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The Red Bluff gold-copper porphyry and associated precious and base metal veins, northwestern British Columbia

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ABSTRACT

The Red Bluff porphyry is a tabular 2 km long northwest-trending Early Jurassic quartz diorite to monzodiorite body that intrudes a folded Triassic greywacke sequence in the Iskut River area, northwestern British Columbia. The porphyry is 500 m to 800 m northeast of the Snip orebody, which is a southwest-dipping shear-vein, termed the Twin zone, that contains approximately 35 tonnes of gold.

The intrusion associated with the mineralization is characterized by 0.3 cm to 4 cm phenocrysts of K-feldspar in a medium-grained plagioclase porphyritic matrix. It is overprinted by pervasive sericite + quartz ± K-feldspar ± biotite (potassic) alteration characterized by intense stockworking of quartz veins containing magnetite-hematite bands. This assemblage is cut successively by quartz veins with minor iron-oxides and pyrite, and by younger pyrite veins with phyllic envelopes. The system is gold-rich but copper-poor, with typical grades between 0.25 g/t and 0.6 g/t Au, and 0.1% and 0.2% Cu. All styles of alteration and veining have similar abundances of these metals. Where southwest- and northeast-dipping shear zones are developed in the porphyry, veins of all types are sheeted and foliation parallel. These sheeted zones are interpreted to be syntectonic. Asymmetric phenocrysts, folded veins and oblique foliations developed in the 130 haulageway of the Snip mine imply oblique normally-directed shear on the southwest-dipping foliation.

The adjacent Twin zone is a high-grade auriferous shear-vein system that is internally banded with: (1) carbonate-chlorite-biotite veins, with textures indicating formation at least partially by wall-rock replacement, and (2) dilatant quartz-sulphide veins. Veins commonly have potassic alteration envelopes that contain biotite ± calcite ± K-feldspar. The zone is highly deformed and schistose, with numerous kinematic indicators including shear bands, asymmetric folds, rotated porphyroclasts and oblique foliations that indicate a normally-directed shear sense which is parallel to that indicated by fabrics within the porphyry.

Precious and base metal veins within 2 km or 3 km of the Red Bluff porphyry are zoned. Veins and shear-veins proximal to the intrusion, such as the Twin zone, are typically enriched in gold, copper and molybdenum, and have potassic alteration envelopes dominated by biotite. Distal veins usually contain relatively abundant zinc and lead and have sericitic alteration envelopes. Structures of both types have an Early Jurassic galena Pb-Pb isotope signature.

The similarities in structural fabrics and alteration histories in both the Twin zone and the porphyry, the zoning of the vein systems in the area, and the apparently concordant Early Jurassic zircon U-Pb age from the porphyry and galena Pb-Pb dates from the Twin zone and surrounding vein systems suggest that intrusion, semi-brittle deformation and a large mineralizing hydrothermal system were closely related temporally and genetically.

Introduction

The Red Bluff porphyry intrusion is within the metallogenetically important Stewart-Iskut River area, northwestern British Columbia (Fig. 1). The porphyry is a tabular intrusion overprinted by a well-developed gold-copper porphyry system. The intrusion is elongate parallel to the strike of the Snip orebody, a southwest-dipping shear-vein system termed the Twin zone, located 500 m to 800 m to the southwest. Snip is currently the largest gold producer in British Columbia, with published reserves and production of greater than 35 tonnes of gold

This paper documents the geology of the Red Bluff porphyry intrusion and its related porphyry-style hydrothermal system and the possible genetic relationships between these events and the formation of mineralized shear zone-hosted veins and shear-veins developed in the Snip mine and surrounding area. The information is based on geologic mapping, drill core examination, petrographic studies and data compilation completed between 1991 and 1993 (Rhys, 1993).

The Red Bluff porphyry and adjacent Snip mine are located on the south side of the Iskut River valley on the northwest end of Johnny Mountain (Figs. 2 and 3). The area is approximately 110 km northwest of Stewart, British Columbia. The terrain is extremely rugged, with many local peaks above 1900 m in elevation. Glaciers are common, some extending to low elevations (400 m to 800 m) in the valleys. The area is thickly vegetated with a forest of mountain hemlock and Sitka spruce. Steeper slopes and gullies are commonly covered with thickets of slide alder and devils club, which make traversing extremely difficult. Access is by air to the Snip (Bronson) or Skyline airstrips. The Snip mine is also serviced by hovercraft, which ferries supplies along the Iskut River to and from Wrangell, Alaska. There is no road connection to the area.

History

Claims were first staked over the Red Bluff porphyry in 1909 by the Iskut Mining Company, based in Wrangell, Alaska (British Columbia Department of Mines, 1907). Between 1909 and 1911, several short adits were started on various showings in the claim group, and some trenching was done. Subsequently, no significant work was done in the area until 1949, when Kennecott Explorations (B.C.) Limited ran a brief prospecting program in the Bronson Creek area. The Red Bluff area was explored in detail by Cominco Ltd. between 1964 and 1966. Eight holes totalling 342 m were drilled within and adjacent to the porphyry during 1965 (Parsons, 1966). In addition, an auriferous shear zone containing visible gold was discovered by Cominco geologists on the steep north end of Johnny Ridge (Nagy, 1966). However, considering the remoteness of the area and the low price of gold, the exploration results were considered disappointing and the property was abandoned.

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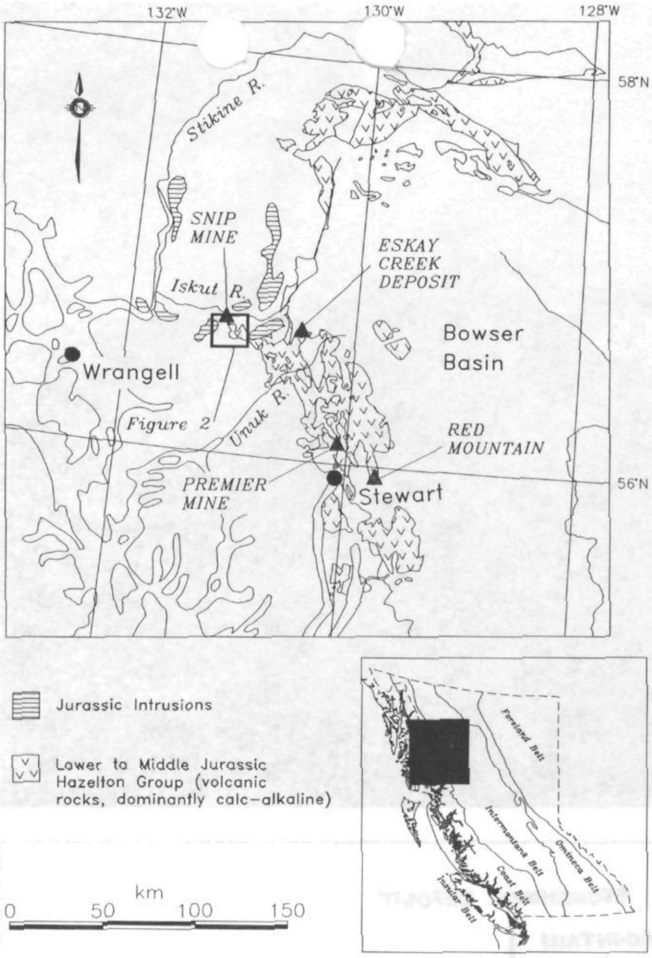

FIGURE 1. Map of northwestern British Columbia showing the location of the Snip mine, other significant gold deposits in the area and Figure 2. Jurassic intrusions, including the Texas Creek Plutonic Suite, and Jurassic volcanic rocks are shown. The map area is outlined in the inset (lower right).

Cominco Ltd. re-staked the area covering the 1966 gold showing with the Snip claim group in 1980, and commenced soil sampling, mapping and trenching. Between 1986 and 1990, under a joint venture agreement with Delaware Resources Ltd., intensive surface and underground drilling by Cominco tested the gold vein system, now known as the Twin zone (Nichols. 1987), and outlined by late 1990 a diluted reserve of 936 000 tonnes grading 28.6 g/t Au (A. Samis, pers. comm., 1991). Delaware Resources, now incorporated into Prime Resources Group Inc., had by this time earned a 40% interest in the property by funding exploration between 1986 and 1990. Production began in January 1991. As of January 1, 1994, the Snip mill had processed 458 291 tonnes grading 30.6 g/t Au, and measured diluted reserves, including 20% at 0 grade, stood at 655 000 tonnes grading 27.0 g/t Au with a further inferred resource of 156 000 tonnes grading 23.7 g/t Au (T. Hodson, pers. comm., 1994). Mining is by trackless mechanized and conventional cut and fill. Approximately 35% of the gold is recovered by gravity circuit and the remainder is in sulphide flotation concentrate.

Between 1988 and October 1994, Skyline Explorations (now International Skyline Gold Corporation) tested the Red Bluff porphyry and its margins with 3.8 km of drilling in 31 drill holes. The drilling outlined a resource of 102 million tonnes; grading 0.72 g/t Au, 0.15% Cu and 4.1 g/t Ag, that contains a higher grade deposit of 37 million tonnes grading 0.74 g/t Au, 0.23% Cu, and 5.60 g/t Ag (International Skyline Gold Corporation, 1994). Other significant deposits in the area include the Johnny Mountain mine, located 6 km south of the Red Bluff porphyry, and the Inel deposit,

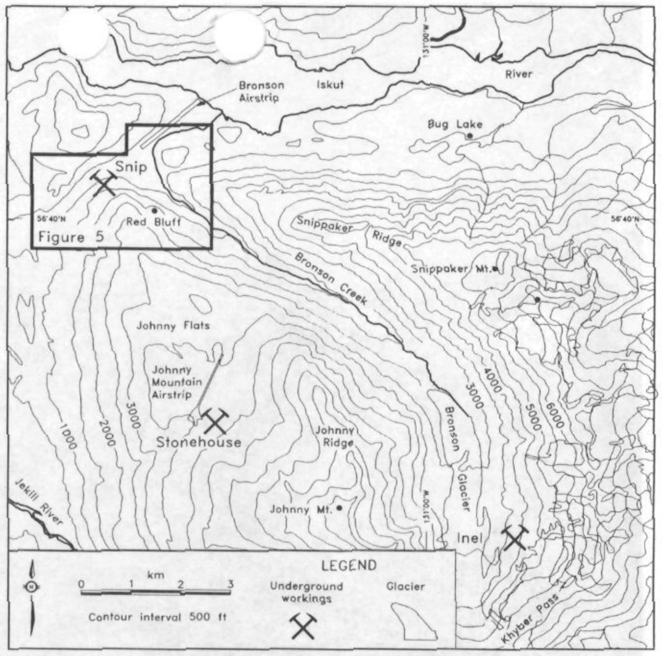

FIGURE 2. Location map of the Johnny Mountain area showing the location of Red Bluff, the Snip mine, Stonehouse deposit, Inel deposit, Figure 5 and geographic features mentioned in the text.

12 km to the southeast (Fig. 2). The Johnny Mountain mine (Stonehouse gold deposit), operated by International Skyline Gold Corporation, produced approximately 2.9 tonnes of gold, 4.5 tonnes of silver and 1030 tonnes of copper from 210 000 tonnes of ore during production from 1988 to 1990 and 1993 (C. Turek, pers. comm., 1994). Mining was by conventional shrinkage stoping.

Geologic Setting

The Red Bluff porphyry and the Snip mine are within Intermontane Belt rocks on the western margin of the Stikine terrane. Three distinct stratigraphic elements are recognized in the area (Anderson, 1989): (1) Upper Paleozoic schists, argillites, coralline limestone and volcanic rocks of the Stikine Assemblage, (2) Triassic Stuhini Group, and (3) Lower to Middle Jurassic Hazelton Group volcanic and sedimentary arc-related strata.

Intrusive rocks in the Iskut River region define five plutonic suites (Anderson, 1993). The Stikine plutonic suite comprises Late Triassic calc-alkaline intrusions which are coeval with Stuhini Group strata. The Copper Mountain, Texas Creek and Three Sisters plutonic suites are variable in composition but are roughly coeval and cospatial with Jurassic Hazelton Group volcanic strata. Elements of the Coast Plutonic Complex are represented predominantly by Eocene granodioritic to monzonitic intrusions of the Hyder plutonic suite which are exposed 12 km south of the Red Bluff porphyry (Britton et al., 1990). The age, mineralogy and texture of the Red Bluff porphyry suggest that it belongs to the metallogenetically important Early Jurassic Texas Creek plutonic suite (Alldrick, 1985, 1987; Brown, 1987). Plutons of this suite are widespread in the Stewart-Iskut River region and range in age from 196 Ma to 185 Ma (Anderson, 1993; Macdonald et al., 1992, and in preparation).

Geology of the Johnny Mountain Area

A folded sequence of turbiditic feldspathic greywackes with subordinate interbedded siltstones, mudstones, volcanic conglomerate and rare carbonate lenses is intruded by the Red Bluff porphyry on Johnny Mountain (Figs. 3 and 4). The greywackes are massive to crudely bedded. Where present, siltstone and mudstone occur as graded interbeds. Individual graded beds may have sharp, scoured basal contacts and may contain siltstone or mudstone rip up clasts.

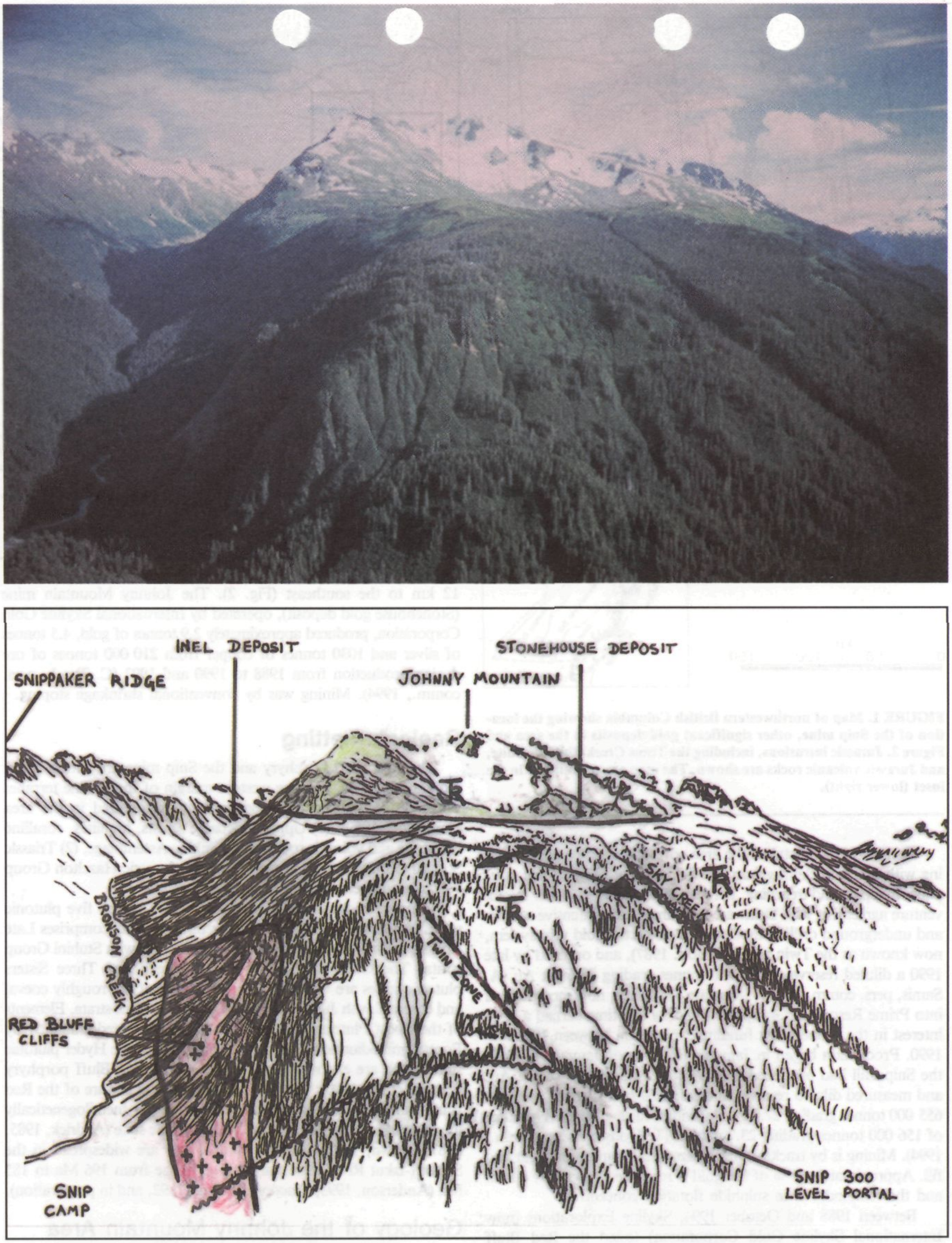

FIGURE 3. Aerial view of Johnny Mountain, northwestern British Columbia. The photograph, looking southeast, was taken approximately 1 km northwest of the Snip camp. Important geologic and topographic features referred to in the text are marked in the accompanying sketch. Volcanic rocks of the Jurassic upper package (Jr) occur at the crest of the ridge, unconformably overlying folded Triassic clastic sediments (Tr). A prominent anticline traces across Johnny flats (upper centre) and plunges gently toward Sky Creek (right). The Red Bluff porphyry (+ +) intrudes the northeast edge of the mountain (left, bottom). The Twin zone at the Snip mine runs through the lower centre of the picture, dipping to the southwest. It is intersected by a northwest-dipping fault near the bottom of the photograph (squiggly lines). Photograph courtesy of Cominco. The photo was taken in 1986 before mine development.

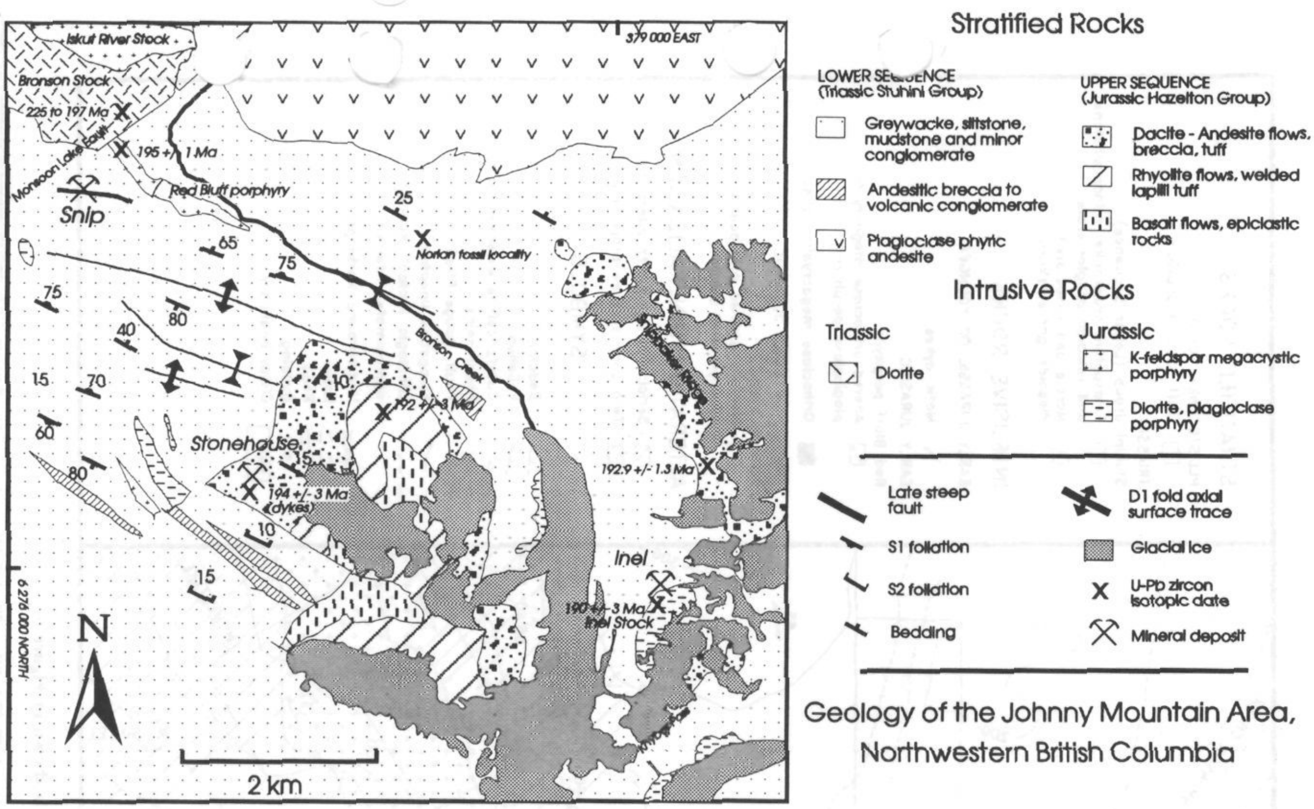

FIGURE 4. Geology of the Johnny Mountain area, northwestern British Columbia. The figure covers the same region as Figure 2.

Pebble to cobble-sized clasts of fine-grained and porphyritic mafic to felsic volcanic rocks are present in coarser beds, and coupled with the common presence of angular to subrounded plagioclase grains in greywacke units, imply a proximal volcanic source. These rocks are probably lateral equivalents of Stuhini Group strata exposed on Snippaker Ridge, 4 km southeast of Snip (Fig. 4), that contain Upper Triassic fossils (Nadaraju and Smith, 1992).

Early Jurassic felsic to intermediate volcaniclastic, pyroclastic and flow rocks that probably belong to the Lower Hazelton Group are exposed to the south and east on Johnny Mountain and Snippaker Ridge (Figs. 3 and 4). They are flat-lying to moderately tilted and unconformably overlie the greywacke sequence (Metcalfe and Moors, 1993; Alldrick et al., 1990). Veins of the Stonehouse gold deposit occur in the basal portions of this overlying sequence.

A variety of Triassic to Tertiary dikes and stocks occur on Johnny Mountain. The Bronson stock is a heterogeneous, medium-grained equigranular plagioclase + clinopyroxene ± amphibole phyric diorite. The stock lies just north of the Snip mine and is separated from the greywacke sequence at the Snip mine by a strong northeast-trending lineament and possible fault (Fig. 4). A poorly constrained Late Triassic U-Pb zircon date (between 197 Ma and 225 Ma) was obtained from a K-feldspar + plagioclase phyric monzodioritic phase of this unit (Macdonald et al., 1992). Several small stocks, sills and dikes of unknown age and intermediate to mafic composition intrude the western side of Johnny Mountain and the Bronson stock. These include several northwest-trending K-feldspar megacrystic porphyry sills that occur 5 km south of the Red Bluff porphyry and Early Jurassic north-dipping plagioclase porphyritic dikes in the workings of the Stonehouse gold deposit (Rhys, 1993).

The Triassic strata on Johnny Mountain are folded into an anticlinal structure defined by tight, locally overturned, northwest-trending regional and parasitic folds (Fig. 4). An adjacent syncline follows the Bronson Creek valley adjacent to the Red Bluff porphyry. The folds are associated with a moderate to steep northeast-dipping axial planar phyllitic flattening fabric (S1), which is best developed on the west side of Johnny Mountain. The folds and associated foliation in the underlying Triassic clastic sequence on Johnny Mountain are truncated by the flat-lying, Early Jurassic angular unconformity. Broad, upright open folds characterize the structure in the overlying Jurassic rocks. All of the structures, and the entire Triassic-Jurassic sequence, were subject to a later deformation resulting in shallowly-dipping to subhorizontal foliation (S2) and mesoscopic recumbant folds (Rhys and Lewis, in preparation). Abundant shallow-dipping extension veins cut the fabrics on Johnny Mountain. Moderate to steep northwest-dipping and southwest-dipping fault sets cut all other lithologies and structures in the area.

The Red Bluff Porphyry System

The Red Bluff Porphyry Intrusion

The Red Bluff porphyry measures approximately 2 km long and 250 m wide, and trends northwest along the northeast edge of Johnny Ridge (Figs. 3 and 5). Contact relationships with country rock are poorly defined but, where intersected by drilling and mine development, are faulted or intrusive. The southwest contact varies from moderately southwest dipping at the north end of the intrusion in the Snip workings (Fig. 6) to subvertical 1 km to the southeast. The northeast contact is subvertical. Screens of altered greywacke up to 40 m wide are common throughout the intrusion (Parsons, 1966).

The Red Bluff porphyry (Fig. 7) is a hydrothermally altered K-feldspar megacrystic, plagioclase porphyritic intrusion of probable quartz diorite to quartz monzodiorite composition. Subhedral tabular pink K-feldspar phenocrysts generally range in length from 2 mm to 20 mm, and are rarely up to 7 cm long. They usually comprise from <1% to 5% of the modal mineralogy (Fig. 7). The matrix to the K-feldspar megacrysts consists of medium-grained porphyry containing phenocrysts of albitic plagioclase (1 mm to 3 mm, 35 to 55 volume %), altered amphibole (up to 4%) and quartz. The plagioclase is usually completely altered to aggregates of sericite ± quartz ± K-feldspar. Mafic phenocrysts, probably originally hornblende from grain shapes, are commonly altered to

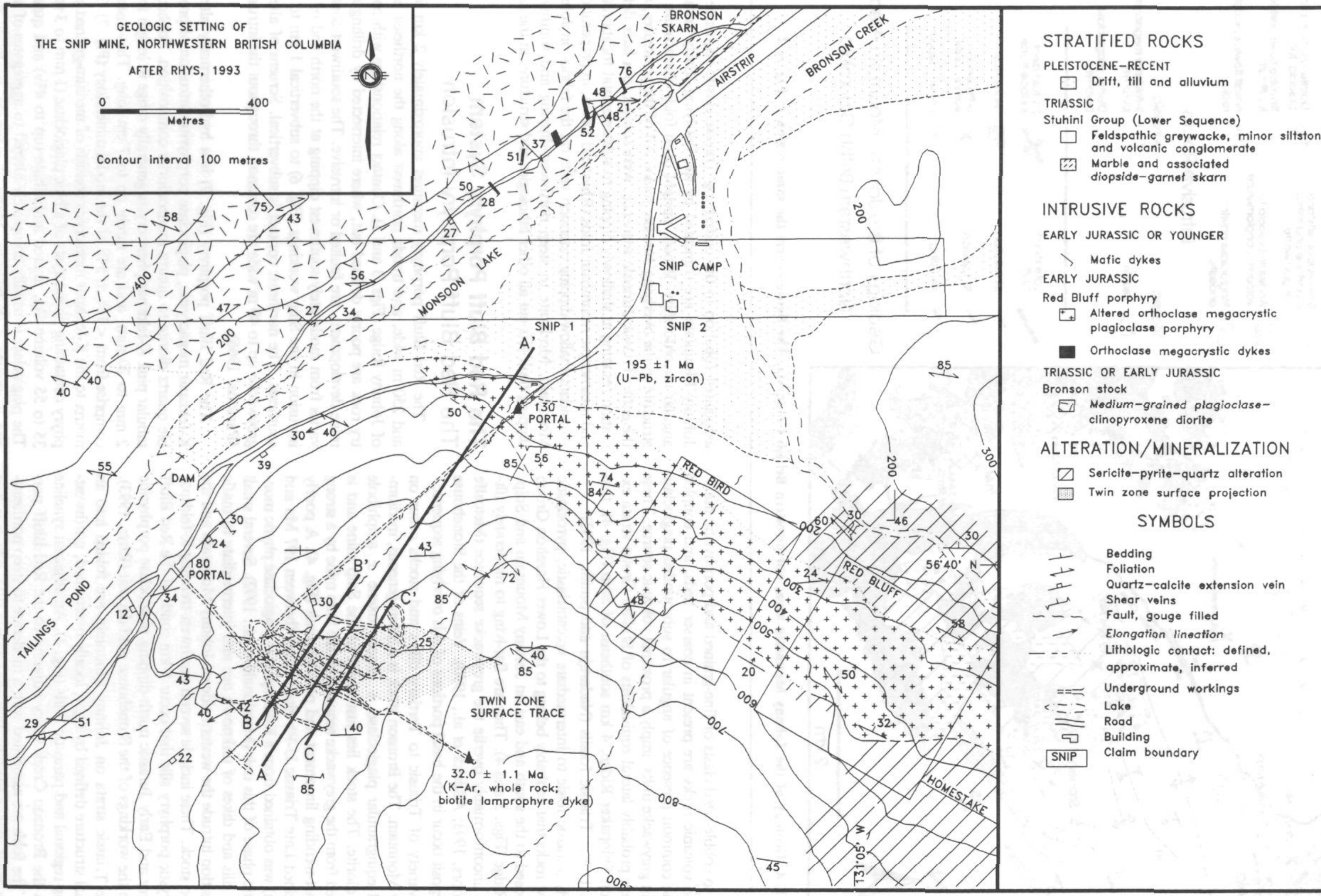

FIGURE 5. Geology of the Red Bluff porphyry and the Snip mine, northwestern British Columbia. Section A-A′ is shown in Figure 6.

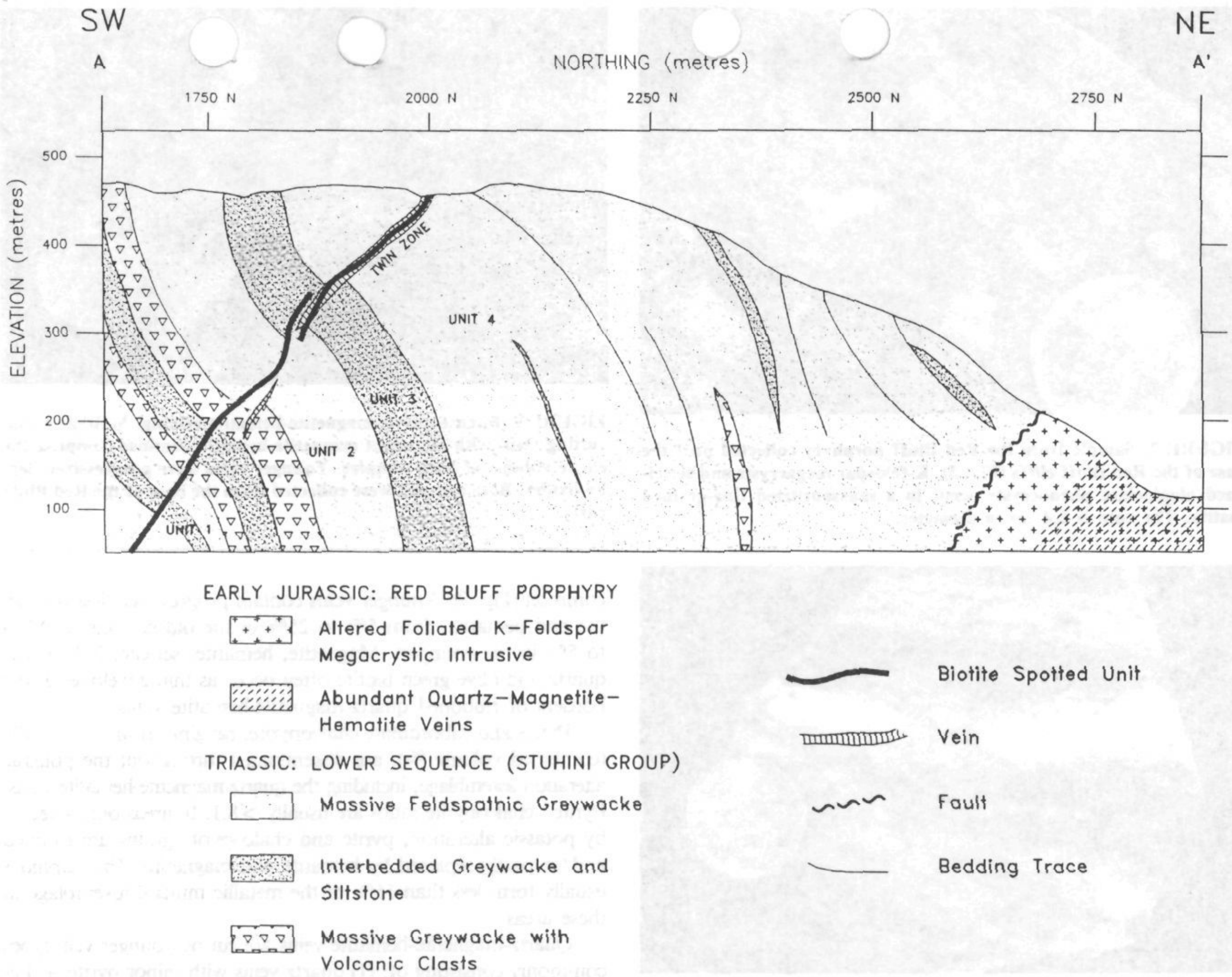

FIGURE 6. Schematic section from the Red Bluff porphyry to the Twin zone, Snip mine. Section, viewed looking northwest, intersects the Twin zone on section 4550 east. The section is located on Figure 5.

magnetite, hematite, pyrite, biotite and chlorite. Equant, clear to smoky subrounded quartz phenocrysts, 0.2 mm to 1.5 mm in diameter, comprise <1% to 4%. In areas of moderate to intense alteration original quartz is difficult to identify because it blends into the alteration assemblage. Accessory minerals include apatite, zircon and titanite. The fine-grained matrix to the phenocrysts forms between 35% and 70% of the rock volume. Unaltered matrix, observed only in two thin sections, consists of a fine-grained aplitic intergrowth of 0.1 mm to 0.2 mm equigranular anhedral quartz (15% to 35%), plagioclase (40% to 70%) and K-feldspar (5% to 15%). Usually, however, the matrix is altered to sericite + quartz ± K-feldspar.

Macdonald et al. (1992) report a U-Pb zircon minimum age of 195 ± 1 Ma from a foliated sericite-K-feldspar altered sample of the porphyry obtained from the north end of the intrusion in the 130 haulage level of the Snip mine (Fig. 5).

Dikes Within the Red Bluff Porphyry Intrusion

Fine-grained, aphanitic, dark grey mafic dikes, commonly 0.5 m to 3 m wide, occur throughout the porphyry. These have variable orientations, but most commonly have northerly strikes and steep dips. Some are porphyritic, with 2% to 5%, 0.5 mm plagioclase and/or 5% to 10% mafic phenocrysts that are altered to green biotite, pyrite, calcite and/or magnetite. The dikes are usually pervasively altered to sericite + green biotite + calcite ± chlorite ± pyrite and may have a schistose to phyllitic foliation that is parallel to the dike margins. Foliation parallel and discordant 0.1 cm to 1 cm wide calcite + chlorite + biotite ± quartz ± Fe-carbonate veinlets are developed in foliated dikes. Subrounded calcite blebs (1 mm to 5 mm wide), probable amygdules, occur in some dikes, and form up to 5% of the dike volume (Metcalfe, 1988). The dikes cut quartz-magnetite-hematite veins of the potassic alteration assemblage (see below), but their relationship to other vein types was not ascertained.

Biotite lamprophyre dikes, undeformed and unaltered, intrude northeast-trending faults in the Red Bluff cliff area (Metcalfe, 1988), as they do to the west in the southern Snip workings. Their confinement to within and immediately adjacent to fault zones, lack of foliation or alteration, and euhedral biotite and subhedral pyroxene phenocrysts distinguish them from earlier foliated and altered mafic dikes within the porphyry. A sample that was collected from one of these dikes in the Snip mine workings returned a K-Ar whole rock date of 32 ± 1.1 Ma (R.L. Armstrong, pers. comm., 1991).

Alteration and Veining Related to the Red Bluff Porphyry Intrusion

The porphyry and adjacent country rocks are affected by several styles of alteration and veining that are dominated by pervasive potassic alteration and associated quartz-magnetite-hematite veins. The main alteration assemblage comprises sericite > quartz + K-feldspar + biotite + magnetite + hematite. This potassic assemblage affects almost the entire accessible volume of the intrusion. Igneous plagioclase is usually completely replaced by a pale green

FIGURE 7. Sample from the Red Bluff porphyry collected near the base of the Red Bluff cliffs (Fig. 3). K-feldspar megacrysts and sericitized plagioclase phenocrysts occur in a saussauritized fine-grained matrix. The coin is 2.4 cm in diameter.

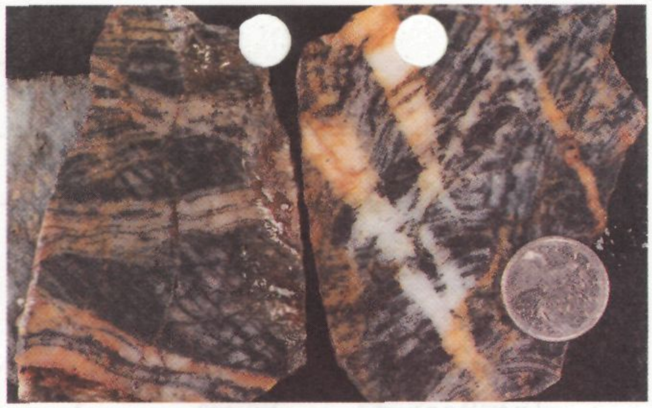

FIGURE 9. Intense quartz-magnetite-hematite veining. Multiple cross-cutting veins with abundant magnetite-hematite laminae comprise the entire volume of both samples. Younger veins have progressively less Fe-oxides. Both samples were collected from the base of the Red Bluff cliffs.

FIGURE 8. Sheeted quartz-magnetite-hematite veins with well developed magnetite + hematite laminae. The veins occur parallel to foliation in a strongly altered phyllitic matrix of dark grey sericite + magnetite + quartz + hematite + biotite. Sample is from the 130 portal at Snip (Fig. 5).

fine-grained felted sericite with minor quartz and K-feldspar. K-feldspar phenocrysts are unaltered to partially replaced by quartz and secondary K-feldspar. In areas of intense quartz-magnetite-hematite veining, pink K-feldspar locally replaces 25% to 50% of the fine-grained quartz-plagioclase igneous matrix. Disseminated and veinlet magnetite with subordinate hematite, constituting between 3% and 10% of the rock volume, occur as individual grains and aggregates that are often intergrown with secondary K-feldspar and olive green biotite after mafic minerals.

Quartz-magnetite-hematite veins are abundant throughout the intrusion, its immediate margins and greywacke screens within it. This variety of vein comprises approximately 80% of all of the veins which cut the intrusion. The veins form dense stockworks that commonly comprise 20% to 60% of porphyry drill intersections. Drill intersections 20 m to >100 m long are commonly composed entirely of intersecting to sheeted sets of quartz-magnetite-hematite veins. Individual veins usually range from 0.5 cm to 3 cm in thickness. Magnetite with subordinate specular hematite constitutes from 0.5% to 25% of the vein volume, often occurring as multiple 0.1 mm to 1 mm wide bands in white quartz (Fig. 8). Magnetite and hematite commonly occur together in individual grains with undulating irregular boundaries separating the two phases. Paragenetic relationships between magnetite and hematite are unclear. Magnetite : hematite ratios are usually greater than 3:1. Multiple generations of obliquely cross-cutting quartz-magnetite-hematite veins are common (Fig. 9). Younger veins contain progressively less magnetite and hematite, from 5% to 25% in the oldest veins to 0.5% to 5% in the youngest. Magnetite, hematite, sericite, K-feldspar, quartz and olive green biotite often occur as thin envelopes at the borders of ribboned quartz-magnetite-hematite veins.

Pyrite and subordinate chalcopyrite, ranging from trace to 4% (combined volume %), are disseminated throughout the potassic alteration assemblage, including the quartz-magnetite-hematite veins. Pyrite : chalcopyrite ratios are usually >8:1. In areas only affected by potassic alteration, pyrite and chalcopyrite grains are rimmed and/or partly replaced by hematite and magnetite. The sulphides usually form less than 15% of the metallic mineral assemblage in these areas.

Quartz-magnetite-hematite veins are cut by younger vein types commonly consisting of: (1) quartz veins with minor pyrite + Fe-oxides, (2) pyrite veins, and (3) calcite-pyrite-biotite-chlorite breccia veins and veinlets.

Quartz > pyrite ± Fe-oxide veins are composed mostly of milky to pale pink quartz. They commonly contain minor (usually less than 2%) disseminated hematite, magnetite, sericite, pyrite, chalcopyrite and/or molybdenite, and are locally vuggy. They are common in the central and southeastern portions of the intrusion where they comprise <1% to 15% of the veining. Veins are commonly 3 cm to 10 cm wide, but locally exceed 60 cm. The veins have no visible alteration envelopes and only rarely contain grey gypsum. They are associated with veinlets of pink K-feldspar ± biotite at the southeastern end of the intrusion.

Pyrite veins and veinlets (Fig. 10) occur both as sheeted and stockwork veins with variable intensity throughout the Red Bluff porphyry, but are most abundant at its northwestern end. They cut quartz-magnetite-hematite veins and the quartz veins described above. The veins comprise between <1% and 10% of the alteration assemblage, depending on location. Chalcopyrite, molybdenite and locally quartz are common vein constituents. Pyrite and subordinate quartz + calcite + sericite ± chlorite veins more than 5 cm in thickness are abundant in the west central portion of the porphyry near its north contact. In other areas, thick pyrite veins are rare and widths of 1 mm to 5 mm predominate. Strong sericite + quartz + pyrite + albite (phyllic) alteration envelopes around many pyrite veins and veinlet stockworks bleach the porphyry groundmass to a pale greenish yellow or grey (Fig. 10). In zones of intense sericitic alteration, magnetite and hematite are completely altered to pyrite and relict ribbon-like banding of textures of the quartz-hematite-magnetite veins are preserved. Sericite, albite, quartz and, more rarely, pink calcite commonly replace K-feldspar phenocrysts and secondary K-feldspar in the alteration envelopes. The altered K-feldspar is chalk white, yellow or pink.

Calcite-pyrite ± biotite ± chlorite veins and breccias are late and cut potassic alteration assemblage and quartz > pyrite ± Fe-oxide veins. Their relationship to pyrite veins was not ascertained. The veins are volumetrically insignificant and comprise less than 1% of the overall alteration assemblage. They occur locally as closely spaced veinlets <2 cm in width. These veins are sometimes associated with pink calcite veinlets. Breccias, 0.3 m to >4 m wide, that are probably related to this style of veining occur at the southeastern end of the intrusion. The breccias contain fragments of altered porphyry, and quartz-magnetite and quartz veins in a matrix of calcite + green biotite + pyrite + quartz + chlorite ± sphalerite ± chalcopyrite (Fig. 11). Disseminated calcite and rhombohedral Fe- or Mg-carbonate grains 0.01 mm to 0.1 mm in diameter, which occur commonly throughout the porphyry and locally form up to 1% of the rock, may be related to this stage of veining.

FIGURE 10. Pyrite veinlets with pale grey sericite envelopes cutting biotite-magnetite-hematite-sericite altered porphyry. Veinlet-controlled pyrite is the most widespread manifestation of phyllic alteration within the Red Bluff porphyry hydrothermal system. The sample is from Skyline drill hole S-1201 (105.3 m), drilled at the southeastern end of the porphyry.

Metal Distribution

The Red Bluff is a gold-rich, copper-poor porphyry system. The system exhibits broad metal zonation with highest gold (0.4 ppm to 0.8 ppm), silver (1 ppm to 7 ppm) and copper (0.1% to 0.3%) values and lowest zinc (<120 ppm) and molybdenum (<50 ppm) obtained from holes drilled in the central portion of the intrusion. The highest average copper and gold values obtained by drilling occur adjacent to this area in altered and veined greywacke screens in the center of the intrusion and in country rock along its central southwest margin (values are typically 0.2% Cu and 0.7 g/t Au). Holes drilled at the southeast and northwest periphery of the intrusion and in adjacent greywacke are significantly enriched in molybdenum (typically 70 ppm to 400 ppm) and depleted in copper (typically <0.08% Cu) and gold (typically <0.35 g/t Au) with respect to the center of the system.

Metal values are usually unaffected by vein type and alteration style or intensity in individual drill holes. For example, both pyrite veins and stockworks and the zones of intense quartz-magnetite-hematite veining that they typically overprint have similar metal values. Locally, however, pyrite veins and veinlets may be significantly enriched in gold and copper with respect to other styles of alteration, grading up to 8.3 g/t Au and 1.3% Cu. Intense zones of quartz-magnetite-hematite veining are locally gold-, silver- and copper-enriched with respect to surrounding altered porphyry, although the reverse has also been observed. The predominance of the quartz-magnetite-hematite veining and related potassic alteration throughout the porphyry, and the consistency of metal values (even in areas affected by younger styles of veining and alteration) suggests that quartz-magnetite veining and related alteration introduced the bulk of the metals. Support for this hypothesis comes from linear correlations between gold and copper in many drill holes (Rhys, 1993), that suggests these two elements were introduced together in a single mineralizing event.

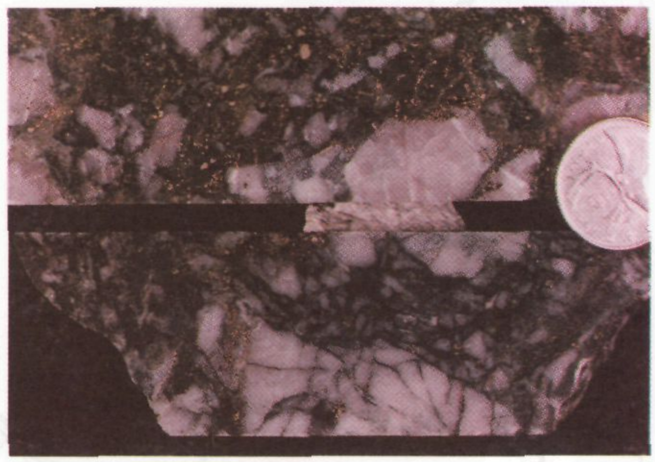

FIGURE 11. Brecciated veins from the southeastern end of the Red Bluff porphyry intrusion (Skyline drill hole S-1200, 89.3 m to 89.5 m). Brecciated pink quartz vein fragments occur in a matrix of green biotite, calcite, pyrite, quartz and chlorite.

Regional Alteration

Veinlet and disseminated brown biotite ± pyrite occurs broadly and abundantly throughout the greywacke sequence of northern and western Johnny Mountain. Biotite abundance is greatest over an approximately 15 km² zone in the greywackes within the Snip mine workings, the southernmost kilometre of the Bronson stock, the northwestern end of Snippaker Ridge, and in greywacke and volcanic conglomerate units along the west side of Johnny Mountain (Fig. 12). The restriction of biotite to this area, its abundance, common veinlet control, and association with pyrite + calcite argues against isochemical crystallization of the biotite and pyrite from the affected units. Instead it suggests the addition of potassium and sulphur, probably by hydrothermal fluid circulation.

Pervasive sericite-quartz-pyrite-K-feldspar alteration is developed in the sedimentary sequence for approximately 1.2 km beyond the southeastern end of the porphyry (Fig. 12). The zone, which reaches a maximum of 600 m in thickness (Metcalfe, 1988), contains both disseminated and veinlet pyrite + sericite ± sphalerite. Several holes drilled in this area (CE zone) averaged 0.47 g/t Au, 6.9 ppm Ag and 3374 ppm Zn over 756 m. Sericite-pyrite-quartz alteration is nearly absent in greywacke adjacent to the northwest end of the intrusion in the Snip workings. A second conspicuous zone of sericite-pyrite alteration affects thickly bedded greywacke in the hanging wall of a southwesterly dipping fault zone along Sky Creek (Fig. 12). The exposed alteration zone is more than a kilometre long, and it affects up to 50 m of stratigraphy. Disseminated pyrite commonly exceeds 3 volume % and is associated with locally abundant pyrite ± chalcopyrite veinlets.

Structure of the Red Bluff Porphyry

Foliation within the Red Bluff porphyry is inhomogeneously developed and large sections are unfoliated. Moderate southwest dipping phyllitic to schistose foliation defined by platy alignment of sericite and flattening of K-feldspar megacrysts outlines a broad shear zone in the Snip 130 portal. Shear bands, asymmetric folds and rotated K-feldspar porphyroclasts indicate a component of normally-directed, simple shear parallel to a westerly plunging elongation lineation on the foliation. Southwest dipping foliation predominates elsewhere in the porphyry, but it is inhomogenously developed and is probably confined to shear zones of variable size.

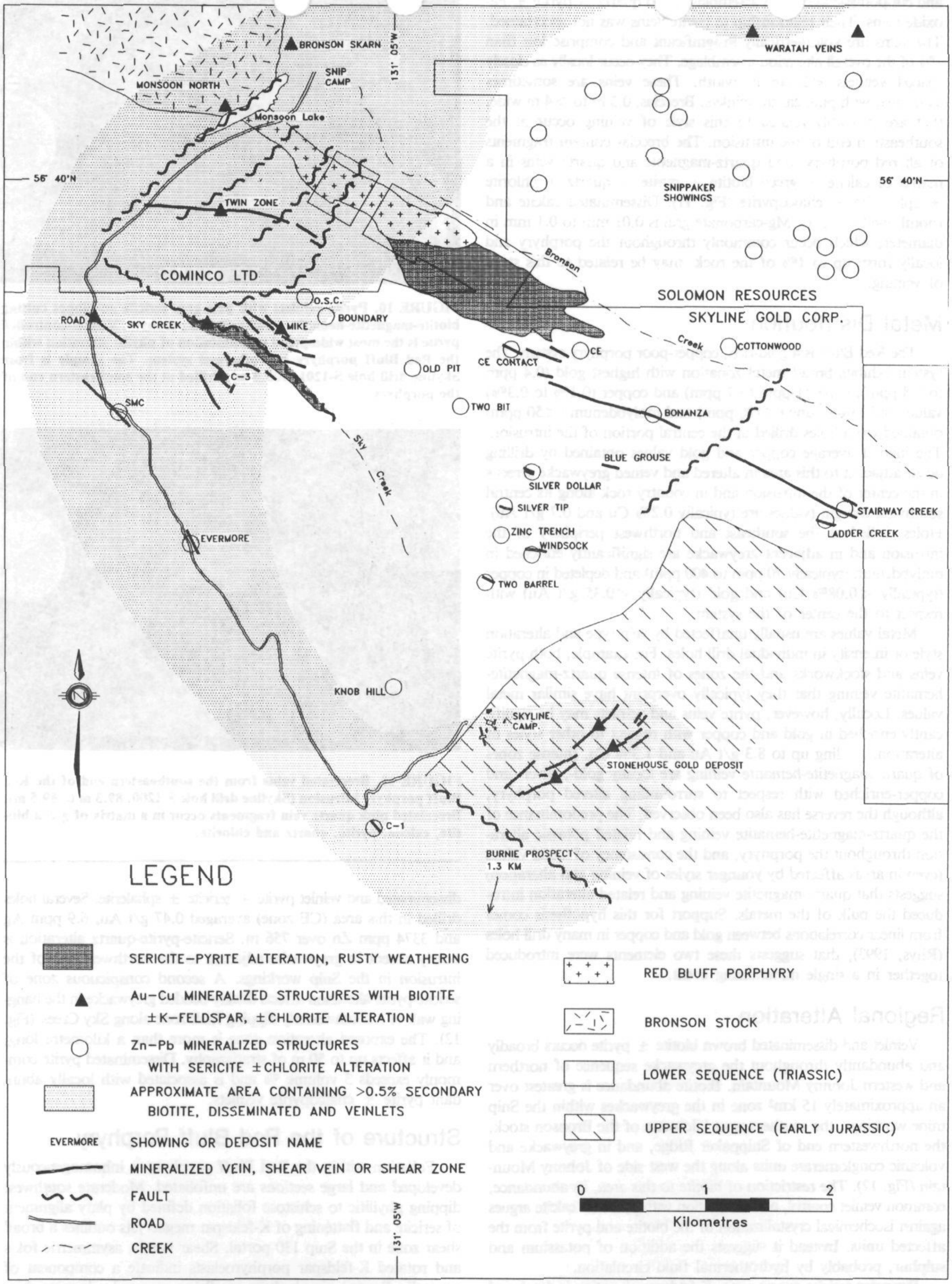

FIGURE 12. Showings and deposits in the northwestern Johnny Mountain area, northwestern British Columbia. The general distribution of secondary disseminated and veinlet biotite is outlined with shading.

Northeast dipping phyllitic foliation is less well developed and was observed at the south end of the porphyry on surface. The significance of this foliation is not understood, but its erratic development suggests that it too may reflect shear zones.

Veins of all generations generally strike subparallel to the length of the intrusion and dip moderately to steeply southwest. Pyrite veins commonly have two orientations that occur together: steep southwest to northeast dipping and moderate to shallow southwest dipping (Moore, 1994). Quartz-magnetite-hematite veins are commonly sheeted, and dip southwest, parallel to foliation where it is developed (Fig. 13).

Angular relationships of foliation parallel quartz-magnetite-hematite veins with subordinate oblique veins, and consistent acute angular relationships between quartz-magnetite-hematite and pyrite veins argue against post vein structural reorientation of the quartz-hematite-magnetite veins into parallelism with the foliation. Thus, the quartz-magnetite-hematite veins are either synchronous with, or younger than, the foliation. Deformation of some sheeted quartz-magnetite-hematite veins (asymmetric folds and boudinage; Fig. 13) together with the preceding argument, argues for coeval development of veins and foliation. Similarly, sheeted southwest and subordinate northeast dipping pyrite veins and veinlets that occur even in the absence of foliation suggest formation during or after deformation.

Steeply dipping, northeast trending gouge-filled faults cut the porphyry and all of the previously described structural features and define pronounced gullies. The faults sometimes contain late quartz-calcite veins with accessory pyrite, and have rusty bleached alteration envelopes. Slickensides, offset markers and drag folding of foliation indicate a right-lateral-reverse sense of displacement (Rhys, 1993).

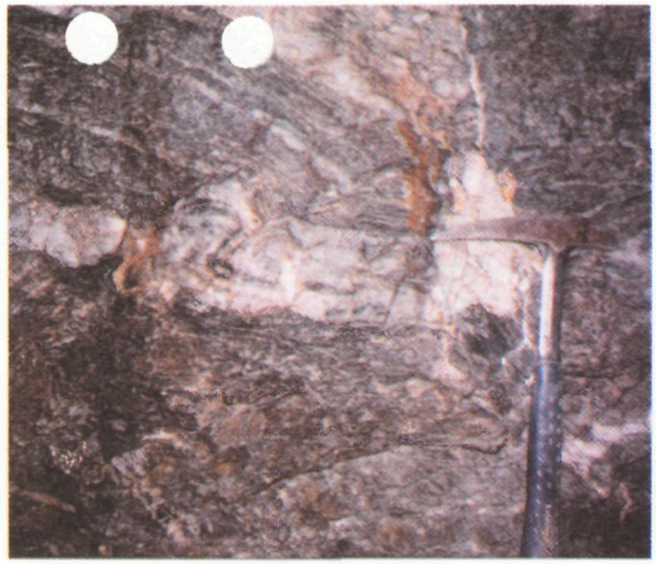

FIGURE 13. Sheeted foliation-parallel quartz veins with magnetite ± pyrite laminae in a matrix of foliated K-feldspar megacrystic porphyry. Note the asymmetric S-shaped fold in the largest vein that suggests a normally-directed shear sense (top of photo to right). A late, thin milky quartz veinlet cuts the other veins and foliation beside the hammer. The view is looking southeast. The photo is from the Snip 130 portal.

Base and Precious Metal Vein Systems, Johnny Mountain Area

Mineralized veins, shear veins and shear zones in the Bronson Creek area are abundant in a northwesterly trending belt which extends from 5 km northwest of Snip on the north side of the Iskut River, to Inel and Khyber pass, 13 km to the southeast (Fig. 12). Vein structures include isolated veins and sets of tabular dilatant sulphide-quartz veins (e.g., the Stonehouse deposit), banded calcite-sulphide-chlorite-biotite shear veins (e.g., Snip and Sky Creek veins), and pervasive sulphide disseminations and veins in phyllonitic shear zones (e.g., SMC, C-3 and Evermore showings). The veins lack textures typical of epithermal systems, such as vuggy, crustiform, banded or comb quartz. With the exception of the Stonehouse veins in the Jurassic volcanic package and shear veins in the Bronson stock, all of the veins on northwestern Johnny Mountain are hosted by the folded Triassic clastic sequence. Mineralized structures are commonly crenulated and folded by the S2 foliation. The structures have galena Pb-Pb isotopic signatures that plot in the Early Jurassic cluster defined for the Iskut River-Stewart areas by Godwin et al. (1991).

The structures have two common orientations, both with moderate to steep dips: southwest dipping and north to northeast dipping. Southwest dipping orientations predominate, usually cutting bedding obliquely to orthogonally. Northerly and northeasterly dipping orientations generally are controlled by pre-existing structural features. North and northeasterly dipping mineralized structures on the east and west sides of Johnny Mountain are parallel to S1 and bedding in the Snip workings, Bonanza zone, C-3 showing and at the SMC showing. Similarly, veins of the Stonehouse deposit obliquely cut, or are subparallel to, north dipping plagioclase porphyritic dikes. The most continuous set of structures occurs along the northeast side of Johnny Mountain and includes the Twin zone, and to the southeast, the CE contact and Bonanza zones (Fig. 12). These define a set of southwest dipping veins that is continuous over a 6 km strike length. Mineralized structures are abundant within 1 km to 2 km west of the Red Bluff porphyry in the Snip mine workings.

Mineralized structures on Johnny Mountain and Snippaker Ridge display zoning of both alteration mineralogy and base metals. West and southwest of the Red Bluff porphyry, relatively gold-copper enriched structures with potassic alteration envelopes occur over an area of approximately 8 km^2 (Fig. 12). These are laminated calcite-biotite-chlorite-quartz or massive pyrite ± pyrrhotite ± magnetite with or without envelopes of biotite and/or K-feldspar, such as the Twin zone at Snip. The veins are relatively copper- and gold-rich, but zinc-poor; Zn:Cu ratios are usually less than 5:1.

Zinc-lead enriched structures with sericite-quartz ± K-feldspar alteration envelopes and assemblages occupy an area of greater than 35 km^2 east and southeast of the porphyry, and south of the previously described region (Fig. 12). The structures include: (1) sericite-quartz-K-feldspar ± biotite shear zones with pervasive sulphide dissemination, such as the SMC and C-3 showings, and (2) pyrite-sphalerite-quartz veins and shear veins (e.g., Silver Dollar, Windsock and Silvertip). The structures are zinc- and lead-enriched, but copper- and gold-poor, although high gold grades occur locally. Zn:Cu and Ag:Au ratios are typically greater than 15:1 and 5:1, respectively. K-feldspar megacrystic felsite stocks, dikes and S1 parallel sills are spatially associated with several of these showings. The intrusions are commonly mineralized and altered, indicating that they predate the termination of the mineralizing event.

Veins of the Stonehouse deposit define a second zone of gold-copper enriched veins with potassic alteration assemblages (Fig. 12).

The Twin Zone and Related Shear-veins at the Snip Mine

The Twin zone shear-vein system strikes 120° and dips 30° to 60° southwest (Figs. 5, 6 and 14). It is the largest of many shear veins in the Snip mine. Thickness ranges up to a maximum of 13 m, but averages approximately 2.5 m. In the eastern and lowest parts of the mine, the zone becomes a series of discontinuous pyrite veins and veinlets. Several smaller *en echelon* shear veins occur below its lower termination. The Red Bluff porphyry occurs northeast of, and has a parallel strike to, the Twin zone (Fig. 5). Distance to the porphyry varies with elevation (Figs. 5 and 6), but averages approximately 600 m.

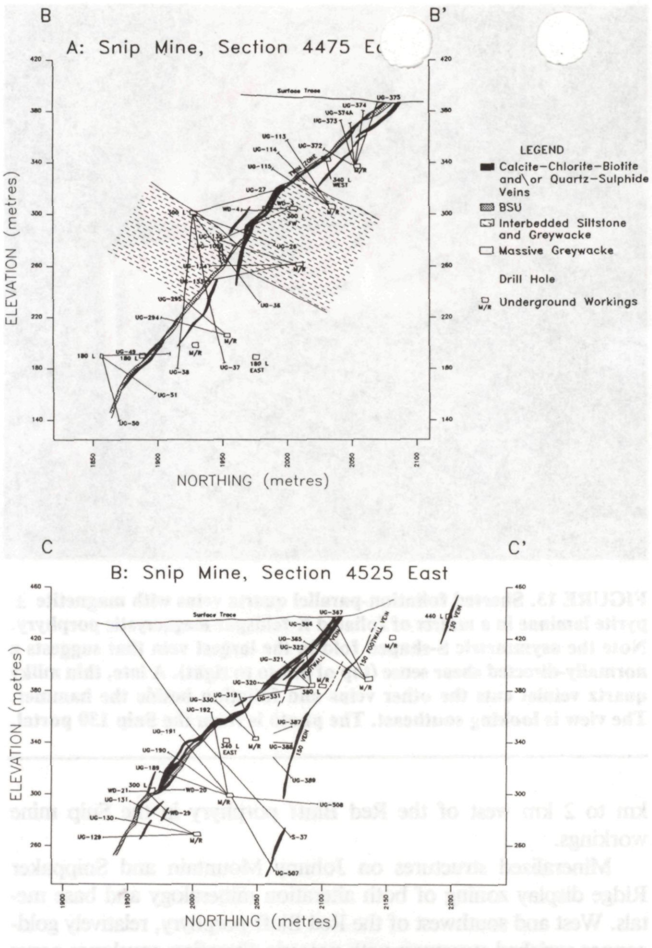

FIGURE 14. Cross-sections through the Twin zone and related veins, Snip mine. View is to the northwest (toward 300° azimuth). The cross-sections are located in Figure 5. Sections are along 030° azimuth. A: Section 4475 East. The dip of the Twin zone changes from approximately 40° above 320 m elevation to >50° below this level. The Biotite Spotted unit (BSU) intrudes the zone and intersects veins below it. Sedimentary units are offset in a normal sense. Note that the Twin zone steepens where it intersects fine clastic units. B: Section 4525 East. Note the Footwall vein, the 150 Footwall vein and the 130 vein; each in turn occurs progressively deeper into the footwall of the Twin zone. These veins have generally steeper dips than the Twin zone.

The Twin zone has a pronounced internal layering of several vein types (Rhys, 1993). Veins of calcite-chlorite-biotite, which typically contain 15 g/t Au to 40 g/t Au, comprise approximately 60% of the zone. They are commonly compositionally layered with alternating laminae of schistose chlorite-biotite and calcite (Fig. 15). Dilatant pyrite-pyrrhotite and quartz veins (Figs. 15 and 16), typically grading >60 g/t Au, form discrete foliation-parallel veins, and occur independently of or within a matrix of the other ore types. Chlorite-biotite and carbonate ore types display progressive alteration sequences suggesting that they were formed by a combination of both replacement and dilation. Alteration envelopes of black biotite 0.5 cm to 2 cm wide surround many veins, internal to an outer bleached K-feldspar-calcite-quartz-sericite envelope. Biotite-rich veins and sulphide veins, common in the lowermost and eastern parts of the zone, have elevated copper grades (0.15% to 0.5% Cu). Chloritic veins are most abundant in the western and uppermost portions of the orebody and are associated with the highest molybdenum grades (0.01% to 0.05% Mo). Coarse visible gold commonly occurs with molybdenite in chlorite-rich veins.

Structures internal to the Twin zone suggest it formed as a dilatant shear zone with a predominantly normal sense of movement. Down-dip verging folds (Fig. 15), sheath folds, synthetic shear bands (Fig. 16), asymmetric augen, rotated quartz and pyrite

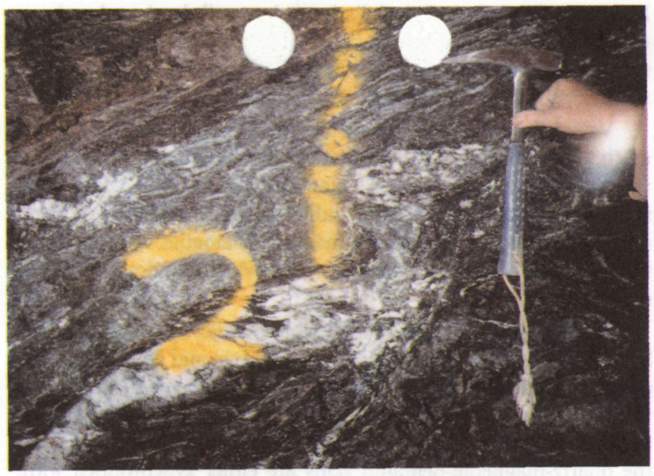

FIGURE 15. Twin zone, 4061 stope undercut, Snip mine. Calcite >chlorite + biotite + pyrite (carbonate ore, above) and quartz (below) veins in a thin portion of the Twin zone. Note the asymmetric fold and pronounced lamination of the veins. The fold vergence suggests a normally-directed shear sense (top of photo to left). View is to the northwest.

porphyroclasts, and oblique subhorizontal foliations are common to the Twin zone and other shear zones in the Snip workings. They indicate an oblique normally-directed shear sense parallel to an oblique southwesterly-plunging lineation developed on foliation surfaces. This slip direction is parallel to the shear sense indicated on shear zones in the Red Bluff porphyry (Rhys, 1993). Deformation is localized and is confined to the southwest-dipping phyllitic and schistose foliation within the shear zones. The fabrics suggest that deformation was accomplished without loss of cohesion at a mesoscopic scale and predominantly by semi-brittle processes. The occurrence of both deformed and undeformed quartz veins, and stacked sets of discrete quartz and/or sulphide veins suggest several generations of syntectonic quartz and sulphide veining during formation of the Twin zone.

A southwest-dipping unmineralized basic biotitic dike, termed the "Biotite Spotted Unit" (Nichols, 1989; Fig. 14), intrudes the Twin zone, and commonly obliquely cuts fabrics and veins developed in the zone. Felted black biotite spots, 0.5 mm to 4 mm long, typically comprise 5 vol.% to 15 vol.% in a fine-grained matrix of intergrown plagioclase with biotite and subordinate sericite. A pervasive phyllitic to schistose foliation defined by the alignment of biotite parallels the dike contacts. Elongation of the biotite plunges parallel to the lineation developed on Twin zone vein foliations. Foliation-parallel calcite veinlets with minor chlorite are commonly developed in the dike where foliation is strongly developed. This dike is texturally and mineralogically similar to mafic dikes in the Red Bluff porphyry.

Discussion

Geologic relationships and characteristics of the Red Bluff porphyry and the Twin zone suggest several common important temporal and genetic relationships. These include:

1. A close spatial association of the Red Bluff porphyry and the Twin zone. Elongation of the porphyry is parallel to the Twin zone.
2. Both have potassic alteration.
3. Mineralized structures on northern Johnny Mountain have metal and alteration zoning consistent with distal portions of a porphyry system.
4. Both have probable syn-kinematic veins. A normally-directed shear sense is indicated on both the Twin zone and Red Bluff foliations.

5. Offset caused by normally-directed simple shear on the Twin zone was coeval [illegible] ore type f[illegible]tion and gold mineralization, before intrusion of the BSU dike and before termination of the biotite-forming hydrothermal system in the Twin zone. Therefore, if the Twin zone predates the intrusion of the Red Bluff porphyry, deformation of the Red Bluff porphyry must postdate the Twin zone. There is no evidence in the Twin zone for a second period of deformation as intense as that observed in the Red Bluff porphyry in the Snip 130 portal.
6. Pb-isotopic data from the Twin zone and other Johnny Mountain structures are consistent with the Early Jurassic U-Pb zircon age of the Red Bluff porphyry.
7. Deformed and biotite-sericite-calcite-pyrite altered mafic dikes occur both in the porphyry and the Twin zone where they cut quartz-magnetite-hematite veins and Twin zone veins, respectively. This suggests that they intruded both areas late during potassic alteration and mineralization. Their abundance within the intrusion suggests that they may be related to late magmatic activity comagmatic with the Red Bluff porphyry, and may thus represent a late stage of emplacement of less differentiated and fluid depleted magma.
8. The Red Bluff porphyry is a gold-rich porphyry system that could have contributed gold and other components to the Twin zone.

Taken together, these relationships suggest that: (1) mineralized structures on northwestern Johnny Mountain with Early Jurassic galena Pb isotopic signatures formed during one magmatically driven hydrothermal event that was synchronous with deformation; (2) metals were not mobilized into the structures by later fluid circulation during a younger phase of hydrothermal activity or deformation; (3) hydrothermal activity and mineralization in the Red Bluff porphyry and the Twin zone were synchronous, and thus the Red Bluff porphyry is a potential fluid source for the Twin zone; and (4) the biotite envelopes on the Twin zone and shear veins are contemporaneous with the potassic alteration event in the porphyry. Mineralized structures on northwestern Johnny Mountain may have formed initially by fluid overpressuring and resultant brittle failure subsequent to release of a hydrous magmatic fluid from the Red Bluff porphyry or a batholithic parent. Once formed, these structures may have acted as channelways, distributing hydrothermal fluids throughout northwestern Johnny Mountain, and localizing deformation. Elevated temperature and presence of the fluids may have facilitated semi-brittle deformation in these structures. Lateral and vertical fluid migration through these structures and mixing with cooler pore fluids would have generated a decreasing temperature and fluid pressure gradient from the porphyry outward with corresponding changes in alteration style, metal content and dilatancy.

The distribution and abundance of biotite in areas distal to the Red Bluff porphyry along the west side of Johnny Mountain and the huge area containing mineralized veins argues against an origin related solely to the Red Bluff hydrothermal system and suggest a larger fluid source, possibly an underlying batholithic parent to the Red Bluff porphyry. Sills and dikes similar in age, mineralogy and texture to the Red Bluff porphyry (e.g., Stonehouse dikes) that lie within or just east of the zone of biotite development and the phyllic alteration zone on Sky Creek may represent the effects of dikes and cupolas derived from a hypothetical buried pluton that also may be the ultimate source of hydrothermal fluids. A cupola underneath the Sky Creek alteration zone may also explain why the distribution of veins with potassic alteration is skewed to the southwest of the Red Bluff porphyry (Fig. 12).

The following sequence of probably overlapping events during the formation of the Early Jurassic Red Bluff porphyry system, suggested by the relationships described above, are:

1. Early pervasive and veinlet biotite formed over an arcuate area of >15 km^2 on northern Johnny Mountain, possibly due to the intrusion of a buried batholithic parent to the Red Bluff porphyry.
2. Intrusion and crystallization of the Red Bluff porphyry with release of a fluid phase was followed by brittle failure and development of fluid channeling structures, and development of a large zoned hydrothermal system. Alteration zones are as follows (Fig. 12): (1) inner potassic, confined to the Red Bluff porphyry, characterized by the development of abundant quartz-magnetite-hematite veins; (2) outer potassic alteration characterized by biotite + K-feldspar associated with auriferous shear veins (e.g., Twin zone) and veinlet and pervasive biotite development; and (3) distal sericite-pyrite alteration associated with zinc-rich veins, shear zones and shear veins.
3. Sericite-pyrite alteration and associated pyrite veins overprinted potassic assemblages within and southeast of the porphyry, and at Sky Creek.

FIGURE 16. Twin zone sulphide and quartz ore types. Interlayered quartz, pyrite and quartz > calcite + chlorite veins. A synthetic shear band crosses the compositionally layered calcite > quartz + chlorite vein in the centre of the picture and indicates a left lateral apparent shear sense (top side to the left) which corresponds to an in situ normal sense of shear.

Similar relationships between gold deposits and intrusions occur throughout the Bronson Creek area in a northwest-trending belt (Rhys and Lewis, 1993). South of the Red Bluff porphyry (Fig. 2) at the Stonehouse (Johnny Mountain Gold mine) and Inel deposits, and east of the porphyry on the Waratah claims, Early Jurassic K-feldspar megacrystic dikes are cospatial and subparallel to relatively zinc-poor auriferous veins that have potassic alteration envelopes. In addition, auriferous porphyry systems with quartz-magnetite-hematite vein systems and associated K-feldspar megacrystic intrusions occur at Khyber Pass and Sericite Ridge, 10 km and 15 km southeast of the Red Bluff porphyry, respective' 'lasts conta' ' laminated quartz-magnetite-hematite ve. .n a strong .ericite altered matrix identified in Early Jurassic (192.9 Ma + 1.2 Ma U-Pb zircon; J. Gabites, pers. comm., 1993) dacites on Snippaker Ridge suggest timing of this style of mineralization soon after intrusion (J. Macdonald, pers. comm., 1993). Elsewhere in the Stewart-Iskut River area, many significant gold deposits and showings that have Pb-Pb isotopic data consistent with a Lower Jurassic age are hosted by, spatially related to, and generally within 500 m of Early Jurassic intrusions and dikes of the Texas Creek plutonic suite suggesting that intrusion and mineralization are broadly coeval (Alldrick, 1993; Godwin et al., 1991; Macdonald et al., 1992). Examples include auriferous sulphide-rich vein systems and stockworks at Red Mountain and Premier (Fig. 1), each with production or reserves of >25 tonnes contained gold, and porphyry gold ± copper deposits at Kerr and Sulphurets.

The relationships described here suggest that porphyry systems, and in particular those related to the Early Jurassic Texas Creek plutonic suite, can contain significant shear zone hosted gold deposits. Porphyry environments have not been traditionally explored for this style of mineralization. Exploration guidelines include (1) syntectonic porphyry intrusions, (2) magnetite-rich porphyry hydrothermal systems, (3) shear zones in or near porphyry systems, and (4) base metal showings.

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