Geology, alteration, and mineralization of the Sato porphyry copper prospect, southwestern Yukon

Jeff Lewis[1,2] and Jim Mortensen[1]

[1] Department of Earth and Ocean Sciences, University of British Columbia, 6339 Stores Rd., Vancouver, B.C. V6T 1Z4, e-mail: jmortens@eos.ubc.ca

[2] Presently at: Homestake Canada Inc., 1000-700 West Pender St., Vancouver, B.C. V6C 1G8

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ABSTRACT

The Sato prospect is located between Aishihik Lake and Long Lake in southwestern Yukon Territory. Low grade porphyry-style copper mineralization was discovered on the property in 1969. The main country rock in the study area is a potassium feldspar megacrystic granite that is correlated with the Early Jurassic Aishihik and/or Long Lake plutonic suite. Mineralization on the property is hosted by a multiphase intrusive complex that is thought to represent a high level intrusive member of the Late Cretaceous Mount Creedon volcanic suite. The complex consists of three distinct phases, medium-grained diorite; coarse-grained diorite; and porphyritic quartz monzodiorite. U-Pb zircon dating of the medium-grained diorite and porphyritic quartz monzodiorite phases gives ages of 78.2 ± 0.1 Ma and 78.8 ± 0.2 Ma, respectively, which supports the correlation with the Mount Creedon Volcanic Suite.

Four alteration zones are recognized on the property. Alteration is mainly developed in the medium-grained diorite and quartz monzodiorite phases. In order of decreasing intensity, these zones include potassic, phyllic, albitic, and propylitic. Copper mineralization consists of chalcopyrite, which occurs as a replacement of earlier-formed magnetite in the potassic and phyllic zones, and malachite which occurs on weathered fracture surfaces.

Alteration and mineralization on the property are thought to be related either to fluids evolved during the latest stages of crystallization of the main phase diorite unit or from a buried, younger phase of the intrusive complex.

RÉSUMÉ

La zone d'intérêt de Sato est située entre le lac Aishihik et le lac Long, dans le sud-ouest du Yukon. Une minéralisation cuprifère de type porphyrique à faible teneur a été découverte sur le terrain en 1969. La principale roche encaissante de la région prospectée est un granite mégacristallin à feldspath potassique associé à la suite plutonique d'Aishihik et/ou de Long Lake, qui date du début du Jurassique. La minéralisation sur le terrain est incluse dans un complexe intrusif polyphasé, vraisemblablement un membre intrusif de haut niveau de la suite volcanique de Mount Creedon, du Crétacé tardif. Le complexe comprend trois phases distinctes : une diorite à grain moyen, une diorite à grain grossier et une monzodiorite quartzique porphyrique. La datation à l'U-Pb de zircons des phases à diorite à grain moyen et à monzodiorite quartzique porphyrique a fourni respectivement des âges de 78,2 ± 0,1 Ma et de 78,8 ± 0,2 Ma, ce qui corrobore la corrélation avec la suite volcanique de Mount Creedon.

On distingue quatre zones d'altération sur le terrain. L'altération est plus poussée dans les phases à diorite à grain moyen et à monzodiorite quartzique. Par ordre d'intensité décroissante, il s'agit des zones potassique, phylliteuse, albitique et propylitique. La minéralisation cuprifère se compose de chalcopyrite, qui se présente sous forme de remplacement d'une magnétite formée antérieurement dans les zones potassique et phylliteuse, et de malachite, présente sur les surfaces de cassures altérées.

On admet que les phénomènes d'altération et de minéralisation sur le terrain sont liés à une phase souterraine, tardive et de haut niveau du complexe intrusif.

INTRODUCTION

The Sato occurrence (Yukon Minfile 115H 021) is located in southeastern Yukon Territory, between Aishihik Lake and the northern tip of Long Lake (Fig. 1). The host rock is a multiphase, dioritic to quartz monzodioritic intrusive complex that is thought to be the intrusive equivalent of the Late Cretaceous Mount Creedon Volcanic Suite.

The property was discovered and initially explored as a porphyry copper-molybdenum prospect in 1968-1971. The high concentration of magnetite and the mafic composition of the rocks that host the mineralization suggested that the system might be gold-enriched. As the property had not previously been specifically assayed for gold, it was re-examined by Homestake Canada, Inc., during the summer of 1996 for possible gold potential. This paper is based on 1:2 000 and 1:500 scale geological mapping conducted by the senior author and H. Marsden of Homestake Canada during the 1996 field season, as well as petrographic, geochemical, and geochronological studies of samples from the property. A total of thirteen samples were analyzed for 30-element ICP, seven samples were analyzed for major and trace element geochemistry, two samples were dated by U-Pb zircon methods, and thirty-four thin and polished thin sections were examined. In this paper we provide a brief summary of the property geology, report new U-Pb zircon ages for two intrusions on the property, and describe the alteration and mineralization present.

LOCATION AND ACCESS

The property is situated halfway between the villages of Carmacks to the north-northeast and Haines Junction to the south-southwest (Fig. 1). It is located at 61° 29' N and 136° 45' E (UTM Zone 8, 40800E 6817150N) in the Hopkins Lake map area (115H/7). Access to the property is by helicopter from Carmacks or Haines Junction, each about 75 km distant. The Aishihik Road extends to within 15 kilometres of the property.

Exposure in the region is generally less than one percent, and is mainly restricted to ridge tops. Exposure is slightly better on the property, however, and includes abundant local felsenmeer and partially collapsed exploration trenches.

PREVIOUS WORK

Cockfield (1927) carried out reconnaissance-scale mapping in the area immediately south of Long Lake and between Aishihik and Sekulmun lakes to the west. Tempelman-Kluit (1973) conducted a more comprehensive study of the area, including 1:250 000 scale mapping of the 115A, 115F, 115G, 115H, and 115K map sheets. Limited age constraints and poor exposure made regional correlation of units very speculative. Subsequent work in the region focussed on the area immediately surrounding Aishihik Lake (Gordey, 1973; Morin, 1981). S.T. Johnston mapped several 1:50 000 map sheets in the Aishihik Lake map area between 1988 and 1993. His work specifically studied the nature of the Aishihik Batholith in this region (e.g., Johnston et al., 1996). The most recent mapping in the area was carried out by Johnston and Timmerman (1993), who produced revised geological maps and a geological synthesis for the 115H/6 and 115H/7 map sheets.

Only limited work has been done on the Sato property itself. The property was first staked as the KL claims in August, 1969, by the Mitsubishi Metal Mining Co., Ltd., to cover a large soil geochemical anomaly. Geological mapping and geochemical sampling in 1970 produced encouraging copper assays, and subsequent geophysical surveys outlined a large magnetic anomaly on the property. During 1971, a total of eight trenches were dug and seven diamond drill holes, totaling 790 m, were completed (Kikuchi, 1970; Cathro, 1971; Norgaard, 1971). The

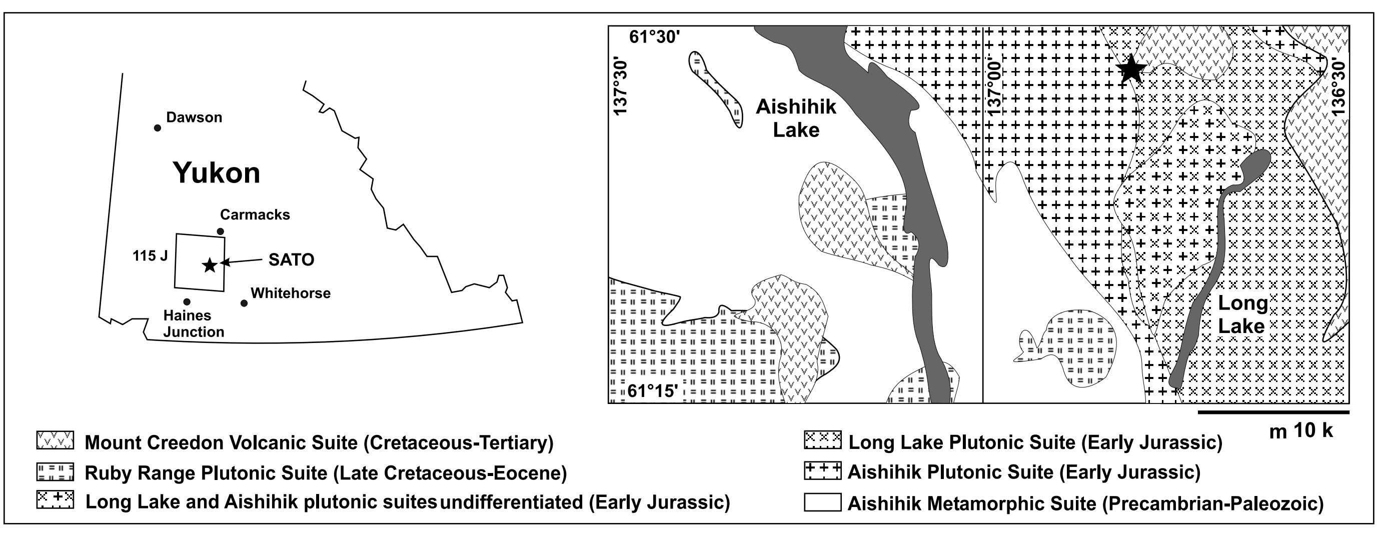

Figure 1. *Location and generalized geologic map of the Aishihik and Hopkins Lake map areas (modified from Johnston and Timmerman, 1993).*

results were generally negative, with copper grades in the 0.1% to 0.2% range, and molybdenum grades mainly at or below detection limits. The property was inactive until 1989, when Golden Quail Resources Ltd. restaked the property as the NICK claims. They performed an airborne geophysical survey in the spring of 1990, and ground VLF magnetic surveys, geochemical work, and geological mapping later in the season. They reported highly anomalous pan concentrates of gold, platinum, and palladium, but the overall results were not sufficiently encouraging enough to warrant further work at that time.

REGIONAL GEOLOGY

A simplified geological map of the 115H/6 (Aishihik Lake) and 115H/7 (Hopkins Lake) map sheets is shown in Figure 1. Johnston and Timmerman (1993) divided the area into five distinct lithotectonic suites. The *Aishihik Metamorphic Suite* comprises penetratively deformed and metamorphosed sedimentary and igneous rocks, and is broadly divided into two sub-suites; a feldspathic quartz-mica-schist lower package, and a black quartzite-marble-metaigneous upper package.

The metamorphic rocks have been intruded by four distinct intrusive suites. The *Aishihik Plutonic Suite* forms the Aishihik Batholith in this area, and consists predominantly of granodiorite with less abundant quartz monzonite and quartz diorite. The rock is generally coarse-grained and equigranular; however large megacrysts of pink potassium feldspar are commonly present. The Aishihik Suite typically displays a weak to stong foliation that is thought to have formed during magmatic emplacement (Johnston, 1993; Johnston and Erdmer, 1994). Johnston et al. (1996) report U-Pb zircon and titanite ages of 186 ± 2.8 Ma for the Aishihik Batholith.

The *Long Lake Plutonic Suite* consists of equigranular to locally porphyritic, leucocratic quartz monzonite and granite plutons that intrude rocks of the Aishihik Suite. Long Lake plutons only locally contain a foliation, and in many areas are clearly intrusive into the Aishihik Plutonic Suite. The Long Lake Suite has given a U-Pb zircon age of 185.6 +2.0/-2.4 Ma (Johnston et al., 1996).

The *Ruby Range Plutonic Suite* comprises the Ruby Range Batholith, a large granodiorite plutonic body that is mainly centered south of the Aishihik Lake map area, as well as several relatively small plutons located north of the batholith. Overall compositions range from granodiorite to less abundant monzonite and diorite. Plutons of the Ruby Range Suite intrude the Aishihik Metamorphic Suite in the westernmost part of the area, but there are no known contacts with either the Aishihik or Long Lake plutonic suites. Recent U-Pb zircon dating on the various members of this suite have given ages between ~78 Ma and 58 Ma (Johnston, 1993).

The *Mount Creedon Volcanic Suite* includes a variety of high level intrusive rocks and their volcanic equivalents. The suite is widespread in the Aishihik Lake area and the extrusive components typically unconformably overlie all of the previously mentioned rock units. The Mount Creedon Suite includes a wide range of compositions and rock types, making regional correlation of rock units difficult. Tempelman-Kluit (1974) was the first to describe these units in detail. He broadly separated the volcanic rocks west of Aishihik Lake from those that occur to the east and north of Long Lake, but considered both groups of rocks to be Eocene or younger in age. He correlated the "west Aishihik Lake rocks" with alaskitic intrusives found in the Sekulmun Lake area, and suggested their correlation with the Mount Nansen Group. Volcanic rocks east and north of Long Lake rocks were correlated with the Carmacks Group. The Mount Creedon Volcanic Suite is currently considered to be mainly Late Cretaceous to possibly Eocene in age, based on geological mapping and regional isotopic dating studies (Johnston and Timmerman, 1993).

PROPERTY GEOLOGY

The geology of the Sato property is shown in Figure 2. The immediate area of the property is underlain by two of the rock

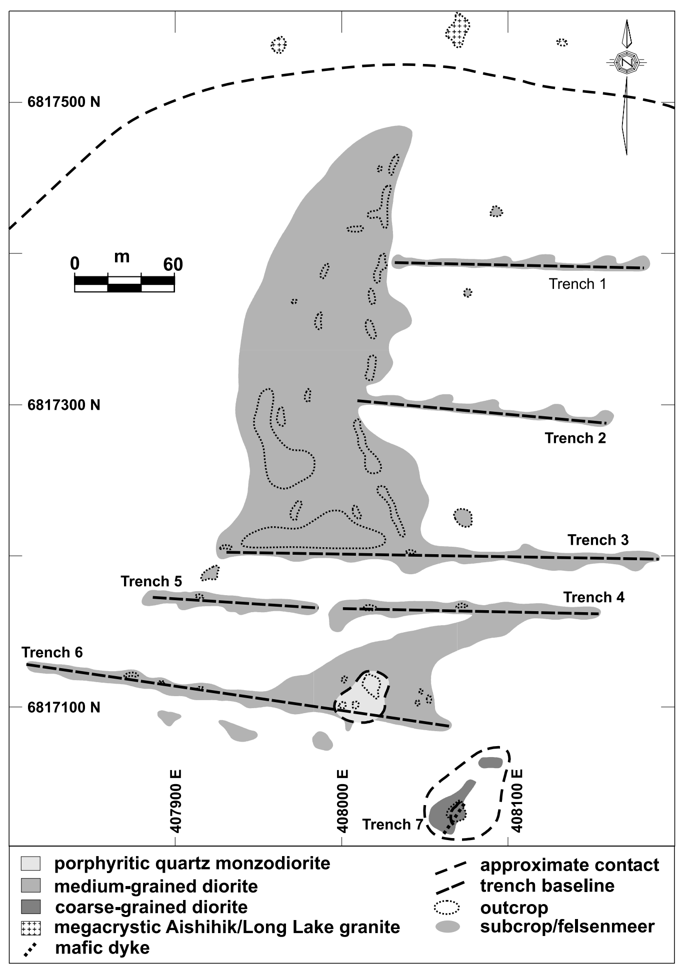

Figure 2. *Geologic map of the Sato property.*

suites described above. Megacrystic granite makes up much of the country rock. This is intruded by a multiphase intrusion that forms the main host to mineralization. Andesitic volcanic rocks crop out at several localities in the vicinity of the property.

K-spar megacrystic granite is the dominant country rock on and around the property. It is unclear whether this unit belongs to the Aishihik or Long Lake plutonic suite. In hand specimen, the rock is characteristically weathered to a pinkish-orange colour due to the abundance of potassium feldspar megacrysts, which are lath-shaped and up to 4 cm long. The other main minerals present include coarse, anhedral quartz grains, and coarse plagioclase laths. Biotite is rare and appears to be the only mafic mineral present. A weak foliation is visible, mainly defined by a preferred orientation of the potassium feldspar megacrysts. Seen in thin section the feldspars are partially altered to sericite, and there are small amounts of hematite and various other opaque minerals present. Johnston and Timmerman (1993) mapped the megacrystic granitic in the area of the property as Aishihik Plutonic Suite; however some of these characteristics of the unit suggest a closer resemblance to the Long Lake Suite.

The intrusive complex that hosts mineralization on the property can be divided into three sub-units; medium-grained diorite, a coarser-grained variety of the diorite, and a more felsic, porphyritic quartz monzodiorite unit. The main phase of the intrusive is a greenish-grey, medium-grained, variably altered rock of dioritic composition that intrudes the K-spar megacrystic granite. Vesicular andesite, which occurs in the vicinity of the property, has been included in the Mount Creedon Volcanic Suite by Johnston and Timmerman (1993). Although these authors do not include intrusive rocks in the Mount Creedon Suite, the diorite is thought to be the intrusive equivalent of the andesite. The surface exposure of the intrusive complex is roughly oval in plan view, and covers an area of approximately 2 km^2. Where relatively unaltered, the diorite is greenish-grey in colour, and is very slightly magnetic. The unit consists mainly of saussuritized plagioclase (70%), mafic minerals (25%), including biotite, hornblende, clinopyroxene and epidote, and minor interstitial quartz and orthoclase. The remaining 5% of the rock consists of opaques, most of which is magnetite, with lesser pyrite and chalcopyrite. An alignment of the plagioclase grains is commonly visible in thin section.

Coarse-grained diorite is exposed only in Trench 7 (see Fig. 2 for trench locations), with a mapped surface area of about 400 m^2. Contacts with the main diorite phase are not exposed, however this unit is geochemically and mineralogically somewhat distinct from the main diorite, and appears to represent a separate intrusive phase. In hand sample, the coarse-grained diorite phase is dark greenish grey, and highly magnetic. The rock consists mainly of light to dark green altered plagioclase laths (55%), together with strongly altered clinopyroxene and hornblende (40%). The remainder of the rock consists of interstitial orthoclase and opaque minerals, including magnetite, pyrite, and lesser amounts of chalcopyrite and hematite.

Porphyritic quartz monzodiorite underlies an area of about 300 m^2, and is wholly contained within the main phase diorite. This is the most felsic and porphyritic phase present in the intrusive complex, and also hosts a significant amount of the copper mineralization. The typical whitish weathering character of this unit is mainly due to sericitic and clay alteration. This unit was not recognized as a separate phase during field mapping, but rather was thought to be represent a strong phyllic alteration overprint on the main phase diorite. Plagioclase occurs as a phenocryst phase and comprises 60% of the rock by volume. Quartz (15%) and orthoclase (10%) occur both as phenocrysts and as interstitial phases. The only mafic minerals present are biotite (up to 5%) and epidote (3-5%), both of which appear to be secondary minerals. Opaque minerals (5%) include abundant chalcopyrite, pyrite, and magnetite. This phase also contains both titanite and zircon as accessory minerals.

Two distinct compositions of dykes occur on the property. A 1.5 m wide, strongly altered plagioclase- and pyroxene(?)-phyric mafic dyke intrudes the coarse-grained diorite phase in Trench 7 (Fig. 2). Several thin (<1 m wide) quartz-feldspar porphyry dykes also intrude the K-spar megacrystic granite.

GEOCHRONOLOGY

A U-Pb dating study of the intrusive phases in the area of the Sato property was undertaken in order to constrain the timing of magmatism and mineralization. Zircons were separated from two samples, the main phase diorite and the porphyritic quartz monzondiorite. Analytical methods are as described by Mortensen et al. (1995). Analytical data is given in Table 1 and the results are shown graphically in Figure 3. Errors are given at the 2σ level.

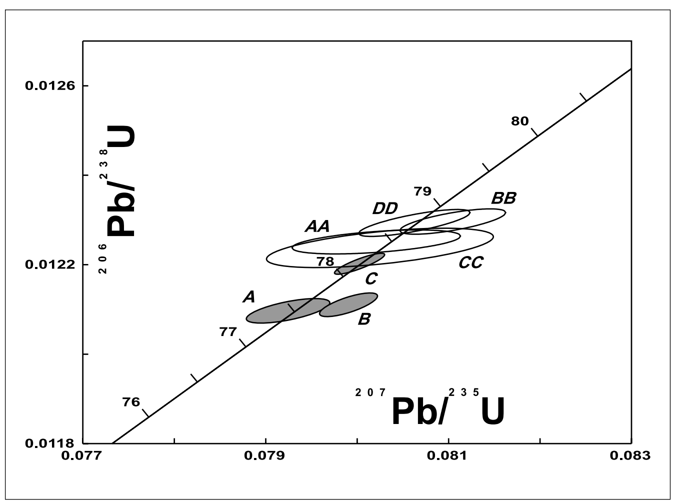

Figure 3. *U-Pb concordia diagrams. Shaded ellipses are analyses from the medium-grained diorite phase and the open ellipses are analyses from the porphyritic quartz monzodiorite.*

The diorite sample consisted of approximately 25 kg of relatively unaltered material. Three fractions of strongly abraded zircon were analyzed. Two of the fractions give concordant analyses; with $^{206}Pb/^{238}U$ ages of 77.6 ± 0.3 Ma and 78.2 ± 0.1 Ma. The third fraction (B) falls slightly to the right of concordia, indicating the presence of a minor inherited zircon component. The spread in $^{206}Pb/^{238}U$ ages is thought to result from minor post-crystallization Pb-loss from fraction A, and best estimate for the crystallization age of the rock is therefore given by the $^{206}Pb/^{238}U$ age of fraction C, at 78.2 ± 0.1 Ma. The porphyritic quartz-monzodiorite sample consisted of a single, fist-sized sample weighing approximately 1 kg. Four fractions of strongly abraded zircon were analysed. All four analyses are concordant or nearly so, and the best estimate for the crystallization age of the rock is given by the $^{206}Pb/^{238}U$ ages of fractions BB and DD, at 78.8 ± 0.2 Ma.

The new U-Pb age data indicates that both phases are Late Cretaceous in age, and supports a correlation with the Mount Creedon Volcanic Suite. It had been expected that the porphyritic phase, being somewhat more felsic and differentiated, would be the younger of the two units dated. Although the two ages are similar, the data indicates that the porphyritic phase is actually slightly older than the main phase diorite. The porphyritic unit is now interpreted to be a slightly earlier phase of the intrusive complex that was entrained as a raft within the main phase diorite as it was being emplaced.

ALTERATION

Four distinct alteration zones have been distinguished on the Sato property (Fig. 4), including potassic, phyllic, albitic, and propylitic. Scarcity of outcrop hampers detailed mapping of the extent of, and possible overprinting relationships between, the different alteration facies.

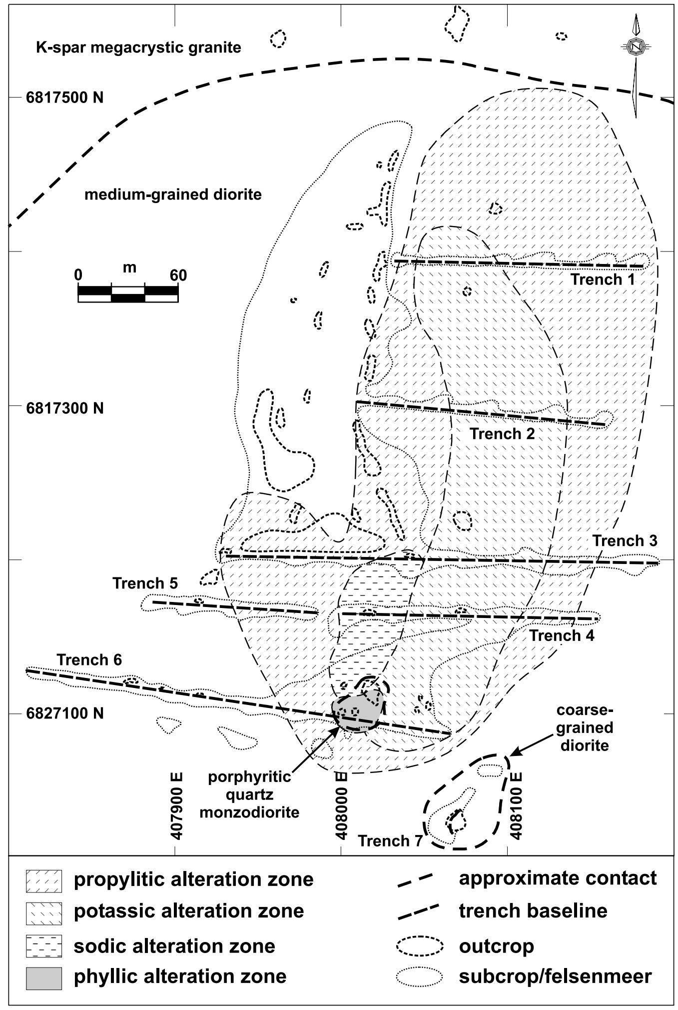

Figure 4. *Alteration zones on the Sato property.*

Description[1]	Wt (mg)	U (ppm)	Pb[2] (ppm)	$^{206}Pb/^{204}Pb$ (meas.)[3]	total common Pb (pg)	% ^{208}Pb[2]	$^{206}Pb/^{238}U$[4] (±% 1σ)	$^{207}Pb/^{235}U$[4] (±% 1σ)	$^{207}Pb/^{206}Pb$[4] (±% 1σ)	$^{206}Pb/^{238}U$ age (Ma, ±%2σ)	$^{207}Pb/^{206}Pb$ age (Ma, ±%2σ)
Sample DIO-UM (medium-grained diorite)											
A: N2,>105	0.092	1058	14.6	1436	51	20.8	0.01210(0.11)	0.07924(0.29)	0.04751(0.23)	77.5(0.2)	75.0(10.9)
B: N2,>105	0.030	797	10.9	2891	6	19.9	0.01211(0.11)	0.07992(0.20)	0.04786(0.13)	77.6(0.2)	92.3(6.2)
C: N2,>105	0.095	1173	16.4	3912	22	21.2	0.01220(0.09)	0.08003(0.18)	0.04760(0.10)	78.2(0.1)	77.9(4.8)
Sample DIO-PORP (porphyritic monzodiorite)											
AA: N2,>105	0.245	108	1.4	683	30	13.1	0.01225(0.11)	0.08021(0.57)	0.04749(0.53)	78.5(0.2)	73.7(25.2)
BB: N2,>105	0.082	136	1.7	770	11	13.0	0.01230(0.12)	0.08105(0.36)	0.04780(0.29)	78.8(0.2)	89.5(13.7)
CC: M2,>105	0.090	125	1.6	393	23	12.2	0.01224(0.18)	0.08028(0.78)	0.04759(0.70)	78.4(0.3)	78.7(33.1)
DD: M2,>105	0.153	150	1.9	648	28	12.8	0.01229(0.12)	0.08063(0.38)	0.04757(0.29)	78.8(0.2)	77.8(14.0)

Analyses done at the Geochronology Laboratory, University of British Columbia
[1] N2 = non-magnetic at one degree side slope on Frantz isodynamic magnetic separator; grain size given in microns
[2] radiogenic Pb; corrected for blank, initial common Pb, and spike
[3] corrected for spike and fractionation
[4] corrected for blank Pb and U, and common Pb.

Table 1. *U-Pb Analytical data*

Potassic alteration is the most intense and pervasive form of alteration on the property. It is best developed in Trench 6, but extends north-northeastward past Trench 1 (Fig. 4). In hand sample, alteration is characterized by an overall darkening of the diorite. This darkening is due to the formation of secondary biotite and the replacement of various primary mafic minerals by magnetite, making the rock strongly magnetic. The zone is also characterized by a suite of quartz and pink potassium feldspar (locally with graphic textures) veins up to 1 cm wide. These veins are themselves cut, and commonly offset, by thinner quartz and potassium feldspar veins that contain secondary biotite. In the areas around Trenches 1 and 2, potassium feldspar-magnetite-actinolite-epidote veins are also common.

Seen in thin section, the felted, feathery masses of secondary biotite occur as rims on corroded hornblende and primary biotite phenocrysts. Magnetite is seen replacing various mafic minerals, including biotite and hornblende. In portions of the potassic zone where the diorite appears to have been hydrothermally brecciated, microfractures are commonly healed by quartz and potassium feldspar veinlets.

Phyllic alteration is only developed within the porphyritic quartz monzodiorite unit in Trench 6. In hand sample, the phyllic zone is characterized by an overall bleaching of the entire rock, destruction of primary textures, as well as strong sericitization of feldspars, replacement of primary magnetite by pyrite, and alteration of early(?) secondary biotite to sericite and/or clay. Fine quartz veinlets are abundant throughout the unit.

Albitic alteration is the least pervasive form of alteration on the property. In hand sample, this alteration zone is characterized by an overall lightening in colour of the affected rock, and the formation of intense albitic envelopes around the microveinlets that are common in this zone. The albitized envelopes are bright white in colour and are up to an order of magnitude wider than the veinlets themselves. This form of alteration is seen only between Trenches 4 and 6 (Fig. 4). In thin section this style of alteration is distinguished by the presence of abundant fine laths of secondary albite, along with minor secondary biotite. Diorite within this zone has been hydrothermally micro-brecciated, and the thin veinlets and their albite envelopes are commonly truncated and displaced slightly by later veinlets. Breccia fragments have not been obviously rotated however, and many veinlets crosscut faulted veinlets, indicating the the veining and brecciation overlapped in time.

Propylitic alteration is the most widespread and least intense of the four recognized alteration facies on the property. It is characterized by the presence of significant amounts of chlorite and epidote, which impart a medium to dark green colour to the diorite in which it occurs. Magnetite is considerably more abundant in propylitic-altered diorite than in unaltered diorite. The “unaltered” diorite actually contains significant concentrations of secondary chlorite and epidote, and it was not until the differing magnetite content was noticed that a clear boundary for the propylitic alteration zone could be defined. The secondary magnetite occurs with chlorite as replacements of primary mafic minerals.

MINERALIZATION

Copper is the only commodity of potential economic interest on the Sato property, as gold and molybdenum are far below economic grades. The main copper minerals present are chalcopyrite, malachite and very rare native copper. Copper mineralization is concentrated in the potassic alteration zone, and to a lesser extent, in the albitic and phyllic zones. Chalcopyrite occurs in veinlets and as fine disseminations within the altered host intrusions. It appears to be intimately associated with pyrite and magnetite. Malachite commonly forms on weathered fracture surfaces, and is especially common in the potassic alteration zone closest to the quartz-monzodiorite porphyry, where the diorite has been hydrothermally brecciated. The malachite appears to be a secondary weathering product. Unlike the Casino porphyry copper deposit 175 km to the northwest, no significant supergene enrichment has been developed on the Sato property, although a trace amount of native copper of possible supergene origin was identified in float in Trench 6.

Examination of polished sections of mineralized samples shows a close relationship between magnetite, pyrite and chalcopyrite. Magnetite occurs as disseminations within all of the alteration facies on the property, and in the potassic, phyllic and albitic alteration zones it occurs both as disseminations and in veinlets. The disseminated magnetite forms as a replacement of mafic minerals such as hornblende and biotite. In the innermost three alteration zones (potassic, phyllic and albitic), disseminated and veinlet magnetite is commonly partially to wholly replaced by pyrite and/or chalcopyrite. The degree of replacement of magnetite by pyrite or chalcopyrite appears to be random, suggesting that the replacement mineralization was controlled by fluids movement along selected microfractures, rather than by wholesale infiltration of the rock.

There is a close relationship between copper grade and alteration facies. The potassic zone, on average, contains the highest copper grades, followed by the phyllic zone and albitic zones.

PROPOSED DEPOSIT MODEL

In the field-based model for copper mineralization on the Sato property, the porphyritic quartz-monzodiorite phase was thought to be the latest and most highly differentiated phase of the intrusive complex, and was considered to be the likely source of the fluids responsible for hydrothermal alteration and mineralization on the property. However the potassic alteration zone, which is typically the most intense and most centrally located within porphyry systems, is not spatially associated with the porphyritic intrusion, which experienced mainly phyllic alteration.

The new U-Pb age data indicate that the main phase diorite was emplaced slightly later than the porphyitic unit, and that the alteration and mineralization post-dates both units. The cause of the brecciation, alteration, and mineralization is therefore unresolved. The coarse-grained diorite unit and either of the two dyke units present on the property represent possible sources of the mineralizing fluids, but these units occur well away from the main area of alteration and mineralization. The mineralization may be related either to fluids evolved during the final stages of crystallization of the main phase diorite, or from a younger intrusive phase that is not exposed at the present level of erosion. The phyllic alteration seen mainly in the porphyritic quartz monzodiorite unit appears to simply result from the interaction between a more felsic rock composition and the mineralizing fluids.

DISCUSSION AND CONCLUSIONS

The Sato property is underlain by K-spar megacrystic granite of the Aishihik or Long Lake plutonic suite, which has been intruded by a multiphase intrusive complex that is the intrusive equivalent of the Late Cretaceous Mount Creedon Volcanic Suite. Porphyry copper-style mineralization is hosted within the Late Cretaceous intrusive complex and is thought to be related to the emplacement of a late phase of the complex.

The Late Cretaceous intrusive complex includes at least three separate phases. The main phase is a medium-grained diorite (U-Pb zircon age of 78.2 ± 0.1 Ma) which makes up approximately 95% of the surface area of the complex. A porphyritic quartz monzodiorite (U-Pb zircon age of 78.8 ± 0.2 Ma) is volumetrically minor, occurring only as one small outcrop in the middle of the property. The age data indicates that it is the oldest phase present and it appears to occur as a raft within the younger diorite. The third phase recognized is a coarse-grained diorite. Contact relationships between this and the two other phases of the intrusive complex are not exposed. Minor mafic and felsic dykes seen on the property may or may not be related to the complex.

Four alteration facies are recognized on the property. Potassic alteration is the most pervasive and intense style of hydrothermal alteration. It affects the main phase diorite and is characterized by the formation of secondary biotite at the expense of primary biotite and hornblende. Also characteristic of this zone are abundant quartz-potassium feldspar-biotite veins and veinlets that locally contain magnetite, epidote, and actinolite. These veins and veinlets appear to heal fractures within a zone of brecciated diorite. The second alteration facies is albitic, and also affects the diorite in the outer edge of the brecciated zone. This alteration is characterized by thin microveinlets of quartz, feldspar and minor secondary biotite that have intensely bleached envelopes. These envelopes are composed of sodic plagioclase and possible sericite. The alteration is generally limited to the area immediately surrounding the veinlets, but a slight wholesale enrichment of plagioclase may be present throughout the zone as a slight lightening in colour of the diorite is recognized. Phyllic alteration is characterized by the formation of quartz and sericite, and bleaching of the rock. This style of alteration is only apparent in the porphyritic quartz monzodiorite unit and is thought to reflect the more felsic primary rock composition. The widespread propylitic alteration is characterized by the presence of significant chlorite and epidote and the formation of magnetite at the expense of biotite and hornblende. Magnetite replacement similar to this is common to the other zones as well, but it can be used as an indicator of the propylitic zone because unaltered diorite contains comparatively little primary magnetite.

Mineralization on the property is intimately associated with the hydrothermal alteration. Copper grades are carried mainly in chalcopyrite, which occurs with pyrite as a replacement of hydrothermal magnetite. Grades are highest in the potassic alteration zone and decrease outwards. Copper grades range from ~0.1 to 0.38% in the potassic zone, from 0.1 to 0.15% in the phyllic zone, and ~0.08% in the albitic zone. Mineralization is thought to have resulted from either fluids evolved during the latest stages of crystallization of the main phase diorite or from a buried intrusion that represents a later, high-level phase of the Late Cretaceous intrusive complex.

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