Tom Schroeter

The Sulphurets Gold zone, northwestern British Columbia

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Drill-indicated resources (Placer Dome, SW-June 7/00) 54.8 Mtonnes @ 1.02 g/t Au (0.50 g/t Au cut-off) [est. 1.3 Moz Au]

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ABSTRACT

The Sulphurets Gold zone is located on Mitchell-Sulphurets Ridge near the headwaters of Sulphurets Creek 65 km north of Stewart, British Columbia. The zone lies within a cluster of porphyry and transitional copper and/or gold prospects that are closely associated with a distinct suite of Early Jurassic (Texas Creek) porphyritic and felsic intrusive rocks. These rocks commonly intrude their own volcanic piles and, by inference, are genetically related to the spatially associated base and/or precious metal mineralization.

Disseminated copper-gold mineralization in the Sulphurets Gold zone is centred about a hydrothermal breccia (Breccia Gold zone) and dike complex (Raewyn Copper-Gold zone) representing the higher levels of a monzonite-related copper-gold porphyry system. The zone trends northeasterly and lies in strongly altered and fractured volcanic and immature sedimentary rocks of the Hazelton Group, below the Sulphurets Thrust Fault. There is evidence to suggest that the Sulphurets Gold zone represents one or more porphyry copper-gold system(s) that have been structurally disrupted and transposed by southeast-vergent thrust faulting. Copper and gold mineralization in the Sulphurets Gold zone is concentrated within a K-feldspar alteration halo centred about intensely altered hydrothermal breccias and monzonite dikes. Features of these rocks have been largely overprinted by later silicification (including siliceous hydrothermal pipes) in the Breccia Gold zone and strong biotite, silica and local chlorite-albite alteration in the Raewyn Copper-Gold zone. Both zones are enveloped by a broad halo of phyllic-quartz, sericite, pyrite alteration along the length of the Raewyn structural panel. Alteration overprinting in proximal areas was accompanied by significant local remobilization of copper and gold. Late faulting within the Raewyn panel was probably associated with regional scale Cretaceous compression and has further complicated relationships.

The Sulphurets Gold zone contains two distinct styles of gold-copper mineralization which are central to a complex series of overlapping hydrothermal alteration zones. The Breccia Gold zone contains gold in the 2.0 g/t to 4.0 g/t range, minor copper and, possibly, an association between gold and coarse pyrite. The Raewyn Copper-Gold zone has a significant copper content as chalcopyrite with closely associated gold and local molybdenum mineralization. Values in the range of 0.30% Cu to 0.80% Cu and 0.4 g/t Au to 1.0 g/t Au are common.

Placer Dome Incorporated conducted the first detailed diamond drill program on the Sulphurets Gold zone in 1992. Previous work was by Granduc Mines Limited (1960s and 1970s), Esso Minerals Canada Limited (early 1980s) and Newhawk Gold Mines Limited (1991). The exploration work completed to date can be regarded as preliminary. Mineralization remains largely open along strike and to depth.

Introduction

The Sulphurets Gold zone is located in the Sulphurets district of northwestern British Columbia. Extensive hydrothermal alteration zones and associated gossans are centred about Lower Jurassic quartz monzonite, syenite, diorite and monzodiorite. These "Mitchell Intrusions" are developed over an eight square kilometre area in this district.

This paper describes the geology and mineralization of the Breccia Gold and the Raewyn Copper-Gold zones, which comprise the Sulphurets Gold zone. Observations and interpretations presented herein are mostly derived from Placer Dome Inc.'s 1992 exploration program on the Sulphside property. Results are preliminary; geological and paragenetic models will no doubt be modified with additional exploration.

The Sulphurets Gold zone and encompassing Sulphide property are presently held by Placer Dome Canada Limited. They are located in the Iskut district of northwestern British Columbia, 65 km north of Stewart at latitude 56°30′ north, longitude 130°15′ west (Fig.1). The Sulphurets Gold zone is situated on the south-facing upper reaches of the Mitchell-Sulphurets Ridge; the Kerr porphyry copper-gold deposit lies across the Sulphurets valley 3 km to the south.

Access to the property is by helicopter from Stewart or from various points along the Stewart-Cassiar Highway, including Bob Quinn, located 53 km to the north, and Bell II Crossing, located 42 km to the northeast. In the summer months access is also available from the Tide Lake airstrip situated at the northern terminus of the Granduc road, some 28 km to the southeast.

Terrain in the area is extremely rugged. Deeply incised, glacier-occupied "U" shaped valleys with open cliffs or forested slopes, alpine tundra, broad icefields and nunatacs are common. Elevations range from 670 m at Sulphurets Lake to 1906 m on top of Mitchell-Sulphurets Ridge. Elevation at treeline is approximately 1450 m.

History

The exploration history for the Mitchell-Sulphurets Ridge area is summarized in Table 1. Difficult access into this rugged region hampered exploration until the 1960s when work by Granduc Mines Ltd. resulted in discovery of a number of areas of significant copper-gold mineralization including the Sulphurets Gold zone. Esso Minerals Canada Ltd. conducted a large program in the Sulphurets area during the early 1980s. The main targets were low-grade copper-gold porphyry and high-grade precious metal vein deposits. Significant copper and gold values were returned from six holes testing the Sulphurets Gold zone. In 1991, Newhawk Gold Mines Ltd. drilled five widely-spaced holes north and northeast of the area explored by Esso. Porphyry-style copper-gold mineralization was encountered; hole SG 91-389 intersected a 95.6 m zone averaging 0.53% Cu and 0.45 g/t Au.

Placer Dome Inc. purchased the Sulphside property from Newhawk early in 1992. Placer Dome's exploration program during the summer of 1992 concentrated on evaluating the bulk tonnage potential of porphyry-style mineralization in the Sulphurets Gold zone, and consisted of 5577 m of NQ diamond drilling in

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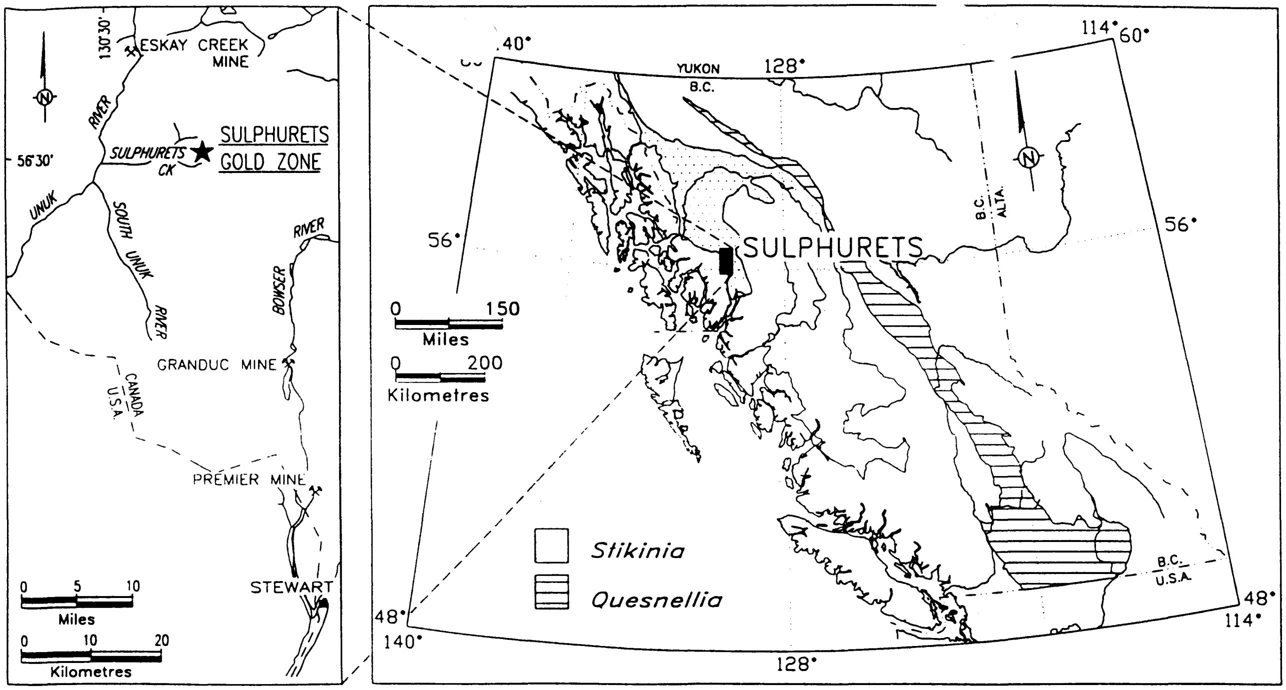

FIGURE 1. Location of the Sulphurets district and the Sulphurets Gold zone.

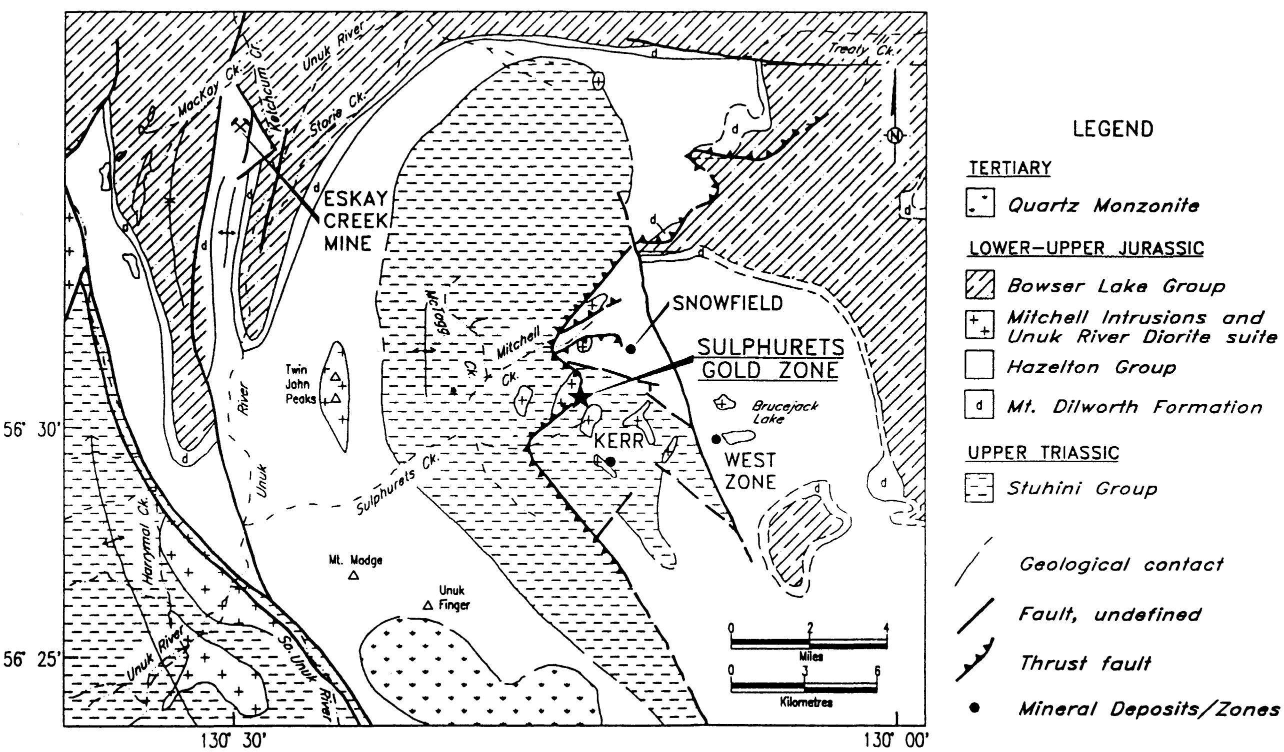

FIGURE 2. Regional geology for the Sulphurets district modified from Kirkham and Margolis (1995).

23 holes over a 1 km strike length. Detailed geological mapping and sampling were also conducted over the drilled area. Petrographic and limited lithogeochemical studies were completed later in the year on suites of representative samples.

Regional Geology

The Sulphurets district is located near the western edge of the middle Jurassic to Cretaceous age Bowser Basin within the Stikine terrane. The district is centred over the breached core of the northerly plunging McTagg anticlinorium which exposes upper Triassic Stuhini Group volcanic and sedimentary rocks that are overlain by lower Jurassic Hazelton Group rocks (Fig. 2).

The Hazelton Group is inferred to represent a volcano-sedimentary island arc and back-arc complex. Principal lithologies range from submarine sedimentary rocks, mafic to felsic volcanic and volcaniclastic rocks and subaerial intermediate to felsic volcanic rocks (Macdonald et al., 1993). These are intruded by a suite of porphyritic early Jurassic rocks, including alkali feldspar granite, quartz monzonite, syenite and granodiorite. In the Sulphurets district, these have been collectively referred to by Kirkham (1963) as the Mitchell Intrusions. Alldrick et al. (1987) and Anderson (1993)

TABLE 1. Exploration h[illegible] of Mitchell-Sulphurets Ridge

Period	Operator	Work performed
1880s 1980s	?	Placer gold reported in Sulphurets Creek
1935	Bruce & Jack Johnstone	Lode copper discovered on Sulphurets Ridge (Main Copper zone)
1950s	?	Lode gold and silver discovered near Brucejack Lake
1960	Granduc Mines Ltd.	Staking, reconnaissance airborne and ground geophysics, geological mapping; resulted in the discovery of the Sulphurets Gold zone and Iron Cap
1961-1968	Granduc Mines Ltd. (Newmont)	Detailed mapping, airborne magnetics, geochemical orientation survey, prospecting, etc. Drilling of 32 packsack holes (224.9 m) on 4 copper showings, one hole (308.5 m) on Main Copper, 4 holes (493.25 m) on Sulphurets Gold zone and 1 hole (214.3 m) on the Pack Sack showing
1971-1976	Granduc Mines Ltd.	Property scale lithogeochemical sampling, reconnaissance work, petrographic work, trenching
1980-1981	Esso Minerals Canada	Optioned property and conducted extensive regional and detailed geological mapping, geochemical sampling and trenching. Diamond drilling included 6 holes (968.8 m) on the Canyon zone, 6 holes (1100.6 m) on the Sulphurets Gold zone, 2 holes (205.8 m) on the Sulphurets Lake Gold zone, and numerous holes near Brucejack Lake
1986-1990	Geological Survey of Canada	Conducted lithogeochemical survey over Sulphurets area (1000+samples)
1991	Newhawk Gold Mines Ltd.	Optioned ground and carried out mapping, prospecting sampling and diamond drilling of 5 holes (1162.1 m) on the Sulphurets Gold zone, 2 holes (114.2 m) on Main Copper, 3 holes (498.5 m) on Mitchell Gold zone and 1 hole (148.5 m) on the Alder zone. Newhawk also commissioned an airborne mag and radiometric survey of the entire area.
1992	Placer Dome Inc.	Purchased Sulphside property and diamond drilled 5577 m in 23 holes on the Sulphurets Gold zone

refer to the 195 Ma to 189 Ma intrusions as the Texas Creek Plutonic Suite. These rocks commonly intrude their own volcanic piles and are, by inference, genetically related to spatially-associated base metal and precious metal mineralization.

Northwest-directed compression in the Iskut area during the Cretaceous resulted in large-scale fold structures such as the McTagg anticlinorium and temporally- and kinematically-related thrust faults, mesoscopic folds and foliation (Macdonald et al., 1993). References have been made to a possible Early Jurassic deformation event (Anderson and Thorkelson, 1990) which, if present, could coincide with emplacement of the Texas Creek intrusions. The regional structure is further complicated by local north-south and east-west trending zones of steeply dipping flattening fabrics, as well as numerous late brittle faults with minor throw (Henderson et al., 1992).

The Sulphurets District

The geology of the Sulphurets district is illustrated in Figure 3. The copper and copper-gold zones/deposits in the district are described below. The number and distribution of occurrences indicates the magnitude of the mineralizing system(s) and the propensity of bulk t[illegible] [illegible]pper-gold exploration targets in this area.

The Kerr [illegible]osit is the largest and most advanced (in terms of exploration) porphyry copper-gold prospect in the district. A geological resource of 135 million tonnes grading 0.76% Cu and 0.34 g/t Au has been defined about a series of highly altered potassic monzonite porphyritic intrusions in a broad pyritic deformation zone (Ditson et al., this volume).

Newhawk Gold Mines Ltd.'s Snowfield deposit, located 3 km northeast of the Sulphurets Gold zone, has been described as a porphyry gold deposit (Macdonald et al., 1993) or an adularia-sericite epithermal gold deposit (Margolis, 1993). It contains a drill-indicated resource of 6.3 million tonnes averaging 2.57 g/t Au (Vancouver Stockwatch; February 6, 1992).

The Mitchell Gold zone, situated at the toe of Mitchell Glacier, is a deformed copper- and gold-bearing quartz stockwork. This occurrence is located peripheral to a chloro-potassic core area and may be related to a "Mitchell type" intrusion at depth (Margolis, 1993). Mineralization is defined by a broad 1200 m by 300 m lithogeochemical anomaly averaging 0.66 g/t Au and 0.10% Cu. Preliminary diamond drilling of the Mitchell Gold zone by Newhawk Gold Mines in 1991 returned an intersection averaging 0.26% Cu and 0.82 g/t Au over 128.5 m (S91-395). Additional diamond drilling is warranted on this prospect.

The Iron Cap showing, located 3.5 km north of Snowfield, consists of three vein zones 1 m to 3 m wide, of auriferous, massive pyrite within a broad potassic alteration zone. Limited drilling of these veins by Esso Minerals in 1980 met with little success. However, step-out hole S80-16 penetrated nearly 300 m of potassic alteration about a buried syenite intrusion, averaging 0.2% Cu over the entire interval.

Five significant intrusion-related copper, copper-gold and gold zones occur in proximity to the surface trace of the Sulphurets Thrust Fault, over a distance of 3 km from Sulphurets Lake at the valley bottom to the crest of Sulphurets Ridge. The Main Copper and Packsack No. 3 zones are porphyry copper occurrences situated along the contact of a megacrystic monzonite stock and emanating dikes which intrude chloro-potassically altered trachyandesite volcanic rocks in the hangingwall of the Sulphurets Thrust Fault. Both prospects constitute significant porphyry copper exploration targets.

The Sulphurets Lake Gold zone, Canyon zone and Sulphurets Gold zone all occur in highly altered rocks in the footwall of the Sulphurets Thrust Fault along the south face of Sulphurets Ridge. Limited work by Esso Minerals (1980-1981) suggests low-grade gold mineralization (1.0 g/t to 7.0 g/t Au) is intimately associated with coarse pyrite in fragmental volcanic rocks and intrusion breccias in the Sulphurets Lake Gold zone and Canyon zones, respectively.

The Sulphurets Gold zone consists of two discrete zones of copper-gold and gold mineralization. The Breccia Gold zone is an intrusion or hydrothermal breccia zone containing 2.0 g/t to 4.0 g/t Au, minor copper and possibly a coarse pyrite-gold association. The Raewyn Copper-Gold zone has chalcopyrite and gold mineralization associated with biotite (potassic) alteration surrounding highly altered quartz monzonite dikes within a structural panel. Copper values in the 0.30% to 0.80% range and gold values of 0.40 g/t to 1.0 g/t are common.

Other mineral deposit styles are also present in the Sulphurets district. Vein-style gold and silver mineralization occurs in the Brucejack Lake area, west of the Brucejack Lineament. Newhawk Gold Mines Ltd. has outlined in excess of 30 zones of gold-silver mineralization, occurring either as discrete mesothermal veins containing copper and arsenic or, more importantly, as syn-tectonic quartz ± carbonate, K-feldspar and/or barite vein stockworks or breccias with Fe, As, Pb, Zn, Cu and Sb sulphides. One of these deposits, the West zone, contains geological reserves of 750 000 tonnes grading 15.43 g/t Au and 644.58 g/t Ag (Roach and Macdonald, 1992).

Table 2 lists exploration results from the more significant bulk tonnage Au±Cu prospects on Placer Dome's Sulphside property.

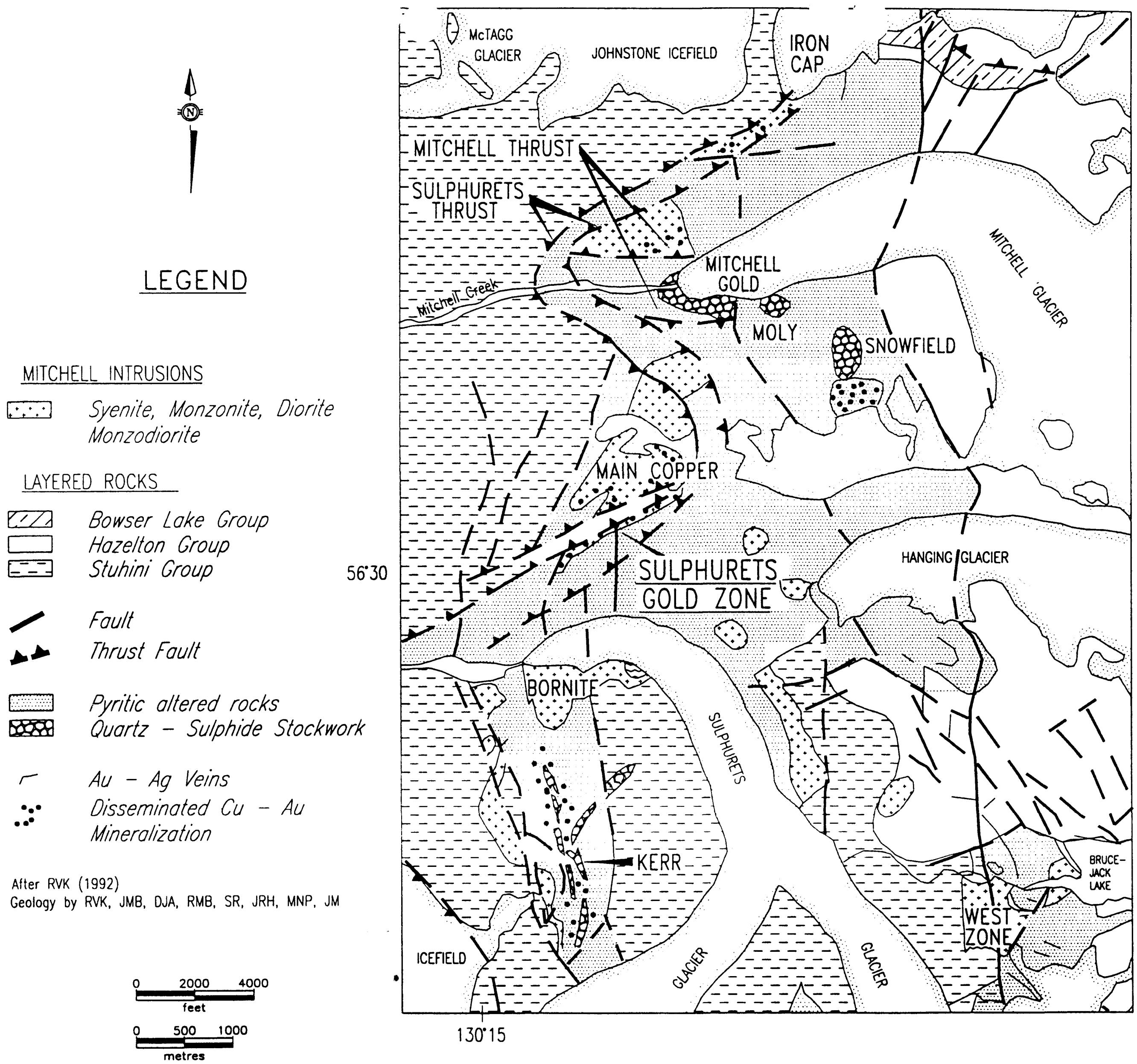

FIGURE 3. Sulphurets Camp, geology, structure, alteration and mineralization.

Exploration Techniques

Methodical prospecting has been the most successful exploration technique in the Sulphurets district due to the excellent rock exposure afforded along ridges and cliff faces. Lithogeochemical surveys have also been helpful in outlining broad areas of porphyry-related base and precious metals mineralization. A multi-element rock lithogeochemical database comprising more than 5000 samples exists for the Sulphurets district; this is the compilation of results from surveys at various scales undertaken by previous operators and the Geological Survey of Canada. Studies by the Geological Survey of Canada (Kirkham, Ballantyne and Harris, in preparation) and by Kirkham and Margolis (this volume) clearly illustrate the spatial relationship between monzonitic to syenitic Mitchell Intrusions and base and precious metal distributions in the Sulphurets district. On the deposit scale, copper and gold lithogeochemical data for the Sulphurets Gold zone (Fig. 4) show the copper-gold distribution about the Raewyn monzonites and gold-only distribution over the Breccia and Canyon zones. A large copper anomaly occurs over the Main Copper occurrence above the Sulphurets Thrust.

TABLE 2. Major mineral occurrences on the Sulphside property

Prospect	Significant results
Upper plate of the Sulphurets Thrust Fault	
Main Copper	0.45 g/t Au, 0.56% Cu over 32.1 m; DDH S91-398
Packsack No. 3	0.45 g/t Au, 0.17% Cu over 221.8 m; DDH 68-1
Lower plate of the Sulphurets Thrust Fault	
Raewyn Copper-Gold zone (Sulphurets Gold zone)	1.32 g/t Au, 0.86% Cu over 8.260 m; DDH SG 92-2
Breccia Gold zone (Sulphurets Gold zone)	2.19 g/t Au, 0.14% Cu over 121.86 m; DDH SG 92-15
Canyon zone	1.15 g/t Au, 0.14% Cu over 92.12 m; DDH 81-23
Sulphurets Lake Gold zone	30 m averaging 2.40 g/t Au, 1950 g/t Ag; trench sample
Mitchell Gold zone	0.75 g/t Au, 0.17% Cu over 153.7 m; DDH S91-386
Iron Cap	0.31 g/t Au, 0.20% Cu over 296.16 m; DDH 80-16

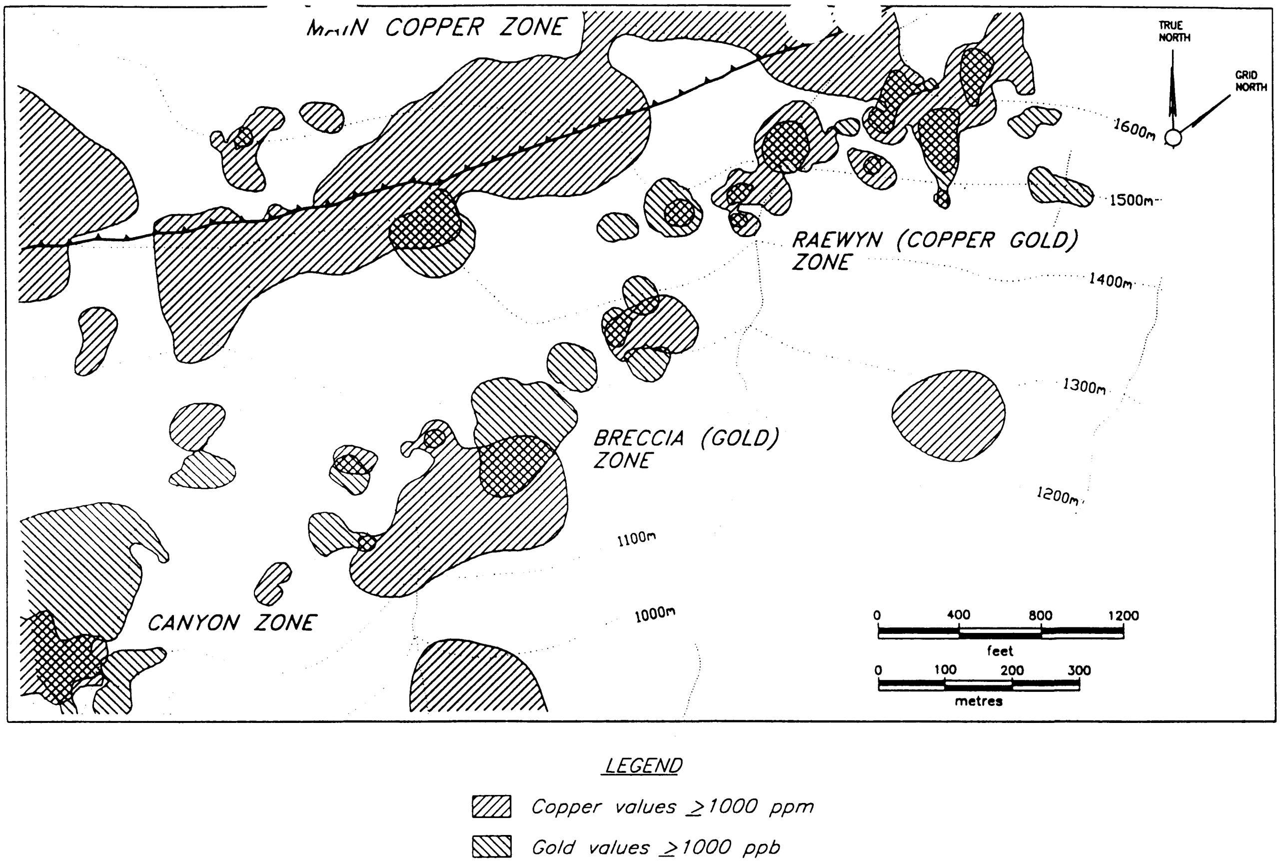

FIGURE 4. Copper and gold lithogeochemical map for the Sulphurets Gold zone.

Reconnaissance and grid-scale ground VLF-EM, magnetic and induced polarization surveys have been successful in defining porphyry-style mineralization in areas where topography permits, for example at the Kerr deposit. The lack of any systematic ground geophysics over the Sulphurets Gold zone is due to difficult topography.

Airborne magnetic, electromagnetic and radiometric surveys in the Sulphurets district have been useful aids to geological interpretation. In particular, radiometric surveys appear to be a useful tool for identifying potassium alteration associated with porphyry copper mineralization in the Sulphurets district. Broad potassium anomalies (> 70 total counts) occur over the Sulphurets Gold, Main Copper, Mitchell and Iron Cap zones (Fig. 5).

The total magnetic field in the Sulphurets district ranges from less than 56 800 nT to 58 000 nT. The Sulphurets Gold zone is represented by an arcuate regional magnetic low (less than 57 200 nT), which correlates with magnetite-depleted sericitic alteration.

Local Geology

Sulphurets Gold Zone

The Sulphurets Gold zone occurs in a unique and complex structural environment. Deeper levels of a syenite-centred porphyry copper-gold deposit (Main Copper zone) have been thrust over and immediately overlie the higher level, transitional porphyry copper-gold system (Sulphurets Gold zone-Fig. 6). The intervening Sulphurets Thrust Fault is an inferred Cretaceous-age, east-verging regional structure of undetermined displacement (Lewis, 1993; Henderson et al., 1992; Alldrick and Britton, 1991) whose surface trace occupies a talus covered break-in-slope transecting much of the Sulphurets Ridge.

Volcanic sequences on either side of the thrust are thought to belong to the Unuk River Formation of the Hazelton Group (Upper Triassic to Middle Jurassic). In the upper plate, the volcanic rocks consist of variably altered (propylitic to potassic) massive to tuffaceous trachyandesites (latites) that are intruded by numerous northerly-trending feldspar porphyry dikes. Porphyry-style chalcopyrite mineralization is common along potassically altered (K-feldspar and biotite) intrusive/volcanic contact areas throughout much of the upper plate at the Main Copper and Packsack No. 3 zones.

Below the Sulphurets Thrust Fault the volcanic package is more variable with locally significant sedimentary and epiclastic components. These are caught up in a complex zone of strong faulting and phyllic/quartz-sericite-pyrite, intermediate argillic, and potassium silicate alteration. This zone trends northeasterly subparallel to the Sulphurets Thrust Fault, and is called the Raewyn Fault zone (Fig. 6). The Raewyn Fault zone is well exposed for much of its length along the main cliff, occurring as a prominent panel of quartz-sericite-pyrite alteration. At surface it appears to have a shallow northwesterly dip and a variable width of between 75 m and 200 m.

Copper-gold mineralization is associated with the Raewyn panel, usually coincident with areas of strongest fracturing and potassium silicate alteration. The bulk of the copper mineralization is exposed along the top of the cliff and in old trenches. It is associated with a concordant zone of brecciated and intensely altered felsic intrusions. For the purposes of this paper, this style of mineralization constitutes the Raewyn Copper-Gold zone. At the southern end of the map area and still within the Raewyn panel, poorly exposed auriferous hydrothermal breccias occur. This is the Breccia Gold zone. The Raewyn and Breccia zones are probably related high level systems that have been variably overprinted and modified by later intrusive, hydrothermal and structural events.

Lithology

The surface geology of the Sulphurets Gold zone is illustrated in Figure 6 and lithological units are listed in Table 3. The main geological units below the Sulphurets Thrust Fault were defined dur-

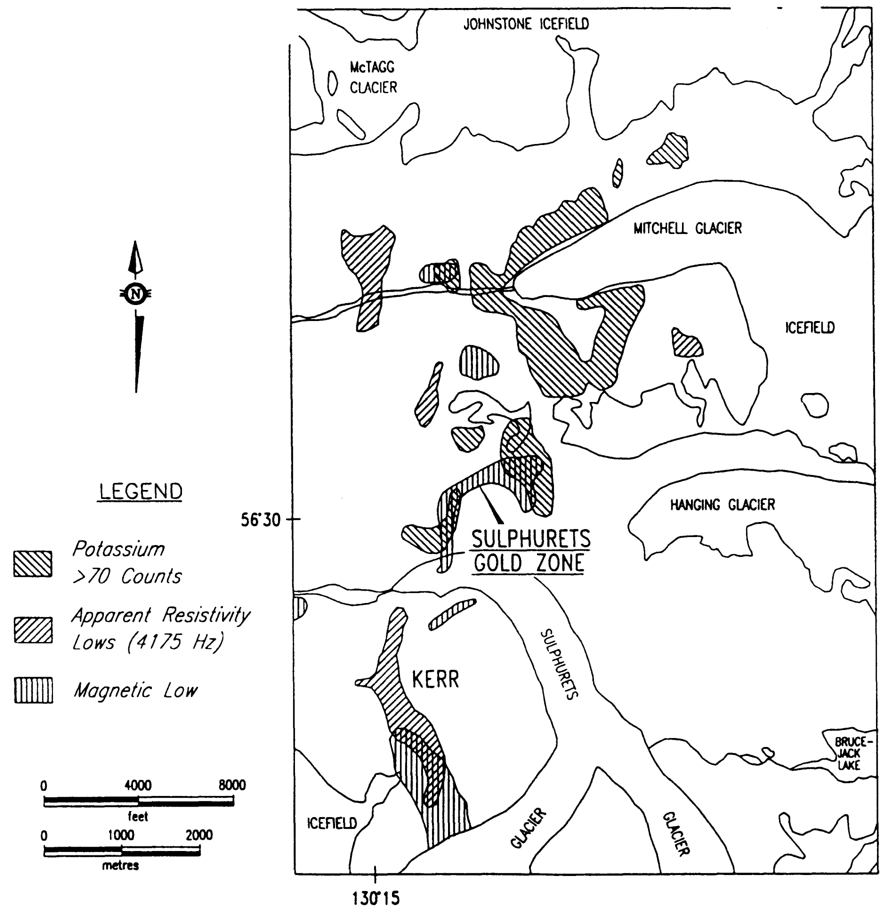

FIGURE 5. Airborne geophysical features for the Sulphurets district.

ing geological mapping and diamond drilling in 1992.

The southern edge of Main Copper zone is exposed above the thrust and consists of intermediate volcanic rocks (Unit 8), massive green flows and tuffs intruded by feldspar porphyry dikes (Unit 9). None of the dikes cross the thrust; they are deformed and clearly pre-date the fault. Petrographic work indicates that the intrusive rocks are quartz syenites or highly potassic monzonites to quartz monzonites. Volcanic rocks which occur adjacent to the dikes are K-feldspar altered and contain disseminated and fracture-controlled chalcopyrite. Away from the dikes, the K-feldspar altered rocks are succeeded by chlorite-altered volcanic rocks which also contain patchy epidote, magnetite, hematite and sparse chalcopyrite.

Radiometric Ages

Samples of Upper Plate, Main Copper zone feldspar porphyry (Unit 9) and Lower Plate, Sulphurets Gold zone-Raewyn quartz monzonite (Unit 4) were collected for U-Pb zircon geochronometric dating by the Mineral Deposit Research Unit (J. Macdonald) in

TABLE 3. Lithology

Unit	Rock type	Description
		Above the Sulphurets Fault
9	Feldspar porphyry intrusions	Mottled pinks and greens with coarse plagioclase or K-feldspar rich groundmass, variable chlorite and epidote alteration. Potassic monzonite to syenite.
8	Intermediate volcanics, massive green flows and tuffs	Massive, medium-green variable K-feldspar, chlorite and carbonate alteration with epidote, magnetite and hematite.
		Below the Sulphurets Fault
7	Late mafic intrusions	Grey hornblende and/or plagioclase porphyrytic monzonite stocks, narrow mafic monzonite and monzogabbro sills.
6	Altered volcanics; QSP, QB, QA and S1)	Any combination of QSP (quartz-sericite-pyrite), QB (biotite), QA (albite) or SI (silicification) hydrothermally altered intermediate volcanics (unit 1).
5	Intrusion/hydothermal breccias	Gross categorization of siliceous hydrothermal breccias (5b), potassic hydrothermal/intrusion breccias (5a) or undifferentiated hydrothermal breccia (5).
4	Raewyn quartz monzonites	Light-grey, strongly altered and brecciated, porphyritic to equigranular quartz monzonites to monzonites. Quartz fragments common, K-feldspar groundmass overprinted by silicification, sericite, local strong biotite, patchy albite.
3	Volcaniclastics/argillites	Green, grey to black argillites, siltstones, volcanic sandstones (epiclastic)
2	Chemical sediments	Light-green, grey to brown cherts, cherty tuffs with minor argillite and ash/dust tuffs.
1	Intermediate volcanics	Light- to medium-green trachyandesite tuffs (latites), flows, bedded tuffs, breccia crystal and ash tuffs.

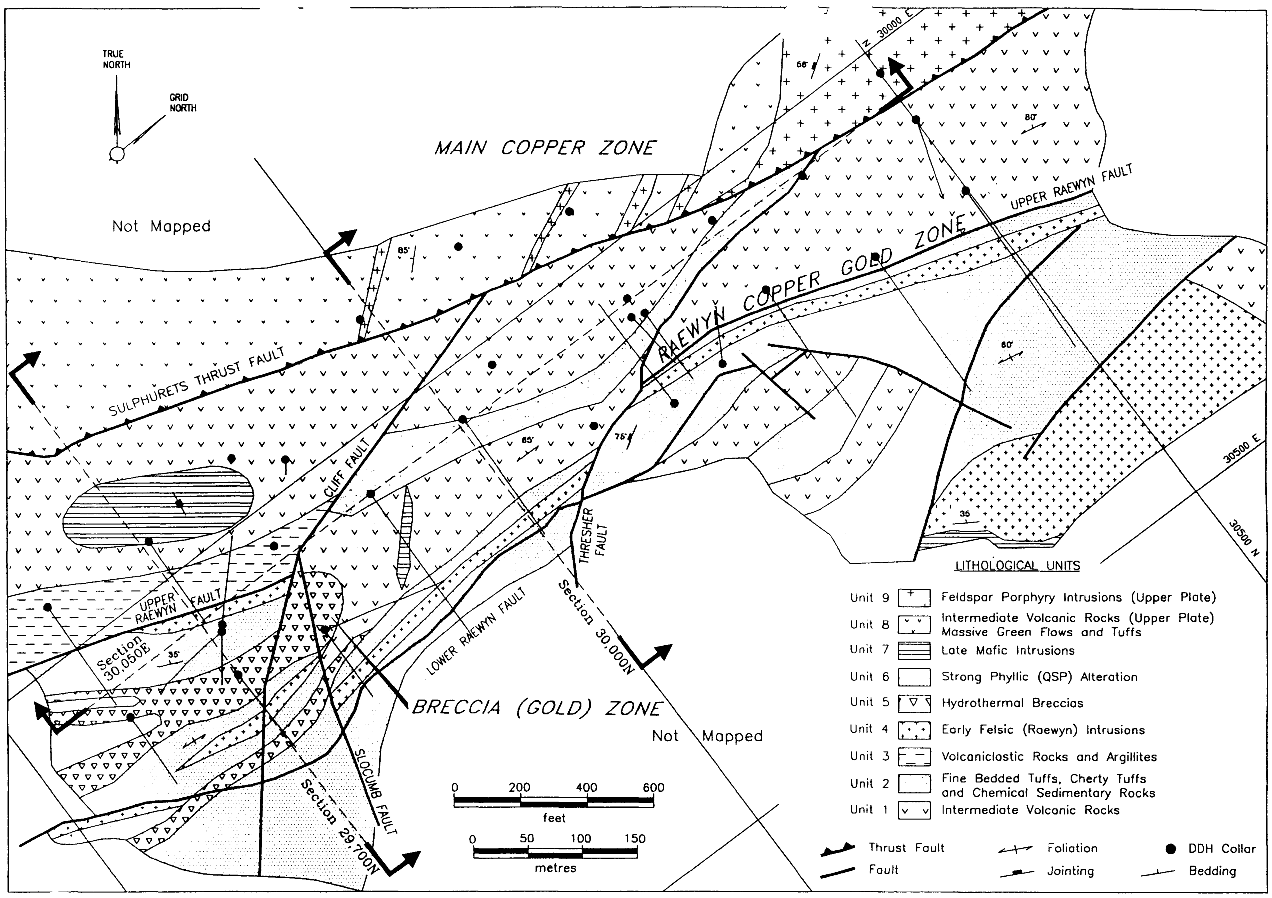

FIGURE 6. Interpreted surface geology of the Sulphurets Gold zone.

1992. A preliminary date of 196 +17/-32 Ma is indicated for the Raewyn intrusion, and an age of 191.8 +6.5/-1.0 Ma for the sample of the Main Copper feldspar porphyry. Both dates correlate with the 195 Ma to 185 Ma age range for Texas Creek intrusions in the Iskut region.

Structure

The main structural features of the Sulphurets Gold zone are illustrated in Figures 6, 7 and 8. The structural interpretation of this complex zone is based on detailed geological mapping by Roach (1991) and Wells (1992), and on information from diamond drilling. Brittle fracturing is widespread in the upper plate rocks; numerous northerly to north-northeasterly striking, commonly steep-westerly dipping fractures and fracture zones are present. Many of the fracture zones pre-date the dikes and potassic alteration. Others, especially the north-northeasterly set, are later and locally related to sericitic alteration.

Below the Sulphurets Thrust Fault, the most prominent feature is the subparallel, 30° to 40° northeasterly-dipping Raewyn structural-alteration panel. This panel is separated from the Sulphurets Thrust Fault by a 100 m to 200 m wide section of less deformed and less altered (propylitic assemblages) volcanic rocks.

The panel is structurally complex. It is transected by shallowly and steeply dipping fault sets of more than one age. To a large extent, the present geometry of the panel is controlled by fairly late shallow-dipping structures like the upper and lower Raewyn Faults. These may be of similar (Cretaceous) age to the Sulphurets Thrust Fault and are clearly later than the porphyry mineralization.

Within the panel, there are a large number of steeply dipping structures with northerly to northeasterly trends. Some of these predate the biotite alteration in the Raewyn zone and the late siliceous hydrothermal breccias in the Breccia zone. They are displaced by later faults.

A strong northeasterly trending and steeply dipping foliation is present throughout the Raewyn panel in areas of greater sericitic alteration. It is highly probable that this foliation developed during the Cretaceous compression that produced the Sulphurets and, possibly, Raewyn faults. Some of the latest fault movements were along the prominent northeasterly trending Cliff, Slocumb and Thresher faults (Fig. 7). These faults dip steeply westward and have consistent reverse movement (west side up) with some strike-slip component. Relationships suggest that these faults were active before and possibly during thrusting. In the Raewyn panel, there often appears to be an interplay between these two sets of faults.

No significant fold structures were indicated by the geological mapping. Small-scale folds do occur in thinly bedded sedimentary rocks. Bedding, where visible, dips at fairly steep angles to the north and northwest but it is not as steep as the sub-vertical foliation.

Metamorphism

It is difficult to distinguish between the effects of metamorphism and alteration within the Sulphurets Gold zone. A lower greenschist grade of regional metamorphism is suggested.

Alteration and Mineralization

The Breccia Gold Zone

The 1992 drilling on the Breccia zone returned significant gold intersections with minor copper values. Hole SG 92-15 intersected 2.38 g/t Au and 0.11% Cu in potassically-altered breccia over a core length of 107.43 m. Section 29,700N (Fig. 9) is a cross-section through the central portion of the Breccia Gold zone. Table 4 summarizes the characteristic minerals for the various alteration types within the zone and reference Cu:Au ratios. Integrated studies indicate the following sequence of events in the Breccia zone area:

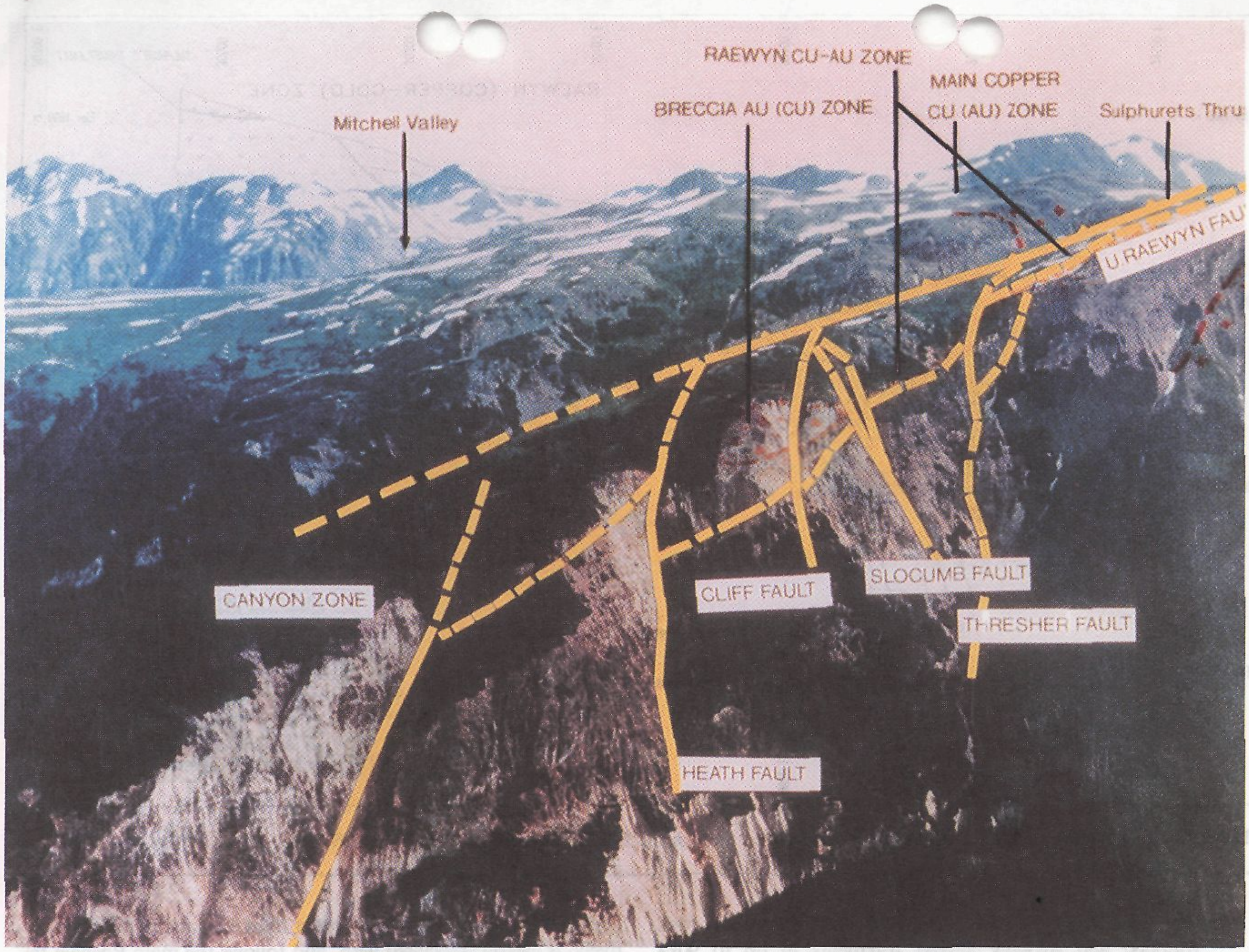

FIGURE 7. The Sulphurets Gold zone looking north from the Kerr deposit. Location of main faults and mineralized zones. The distance between the Cliff and Thresher faults is approximately 300 m (G.M. Ditson photo).

(1) intrusion of Raewyn monzonite (Unit 4) followed by (2) main phase of hydrothermal breccias with K-feldspar alteration and (3) late-stage siliceous hydrothermal activity with local breccia pipes.

The K-feldspar and siliceous breccias within the Breccia zone are fairly distinct when separate but widespread and variable overprinting by the siliceous event makes it difficult to distinguish them in many areas. The K-feldspar hydrothermal breccias (Fig. 10a) are characterized by:

1. numerous, subangular to rounded, monolithic to heterolithic fragments, generally in the 0.5 cm to 3.0 cm size range, which are groundmass supported;
2. K-feldspar rich, fine-grained and locally recrystallized groundmass;
3. pyrite content of 5% to 20%, consisting of fine disseminated anhedral pyrite, coarse subhedral pyrite aggregates, aureoles to fragments and local veins. Locally disseminated to fracture-controlled chalcopyrite is also present;
4. chemistry of 7% to 11% K_2O and 6% to 14% Fe_2O_3;
5. gold content (as assessed from 1992 drill core assay data) ranges from 0.12 g/t to 5.6 g/t, averaging 1.16 g/t; and a low but variable copper content, averaging 0.10%.

The main features of the siliceous breccias (Fig. 10b) are:

TABLE 4. Alteration and mineralization zoning — Breccia Gold zone

Classic alteration type	Unit	Characteristic minerals	Reference Cu:Au ratios* 0 – 2.0
Potassic	PKBX	Ks, qtz, ser, py, cpy (largely overprinted)	
Silica flooding	PSBX	qtz, ser, tour, py (carb ± pyroph)	
Phyllic	QSP	qtz, ser, py, tour, remnant Ks, (cpy, mo)	
Intermediate argillic**		green ser, chl, py	Insufficient data
Propylitic	PR	chl, ep, py, carb, mag	Insufficient data
Late quartz veins		Not recognized	Insufficient data

* % Cu:g/t Au
** only recognized as significant alteration component subsequent to 1992 drill campaign

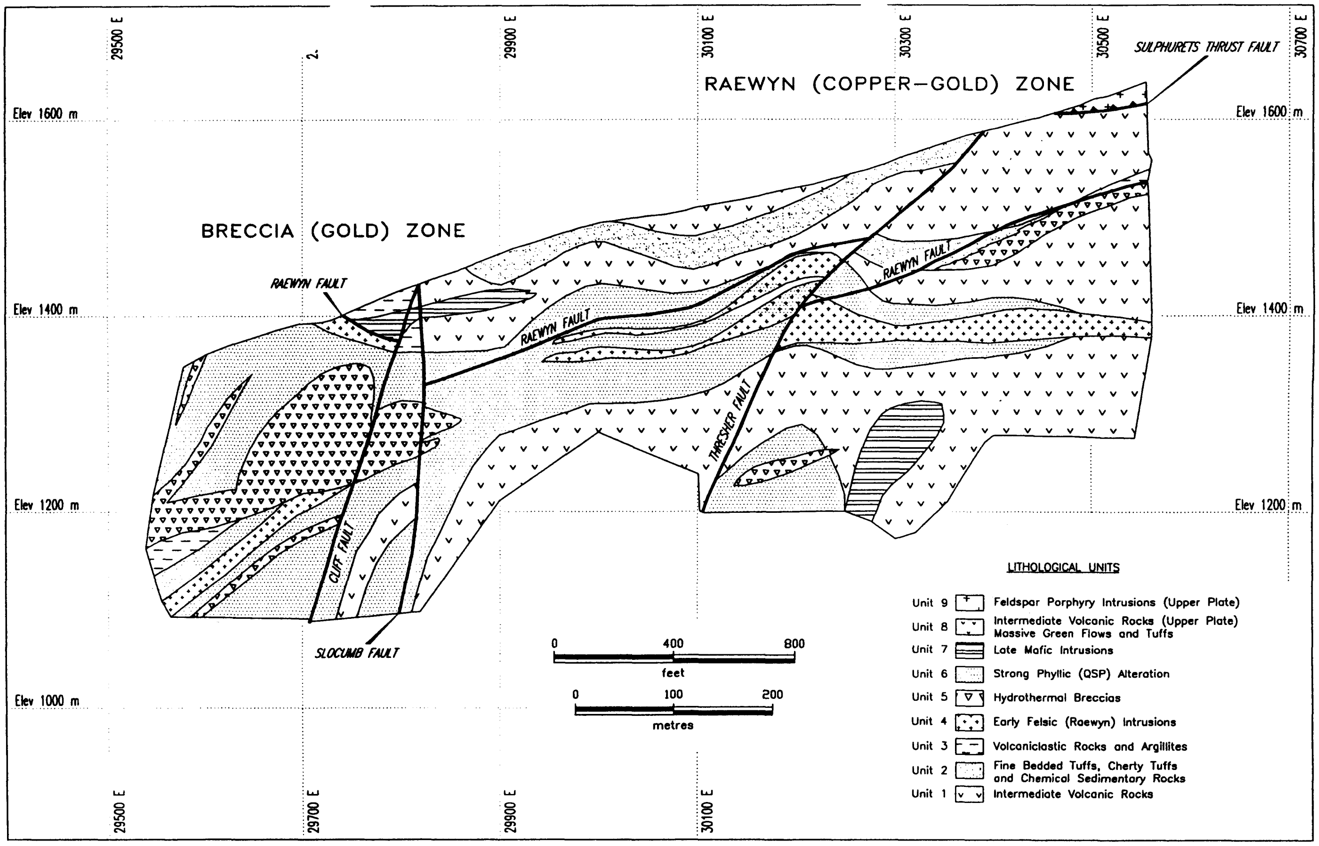

FIGURE 8. Longitudinal section for the Sulphurets Gold zone through the 1992 drilled area (for location see Fig. 6).

1. few, generally small (less than 1.5 cm), commonly well rounded and strongly altered fragments in up to 90% groundmass;
2. fine-grained, commonly grey, siliceous, locally sericitic groundmass exhibiting, in places, linear (fluidization) fabrics;
3. highly variable pyrite content (Fig. 10c) which locally exceeds 20%, and consists of a number of generations of pyrite and pyrite veining. Some veins contain coarse, massive to brecciated pyrite. Chalcopyrite is rare;
4. chemistry largely reflects the protolith, comprising a high SiO_2 content (up to 78.5%) and generally, significantly less Fe_2O_3 and K_2O than K-feldspar breccias;
5. gold content is more variable, ranging from 0.10 g/t to 21.20 g/t, averaging 1.52 g/t, and very low copper values, averaging 0.03%.

Both breccias locally contain significant amounts of dark-coloured tourmaline (schorl) as aggregates and rosettes. The tourmaline often appears to be related to the later siliceous event but this is not conclusive.

Limited petrographic work on the pyritic hydrothermal and siliceous breccias did not isolate visible gold. Higher gold values are often associated with sections containing coarse brecciated pyrite. This has important implications from a metallurgical point of view and further studies are required.

Raewyn Copper-Gold Zone

The Raewyn Copper-Gold zone is located within and near the top of the main structural-phyllic alteration zone in the Raewyn panel. Chalcopyrite mineralization can be traced northeasterly along strike for 700 m across a number of structural breaks from the Slocumb Fault in the southwest to the northeast end of the grid at Section 30,500N.

It is apparent from diamond drilling in 1992 that copper-gold mineralization continues the full length of the 1 km grid. Gold and copper mineralization, grading better than 0.6 g/t and 0.3% respectively, is clearly associated with, and follows the main Raewyn felsic dike system (Figs. 10d and 10e; Fig. 11-Unit 4). Below the Raewyn panel, northeast of the Thresher Fault, the mineralized zone dips steeply, at 60° to 70° to the northwest, along the dikes and is up to 80 m wide. Within the Raewyn panel the zone is structurally controlled; it is between 30 m and 60 m wide and has shallower northwesterly dips of 30° to 45°. Section 30,000N (Fig. 11) illustrates a well mineralized part of the zone. Northeast of the Slocumb Fault, copper-gold mineralization comprises a single zone with local displacements.

There are also a number of deformed, mineralized felsic dikes/sills southwest of the Slocumb Fault in the Breccia zone area (Fig. 9). The most continuous copper-gold mineralization in this area is located in the footwall of the Upper Raewyn Fault; this zone has widths of 20 m to 40 m.

Average copper and gold values from the mineralized zones below and within the Raewyn panel are fairly consistent; copper values range from 0.3% to 0.7% and gold values are 0.4 g/t to 1.2 g/t. The variation of the copper and gold grades is more pronounced within the panel than in the footwall. This is interpreted to reflect the variable and locally strong hydrothermal remobilization and overprinting within the Raewyn panel. The highest average copper and gold values for "Raewyn style" mineralization (Fig. 10e) occur within the Raewyn panel between the Slocumb and Thresher faults. An example of this is in hole SG 92-2 (Fig. 11), which intersected a 82.6 m section that averages 0.86% Cu and 1.32 g/t Au. In the Breccia zone area southwest of the Slocumb Fault, Au:Cu ratios are significantly higher than in the rest of the zone, possibly reflecting overprinting by later hydrothermal events. Hole SG 92-15, drilled in this area (Fig. 9), intersected a 19.82 m interval averaging 0.37% Cu and 1.56 g/t Au.

Strong quartz-sericite-pyrite (phyllic) alteration largely overprints earlier alteration within the Raewyn panel. In the phyllic zone, sericite and pyrite alteration predominates and quartz occurs locally.

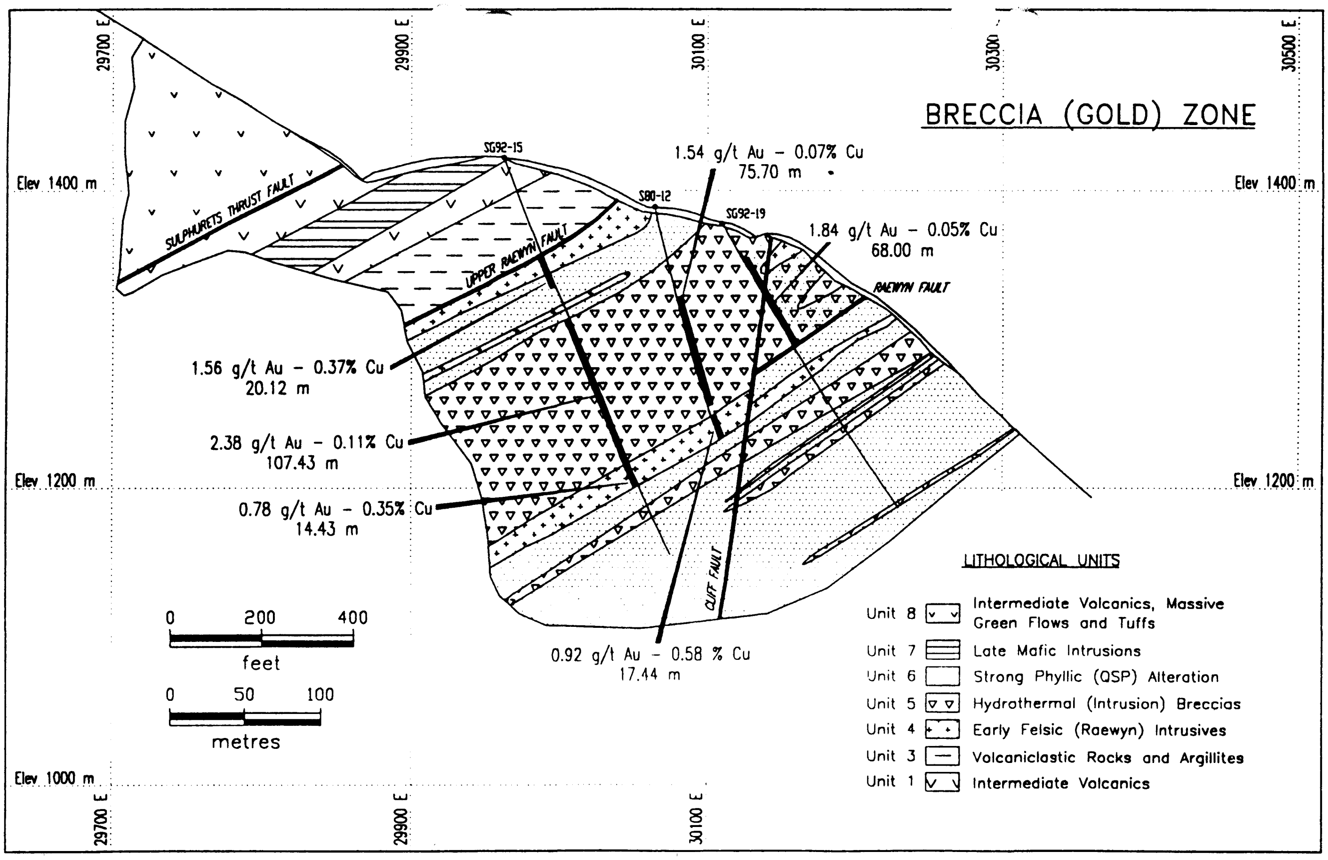

FIGURE 9. Section 29,700N through the Breccia Gold zone (for location see Fig. 6).

Staining of rock specimens shows that abundant K-feldspar is present from an early widespread potassic alteration event. Outboard from the quartz-sericite-pyrite alteration and the felsic dike system, the volcanic rocks are chlorite-altered and locally contain epidote, magnetite and variable carbonate (propylitic assemblage). Pale green sericite, rare hematite and 2% to 5% disseminated pyrite (intermediate argillic) assemblages were noted locally near the contact. It appears that the original K-feldspar alteration associated with the dikes graded rapidly into background propylitic alteration, possibly with a narrow intermediate argillic zone (largely overprinted). Table 5 shows the characteristic minerals for the various alteration types as well as reference Cu:Au ratios for the Raewyn zone.

Petrographic examination of drill core samples from the core area of mineralized zones shows multiphase brecciation, alteration, veining and widespread recrystallization, especially in the Raewyn panel. Early K-feldspar alteration has been overprinted by a number of alteration and vein assemblages which can be summarized as:

1. chalcopyrite, quartz, chlorite, sericite ± albite and carbonate (QA);
2. chalcopyrite, quartz, pyrite, biotite, sericite, minor chlorite and molybdenite (QB);
3. milky quartz veins with coarse blebby chalcopyrite, minor pyrite and chlorite.

The above three assemblages often occur in very close proximity, overlap and, in places, cannot be readily separated. Chalcopyrite commonly occurs as wormy intergrowths with quartz and secondary albite in veins and narrow pervasive zones in the QA type or as wormy intergrowths with quartz and pyrite in QB type and locally in the milky quartz veins.

Below the Raewyn panel, biotite alteration (QB-Fig. 10f) may extend for ten or more metres from the intrusion into the wallrocks and contains fracture and veinlet controlled chalcopyrite. This alteration clearly overprints earlier K-silicate assemblages. Copper and gold grades are higher in these biotitic zones than in the background phyllic alteration. In these areas, biotite alteration, which may be accompanied by molybdenite mineralization, occurs along steeply dipping fractures and fracture zones commonly located near interpreted intrusive contacts.

Biotite alteration (QB) with enhanced copper and gold values is best developed where the mineralized intrusive zone lies within the Raewyn panel, especially between the Slocumb and Thresher faults. In thin section, biotite occurs as fine- to medium- green grains within groundmass chlorite (patchy to pervasive) alteration or as coarse tabular (subhedral) grains in the wallrocks of, and locally within, quartz-pyrite-chalcopyrite veins. Fine- to coarse-grained, fracture-controlled molybdenite is commonly associated with the biotite, especially near major structures like the Thresher and Cliff faults. Biotite alteration within the Raewyn panel coincides with the strongest early K-feldspar alteration, strongly brecciated (Unit 4) intrusions and copper-gold mineralization. K_2O values are quite similar whether biotite is present or not, suggesting that there was limited migration of potassium during the late K-silicate alteration.

Some alteration appears to be related to steeply dipping and northerly trending structures in the Cliff-Thresher Fault area. Locally, siliceous-potassic (biotite) hydrothermal breccias occur within the panel. Fracture-controlled and pervasive biotite alteration is rare above the panel except in the Thresher Fault area where biotite alteration occurs near the top of a significant copper-gold intersection (95.6 m averaging 0.53% Cu and 0.45 g/t Au) in hole SG 91-389.

Heterolithic, siliceous hydrothermal breccias occuring in the area of the Thresher Fault have significant gold values and little copper. Drill hole SG 92-02 (Fig. 11) returned 13 m averaging 7.11 g/t Au and 0.051% Cu. The geometry of these gold-rich breccias is unknown. Siliceous hydrothermal breccias also occur below the Raewyn panel northeast of the Thresher Fault. These are associated with a lower phyllic alteration zone and have associated dark tourmaline. During 1992 core logging, unrecognizable siliceous rocks

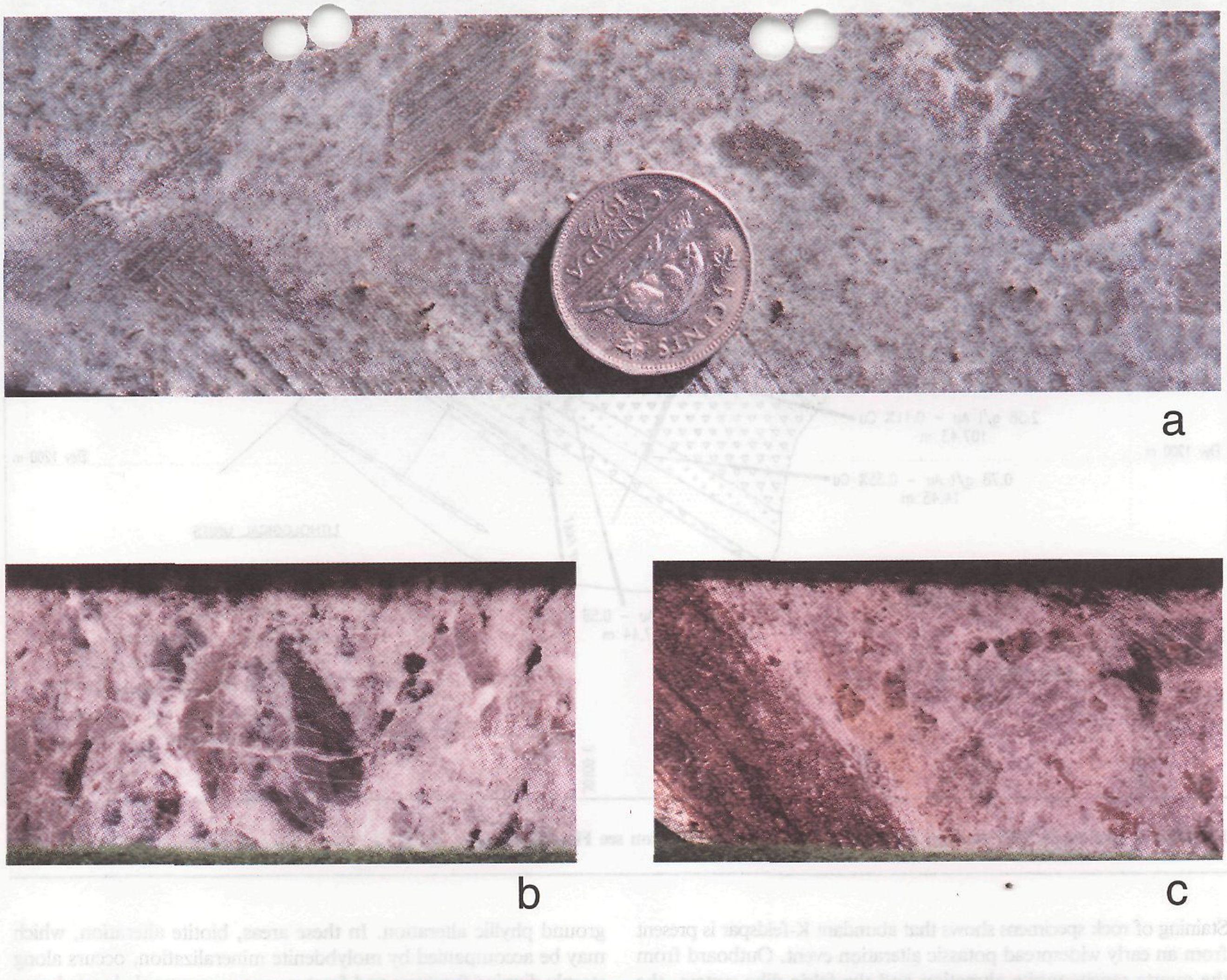

FIGURE 10. Breccia Zone a, b, c: (a) heterolithic K-feldspar breccia with strong siliceous overprint and numerous quartz veinlets (0.21% Cu, 0.42 g/t Au); (b) strongly altered and pyrite-rimmed clasts in potassic breccia. K-feldspar rich matrix. (R.C. Wells photo); and (c) grey siliceous (hydrothermal) breccia with coarse pyrite veins (0.06% Cu, 2.73 g/t Au) (T.G. Schroeter photo). All are NQ core samples.

Raewyn zone d, e, f: (d) silicified and quartz veined quartz monzonite dike (Unit 4). Vague primary textures; (e) strongly fractured and silicified wall-rocks to dike with fracture controlled chalcopyrite and pyrite; (f) silicified and brecciated monzonite dike (?) with strong biotite alteration (overprint). (T. G. Schroeter photo)

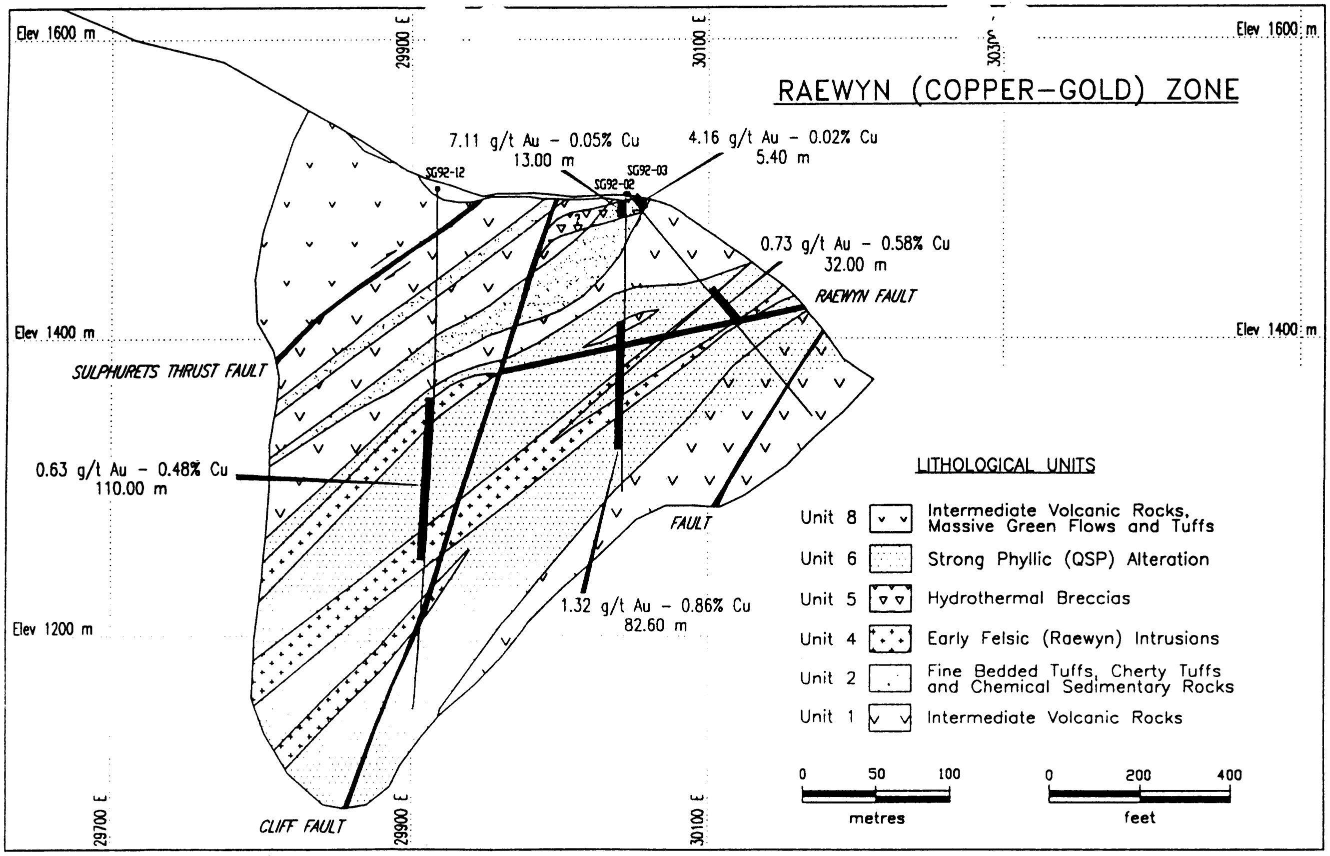

FIGURE 11. Section 30,000N through the Raewyn Copper-Gold zone (for location, see Fig. 6)

were grouped into alteration unit SI. Later on, it was evident that this group included altered early felsic intrusions, silica flooding and also silicified zones near siliceous hydrothermal breccias. This is reflected in the bimodal Cu:Au ratios for this alteration unit.

Late high-angle quartz veins, ranging from a few centimetres to 3 m wide, occur throughout the Raewyn zone but are most common close to the Thresher and related faults. Coarse chalcopyrite, elevated gold grades, pyrite, tetrahedrite ± arsenopyrite and molybdenite occur in these milky white quartz veins that clearly cross-cut all previously mentioned alteration domains.

Statistics

The copper and gold distribution in Sulphurets Gold zone lithologies, as determined from diamond drilling in 1992, are presented in Tables 6 and 7. Rock types were classified as Unit 6 — altered rocks — regardless of alteration type when protolith identification was not possible. None of the samples were taken more than 100 m from mineralized zones. Consequently, all units appear to have elevated values and no estimate can be made for background copper and gold values. Copper and gold distributions within specific alteration domains, as defined in Tables 4 and 5, are presented in Tables 8 and 9.

Tables 6 and 7 illustrate the higher copper and gold values in Raewyn monzonites (Unit 4), the high gold-elevated copper values associated with potassic breccias (Unit 5a), and the high gold-low copper values in siliceous breccias (Unit 5b). The enveloping phyllic-altered volcanic rocks (Unit 6) also have significantly elevated copper and gold values.

The copper and gold distribution within four alteration facies identified during the exploration program in 1992 are presented in

TABLE 5. Alteration and mineralization zoning — Raewyn Copper-Gold zone

Classic alteration type	Unit	Characteristic minerals	Reference Cu:Au ratios* 0 – 2.0
Potassic	KP	Ks, qtz, py, cpy (largely overprinted)	Insufficient data
Potassic	QB	bio, qtz, py, cpy (chl, ser, mo)	
Silica flooding	SI	qtz, py, cpy (tour, ser)	
Albitic (Core Area)	QA	alb, carb, chl, py, cpy (ser)	
Phyllic	QSP	qtz, ser, py, tour, remnant Ks, (cpy, mo)	
Intermediate argillic**	-	green ser, chl, py	Insufficient data
Propylitic	PR	chl, ep, py, carb, mag	Insufficient data
Late quartz veins	-	qtz, py, cpy, tet (aspy, mo)	Insufficient data

* % Cu:g/t Au
** only recognized as significant alteration component subsequent to 1992 drill campaign

TABLE 6. Assay statis' rock unit Au (g/t)

Unit	No. of samples	Mean	Standard deviation	Variance	Maximum	Median	Minimum
7	122	0.0892	0.1207	1.3540	0.7000	0.0350	0.0100
6	284	0.6534	0.6840	1.0469	7.1700	0.4400	0.0600
5a	154	1.1899	0.9603	0.8070	5.6600	0.8950	0.1200
5b	79	1.5227	2.7491	1.8055	21.200	0.6900	0.1000
5c	27	0.3322	0.7122	2.1438	3.9200	0.1800	0.0300
4	240	0.7286	0.7793	1.0696	8.2400	0.5400	0.0200
3	171	0.2097	0.2704	1.2892	2.0700	0.1100	0.0000
2	177	0.2530	0.2923	1.1554	2.9500	0.1900	0.0200
1	1103	0.3353	0.3436	1.0247	4.5400	0.2400	0.0000

Unit 1 — Intermediate volcanics; Unit 2 — bedded tuffs, chemical sediments; Unit 3 — volcaniclastics, argillites; Unit 4 — Raewyn quartz monzonites; Unit 5a — potassic hydrothermal breccia; Unit 5b — siliceous hydrothermal breccia; Unit 5c — mixed hydrothermal breccia; Unit 6 — altered "QSP" rocks; Unit 7 — late mafic intrusives

TABLE 7. Assay statistics by rock unit Cu(%)

Unit	No. of samples	Mean	Standard deviation	Variance	Maximum	Median	Minimum
7	121	0.0356	0.0719	2.0190	0.5400	0.0100	0.0000
6	281	0.2386	0.2823	1.1831	2.5400	0.1400	0.0000
5a	149	0.1016	0.1004	0.9878	0.5700	0.0600	0.0000
5b	79	0.0323	0.0762	2.3614	0.6200	0.0100	0.0000
5c	26	0.0527	0.0714	1.3549	0.2600	0.0100	0.0000
4	217	0.4230	0.2631	0.6220	1.3900	0.3800	0.0100
3	171	0.0275	0.0405	1.4690	0.2800	0.0100	0.0000
2	177	0.0805	0.0612	0.7606	0.5200	0.0600	0.0100
1	1071	0.1635	0.1813	1.1085	1.9000	0.1000	0.0000

Unit 1 — intermediate volcanics; Unit 2 — bedded tuffs, chemical sediments; Unit 3 — volcaniclastics, argillites; Unit 4 — Raewyn quartz monzonites; Unit 5a — potassic hydrothermal breccia; Unit 5b — siliceous hydrothermal breccia; Unit 5c — heterogeneous hydrothermal breccia; Unit 6 — altered 'QSP" rocks; Unit 7 — late mafic intrusives

TABLE 8. Assay statistics by alteration type Au (g/t)

Alteration Unit	No. of samples	Mean	Standard deviation	Variance	Maximum	Median	Minimum
QSP	1012	0.5859	0.9199	1.5702	14.7000	0.3600	0.0100
Si	181	0.6839	0.6700	0.9796	5.5600	0.4700	0.0800
QB	118	0.8141	0.5550	0.6817	3.2200	0.6850	0.0500
QA	176	0.5585	0.7433	1.3309	8.2400	0.4200	0.0700

QSP = quartz-sericite-pyrite or phyllic alteration; SI = silicification or silica flooding; QB = biotite, potassic alteration; QA = albitic alteration

TABLE 9. Assay statistics by alteration type Cu (%)

Alteration unit	No. of samples	Mean	Standard deviation	Variance	Maximum	Median	Minimum
QSP	998	0.1514	0.1959	1.2939	1.4700	0.0700	0.0000
SI	158	0.3883	0.2645	0.6812	1.3400	0.3400	0.0100
QB	118	0.5996	0.3892	0.6491	2.5400	0.5350	0.0600
QA	174	0.2836	0.2662	0.9386	1.4700	0.1900	0.0000

QSP = quartz-sericite-pyrite or phyllic alteration; SI = silicification or silica flooding; QB = biotite, potassic alteration; QA = albitic alteration

Tables 8 and 9. Copper and gold values are highest in siliceous (SI) and biotitic (QB) alteration. These occur proximal to the Raewyn monzonites and constitute the principal ore shell of the deposit.

Gold values in the phyllic (Unit 6, QSP) and albite-altered (QA) samples are similar, whereas copper values in the albite-altered rocks are almost double those in the phyllic zone. This may reflect deposition in the more sodic environment outboard from the proximal biotite zones.

Preliminary statistical analysis of assay and multi-element ICP data from the Breccia Gold zone potassic breccia (Unit 5a) indicates no correlation exists between gold and molybdenum or copper (correlation coefficients of -0.006 and 0.192 respectively). The best positive correlatives to gold are arsenic and antimony: correlation coefficients are 0.625 and 0.624 respectively. There is no correlation between gold and silver, lead or zinc.

Statistics suggest that gold is a "stand alone" element in the siliceous hydrothermal breccia (Unit 5b). Poor correlation exists between gold and silver (0.493) and copper (0.337), and no correlation exists with molybdenum, lead or zinc. Correlation coefficients for arsenic and antimony are comparable to observations in Unit

5a, being 0.793 and 0.608 respectively.

The best copper-gold correlation for intrusive rocks is 0.371 for the Raewyn monzonites (Unit 4). Coefficients for copper-molybdenum and gold-molybdenum for this unit are 0.772 and 0.095 respectively. This copper, gold and molybdenum association is not unusual for the Sulphurets camp; a similar correlation exists in the Kerr deposit (Ditson et al., this volume).

Economics

A reserve estimate has not been announced for the Sulphurets Gold zone since drilling to date is widely spaced. The potential for higher grade gold mineralization along the Sulphurets Gold zone trend, comparable to deposit(s) size and tenor at Red Mountain near Stewart, British Columbia, is considered excellent. The main deterrents to continued exploration are low current metal prices and difficult access.

Discussion and Conclusions

The Raewyn Copper-Gold and Breccia Gold mineralized zones, which comprise the Sulphurets Gold zone, appear to represent the upper levels of a strongly deformed porphyry system (Fig. 12). These zones were originally located above a Jurassic Mitchell-type intrusion with a suggested monzonite composition. The Raewyn zone is a copper-gold mineralized dike system. The Breccia zone is a dominantly gold (with some copper) mineralized hydrothermal breccia complex. Both zones were part of a widespread K-silicate hydrothermal and intrusive-related event. K-feldspar alteration is centred around the intrusions and is in turn enveloped by a broad propylitic halo. A narrow intermediate argillic zone may be present in the Raewyn panel between the two mineralized zones. Both the Raewyn and Breccia zones have been subjected to deformation and overprinting by later structural, hydrothermal and postmineral intrusive events.

Textural relationships strongly suggest that there was some structural preparation prior to biotite and siliceous hydrothermal alteration. Early monzonite dikes were brecciated before biotite alteration, and siliceous hydrothermal breccias locally follow cross-cutting structures. These alteration events are related to significant local remobilization of copper and gold and possibly some introduction of gold mineralization. Two intrusion-related hydrothermal events are suggested, however, the time span between them may be relatively short, in the order of 4 Ma to 5 Ma K-feldspar alteration occurred early, whereas biotite alteration and silicification appear to be related to mid-life to waning stage events of the same system. Widespread phyllic alteration with quartz, sericite and significant pyrite may also be middle or late stage. In general, this paragenesis agrees with observations made by Margolis (1993) for the northern part of the Sulphurets district.

In the vicinity of the Breccia zone, siliceous hydrothermal breccia pipes occur in some of the widest parts of the phyllic alteration zone and may represent a "core" of the mineralizing system. It is not clear whether the gold-bearing siliceous breccias located to the northeast in the Raewyn zone can be related to this event, however, a number of strong similarities exist.

The Raewyn panel appears to have had a long structural history, possibly spanning the Jurassic and Cretaceous periods. Some of the more obvious structural features in the panel, such as the Raewyn Fault and the foliation, are probably related to Cretaceous compression. During this period the Main Copper zone was thrust over the Sulphurets Gold zone along the Sulphurets Thrust Fault. The relationship between these two zones is unknown. Some mafic stocks and dikes follow the structures and may be Tertiary in age. Some movements have taken place along the Cliff, Slocumb and Thresher faults.

The mineralized zones feature two distinct ore types. The Breccia zone contains 2.0 g/t to 4.0 g/t Au, little copper, and is possibly associated with coarse pyrite. The Raewyn zone contains copper

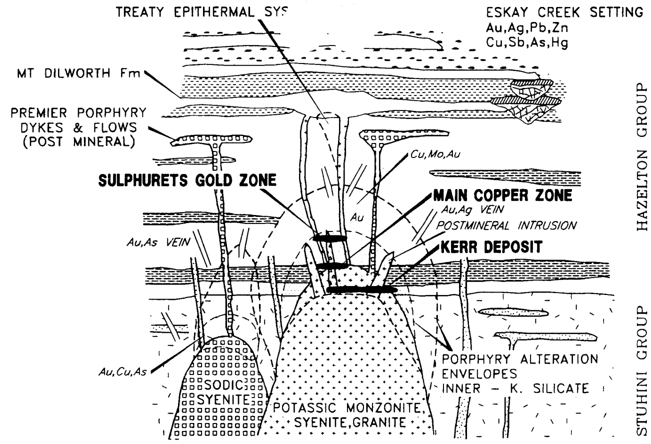

FIGURE 12. Schematic stratigraphy and syn-intrusive, syn-volcanic mineral deposits. After Kirkham et al., 1991.

mineralization which is closely associated with gold and, locally, molybdenum mineralization. Copper values in the 0.30% to 0.80% range and gold grades of 0.40 g/t to 1.0 g/t are common. From a metallurgical perspective, the two ore types would require different gold extraction processes.

The Sulphurets Gold zone has had a complex intrusive, hydrothermal and structural history. Some features, such as quartz veins and the local molybdenum content, are characteristic of calc-alkaline magmatism whereas others, such as the alteration and composition of intrusions, are more typically alkalic. Consequently, additional research and field studies are required before this porphyry system can be further classified.

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