

Spectral and Geochemical Characterization of the Silver Pond Argillic– Advanced Argillic Alteration Lithocap, Lawyers Property, Toodoggone District, North-Central British Columbia (Part of NTS 094E)

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Voegeli, P. and Lecumberri-Sanchez, P. (2022): Spectral and geochemical characterization of the Silver Pond argillic–advanced argillic alteration lithocap, Lawyers property, Toodoggone district, north-central British Columbia (part of NTS 094E); *in* Geoscience BC Summary of Activities 2021: Minerals, Geoscience BC, Report 2022-01, p. 21–38.

Introduction

The Toodoggone district of north-central British Columbia (BC) hosts several historical precious and base-metal producers, including the Baker (MINFILE 094E 026, MapPlace, 2021), Cheni (MINFILE 094E 066), Shasta (MINFILE 094E 050) and Kemess (MINFILE 094E 094) mines, and has emerged as a high priority exploration area with major discovery potential. The Lawyers property is the site of the historical Cheni mine and lies in the central region of the Toodoggone district (Figure 1). The Lawyers property is the site of a well-preserved epithermal system that hosts an indicated resource of 2.05 million oz. Au-Ag and is currently being explored (Benchmark Metals Inc., 2021).

The majority of known Au-Ag mineralization present at the Lawyers property is hosted in narrow multiphase quartzcarbonate, guartz-adularia, guartz-sulphide vein, stockwork and hydrothermal breccia zones, typical of low sulphidation epithermal systems (Duuring at al., 2009). Mineralization is often closely associated with narrow (~5-30 m) potassic (potassium feldspar+sericite±kaolinite) alteration zones and broad regional-scale propylitic alteration (chlorite+hematite±epidote). Proximal to the extensively developed, low sulphidation-style prospects of Cliff Creek, Amethyst Gold Breccia (AGB) and Dukes Ridge (MINFILE 094E 066), but separated from them by a regional-scale fault, there is a less explored group of prospects known as Silver Pond (MINFILE 094E 163; Figure 2). In contrast to the Lawyers property's dominant mineralization style, the Silver Pond prospects exhibit several characteristics of high sulphidation-style epithermal systems. In this system, the condensation of magmatic gas into groundwater results in the disproportionation of SO_2 ,

forming H_2SO_4 and H_2S , resulting in the formation of a highly acidic solution (pH <1; Sillitoe, 1973; Arribas, 1995). The acidic solution reacts with hostrocks in a series of hydrolysis reactions that progressively neutralize acidity and form a characteristic zonation of alteration assemblages (Steven and Ratte, 1960), including a core zone of residual or vuggy quartz rimmed by an advanced argillicalteration assemblage, which typically has a mineralogical composition dominated by alunite, pyrophyllite, dickite, quartz, anhydrite, diaspore and topaz. The narrow advanced argillic-alteration rim typically has an outer broad argillic alteration zone composed of illite, chlorite and montmorillonite (Arribas, 1995; John et al., 2018).

The Silver Pond prospects broadly resemble a 'lithocap', which is a broad subsurface alteration domain that is laterally and vertically extensive (Cooke et al., 2017) and commonly occurs as the near-surface expression of porphyry systems (Bouzari et al., 2019). Mineralogical and geochemical evidence suggest that the Silver Pond prospects are genetically distinct from the surrounding low sulphidation–style epithermal deposits present on the Lawyers property.

The main objective of this study is to determine the spatial distribution of the broad hydrothermal system (low sulphidation, high sulphidation and potential porphyry zones) with respect to the Silver Pond prospects as well as the potential structural/lithological controls that have led to the distribution of different deposit types within the Toodoggone region. This main objective is being pursued through determination of the spatial and paragenetic distribution of minerals in the Silver Pond prospects.

Geological Setting

The Toodoggone district is located in the Stikine terrane of north-central BC and is predominantly hosted in an ~2 km thick package of Lower Jurassic intermediate volcanic rocks belonging to the Toodoggone Formation, which is part of the regionally extensive Hazelton Group. The domi-

¹The lead author is a 2021 Geoscience BC Scholarship recipient.

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Figure 2. Geology of main prospect areas of the north-central part of the Lawyers property: Amethyst Gold Breccia (AGB), Cliff Creek, Phoenix and Dukes Ridge (MINFILE 094E 066, MapPlace, 2021). The study area is focused on the Silver Pond group of prospects (Silver Pond North, Silver Pond Clay, Silver Pond West; MINFILE 094E 163). The Silver Pond leach cap is the surface expression of the argillic alteration assemblages that define the high sulphidation–style prospect area. Geological unit boundaries and faults are from the BC Geological Survey's MapPlace dataset (MapPlace, 2021). All co-ordinates are in UTM Zone 9, NAD 83.

nant rocks of the Toodoggone Formation are latite to dacite volcanic strata deposited in a north-northwest-elongated volcano-tectonic depression of the Lower Triassic Takla Group volcanic rocks and Permian carbonate rocks (Diakow et al., 1991). Following the depositional hiatus of the Middle to Upper Jurassic, a thick package of Cretaceous sedimentary rocks known as the Sustut Group was deposited and represents the top of bedrock in the Lawyers property and surrounding region (Diakow et al., 1991). The late sedimentary units are credited with being responsible for the preservation of the epithermal deposits, hosted in the Toodoggone volcanic rocks, during subsequent uplift (Bouzari et al., 2019). A series of porphyritic plutons known as the Black Lake intrusive suite, which consists of granodiorite to quartz monzonite crosscut by a series of felsic-intermediate cogenetic dikes, occurs in the southeastern portion of the Lawyers property and crosscuts the stratigraphy of the Toodoggone district. Unaltered late basalt dikes, trending north-northwest, crosscut the volcanic and plutonic units, and appear to have exploited deep-rooted extensional faults based on their similar orientation and

common appearance along fault planes throughout the Lawyers property.

The Lawyers property has a relatively simple structural history that is dominated by a brittle deformation regime. The dominant property-scale structures consist of steeply dipping, north-northwest-trending (~310-340°) synvolcanic faults, which formed during extension in the Early Jurassic. This synvolcanic faulting formed a series of horst-graben blocks (Diakow et al., 1991), which define the structural geometry and displacement of the local and regional stratigraphy. Most fault blocks exhibit normal displacement with rare kinematic indicators (conjugate riedel structures and lineations) of minimal displacement and/or strike-slip movement. Major fault gouge zones are associated with potassic and propylitic alteration assemblages and are commonly pervasively silicified. The main Lawyers trend, which hosts the known hydrothermal breccia zones and their associated Au-Ag mineralization and alteration assemblages, is strongly structurally controlled, with the north-northwest-trending fault structures functioning as key fluid conduits. Isolated dilation jogs and intersections



of north-northwest- and west-trending faults appear to concentrate ore shoots within the Lawyers trend. The argillic alteration assemblages of the Silver Pond prospects appear to have a strong association with deep-rooted north-northwest-trending fault structures. These faults have similar orientations to the main regional fault structures that serve as major controls for mineralization in the adjacent low sulphidation–style prospects.

Material and Methods

Shortwave Infrared Analysis

In this study, two principal datasets were acquired for shortwave infrared (SWIR) analysis to determine mineralogical composition and the alteration assemblages present. The first dataset was collected in the 2018 field season with Malvern Panalytical Ltd's portable ASD TerraSpec[®] Halo spectrometer, and the second dataset was collected in the 2020 and 2021 field seasons using Malvern Panalytical Ltd's stationary ASD TerraSpec 4 Hi-Res Mineral spectrometer. All datasets were collected by APEX Geoscience Ltd staff. Surface datasets were collected with the ASD TerraSpec Halo in a 50 by 50 m grid using a GPS for navigation. Sample locations varied by up to 20 m from the grid spacing when necessary to access adequate clay exposure. Surface clay samples contained at least 1 cm of soil/clay and were scanned only when dry. In addition to surface clay, flat unweathered/unoxidized representative hostrock samples were scanned where available. The SWIR analysis of the drillcore was performed with the stationary ASD TerraSpec 4 Hi-Res unit. All drillcore SWIR analysis were performed at regular 3 m intervals on a broken flat surface of representative core, which had been dried before scanning. In order to ensure measurements were accurate and to limit noise during acquisition, the lens was regularly cleaned and calibrated with a white standard puck. The SWIR data acquired consists of 1866 spectra from 496 surface samples and 1370 core samples.

After the initial acquisition effort, all measured spectra were processed using Commonwealth Scientific and Industrial Research Organisation's The Spectral Geologist (TSGTM), Spectral International Inc.'s SpecMinTM and IMDEXTM Limited's aiSIRISTM software. The Spectral Geologist extracted spectral signatures identified at wavelengths between 350 and 2500 nanometres (nm), representing the visible, near-infrared and shortwave infrared spectral ranges. Spectra with abnormal absorption features or excessive noise likely resulted from poor calibration, a dirty lens or the scanned samples were still wet upon analysis; these spectra were therefore discarded. In order to verify mineralogy picks assigned to individual spectra by the TSG algorithm, each spectral signature was compared against and verified with reference spectrum using Spec-Min software. In order to account for possible variances

due to factors such as compositional differences between the analyzed spectra and the reference spectra, and/or the presence of more than one mineral type being included in the sample interval during scanning (resulting in a mixed spectra than contains signatures of more than one mineral), each spectra was compared to multiple reference samples taken from numerous different deposits. The SpecMin software's 'stacking' feature was used to overlay multiple reference spectra of one or more mineral signatures and was then compared to the spectra gathered with ASD TerraSpec to confirm the results provided by TSG. Key absorption features used to identify diagnostic mineral signatures include 1400, 1900, 2160, 2180, 2200, 2250, 2330 and 2350 nm wavelengths. The bulk of the identified signatures belonged to illite, smectite, kaolinite, pyrophyllite-talc, sulphate and chlorite group minerals.

In addition to identifying minerals, crystallinity indices for white mica and kaolinite group minerals were determined using arithmetic expressions within TSG software as well as machine learning algorithms used by aiSIRIS software. Manual processing through TSG identified the relevant samples using a filter for white mica (muscovite series, paragonite) and a filter for kaolinite group minerals (kaolinite, dickite, nacrite, halloysite), resulting in an output table of the TSG results. For white mica, the 2200 nm absorption feature was divided by the 1900 nm absorption feature to provide the white mica crystallinity index (Guggenheim et al., 2002). For kaolinite, the mean 2181 nm absorption feature was divided by the 2161 nm absorption feature to provide the kaolinite crystallinity index (Hauff et al., 1990). A subset of 1000 spectra was processed through aiSIRIS. The aiSIRIS trial output provided mineral picks for the presence of other minerals present in the initial scan and provided proportions of all other mineral types identified in the spectra. To ensure consistency between processing methods, 25 spectra from the aiSIRIS subset were also processed through TSG and similar results were obtained.

In order to validate the outputs provided by TSG and aiSIRIS, as well as help define the paragenetic relationships, compositional variances and relative abundances of the different minerals identified, samples of clay species and alteration types were analyzed with a hyperspectral core scanner. Sampling procedures included identifying sections of core with key diagnostic minerals, as identified through TSG or aiSIRIS, or interesting overprinting relationships and alteration textures. These core were then cut into 2-10 cm sections of half-core for hyperspectral analysis. All samples were then secured on plywood sheets and run through SPECIM, Spectral Imaging Ltd.'s SisuROCK hyperspectral scanning system at the Imaging Spectroscopy Laboratory, University of Alberta (Edmonton, Alberta). The core were analyzed for aluminum minerals, water and hydroxyl absorption, rock chemistry index, Fe-Mg minerals as well as sulphates and carbonates. The hyper-



spectral data are presented in the form of GeoTIFF files with 250 μ m/pixel resolution, which provide colour-coded schemes for the spatial distribution of the wavelength of key absorption features within each sample as well as grey-scale maps indicating the relative abundances of each identified mineral type. The hyperspectral scans produced mineral (abundance) maps of the samples, which were then used to confirm representativity of field sample analysis, evaluate the abundance of each respective mineral and define paragenetic relationships of mineral assemblages, including key high temperature minerals (pyrophyllite, dickite).

Minerals identified with SWIR analysis were categorized into alteration assemblages, which grouped minerals present in similar temperature and pH conditions, and will then be used to help determine the geological setting of each alteration zone. The classification scheme summarized all processed spectra into a total of three separate alteration assemblages including propylitic (chlorite, epidote, hematite, carbonate), argillic (illite, smectite±kaolinite) and advanced argillic (alunite, dickite, kaolinite, pyrophyllite). Due to kaolinite occurring in multiple environmental settings with different genetic implications, mineral associations were used to preliminarily categorize which environment kaolinite had the most likely association with (e.g., if kaolinite occurred with dickite, alunite and pyrophyllite, the sample would be categorized as advanced argillic alteration). All processed spectral data was input into Micromine Pty Ltd's MicromineTM 2019 modelling software in order to visualize the spatial relationship for defined alteration assemblages and to overlie other datasets such as geophysics, geochemistry and core logging observations.

Geochemical Characteristics and Vectoring

Geochemical samples collected at the Silver Pond prospects include soil, rock and drillcore samples. Soil samples were collected in a 50 by 50 m grid and only samples considered to be in situ were targeted, sections with Quaternary overburden were avoided. The Silver Pond prospects generally have poor outcrop exposure, with most rock samples categorized as subcrop. Therefore, rock samples were taken at mapping stations and not at regular sampling intervals. Drillcore sampling varied depending on factors such as degree of veining, alteration and mineralization and the presence of key structural contacts. Sections of core that appeared to be relatively fresh hostrock with little to no mineralization were sampled at a 2 m interval, and samples with significant veining, increased alteration intensity and/ or mineralization were sampled at a 1 m interval. In sections of core with major structural breaks, isolated mineralization and/or veining, sampling intervals were adjusted to isolate the zone of interest with a minimum sample interval of 30 cm.

All samples were analyzed by ALS-Geochemistry (Vancouver, British Columbia) for gold, silver and an additional 46 elements. Gold was analyzed by fire assay of a 30 g sample followed by inductively coupled plasma-atomic emission spectroscopy (ICP-AES), with a lower detection limit of 0.001 ppm. All samples that exceeded 10 ppm gold were reassayed by fire assay of a 30 g sample with a gravimetric finish; the upper detection limit was 10 000 ppm. The silver and additional 46 elements were analyzed by four-acid digestion followed by inductively coupled plasma-mass spectrometry (ICP-MS), with samples that returned silver assays in excess of 1500 ppm being reanalyzed by fire assay of a 30 g sample with a gravimetric finish. Quality assurance and quality control samples were inserted at a minimum of every 10 samples, with duplicates being taken in mineralized zones.

Assay data were used to evaluate depletion and addition of rock-forming elements (such as Ca, K, Na and Mg) and common pathfinder elements (such as Mo, As and Te). In particular, the epithermal elemental suite, including As, Sb, Hg, Se, Te, Tl, Mo and W, was considered. This analysis was applied to surface and drillcore data to evaluate the relationship of alteration and alteration intensity with Au-Ag pathfinders, and determine the usefulness of SWIR analyses as a field-ready pathfinder tool in the Silver Pond and geochemically similar prospects.

Isocon plots were used to observe quantitative changes in elemental concentrations of the rock-forming and epithermal suite elements as compared to immobile elements in order to determine the relationship between alteration types and addition/subtraction of elements (Grant, 2005). An unaltered reference was calculated from 10-15 m sections of unaltered core from 14 separate holes across the property with the same lithology as the Silver Pond prospects. In total, 179.9 m of core was used to calculate the unaltered reference. The mean, median and standard deviations of each of the elements analyzed were determined to help ensure that samples selected were representative of unaltered sections, and to remove any potential outliers within the selected sections. The mean value was then used as the unaltered reference against all sections of interest. Elements that experienced no net loss or gain lay on the line with a slope of 1, with enriched elements having a value greater than one and depleted elements having a value of less than one, and immobile elements (i.e., Al) generally staying on the line regardless of the influence of alteration events. Mineralized sections, alteration assemblages and individual alteration minerals identified by SWIR were plotted against the unaltered reference mean to help understand the composition of hydrothermal fluids responsible for mineralization and alteration.



Results

Spatial Distribution of Minerals

Three main alteration types are present at the Silver Pond prospects and their distinct mineralogy, spatial distribution and textural characteristics are different from the alteration types present at the low sulphidation targets on the Lawyers property. The analysis of the surficial and drillhole data revealed that the highest intensity hydrothermal alteration zoning at the Silver Pond prospects is an elongated eastwest advanced argillic-alteration core, with south and north shoulder zones predominantly composed of argillic and propylitic alteration assemblages. The core of the hydrothermal alteration zone is defined by the presence of high temperature, low pH, advanced argillic-alteration assemblages identified in surface clays and at depth (Figure 3a-c; drillholes 20SPCDD004, 20SPCDD008, 20SPCDD009). The advanced argillic-alteration core zone is predominantly altered to alunite, kaolinite, dickite and high crystallinity white mica with isolated occurrences of pyrophyllite and gypsum. The south and north shoulder zones exhibit a transition from advanced argillic-alteration to argillic alteration. The argillic alteration represents lowmoderate temperature and moderate pH conditions and is observed in the surface clays and at depth in drillholes 20SPCDD005, 20SPCDD006 and 20SPCDD007. These shoulder zones are surrounded by a broader regional-scale alteration zone that is defined by an argillic to propylitic transition and is altered predominantly to white mica, montmorillonite and chlorite assemblages. The majority of chlorite identified within the Silver Pond prospects has a low wavelength absorption feature (~2246-2252 nm) indicating a magnesium-rich end member, which commonly occurs in the more proximal portions of a hydrothermal system. The observed hydrothermal alteration zones and their respective assemblage classifications are complemented by key geochemical features, including a depletion in rock-forming elements and enrichment in epithermal suite elements (Figure 4a-d), which is a strong indication and proxy for the influence of hydrothermal magmatic fluids.

At the Silver Pond prospects, drillholes that intersect a range of mineral assemblages also show a transition from muscovite to phengite with increasing depth (Figure 5a, b) and a proximity to higher temperature assemblages. This transition is reflected in changes in the 2200 nm absorption feature, in which white mica of phengitic composition show a characteristic increase in the 2200 nm absorption feature to the ~2210 nm range. The 2200 nm absorption feature can also migrate to a shorter average wavelength (~2190 nm) and typically reflects a sericite-muscovite reaction (Cohen, 2011). In drillholes surrounding the central advanced argillic-alteration zone, both kaolinite and white mica crystallinity values show a trend toward increasing

crystallinity with depth (Figure 5c, d) and/or proximity to advanced argillic-alteration zones.

The presence and abundance of pyrophyllite and dickite, as examples of high temperature phases with vectoring potential, was confirmed through hyperspectral core scans. Several samples contain over 90% volume of dickite or pyrophyllite (Figure 6c, d). Preliminary paragenetic relationships extracted from these scans also show that kaolinite postdates dickite (Figure 6b), with kaolinite veins crosscutting samples pervasively altered to dickite, and gypsum veins crosscutting both the kaolinite and dickite. Isolated sections of the advanced argillic-alteration core zone exhibit a pervasive alunite overprint of the groundmass and the phenocrysts of the relic hostrock (Figure 6a).

Geochemical Characteristics and Vectoring

The surface area of the Silver Pond leach cap is characterized by a systematic depletion in common rock-forming elements, such as Mg, Ca and Na, as well as enrichment in epithermal suite elements, such as Tl, Te, Se, As and Sb (Figure 4a, b, 7b–d). Similar chemical relationships were also displayed in the subsurface with the highest degree of relative enrichment closely correlating with the intensity and type of clay alteration present. Highly altered, advanced argillic-alteration assemblages generally exhibit the highest degree of enrichment in epithermal suite elements and corresponding depletion in rock-forming elements (Figure 7b), with argillic and propylitic alteration assemblages sequentially having a lower degree of enrichment/depletion of indicative element suites (Figure 7a).

Select samples within isolated mineralized intervals (0.3– 1 m) from two different drillholes (20SPCDD005, 20SPCDD009) show a correlation between the occurrence of Au-Ag and W, Pb, Bi, Cu, Te, Mo and Se (Figure 7c, d). In addition, positive anomalies of Mo, Se, Te, Pb, Bi and Sn systematically increase from argillic to advanced argillicalteration zones.

A series of modelled and logged north-northwest-trending faults appear to have an influence on the spatial distribution of geochemical trends, with areas proximal to the fault system experiencing a higher degree of enrichment in select epithermal suite elements (Figure 4c, d). Similar degrees of enrichment and elemental associations can be found within isolated Au-Ag intersections. Historical drilling on the Silver Pond prospects also indicates select zones of mineralization occur along a northern extension of the fault system, possibly indicating extensive mineralization along the strike of these major fault structures. The close spatial correlation of the enrichment of pathfinder elements with high temperature, low pH and clay assemblages provides evidence that the system at the Silver Pond site has a strong structural control.







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Figure 3 (continued). b) North-northwest cross-section A–A' (from Figure 3a; Silver Pond prospects and surrounding area) shows a high temperature advanced argillic-alteration core (red; drillholes 20SPCDD008, 20SPCDD009) surrounded by a broad argillic-alteration zone (yellow). All co-ordinates are in UTM Zone 9, NAD 83, and elevation is in metres (m) above sea level.



Figure 3 (continued). c) South-southwest cross-section B–B' (from Figure 3a; Silver Pond prospects and surrounding area) shows the lateral extent of the advanced argillic-alteration core zone and confirms that the surface expression of the advanced argillic-alteration zone is vertically extensive and continues into deeper high temperature clay assemblages in the subsurface. Drillhole locations indicated by 20SPCDD00X. All co-ordinates are in UTM Zone 9, NAD 83, and elevation is in metres (m) above sea level.

 \mathbf{c}



Figure 4. a) Plan view of Silver Pond prospects (outlined in red) and surrounding area displays a systematic depletion in rock-forming elements (i.e., Ca) at surface, which illustrates the leach-ing of the hostrock by high temperature, low pH, magmatic fluids. Relative concentrations of Ca are indicated using a colour scheme with a corresponding scale factor of the representative cir-cles within each concentration range. See Figure 4c, d for cross-section A-A'. All co-ordinates are in UTM Zone 9, NAD 83.

a)







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Figure 6. Hyperspectral core scans confirm the pervasive alteration of key indicator minerals used for constraining temperature and pH conditions within the categorized alteration zones, including a) alunite, b, c) dickite and kaolinite and d) pyrophyllite. Locations of drillholes (20SPCDD00X) shown on Figure 3.

Discussion

The SWIR techniques and results were used to help determine the mineralogy of the Silver Pond prospects with the aim of understanding 1) the type of alteration system and 2) what portion of a magmatic-hydrothermal system is present at the Silver Pond site, with the purpose of exploring the potential for economic mineralization. Previous research and exploration programs at the Silver Pond prospects generally describe the area as a lithocap, defined by a high degree of clay alteration caused by a downfaulted acid sulphate outflow, possibly representing the upper portion of the Lawyers property hydrothermal system (Diakow et al., 1991). The combined SWIR analysis of surface clay and drillcore samples confirmed the extent and depth of the lithocap, with the presence of key clay assemblages and mineralogical transitions suggesting that sections of the Silver Pond clay alteration zone formed in high temperature and low pH conditions typical of intermediate to high sulphidation-type settings (Arribas, 1995). The advanced argillic-alteration assemblages discussed have been known to commonly cap porphyry copper systems (Sillitoe, 1973), which is a plausible setting in the context of the regional stratigraphy of the Toodoggone district. This district hosts a series of low and high sulphidation systems some of which have demonstrable base-metal associations, indicative of a deeper hydrothermal system(s) that affected shallower mineralization and alteration domains.

The temperature and pH conditions and their associated alteration assemblages exhibited at the Silver Pond prospects indicate that this may be the site of the portion of the magmatic-hydrothermal system(s) that typically hosts Au-Ag mineralization in analogous deposit types. The system did not undergo complete erosion at the Silver Pond prospects, as the associated alteration zonation is expressed at surface and at depth. The type and distribution of clay assemblages that occur at the Silver Pond prospects are typically associated with hypogene hydrothermal-magmatic environments. Large alunite-kaolinite-dickite haloes with isolated sections of pyrophyllite correspond to intervals that display the highest degree of texturally destructive alteration and intense leaching of the hostrock and likely represent feeder zones. The narrow advanced argillic-alteration zones bounded by a broad argillic alteration zone (dominantly illite-smectite) are characteristic of intermediate to high sulphidation deposits as classified by John et al. (2018). To date, exploration efforts have intersected the main alteration envelopes (i.e., sericite-pyrophyllite, quartz-dickite/ kaolinite, quartz-alunite, illite-smectite) but not a zone of residual quartz, which typically hosts Au-Ag mineralization in high sulphidation systems. The confirmed intersections of quartz-alunite, quartz-dickite/kaolinite and sericite-pyrophyllite zones are possible indicators of proximity to a residual or vuggy silica zone.







The propylitic mineralogy in the north and south shoulders of the Silver Pond prospects are characteristic of low-moderate temperature (0–250°C) and neutral pH conditions. The mineralogy of the argillic-advanced argillic alteration assemblages in the core of the system indicates a temperature range of ~200–350°C in moderate to highly acidic conditions (pH <2–4). The mineralogy identified by SWIR analysis in the central zone of the prospects reveals a systematic shift to higher temperate and lower pH conditions, indicating that this zone is more proximal to focused fluid flow or a hydrothermal-magmatic source, which likely exploited deep-rooted north-northwest-trending faults as fluid conduits.

The results from the SWIR analysis were overlain with geochemistry, core logging and geophysical data and strong correlations were evident between enrichment in epithermal suite elements, magnetic signatures and key structural controls. The distribution of alteration assemblages appears to have a strong correlation with a series of north-northwest-trending faults, with increased alteration intensity, as well as the presence of advanced argillic alteration, occurring proximal to the fault system. The main north-northwest-trending faults have a similar orientation to the fault system that served as a key control for mineralization in the adjacent low sulphidation–style deposits in the property.

Analysis of relative crystallinity values for white mica and kaolinite group minerals were used as an additional proxy for the influence of hydrothermal fluids, which helped with understanding temperature regimes within the Silver Pond prospects. Higher crystallinity values indicate more ordered crystal structures, which occur in higher temperature environments. Shifts in the crystallinity index of kaolinite group minerals and white mica can therefore be used to indicate temperature regimes and aid in the vectoring of higher temperature alteration zones and assemblages. A general increase in crystallinity of both kaolinite and white mica correlates strongly with an increase in depth and/or proximity to high temperature assemblages (Figure 5c, d), indicating a broad-scale trend of increasing temperature regimes with proximity to fault surfaces at depth within the Silver Pond clay alteration zone.

The observed transition of muscovite to phengite with depth (Figure 5a, b) provides additional information on the pH conditions present in select areas of the Silver Pond prospects. This transition is demonstrated in drillhole 20SPCDD008 (Figure 3b, c), where a shallow, fault-bounded, advanced argillic-alteration zone correlates with an overlap of predominantly muscovitic white mica, which has a higher stability in lower pH conditions and when occurring in conjunction with pyrophyllite, likely formed in a moderate to high temperature regime of 280–400°C (Monier and Robert, 1986; Cohen, 2011).

Epithermal deposits are commonly enriched in elements such as As, Sb, Hg, Se, Te, Tl, Mo and/or W (White and Hedenquist, 1995; Saunders et al., 2014). The three types of epithermal deposits (low, intermediate and high sulphidation) also exhibit large variations in absolute and relative concentrations of elements (John et al., 2018) and commonly exhibit distinct zonation patterns. The geochemical fingerprint of the Silver Pond prospects, as illustrated in the isocon plots (Figure 7b–d), shows high levels of enrichment in key elements such as Mo, Se, Te, Pb, Bi, Th and Sn, which coincides with the signature of other known intermediate to high sulphidation epithermal systems (i.e., La Coipa, Chile; Summitville, United States; Pueblo Viejo, Dominican Republic), which are commonly enriched in Cu, Pb, Zn, Mo, Bi, Sn, Te, Th and Se (John et al., 2018).

Conclusions

The clay assemblages identified by shortwave infrared analysis as well as the geochemical signature of zones that experienced intense fluid flow indicate that the alteration zones and characteristics present at the Silver Pond prospects were likely formed as part of a hydrothermal-magmatic system within a high sulphidation-type epithermal setting. The shortwave infrared analysis as well as field observations have documented the presence of a low pH zone dominated by alunite, dickite, anhydrite±pyrophyllite assemblages with a broad illite-smectite, montmorillonite zone. To date, only very narrow (~5-30 cm) occurrences of the vuggy quartz zone, which typically hosts Au-Ag ore, have been encountered. The Silver Pond prospects remain largely underexplored and have strong discovery potential due to the presence of promising alteration assemblage and zonation relationships, geochemical indicators and the proven broad-scale resource potential of the hydrothermalmagmatic system in the greater Lawyers property.

Acknowledgments

This project was supported through scholarships to the lead author from Geoscience BC and Natural Sciences and Engineering Research Council of Canada (NSERC). Benchmark Metals Inc. provided samples and access to data. The authors would also like to thank V. Elongo for guidance and review of the presented research to date.

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