MINERALOGIC VARIATION OBSERVED AT THE SILVER QUEEN MINE, OWEN LAKE, CENTRAL BRITISH COLUMBIA (93L/2)*

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INTRODUCTION

The Silver Queen (Owen Lake, Nadina) vein system, lies within the Buck Creek basin near Houston, 100 kilometres southeast of Smithers, in the Bulkley Valley region of central British Columbia (Figure 2-4-1). The mine, which produced 98 285 grams of gold, 5225 kilograms of silver, 405 000 kilograms of copper, 703 000 kilograms of lead, 5 million kilograms of zinc and 15 800 kilograms of cadmium from 190 700 tonnes of ore over a brief period from 1972 to 1973, has current reserves of approximately 500 000 tonnes grading 3 grams gold and 200 grams silver per tonne, 0.23 per cent copper, 0.92 per cent lead and 6.20 per cent zinc. Problems arising from the complex mineralogy and variability of the ore zones were, to some extent, responsible for the closure of the mine. The mineralogic study of the Owen Lake property reported on here is part of a more extensive project dealing with the geology and origin of polymetallic vein deposits in the Owen Lake area.

REGIONAL SETTING

West-central British Columbia lies within the Stikine Terrane, which includes submarine calcalkaline to alkaline immature volcanic island-arc rocks of the Late Triassic Takla Group, subaerial to submarine calcalkaline volcanic, volcaniclastic and sedimentary rocks of the Early to Middle Jurassic Hazelton Group, successor basin sedimentary rocks of the Late Jurassic and Early Cretaceous Bowser Lake, Skeena and Sustut groups, and Late Cretaceous to Tertiary calcalkaline continental volcanic-arc rocks of the Kasalka, Ootsa Lake and Endako groups (MacIntyre and Desjardins, 1988). The younger volcanic rocks occur sporadically throughout the terrane, mainly in downthrown fault blocks and grabens. Plutonic rocks of Jurassic, Cretaceous and Tertiary ages form distinct intrusive belts (Carter, 1981), with which porphyry copper, stockwork molybdenum, mesothermal and epithermal base and precious metal veins are associated.

The area surrounding the Silver Queen mine forms part of the Buck Creek basin, characterized as a resurgent caldera with the Equity Silver mine (Figure 2-4-1) located within the central uplift area (Church and Barakso, 1990). The study area lies on the western margin of the basin, which is roughly defined by a series of rhyolite outliers and a semicircular alignment of Upper Cretaceous and Eocene volcanic centres. Block faulting is common within the basin, locally juxtaposing the various sequences of volcanic rocks. The Silver Queen veins are hosted by some of the oldest rocks in the basin and the succession has been correlated with rocks of the Kasalka Group (Leitch *et al.*, 1990). However, Armstrong (1988) argues that this correlation is incorrect and that the rocks hosting the Silver Queen deposit are, in fact, part of the Tip Top Hill Formation, as suggested originally by Church (1970). The type section of the Kasalka rocks, which are Late Cretaceous (MacIntyre, 1985) or Early Cretaceous (Armstrong, 1988) in age, is in the Kasalka Range near Tahtsa Lake, approximately 75 kilometres southeast of Houston.

PROPERTY GEOLOGY

The stratigraphy hosting the Silver Queen deposit is subdivided into five major units which form a gently northwest-dipping succession (Leitch *et al.*, 1990). The oldest rocks are exposed near Riddeck Creek in the south and the youngest in Emil Creek to the north (Figure 2-4-1). The lowest unit in the succession is a reddish purple, polymictic conglomerate (Unit 1). It is overlain by fragmental rocks ranging from thick crystal tuff (Unit 2) to coarse lapilli tuff and breccia (Unit 3), which are succeeded upwards by a thick feldspar-porphyritic andesite flow unit (Unit 4). The flows are intruded by microdiorite sills (Unit 5) and other feldspar porphyry (Unit 5a) and quartz porphyry (Unit 5b) dikes and stocks. All the units are cut by dikes that can be divided into three groups: amygdaloidal dikes (Unit 6), bladed-feldspar trachyandesite dikes (Unit 7), and diabase dikes. The succession is unconformably overlain by basaltic to possibly trachyandesitic volcanic rocks that outcrop in Riddeck Creek and farther south. These volcanics may be correlative with the Goosly Lake Formation of the Equity Silver mine area (Church and Barakso, 1990).

The bladed-feldspar trachyandesite (Unit 7) and amygdaloidal dike (Unit 6) units are of particular importance in relation to age of mineralization. Rocks of Unit 7 are generally unaltered in the vicinity of major veins and give a whole-rock K-Ar date of 51.9±1.2 Ma, whereas Unit 6, which is commonly strongly altered near veins, produces a whole-rock K-Ar date of 51.3±1.2 Ma. These dates allow for close bracketing of the age of mineralization, with all three dike types commonly paralleling the strike of the major vein systems. The major veins, including the No. 3 vein (Figure 2-4-1) which is the most important economically, tend to strike northwest and are controlled by both strike-slip and reverse faults.

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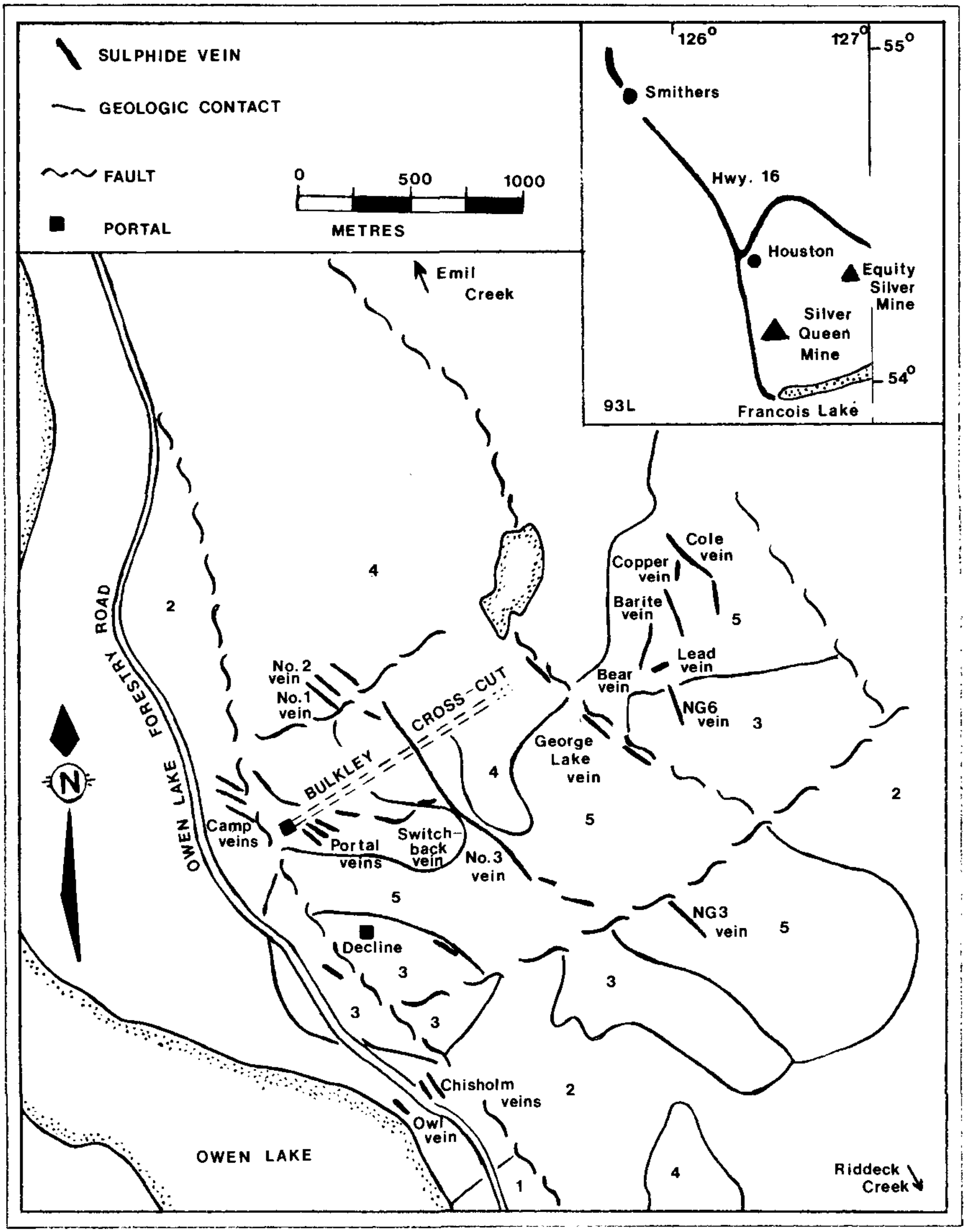


Figure 2-4-1. Map of Silver Queen mine showing locations of geologic contacts (Leitch *et al.*, 1990) and major mineralized structures. Legend: 1=polymictic basal conglomerate; 2=crystal tuff; 3=medium to coarse tuff-breccia; 4=feldspar-porphyritic andesite; 5=microdiorite.

Inset: Location of Silver Queen mine.

VEIN MINERALOGY

The Silver Queen vein system displays a great degree of complexity on the centimetre to metre scale, but, when examined over the strike lengths of individual structures, such as the No. 3 and George Lake systems, several large-scale patterns become evident. The No. 3 vein, with its extensive surface exposure, large number of drill-hole intersections, and structural continuity, provides the best opportunity for analysis of a complete system. Despite differences in mineralogy within the No. 3 structure and other veins on the Owen Lake property, a surprising paragenetic continuity (summarized in Tables 2-4-1 and 2) exists throughout the mineralized area.

TABLE 2-4-1
MINERALOGY OF MAJOR VEIN SYSTEMS

Vein	Mineralogy		Important Textures
	Sulfide	Gangue	
#3 North (Zone I)	sphl, gln, py, tet cpy, sel, elec	rho, qtz Mn-sid, pybit	banded (rho) sparry (qtz) coarse-grained euhedral (sphl, gln)
#3 Cpy-rich (Zone II)	cpy, ten, py, sphl mtd, ber, aik gln, elec, hem-mag, pc-pb	rho, qtz, Mn-sid, pybit	breccia (qtz, py) myrmekitic (cpy gln, ten, mtd)
#3 Central (Zone III)	cpy, sphl, gln, py tet-ten, hem-mag, sel, elec, mc	qtz, Mn-sid, ba, rho	sparry (qtz Mn-sid) breccia (py, mc) colloform (sphl, py) myrmekitic (sel, tet-ten)
#3 South (Zone IV)	gln, aik, tet-ten, sphl, aspb, fr, py, pyg, sel, elec, bn, cv, cc, UNssx #2	ba, qtz, clc, pybit, hins, svan, Ti-ox	colloform (py, sphl), breccia (py-qtz), bladed (ba), myrmekitic (sel, cpy, tet-ten), web (aik, tet-ten, gln)
NG3 (Zone V)	gln, sphl, tet-ten, cpy, pu-pyg, UNssx #1, bs, cpb, py	ba, clc, qz, hins, svan	web (bis, cpb), lamellae(UNssx #1, cpb, bs), myrmekitic (pu-pyg, UNssx #1, tet-ten, gln)
Twinkle Zone	sphl, tet-ten, gln cpy, py	clc, qtz	
Portal	cpy, sphl, gln, mtd, tet-ten, py, elec, aik, aspy, mc, pc	qtz, rho Mn-sid, ba, pybit	sparry (qtz, Mn-sid), breccia (py, ba, sphl) myrmekitic (mtd, gln, aik, cpy, tet-ten)
Camp	py, aspy, sphl, gln, tet-ten, po, pu-pyg, elec, pc-plb, dig, ac, bn, fr, cpy	qtz, ba, rho, Mn-sid, pybit	dendritic (aspy, py) colloform (sphl), myrmekitic (py, tet-ten, gln, cpy) breccia (py, aspy)
George Lake	sphl, py, gln, cpy hem-mag, tet-ten, mc, pc-plb, elec	qz, clc, ba	breccia (py-qtz) myrmekitic (gln, tet-ten) crustiform (py on hem-mag)
Cole Lake	sphl, cpy, py, mc, hem-mag, aspy, fr, tet-ten, aik, gln, mtd, elec, sel, pc-plb, UNssx #3	qz, ba, rho Mn-sid, clc, pybit	sparry (qtz, rho) myrmekitic (gln, aik, mtd, sel) breccia (py-qtz)
#1	aspy, py, elec, po, pc-plb, cpy, tet-ten, sphl, gln	rho, qtz, pybit	breccia (py, aspy)
#2	aspy, py, tet-ten, pu-pyg, elec, mc, sphl, gln, cpy, pc-plb, hem-mag	rho, qz, pybit	sparry (qtz) breccia (py) banded (rho)
Chisholm/ Owl	sphl, py, gln, cpy, tet-ten, sel, pu-pyg, pc-plb	qtz, ba, clc	breccia (py, aspy) myrmekitic (gln, sel)

**Symbols for minerals are as follows:

qtz= quartz
clc= calcite
gln= galena
aik= aikinite
pc= pearcite
ber= berryite
pu= proustite
cb= unidentified carbonate
UNssx= unidentified sulfosalt
hem= hematite
cv= covellite
ac= acanthite
hins= hindalite

ba= barite
pybit= pyrobitumen
cpy= chalcopyrite
sphl= sphalerite
plb= polybasite
tet= tetrahedrite
elec= electrum
py= pyrite
bn= bornite
mag= magnetite
mc= marcasite
cc= chalcocite
fr= freibergite

Mn-sid= Mn-rich siderite
rho= rhodochrosite
sel= seligmannite
aspb= arsenpolybasite
pyg= pyrargyrite
ten= tennantite
cpb= cuprobismutite
bs= bismuthinite
mtd= matildite
po= pyrrhotite
dig= digenite
svan= svanbergite
Ti-ox= titanium oxide phase

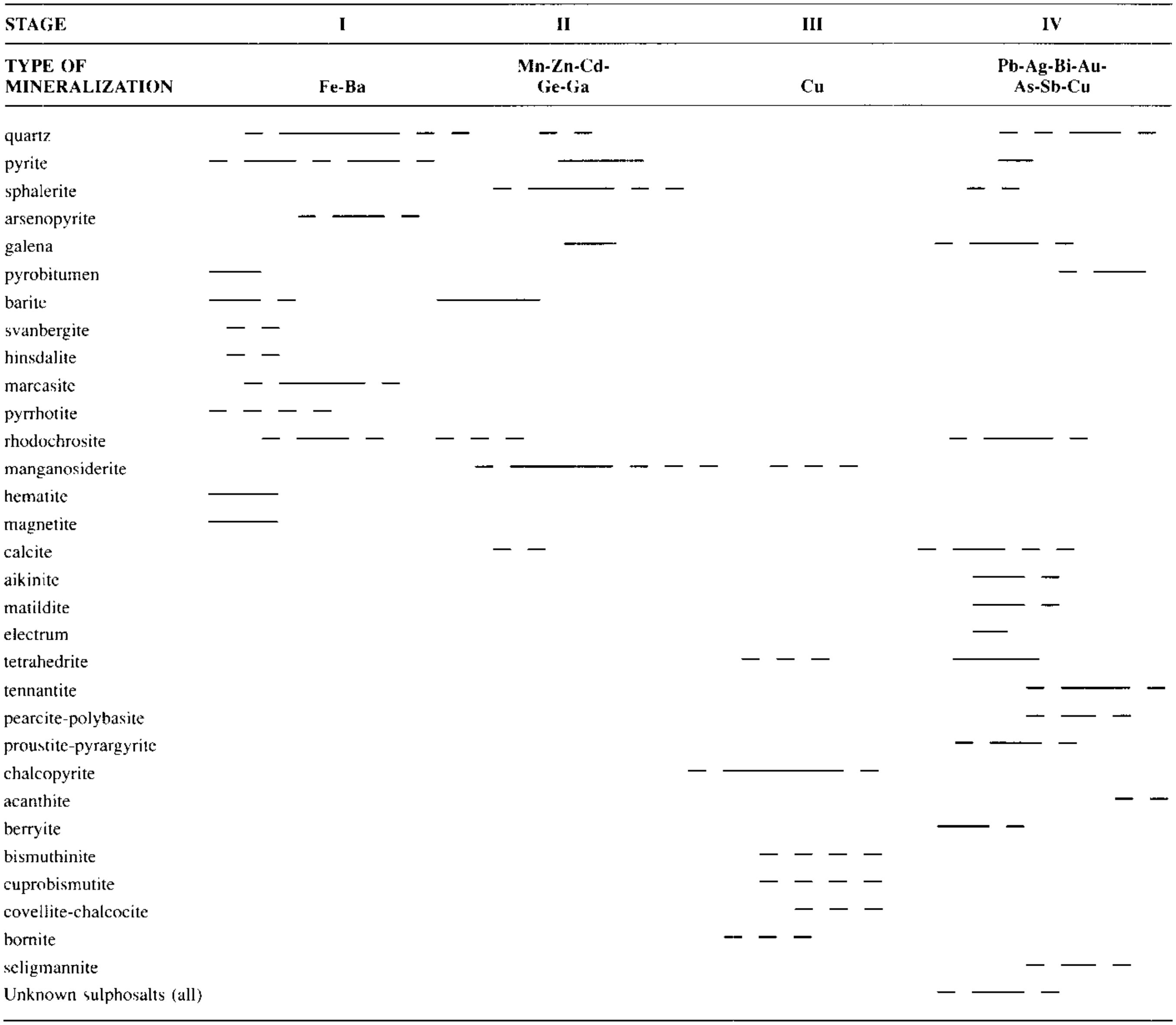
NO. 3 VEIN SYSTEM

The No. 3 vein system is the largest and, to date, most intensively explored structure at the Silver Queen mine. It is well defined on surface, underground and in drill-hole intersections, and displays a wide range of mineralogies over the length of the structure. Several smaller veins with similar mineralogy lie adjacent to the main vein.

The No. 3 vein can be divided into five zones based on bulk mineralogical content (Table 2-4-1). The northernmost segment of the vein system (Zone I) consists of narrow, commonly multiple, smaller veins dominated by interbanded rhodochrosite and quartz. Prominent, if irregular, bands of coarse-grained euhedral sphalerite and galena are an important distinguishing feature. Toward the south, hematite, chalcopyrite and the sulphosalts (matildite, aikinite and berryite) increase in abundance until a distinct new zone (Zone II) is entered. Chalcopyrite, comprising as much as 60 volume per cent of the opaque assemblage, is the definitive mineral for Zone II, with bismuth-bearing sulphosalts and tennantite present in significant amounts. Vein walls are generally brecciated in this segment, with hematite, pyrite and carbonate among the first minerals to be deposited. To the south of the relatively short chalcopyrite-rich zone, the mineralogy in Zone III becomes less complex. The vein attains widths of up to 2.5 metres in this central segment and is generally very lean (<10 per cent) in opaque minerals. The sulphide assemblage is dominated by pyrite and sphalerite, commonly occurring as colloform masses overgrowing carbonate (manganosiderite) and quartz. Hematite is also present and in some places has been overgrown and replaced by later sphalerite, pyrite and galena. Seligmannite-bournonite and tetrahedrite-tennantite are present in minor amounts, generally as myrmekitic intergrowths with galena.

The most unusual zone (Zone IV) within the No. 3 system forms the southern one-third of the structure exposed underground. The vein displays well-defined boundaries, but locally splits into several closely associated narrower veins. The mineralogy is generally dominated by pyrite and sphalerite, with an earlier pyrite-quartz-barite phase frequently brecciated and surrounded by later, finer grained pyrite and quartz. Complexly intergrown galena and multiple-composition tetrahedrite-tennantite locally form up to 40 per cent of the opaque assemblage and are the princi-

TABLE 2-4-2
PARAGENESIS IN THE SILVER QUEEN VEIN SYSTEM



pal host for gold (in the form of electrum grains within the galena) and silver (some tetrahedrite contains as much as 8 per cent silver). Of particular interest is a northwesterly plunging section of the vein system, centred on the decline area, displaying anomalously high (up to 3 per cent of opaque minerals) amounts of aikinite intergrown with galena and tetrahedrite-tennantite. Myrmekitic intergrowths of seligmannite and galena are also widespread in the southern part of the vein.

The least defined of the No. 3 vein segments is that known as the NG3 vein (Zone V). This part of the structure has only been intersected in a few widely spaced drill holes and few samples are available. The mineralogy appears to be dominated by coarse-grained galena, sphalerite and pyrite, with earlier barite and quartz gangue. The whole assemblage is cut and brecciated by calcite. Unusual exsolution features, consisting of proustite and an unidentified silver-bearing sulphosalt, are present in galena from drillhole NG3. Bismuthinite and cuprobismutite were recorded occurring in tetrahedrite from a pyrite-rich portion of the vein and appear to be penecontemporaneous with a period of silver-bearing tetrahedrite mineralization.

PORTAL AND CAMP VEINS

The Portal veins are a series of highly irregular structures near the entrance to the Silver Queen underground workings (Figure 2-4-1). Orientation, thickness and mineralogy vary from vein to vein; individual structures attain widths of up to a metre, only to disappear tens of metres away. The veins can, however, be roughly classified into three groups on the basis of mineralogy. The most important economically are those containing substantial amounts of chalcopyrite (up to 60 per cent of the total sulphide) and associated later galena-matildite intergrowths. Widespread tennantite veining cuts this assemblage, with manganosiderite and quartz making up the gangue mineralogy. In places, spectacular concentrations of electrum are also associated with the galena-matildite assemblage characteristic of chalcopyrite-rich veins.

Several of the westernmost veins within the Portal system have mineralogies closely resembling the nearby Camp veins (*see* description below). Early, bladed barite, with quartz, pyrite and rare arsenopyrite, followed by coarse-grained sphalerite and lesser galena and chalcopyrite, are the dominant components of this group of veins. Later sulphosalts, electrum, rhodochrosite and pyrobitumen are conspicuously absent. Many of the easternmost veins, and the Switchback vein (Figure 2-4-1), are dominated by early phases (barite, quartz, pyrite and sphalerite), with relatively minor amounts of chalcopyrite, carbonate and tetrahedrite-tennantite usually confined to narrow bands near the footwall of each vein.

The Camp veins lie to the west of the Portal vein system (Figure 2-4-1) and are known only from an extensive pattern of drill-holes. They are distinctive because of their anomalously high silver grades associated with pearceite, acanthite and the ruby silvers. Many of the veins are actually mineralized breccias, with the first episode of mineralization characterized by narrow drusy-quartz bands surrounding fragments. Bladed barite, pyrite, sphalerite and arsenopyrite follow, forming up to 50 per cent of the mineral assemblage, and galena, tetrahedrite-tennantite and the silver-bearing minerals are the final phases of economic interest. A volumetrically important period of rhodochrosite deposition was the last major episode of mineralization in the Camp veins.

GEORGE LAKE VEINS

The George Lake veins (Figure 2-4-1) are part of the second most important vein system (next to the No. 3 vein) on the property, in terms of structural continuity and potential reserves. Overall mineralogy roughly compares to that of the No. 3 system, with slightly greater abundances of fine-grained quartz and hematite being the chief difference. Sulphosalts are generally absent in the available samples and pyrite is the most important sulphide constituent throughout the vein. Galena, tetrahedrite-tennantite and rare pearceite-polybasite are most commonly found filling fractures within the pyrite and sphalerite. As with the No. 3 vein system, chalcopyrite and manganoan carbonates generally appear to increase in abundance towards the north.

COLE LAKE VEINS

The Cole Lake veins (Figure 2-4-1) are a widely spaced group of structures with a northerly trend and highly varied mineralogy. Mineralogy is somewhat similar to the Portal vein system; in the Cole Lake veins, the characteristic assemblage changes from hematite-carbonate-pyrite in the westernmost veins (Bear vein), through chalcopyrite and sulphosalt-bearing assemblages in the central veins (Copper and Lead veins) to sphalerite and barite-rich veins in the easternmost area (Cole vein). The Cole vein has the longest strike length in the Cole Lake system, but presents a relatively simple mineralogy in contrast to smaller but more complex veins such as the Copper vein. The sulphide mineralogy in the Cole vein is dominated by coarse-grained, euhedral sphalerite and galena in a matrix of manganoan carbonate, barite and quartz. Toward the north, arsenopyrite becomes abundant, overgrowing pre-existing hematite grains that have been replaced by carbonate, pyrite and galena. Freibergite (argentian tetrahedrite) also appears within this portion of the vein.

In contrast to the relatively simple Cole vein, the adjacent Copper vein is mineralogically complex. Although the walls of the vein are similar to the Cole vein, the Copper vein is distinctive because of an important later chalcopyrite-sulphosalt episode (possibly correlative with Stage IV of the No. 3 vein). Symplectic intergrowths of galena, aikinite and matildite are widespread, with rare tennantite veinlets cutting the entire assemblage. To the west of the Copper vein, the Barite, NG6 and Lead veins, though chalcopyrite poor, contain unusual concentrations (to 3 per cent of total sulphide) of pearceite-polybasite and seligmannite. The Bear vein is the westernmost vein within the system and is characterized by early stage mineralization dominated by hematite, carbonate, pyrite and quartz.

OTHER VEINS

The most important of the remaining veins are the Chisholm veins (Figure 2-4-1), located near the south boundary of the property. Mineralogy of these veins is similar to the Camp veins, dominated by early quartz, barite, pyrite, arsenopyrite and sphalerite, followed by less abundant galena, carbonate, quartz and tetrahedrite-tennantite. Up to 5 per cent of the galena in sections from the Chisholm veins and the nearby Owl vein (Figure 2-4-1) has undergone replacement by ruby silvers, pearceite-polybasite and tennantite. Very fine grained symplectic intergrowths of seligmannite in galena have also been noted.

The No. 1 and No. 2 veins split off the northern segment of the No. 3 vein and retain many of its characteristics. The No. 2 vein, actually a set of closely associated parallel veins, is quite similar to Zone I of the No. 3 vein in that the mineralogy is dominated by banded rhodochrosite and quartz, with prominent coarse-grained sphalerite bands throughout. Farther north on the No. 2 system, arsenopyrite, pearceite-polybasite and the ruby silvers appear within the opaque assemblage.

The No. 1 vein is singular in that arsenopyrite forms an important part of the assemblage (up to 10 per cent of the total sulphide), surrounding and brecciating pre-existing pyrite while predating other sulphides. Pearceite-polybasite and possibly acanthite are also present within the vein, representing the final stage of sulphide mineralization.

The remaining mineralized structures on the property are quite simple mineralogically, generally consisting of pyrite, sphalerite and galena with quartz-carbonate-dominated gangue. A vein intersected in Hole NG4 (near the south boundary of the property) containing an anomalous amount of late chalcopyrite (to 5 per cent of sulphide component) is perhaps the most unusual.

DISCUSSION

The mineral assemblages in the Silver Queen vein system present a paragenetic sequence that is remarkably consistent throughout the property (summarized in Table 2-4-2). This suggests that all veins at Owen Lake originated from a single source during a single mineralizing event, a concept that is generally supported by relationships with the series of dikes that closely bracket the time of mineralization (Leitch *et al.*, in preparation). Evolution of the deposit can be divided roughly into four stages, each displaying typical characteristics of low-temperature, open-space deposition (*i.e.* colloform sphalerite, sparry quartz, vuggy nature throughout). The first stage (refer to Table 2-4-2) is distinguished by an initial minor quartz-pyrite episode, followed by hematite, pyrobitumen, barite, svanbergite and hinsdalite (the latter two minerals are unusual strontium-bearing sulphates). More voluminous influxes of pyrite, quartz and minor carbonate followed, with later arsenopyrite, pyrite and marcasite marking the end of this stage. The second stage is defined by the deposition of sphalerite (containing up to 0.1 weight per cent germanium), galena, minor pyrite, and manganosiderite, followed by a stage of copper-bearing mineralization and associated manganoan carbonates. The latter stage is particularly prominent toward the north of the property, although isolated occurrences of relatively chalcopyrite-tetrahedrite-rich material occur in the southernmost areas as well. The final stage is characterized by rhodochrosite (or calcite in the south), galena and sulphosalts, and is associated with the deposition of electrum, the principal source of gold at Silver Queen mine. The galena-sulphosalt assemblage is cut by tennantite veining (consisting of bismuth and arsenic-bearing phases) in the north and a weak quartz-pyrobitumen event marks the end of mineralization in Stage IV and in the system as a whole.

Textures within the individual veins indicate that the veins were deposited along fractures and joints that were repeatedly opened and sealed as mineralization proceeded. The initial quartz-pyrite vein material has, in many sites, undergone brecciation and has subsequently been surrounded by later pyrite. These breccias often show signs of renewed vein dilation and subsequent sealing by later phases such as galena. Remobilization of the "soft sulphides", such as galena, has been discounted to a large extent due to the preservation of the more fragile open-space filling textures. A single exception to the above observation was noted in the George Lake vein, where postmineralization fault movement has resulted in the formation of "sulphide slickensides". Of particular note are offsets perpendicular to the veins that cut Stages I and II material, but are often filled by later minerals such as galena. Dilation and lateral motion were, therefore, active processes during mineralization.

Constraints on pressure, temperature and composition of the ore fluids are conjectural at this stage. A more in-depth examination of the more complex mineral assemblages (particularly where multiple compositions of the fahlore group are concerned) as well as stable isotope and fluid inclusion work, will be conducted.

CONCLUSION

The Owen Lake property covers a series of base and precious metal veins that display great consistency with respect to mineral paragenesis. Four distinct stages of mineralization are recognized within most of the major structures and are interpreted to be derived from a single fluid source with deposition accompanied by repeated opening and sealing of the individual veins.

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