



## PRELIMINARY STRUCTURAL INTERPRETATION OF THE SNIP MINE (104B/11)

By David A. Rhys and Colin I. Godwin  
Mineral Deposit Research Unit  
The University of British Columbia  
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### INTRODUCTION

The Snip mine, on the south side of the Iskut River, is 70 kilometres east of Wrangell, Alaska, and 110 kilometres northwest of Stewart, British Columbia. The mine is jointly owned by Cominco Ltd. (60%) and Prime Resources Group Inc. (40%). Production began in January, 1991, at a rate of 360 tonnes per day.

Gold-bearing quartz veins were first discovered by Cominco prospectors. Limited trenching on the showings in 1966 yielded mixed results and the claims were allowed to lapse. Cominco restaked the area in 1980 as the Snip claim group. Delaware Resources Corporation, now Prime Resources Group Inc., funded an intensive exploration program on the property between 1986 and 1990 as part of a joint venture agreement with Cominco (Nichols, 1989). The exploration program delineated a reserve of 960 000 tonnes at a grade of 28.5 grams per tonne gold (A. Samis, personal communication, 1991).

The deposit is within the Stikine Terrane at the eastern margin of the Coast Plutonic Complex. The regional geology is outlined in Britton *et al.* (1990).

During 1991, Rhys spent 98 days at Snip doing 1:500-scale structural mapping in the accessible mine workings and on surface. In addition, over 500 drill intersections of the Snip orebody were re-logged for mineral zoning and ore-type distribution studies. Extensive sampling was done for detailed petrography, structural analysis, fluid inclusion microthermometry, alteration, stable isotope analysis and geochronology.

### LOCAL GEOLOGY

Two major lithologic units are exposed in the area of the Snip mine (Figure 6-9-1). The host unit is a thick sequence of tuffaceous biotitic feldspathic greywacke. This is intruded by an elongate orthoclase-porphyrritic quartz monzonite stock.

The greywackes contain rare interbeds of graded siltstone and matrix-supported pebble conglomerate, which suggest a turbiditic origin for portions of the sequence. Bedding is upright and dips moderately to steeply northwesterly.

The quartz monzonite stock, known as the Red Bluff porphyry, forms a prominent cliff along the west side of Bronson Creek (Figure 6-9-1). A large alteration zone flanks this intrusion to the southwest (Kerr, 1948). The intrusion comprises lenses of orthoclase porphyry in a rock

composed of sheeted quartz veinlets with magnetite bands in a magnetic, siliceous dark grey matrix. A U-Pb zircon minimum age of  $195 \pm 1$  Ma was obtained from a sample of orthoclase porphyry collected from the 130 haulage level of the Snip workings (Macdonald *et al.*, 1992).

### CHARACTER OF THE SNIP OREBODY

Ore at the Snip mine is contained within a shear-vein system termed the Twin zone (Nichols, 1987) which strikes  $120^\circ$  and dips  $30^\circ$  to  $60^\circ$  southwest (Figure 6-9-2). It has been traced by drilling for 500 metres, both horizontally and vertically. Thickness varies to a maximum of 13 metres, and averages approximately 2.5 metres. In the eastern and lowest parts of the mine, the Twin zone dies out in a series of discontinuous quartz-carbonate-sulphide stringers. Erosion has removed the westernmost and upper parts of the orebody.

An unmineralized basic biotitic dike, termed the biotite spotted unit (BSU of Nichols, 1989; *also see* Figure 6-9-2), intrudes the Twin zone above the 280 level (Figure 6-9-2), and commonly obliquely cuts fabrics and veins developed in the zone. Below this level, the dike diverges into the hangingwall. It typically contains 15 per cent black to dark green felted biotite spots, 0.5 to 4 millimetres long, in a fine-grained biotitic matrix. It has a pervasive phyllitic foliation that parallels its margins. Common elongation of the biotite spots defines a lineation on the foliation that plunges  $35^\circ$  southwest. The phyllitic foliation locally grades into a schistosity on the dike margins. In such cases it can be difficult to distinguish foliated dike from biotitic Twin zone mineralization.

The Twin zone has a pronounced internal banding of four different ore types, all of which carry gold:

**Biotite mineralization** consists dominantly of two varieties of biotite: black (Mg, Fe) biotite, and the green, iron end-member of the biotite group, annite (McLeod *in* Nichols, 1989). Alternating laminae of schistose biotite/annite and calcite, 1 to 15 millimetres thick, are common, but some drill holes intersect intervals of almost pure annite. Quartz is locally abundant as augen or foliation-parallel veinlets (Figure 6-9-3A and 6-9-3C). Total sulphide content, mainly pyrite and minor pyrrhotite, seldom exceeds 2 per cent. Streaks of pink calcite and potassium feldspar occur in some annite-rich areas. These areas are also associated with high molybdenite (up to 2%) and gold (generally greater than 120 g/t) content. The streaks may represent slices of potassically altered wallrock.

A gradual transition, 3 to 25 centimetres wide, from weakly foliated biotitic greywacke to schistose biotite ore occurs in some drillholes. Remnant carbonate/potassium feldspar altered wacke grains are often present in annite-rich sections of this ore type. These observations suggest that the biotite ore may have formed by progressive wallrock alteration.

**Carbonate mineralization** occurs as bands of granular calcite and lesser iron carbonate, often with patches of potassically altered wallrock. Bands and stringers of sphalerite are common, but seldom exceed 1 per cent of the volume of the carbonate ore. Disseminated pyrite occurs in most drill intersections. Streaks of black biotite and annite commonly comprise 5 to 25 per cent of the carbonate ore and there is a complete compositional gradation from the carbonate ore to the biotite ore, indicating they are closely related genetically.

**Massive sulphide mineralization** contains a high diversity of sulphide minerals. Massive sulphides occur in foliation-parallel veins of predominantly massive pyrite 5 centimetres to more than 1 metre thick. Massive pyrrhotite is present locally. Other significant sulphides include, in decreasing order of abundance, arsenopyrite, sphalerite, chalcopyrite and galena. Streaks of magnetite occur in some pyrite veins with 1 to 5 per cent disseminated pyrrhotite. Both black biotite and annite streaks are associated with the sulphides, but seldom exceed more than 10 per cent of the vein volume. Calcite is interstitial to sulphide grains in most veins and quartz eyes are common in pyrrhotite-rich ore. Both chalcopyrite and fine (<mm) visible gold are commonly spatially associated with the quartz.

**Quartz mineralization** consists of foliation-parallel quartz veins containing the same sulphide species as the massive sulphide veins, but sulphide content seldom

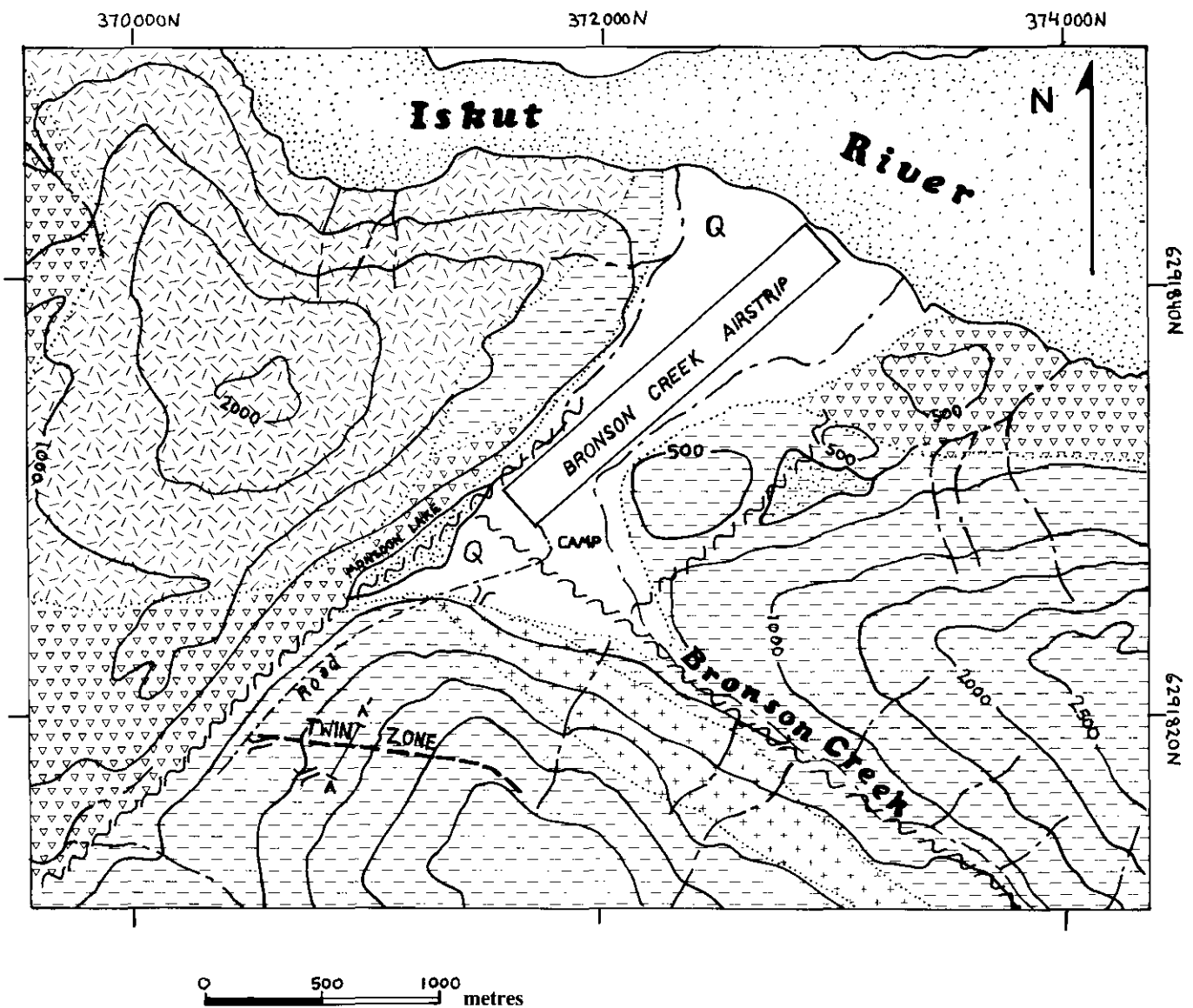


Figure 6-9-1. Local geology of Snip mine area, British Columbia. Base map after Nichols (1989) and geology modified after Alldrick *et al.* (1990).

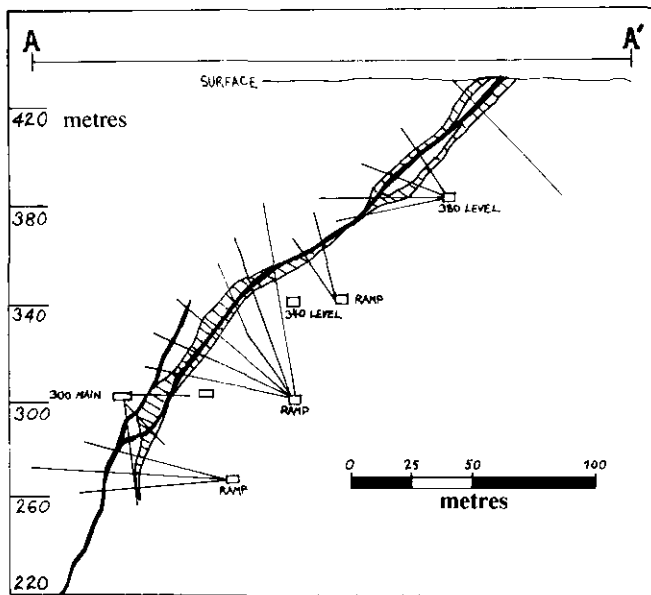


Figure 6-9-2. Cross-section through the Twin zone at 4512.5 east, Snip mine grid, showing the relationship of the biotite spotted unit (BSU). The BSU is shown in black and the Twin zone is hatched. Section is parallel to the 030° azimuth. Underground-drill intersections and workings are shown. Modified from a section drawn by A. Samis (Cominco Ltd.).

exceeds 2 per cent. The relative abundance of pyrite is generally less than that in massive sulphide mineralization; other sulphides, notably pyrrhotite and chalcopyrite, are proportionally more abundant. Annite, and less abundantly, black biotite, commonly comprises 5 per cent of the quartz veins, but locally forms up to 50 per cent of the vein. Bladed quartz-annite intergrowth is common in veins with abundant annite (Figure 6-9-3B). Blades are generally perpendicular to the vein walls.

Quartz veins are invariably strongly fractured and have been previously described as "crackle quartz" (Nichols, 1989). Fractures are usually filled with calcite and/or iron carbonate, giving the quartz veins a carbonate content of 1 to 4 per cent. Annite and sulphides may also occur as fracture fill. Visible gold is usually associated with or enclosed in sulphides and annite as fine, free gold, but may also occur as disseminations in unfractured quartz.

Progressive increase in sulphide content over distances of 1 to 2 metres commonly produces a gradation from quartz to sulphide vein mineralization, implying a genetic relationship between these two ore types.

Individual drill intersections of the Twin zone consist of one or more of the four ore types, often layered in an apparent stratigraphy. All ore types occur throughout the Twin zone, but sulphide veins are more abundant in the eastern part of the orebody (Nichols, 1989). Slivers of greywacke are also common within the Twin zone.

## ALTERATION

The Twin zone rarely exhibits a well-developed alteration halo. In many instances, especially in sections of carbonate

or quartz ore, no alteration envelope is apparent. Sulphide mineralization, however, commonly has an envelope of felted black biotite with disseminated pyrite or pyrrhotite 1 to 50 centimetres wide. In some locations, this biotitic envelope forms an inner halo within an outer zone of potassically altered wacke.

The greywackes throughout the mine have abundant black biotite alteration. The biotite is predominantly fracture controlled and, less commonly, pervasive. Biotite-filled fractures commonly contain pyrite and have bleached potassium feldspar envelopes, mimicking the progressive alteration envelopes that surround some sulphide mineralization in the Twin zone. Siltstone interbeds in the greywackes appear most strongly altered; some graded beds have a matrix composed entirely of pale pink potassium feldspar. Patches of potassium feldspar flooded greywacke with up to 60 per cent potassium feldspar are often found in drill core (Nichols, 1988).

Southwest-dipping laminated biotite-carbonate-quartz-sulphide-filled shear zones of variable thickness (2 cm to 1.2 m) occur throughout the mine workings up to the contact with the Red Bluff porphyry. They are spaced 7 to 15 metres apart and have the same internal structure and similar mineralogy to the Twin zone. The abundance of these shear zones suggests a large hydrothermal system was active in the area at the time of the formation of the Twin zone. Their spacing may be sufficient to explain the pervasive biotite and potassium feldspar alteration in areas distant from the Twin zone.

## INTERNAL STRUCTURE OF THE TWIN ZONE

Structures internal to the Twin zone suggest it formed as a dilatant shear zone with a predominantly normal sense of movement.

Drag folds commonly occur in all Twin zone mineralization types (Figures 6-9-3A, 6-9-3C). Fold amplitudes range from 2 centimetres in biotite and carbonate mineralization to 20 to 70 centimetres in the more competent quartz vein mineralization. Fold axes are contained within the Twin zone boundary plane orientation. Most fold axes are either subhorizontal or southwesterly plunging, but there is a range of intermediate plunge directions. Folds with subhorizontal axes verge down-dip and are common in all mineralization types. Folds with southwesterly plunging axes verge both east and west, and are common in the biotite and carbonate ore types. The dual west and east vergence of folds developed in the relatively incompetent carbonate and biotite ores suggests the presence of sheath folds (Cobbold and Quinquis, 1980) formed by progressive deformation of initially rectilinear fold axes. Figure 6-9-3 illustrates both down-dip verging (Figure 6-9-3A) and west-verging (Figure 6-9-3B) folded quartz veins in biotite mineralization.

Sulphide veins commonly have undulose margins, but rarely exhibit clear folds. In some stopes, these undulations form apophyses that project up to 1.5 metres into the wall-rock and terminate at a point (Figure 6-9-4). Cleavage in adjacent biotite or carbonate ore commonly curves around

these structures, itself defining folds. Well-rounded pyrite grains are common and suggest intergranular flow.

C-S fabrics are locally developed in the biotite and carbonate mineralization. In these locations, flattening (S) fabrics have shallow to subhorizontal dips, whereas the shear (C) fabrics parallel the margins of the shear zone, consistent with a normal shear sense. Asymmetric quartz augen indicate a compatible shear sense. Synthetic Riedel shears, although not common, occur in the Twin zone (Figure 6-9-3D). These have a 60° to 75° southwest dip and record a normal sense of motion.

A striation lineation with an oblique southwesterly down-dip plunge is defined by biotite throughout the Twin zone. Pyrite is commonly streaked along the lineation. The southwesterly plunging drag-fold axes and the elongate biotite spots in the biotite spotted unit parallel this lineation.

## STRUCTURAL FEATURES OUTSIDE THE TWIN ZONE

The internal structural features of the Twin zone also occur in the southwest-dipping laminated shear zones that are present throughout the mine. A subhorizontal cleavage is locally developed for up to several metres into the hangingwall and footwall of the larger shear zones. This cleavage also occurs locally in the footwall of the Twin zone. The hangingwall, however, is not exposed. The cleavage commonly curves to steeper dips adjacent to the shear veins, consistent with drag folding due to normal motion on these zones.

Two orientations of extension veins with moderate north-east and southeast-dipping orientations occur abundantly through the greywacke sequence. They cut fabrics developed in the Twin zone and laminated shear zones, and the biotite spotted dike. Both vein sets consist of blocky to

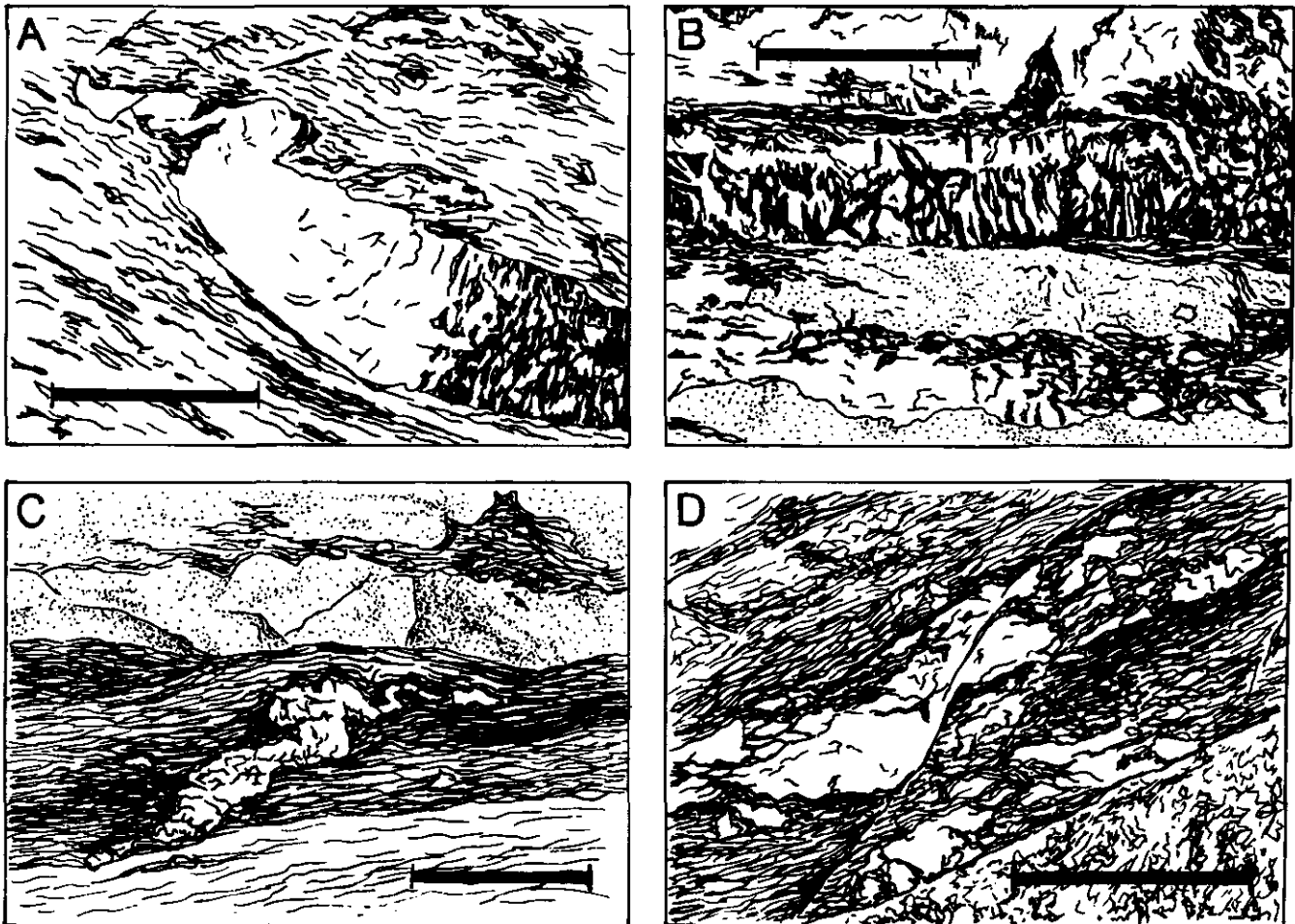


Figure 6-9-3. Internal structure of the Twin zone, drawn from photographs. Massive sulphides are stippled. The scale bar is 20 centimetres long: (A) 420-level undercut, footwall vein, looking southeast. Folded quartz vein in a matrix of laminated calcite and black biotite/annite; (B) 420-level undercut, west pillar, footwall vein, looking north. Alternating quartz and massive pyrite veins. The quartz veins exhibit a coarse bladed intergrowth of annite and quartz; (C) 340-level undercut access, east wall, footwall vein, looking north. West-verging folded quartz veinlet in a band of black biotite ore. Massive pyrite veins and footwall greywacke appear in the upper and lower portions of the picture, respectively; (D) 340-level undercut access, west wall, footwall vein, looking northwest. A synthetic Riedel shear normally offsets a large quartz augen in a matrix of black biotite ore. Below are footwall greywackes.



Figure 6-9-4. 150 vein, 400-level west access, looking southeast. Two massive pyrite-pyrrhotite veins are separated by strongly biotite-altered greywacke. Note the undulose margin of the sulphide vein on the left side of the picture, and the tongue of sulphide that joins the two veins. Drawn from photographs. The scale bar is 1 metre long.

fibrous quartz, calcite, green mica (probably annite), iron carbonate and pyrite, with rarer epidote, pyrrhotite, chalcopyrite and galena. Typical veins are 30 centimetres to 1 metre long and 1 to 4 centimetres wide, and occur at a spacing of 0.5 to 1.0 metre. Where observed, fibres are generally perpendicular to the vein walls. The southeast-dipping vein set frequently forms conjugate en echelon arrays with varying degrees of sigmoidal folding indicative of a reverse sense of shear. Crosscutting relationships indicate that the southeast-dipping set, which is also the most abundant, is younger than the northeast-dipping set. The extension veins are often boudinaged, with subhorizontal, linear boudin axes striking south-southeast. Where they cut laminated shear veins and Twin zone fabrics, the extension veins often show minor normal offset.

The Red Bluff porphyry is intersected for 120 metres by the mine haulage level, and has a strong southwest-dipping foliation throughout. Orthoclase phenocrysts are augenized and flattened parallel to a phyllitic fabric. Locally, elongated phenocrysts are sigmoidally folded. The asymmetry of these folded phenocrysts and occasional drag folding of quartz-magnetite sheeted veinlets suggest a normal sense of movement. A striation lineation developed by micas on the foliation plunges westerly. Southeast-dipping extension veins cut these fabrics.

Brittle fault sets cut all other structural features in the mine. Displacement appears variable, but one northeast-striking set offsets the Twin zone by approximately 80 metres of oblique-reverse displacement, based on offset, thickened portions of the orebody and a consistent slicken-side orientation. These faults are filled with gouge which sometimes contains vuggy quartz-calcite-ankerite-pyrite veins. They commonly have bleached envelopes 1 to 2 metres wide.

## DISCUSSION AND CONCLUSIONS

Down-dip verging folds, probably sheath folds, C-S structures, synthetic Riedel shears, asymmetric augen, sub-horizontal cleavage, and a striation lineation, are common to both the Twin zone and laminated shear zones; all indicate an oblique normal sense of motion. Deformation is relatively localized and brittle-ductile, and is confined to the southwest-dipping phyllitic and schistose foliation ( $S_1$ ) within the laminated shear and Twin zone. In contrast, widespread fabric development within the Red Bluff porphyry indicates more distributed deformation.

The relative abundance of sheath folds in biotite and carbonate mineralization types is probably related to the competency of these rock types. Preferential fold development in biotite and carbonate mineralization types suggests they were less competent during deformation than other mineralization types such as the quartz vein.

The presence of both deformed and undeformed quartz veins (Figure 6-9-3A and 6-9-3B) suggests that several generations of syntectonic quartz veining formed during Twin zone formation. Periodic intervals of extremely high hydrostatic pressure during deformation may have caused dilatency along the cleavage of the zone, allowing the formation of veins parallel to the pre-existing biotite cleavage. A similar mechanism of hydrostatic pressure cycling has been suggested for the formation of crack-seal type veins in comparable deposits, such as Bralorne (Leitch, 1990).

The two extension vein sets record a later phase of deformation than the event which formed the Twin zone. Their moderate to gentle easterly dips, sigmoidal arrays with reverse shear sense, and crosscutting relations with  $S_1$  fabrics indicate they formed in a different stress field than the Twin zone and laminated shear zones. Limited normal movement along Twin zone and laminated shear zones after the formation of the extension veins is indicated by their slight displacement. This phase of movement may have caused the boudinage of the gash veins.

Intrusion of the biotite spotted unit probably occurred late during the first phase of movement on the Twin zone, as it has developed penetrative fabrics similar to those in the zone. Extension veins which cut this dike indicate it must have been in place before the widespread extension veining event.

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