GEOLOGY OF THE SILVER QUEEN MINE AREA, OWEN LAKE, CENTRAL BRITISH COLUMBIA
(93L)

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INTRODUCTION

The Silver Queen (Nadina, Bradina) mine of Pacific Houston Resources Inc. is near Owen Lake, 35 kilometres southeast of Houston, and 100 kilometres southeast of Smithers, in the Bulkley Valley region of central British Columbia (Figure 2-8-1). The geology of the 20 square kilometre area surrounding the deposit has been mapped, and results suggest that the stratified rocks hosting this epithermal gold-silver-zinc-lead-copper vein deposit (the Late Cretaceous Tip Top Hill volcanics; Church, 1971) may be correlative with rocks hosting the Equity Silver deposit, and are lithologically similar to the Kasalka Group of late-Early to early-Late Cretaceous age. The geological mapping is part of a more extensive project dealing with the geology and origin of polymetallic vein deposits in the Owen Lake area.

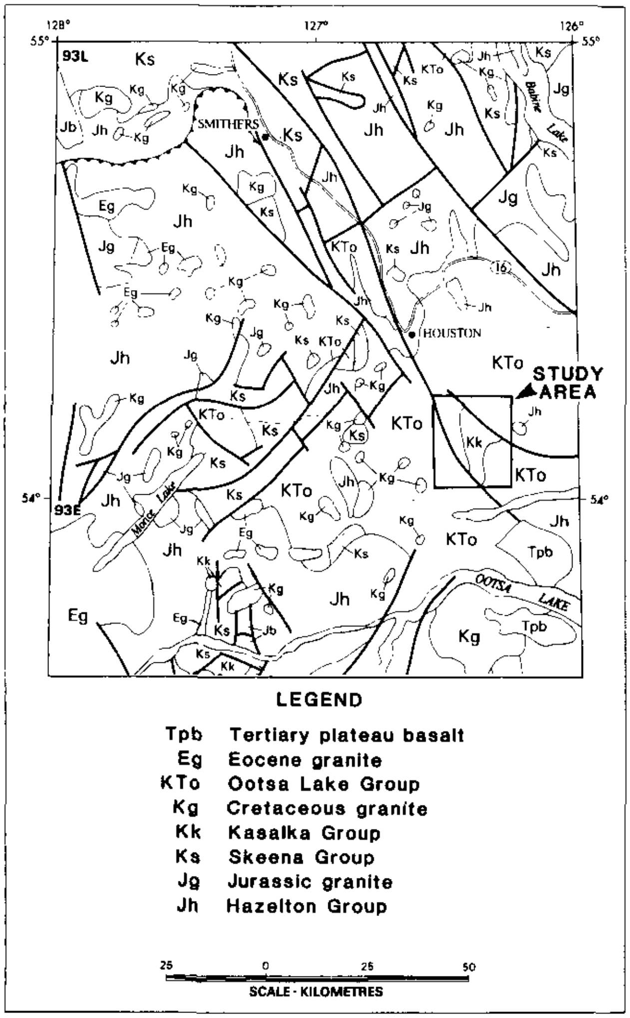

Figure 2-8-1. General geology of west-central British Columbia, showing the regional setting of the study area. Taken from MacIntyre (1985).

REGIONAL GEOLOGIC SETTING

West-central British Columbia lies within the Stikine Terrane, which includes submarine calcalkaline to alkaline immature volcanic islandarc rocks of the Late Triassic Takla Group, subaerial to submarine calcalkaline volcanic, volcaniclastic and sedimentary rocks of the Early to Middle Jurassic Hazelton Group, Late Jurassic and Cretaceous successor basin sedimentary rocks of the Bowser Lake, Skeena and Sustut groups, and 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 area, mainly in downthrown fault blocks and grabens. Plutonic rocks of Jurassic, Cretaceous and Tertiary age form distinct intrusive belts (Carter, 1981), with which porphyry copper, stockwork molybdenum and mesothermal and epithermal base and precious metal veins are associated.

The Kasalka Group (Armstrong, 1988) is considered to be a late-Early (Armstrong, 1988) or early-Late Cretaceous (MacIntyre, 1985) continental volcanic succession that is predominantly porphyritic andesite and associated volcaniclastic rocks. It is well exposed in the Kasalka Range type section near Tahtsa Lake. In the type area, it includes a basal polymictic conglomerate that is strikingly red in colour and lies in angular unconformity on older rocks. The unit is generally between 5 and 10 metres thick (locally 50 metres in channel-fill deposits), and includes interfingering lenses of sandstone. The conglomerate is overlain by a felsic fragmental unit over 100 metres thick, consisting of grey to cream-coloured, variably welded siliceous pyroclastic rocks (lithic lapilli tuff, crystal and ash-flow tuff, minor breccia) with interbedded porphyritic flows. These fragmental rocks are in turn overlain by a major unit of columnar jointed, massive, greenish grey flows or sills of hornblende-feldspar-porphyritic andesite to dacite, at least 100 metres thick. The andesite flows are conformably overlain by a chaotic assemblage of volcanic debris flows (lahars), at least 200 metres thick, in which most clasts are identical to the

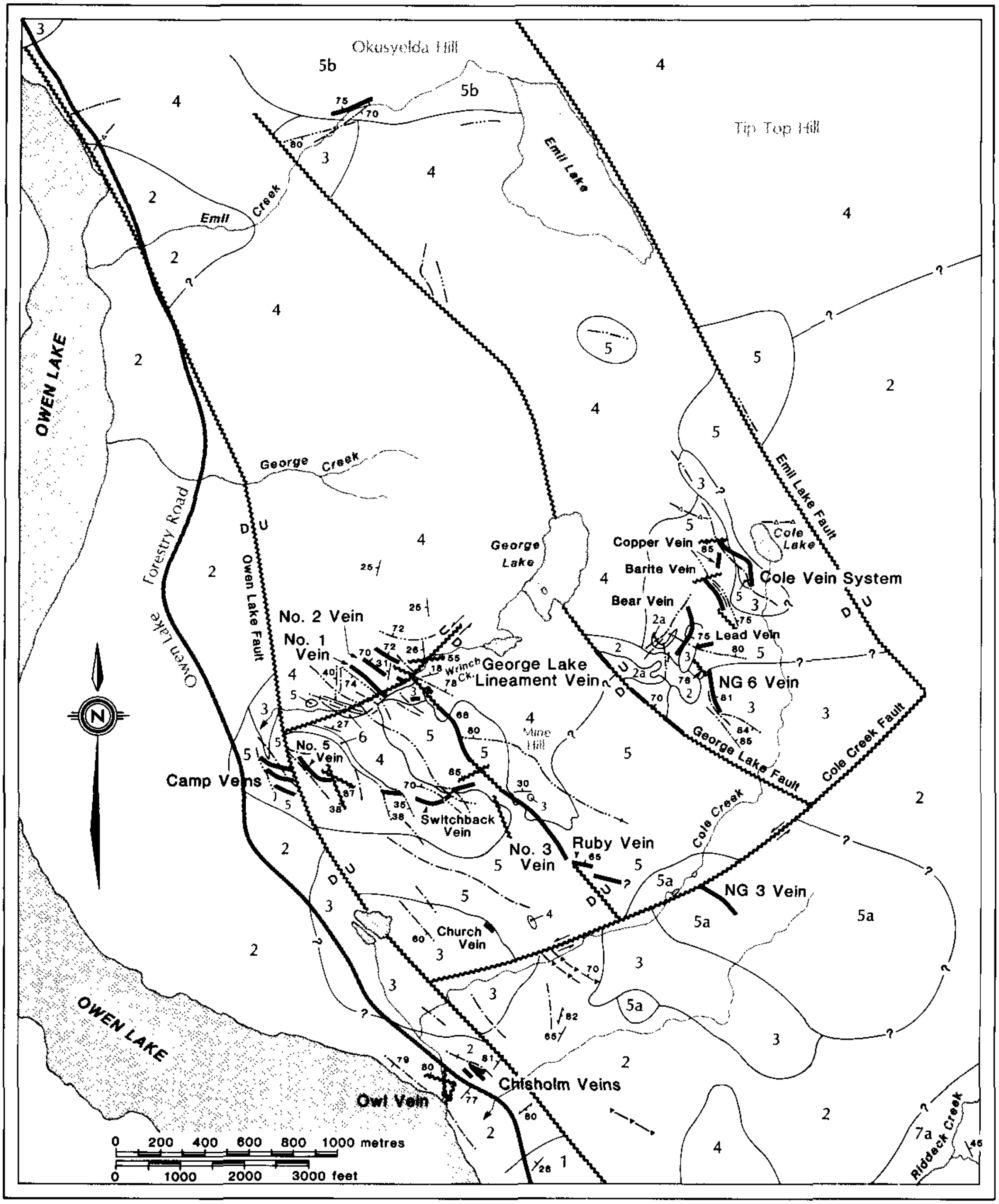

Figure 2-8-2. Detailed property geology of the Silver Queen property. Owen Lake area, west-central British Columbia. Units are defined in Table 2-8-1.

underlying flows and sills. Rhyolite flows and tuffs and columnar jointed basalt flows, together more than 100 metres thick, cap the succession (the basalts may be significantly younger: MacIntyre, 1985).

A mid to Late Cretaceous age is assigned to the Kasalka Group volcanic rocks because they unconformably overlie sedimentary rocks containing latest Early Cretaceous (Albian) fauna (Duffel, 1959). Dacitic lapilli tuffs near the base of the group give an isotopic age of 108 to 107 ± 5 Ma by K-Ar on whole rock, and intrusions dated at 87 ± 4 to 83.8 ± 2.8 Ma cut the stratified units (MacIntyre, 1985).

Volcanic rocks of similar age and lithology are not widely known in west-central British Columbia, but possible correlatives *are rocks found in the Mount Cronin area northeast* of Smithers (MacIntyre and Desjardins, 1988). The correlative rocks near Mount Cronin were formerly mapped as Brian Boru formation by Tipper and Richards (1976), and correlated to Brian Boru rocks as defined by Sutherland-Brown (1960) in the Rocher Déboulé Range northwest of Smithers. In the Mount Cronin area, MacIntyre and Desjardins separate the Kasalka Group into lower and upper divisions. As in the Kasalka Range, the succession begins with a heterolithic, maroon basal conglomerate *with interbedded sandstone,* siltstone and mudstone. This is followed by thin-bedded tuffs and epiclastics, mafic flows, and pyroclastic rocks that include lapilli tuff and breccia, bedded lahar, and siliceous ash-flow tuff and breccia. The upper division comprises a thick section of poorly bedded volcanic breccia with angular clasts, grading upward to hornblende-feldspar crystal tuff and interbedded to overlying hornblende-feldspar-porphyritic andesite, most of which are flows but some intrusive stocks and sills may also be present.

In spite of very similar lithology, the Tip Top Hill volcanics of the Buck Creek basin in the Parrot Lake and Owen Lake area, and volcanic rocks hosting The Equity Silver deposit, cannot be correlated with the Kasalka Group on the basis of currently available isotopic dates.

GEOLOGY OF THE BUCK CREEK BASIN

The Buck Creek basin has been characterized as a resurgent caldera, with the important Equity Silver mine located within a window eroded into the central uplifted area (Church, 1985). The Silver Queen mine lies on the caldera rim or perimeter of this basin, which is roughly delineated by a series *of rhyolite outliers and semicircular alignment* of Upper Cretaceous and Eocene volcanic centres scattered between Francois Lake, Houston and Burns Lake (*see* Figure 59 of Church, 1985). A prominent lineament 30 kilometres long and trending east-northeasterly from the Silver Queen mine towards the central uplift hosting the Equity mine, appears to be a radial fracture coinciding with the eruptive axis of the Tip Top Hill (Kasalka Group) volcanics and a line of syenomonzonite stocks and feeder dikes to an assemblage of "moat volcanics" that include the Goosly Lake formation (Church, 1985). Block faulting is common in the basin, locally juxtaposing the various ages of volcanic rocks found within it.

In broad outline, a Mesozoic volcanic assemblage is overlain by a Tertiary volcanic succession. The oldest rocks exposed within the basin are at the Equity Silver and Silver Queen mines. The sequence at the Equity mine has been characterized by Church (1984) as Jurassic Hazelton Group rocks of the Telkwa formation overlain with angular unconformity by Lower Cretaceous Skeena Group sedimentary rocks. However, Wetherell *et al.* (1979) and Cyr *et al.* (1984) correlate the sequence hosting the Equity orebodies with the Upper Cretaceous Kasalka Group, and Wojdak and Sinclair (1984) list as possible correlatives the Lower Cretaceous Skeena Group, the Kasalka Group and the Brian Boru formation. The geology of the Equity mine area is obviously as yet imperfectly known.

Large areas of Upper Cretaceous rocks are exposed westwards *from the Equity mine to the Owen Lake area, where* they host the Silver Queen deposit (Church, 1984). These rocks, which have been dated at 77.1 ± 2.7 to 75.3 ± 2.0 Ma by K-Ar on whole rock (Church, 1973) are described by Church (1984) to consist of a lower, acid volcanic uni overlain by the Tip Top Hill formation andesites to dacites This subdivision is based on "rhyolitic volcanic rocks below the Tip Top Hill formation in the Owen Lake area in extensive drill holes in the vicinity of the Silver Queen mine" (Church 1973), which he considers to be "lateral equivalents of quartz porphyry intrusions exposed nearby on Okusyelda Hill" (Figure 2-8-2). Current mapping indicates that the lower volcanic unit exposed in the drill holes may in part be a strongly altered equivalent of the Tip Top Hill volcanics. The quartz porphyry of Okusyelda Hill could correlate with dacitic quartz porphyry sills, dikes and laccoliths common within the type Kasalka Group section in the Tahtsa Lake area. Late quartz feldspar porphyry dikes are also found at the Equity mine (Cyr *et al.*, 1984; Church, 1985), although these are dated at 50 Ma and thus belong to the younger Ootsa Lake Group.

The Upper Cretaceous rocks are overlain by the Eocene Ootsa Lake Group, which includes the Goosly Lake and Buck Creek formations of Church (1984). The Goosly Lake andesitic to trachyandesitic volcanic rocks are dated at 48.8 ± 1.8 Ma by K-Ar on whole rock, and this is supported by dates of 49.6 ± 3.0 to 50.2 ± 1.5 Ma for related sye*nomonzonite to gabbro stocks with distinctive bladed pla*gioclase crystals (Church, 1973) at Goosly and Parrot lakes The Buck Creek andesitic to dacitic volcanic rocks, which directly overlie the Goosly Lake formation, are dated at 48.1 ± 1.6 Ma by K-Ar on whole rock. These ages correlate with whole rock K-Ar ages of 55.6 ± 2.5 Ma for dacite immediately north of Ootsa Lake (Woodsworth, 1982) and 49.1 ± 1.7 Ma on biotite for Ootsa Lake Group rocks in the Whitesail Lake area immediately south of Tahtsa Lake (Diakow and Koyanagi, 1988).

Basalts of the upper part of the Buck Creek formation (Swans Lake member: Church, 1984) may correlate with the Endako Group of Eocene-Oligocene age. These rocks give whole rock K-Ar ages of 41.7 ± 1.5 to 31.3 ± 1.2 Ma on samples from the Whitesail Lake map area (Diakow and Koyanagi, 1988).

The youngest rocks in the Buck Creek basin are cappings of Miocene columnar olivine basalt, called the Poplar Buttes formation by Church (1984) and dated at 21.4 ± 1.1 Ma by K-Ar on whole rock (Church, 1973).

GEOLOGY OF THE STUDY AREA

The preliminary geology of the study area immediately surrounding the Silver Queen mine, as determined by fieldwork and petrological studies completed in 1989, is shown in Figure 2-8-2 (units are defined in Table 2-8-1). Relationships between the map units are shown diagrammatically in Figure 2-8-3. The succession is similar to that observed in the Kasalka Range and on Mount Cronin.

The rocks of the study area have been subdivided into five major units plus three dike types; Table 2-8-1 lists the map units defined to date. A basal reddish purple polymictic conglomerate (Unit 1) is overlain by fragmental rocks ranging from thick crystal tuff (Unit 2) to coarse lapilli tuff and breccia (Unit 3), and this is succeeded upwards by a thick feldspar-porphyritic andesite flow unit (Unit 4), intruded by microdiorite sills and other small intrusions (Unit 5). The stratified rocks form a gently northwest-dipping succcession, with the oldest rocks exposed near Riddeck Creek to the south and the youngest exposed in Emil Creek to the north (Figure 2-8-2). All the units are cut by dikes that can be divided into three groups: amygdaloidal dikes (Unit 6), bladed feldspar porphyry dikes (Unit 7), and diabase dikes (Unit 8). The succession is unconformably overlain by basaltic to possibly trachyandesitic volcanics that crop out in Riddeck Creek and farther south. These volcanics may be correlative with the Goosly Lake formation (Church, 1973).

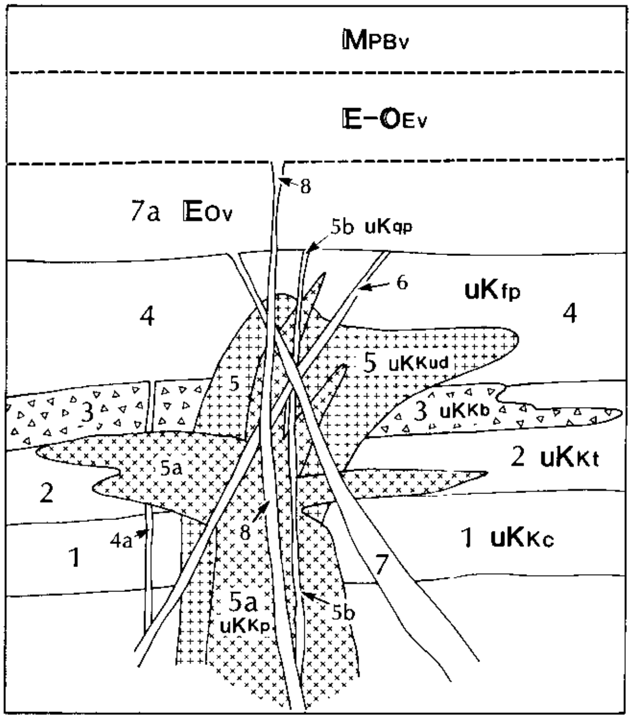

Figure 2-8-3. Schematic diagram of stratigraphic and intrusive relationships, Owen Lake area, west-central British Columbia. Units are defined in Table 2-8-1.

Mineralization on the property is mainly restricted to quartz-carbonate-barite-specularite veins, 1 to 2 metres thick, that contain disseminated to locally massive pyrite, sphalerite, galena, chalcopyrite, tennantite and argentian tetrahedrite. Locally, in chalcopyrite-rich samples, there is a diverse suite of Cu-Pb-Bi-Ag sulphosalts such as aikinite, matildite (in myrmekitic intergrowth with galena), pearcite-arsenpolybasite, and possibly schirmerite (berryite, guettardite and meneghinite have also been reported but not yet confirmed). Native gold with unusually low fineness of 510 to 620 (actually electrum) is present in minor amounts. The veins cut the amygdaloidal, fine-grained plagioclase-rich dikes (Unit 6), and are cut by the series of dikes with bladed plagioclase crystals (Unit 7). Both these dike types are possibly correlative with the Ootsa Lake Group Goosly Lake volcanics of Eocene (approximately 50 Ma) age. The bladed feldspar porphyry dikes cut the amygdaloidal dikes, and both

TABLE 2-8-1
TABLE OF FORMATIONS, OWEN LAKE AREA

Period	Epoch	Age (Ma)	Formation	Symbol	Unit	Lithology
TERTIARY	Miocene	21	Poplar Buttes	M_{PBv}		Olivine basalt
	Eocene-Oligocene	40-30	Endako Group	EO_{Ev}	8	Basalt, diabase dikes
	Eocene	56-	Ootsa Lake	E_{Ov}	7a	Trachyandesite, basalt
		47	Group		7	Bladed feldspar porphyry dikes
			— MINERALIZED VEINS —			
					6	Amygdular dikes
CRETACEOUS	(Late)		"Okusyelda"	uKqp	5b	Quartz-eye rhyolite dikes, stock
			Tip Top Hill volcanics	uKKp	5a	Intrusive porphyry sills, stocks
		75		uKKud	5	"Mine Hill" microdiorite
		77			4a	Feldspar biotite porphyry dikes
				uKKfp	4	"Tip Top Hill" feldspar porphyry (voluminous porphyritic andesite)
				uKKb	3	Medium to coarse tuff-breccia
				uKKt	2	Crystal tuff, local lapilli tuff
					2a	Fine ash tuff
				uKKc	1	Polymictic basal conglomerate, sandstone and shale interbeds

are cut by the diabase dikes that may correlate with Endako Group volcanism of Eocene-Oligocene (approximately 40 to 30 Ma) age.

TIP TOP HILL VOLCANICS

Units 1 to 5, as defined in the map area, fall within the Tip Top Hill formation (Church, 1984), but correspond closely with the units defined in Kasalka Group rocks elsewhere. The units are described in detail below, to facilitate comparison with other, possibly correlative rocks.

BASAL POLYMICTIC CONGLOMERATE (UNIT 1)

The basal member of the succession is a reddish to purple, heterolithic, poorly sorted pebble conglomerate that contains rounded to subangular small white quartz and grey-brown to less commonly maroon tuff and porphyry clasts. Local interbeds of purplish sandstone with graded bedding are found within the unit, as are rare black shaly partings. The matrix is composed of fine sand, cemented by quartz, sericite and iron oxides. The best exposure is found in a roadcut at the southern tip of Owen Lake, where the unit is about 10 metres thick and dips 25° to the northwest. The base is not exposed and the unit is in presumed fault contact with the younger volcanic rocks of the Ootsa Lake Group (Goosly Lake formation; Unit 7) exposed at higher elevations farther south along the road. In drill holes farther north, near the centre of the property, the upper contact of the conglomerate with overlying porphyry is sharp and appears conformable, but the porphyry may be an intrusion rather than a flow.

CRYSTAL-LITHIC TUFF (UNIT 2)

In outcrop, the next major unit is a sequence of mainly fragmental rocks that are mostly fine crystal tuffs with thin interbeds of laminated tuff, ash tuff, lapilli tuff, and less abundant breccia. The unit may be as much as 100 metres thick. The most widespread rock type is a massive, grey to white, strongly quartz-sericite-pyrite altered, fine crystal tuff that grades imperceptibly into a porphyry of similar appearance and composition; the latter may be partly flow, intrusive sill, or even a welded tuff. Only the presence of broken phenocrysts and rare interbeds of laminated or coarsely fragmental material suggest that the bulk of this unit is tuffaceous. In thin section, the rock is seen to be made up of 1 to 2-millimetre broken, altered plagioclase relics and 0.5-millimetre anhedral quartz grains (that may be partly to entirely secondary) in a fine matrix of secondary sericite, carbonate, pyrite and quartz. Drill-core exposures show that the basal contact of Unit 2 with the underlying conglomerate is commonly occupied by the porphyry rather than the tuff. The best exposures of Unit 2 are in the area of Cole Creek and the Chisholm vein (Figure 2-8-2), where thin (10 centimetre) interbedded laminated tuff bands occur, many with variable dips to near-vertical, although coarser lapilli tuff lenses, up to 1 metre thick, display gentle northerly dips. In drill core, sections of laminated tuffs with faint but discernible layering on a centimetre scale, may be up to 10 metres thick; angles with the core axis suggest a gentle dip for the banding.

Outcrops on the northeast side of the George Lake fault (Figure 2-8-2) have rare interbeds of a very fine, uniform "ash tuff" that are up to several metres thick (Unit 2a). Typically they are dark grey to medium grey-green and have a siliceous appearance. Locally they contain angular fragments of either mixed origins (heterolithic clasts) or of larger blocks that are only barely distinguishable from the matrix (monolithic clasts).

The composition of Unit 2 is not known from chemica analyses. Although it looks felsic (*cf.* Church, 1973) the highly altered nature may give a misleading impression of its original character; it may have been originally andesitic as are the overlying units.

COARSE FRAGMENTAL UNIT (UNIT 3)

A distinctive coarse fragmental unit overlies or in some places is interlayered with the upper part of Unit 2. It is composed of blocks and bombs(?) (*cf.* MacIntyre, 1985) of feldspar-porphyritic rock similar in appearance to both the underlying porphyry and the overlying porphyritic andesite. The clasts are mostly angular to subangular and about 2 to 5 centimetres in diameter, but some are much larger (up to 0.5 metre); the matrix makes up a widely variable percentage of the rock, from almost zero to 90 per cent, so that in places the rock has the appearance of an intrusive breccia with little or no rotation of fragments. In other places the fragments are clearly unrelated and "accidental" or unrelated clasts of chert or fine tuff are common, although still volumetrically minor; this has the appearance of a lahar.

In outcrop near the Cole veins (Figure 2-8-2), this breccia or lahar(?) unit forms discontinuous lenses generally less than 10 metres thick, with a suggestion of gentle northerly dips. The lenses appear to be conformable with the underlying or enclosing tuffs. In drill core, two distinctly different modes of occurrence are noted for this unit: in one, it appears to be conformably overlain by Unit 4 porphyritic andesites (the total thickness of the breccia unit is up to 30 metres); in the other, it appears to have subvertical contacts, implying it is an intrusive breccia. Good examples of the latter distribution are found in the Cole Lake area, the Camp vein system and around the southern end of Number 3 vein. There is thus a rough correlation between the subvertical breccia bodies and mineralized areas, just as there is between the microdiorite and mineralized areas (*see* below).

In thin section, the clasts of the breccia are seen to be composed of strongly altered feldspar porphyry, fine tuff and quartz or quartzofeldspathic rocks, enclosed in a fine tuffaceous matrix. Alteration in the mine area is usually carbonate-sericite-quartz-pyrite, and is intense enough to largely obscure the original texture.

FELDSPAR PORPHYRY (UNIT 4)

The fragmental rocks appear to be conformably overlain by a thick, massive unit of porphyritic andesite that outcrops over much of Mine Hill and is best developed north of Wrinch Creek (Figure 2-8-2). This unit is equivalent to the Tip Top Hill volcanics of Church (1970), although in most places on the property the porphyry is coarser and contains sparser phenocrysts than the exposures on Tip Top Hill. In exposures in Wrinch Creek canyon, a distinct flow lamination is developed by trachytic alignment of phenocrysts, best seen on weathered surfaces. This suggests that these porphyries are mostly flows, with gentle northerly to northwesterly dips. However, some of the coarsest material probably forms intrusive sills and stocks [*cf.* the type sections of MacIntyre and Desjardins (1988) and MacIntyre (1985)] and in many places the porphyry grades into intrusive microdiorite (Unit 5).

Parts of this unit, particularly in Emil Creek, west of Emil Lake, and on Tip Top Hill itself (Figure 2-8-2), may actually be crystal tuffs. In these exposures, the feldspar phenocrysts are smaller, much more crowded and in places broken, and rare lithic fragments are visible.

This unit has been dated at 77.1 ± 2.7 Ma by K-Ar on whole rock (Church, 1973). Rhyolite from Tsalit Mountain on the west side of Owen Creek valley, 10 kilometres northwest of the Silver Queen mine, gives a very similar isotopic date of 77.8 ± 3.0 Ma, also by K-Ar on whole rock (Church, 1973). Church correlated this rhyolite with the "Okusyelda" quartz porphyry (Unit 5b of this study, thought to be slightly younger than Unit 5 microdiorite) found in Emil Creek and on Okusyelda Hill (Figure 2-8-2).

In thin section, the feldspar porphyry is seen to contain abundant 2 to 3-millimetre euhedral crystals of andesine. Oscillatory zoning is present, but with little overall change in composition within a given specimen, from An_{45} to An_{35}. Mafic minerals include roughly equal amounts (about 5% each) of 1 to 2-millimetre clinopyroxene and hornblende, though both are strongly altered to carbonate, hydrobiotite and apatite. Euhedral 1 to 2-millimetre biotite phenocrysts are generally less altered. The groundmass is an aphanitic mesh of intergrown feldspar with minor opaque grains; primary magnetite is abundant in the fresh specimens.

The average composition of the feldspar porphyry is between andesite and dacite, as indicated by arc-fusion determinations and chemical analyses (Church, 1973). Apart from a lower potash content, the chemistry of the feldspar porphyry is remarkably similar to that of the microdiorite (Unit 5).

BIOTITE FELDSPAR PORPHYRY DIKES (UNIT 4A)

Rare, thin (1 metre or less) dikes with similar composition and appearance to the flows of Unit 4 probably represent feeders to overlying flows. They are distinguished by prominent scattered books of black biotite up to 3 millimetres across, as well as abundant 1 to 2-millimetre plagioclase phenocrysts. These dikes have only been recognized near the north end of Cole Lake and on the highway at the north end of Owen Lake (Figure 2-8-2), but they may be more extensive (they are difficult to recognize because of their similarity to Unit 4).

MICRODIORITE (UNIT 5)

Microdiorite forms subvolcanic sills, dikes, and possibly small irregular stocks on the Silver Queen mine property. These intrusions are centrally located in the two main mineralized areas, the No. 3 Vein and Cole vein areas (Figure 2-8-2). Contacts with the feldspar porphyry are indistinct or gradational over about 1 metre, but dikes are seen cutting older units. The gradational contacts probably caused earlier workers such as Marsden (1985) to propose two divisions of microdiorite, one with quartz and biotite and one without. With further work, it can now be seen that the biotite-bearing phase belongs to the feldspar porphyry (Unit 4).

Typically the microdiorite is a medium to fine-grained, dark greenish grey equigranular to porphyritic rock characterized by small (1 millimetre, but locally glomeratic to 4 millimetres) plagioclase phenocrysts and 0.5-millimetre mafic relics in a phaneritic pink feldspathic groundmass. Primary magnetite is found in the less-altered specimens. It is distinguished in outcrop by its relatively fine-grained, even-weathering texture, lacking flow structure compared to the feldspar porphyry. Because of the gradational relationship to the feldspar porphyry, mineralogical distinction is not reliable. In thin section, the plagioclase is the same as in the feldspar porphyry (oscillatory zoned andesine, An_{45-30}), and euhedral clinopyroxene phenocrysts, partly altered to carbonate, are the most abundant mafic. Apparent hornblende relics are completely altered to chlorite. No biotite is seen, but rare scattered quartz phenocrysts, displaying late-stage overgrowths of quartz, are observable ranging up to 1 millimetre in size (these are not visible in hand specimen). The groundmass is composed of fine (0.1 millimetre) quartz, plagioclase and potassium feldspar.

Chemically, the microdiorite is the same as the feldspar porphyry (Church, 1970, 1971). This relationship is the same as that observed by MacIntyre (1985) in the Kasalka Range near Tahtsa Lake. The chemistry compares closely to that of an average augite andesite (Daly, 1933, cited in Church, 1970) or quartz-bearing latite andesites from Chile (Seigers *et al.*, 1969, cited in MacIntyre, 1985). Because of the relatively high K_2O content, both the microdiorite and the feldspar porphyry classify as latite-andesites or dacites by the scheme of Streckeisen (1967; *cf.* MacIntyre, 1985).

The microdiorite has been dated isotopically at 75.3 ± 2.0 Ma by K-Ar on whole rock (Church, 1973). The two main outcrop areas of the microdiorite correlate with the two main areas of mineralization, but this relationship may be only coincidental.

PORPHYRY (UNIT 5A)

Large bodies of a coarsely feldspar-porphyritic rock, up to 1000 metres across, crop out in the vicinity of Cole Creek and are also found in drill core from the south end of the Number 3 vein system, where the porphyry body usually occurs between Units 1 and 3. The rock is composed of roughly 50 per cent variably saussuritized or sericitized plagioclase phenocrysts of up to 5 millimetres in diameter and 10 to 20 per cent smaller altered mafic relics in a fine feldspathic groundmass. The porphyry is distinguished from the feldspar porphyry, Unit 4, by its coarser texture and by the absence of flow textures. It probably represents subvolcanic or high-level intrusive bodies that were emplaced below or postdate the extrusive feldspar porphyry, but are related to the same magmatic event that produced it. Such subvolcanic intrusive bodies, with identical mineralogy to the extrusive porphyritic andesites, have also been noted in the Kasalka Group near Tahtsa Lake (MacIntyre, 1985).

QUARTZ FELDSPAR PORPHYRY (UNIT 5B)

Quartz feldspar porphyry that appears to be part of a subvolcanic intrusive stock crops out along Emil Creek and on Okusyelda Hill to the north of the creek. This unit was formerly called "Okusyelda" dacite (rhyolite) by Church (1970). Although its contact relationships are uncertain, it appears to intrude Unit 4 (Tip Top Hill volcanics). Church (1984) correlates the quartz porphyry intrusions on Okusyelda Hill with acid volcanic rocks in the Tchesinkut Lake and Bulkley Lake areas, and possibly with the Tsalit Mountain rhyolite of 77.8 Ma (*see* under Unit 4). However, in the Kasalka Range, MacIntyre (1985) found sills and dikes of quartz-porphyritic dacite and rhyolitic quartz-eye porphyry, commonly associated with mineralization, that cut stocks dated at approximately 76 Ma (Carter, 1981). Hence, the quartz porphyry is considered to be younger than the microdiorite/feldspar porphyry in the Owen Lake area. It is cut by thick calcite veins and quartz-sericite-pyrite alteration on the extension of the George Lake vein (Figure 2-8-2) and so is probably pre-mineral.

Thin sections show the quartz porphyry consists of 10 to 15 per cent 2-millimetre quartz phenocrysts and slightly smaller euhedral andesine plagioclase crystals, plus smaller relic mafic grains, in a microgranular groundmass of roughly equal amounts of quartz, plagioclase and potash feldspar. Quartz, and to a lesser extent plagioclase, also occur as angular fragments or shards.

AMYGDALOIDAL DIKES (UNIT 6)

Units 1 to 5 are cut by a series of variably amygdaloidal dikes that are concentrated in the two main areas of mineralization (No. 3 vein and Cole vein areas). They generally trend northwesterly, parallel to the mineralized veins, but north, east and northeast-trending examples are known. Dips are either subvertical to steep, or else gentle (as low as 20°). These dikes are irregular and anastamosing in some parts of the property, for example between the Camp and Switchback vein systems. Strongly altered examples are commonly found adjacent to and parallel to veins; elsewhere veins cut through these dikes. These dikes have been referred to previously as "pulaskite" at both the Silver Queen and Equity deposits, but this is a highly inappropriate term, implying an alkali-rich mineralogy including soda orthoclase, alkali pyroxene or amphibole and feldspathoids, and it is avoided in this study.

In underground exposures the dikes range from dark grey-green where fresh, to pale green or creamy buff where strongly altered; they are purplish in weathered surface outcrops. They are typically fine grained and are characterized by amygdules filled by calcite or, less commonly, iron oxides, particularly at their chilled margins (dikes less than 2 metres wide may lack the amygdules). Flow orientations are generally parallel to the walls, and provide an indication of attitude in surface outcrops, but in the larger dikes (up to 10 metres thick) the flow orientations are random.

In thin section, the most striking feature of these dikes is the abundance of fine trachytic-textured feldspar microlites that average about 0.25 millimetre long. Alteration to carbonate and sericite is extensive, but the texture is generally preserved and links these dikes to the trachytic-textured dikes of Unit 7, which have similarities to Goosly Lake volcanics (*see* below).

BLADED FELDSPAR PORPHYRY DIKES (UNIT 7)

Trachytic-textured porphyry dikes, 1 to 5 metres wide and characterized by coarse (up to 1 centimetre long) bladed plagioclase phenocrysts, cut and slightly offset the amygdaloidal dikes. The complete lack of alteration in the bladed feldspar porphyry dikes, and the fact that they distinctly crosscut mineralized veins (*e.g.*, the Bear Vein, Cole Lake area: Figure 2-8-2), indicates that they postdate mineralization. Their spatial distribution is similar to that of the amygdaloidal dikes, with concentrations in the two main mineralized areas; orientations are also similar, with subvertical dips.

The similarity of these post-mineral bladed feldspar porphyries to the Goosly and Parrot Lake syenomonzonite stocks, and bladed feldspar andesite dikes at Equity dated at 50.7 ± 1.8 Ma by K-Ar on whole rock, suggest that they are probably of the same age. The pre-mineral amygdaloidal dikes, although considerably finer grained, also have similar characteristics (trachytic-textured feldspar), but their age is not yet established.

In thin section, the bladed feldspar porphyry dikes are seen to be composed of large (4 to 10 millimetres) plagioclase phenocrysts and rare to locally abundant clinopyroxene crystals up to 5 millimetre across, set in a dark purplish groundmass of feathery, interlocking plagioclase microlites with interstitial quartz, alkali feldspar, opaques and skeletal rutile(?). The plagioclase forms strongly zoned, oscillatory crystals that range from cores of andesine (An_{50}) to rims of oligoclase (An_{15}). The pyroxene has a strong green colour and is probably iron-rich.

If the dikes of Unit 7 are feeders for the Goosly Lake volcanics or related to the Goosly and Parrot Lake syenomonzonite as postulated, then they probably have similar trachyandesite compositions (*see* analyses 3, 4 and 6 of Church, 1971).

DIABASE DIKES (UNIT 8)

Black fine-grained dikes of probable basaltic composition cut all other units on the property. They are much more limited in distribution than the older dikes, with subvertica dips and northwest or east-west strikes. However, they stil seem to be concentrated in areas of veining, and are subparallel to the veins: for example, where a vein strikes east as in Emil Creek (Figure 2-8-2), a diabase dike has the same orientation.

It is likely that these dikes were feeders to a younger volcanic group such as the Endako Group of Eocene-Oligocene age (40 to 30 Ma), but the possibility cannot be ruled out that they are related to the Buck Creek volcanic uni (48 Ma). There is little possibility that they are related to the Miocene Poplar Buttes volcanic rocks (21 Ma), as they lack olivine. Thin sections show they are composed of diabasic-textured plagioclase in clinopyroxene, with accessory opaques.

STRUCTURE

The structure of the Silver Queen mine area is dominated by a gently north to northwest-dipping homocline. There is no folding apparent at the scale mapped; the sequence presumably has been tilted 20° to 30° from the horizontal by block faulting.

Two prominent sets of faults displace this homoclinal sequence, cutting it into a series of fault panels: a northwest-trending set and a northeast-trending set. The former predates or is contemporaneous with mineralization, whereas the latter is mainly post-mineral. Most of the mineralized veins and the dikes follow the northwest-trending faults, whereas veins are cut off and displaced by the northeast-trending set. The northwest-trending faults dip 60° to 80° to the northeast, and the northeast-trending set appears to be subvertical.

The sense of motion on the northwest-trending faults is such that each successive panel to the east is upthrown, leading to successively deeper levels of exposure to the east. Thus, in the panel between the George Lake and the Emil Lake faults (Figure 2-8-2), there is considerably more of the lower fragmental rocks (Units 2 and 3) exposed than in the next panel to the west, between the Owen Lake and the George Lake faults. There does not seem to be much displacement across the No. 3 vein fault; slickensides seen underground on this structure suggest a reverse sense of movement.

The sense of motion on the the northeast-trending faults appears to be south side down, with a small component of sinistral shear. Offsets of No. 1 and 2 veins across fault along Wrinch Creek (Figure 2-8-2) suggest a few metres of left-lateral displacement, but the displacement of an amygdaloidal dike near the portals of the 2880 level suggests the south side must have dropped as well. The boundaries of this fault zone, and its dip, are not well constrained; in outcrops in Wrinch Creek, it appears as a vaguely defined zone up to 10 metres wide, with segments that have possible shallow to moderate dips to the north. The Cole Creek fault is not well exposed at surface; a splay from it may cause the change in orientation of the No. 3 vein to the Ruby vein (Figure 2-8-2). A considerable left-lateral offset of perhaps as much as 200 metres is suggested by drill-hole intersections of the NG3 vein, which may be a faulted extension of the No. 3 vein south of the Cole Creek fault. Underground, this fault is exposed at the southernmost extent of drifting as a gouge zone 1 to 2 metres thick (Plate 2-8-1). Other examples of minor northeast-trending faults are seen underground.

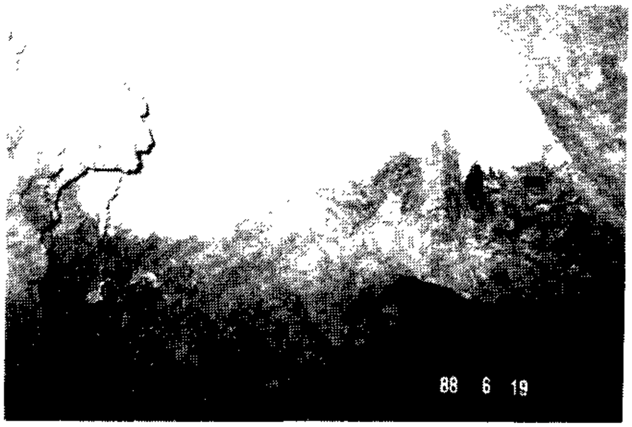

Plate 2-8-1. Late northeast-trending fault cutting the vein (here trending along the adit). Two-metre gouge zone (top of photo), slickensided face (bottom).

DISCUSSION

The sequence of rocks exposed in the Silver Queen mine area, mapped as Tip Top Hill formation (Church, 1984) is petrographically and stratigraphically similar to the Kasalka Group as defined in the Tahtsa Lake area by MacIntyre (1985) and the Mount Cronin area by MacIntyre and Desjardins (1988). The section in all three areas, comprises a sequence from a basal, reddish purple heterolithic conglomerate, upwards through a sequence of fragmental volcanic rocks, to a widespread, partly intrusive porphyritic andesite, all intruded by a distinctive microdiorite. It is similar to type sections of the Kasalka Group.

Potassium-argon isotopic dating suggests that the rocks in the Silver Queen mine area are of Late Cretaceous age; the porphyritic andesite volcanics are about 77 Ma, and are intruded by microdiorite of 75 Ma age (Church, 1973). This is younger than the Kasalka Group rocks in the type section near Tahtsa Lake, which give dates of 108 to 107 Ma near the base, and are cut by intrusions dated at 87 to 84 Ma (MacIntyre, 1985). These dates actually straddle the Early to Late Cretaceous boundary (Harland *et al.*, 1989). Thus, in spite of the similarities in lithology between the Silver Queen mine area and the Kasalka Group rocks elsewhere, a correlation is not supported by the available isotopic dating. Possibly the magmatic front associated with this Late Cretaceous volcanic activity took longer to arrive further inland [65 kilometres in 30 Ma gives a rate of advance of 0.22 centimetres per year, comparable to the rate of 0.25 centimetres annually suggested by Godwin (1975); *cf.* Armstrong (1988) and Leitch (1989)].

Mineralization in epithermal veins at the Silver Queen mine occurred between the time of deposition of the Late Cretaceous Tip Top Hill volcanics and intrusion of Early Tertiary dikes. The latter may correlate to the Goosly Lake trachyandesite volcanics (49 Ma) of the Ootsa Lake Group and syenomonzonite stocks (50 Ma) found at Equity Silver mine and Parrot Lakes (Church, 1973). The veins are also cut by diabase dikes that may correlate with the Buck Creek volcanics, dated at 48 Ma (Church, 1973), or to Endako Group volcanics dated at 40 to 30 Ma (Diakow and Koyanagi, 1988). Additional radiometric dating is in progress, including U-Pb on zircon from the quartz-eye rhyolite and K-Ar (whole rock and biotite separates) from other major units.

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