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Geological Significance of New Aeromagnetic Data from the Kamloops Survey Area (Portions of NTS 92I (Ashcroft) and 82L (Vernon)), 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 centred approximately on Kamloops, British Columbia was completed in July 2008. It is identified as the "Kamloops survey". The area falls mainly in the northeastern corner of NTS map sheet 92I (Ashcroft) and a smaller adjacent portion of the northwestern corner of NTS sheet 82L (Vernon). Its northern boundary is coincident with the southern boundary of a high resolution aeromagnetic/radiometric survey completed as part of the Targeted Geoscience Initiative III in 2006, covering much of the eastern two-thirds of NTS sheet 92P (Bonaparte Lake), and a very small area of NTS sheet 93A (Quesnel Lake) to the north. The Kamloops survey was flown at 400 m line spacing and 125 m mean terrain clearance.

This report focuses on relationships between geology and the magnetic field, providing comment on the significance of relationships, and interpretation of specific magnetic anomalies and patterns. Radiometric data are not systematically analyzed. All magnetic and radiometric data, 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

Geological Setting of the Area

The geological setting of the survey area is shown in Figure 1, which covers the area itself and a bordering area to provide a regional context. A legend for the geology is provided as Figure 2. The geology in Figure 1, and in other figures in this report, is based on the geological map of British Columbia accessed on the MapPlace website* (http://www.em.gov.bc.ca/Mining/Geolsurv/MapPlace/) maintained by the British Columbia Geological Survey. This map provides a uniform picture of the geology of the area, and most descriptions of geology are with respect to this map. Some descriptions relating to more detailed mapping in certain areas are appropriately referenced. A geological map corresponding to the survey area itself is provided in Figure 3, which includes locations of mineral occurrences and names of some faults.

Most geological units in the region lie within the morphogeological Intermontane Belt ("superterrane") of the Canadian Cordillera, an orogen-parallel structural depression extending for almost 2000 km and attaining about 300 km in width (Gabrielse et al., 1991, Figure 2.1). It includes accreted marine and non-marine volcanic and sedimentary rocks and intrusive rocks that are in parts coeval with some of the volcanic rocks. The Quesnel Terrane stretches along the eastern side of the belt and underlies most of the study area, whereas the related Slide Mountain and Cache Creek terranes are not represented. The Quesnel Terrane is dominated by Upper Triassic to Early Jurassic sedimentary and volcanic rocks of the Nicola Group, Devonian to Triassic sedimentary rocks of the Harper Ranch Group and mixed sequences of Harper Ranch and Nicola (?) groups. The latter map unit, which includes the Harper Ranch Group and possibly the Nicola Group, is henceforth referred to more simply as the Harper Ranch-(?)Nicola Group. The terrane is intruded by a variety of Late Triassic to Early Jurassic granitoid rocks.

A minor portion of the adjacent Omineca Belt, represented by the Kootenay Terrane, occurs along the eastern margin of the study area. This belt displays a high level of regional metamorphism and intrusive activity as a result of its position as a suture between North American rocks of the Cordilleran miogeocline and accreted rocks of the Intermontane Belt. The Kootenay Terrane includes a variety of

* The website is a portal to extensive information on the geology and mineral occurrences of British Columbia, among other information. The two internal links used extensively for information used in this report are: 1) Main Maps, and 2) Site Map for MINFILE, the first for geological information, and the second mainly for information on mineral occurrences. Reference to such information is achieved using MapPlace and MINFILE, respectively.

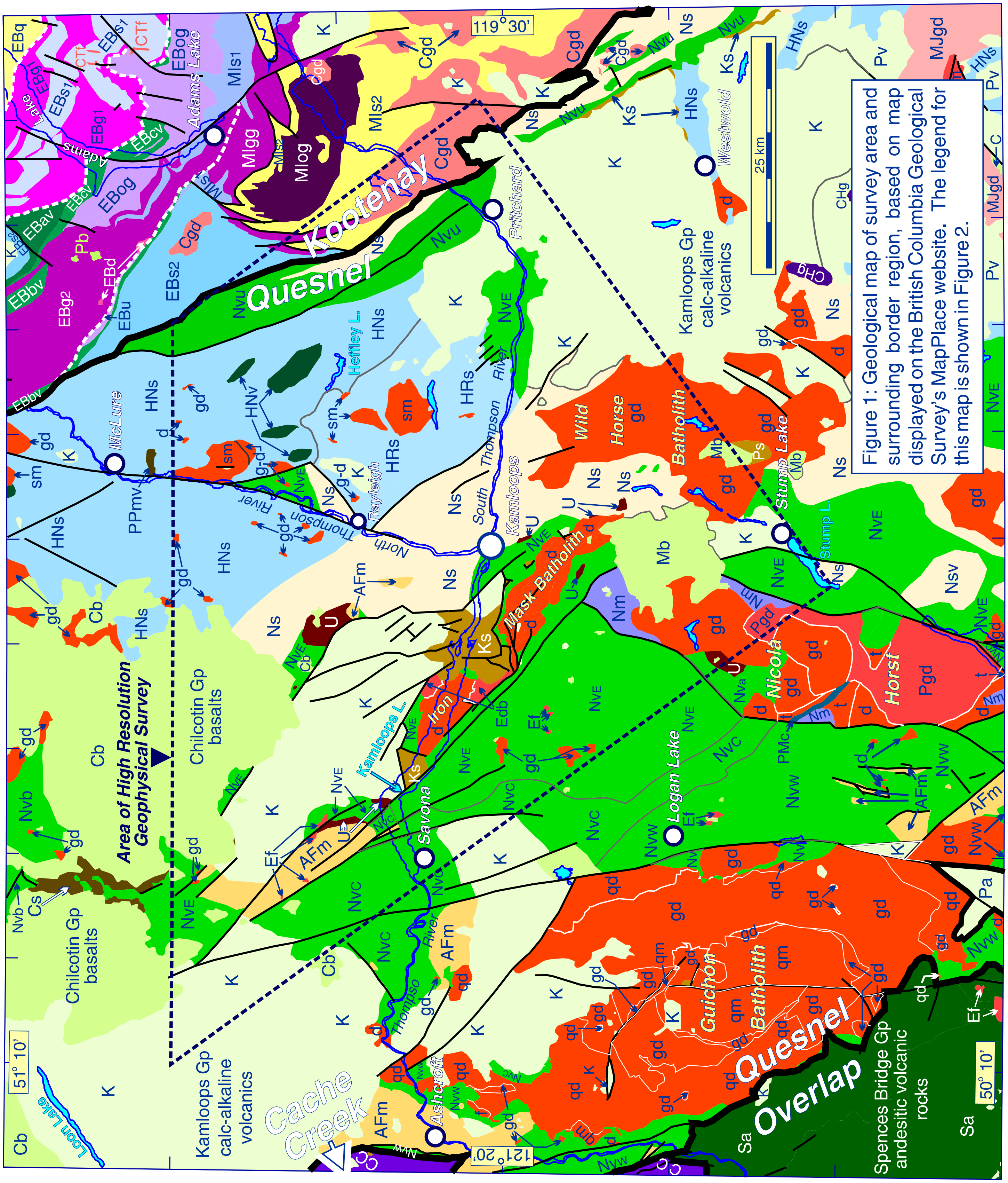


Figure 1: Geological map of survey area and surrounding border region, based on map displayed on the British Columbia Geological Survey's MapPlace website. The legend for this map is shown in Figure 2.

Figure 1

Geological Legend

Pleistocene - Holocene
H alkaline volcanic rocks

Pleistocene
Pb basaltic volcanic rocks

Pliocene - Pleistocene
PPmv marine sedimentary and volcanic rocks

Miocene - Pleistocene
Cb Chilcotin Group, basaltic volcanic rocks
Cs Chilcotin Group, coarse sedimentary rocks

Miocene
Mb basaltic volcanic rocks

Eocene
K Kamloops Group, undivided volcanic rocks
Ks Kamloops Group, sedimentary rocks
Pa Princeton Group, andesitic volcanic rocks
Ps Princeton Group, sedimentary rocks
Pv Penticton Group, undivided volcanic rocks
Ef felspar porphyritic intrusive rocks
Esm syenitic to monzonitic intrusive rocks
Edb Battle Bluff Complex, diabase, intrusive basaltic rocks

Paleocene
Pgd granodioritic intrusive rocks

Cretaceous - Tertiary
CTf quartz phyric, felsitic intrusive rocks

Cretaceous
Cgd granodioritic rocks

Lower Cretaceous
Sa Spences Bridge Gp., andesitic volcanic rocks

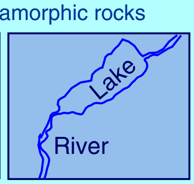
Middle Jurassic
MJgd granodioritic rocks

Lower Jurassic - Middle Jurassic
As Ashcroft Formation, sedimentary rocks

Late Triassic - Early Jurassic
U ultramafic rocks
d dioritic intrusive rocks
f quartz phyric felsitic intrusive rocks
gd granodioritic intrusive rocks
g-d gabbroic to dioritic intrusive rocks
qm quartz monzonitic intrusive rocks
sm syenitic to monzonitic intrusive rocks
t tonalitic intrusive rocks

Upper Triassic - Early Jurassic
Nvu Nicola Group, undivided volcanic rocks

Upper Triassic
Nva Nicola Group, andesitic volcanic rocks
Nvb Nicola Group, basaltic volcanic rocks
NvC Nicola Gp. (Central facies), andesitic volc. rocks
NvE Nicola Gp. (Eastern facies), basaltic volc. rocks
NvW Nicola Gp. (Western facies), undivided volc. rocks
Ns Nicola Gp., fine-grained sedimentary rocks
Nsv Nicola Gp., marine sedimentary and volc. rocks
Nm Nicola Group, metamorphic rocks



Pennsylvanian - Upper Triassic
CC Cache Creek Complex, serpentinite ultramafic rocks

Devonian - Triassic
HNv Harper Ranch & (?) Nicola groups, basaltic volcanic rocks
HNs Harper Ranch & (?) Nicola groups, mudstone, siltstone, shale, fine clastic sedimentary rocks

Devonian - Permian
HRs Harper Ranch Group, mudstone, siltstone, shale, fine clastic sedimentary rocks

Permian
CHg Chapperon Group, greenschist, greenstone metamorphic rocks

Paleozoic - Mesozoic
PMc conglomerate, coarse clastic sedimentary rocks

Mississippian
EBs2 Eagle Bay Assemblage (Slate Creek Unit), mudstone, siltstone, shale, fine clastic sedimentary rocks

Devonian - Mississippian
EBav Eagle Bay Assemblage (Foghorn Mountain Unit), andesitic volcanic rocks

Devonian
EBbv Eagle Bay Assemblage (Dixon Ridge Unit), basaltic volcanic rocks
EBcv Eagle Bay Assemblage (Skwaam Bay Unit), calc-alkaline volcanic rocks
EBd Eagle Bay Assemblage, dioritic intrusive rocks
EBu Eagle Bay Assemblage, serpentinite ultramafic rocks
EBog Eagle Bay Assemblage, orthogneiss metamorphic rocks

Lower Palaeozoic
EBg2 Eagle Bay Assemblage (Forest Lake Unit), greenstone, greenschist metamorphic rocks
MIs1 Mount Ida Assemblage (Sicamous Fm.), mudstone, siltstone, shale, fine clastic sedimentary rocks
MIgg Mount Ida Assemblage, greenstone, greenschist metamorphic rocks

Ordovician
MIog Mount Ida Assemblage, Little Shuswap Orthogneiss, orthogneiss metamorphic rocks

Lower Cambrian
EBs1 Eagle Bay Assemblage, limestone, slate, marble, calcareous & fine clastic sedimentary rocks, siltstone, argillite, mudstone, shale
EBg1 Eagle Bay Assemblage (Johnson Lake Unit), greenstone, greenschist metamorphic rocks

Upper Proterozoic - Palaeozoic
MIs2 Mount Ida Assemblage (Silver Creek Formation), mudstone, siltstone, shale, fine sedimentary rocks

Upper Proterozoic - Lower Cambrian
EBq Eagle Bay Assemblage (Graffunder Lakes Unit), quartzite, quartz arenite sedimentary rocks

Gp. = Group
Fm. = Formation

Note: Abbreviations for units are designated by the author, and are not those used on the MapPlace web site.

Figure 2: Geological legend for Figure 1.

Figure 2

Figure 3

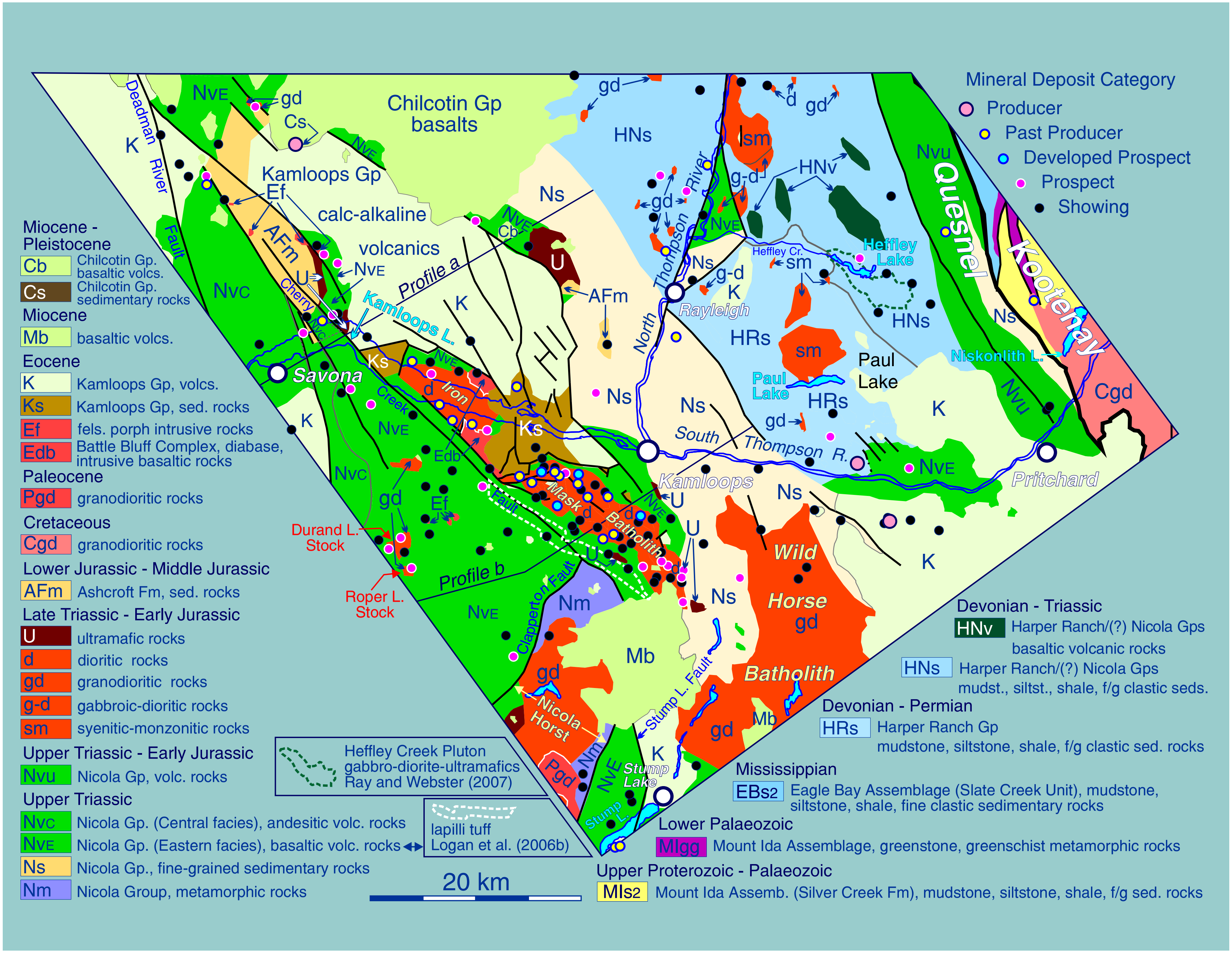


Figure 3: Geological map of survey area based on map displayed on the British Columbia Geological Survey's MapPlace website. Locations of categorized mineral occurrences and Profiles 'a' and 'b' shown in Figure 11 are plotted.

sedimentary, volcanic, metamorphic and intrusive rocks belonging mainly to the Proterozoic-Palaeozoic Mount Ida Assemblage and Eagle Bay Assemblage, and Cretaceous granodioritic rocks.

Various geological elements designated as terranes on the MapPlace website transgress boundaries of other terranes or of morphogeological belts. Their characterization as terranes is, therefore, debatable as they lack many of the fundamental features required of terranes. They are all younger in age than mid-Jurassic accretionary processes of the Cordillera orogen, hence their distribution across tectonic boundaries. Overlap assemblages ("Overlap Terrane from MapPlace") in the region consist of continental arc sequence volcanic and sedimentary rocks of the lower Cretaceous Spences Bridge Group and undivided volcanic rocks of the Eocene Kamloops Group (Fig. 1). Similarly, basaltic volcanic rocks of the Miocene-Pleistocene Chilcotin Group and an unnamed unit of Miocene basaltic volcanic rocks ("Younger Volcanics Terrane from MapPlace") are found flooding the region and covering older rock units. Numerous post-accretionary intrusive bodies ("Post Accretionary Terrane from MapPlace") are represented by Paleocene and Cretaceous granodioritic rocks.

Surficial Geology of the Survey Area

Surficial geology maps published by Fulton (1975) cover the entire survey area, apart from the small segment west of 121^{o}W, and cover also the bordering region to the south, southeast and east. These indicate that approximately 50% of the survey area is covered by overburden of mainly glacial origin. Most of the overburden is categorized as nonstratified drift in the form of morainal deposits composed mainly of till. This drift unit occurs as a locally discontinuous sheet up to 3 m thick in upland* areas and on slopes, and as a more continuous sheet in midland areas having an average maximum thickness of about 4.5 m. These areas essentially cover the ground outside valleys. The other 50% or so of the area is mapped as "rock outcrop and areas of near-surface rock", a unit that is somewhat more prevalent along Kamloops Lake and the North and South Thompson rivers. It is described as "where rock was judged to be mostly less than 3 feet (1 m) below the surface" (Fulton, 1975). Thus even within areas of this unit bedrock could be largely hidden.

Other types of surficial deposits occupy limited areas. Noteworthy are glaciation-related lacustrine deposits found mainly along the South Thompson River and Heffley Creek, and modern alluvium and fan deposits along the North Thompson and South Thompson rivers. Specific thicknesses for lacustrine deposits within the survey area are not provided, but one of the thickest developments was noted along the South Thompson River between Kamloops and Pritchard (Fulton, 1975). Within the entire area documented by Fulton (1975), lacustrine deposit thicknesses range from less than 1 m to more than 90 m, modern alluvium floodplain deposits are generally less than 15 m thick and delta thicknesses are 50 m or more. The Thompson River delta at the east end of Kamloops Lake is a major delta. Fan deposits can be extensive, but most are less than 9 m thick. The thicknesses observed by Fulton (1975) for the various deposits and physiographic regions are characteristic of many parts of the Cordillera (Travis Ferbey, personal communication, 2010).

The main problem of surficial deposits for geological mapping is their distribution, which is ubiquitous in many regions of the Cordillera. The aeromagnetic method is able to penetrate this surficial veneer, outline patterns of magnetic anomalies and thereby provide critical insight into underlying bedrock geology.

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* "Upland" is defined as a block of hills and plateaus generally bounded by large valleys; "Midland" is intermediate between upland and valley, though apparently more closely related to upland, occurring as either benches along major valleys or broad basin-like areas perched above valleys.

Bedrock Geology of the Survey Area

Quesnel Terrane: Within the survey area (Fig. 3) the Quesnel Terrane is dominated by Upper Triassic to Early Jurassic sedimentary and volcanic rocks of the Nicola Group intruded by a variety of Late Triassic to Early Jurassic granitoid rocks southwest of a northwest-trending line passing near Rayleigh, and by Devonian to Triassic sedimentary rocks of the Harper Ranch Group and Harper Ranch-(?)Nicola Group northeast of the line. Large areas of Tertiary volcanic cover represented by the Kamloops and Chilcotin groups are also present.

Chilcotin Group Basaltic Volcanic Rocks: A large area of Miocene-Pleistocene Chilcotin Group basaltic volcanic rocks is mapped along the northern boundary of the area (Fig. 3), at the southern margin of an extensive area of these rocks covering more than 30,000 square kilometres (Andrews and Russell, 2008). The rocks are typically flat to gently dipping and < 50 m thick across most of their distribution (Andrews and Russell, 2008).

Kamloops Group Volcanic Rocks: Significant areas of Eocene Kamloops Group volcanic rocks are present northeast of Savona and west of Pritchard (Fig. 3). Ewing (1981) reported thicknesses greater than 1000 m near Kamloops, and common occurrences of flat lying basaltic andesite flows about 600 m thick elsewhere. Near Kamloops the group comprises the older volcano-sedimentary Tranquille Formation (up to 450 m thick) and younger volcanic Dewdrop Flats Formation (Ewing, 1981), which is > 1000 m thick. According to the MapPlace geological map the Tranquille Formation (Ks in Fig. 3) is composed of sedimentary rocks.

Nicola Group Volcanic and Volcaniclastic Rocks: The largest development of volcanic rocks of the Nicola Group is along the western margin of the survey area from where it extends west and southwest, eventually making contact with much of the eastern margin of the Guichon batholith (Fig. 1). It is limited to the northwest by calc-alkaline volcanic rocks of the Kamloops Group, to the southeast by the granitoid-cored Nicola horst, and along its eastern margin it envelopes almost completely the Iron Mask batholith. Nicola Group volcanic rocks are present also along the eastern boundary of the Quesnel Terrane forming an extensive north-northwest-trending belt. Smaller units of the group are found southeast of the Nicola horst, near Stump Lake, along the eastern side of the Iron Mask batholith, along the South Thompson River, and in various localities in the northern part of the area.

Nicola Group volcanic rocks in this part of central British Columbia, including volcanic rocks between the Iron Mask and Guichon batholiths, west of the Guichon batholith and east of the Iron Mask batholith (Fig. 1) have been divided into three belts (or facies) on the basis of their distinct facies and assemblages, following their recognition by Preto (1979): (1) a western belt consisting predominantly of subaqueous felsic, intermediate and mafic volcanic rocks of calcalkalic affinity that grade upward into volcaniclastic rocks, (2) a central belt that includes alkalic and calcalkalic subaqueous and subaerial basalt and andesite flows, volcanic breccias and lahars, and (3) an eastern belt comprised predominantly of subaqueous and subaerial alkalic intermediate and mafic volcanic flows, fragmental and epiclastic rocks (Owsiaki, 2003). These three facies are labelled NVW, NVC and NVE, respectively (Figs. 1, 3). Only the central and eastern facies are represented in the survey area. The eastern facies is widespread, but the central facies is restricted to the northwestern part of the area near Savona. The belt of Nicola Group volcanic rocks along the eastern margin of the area is designated as undivided volcanic rocks (NVU) (MapPlace).

Nicola Group Sedimentary Rocks: The main area of Nicola Group sedimentary rocks is represented by a partially fault-bounded, northwest-trending belt in the central part of the survey area between Rayleigh and Kamloops (Fig. 3). Smaller units are present just east of Rayleigh, and along the boundary with the Kootenay Terrane. The central belt disappears under a cover of Chilcotin Group basaltic volcanic rocks to the northwest, and is terminated mainly by the Wild Horse batholith to the southeast, though in places disappears under Eocene (Kamloops Group) and Miocene volcanic rocks. Monger and McMillan (1989) note that the sedimentary rocks include argillite, sandstone and tuff, and local chert-carbonate-volcanic conglomerate, whereas MapPlace indicates the constituent rock types to be mudstone, siltstone, shale and fine clastic sedimentary rocks.

Harper Ranch Group and Harper Ranch-(?)Nicola Group Sedimentary Rocks: To the east of the central belt of Nicola Group sedimentary rocks is a much broader belt of sedimentary rocks belonging specifically to the Devonian to Permian Harper Ranch Group, and also to the Harper Ranch Group in possible association with the Nicola Group, for which the indicated age is Devonian to Triassic (MapPlace) (Fig. 3). The Harper Ranch Group is restricted to the southwest portion of this belt between the South Thompson and North Thompson rivers and comprises argillite, cherty argillite, siltstone, volcanic and chert grain sandstone; chert pebble conglomerate; felsic to mafic volcaniclastic rocks, and minor carbonate (Monger and McMillan, 1989). MapPlace lists included rock types to be the same as in the Nicola Group, which are also the same for the more widely distributed Harper Ranch-(?)Nicola Group. Monger and McMillan (1989) include meta-augite porphyry, argillite, phyllite, volcanic sandstone, semischist and local carbonate in the latter group.

Scattered within the Harper Ranch-(?)Nicola Group sedimentary assemblage north of Heffley Lake are four elongate, northwest to north-northwest-trending units of basaltic volcanic rocks (MapPlace) having the same age and group attribution as the sedimentary assemblage. Monger and McMillan (1989) show these units to contain chlorite schist and meta-augite porphyry.

Ashcroft Formation: Mudstones, shales and fine-grained sedimentary rocks of the Lower-Middle Jurassic Ashcroft Formation form a northwest-trending belt in the northwest corner of the study area (Fig. 3).

Intrusive Rocks: The Quesnel Terrane is punctuated by many intrusions of different ages and dimensions. The earliest intrusions are Late Triassic-Early Jurassic. The largest, the composite Guichon batholith, lies just west of the survey area (Fig. 1) and hosts the producing Highland Valley Copper and Lornex porphyry copper deposits. The largest intrusions within the survey area are the Iron Mask and Wild Horse batholiths and the core of the Nicola horst (Fig. 3). Several smaller yet prominent intrusions are observed in the northeast portion of the area within the region underlain by the Harper Ranch Group and Harper Ranch-(?)Nicola Group. These are granodioritic, syenitic to monzonitic, or gabbroic to dioritic in composition.

The Iron Mask batholith is a relatively narrow, northwest-trending, composite Late Triassic alkaline intrusion (Logan et al., 2006a, b) sitting along the northeastern margin of the principal belt of Nicola Group volcanic rocks. It comprises three main phases: Sugarloaf (porphyritic hornblende diorite), Cherry Creek (biotite monzonite to monzodiorite) and Pothook (biotite pyroxene diorite). Additionally, a large portion of the batholith, the Hybrid unit, is underlain by a unit of hybrid rocks, which are xenolith-rich components of the Sugarloaf and Pothook phases.

The Wild Horse batholith, comprising granodiorite and quartz diorite (Moore and Pettipas, 1990), lies southeast of the Iron Mask batholith, and has an overall north-northeast trend. The north-northeast-trending Nicola horst is bounded by Tertiary faults and surrounded by Nicola Group volcanic rocks (Moore and Pettipas, 1990; Moore, 2000). In the survey area it is cored largely by Late Triassic to Early Jurassic granodiorite, along with a small area of Palaeocene granodioritic rocks. Several relatively small Late Triassic to Early Jurassic ultramafic intrusions are scattered within the western part of the survey area, typically in contact with rocks of the Nicola Group.

The youngest intrusive rocks in the survey area belong to the Eocene Battle Bluff plutonic complex present on either side of the Iron Mask batholith near Kamloops Lake. The component rocks are described as diabase and intrusive basaltic rocks (MapPlace).

Kootenay Terrane: The Kootenay Terrane covers a very small section of the eastern margin of the survey area, about half of which is underlain by Cretaceous granodiorite (Fig. 3). The remainder is underlain by sedimentary and greenstone/greenschist units of the Proterozoic-Palaeozoic Mount Ida

Assemblage and fine-grained sedimentary rocks of the Palaeozoic Eagle Bay Assemblage. Geological strike in all cases is roughly north-northwest.

Faults: Faults are evident throughout the survey area (MapPlace) with most having a northwest to north-northwest orientation. The Deadman River and Cherry Creek faults (Fig. 3) are two that are named on the Ashcroft 1:250,000 scale geological map by Monger and McMillan (1989). A few faults trend predominantly northeast to north-northeast. These include the Clapperton fault bounding the northwestern margin of the Nicola horst, the nearby Stump Lake fault to the east of the horst, and an unnamed fault following the course of the North Thompson River. According to the MapPlace geological map all of these faults are designated as faults with no qualifier, e.g., normal, thrust, etc. Moore and Pettipas (1990) note that the Nicola horst is bounded by steep Tertiary faults, and that the Clapperton fault system appears to be normal.

Mineral Occurrences in the Area

Producers: There are only 3 producing mineral operations in the area, all producing industrial minerals. In the northwest corner of the area the Red Lake deposit yields Fuller's earth and diatomite from a very small occurrence (hidden by the deposit symbol in Fig. 3) of Chilcotin Group sedimentary rocks. In the eastern part of the survey area, the Harper Ranch deposit produces limestone developed within the Harper Ranch Group just north of the South Thompson River, and the Buse deposit south of the river produces volcanic ash, silica and kaolinite from a rhyolite ash tuff within the Kamloops Group.

Past Producers: Past producing deposits are significantly more numerous, a total of 23 being recorded in MapPlace's MINFILE mineral directory. Probably the most important category of mineral deposit is the alkali porphyry category, of which 12 examples were exploited in the survey area. These are, without exception, associated with the alkaline Iron Mask batholith, described as Latest Triassic in age (Logan, 2006 a, b). All of these deposits, with the exception of Cliff and Glen Iron, contained Cu, Au and Ag, and some contained in addition one or more of the following commodities: U, Mo, Pd. These deposits were Maxine, Copper King, Afton, Crescent, Iron Cap, Iron Mask, Galaxy, Python, Ajax East and Ajax West. The Cliff deposit was characterized by Cu, Au, Fe and magnetite, and the Glen Iron deposit by magnetite and iron.

In recent years, one of the more important past producers, Afton, has been explored and assessed for a new phase of production. DeGrace et al. (2008) reported that New Gold Inc. had obtained a Mines Act permit approving a request to construct the New Afton underground mine to access reserves below the open pit that produced from 1977 to 1987. Combined measured and indicated resources in the Main Zone are estimated at 66 million tonnes grading 1.02% Cu, 0.77 g/t Au and 2.59 g/t Ag.

Past gold-producing placer deposits in the survey area number 4, and are all located north of the 'line' delineated by Kamloops Lake and the South Thompson River. There are 3 polymetallic vein deposits. The Joshua and Enterprise deposits lie close to the southern boundary of the survey area near Stump Lake, hosted by Nicola Group sedimentary rocks (Fig. 3). The MINFILE description of the host rocks in this specific locale notes the additional presence of “intermediate volcanics” and “volcaniclastics”, and comments “These greenstones consist of massive, chlorite-epidote altered andesite and basalt, augite porphyry, andesitic flow breccia and tuff, and minor interbedded argillite, conglomerate and limestone.” Alteration and mineralization apparently is controlled by numerous small faults forming a complex fracture pattern. The Joshua and Enterprise deposits are categorized as Ag-Pb-Zn ± Au polymetallic veins; Cu was also present in both, and W in Joshua. On the eastern margin of the area, the FS deposit is a polymetallic vein deposit (Ag-Pb-Zn ± Au) situated on a Cretaceous granodiorite within the Kootenay Terrane (MapPlace). MINFILE reports that mineralization is hosted in quartz veining apparently within a fault zone near the contact between rocks of the Silver Creek Formation (Mount Ida

Assemblage) and the Cretaceous (?) granite. Other past producers have been worked for limestone, sodium carbonate/sulphate and mercury.

Developed Prospects: There are only 4 developed prospects in the survey area, all alkali porphyry Cu-Au type and all located within the Iron Mask batholith. The DM developed prospect contains Cu and Au, as does the Big Onion and Kimberly prospects which also include Ag. Rainbow contains the preceding commodities as well as Mo and Pd.

Prospects: Prospects, totalling 31, though scattered throughout the area, are concentrated mainly in the western half where the vast majority are associated with the Iron Mask batholith or volcanic rocks of the Nicola Group, and typically those of the eastern facies.

Those prospects within the Iron Mask batholith are generally alkali porphyry Cu-Au occurrences. The Admiral Dewey and Grey Mask prospects also contain Ag, and the Phil prospect contains Pd. Also within the confines of the Iron Mask batholith are 2 prospects of playa and alkaline lake evaporite type. The Ironmask Lake prospect contains sodium and magnesium sulphate, and the Cedars prospect contains sodium sulphate. The latter, though plotting on the batholith (MapPlace), is reported to lie in a southeast trending basin on a faulted contact between the batholith and volcanic rocks and mafic sills of the Eocene Kamloops Group (MINFILE).

West of the Iron Mask batholith within the eastern volcanic facies of the Nicola Group and/or included intrusions are 7 prospects classified as epithermal Au-Ag-Cu (Pat Lake, Newmont), alkali porphyry Cu-Au (Rag, Rabbit, Ned) or porphyry molybdenum (Roper Lake); the Walloper prospect includes both epithermal Au-Ag-Cu and polymetallic veins hosting Ag-Pb-Zn ± Au. Intrusions of one kind or another are observed at most of these properties. The Rag and Rabbit prospects are associated with the Triassic diorite-monzonite Durand Lake stock. Mineralization is present within the intrusion and the marginal volcanic rocks of the Nicola Group. The Roper Lake prospect is underlain by the Tertiary(?) zoned quartz monzonite Roper Lake stock. Here, mineralization is widely distributed within the stock and present in the peripheral areas of the intruded Nicola Group volcanic rocks (MINFILE). The Walloper prospect is associated with a Triassic intrusion varying in composition from gabbro to diorite to monzonite to monzonite-diorite breccia, and mineralization, apparently, is concentrated in the contact zone between the intrusion and Nicola Group volcanic rocks. The antimony-bearing Pat Lake prospect has been linked to high-level quartz eye porphyry intrusions. At the nearby property of the Newmont prospect, many late Cretaceous(?) or early Tertiary(?) discordant felsic dikes, some with quartz-eye phenocrysts, have been observed, bordered by replacement zones anomalous in As, Sb, Au and Ag.

North of the western end of Kamloops Lake, and located near major northwest-trending faults are 4 hot spring Hg prospects: Sharp Mercury, Sabiston Flats, Hardie Mountain and Hardie Hill. All are underlain by volcanic rocks of the Nicola Group (central or eastern facies), with accompanying sedimentary rocks in two cases. Intrusions are reported from 3 of the properties. At Hardie Mountain the Nicola group is intruded by fine grained felsites including feldspar porphyry and associated dikes. Disseminated cinnabar is noted within and marginal to brecciated shear zones within or closely associated with the porphyry intrusions and particularly the dikes (MINFILE). Fine grained felsites including feldspar porphyry and associated dikes are also present at the Hardie Hill property, while at Sharp Mercury Cretaceous or Tertiary felsic stocks intrude the Nicola Group.

There are few prospects in the eastern half of the survey area. All are vein-type deposits, with the exception of the Heff magnetite skarn prospect near Heffley Lake. The prospect is located within the Harper Ranch-(?)Nicola Group comprising mainly argillites and calcareous siltstones, lesser andesitic ash and lapilli tuff, and some limestone. The skarn may have formed by infiltration of hydrothermal fluids from the mafic-ultramafic Heffley Creek pluton, a probable Alaskan-type intrusion immediately south of the prospect, much of which underlies most of Heffley Lake (MINFILE No. 092INE096).

Further details of the geology and mineralization in the area of the prospect are provided by Ray and Webster (2000, 2007).

North of Rayleigh, within the Harper Ranch-(?)Nicola Group, are the Bear Cat and Homestake polymetallic veins, both of Ag-Pb-Zn ± Au type; Cu is an additional commodity listed for Bear Cat. At Bear Cat mineralization is associated with a quartz vein and consists of sparse pyrite, chalcopyrite, sphalerite and galena. The wall rocks are highly contorted limy phyllites and graphitic and sericitic schists, intruded by porphyry dikes and sills varying in composition from diorite to feldspar porphyry to more felsic types. On the Homestake property a highly fractured porphyritic quartz monzonite intrudes biotite and sericite schist and argillite belonging to the Harper Ranch-(?)Nicola Group. Mineralization is associated with a zone of shearing, which is well defined in the quartz monzonite intrusion and contains quartz veins and branching stringers. The veins traverse the quartz monzonite and the metasedimentary rocks, and are mineralized with scattered grains of pyrite, galena, arsenopyrite and sphalerite.

The Riverside prospect between Paul Lake and the South Thompson River is another polymetallic vein occurrence of Ag-Pb-Zn ± Au type containing also Cu. Mineralization is associated with a chert breccia within a broad shear zone cutting the Harper Ranch Group, and is found within quartz veins and stringers. Pyrite and minor amounts of chalcopyrite, galena, tetrahedrite, malachite and azurite are reported.

Approximately 8 km east-southeast of the Riverside prospect is the Pooley Lake epithermal Au-Ag (with Cu) prospect located within the eastern volcanic facies of the Nicola Group, which is cut by feldspar porphyritic syenodiorite and diorite dikes. Significant brittle fracturing is associated with faulting, occurring as well defined single fractures, zones of multiple fractures, breccia zones and areas of pervasive weak brecciation with gradational boundaries. Three dominant fracture orientations control veining and alteration. Mineralization is hosted by quartz-carbonate veins. Some higher gold values are assayed from veins exhibiting a close spatial relationship with intrusive dikes having a similar trend.

Showings: Showings number 99, and though significantly more numerous than prospects, have a broadly similar distribution to prospects across the survey area. Again there are concentrations within the Iron Mask batholith and the volcanic facies of the Nicola Group west of the batholith. There are, however, considerably more occurrences in the eastern half of the area, particularly within areas covered by the Harper Ranch Group and Harper Ranch-(?)Nicola Group. There are also showings within the Wild Horse batholith and volcanic rocks of the Kamloops Group.

In a general sense, the categories of deposit type are similar to those of the prospects, and have a similar distribution. For example, hot spring mercury showings are concentrated in the northwestern corner of the area, alkali porphyry Cu-Au showings are found in the Iron Mask batholith and in the Nicola Group volcanic facies west of the batholith, and polymetallic vein showings are scattered within the sedimentary terrain of the Harper Ranch Group and Harper Ranch-(?)Nicola Group in the eastern half of the area. In addition, showings of playa-alkaline lake evaporites (hydromagnesite, sodium carbonate) are present within the area of Kamloops Group volcanic rocks east of the Wild Horse batholith, and within the boundaries of the batholith itself. An interesting showing within the Wild Horse batholith is the Vicars Pass development of surficial uranium, present within a 3 m thick layer of surficial sediments.

There are showings of other deposit types also, such as bentonite, diatomite, fireclay, epithermal and hot spring Au-Ag, porphyry Cu±Mo±Au, Fe skarn, and Besshi massive sulphide Cu-Zn. Details of all of these showings can be found on the MapPlace website.

Magnetic Field in the Survey Area

Introduction: The magnetic field of the survey area is displayed in images of the residual total magnetic field (Figs. 4, 5, 6), and first and second vertical derivatives of the total magnetic field (Figs. 7 and 8, respectively). All magnetic images are shaded by a simulated light source to enhance features of the magnetic field. Comparison of the images reveals an apparent variation in the amount of portrayed detail. The image of the residual total magnetic field image, seemingly, is least detailed, and the second vertical derivative most detailed. However, every image plays an important role in understanding the geology. The total magnetic field image is critical, because it indicates the relative intensity of the magnetic field, highlighting areas underlain by strongly or weakly magnetized rock units. The vertical derivative images of the magnetic field represent essentially filtered versions of the residual total magnetic field, in which shorter wavelength features are emphasized at the expense of longer wavelengths, which are effectively eliminated. These images resolve the finer scale elements of the magnetic field related to individual geological features, and the observed patterns typically reflect finer details of the structural fabrics within a region.

A total magnetic field image may display an area of strongly positive magnetic anomaly over a granitic intrusion, for example, characterized by several perturbations or culminations indicative of magnetic heterogeneity within the intrusion. A first vertical derivative (= vertical gradient) image will resolve the perturbations and culminations into individual magnetic features that may then be interpreted in terms of individual intrusive phases, dikes, faults, etc. The second vertical derivative can be likened to a "fine tuning" of the first vertical derivative, providing even more resolution and delineating some of the most detailed features of the magnetic field. A property of first vertical derivative maps of particular relevance to geological mapping is that theoretically the zero value contour coincides with contacts between rock units having contrasting magnetizations (Hood and Teskey, 1989). This property is contingent on both the contact and the inclination of the Earth's magnetic field being steep, i.e. it is most effective at high magnetic latitudes. Considering the inclination in the survey area is about 72°, the zero contour should provide a reasonable 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. Relative magnitudes of highs may, however, be easily distinguished on a 3D image of the magnetic field, such as those portrayed in Figures 5 and 6.

A characteristic of most total magnetic field images in Canada 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, 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 negative anomaly, which is weaker because of increased distance to the measuring magnetometer. The Earth's magnetic field is inclined (dips steeply northward in Canada), resulting in horizontal displacement of the lower pole from the upper pole in the direction of the north magnetic pole. Thus induced anomalies typically take 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 images of the total magnetic field, have geological contacts and faults as displayed in Figure 3 superposed to provide a geological reference framework.

Gravity data are used in this study in an auxiliary manner and are presented in the images of the Bouguer gravity anomaly (Fig. 9) and of the first vertical derivative of the Bouguer anomaly (Fig. 10). Gravity station spacing is generally quite wide, an approximate average being about 8.5 km, although spacing along some roads is as close as 1 km. In spite of the low resolution of the

Figure 4

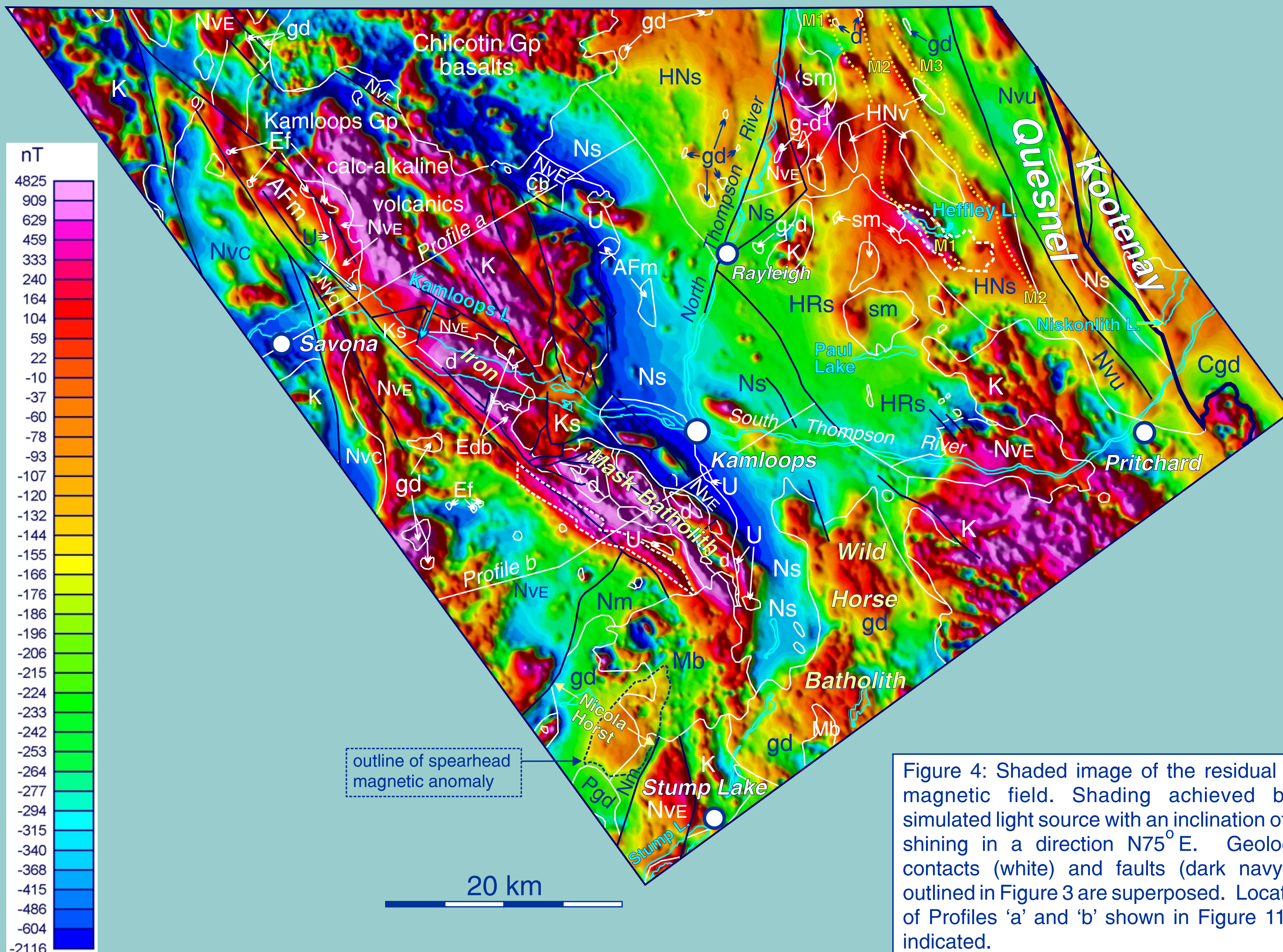


Figure 4: Shaded image of the residual total magnetic field. Shading achieved by a simulated light source with an inclination of 40°, shining in a direction N75° E. Geological contacts (white) and faults (dark navy) as outlined in Figure 3 are superposed. Locations of Profiles 'a' and 'b' shown in Figure 11 are indicated.

Figure 5

3D Image of Total Magnetic Field - Kamloops Survey Area

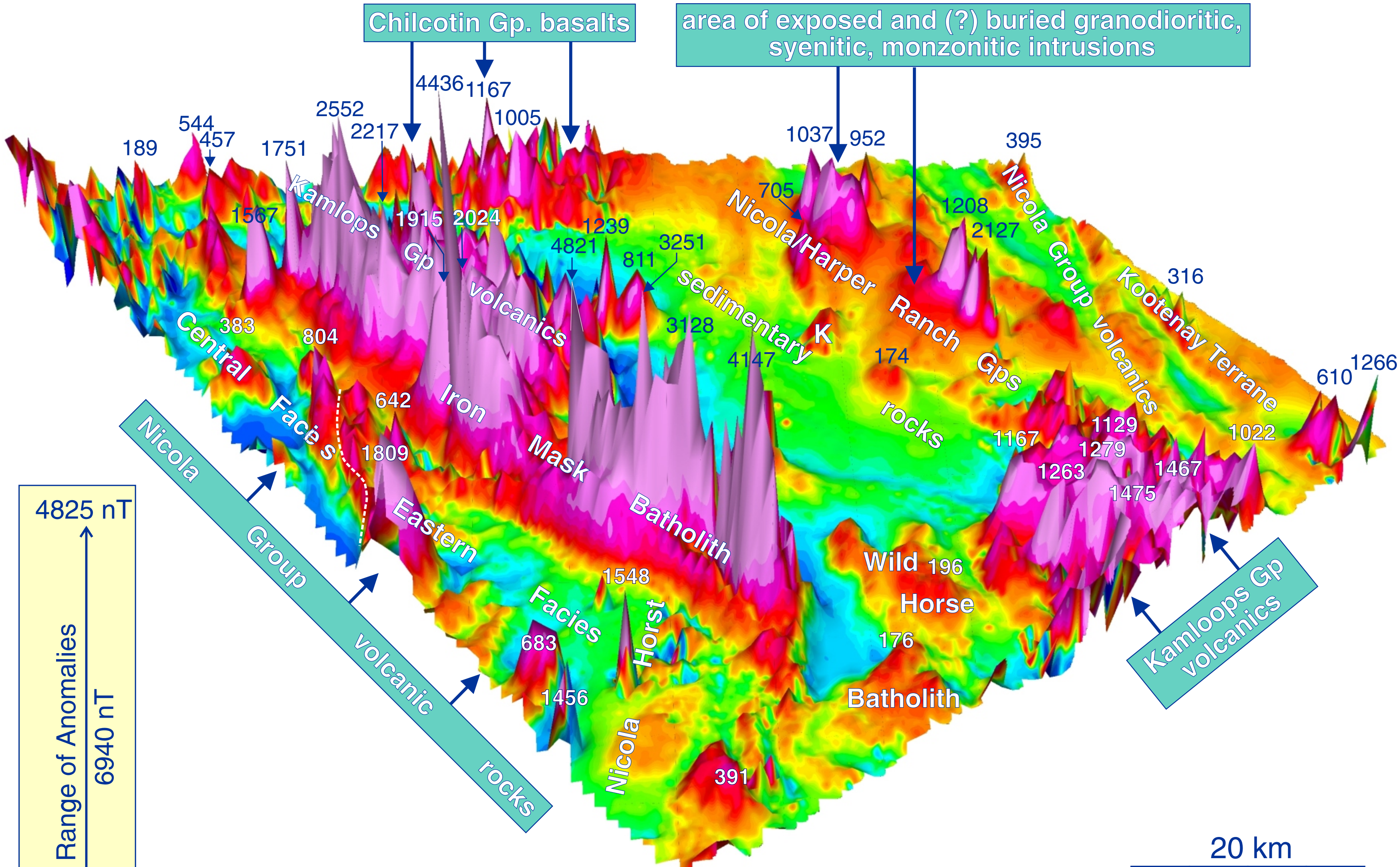


Figure 5: 3D view looking northward of the total magnetic field of the Kamloops survey area displayed in Figure 4. Peak values of certain anomalies are indicated. These values approximate the amplitudes of the anomalies, but are slightly smaller, amplitude being the difference between peak value and local background value of the magnetic field, which varies slightly throughout the area.

Figure 6

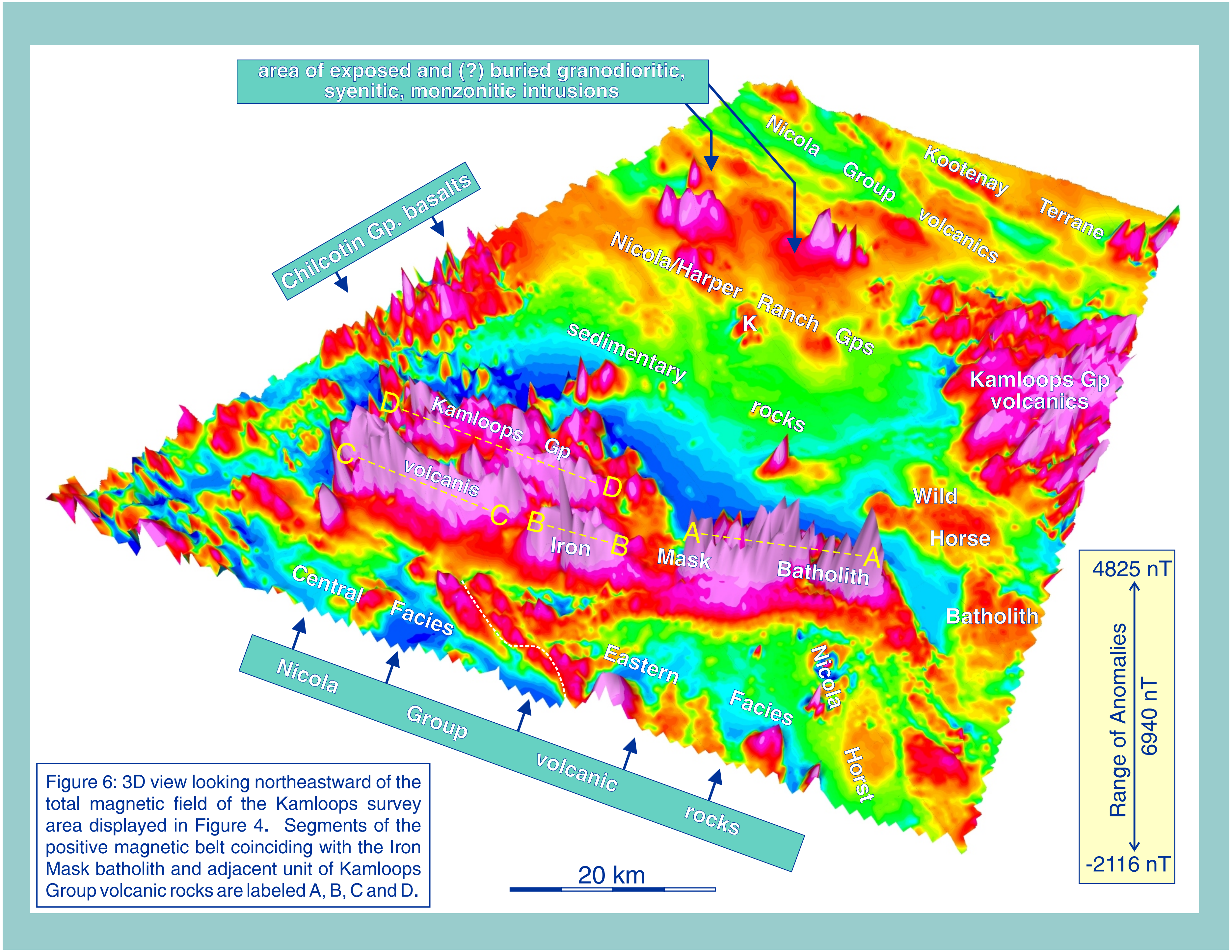


Figure 6: 3D view looking northeastward of the total magnetic field of the Kamloops survey area displayed in Figure 4. Segments of the positive magnetic belt coinciding with the Iron Mask batholith and adjacent unit of Kamloops Group volcanic rocks are labeled A, B, C and D.

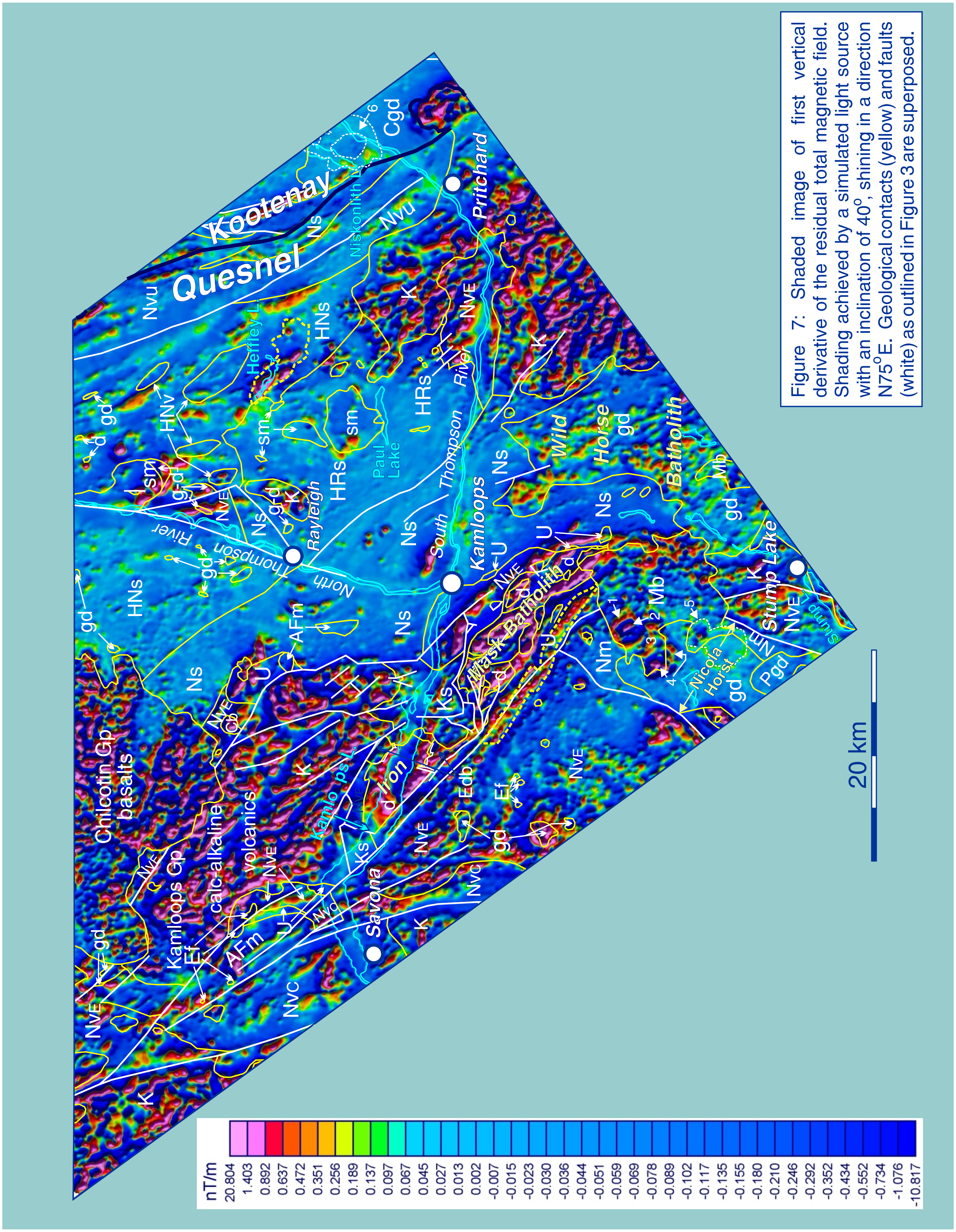


Figure 7: Shaded image of first vertical derivative of the residual total magnetic field. Shading achieved by a simulated light source with an inclination of 40°, shining in a direction N75°E. Geological contacts (yellow) and faults (white) as outlined in Figure 3 are superposed.

Figure 7

Figure 8

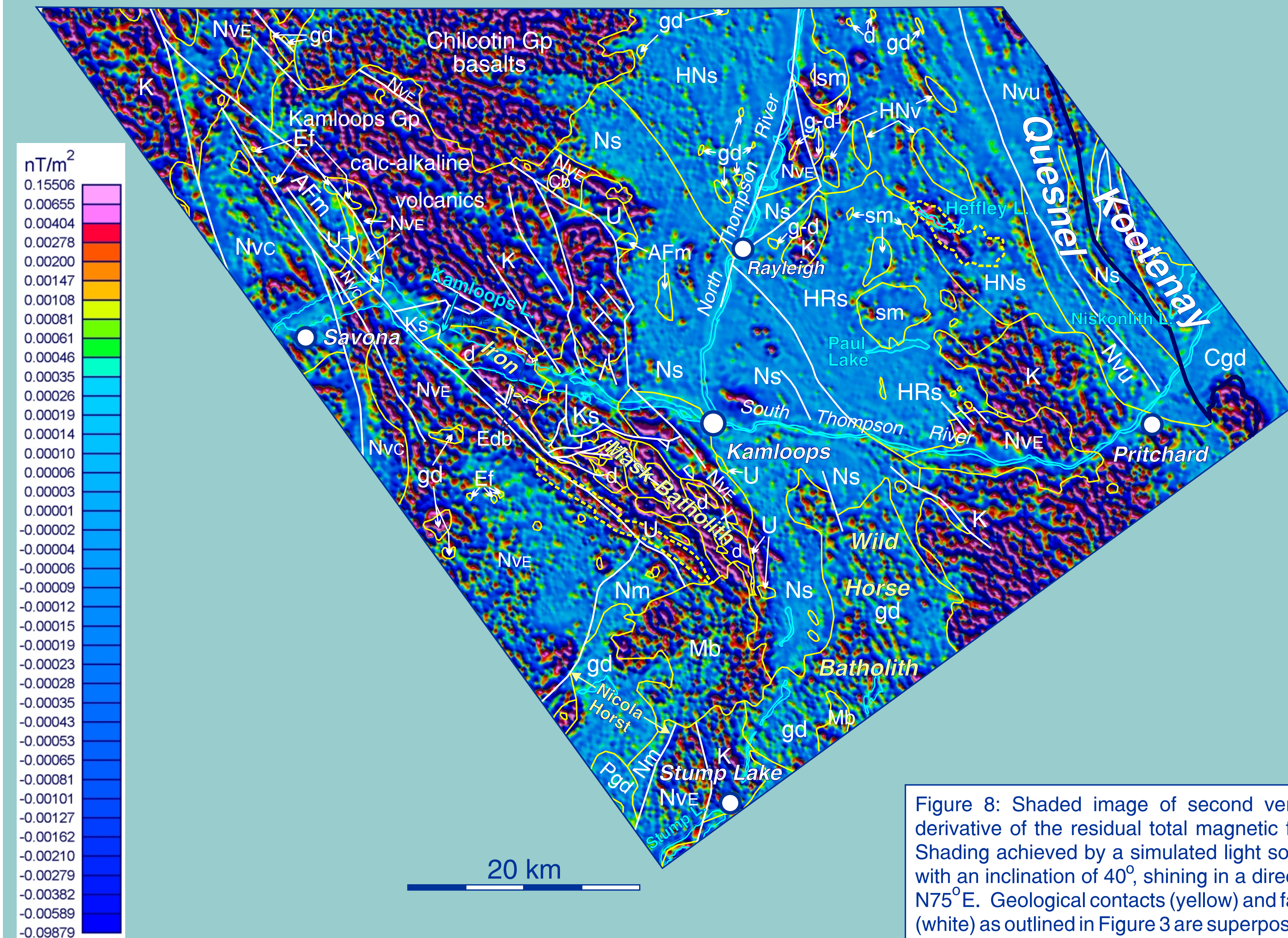


Figure 8: Shaded image of second vertical derivative of the residual total magnetic field. Shading achieved by a simulated light source with an inclination of 40°, shining in a direction N75°E. Geological contacts (yellow) and faults (white) as outlined in Figure 3 are superposed.

gravity coverage the data provide geologically significant information on density distributions in the survey area.

Magnetic Signatures and their Relationship to Geology: The total magnetic field signature is exceedingly variable across the survey area. The range of anomaly values is 6941 nT, maximum and minimum values being +4825 nT and -2116 nT, respectively. Peak value, as used in this report, refers to the maximum value within a single residual total magnetic field anomaly, which may be isolated, lie within a general area of relatively positive anomaly or fall along a linear anomaly. Peak values are absolute values and should not be confused with amplitude values, which are relative values obtained by subtracting an estimated local background level of the magnetic field from a peak value. The background field in the survey area, basically represented by shades of green in Figure 4, generally falls between approximately -250 and -200 nT. Trends of anomalies in the area are typically approximately northwest reflecting the prevailing regional geological strike in the area.

Iron Mask Batholith: The dominant magnetic feature in the survey area is a large belt of positive magnetic anomaly extending from the southeast end of the Iron Mask batholith northwestward along the batholith and beyond into a large adjacent area of Kamloops Group volcanic rocks north of Kamloops Lake. The large amplitudes of the component anomalies of this belt are easily appreciated in the 3D images of the total magnetic field (Figs. 5, 6). In detail, this regional scale magnetic high includes 4 first order segments, each of which comprises a number of smaller scale elements, as clearly portrayed in the 3D image of Figure 6. The batholith is associated with two of the segments (labelled **A** and **B**, Fig. 6), which are separated by an area of relatively suppressed magnetic field coinciding with a unit of Kamloops Group sedimentary rocks. The third segment (**C**) exhibits a close correlation with the western portion of a unit of Kamloops Group volcanic rocks north of Kamloops Lake. It is separated from the northern segment (**B**) of the batholith by a northwest-trending magnetic low coinciding partially with Nicola Group volcanic facies and a small area of Kamloops Group sedimentary rocks. The fourth segment (**D**) is associated with the eastern portion of the unit of Kamloops Group volcanic rocks north of the lake. Anomalies in this segment are more fragmented and are generally of lower amplitude than those in other segments. A comparison between anomalies in segments **C** and **D** is shown in profile format in Figure 11a.

This major belt of magnetic high contains the largest peak values in the survey area. The three largest, +4821, +4436 and +4147 nT, are associated with the Iron Mask batholith. A few other peak values are > +3000 nT. This strong expression is not unexpected given that all rock varieties in the Hybrid unit, underlying roughly 40% of the batholith, are described as containing magnetite that often attains more than 10% by volume (Robinson, 2010), and magnetite is commonly associated with mineralization within the batholith (Logan, 2003; Logan et al., 2006a). Stanley et al. (1994) report magnetite concentrations ranging from 10 to 15% in various phases of the batholith. On a more general note, Sillitoe (1979) noted that gold-rich porphyry copper deposits worldwide, including Cordilleran examples, are associated with high magnetite contents, commonly attaining 5 to 10% by volume, and Clark and Arancibia (1996) document many examples of magnetite associated with hydrothermal alteration zones related to porphyry mineralization.

Kamloops Group Volcanic Rocks*:* The strong cohesive magnetic signature over the Kamloops Group volcanic unit north of Kamloops Lake (Fig. 4) is somewhat surprising given the relatively moderate signatures observed in a study of aeromagnetic data (Thomas and Pilkington, 2008) covering much of the adjoining 1:250,000 NTS map sheet 92P (Bonaparte Lake) to the north. There, a belt of Kamloops Group volcanic rocks stretching between Canim and Bonaparte lakes is associated with magnetic highs that are generally separated by significant areas of magnetic low, presenting a somewhat fragmented pattern. Peak values within much of that belt are < +200 nT, even over comparatively positive features, though larger peak values, generally widely distributed, in the +200 to +1000 nT range are observed over some stronger magnetic highs. Several peak values in the range +1000 to +1830 nT that are generally, but not always, isolated are also observed.

Over one hundred in situ measurements of magnetic susceptibility at 7 exposures of Kamloops Group volcanic rocks in the Bonaparte Lake map area yielded a mean value of 11.56 x 10^{-3} SI (standard deviation ± 12.11 x 10^{-3} SI). Maximum and minimum values are 40.40 and 0.27 x 10^{-3} SI, respectively. Massive volcanic rocks at 3 outcrops yielded reasonably large mean susceptibilities ranging from 22.34 to 25.16 x 10^{-3} SI, with another outcrop yielding a much lower mean value of 4.54 x 10^{-3} SI. Massive amygdaloidal volcanic rocks at one outcrop produced a slightly lower mean value of 2.39 x 10^{-3} SI. The lowest susceptibilities are associated with apparently fragmental volcaniclastic varieties of the Kamloops Group, values at 3 outcrops ranging from 0.37 to 2.51 x 10^{-3} SI. These limited susceptibility data demonstrate the potential for volcanic rocks of the group to produce significant positive anomalies, and also to produce a variable signature, depending on the prevailing rock type.

Compared with relatively muted magnetic signatures over Kamloops Group volcanic rocks in the Bonaparte Lake map area, the belt of positive anomalies immediately north of Kamloops Lake is associated with exceptionally large amplitudes, particularly those in segment **C** (Fig. 6). Here peak values are generally > +500 nT, with many in the range +1000 to +2000 nT, and 5 peaks along the axis of the segment fall in the range +2000 to +2550 nT. In segment **D** peak values are lower and characteristically in the range +500 to +1000 nT; a few are between +1000 to +1585 nT. Segment **C** values are, therefore, distinct from those in the Bonaparte Lake map area where peak values over stronger anomalies range from about +200 to +1000 nT, with a few larger values ranging up to +1830 nT. Segment **D** values are marginally stronger than those in the Bonaparte Lake map area, peak values typically being +500 to +1000 nT compared to +200 to +1000 nT. In Bonaparte Lake map area magnetic highs within the unit of Kamloops Group volcanic rocks between Canim and Bonaparte lakes tend to be separated from neighbours, and do not form a continuous positive feature. Segment **D** anomalies show a tendency for slight separation, in part influenced by faulting, whereas segment **C** presents a more cohesive belt of positive magnetic signature.

The large peak values in segment **C**, the cohesiveness of component magnetic highs and location of **C** virtually along strike from the Iron Mask batholith invite speculation that the batholith extends beneath segment **C**. Gravity data (Figs. 9, 10) were examined to further explore this possibility, but could not provide unequivocal support. A large gravity high, approximately 25 mGal amplitude and partially coincident with magnetic segment **A**, is associated with the batholith southeast of the unit of Kamloops Group sedimentary rocks. In contrast, no such distinct gravity high is present over the batholith northwest of the unit coincident with magnetic segment **B**, nor is a gravity high present over Kamloops Group volcanic rocks associated with segment **C** magnetic anomalies. Rather these latter two geological elements lie along a northwest-trending belt of steep gravity gradients, though a relatively weak gravity high is centred near the northern tip of the batholith. In conclusion, gravity data do not necessarily rule against the possibility of a northwestward extension of the Iron Mask batholith, given the contrasting gravity signatures of its northwestern and southeastern portions. However, the large magnetic anomalies along segment **C** might be explained uniquely by a large thickness of volcanic rocks having fairly high magnetic susceptibilities. The reported thickness of more than 1000 m of Kamloops Group volcanic rocks in this area (Ewing, 1981) lends credence to this explanation. A comparison of the magnetic signatures across the Kamloops Group volcanic rocks and the Iron Mask batholith is presented in Figure 11.

An extensive area of Kamloops Group volcanic rocks is observed in the southeast corner of the survey area near Pritchard. Total magnetic field anomalies produce a crude linear grain oriented roughly northwest to north-northwest (Fig. 4), which is readily appreciated in the derivative magnetic maps (Figs. 7, 8). Peak values are generally between +500 to +1500 nT over the group south of the South Thompson River, except in a small area immediately south of Pritchard. These values are similar to

Figure 9

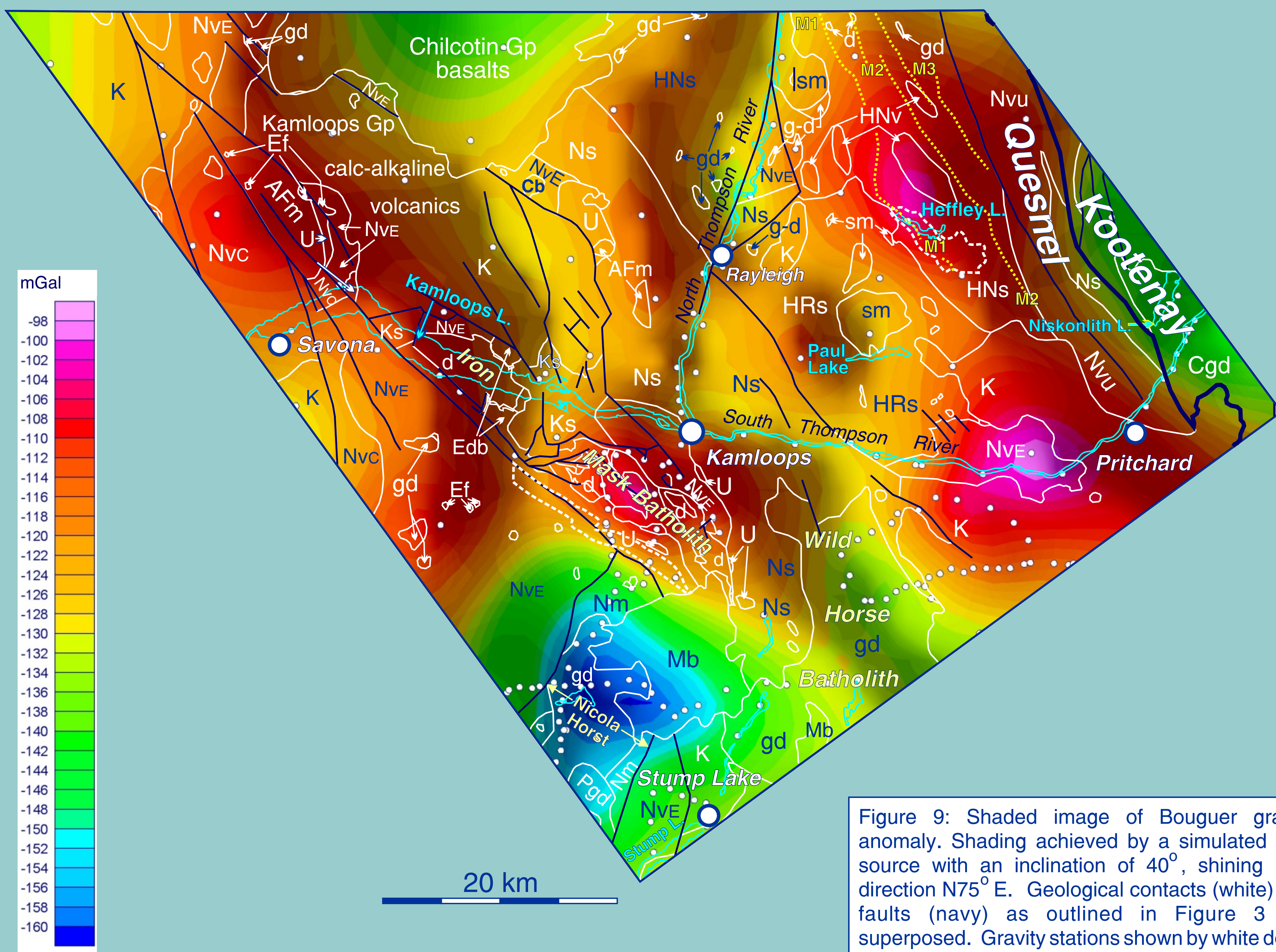


Figure 9: Shaded image of Bouguer gravity anomaly. Shading achieved by a simulated light source with an inclination of 40°, shining in a direction N75° E. Geological contacts (white) and faults (navy) as outlined in Figure 3 are superposed. Gravity stations shown by white dots.

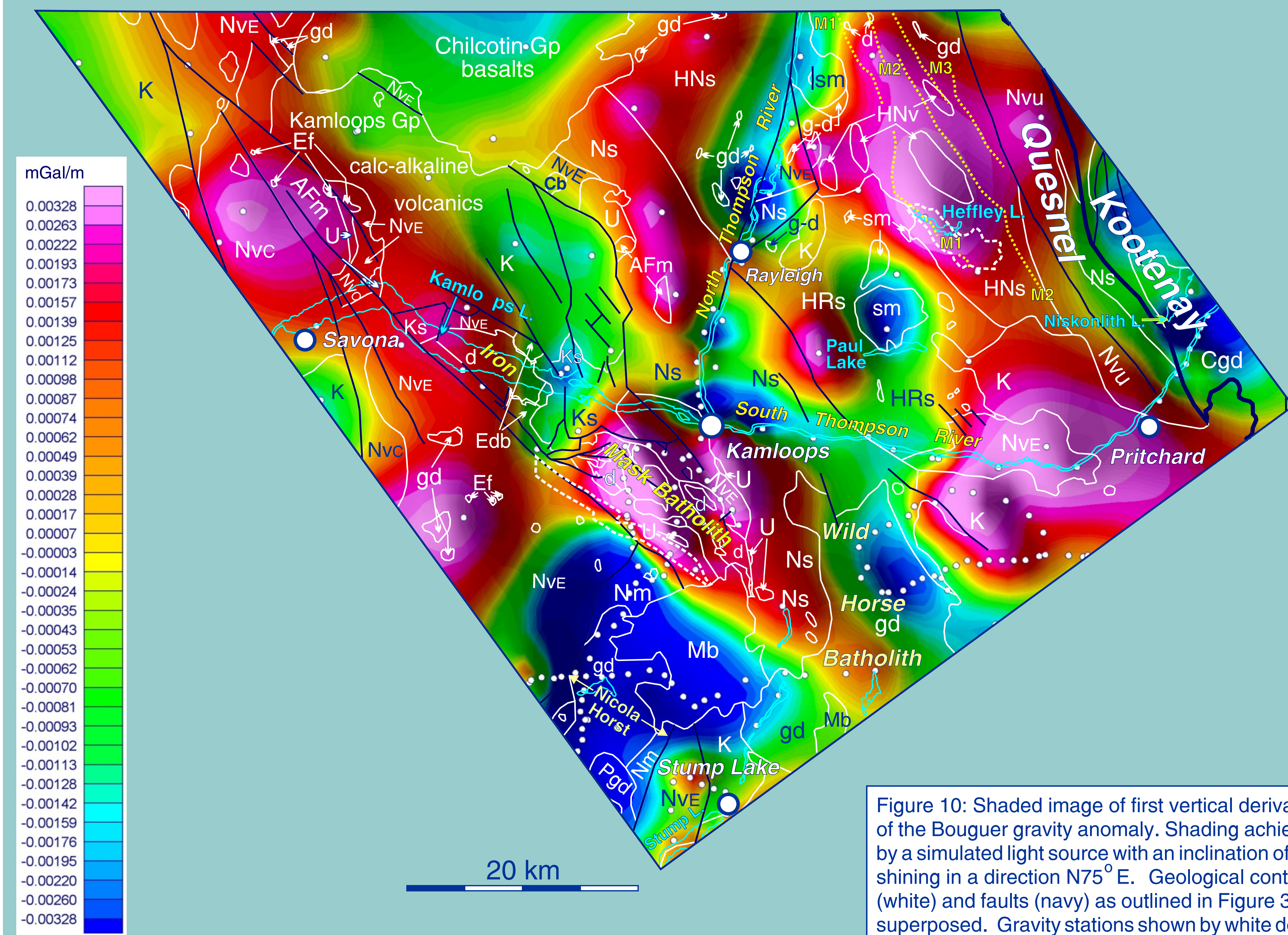


Figure 10: Shaded image of first vertical derivative of the Bouguer gravity anomaly. Shading achieved by a simulated light source with an inclination of 40°, shining in a direction N75° E. Geological contacts (white) and faults (navy) as outlined in Figure 3 are superposed. Gravity stations shown by white dots.

Figure 10

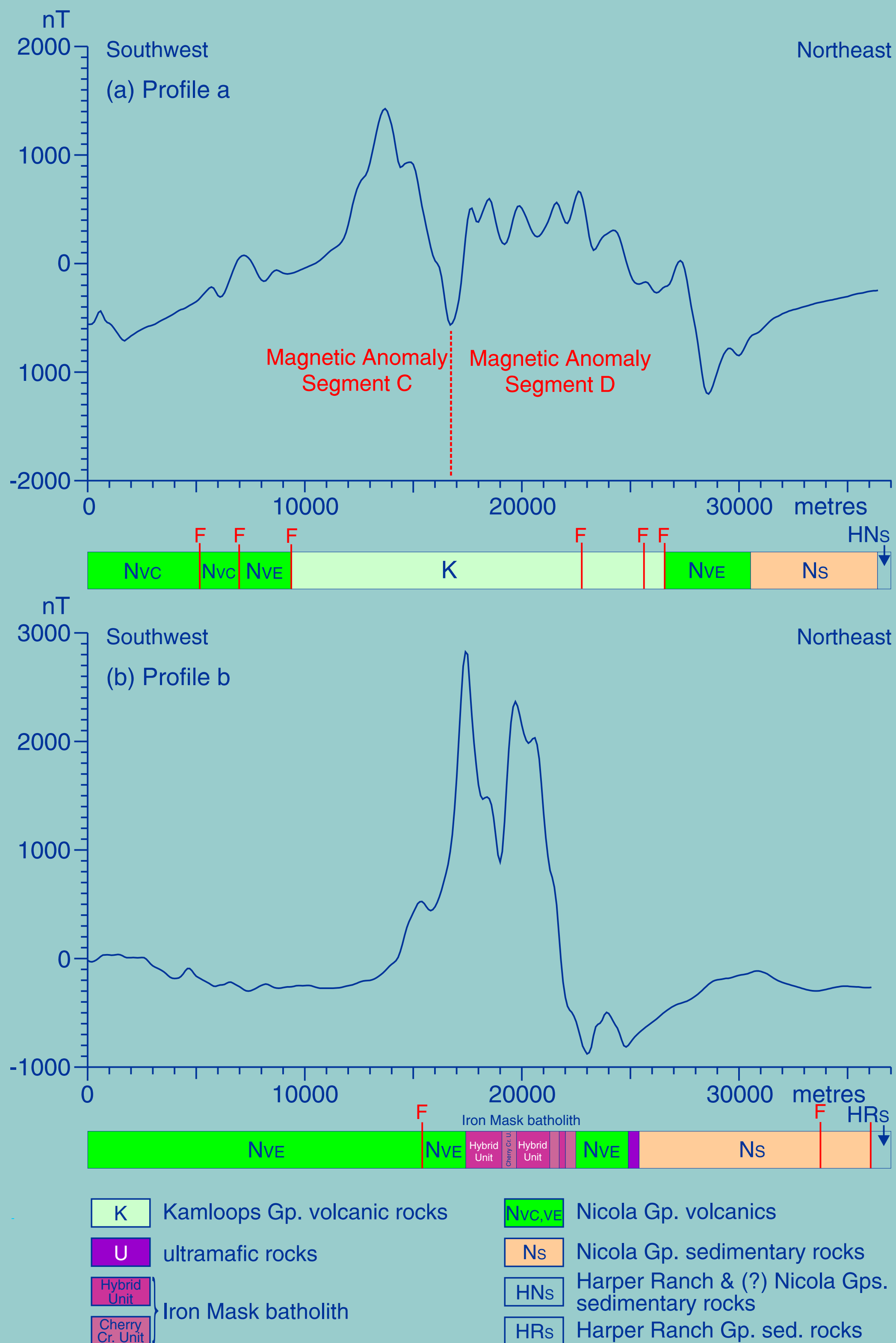


Figure 11. Profiles 'a' and 'b' of total magnetic field (see Figs. 3 and 4 for locations of profile lines).
(a) Runs northeastward from near Savona and crosses Kamloops Group volcanic rocks wedged between rocks of the Nicola Group.
(b) Runs northeastward and crosses the Iron Mask batholith just south-southeast of Kamloops. It crosses rocks of the Nicola Group either side of the batholith.

Figure 11

those over segment **D** of the positive anomaly belt north of Kamloops Lake. The branch of the Kamloops Group northwest of the South Thompson River near Pritchard contains peak values < +500 nT, low values which continue southeastward across the river to the boundary of the survey area. The lower peak values, the more fragmented nature of the magnetic highs and development of magnetic lows indicate that the Kamloops Group is probably thinner and/or of lower magnetic susceptibility in this area, and may not be present in some localities.

In the extreme northwest corner of the survey area another unit of Kamloops Group volcanic rocks is associated with magnetic highs. These are discontinuous and separated by intervening lows, a pattern probably influenced in part by faults, several of which have been interpreted within the unit. Peak values are typically < +500 nT, with a few peaks in the range +500 to +1000 nT.

Chilcotin Group Basaltic Volcanic Rocks*:* A large area of basaltic volcanic rocks of the Chilcotin Group is mapped along the northern margin of the survey area. Much of its eastern portion along the boundary with the Bonaparte Lake map area to the north has a total magnetic field expression similar to that associated with Kamloops Group volcanic rocks in that map area (Thomas and Pilkington, 2008). This magnetic expression is comparable also to that over Kamloops Group volcanic rocks near Pritchard in the southeastern part of the present study area (Figs. 4, 5, 6).

In the Bonaparte Lake map area the texture of the Chilcotin Group in derivative magnetic maps is characterized by positive features having generally small aspect ratios and lacking a preferred orientation, whereas the texture of the Kamloops Group is defined by anomalies having generally larger aspect ratios that locally present a linear fabric. The range of derivative values over the Kamloops Group is typically larger than the range over the Chilcotin Group, and amplitudes of residual high pass filtered residual anomalies are also significantly larger. Based on such differences Thomas and Pilkington (2008) proposed that an area mapped as Chilcotin Group volcanic rocks in the Bonaparte Lake map area immediately north of volcanic rocks mapped in this study area was probably underlain by Kamloops Group volcanic rocks. This interpretation is applied also to the portion of Chilcotin Group characterized by a Kamloops Group magnetic signature in this study area. Details of the interpretation are shown in figures displaying interpreted magnetic domains (Figs. 12, 13) and in the summary interpretation map (Fig. 16). In spite of the predominance of a Kamloops Group magnetic signature it is cautioned that Chilcotin Group volcanic rocks may still be present overlying older Kamloops Group volcanic rocks.

Wild Horse Batholith*:* The Wild Horse batholith is characterized generally by a positive magnetic expression (Figs. 4, 5, 6). Peak amplitudes are generally small, two of the largest being +196 and +176 nT, though a partially defined magnetic high on the southeastern boundary attains a peak value of +510 nT. Derivative magnetic maps (Figs. 7, 8) reveal the magnetic texture of the intrusion to be crudely linear with a general northwest orientation. Although the batholith is quite extensive it does not appear to have a related gravity signature (Figs. 9, 10). Variations in gravity within the intrusion, apparently, are related mainly to gradients flanking a gravity high over the southeastern part of the Iron Mask batholith and a prominent low that is presumably linked to the large granodiorite intrusion within the Nicola horst.

Miocene Basaltic Rocks: A significant occurrence of Miocene basaltic rocks is present north of Stump Lake (Fig. 3). Although the total magnetic field is variable with a generally positive expression along its northeastern margin, a more neutral to slightly positive signature over its central and southwestern areas, and a more 'active' northwestern corner, there is also a hint of a superimposed variegated pattern of small (dimensions and amplitudes) magnetic highs reminiscent of patterns observed over Miocene-Pleistocene Chilcotin Group basalts. This pattern is much more obvious in magnetic derivative images (Figs. 7, 8). The presence of the other described signatures suggests that this basaltic cover is quite thin. The positive signature along the northeastern margin probably relates to southeastward extensions of the Iron Mask batholith (extreme northeast corner) and a prominent linear magnetic high along the Cherry Creek fault that is later ascribed to a unit of lapilli tuff within Nicola Group volcanic rocks.

The 'active' area of magnetic expression in the northwest portion of the Micocene basalts is intriguing. Below the basalts it should coincide partly with granodioritic rocks coring the Nicola horst and partly with metamorphic rocks of the Nicola Group. Whether the component anomalies are related to either of these lithological units is debatable, since their characteristics suggest they may represent distinct intrusive events. One distinctive, relatively low amplitude anomaly has the form of an incomplete ring (anomaly 1, Fig. 7) characterized by several peaks, of which the largest attains about +95 nT. It encloses partially a strong quasi-circular negative anomaly, minimum value -830 nT, containing a single small (horizontal dimensions) oval magnetic high (anomaly 2, Fig. 7) near its centre. It is a reasonably strong anomaly having a peak value of about +724 nT. An arcuate magnetic high (anomaly 3, Fig. 7) flanks the ring anomaly (1) to the southwest. Collectively these anomalies suggest the presence of a buried intrusion or intrusions, and those having arcuate geometries may be imaging marginal phases (Fig. 16). Another arcuate high (anomaly 4, Fig. 7) just to the southwest contains two significant peaks at its western end (+823 and +1550 nT) related to two of the component anomalies. These are attributed to small intrusive stocks or feeder pipes (Fig. 16).

Nicola Horst*:* The Nicola horst has a generally neutral and featureless total magnetic field expression, apart from the anomalies described in the 'active' area of the Miocene basalts having a possible source within the underlying horst. The southeastern part of the integral granodiorite unit does, however, correlate with slightly elevated total magnetic field values distributed over an area shaped like a spearhead (Figs. 4, 16). The pointed end extends into the area of Miocene basaltic cover, again suggesting that the cover is thin. On derivative maps (Figs. 7, 8) a pattern of highs shaped like a number 8 (anomaly 5, Fig. 7) is superposed on the spearhead. The pattern is suggestive of a marginal phase of an intrusion, or possibly a contact metamorphic aureole related to an intrusion. The granodiorite unit can be linked to a more or less coincident large gravity low having an estimated amplitude of at least 30 mGal (Fig. 9). The manner in which this anomaly extends well beyond the surface boundary of the granodiorite is particularly well portrayed in the image of the first vertical derivative of the gravity field (Fig. 10).

Nicola Group Volcanic Rocks near Stump* Lake*: A positive total magnetic field signature is present over most of a fault-bounded block of Nicola Group eastern volcanic facies running north-northeast from Stump Lake. The positive expression is generally continuous with only small interspersed areas of relatively negative magnetic field. Derivative maps (Figs. 7, 8) indicate linear to roughly oval component anomalies striking mainly roughly northwest or north to north-northeast. East of the fault block, parallel linear anomalies fall on a small unit of Kamloops Group volcanic rocks. These do not produce the continuity of positive magnetic expression observed over the Nicola Group, and peak values are somewhat larger. They probably represent a signature of the Kamloops Group, rather than of possible underlying Nicola Group volcanic rocks.

Nicola Group Volcanic Rocks and Intrusions West of the Iron Mask Batholith: An extensive belt of Nicola Group rocks belonging to the central and eastern volcanic facies runs along the western margin of the survey area west of the Iron Mask batholith. Its associated magnetic field presents a picture of a generally neutral to slightly negative background punctuated by several magnetic highs of various amplitudes, dimensions, shapes and orientations. Clues to possible origins of the highs are afforded by the few occurrences of intrusions within the volcanic rocks.

The Late Triassic-Early Jurassic Durand Lake granodioritic stock (Fig. 3) is associated with a fairly large amplitude (peak values range from about +1030 to +1810 nT) magnetic high. The Roper Lake granodioritic stock sits on the flank of this high, but derivative images indicate that the stock does not have a positive magnetic response. The images also suggest that the Durand Lake stock includes a broad annular marginal phase (Fig. 16).

A granodioritic stock about 6 km north of the Durand Lake stock lies near the southeastern end of a west-northwest- to northwest-trending belt of positive total magnetic field anomalies (Fig. 4) characterized by small culminations trending along the belt and having peak values between -93 to +180 nT. The stock does not correlate with any particular anomaly or pattern of anomalies, and if anything is oblique to trends displayed in magnetic derivative images (Figs. 7, 8). Probably, it contributes little to the positive attribute of the belt. This belt extends eastward from the stock, and though locally dissected and disrupted by interpreted faults, apparently it links with another positive belt along the Cherry Creek fault. The latter is herein attributed to a unit of lapilli tuff mapped by Logan et al. (2006b), which may also explain the positive magnetic belt containing the granodioritic stock.

Three very small Eocene felsic porphyry intrusions east of the Durand Lake stock seemingly have no associated magnetic signature, falling mainly on the flanks of a distinct negative anomaly. A small intrusion of ultramafic rocks within the Nicola horst at the southern extremity of the belt of Nicola Group volcanic rocks is associated with a prominent magnetic high having a peak value of +1440 nT, which rivals large peak values associated with the Durand Lake stock. Yet with the exception of the ultramafic body west of Rayleigh other ultramafic bodies in the area produce little magnetic response. Significant peak values within the Nicola Group volcanic rocks, where not related to the Durand Lake stock, generally fall in the range +225 to + 685 nT. Available evidence suggests, therefore, that such peaks are probably related to very shallow or drift-covered “granitic” intrusions of Late Triassic-Early Jurassic age.

Several anomalies that may not conform to the “granitic” intrusion association are elongate magnetic highs along both sides of the boundary between the central and eastern volcanic facies near Savona. Peak values generally range from +260 to +675 nT. A variety of volcanic rocks, along with some sedimentary rocks, is present in both facies (Preto, 1979; Owsiaki, 2003). It is likely that these different rock types will have different magnetic susceptibilities. If true, the elongate nature of these magnetic highs may reflect particular lithological horizons within the volcanic successions, rather than intrusions.

The presence of fairly strongly magnetic horizons within the Nicola Group volcanic belt is supported by the belt of positive magnetic anomalies along the southeastern part of the Cherry Creek fault (Figs. 4, 7). It runs southeast from a point west of the large unit of Kamloops Group sedimentary rocks to the southeast end of the Nicola Group, and apparently continues with diminishing amplitude into an adjacent unit of Miocene basaltic rocks. The belt commences on the west side of the Cherry Creek fault, then straddles the fault northwest of the Clapperton Fault before crossing to the east side. It correlates closely with a unit of feldspar-pyroxene-porphyritic lapilli tuff of the Nicola Group outlined by Logan et al. (2006b) on a detailed geological map of the Iron Mask batholith. Peak values along the belt are consistently of moderate magnitude, ranging mostly between about +340 and +860 nT. The vertical derivative maps (Figs. 7, 8) resolve the total magnetic field anomaly into two subparallel magnetic features northwest of the Clapperton fault. The eastern one lies only partially and marginally on the tuff, supporting eastward relocation of the eastern boundary of the tuff (Fig. 16).

Logan et al. (2006b) place the Cherry Creek fault along the south side of the lapilli tuff unit, a position differing from that shown on MapPlace. Northwest of the Clapperton fault it is displaced roughly 1 km to the southwest, converges on the MapPlace position close to the latter fault and then crosses to the east side. Magnetically, there is little expression of either fault position. A narrow derivative low correlating with a unit of Nicola Group sedimentary rocks having an augite porphyry source (Logan et al., 2006b) lies between derivative highs associated with the tuff and derivative highs related to the Iron Mask batholith.

The northwest-trending, fault-bounded unit of Ashcroft Formation sedimentary rocks north of Savona is surrounded mainly by Nicola Group volcanic rocks, though it contacts also Kamloops Group volcanic rocks and ultramafic rocks. The unit is characterized by generally linear magnetic highs oriented northwest to north-northwest. Those in the southeast are relatively narrow and linear, features well displayed in the derivative magnetic maps (Figs. 7, 8), whereas the northwestern portion is dominated by an essentially single, wider magnetic high whose component elements in derivative maps tend to be shorter, wider, more globular and lack a precise linear distribution. Peak values are highest in the northwestern apex of the unit ranging from about +465 to +535 nT. A few peaks in the central portion (north-south sense) range from about +220 to +250 nT, and those in the southeastern portion are generally less than zero nT. An exceptionally strong anomaly is present in the centre of this unit of the Ashcroft Formation. It is roughly oval in shape, oriented east-northeast and peaks at +1570 nT.

Three very small Eocene feldspar porphyritic intrusions occur within the Ashcroft Formation, but only one coincides with a total magnetic field peak. Similar Eocene intrusions east of the Durand Lake stock are associated with a relatively negative magnetic response. It is concluded that Eocene intrusions are not responsible for magnetic highs within the Ashcroft Formation. Ultramafic rocks on the eastern margin likewise are discounted as a source of positive magnetic expression. Magnetic fabrics within the boundaries of the Ashcroft Formation in the derivative images (Figs. 7, 8) are characterized by generally north-northwest-trending, narrow linear highs distributed within a featureless background field. They are similar to those over adjacent areas of Nicola Group volcanic rocks to the west, east and north, prompting speculation that the Ashcroft Formation is underlain by similar rocks. An exception may be in the central part of the formation, which coincides with the roughly oval magnetic high, peak value +1570 nT. Its east-northeast orientation is unusual and its southern flank apparently truncates linear highs striking north-northwest (Figs. 7, 8), features that suggest it is related to a “granitic” intrusion, probably of Late Triassic-Early Jurassic age (Fig. 16).

A very small unit of Chilcotin Group basaltic rocks mapped near the Clapperton fault coincides partially with a distinct circular anomaly having a peak value of about +430 nT, and amplitude relative to estimated background of about 690 nT. This is attributed to a possible feeder stock to the basaltic rocks (Fig. 16).

Much of the Nicola Group west of the Iron Mask batholith is coincident with a gently arcuate gravity high, convex to the east (Figs. 9, 10). Its axis runs from the region of the Roper Lake and Durand Lake stocks northward to Kamloops Lake, where it swings northwestward and continues to the vicinity of the Deadman River fault. The association of a positive gravity anomaly with rocks of the Nicola Group, both volcanic and sedimentary, has been observed to the north in the Bonaparte Lake area.

Nicola Group Sedimentary Rocks: Sedimentary rocks belonging to the Nicola Group occur exclusively east of the Iron Mask batholith, the main development being the moderately wide northwest-trending belt passing between Kamloops and Rayleigh (Fig. 3). This expanse of sedimentary rocks is practically devoid of other included geological units, apart from two very small occurrences of Nicola Group volcanic rocks west of Wild Horse batholith, a small unit of Chilcotin Group basaltic rocks near the northeastern tip of the batholith, and a larger unit of Ashcroft Formation sedimentary rocks southwest of Rayleigh. The total magnetic field over the Nicola Group sedimentary rocks and the few included units is relatively featureless and characterized mainly by its progressive decrease from northeast to southwest. This gradient probably represents the northeastern flank of the negative component of a dipolar magnetic signature generated by the strongly magnetic Kamloops Group volcanic rocks and Iron Mask batholith. The gradient is fairly substantial with values decreasing from a range of about -215 to -260 nT along the northeastern boundary of the Nicola Group to about -600 to -900 nT along the southwestern boundary. The small included units, themselves, produce little or no noticeable magnetic signature, though the unit of the Chilcotin Group coincides with a small, approximately 60-70 nT amplitude magnetic high.

The aforementioned gradient is generally smooth and featureless, and the few magnetic highs that perturb it fall on Nicola Group sedimentary rocks, with the exception of one partly coincident with an ultramafic unit west-northwest of Rayleigh. There are few clues as to the nature of the sources. The ultramafic unit near Rayleigh is oriented north-northwest, and the partially coincident magnetic high strikes east-southeast across its eastern margin. The largest peak value within the unit is +1240 nT, and the largest along strike within the Nicola Group is +810 nT. Other occurrences of ultramafic rocks in the survey area are relatively small and do not produce significant magnetic signatures, apart from a prominent high associated with an ultramafic unit within the Nicola horst (peak value = +1456 nT).

Serpentinized ultramafic rocks may contain significant amounts of magnetite. If the magnetic high associated with the ultramafic unit near Rayleigh is a product of serpentinization, and the mapped distribution of the unit (Fig. 3) is correct, serpentinization within the unit is apparently localized. The east-southeastward extension of the high into the Nicola Group could reflect a serpentinized portion of the ultramafic unit (Fig. 16). If serpentinized ultramafic rocks are not the source, observations relating to peak values elsewhere in the survey area favour a Late Triassic-Early Jurassic 'granitic' intrusion or magnetite-rich pyroxenites and/or hornblendites such as mapped within the Heffley Creek pluton (Ray and Webster, 2000, 2007) as potential sources.

A prominent elongate magnetic high runs west-northwest across the South Thompson River near Kamloops culminating in a peak value of +1548 nT north of the river, where the high is more strongly developed. Its shape does not conform to the more typical oval or circular shape of a granitic pluton, but its large amplitude is considered compatible with such a source (Fig. 16). North of this high three small (~ 600 - 800 m diameter) circular magnetic highs stand out in the neutral background of the magnetic field. Their amplitudes are not huge (roughly 110 to 240 nT), but nevertheless they are distinct. By comparison with the small high associated with Chilcotin Group rocks near the Wild Horse batholith, a similar attribution is proposed (Fig. 16). Three similar small yet distinct oval magnetic highs are present on the west side of the North Thompson River near Rayleigh. Examined in the context of the derivative magnetic maps two apparently fall on linear magnetic ridges and might therefore be related to magnetic horizons within the Nicola Group sedimentary rocks, possibly a magnetite-rich sedimentary layer or a volcanic layer (Fig. 16).

Almost the entire area of Nicola Group metasedimentary rocks west of the North Thompson River is associated with a north-northwest-trending gravity high (Figs. 9, 10) approximately +10 mGal in amplitude. It swings northeastward as it crosses into the Harper Ranch-(?)Nicola Group and covers much of the northwestern margin of the group. Nicola Group metasedimentary rocks south of the South Thompson River are also associated in large part with a gravity high, about +15 mGal in amplitude, which extends westward across Nicola Group volcanic rocks and the southeastern portion of the Iron Mask batholith. This association of the Nicola Group with a positive gravity expression is commonly observed elsewhere in the Quesnel Terrane.

Harper Ranch Group and Harper Ranch-(?)Nicola Group Sedimentary Rocks: These two units cover a broad belt between the Nicola Group sedimentary rocks and a narrow belt of Nicola Group volcanic rocks along the eastern margin of the Quesnel Terrane. Description of the magnetic field associated with these units is presented in two parts: one for the area west of the North Thompson River, and the other for the area to the east.

<u>Area West of the North Thompson River:</u> This area is underlain almost exclusively by mudstones, siltstones, shales and fine clastic sedimentary rocks of the Harper Ranch-(?)Nicola Group (MapPlace). It is penetrated by a few small and generally widely distributed Late Triassic-Early Jurassic granodioritic intrusions. The total magnetic field is characterized by two main levels, each of which is essentially devoid of prominent anomalies. The lower level, representing a general background level, is defined by shades of green (Fig. 4) occurring mainly along the southwestern margin of the Harper Ranch-(?)Nicola Group and in patches along the river. Values range typically from about -200 to -250 nT. The higher level, characterized by shades of orange and many peak values ranging from about -98 to -20 nT, covers much of the northern portion of the Harper Ranch-(?)Nicola Group, and also extends southward as a gently curved belt some 2 -3 km wide. This belt is noteworthy for the cluster of five granodioritic intrusions that fall within it or on its margins (Fig. 4). It is distinguishable as a discrete feature within the northern area of elevated field. Peak values in the area associated with granodioritic intrusions, though not all coincident with the intrusions, range from about -82 to -112 nT.

In the extreme northwestern corner of the higher level sub-area three peak values ranging from +55 to +87 nT lie near the contact with mapped Chilcotin Group basaltic rocks (herein interpreted to be

Kamloops Group volcanic rocks). It is speculated that areas of Kamloops Group (Fig. 16), as yet unrecognized, are responsible for the larger peak values.

Identifying a source for the higher level magnetic field in the northern part of the area is problematical. Apart from metasedimentary rocks of the Harper Ranch-(?)Nicola Group, only two small and widely separated granodioritic intrusions are mapped in the area, and neither coincides with a discrete magnetic peak. On the other hand, the limited correlation of the cluster of granodioritic intrusions north of Rayleigh with the north-south belt of relatively positive magnetic field suggests that such intrusions could generate a positive signature. Support for a large buried composite intrusion that includes these intrusions is provided by the gravity images (Figs. 9, 10), in which the granodioritic intrusions fall within or on the flanks of a gravity low. No such support for a similar body related to the two granodiorite intrusions near the northern margin of the area is evident. These intrusions fall on a gravity high, suggesting that they are quite thin or more mafic than current mapping indicates, possibly including more dense dioritic or gabbroic phases, which are more consistent with a gravity high. In light of the association of dioritic and gabbroic bodies with positive magnetic anomalies east of the North Thompson River, the higher level magnetic field in the north of the area may be related to similar bodies at shallow depth below the Harper Ranch-(?)Nicola Group or glacial cover.

Images of vertical derivatives of the magnetic field suggest the presence of a fine, dispersed and discontinuous linear structural grain within much of the northern area and southward-branching arm of elevated magnetic field. Within the arm and its northern projection the grain is oriented northward, whereas further west the orientation is northwest to north-northwest. There is a suggestion that the region of the arm is at least partially fault-bounded, with the trajectory of the western fault marking the boundary between the two sets of structural orientations.

Area East of the North Thompson River: This eastern area is dominated by mudstones, siltstones, shales and fine clastic sedimentary rocks of the Harper Ranch Group and the Harper Ranch-(?)Nicola Group, and intruded by Late Triassic-Early Jurassic intrusions, four of which are considerably larger than intrusions west of the river. Three are syenitic-monzonitic, rather than granodioritic, and the fourth is the gabbroic, dioritic and ultramafic Heffley Creek pluton near Heffley Lake (Ray and Webster, 2000, 2007). Two small granodioritic intrusions and several small dioritic and gabbroic-dioritic intrusions are also present. Several significant areas of Harper Ranch-(?)Nicola Group basaltic rocks are mapped north of Heffley Lake, and a fault-bounded block containing Nicola Group sedimentary and volcanic rocks is present immediately north of Rayleigh.

The total magnetic field along the southwestern margin of this area is relatively featureless and represents background level (shades of green), with values ranging generally from about -200 to -250 nT, similar to background values west of the river. Most of the eastern area, however, is dominated by an overall relatively positive signature that includes significant undulations representing many prominent magnetic highs. Peak values of the strongest anomalies range from +100 to +2133 nT, but even anomalies having peaks < +100 nT may be prominent compared to a background field that is generally < -200 nT. Several magnetic highs have a linear or oval aspect and a preferred orientation aligned north-northwest. This linear aspect of the structural fabric is well displayed in the vertical derivative images (Figs. 7, 8), where it is best developed within the Harper Ranch-(?)Nicola Group east and north of Heffley Lake. In contrast, the adjacent unit of Harper Ranch Group sedimentary rocks east of Rayleigh lacks a noticeable linear magnetic fabric. Here, the pattern of anomalies is more variegated, though a few narrow and short linear elements are observed.

The three largest syenite-monzonite bodies (labelled 1, 2, 3 in Figure 16) correlate mainly with a relatively negative or neutral magnetic expression (Fig. 4). Most of body 1 north of Paul Lake coincides with a negative anomaly bordered, except to the south, by a relatively positive magnetic field. The western margin coincides with a prominent magnetic high that extends beyond the western limit of the intrusion, and which internally has a maximum peak value of +175 nT. By comparison with peak values of +88 and +165 nT on two magnetic highs close to and/or traversing two small units of dioritic rocks near the northern margin of the study area, this western marginal area is considered to be more dioritic in composition (Fig. 16). The adjacent smaller syenite-monzonite body 2 to the north apparently lacks a total magnetic field signature. It lies on a gentle gradient, suggesting that it is non-magnetic and/or very thin. Both of these syenite-monzonite bodies lie within a roughly oval-shaped gravity low (Figs. 9, 10) hinting at possible connection at depth to form a larger mass. If this is the case, the smaller body may not be thin, but rather is weakly magnetic. Possible local expressions of the margin of the smaller syenite-monzonite unit (2) are evident in the form of small magnetic highs that are more evident in the derivative images, in which they lie mainly outside the mapped margin, and possibly reflect contact metamorphism (Fig. 16).

The third large syenite-monzonite body (3) lies east of the North Thompson River, bounded to the west by a fault along the river, and to the south by a small gabbroic-dioritic unit. Its northeastern sector coincides with a neutral to relatively negative magnetic field interrupted locally by a few small magnetic highs (Fig. 4). The southwestern segment correlates with a strong north-northwest-trending high (peak values between about +660 and +1040 nT), which swings eastward at its south end into the gabbro-diorite unit (maximum peak value +740 nT). From there it resumes a south-southeast trend for approximately 5 km within metasedimentary rocks of the Harper Ranch-(?)Nicola Group. Close to the gabbro-diorite unit it attains a peak value of +745 nT before progressively decreasing in amplitude southward. The correlation of strong peak values with the gabbro-diorite body, and with two gabbro-diorite units (+485 and +705 nT) immediately to the south-southwest, is persuasive evidence that the southwestern margin of the syenite-monzonite unit includes gabbroic-dioritic rocks (Fig. 16). The portion of the magnetic high extending south-southeast across the metasedimentary rocks is likewise interpreted to be underlain by dioritic or gabbroic-dioritic rocks hidden by glacial cover or buried at shallow depth in the bedrock (Fig. 16).

Two very small syenite-monzonite bodies west of Heffley Lake produce no magnetic signature. The gabbro-diorite unit within the fault-bounded block of Nicola Group volcanic rocks north of Rayleigh is associated with a north-northwest-trending magnetic high extending well outside the limits of the body, both to the north and south. Peak values diminish from +705 nT within the unit to +498 nT to the north and +205 nT to the south. This high undoubtedly tracks the gabbro-diorite at shallow depth within the volcanic succession (Fig. 16).

Unlike the two large syenite-monzonite bodies (1 and 2) between Paul and Heffley lakes body 3 is not centrally positioned with respect to a gravity low, but lies on the eastern flank of a gravity low running along the North Thompson River (Figs. 9, 10). This low is a somewhat subdued extension of the more intense oval-shaped low coinciding with the cluster of small granodiorite intrusions north of Rayleigh. Lack of any positive gravity signature relating to mapped or interpreted gabbroic-dioritic rocks is ascribed to the wide spacing of gravity stations.

Three belts of positive magnetic anomaly (M1, M2, M3 in Figure 4) fall mainly on sedimentary rocks of the Harper Ranch-(?)Nicola Group along the northeastern tract of the area, but certain evidence indicates a link with mafic-ultramafic rocks. Belt M1 runs north-northwest through Heffley Lake and terminates near a small diorite intrusion close to the northern boundary of the survey area. Peak values range generally from about +50 to +2130 nT. The portion of M1 near Heffley Lake is associated with the largest peak values of +1208 nT and +2133 nT and correlates with the western, northwest-trending portion of the Heffley Creek pluton, described as an Alaskan-type intrusion comprising ultramafic rocks along with some gabbros, diorites, quartz diorites and monzodiorites (Ray and Webster, 2000). The ultramafic rocks contain up to 10% disseminated magnetite that produces "an elongate aeromagnetic anomaly that extends south-east of Little Heffley Lake" (Ray and Webster, 2000), and which is part of M1. These ultramafic rocks include pyroxenites and hornblendites, and tend to occupy the central part of the pluton according to Ray and Webster (2007), though their map showing rock type at the few outcrops within the pluton displays ultramafic rocks at only two localities. Little Heffley Lake is located roughly 600 m west-northwest of Heffley Lake.

Another contributor to M1 in this area is the Heff magnetite skarn located along the northern margin of the Heffley Creek pluton. The close association of the M1 positive magnetic belt with mafic-ultramafic intrusions near Heffley Lake and the near coincidence of a small diorite unit with a circular magnetic high (+165 nT peak value) at the north end of M1 may signify continuity of mafic-ultramafic rocks along the length of the belt, possibly buried at shallow depth (Fig. 16). Another circular high on the M1 trend just south-southeast of the diorite unit has a peak value of +950 nT. The M1 trend cuts across three magnetic domains, defined in a subsequent section, but this does not necessarily violate geological-magnetic compatibility. The domains are defined principally, though not entirely, on the basis of patterns in the derivative images, which to a large extent reflect smaller and shallower crustal elements, whereas the M1 trend is based on total magnetic field anomalies that can reflect both surface and deeper geological elements.

The belt of positive magnetic anomalies M2 runs subparallel to M1 and also extends to the northern boundary of the study area. It is generally quite narrower than M1, more linear and has significantly lower peak values, the largest being about +290 nT. The only geological unit depicted on MapPlace falling on the belt, and which from other observations could possibly relate to the belt, is a small diorite unit at its north end. This falls on a narrow linear anomaly stretching north-northwest and south-southeast beyond the confines of the unit, which displays an en echelon relationship with the greater part of M2. The linearity of the anomaly might be considered evidence against an intrusive source given that many intrusions are round to oval, yet the example of a linear anomaly partially coincident with a gabbro-diorite unit within Nicola Group volcanic rocks north of Rayleigh supports the presence of linear intrusions. Ray and Webster (2000) cite structural data in the Heffley Lake area indicating moderately to steeply dipping beds, and tight folds having steep axial planes. The possibility of deformed intrusions having a preferred strike should not, therefore, be discounted, particularly if the original intrusions had a lens-like or sheet-like geometry. It is concluded that some sections of magnetic belt M2 are associated with gabbroic-dioritic intrusions, possibly accompanied by ultramafic components (Fig. 16).

The en echelon positive linear belt of anomalies M3 is even narrower and less intense than M2 (Fig. 4), the larger peak values ranging from about -110 to -70 nT. These are significantly lower than peaks associated with diorite or gabbro-diorite units, suggesting that such rock types are not linked with the belt. Nevertheless, intermediate or felsic intrusions are potential sources, considering that some magnetic highs within Nicola Group volcanic rocks west of the Iron Mask batholith coincide with Late Triassic-Early Jurassic granodioritic intrusions. A small elongate body of granodiorite is mapped just east of the northern extremity of M3, but has no magnetic expression. Possible volcanic horizons within the predominantly sedimentary Harper Ranch-(?)Nicola Group could also provide a source (Fig. 16).

The three magnetic belts, M1, M2 and M3, which are mainly linked or potentially linked to mafic-ultramafic intrusions, and units of Harper Ranch-(?)Nicola Group basaltic volcanic rocks fall on a prominent broad gravity high centred north of Heffley Lake (Figs. 9, 10), which is consistent with the presence of an extensive development of similar higher density rocks in the upper crust.

Basaltic rocks of the Harper Ranch-(?)Nicola Group occur in four units north and northwest of Heffley Lake, none of which seemingly generate a specific signature in the total magnetic field. The associated signatures are variable and generally relatively negative with respect to the adjacent magnetic field. The sole exception is the westernmost unit which has a distinct oval magnetic high (+158 nT peak value) near its centre. Its proximity to units of gabbro-diorite and the significant peak value indicate that this anomaly is probably related to a mafic intrusion rather than to basaltic rocks (Fig. 16). The second vertical derivative image (Fig. 8) hints at a north- to north-northwest-trending linear magnetic grain within the largest basaltic unit that is apparently concordant with a discontinuous linear grain marginal to the unit. An inference is that the basaltic rocks are both weakly magnetic and quite thin allowing sub-basaltic magnetic signatures to be expressed.

The only other geological unit of significant size within the broad expanse of Harper Ranch-(?)Nicola Group sedimentary rocks east of the North Thompson River is a unit of Kamloops Group volcanic rocks east of Rayleigh. Most of its distribution is associated with a multi-peaked magnetic high comprised of several coalescing oval-shaped anomalies. Larger peak values range from about +95 to +340 nT, smaller ones from roughly -55 to +50 nT. The pattern of anomalies and range of peak values are similar to those associated with Kamloops Group volcanic rocks northwest of Pritchard. The pattern of anomalies near Rayleigh suggests that the mapped limits of the unit require minor to moderate revision (Fig. 16).

Undivided Nicola Group Volcanic Rocks along the Eastern Margin of the Quesnel Terrane: A belt of Nicola Group volcanic rocks, maximum width about 5.5 km, runs along the eastern margin of the Quesnel Terrane, its southern track split longitudinally by a fault (Fig. 3). The northern half is characterized by a comparatively featureless magnetic field, typically ranging from about -270 to -220 nT, similar to background levels over Nicola Group volcanic rocks (eastern facies) west of the Iron Mask batholith. A few linear and oval magnetic highs are present along the northeastern margin of this sector, the most intense with a peak value of + 397 nT, but other principal peaks are much lower (-48 to 0 nT). Possible sources are granodioritic intrusions (Fig. 16), as present in the eastern volcanic facies of the Nicola Group west of the Iron Mask batholith, dioritic-gabbroic intrusions or a magnetic volcanic facies within the Nicola Group itself. If they are intrusions, the linear nature of the highs, which are particularly evident in the derivative images, suggest that they have been structurally modified to conform to the local structural grain.

The southern tract of volcanic rocks is associated with a distinct yet relatively weak positive magnetic expression both sides of the longitudinal fault, though the field descends to background levels east of the fault north of Pritchard. A continuous belt of positive magnetic anomaly occupies most of the volcanic terrain west of the fault. Peaks in the southern portion range from about -96 to -35 nT, whereas in the broader northern portion peaks are less prominent and attain -121 to -108 nT. This belt is virtually collinear with positive magnetic belt M2 attributed to gabbroic and dioritic rocks, with magnetic derivative maps hinting at continuity or a possible en echelon relationship. Peak values are generally significantly lower than those in M2, though the two highest peaks (-35 nT, -42 nT) match values of the two lowest peaks (-38 nT, -47 nT) in M2. Attribution would once again seem to favour a plutonic source (Fig. 16), though as for the northern sector of the unit a magnetic facies of volcanic rocks is a possibility. The positive signature in the portion of the southern tract east of the fault is described in the next section, since its source may lie within Nicola Group sedimentary rocks.

Nicola Group Sedimentary Rocks along the Eastern Margin of the Quesnel Terrane: A narrow belt of Nicola Group sedimentary rocks, maximum width about 2 km, lies wedged between volcanic rocks of the group and the Kootenay Terrane along the eastern margin of the study area (Fig. 3). The magnetic field in the southern part is fairly featureless and hovers around background values. The northern part is characterized by a positive expression dominated by three closely spaced, narrow linear magnetic highs. The westernmost high has the highest peak values (0 to +55 nT) and lies very close to the boundary with volcanic rocks of the group to the west, its axis crossing into the volcanic rocks at both extremities and giving cause to suggest slight revision to the boundary position. The array of three linear anomalies is suggestive of a layered sequence of alternating magnetic and non-magnetic horizons. The nature of the magnetic horizons within this sedimentary sequence, described as mudstone, siltstone, shale and fine clastic sedimentary rocks, is puzzling. Any sedimentary candidate would have to contain significant amounts of detrital magnetite, and to the author's knowledge such horizons have not been described. This entertains the possible presence of volcaniclastic or volcanic horizons within the sedimentary sequence (Fig. 16), or once again an appeal to stratiform plutonic intrusions.

Kootenay Terrane: This terrane is present in a roughly wedge-shaped belt along the eastern boundary of the survey area (Fig. 3). A series of north-northwest trending units forms the northern taper of the wedge and a Cretaceous granodioritic unit the southern portion. The Mississippian Eagle Bay Assemblage (Slate Creek Unit), at the north tip of the wedge, is associated with a moderately wide, north-trending magnetic high at its north end. The first vertical derivative image (Fig. 7) shows peaks distributed along a linear ridge close to the western margin of the unit. Principal peak values range from +42 to +155 nT. According to MapPlace the assemblage comprises mudstone, siltstone, shale and fine clastic sedimentary rocks. The nature of the source is equivocal with volcanic horizons or sheet-like plutonic units being possible explanations. The Eagle Bay Assemblage is succeeded eastward by a narrow unit of metamorphic greenstone and greenschist, and then a wedge-shaped unit of the metasedimentary Silver Creek Formation. Both units belong to the Mount Ida Assemblage and both have an essentially neutral magnetic expression.

Another development of greenstone and greenschist (Mount Ida Assemblage) lies east of the Silver Creek Formation, but unlike its western counterpart, it is associated with a prominent linear magnetic high, running close to and partially along the greater part of its western boundary. Comparison of peak values (range from +55 to +315 nT) with local background values (range from about -220 to -205 nT) demonstrates that this is a reasonably strong feature, whose source is probably a specific metamorphic unit within the greenstone-greenschist package. This magnetic high continues to trend south-southeast into the adjacent body of Cretaceous granodiorite for about 5.5 km, as far as Niskonlith Lake. Peak values range from +65 to +150 nT near the northern boundary of the granodiorite, but diminish to -20 to 0 nT farther south. The continuation of the anomaly suggests that the boundary of the granodiorite needs local revision to reflect the incursion of these metamorphic rocks (Fig. 16). The southward decrease in the peak values indicates that the source, if similar, is becoming less magnetic and/or thinner.

The magnetic signature of the Cretaceous granodiorite is generally smooth and relatively positive over the northern half and relatively negative over the southern half. It contains no abrupt perturbations indicative of local anomalous sources, with the exception of the linear anomaly attributed to southward continuation of greenstone and greenschist rocks of the Mount Ida Assemblage described above. The southern negative expression of the intrusion is probably a negative dipolar effect related to the strong anomalies over adjacent Kamloops Group volcanic rocks. In the absence of this effect the signature could be similar to that over the northern portion where values characteristically fluctuate gently between about -120 and -70 nT. The total magnetic field (Fig. 4) outlines a broad, weak, roughly annular magnetic high centred between the South Thompson River and Niskonlith Lake. There is the faintest hint of such a feature in the first vertical derivative image (anomaly 6, Fig. 7), which might relate to a separate intrusive body within a composite intrusion (Fig. 16). A negative gravity anomaly coinciding with much of the Kootenay Terrane (Figs. 9, 10) suggests that the Cretaceous granodiorite may be more extensive at depth beneath rocks of the Mount Ida Assemblage.

Magnetic Domains

The foregoing presentation describing relationships between magnetic field signatures and geological units has revealed various degrees of correlation between the two entities. Another way to evaluate such correlations is to compare a map of magnetic domains with the mapped geology. A map of 27 magnetic domains is shown superposed on an image of the first vertical derivative of the magnetic field in Figure 12, and on the geological map of Figure 3 in Figure 13. The domains were defined principally on the basis of patterns of anomalies viewed on the derivative maps, but the total magnetic field image was also consulted. Patterns were defined taking into consideration the plan view shapes, lengths, orientations and density of distribution of positive anomalies. The domains were defined without consultation of any geological maps.

Domains 1, 4, 5, 25, 26: There is a close similarity in the first vertical derivative patterns associated with these 5 domains. The pattern is one of mainly globular to slightly elongate oval anomalies, many of which coalesce longitudinally to produce somewhat irregularly linear "beaded" anomalies, generally of no great length, but together lending a linear aspect to the pattern. Several linear negative features within these domains reflect faults. Domains 1, 25 and 26 are closely associated with Kamloops Group volcanic rocks, with only minor disagreement between mapped geological and magnetic domain boundaries. These discrepancies could be equally indicative of revisions to either type of boundary. Domains 4 and 5 have very similar patterns and could be regarded as a single magnetic domain, but are distinguished by the different orientations of the magnetic fabric. Domain 4 tends to have a north-trending magnetic grain, whereas the grain in Domain 5 trends predominantly northwest to north-northwest. Domain 5 is a large domain, most of which correlates with volcanic rocks of the Kamloops Group, though a significant area in the northern part falls on volcanic rocks of the Chilcotin Group. It is speculated that this northern sector, together with Domain 4, which is entirely underlain by Chilcotin Group volcanic rocks, reflects volcanic rocks of the Kamloops Group. Chilcotin Group volcanic rocks are younger, and could be present, but if so they are probably sporadic and/or quite thin.

Domain 2: A north-northwest-trending domain characterized to some extent by a "broken" linear grain, which is particularly noticeable along the eastern stretch of the domain, where narrow "beaded" anomalies of varying length are concentrated. In the western portion of the domain anomalies are more intermittent, more globular in shape and consequently shorter. The domain exhibits a good correlation with an area dominated by volcanic rocks of the Nicola Group (central and eastern facies present) and including sedimentary rocks of the younger Ashcroft Formation. It has been argued previously that magnetic signatures over the latter formation probably reflect underlying Nicola Group volcanic rocks. The linear trends along the eastern boundary of the domain generally truncate trends within domains to the east. Thus, this domain boundary is well defined. The western boundary is likewise tightly defined, separating a more or less continuous linear high to the west from a pattern of small, widely separated, globular highs within the domain.

Domain 3: The domain covers mainly an area of Chilcotin Group volcanic rocks and a smaller area of Kamloops Group volcanic rocks. It is characterized by generally closely packed, extremely small (horizontal dimensions) oval and quasi-circular highs and a few very narrow "beaded" linear highs that produce a pattern similar to those observed over extensive developments of Chilcotin Group volcanic rocks in the Bonaparte Lake map area to the north (Thomas and Pilkington, 2008). Accordingly, it is proposed that the domain is underlain by basaltic volcanic rocks of the Chilcotin Group.

Domains 6, 7: These domains are distinguished by their atypical northwest trend and association with the Iron Mask batholith, but internally there are differences in the magnetic fabric (Fig. 12). In Domain 6 the batholith underlies only the central portion, characterized by prominent "beaded" linear and curvilinear magnetic highs in the first vertical derivative image (Fig. 12), which correspond to the positive total magnetic field segment **B** of Figure 6. These highs enclose a relatively neutral expression of the magnetic field along a portion of Kamloops Lake. The domain is underlain at both ends mainly by sedimentary rocks of the Kamloops Group, together with small areas of volcanic rocks belonging to both Kamloops and Nicola groups. At the northwest end these rocks produce a relatively negative to neutral signature punctuated by a few very small oval highs in the first vertical derivative image (Fig. 12). A similar pattern is observed at the southeast end, but with a much higher density of such highs. This latter area is dominated by Kamloops Group sedimentary rocks that would supposedly suppress a signature from any underlying batholithic (Iron Mask) rocks, and such suppression is evident in the expression of the total magnetic field (Fig. 4). The small magnetic highs suggest, however, that there is a surface contribution to the magnetic field. The source(s) of these small first vertical derivative highs is uncertain, given the sedimentary nature of the surface rocks.

Domain 7 presents a more cohesive magnetic pattern with prominent narrow linear/curvilinear highs distributed throughout the domain and separated by intervening magnetic lows (Fig. 12). The northeastern flank of the domain falls partly on volcanic rocks of both the Kamloops and Nicola groups and on sedimentary rocks of the Nicola Group. A linear first vertical derivative high is associated with that portion of the flank immediately southwest of Kamloops running through volcanic rocks of the Kamloops and Nicola groups. Its total magnetic field counterpart has a maximum peak value of +790 nT and is visibly separated from other anomalies, some of which have peaks of a few thousand nT. Whether this reflects batholithic or other intrusive rocks is debatable. Its separation from the mapped batholith suggests that it probably does not have an intrusive source, nevertheless it might warrant consideration as a prospective area for porphyry-type mineralization. This area (**'a'**) is outlined in Figure 16 displaying a visual summary of interpreted geological features.

Two linear anomalies within the southeastern portion of the domain extend from within the batholith into adjacent rock units to the south-southeast. One, near the eastern margin of the batholith, traverses units of Nicola Group volcanic rocks and Nicola Group sedimentary rocks. Most peak values range from about +670 to +1622 nT. The presence of such an anomaly extending outside the batholith earmarks it as a possible exploration target (**'b'** in Fig. 16). The second anomaly, near the western margin, extends into a unit of Miocene basaltic rocks, again signaling the likely presence of batholithic rocks at shallow depth, and possibly prospective ground (**'c'** in Fig. 16).

Domain 8: Domain 8, in common with adjacent Domains 6 and 7, trends northwest and is characterized by a linear magnetic fabric (Fig. 12). The fabric is defined by “beaded” linear highs, particularly well developed in the southeast half of the domain where they correlate with a unit of feldspar-pyroxene-porphyritic lapilli tuff within the Nicola Group (Logan et al., 2006b). The northwest half of the domain is significantly wider and linear highs are less extensive and continuous, and laterally more widely spaced. Several highs are globular or oval. In spite of the moderate differences in magnetic fabrics in the two sectors, the overall linear nature of the fabric and the distinctive northwest orientation distinguishes the domain as a separate entity. It is speculated that the unit of lapilli tuff mapped in the southeast extends throughout much of the domain (Fig. 16), though it may experience facies changes along strike and is possibly interlayered with other rock types in the northwest.

Domain 9: Domain 9 is distinguished mainly by its lack of a linear magnetic fabric, a generally featureless magnetic expression and a variably developed variegated pattern of small (dimensions and amplitudes) magnetic highs. The domain includes some prominent local highs such as associated with the Durand Lake stock, discussed previously, and the small domains 10 and 11. Most of the domain is underlain by volcanic rocks (eastern facies) of the Nicola Group, though the southeastern margin is underlain by a unit of metamorphic rocks of the Nicola Group and part of a large Late Triassic-Early Jurassic granodioritic body. The magnetic expression/texture of these three groups of rocks southeast of Domain 10 is virtually indistinguishable. The example of this domain underlines the fact that magnetic mapping may meet with limited success in certain cases.

Domain 10: This is a small domain within Domain 9 falling entirely within eastern facies volcanic rocks of the Nicola Group. It is defined on the basis of a variegated pattern of small (dimensions and amplitudes) magnetic highs that collectively give the impression of a northeast-trending grain. The domain coincides partially with one of a series of broad topographic ridges having a northeast orientation, and partially with an intervening valley, suggesting that topographic relief is not the principal control on its magnetic signature. Two irregularly shaped magnetic highs of relatively moderate amplitude trend and attenuate northeastward across the domain (Fig. 4). One is essentially coincident with the valley and the other with the ridge, again pointing to minor topographic influence. The fabric in the derivative images is similar to fabrics observed over a portion of the large area of

Chilcotin Group volcanic rocks mapped along the northern boundary of the survey area and over the western portion of the unit of Miocene basaltic rocks north of Stump Lake (partially coincident with Domain 12). It is speculated that Miocene volcanic rocks may be present within Domain 10.

Domain 11: This is a small domain within Domain 9 sitting mainly on Miocene basaltic volcanic rocks, and extending slightly onto an adjacent body of Late Triassic-Early Jurassic granodiorite northwest of Stump Lake. It is defined by distinct arcuate magnetic highs in both the total magnetic field and derivative images, some of which form an incomplete ring. It has been suggested that these anomalies reflect intrusions that possibly include small stocks and feeder pipes that invade the large granodioritic body and Nicola Group metamorphic rocks of the Nicola horst (Fig. 16). It is presumed that the Miocene volcanic cover is quite thin.

Domain 12: An elongate domain trending north-northeast along an eastern portion of the granodiorite unit northwest of Stump Lake and the central portion of the adjacent unit of Miocene basaltic rocks to the north. The domain is defined principally on the pattern of moderately closely spaced, small globular and roughly circular first vertical derivative anomalies. This pattern is distinct from patterns defining adjacent domains. A certain linearity imparted to the eastern part of the domain, where it coincides with Miocene basaltic rocks, is attributed to interpreted faults coincident with narrow linear lows. A ring-like development of short curvilinear highs observed over the granodiorite unit extends into marginal areas of contiguous units of Miocene basaltic volcanics and Nicola Group metamorphic rocks. The ring has a diameter of approximately 4 km and is thought to reflect an annular marginal phase of an intrusion or possibly a contact metamorphic reaction within country rocks (Fig. 16). The relevant portion of granodiorite correlates with slightly elevated total magnetic field values defining a broad magnetic high across which values vary smoothly. The high continues northeastward into the area of Miocene volcanic cover where it is more textured and fluctuations are somewhat larger, characteristics attributed to the Miocene basaltic cover. The variegated pattern of derivative anomalies over the Miocene rocks is reminiscent of patterns over the Miocene-Pleistocene Chilcotin Group volcanic rocks. This and the similarity in ages are suggestive of a correlative link.

Domain 13: This domain runs north-northeast from Stump Lake to the southeast tip of the Iron Mask batholith falling successively on Nicola Group volcanic rocks, Kamloops Group volcanic rocks, Miocene basaltic volcanic rocks and Nicola Group sedimentary rocks. It is defined on the basis of an overall irregular linear derivative fabric (first and second vertical derivative) within which linear magnetic highs are themselves irregular. Some are "beaded", and some are simply a line of disconnected oval highs. They are not very extensive and trend between west-northwest and east-northeast. The irregular linear aspect is present in the total magnetic field image, but is not as obvious because the highs are much wider.

The unit of Nicola Group volcanic rocks north of Stump Lake is associated with a continuous positive signature spanning almost the entire width of the unit. In essence, the signature is formed by the coalescence of short individual linear elements of various orientations. Total magnetic field anomalies over Kootenay Group volcanic rocks and Miocene basaltic rocks are narrower, and while irregular and sometimes mutually interfering they tend to define a singular pattern, which may be better appreciated in the derivative images (Figs. 7, 8). The derivative patterns within Domain 13 contrast significantly with patterns over Miocene basaltic rocks in the adjacent Domain 12 to the west. Surprisingly, the boundary between the domains runs more or less down the middle of the Miocene unit. Derivative patterns over the eastern side of the Miocene unit are more like the patterns over areas covered by Kamloops Group volcanic rocks than patterns over other Miocene volcanic rocks, such as those of the Chilcotin Group. It is tempting to speculate that the portion of Domain 13 mapped as Miocene basaltic rocks is underlain mainly by Kamloops Group volcanic rocks.

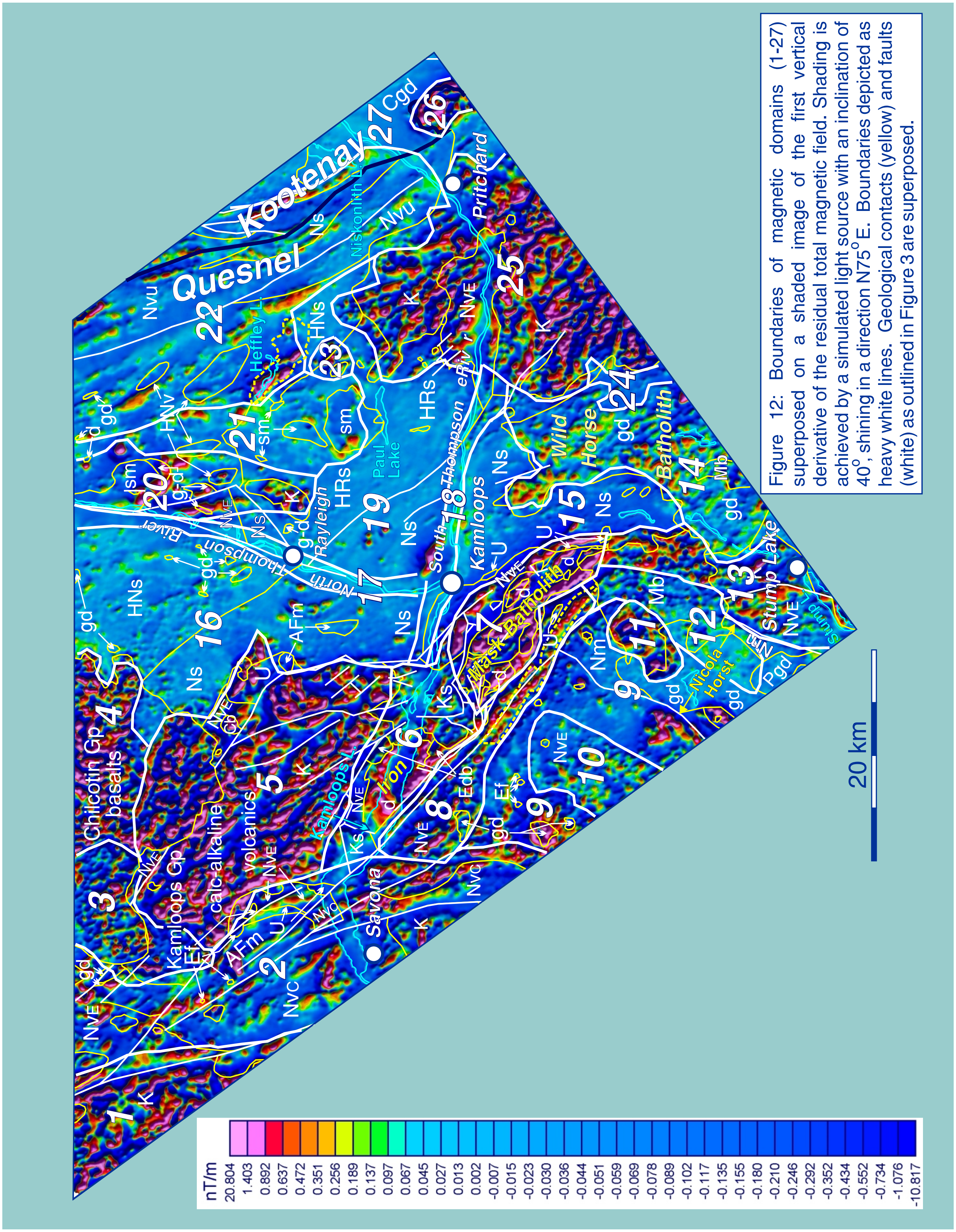


Figure 12: Boundaries of magnetic domains (1-27) superposed on a shaded image of the first vertical derivative of the residual total magnetic field. Shading is achieved by a simulated light source with an inclination of 40°, shining in a direction N75°E. Boundaries depicted as heavy white lines. Geological contacts (yellow) and faults (white) as outlined in Figure 3 are superposed.

Figure 12

Figure 13

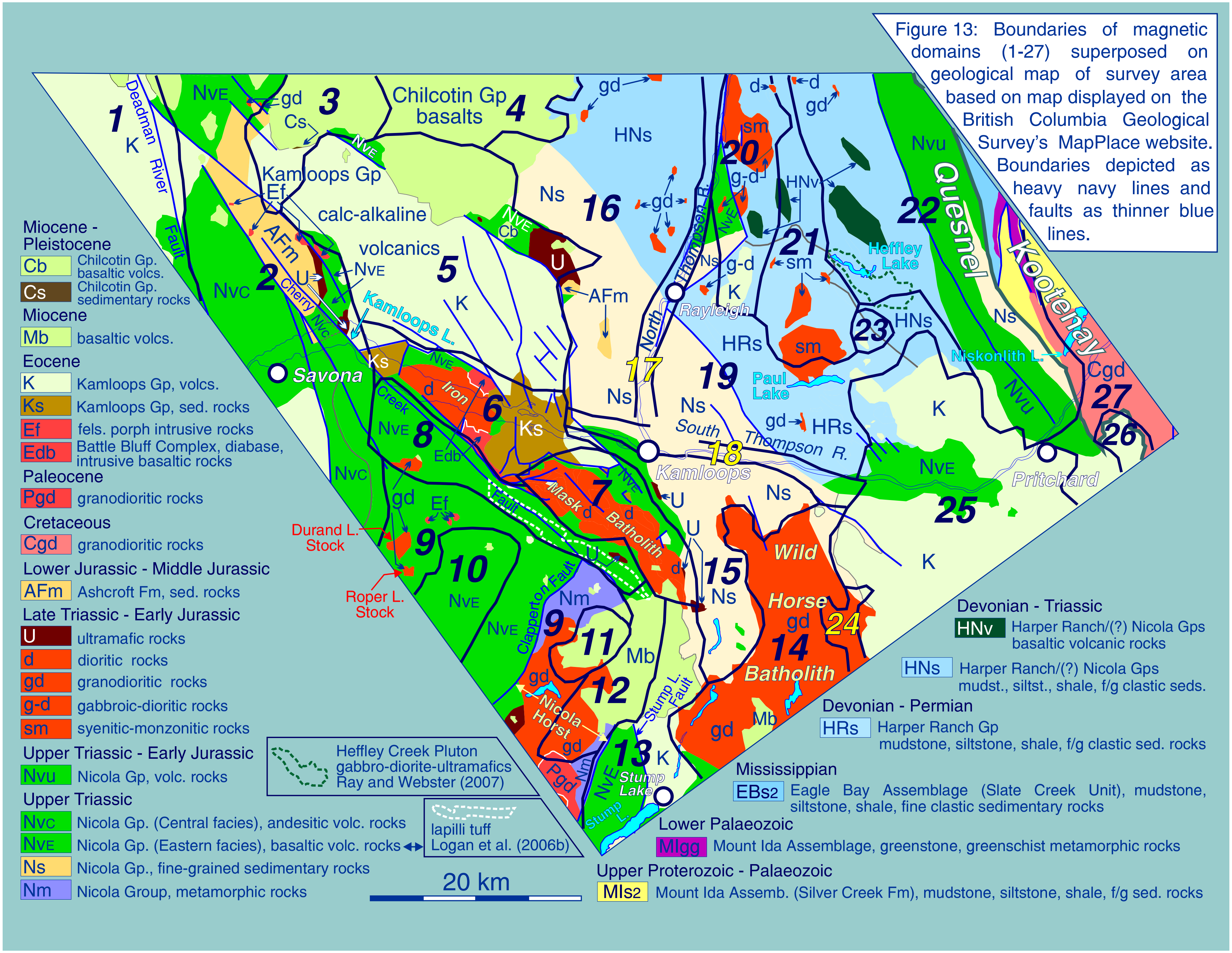


Figure 13: Boundaries of magnetic domains (1-27) superposed on geological map of survey area based on map displayed on the British Columbia Geological Survey's MapPlace website. Boundaries depicted as heavy navy lines and faults as thinner blue lines.

Domain 14: This domain correlates almost perfectly with the Wild Horse batholith as mapped (Figs. 12, 13). Minor differences might imply revision to either the magnetic domain boundary or the geological boundary. The domain has an overall positive total magnetic field expression with many culminations, the largest peak values ranging from +100 to +200 nT. In detail this positive signature includes three main sub-areas. The first is small, oval-shaped, coincides closely with the northwestern lobe of the batholith, and has peak values ranging from about +25 to +115 nT. The second much larger sub-area coincides with the north-northwest-trending northern section of the batholith. The strongest peak values fall roughly in the central part of the sub-area with several lying between +100 and +200 nT. The third sub-area coincides with most of the southwest-trending portion of the batholith, being significantly more positive (0 to +155 nT) in the northeast compared to the southwest where the magnetic field is noticeably weaker (-50 to -150 nT). There are smaller areas of the batholith, notably at the southeast end of the second sub-area, where the magnetic field is essentially featureless and smooth and representative of background levels.

The derivative magnetic maps (Figs. 7, 8, 12) indicate that the eastern part of the batholith has a weak linear fabric trending north-northwest, parallel to the trend of this section of the batholith. This fabric is doubtless influenced by the presence of faults having the same trend, interpreted from the magnetic data. Similar faults are interpreted in the southwest section of the batholith, but here a linear fabric is not readily discerned, though hints of north-northwest trends are recognized.

The sub-areas defined by positive magnetic signatures, internal variations within these signatures and fabrics defined by derivative maps point to significant heterogeneity within the batholith.

Domains 15, 18: Domain 15 is defined by its featureless magnetic expression in both total magnetic field and derivative images, which is expected for a domain that coincides with Nicola Group sedimentary rocks, and only marginally enters Nicola Group volcanic rocks south and west of Kamloops. The boundary between the two groups of rocks is invisible in the magnetic signature. Some weak “beaded” very narrow linear highs trending northwest to north-northwest apparent within the western portion of the domain in both derivative images probably trace the strike of bedding.

The narrow Domain 18 stretches along the valley of the South Thompson River. Correlation with the valley, though close, is not everywhere perfect. The domain is noticeably narrower than the valley near Kamloops, and noticeably wider at its eastern end. It is defined by very small oval and roughly circular highs in the first and second vertical derivative images, there being no noteworthy expression in the total magnetic field image. The highs are strung out along the river valley, with some arranged in a linear fashion producing “beaded” linear features. The subtle nature of the magnetic expression, particularly west of Kamloops, suggests that some highs relate to concentrations of detrital magnetite in unconsolidated sediments along the valley floor, though a narrow, “beaded” linear high at the east end of the domain transecting the southern wall of the valley and running across Nicola Group volcanic rocks might reflect bedrock layering. Some highs may be linked to small fault blocks related to faulting that presumably controls the course of the South Thompson River.

Domains 16, 17: Domain 16 is defined by its magnetically quiet signatures in the derivative images. The total magnetic field is also relatively quiet and dominated by a progressive increase from southwest to northeast, across a gradient that varies in steepness. A few small sporadic oval magnetic highs and a roughly north-trending belt-like magnetic high are superposed on the gradient. The domain is wedged between the strong magnetic expressions of domains 4 and 5 to the west, and the linear domain 17 along the North Thompson River to the east. It coincides almost exclusively with sedimentary rocks of the Nicola Group and Harper Ranch-(?)Nicola Group, whose mutual boundary lacks magnetic expression. A few very small bodies of Late Triassic-Early Jurassic granodioritic rocks punctuate these sedimentary rocks. The domain is characterized by a stippled pattern of very small oval to circular highs in the first and second vertical derivative images (Figs. 7, 8). The stippling is better defined in the second vertical derivative image, and tends to be more concentrated and evenly distributed.

There are ghost-like hints of extremely subtle and very narrow "beaded" linears in the narrow southern portion of the domain in the area covered by the Nicola Group, and in the eastern part of the area covered by the Harper Ranch-(?)Nicola Group. These trend variously between roughly north-northwest and north-northeast in harmony with weak topographic grains. If they reflect bedding trends then the trends are markedly oblique to the boundary between the Nicola Group and Harper Ranch-(?)Nicola Group. A small incursion of Domain 16 into an area mapped as Chilcotin Group basalts near Domain 4 indicates the presence of Nicola Group sedimentary rocks within the incursion (Fig. 16).

Domain 17 coincides closely with the valley of the North Thompson River, though is offset very slightly to the west near the northern boundary of the study area. It is defined by a very subtle sinuous high in the derivative images along the southern two-thirds of its extent, and by a relatively negative expression in the northern third. The high is thought to be an expression of detrital magnetite in sediments of the valley floor.

Domain 19: This domain is wedged between the North Thompson and South Thompson rivers mainly falling on sedimentary rocks of the Nicola Group, Harper Ranch Group and Harper Ranch-(?)Nicola Group. It is perhaps the quietest magnetic domain in the area presenting a very flat appearance in the derivative images with only sporadic development of very small oval or circular highs that are only rarely arranged in a "beaded" linear. The total magnetic field is likewise quite featureless. An exception is the presence of three small yet prominent circular magnetic highs south of Rayleigh within Nicola Group sedimentary rocks (amplitudes in the range 110 to 240 nT) attributed to basaltic rocks of the Chilcotin Group (Fig. 16).

Domain 20: A north-trending belt-like domain along the east side of the North Thompson River, recognized by the inclusion of several prominent oval, circular and short linear highs loosely distributed throughout the domain along with several similar highs of significantly smaller amplitude. A noticeable linear fabric is not developed, but the odd linear anomaly tends to be oriented northward. The domain falls over several different geological units (Nicola Group sedimentary rocks, Nicola Group volcanic rocks, Kamloops Group volcanic rocks, Harper Ranch-(?)Nicola Group volcanic rocks, and dioritic, gabbro-dioritic and syenitic-monzonitic intrusive units) so is not a good example to extol the virtues of magnetic mapping! Nevertheless it draws attention to a magnetically distinct block of crust. Much of this distinction, it seems, can be linked to the presence of magnetic dioritic and gabbroic-dioritic intrusions, which produce the strongest anomalies. A unit of Kamloops Group volcanic rocks within the domain produces derivative signatures not unlike those of the aforementioned intrusive rocks, although amplitudes of total magnetic field highs, while significant, are appreciably smaller. Without any knowledge of geology it is doubtful that the group of anomalies associated with the Kamloops Group would have been interpreted any differently from groups of anomalies related to the intrusive units.

Domain 21: This is a north-south trending, northward tapering domain along the east side of Domain 20 from which it is distinguished by its lack of strong derivative anomalies. It is defined by derivative image patterns characterized by small oval and circular anomalies that are generally of small and variable amplitude and are relatively loosely and somewhat randomly distributed. A linear fabric is not apparent, though a few narrow weak "beaded" linear highs tend to trend northward. The absence of such a fabric distinguishes Domain 21 from the adjacent Domain 22 to the east. On the total magnetic field image most of the domain coincides with a broad belt of relatively positive magnetic field that includes many local peaks. The main exception is the south end of the domain where a negative total magnetic field anomaly coincides with a large part of the syenite-monzonite intrusion north of Paul Lake. It is interesting to note the difference in the magnetic expressions of a domain that includes mainly dioritic and gabbroic-dioritic intrusions (Domain 20) and one that includes mainly syenitic-monzonitic intrusions (Domain 21).

Domain 22: This domain covers most of the eastern margin of the survey area north of the South Thompson River. It spans units of Harper Ranch-(?)Nicola Group sedimentary rocks, Nicola Group volcanic rocks and Nicola Group sedimentary rocks in the Quesnel Terrane, and units of sedimentary and metamorphic rocks belonging to the Eagle Bay and Mount Ida assemblages, and Cretaceous granodioritic rocks in the Kootenay Terrane. It is defined by a series of narrow linear anomalies observed in the total magnetic field and derivative images. They trend north-northwest, are present throughout the length of the domain, are of varying length and may be separated laterally by relatively broad linear zones of relatively negative or neutral magnetic field. Relationships of the many anomalies within this domain to the geology have already been presented. This is a domain that does not portray a close relationship with a particular geological unit(s), underscoring the limitations of the magnetic method in certain geological environments. It does, however, draw attention to a region where bedding/layering is discernible in the magnetic signature, thereby assisting the tracing of favourable horizons, once recognized, and where structure may be more easily deciphered.

Domain 23: A very small domain underlain mainly by sedimentary rocks of the Harper Ranch Group and Harper Ranch-(?)Nicola Group, but also falling on a small unit of Kamloops Group volcanic rocks. It is proposed that the entire domain is underlain by these volcanic rocks.

Domain 24: This very small domain is defined by a magnetically quiet area between the much stronger magnetic expressions of domains 14 and 25 related to the Wild Horse batholith and Kamloops Group volcanic rocks, respectively. Although the domain largely overlies the batholith, it may signal a greater distribution of Nicola Group sedimentary rocks, which are present at the northern tip of the domain.

Domain 27: A small domain in the eastern apex of the area coinciding mainly with Cretaceous granodioritic rocks, and also smaller areas of Kamloops Group and Nicola Group volcanic rocks, and sedimentary rocks of the Mount Ida Assemblage. The domain is defined by its featureless and smooth derivative signatures. It is proposed that the section of the domain between Domains 25 and 26, mapped as underlain by Kamloops Group volcanic rocks, reflects volcanic rocks of the Nicola Group (Fig. 16). The smooth nature of the rest of the domain is an expression of the Cretaceous granodioritic rocks and Mount Ida Assemblage sedimentary rocks which cannot be distinguished on the basis of magnetic signature.

Magnetic Mapping of Faults

Faults in aeromagnetic maps are generally expressed by linear negative anomalies, linear belts of steep gradients or by offsets of anomalies. The association with negative anomalies is related to oxidization of magnetite to hematite, with its concomitant significant reduction in magnetic susceptibility. Magnetite is unstable in the low temperature, highly oxidizing environment of chemical weathering and sedimentation (Grant, 1985). Enhanced permeability along faults and associated fractures facilitates circulation of groundwater, with ensuing oxidation of magnetite to hematite.

Faults have been interpreted using images of the total magnetic field and first and second vertical derivatives of the field. They are plotted on an image of the second vertical derivative of the magnetic field (Fig. 14). Faults interpreted from a digital elevation model prepared from Shuttle Radar Topography Mission (SRTM) data and geologically mapped faults are also incorporated in Figure 14. Mapped geological contacts are displayed to provide a reference framework, but labels of geological units are omitted in the interest of clarity.

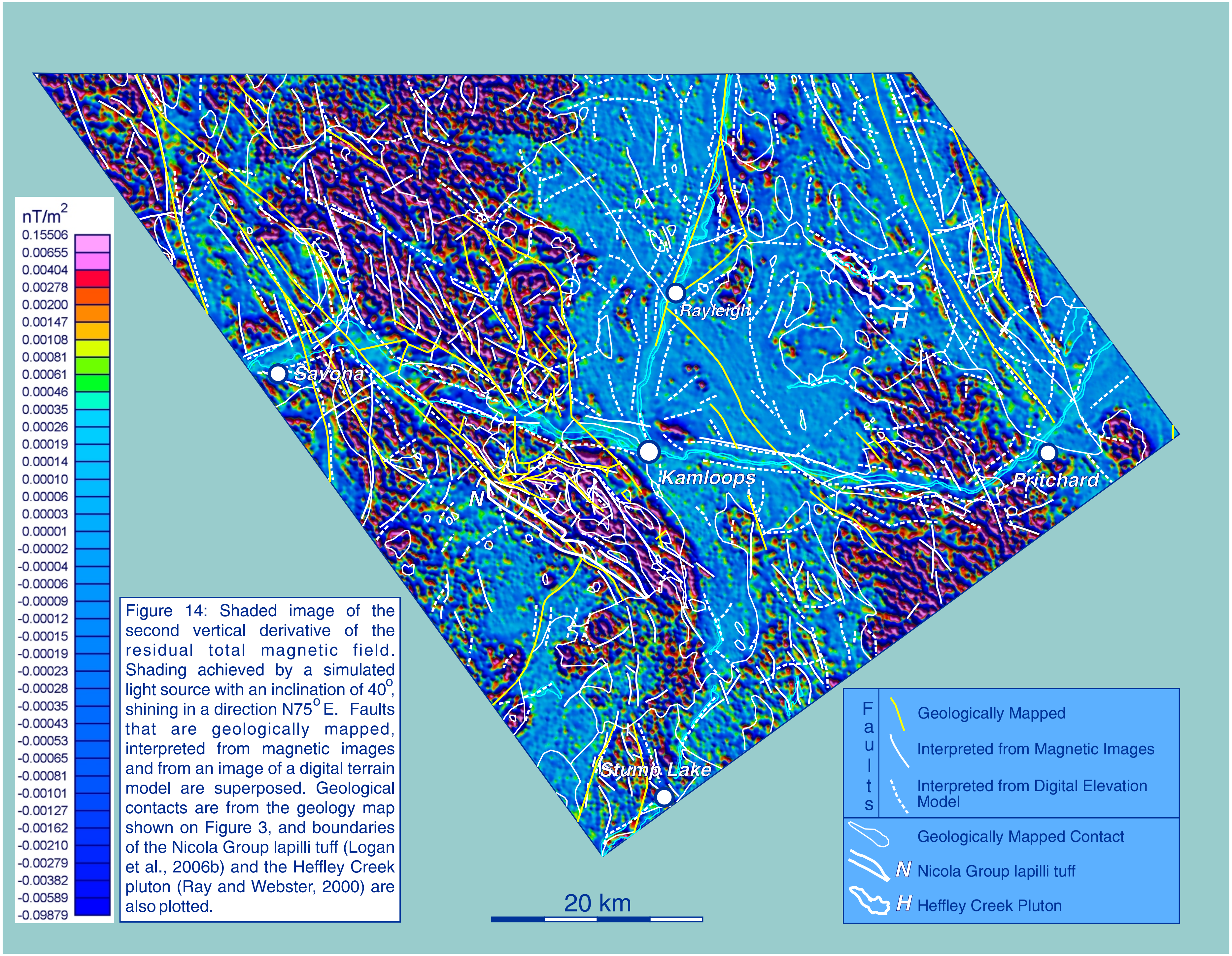


Figure 14: Shaded image of the second vertical derivative of the residual total magnetic field. Shading achieved by a simulated light source with an inclination of 40°, shining in a direction N75° E. Faults that are geologically mapped, interpreted from magnetic images and from an image of a digital terrain model are superposed. Geological contacts are from the geology map shown on Figure 3, and boundaries of the Nicola Group lapilli tuff (Logan et al., 2006b) and the Heffley Creek pluton (Ray and Webster, 2000) are also plotted.

Figure 14

Faults interpreted from magnetic data generally fall within rock units producing strong magnetic signatures, such as units of Kamloops Group volcanic rocks and the Iron Mask batholith. In such strongly magnetic environments negative signatures related to hematization presumably are relatively enhanced, whereas in weakly magnetized rocks the contrast is less evident and negative signatures are more difficult to discern. The latter situation probably applies to the eastern part of the survey area covered by sedimentary rocks belonging to the Harper Ranch and Nicola groups and to the Harper Ranch-(?)Nicola Group, where very few faults are interpreted from magnetic data. Several faults are present also over areas mapped as Chilcotin Group basaltic rocks, though discussion in the section on Magnetic Domains indicates that significant portions of these areas are probably underlain by volcanic rocks of the Kamloops Group.

Most faults interpreted from magnetic images trend northwest to north-northwest parallel to the regional geological strike. They are, generally, not very extensive, though some which are collinear or arranged in an en echelon pattern, collectively are more extensive. A much smaller population of faults strikes northeast. These are quite short and tend to be sporadic and widely separated. Faults interpreted from the SRTM digital elevation model are more evenly distributed within the survey area, and like their magnetically-interpreted counterparts are generally not very extensive, and trend predominantly northwest to north-northwest and orthogonally to the northeast. Other fault trends are recognized along the South Thompson River, where moderately extensive faults (west-northwest-trending) are interpreted from magnetic and topographic data, and along the North Thompson River where faults (north-northeast-trending) are interpreted from topographic data. The interpreted faults provide a picture of crustal fractures where little or no such information is present on the MapPlace geological map (Figure 3).

Significance of New Aeromagnetic Data for Mineral Exploration

One of the principal contributions of the magnetic data to mineral exploration, from a general rather than a targeted perspective, is provision of a detailed picture of the geological fabric of the region via the derivative maps (Figs. 7, 8). The magnetic fabrics in these maps are proxies for structural fabrics, outlining local geological features not apparent in the mono-coloured geological units (Fig. 3). They provide information on orientation, extent and width. Examples of such local features abound within most geological units in the region, e.g. Harper Ranch Group and Harper Ranch-(?)Nicola Group.

A more targeted contribution is the magnetic mapping of faults (Figs. 14, 15), in this case augmented by faults interpreted from Shuttle Radar Topographic Mission data. Faults based on these data sets present a picture of faulting across the entire survey area, complementing a more limited picture based on geological mapping. Faults are key structures in the development and ultimate siting of many deposit types. Their relationship to mineral occurrences from the MINFILE data base is illustrated in Figure 15. A significant number fall along or close to faults, among which are examples of polymetallic veins, invariably described to be associated with faults and/or shear zones and/or fractures and/or breccia zones. The framework of faulting defined in Figure 15 provides loci for exploration of vein-type deposits, and also a context for evaluation of the regional stresses responsible for faulting, thereby introducing a dynamic element into mineral exploration.

Targets are also defined for porphyry-type deposits, which historically have been the most important metal producers in the survey area, most of which are associated with the alkalic Iron Mask batholith (Fig. 3). The association of magnetite with hydrothermal alteration zones related to porphyry mineralization has been documented globally, e.g. Sillitoe (1979) and Clark and Arancibia (1996). Magnetite commonly attains 5 to 10% by volume, and in some cases the highest magnetite contents coincide with the richest ores. The new magnetic data provides detailed images of magnetic anomalies, which are further resolved into individual elements in derivative images. These present targets for exploration. The challenge is to select those particular magnetic anomalies holding the greatest

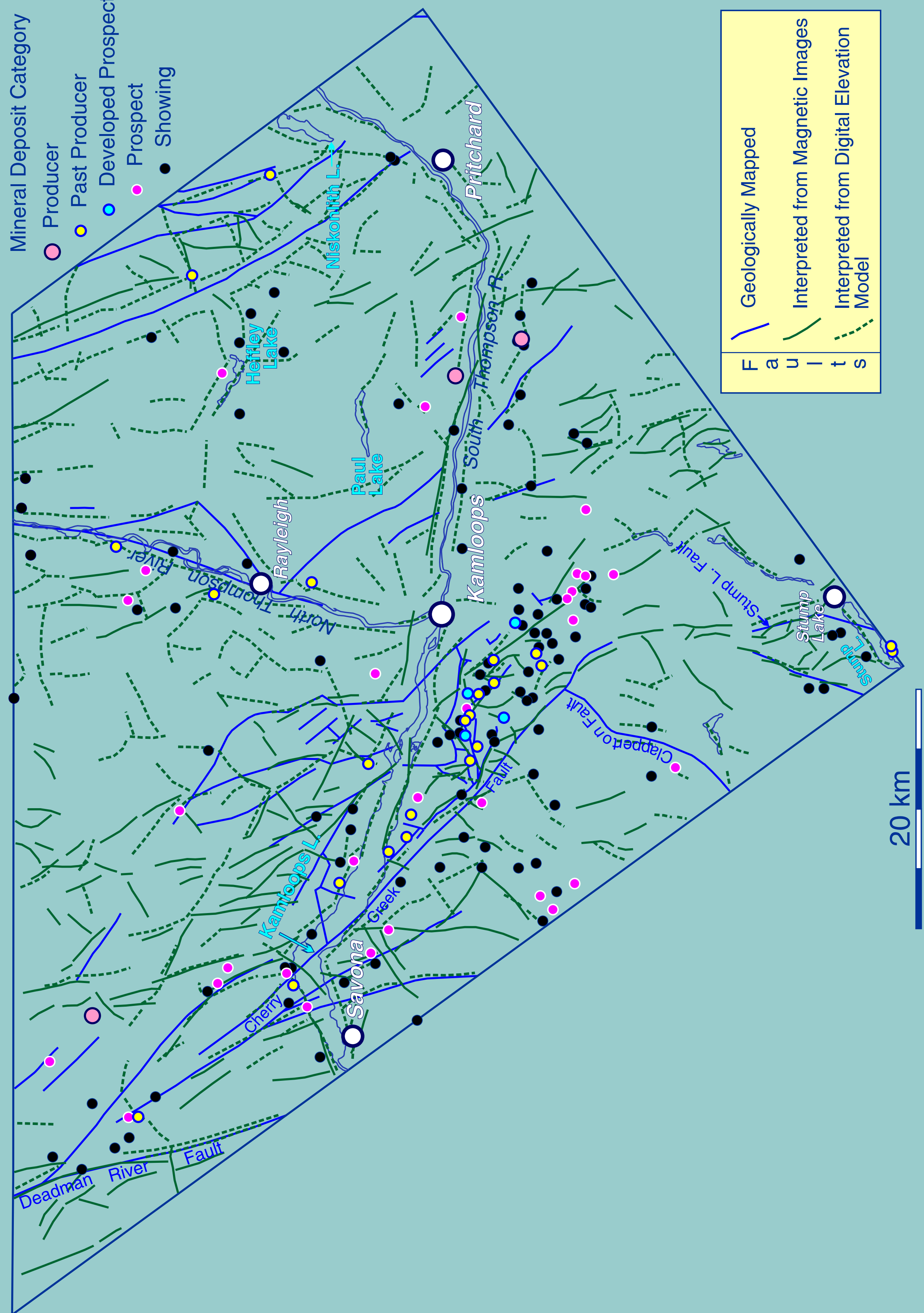


Figure 15: Map of faults derived by various methods with plot of mineral occurrences.

Figure 15

Figure 16

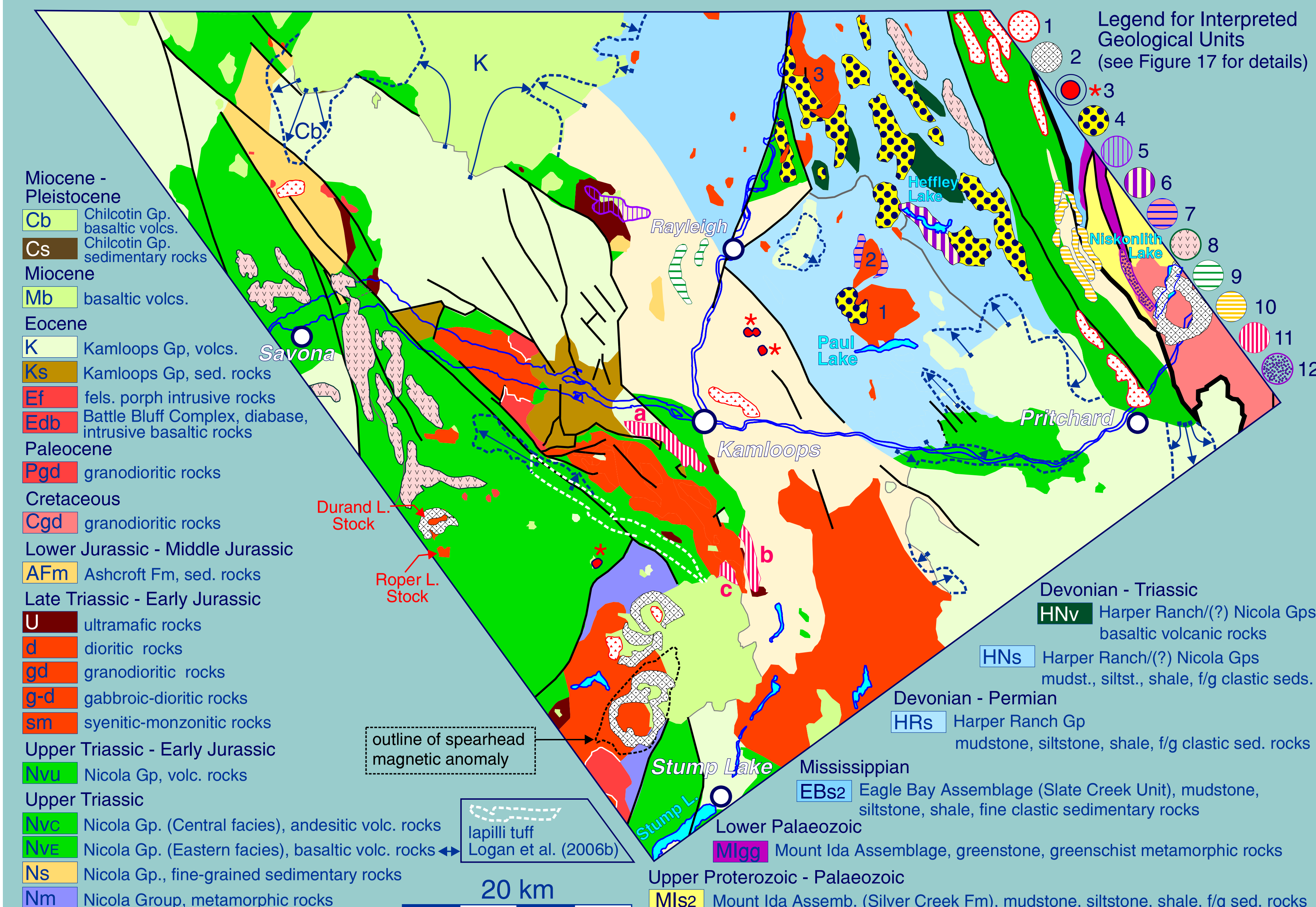


Figure 16: Summary diagram showing some of the principal geological features interpreted or revised on the basis of the magnetic images.

Geological Legend for Figure 16

Preferred sources for specific magnetic anomalies

1 "granitic" intrusion/stock/feeder pipe
(dioritic-gabbroic intrusions and/or magnetic volcanic horizons may contribute within Nicola Group undivided volcanic rocks on eastern margin of area)

2 discrete phase (mainly marginal) of "granitic" intrusion

* 3 stock or feeder pipe to Chilcotin Group basaltic rocks

4 dioritic and/or gabbroic and/or dioritic to gabbroic intrusion

5 serpentinized portion of ultramafic body and/or magnetite-rich pyroxenites/hornblendites

6 magnetite-rich pyroxenites/hornblendites of Heff Creek pluton

7 metamorphic aureole in metasedimentary country rocks

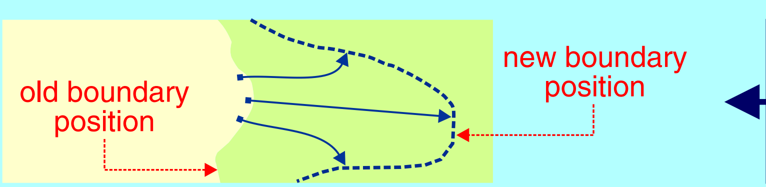
8 magnetic volcanic horizons within Nicola Group volcanic rocks
(possible contribution from "granitic" intrusions)

9 relatively magnetite-rich sedimentary or volcanic horizon

10 magnetite-rich sedimentary horizons
(possible magnetite-rich volcanic horizons; possible "granitic" intrusions)

11 possible prospective zones near Iron Mask batholith; 'b' and 'c' considered more prospective than 'a'

12 magnetic facies within Mount Ida Assemblage greenstone and greenschist unit continuing south into ground mapped as Cretaceous granodiorite



Unit embracing square at one end of arrow moves in direction of arrow to fill area between old and new boundaries

Figure 17: Legend for interpreted features shown in Figure 16. The term "granite" is used in a general sense, and includes such rock-types as granite, granodiorite, quartz syenite, syenite, quart monzonite and monzonite, generally containing less ferromagnesium minerals, particularly hornblende and pyroxene, than more mafic rock-types such as quartz monzodiorite, quartz monzogabbro, monzodiorite, monzogabbro, diorite and gabbro.

Figure 17

potential for associated mineralization. Shives et al. (1997) address this issue targeting low eTh/K ratios, the rationale being that Th enrichment generally does not mimic potassium enrichment during hydrothermal alteration, and hence alteration zones are characterized by low ratios. Accordingly, a high magnetic signature in the vicinity of an area of low eTh/K ratios in the appropriate batholithic setting warrants further investigation. Coincidental or near coincidental occurrences of magnetic highs and eTh/K lows within the Iron Mask batholith have been noted by R. Shives (personal communication, 2005). Shives' observations were based on aeromagnetic and radiometric data that were collected at slightly lower resolution than the present survey; 500 m line spacing (Shives and Carson, 1995) as compared to 400 m line spacing. A detailed study to examine the new magnetic and radiometric data sets for the Iron Mask batholith is desirable, but beyond the scope of this current more regional synopsis of the new magnetic data.

Several intrusions and/or intrusive phases have been outlined within various metasedimentary, volcanic and plutonic units (Fig 16). Critically, however, ground follow-up investigations are required to determine whether such features are present at the bedrock surface or reside at depth. Apart from possible mineralization within these intrusive bodies themselves, the marginal areas may have potential for skarn or vein deposits. The Heff magnetite skarn near Heffley Lake is a known skarn classified as a prospect (MINFILE No. 092INE096) that is probably related to hydrothermal fluids from the Late Triassic-Early Jurassic alkalic and Fe-rich mafic-ultramafic Heffley Creek pluton. The pluton is similar to several others within the Quesnel Terrane, some of which host Cu-Au porphyry mineralization, and less commonly are associated with magnetite-apatite veins or with magnetite-rich Cu-Au skarns such as the Heff occurrence (Ray and Webster, 2007). The large ultramafic intrusion west of Rayleigh, based on its large peak values, may represent another such intrusion, though its potential for skarn-related mineralization may be limited given that adjacent carbonate rocks are not present on the MapPlace geological map.

Two areas of particular interest for follow-up investigations of intrusions are the Nicola horst, where large “granitic” bodies including marginal phases and smaller singular “granitic” intrusions are proposed, and the broad, mainly sedimentary area of the Harper Ranch Group and Harper Ranch-(?)Nicola Group east of the North Thompson River, where several dioritic to gabbroic intrusions are outlined (Fig. 16). Other potential intrusive targets are three zones (a, b, c in Fig. 16) which may be underlain at shallow depth by the prospective Iron Mask batholith.

Summary

The new high resolution aeromagnetic data provide unprecedented detail of the magnetic field in the Kamloops survey area through various magnetic images based on 100 m grids. This detail reflects the bedrock geology buried under a veneer of Quaternary surficial cover. Thus new insights into several aspects of the geology of the Kamloops survey area are revealed. The images provide a detailed picture of the structural fabric of the area, map new faults, outline new intrusions and intrusive phases, query positions of some geologically mapped boundaries and provide a geophysical framework that should have benefits for exploration strategies.

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http://gdr.nrcan.gc.ca/index_e.php