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Geological Significance of New Aeromagnetic Data from the Quesnel Survey Area (Portions of NTS 93G E Half and 93H W Half), Central British Columbia: A Mountain Pine Beetle Program Contribution

M.D. Thomas

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Introduction

A combined airborne magnetic and radiometric survey flown as a contribution to the Mountain Pine Beetle Program in an area lying largely east of Highway 97 between the towns of Prince George and Quesnel (Fig. 1) was completed in July 2008. The survey is identified as the "Quesnel survey". Most of the area falls within the east half of the Prince George map area (93G), but its eastern marginal portion extends into the McBride map area (93H). The survey was flown at 400 m line spacing and 125 m mean terrain clearance.

All magnetic and radiometric data discussed in this report, and other data collected during the geophysical survey, may be downloaded at no cost from Natural Resources Canada's Geoscience Data Repository accessible through the following website: http://gdr.nrcan.gc.ca/index_e.php

Geology of the Area

The geology of the area (Fig. 1) is based primarily on the geological map of British Columbia available on the MapPlace web site maintained by the British Columbia Geological Survey (http://www.em.gov.bc.ca/Mining/Geolsurv/MapPlace/default.htm). Modifications based on mapping by Struik et al. (1990) in NTS map 93 G (East Half), and by Moynihan and Logan (2009) along the western margin of the Naver pluton are incorporated in Figure 1. Related descriptions of geological units are presented in the geological legend (Fig. 2).

The area is underlain mainly by rocks of the Quesnel Terrane, but significant areas are underlain by the Slide Mountain and Kootenay terranes. The Kootenay Terrane in the survey area has been referred to as the Barkerville Terrane (Struik, et al., 1990), a term used henceforth in this report. The most prominent geological feature of the area is the roughly pear-shaped Cretaceous Naver pluton, which is almost completely surrounded by Proterozoic (?) to Palaeozoic (?) rocks belonging to the Snowshoe Group. The southern tip of the pluton invades Middle - Upper Triassic rocks of the Nicola Group.

Barkerville Terrane**:** The Barkerville Terrane is formed of Proterozoic (?) to Palaeozoic (?) metasedimentary rocks of the Snowshoe Group bounded on its western and northern margins and along most of its eastern margin by a single continuous thrust, the Eureka thrust. The terrane and the Naver pluton, together, are believed to form the core of a broad northwestward plunging arch, around which the thrust is folded (Struik et al., 1990). On the eastern side of this core the Eureka thrust terminates southward against a northeast-trending fault passing by Teapot Lake (henceforth referred to as the Teapot Lake fault). South of the fault, offset roughly 600 m to the east, the Eureka thrust is seemingly replaced by the Willow River fault, described as a strike-slip fault (Struik et al., 1990), which separates the Barkerville and Slide Mountain terranes.

On the western, northern, northeastern and southeastern margins of the Naver pluton, the Snowshoe Group (subunit **c**, Fig. 1) is represented by schistose quartzite, schist, phyllite, marble, amphibolite, siltite and minor quartzite, whereas along the eastern margin of the Barkerville Terrane the group (subunit **d**) includes orthoquartzite, schistose quartzite, schist and phyllite (Struik et al., 1990).

Slide Mountain Terrane: The Slide Mountain Terrane forms the eastern margin of the survey area, where it includes Lower Mississippian-Permian basaltic volcanic rocks of the Slide Mountain Complex east of the Narrow Lake fault, and the Mississippian-Permian Antler Formation west of the Stoney Lake fault (MapPlace). All of these rocks, where mapped west of longitude 122°W, are assigned to the Mississippian-Permian Antler Formation of the Slide Mountain Group by Struik et al. (1990), and comprise basalt pillows and breccia, diorite and minor serpentinite.

The Mississippian-Permian Crooked Amphibolite is also assigned to the Slide Mountain Terrane (Struik et al., 1990). It occurs in discontinuous narrow units along the Eureka thrust west of the Naver pluton, and as a small triangular unit bounded by the northern margin of the pluton and a thrust (Fig. 1). Moynihan and Logan (2009) describe its occurrence as discontinuous slivers along the boundary

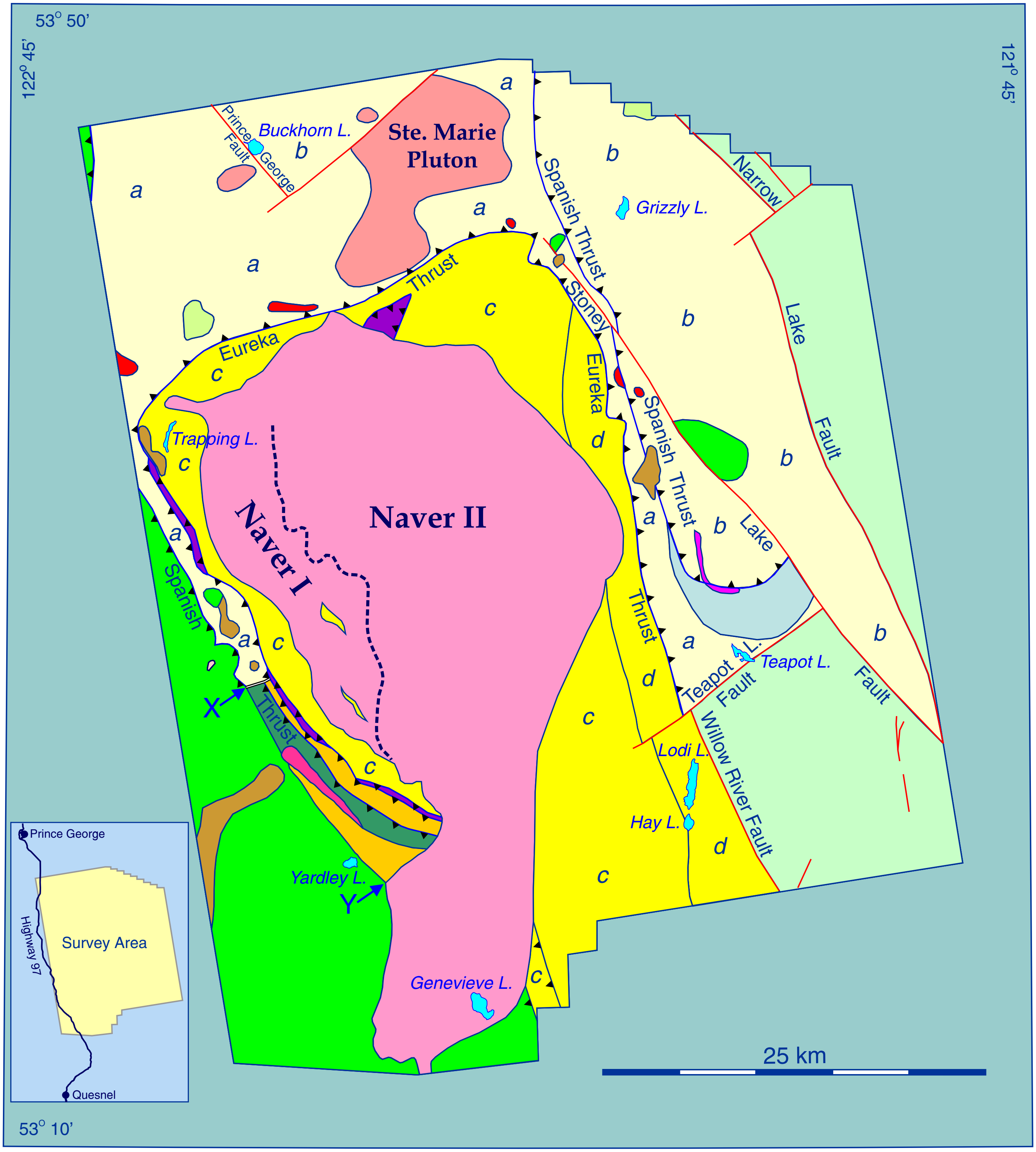

Figure 1: Geological map of the Quesnel survey area based principally on the map of British Columbia available on the British Columbia Geological Survey's MapPlace web site (http://www.em.gov.bc.ca/Mining/Geolsurv/MapPlace/default.htm), itself based largely on mapping by Struik et al. (1990). Modifications along the southwestern margin of the Naver pluton, between X and Y, and the boundary between Naver I and Naver II portions of the pluton, all of which are based on Moynihan and Logan (2009), and a mafic-ultramafic body north of Teapot Lake (Struik, 1985) are incorporated. The X and Y labels and the boundary between Naver I and Naver II are included in all figures with the exceptions of Figures 2 and 5. The legend for this map is provided in Figure 2.

Figure 2: Geological legend for Figures 1, 3 and 10. Letters in parentheses refer to the source of information, i.e., reference: M, British Columbia Geological Survey's MapPlace web site (http://www.em.gov.bc.ca/Mining/Geolsurv/MapPlace/default.htm); ML, Moynihan and Logan (2009); S, Struik et al. (1990); S85, Struik (1985).

between the Nicola and Snowshoe groups, i.e. effectively between the Quesnel and Barkerville terranes. The unit includes serpentinite, sheared ultramafic rocks, amphibolite and talc (Struik et al., 1990).

Quesnel Terrane: MapPlace shows the Quesnel Terrane to consist mainly of volcanic, volcaniclastic and sedimentary rocks belonging to either the Takla Group (north of latitude 53°N) or the Nicola Group (south of 53°N). In essence the groups represent the same stratigraphic interval; the arbitrary change in name at 53°N is presumably an artifact of mapping in different areas by different geologists. In this report, Nicola Group is adopted for this stratigraphic interval following the usage of Struik et al. (1990), who assign a Middle to Upper Triassic age. Volcanic and volcaniclastic rocks of this group are present west of the Naver pluton, in contact along the Spanish thrust with a narrow development of Nicola Group sedimentary rocks, which is separated from the pluton by a narrow belt of sedimentary rocks of the Snowshoe Group. The contact between the two sedimentary units is the Eureka thrust (Struik et al., 1990). Enigmatically, mapping by Moynihan and Logan (2009) failed to reveal evidence for thrust-sense shearing along the contact. They concluded that a large contrast in metamorphic grade between the units and the presence of normal-sense kinematic indicators near the contact were indicative of a normal fault or shear zone.

Struik et al. (1990) describe volcanic/volcaniclastic rocks of the Nicola Group west of the Naver pluton as augite porphyry basalt tuff, breccia, minor flows and tuffaceous argillite and siltite, together with local andesitic basalt. Sedimentary rocks of the group west, north and immediately east of the pluton (subunit **a**) include slate, argillite, phyllite, fine-grained and minor coarse-grained greywacke, and lesser amounts of tuff and tuffaceous siltite and argillite. On the west side of the pluton subunit **a** is terminated to the southeast by the Naver pluton. In this area (between X and Y, Fig. 1) Moynihan and Logan (2009) mapped the subunit as a black phyllite unit, mapping also a separate belt of these rocks within the volcanic/volcaniclastic unit of the Nicola Group (Fig. 1). For compatibility with the revised geology of Moynihan and Logan (2009) positions of thrusts mapped by Struik et al. (1990) have been repositioned to follow the revised positions of respective geological units separated by the thrusts.

The narrow development of Nicola Group sedimentary rocks west of the Naver pluton broadens considerably north and east of the pluton, where it is cut by the Spanish thrust and the Prince George and Stoney Lake faults. It is bounded to the east by the Narrow Lake fault. East of the Spanish thrust and near Buckhorn Lake Nicola Group sedimentary rocks (subunit **b**) are more tuffaceous, and include basaltic tuff, tuffaceous siltstone and argillite, greywacke and shale, and minor basalt breccia and agglomerate (Struik et al., 1990).

Also present in the Quesnel Terrane are scattered small developments of Oligocene-Pliocene conglomerate and coarse clastic sedimentary rocks, and small areas of Miocene-Pleistocene basaltic volcanic rocks belonging to the Chilcotin Group.

Intrusive Rocks: The earliest intrusion in the survey area is a very small Early Jurassic syenitic-monzonitic intrusion within volcanic/volcaniclastic rocks of the Nicola Group just west of the Spanish thrust (Fig. 1). Younger Middle Jurassic quartz monzonitic intrusions of the Ste. Marie Plutonic Suite hosted by Nicola Group sedimentary rocks are present north of the Naver pluton. U-Pb dating of a sample within the largest intrusion produced an age of 168 ± 2 Ma (Struik et al., 1992). A narrow, elongate Jurassic mafic-ultramafic complex has been mapped north-northwest of Yardley Lake by Moynihan and Logan (2009). It is a composite intrusion that includes gabbro, pyroxenite and hornblendite, together with lesser amounts of quartz diorite and felsic segregations. A narrow curvilinear ultramafic intrusion (Jurassic or younger), possibly a dyke, has been mapped by Struik (1985) north of Teapot Lake.

The largest intrusion in the survey area, and the most prominent geological feature, is the pear-shaped Early Cretaceous Naver pluton. It comprises mainly granite and granodiorite, and has yielded a U-Pb age of 113 ± 1 Ma (Struik et al., 1992). It intrudes mainly the Barkerville Terrane, though its southern "tail" crosscuts the Quesnel Terrane and the Crooked Amphibolite. The pluton cuts, also, a triangular area of Crooked Amphibolite on its northern margin. Studies along the western margin of the Naver pluton reveal it to be a composite intrusion made up of a deformed western part, and undeformed eastern and southern portions, named, respectively, Naver I and Naver II plutons (Moynihan and Logan, 2009). The penetratively deformed Naver I pluton is considered to be older than the "post-tectonic 113 Ma part of the composite body", i.e. the Naver II pluton, which truncates the elongate Naver I pluton at its southern end.

The Bayonne Plutonic Suite is a later group of very small Mid Cretaceous intrusions hosted by Nicola Group sedimentary rocks fringing the northwestern, northern and northeastern margins of the Barkerville Terrane. They include granite and alkali feldspar granite (MapPlace).

Mineral Occurrences in the Area

According to MapPlace there are no producing mines or other mineral producers in the survey area and its immediate border region (Fig. 3). There are several past producers, most of which are placer deposits yielding gold. All information in this section is derived from MapPlace.

Past Producers - Placers: Within the survey area itself, Government Creek, Hixon Creek, Terry Creek and Canyon Creek placers are located west of the Naver pluton, sitting on a variety of geological units. The George Creek placer near Grizzly Lake is underlain by sedimentary rocks of the Nicola Group, and the Ahbau Creek placer south of Hay Lake is underlain by schist of the Snowshoe Group in an area where quartz veins are present.

In the northwest border region of the survey area, the Tabor Creek placer lies on Oligocene-Pliocene sedimentary rocks. In the southeast border region the Barry Creek placer is located on a unit of the Snowshoe Group comprising greenstone and greenschist metamorphic rocks. The Cooper Creek and Sugar Creek placers are located on the same unit east of the Barry Creek placer just outside the area of Figure 3. All aforementioned placers produced gold with the Sugar Creek placer yielding in addition silver and lead.

Past Producers - Bedrock (metalliferous): Metalliferous bedrock past producers in the survey area are limited to the Pioneer and Quesnel Quartz properties located within sedimentary rocks of the Nicola Group, close to the boundary with volcanic/volcaniclastic rocks of the Nicola Group to the west. The Pioneer mineralization is within carbonaceous shale, and consists mainly of argentiferous galena and sphalerite within a quartz vein, which also yielded anomalous gold values. In 1927 four tonnes of ore was mined producing 809 grams of silver, 126 kilograms of lead and 2 kilograms of zinc. In spite of its location within sedimentary rocks of the Nicola Group, the Quesnel Quartz deposit is reported to be associated with a highly sheared and hydrothermally altered zone within which greenstones contact quartz sericite schists. Steeply dipping, fairly closely spaced quartz veins, a few centimetres to about 1.8 m wide, occur in the greenstone near the contact. Gold mineralization occurs in the veins and to a lesser extent in the greenstone. Mineralization includes native gold, native silver, galena, sphalerite, chalcopyrite, molybdenite, arseno-pyrite, pyrrhotite and pyrite.

Developed Prospect: The G-South occurrence is a polymetallic vein just outside the survey area near the southern tip of the Naver pluton. It lies within a unit of volcanic/volcaniclastic rocks of the Nicola Group, and is associated mainly with augite porphyry, basaltic breccias and argillites, intruded by several rhyolite dikes. Sulphide mineralization is disseminated in the country rocks, and is present in stockworks and breccia infillings along with quartz, calcite, epidote and chlorite. Mineralization occurs mainly as: (1) disseminated and fracture-controlled pyrite, pyrrhotite and rare chalcopyrite in volcanic rocks or along contacts with rhyolite dikes, and (2) massive sulphides, including pyrite, arsenopyrite and sphalerite, and occasionally chalcopyrite and galena, within gouge zones up to 1.9 m wide. Apparently, high gold and silver values are not related to the abundance of sulphides, and the best mineralization is present at or near the intersection of regional fault structures.

Showings - Bedrock (metalliferous): Four metalliferous bedrock showings occur in the survey area. The Stone Creek showing falls within the mainly metasedimentary subunit **a** of the Nicola Group

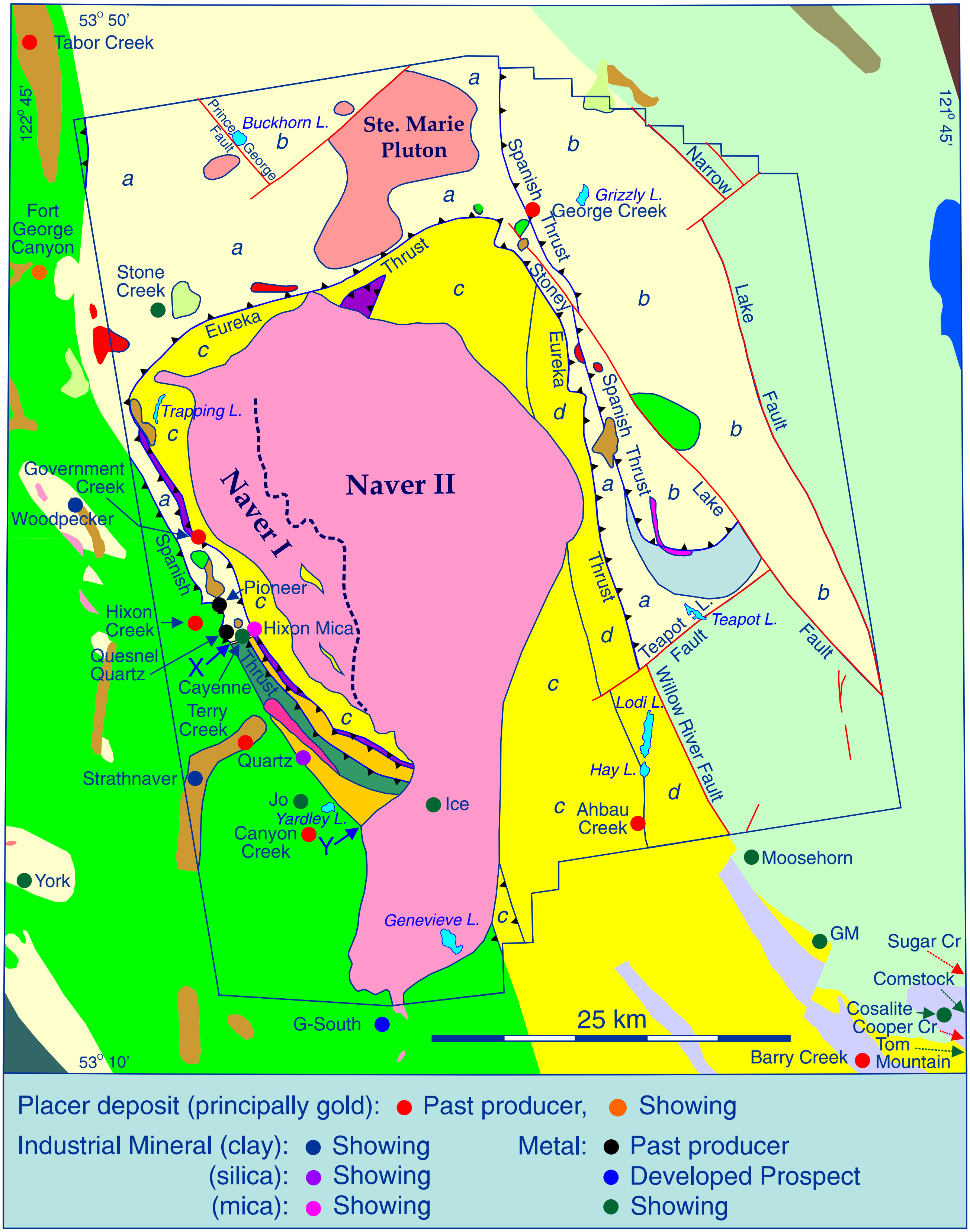

Figure 3: Geological map of the Quesnel survey area and immediate border region showing locations of mineral occurrences, which are classed as past producer, developed prospect or showing. Based on information on the British Columbia Geological Survey's MapPlace web site (http://www.em.gov.bc.ca/Mining/Geolsurv/MapPlace/default.htm). The legend for this map is provided in Figure 2.

(Quesnel Terrane) near the northwestern margin of the Naver pluton, yet is reported to be underlain by the Barkerville Terrane. The area of the showing is characterized by brecciated and fractured quartzite, phyllite and black argillaceous schist. Mineralization is present in a 3.5 m wide zone containing quartz and calcite, within which gold, silver and lead values have been reported from a brecciated quartzose phyllite containing disseminated pyrite and pyrite in quartz stringers. Pyrite and chalcopyrite associated with quartz occur within black clay-rich schist. The Cayenne showing, containing gold and silver and lying just west of the Naver pluton, is also located on metasedimentary subunit **a** of the Nicola Group. It includes a 0.6 to 1.2 m wide quartz vein and several smaller quartz stringers cutting highly altered and weathered quartz sericite schist. The schist is cited as evidence for association with the Barkerville Terrane, though a lack of detailed mapping is noted as cause for uncertainty.

The Jo showing is located within volcanic/volcaniclastic rocks of the Nicola Group near Yardley Lake, and consists of chalcopyrite mineralization within sheared basalt. The Ice showing is different from previously mentioned metallic mineral occurrences in the sense that is falls within intrusive rocks, in this case forming part of the Naver pluton. Mineralization is in the form of molybdenite within granodiorite. In a later section of this report the Ice showing is proposed to lie on a distinct fault interpreted from magnetic data.

Several metallic showings occur in the southeast border region of the survey area (Fig. 3). The Comstock, Cosalite and Tom Mountain showings occur in a cluster hosted by regionally metamorphosed (greenschist facies) limestone, phyllite and quartzite within a greenstone and greenschist unit of the Snowshoe Group. The GM showing is within undivided metamorphic rocks of the Snowshoe Group, and the Moosehorn showing is located within basaltic rocks of the Antler Formation. The Comstock and Tom Mountain showings plot just outside Figure 3, but are included in discussion to demonstrate the potential for vein-type mineralization in the region.

The lead-bearing Cosalite showing is an area of quartz veining that both cuts and is conformable with bedding. Veins attain 3.5 m in width, are exposed for up to 4 m along strike, and contain galena and pyrite mineralization with trace amounts of gold and silver. The Comstock showing contains lead, zinc and gold, and is underlain by sheared quartzite and conglomerate containing quartz veins up to 10 m wide. The veins are sparsely mineralized with galena and pyrite, and gold values are low. Galena and sphalerite are present in a small seam, a few centimetres wide. The Tom Mountain showing includes several quartz veins distributed over a distance of about 2 km, hosted by phyllite, slaty argillite and garnet mica schist of the Downey Succession, Snowshoe Group. Mineralization consists of galena, sphalerite and pyrite, with associated gold and silver values within some of the quartz veins.

The GM showing is a polymetallic vein deposit containing lead, zinc, copper, gold and silver in an area underlain by quartz mica schist, micaceous quartzite, pyritiferous argillite and phyllite. The showing includes a 1 m wide quartz-carbonate vein and stockwork zone. Mineralization is in the form of disseminated to locally massive galena and minor pyrite, sphalerite and chalcopyrite. Galena is also disseminated in siliceous bands within crenulated to gently folded metasedimentary rocks adjacent to the vein structure.

The Moosehorn showing is hosted within quartz veins, stringers, lenses and boudins that pervade a black pyritiferous argillite and phyllite sequence of the Antler Formation. The quartz bodies contain selvages, masses and disseminations of galena, sphalerite and pyrite. The boudins also contain coarse crystalline masses of mineralization 10 to 20 cm in diameter. Values of 41.136 grams per tonne silver, 0.1714 grams per tonne gold, 2.88 per cent lead and 0.04 per cent zinc have been reported from this showing.

Showings - Industrial Minerals: Clay occurs in the Woodpecker and Strathnaver showings, mica in the Hixon Mica showing and silica in the Quartz showing.

Magnetic Field in the Survey Area

Introduction: The magnetic field of the survey area is portrayed in images of the residual total magnetic field (Figs. 4, 5), and of the first and second vertical derivatives of the total magnetic field (Figs. 6 and 7, respectively). All images are shaded by a simulated light source to enhance features of the magnetic field. There is noticeable variation in the amount of apparent detail in the images. The residual total magnetic field image is least detailed, but is important since it indicates the relative intensity of the magnetic field, highlighting areas underlain by strongly or weakly magnetized rock units. The 1st vertical derivative (vertical gradient) of the magnetic field can be likened to a filtered version of the residual total magnetic field, in which shorter wavelength features are emphasized at the expense of longer wavelengths, which are effectively eliminated. The 2nd vertical derivative further enhances detail provided by the 1st vertical derivative, delineating some of the finest features of the magnetic field. Compared to a total magnetic field image, derivative images provide a more detailed representation of the structural fabric of a region. 1st vertical derivative maps are useful also for mapping geological contacts, consequent on the zero value contour being coincident with contacts between rock units having contrasting magnetizations, provided a contact is steep. This property is valid at high magnetic latitudes, where the inclination of the Earth's magnetic field is steep. Considering the inclination in the survey area is about 74^{o}, the zero contour should provide an acceptable proxy for contact positions.

Although magnetic highs stand out in a conventional portrayal of the total magnetic field, such as the shaded image in Figure 4, their relative intensity may not be so readily appreciated, mainly because of difficulty in discriminating between various shades of red. However, relative magnitudes of highs are easily distinguished in a 3D image of the magnetic field, such as that portrayed in Figure 5.

A characteristic of total magnetic field images that needs to be recognized in examining such images is the presence of negative anomalies on the northeastern through northwestern flanks of magnetic highs. This pairing of highs and lows is related to the dipolar nature of induced magnetization in a single body, which may be approximated by two separate poles aligned along the local direction of the Earth's magnetic field. The pole nearer the surface produces a positive anomaly, whereas the deeper pole generates a weaker negative anomaly because of the increased distance to the measuring magnetometer. Because the Earth's magnetic field is inclined (dips north in Canada), the lower pole is displaced horizontally from the upper pole in the direction of the north magnetic pole. Hence, an induced anomaly typically has the form of a strong positive anomaly accompanied by a significantly weaker negative anomaly on its northern side. Such negative anomalies, therefore, do not necessarily signify the presence of a non-magnetic or weakly magnetic body.

All of the magnetic images, with the exception of the 3D image of the total magnetic field, have geological contacts and faults superposed to provide a geological reference framework.

Magnetic Signatures and their Relationship to Geology: The range of values of magnetic anomalies in the area is 6511 nT (maximum: 5927.7 nT; minimum: -583.7 nT). A striking feature of the magnetic characteristics of all geological units is the heterogeneity of the magnetic signature, indicating that the units are likewise heterogeneous, and geologically more complex than suggested by current geological maps. Trends of most anomalies are north-northwest to north reflecting the prevailing geological strike.

Area East of the Spanish Thrust-Eureka Thrust-Willow River Fault Line

A subtle difference in the total magnetic field across the study area is the generally lower level and less variable nature of the field east of a composite line formed by the Spanish thrust north of the Stoney Lake fault, the Eureka thrust between the latter portion of the Spanish thrust and Teapot Lake fault and the Willow River fault. This eastern area is underlain mainly by basaltic volcanic rocks of the Antler Formation and metasedimentary rocks of the Nicola Group.

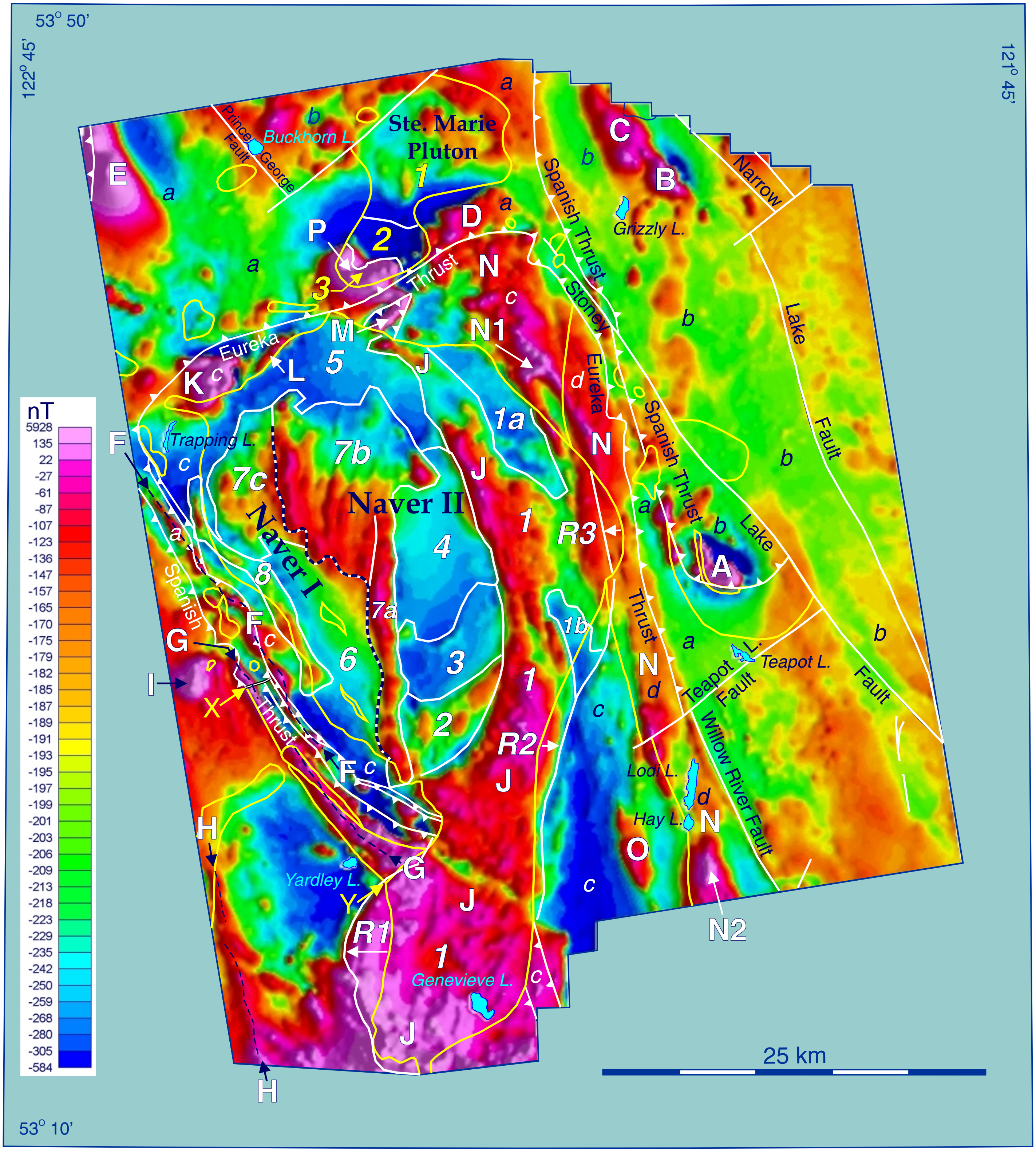

Figure 4: Shaded total magnetic field map of Quesnel survey area with geological contacts and faults as displayed in Figure 1 superposed (contacts as yellow lines; faults as white lines). Domains of the Naver and Ste. Marie plutons based on magnetic signatures are indicated by numbers, subdomains have added lower case letters. Boundaries between domains are drawn as white lines. R1, R2 and R3 indicate proposed changes in position of boundary of Naver pluton, from position marked with yellow line to position marked by white line. Specific magnetic highs discussed in text are indicated by letters A through P. The same anomalies are identically labeled in the 3D view of the magnetic field in Figure 5.

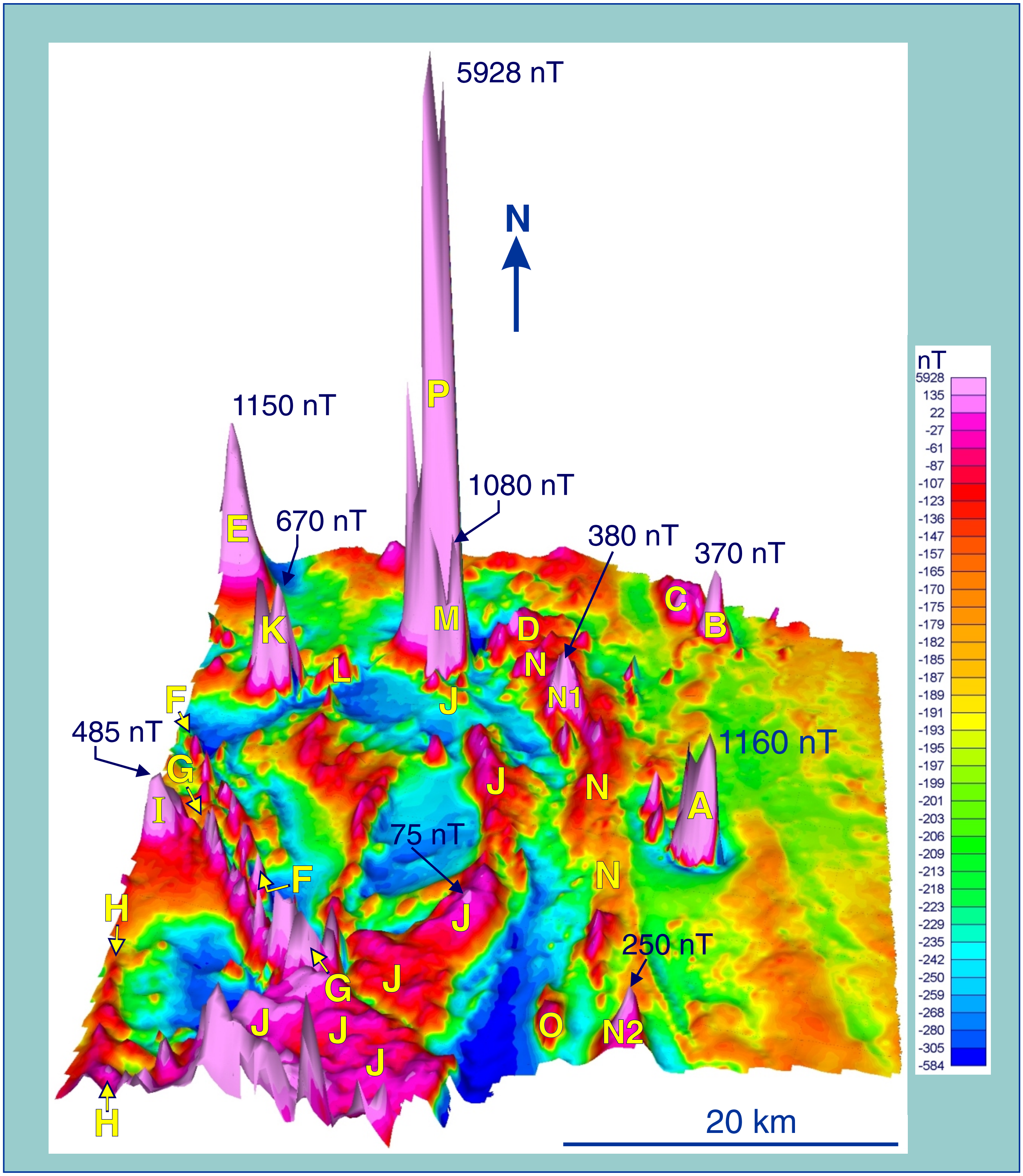

Figure 5: 3D view of the shaded total magnetic field of Quesnel survey area displayed in Figure 4. Specific magnetic highs discussed in text are indicated by letters A through P, and are identically labeled in the traditional view of the magnetic field in Figure 4. Peak values of certain anomalies are indicated. These values approximate the amplitudes of the anomalies, but are slightly larger, amplitude being the difference between peak value and local background value of the magnetic field, which varies slightly throughout the area. Because of the perspective, the scale bar applies mainly to the foreground, its accuracy diminishing from bottom to top of the image.

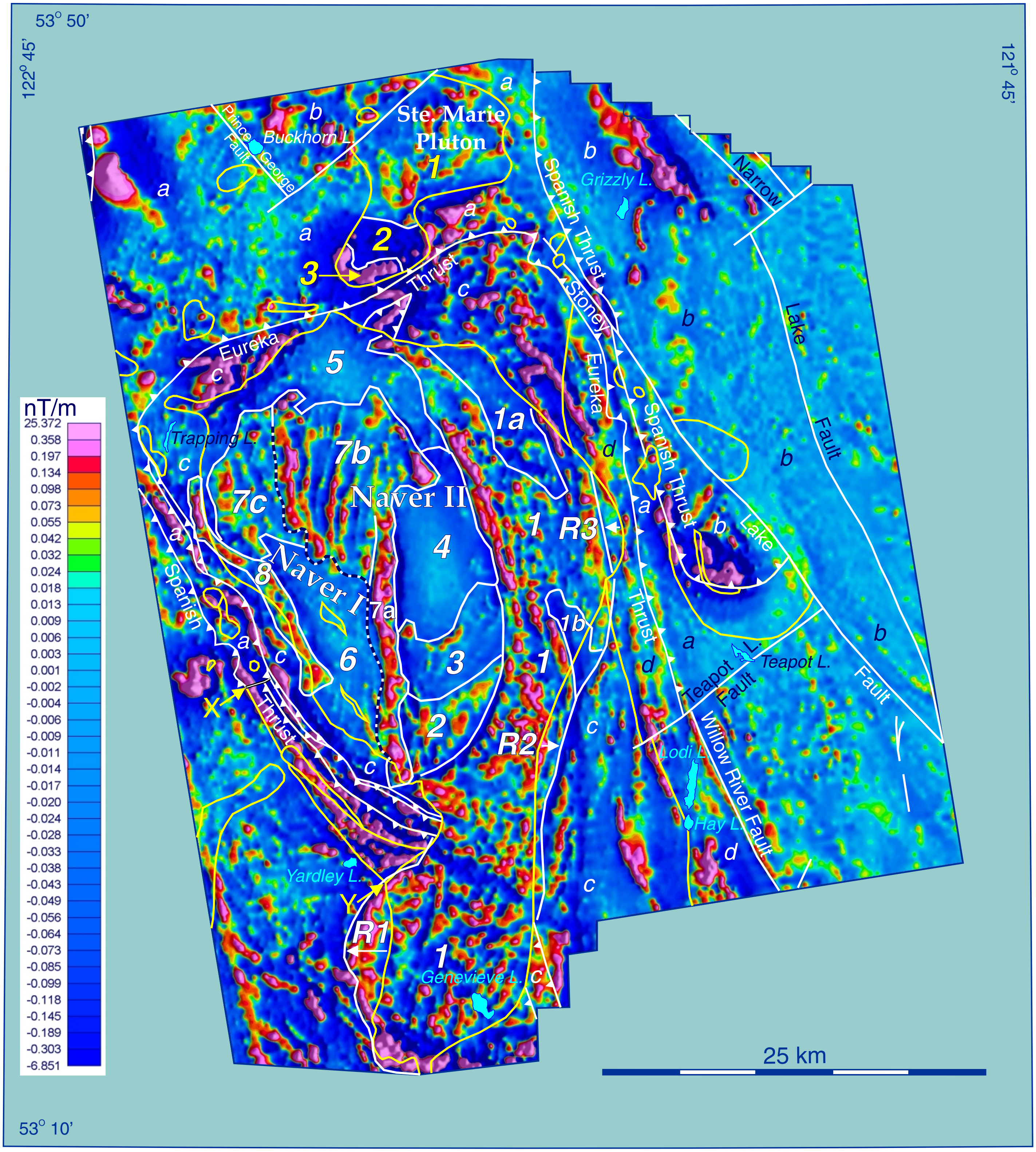

Figure 6: Shaded image of the first vertical derivative of the total magnetic field map of the Quesnel survey area with geological contacts (yellow lines) and faults (white lines; thrust faults have triangles on hanging wall). Domains of the Naver and Ste. Marie plutons based on magnetic signatures are indicated by numbers, subdomains have added lower case letters. Boundaries between domains are drawn as white lines. R1, R2 and R3 indicate proposed changes in position of boundary of Naver pluton, from position marked with yellow line to position marked by white line.

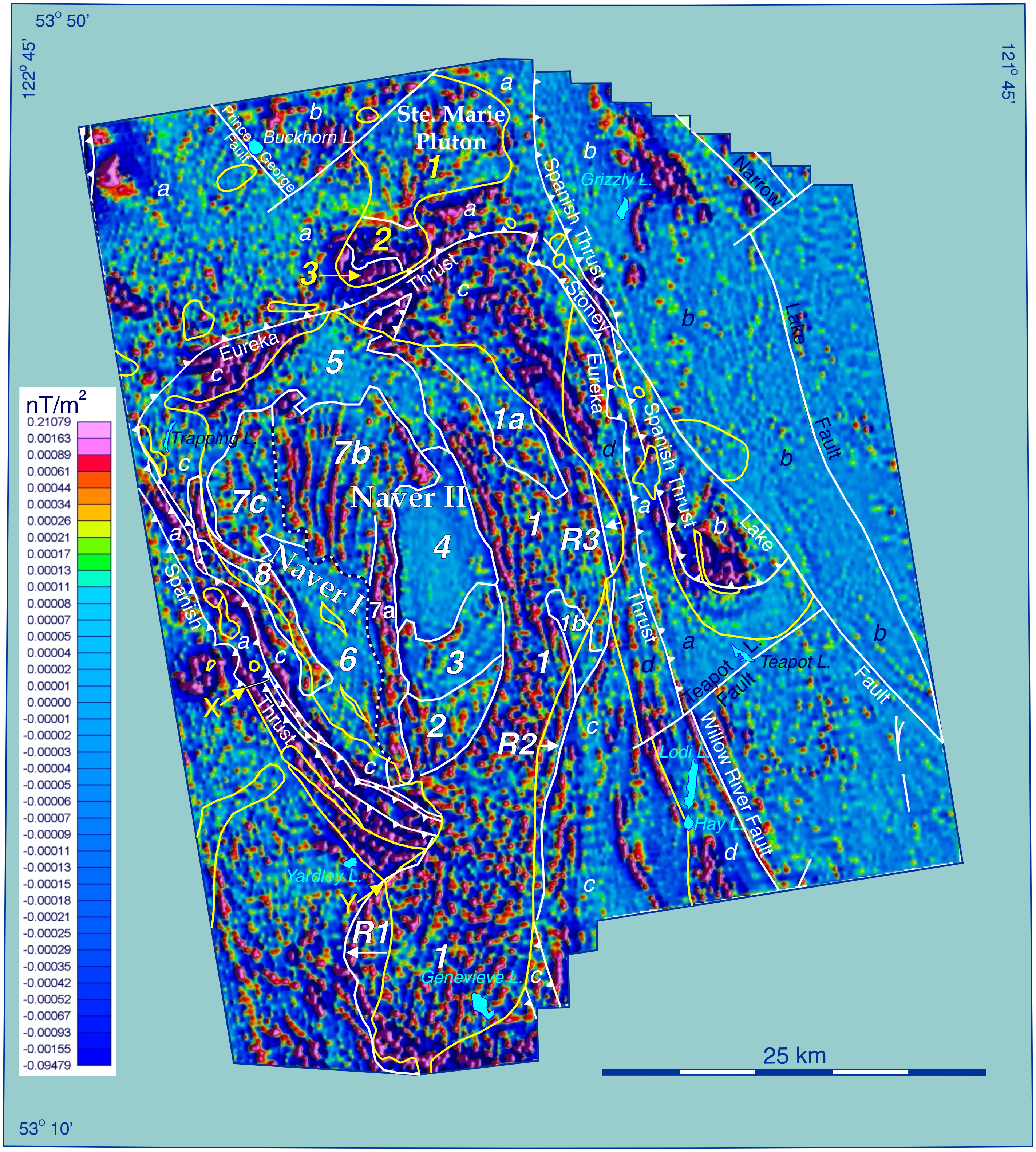

Figure 7: Shaded image of the second vertical derivative of the total magnetic field map of the Quesnel survey area with geological contacts (yellow lines) and faults (white lines; thrust faults have triangles on hanging wall). Domains of the Naver and Ste. Marie plutons based on magnetic signatures are indicated by numbers, subdomains have added lower case letters. Boundaries between domains are drawn as white lines. R1, R2 and R3 indicate proposed changes in position of boundary of Naver pluton, from position marked with yellow line to position marked by white line.

Antler Formation: East of the Narrow Lake fault basaltic rocks of the Antler Formation produce generally a relatively weak positive expression, lacking any prominent development of a magnetic fabric, though locally ovoid anomalies are evident. The northern part of the fault coincides closely with a change from a relatively positive magnetic field over the basaltic volcanic rocks to a more subdued and featureless field over metasedimentary rocks of the Nicola Group to the west.

In the area of basaltic rocks south of Teapot Lake a singular broad belt of positive magnetic anomaly, trending north-northwest, is discernible over the central portion of the area. Its general signature and amplitude are similar to those of relatively positive areas of magnetic field over basaltic rocks east of the Narrow Lake fault. This anomaly apparently crosses the Teapot Lake and Stoney Lake faults without noticeable disruption. The significance of this may be that revisions to local geology should be considered, or that the causative rocks (belonging to the Antler Formation?) are present at shallow depth below rocks mapped as Nicola Group. The eastern margin of this magnetic high is linear, suggesting possible fault control. Any such fault would cross, and not displace, the Stoney Lake fault near its intersection with the Teapot Lake fault.

East of the central high a narrow low trends north-northwest. It includes some small (amplitude and areal distribution) ovoid highs, and like the central high traverses the Stoney Lake fault, continuing into the unit of metasedimentary rocks of the Nicola Group. A low to the west of the central high is broader, more irregular and contains several small highs. The northern part of the low terminates abruptly to the west along the Willow River fault, where it is flanked by a magnetic high falling within the Snowshoe Group. The low broadens northward across the Teapot Lake fault into the area underlain by the Nicola Group, where it lacks the small magnetic highs observed over the Antler Formation.

Nicola Group - Metasedimentary Rocks: Metasedimentary rocks of the Nicola Group occupy a broad north-northwest-trending belt, transected diagonally by the Stoney Lake fault. Subunit **a** occurs in a narrow belt along the east side of the Eureka thrust, and comprises mainly slate, argillite and phyllite together with minor greywacke. In keeping with its metasedimentary nature the magnetic expression of much of the belt is characterized by a relatively low and featureless signature. A limestone unit north of Teapot Lake produces a similar signature, though the central high over the Antler Formation to the south invades the eastern part of the unit.

Subunit **b** containing mainly basaltic tuff, tuffaceous siltite and argillite, greywacke and slate covers all of the area east of the Spanish thrust. Much of the subunit is associated with a relatively neutral and featureless magnetic field, consistent with a metasedimentary succession, albeit with volcaniclastic components. However, the presence of several positive magnetic features, some very strong, indicates a link with other rock types. The example of magnetic high **A** having a large peak value of 1160 nT bears testament to such linkages. This magnetic high is located in the hanging wall of the Spanish thrust just north of Teapot Lake, in an area where a 1:250,000 scale bedrock geology map (Struik et al., 1990) indicates basaltic tuff, tuffaceous siltite and argillite, greywacke and shale to be the principal rock types. Not shown on this map, but plotted on a figure (*Figure 34.1*) published by Struik (1985) is a thin, curvilinear unit containing well formed pyroxenite crystals and believed to be a Jurassic or younger ultramafic intrusive, possibly a dyke. This intrusion coincides partially with magnetic high **A**, and is the undoubted source of **A**.

Prominent magnetic highs occur also north and northeast of Grizzly Lake, over rock types similar to those described in the region of anomaly **A**. These highs are arranged in a well defined north-northwest-trending belt whose defining flanks are linear, suggesting possible fault control. The largest peak in this belt, **B**, is located east-northeast of Grizzy Lake, with a value of almost 370 nT; other peak values, collectively labelled **C** in Figures 4 and 5, are very much smaller (<80 nT). It is speculated that these anomalies reflect a series of "granitic" intrusions, though basaltic volcaniclastic rocks, which may be present in the Nicola Group in this area (Struik et al., 1990), offer one alternative explanation.

An irregular belt of low amplitude highs striking south-southwest from anomaly **B** point to other heterogeneities within subunit **b** and possible associated structures having the same trend.

Area West of the Spanish Thrust-Eureka Thrust-Willow River Fault Line

Nicola Group - Metasedimentary Rocks: Metasedimentary rocks of the Nicola Group are present in the area north and west of the shell of Snowshoe Group sedimentary rocks surrounding the Naver pluton. Generally they belong to subunit **a** (slate, argillite, phyllite, greywacke; lesser amounts of tuff and tuffaceous siltite and argillite), but in a partially fault-bounded triangular area near Buckhorn Lake, they belong to subunit **b** (basaltic tuff, tuffaceous siltite and argillite, greywacke and slate).

The magnetic signature of subunit **a** north of the Naver pluton is variable, with no prevailing trend of anomalies, or indeed development of any strongly defined linear anomalies suggestive of a trend of bedding or structure. Much of the area is magnetically "active", with individual magnetic highs or areas of magnetic high being prominent. Three such occurrences are observed on the northwestern, northeastern and southeastern margins of the Ste. Marie pluton. Patterns and amplitudes of the highs on the northwestern and northeastern margins are similar, though underlain by different rock types. The northwestern margin, approximately coincident with the triangular area of subunit **b**, is underlain principally by basaltic tuffs and tuffaceous metasedimentary rocks, whereas the northeastern margin is underlain principally by metasedimentary rocks (Struik et al., 1990). The positive magnetic expression in the northeast may reflect a significant presence of volcaniclastic rocks. It may also signal the presence of satellitic quartz monzonitic intrusions related to the Ste. Marie pluton, given that a single small intrusion immediately north of the pluton correlates precisely with a local magnetic peak. On the other hand, a larger satellite near Buckhorn Lake seemingly lacks any positive signature, and the Ste. Marie pluton itself has a variable magnetic expression.

The positive signature northeast of the Ste. Marie pluton extends into the marginal area of the pluton, suggesting that if it is indeed linked to the Nicola Group, the pluton is very thin along this margin. Alternatively, the position of the boundary may require revision. An area of positive magnetic anomalies on the southeastern margin of the pluton, between the pluton and the Eureka thrust (labelled **D**, Figs. 4, 5), apparently represents the northern extremity of a belt of magnetic highs continuing southward from the thrust along the Snowshoe Group. Close inspection suggests, however, that the area of positive anomaly **D** is separated, and distinct, from the belt of magnetic high over the Snowshoe Group. A narrow east-northeast-trending low, more obvious in the image of the vertical gradient of the magnetic field (Fig. 6), apparently intervenes between the two areas of magnetic high. This and the general east-northeast trend of positive anomalies within area **D** indicate that **D** is unrelated to the Snowshoe Group. **D** coincides with rocks mapped as mainly metasedimentary rocks of the Nicola Group, but like the area of positive magnetic expression northeast of the pluton, it too may be underlain by volcaniclastic rocks and/or small satellites of the Ste. Marie pluton.

West of the Ste. Marie pluton and the triangular area of subunit **b,** the magnetic field over the mainly metasedimentary rocks of subunit **a** is fairly neutral and featureless, with the exception of the large (amplitude and area), magnetic high **E** immediately east of the Spanish thrust in the northwest corner of the survey area. This high has a peak value of 1150 nT. The texture of this magnetic anomaly is quite smooth, as is the texture of its vertical gradient equivalent, suggesting that the greater part of its source lies at some depth, though the top may be close to surface along the north-northwest-trending axis of the anomaly (Fig. 4). The peak value (1150 nT) of **E** is similar to that of anomaly **A** (1160 nT), which coincides with an ultramafic intrusion. An ultramafic source is similarly proposed for **E**.

On the west side of the Naver pluton subunit **a** of the Nicola Group forms a narrow western belt between the Snowshoe Group and volcanic/volcaniclastic rocks of the Nicola Group. Mapping by Moynihan and Logan (2009) has resulted in revision of the southeastern portion of subunit **a** (between points X and Y, Fig. 1) as mapped by Struik et al. (1990). This portion is now represented by a black phyllite unit that includes metapelitic phyllite, metasiltstone and calcareous phyllite containing abundant pyrite porphyroblasts.

The black phyllite unit has a variable magnetic signature, including a series of small (in amplitude and area) magnetic highs distributed along its length. Those near an adjacent unit of Crooked Amphibolite are roughly globular, with some coalescing, and they overlap to varying degrees the Crooked Amphibolite, which is their probable source. The high at the northwest end of the phyllite unit is barely within the unit, migrating northward into a unit of Crooked Amphibolite and then into the margin of the Snowshoe Group. This high has a more linear aspect**.** It and several other highs northwest of the phyllite unit form a narrow curvilinear belt (labeled **F** in Figs. 4 and 5) of highs about 23 km long. This belt follows closely the boundary between subunit **a** of the Nicola Group and the Snowshoe Group, wandering from one side to the other, and sometimes coinciding with intervening strips of Crooked Amphibolite. It is believed that magnetic highs along the belt **F** coincide with developments of Crooked Amphibolite. The nature of rock types along the belt, and the partial coincidences of the highs with mapped occurrences of Crooked Amphibolite (Moynihan and Logan, 2009; Struik et al., 1990) support this conclusion. Aside from the highs, the remainder of this western belt of the Nicola Group is characterized by a relatively negative to neutral negative field, consistent with its metasedimentary nature. A local exception is a small magnetic high coinciding partially with a small area mapped as volcaniclastic rocks (MapPlace) belonging to the Nicola Group.

Metasedimentary rocks of the Nicola Group are present also north of Yardley Lake, where they form a long, wedge-shaped unit of black phyllite separated from the aforementioned black phyllite unit by a belt of volcaniclastic rocks of the Nicola Group and a Jurassic mafic-ultramafic composite intrusion (Moynihan and Logan, 2009). The wedge-shaped phyllite unit is characterized mainly by a northwest-trending linear magnetic high (**G**) that apparently migrates into the flanking mafic-ultramafic intrusion, and continues northwest along and beyond the intrusion across volcaniclastic rocks of the Nicola Group. The volcaniclastic rocks are dismissed as a possible source of the high, because their magnetic susceptibilities are low (Moynihan and Logan, 2009). The black phyllite unit, also, is an unlikely source, because the black phyllite unit further north is dominated by a negative signature. Considering that mafic-ultramafic intrusions commonly produce distinct magnetic highs, the linear high **G** is interpreted to reflect a greater distribution of the mapped mafic-ultramafic intrusion at depth, under the phyllite and adjacent volcaniclastic rocks.

Nicola Group - Volcanic and Volcaniclastic Rocks: West of the Spanish thrust the volcaniclastic rocks of the Nicola Group are almost exclusively augite porphyry basalt tuff, breccia, minor flows, and tuffaceous argillite and siltite, together with local andesitic basalt (Struik et al., 1990). Moynihan and Logan (2009), mapping north of Yardley Lake, describe volcaniclastic rocks to be formed largely of conglomerate containing volcanic and subvolcanic clasts, interbedded with deposits of lithic and crystal sandstone and siltstone, and lesser fine cherty sedimentary rocks. These epiclastic units are interlayered with coarse pyroxene-phyric±pyroxene-plagioclase-phyric basaltic breccia flows and hyaloclastite deposits.

The total magnetic field signature of the volcanic/volcaniclastic unit of the Nicola Group changes dramatically across a curvilinear unit of Oligocene-Pliocene conglomerate and coarse clastics trending north-northeast to northeast across the volcanic/volcaniclastic unit. To the northwest the level of the magnetic field is relatively positive compared to that to the southeast. The lower level west and south of Yardley Lake in the southeast may reflect to some extent the dipolar effect of magnetized bodies described earlier in this report, being related to the same body producing the area of prominent magnetic high between Yardley and Genevieve lakes, much of which coincides with the southern tail of the Naver pluton. A northwestward increase in magnetic susceptibility within the volcanic/volcaniclastic unit could also contribute to this regional difference in level of the magnetic field, which might be imaging a change in the underlying lithologies.

Notwithstanding the regional differences in level, the field over the volcanic/volcaniclastic unit is relatively featureless, with generally only small ovoid highs punctuating the background field, their morphology suggesting association with small granitoid intrusions. Two notable exceptions are a linear north-northwest-trending magnetic high (**H**) along the southwestern margin of the survey area, and a prominent ovoid high (**I**) further north along the margin. The amplitude of **H** is variable along its length (Fig. 4), the vertical gradient image (Fig. 6) suggesting it comprises several shorter segments. On the eastern flank of the southern portion of magnetic high **H** short linear anomalies oriented obliquely northwest are observed, some giving the impression of merging with segments of **H**. The similarity in amplitude, linearity and width of all of these anomalies suggests a similar source. Given that similar chains of magnetic highs (**F, G**) have been linked with mafic-ultramafic rocks, it is tempting to consider such a link for **H**. Alternatively, **H** could be related to a particular lithological unit within the volcanic/volcaniclastic unit of the Nicola Group. Correlative pyroxene-phyric volcaniclastic rocks southeast of the survey area have moderate-high magnetic susceptibilities (Moynihan and Logan, 2009). Such rocks could be a candidate to explain **H** and the adjacent linear anomalies.

The singular anomaly **I** to the north has a peak value of about 485 nT, and is attributed to a granitoid intrusion, evidence for which is a very small occurrence of syenitic-monzodioritic rocks of probable Lower Jurassic age (Struik et al., 1990) on the northeast flank of the anomaly.

Central Part of the Study Area: The Naver and Ste. Marie Plutons and Snowshoe Group

Naver Pluton: A central feature of the Quesnel survey area is the granitic Naver pluton, which magnetically has a heterogeneous signature. On the basis of patterns and amplitudes of magnetic anomalies observed on the total magnetic field image, and patterns and texture on vertical gradient images, the pluton has been subdivided into 8 domains.

The largest and most pronounced is Domain 1 that includes the southern tail of the pluton, and stretches northward along the eastern margin. It is defined principally by its positive magnetic expression (belt of magnetic highs labelled **J** in Figs. 4, 5), and by the north-northeast- to north-northwest-trending linear fabric apparent in the vertical gradient image (Fig. 6). The positive expression is strongest in the southern tail, south of an unmapped fault, expressed in the magnetic images by a prominent northwest-trending linear magnetic low. The pattern of anomalies south of this fault supports repositioning of the western boundary of the pluton to the west side of a curvilinear pattern of magnetic highs. North of the fault magnetic signatures support a slight eastward adjustment of the eastern boundary (Figs. 4, 6). The two repositioned segments of the boundary are identified, respectively, by R1 and R2 in Figures 4 and 6. On the vertical gradient image (Fig. 6) the revised position of the western boundary is located west of a narrow, more or less singular, curvilinear magnetic high, with the caveat that such marginal anomalies may reflect contact metamorphism in the country rocks. Patterns of the total magnetic field (Fig. 4) and derivatives of the field (Figs. 6, 7) also support a slight westward repositioning (R3) of a short curved segment of the eastern boundary north of R2. The new position falls on the eastern flank of a distinct linear magnetic high and immediately east of a site yielding a sample of the Naver pluton for age dating (Struik et al., 1990; Struik et al., 1992).

The strongest magnetic peaks within Domain 1 occur at the southern tip of the domain, south of which high resolution magnetic data from another survey define a major magnetic high (peak values > 5500 nT) over the Ahbau Creek stock (Logan, 2008) some 2 km south of the Naver pluton. The stock is a Late Triassic to Early Jurassic (?) Alaskan-type mafic-ultramafic complex having elevated magnetite content in mafic biotite-bearing phases (Logan, 2008). The Naver pluton's proximity to the Ahbau Creek stock and its relatively strong southern marginal positive expression invite speculation about mafic phases within the pluton. Potassium concentrations determined by the radiometric component of the Quesnel survey decrease noticeably from the northern part of the pluton southward along the southern tail (Fig. 8), supporting a more mafic composition in the south.

Two subdomains (1a, 1b) are defined in the northern part of Domain 1, principally on the basis of relatively negative total magnetic field signatures. Furthermore, a negative signature persists between the subdomains. The signature of this combined negative belt is less distinct on the vertical gradient

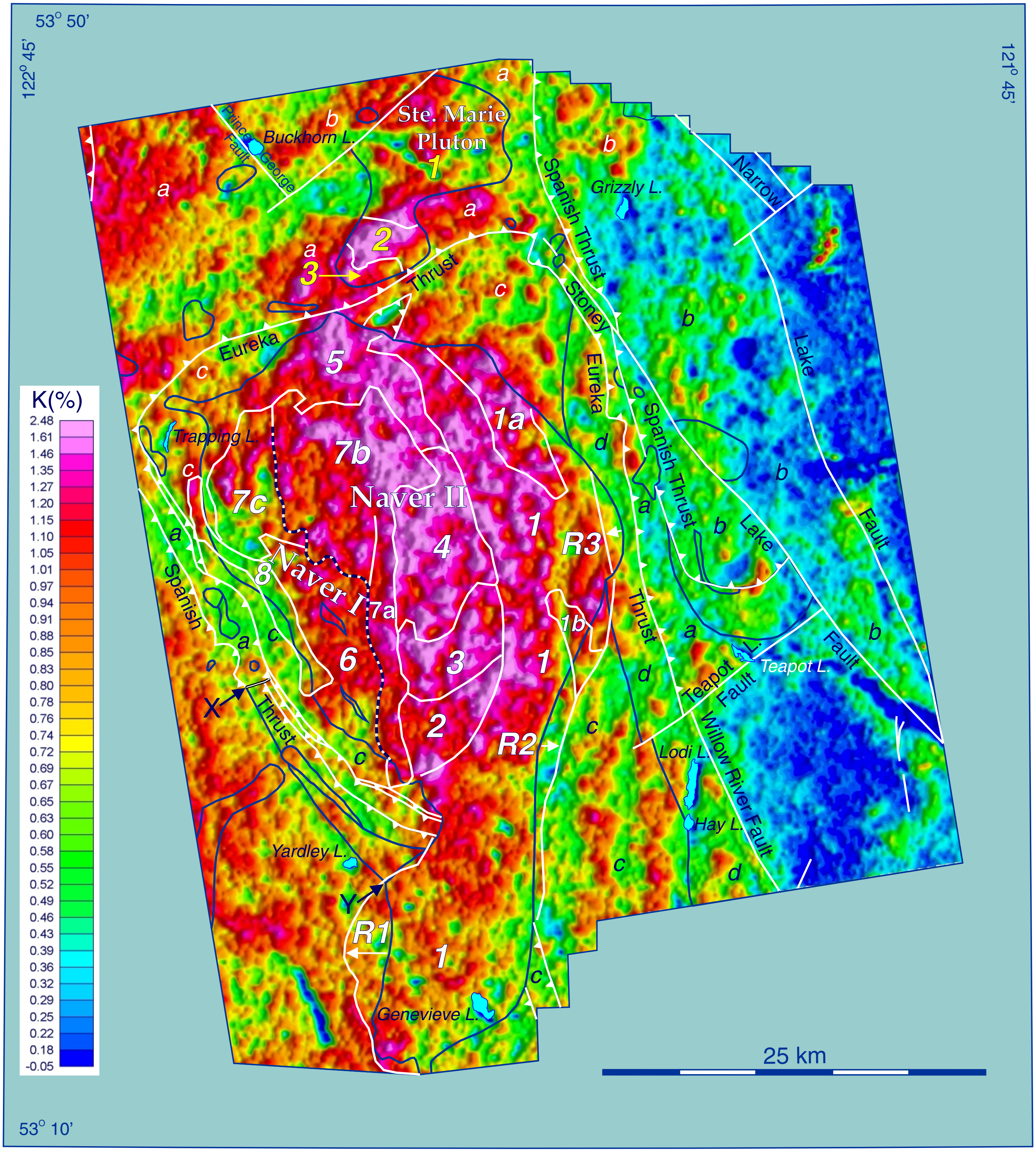

Figure 8: Shaded image of a map of the potassium concentration (%) in the Quesnel survey area with geological contacts (navy lines) and faults (white lines; thrust faults have triangles on hanging wall). Domains of the Naver and Ste. Marie plutons based on magnetic signatures are indicated by numbers, subdomains have added lower case letters. Boundaries between domains are drawn as white lines. R1, R2 and R3 indicate proposed changes in position of boundary of Naver pluton, from position marked with navy line to position marked by white line.

image, but nevertheless distinguishable as an area containing less pronounced positive features. The significance of these 2 subdomains and joining trough may be development of a more felsic phase of the intrusion.

The northern part of Domain 1 contacts Domains 2, 3, 4, and 5 to the west. Domain 2 is distinguished from the others by its moderately positive total magnetic field signature, which produces a stronger fabric in the vertical gradient image, not unlike the fabric over portions of Domain 1. Domains 3, 4, and 5, in contrast, are characterized by a relatively negative and featureless total magnetic field signature, and a weak fabric in the vertical gradient image. Domain 4, in particular, presents a very smooth magnetic fabric. The magnetic signature of Domain 6, lying west of the strong linear magnetic high defining subdomain 7a, is very similar to those of Domains 3, 4 and 5, and it is proposed that this group of four domains reflects portions of the Naver pluton having a similar composition. The muted magnetic signatures suggest a more felsic composition, a conclusion supported by relatively high concentrations of potassium (Fig. 8), particularly within Domains 3 and 4, and the eastern portion of Domain 5.

Domain 7 is identified by its positive magnetic expression in the western half of the broad northern portion of the Naver pluton. A notable characteristic of its magnetic signature is the linearity and continuity of individual magnetic anomalies. It has been subdivided into 3 subdomains, principally on the basis of magnetic fabric patterns in the vertical gradient image (Fig. 6). Subdomain 7a is very narrow (approximately 1 to 1.5 km wide), and defined by a prominent magnetic high running northward for about 17 km from the southwestern margin of the pluton. The linearity of Subdomain 7a suggests that it is fault-bounded on each side. On the vertical gradient image, the northern part of the high apparently merges with the magnetic fabric of Subdomain 7b, which is defined by a series of alternating north- to north-northeast-trending linear highs and lows. The magnetic fabric of Subdomain 7c is not unlike that of 7b, though linearity and continuity of magnetic features is somewhat lacking, and trends apparently are north-northwest. The predominantly linear fabric of Domain 7 is interpreted to reflect the signature of a large pendant-like block of country rock representing the roof area of the former magma chamber. A search for similar fabrics in surrounding country rocks indicates the most likely match to be the linear fabric observed over the metasedimentary subunit **d** of the Snowshoe Group in the footwall of the Eureka thrust west of Teapot Lake. This subunit has a positive expression having peak values similar to those in Domain 7. This and the fact that rocks of the Snowshoe Group surround much of the pluton are convincing evidence for the presence of similar rocks within Domain 7.

South of Trapping Lake, on the western margin of the pluton, the narrow, curvilinear Domain 8 is defined by a series of magnetic highs of low to moderate amplitude. The domain straddles the boundary of the pluton in places, and the northern extremity lies outside the margin, within metasedimentary rocks of the Snowshoe Group. Its marginal position, partial correlation with rocks of the Snowshoe Group and similar amplitudes of magnetic highs to those within Domain 7 indicate affiliation with the Snowshoe Group, rather than with the pluton. If such is the case, revision of the relevant section of the mutual boundary is required.

Snowshoe Group - Metasedimentary Rocks: Metasedimentary rocks of the Snowshoe Group define a roughly horseshoe-shaped belt that wraps around most of the Naver pluton, and has a variable magnetic signature. The belt is divided into western and eastern halves separated by the northernmost tip of the Naver pluton at its contact with the Eureka thrust.

The western half is underlain by rocks of subunit **c** that include schistose quartzite, schist, phyllite, marble, amphibolite, siltite and minor quartzite (Struik et al., 1990). The segment north of Trapping Lake, on the northwestern margin of the Naver pluton, has a variable magnetic signature dominated by a large, roughly oval magnetic high (**K**) having a peak amplitude of ~670 nT, and including also a lower amplitude, linear magnetic high (**L**). The large amplitude and oval morphology of magnetic high **K** draw comparison with magnetic high **A**, coinciding with and attributed to an ultramafic intrusion. The linear nature of **L** points to Crooked Amphibolite as the source. Similar linear anomalies are potentially linked to Crooked Amphibolite along the western margin of the Naver pluton, and a triangular unit of

Crooked Amphibolite some 5 km to the east is associated with a linear magnetic high **M**.

The segment of subunit **c** southeast of Trapping Lake is characterized by a negative total magnetic field signature at both extremities, whereas the central portion has a relatively positive magnetic expression, partially coinciding with Domain 8 of the Naver pluton where the domain extends beyond the margin of the pluton, and with magnetic highs, or portions thereof that may relate to bodies of Crooked Amphibolite. The variable signature along this western segment is attributed to the variability of lithologies comprising subunit **c** (Moynihan and Logan, 2009; Struik et al., 1990), the influence of bodies of Crooked Amphibolite and possible contact metamorphic effects produced by intrusion of the Naver pluton.

The Snowshoe Group east of the Naver pluton is underlain by subunits **c** and **d**. Subunit **c** is divided into two segments by the eastern bulge of the Naver pluton, and their magnetic signatures are quite different. The northern segment lying southwest of Grizzly Lake is dominated by a strong positive expression, whereas the southern segment west of Lodi and Hay lakes is characterized by a mainly negative signature.

The western part of the northern segment is associated with a neutral to negative magnetic signature punctuated by some very small oval magnetic highs. In contrast the eastern portion corresponds to a relatively broad, prominent belt (**N**) of positive magnetic anomalies that extends south-southeastward across the contact with subunit **d**, continuing along subunit **d**, crossing the Teapot Lake fault and extending to the south end of subunit **d**. The largest peak value (**N1** - 380 nT) in the northern segment is associated with a short, east-northeast-trending linear anomaly in the southern part of subunit **c**, which lies close to several strong peak values along a linear anomaly having a more typical northwest to north-northwest trend. The image of the vertical gradient of the magnetic field (Fig. 6) highlights the linear nature of the latter anomaly. An important observation with respect to this anomaly is its continuity across the north-northeast-trending contact between subunits **c** and **d**. This continuity across a contact supposedly separating subunits comprising different assemblages of rock, questions the validity of the contact.

Well developed linear anomalies are not present in the northern part of the northern segment of subunit **c**, where linear anomalies are quite short, rarely collinear and have various orientations. This irregular pattern may be influenced by the change in orientation of the Snowshoe Group in this area from east-northeast to south-southeast, a change that probably involves folding, which may mimic the bounding Eureka thrust. In the northern apical region of subunit **c**, there are hints of an arcuate pattern of anomalies (Figs. 6, 7) that mimic the curvature of the nearby Eureka thrust.

The contrasting magnetic signatures within the northern segment of subunit **c** points to the presence of two principal assemblages of rocks. Considering the rock types listed within the subunit (Struik et al., 1990), the western portion may be underlain by a greater proportion of schistose quartzite, marble and siltite, whereas the eastern portion may include more schist, phyllite and amphibolite, lithologies possibly having greater potential for higher magnetic susceptibilities, though in the absence of any measurements this is simply speculation.

The southern segment of subunit **c** southeast of the Naver pluton is characterized by a relatively negative total magnetic field that is also relatively featureless (Fig. 4). This negative signature is more intense over the western half of the subunit, probably as a result of a negative contribution from dipolar induced magnetization within the southern tail of the Naver pluton. It is conjectured that the western portion of the southern segment of subunit **c**, like its northern counterpart, is underlain mainly by schistose quartzite, marble and siltite. The vertical gradient of the magnetic field is characterized by a weak, somewhat irregular, yet recognizable linear fabric defined by short linear to ovoid anomalies along the western margin and northern apical region of the subunit. The grain of the fabric is oriented north-northeast, slightly oblique to the trend of the subunit as a whole. An eastern marginal portion of subunit **c** southwest of Lodi Lake has a relatively positive expression culminating in the prominent magnetic high **O**. The vertical gradient image reveals a linear component of this high oriented north-

northwest. A less prominent linear total magnetic field anomaly runs southward from the western end of the Teapot Lake fault. The trends of the anomalies in the eastern marginal area differ from those in the western portion raising the possibility of a structural break between the two portions, though other than the difference in trends there is no obvious magnetic signature that can be linked to such a break.

Subunit **d** of the Snowshoe Group forms a north-northwest-trending belt bounded to the east by the Eureka thrust and Willow River fault. It is associated with an essentially co-spatial belt of positive magnetic anomalies, which present a well developed linear fabric north of Teapot Lake fault. The continuation of one particularly prominent linear high across the contact with subunit **c** has been discussed previously with respect to the validity of this contact. The positive signature of the subunit is somewhat enigmatic given that the unit includes orthoquartzite and schistose quartzite, lithologies that would generally be considered relatively non-magnetic. However, the subunit also contains schist and phyllite (Struik et al., 1990), and the presence of "granitic" rocks of a variety of compositions and ultramafic rocks cannot be ruled out, particularly where magnetic highs are reasonably strong, e.g., anomaly **N2** (250 nT).

Ste. Marie Pluton: The Middle Jurassic quartz monzonitic Ste. Marie pluton may be described in terms of 3 distinct total magnetic field signatures corresponding to 3 domains, 1, 2 and 3 (Figs. 4, 6). Characteristics of the total magnetic field and vertical derivatives were used to define domains, but the boundaries are based on patterns in the vertical gradient image (Fig. 6). Domain 1 coincides with the broad northern lobe of the pluton, characterized by relatively small (amplitude and horizontal dimensions) oval to linear magnetic highs arranged in no particular pattern, some of which coalesce. There are hints of linear trends in the vertical gradient image, but these are discontinuous and have various orientations. This generally positive signature of the northern lobe is attributed to the pluton, though as noted previously the positive signature along the northeast margin may reflect the Nicola Group beneath a thin pluton margin.

In the southern lobe of the pluton, Domains 2 and 3 coincide, respectively, with a negative and positive magnetic expression. Domain 3 is defined by a single magnetic high (**P**), the largest in the area, attaining a peak value of about 5930 nT. It sits on the southwest margin of the pluton, and is accompanied by a prominent magnetic low covering the rest of the southern lobe. This pair of anomalies is a good example of a dipolar signature emanating from a single magnetized body. The huge amplitude of the anomaly defining Domain 3 rivals those of strong anomalies associated with the Iron Lake and Aqua Creek mafic-ultramafic intrusions near Canim and Mahood lakes further south (Schiarizza and Boulton, 2006), both of which invade Middle to Upper Triassic rocks of the Nicola Group. It is proposed that a similar mafic-ultramafic complex underlies Domain 3 at the southwestern margin of the Ste. Marie pluton. North of the proposed complex, within the area of negative total magnetic field anomaly, Domain 2, there is a hint of an east-west fabric in an image of the second vertical derivative (Fig. 7). This fabric contrasts with that of Domain 1, and signifies a distinct component of the Ste. Marie pluton. The trend of the fabric in Domain 2 is subparallel to the linear vertical gradient anomaly defining the peak region of the principal magnetic high in Domain 3 along the southeastern margin of the pluton. Possibly the fabric in Domain 2 reflects a separate intrusion postdating the Ste. Marie pluton.

Mapping Faults: Aeromagnetic maps provide an effective means for mapping faults, which commonly are expressed as linear negative anomalies, or recognized by offsets of other anomalies. Linear belts of steep gradients may also signify the presence of a fault. The association of faults with negative anomalies is related to the oxidization of magnetite to hematite, resulting in a significant reduction in magnetic susceptibility. Magnetite is unstable in the low temperature, highly oxidizing environment of chemical weathering and sedimentation (Grant, 1985). Faults and associated fractures represent loci of increased permeability, providing pathways for circulating groundwater, which oxidizes magnetite to hematite:

$$2Fe_3O_4 + \tfrac{1}{2}O_2 \longleftrightarrow 3Fe_2O_3$$

magnetite hematite

Faults were interpreted from the Quesnel survey data using images of the total magnetic field and the first and second derivatives of the field. They are displayed on an image of the first vertical derivative (Fig. 9), and on a figure illustrating geologically mapped contacts and faults, and geophysically derived faults, revised contact positions for the Naver pluton, and internal domains of the Naver and Ste. Marie plutons (Fig. 10).

Few faults are interpreted east of the Spanish thrust-Eureka thrust-Willow River fault line, probably as a result of the generally weaker magnetic field in the area, and possibly reflecting a relative lack of faults in this region. Most faults have been interpreted within and adjacent to the Naver pluton, where greater magnetic relief helps recognition of fault signatures. Some coincide with segments of internal domain boundaries of the pluton. Most faults are oriented within about 25^{o} of north. Four faults oriented roughly N60^{o}W are interpreted north and east of Yardley Lake. The two shortest faults coincide with the revised position (see discussion in section on ***Geology of the Area/Quesnel Terrane***) of the geologically mapped Spanish thrust fault, adding support to the repositioning. A third fault exhibits partial spatial coincidence with the revised position of the Eureka thrust, but also extends southeast into the Naver pluton. The fourth fault crosses the southern tail of the pluton. Coincidentally, the only mineral occurrence within the Naver pluton, the Ice showing (occurring as molybdenite within granodiorite), lies along this proposed fault.

Implications for Mineral Exploration

Apart from mainly gold-producing placer deposits (Fig. 3), the survey area has not witnessed major production of metals from bedrock sources. Yet the area lies partially within the Quesnel Terrane, characterized by Triassic to Early Jurassic volcanic and sedimentary arc rocks and high-level, comagmatic alkaline intrusions (Jonnes and Logan, 2007), considered to have significant potential for Cu-Au porphyry mineralization (Logan, 2008). A good example of this type of mineralization is located on the Mouse Mountain property (a past producer), outside the survey area, but only some 18 km south of the Naver pluton, where 3 separate zones of copper-gold mineralization and associated alteration are present (Jonnes and Logan, 2007). The Valentine zone exhibits classic alkalic porphyry characteristics centred on a composite monzonite intrusion, with potassium metasomatism enclosed by peripheral propylitic alteration and stockwork breccia copper-gold mineralization.

Another potential target for mineral exploration is Late Triassic to Early Jurassic (?) Alaskan-type mafic-ultramafic plutonic complexes, several of which are described from the Cottonwood map sheet immediately south of the Quesnel survey area (Logan, 2008), e.g., the Ahbau Creek, Cottonwood Canyon, Cottonwood River and 12 Mile stocks. Although these intrusions apparently do not have associated gold or copper sulphide mineralization (Logan, 2008), further south near Canim Lake Schiarizza and Boulton (2006) report widespread, low grade Cu mineralization, locally accompanied by Au, Pt and Pd, from within and adjacent to the Iron Lake mafic-ultramafic complex. Ni and Co have also been assayed.

A third type of target takes the form of vein-type mineral occurrences, such as Au-quartz veins and polymetallic veins, several of which are described in the section on ***Mineral Occurrences in the Area***. These are associated variously with shear zones, stringers, stockworks, breccias, gouge zones and fractures, underlining the influence of brittle fracturing. These occurrences are located in all of the terranes within the survey area.

How can the new aeromagnetic data help promote discovery of these 3 principal types of mineralization targets in the region? In a general way, search for all deposit types is supported by the improved geological framework provided by the magnetic images. The total magnetic field image

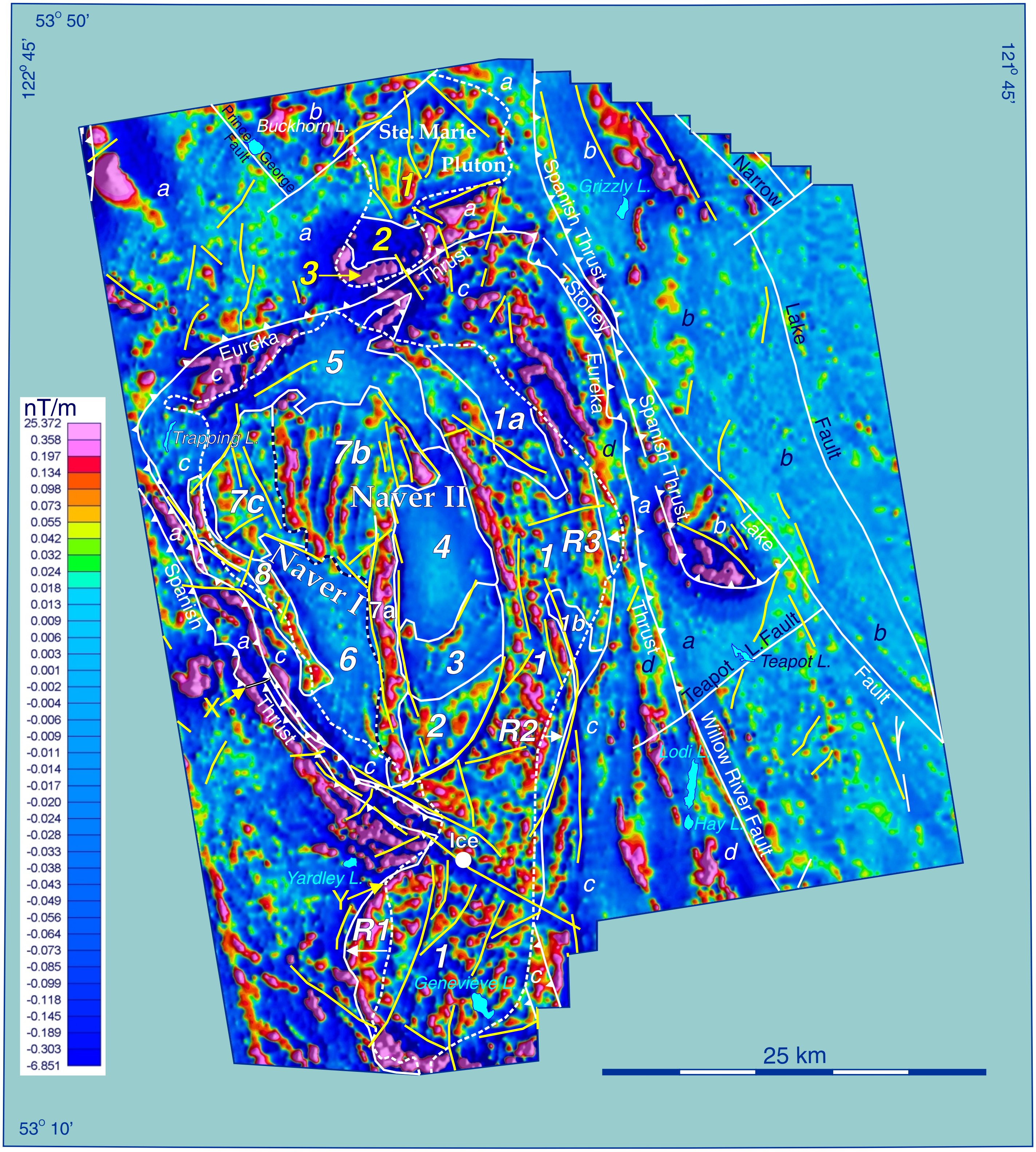

Figure 9: Shaded image of the first vertical derivative of the total magnetic field map of the Quesnel survey area showing interpreted faults (yellow lines) and geologically mapped faults (white lines; thrust faults have triangles on hanging wall). The Naver and Ste. Marie plutons are outlined by dashed white lines. Domains of these plutons based on magnetic signatures are indicated by numbers, subdomains have added lower case letters. Boundaries between domains are drawn as white lines. R1, R2 and R3 indicate proposed changes in position of boundary of Naver pluton, from position marked with dashed white line to position marked by solid white line.

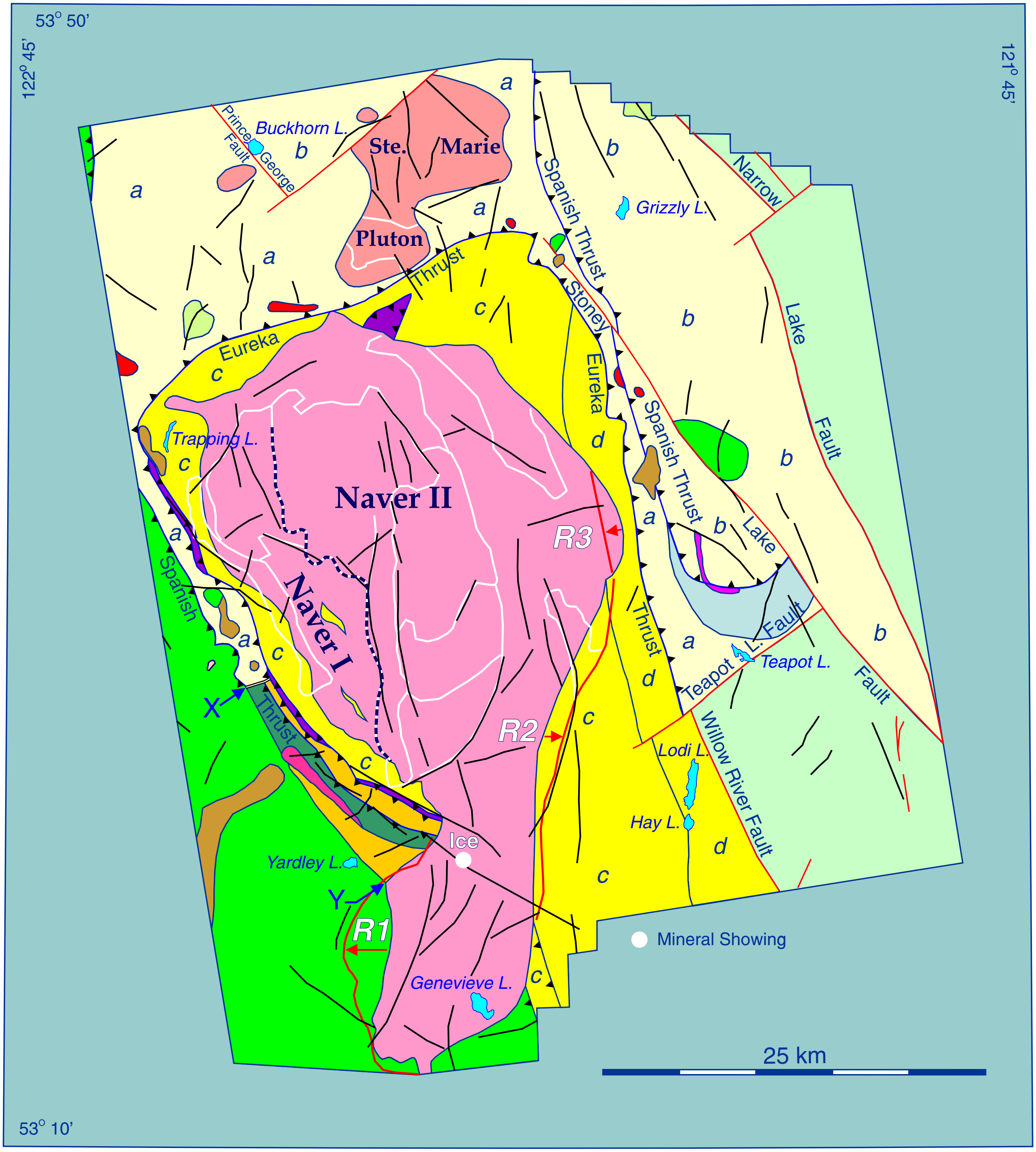

Figure 10: Geological map of Quesnel survey area as shown in Figure 1, with interpreted faults (black lines) and domains/subdomains of the Naver and Ste. Marie plutons. Boundaries between domains are drawn as white lines. Legend for map is shown as Figure 2. R1, R2 and R3 indicate proposed changes in position of boundary of Naver pluton, from position marked with navy line to position marked by red line.

draws attention to previously unmapped intrusions, and reveals the heterogeneous nature of geological units. The derivative images of the magnetic field provide a picture of the fine structural fabric of the area, and thereby a better defined geological framework for exploration.

With respect to porphyry deposits, Sillitoe (1979) reported that gold-rich porphyry copper deposits worldwide, including examples from the Cordillera, are associated with potassium silicate alteration and high magnetite contents, commonly attaining 5 to 10 % by volume. Clark and Arancibia (1996) document many examples of the association of magnetite with hydrothermal alteration zones related to porphyry mineralization, noting in some cases that the richest ores coincide with the highest magnetite contents. Copper porphyry mineralization may be associated with alteration/magnetite-rich zones on the order of 100s of metres in lateral extent, which present compact and well-defined magnetic targets.

The problem for exploration of porphyry-type mineralization based on the presence of a magnetic high is that magnetic highs reflect many different types of geological feature. Fortunately, the association of potassic alteration with porphyry-type mineralization affords a means of eliminating many magnetic anomalies for further consideration. However, the presence of high potassium brings its own problems, since it is necessary to discriminate between high potassium associated with mineralization and high potassium related to normal lithological variations. Shives et al. (1997) offer a solution to this problem by utilizing Th/K ratios, noting that thorium enrichment generally does not mimic potassium enrichment during hydrothermal alteration. Consequently, alteration zones are characterized by low Th/K ratios, and the presence of a high magnetic signature along with a low Th/K ratio in the appropriate geological environment provides a vector for further investigation. Such coincidental signatures have been noted within the alkalic Iron Mask batholith near Kamloops (R. Shives, personal communication, 2005).

In the Quesnel survey area, within the Quesnel Terrane, distinctive magnetic highs having significance for porphyry mineralization are not conspicuous. The magnetic high **I** on the western side of the Naver pluton within volcanic rocks of the Nicola Group (Figs. 4, 5) may be a candidate, given its apparent link with a small area of syenitic-monzodioritic rocks of probable Lower Jurassic age (Struik et al., 1990), but potassium levels are not exceptional (Fig. 8), and there is an absence of a distinctive Th/K low (Fig. 11). More promising, perhaps, is the short belt of magnetic highs **C** north of Grizzly Lake within sedimentary rocks of the Nicola Group (Fig. 4). Portions of the belt have relatively elevated potassium values and coincidental development of local Th/K lows. The Middle Jurassic Ste. Marie pluton includes a distinctive area of Th/K low covering Domain 2 and the southeastern portion of Domain 1, which coincides with elevated K values. However, there is no accompanying prominent magnetic high. Magnetic high **P** is close, but its huge amplitude favours a mafic-ultramafic source. Other magnetic highs deserving investigation for mafic-ultramafic bodies, and possible related mineralization, are **K** and **E**.

Conclusions

The Quesnel airborne geophysical survey has provided important magnetic images that help enhance knowledge of the geology in an area where ubiquitous glacial cover obscures many of the details. This knowledge relates to a better understanding of internal variations (compositional/lithological) within geologically mapped units, and of the structural fabric of the area. The net result is provision of a more rigorous geological framework that should contribute to exploration strategies. The knowledge gained from the magnetic data may be further enhanced by integration with radiometric data obtained in the same geophysical survey. Discussion of the latter has been limited in this report, because of the emphasis on magnetic data. A few potential exploration targets have been suggested on the basis of the new data, but in the case of porphyry-type targets one or other of the geophysical signatures may be weak or lacking. Some prominent magnetic highs hold more promise for the presence of mafic-ultramafic intrusions.

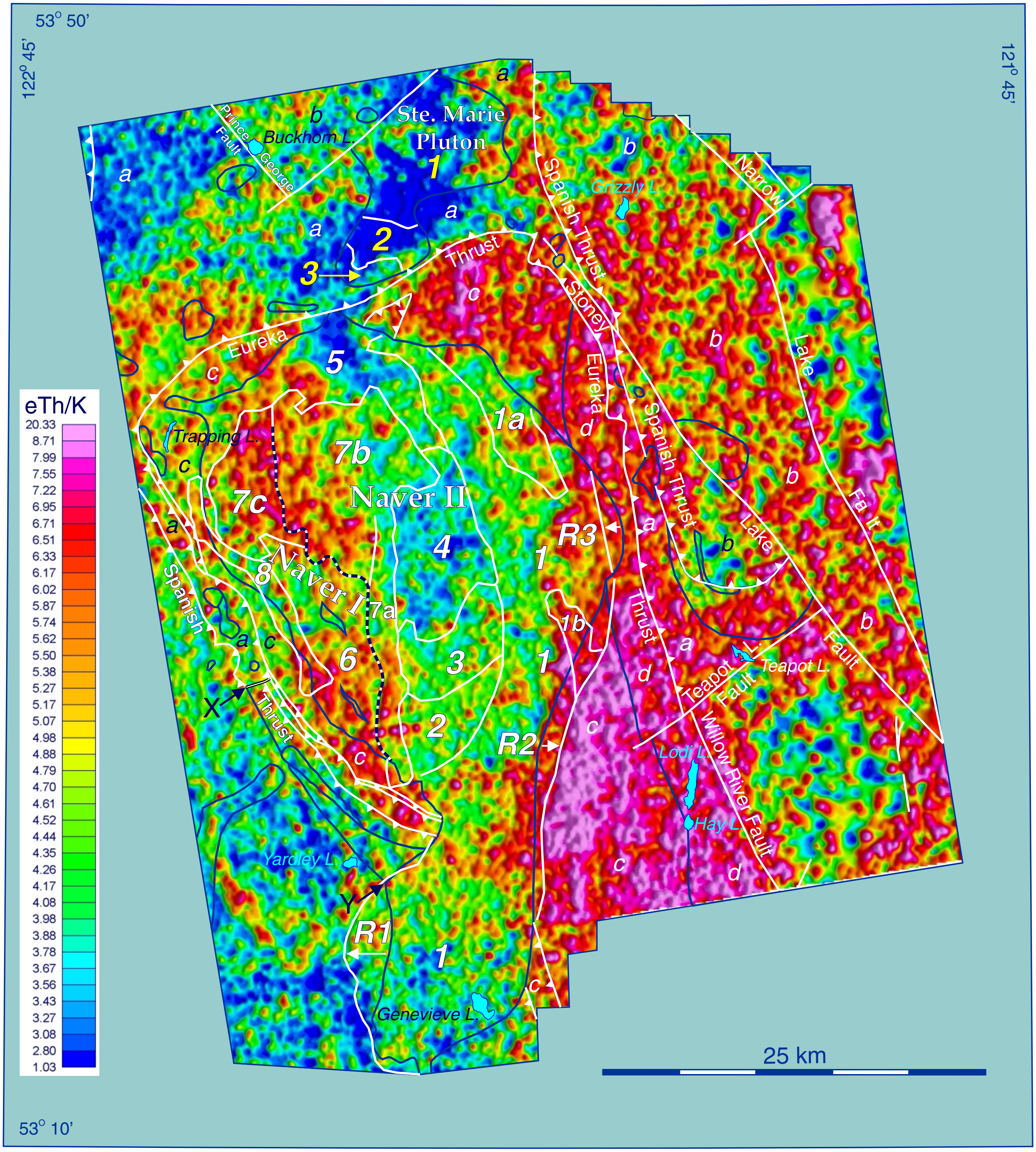

Figure 11: Shaded image of a map of the equivalent thorium/potassium ratio in the Quesnel survey area with geological contacts (navy lines) and faults (white lines; thrust faults have triangles on hanging wall). Domains of the Naver and Ste. Marie plutons based on magnetic signatures are indicated by numbers, subdomains have added lower case letters. Boundaries between domains are drawn as white lines. R1, R2 and R3 indicate proposed changes in position of boundary of Naver pluton, from position marked with navy line to position marked by white line

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http://www.em.gov.bc.ca/Mining/Geolsurv/MapPlace/default.htm

Natural Resources Canada's Geoscience Data Repository: a collection of Earth Sciences Sector geoscience databases and information.
http://gdr.nrcan.gc.ca/index_e.php