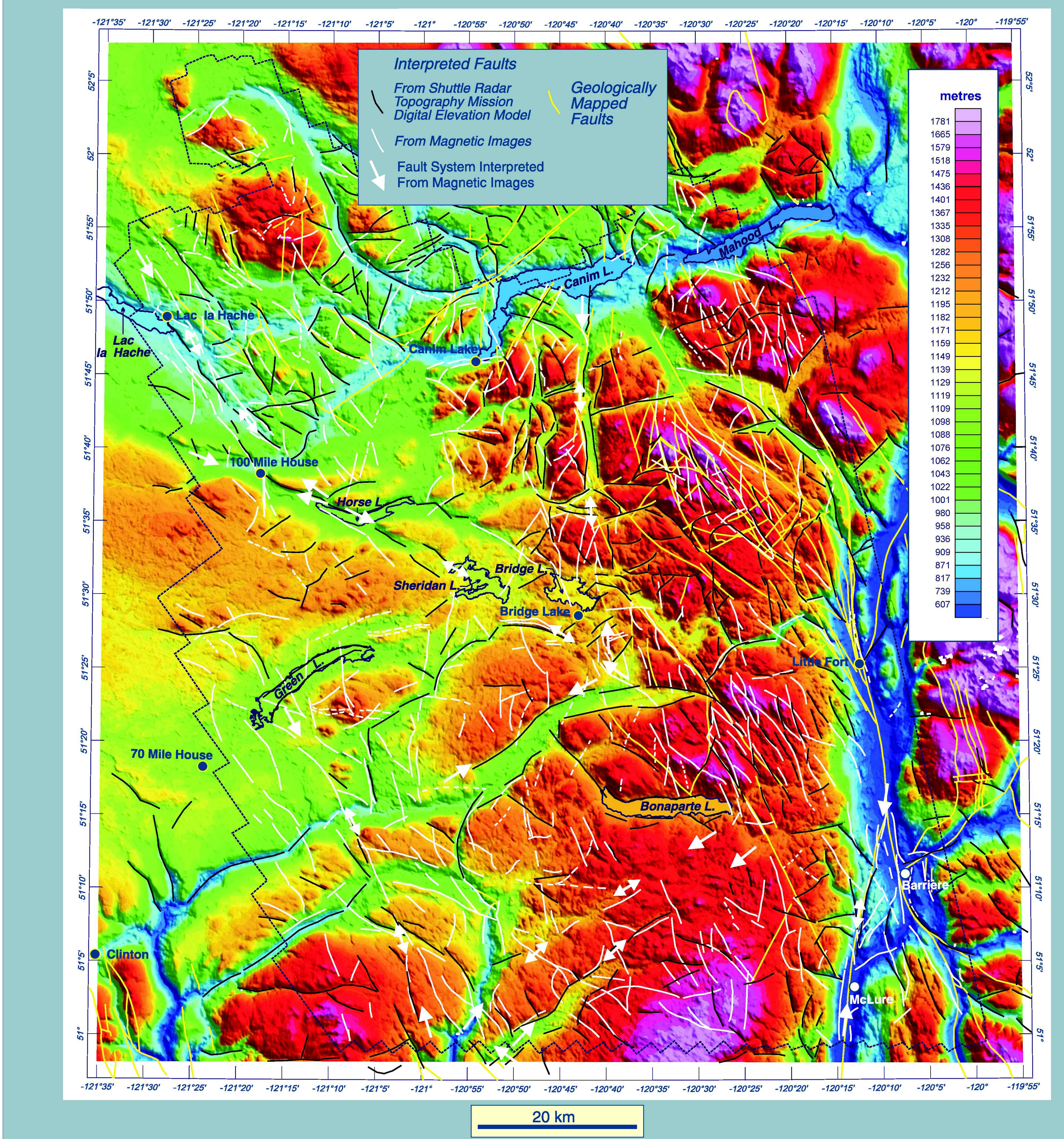
Sheet 3

(1) Map of First Vertical Derivative of the Residual Total Magnetic Field with Interpreted Faults



(3) Shuttle Radar Topography Mission Digital Elevation Model + Interpreted/Mapped Faults



Interpretation of Faults

Conventional geological mapping has identified many faults in the area of the Bonaparte Lake high resolution aeromagnetic survey. These are portrayed on the digital geological map of British Columbia on the MapPlace website, http://www.em.gov.bc.ca/Mining/Geosurv/MapPlace, and on 1:50 000 scale maps produced by Schiarizza et al. (2002a,b) and Schiarriza and Boulton (2006). Typically, these are mapped in areas outside the extensive Tertiary volcanic cover, and outside the large Mesozoic batholiths. Thus, they are concentrated in the eastern part of the survey area. A lesser concentration is observed in the northwest part of the area, where they affect rocks of the Nicola Group. Faults in the region on all aforementioned maps are categorized as 'faults' or 'thrusts'. It is presumed that 'faults' includes normal, reversed and strike-slip faults, and that these are quite steep. Thrusts are generally restricted to the eastern margin of the area. Faults and thrusts are not differentiated in the figures presented in this open file report.

Most of these geologically mapped/interpreted faults trend NNW to NW, in harmony with the overall trend of the Quesnel and adjacent terranes, and their constituent rock units. A lesser number trend N to NNE. A noticeable subset of trends has orientations ranging from about NE to ENE, practically perpendicular to the majority of other faults. Faults with this trend tend to be much shorter.

Faults are an important element of the geological framework, providing information on relative motions, timing of events and tectonic history in general. They also provide pathways for fluid flow, and may be instrumental in controlling loci of mineralization. Knowledge of fault locations is, therefore, a critical factor in developing an exploration strategy.

Faults Interpreted from Magnetic Data

The wide coverage of aeromagnetic data provides a means for mapping faults in the areas of Tertiary volcanic cover and Mesozoic batholiths. To assist in this exercise several types of magnetic images, both shaded and non-shaded, were used. These were: the residual total magnetic field (RTMF), shown in the lower right panel (4); the first vertical derivative of the RTMF, shown in the upper left panel (1); the second vertical derivative of the RTMF (shown in panel 3 on Sheet 2); and the tilt angle of the residual total magnetic field, shown in the upper right panel (2). The RTMF and its first vertical derivative and their respective utilities have been discussed on Sheet 1. Brief descriptions of the second vertical derivative and tilt angle follow.

The second vertical derivative of the magnetic field (= vertical gradient of the first vertical derivative) provides greater resolving power than the first derivative, but its successful computation requires high quality data. Like the first vertical derivative it is useful for mapping contacts, and its patterns may be used to map geological units, and provide a perspective on the structural fabric of a region. The tilt angle of the RTMF is a derivative product having similar qualities to the second vertical derivative. Miller and Singh (1994) developed the concept of potential field tilt, the ratio of the first vertical derivative of the magnetic field to the absolute horizontal gradient of the field, which defines the tilt angle: tilt = $\tan^{-1}$(vertical gradient/magnitude of the horizontal gradient). The tilt angle is positive over a magnetic source, is zero near or over a contact, and is negative outside the source. Because the tilt angle is based on a ratio, it has the advantage over first or second vertical derivative maps, in that it responds well to both shallow and deep sources.

The image of horizontal gradient contacts, discussed briefly and shown on Sheet 2, was also used. This gradient is simply the rate of change of the magnetic field over a horizontal distance. A horizontal gradient profile crossing a contact separating units having contrasting magnetizations peaks at the contact. Hence, plots of the peak positions define locations of such contacts, as in the lower right panel (4), Sheet 2, and provide yet another pattern related to the magnetic field useful for geological mapping.

The typical expression of a fault on a RTMF map is a narrow, linear negative anomaly. Faults and their associated fracturing represent loci of increased permeability, and because magnetite is unstable in the low temperature, highly oxidizing environment of chemical weathering and sedimentation (Grant, 1985), circulating groundwater oxidizes magnetite to hematite, an alteration process termed martitization by Henkel and Guzman (1977). The chemical changes are indicated in the following reaction:

$$\underset{\text{magnetite}}{2Fe_3O_4} + ½O_2 \leftrightarrow \underset{\text{hematite}}{3Fe_2O_3}$$

The magnetic susceptibility of magnetite is two orders of magnitude larger than that of hematite. Accordingly the destruction of magnetite is associated with a coincidental decrease in magnetization and a zone of relatively negative magnetic field on a RTMF map. On magnetic maps, faults are recognized by their linear character, which may take the form of a magnetic low cross-cutting trends of other anomalies. The low may dominate the image in terms of its continuity and relative amplitude, or it may be present as a more discontinuous and subtle feature that is collectively discernible by its disruption of a series of magnetic anomalies. Sometimes the low is associated with an obvious offset of magnetic patterns to either side, which allows the strike-slip component of relative motion to be evaluated. It has been observed that magnetic lows associated with faults may have widths of the order of 10s or 100s of metres.

The concept of linear magnetic lows as a signature of faults has been the foundation for the interpretation of faults shown here. The entire series of magnetic images was used in concert to determine which magnetic features were probably fault-related. Shading of the images was also employed, since directional shading can enhance features having a particular trend. Caution was exercised in interpreting linear magnetic lows parallel to magnetic highs as fault signatures, because such lows could equally well signify relatively non-magnetic sedimentary formations, for example.

Faults Interpreted from Shuttle Radar Topographic Mission Digital Elevation Model

A model of the terrain, based on data acquired by the Shuttle Radar Topography Mission (SRTM), has been used to map faults. SRTM utilized dual Spaceborne Imaging Radar (SIR-C) and dual X-band Synthetic Aperture Radar (X-SAR) configured as a baseline interferometer, and acquired two images at the same time, which were combined to produce a 3-D image of the topography. The SRTM data have a horizontal resolution of 90 m, and horizontal and vertical accuracies of 20 m (circular error at 90% confidence) and 16 m (linear error at 90% confidence), respectively, as specified for the mission, although the vertical accuracy is significantly better than 16 m, and closer to +/- 10 m according to the United States Geological Survey website from which the data are available (http://seamless.usgs.gov/website/seamless/faq/srtm_faq.asp).

The topographic expression of faults commonly takes the form of river or rift valleys, and steep-sided scarps, and typically these features are linear.

Presentation and Discussion of Faults

The interpreted faults from both magnetic and SRTM data are displayed on the first vertical derivative and tilt angle images (panels 1 and 2, respectively), and along with geologically mapped faults on the SRTM and RTMF images (panels 3 and 4, respectively). The relationships of faults to the various magnetic features and topography may be readily appreciated, and help illustrate the rationale for interpretation. Based on these observed relationships, a reader will probably see many other examples of features where an associated fault could be expected. This report presents a preliminary interpretation matching the scale of the survey coverage, and is intended to illustrate the utility of the magnetic data. Obviously, finer scales of investigation will result in the identification of many more faults.

Faults have been recognized throughout the survey area, and have essentially the same density of occurrence. Characteristically, they extend on the order of kilometres, though series of collinear fault segments suggest some fault systems extend for 10s of kilometres. Examples of the latter are two NNW-trending series of faults extending from the area of Lac la Hache to the vicinity of 100 Mile House, another NNW-trending series extending from Green Lake to the southern boundary of the survey area near longitude 120° 55', and a N-S series running from just east of Bridge Lake northward towards Canim Lake.

Trends of interpreted faults mimic those mapped geologically. Again there is a strong presence of faults trending NNW to NW, and a significant presence of faults trending N to NNE. A fair number of faults trend E to ENE, and other trends are also observed. The patterns of the faults themselves considered with the pattern of contacts derived from the first vertical derivative image suggest the presence of other fault systems. Notable are the systems extending SE from the vicinity of 100 Mile House to just south of Bridge Lake, and two systems striking SW from just south of Bonaparte Lake. A smaller system strikes SW from just south of Bridge Lake. These are indicated by the white arrows on all of the images on this sheet. Most segments of many of these systems have significant expression in the SRTM topographic image. These systems, with one exception (the SW-striking smaller system), are not defined by a single fault, though several long faults occur along some of them. It is speculated that they represent fault zones comprising a closely spaced network of faults, perhaps en echelon or interleaved. As such they would provide permeable pathways for fluid flow and attendant mineralization. Interestingly, they cross the prevailing geological strike of the region, and the strike of most faults, at high angles (~45° or ~90°). The intersections of these systems with more typically oriented faults may represent loci of enhanced fluid flow, and subject to other considerations may be favourable targets for exploration. Some white arrows highlight some of the collinear series of faults mentioned previously.

Application of Aeromagnetic Data for Mineral Exploration

According to the British Columbia Geological Survey's MapPlace there are 190 mineral occurrences recorded in the survey's MINFILE data base for the Bonaparte Lake map area, and the area is thought to contain some of the highest mineral potential in the province. At the moment there are no active mines in the map area. MINFILE occurrences within and adjacent to the area of the magnetic survey are plotted in the RTMF panel (4) on the lower right, and they are categorized into developed prospect, past producer, and showing/prospect. Many of the past producers are playa and alkaline lake evaporites (in the west) and placer gold deposits (in the east). The following discussion of mineral deposits in the region is based on information posted on the MapPlace web site.

Several types of mineralization are present in the region. Along the eastern margin, basaltic rocks of the Fennell Assemblage host *volcanic massive sulphide (VMS)* mineralization (e.g. Chu Chua deposit), and *polymetallic and gold-quartz vein mineralization*. Gold-quartz mineralization is also present along the southern margin of the area in quartz dioritic intrusions, metasedimentary rocks of the Harper Ranch Group and metavolcanic rocks of the Nicola Group. A variety of *copper and copper-gold skarn* and *porphyry-type mineralization* is commonly observed in association with andesitic and basaltic rocks of the Nicola Group and related subvolcanic intrusions. Many of these occur in the northwest part of the area in and around the Takomkane batholith. Others are found within and in the marginal areas of the Thuya batholith.

The successful application of the aeromagnetic method in the search for ore deposits is very much dependant on the mineralogy of the ore deposit itself, of associated alteration zones and of the host rocks. The principal minerals controlling the magnetic signature of these various elements are magnetite and pyrrhotite. Fortunately, one or other or both of these minerals have been recorded in association with *VMS* and *skarn* mineralization in the Bonaparte Lake area. For example, lenses of magnetite are present in the Chu Chua *VMS* deposit, and lenses, pods and veins of magnetite or pyrrhotite accompany the Lakeview iron-copper-gold *skarn*. Magnetic highs should, therefore, provide a fingerprint for these types of deposits. The challenge is to be able to discriminate such potentially economic highs from those associated with barren ground.

The aeromagnetic method also has significant potential for discovering *porphyry* deposits. Gold-rich porphyry copper deposits worldwide, including examples from the Cordillera, are associated with high magnetite contents, commonly attaining 5 to 10 % by volume Sillitoe (1979), which should produce prominent magnetic highs. In recent years, several combined aeromagnetic/radiometric surveys have been carried out in the Quesnel Terrane, targeting such properties/areas as Mount Milligan, Mount Polley, Horsefly and Horsefly-Canim Lake. These have demonstrated that the combination of magnetic and radiometric surveys offers a powerful tool for detecting and delineating porphyry copper deposits. Porphyry deposits are accompanied by zones of potassium silicate alteration, which generate large potassium anomalies. Distinguishing between potassium anomalies related to zones of hydrothermal alteration and anomalies associated with high-K rocks may be achieved by examination of eTh/K ratios (Shives et al., 1997). Because thorium is relatively immobile it is not augmented in alteration zones, which are thus identified by low eTh/K ratios. Shives (personal communication, 2005) has noted that discreet eTh/K lows are invariably accompanied by a roughly coincident or flanking magnetic high. The two methods used in unison provide an effective exploration strategy.

The importance of aeromagnetic data for finding vein deposits lies in the ability of the magnetic method to outline faults, potential hosts of mineralization. The method also provides a structural framework. Such frameworks, besides defining strikes and possibly dips of fault/fracture/vein systems, may help establish kinematic models, which could be used to predict favourable sites for mineralization.

Another utility of the magnetic data is in tracing mineralization along a particular horizon. A cluster of mainly showings occur within volcanic and volcaniclastic units of the Nicola Group, and along the eastern margin of the Thuya batholith near Little Fort. Some are arranged in a linear fashion. Detailed inspection of the second vertical derivative image in this area reveals a fine NNW to NW trending linear grain defined by some linear anomalies, and also by globular anomalies distributed in a linear fashion. Some of the showings fall on or very close to linear anomalies. If these high resolution magnetic data had been available prior to discovery of the showings, they might have facilitated their detection.

Conclusions

New high resolution magnetic images from the Bonaparte Lake aeromagnetic survey provide unprecedented detail of the bedrock geology underlying an extensive Quaternary glacial cover, and insights into geology beneath Tertiary volcanic cover. They support existing geological mapping in many places, but also raise questions regarding the validity of mapping in other locations. The new images have been used to delineate contacts and faults, and to define internal structural fabrics and variations in composition within several geological units. A series of magnetic domains has been defined and their geological significance has been discussed. Some interpretations and comments are speculative, and the nature of some domains is debatable. This reflects the state of current knowledge. The requirement for ground follow up to investigate uncertainties cannot be over emphasized. One of the purposes of this report is to present ideas that can be investigated and tested.

Whereas discussion has focussed generally on the regional picture, it is hoped that the presented images and information will benefit exploration at both the district and property scale. Re-evaluation of current opinion regarding the nature and limits of prospective geological units may help focus such exploration.

It is strongly recommended that the new aeromagnetic data be used in concert with the radiometric data acquired during the same survey. Both data sets can be downloaded for no cost from the Natural Resources Canada web site: http://gdr.nrcan.gc.ca/

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Web Sites

British Columbia Geological Survey Digital Map of British Columbia:
(http://em.gov.bc.ca/Mining/Geosurv/MapPlace)

Shuttle Radar Topographic Mission Digital Elevation Data:
(http://seamless.usgs.gov/website/seamless/faq/srtm_faq.asp)

High Resolution Aeromagnetic and Radiometric Data:
(http://gdr.nrcan.gc.ca/

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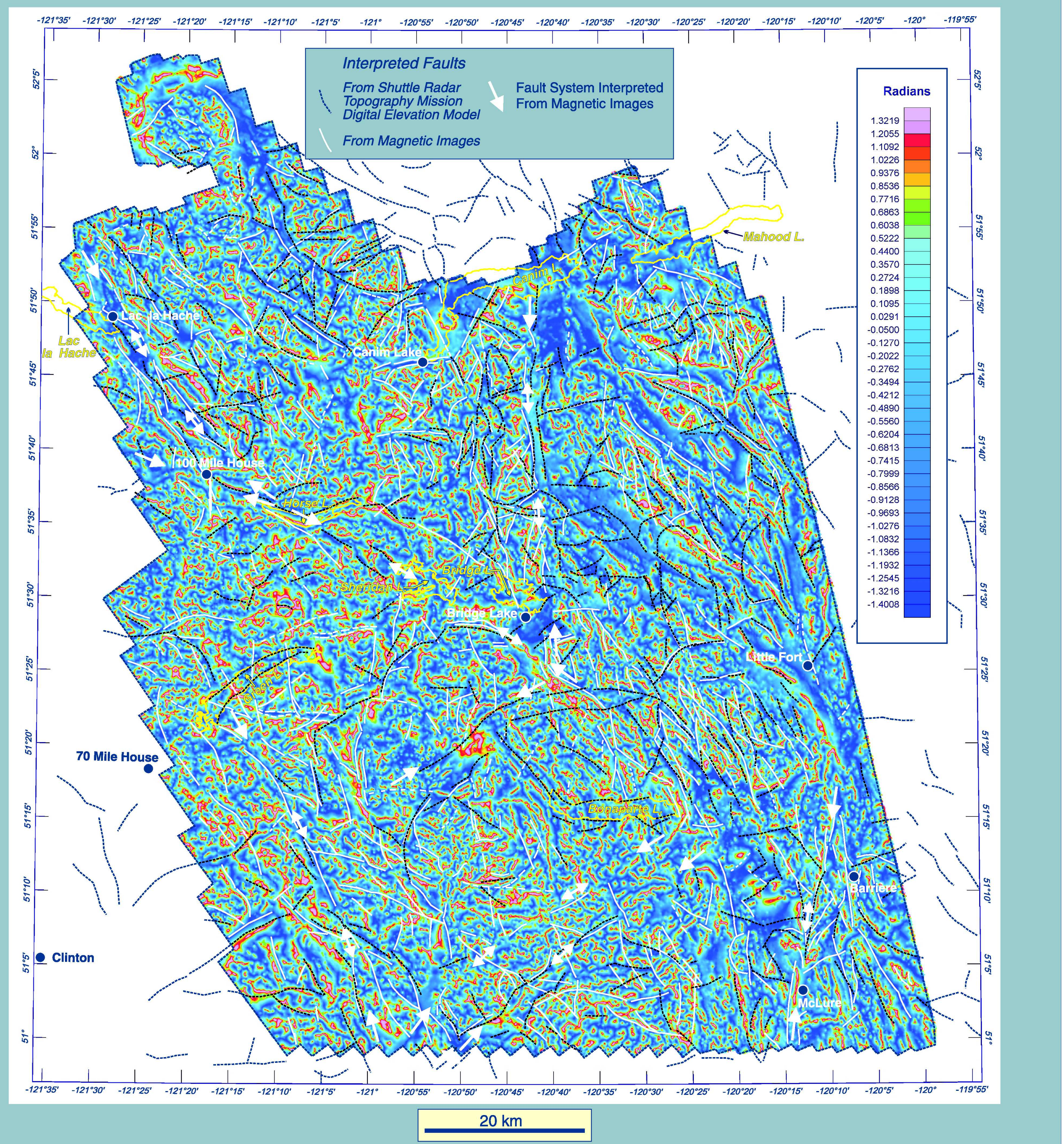
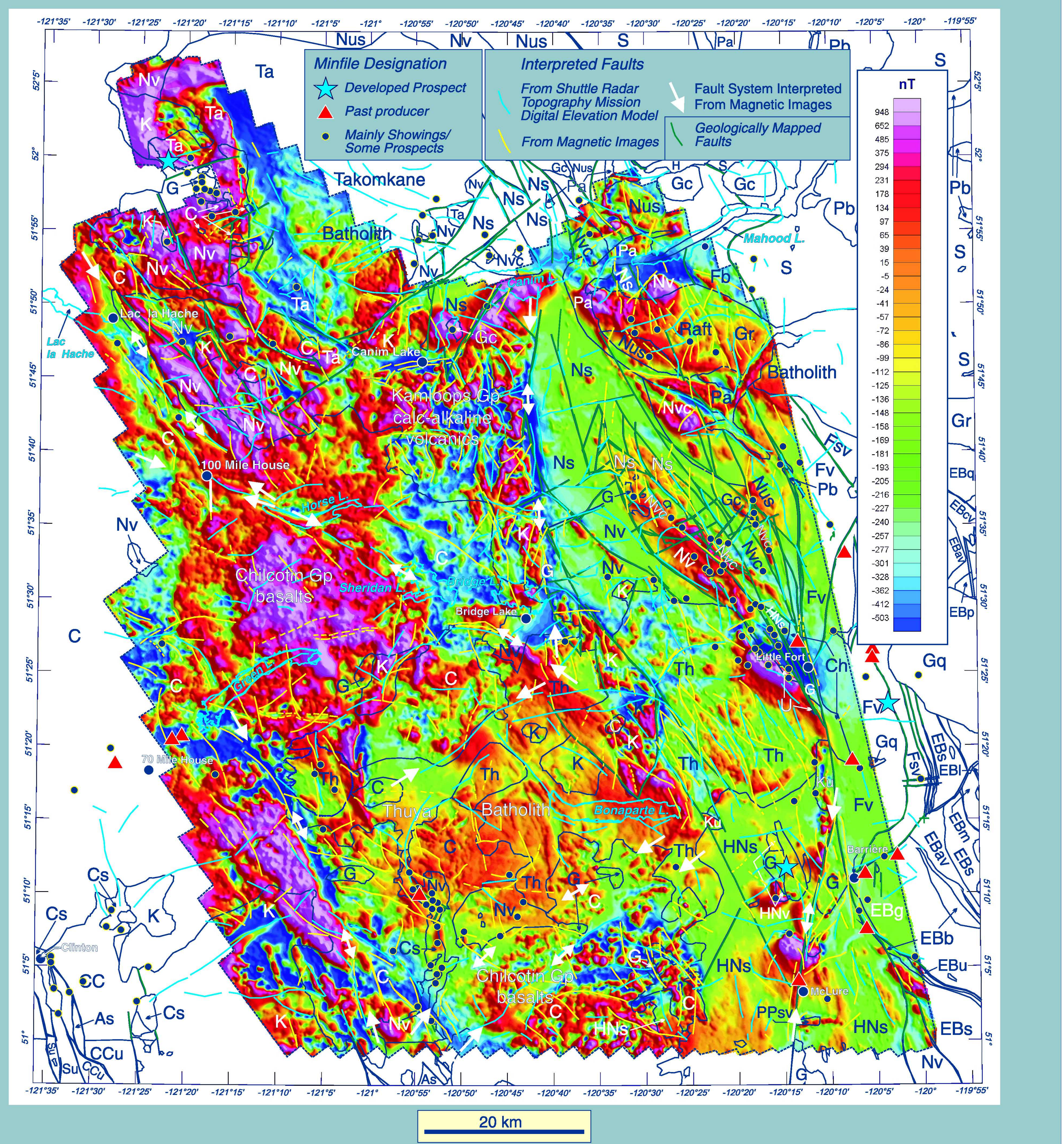
(2) Map of Tilt Angle of the Residual Total Magnetic Field with Interpreted Faults



(4) Shaded Residual Total Magnetic Field Map with Locations of Mineral Occurrences



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