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TECTONIC AND STRATIGRAPHIC CONTROLS OF GOLD-COPPER MINERALIZATION IN THE ROSSLAND CAMP, SOUTHEASTERN BRITISH COLUMBIA (82F/4)

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INTRODUCTION

Historically, the Rossland camp (Figure 2-4-1) is the second largest lode gold producing district in British Columbia, with recovery of more than 84 000 kilograms of gold, 107 000 kilograms of silver and 54 295 tonnes of copper between 1894 and 1957. Molybdenum deposits on the western and southern slopes of Red Mountain, also regarded as being within the Rossland camp, produced 1.75 tonnes of molybdenum between 1966 and 1972.

The geology of the Rossland camp (Figure 2-4-2) has been the focus of a number of studies. Drysdale (1915) presented the first comprehensive description of many of the mines; Thorpe (1967), in an unpublished Ph.D. thesis, described vein and skarn mineralogy in detail and proposed a camp zonation. The regional geology of the Rossland-Trail area has been described by Little (1982) and Höy and Andrew (1991a), and in the vicinity of the camp itself, by Fyles (1984). Recent work by staff of the Geological Survey Branch has focused on Early and Middle Jurassic plutons (Dunne and Höy, 1992, this volume), ultramafic rocks south and west of Rossland (Ash and MacDonald, 1992, this volume), and molybdenum deposits on Red Mountain (Webster *et al.*, 1992, this volume).

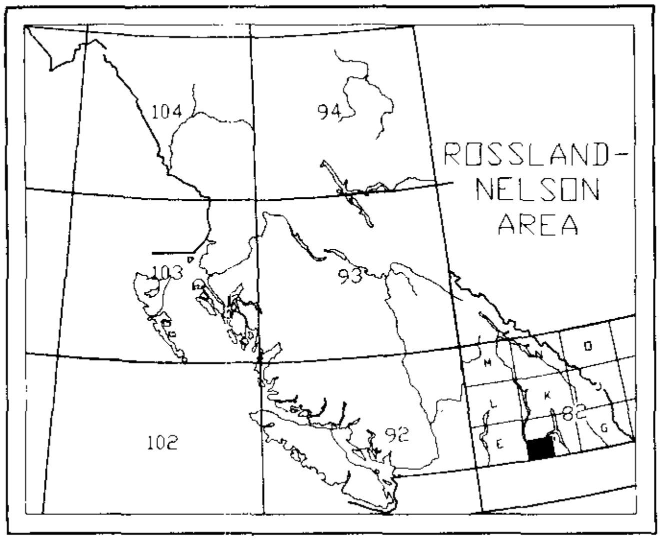


Figure 2-4-1. Location of the Rossland gold camp in southeastern British Columbia.

The field component of the Rossland project, from 1987 to 1990, concentrated on regional mapping of the Rossland Group from Nelson south to Salmo, and west to the town of Rossland. This mapping, with additions from P. Simony and J. Einersen (personal communication, 1990) has been incorporated into a 1:100 000 compilation map (Andrew *et al.*, 1991). The main purpose of the project is to better understand the regional controls and timing of the variety of mineral deposits that occur in the Rossland Group, including shear-related gold deposits southwest of Nelson, alkali porphyry copper-gold deposits such as the Katie, Moochie and Shaft, the numerous lead-silver-zinc and gold-copper veins, both copper and gold skarn deposits, and the vein system of the Rossland camp itself. Continuing work includes some detailed deposit descriptions, fluid inclusion studies, geochemical analyses and stable isotope work.

This paper is intended to serve as an overview of the geology of the Rossland camp, expanding on the preliminary report released in *Fieldwork 1990* (Höy and Andrew, 1991a), to attempt to place constraints on the controls and timing of the deposit types that occur in the camp, and to present data on veins that are now being actively explored -- the Evening Star, Iron Colt and Gertrude.

REGIONAL GEOLOGY

The stratigraphic succession in the Rossland area is illustrated in Figure 2-4-3. The Mount Roberts Formation comprises a succession of dominantly fine-grained siliceous rocks, argillite, carbonate and minor greenstone of Pennsylvanian and possibly Permian age (Little, 1982). Although the Mount Roberts Formation has been assigned to the Harper Ranch Subterrane of the Quesnel Terrane (Monger and Berg, 1984), it may correlate with the westernmost assemblages of the Milford Group, which are assigned to the lower part of the Slide Mountain Terrane (Klepachi, 1985). The Mount Roberts Formation is exposed at Patterson near the United States border and in two thrust sheets just west of the Rossland gold-copper camp (Höy and Andrew, 1991a). It hosts the molybdenum skarn-breccia deposits on the western and southern slopes of Red Mountain.

The Rossland Group unconformably overlies the Mount Roberts Formation. It comprises coarse to fine clastic rocks of the Archibald Formation, volcanic rocks of the Elise Formation and generally fine clastic rocks of the overlying Hall Formation (Figure 2-4-3). The Rossland Group is Early Jurassic in age, bracketed by Sinemurian fossils in the

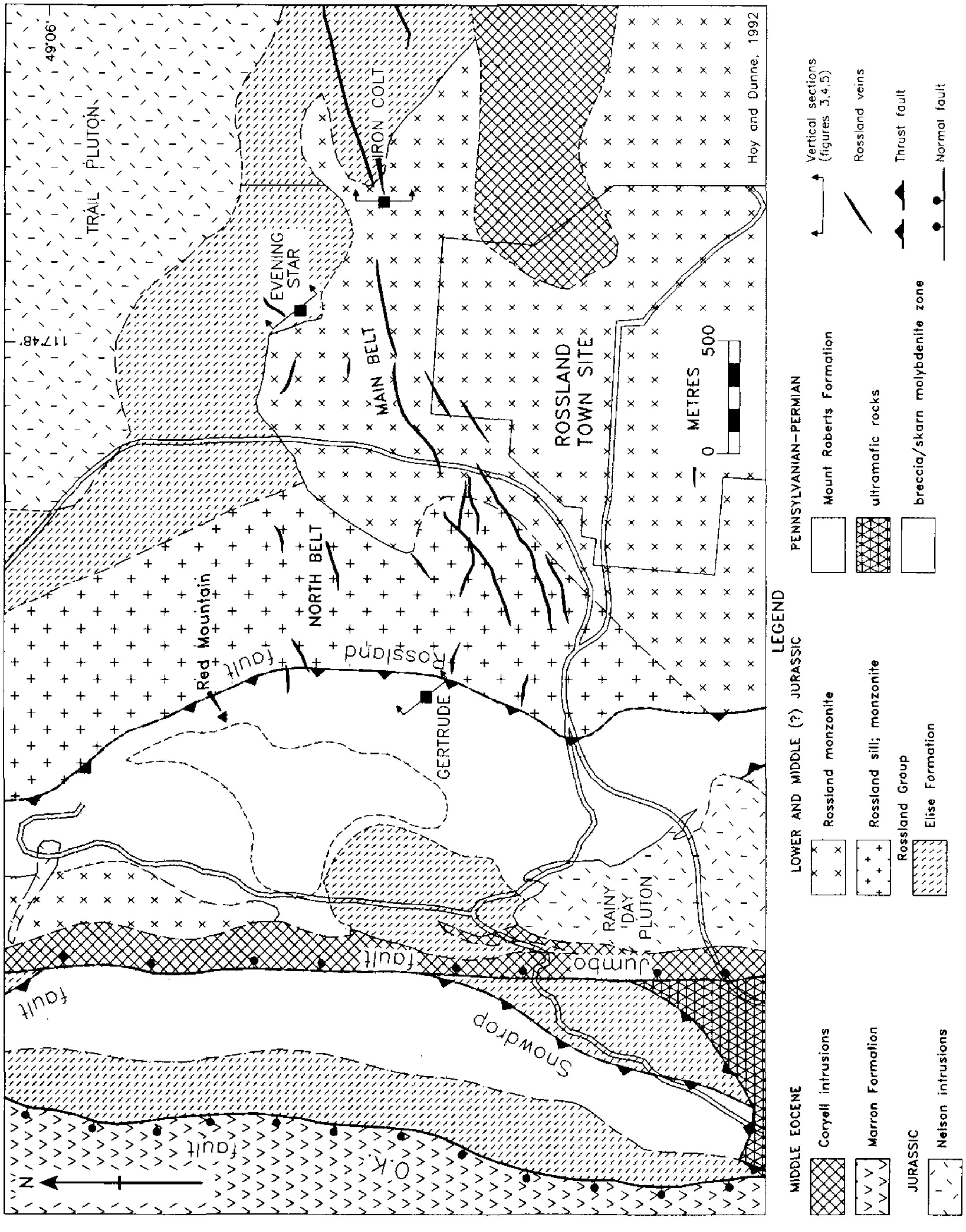
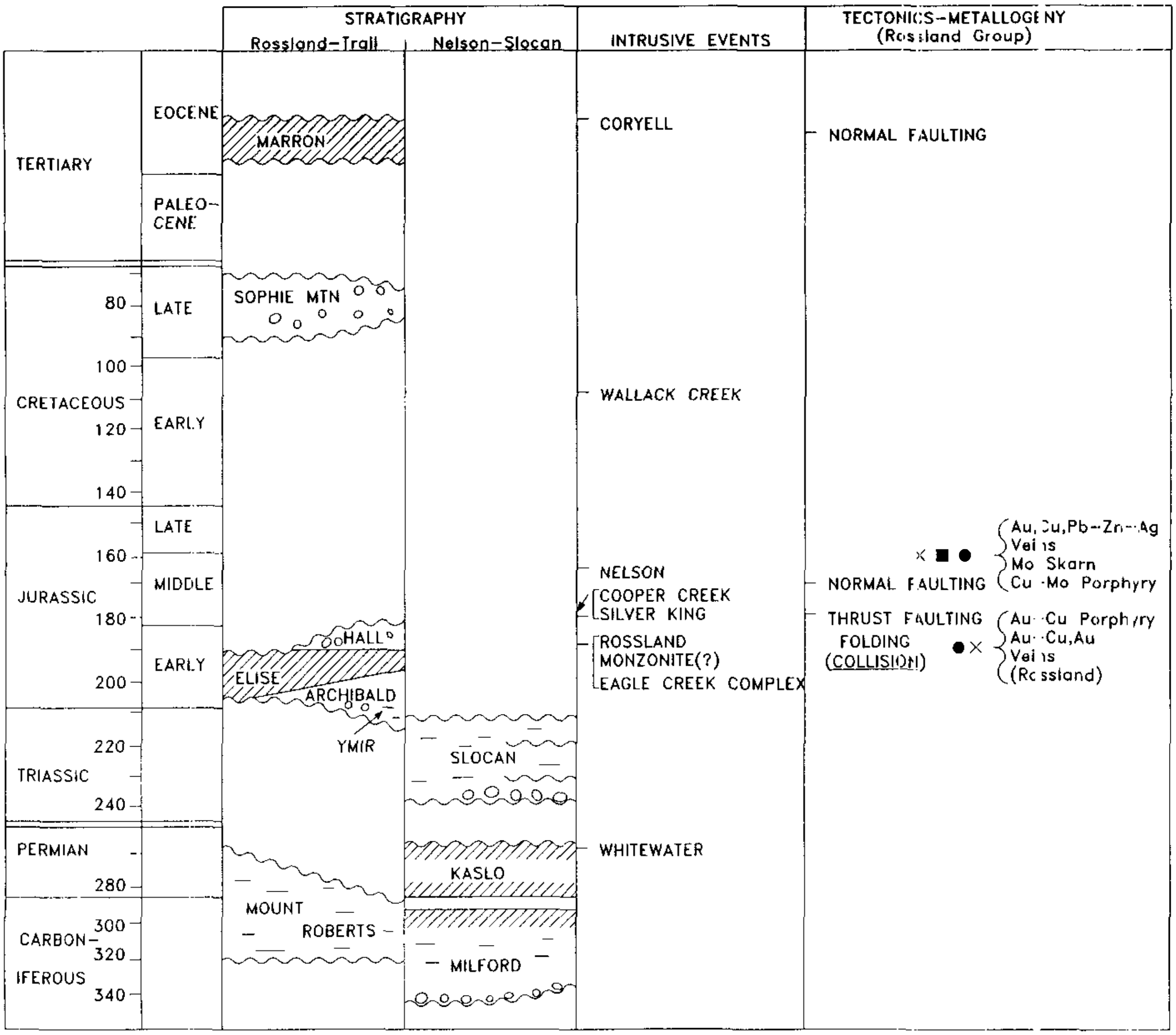


Figure 2-4-2. Geology of the Rossland area, showing distribution and orientation of the main and north copper-gold veins; geology after Höy and Andrew (1991b), Fyles (1984) and Drysdale (1915).



Höy and Dunne, 1992

Figure 2-4-3. Summary diagram showing stratigraphy, intrusive events, tectonics and metallogeny of the Rossland Group.

Archibald (Frebold and Tipper, 1970; Tipper, 1984) and Pliensbachian and Toarcian macrofossils in the Hall (Frebold and Little, 1962).

The Archibald Formation is characterized by pronounced facies and thickness changes (Andrew *et al.*, 1990). It comprises coarse alluvial fan conglomerates near Fruitvale, proximal turbidites farther east in Archibald Creek and more distal turbidites and argillites farther north. In the Rossland area, the Archibald Formation is either missing or comprises a thin veneer of coarse conglomerates (Höy and Andrew, 1991a). These facies changes indicate that the Archibald Formation records deposition on a tectonic high in the Rossland-Trail area and in a fault-bounded structural basin located to the east. The faulted eastern boundary of the tectonic high has been the locus of later movements and intrusive activity, including Eocene normal faulting along the Champion Lake fault and a swarm of Eocene dikes that trend north from Waneta near the western banks of the Columbia River.

The Elise Formation is dominantly a volcanic succession. In the Nelson area, it is divisible into a lower unit of mafic augite-phyric flows overlain by an upper unit of pyroclastic rocks (Höy and Andrew, 1989). Elsewhere, mafic flows and tuffs occur throughout the succession. In the Rossland area, it comprises dominantly tuffaceous conglomerates, water-lain crystal and lapilli tuffs, and some interlayered argillite and siltstone. Basal Elise rocks, exposed just west of Waneta, thin and pinch out to the west along the eastern margin of the Rossland paleohigh.

The Hall Formation, the youngest formation in the Rossland Group, is exposed in the Nelson-Salmo area. Facies changes indicate that it was deposited in a shallow-marine, fault-bounded basin at the end of the explosive Elise volcanism (Andrew and Höy, 1991). It is absent in the Rossland area where Elise rocks are unconformably overlain by late Cretaceous conglomerates of the Sophie Mountain Formation or Eocene volcanic rocks of the Marron Formation, suggesting renewed up-lift of the paleohigh in late or post-Rossland time.

Intrusive rocks in the Rossland area include the Rossland monzonite, Rossland sill and a number of small gabbro stocks and sills that are compositionally similar to Elise volcanic rocks and are assumed to be synvolcanic (Dunne and Höy, 1992, this volume). The Rossland sill (Fyles, 1984), an intrusive diorite that underlies the eastern slopes of Red Mountain, has similar mineralogy to the Rossland monzonite and hosts a number of the Rossland veins. The Rossland monzonite intrudes the Rossland sill, but is cut by the Late Jurassic Trail pluton.

Preliminary U-Pb data on the Rossland monzonite (J. Gabites, personal communication, 1991) suggest a 190 Ma age, indicating it may be comagmatic with the Rossland Group. A small ultramafic body within the Rossland monzonite, a coarse-grained biotite clinopyroxenite at the Centre Star vein, suggests that the Rossland monzonite may be a more evolved phase of an Alaskan-type mafic-ultramafic complex. These complexes are typically coeval and cogenetic with their hostrocks (Nixon, 1990). The Eagle Creek Plutonic Complex west of Nelson, an early, pre-tectonic intrusion that may be coeval with the Rossland monzonite, also contains phases that resemble rocks associated with Alaskan-type complexes (Dunne and Höy, 1992).

ROSSLAND CAMP STRUCTURE AND TECTONICS

The structure of the Rossland area has been described by Fyles (1984), Little (1982) and Höy and Andrew (1991a). Three phases of deformation are recognized. Extensional tectonics in the Early Jurassic produced a block-faulted terrain, with a tectonic high in the Rossland area and a structural basin to the east. The western and northern margins of the tectonic high probably controlled the location and orientation of later thrusts and normal faults, as well as the northeast-trending Rossland break, a zone of structural weakness that is aligned with ultramafic bodies, the Rossland monzonite, the Rossland gold-copper veins and the southwestern extension of the thrust faults.

Compressional tectonics produced east-directed thrusts that carried Mount Roberts Formation, unconformably overlying Rossland Group and ultramafic bodies, over Rossland Group rocks that were deposited on the Rossland paleohigh. This phase of deformation probably correlates with the early compressive deformation recognized in more eastern exposures of the Rossland Group (Höy and Andrew, 1990) and records collision of the eastern edge of Quesnellia with cratonic North America. The age of this compressive deformation is early Middle Jurassic, defined by the syntectonic Silver King intrusive suite (*ca* 182-178 Ma; Dunne and Höy, 1992, this volume) and a post-tectonic intrusion (*ca* 180 Ma) in the Goat River area northwest of Kootenay Lake, called the Cooper Creek stock (Klepacki, 1985).

North-trending normal faults are related to a regional extensional event in southern British Columbia in the Eocene (Parrish *et al.*, 1988; Corbett and Simony, 1984).

ROSSLAND CAMP

The Rossland mining camp includes two separate and distinct deposit types: molybdenite deposits occur in brecciated and skarned Mount Roberts Formation sedimentary rocks on Red Mountain and gold-copper veins in structurally underlying Rossland Group rocks and the Rossland monzonite.

Considerable controversy exists regarding the timing and origin of Rossland gold-copper veins and their relationship with the molybdenite skarn deposits. Early workers (Drysdale, 1915; Gilbert, 1948) contended that sulphide mineralization postdated lamprophyre dikes, hence implying a Tertiary age. Little (1963) generally concurred with that conclusion, citing evidence of sulphide stringers cutting lamprophyre dikes.

Thorpe (1967) noted a camp zonation, with a central copper-gold zone that was centred on the main producing mines, an intermediate zone that contains deposits with a variety of sulphide mineralogies, including molybdenite, cobaltite and bismuthinite, and an outer zone defined by the presence of galena and tetrahedrite. Implicit in Thorpe's model is a genetic link between molybdenite deposits, gold-copper veins and the Rossland monzonite. Thorpe (*op cit.*) attributes heating and fluid generation to the underlying Trail pluton as well as the Rossland monzonite; however, preliminary U-Pb dating of the monzonite indicates a 190 Ma age, an intrusive event 25 million years earlier than the age of the Trail pluton.

Fyles (1984) first established that the Rossland monzonite is older than the Trail and Rainy Day plutons. He concluded that the molybdenum mineralization is associated with these younger plutons, but that the gold-copper veins have a more complex history, with mobilization and redeposition of Early Jurassic mineralization in the Middle Jurassic and Tertiary.

We propose a model that differentiates between early gold-copper vein mineralization and later molybdenum skarn mineralization. We concur with the conclusion that molybdenite deposits are spatially and genetically associated with the late Middle Jurassic Rainy Day and Trail plutons but believe that the copper-gold veins are related to the Early Jurassic Rossland monzonite. We argue that a compressional tectonic event separates these two mineralizing events; gold-copper veins formed prior to the thrust faulting, whereas molybdenite mineralization formed primarily in an upper thrust plate, after its emplacement on the Rossland sill, Rossland monzonite and Elise volcanic rocks.

GOLD-COPPER VEINS

The Rossland veins are dominantly pyrrhotite with chalcopyrite in a gangue of altered rock with minor lenses of quartz and calcite. Pyrite and arsenopyrite are common accessory sulphides. The veins are in three main groups referred to as the north belt, the main veins and the south belt. The north belt and main veins are shown on Figure 2-4-2; the south belt veins are within the Rossland Group several hundred metres to a kilometre south of the Rossland monzonite.

In the north belt, a zone of discontinuous veins extends eastward from the northern ridge of Red Mountain to Monte Cristo Mountain. The veins trend east and dip north at 60° to 70°. The largest, on the Cliff and Consolidated St. Elmo claims, is hosted by the Rossland sill. The Evening Star vein (Figure 2-4-2) is within Elise volcanic rocks near the eastern limit of the north belt.

The main veins form a continuous well-defined, steeply dipping fracture system that trends 070° from the southern slopes of Red Mountain northeastward to the eastern slopes of Columbia-Kootenay Mountain. More than 98 per cent of the ore shipped from the Rossland camp was produced from deposits in a central core zone between the large north-trending Josie and Centre Star dikes. These deposits included the Le Roi, Centre Star, Nickel Plate, Josie and War Eagle orebodies. The Gertrude is on a north-northwest-trending segment of the main vein system, straddling the Rossland thrust fault. The Iron Colt is within Rossland monzonite on an eastern extension of the main vein system.

The principal veins in the south belt, including the Bluebird and Mayflower, trend 110° and dip steeply north or south (Fyles, 1984).

EVENING STAR (82FSW102)

The Evening Star produced 56.7 kilograms of gold, 21.5 kilograms of silver and 1276 kilograms of copper from 2859 tonnes of ore during the periods from 1896-1908 and 1932-1939 (Fyles, 1984). This production was mainly from a wide and irregular northeast-trending vein of arsenopyrite, pyrrhotite, pyrite and chalcopyrite (Drysdale, 1915). The veins have a high cobalt content with danaite, a cobaltiferous arsenopyrite, identified and samples of the pyrrhotite containing 1.58 per cent cobalt and 0.67 per cent nickel oxide (Drysdale, *op cit.*). Sulphides are also disseminated in silicified, skarned country rock – siltstone and augite porphyry of the Elise Formation.

Recent drilling beneath the mined veins has intersected both thin, irregular veins and zones of mineralized and altered country rocks (Figure 2-4-4). These zones are at the immediate contact with the Rossland monzonite or in thin selvages between tongues of monzonite. The best intersection, in diamond-drill hole 88-37, (not shown on the plane of the section in Figure 2-4-4) contained 35.7 grams per tonne gold over 4.4 metres.

The zone intersected in drill hole 89-92 comprised dominantly diopside skarn with variable amounts of garnet and hornblende or actinolite. Petrographic analyses of three samples indicate that diopside is commonly partially replaced by epidote or actinolite; hornblende commonly has minor chlorite-epidote alteration. Calcite is interstitial and thin quartz-calcite veins with sulphides cut the skarn. Pyrrhotite is the dominant sulphide, occurring in massive, irregular veins, thin discontinuous veinlets and as disseminated grains in skarn. Chalcopyrite is intimately intergrown with pyrrhotite or occurs as finely dispersed grains. Only minor sphalerite was recognized, enclosed within pyrrhotite. Sample 92-392 contained isolated grains of arsenopyrite, also enclosed in pyrrhotite.

Chemical analyses of three skarn samples are given in Table 2-4-1. Gold content in Sample 92-385 is 1.9 ppm; high cobalt and arsenic values in this sample probably reflect the presence of cobalt-rich arsenopyrite. Lead and zinc values are low in all three samples.

FLUID INCLUSIONS

Fluid inclusions in quartz from the Evening Star vein were studied to better define the environment of deposition for this deposit as well as others in the Rossland Group (in progress). Quartz is an ideal mineral for study of fluid inclusions because it has high tensile strength and is stable under most metamorphic conditions in the crust. It is also readily mobilized by fluids and reprecipitated in veins and pods.

Samples from the Evening Star vein show 'wispy' textures (millions of healed microfractures) characteristic of veins generated at depths of greater than 4 kilometres (J. Reynolds, personal communication, 1991). Although most fluid inclusions are less than 1 micron, some range from 6 to 12 microns in maximum dimension. They occur along healed fracture planes or as irregular, three-dimensional clusters and are secondary in origin. Secondary inclusions, formed by sealing and healing of fluid-filled fractures in minerals (Shelton and Orville, 1980; Smith and Evans, 1984), are common in rocks with low porosity or in environments in which grains are subject to tectonic or thermal stresses during or after growth (Crawford and Hollister, 1986).

Measurements were made on microfractures defined by secondary inclusions with uniform liquid to vapour ratios. These occur near or within quartz embayments in sulphide grains (Plate 2-4-1), or on similar microfractures with sulphides occuring along the plane of the fracture. Because the fluid inclusions in the ore minerals cannot be studied, one cannot state with confidence that the inclusions in the quartz embayments contain samples of the ore-forming fluid. However, the proximity of these inclusions to sulphide grains suggests at least a close temporal relationship to the ore fluid.

Three compositional types of fluid inclusions have been identified in quartz through observation of phases present at room temperature (21°C) and freezing (to -130°C) and heating (to 30°C) experiments.These are: an aqueous fluid of low salinity; a fluid of low salinity containing varying proportions of water and carbon dioxide; and a non-saline carbon dioxide rich fluid containing varying amounts of methane and nitrogen (Table 2-4-2).The compositions of fluid inclusions in Rossland Group veins (H_2O, CO_2 and $CH_4 + N_2$, in that order of abundance) are similar to those found in deep environments typical of mesothermal veins.

The wispy textures in quartz veins at the Evening Star deposit and abundant carbon dioxide and methane phases in fluid inclusions are typical of veins generated at depths of greater than 4 kilometres. Homogenization temperatures for

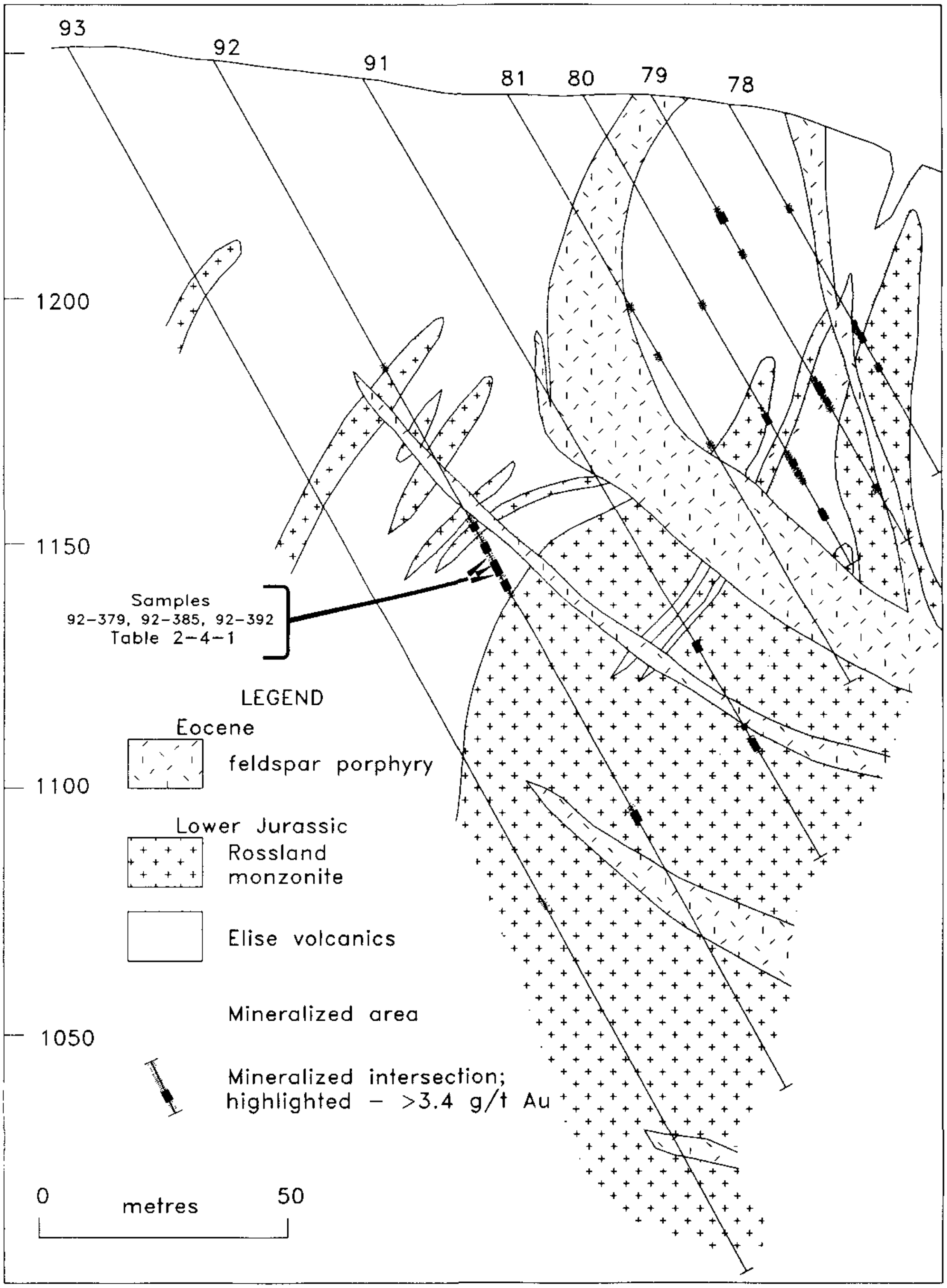


Figure 2-4-4. Vertical section through the Evening Star deposit, viewed to the northeast (*see* Figure 2-4-2 for location); section and data from D. Wehrle, Vangold Resources, Inc.

TABLE 2-4-1
ANALYSES OF SELECTED SAMPLES OF DRILL CORE FROM THE EVENING STAR AND GERTRUDE DEPOSITS

Sample No.	Au (ppb)	Ag (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	As (ppm)	Ba (ppm)	Co (ppm)	Cr (ppm)	Mo (ppm)	Ni (ppm)	Bi (ppm)	Fe (%)	Mn (ppm)	Cd (ppm)	Li (ppm)
92-379	313	0.75	0.20%	5	114	9	—	87	13	<5	8	8	26.4	0.40%	0.3	16
92-385	1920	<0.5	19	11	62	14	—	25	—	<5	2	24	10.5	0.44%	0.4	10
92-392	1210	2.5	0.19%	50	80	4500	220	438	62	<5	74	40	14	957	0.4	29
91-16-531	474	0.5	231	23	45	16	3300	45	120	<5	109	5	6.06	705	<0.3	20
91-16-546	26100	3.0	0.12%	12	108	32	350	53	130	25	122	104	10.1	996	1	26

Samples 92-379, 385, 392 from Evening Star; samples 91-16-546, 531 from Gertrude. Sample locations are shown on Figures 2-4-4 and 2-4-5.

Plate 2-4-1a. Microfractures in quartz (white) defined by secondary fluid inclusions, Evening Star vein (field of view = 93 microns).

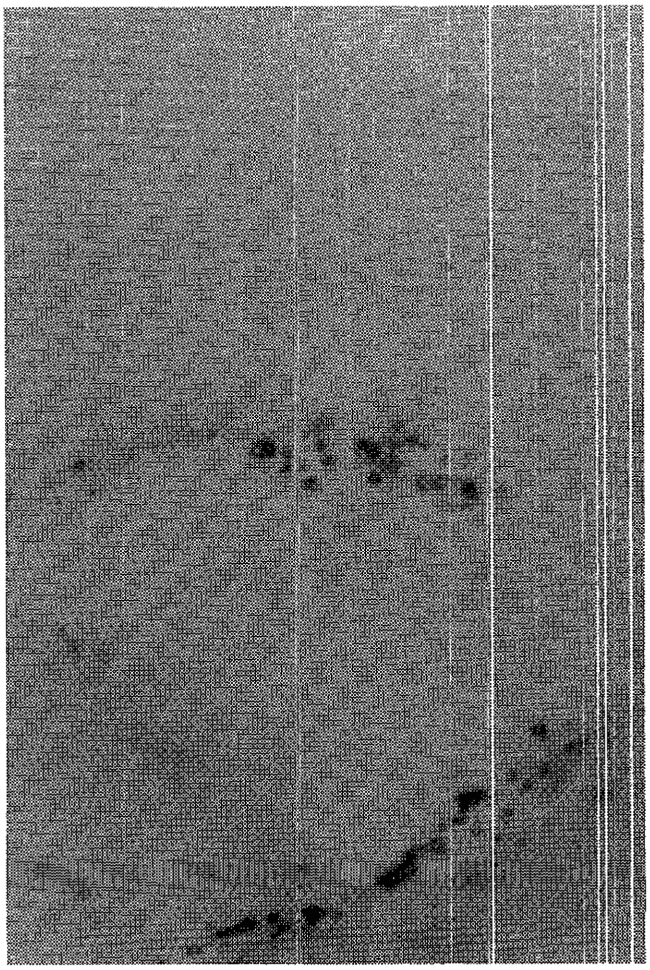


Plate 2-4-1b. Detail of microfractures, note uniform liquid to vapour ratios (field of view = 93 microns).

aqueous fluid inclusions range from 307 to 313°C; three-phase carbon dioxide and water inclusions homogenize at 350°C. These high temperatures are reasonable for mesothermal veins generated by either regional greenschist metamorphism or possibly contact metamorphism.

GERTRUDE (82FSW108)

Development of the Gertrude claim near the turn of the century consisted of a tunnel and prospect shaft (Drysdale, 1915). At that time, material on the dumps comprised pyrrhotite, chalcopyrite, pyrite, arsenopyrite and minor molybdenite. Recent drilling by Vangold Resources, Inc. has intersected a number of mineralized intervals, dominantly in augite monzonite of the Rossland sill at the contact of, or structurally beneath the overlying Mount Roberts Formation (Figure 2-4-5). The best intersection was 4.5 metres containing 14 grams per tonne gold.

The section through the Gertrude vein system in Figure 2-4-5 shows that the contact of the Mount Roberts Formation and Rossland sill is cut by lamprophyre and feldspar porphyry dikes of probable Tertiary age.

TABLE 2-4-2
TEMPERATURE (°C) AND COMPOSITION DATA FOR FLUID INCLUSIONS AT THE EVENING STAR PROPERTY, ROSSLAND AREA

Sample Number	CO_2 Melting	H_2O Initial Melting	H_2O Final Melting	Clathrate Melting	CO_2 Homogenization	H_2O Homogenization	Decrepitation	Salinity NaCl eq.wt. %
Type I: low-salinity aqueous inclusions								
1	—	-24.3	-3.0	—	—	313.1	—	4.9
2	—	-25	-3.4	—	—	307.8	—	5.5
3	—	—	—	—	—	312.8	—	—
Type II: CO_2-H_2O inclusions								
4	-57.4	—	-1.1	—	21.9	—	—	—
5	—	-26	-2.4	7	25.4	—	—	—
6	-57.4	—	-0.9	—	21.6	—	346	—
7	-58.5	—	-2.8	—	24.2	351.5	—	—
8	-57.3	—	—	—	10.8	—	—	—
9	-58.5	—	—	10.2	23.9	—	—	—
Type III: CO_2-CH_4 inclusions								
10	-58.7	—	—	—	13	—	—	—
11	-59.2	—	—	—	8.5	—	—	—
12	-57.1	—	—	—	7.1	—	—	—

Thermometric data was obtained using a Fluid-Inc. adapted U.S.G.S. gas-flow heating-freezing system.
Measurements of phase transitions in any inclusion between -65°C and +30°C were reproducible to ±0.2°C.
At >30°C, results are reproducible to ±1.0°C.

Mineralization is in steep north-dipping veins and veinlets that carry pyrrhotite and minor chalcopyrite. Skarn alteration up to several metres thick is associated with the veins. The skarn comprises mainly diopside with minor garnet, epidote, amphibole (hornblende), chlorite and garnet. Petrographic examination indicates that the diopside is early, commonly replaced by epidote and amphibole, and calcite is interstitial. The dominant sulphide is pyrrhotite, occurring in large irregular grains, disseminated, or in feathery veinlets. Chalcopyrite is intergrown with pyrrhotite but also occurs as small isolated grains in silicates.

Chemical analyses of two skarn samples from diamond-drill hole 91-16 are given in Table 2-4-1. Gold content in Sample 91-16-546 is 26 ppm and copper, 0.12 per cent.

IRON COLT (82FSW100)

The Iron Colt (Figure 2-4-2) is part of the eastern extension of the main vein system. This system continues eastward to the Columbia-Kootenay vein. Although the Iron Colt has had considerable underground development, it has had minimal production, with 186 grams of gold and 466 grams of silver recovered from 20 tonnes of ore (Fyles, 1984). The vein strikes north-northeast and dips steeply north (Drysdale, 1915). It comprises massive pyrrhotite with some chalcopyrite in altered Rossland monzonite.

Recent work on the Iron Colt includes diamond drilling in a joint venture by Antelope Resources, Ltd and Bryndon Ventures, Inc. Current work by Vangold Resources, Inc. includes continued drilling and rehabilitation of old underground workings.

A vertical section through the Iron Colt is illustrated in Figure 2-4-6. Steep north-dipping veins and associated alteration occur at the contacts of phases of the Rossland monzonite or in thin selvages of the Elise Formation within the monzonite. Mineralization is cut by Tertiary lamprophyre and feldspar porphyry dikes. The best assay, in diamond-drill hole 89-87, returned 243 grams per tonne gold over a 2.5 metre interval. Up-dip, in drill hole 90-1, a 1.8-metre interval assayed 8.2 grams per tonne gold. A second vein, approximately 20 metres to the south, assayed 3.77 grams per tonne gold in a 1.3 metre interval and 0.48 grams per tonne over 6.7 metres in drill holes 89-87 and 90-1, respectively (Figure 2-4-6). Other mineralized intersections included 14 grams per tonne gold over 4.6 metres in hole 91-16. These veins are surrounded by alteration zones a few metres wide that contain only minor disseminated sulphides.

SUMMARY AND DISCUSSION

The Rossland camp has many similarities with Archean mesothermal gold deposits or "greenstone gold deposits" (Hodgson *et al.*, 1982). It occurs in a dominantly mafic volcanic pile spatially associated with an oceanic assemblage (Mt. Roberts Formation), is associated with felsic intrusive rocks and ultramafic bodies, and occurs along a major structural break.

The origin of these mesothermal gold deposits is debatable (Kerrich, 1991; Pantaleyev, 1992), with most models relating mineralization to spatially associated intrusions (*see*, for example, Burrows *et al.*, 1986), discharge of metamorphic fluids (Kerrich, 1989), or possibly deep circulation of meteoric water (Nesbitt and Muehlenbachs, 1989). Most commonly, gold mineralization is interpreted to have formed in an accretionary tectonic setting, considerably later than the host volcanic rocks, with fluid flow focused by crustal faults (Kerrich and Wyman, 1990). Despite the apparent similar tectonic setting for Rossland Group rocks, on the eastern margin of an accreting plate, additional geochronological and isotopic data are necessary to conclude that Rossland mineralization is related to this accretionary process.

The Rossland gold-copper camp is within and along the margins of the Rossland monzonite. This has led recent

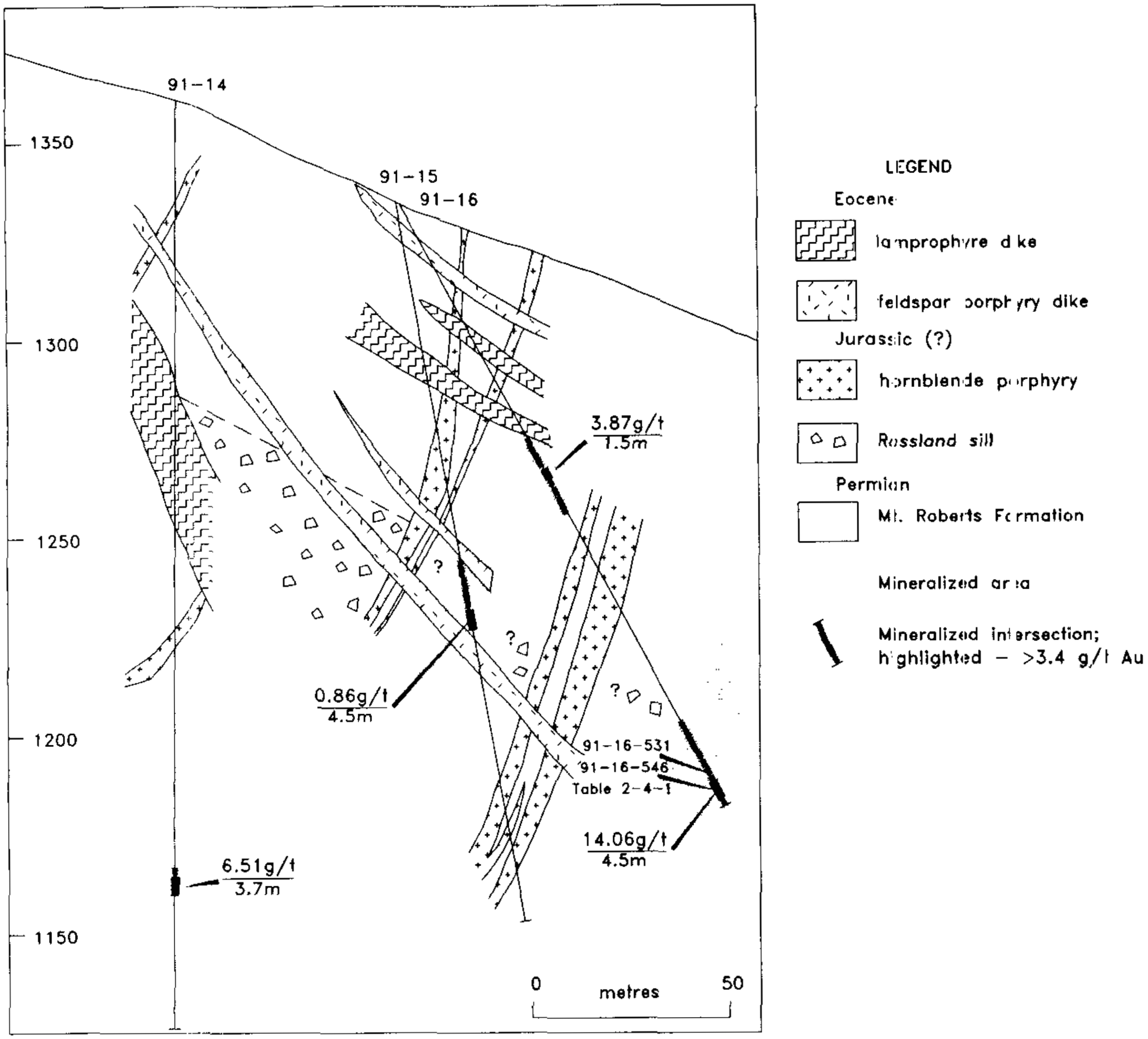


Figure 2-4-5. Vertical section through the Gertrude deposit, viewed to the northeast (*see* Figure 2-4-2 for location); section and data from D. Wehrle, Vangold Resources, Inc.

workers (Fyles, 1984; Thorpe, 1967) to relate the vein system to the intrusion. As well, the close spatial association of mineralization with thin selvages of Elise volcanic rocks in the Rossland monzonite (*see* Figures 2-4-4 and 6) and the association of veins with gold-copper skarn mineralization suggests a relationship with the intrusion. These features, as well as the massive, high sulphide content of the ore and relatively minor carbonate-quartz gangue contrast with more "typical" greenstone gold deposits.

Rare gold-copper veins that crosscut Tertiary dikes have been used as evidence for a Tertiary age of mineralization; however, these can be explained by remobilization and redeposition of sulphides during a widespread Tertiary thermal and tectonic event.

The tectonic history of the Rossland area includes Early Jurassic extensional tectonism that produced a fault-bounded tectonic high in the Rossland area. This paleohigh modified and locally controlled the distribution, thickness and facies of Rossland Group rocks. Furthermore, the early growth faults may have controlled the distribution of early comagmatic plutons, including the Rossland monzonite (*ca* 190 Ma), and the distribution of the Rossland vein system.

After intrusion of the Rossland monzonite (*see* Figure 2-4-3), thrust faults carried Mount Roberts Formation rocks eastward over Rossland Group rocks that were deposited on the Rossland paleohigh. As well, dunitic to wehrlitic ultramafic cumulates of probable oceanic affinity, perhaps part

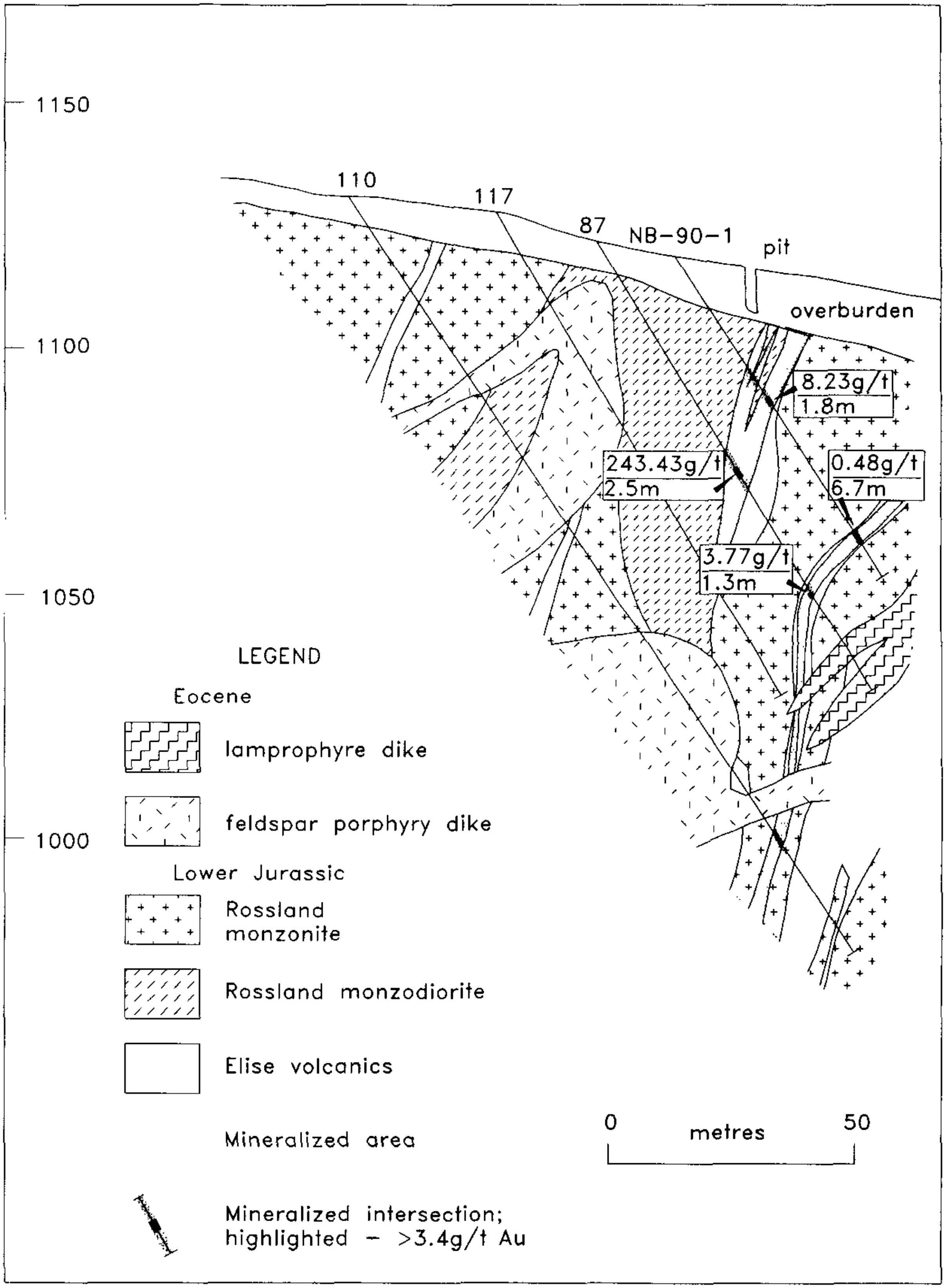


Figure 2-4-6. Vertical section through the Iron Colt deposit, viewed to the east (*see* Figure 2-4-2 for location); section and data from D. Wehrle, Vangold Resources, Inc.

of the Slide Mountain Terrane (C. Ash, personal communication, 1991; Ash and Macdonald, 1992), were thrust onto the high. These faults are probably related to widespread compressional tectonics as the eastern edge of Quesnellia impinged on cratonic North America (*ca* 182-178 Ma). They are parallel to and aligned with the northeast trend of the Rossland break, the Rossland monzonite and the Rossland veins, indicating the continued influence of deep crustal structures on tectonism and mineralization.

Early to Middle Jurassic post-tectonic intrusions (*ca* 165 Ma), including the Trail and Rainy Day plutons, cut the thrust faults. Molybdenite skarn and breccia mineralization is associated with these intrusions on the western and southern slopes of Red Mountain (Fyles, 1984; Webster *et al.*, 1992, this volume). To the east, thermal metamorphism, skarn alteration and molybdenite mineralization have locally overprinted Rossland gold-copper mineralization; elsewhere, gold and copper have been remobilized and deposited in rare, thin, late veins that cut the Mount Roberts Formation and molybdenite mineralization.

Extensional tectonics during the Eocene produced north-trending normal faults and a swarm of north-trending dikes. The dike swarm west of Waneta closely follows the inferred eastern faulted margin of the Rossland paleohigh; in the Rossland area, Tertiary faults follow the loci of earlier thrust faults and may be associated with extrusion of Marron Formation volcanic rocks (Figure 2-4-3).

In summary, Rossland gold-copper mineralization has a complex history. However, the fundamental control on mineralization appears to be deep crustal structures that were reactivated through time, controlling the distribution of Early Jurassic Rossland Group rocks, comagmatic (?) intrusions, gold-copper mineralization, Early to Middle Jurassic thrust faults, Middle Jurassic molybdenite mineralization, and Tertiary structures and associated igneous activity.

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