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Preliminary interpretations of new aeromagnetic data for the Atlin map area, British Columbia[1]

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Abstract: Approximately 30 375 line kilometres of high-resolution aeromagnetic data were acquired in the Atlin map area (NTS 104 N), northwestern British Columbia, between September 2000 and March 2001. The survey, flown by SIAL Geosciences Inc. under contract to the Geological Survey of Canada, was funded by the federal government's Targeted Geoscience Initiative. Much of the surveyed area is underlain by oceanic sedimentary, volcanic, and volcaniclastic rocks interleaved with structural panels of ultramafic and other ophiolitic rocks that make up the Cache Creek Terrane. Significant contrasts in magnetic properties among many of these rock types result in a data set that is rich in magnetic anomalies and trends and, as such, a valuable aid to bedrock mapping and mineral exploration currently underway in the region.

Résumé : Entre septembre 2000 et mars 2001, des données aéromagnétiques à haute résolution ont été enregistrées sur environ 30 375 kilomètres linéaires dans la région cartographique d'Atlin (SNRC 104 N), dans le nord-ouest de la Colombie-Britannique. Réalisé à contrat pour le compte de la Commission géologique du Canada par la société SIAL Géosciences inc., le levé a été financé par l'Initiative géoscientifique ciblée du gouvernement fédéral. La majeure partie de la région couverte par le levé est composée de roches sédimentaires, de roches volcaniques et de roches volcanoclastiques de milieu océanique dans lesquelles sont imbriqués, par le jeu de mécanismes tectoniques, des panneaux de roches ultramafiques ou d'autres unités de complexes ophiolitiques qui composent le terrane de Cache Creek. D'importants contrastes de propriétés magnétiques entre plusieurs de ces lithologies produisent un ensemble de données riches en anomalies et alignements magnétiques. Cet ensemble de données magnétiques s'avère ainsi très utile aux travaux d'exploration minière et de cartographie géologique du substratum rocheux qui ont cours dans la région.

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[1] Contribution to the Atlin TGI Project

INTRODUCTION

In 2000, the three-year Atlin Integrated Geoscience Project was initiated to address fundamental questions regarding the geological evolution of the northern Cache Creek Terrane. Specific project objectives, each of which carries important implications for the mineral-resource potential of the area, include the following:

- establishing the stratigraphy of the northern Cache Creek Group
- investigating the origin and significance of ultramafic rocks within the Cache Creek terrane
- examining the relationship between the Cache Creek and Stikine terranes during the Triassic and Jurassic
- investigating the timing and processes involved in the emplacement of the Cache Creek Terrane
- evaluating the postaccretionary magmatism and deformation of the Cache Creek terrane.

These objectives are being achieved primarily through the acquisition, integration, and interpretation of new geological and geophysical data sets for the region (Mihalynuk et al., in press; English et al., in press). The project is being funded in large part by the Geological Survey of Canada's Targeted Geoscience Initiative and the British Columbia Geological Survey Branch, with significant in-kind support from a number of Canadian and European universities. More comprehensive descriptions of the project are presented in Lowe and Mihalynuk (2002) and on the project website (www.pgc.nrcan.gc.ca/atlintgi/).

This paper describes an aeromagnetic survey of the 1:250 000 Atlin map area (NTS 104 N; Fig. 1) that was undertaken during the first phase of the project in 2000–2001. Ground follow-up investigations of selected anomalies and in situ magnetic-susceptibility measurements were conducted during a two-week period in August 2001. Results from these activities are included here, along with a discussion that provides a preliminary interpretation of the new data focusing on their application to the bedrock mapping and mineral exploration objectives of the project.

GEOLOGICAL SETTING AND MINERAL OCCURRENCES

The regional geology of this area is described by Aitken (1959). Numerous other published reports including Monger (1975), Terry (1977), Ash and Arksey (1990), Bloodgood and Bellfontaine (1990), and Mihalynuk (1999) provide details on selected portions of the map area.

Much of the region is underlain by the Cache Creek Group, which is dominated by pelagic sedimentary rocks, metavolcanic rocks, carbonate, and wacke structurally imbricated with panels of ultramafic rock, chert, and argillite of ophiolitic origin. Collectively, the rocks constitute the allochthonous remnants of a Late Paleozoic to early Mesozoic Tethyan ocean (Monger, 1975; Terry, 1977; Ash and Arksey, 1990). Destruction of the ocean basin during the Mesozoic influenced the development of the island-arc terranes of Quesnel and Stikine that presently border the Cache Creek Terrane along the Teslin and Nahlin faults to the northeast and the southwest, respectively. The postaccretionary evolution of all three terranes includes significant Mesozoic and Tertiary magmatism, deformation, and metamorphism. Relatively few of the plutons within the Atlin project area have been mapped or dated. Their magma sources and mode and depth of emplacement are generally poorly understood. Overlap and Mesozoic arc assemblages include intermediate to mafic volcanic and volcaniclastic rocks in the Triassic–Jurassic Stuhini Group, quartz wacke, argillite, and conglomerate in the Jurassic Laberge Group, isolated exposures of Triassic and Jurassic volcanic and volcaniclastic rocks in the Lewes River Assemblage, as well as Tertiary volcanic and volcaniclastic rocks in the Sloko Group. (Fig. 1).

One hundred and thirty-five known mineral occurrences are recorded in the provincial Minfile database for the project area. Gold accounts for all but two of the twenty-seven past producers with placer gold being the most important (note: more placer gold has been recovered from either Spruce Creek or Pine Creek than from any other creek in British Columbia). Lode gold exploration intensified in the area during the 1990s with listwanite-hosted mesothermal veins being of principal interest (e.g. Yellow Jacket, Minfile #104N043, and Shuksan, Minfile #104N098). Historically, production has also come from polymetallic veins within granitic intrusions, as well as within the Atlin ultramafic allochthon (Fig. 1). However, despite a wealth of prospective rock types and geological environments, the region remains underexplored for base- and other precious-metal deposits.

ACQUISITION, PROCESSING, AND ENHANCEMENT OF MAGNETIC DATA

SIAL Geosciences Inc. conducted the aeromagnetic survey between September 10, 2000, and March 15, 2001, and was responsible for compilation of the new data. A pre-survey flight plan was designed using 25 m digital-elevation data acquired from the British Columbia Terrain and Resource Information Management database to accommodate the considerable topographic relief within the project area. This flight plan limited the maximum flight-line slope to 10% and the terrain clearance to a minimum of 200 m. It was subsequently implemented using a Trimble 400SE real-time differential GPS navigation system onboard a Cessna model 421-B aircraft.

In total, 30 375 line kilometres of aeromagnetic data were acquired using a cesium-vapour magnetometer (Geometrics model G822A). Flight lines (average separation 500 m) were oriented northwest-southeast perpendicular to the geological strike. Control lines were flown approximately 3 km apart. Diurnal corrections were applied to the data, using information from the national geomagnetic station in Whitehorse, and the data were leveled by minimizing differences at flight- and control-line intersections. Processed data were then

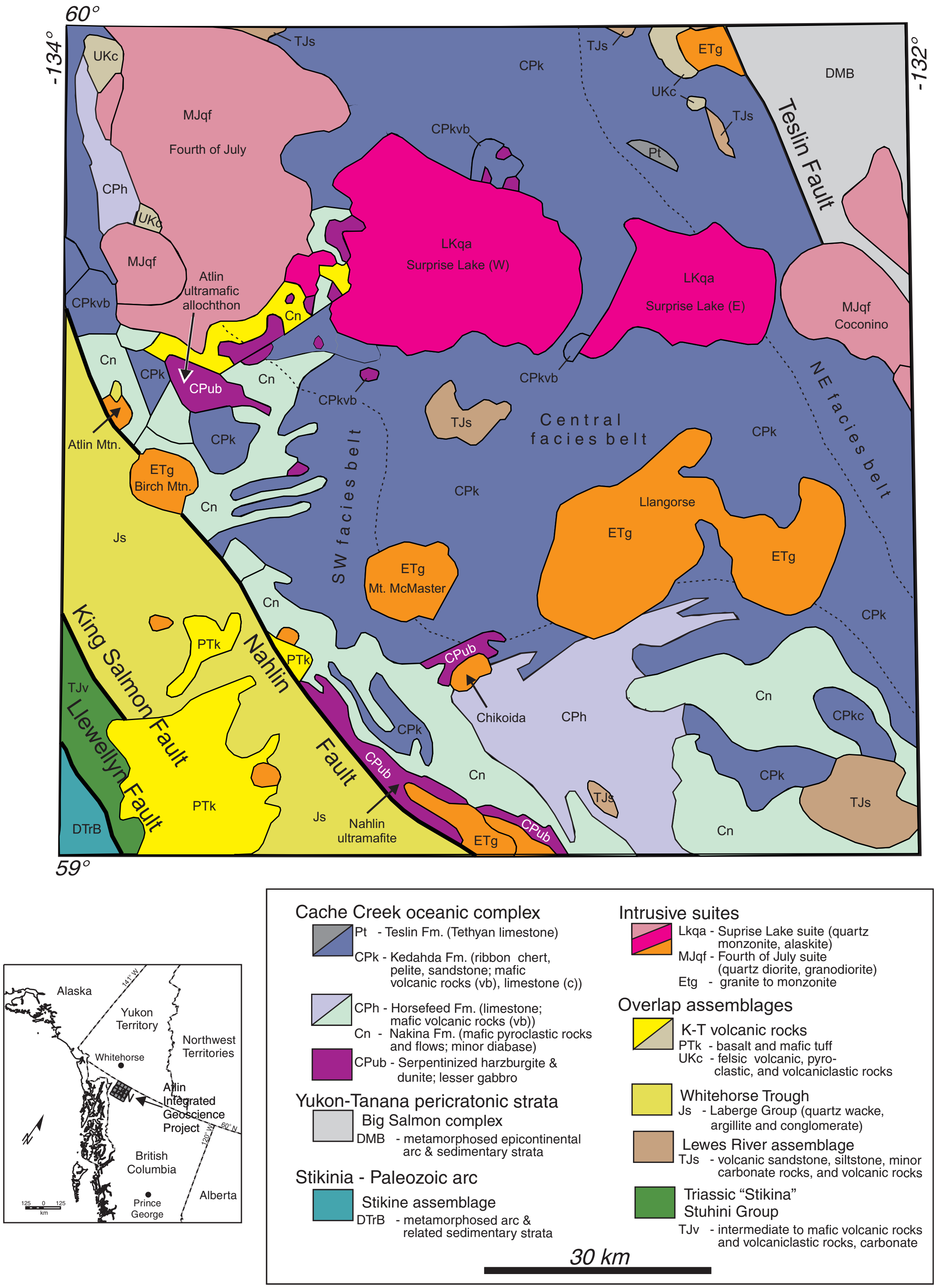

Figure 1. Generalized geology of the Atlin map area (modified from *Mihalynuk et al., 1996).*

interpolated onto a 100 m grid. The GSC's Aeromagnetic Surveys Group monitored data quality throughout the acquisition, processing, and compilation phases and used the processed data to produce a set of sixteen 1:50 000-scale, total-field magnetic maps (Dumont et al., 2001a to o).

The processed data (Fig. 2) reflect a superposition of anomalies resulting from magnetic sources at all depths. To facilitate correlation with the mapped geology and focus on anomalies of possible economic interest, the data were subsequently filtered using enhancement procedures that suppress long-wavelength anomalies related to deep magnetic sources. First, the predominant northeast-trending gradient related to the core magnetic field was removed and the resulting residual data displayed in shaded relief to highlight linear magnetic trends of possible structural origin (Fig. 3a). Shallow magnetic contacts were further enhanced on calculated spatial-derivative and magnetic-tilt images (Fig. 3b, c, d).

MAGNETIC-SUSCEPTIBILITY DATA

Magnetic susceptibility, which measures the degree to which a rock may be magnetized, is an important constraint in the interpretation of magnetic-anomaly data. During the ground follow-up investigations, in situ magnetic-susceptibility (k) measurements were conducted on 135 surface outcrops using a hand-held Exploranium KT-9 magnetic-susceptibility meter. An additional 110 measurements were undertaken on rock samples collected in the project area during previous geological surveys. In each case, a minimum of ten measurements were taken and the mean value recorded. Table 1 provides a statistical summary of the data for each of the main geological units. It should be noted that not all the mapped geological units nor all the rock types characterizing those units were analyzed. Furthermore, susceptibility is highly variable, laterally and vertically, and consequently, units with small sample numbers may not be representative of the bulk or average magnetic properties within the unit. Nonetheless, a few generalizations are apparent.

Ultramafic rocks in the Cache Creek oceanic complex have the greatest range in magnetic susceptibility of any sampled unit. Serpentinite yields the highest susceptibility values (mean k = 58.09 x 10^{-3} SI) and listwanite, a silica-carbonate-altered ultramafic rock, the lowest ultramafic susceptibility values (mean k = 3.14 x 10^{-3} SI). Harzburgite and dunite have mean magnetic susceptibilities intermediate between these end members (23.9 x 10^{-3} SI and 13.90 x 10^{-3} SI, respectively). As expected, sedimentary rocks throughout the complex have low magnetic susceptibilities; chert, argillite, and other siliceous sedimentary rocks in the Kedhada Formation have a mean value of just 0.23 x 10^{-3} SI, and limestone in the Horsefeed Formation is commonly diamagnetic (mean k = -0.01 x 10^{-3} SI). Mafic volcanic and volcaniclastic rocks in the complex have unexpectedly low magnetic susceptibilities; mean values for the Nakina, Kedhada, and French Range formations are 0.45 x 10^{-3} SI, 0.63 x 10^{-3} SI, and 0.33 x 10^{-3} SI, respectively (Table 1).

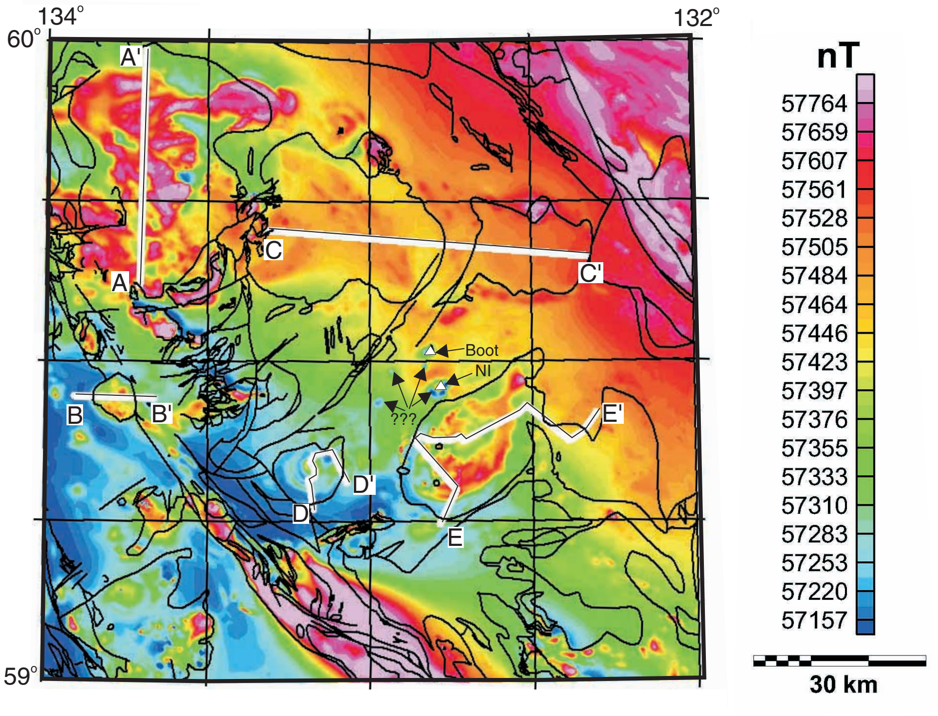

***Figure 2**. Total-field magnetic-anomaly data for the Atlin map area with geological linework overlay (*see *Figure 1 for geology details).*

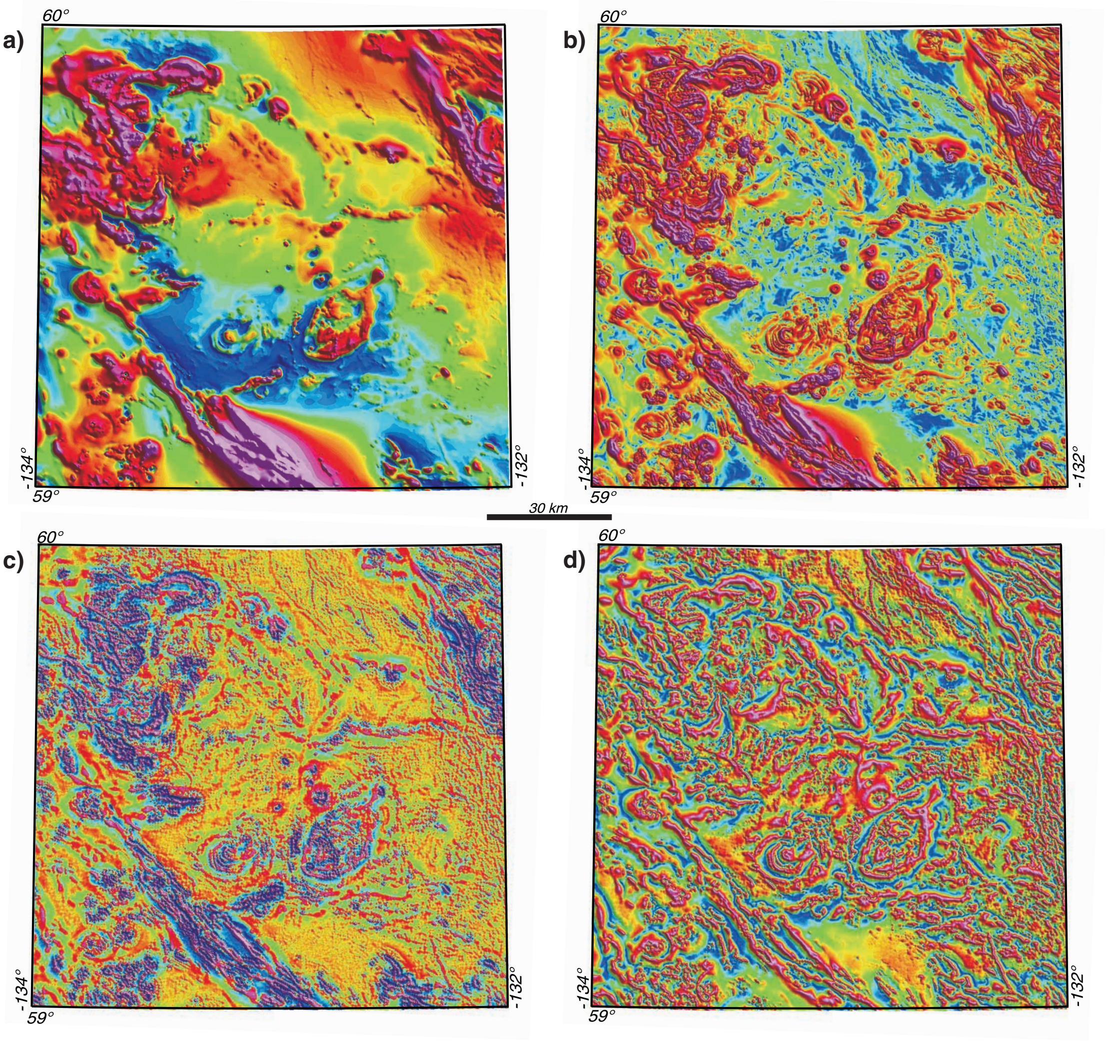

Figure 3. Processed magnetic-anomaly images: ***a)*** *shaded-relief image illuminated from the north;* ***b)*** *horizontal gradient;* ***c)*** *second vertical derivative;* ***d)*** *magnetic tilt. In all cases, high anomaly values are shown in hot colours and low anomaly values, in cool colours.*

Our measurements indicate that quartz diorite and granodiorite in the Middle Jurassic Fourth of July suite have the highest magnetic susceptibility of all intrusions sampled (mean k = 7.57 x 10^{-3} SI), whereas quartz monzonite and alaskite in the Late Cretaceous Surprise Lake suite have the lowest (mean k = 0.04 x 10^{-3} SI). The mean magnetic susceptibility of the Llangorse, Mount McMaster, and Chikoida plutons is 1.99 x 10^{-3} SI, 6.52 x 10^{-3} SI, and 0.07 x 10^{-3} SI, respectively, and distinct spatial variations are recognized within the Llangorse and Mount McMaster plutons.

With the exception of some greenstone (mean k = 1.71 x 10^{-3} SI) and a biotite porphyroblastic unit (mean k = 9.72 x 10^{-3} SI), the metamorphosed epicontinental arc and sedimentary strata of the Big Salmon complex have magnetic susceptibilities that are typically <0.5 x 10^{-3} SI. Feldspathic wacke and volcaniclastic rocks in the Stuhini Group (part of the Stikine Terrane) yield a mean magnetic susceptibility of 3.05 x 10^{-3} SI, considerably higher than similar units in the Cache Creek Group, and higher than the felsic volcanic and volcaniclastic rocks in the Late Cretaceous Windy Table suite (mean k = 0.24 x 10^{-3} SI). The quartz wacke and conglomerate in the Laberge Group have a mean magnetic susceptibility of 0.18 x 10^{-3} and 8.08 x 10^{-3} SI, respecitvely. High magnetic susceptibilities characterize felsic to mafic volcanic and volcaniclastic rocks in the Eocene Sloko Group (mean k = 7.57 x 10^{-3} SI).

DISCUSSION

Magnetic anomalies associated with ultramafic rocks

Consistent with the magnetic-susceptibility data discussed above, distinct and intensely positive magnetic anomalies correlate with mapped exposures of ultramafic rock within the project area. Examples include the Nahlin ultramafic

Table 1. Magnetic susceptibilities of some bedrock units in the Atlin map area.

Geological unit	Map unit (Fig. 1)	Magnetic susceptibility (x 10^{-3} SI)		No.
		Mean	Range	
Cache Creek Terrane				
French Range Formation	Pfr	0.33	0.14– 0.43	6
Kedhada Formation	CPk	0.26	-0.09–1.40	29
Horsefeed Formation	CPh	-0.01	-0.07–0.00	3
Nakina Formation	Cn	1.46	0.19–12.60	13
ultramafic rock	CPub	35.42	0.05–102.00	47
Intrusive suites				
Atlin Mountain pluton	ETg	8.25	6.75–10.40	5
Llangorse batholith	ETg	6.52	0.15–25.20	32
Mount McMaster pluton	ETg	1.99	0.04–9.40	16
Chikoida pluton	ETg	0.07	0.00–0.14	2
Surprise Lake batholith (W)	LKqa	0.04	0.01–0.07	3
Surprise Lake batholith (E)	LKqa	0.06	0.05–0.06	2
Fourth of July batholith	MJqf	7.57	0.35–18.40	10
Coconino batholith	MJqf	5.52	1.39–9.69	2
Yukon–Tanana Terrane pericratonic rocks				
Big Salmon complex	DMB	1.02	-0.01–9.72	24
Arc and overlap assemblages				
Triassic Stikine terrane				
Stuhini Group	TJv	3.05	0.04–13.9	6
Whitehorse Trough				
Laberge Group	Js	1.7	0.07–23.80	19
Windy Table suite	lKtv	0.24	-0.12–0.66	6
Sloko Group	PTk	4.88	0.07–26.10	20

body in the south-central project area, the Atlin ultramafic allochthon near the Atlin townsite, as well as numerous smaller ultramafic bodies exposed north, west, and southwest of the Surprise Lake batholith in the northwestern project area (compare Fig. 1 and 3). In addition, during ground investigations of elevated magnetic anomalies in NTS 104 N/1 and N/2 map areas, led to the discovery of serpentinite mélange in areas previously thought to be underlain by volcaniclastic rocks of the Kedhada Formation (Table 1) (Mihalynuk et al., in press).

Examination of the magnetic anomalies associated with some ultramafic bodies provides important new insight into their subsurface distribution. For example, the Nahlin ultramafic body underlies a series of northwest-trending anomalies and lineaments, some with peak amplitudes in excess of 2000 nT, which correlate with elongate lenses of foliated peridotite, dunite, and serpentinized harzburgite mapped within the body by Terry (1977). However, magnetic data (Fig. 2, 3, 4) show that the high anomaly values associated with the ultramafic body persist much farther north and east than the mapped exposures, indicating that the body may be significantly more extensive in the shallow subsurface than previously recognized. The observation has important implications for the subsurface shape of the body and orientation of the fault that bounds it. Souther (1971) and Monger (1975) interpreted the northeast boundary of the ultramafic body as a nearly vertical fault, but the new magnetic data suggest a significant component of northeasterly dip for the structure.

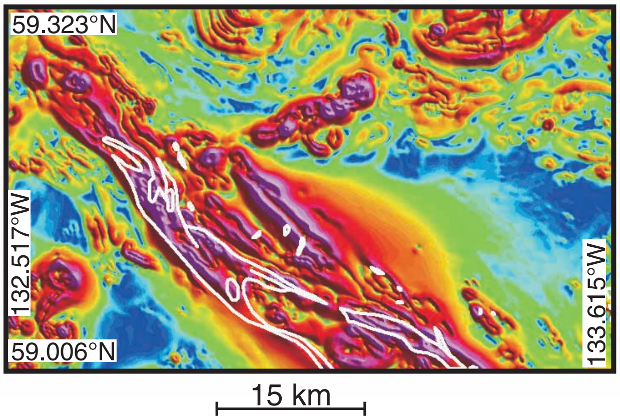

Figure 4. Horizontal-gradient magnetic data (high values are shown in hot colours and low values, in cool colours) for the south-central project area showing the mapped distribution (white lines) of ultramafite in the Nahlin ultramafite body (from *Mihalynuk et al., 1996).* See also *Figures 2 and 3.*

A positive magnetic anomaly near Union Mountain, approximately 10 km southeast of the Atlin townsite, is characterized by magnetic intensities that are greatest, up to 1200 nT, beneath the northern flank of the mountain where metabasaltic rocks with up to 10% pyrite are mapped (Ash, 1994). Lower anomaly values are observed over fault-bounded blocks of harzburgite and serpentinite–bastite that outcrop east and west of the flank. The metabasalt is not expected to be as magnetic as ultramafic body, an interpretation supported by the lower magnetic-anomaly amplitudes associated with metabasalt exposures elsewhere in the project area, as well as the susceptibility data presented in Table 1. Therefore, a substantial ultramafic mass, probably highly serpentinized, is inferred to underlie the metabasalt at relatively shallow depths beneath the northern flank.

A close spatial association exists between ultramafic rocks in the Cache Creek Terrane and placer gold throughout the Atlin map area, but a hypothesis of the ultramafic rock as the source of the placer gold is not yet proven. The distribution, age, origin, and structural setting of the ultramafic bodies are key to establishing their gold potential. The two examples just described illustrate the capacity of the new magnetic data to advance this understanding. Furthermore, we note that the magnetic anomaly associated with some ultramafic bodies provides insight into the nature and extent of associated alteration. For example, in the case of the Atlin ultramafic allochthon (Fig. 5), the largest magnetic intensities are typically associated with those exposures displaying the highest degrees of serpentinization, whereas the lowest relative intensities correlate with zones of pervasive carbonatization. The observation, which is consistent with measured magnetic-susceptibility data (Table 1), is also important given the recognition by Ash (1994) that mesothermal gold-bearing quartz veins within the Atlin placer camp are consistently associated with carbonatized ultramafic rocks. Therefore, magnetic data should be useful in targeting prospective zones within other less well mapped ultramafic bodies in the region.

Magnetic anomalies associated with plutonic rocks

Major differences in the magnetic response of post-accretionary plutonic rocks are recognized; the Fourth of July, Birch Mountain, Atlin Mountain, and Coconino intrusions correlate with heterogeneous, but generally strong, positive magnetic anomalies (Fig. 6). The magnetic fields over the Llangorse, Mount McMaster, and Chichoida plutons are also heterogeneous, but spatially distinct zones of positive and negative magnetic anomalies are recognized within each and magnetic amplitudes are generally much lower than those observed over the former group of intrusions. The Surprise Lake batholith is magnetically subdued with amplitudes rarely exceeding ±60 nT. In general, mafic intrusive rocks are more magnetic than felsic intrusive rocks (Carmichael, 1982; Telford et al., 1990), a fact that readily explains some of the large-scale magnetic differences between the plutonic

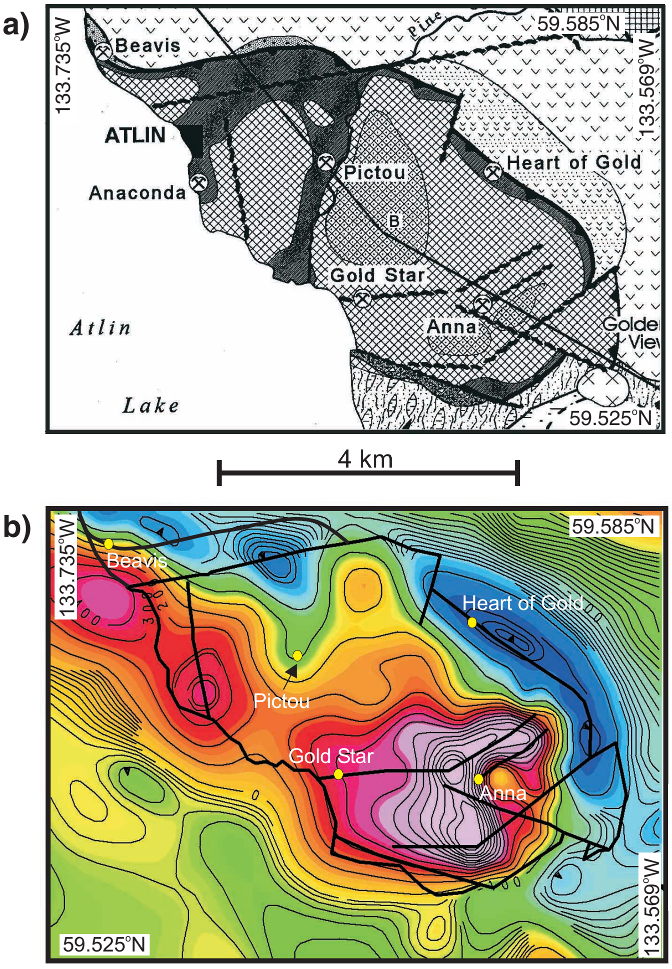

Figure 5.

***a)** Detailed geological map of the Atlin ultramafic allochthon (from Ash, 1994); **b)** corresponding magnetic-anomaly data (high anomaly values are shown in hot colours and low anomaly values, in cool colours).*

bodies. The Surprise Lake batholith is the most felsic of the plutonic bodies (>76% SiO_2) and it is significantly depleted in iron oxides relative to many other intrusions (Ballantyne and Littlejohn, 1981). In contrast, the Atlin Mountain pluton contains up to 25% mafic minerals and magnetite (Mihalynuk, 1999).

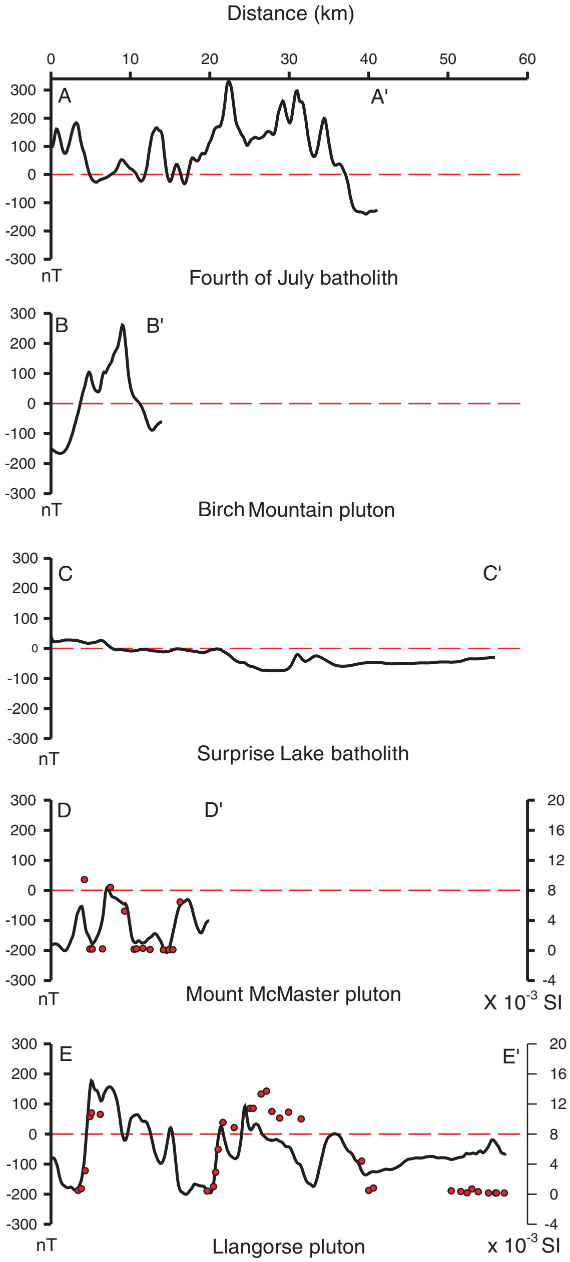

Figure 6. *Residual magnetic-anomaly cross-sections of selected plutonic bodies in the project area* (see *Figure 2 for profile locations). The measured magnetic susceptibilities and mapped geology along the Mount McMaster and Llangorse traverses are also indicated.*

Similarly, compositional variations mapped within individual bodies account for some observed magnetic variations. For example, granodiorite and gabbro within the border phases of the Fourth of July batholith correlate with higher magnetic intensities compared to the biotite granite and alaskite phases exposed elsewhere within the batholith. Higher magnetic-anomaly values are also observed over the southern margin of the Birch Mountain pluton where diorite and gabbro dominate over the more widespread quartz monzonite compositions (Bloodgood and Bellefontaine, 1990). Elsewhere, magnetic data appear to reflect more subtle compositional variations than can be recognized in reconnaissance bedrock geological mapping. For example, in situ magnetic-susceptibility measurements conducted along selected traverses across the Mount McMaster and Llangorse plutons directly correlate with observed variations in magnetic intensity, i.e. areas of high relative magnetic intensity are underlain by rocks with high relative magnetic susceptibility and vice versa (Fig. 6). The observations imply spatial variations in the magnetic properties of the *surface* rocks; however, such variations do not always correlate with corresponding megascopic compositional variations. Mineralogical and geochemical analyses of the plutonic bodies are being undertaken to investigate the nature and significance of the magnetic variations.

A recent re-analysis of provincially acquired regional geochemical survey samples, which for the first time included gold in the analytic suite, predictably indicates that creeks draining ultramafic sources have elevated gold concentrations. Surprisingly, those that drain plutonic sources yield even higher gold concentrations (Jackaman, 2000). The results underscore the importance of evaluating the intrusive rocks and their thermal aureoles as potential alternate sources for the Atlin gold placers. Despite well documented intrusive rock–lode gold associations in accreted oceanic terranes elsewhere (e.g. Kerrich, 1993), this metallogenic environment has remained largely untested within the Atlin project area. The new magnetic data provide an important contribution to mineral exploration by delineating compositional differences, in some instances previously unrecognized or too subtle to be detected in field mapping, within and between exposed plutonic bodies. The reconnaissance geological mapping and associated investigations of the intrusive rocks initiated by R.G. Anderson (GSC Pacific) in 2000 will be expanded in 2002 to provide a more comprehensive and complete evaluation of their mineral potential (*see* Lowe and Mihalynuk, 2002).

North and northeast of the Llangorse pluton in the central map area, several small, suboval magnetic anomalies are imaged (Fig. 2, 3). The anomalies are of small areal extent (maximum diameter <3 km), indicative of shallow magnetic source bodies, and with one exception all are negative (peak amplitudes typically range from -130 to -400 nT). They occur in areas underlain by sedimentary rocks of the Kedhada Formation (Mihalynuk et al., 1996), although examination of the Minfile database reveals that outcrops and subcrops of porphyry intrusions and known mineralization occur at two anomaly localities (NI, Minfile #104N067; Boot, Minfile

#104N078). Both these localities were investigated during the ground follow-up surveys, but in neither case was the magnetic source identified.

At the NI showing (Fig. 2; Minfile #104N067), molybdenite occurs as disseminations within a small (100 m by 360 m) quartz-feldspar porphyry stock. There, a pronounced reddish-brown gossan is developed over the mineralized zone and an area of sericite-kaolinite alteration in the porphyry and enclosing brecciated chert extends over an area 800 m wide. In situ magnetic-susceptibility measurements revealed that the altered porphyry and associated gossan are characterized by very low magnetic susceptibilities (average 0.04 x 10^{-3} SI); however, as the chert intruded by the porphyry has essentially the same magnetic properties (average magnetic susceptibility = 0.05 x 10^{-3} SI), the porphyry cannot account for the positive anomaly observed at this locality.

Farther north, at the Boot showing (Fig. 2; Minfile #104N078), pockets and disseminations of galena, sphalerite, and chalcopyrite are reported in limestone bands within chert and argillite of the Kedhada Formation. The mineralization is developed where the host rocks are metamorphosed around small feldspar porphyry intrusions, dykes, and/or sills. In situ magnetic-susceptibility measurements conducted on porphyry outcrops at this locality yield an average value of 0.86 x 10^{-3} SI. However, as the adjacent host rocks have an even smaller average magnetic susceptibility of 0.03 x 10^{-3} SI, the porphyry intrusions cannot account for the -210 nT anomaly observed in the area. Despite the failure of ground investigations to reveal the source of the negative anomalies at these two localities, the presence of mineralization is nonetheless intriguing and suggests that the other suboval anomalies in the region may warrant investigation (*see* features labeled '???' in Fig. 2).

Magnetic lineaments

Prominent magnetic lineaments mirror the surface trace of several mapped faults. Particularly obvious are those along the crustal-scale, northwest-trending Teslin and Nahlin faults (Fig. 1, 2), which juxtapose rocks having significantly contrasting magnetic susceptibilities. A linear zone of steep magnetic gradient (up to 4.27 nT/m) is observed where the Nahlin Fault juxtaposes high-susceptibility ultramafic rocks in the Cache Creek Group against weakly magnetic (Table 1) sedimentary rocks of the Laberge Group. Similarly, the juxtaposition of mafic volcanic rocks in the Big Salmon complex with sedimentary rocks in the Kedhada Formation generates magnetic gradients up to 2.55 nT/m across the Teslin Fault zone.

However, numerous additional northwest- and north-northwest-trending lineaments are recognized where no faults have been mapped. Particularly prominent is the series of lineaments observed over the eastern portion of the Surprise Lake batholith and adjacent aureole (Fig. 7), as well as isolated lineaments in NTS 104 N/1 and N/15 map areas. In all cases, the lineaments are characterized by relatively narrow zones of elevated magnetic anomalies indicative of shallow magnetic source bodies. Peak amplitudes, which vary considerably from lineament to lineament and, in some instances, along the strike of individual lineaments, rarely exceed 100 nT.

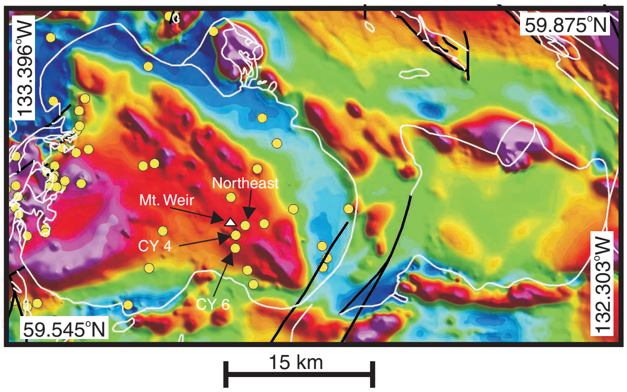

Figure 7. *Residual magnetic-anomaly data (high anomaly values are shown in hot colours and low anomaly values, in cool colours) over the Surprise Lake batholith illustrating a series of prominent northwest-trending magnetic lineaments. The locations of known mineralization are indicated.* See *text for details.*

Given that the Surprise Lake batholith is generally depleted in iron and titanium oxides (Ballantyne and Littlejohn, 1982) and weakly magnetic (Table 1), what is the source of the northwest-trending lineaments with positive magnetic amplitudes observed within this batholith? Ground follow-up investigations of the anomalies were not conducted during the limited 2001 field season; however, an analysis of the Minfile database and the report of Ballantyne and Littlejohn (1982) offer some insight. The latter authors mapped numerous fracture zones within the Surprise Lake batholith, and although they provide no information on fracture orientation, they note that on Mount Weir, the fractures are infilled with sphalerite-magnetite veins (Fig. 7). They also observed base-metal and magnetite enrichments in fractures from drill cores near Trout Lake, approximately 14 km east of Mount Weir. At the CY 6 showing (Minfile #104N089), veins containing up to 15% magnetite and 20% sphalerite are reported intruding the alaskite. Similarly, at the Northeast showing (Minfile #104N074), mafic-rich dykes with sphalerite, galena, magnetite, hematite, quartz, and danalite are reported, and at the CY 4 showing (Minfile #104N087), fractures filled with smokey quartz veins and hosting galena, sphalerite, magnetite, and hematite occur in coarse-grained alaskite. All the localities occur along, or proximal to, magnetic lineaments (Fig. 7), suggesting that a probable source of the magnetic anomalies is the magnetite contained in the late-stage mineralized veins and intrusions. If confirmed, the magnetic data could prove valuable for targeting other base-metal occurrences within the batholith and adjacent aureole rocks.

Three regionally extensive (>30 km long) and several shorter east- to east-northeast-trending magnetic lineaments are imaged in the new magnetic data set (Fig. 3). Among the most easily recognized are those that mark the southern margins of the Surprise Lake, Mount McMaster, and Llangorse intrusions, as well as those that extend across the Fourth of July and adjacent rocks in the northwestern project area. They are typically characterized by narrow strings of positive magnetic anomalies with peak amplitudes rarely exceeding 200 nT. Although digital elevation models of the Atlin map area delineate an impressive series of subparallel, east-northeast-trending topographic scarps in the northwestern portion of the map area, structures with this orientation have not been recognized previously in this or any other part of the Atlin map area. However, east-northeast-trending faults are mapped in the Tagish map area farther west (Mihalynuk, 1999). Lack of bedrock exposures precluded identification of the magnetic source(s) during ground follow-up investigations of the lineament along the southern margin of the Surprise Lake batholith. Although the mode and depth of emplacement of the intrusive bodies in the Atlin project area are largely unknown, we speculate that the magnetic lineaments may reflect structures that controlled their emplacement.

SUMMARY

Magnetic-anomaly data for the Atlin map area accurately delineate many mapped rock units and structures. However, the value of the new data set lies not just in the confirmation of the published bedrock geology, but also in the recognition of numerous additional anomalies and trends whose sources were hitherto unknown. Analysis of these features provides important new insights into the surface and shallow subsurface geology of the region. In our preliminary analysis of the new data, we show that the Nahlin ultramafic body dips to the northeast and is more extensive than previously recognized. Within individual ultramafic bodies, magnetic intensities increase with increasing serpentinization and decrease with increasing carbonatization; these features should be useful for targeting prospective lode-gold zones within ultramafic bodies that have not been mapped in detail. Large differences exist in the magnetic response of the postaccretionary plutonic rocks within the map area and, in the Mount McMaster and Llangorse plutons, the observed differences appear to reflect subtle compositional variations not readily apparent in bedrock mapping. We speculate that magnetite in mineralized veins is the probable source of subtle northwest-trending magnetic anomalies at several localities in the eastern part of the Surprise Lake batholith and we identify other targets for base-metal exploration within the batholith and adjacent country rocks.

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Geological Survey of Canada Project 000024