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Variation in vein mineralogy and mineral chemistry around the Marathon Cu-Pd deposit, Ontario: Insights into the development of an exploration tool

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ABSTRACT

The Marathon Cu-Pd deposit (125 Mt at 0.26% Cu, 0.72 ppm Pd, 0.25 ppm Pt, and 0.08 ppm Au) is hosted within the Two Duck Lake Intrusion (TDLI), a late-stage phase of the Eastern Gabbro in the Coldwell Complex. Late-stage chlorite±calcite veins are present in and around the Marathon deposit, indicating sub-solidus movement of fluids throughout mineralized and barren rocks. The hypothesis to be tested is did fluids migrating upwards through mineralized rock mobilize metals into overlying barren rock and was this movement recorded in the chemistry of vein minerals? Chlorite- and calcite-bearing veins were collected from drillholes throughout the deposit. The drill-core samples contain veins hosted in variably mineralized and barren host rocks. Chlorite, the dominant phase, occurs as very fine-grained, bladed crystals in massive, radiating, or aligned aggregates. The veins also contain minor saponite, talc, serpentine, and/or amphibole. Mineral chemistry data from energy- and wavelength-dispersive spectroscopy indicate that the Fe/Mg ratio in chlorite (chamosite to clinochlore) is highly variable, and varies as a function of host-rock type.

Laser ablation ICP-MS analyses were carried out on 52 chlorite samples collected throughout the deposit and barren host rocks. Transition metals were detected in all chlorite veins, whereas metalloids were only detected in a subset of samples. Titanium, Cr, Mn, Zn, and metalloid concentrations do not correlate with host-rock type. Transition metal concentrations in vein chlorite that crosscuts plagioclase, pyroxene, and pyrrhotite are comparable; however, chlorite in veins that occur in magnetite, altered olivine, and chalcopyrite have distinctive transition metal signatures (e.g. significantly higher Ti and V concentrations in veins hosted by magnetite), indicating that chlorite chemistry was controlled on a very local scale. Cobalt, Ni, and Cu concentrations are greater above mineralization than within mineralization. The Mn concentrations in chlorite increase linearly towards mineralization, whereas Co, Ni, and Zn decrease. When employing chlorite chemistry as a vector to mineralization, grain-scale variations in chlorite must be considered. Our results show that when these small-scale controls on chlorite composition are recognized, the chemistry of chlorite can be a successful exploration tool.

INTRODUCTION

Mineral deposits generally occupy small areas and/or may be located below the surface, making them difficult to locate using normal surface mapping techniques. To increase the target area, geochemical-mineralogical haloes can be used to vector towards deposits (Kelley et al., 2006). However, very few studies have focused on using the chemistry of vein minerals for Cu-PGE exploration.

The contact-type Marathon Cu-platinum-group element (PGE) deposit, located near Marathon, Ontario, is hosted within the Two Duck Lake (TDL) gabbro, a late-stage intrusion within the Eastern Gabbro of the Coldwell Complex (Watkinson and Ohnenstetter,

1992; Good and Crocket, 1994; Dahl et al., 2001; Good et al., in press). The Eastern Gabbro is an arcuate, composite intrusion located at the base of the Coldwell Complex, and is the oldest intrusive phase within the complex (Shaw, 1997; Barrie, 2002; Good et al., in press). Recent studies by Good et al. (in press) have led to new subdivisions of the Eastern Gabbro into three gabbroic series: the Fine-Grained Series, the Layered Series, and the Marathon Series, the latter of which is host to the majority of the mineralization.

The Fine-Grained Series is tholeiitic in composition, occurs at the base of the Eastern Gabbro, and is compositionally homogenous (Good et al., in press). The Layered Series makes up the majority of the Eastern
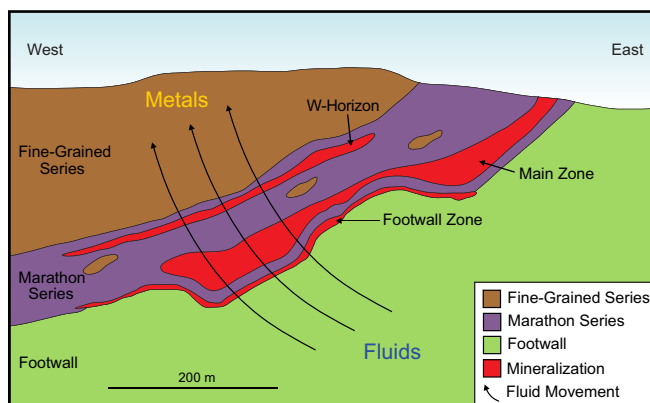
Figure 1. East-west cross-section of the Marathon deposit showing relative locations of the main rock series and mineralized zones (modified after Ruthart, 2013). Curved arrows illustrate the hypothetical movement of fluid upward through mineralized and barren rock.

Gabbro and occurs stratigraphically above the Fine-Grained Series. It is geochemically and texturally similar throughout the Coldwell Complex and is characterized by massive to modally layered olivine gabbro (Good et al., in press). The Marathon Series is defined as including all mafic and ultramafic intrusive rocks that host Cu and PGE mineralization (Good et al., in press). It comprises mainly the TDL gabbro, an unmetamorphosed and undeformed body formed from multiple intrusions of crystal-laden magma into the Fine-Grained Series (Good and Crocket, 1994; Good et al., in press). It is coarse grained to pegmatitic and displays ophitic to subophitic textures (Good and Crocket, 1994; Good et al., in press).

Mineralization within the Marathon Series occurs in three zones: the Footwall Zone, the Main Zone, and the W-Horizon (Ruthart, 2013; Good et al., in press). The Footwall Zone is located between the contact of the footwall and TDL gabbro (Ruthart, 2013; Good et al., in press). Sulphides are interstitial to the silicates and consist of, in decreasing abundance, pyrrhotite, chalcopyrite, pyrite, and pentlandite. The sulphides are typically disseminated, but can occur as net-textured assemblages and as semi-massive blebs (Ruthart, 2013; Good et al., in press). The Main Zone is located in the lower part of the TDL gabbro (Ruthart, 2013; Good et al., in press). Sulphides here are dominated by chalcopyrite and pyrrhotite with minor bornite, pentlandite, and pyrite, and occur as lenses of disseminated mineralization where chalcopyrite commonly replaces pyrrhotite (Good and Crocket, 1994; Dahl et al., 2001). Platinum-group minerals are, in part, associated with chalcopyrite and an alteration assemblage dominated by chlorite and/or actinolite, with or without epidote, sericite, and calcite (Watkinson and Ohnenstetter,

1992; Dahl et al, 2001). The W-Horizon is hosted by the TDL gabbro and sits above the Main Zone, but off-set from it. Due to the low sulphide content of the W-Horizon, it can only be distinguished from the Main Zone by its distinctly low S contents, low Cu/Pd (average <3500, high grade <215) and S/Se ratios, and a mineralogy that comprises chalcopyrite and bornite, rather than chalcopyrite and pyrrhotite (Ruthart, 2013; Good et al., in press).

The presence and effects of fluids within the Marathon deposit were described by Watkinson and Ohnenstetter (1992) and Barrie et al. (2002). The working hypothesis of this study is that fluids passing through the Cu-PGE deposit mobilized metals (e.g. Cu, Ni) out of the mineralized Marathon Series and into the barren Marathon and Fine-Grained Series, and influenced the chemistry of the vein minerals (Fig. 1). The objective of this study is to systematically characterize variations in late vein-mineral chemistry and determine which, if any, elements and minerals may be used as a vectoring tool for Cu-PGE exploration in the Coldwell Complex and elsewhere. Understanding how and why mineral chemistry varies is critical in the development of an exploration vector because controls on mineral chemistry at, for example, the grain-scale, may complicate or invalidate its use as an exploration tool.

RESULTS AND DATA ANALYSIS
Drillhole Sampling and Vein Density
Samples of veins were collected from ten drillholes, which are distributed along a 5.2 km line from the northern end of the 4 km long Marathon deposit to its southern end. Samples were taken from within and above the mineralized zones, at varying distances from the mineralization. Thin (<1 mm) veins are ubiquitous in the Marathon deposit and the surrounding barren gabbros. Vein density, quantified by counting the number of veins occurring over a 3 m interval, varies considerably (Fig. 2). An obvious correlation exists between vein density and mineralization, with mineralized rocks having distinctly lower vein densities; this relationship was observed in all of the drillholes examined, and is particularly obvious in drillhole M-06-221.

Petrography
Chlorite and calcite are the only abundant vein minerals that were observed. Chlorite is extremely fine grained, and occurs as randomly oriented, radiating, or aligned aggregates of bladed crystals (Fig. 3). In thin section, chlorite is commonly light to dark brown, but can also be colourless, pale to light green, yellow, or orange. It exhibits weak pleochroism and a range of first-order interference colours. Multiple optically distinguishable varieties of chlorite are generally present within a given vein, either intergrown or in separate
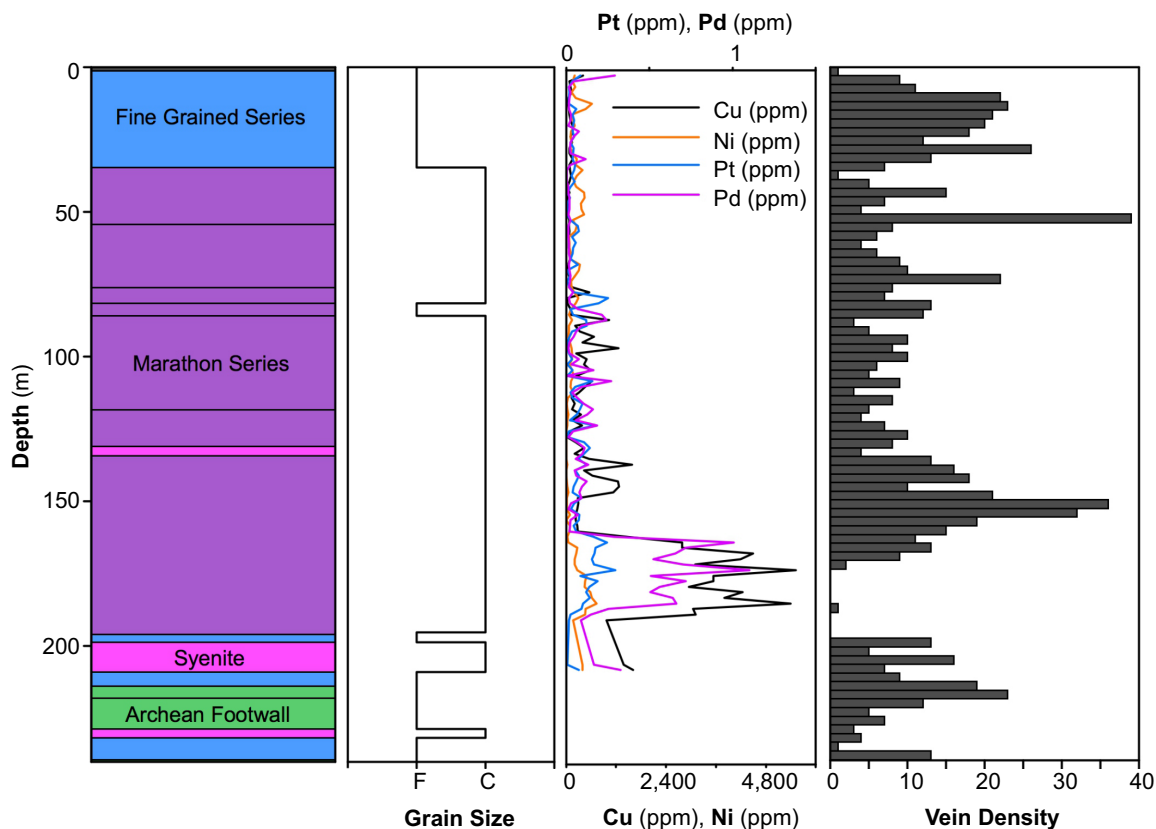
Figure 2. Downhole profile of drillhole M-06-221 illustrating the lithology, grain size, Cu, Ni, Pt, and Pd assay (ppm), and vein density.

zones with gradational or sharp contacts (Fig. 3). Light green to colourless Mg-rich chlorite is restricted to the outer zones of veins, where they crosscut plagioclase, and is absent from veins that crosscut pyroxene or olivine (Fig. 3c,d).

Calcite is commonly a vein component (Fig. 3g,h), but is much less abundant than chlorite, typically occupying <10 to 20% of the vein. Fine-grained anhedral calcite grains occur in aggregates in the vein cores, as isolated crystals, and occasionally as very fine-grained disseminated crystals. Calcite is rarely the dominant vein mineral, but can comprise up to ~80 to 90% (Fig. 3g,h). Results from energy-dispersive spectroscopy (EDS), wavelength-dispersive spectroscopy (WDS), and Raman spectroscopy (described below) indicate that minor amounts of amphibole, serpentine, talc, and/or saponite are present in the veins. They are very fine-grained and exist as mixtures with chlorite or as the main phase within the vein; however, they are not distinguishable optically as their optical properties are similar to those of chlorite. Sulphides do not occur in the veins.

Major Element Chemistry

Chlorite from 61 vein samples was analyzed by EDS, and a subset of these by WDS. Analyses of single crystals proved difficult due to the extremely small size of most of the chlorite crystals (<1–10 μm) and, as a result, analyses represent the composition of crystal aggregates. Typically 3 to 5 analyses within individual zones in the veins were used to confirm homogeneity of chlorite composition. Aluminum contents of chlorite do not vary significantly, however, the Si/Al ratio and the concentration of Fe and Mg vary among rock series. The Si/Al ratio is only slightly higher (mean = 4.5) in veins hosted within Archean footwall and slightly lower (mean = 2.75) in veins hosted in Layered Series gabbro, compared to the other rock series. Average total Fe concentrations range from ~6 to ~13 at.%; the lowest average values are in veins hosted by Archean footwall, and the highest in veins hosted in augite syenite, with gabbro-hosted chlorite ranging from ~7 to ~10 at.%. Magnesium concentrations show the opposite trend. Calcium was detected (<1 at.%) in many analyses, with concentrations slightly higher in veins hosted in Archean footwall and Layered Series rocks, compared to the other rock types.

Figure 4 illustrates the relative proportions of Al, Fe, and Mg in vein chlorite, which ranges in composition from clinochlore to chamosite; average atomic Mg/(Mg+Fe) ratios are between ~0.15 and ~0.6. Both chamosite and clinochlore veins are present in all of the rock series in the Eastern Gabbro. Some veins have compositions that are consistent with the presence of
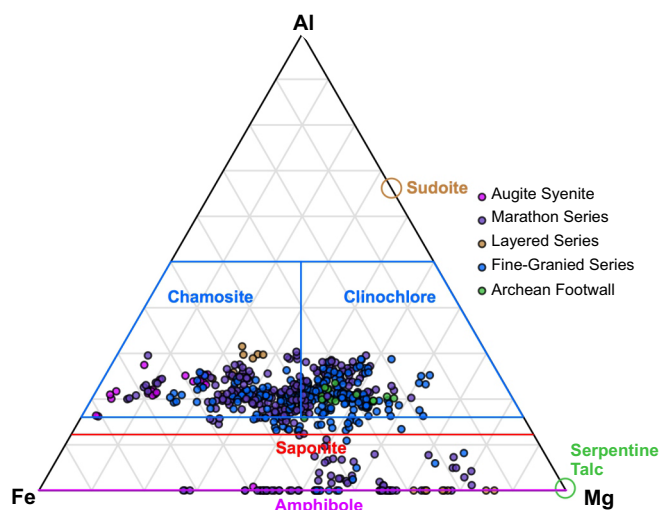
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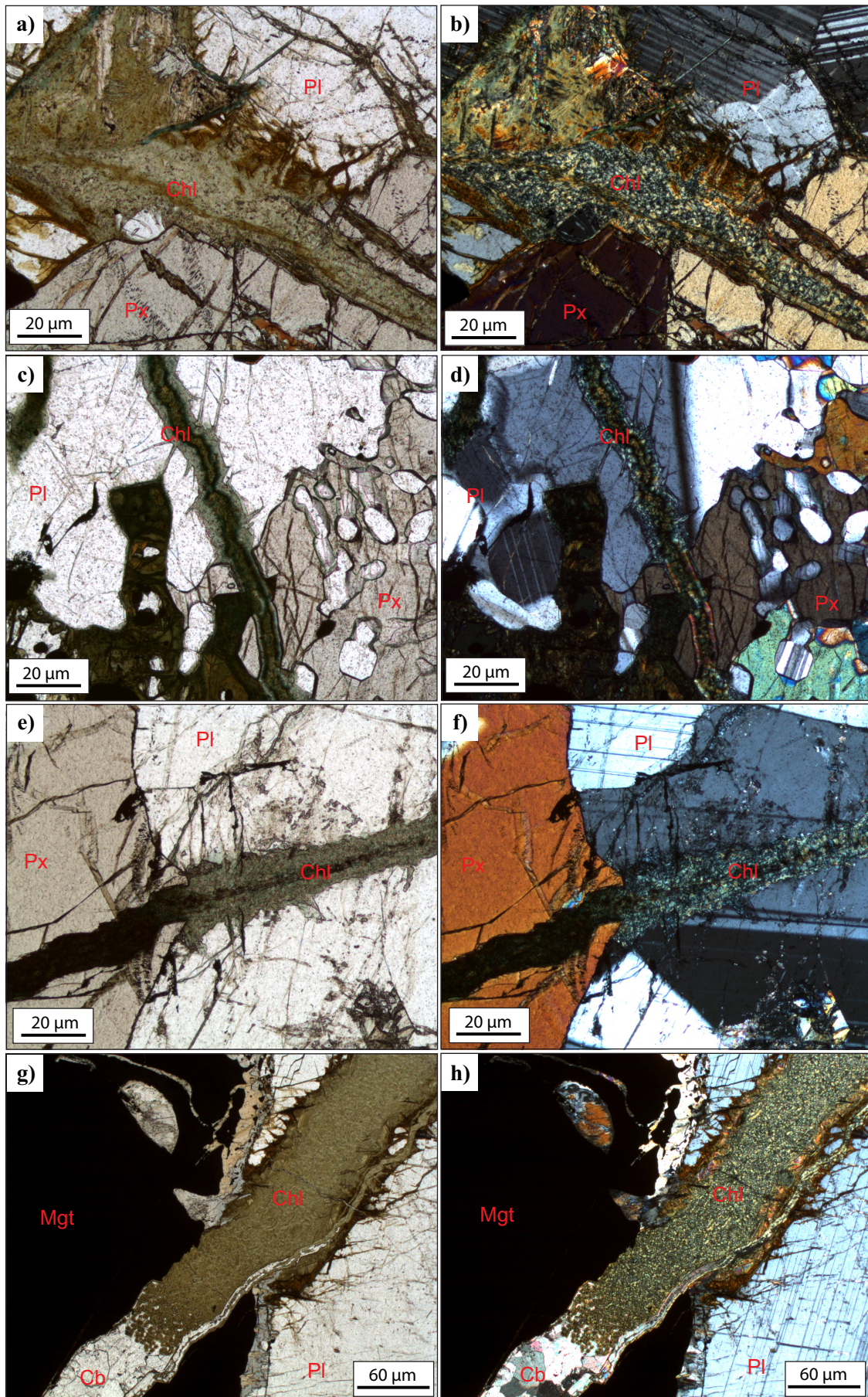
Figure 4. Ternary diagram showing the relative atomic proportions of Al, Fe, and Mg in vein minerals. Compositional fields for chlorite, saponite, amphibole, serpentine, talc, and sudoite are also shown (Bailey, 1988; Deer et al., 1996). Symbol colours represent the host-rock type.

saponite, amphibole, serpentine, and talc, or some combination of these minerals. Pale green and colourless chlorite varieties are consistently devoid of Ca and have the most consistent Si concentrations.

Raman Spectroscopy and Micro X-Ray Diffraction

Raman spectroscopy (McMillan, 1989) and micro X-ray diffraction (Flemming, 2007) were useful tools for identifying vein minerals, as these instruments are capable of identifying minerals occurring as mixtures with high degrees of spatial resolution. Both techniques were used to identify different hydrous silicates occurring as mixtures within the veins (e.g. chlorite versus serpentine, amphibole), however, the spectra did not allow us to distinguish different varieties of chlorite (i.e. chamosite versus clinochlore).

Trace Element Chemistry

Chlorite veins from 52 thick sections, collected at various depths in nine drillholes spanning the entire Marathon deposit, were analyzed by LA-ICP-MS for major elements, transition metals (Ti, V, Cr, Mn, Co, Ni, Cu, Zn, Cd), and metalloids (As, Sn, Sb, Pb, Bi). Transition metals are present in all the chlorite veins analyzed, whereas metalloids in only a subset. With the exception of Cd, all transition metals are present in higher concentration than metalloids. Median concentrations for transition metals range from 0.15 ppm for

Cd up to 1500 ppm for Mn, whereas those for metalloids range from as low as 0.03 ppm for Bi to 0.64 ppm for As. Representative metal concentrations of vein chlorite are provided in Table 1.

Local Controls on Chlorite Trace-Element Chemistry

It is important to understand the effects that other variables (e.g. host-rock type, host mineral) have on vein chlorite chemistry so that such effects can be taken into account when interpreting the relationship between chlorite chemistry and mineralization. Chlorite veins hosted in Marathon Series (±Cu-PGE), Fine-Grained Series (barren), Layered Series (barren), and Archean Footwall rocks were analyzed. Vanadium is present in greater concentrations, and Cd in lower concentrations, in chlorite veins hosted within Archean Footwall compared to those hosted in other rock types. Cobalt and Ni, and to some extent, Cr and Zn, are present in higher concentrations in chlorite veins hosted in Archean Footwall and Fine-Grained Series rocks compared to those hosted in the other mineralized and barren rock types. To assess the spatial variations in chlorite chemistry independent of any host-rock influence, metal concentrations were normalized to a representative host-rock metal content for the Fine-Grained Series and Marathon Series (Table 2). Normalized Co, Ni, and Cu concentrations are greater in chlorite veins hosted in Fine-Grained Series than in Marathon Series rocks. The unnormalized concentration of Cr, Co, and Ni is greater in some chlorite veins hosted by rocks with high magnetite content compared to those with low magnetite content, whereas Mn concentrations are lower.

The concentrations of transition metals and metalloids in chlorite hosted by plagioclase, pyroxene, and pyrrhotite show similar ranges throughout the sample suite. The exception is Cd, which has significantly higher concentrations in pyrrhotite-hosted veins compared to those hosted in the other minerals. Magnetite-hosted veins consistently have higher concentrations of Ti and V compared to those in other mineral hosts. Although few chalcopyrite-hosted and altered olivine-hosted veins were present and analyzed, some notable correlations were observed. Chlorite hosted by chalcopyrite has anomalously high Cu concentrations; however, the concentrations of Ti and Co are only marginally lower than those in the previously mentioned minerals. Altered olivine-hosted veins have significantly lower Ti and V, but significantly higher Co, Ni,

Figure 3 (opposite page). Photomicrographs in plane-polarized and cross-polarized light illustrating (**a-b**) mixtures of chlorite with other minerals in a vein, (**c-f**) variations in chlorite morphology and optical properties as a function of host mineral, and (**g-h**) a chlorite-calcite vein in which calcite is the predominant mineral in portions of the vein. Abbreviations: Cb = carbonate, chl = chlorite, mgt = magnetite, pl = plagioclase; and px = pyroxene.

Table 1. Representative trace metal concentrations (ppm) in vein chlorite from mineralized and barren sections of each drill-hole sampled. Concentrations for each sample represent an individual laser ablation analysis.

Sample	Location to Mineralization	Host-Rock Series	Ti ppm	V ppm	Cr ppm	Mn ppm	Co ppm	Ni ppm	Cu ppm	Zn ppm	As ppm	Cd ppm	Sn ppm	Sb ppm	Pb ppm	Bi ppm
MB-151-04	Above	Fine-Grained	93	0.9		1574	24	7	37	13			11		3	
MB-151-20	Within	Marathon	65	3	0.7	1678	10	2	17	9			1	0.03	16	
MB-221-026	Above	Marathon	84	9	6	1168	4	15	5	8		0.06	0.2	0.09	0.4	
MB-221-035	Within	Marathon	46	8	3	1357	3	30	5	6			0.3		0.2	
MB-366-23	Above	Fine-Grained	332	19	21	446	50	164	3	16	2	0.1	5		2	0.01
MB-366-40	Within	Fine-Grained	59	77	0.9	1213	4	4	11	4			10		0.4	
MB-391-25	Above	Marathon	127	35		1296	80	453	1	52		0.2	0.5		0.1	0.08
MB-391-31	Within	Marathon	31	79	2	1707	14	36	13	27		0.2	8		0.6	
MB-424-017	Above	Fine-Grained	8			1995	90	297	0.8	48			0.2		0.07	
MB-424-036	Within	Marathon	38	4	2	1761	58	98	7	59			0.3		1	
MB-513-003	Above	Augite Syenite	22			8606	3	2	0.4	1		0.07	0.3		0.1	
MB-513-011	Within	Marathon	75	1		4705	28	149	3	95	0.4		0.2	0.08	2	
MB-99-10	Above	Fine-Grained	178	52	47	867	1	7	1	7		0.1	0.7		0.9	
MB-99-16	Within	Marathon	52	3	0.5	1541	1	16	2	6		0.07	0.2		0.07	
MB-MW05-02	Above	Marathon	70	8		1997	16	2	1	5			0.2		0.09	
MB-MW05-05	Within	Marathon	25	0.8	0.5	2480	8	11	37	13			1		8	
MB-MW06-01	Above	Layered	255	9		6108	13	0.9	1	7		0.1	1		0.1	

Note: Blank cells represent elements that are below detection.

Table 2. Metal concentrations (ppm) of host rocks from Good et al. (in press) used to normalize metal concentrations in vein chlorite. Representative host rock normalized trace metal concentrations (ppm) of vein chlorite from mineralized and barren sections of each drillhole sampled. Concentrations for each sample represent an individual laser ablation analysis.

Rock Type	Co ppm	Cr ppm	Cu ppm	Ni ppm	V ppm	Zn ppm	TiO$_2$ wt%	MnO wt%
Augite Troctolite	76.7	67.7	71.0	172	238	97	0.7	0.2
Olivine Gabbro	60	10	300	7	259	210	3.12	0.34
Two Duck Lake Gabbro	74.3	146	1766	242	393	86	0.86	0.17
Gabbro	57.1	348	51	146	351	97	1.26	0.18
Picritic Gabbro	101	1523	88	853	263	112	1.25	0.21
Lower Oxide Melatroctolite	126	233	1634	148	1623	331	6.28	0.38

Sample	Co	Cr	Cu	Ni	V	Zn	Ti	Mn
MB-151-04	0.4		0.7	0.05		0.1	0.01	1
MB-151-20	0.1		0.01	0.01	0.01	0.1	0.01	1
MB-221-026	0.05	0.04		0.06	0.02	0.09	0.02	0.9
MB-221-035	0.05	0.02		0.1	0.02	0.07	0.01	1
MB-366-23	0.9	0.06	0.05	1	0.06	0.2	0.04	0.3
MB-366-40	0.07		0.2	0.03	0.2	0.04	0.01	0.9
MB-391-25	1			2	0.09	0.6	0.02	1
MB-391-31	0.2	0.02	0.01	0.2	0.2	0.3	0.01	1
MB-424-017	2		0.02	2		0.5		1
MB-424-036	0.8	0.02		0.4	0.01	0.7	0.01	1
MB-513-011	0.2			1		0.3		2
MB-99-10	0.01	0.03	0.01	0.01	0.2	0.06	0.02	0.5
MB-99-16	0.01			0.07	0.01	0.07	0.01	1
MB-MW05-02	0.2			0.01	0.02	0.06	0.01	2
MB-MW05-05	0.1		0.02	0.04		0.2		2
MB-MW06-01	0.2			0.1	0.03	0.03	0.01	2

Note: Blank cells represent elements that are below detection; host-rock metal concentrations from Good et al. (in press)

and Zn concentrations than veins hosted by other minerals.

Relationship between Trace-Element Chemistry and Mineralization

Figure 5 illustrates the spatial relationship between chlorite trace-element chemistry and Cu-PGE mineralization in aggregated downhole plots that incorporate data from all of the drillholes sampled. The boundary of the mineralization is defined as the initial spike in Cu and Ni in the downhole assay data. As mineralization is approached, vein-chlorite concentrations of Mn, Co, Ni, and Zn vary systematically. Manganese concentrations increase linearly by roughly an order of magnitude, whereas Co, Ni, and Zn concentrations decrease by almost two orders of magnitude as mineralization is approached. Concentrations of Co, Ni, and Zn all decrease nonlinearly, however, the trend for Ni is different from that of Co and Zn.

Patchy Chlorite Alteration

In addition to occurring in late-stage veins, chlorite also occurs in patchy alteration as aggregates of fine- to coarse-grained crystals that have replaced pyroxene and plagioclase in the TDL gabbro. This patchy chlorite is commonly associated with sulphides, but can occur where no sulfides are present. The major element chemistry of this chlorite is distinctly different from that of vein chlorite. Silicon is greater in vein chlorite compared to patchy chlorite (mean = 15 versus 11 at.%), whereas Al has the opposite relationship (mean = 4.5 versus 8 at.%), resulting in a Si/Al ratio that is consistently greater in vein chlorite (mean = 3.5 versus 1.5). There is generally no Ca detected in patchy chlorite, whereas up to 1 at.% is present in vein chlorite. The major element chemistry of patchy chlorite displays no difference whether or not it is associated with sulphides. However, the trace element chemistry of patchy chlorite is different from that of vein chlorite. Concentrations of Cr, As, Sn, and Sb are greater in vein chlorite than patchy chlorite, whereas Mn, Co, Ni, and Zn concentrations are greater in patchy chlorite. These concentration differences are less than an order of magnitude. Concentrations of trace metals are comparable in patchy chlorite associated with sulphides with those isolated from sulphides.

DISCUSSION

Few studies (e.g. Hanley and Bray, 2009; Tuba et al., 2014) have been published that have characterized silicate vein mineral chemistry and its relationship to Ni-Cu-PGE mineralization. A recent study by Hanley and Bray (2009) tested Ni concentrations in vein amphibole as an exploration vectoring tool for Cu-(Ni)-PGE mineralization in the Sudbury footwall of the Sudbury Igneous Complex. Their study showed that the concentration of Ni in vein-hosted amphibole ($[Ni]amp$) increased with increasing proximity to mineralization based on the model $[Ni]amp = 5100 \, (D)^{-0.45}$, where D is the distance in metres from the initial signs of mineralization. Amphibole poikiloblasts contained only background Ni values.

Chlorite and/or chlorite-calcite veins are ubiquitous throughout the Marathon Cu-PGE deposit and Eastern Gabbro and their density varies with respect to mineralization (Fig. 2). Therefore, vein density itself may have the potential to be used as an exploration tool by vectoring towards areas with low vein density. Chlorite mineral chemistry is variable, ranging from Fe-rich varieties (chamosite) to Mg-rich varieties (clinochlore). The aluminum content, however, does not vary significantly, suggesting that all vein chlorite formed at similar temperatures (cf. Cathelineau, 1988). Patchy chlorite has consistently higher Al concentrations, suggesting that it formed at higher temperatures than the vein chlorite. Calcium is typically not incorporated into chlorite (Bailey, 1988), but is present in some vein chlorite from Marathon, yet generally absent from patchy chlorite. This, along with mineral compositions that fall outside of the chlorite compositional field (Fig. 3), indicates that, in some cases, the veins comprise mixtures of chlorite and other hydrous silicates containing Ca or fine-grained crystals of calcite, whereas patchy chlorite does not. Trace element contents of vein and patchy chlorite are also different (e.g. Cr, Co, Ni, and Zn). These observations demonstrate that patchy and vein chlorite formed during different events and at different temperatures, with the former associated with an earlier event that was more closely tied to the mineralization.

Revised Model

The trace element chemistry of vein-hosted chlorite is consistent with a model whereby fluids moved upwards through mineralized gabbros (TDL) at some time after the rocks had been mineralized, and carried metals into the overlying, barren gabbros. Cobalt, Ni, and Cu are elements indicative of fertility, whereby their normalized concentrations in chlorite are greater in veins hosted by the barren Fine Grained Series that lies above mineralization compared to veins hosted in mineralized Marathon Series. Of the transition metals analysed, only Mn, Co, Ni, and Zn show a variation with proximity to mineralization; Mn concentrations increase linearly with proximity to mineralization, and Co, Ni, and Zn concentrations decrease nonlinearly, providing new pathfinder elements for the Cu-PGE mineralization in the Coldwell Complex. It is expected that metal concentrations in vein chlorite would be greatest proximal to mineralization as that is where an
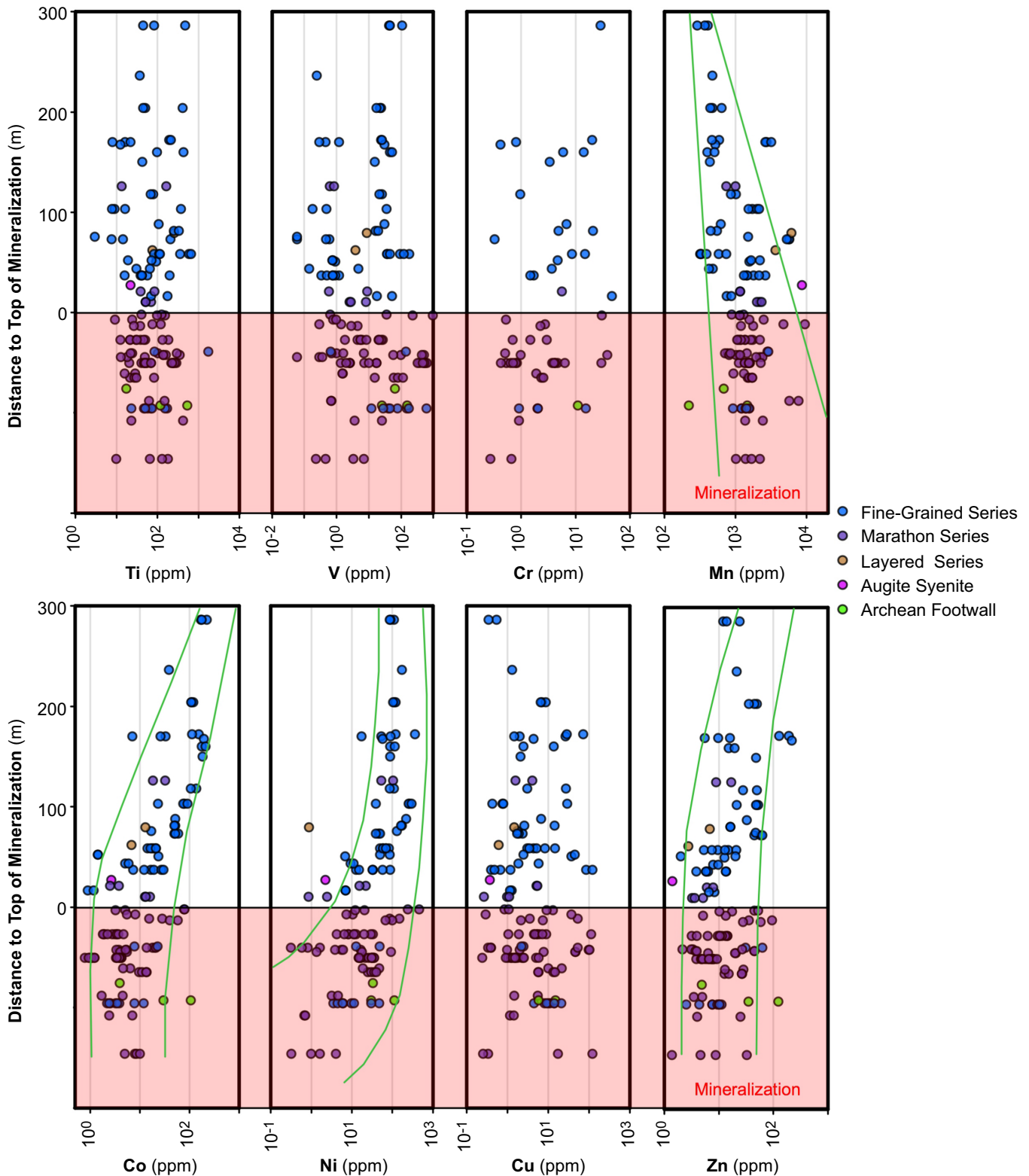
Figure 5. Composite downhole trace-element profiles demonstrating variations in vein-chlorite metal concentration as a function of proximity to mineralization. The top of mineralization was taken as the initial spike in Cu, Ni, Pt, and Pd in assay data. Symbol colours represent veins hosted in different rock series.

upwardly migrating fluid, having passed through a mineralized section and subsequently precipitated chlorite, would have the greatest concentration of metals. Manganese concentrations follow this trend; how-

ever, Co, Ni, and Zn display the opposite trend and decrease with proximity to mineralization. The reason for this is not yet understood, however, two things to consider are (1) a model in which fluids migrated

solely in an upward direction may be an oversimplification, and (2) the behaviour and sources of Mn, versus Co, Ni, and Zn are fundamentally different.

Care must be taken when analyzing vein-hosted chlorite and interpreting the relationships between mineral chemistry and mineralization, as host-rock mineralogy (i.e. the mineral in which the vein occurs) has an effect on vein chlorite chemistry. Interpretations should be based on those veins hosted by plagioclase, pyroxene, and pyrrhotite, as these minerals do not appear to exert a strong influence on the trace element chemistry of chlorite at a local scale.

IMPLICATIONS FOR EXPLORATION

Although the use of mineral chemistry as vectoring tool towards mineralization is not a new concept for many ore deposit types (i.e. indicator minerals), the relationship between post-mineralization vein-hosted mineral chemistry (e.g. chlorite) and Cu-PGE magmatic(-hydrothermal) mineralization has rarely been tested. In this study, we have illustrated how the chemistry of vein-hosted chlorite can be used to vector towards Cu-PGE mineralization in the Marathon deposit, and identified a few caveats to consider when interpreting an exploration survey database. Given the ubiquity of veins throughout mineralized and barren rocks, this exploration method has the potential to be applicable to a wide array of Cu-PGE ore systems.

ACKNOWLEDGEMENTS

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