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MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES
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GEOLOGICAL SETTING OF THE ROSSLAND MINING CAMP

SUMMARY

This report summarizes geological work near the city of Rossland in the West Kootenay district of southeastern British Columbia carried out by the writer mainly between 1967 and 1970. The purpose of the work was to clarify the geological setting of the molybdenum deposits on Red Mountain.

In the Rossland area Upper Paleozoic and Lower Jurassic volcanic and sedimentary rocks are intruded by plutons of monzonite, granodiorite and syenite, and many dykes of related composition. The Carboniferous Mount Roberts Formation consists of grey siltstone, sandstone, conglomerate, and minor limestone. The Rossland Group is mainly andesitic volcanic breccia, sandstone and conglomerate, and lenses of grey to black siltstone. These rocks are folded, faulted, and variably metamorphosed and intruded by the Rossland monzonite, the Trail pluton of granodiorite, and the Coryell batholith of syenite.

The map-area contains two structural domains separated by an irregular line of intrusions and faults trending east-northeast and referred to as the Rossland break. The southern domain contains northeasterly trending structures whereas the northern domain, in which the major mineral deposits occur, contains northerly trending structures.

Two well-defined steeply dipping fracture sets occur throughout the area; one, referred to as the fault-dyke set, trending northward and the other, the vein set, trending eastward. The fault-dyke set consists of extension fractures containing Tertiary dykes with dominant fault movements down on the west. The vein set, which contains the copper-gold veins of the old Rossland camp, includes conjugate fracture sets dominated by attitudes of north 60 to 70 degrees east and north 60 degrees west with east-west fractures between these directions, all with steep northerly dips.

Three types of mineral deposits have been mined in the Rossland area: (1) copper-gold veins with minor lead and zinc, (2) gold veins, and (3) molybdenum deposits.

The copper-gold veins are composed of pyrrhotite and chalcopyrite in a gangue of more or less altered wallrock with local lenses of quartz and calcite. They formed by replacing wallrock along well-defined fractures and by filling fractures and fault zones. Between 1894 and 1941 a total of 5 600 000 tonnes of ore with an average grade of 13 grams gold per tonne, 17 grams silver per tonne, and 1 per cent copper was produced from these veins; there has been no production since.

The gold veins, which are discontinuously mineralized faults and fractures southwest of Rossland, contain small shoots of spectacularly high-grade gold mineralization. Between 1899 and 1974, 10 492 tonnes of ore was produced from these veins with an average grade of 101 grams gold per tonne and 14 grams silver per tonne.

Molybdenum produced by Red Mountain Mines Limited between 1966 and 1972 amounted to 1 652 970 kilograms from almost a million tonnes of ore. The ore zones consist of molybdenite with very minor amounts of scheelite along fractures in a breccia complex composed mainly of hornfelsic siltstone. The mineralization was derived from the Trail pluton and associated dykes and apophyses. New age determinations based on a sample of zircon from the pluton 1.5 kilometres northeast of the mine give concordant uranium-lead dates of 159 and 162 Ma. Geological relationships, as well as potassium-argon dating of dykes, indicate that the copper-gold mineralization is younger than the molybdenum; at least in part it is Tertiary.

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INTRODUCTION

PURPOSE AND BACKGROUND

This report summarizes geological work near the city of Rossland in the West Kootenay district of southeastern British Columbia carried out more than 10 years ago (Fig. 1). The purpose of the work was to clarify the geological setting of the molybdenum deposits on Red Mountain west of the city, which at that time were being mined. The work led to a new geological map of the Rossland camp and to the recognition of some new geological relationships.

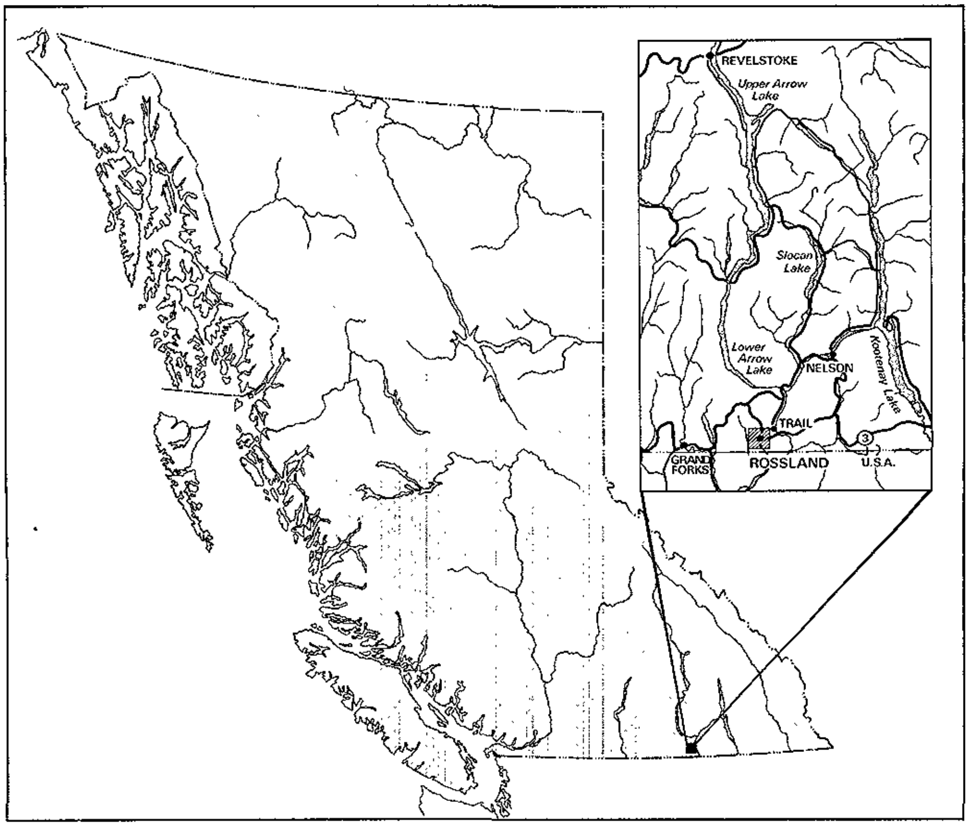

Figure 1. Index map showing location of Rossland area, 82F.

Plate I. Red Mountain from the northwest with the Red Mountain mill in the foreground and the ski runs beyond.

Plate II. Red Mountain molybdenum mine from the west showing the open pits, May 1981.

The Rossland mining camp, which flourished between about 1890 and 1930, provided the stimulus for the early development of the mining industry in the West Kootenay district and established settlement patterns in that area. The residential and industrial cities of Rossland and Trail are within 10 kilometres of the International Boundary and 300 kilometres east of Vancouver. They grew out of the mining activity at Rossland. Principal production of copper and gold was between 1894 and 1928; minor but important production resulted from the work of lessees between 1933 and 1941. Small amounts of lead and zinc were also produced. Among the most important mines were the Le Roi, Centre Star, War Eagle, and Josie in the core of the camp, all of which were deep shaft mines famous during the first decade of the century. Total production of copper-gold ore from the Rossland area has amounted to 5 640 000 tonnes (6,200,000 tons, Cominco Ltd. estimate) with average grade of 13 grams gold per tonne (0.47 ounce per ton), 17 grams silver per tonne (0.6 ounce per ton), and 1 per cent copper (Gilbert, 1948, p. 189). An attempt to reopen some of the mines of the main camp was made in 1969 and 1970 when Falaise Lake Mines Ltd. drove a crosscut westward from the valley of Trail Creek under the city to intersect the Le Roi mine No. 8 level at an elevation of about 915 metres above sea level. Diamond drilling was carried out but has not yet led to development or production.

Molybdenum was known from the early days but not produced. Interest in molybdenum in the camp began soon after 1960. In 1964 significant zones of molybdenum mineralization were found on Red Mountain, about a kilometre west of the core of the main copper-gold camp in drilling by Torwest Resources Ltd. Red Mountain Mines Limited (a subsidiary of Inco) began production from an open pit on the west side of Red Mountain in 1966 and continued until early in 1972 (Plates I and II). Almost a million tonnes of ore was mined and 1.65 million kilograms of molybdenum was recovered. Subsequently, an extensive geological and deep drilling program was carried out, but production has not resumed.

Plate III. Red Mountain from Monte Cristo Mountain. Old dumps and workings on the Cliff and Consolidated St. Elmo claims in the foreground.

GEOLOGICAL WORK

The geology of the Rossland mining camp was thoroughly studied during the years of discovery, development, and production by geologists of the Geological Survey of Canada. The area was visited by R. G. McConnell in 1894 and 1896, by R. W. Brock in 1900, and by R. A. Daly on the International Boundary Survey in 1902. In 1905 and 1906 geological mapping of the camp was undertaken by G. A. Young and property examinations by R. W. Brock. C. W. Drysdale reviewed all this work in 1913 and 1914 and the results were published in 1915 as Geological Survey of Canada Memoir 77 which became the classic source of geological information. Drysdale's field assistant, E. L. Bruce, prepared a Ph.D. thesis on the area which was published by the British Columbia Department of Mines in 1917. This early work, much of it of high quality in its day, outlined the principal rock units, gave detailed petrographic descriptions, particularly of the igneous rocks, and provided invaluable records of the mineral deposits, many of which have been inaccessible since that time or have become obscured by erosion and the growth of vegetation.

As mining progressed most of the important properties were taken over by The Consolidated Mining and Smelting Company of Canada, Limited (now Cominco Ltd.) who were the principal owners during the period of leasing and into the early 1960's. Intensive geological work and appraisal of the mineral potential were carried out by the company between 1941 and 1943. A summary of the geological results of this work was published (Gilbert, 1948) and private company reports and drawings were made available by the company to geologists working in the area after this date.

Regional geological maps of the area were revised by H. W. Little who did fieldwork in the general region between 1947 and 1962 with emphasis on the Rossland area in 1949, 1961, and 1962 (*see* Little, 1960, 1962, 1963). During 1962, R. I. Thorpe, working with Little, remapped the Rossland camp and studied the mineralogy of the deposits of the region (Thorpe, 1967). Little revisited the area briefly in 1978 and subsequently published a report and coloured map (Little, 1982).

Interest in the molybdenum mineralization on Red Mountain in 1964 sparked interest in the geology of that area by company geologists and the British Columbia Department of Mines and Petroleum Resources (*see* Holland, 1965; Eastwood, 1966). The present work, carried out intermittently between 1967 and 1971, is an extension of this interest; it has made use of both published and unpublished reports.

ACKNOWLEDGMENTS

Many geologists, engineers, and prospectors have worked in the area and have contributed to the development of the Rossland camp. This report records progress in our understanding of the geology and mineral resources of Rossland. Technical assistance and many courtesies were extended to me by a number of people while I worked in the area. Mr. Leo Telfer, the 'dean' of Rossland mining, shared his intimate knowledge of the mines and exploration activities in the camp. He and Mr. Jack McKay, both retired Cominco Ltd. engineers, were responsible for driving the 3045 level of Falaise Lake Mines Ltd. in 1969 and 1970 and assisted me in understanding the main camp and the Red Mountain area. Messrs. Brian Fellingham, manager, and Nigel Stonestreet, engineer of Red Mountain Mines Limited during the years of production provided maps and access to the workings, drill core, and records on that property. Mr. Roger Trehune, prospector, provided valuable information on the history of some of the properties, and Mike Delich, prospector and purveyor of mineral claims, encouraged me to visit old prospects which I would not otherwise have visited.

Discussions with Drs. P. S. Simony of the University of Calgary, W. H. White of the University of British Columbia, and H. W. Little and R. I. Thorpe of the Geological Survey of Canada about various aspects of the geology of the region made valuable contributions to my interpretation and understanding of the complex geology of this area. The persistence of Dr. R. L. Armstrong and co-workers at the geochronology laboratories at the University of British Columbia in carrying out the age determinations on the Trail pluton is gratefully acknowledged.

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GENERAL GEOLOGY

INTRODUCTION

The Rossland mineral deposits occur within an area of plutonic and dyke rocks which intrude Upper Paleozoic and Lower Jurassic volcanic and sedimentary rocks, the ages of which have been determined by a limited number of fossils. The Carboniferous Mount Roberts Formation consists of grey siltstone, sandstone, conglomerate, and minor amounts of limestone. The Jurassic Rossland Group is mainly andesitic volcanic breccia, lapilli tuff, volcanic sandstone and conglomerate, and lenses of grey to black siltstone. These rocks are variably metamorphosed and intruded by three principal groups of plutonic rocks: the Rossland monzonite, the Trail pluton, and the Coryell batholith. They are also cut by a large number of dykes including diorite, lamprophyre, and syenite.

The camp is on the Rossland break (*see* Fig. 4), a poorly defined ancient zone of movement that trends northeastward through the volcanic and sedimentary rocks. South of the break the dominant structures trend northeast, whereas north of it they trend north. Five kilometres north of the break these northerly trending structures terminate against schistose rocks which dip at low angles to the south and southwest. The distribution of intrusive facies of the Lower Jurassic Rossland Group suggests that the break originated during or before the Rossland volcanism. Subsequently it became a locus for repeated intrusion and now contains the Rossland monzonite and a group of serpentinite stocks.

The area is adjacent to the southwestern corner of the Trail pluton of granodiorite and quartz monzonite. The southern margin of the pluton dips beneath the main camp and irregular dykes, breccias, and stocks that occur to the west are also found in deep drilling beneath Red Mountain. The eastern margin of the Coryell batholith occurs 1 kilometre west of the camp and related dykes and irregular stocks are present within it. Each of these intrusions is surrounded by a zone of thermal metamorphism.

Mineralization includes copper-gold and lesser lead-zinc in veins of the main camp and the South belt, molybdenum-tungsten on Red Mountain and within or adjacent to the Trail plutonic rocks, and gold adjacent to serpentinite bodies within the Rossland break. The mineralization is a product of the complex structural and intrusive history of the camp.

MOUNT ROBERTS FORMATION

The oldest rocks in the area, which belong to the Mount Roberts Formation, form a lens on the eastern slopes of Mount Roberts (Plate IV) and O.K. and Granite Mountains. On the west the formation is in contact with rocks of the Tertiary Marron Formation, and on the east with greenstone of uncertain age and correlation. Both of these contacts are probably faults and that on the west is also an unconformity. This remnant of Mount Roberts Formation dips steeply west and consists of three members: a coarse sedimentary breccia that lies west of and grades into a greyish and greenish thinly laminated sandstone that grades eastward into thinly bedded grey siltstone and argillite. The breccia and siltstone dominate the formation and both are about 300 metres thick; the sandstone member, which lies between them, is 40 to 60 metres thick. Primary structures indicate that the breccia is stratigraphically below the argillite and the stratigraphic top is to the east (*see* Fig. 2, section A-A').

The breccia is greenish to light grey, composed of angular to subrounded fragments of quartz, feldspar, and various types of rock, and has a matrix of greenish or brownish siltstone. The sedimentary rock fragments are chips of greenish or brownish siltstone, and angular to rounded pieces of chert, jasper, limestone, and mafic volcanic rocks. The largest fragments are 15 centimetres long.

Clastic grains of quartz are common, and those of plagioclase less common. Chert fragments are abundant and some of them under the microscope contain clear spots that may be remnants of radiolaria. Volcanic fragments are greenish porphyritic andesite with phenocrysts of plagioclase and hornblende. Small fragments of quartz-feldspar granite gneiss can be found but are not abundant.

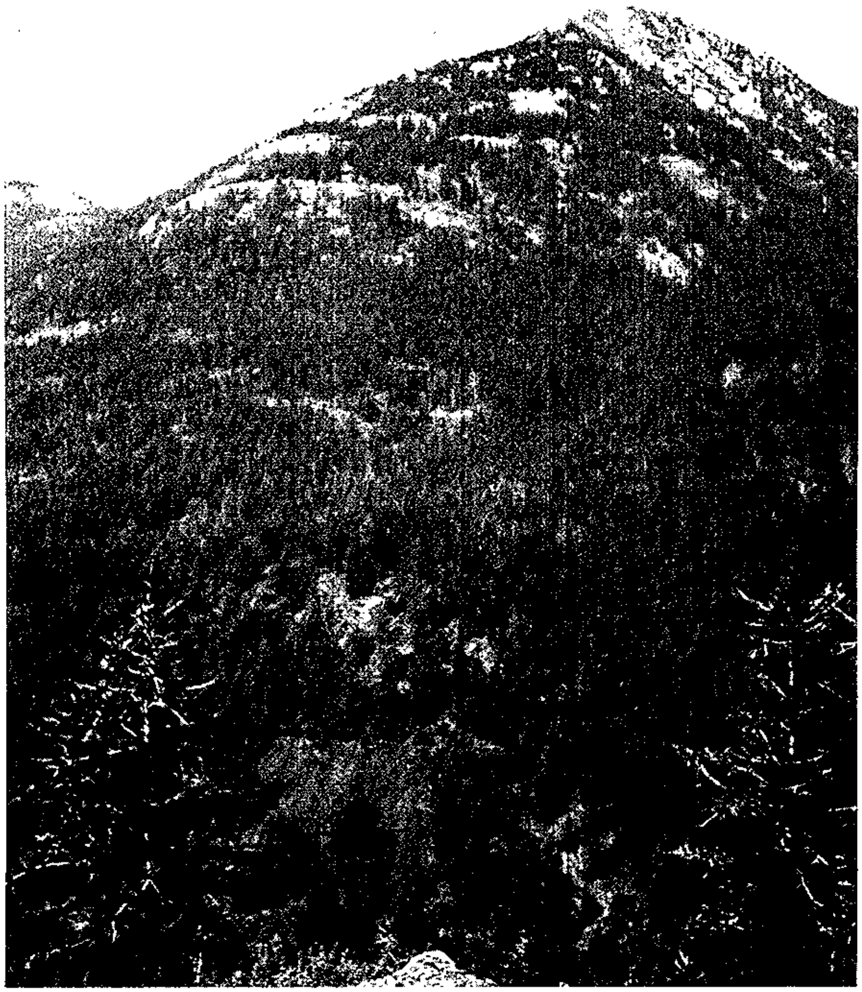

Plate IV. Mount Roberts from the northeast with dumps from the old Jumbo property in the foreground.

In general the breccia lacks bedding but alignment of coarser fragments produces a poor foliation parallel to the regional attitude of the formations. Locally, lenses of siltstone and sandstone within the breccia show bedding. The breccia member grades rapidly into the sandstone member.

The sandstone member consists of beds of fine-grained sandstone up to several centimetres thick grading into and interbedded with thin-bedded greyish and greenish siltstone. Graded beds, scour, and locally fine cross-laminations indicate the stratigraphic top is to the east. Within the lower 15 metres of the sandstone member is a lenticular zone that consists of a series of layers of calcareous sandstone and limestone up to a metre or so thick. These rocks are buff weathering, grey, blocky, and form in beds a few centimetres to several centimetres thick. Rocks of the sandstone member, seen in thin section, contain angular and subrounded grains of quartz and chert and a few clastic grains of plagioclase and potassic feldspar commonly about 0.1 millimetre across. The matrix and dark-coloured beds are very fine grained and consist of quartz, biotite, carbonate, and probably feldspar. Greenish laminations of chlorite and grains of hornblende are common. Calcareous sandstones contain pyroxene and albite and are recrystallized so that primary grains are obscure.

The calcareous beds appear to be at, or close to, one stratigraphic position within the lower part of the sandstone member. From one of these beds, on the eastern slope of O.K. Mountain at an elevation of about 1 220 metres, R. W. Brock collected fossils in 1906 (*see* Drysdale, 1915, p. 199; Bruce, 1917, p. 9) which were assigned to the Upper Carboniferous. At this locality the limestone occurs in irregular impure pods between, and forming matrix for, lenticular intercalations of sandstone and breccia. Unidentifiable fossil fragments also occur in the limestone at about the same stratigraphic position along the eastern slopes of Mount Roberts and Granite Mountain (*see* Fig. 2).

The uppermost member of the Mount Roberts Formation is dominantly thin-bedded dark grey to black siltstone. It is typically light grey weathering or rusty with beds up to a few centimetres thick; it rarely shows primary sedimentary structures indicative of the stratigraphic top. Locally these siltstones contain interbeds of greenish grey sandstone. Metamorphism, particularly apparent along the Cascade Highway near the Snowdrop mine, gives the grey siltstone a conchoidal fracture and a purplish brown colour that is caused by disseminated fine biotite.

Drysdale (1915, p. 200) described the breccia on Mount Roberts as Triassic (?) volcanic agglomerate, however, it is sedimentary in origin and the limestone lenses containing the Carboniferous fossils are clearly part of the breccia-siltstone stratigraphic succession. This succession, which is at the type locality of the Mount Roberts Formation, is quite different from the one near Patterson which yielded many fossils and is described in detail by Little (1960, pp. 47-51; 1982, pp. 10-12).

Several masses of dark grey siltstone and argillite were assigned to the Mount Roberts Formation by Drysdale (1915), but correlations based on lithology are uncertain because of the variable nature of the Mount Roberts Formation and the fact that some beds of grey siltstone in the area contain Lower Jurassic fossils. On Monte Cristo and Columbia Kootenay Mountains, siltstone mapped by Drysdale as Mount Roberts Formation is shown as part of the Rossland Group on Geological Survey of Canada Map 23-1963 (Little, 1963). Grey siltstone on Red Mountain, which contains the molybdenum orebodies of Red Mountain Mines Limited, is traditionally regarded as part of the Mount Roberts Formation but there is no direct evidence for this correlation. In the present mapping it is placed in the Rossland Group because of the structural association with other rocks of the Rossland Group and its similarity to other siltstones in the Rossland succession.

ROSSLAND GROUP

The Rossland Group consists of a complex succession of volcanic and sedimentary rocks in which four stratigraphic units have been mapped (*see* Fig. 2). These are, in decreasing order of abundance: green volcanic conglomerate, breccia and related volcanic rocks (map unit 2e); augite porphyry sills and dykes (map unit 2f); grey to black siltstone and argillite (map unit 2c); and massive greenstone of uncertain origin (map unit 2d). The grey siltstone and argillite are locally metamorphosed to hornfels (map unit 2b) and on Red Mountain they are brecciated (map unit 2a).

In the past these rocks, with the exception of the siltstone hornfels and breccia on Red Mountain, have been mapped as Rossland Group. Although there should be a Rossland 'type locality,' one has not been defined. Lower Jurassic fossils have been found at three localities in the Rossland argillite on Ivanhoe Ridge (*see* Fig. 2). In the present work beds of black siltstone and argillite were carefully mapped and were found to be more extensive than previously noted. These markers indicate that the group is complexly folded; because of this and because of faulting and widespread intrusion, it has not been possible to determine the local stratigraphic succession. The regional stratigraphy of the Rossland Group has been studied over a period of 20 years by Little and co-workers and the results are summarized in Geological Survey of Canada Paper 79-26 (Little, 1982, pp. 12-18).

CLASTIC ROCKS

Most of the Rossland Group in the area is composed of clastic rocks which have been subdivided into two units for mapping purposes: (1) grey to black siltstone and argillite (unit 2a on Fig. 2), and (2) green volcanic breccia, conglomerate, sandstone, and tuff (unit 2c on Fig. 2). Previously the green volcanic breccia and conglomerate have been called flow breccias and agglomerates; however, flow structures and amygdules are rarely seen, clastic detrital textures are common, and the rocks grade into and are intercalated with thin-bedded volcanic sandstones. Finer grained rocks of the Rossland Group also are mainly clastic. Those studied under the microscope are mainly of detrital origin, though some are pyroclastic and many are mixed pyroclastic and waterlain marine (?) sedimentary rocks. Quartz occurs as angular to subrounded grains in all the grey siltstone; it is present in variable but minor amounts in some of the green siltstones and volcanic sandstones. Plagioclase, either andesine or labradorite, is present in all the green rocks and in some of the grey siltstones. Angular broken plagioclase crystals and clastic grains of augite in green thin-bedded sedimentary rocks, particularly well exposed on the southeast slope of Columbia Kootenay Mountain, are of pyroclastic origin. At least some of the plagioclase crystals in other rocks are of pyroclastic origin but many are rounded and most of these rocks are of mixed volcanic and sedimentary origin. The green colour is produced mainly by hornblende occurring as both large ragged grains, some of which contain cores of augite, and as fine shreds in the matrix. The grey siltstones are essentially nonvolcanic although some plagioclase crystals may be pyroclastic.

The volcanic breccias and conglomerates contain rounded and angular fragments 2 to 8 centimetres across in a green aphanitic matrix. Just north of Rossland a bed of conglomerate is exposed on the west side of the reservoir and in road cuts 0.75 kilometre to the north. It consists of rounded and angular fragments of volcanic rock, and rare chert in a greenish sandstone matrix. The volcanic fragments are hornblende or hornblende feldspar porphyry and the matrix contains angular and rounded grains of quartz and intermediate plagioclase. Needles of hornblende throughout the rocks give them a greenish cast. This conglomerate, which is a few metres thick and dips at moderate angles to the west, grades eastward into massive green volcanic sandstone and fragmental volcanic rocks of uncertain origin that are well exposed on Monte Cristo Mountain. They in turn grade eastward into green and grey siltstones. Similar rocks, probably of the same units, occur north of Topping Creek and lie west of grey siltstones at the Union property on Blackjack Mountain. More west-dipping fragmental volcanic rocks occur east of the siltstones on Columbia Kootenay Mountain and on the hill east of Blackjack Mountain and north of the Trail granodiorite. On Columbia Kootenay Mountain the unit east of the grey siltstones is a group of bedded green volcanic breccias, sandstones, and crystal tuffs. These beds, which dip steeply to the west, vary from a fraction of a centimetre to a few metres thick. Graded bedding and cross-laminations indicate that the stratigraphic top is to the west and the beds are right-side-up. The tuffs consist of broken crystals of plagioclase (andesine or labradorite) and hornblende, and fragments of volcanic rock and siltstone; locally they contain rounded detrital quartz grains. Coarser varieties contain angular and rounded fragments of chert and volcanic rocks, mainly hornblende (or augite) porphyry and feldspar porphyry, in a matrix of crystal tuff. Wispy metamorphic hornblende occurs in all the rocks. The plagioclase is clouded with minute grains of epidote and sericite and locally coarser grains of epidote are abundant.

North of the Trail granodiorite and east of Blackjack Mountain, most of the Rossland Group consists of breccia and conglomerate with angular and rounded fragments of volcanic rock as much as several centimetres across in a green sandstone or tuffaceous matrix. Bedding is generally lacking in this area; the well-bedded tuffs and tuff breccias of the section on the southeast slope of Columbia Kootenay Mountain are not present.

Large areas of green volcanic breccia, sandstone, and conglomerate occur south of Rossland between Cherry Ridge and Little Sheep Creek and on Ivanhoe Ridge. Where bedding is visible dips are to the west and northwest but the stratigraphic top and internal fold structure are not known. A thick grey siltstone in the valley of Tiger Creek, which extends over the top of Baldy Mountain, lies east of, and probably is stratigraphically beneath, green volcanic breccias and conglomerates that are interbedded with green volcanic sandstones and tuffaceous rocks. The coarse rocks contain rounded and angular fragments of hornblende and feldspar porphyry, limestone, chert, and siltstone up to 10 centimetres across. The finer rocks are thin bedded to massive and contain rock fragments and crystals of plagioclase and hornblende. These rocks grade westward into massive volcanic breccia and conglomerate which outcrop on the hills on the eastern side and around the head of Gopher Creek. Rocks of this group, exposed southeast of the Mayflower workings, are described by White as follows (*Minister of Mines, B.C.*, Ann. Rept., 1949, p. 159):

> The augite porphyrite breccia gives place southeastward to conglomerate composed of subrounded and rounded pebbles of augite porphyrite, granite, diorite, and quartz in a matrix of very fine-grained dark-coloured silt-like material. The matrix weathers out readily, leaving the pebbles protruding from the surface. Most of the pebbles range in size from 1 to 3 inches [2.5 to 7 centimetres], but in places pea-size pebbles and coarse sand occur in stratified lenses that strike about north 40 degrees east and dip about 60 degrees to the southeast. Grain-size gradations in the stratified beds are right-side up. Preferential replacement of the matrix and of certain of the pebbles by epidote is a common feature.

Farther to the west near Highway 22 volcanic breccias commonly have a calcareous cement.

On Ivanhoe Ridge the rocks dip to the northwest at moderate angles. Two siltstone members are interbedded with green volcanic sandstones and conglomerates which grade northward into massive green volcanic rocks of uncertain origin.

SILTSTONE

Grey to black siltstone and argillite grading into hornfels form a number of distinct layers within the volcanic breccias. These rocks are mapped as part of the Rossland Group but the internal stratigraphic relationships are uncertain. Map patterns suggest that siltstones occur at several horizons and grade laterally into sandstone and breccia. Small ammonites of probably Sinemurian (Early Jurassic) age are reported (*see* Little, 1963, 1982) from one of the two layers of siltstone on Ivanhoe Ridge but no fossils were found in any of the siltstones in the present work.

On Ivanhoe Ridge the beds dip 50 to 70 degrees northward forming an apparently homoclinal succession facing northward. Volcanic conglomerate with rounded cobbles of porphyry and some limestone 2 to 8 centimetres in diameter grade northward through green volcanic sandstone into the southernmost grey siltstone shown on Figure 2. These rocks consist of about 60 metres of grey to purplish grey thin-bedded siltstone with several metres of greenish sandstone in the centre. They grade northward into green volcanic sandstones and conglomerates which are overlain by the second band of siltstone shown on Figure 2. These grey to purplish grey siltstones and argillites are interbedded with green volcanic sandstones on the north and grade northward into green volcanic breccias and massive greenstones of uncertain origin.

Farther north on the north slope of Ivanhoe Ridge is an irregular, poorly exposed mass of highly contorted dark grey siltstone. To the east, in the valley of Little Sheep Creek, the siltstones are contorted and, where exposed on Highway 22, are cut by a number of faults. They appear to be part of a fairly continuous folded and faulted layer extending from the western slope of Deerpark Hill southward along Little Sheep Creek and northeastward to the area of the Blue Bird and other mines of the South belt. West of Deerpark Hill the siltstones have a poor cleavage, are locally hornfelsic, and are intruded by sill-like bodies of augite porphyry into which they lens out southwestward. Farther south, on the slopes of Highway 22, the siltstones are contorted, friable, unmetamorphosed dark grey rocks which form a continuous layer lying within volcanic breccia. The siltstone layer curves southward and eastward around the trough of a northeasterly plunging syncline. To the east the siltstone is discontinuous because of faulting and intrusions of augite porphyry and monzonite; however, remnants of black, commonly rusty weathering siltstone can be traced through the showings on the Zilor, Lily May, and Richmond claims to the Blue Bird mine. These rocks pass northward into cherty hornfels adjacent to the Rossland monzonite.

Another wide band of grey siltstone that occurs in the valley and on the western slopes of Tiger Creek crosses the upper part of Baldy Mountain. It lies east of a thick section of green volcanic conglomerate and sandstone and contains a number of concordant layers of augite porphyry.

North of Rossland grey siltstone more or less altered to hornfels occurs between Monte Cristo and Columbia Kootenay Mountains and on the Union property on strike to the north of the Trail pluton. These siltstones are within a group of volcanic breccias, conglomerates, tuffs, and sandstones which dip steeply to the west. The siltstone on the Union property is hornfelsic and lenses out northward into schistose volcanic breccias.

Siltstone, previously considered to be part of the Mount Roberts Formation, forms the upper part and western slopes of Red Mountain. Because of its close association with Rossland volcanic rocks and similarity with siltstone elsewhere in the Rossland Group, it is referred herein to that group. This siltstone is mainly metamorphosed to hornfels but in the valley of Little Sheep Creek south of Red Mountain mine it consists of rusty weathering dark grey to black thin-bedded carbonaceous siltstone. These rocks are well indurated, rich in finely disseminated pyrrhotite, and grade into light grey, greenish, and purplish hornfels containing very fine pyroxene or biotite. On the lower east side of Little Sheep Creek, about 400 metres north of the Cascade Highway, a few metres or so of thin-bedded dark blue-grey calcareous siltstone and argillaceous limestone are exposed. A lens of light grey marble a few metres long is present in the hornfelsic siltstone on the southeast slope of Red Mountain on the Gertrude claim. The section is transected on the west by syenite and monzonite; the overlying rocks are not exposed in the Red Mountain area. This section of siltstone and hornfels is 250 to 300 metres thick.

AUGITE PORPHYRY

The principal occurrence of augite porphyry is on the eastern slope of Red Mountain (Plate III) in a series of outcrops extending from the vicinity of the main Rossland mines northward to beyond Topping Creek. In this area the augite porphyry forms a sill called the Rossland sill that is as much as 760 metres thick and dips at low angles to the west. It lies beneath hornfelsic siltstone forming the upper part of Red Mountain and above volcanic breccia, sandstone, and conglomerate exposed near the reservoir and in Topping Creek. The upper contact, though not exposed, is well defined on surface and is penetrated by a number of drill holes. It appears to be concordant, but is transgressive in detail. Subsidiary sills and parallel dykes are found in drill core. The lower contact is poorly defined because it is difficult to distinguish the massive volcanic sandstones with scattered hornblende crystals from the augite porphyry in which the phenocrysts are partly altered to hornblende. The sill thins northward and has not been recognized far north of Topping Creek.

In the principal mines (for example, Le Roi, Centre Star, and War Eagle) augite porphyry is intruded by the Rossland monzonite and extends to the lowest levels (*see* Drysdale, 1915). In these mines the porphyry occurs more than 450 metres vertically below the footwall of the sill as projected southward from exposures near the reservoir. Thus, before intrusion by the monzonite, the augite porphyry in the mine area was probably transgressive and may have been a stock or dyke-like feeder for the sill that is exposed on the surface and thins and lenses out to the north away from the feeder.

Other masses of augite porphyry occur on Columbia Kootenay Mountain and in the South belt. They are sills and irregular masses commonly difficult to distinguish from other members of the Rossland Group, particularly where they have been metamorphosed. Only the largest bodies are shown on Figure 2. Augite porphyry is more abundant in the thin-bedded sedimentary and volcanic rocks than in the massive volcanic breccias and conglomerates. In the South belt there seems to be more frequent and thicker masses of augite porphyry near the Rossland monzonite than farther south.

The augite porphyry has been described petrographically in detail by Drysdale (1915, pp. 202-208) and referred to by Bruce (1917, p. 10), Gilbert (1948, p. 190), Little (1960, p. 65), and White (1949, p. 150). The porphyry is dark green with phenocrysts of dark augite or hornblende up to 3 millimetres across in an aphanitic matrix. The proportion of phenocrysts varies widely and in thin section the augite is seen to be more or less converted to hornblende. The matrix is composed of laths of labradorite, commonly with a flow structure, and interstitial very fine hornblende and augite. Commonly the rock is fragmental with subrounded blocks a few centimetres to as much as a metre across that are somewhat lighter in colour than the main mass of porphyry but essentially of the same composition. The fragments are composed of augite porphyry in which the matrix is richer in plagioclase than the matrix of the surrounding porphyry. Fragmental augite porphyry near the hangingwall of the sill is well exposed on the natural gas pipeline and the old wagon road for a kilometre north of the Rossland Museum as well as in outcrops near the Red Mountain Motel and road to the lower terminal of the ski lifts.

GREENSTONE

Part of the Rossland Group is greenstone, much of which is of uncertain origin. These rocks are shown as unit 2d on Figure 2 and are commonly associated with augite porphyry or volcanic sandstone and breccia. In most localities primary structures are not present and these greenstones are considered to be massive volcanic sandstone but may include flows and aphanitic mafic intrusions.

A northerly trending narrow band of greenstone that is bounded by faults and presumed to be part of the Rossland Group extends from the Cascade Highway near the Snowdrop mine to the upper valley of Topping Creek. These rocks lie east of the grey siltstone member of the Mount Roberts Formation and west of the Jumbo fault, a prominent northerly trending late fault. They are well exposed in road cuts and outcrops near the Cascade Highway and poorly exposed elsewhere. On the highway and near the upper mine portal they are greyish green amygdaloidal aphanitic rocks containing lenses of grey limestone up to 0.50 metre long, and irregular hematitic bands. Thin sections show these rocks to be a felted mass of hornblende with interstitial altered laths of plagioclase. The amygdules are mainly calcite and calcite is common in the matrix.

PLUTONIC ROCKS

The main bodies of plutonic rock within the area are the Rossland monzonite, the western part of the Trail pluton, the Rainy Day pluton, the eastern edge of the Coryell batholith, irregular intrusions of syenite and monzonite related to the Coryell, and serpentinite. All these bodies are shown on previously published maps and some have been studied and discussed in detail. Emphasis in this report has been placed on the shape and structural relationships of the plutonic bodies and their relationship to metamorphism and molybdenum mineralization.

ROSSLAND MONZONITE

The Rossland monzonite has been mapped and described by all previous workers: Drysdale (1915, pp. 219-227), Bruce (1917, pp. 222, 223), Gilbert (1948), and Little (1960, pp. 77-80; 1963, p. 4). In these writings there is some disagreement regarding the age in relation to the Trail pluton, and the origin, whether by intrusion or replacement of the surrounding country rocks. The present study has not changed the map distribution of the Rossland monzonite except that a small mass of the monzonite not shown on previous maps has been recognized northwest of Red Mountain. Studies of metamorphism show that the Rossland monzonite is an intrusive, stock-like mass with a wide aureole of thermal metamorphism. It is older than the Trail pluton and Rainy Day pluton and is therefore the oldest calc-alkaline intrusion in the area. The Rossland monzonite forms an elongate westerly trending stock, the western end of which is shown on Figure 2 (*see also* Little, 1982, Map 1504A). The contacts with the country rock vary from sharp to gradational over a few tens of metres. Irregular dyke-like bodies protrude northeastward from the stock on Columbia Kootenay Mountain and north from it east of Monte Cristo Mountain. The western margin is highly irregular. In the vicinity of the main mines two westerly protrusions are separated by an eastward-plunging arch-like mass of augite porphyry that is outlined in the mine workings (*see* Gilbert, 1948, p. 194). The east-plunging arch and irregularities in the contact to the south suggest that the western margin consists of a series of east-dipping tongue-like protrusions. The small body of Rossland monzonite exposed northwest of Red Mountain may be one such protrusion which reaches the surface. The southern margin of the stock is relatively straight and probably has a steep dip.

Several large inclusions of older rocks are present within the monzonite and many dykes and a large body of later (Coryell) monzonite occur within it. The Rossland monzonite is in contact with the Rainy Day pluton on the northwest slope of Deerpark Hill. Although relationships between the two stocks are not entirely conclusive, dyke-like masses of quartz diorite appear to extend from the Rainy Day pluton into the Rossland monzonite indicating that the monzonite is older.

Rossland monzonite is a grey to greenish grey, fine to medium-grained rock which varies somewhat in appearance from place to place. Variations are caused by alteration, and proximity to margins of the intrusion and to large inclusions within it. Fractures lined with hornblende are present in most outcrops in the central and northern parts of the stock. The average composition, based on estimated modes of 10 thin sections, is as follows: plagioclase (46 per cent), hornblende (15 per cent), orthoclase microperthite (13.5 per cent), augite (12.5 per cent), biotite (11 per cent), and quartz (2 per cent).

The plagioclase is calcic andesine. Hornblende commonly replaces augite; biotite has replaced hornblende in some thin sections. Magnetite and apatite are present in all the rocks studied under the microscope. Small amounts of chlorite, epidote, pyrite, and pyrrhotite are common. A chemical analysis of a specimen of monzonite from the 700-foot level of the Le Roi mine is given by Daly (1912, p. 343; *see* Drysdale, 1915, p. 223 or Little, 1960, p. 78).

TRAIL PLUTON

The western lobe of the Trail pluton lies north of Rossland and an elongate subsidiary granodiorite stock occurs west of it. The pluton, as shown on regional maps, is an irregular mass of granodiorite roughly 12 kilometres across extending eastward from the area shown on Figure 2 to east of the Columbia River (*see* Little, 1982). In the Rossland area the contacts are mainly sharp and irregular. On the north slope of Columbia Kootenay Mountain the contact trends east and dips to the south. Granodiorite exposed in the lowest levels of the War Eagle mine (elevation, 450 to 500 metres) indicates that the granodiorite contact between Columbia Kootenay Mountain dips on the average 40 degrees to the south. Quartz diorite encountered in drill holes beneath Red Mountain at elevations of 500 to 600 metres is probably the extension of the quartz diorite exposed northwest of Monte Cristo Mountain. The northern contact north of Topping Creek also trends east but dips steeply. The northerly trending elongate stock of granodiorite in upper Topping Creek west of Highway 3A (*see* Fig. 2) is presumed to join the Trail pluton at depth and to form an elongate cupola on the upper western surface of the main pluton.

The Trail granodiorite is a relatively fresh, medium-grained blocky grey rock rarely cut by narrow quartz veins and fractures coated with epidote. Specimens studied in thin section contain andesine (47 per cent), orthoclase microperthite (20 per cent), quartz (18 per cent), hornblende (10 per cent), biotite (5 per cent), and minor amounts of apatite, sphene, zircon, chlorite, epidote, and sericite.

RAINY DAY PLUTON

The Rainy Day pluton is a small mass of quartz diorite exposed in the upper part of Little Sheep Creek, on Highway 22, and on the northwest slope of Deerpark Hill. It is named after the Rainy Day Crown-granted claim which covers the central part of the pluton. It is in contact with a number of different older rocks on the north, east, and south and is intruded *by younger (Coryell) syenite and monzonite on the west.*

The intrusive margins of the stock are sharp and irregular; their dip is not predictable from surface exposures. Maps of the Le Roi 1650 level about 300 metres below the surface suggest that the stock may be floored by older rocks or that it may be a tabular body with a low to moderate dip (*see* Fig. 2, section B-B').

Surface exposures are of light grey porphyritic and nonporphyritic quartz diorite. The nonporphyritic facies forms a central core and the porphyritic a marginal zone; both are truncated on the west by the Coryell syenite. The porphyritic and, to a lesser extent, the nonporphyritic quartz diorite are highly fractured with a network of intersecting veinlets containing very fine-grained pyroxene, quartz, hornblende, biotite, chlorite, carbonates, and sulphides (pyrite and molybdenite).

Specimens studied in thin section contain andesine (50 per cent), quartz (15 to 20 per cent), orthoclase microperthite (5 to 15 per cent), biotite (10 to 15 per cent), hornblende (5 per cent), and augite (5 per cent). Accessory minerals are apatite, sphene, magnetite, and zircon. The phenocrysts, up to 4 millimetres across, are andesine and the matrix commonly consists of orthoclase and very fine-rounded grains of quartz.

Three dykes similar in composition to the Rainy Day pluton occur to the north on Red Mountain. They are irregular, discontinuous, steeply dipping, and, in general, trend easterly. The northernmost, which straddles the valley of Little Sheep Creek near the tailings pond of Red Mountain mine, is as much as 100 metres thick and 600 metres long. The second dyke is 1 kilometre to the south in the northern part of the pit area on the Mountain View claim of Red Mountain Mines Limited. It is 4 to 6 metres wide and 100 to 200 metres long. The third dyke is about 300 metres farther south at the southern edge of the A zone orebodies. Both these smaller dykes are described by Eastwood (1966, p. 205) and both are associated with breccia. The A zone dyke is brecciated and strongly mineralized with molybdenite. The Mountain View dyke is not brecciated or significantly mineralized but terminates beneath brecciated hornfelsic siltstone. The A zone dyke is referred to as quartz diorite breccia by Eastwood (1966) and consists of angular and subrounded fragments of quartz diorite and banded hornfels up to 30 centimetres or more across. The matrix, which varies from place to place, ranges from medium-grained quartz diorite to green aphanitic rock composed mainly of pyroxene, quartz, and potassic feldspar. Both dykes are lenticular and follow irregular east-west fractures along which there is local bleaching and brecciation. The bleaching is caused by an abundance of medium-grained potassic feldspar (orthoclase and orthoclase microperthite). Such bleaching is common along the southern of the two dykes in the pit area and affects the hornfels as well as the quartz diorite. The bleached rock is riddled with narrow pyroxene-quartz veinlets, some of which contain molybdenite and pyrrhotite.

The A zone dyke has a complex history, several stages of which can be inferred from internal structures. The quartz diorite appears to have been intruded as lenticular masses along an east-west fracture and to have incorporated fragments of hornfelsic wallrock during intrusion. After consolidation the dyke was brecciated and partly feldspathized. Feldspathization followed the original fracture and affected both the dyke and the country rock hornfels. Subsequently the dyke (and the hornfels) were lightly fractured and mineralized with pyroxene, quartz, and sulphides.

The Rainy Day pluton and the dykes on Red Mountain are grouped together because of their similar composition and because of the associated alteration. Veinlets of quartz and mafic minerals within the pluton and feldspathization locally developed at its margins are features also associated with the dykes. The dykes differ somewhat from the pluton and from each other but all have associated veinlets and alteration zones indicating the presence of endogenous, late-stage fluids. Probably all these bodies are closely associated with the Trail pluton, the western margin of which lies beneath Red Mountain (*see* Fig. 2, section A-A').

SERPENTINITE

Lenticular masses of serpentinite form part of a linear belt extending 10 kilometres southwest from Rossland where it is truncated by the Coryell batholith. The serpentinite is thought to have been emplaced along the Rossland break, which was a locus of dislocation and intrusion before the emplacement of the Coryell syenite.

The two masses within the Rossland map-area have relatively straight and transgressive margins. They are probably in faults, though it is not possible to demonstrate that all the contacts are faults. The northerly trending eastern and western margins of the small serpentinite mass in Little Sheep Creek are known to be faults. The northern contact exposed in the workings of the Midnight and I.X.L. mines is highly sheared and associated with a zone of intense fracturing. The volcanic rocks and grey siltstones adjacent to the southern contact, exposed east of Highway 22 on the Poor property, are highly schistose. Evidence for faulted margins of the mass at the head of Sophia Creek is not conclusive, but the relationships between it and volcanic rocks of the Marron Formation to the north strongly suggest that the northern contact of the serpentinite is a fault.

The serpentinite is brown weathering and stands out as open outcrops with sparse vegetation. It is a very fine-grained dark green to black rock which commonly contains veinlets and coatings of yellowish green and locally bluish fibrous serpentine.

The serpentinite has been explored for deposits of nickel and chromium. Chromite occurs on the west side of the ridge between the two main forks of Sophia Creek about 300 metres southeast of the natural gas pipeline. Three shallow pits expose fine-grained serpentinite with many fractures and abundant light green serpentine. Chromite associated with these fractures is fairly abundant in one pit. Two samples of selected material from this pit assayed 3.24 and 12.00 per cent chromium and 0.10 and 0.20 per cent nickel. Samples from another trench near the northern edge of the same mass of serpentinite assayed 0.23 per cent chromium and 0.17 per cent nickel.

In 1969, near the northern contact of a mass of serpentinite on the Midnight property along the western side of Little Sheep Creek, exploration companies sampled underground workings and reported several thousand tonnes of serpentinite averaging 0.25 per cent nickel. Selected samples assayed as high as 0.45 per cent nickel. In samples submitted by the companies to R. V. Kirkham of the Geological Survey of Canada, pyrite, millerite (NiS), and a mineral of the linnaeite group were identified. Ten samples taken by the writer at various places throughout the two masses of serpentinite exposed in the area gave nickel assays of less than 0.24 per cent.

CORYELL INTRUSIONS

The Rossland camp is east of a large mass of syenite known as the Coryell batholith and contains within it small irregular bodies of related rocks. The Coryell batholith consists mainly of pink, medium to coarse-grained syenite which is commonly highly fractured and deeply weathered. Within the area mapped, the eastern margin of the batholith is exposed west of Record Creek and Granite Mountain. Syenite of the same type occurs in a northerly trending dyke-like mass on the western side of Little Sheep Creek. It is bounded on the west by a major northerly trending fault so that the original shape of this dyke-like body is not known; it may be part of a much larger mass lying to the west.

These rocks are fresh, medium to coarse-grained pink syenites composed of 75 per cent orthoclase microperthite, about 15 per cent biotite, and 5 per cent each of hornblende and quartz. Common accessory minerals are sphene, zircon, apatite, and allanite.

Small masses of syenite and monzonite forming part of the Coryell plutonic suite range widely in composition and in form. The largest mass is exposed on a prominent hill in the eastern part of the city of Rossland and on the southeastern ridge of Columbia Kootenay Mountain. It is a grey, medium to coarse-grained augite-biotite monzonite composed of orthoclase microperthite (about 45 per cent), augite (10 per cent), biotite (10 per cent), andesine (10 per cent), and hornblende (5 per cent). The rock has been used for building stone and is described by Parks (1917, pp. 117-120). Other bodies of similar composition ranging from fairly continuous dyke-like masses to very irregular small stocks are shown on Figure 2; others too small to show are common. One mass, well exposed on Highway 3A just north of Topping Creek, is a medium-grained hornblende monzonite composed of orthoclase microperthite (50 per cent), andesine (20 per cent), biotite (15 per cent), and hornblende (15 per cent).

The margins of the Coryell plutonic bodies are sharp and most masses have narrow halos of thermal metamorphism. On Granite Mountain, for example, the metamorphic halo in trachytes of the Marron Formation is 150 metres or less in width. On the Jumbo property grey carbonaceous siltstones in sharp contact with Coryell syenite and intruded by many dyke-like offshoots of Coryell rocks are bleached and metamorphosed to tough quartz-pyroxene hornfels only locally. Just north of the property Rossland monzonite along the contact zone with Coryell syenite is a breccia consisting of angular fragments of fine-grained monzonite surrounded by medium-grained syenitic material apparently derived from the Coryell intrusion. Although mineralogical changes seem to be of limited extent, Coryell and related intrusions may have had a widespread heating effect causing a resetting of the potassium-argon ratios in both the Rossland monzonite and the Trail pluton as suggested by Thorpe and Little (1973, p. 1338).

MARRON FORMATION (O.K. VOLCANIC GROUP)

Flows and related volcanic rocks forming the summits and upper slopes of Record Ridge, O.K. Mountain, and Mounts Roberts, Grey, and Kirkup are referred to informally as the O.K. Volcanic Group. They have recently been correlated by Little (1982, pp. 22-25) with the Middle Eocene Marron Formation. They consist of porphyritic and amygdaloidal trachyte and andesite with interlayered volcaniclastic rocks. They were previously mapped as part of the Rossland Group but closely resemble Tertiary lavas exposed on Old Glory Mountain, 16 kilometres northwest of Rossland. Exposures of these rocks on Record Ridge are shown in a photograph in Daly's classic memoir (1912) on the 49th parallel, and descriptions and analyses of specimens from this locality are given in the memoir (p. 325). Gilbert (1948, p. 190) recognized that this group of flows is distinctive from other members of the Rossland Group and considered them to mark the western limit of the Rossland type of mineralization. In mapping the Rossland sheet, Little (1963, p. 4) concluded that lavas capping Old Glory Mountain, which previously had been regarded as part of the Rossland Group, are more alkaline than the Rossland Group and that they closely resemble lavas of Early Tertiary age. Those in the Rossland area are essentially the same as those on Old Glory Mountain and are distinctly different from rocks of the Rossland Group. A single whole rock potassium-argon age determination of a specimen (F6-203) from Record Ridge gave 51.6 ± 1.7 Ma; the volcanic rocks are therefore Tertiary. Although the stratigraphic succession is not well known, the sample dated appears to be more than 600 metres above the base of the lava pile.

The Marron Formation in the Rossland area consists of grey-weathering, dark grey to dark green and locally light purplish grey aphanitic rocks that form bold open outcrops. They are mainly flows which are commonly porphyritic, amygdaloidal, and, in places, fragmental. The flows are interlayered with greenish clastic rocks which are mainly tuff, lapilli tuff, and volcanic sandstone and conglomerate. A few feldspar porphyry dykes transect the layered rocks.

Most of the flows are porphyritic with phenocrysts of plagioclase and lesser amounts of augite and biotite. Plagioclase phenocrysts are well formed or partly resorbed; they are calcic andesine or labradorite. The matrix is aphanitic or microspherulitic. Many samples studied petrographically are trachyte; some are more basic and are properly termed andesite; a few, which are still more basic, are basaltic andesite. Amygdules are commonly quartz, carbonate, epidote, and chlorite. They occur in well-formed scattered vesicles or in highly clustered irregular ones which give the rock a mottled appearance.

The thickest section of sedimentary rocks in the Marron Formation is on the upper eastern slope of Mount Roberts (Plate IV). Rocks capping Mount Roberts are dark greyish green amygdaloidal andesite flows which dip at moderate angles to the west and lie above thin-bedded pyroclastic and sedimentary rocks that are as much as 150 metres thick. These rocks are dominantly volcanic breccia and volcanic sandstone with subordinate crystal lapilli tuff and grey siltstone. The breccia consists of angular fragments of porphyritic volcanic rock in a matrix of smaller rock fragments and, in places, scattered crystals of pyroxene, hornblende, and feldspar. Commonly the matrix is extensively altered to fine-grained hornblende, biotite, and chlorite.

Lenticular bodies of thin-bedded dark greyish green volcanic sandstone a few metres thick, commonly with thin white feldspar-rich beds, occur at many places in the O.K. Volcanic Group. Coarser grained purplish to greyish breccia and volcanic conglomerate are less common but are well exposed below the Cascade Highway west of Record Creek near the natural gas pipeline. In a road cut on Cascade Highway west of Record Creek, purplish lavas are underlain by thin-bedded greyish and purplish volcaniclastic rocks.

DYKES

Dykes in the Rossland camp have been described in detail by previous workers and only their general characteristics will be outlined in this report. Potassium-argon dating of eight dykes of various types shows that all the prominent dykes are Tertiary. Possibly older dykes are associated with the augite porphyry of the Rossland Group and the Rossland monzonite which herein are considered to include the diorite porphyrite of Drysdale (1915). The Tertiary dykes are referred to as lamprophyre, diorite, and diorite porphyry.

LAMPROPHYRE

Many lamprophyre dykes of various sorts are present in the Rossland area. They trend north 10 to 20 degrees west, dip steeply, and range from a few centimetres to a few tens of metres thick. They occur throughout the area and are most abundant east of the Jumbo fault. In the main mines, where many of the dykes were named, the Josie and Nickel Plate dykes are two of the most important. They average more than 20 metres in thickness and appear to control the concentrations of copper and copper-gold ore (*see* Gilbert, 1948, p. 193). The Nickel Plate dyke is not exposed on surface because it follows the valley west of Monte Cristo Mountain. Where it was encountered in the 3045 adit of Falaise Lake Mines Ltd., it is about 70 metres thick. It is a dark greenish dyke with prominent crystals of biotite and abundant potassic feldspar. Minor amounts of serpentine on blocky joint faces caused unstable ground in driving the adit. A petrographic description is given in Appendix C. This dyke is very similar to many other lamprophyres in the area, including the Headwall dyke in the A pit of Red Mountain Mines Limited, and a large dyke in the valley west of the mine which is well exposed on the Cascade Highway near Little Sheep Creek. In other biotite-rich dykes, such as the Mayflower dyke, plagioclase is the dominant feldspar. The Spokane dyke (*see* Drysdale, 1915, p. 30) is well exposed on the eastern side of a large rock cut on Highway 3A near the Rossland reservoir. It contains phenocrysts of plagioclase, hornblende, and biotite, many of which are more than 2 centimetres across. The Conglomerate or White dyke attracted the interest of geologists who studied the camp in its early days (*see* Drysdale, 1915, p. 3, Plate VIII; Bruce, 1917, p. 17). It is exposed on Highway 22 less than 400 metres south of the Rossland Museum. The dyke is a lamprophyre crowded with fragments of wallrocks including a high proportion from formations and intrusions which do not occur at the surface in the Rossland area, such as white quartzite, gneiss, syenite, vein quartz, and aplite. The largest fragment described by Drysdale (1915) is more than 50 centimetres long. The petrography of the dyke is given in Appendix C. A similar dyke crosses the southeastern ridge of Columbia Kootenay Mountain and is well exposed in a deep gully just west of the Rossland Mining School.

DIORITE

Dykes described as diorite occur mainly on Red Mountain where they form a prominent swarm trending north 20 degrees west across its southern slope and pass through Red Mountain mine. They also occur in several swarms to the east and are particularly prominent on Monte Cristo and Columbia Kootenay Mountains. The dykes are green to greenish brown, aphanitic, and very fine grained or porphyritic. Fine needles of hornblende are the only minerals readily distinguished in hand specimens, but small bleached spots with a core of pyrite are fairly common. The petrography of a typical diorite is given in Appendix C.

DIORITE PORPHYRY

One of the most difficult rocks to recognize and to map is diorite porphyry, referred to by Drysdale (1915) and Gilbert (1948) as diorite porphyrite and by later workers as diorite (Eastwood, 1966, p. 203), andesite, and hornblende porphyry. These rocks are common in the underground workings of the main copper-gold mines but not well exposed on surface in that area. They are abundant on Red Mountain and well exposed in the open pits of the Red Mountain mine.

These rocks are dark green, grey to brownish, and mostly porphyritic with phenocrysts of hornblende that commonly have a parallel orientation reflecting a flow structure. The matrix is mainly plagioclase crystals which also are commonly subparallel. These fairly distinctive rock types grade into very fine-grained to aphanitic equigranular rocks difficult to distinguish from some facies of the Rossland sill and Rossland monzonite, from Tertiary diorite dykes, and from some types of hornfels on Red Mountain.

In the area of the main copper-gold mines they form steeply dipping dykes trending either 60 degrees or approximately north; they generally parallel the main fracture systems. On Red Mountain, diorite porphyries form very irregular masses several metres across or lenticular sill-like sheets up to a few metres thick lying parallel to bedding in the hornfelsed siltstones. Drill core clearly shows aphanitic chilled margins on the dykes and banding parallel to the margins of the dykes, probably caused by flow during intrusion.

Drysdale (1915, p. 215) considered the diorite porphyrite to be a border or dyke facies of the Trail granodiorite. Gilbert, however, after carefully studying the relationships between these rocks and the Rossland monzonite, concluded that the diorite porphyry grades into Rossland monzonite and probably is an early dyke facies of the monzonite (*see* Gilbert, 1941, p. 13). From observations on Red Mountain it is clear that the diorite porphyry, which is thermally metamorphosed, fractured, bleached, and mineralized with pyrrhotite and molybdenite, is older than the dykes related to the Trail granodiorite. While direct evidence is difficult to find, the complex marginal zone of the Rossland monzonite in the area of the main copper-gold mines contains hornblende porphyry which grades into Rossland monzonite. These observations support Gilbert's conclusion that the diorite porphyry is older than the Trail granodiorite and probably is an early marginal facies of the Rossland monzonite.

METAMORPHISM

Rocks of the Rossland area are altered and metamorphosed. In this study metamorphic zones have been mapped on the basis of field observations and mineral identification in a few thin sections. The area has been subject to regional metamorphism and to subsequent thermal events; it is not possible everywhere to distinguish between them. An easterly trending garnet isograd has been defined (*see* Fig. 4) near the northern edge of the map-area which is taken to mark the transition from rocks in the lower amphibolite facies of regional metamorphism (*see* Simony, 1979) to greenschist facies south of the isograd. On the northern slopes of Blackjack Mountain and in scattered outcrops on Highway 3B to the west, rocks of the Rossland Group exhibit a low-angle, south-dipping schistosity which is not seen to the south. The schistosity is caused by the parallel orientation of fine flakes of biotite and ragged hornblende crystals. In metasedimentary rocks small red-brown garnets are common. On Blackjack Mountain some of these rocks grade rapidly southward into blocky grey siltstone containing fine biotite and local pyroxene. This apparently rapid increase in metamorphic grade is unrelated to the Trail pluton — the northwestern margin of which transects the garnet isograd.

Rocks of the amphibolite facies are probably present at depth beneath Rossland because the conglomerate dykes contain fragments of schist, quartzite, and gneiss apparently ripped off the dyke walls and rafted upward. On surface, however, all of the rocks of the Rossland Group and Mount Roberts Formation have greenschist facies mineral assemblages; those of the Marron Formation probably reflect still lower grades of metamorphism. None of these rocks have a pervasive schistosity. Except in areas of intense thermal metamorphism, they retain original minerals and structures. Probably the grade of regional metamorphism decreases southward but superimposed thermal metamorphism obscures this transition. Along the southern edge of the map-area grey siltstones and greenish tuffaceous siltstones contain secondary muscovite, sericite, chlorite, and, locally, very fine biotite. Mafic volcanic rocks carry ragged fine-grained hornblende, chlorite, and epidote. Rocks of the Marron Formation in the western part of the map-area, where they are away from the Coryell syenite, show differing amounts of alteration. Many of the lavas are fresh with clear phenocrysts of feldspar and biotite. Others are altered to chlorite, sericite, epidote, and carbonate; this alteration appears to be more extensive in the fragmental varieties than in the massive lavas.

In mapping the margins of the major plutons, zones of thermal metamorphism can be recognized. These are most striking and widespread adjacent to the Rossland monzonite. Along the southern margin of the monzonite a zone 300 to 500 metres wide contains hornfels and hornfelsic siltstone that are derived from and grade southward into grey and greenish tuffaceous siltstone. These rocks are well-indurated biotite hornfels; they are locally bleached and very siliceous and contain, in places, pyroxene and garnet. A similar zone of thermal metamorphism is present on Columbia Kootenay Mountain but patterns are complicated by the Trail pluton to the north. To the west, where Highway 3B passes through a deep rock cut near the reservoir, Rossland monzonite grades northward into volcanic conglomerate over a distance of about 300 metres. In this distance, as seen in outcrop, fragmental structure becomes gradually more obscure and the rock becomes a very fine-grained granoblastic rock with mottled structure; further south it grades into a fairly uniform fine-grained monzonite. In thin sections the least altered volcaniclastic rocks show ragged hornblende overgrowths on pyroxene. Farther south there is a progressive development of biotite and porphyroblastic potassic feldspar and eventually thin sections show the granitic texture of normal Rossland monzonite.

By contrast, the Trail pluton and Coryell syenite have sharp contacts and relatively narrow zones of thermal metamorphism. The Trail pluton, however, has extensive irregular zones of feldspathization associated with it. At least in part these appear to be later than the thermal metamorphism.

Based on field mapping, the distribution of hornfels in siltstone is shown on Figure 4. The hornfels within these zones is either a light green to cream-coloured, laminated or massive cherty rock or, north of Red Mountain, rusty pyrrhotitic amphibolite. In thin section the cherty hornfels has a very fine-grained granoblastic texture and generally contains quartz, biotite, green pyroxene, and plagioclase. Some specimens carry pale green hornblende, plagioclase (oligoclase to andesine), garnet, and idocrase. The amphibolite rarely shows primary banding. It is composed of green hornblende, quartz, plagioclase, biotite, and disseminated pyrrhotite. Potassic feldspar is locally abundant, particularly in the cherty hornfels. Bleached zones that grade into pyroxene-bearing quartz diorite have been mapped in the Red Mountain mine area. Similar zones are also present around the Rainy Day pluton and on the western slope of Blackjack Mountain. These bleached zones grade laterally into hornfels and the hornfels into grey hornfelsic siltstone containing disseminated biotite which is distributed widely. None of these zones of thermal metamorphism seem to coincide with the surface or the known underground shapes of either the Rossland monzonite or the Trail pluton. Nor do they fit the zones of hydrothermal sulphide mineralization defined by Thorpe (1967, p. 10).

3

GEOLOGICAL STRUCTURE

REGIONAL SETTING

In the Rossland area the oldest sedimentary and volcanic rocks not only are intruded by a succession of plutons and near-surface intrusions, but also are truncated by many faults. Because of the dismembered nature of the pre-intrusive rocks, it is not possible to make either stratigraphic or structural correlations on the basis of data collected within the map-area alone. Coupled with regional maps by Little, however, patterns indicate that the map-area contains two structural domains separated by an irregular line of intrusions and faults. The intrusions include the bodies of serpentinite, the Rainy Day pluton, and the Rossland monzonite; the faults are inferred from discontinuities across these intrusions. This line of intrusions and faulting trends east-northeast and is referred to as the Rossland break (*see* Fig. 4). It separates northeasterly trending structures in the southern domain from northerly trending structures in the northern one. This change in structural trend, which extends for many kilometres both north and south of the map-area, reflects the southernmost curvature of the Kootenay Arc and may be related to it.

The Rossland break is not a simple fault zone, although many of the margins of the serpentinite bodies are faults. Pre-intrusive rock units cannot be correlated in detail across the break. However, within the Rossland Group similar lithologies are present north and south of the break. Augite porphyry sills and irregular intrusions, considered to be part of the Rossland Group, increase in size and number toward the break, but no individual intrusions can be correlated across it. Siltstone formations form markers within the Rossland volcanic rocks within the domains both north and south of the break; however, they cannot be correlated across it. South of the break these markers define complex folds close to the break which are not found farther from it.

From these observations it is suggested that the Rossland break is a zone of structural weakness that may have originated when the Rossland Group was being laid down and subsequently formed a locus for intrusion of the serpentinites and the Rossland monzonite and later fault movements.

STRUCTURES SOUTH OF THE ROSSLAND BREAK

Structures in pre-intrusive rocks south of the Rossland break are outlined by interlayers of grey siltstone within the green volcaniclastic and flow rocks of the Rossland Group. These rocks are generally blocky and not foliated, with well-preserved primary structures, except in zones of intense deformation or thermal metamorphism. Primary sedimentary or volcanic structures which can be used to define the stratigraphic top of the formations are very scarce; determination of the structure depends mainly on tracing the siltstone units. The siltstones and the bedding generally trend northeastward and dips are at moderate angles to the northwest. From limited evidence, regardless of faulting, and away from local folds, the section is homoclinal and upright.

Generally bedding in the siltstones is parallel to both formational contacts with the massive volcanic rocks and the bedding within the volcaniclastic rocks. The siltstone layers are probably lenticular, although clear lensing out of siltstone into volcanic rocks which might represent changes in facies has not been mapped. Locally the margins of the siltstone units appear to cut off bedding within the siltstone; such contacts are found to be, or may be assumed to be, intrusive. Aphanitic and porphyritic sills and dykes related to the augite porphyry are difficult to distinguish from these green volcanic rocks and contacts may be either concordant or discordant with the siltstone.

Three areas of folding outlined by siltstones have been mapped. In the first, dark grey siltstones, exposed on Highway 22, 4.5 kilometres south of its junction with Highway 3B, traced eastward into the valley of Gopher Creek define complex folds in that area. Along the highway and on the slopes to the east, the siltstones strike northward and dip at moderate angles to the east. To the southeast, on the crest of the ridge, the strike swings to the east and the dip becomes moderate to the north. Minor folds in the hinge zone plunge at moderate angles to the northeast. The second area is to the east, across the Jumbo fault, where what is probably the same siltstone dips to the northwest. In the valley of Gopher Creek the strike curves northward; there dips are moderate to the west. Though obscured by syenite and augite porphyry intrusions and hornfels metamorphism, attitudes in this area define a southwesterly plunging fold. In the third area, in another lens of siltstone exposed east of Highway 22 on the steep western slopes of Deerpark Hill, beds dip steeply and steep southwesterly plunging Z folds occur within the siltstone.

In these three areas where folds have been mapped no consistent structural pattern is recognized. It seems probable that they are local folds associated with either movements on the Rossland break or deformation around later intrusions or faults, or a combination of these causes.

STRUCTURES NORTH OF THE ROSSLAND BREAK

Structure patterns north of the Rossland break are best known from surface exposures and underground data from Columbia Kootenay, Monte Cristo, and Red Mountains, Mount Roberts, and the mountains to the north and south of Mount Roberts. The structure, shown in two vertical cross-sections (Fig. 2), is known from surface mapping, diamond drilling on Red Mountain, and underground records supplied by Cominco Ltd. in the main camp and beneath Columbia Kootenay Mountain.

The westernmost fault, called the O.K. fault, trends north, dips steeply east, and forms the eastern margin of the Marron Formation. The fault can be closely located but is not known to be exposed. The dip was interpreted from deflection of the trace of the fault as it crossed stream valleys on the eastern slopes of Mount Roberts and Granite and O.K. Mountains. The Marron Formation dips at moderate angles to the west immediately west of the fault but flattens to a low northerly dip within 200 metres of the fault. The volcanic rocks are clearly downthrown along the fault and may have been steepened by drag against it. The amount of vertical displacement is at least 600 metres; however, judging from the attitudes of the volcanic rocks it is probably more than twice this amount.

East of the O.K. fault are steeply dipping sedimentary rocks of the Mount Roberts Formation and greenstones of uncertain correlation. Together these form a panel bounded on the east by the Jumbo fault (*see* Fig. 2). The Jumbo fault, named from the Jumbo property west of Red Mountain mine, is almost exposed at a number of places. Along Highway 22, 1.8 kilometres south of its junction with Highway 3B, the fault brings together shattered syenite on the east and sheared serpentinite on the west. Both rocks contain many steeply west-dipping minor faults and sheared fractures. Close to the fault zone to the north along the old Cascade Highway, in the valley of west Little Sheep Creek, and along the winter ski road to Granite Mountain (elevation, 1 448 metres) shattered syenite lies east of schistose greenstone. The Jumbo and O.K. faults are probably related and may join north of the area mapped. To the south in the valley of Little Sheep Creek, the Jumbo fault probably splits, one branch continuing southward along the western slopes of Deerpark Hill, others following the northern and eastern margins of the serpentine in that area. The Jumbo fault is assumed to be downthrown on the west because abundant intrusions and widespread thermal metamorphism in rocks on the east are taken as evidence that rocks east of the fault represent a deeper thermal regime.

The panel of rocks between the Jumbo and O.K. faults contains steeply dipping strata of the Mount Roberts Formation and volcanic rocks of uncertain correlation. These two rock units are separated by a westerly dipping fault which is probably older and unrelated to the faults which bound the panel. This fault contact, called the Snowdrop fault, is a complex one along which the siltstones to the west are warped and locally brecciated and volcanic rocks to the east are sheared. The steeply dipping siltstones are warped along axes which plunge at steep to moderate angles to the west; on the eastern slopes of Granite Mountain, just under the fault, foliation in the volcanic rocks dips 45 degrees to the west. In this area the fault plane dips westward, judging from the trace of the fault plane on the hillside and the foliation in adjacent greenstones, and farther south it steepens. Near the Snowdrop mine it swings abruptly westward for 100 metres then turns southward again in the south bank of Snowdrop Creek at the point where it crosses the old Cascade Highway. A further 150 to 200 metres south along the highway from the creek, the fault is marked by a spectacular breccia consisting of angular fragments as much as 20 centimetres across of brownish hornfelsic siltstone and porphyritic andesite in a matrix which is dominantly fine-grained hornblende. Quartz, calcite, pyrrhotite, pyrite, coarse-grained hornblende, and locally scheelite are minor constituents of the matrix. The breccia lies between steeply dipping hornfelsic siltstone on the west and amygdaloidal greenstone on the north and east. It is well exposed in rock cuts along the highway and in cliffs for a few tens of metres above it but has not been found beyond these exposures.

East of the Jumbo fault (*see* Fig. 2) is an elongate body of Coryell syenite with a digitated steeply east-dipping eastern contact. Hornfelsic siltstone to the east dips gently westward. On Red Mountain it contains a complex breccia which is host for much of the molybdenite mineralization. Away from the breccia zone the siltstone dips uniformly at 20 to 30 degrees to the west and the upper contact with augite porphyry is concordant with this attitude throughout its exposed length and where encountered in drilling. Volcaniclastic and sedimentary rocks east of the augite porphyry dip more steeply than the siltstones west of it; the eastern contact is probably transgressive. Geological records of the War Eagle, Centre Star, and Le Roi mines show augite porphyry well below the places where it would be expected if the contact was concordant with volcaniclastic and sedimentary rocks to the east.

East of the augite porphyry on Monte Cristo and Columbia Kootenay Mountains the rocks dip fairly uniformly at moderate angles to the west; primary sedimentary structures found at a few places indicate that the beds face westward. Only a few faults have been found; these trend northward and offset on them is probably small.

Shapes of the larger bodies of plutonic rocks are important in defining exploration targets and in developing concepts on the controls of mineralization. Much of the work of The Consolidated Mining and Smelting Company of Canada, Limited geologists in 1939 and 1940, for example, was directed toward determining the shape of the Rossland monzonite in the main camp and beneath Columbia Kootenay Mountain. The gradational nature of the contact and its irregularity on surface make projections underground difficult; consequently, the outlines shown on Figure 2 are based on company data. No monzonite comparable to the Rossland monzonite was encountered in deep drilling beneath Red Mountain even though Rossland monzonite occurs at surface west of Jumbo Creek.

Exposed contacts of the Trail pluton, on the other hand, are well defined and quite uniform in attitude through much of the map-area, although the relationship of the pluton with granitic dykes on Red Mountain and the Rainy Day pluton is speculative. The upper surface of the pluton, as mapped along the slopes north of Columbia Kootenay and Monte Cristo Mountains, trends between west and 20 degrees north of west and dips southward. The dip, as determined from a number of underground workings and drill holes shown on Cominco Ltd. records, is between 30 and 50 degrees; this trend and dip continue down to elevations of 500 metres above sea level where it is 1 100 metres south of the surface trace. Granodiorite encountered in 1974 drilling from Red Mountain mine is lithologically identical with the Trail pluton. It is probably a direct extension of it, but the configuration of the surface of the pluton beneath Red Mountain is uncertain. Contacts of the pluton north of the reservoir and in upper Topping Creek, where the granodiorite is probably an extension of the pluton, suggest that its upper surface may consist of one or more northerly trending valleys and ridges in this area. This trend contrasts with that of easterly trending quartz monzonite dykes and zones of brecciation and feldspathization northwest and west of Red Mountain. It contrasts also with the Rainy Day pluton whose shape is partly defined by surface exposures and underground workings. On surface near the Cascade Highway along the lower south slopes of Red Mountain, the upper contact of the pluton is irregular and appears to have a low dip. At depth, in the Le Roi 1650 level at an elevation of 700 metres and in underground drill holes, quartz monzonite was encountered only in the westernmost extremities (*see* Fig. 2). The data indicate that the pluton is floored by hornfelsic siltstone and augite porphyry. Therefore if the Rainy Day pluton is part of the Trail pluton, it must be a northerly plunging tabular or bulbous offshoot.

FAULTS, VEINS, AND FRACTURES

Fractures and faults in the Rossland area most commonly dip steeply and occur in sets. A complex sequence of fracturing, faulting, mineralization, and filling of fractures by dykes has only been partly deciphered. Evidence suggests that multiple episodes of brittle deformation occurred. Evidently much of this deformation took place in Tertiary time but it is clear that deep-seated pre-Tertiary fractures controlled the Rossland break and that these influenced subsequent deformation. Much remains to be learned about the fracturing, faulting, and mineralization history of the Rossland camp and such studies will prove most useful exploration tools.

Two well-defined steeply dipping fracture sets occur throughout the camp. They are referred to as the fault-dyke set, which trends northward, and the vein set, which trends eastward.

Faults and dykes in the fault-dyke set strike between north and 20 degrees west of north and dip between vertical and 65 degrees to the east. The O.K. and Jumbo faults are members of this set with major displacements; other faults have been defined on Red Mountain in and near the workings of Red Mountain mine. They trend 20 degrees west of north and are downthrown on the west (*see* Fig. 2, section A-A'). In the main camp faults along the northerly trending dykes and fractures have relatively small displacements. Drysdale (1915, p. 56) records normal faulting along the Josie and Nickel Plate lamprophyre dykes which caused horizontal displacements of about 100 metres and 10 metres respectively. Other northerly trending faults with relatively small offsets likely are present within the map-area but none with large offsets were recognized east of the Jumbo fault (*see* Little, 1963).

The northerly trending dykes are spaced at intervals of a few tens of metres, and form part of a regional dyke swarm system which occurs for many kilometres east and west of Rossland. They range from a few centimetres to more than 20 metres thick and most are 0.5 to 1.5 metres thick. Dykes and faults of this set are more numerous and regular in attitude north of the Rossland break than within or south of it. In spite of irregularities in attitude, it is clear that emplacement of the dykes took place at a time of regional east-west extension that resulted in fault-bounded blocks and expansion within them of possibly 5 per cent.

The vein set has been described in detail by Drysdale (1915, pp. 45-53) and is the subject of analysis by Gilbert (1948, pp. 193-195). In the present work the Main veins have not been studied in detail but the structural characteristics of all mineralized fractures encountered in mapping were noted; it is these observations, together with available maps and reports, that form the basis of the following discussion.

The main Rossland veins are described by Gilbert as follows:

> 'The main Rossland veins, especially in the central area, occur on two general strikes, of which the better developed is about N. 60° to 70° E. (Centre Star-Le Roi) and the other N. 60° W. (War Eagle). The smaller veins are either parallel with these or in the acute angle between them (*i.e.*, nearly east-west). The dips in practically all cases are between 60° and 80° N.'

The strongest veins are concentrated in three groups: a northern group, the Main Rossland veins, and a southern group which is referred to as the South belt. The northern group includes the St. Elmo (which is exposed in the uppermost open pits of Red Mountain mine on the south shoulder of Red Mountain), the Cliff, and the Monte Cristo veins. The Main Rossland veins include the White Bear, Le Roi, Centre Star, Josie, War Eagle, Nickel Plate, Idaho, Columbia, and Kootenay veins. The main South belt veins are the Blue Bird-Mayflower and Homestake-Gopher. Within these groups the typical attitudes and vein characteristics described by Gilbert for the Main Rossland veins are maintained, although the detailed structural characteristics and mineralization vary with type of wallrock and the geographic location (Thorpe, 1967). Between the groups of strong veins are mineralized fractures ranging from a few millimetres to more than a metre thick and from less than a metre to several tens of metres long; these contain hornblende, quartz, and sulphides. The attitudes of these mineralized fractures conform to vein directions referred to by Gilbert (*see* Figs. 2 and 3).

The pattern of veins and mineralized fractures suggests that fracturing developed by east-west compressive stresses resulting in shear failures in the 115 and 065-degree directions and tension fractures in the 90-degree direction. All have steep northward dips. The fracture pattern characteristically developed ore shoots whose greatest dimension is on the dip. The area affected by this stress system may not have been much larger than the Rossland camp itself. It represents a significant change from the earlier east-west-directed tensional system that produced the fault-dyke set of fractures and ultimately led to the intrusion of the late dykes and the block faulting. This history of several episodes of fracturing and deformation of the heterogeneous assemblage of Rossland rocks led to the complexities of the vein fractures described by Drysdale (1915, pp. 48-65) and Gilbert (1948, pp. 193-195). These include splits, branches, *en echelon* veins, anomalous attitudes, and variations of vein characteristics with rock type. If the evidence that the sulphide mineralization was later than the dykes is correct (*see* Fyles, *et al.*, 1973, pp. 23, 24), then circulation of mineralizing solutions probably took place during the east-west compressive regime while north-south fractures were closed.

4

MINERAL DEPOSITS

INTRODUCTION

Three main types of mineral deposits have been mined in the Rossland area: (1) copper-gold veins with minor lead and zinc, (2) gold veins, and (3) molybdenum deposits. Ore produced from the copper-gold veins formed the basis for the original development of the camp and for construction of the Trail smelter. Between 1894 and 1941 a total of 5 600 000 tonnes of copper-gold ore was produced from these veins. Two major attempts to revive the mining of these deposits were made after the period of main production, one by The Consolidated Mining and Smelting Company of Canada, Limited between 1941 and 1943 and the other by Falaise Lake Mines Ltd. in 1969 and 1970. Neither attempt led to further production. Although production from these veins in the main camp was copper and gold, minor production of lead and zinc came from the same set of veins peripheral to the main camp.

The gold veins are discontinuous mineralized faults and fractures in volcanic and sedimentary rocks in the valley of Little Sheep Creek south of Red Mountain. They have been mined intermittently since the early days of the camp and continue to attract exploration interest because they contain spectacular shoots of high-grade gold mineralization.

The molybdenum deposits on Red Mountain (Plates I and II) comprise the only significant mining in the camp in recent years; they were the main reason for carrying out the present geological study. In this chapter descriptions of the copper-gold deposits are mainly taken from the work of Drysdale (1915), Bruce (1917), and Gilbert (1948). Data on the gold deposits are also based on this early work supplemented by observations made by the writer on several occasions while the workings were accessible. Data on the geology of the molybdenum deposits are based on Ministry of Energy, Mines and Petroleum Resources and company records, and data collected by the writer during the summers of 1967 through 1971 and in 1981.

OWNERSHIP AND PRODUCTION

Essentially all of the mining properties in the Rossland area have been held as Crown-granted mineral claims and many are so held today. Figure 3 shows these claims as they existed in the records of the British Columbia Department of Lands in 1970. Since that time ownership of many of the claims has reverted to the Crown; for some, the boundary surveys have been cancelled. A search of title made in October 1982 showed that more than 60 per cent of the claims had reverted; only a small proportion had been taken up as mineral leases or recorded claims. The Crown-granted claims are of historic interest because production statistics and other technical records are usually referred to the original name of the claim.

Production from claims within the map-area, as recorded by the Mineral Policy and Evaluation Branch of the Ministry of Energy, Mines and Petroleum Resources, is shown in

TABLE 1. MINERAL PRODUCTION FROM THE ROSSLAND AREA, 1896–1982

Name	Minfile No. 82F/SW	Year	Tonnes Mined	Gold g	Silver g	Copper kg	Lead kg	Zinc kg	Molybdenum kg
Black Bear	105	1919	1 314	5 474	9 891	4 214	—	—	—
Blue Bird	145	1908–1914, 1935, 1951, 1952	2 090	7 338	1 562 428	864	78 086	75 752	—
Centre Star	094	1897–1917	2 065 331	34 164 625	23 147 008	13 366 167	—	—	—
Consolidated St. Elmo	136	1898–1911, 1933–1936	1 915	14 868	99 530	24 195	—	—	—
Coxey	110	1966–1972	943 070	—	—	—	—	—	1 652 970
Curlew	154	1908	6	62	3 608	—	—	—	—
Evening Star	102	1896–1907, 1932–1939	2 859	56 701	21 521	1 276	—	—	—
Georgia	149	1933–1939	49	466	653	—	—	—	—
Giant	109, 113	1898–1913	4 131	113 246	23 265	1 330	—	—	—
Gold Hill	112	1894	9	—	31 103	—	—	—	—
Golden Drip	118	1923–1939	184	5 255	6 843	39	186	—	—
Hattie	142	1934–1939	21	310	1 090	—	—	—	—
Homestake	123	1901–1908	236	933	74 927	91	—	—	—
Iron Colt	100	1936, 1937,	20	186	466	—	—	—	—
Iron Horse	099	1903	27	746	—	272	—	—	—
I.X.L.	116	1899–1974	5 248	809 766	268 291	8 255	129	112	—
Josie	147	1898–1922	568 700	9 792 252	15 544 721	7 965 035	—	—	—
Kootenay	151	1896–1904	144	68 520	—	—	—	—	—
Le Roi	093	1898–1917	1 791 680	24 091 170	37 563 105	21 330 618	—	—	—
Lily May	153	1910, 1935	37	124	18 506	549	407	578	—
Lord Roberts	163	1924	7	—	187	22	—	—	—
Mayflower	146	1907–1910, 1929–1937, 1948, 1949	876	4 136	376 780	—	25 785	49 390	—
Midnight	119	1927–1974	4 760	218 346	124 383	62	2 097	1 460	—
Monday	124	1937	64	—	13 468	—	2 226	3 467	—
Nickel Plate	095	1901–1913	18 685	291 778	335 787	209 376	—	—	—
Norway	120	1936	1	—	156	—	—	—	—
O.K.	117	1909, 1933–1939	293	17 916	14 991	154	—	—	—
Phoenix	132	1912–1915, 1939–1942	279	4 697	16 016	3 212	—	—	—
Red Eagle	155	1908, 1927	7	—	4 603	60	381	15	—
Richmond	143	1912	11	311	14 432	—	912	—	—
Robert E. Lee	131	1896	11	684	—	—	—	—	—
Silverine	286	1934–1944	82	1 493	2 178	—	—	—	—
Snowdrop	115	1931–1937, 1955–1957	6	6 843	16 640	—	—	—	—
Spitzee	121	1900–1905	5 910	55 207	97 290	52 264	—	—	—
St. Elmo	134	1908	70	93	6 874	1 446	—	—	—
Union	164	1937, 1946, 1952	31	187	37 945	—	5 019	2 558	—
Virginia	098	1899	95	2 395	1 866	943	—	—	—
War Eagle	097	1898–1905	300 169	5 659 751	12 036 613	5 021 436	—	—	—
White Bear	114	1903–1920	17 028	72 905	229 104	142 064	—	—	—
Rossland Properties		1918–1942	653 696	9 928 325	15 318 632	6 162 263	—	—	—

Table 1. The final entry, designated 'Rossland Properties,' represents ore mined, in part by lessees, from the main mines (Centre Star, Josie, Le Roi, War Eagle) between 1918 and 1942. The data were recorded by Cominco Ltd. and source claims were not designated. Locations of the claims and some of the veins and workings are shown on Figure 3 but the maze of underground workings in the core of the main camp is not illustrated. The workings shown indicate only the lateral extent of the underground exploration.

COPPER-GOLD AND LEAD-ZINC VEIN DEPOSITS

Early terminology, based on the production and exploration potential of these veins, recognized three main groups: the North belt, extending eastward from the northern crest of Red Mountain through Monte Cristo Mountain; the Main veins, extending northeastward from the southeast slopes of Red Mountain to Columbia Kootenay Mountain; and the South belt, south of the city of Rossland on both sides of Gopher Creek. The surface outcrops of these veins and the claims through which they pass are shown on Figure 3. An analysis made by Gilbert in 1941 showed that more than 98 per cent of the ore shipped came from the Main veins and more than 80 per cent was taken from a central core zone that lies beneath the hills immediately northwest of Highway 3B between the junction with Highway 22 and the south end of the reservoir. Geologically this central core lies between two large northerly trending lamprophyre dykes, the Josie on the west and the Nickel Plate on the east. Gilbert and Malcolm (1942, p. 7) describe this distribution of production as follows:

> 'In the central area, especially in the upper levels of the mines, a great many veins and ore-shoots were worked. In the two adjacent areas [main veins east and west of the central area] the number was smaller but still appreciable. In the outer parts of the camp there are veins similar in many respects to those found in the central part but unfortunately they have few ore-shoots.'

The Rossland veins formed by replacing wallrock along well-defined fractures and by filling fractures and faults. The principal sulphides are pyrrhotite and chalcopyrite; the gangue is more or less altered rock with lenses of quartz and calcite at some places. Pyrite occurs in small amounts, both as well-formed crystals in pyrrhotite and disseminated in the wallrocks. Copper-gold ratios of the ore were highly variable but in general gold values varied directly with copper values. The analyses of production records by Gilbert and Malcolm (1942, p. 4) showed that the ratio of pounds of copper to ounces of gold over the whole camp was approximately 40. However, it ranged in individual years from 19 to 72.

A large number of sulphides and gangue minerals have been identified and described (*see* Drysdale, 1915, pp. 73-85; Bruce, 1917, pp. 31-35; Thorpe, 1967, pp. 10-35). Thorpe studied the distribution of sulphides for the entire camp and included the molybdenum deposits with the veins. He found a well-marked zonal arrangement (Thorpe, 1967, p. 8). The outlines of these zones, taken from Thorpe's Figure 2, are shown on Figure 4.

NORTH BELT

The North belt is a zone of discontinuous veins. On a regional scale they appear continuous but in detail they are lenticular and offset by northerly trending faults. The veins, which trend east and dip steeply north, cross the Mountain View, St. Elmo, Consolidated St. Elmo, Cliff, Monte Cristo, and Evening Star claims. The strongest vein is on the Cliff and Consolidated St. Elmo claims; it occurs in augite porphyry of the Rossland sill. On surface the vein consists of massive pyrrhotite with minor amounts of chalcopyrite. It strikes east and dips 60 to 70 degrees north, is 1 or 2 metres thick, and is exposed for almost 100 metres in trenches and open stopes. At depth it is reported to flatten in dip and thicken to almost 7 metres. Production figures give an average grade of 7.8 grams gold per tonne, 51.8 grams silver per tonne, and 1.27 per cent copper.

To the east on strike a somewhat weaker vein, which crosses the Monte Cristo claim, was developed in a series of shallow underground workings within the northern contact zone of the Rossland monzonite. Farther east on the Evening Star claim there is an apparent extension of the North belt veins that trends 65 degrees and dips at moderate angles to the northwest. Old shafts and trenches expose a very rusty zone crossing hornfelsic siltstone between rocks of the Rossland monzonite on the south and the Trail pluton on the north. In addition to pyrrhotite and chalcopyrite, the vein is reported to carry molybdenite.

To the west veins of the North belt are in hornfelsic siltstone and cross the molybdenum-bearing Breccia complex of Red Mountain mine. On the St. Elmo claim relatively weak, steeply dipping, discontinuous veins trend east. They contain significant amounts of sphalerite as well as pyrrhotite, pyrite, and chalcopyrite. Further west on the Mountain View claim old workings follow a steep rusty fracture containing pyrrhotite and pyrite which strikes east and is part of a zone containing a granodiorite breccia.

Thus veins of the North belt transect a variety of rock types and the host rock appears to control their structural characteristics and mineralogy. The strongest veins are in augite porphyry. The fractures control the emplacement of at least one of the quartz diorite breccia dykes and were therefore in existence at the time of intrusion of the Trail pluton. They were offset by the northerly trending fault-dyke set of fractures.

MAIN VEINS

The Main veins, like the North belt veins, form a continuous well-defined fracture system on a regional scale. The system extends from the southern slopes of Red Mountain northeastward through the uppermost residential area of the city of Rossland to the eastern slopes of Columbia Kootenay Mountain, a strike length of more than 1 kilometre. The Main vein system trends 70 degrees; it consists of a series of veins dipping steeply to the north parallel to this trend, as well as important veins that trend about 120 and 90 degrees and have steep north dips. Production came mainly from the Le Roi, Centre Star, Nickel Plate, Josie, and War Eagle mines. In these mines the vein system was mined to elevations of about 600 metres and explored by drilling to sea level giving a vertical dimension at least equal to, and probably greater than, the strike length. Within the system are a large number of veins, described by Gilbert (1948, pp. 193, 194) as follows:

> The main or Centre Star-Le Roi vein was mined almost continuously over a length of several thousand feet, but in general the veins are a series of ore shoots of no great width or strike length, with their greatest dimension on the dip. On dip they usually die out gradually, either through loss of width or loss of metalliferous content. On the strike the same may occur, but more commonly they end abruptly against a dyke or other cross structure. In some cases a vein consists of a number of ore shoots strung out at intervals along a single fissure, but on the whole the fissures themselves are non-persistent; one dies out and a parallel one appears, possibly connected with the first by a cross break. Most of the veins, therefore, are made up of a series of shoots more or less *en echelon* in strike and dip. As the fissures strike at various angles within a 60° sector, the relations of the shoots are often complex and their positions largely unpredictable. They may split along branching fissures, or be localized at intersections. The larger veins form fairly distinct units, but in many cases it is difficult to determine to what vein a particular shoot belongs.
>
> The heart of the central area, on the surface or on any single level, is a trapezoid, bounded on the east and west by the Nickel Plate and Josie dykes, on the north and south by the Main and War Eagle veins. Within this area lie a number of smaller veins and shoots. North and south of the area no important ore has been found. East of the Nickel Plate various shoots have been mined, roughly on the extension of the main vein, and west of the Josie a number of fairly productive veins were found.
>
> The trapezoid widens with depth. The War Eagle vein is at best only a series of detached ore shoots, and at about the 9th level there is a marked *echelon* to the north. In the main vein, at about the same elevation, there is an equally definite *echelon* to the south. Consequently, although the shoots in each vein have an average dip of 70°, the over-all dip of the main vein is steeper than this

> and that of the War Eagle flatter. As the wedge widens downward the mineralization diminishes. In short, the region in which fissuring is most concentrated and mineralization most intense lies close to the surface and not far west of the Nickel Plate dyke.

In the central area Gilbert describes more than 20 individual veins containing ore shoots that were as much as 350 metres in strike and dip length and 15 metres thick. The veins are mainly in augite porphyry and monzonite, and are commonly associated with contacts of wedge-shaped dykes of diorite porphyry. A complex structural relationship between ore shoots and the irregular shapes of the monzonite intrusion was developed from the detailed studies made by Gilbert (1948, p. 194). Regarding extensions at depth he states (p. 195):

> In the central area, the veins were developed intensively at depth, and a large amount of drilling was done in the search for parallel ore shoots. The lowest levels were almost completely without ore; the individual shoots terminated or lost their mineralization and new ones were not found to replace them.

SOUTH BELT

The principal vein system in the South belt is on the Blue Bird and Olla Podrida (referred to as the Mayflower) claims (*see* Fig. 3), which are on either side of Gopher Creek about 1.2 kilometres south of the centre of the city of Rossland. The vein system trends 110 degrees and dips steeply. North of the Blue Bird another group of old workings tested a vein system on the Homestake, Gopher, and Maid of Erin claims that trends east and dips steeply. Some other deposits in the South belt include isolated showings on several other claims including the Deerpark, Lily May, Zilor, Richmond, Sunset, and Monday. The two vein systems are 100 to 400 metres south of the southern edge of the Rossland monzonite in siltstone, hornfelsic siltstone, volcanic conglomerate, and augite porphyry of the Rossland Group. They are within the zone of thermal metamorphism associated with the monzonite. Many northerly trending lamprophyre dykes and a few granite and diorite porphyry dykes transect these rocks.

Mineral deposits in the South belt were among the earliest discovered in the Rossland camp (the Lily May on the Dewdney Trail, located in 1887, is reported to have been the first discovery in the camp); they have received attention from time to time since. Total production from the South belt, however, has amounted to only 3 625 tonnes with gross contents of 18 100 grams gold, 2 081 160 grams silver, 4 747 kilograms copper, 107 797 kilograms lead, and 129 202 kilograms zinc. Extensive exploration of the principal vein systems was undertaken by Rossland Mines Ltd. between 1946 and 1949 (*see* White, 1949, pp. 156-163).

From the examination of old dumps and accessible workings and from published and unpublished reports, White distinguished three types of mineralization in the South belt:

> The Rossland type is heavy sulphide ore, predominantly pyrite and pyrrhotite with a little chalcopyrite, and yields gold and copper. The South Belt type contains pyrite, pyrrhotite, arsenopyrite, sphalerite, galena, and, locally, boulangerite. A large part of the value is due to silver, lead, zinc, and gold, but the content is low. The Transitional type is gradational in mineralogy and metal content between the Rossland and South Belt types. Usually it contains abundant sphalerite, little or no galena, and is low in silver.

Table 2, modified from White's report (p. 158), shows the distribution of these types.

TABLE 2. CHARACTERISTICS OF THE SOUTH BELT VEINS

Claim	Strike of Deposit	Tonnes Mined	Country Rock	Ore Type
Phoenix	80	279	Monzonite	Rossland
Abe Lincoln	90	?	Monzonite	Rossland
Sunset	?	?	Monzonite	Rossland
Nest Egg	?	?	Monzonite	Rossland
Monday	0–45	64	Hornfelsic siltstone	Transitional
Homestake	100	236	Augite porphyry	Transitional
Gopher	?	?	Augite porphyry	Transitional
Maid of Erin	80	?	Augite porphyry near monzonite	Transitional
Blue Bird	110–115	2 090	Siltstone	South Belt
Mayflower	110	876	Augite porphyry	South Belt
Hattie	90	21	Volcanic near monzonite	Rossland
Deerpark	170	?	Volcanic near monzonite	Rossland
Lily May	135	37	Siltstone	South Belt
Richmond	80	11	Siltstone	South Belt
Robert E. Lee	?	131	Volcanic near monzonite	Transitional
Red Eagle	?	7	Augite porphyry	South Belt
Zilor	90 & 145	?	Siltstone	South Belt
Curlew		6	Augite porphyry	South Belt

White notes that Rossland-type ore occurs either in or near the monzonite. Whereas the most common trend is westerly, anomalous trends are found on the outskirts of the area.

In the vicinity of the Mayflower and Blue Bird workings White describes the geology as follows:

> The predominant rock near the workings is a variation of the type called 'augite porphyrite' in Memoir 77, which here is characterized by prominent dark-green crystals of altered augite and is markedly brecciated. The angular fragments are recognizable only on weathered surfaces and are embedded in a matrix somewhat finer in grain but apparently of the same composition as the fragments. The fragments range from 1 to 12 inches [2.5 to 30 centimetres] across. The prominent augite crystals are scattered evenly throughout both fragments and matrix, and some crystals of augite extend from a fragment across the boundary into the matrix. Near the southeastern border of the augite porphyrite area the outcrops are more severely weathered and coloured red and white by oxidation of iron and kaolinization of the feldspars. In one outcrop 950 feet [290 metres] west of the main adit the augite porphyrite breccia grades first into volcanic agglomerate and finally into thin-bedded reddish material resembling tuff, which strikes north 60 degrees east and dips steeply southeastward.
>
> The augite porphyrite breccia gives place southeastward to conglomerate composed of sub-rounded and rounded pebbles of augite porphyrite, granite, diorite, and quartz in a matrix of very fine-grained dark-coloured silt-like material. The matrix weathers out readily, leaving the pebbles protruding from the surface. Most of the pebbles range in size from 1 to 3 inches [2.5 to 7 centimetres], but in places pea-size pebbles and coarse sand occur in stratified lenses that strike about north 40 degrees east and dip about 60 degrees to the southeast. Grain-size gradations in the stratified beds indicate that the beds are right-side up. Preferential replacement of the matrix and of certain of the pebbles by epidote is a common feature. The contact of the augite porphyrite and conglomerate was nowhere observed, but it would appear to be abrupt. Evidently it represents an erosion surface separating the augite porphyrite and the overlying conglomerate.
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> One thousand feet [305 metres] southwesterly from the Mayflower workings, across the drift-filled valley of Gopher Creek, the contact of augite porphyrite and thin-bedded siliceous slate is exposed in a railroad cut. The augite porphyrite near the contact is massive, fine grained, and not porphyritic, and the slate is indurated and pyritic. The contact strikes north 20 degrees east and is vertical. In the railroad cut the bedding of the slate is parallel to the contact, but 850 feet [259 metres] farther north the slate in the Blue Bird workings strikes north 15 degrees west and dips 50 degrees westward.

Intrusive into these older rocks are diorite porphyry, granite porphyry, and both mica lamprophyre and non-mica lamprophyre dykes. The oldest are dykes and irregular masses and tongues of fine-grained diorite porphyry with distinctive acicular hornblende crystals. The zone of granite porphyry dykes begins near the eastern edge of the area mapped. The granite porphyry is easily distinguished by its subspheroidal crystals of clear quartz about 1 millimetre in diameter, in a fine-grained feldspathic groundmass. The dykes strike north 15 degrees east and dip regularly 50 to 60 degrees eastward. On a railroad cut north of the area a granite porphyry dyke is cut by a lamprophyre dyke.

The ore is composed of fine-grained, disseminated, or rudely banded, massive sulphides in a gangue consisting of thoroughly sericitized rock, a little carbonate, and some quartz. The metallic minerals in their general order of relative abundance include pyrite, pyrrhotite, sphalerite, arsenopyrite, galena, and boulangerite. Locally the relative proportions may vary a good deal. Microscopic examination of polished sections suggests that pyrrhotite was the earliest mineral to form, followed and partly replaced by pyrite and arsenopyrite.

Since White's visit to the area extensive work has been carried out on the Blue Bird vein. Main access to the vein, which is apparently the western extension of the Mayflower vein, is by No. 2 adit, driven at an elevation of 844 metres just above and west of Gopher Creek. The vein, which strikes 110 to 115 degrees and dips steeply to the south, is well mineralized to 61 metres below the level and to 244 metres west of the portal. The host rock is mainly hornfelsic siltstone that dips at moderate angles to the west and is cut by northerly trending dykes. Average grades based on production statistics are: 3.87 grams gold per tonne, 653.8 grams silver per tonne, 3.5 per cent lead, 4.2 per cent zinc, and insignificant amounts of copper.

GOLD VEINS

Veins containing pockets of high-grade gold have been mined for many years on the western slope of the valley of Little Sheep Creek, about 4 kilometres southwest of Rossland. The veins, which were discovered in 1891 and 1892, are on the I.X.L., Midnight, and O.K. Crown-granted claims and the former Dominion claim (Snowdrop vein). Records show fairly continuous production from the I.X.L. of a few tonnes of ore most years between 1899 and 1974 with production every year from 1921 to 1949. All the properties were worked by lessees in the 1930's. The deposits are developed by more than a dozen short complicated underground workings driven northwesterly into the relatively steep slopes of O.K. Mountain below the Cascade Highway. Only parts of the workings have been accessible at any one time and the following descriptions are based on observations made by the writer at the Snowdrop in 1955 and Midnight in 1969, and by J. S. Stevenson on the I.X.L. and Midnight in 1935.

The veins are in greenstone and altered greenstone of the Rossland Group, described by Stevenson (1935) as andesite. They lie adjacent to the northern contact of a body of serpentinite which trends easterly and probably dips steeply to the south. Many small shear zones along this contact suggest that it is an easterly trending fault which is terminated by the Marron Formation on the west and the Jumbo fault on the east. Possibly it represents a transverse splay between the Jumbo fault and the steeply dipping fault-bounded eastern margin of the Tertiary volcanic basin that contains the Marron Formation. On a regional basis it may be significant that these gold-bearing veins are on strike with the main copper-gold vein system of the Rossland camp and are separated from it by the Jumbo fault. One interpretation of this relationship is that all the veins are later than the Jumbo fault.

The veins are quartz-carbonate-filled fissures. On the I.X.L. the three principal veins strike 60 to 80 degrees and dip 35 to 75 degrees to the south. The principal vein on the Midnight trends north to 20 degrees west of north and dips 65 degrees to the west. In the upper Snowdrop workings the veins trend northeast and dip 50 degrees to the southeast. The mineralized parts of the veins pinch and swell and change their attitudes. Widths range from a few centimetres to 0.5 metre and in a few places to as much as 2 metres. The strongest mineralized zones are less than 100 metres long and have been developed for about the same distance up the dip. Three veins were mined on the I.X.L., one strong northerly trending vein and a weak easterly trending vein on the Midnight, and several mineralized pockets on the Snowdrop.

The westernmost workings of the Snowdrop mine and the O.K. mine pass from the greenstone into dark grey siltstone of the Mount Roberts Formation. Irregular masses of Coryell monzonite were encountered in the I.X.L. workings and a few outcrops of these rocks occur on the Midnight and I.X.L. claims. Mafic and lamprophyre dykes, most of which trend northward, are common. Details of the geology are described by Stevenson (1935, p. E5) as follows:

> The andesite is a very fine-grained to dense, massive rock of dark-green to brownish hue. The original texture and composition have been largely destroyed, both by the development in varying amounts of chlorite and of fibrous amphibole and by local silicification and serpentinization. The andesite varies from a uniformly dark-green phase that is highly altered, but contains only small amounts of serpentine and magnetite, to a similar dense, dark-green phase that is mottled by small brown 1-inch [2.5-centimetre] areas containing abundant serpentine and magnetite, and finally to a dense, uniform brownish phase that, in addition to other alteration products, carries a uniform abundance of serpentine and magnetite.

On the Snowdrop property, amygdules and small lenticular inclusions of limestone in the andesite indicate that the rocks, at least in part, are flows.

Stevenson continues:

> The typical massive serpentine is a very dense black rock. Cross-fibre asbestos has filled in many of the joints as 1/16- to 1/4-inch [0.2 to 0.6-centimetre] veinlets and light-green talc has developed in the immediate vicinity of faults. A contact-zone intervenes between the black serpentine and the andesite; it is best seen in the second and third crosscuts to the north from the main fault-drift in the lower O.K. adit. The zone strikes roughly east and varies from 20 to 30 feet [6 to 9 metres] in width. Over this width irregular areas of hard, chocolate-coloured andesite are interspersed with irregular areas of serpentine. It is reported that the quartz veins on the O.K. occur only in the andesite to the north; the Baker lead, where examined by the writer, is in andesite. It is suggested that, although there are faults in the serpentine, those faults which tapped quartz and precious-metal-bearing solutions did not continue from the andesite into the serpentine.
>
> A small intrusion of biotite monzonite is intersected by the lower O.K. adit and by Nos. 350 and 4 I.X.L. adits. This rock varies considerably, but the most characteristic features are its hard, fresh appearance and medium-grained granitic texture. Biotite is so abundant in the marginal facies of the monzonite that the rock is very dark and lamprophyric in appearance. However, in areas at a short distance from the contact, the feldspars are more abundant and the rock becomes dioritic in appearance. The relative amounts of orthoclase and plagioclase feldspar vary; in some phases of the rock they are equal, and in others orthoclase is by far the most abundant. Other than the fact that in the lower O.K. adit the monzonite is traversed by fault-seams, no data relating to the age relationships between the monzonite and the lamprophyre dykes or the veins were obtained. It is, however, definitely later than the andesite.
>
> Lamprophyre dykes are numerous and widely distributed; they occur in most of the workings. These dykes contain abundant biotite, are medium to coarse-grained, and usually decompose to crumbly masses very shortly after being exposed to the air. In addition to the mica lamprophyres, there are a few narrow, very fine-grained dark dykes in which the former presence of either biotite, amphibole, or pyroxene is indicated by a ground-mass of chlorite; orthoclase and plagioclase feldspar occur as phenocrysts and as part of the ground-mass. The lamprophyre dykes occupy faults which cut, and in some places have slightly displaced, the quartz veins.
>
> Although occasional concentrations do occur, sulphides are not common in the quartz veins. These sulphides include pyrite, chalcopyrite, and galena. Pyrite is also quite widely disseminated in small amounts throughout the wall-rock. The only other gangue-mineral in addition to quartz is ankeritic carbonate, which occurs in irregular areas in the vein and occasionally as veinlets in the surrounding rocks. The veins contain free gold, often in particles visible to the naked eye. Minable amounts of gold occur in pockets that are very erratically distributed in the veins. These pockets, however, contain very high-grade gold quartz, so that work along barren sections of the vein is amply rewarded by the discovery of a high-grade lens of ore. A conception of the occasional very high concentration of gold may be formed from the statement made by Drysdale in Memoir No. 77 of the Geological Survey of Canada, page 151: Mr. W. F. Ferrier found 2 1/2 oz. [71 grams] of gold in 6 square inches [39 square centimetres] of ore.

MOLYBDENUM DEPOSITS

INTRODUCTION

The principal molybdenum deposits in the Rossland area on Red Mountain were known from the early days of the camp when copper and gold were being mined nearby. Exploration for molybdenum began in 1962 when Torwest Resources Ltd. drilled old showings on the western and upper slopes of Red Mountain. Exploration of the southern slopes of the mountain and into the upper valley of Little Sheep Creek was undertaken subsequently by Cascade Molybdenum Mines Ltd. and others. Production by Red Mountain Mines Limited (a company owned by Torwest Resources Ltd., Metal Mines Limited, and Canadian Nickel Company Limited) began in 1966 from a series of small shallow open pits; up to January 1972, 939 398 tonnes of ore had been milled from which 1 652 970 kilograms of molybdenum was recovered. The ore contained tungsten but virtually no copper or gold. After closing, Inco engaged Minefinders Inc. of Denver, Colorado to carry out an extensive exploration program based on a porphyry model of mineralization. Geological mapping, geochemistry, geophysics, and deep drilling were carried out in the mine area between 1972 and 1974. In 1980 most of the mineral claims on Red Mountain were sold to David Minerals Ltd. In 1981 that company drilled nine short holes just south of the mine area to test for gold and cobalt, and on the basis of this work a proposal has been made to recommence molybdenum production.

Showings of molybdenite are widely scattered in the Rossland area, mainly near the western margins of the Trail pluton and associated granodiorite intrusions. Molybdenite is reported to have been present with copper-gold mineralization in the War Eagle and Centre Star mines. Thorpe (1967, p. 8) describes molybdenite as a constituent of the intermediate zone of mineralization (*see* Fig. 4).

Molybdenite occurs in quartz veins and aplitic offshoots of the Trail pluton. The known occurrences on the northern slopes of Columbia Kootenay Mountain and along Highway 3A southwest of Topping Creek are about 100 metres from the main mass of the pluton. The Rainy Day quartz diorite contains molybdenite in narrow fractures with pyroxene, quartz, pyrrhotite, and pyrite. These are well exposed in old workings in the upper part of Little Sheep Creek below the Cascade Highway, and along the natural gas pipeline where it crosses the southeastern margin of the quartz diorite south of Highway 22. Deep drilling on Red Mountain encountered a large mass of quartz diorite, probably part of the Trail pluton, about 600 metres below the surface. It contains scattered molybdenite in quartz veinlets for as much as 300 metres below the upper surface of the quartz diorite. The molybdenite on Red Mountain is mainly in small fractures in hornfels throughout an irregular Breccia complex. It is associated with pyrrhotite and erratic scheelite. Dyke-like bodies of quartz diorite that are lithologically similar to the Rainy Day pluton occur within the Breccia complex. They are mineralized and associated with the best grades of molybdenum. However, a large dyke of similar looking quartz diorite north of Red Mountain near the tailings pond is not known to have significant amounts of molybdenite associated with it. Thus, molybdenite is spatially and probably genetically related to the quartz diorites, particularly to the pyroxene-bearing Rainy Day pluton. It also occurs on Red Mountain with similar dykes that have associated feldspathization.

RED MOUNTAIN MOLYBDENUM DEPOSITS

These deposits occur on the west and southwest slopes of Red Mountain, mainly on the Coxey (Lot 122), Golden Queen (Lot 991), Novelty (Lot 958), Giant (Lot 997), St. Elmo (Lot 928), and Mountain View (Lot 682) Crown-granted mineral claims (Plate II). They probably extend to the north into the Red Mountain skiing area, which has not been adequately tested. Because of the topography and geological complexity, the geology of the deposits

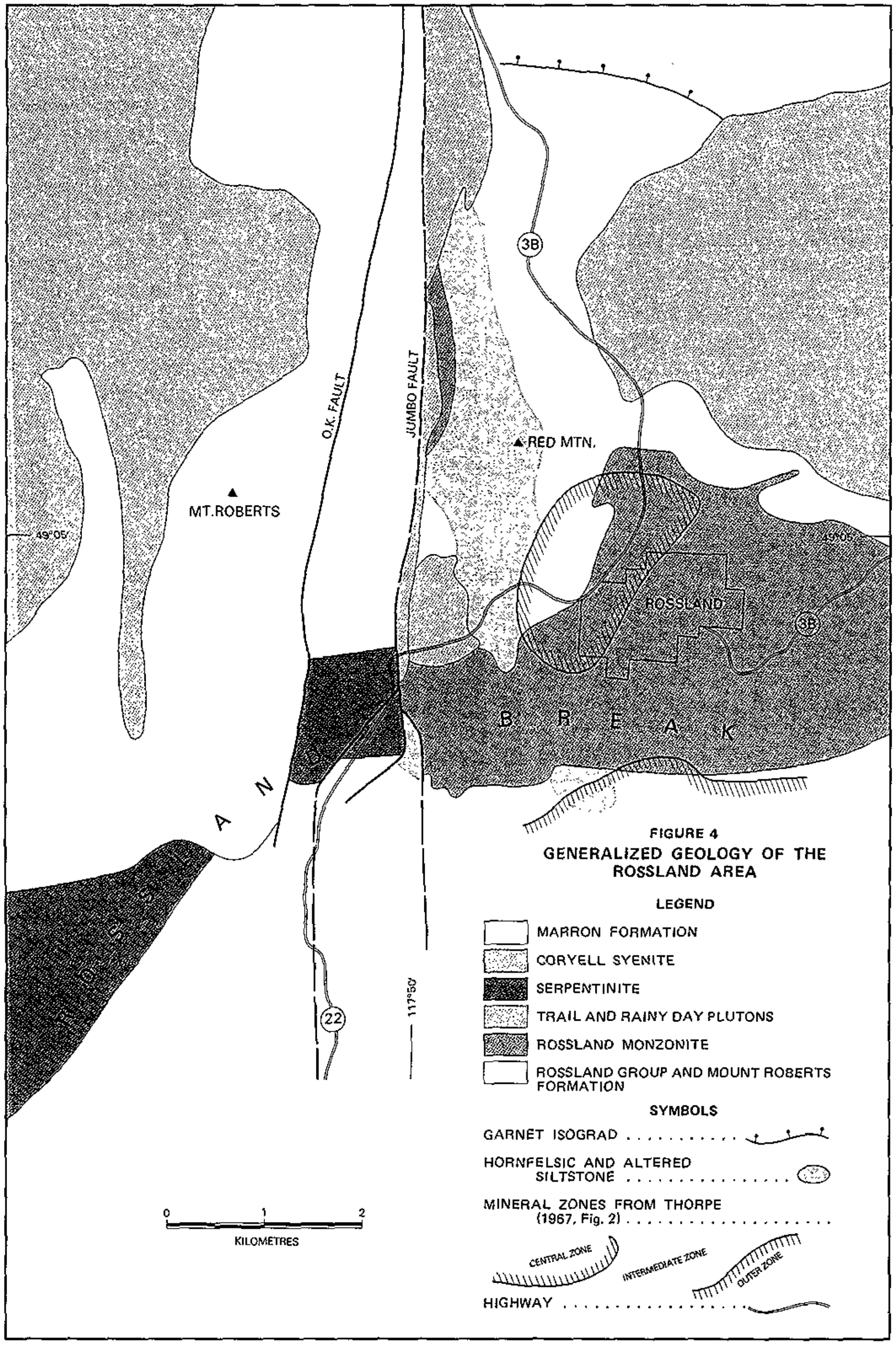

Figure 4. Generalized geology of the Rossland area.

was obscure during the early stages of exploration and reports made at that time differ widely. As mining progressed many of the relationships have been clarified. The deposits are well exposed in the pits and roadways of the mine and some indication of their extensions in depth can be deduced from Minefinders Inc. deep drilling. Figure 5 (in pocket) is based on fieldwork by the writer from 1967 to 1971 and in 1981, and on mapping by I. S. Zajac for Minefinders Inc. in 1972 and 1973. Zajac made detailed lithological subdivisions of the hornfels and the dykes; these are not reflected in the legend.

The principal host for the molybdenum mineralization is siltstone that is extensively metamorphosed to various types of hornfels. Bedding in the siltstone dips at low to moderate angles to the west and over much of the upper western and southern slopes of the mountain these rocks are broken into a spectacular breccia called the Breccia complex. The Rossland sill intrudes the siltstone which, judging from the upper surface, dips to the west beneath Red Mountain (*see* Fig. 2, section A-A'). The siltstone is also intruded by lenticular masses of andesite, irregular bodies of quartz diorite and quartz diorite breccia, and late, steeply dipping mafic dykes which trend northward. Small-scale faults parallel to this trend step the older rocks down on the west.

SILTSTONE AND HORNFELSIC SILTSTONE: The oldest exposed rocks in the sequence are dark grey to black siltstones and argillites that crop out in the lower part of the valley of Little Sheep Creek, on the Cascade Highway, and in road cuts on the upper slopes of Red Mountain where they form small lenses which are not shown on Figure 5. These rocks are the relatively unmetamorphosed equivalents of the hornfels and hornfelsic siltstones which are exposed across the western slopes and upper part of Red Mountain; they grade into them both laterally and across the bedding. In outcrops the siltstone is rusty, sooty, and massive or thinly bedded with a parting parallel to the bedding. In thin sections rounded and angular very fine grains of quartz, plagioclase, and opague carbonaceous material with more or less biotite and hornblende can be identified. Minor amounts of disseminated pyrrhotite and pyrite are common. While it is difficult to distinguish the primary from the metamorphic minerals, some of the plagioclase and hornblende may be of detrital, possibly pyroclastic, origin. Calcareous siltstones are uncommon; only two very small lenses were found at widely separated localities.

The hornfels and hornfelsic siltstones are light greenish grey, green, buff, light and dark grey, or purplish brown. They are thinly laminated and massive hard cherty rocks. They are composed of very fine-grained quartz and feldspar with varying amounts of biotite, pyroxene, and hornblende; locally there is brown garnet and epidote, the proportions of which produce the varieties in colour. As mapped in the field, no stratigraphic succession was identified among the hornfelsic rocks. Minefinders Inc. geologists distinguished seven types of hornfels for core logging but were unable to correlate these types between holes except in a most general manner. Banding, however, reflects bedding, and some distinctive rock types can be traced around the walls of the pits and mapped beyond them. A laminated green (pyroxene) and brown (biotite) hornfels, for example, commonly forms the footwall of the ore zone in the A and B pits. A green magnetite-bearing hornfels occurs on the upper southwest slopes of Red Mountain in and around the E and F pits; a similar rock was encountered both on surface just above the Rossland sill and in deep drilling.

ANDESITE AND META-ANDESITE: Irregular lenses of aphanitic to porphyritic greenish brown andesite occur within the hornfels and hornfelsic siltstone. They are metamorphosed and altered, so are distinguished with difficulty from some of the more massive biotite hornfels; hence they are difficult to map. Figure 5 shows several of the larger masses which appear to be sills, but others are irregular and transgressive. Eastwood (1966, p. 203) describes gradational contacts with hornfels, and drill core shows sharp contacts with chilled margins. In thin sections phenocrysts, which are 1.5 millimetres and less, are hornblende and pyroxene. Hornblende is more or less altered to biotite and pyroxene to hornblende. The very fine-grained matrix consists of plagioclase, minor amounts of quartz, and biotite, hornblende, or pyroxene. It is difficult to distinguish the primary from metamorphic minerals and most of the specimens studied from Red Mountain are recrystallized.

Eastwood (1966) described these rocks as diorite, mine geologists as andesite, and Gilbert (1948) as diorite porphyry. Gilbert correlated them with the diorite porphyrite of Drysdale (1915, p. 27). Although this correlation is plausible, it is by no means certain. The lithology is not distinctive and relationships with neither the augite porphyry nor the Rossland monzonite have been established on Red Mountain.

AUGITE PORPHYRY: A thick massive sill of augite porphyry called the Rossland sill lies beneath the hornfels and siltstone. The upper part of the sill is exposed on the eastern slopes of Red Mountain and shown on Figure 5. Most of the augite porphyry is a uniform dark green rock with phenocrysts of augite up to 3 millimetres across. The upper contact was penetrated by several diamond-drill holes. It is generally planar and dips at about 20 degrees to the west, concordant with the bedding of the hornfels and siltstones. In these holes the hornfels immediately above the sill is rich in hornblende and contains disseminated magnetite. Several narrow dykes or sills of augite porphyry occur within the hornfels in this zone. Thus the augite porphyry appears to be intrusive into the siltstones and to have a narrow thermal contact metamorphic zone of hornblende-magnetite hornfels.

QUARTZ DIORITE AND QUARTZ DIORITE BRECCIA: Irregular discontinuous dykes of quartz diorite and quartz diorite breccia occur within the Red Mountain mine area. Some are associated with the highest grade molybdenite mineralization. The largest of these dykes forms the southeastern corner of the A pit and, after a small right-hand offset, extends at roughly 60 degrees irregularly up the hill for 350 metres (*see* Fig. 5). It appears to dip steeply but is discontinuous and irregular. It consists dominantly of medium-grained quartz diorite and is marked by a fragmental structure. The margins contain blocks of hornfels partly made over into quartz diorite; the central part contains fragments of quartz diorite in a greenish pyroxene-rich matrix. The margins of this and another more massive quartz diorite dyke north of the A pit are fairly sharp but smaller bodies of quartz dioritic rock appear as bleached zones that grade into the surrounding hornfels. Central parts of these zones are medium-grained quartz monzonite containing quartz, potassic feldspar, plagioclase, biotite, and pyroxene. At one place in the B pit a narrow dyke of aplite with sharp margins cuts a bleached zone of quartz monzonite (Plate VIII). One quartz diorite dyke on the Mountain View claim gives way along strike to a breccia with angular fragments of hornfels and grey siltstone.

LATER DYKES AND FAULTS: Steeply dipping mafic dykes trending 160 degrees transect the orebodies. They form a swarm of closely spaced dykes on the western slope and lower south ridge of Red Mountain but are less common on the upper part and eastern slope of the mountain. Superficially they appear to be uniform and continuous with sharply defined walls and chilled margins. Detailed mapping shows discontinuities and irregularities in the dykes and confirms the regional observation that the swarms themselves are discontinuous. The principal rock types are aphanitic to fine-grained biotite lamprophyres and various types of diorite. Petrographic descriptions of two dykes from the mine area are given in Appendix C. These dykes are later than the molybdenite mineralization, the quartz diorite, and the andesite.

Steeply dipping faults trending 160 degrees offset the orebodies. One separates the A from the B orebodies, another passes between the A and upper A orebodies, and yet another passes between the A and E orebodies. A fourth, the St. Elmo fault, follows a gully just below the summit of Red Mountain. From the offset of the orebodies the faults are assumed to be downthrown on the west. The Headwall fault, between the A and upper A orebodies, is followed by a lamprophyre dyke which is locally sheared along the fault. The *quartz diorite breccia is also offset 45 to 50 metres to the right along this fault.*

BRECCIA COMPLEX: Much of the hornfels and hornfelsic siltstone on Red Mountain comprises a breccia with angular blocks ranging up to about 30 metres across. The attitudes of bedding and colour laminations which reflect bedding show that smaller blocks, from a few centimetres to a few metres across, have random orientation. Larger blocks, however, are only slightly disoriented from the normal low westerly dip of the siltstone. The approximate outline of the Breccia complex, which is not everywhere well defined, is shown on Figure 5. Drilling and exposures in the pits, particularly along the south walls of A and B pits, indicate that the margins of the Breccia complex dip steeply and are very irregular. The base appears to be controlled by the bedding. The roof, which is probably represented by the western margin near Jumbo Creek and contacts on the lower slopes of Red Mountain, appears to be irregular; it may also be controlled by the bedding. Most of the molybdenite mineralization lies within the Breccia complex.

Exposures in the pits and in road cuts on Red Mountain display an intriguing array of crosscutting relationships within the Breccia complex and have led to the following interpretations:

(1) The development of the Breccia complex was probably an early event subsequent to lithification. The blocks are angular; very few soft sediment structures have been recognized in the siltstones, either within or away from the Breccia complex. The matrix between blocks is composed of very fine silicates and rock fragments; rarely, it is vuggy with coarse silicates, quartz, calcite, garnet, or scheelite. Thus originally there seems to have been very little open space between breccia fragments.

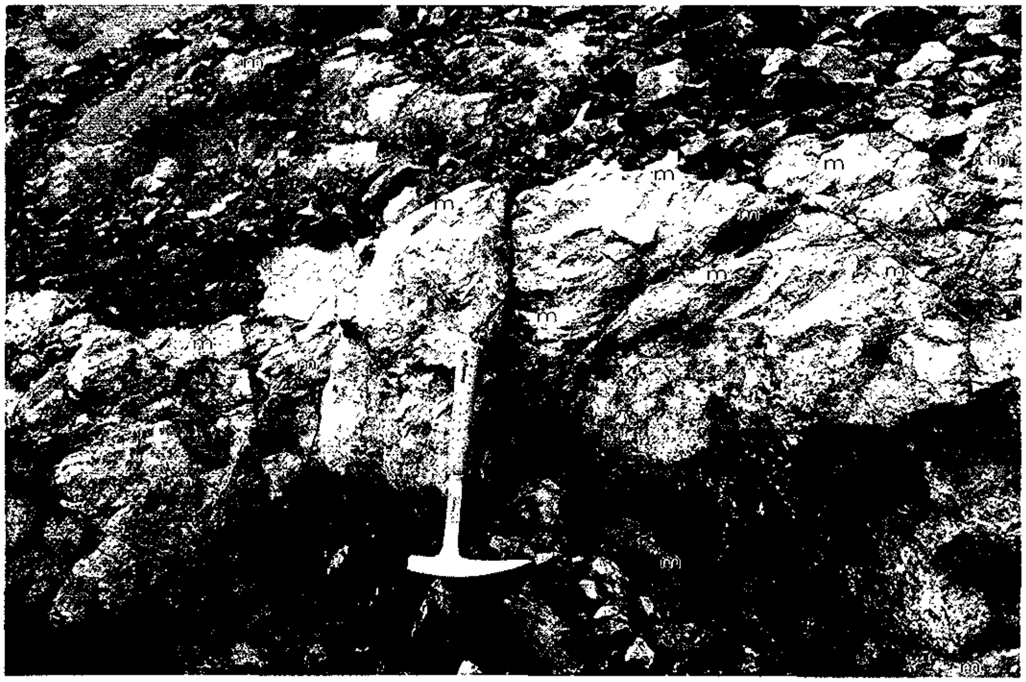

Plate V. Molybdenite in hornfels breccia and banded hornfels near the footwall of the orebody in the E pit; m indicates fracture faces coated with molybdenite.

Plate VI. Broken molybdenum ore, Red Mountain mine, showing a variety of hornfelsic fragments; m indicates molybdenite.

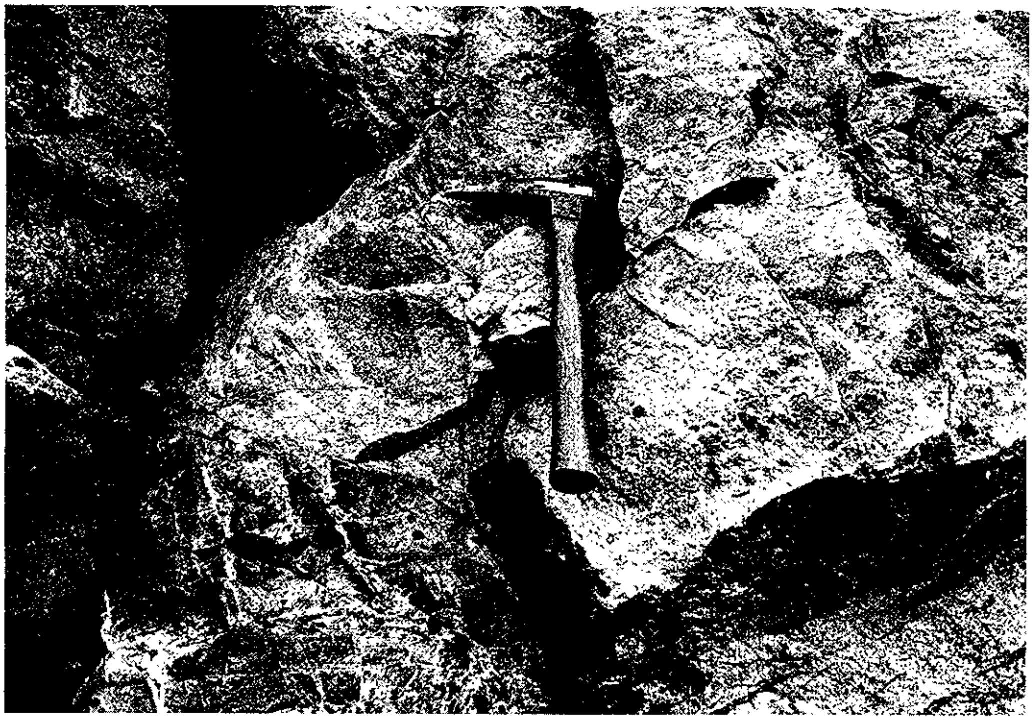

Plate VII. Feldspathized hornfels breccia, Red Mountain mine.

(2) Intrusion of the andesite probably took place later than the formation of the breccia. This is suggested by the concordant shapes of andesites outside the breccia and the irregular shapes within it. Andesite, however, seldom fills spaces between blocks.

(3) Relationships between the Breccia complex and augite porphyry of the Rossland sill are obscure. The two are not known to be in contact. Drilling beneath the pits shows that the upper surface of the sill is not significantly disturbed on dip below this part of the Breccia complex. Nevertheless, it seems possible that the Breccia complex is in some way related to the intrusion of the Rossland sill.

(4) Relationships between the Breccia complex and the Rossland monzonite are also obscure, even though a northerly trending tongue of rock similar to, and correlated with, the Rossland monzonite occurs west of the upper part of Jumbo Creek. The southern end of this tongue is breccia with blocks of normal medium-grained monzonite grading into a coarser grained feldspathic matrix. This monzonite breccia is close to the westernmost part of the Breccia complex, but the actual contact is not exposed.

(5) The hornfels developed after formation of the Breccia complex because the metamorphic silicates cross block margins and reflect the differences in composition between the blocks and the matrix (Plate VII). The varieties of hornfels probably result from differences in composition and structure of the original siltstone. Hornfels within the Breccia complex is further altered by silicification and feldspathization along fractures which in general have a random orientation. The lenticular dykes of quartz diorite and quartz diorite breccia, two of which trend 60 degrees, appear to have originated, at least in part, from this process of feldspathization. Feldspathization is dominant in the pits on the western slope of Red Mountain, whereas silicification is dominant in the Novelty pit. In altered zones hornblende, pyroxene, and epidote commonly line fine fractures.

(6) Molybdenite, usually without other sulphides, occurs in randomly oriented fractures in all types of hornfels breccia and in the granodiorite breccia. Commonly it lies along the margins of breccia blocks and locally is concentrated at junctions between the blocks (Plates V and VI). Rarely, these junctions also contain drusy quartz, scheelite, hornblende, or epidote. Pyrrhotite, and locally pyrite, are disseminated in hornfels and also occur in fractures and as massive lenses between breccia fragments. Its distribution seems to be independent of the distribution of molybdenite. In the Novelty pit fractures in siliceous hornfels contain arsenopyrite, cobalt minerals, bismuthinite, and uraninite (*see* Thorpe, 1967, p. 15). In the southeast corner of the F pit a narrow chalcopyrite-pyrrhotite vein trending 120 degrees and dipping 75 degrees to the north cuts molybdenum-bearing hornfels. It is typical of the copper-gold veins of the main camp, and this exposure is taken as evidence that the copper-gold mineralization is later than the molybdenum mineralization.

MINERALIZATION: Molybdenum mineralization is widespread on Red Mountain; the orebodies and reserves are defined by the grade and continuity of the mineralization. All the ore mined, and essentially all the mineralization in potential orebodies, is within the Breccia complex. Ore mined between 1966 and 1972 is in the widest part of the Breccia complex, within 50 metres of the surface. Although no clear stratigraphic control of the mineralization has been established, the A and B orebodies 'bottomed' on a green and brown hornfels which probably formed a west-dipping floor to the Breccia complex in this area at this horizon. The Headwall and other faults make correlations difficult between the A, B, and C orebodies on the lower slopes of the mountain with the E and F orebodies on the upper slopes. According to one interpretation all the orebodies are within 100 metres of stratigraphic section; according to another they may be at two horizons covering a stratigraphic interval of 200 metres. Because the grade is controlled by the intensity of fracturing, it is concluded that the stratigraphy is a secondary factor in the control of mineralization; the primary control is the intensity of brecciation, which may itself have been influenced by lithology. A line of deep holes beneath the orebodies encountered scattered molybdenum (and tungsten) mineralization but did not provide data that would allow the identification of potential orebodies. The best mineralization encountered is in fractures and quartz veinlets within the hornfels, particularly in the upper part and above the Rossland sill, as well as in the upper part of the quartz diorite (*see* Fig. 2, section A-A').

Production figures indicate that almost a million tonnes with an average grade of about 0.2 per cent molybdenum was milled (*see* Table 1). Company estimates indicate that this material was taken from more extensive mineralized zones within the Breccia complex which totalled some 6 million tonnes grading 0.1 per cent molybdenum. At the time the mine closed, in January, 1972, reserves were estimated to be 107 000 tonnes of 0.25 per cent molybdenum near surface. Subsequently it was estimated that a reserve of about 1 million tonnes of 0.24 per cent molybdenum is present within the Breccia complex close to the mine. Drilling of the Breccia complex on the ridge south of Red Mountain by Cascade Molybdenum Mines Ltd., Scurry-Rainbow Oil Limited, and Continental McKinney Mines Limited led to a consultant's estimate in 1967 of 'reasonably assured' near-surface reserves of 738 000 tonnes of 0.23 per cent molybdenum in five separate orebodies and about an equal amount of various grades at depth. Some of this material is reported to carry minor amounts of gold but estimates of the average grade cannot be made from the data available.

Scheelite, occurring as medium to coarse grains, is scattered through the Breccia complex; rarely, it forms spectacular clusters of grains between fragments. Its occurrence is erratic and company records indicate that the highest grades were found in the E and F orebodies, where the average grade was about 0.10 per cent WO_3 (tungsten trioxide).

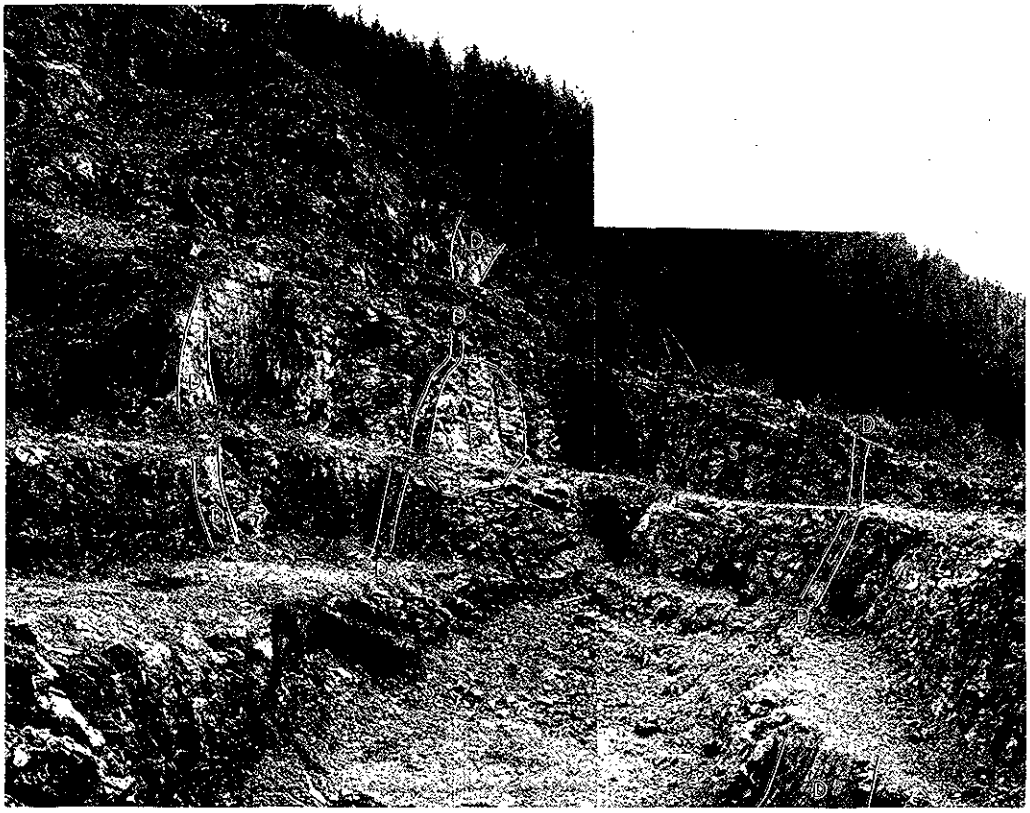

Plate VIII. South wall of B pit, Red Mountain mine. Viewed along the trend of the mafic dykes (D).

GENESIS AND CONTROLS OF MINERALIZATION

The age and origin of the copper-gold mineralization has been a subject of discussion for many years by geologists who have worked in the Rossland camp. The historical development of interest in this subject is summarized by Little (1963, p. 6):

> Brock (1906, pp. 15-18) thought the ore was earlier than the lamprophyre and basic and acidic dykes, though in the Giant and Jumbo mines he saw ore in and around alkali syenite (Coryell) dykes. Drysdale (1915, pp. 85-93, 140, 148) contended that successive intrusions of lamprophyre occur, variously related to the Nelson (Trail), Coryell, and Sheppard intrusions. The first were cut by sulphides, with little or no gold; the second by gold-bearing veinlets; and the third were unmineralized. Drysdale considered that sulphide mineralization with minor gold was related to the Nelson and gold mineralization to the much later Coryell. He admitted the Coryell 'pulaskite' adjacent to the Spitzee and Giant orebodies is slightly impregnated by sulphides but presumably related this to his later period of mineralization. However, it is apparent that the positions of these orebodies are controlled by the 'pulaskite' contact, and the ore, therefore, in the present writer's opinion, is later than Coryell.
>
> Bruce (1917, p. 235) favoured two periods of mineralization, but contended that abundant sulphides accompanied the gold of the later period.
>
> Gilbert (1948, p. 193) could see no good evidence for two periods of mineralization, and concluded that all the dykes in the mines are older than the ore.

Little's own observations were that 'pyrite stringers from the veins cut lamprophyre dykes' and 'long stringers of chalcopyrite from the vein cut a mica lamprophyre.' White (1949, p. 162), working with veins in the Mayflower mine area south of Rossland, noted that 'the lamprophyre dykes are older than the ore minerals, with the possible exception of pyrrhotite, and consequently play an important part in localizing the deposition of ore minerals.'

Thorpe (1967) established the pattern of mineral zoning discussed previously (Fig. 4). He concluded that 'zoning was apparently controlled by the chemical character and evolution of the ore fluids as determined by such factors as wall rock alteration, deposition of ore minerals, and buffering reactions with previously deposited minerals superimposed on the background of a moderate thermal gradient away from the center of mineralization.' He considered the mineralization to be related to the Rossland monzonite and/or the Trail and Rainy Day plutons of quartz diorite.

In 1970, as part of an extensive program by W. H. White of the University of British Columbia for dating sulphide mineralization in the cordilleran region, samples of rocks from critical localities (*see* Fig. 2) were collected for potassium-argon dating. The results of the work (*see* Fyles, *et al.*, 1973), recalculated using revised decay constants adopted in 1976, are tabulated in Appendix A. Critical tests indicated that, with the exception of the samples of Rossland monzonite and the conglomerate dyke, the potassium-argon ratios represented the true ages of the rocks. These results, however, have been questioned (*see* Thorpe and Little, 1973) because of the wide distribution and close spacing of Tertiary dykes and the unknown, but suspected, thermal aureole of the large Coryell batholith to the west, which may have updated or reset the potassium-argon dates. Further testing is in progress. Initial results of samples collected by P. S. Simony of the University of Calgary and the writer are tabulated in Appendix A.

Potassium-argon biotite and hornblende dates for the Trail pluton are mostly Early Tertiary but one mineral pair, for sample TP81-4, is strikingly discordant — biotite giving 53.3 Ma and hornblende 109 ± 4 Ma. This suggests resetting of an older date by the Early Tertiary thermal event.

The Trail pluton proved to be too uniform in rubidium-strontium ratio and $^{87}Sr/^{86}Sr$ ratio to yield an age using the rubidium-strontium whole rock isochron technique. Zircon extracted from the sample of the Trail pluton with discordant potassium-argon dates (TP81-4), collected about 3 kilometres north of Rossland, however, has recently yielded concordant uranium-lead dates of 159 and 162 Ma, Middle to Late Jurassic (Callovian) (*see* Appendix B). Thus, mineralization associated with this pluton, the Rainy Day pluton, or the Rossland monzonite must be pre-Tertiary; the conclusion of the work in 1973 that all the mineralization in the Rossland camp is Tertiary is superseded.

The following field observations are significant in any study of the age and controls of mineralization in the Rossland camp and are consistent with the new age determinations.

(1) Molybdenum and minor tungsten mineralization is associated with the Trail pluton, especially with its upper and western margin, and is now considered to be (Late) Jurassic. Mineralized quartz and quartz-aplite veins in and adjacent to the margins of the Trail pluton are exposed at a number of places on surface and were encountered during the deep drilling program beneath Red Mountain mine; to date stockworks of such veins in sufficient quantity and grade to constitute ore have not been discovered. The Rainy Day pluton and quartz diorite dykes on Red Mountain, and associated feldspathized zones, all of which are thought to be related to the Trail pluton, contain significant quantities of molybdenum and tungsten. Highest concentrations of molybdenite are in the highly fractured hornfels breccia near feldspathized fracture zones and quartz diorite dykes. These characteristics suggest a porphyry type of mineralization and point to all the area around the western edge of the Trail pluton as potential ground for exploration. Feldspathized zones on the western slopes of Blackjack Mountain west of the Union property and tungsten mineralization further to the west (*see* Stevenson, 1943, Blue Eyes) are possible targets in that area. Scheelite in breccia associated with bleached hornfels on the Cascade Highway near the Snowdrop mine forms a similar exploration target.

(2) The fractures containing copper-gold mineralization had a long history. The sets trending 90 and 60 degrees contain the oldest intrusions — diorite porphyry and quartz diorite dykes on Red Mountain — which are probably also Jurassic. Fractures with these trends, as well as those trending 115 degrees, contain quartz, pyroxene, and molybdenite in the Rainy Day pluton, and amphibole, chalcopyrite, and pyrrhotite in the Rossland monzonite. North-south fractures contain major Tertiary dyke swarms. The Main vein fractures (60, 90, and 115 degrees) were probably also reactivated during the Tertiary.

(3) Sulphides and gold within these fractures were probably deposited during more than one interval of time. At least part of the copper-gold mineralization is later than the Tertiary dykes. Observations of sulphides cutting these dykes, made independently by Little, Gilbert, and White, are confirmed by more recent observations in the 3045 crosscut of Falaise Lake Mines Ltd. Where the crosscut encountered the Nickel Plate dyke, chalcopyrite-filled fractures cut the lamprophyre. In addition, on Red Mountain a vein of chalcopyrite cuts molybdenite mineralization which is clearly older than the Tertiary lamprophyre and diorite dykes. The pattern of zoning defined by Thorpe is unrelated to an obvious Tertiary heat source, and Thorpe argues that the copper-gold mineralization is related to the Rossland monzonite (*see* Thorpe and Little, 1973, p. 1338). The pattern of mineral zoning, however, is probably the result of a complex interplay with more than one source for the metals and a succession of structural events, as well as changes in the composition, temperature, and confining pressure of the mineralizing fluids.

(4) Finally, it may be significant that gold veins on the I.X.L. and nearby properties are west of the Jumbo fault and structurally higher than any of the deposits to the east. It is tempting to speculate that they represent the upper extension of the same or a similar mineralizing system as the copper-gold deposits of the main camp.

APPENDICES

The following tables give background data for age determinations for samples collected in the map-area in 1970, 1971, and 1982. The potassium-argon dating was done by J. E. Harakal and the uranium-lead dating by P. van der Hyden at the geochronology laboratories of the University of British Columbia under the direction of Dr. R. L. Armstrong.

APPENDIX A K/Ar AGE DETERMINATIONS
(Table updated from University of British Columbia Geochronology files, March 18, 1983)

Sample No.	Rock Unit	Rock Type	Note	Mineral or Conglomerate	%K ± *σ	A^{40} rad / A^{40} total	A^{40} rad (10^{-5}cc SPT/g)	A^{40} rad / K^{40}	Apparent Age (Ma)	Latitude	Longitude
F69-203	Marron Formation	Trachyte	1	Whole rock	4.29 ± 0.02	0.90	0.8882	0.003059	52.5 ± 1.7	49°04′21″	117°53′13″
R70-12	Diorite dyke	Hornblende gabbro	1	Biotite	7.43 ± 0.03	0.95	1.434	0.002851	49.0 ± 1.5	49°05′23″	117°49′34″
R70-3	Spokane dyke	Lamprophyre	1	Biotite	6.30 ± 0.04	0.71	1.171	0.002747	47.2 ± 1.5	49°05′09″	117°48′07″
R70-3	Spokane dyke	Lamprophyre	1	Hornblende	1.047 ± 0.001	0.78	0.2033	0.002869	49.3 ± 1.5	49°05′09″	117°48′07″
R70-4	Conglomerate dyke	Lamprophyre	1	Whole rock	1.82 ± 0.014	0.83	0.4254	0.003174	60.4 ± 1.4	49°04′45″	117°49′08″
R70-7	Mayflower dyke	Lamprophyre	1	Biotite	7.76 ± 0.02	0.92	1.526	0.002906	49.9 ± 1.4	49°03′31″	117°47′44″
R70-9	Nickel Plate dyke	Lamprophyre	1	Biotite	7.60 ± 0.04	0.92	1.487	0.002891	49.6 ± 1.6	49°04′20″	117°47′59″
R70-11	Dyke	Lamprophyre	1	Biotite	7.22 ± 0.02	0.76	1.426	0.002917	40.1 ± 1.4	49°04′26″	117°48′06″
R70-13	Headwall dyke	Lamprophyre	1	Biotite	5.67 ± 0.05	0.90	1.095	0.002852	49.0 ± 1.6	49°05′23″	117°49′28″
R70-1	Coryell	Monzonite	1	Biotite	7.06 ± 0.01	0.90	1.385	0.002898	49.8 ± 1.4	49°06′35″	117°49′06″
R70-5	Coryell	Monzonite	1	Biotite	7.61 ± 0.04	0.65	1.496	0.002905	49.9 ± 1.5	49°04′45″	117°47′30″
R70-18	Coryell	Syenite	1	Biotite	7.55 ± 0.02	0.91	1.461	0.002860	49.1 ± 1.4	49°06′44″	117°51′22″
R70-14	Siltstone unit	Biotite hornfels	1	Whole rock	3.70 ± 0.04	0.96	0.6974	0.002785	47.8 ± 1.8	49°05′23″	117°49′45″
R70-15	Rainy Day pluton	Quartz diorite	1	Biotite	6.79 ± 0.02	0.86	1.327	0.002888	49.6 ± 1.5	49°04′29″	117°49′54″
R70-16	Trail pluton	Granodiorite	1	Biotite	6.45 ± 0.02	0.86	1.308	0.002997	51.4 ± 1.5	49°05′58″	117°47′32″
R70-17	Trail pluton	Granodiorite	1	Biotite	6.71 ± 0.01	0.94	1.333	0.002935	50.4 ± 1.4	49°06′57″	117°47′37″
R70-2	Rossland monzonite	Monzonite	1	Biotite	5.97 ± 0.03	0.91	1.131	0.002800	48.1 ± 1.5	49°05′18″	117°48′07″
R70-6 Run 1	Rossland monzonite	Monzonite	1	Biotite	7.19 ± 0.03	0.84	2.616	0.005376	91.3 ± 2.8	49°04′13″	117°48′03″
R71-1	Rossland monzonite	Monzonite	1	Biotite	7.45 ± 0.02	0.92	1.760	0.003491	59.8 ± 1.8	49°04′06″	117°48′24″
R70-6 Run 2	Rossland monzonite	Monzonite	1	Biotite	7.02 ± 0.05	0.94	2.585	0.005441	92.3 ± 2.0	49°04′13″	117°48′03″
TP81-4	Trail pluton	Granodiorite	2	Hornblende	1.19	0.812	5.220		109 ± 4.0	49°06′18″	117°47′54″
TP81-4	Trail pluton	Granodiorite	2	Biotite	4.59	0.909	9.571		53.3 ± 1.9	49°06′18″	117°47′54″

*σ —Standard deviation of quadruplicate analyses
** Constants used in modelage calculations: $\lambda_e = 0.581 \times 10^{-10}$ y^{-1}, $\lambda_\beta = 4.96 \times 10^{-10}$ y^{-1}, $K^{40}/K = 1.167 \times 10^{-4}$
1 —Collected by J. T. Fyles and W. H. White
2 —Collected by J. T. Fyles and P. S. Simony
1 and 2 dated by J. E. Harakal

APPENDIX B
U/Pb AGE DETERMINATIONS

SAMPLE TP81-4

LOCATION: Near western margin of Trail pluton, 2 kilometres north of Monte Cristo Mountain.

NTS: 82F *UTM ZONE:* 11

LATITUDE: 49°06.3′N NORTHING: 418

LONGITUDE: 117°47.9′W EASTING: 393

SOURCE ROCK TYPE: Grandiorite

MATERIAL ANALYSED: Zircon (<200 mesh)

COLLECTED BY: J. T. Fyles, P. Simony

ANALYSED BY: P. van der Heyden

ANALYTICAL DATA:

U ppm	Pb ppm	Pb^{206}	Pb^{207}	Pb^{208}	Pb^{204}	Meas. $\frac{206}{204}$	Mole % Blank Pb	$\frac{\text{Rad Pb}}{\text{Rad + Com Pb}}$	Common Pb Age
941.6	24.6	100	6.2757	12.924	0.08694	1110.3	0.51	0.946	160

$\frac{^{206}Pb}{^{238}U}$ ratio ±	$\frac{^{207}Pb}{^{235}U}$ ratio ±	$\frac{^{207}Pb}{^{206}Pb}$ ratio ±
0.025031 ±	0.17250 ±	0.049983 ±

UNCERTAINTY: 2σ 2% U/Pb; 0.15% Pb/Pb

APPARENT AGES:
^{238}U–^{206}Pb date 159 ± 3
^{235}U–^{207}Pb date 162 ± 3.5
^{207}Pb–^{206}Pb date 194 ± 3.5

APPENDIX C

PETROGRAPHIC DESCRIPTIONS OF SAMPLES USED FOR AGE DETERMINATIONS

R70-1 CORYELL MONZONITE

NAME: Hornblende monzonite
TEXTURE: Medium-grained hypidiomorphic, feldspars up to 5 millimetres, mafics up to 3 millimetres across
ORTHOCLASE MICROPERTHITE (50%): Anhedral grains enclosing mafic minerals and apatite
ANDESINE (20%): Complexly twinned somewhat zoned anhedral grains
BIOTITE (15%): Subhedral grains, dark brown to straw coloured, essentially no alteration, rare inclusions of apatite, biotite mainly in the feldspars, some in the hornblende
HORNBLENDE (15%): Pale green to straw-coloured subhedral grains showing rare minor alteration to chlorite
ACCESSORIES (2%): Sphene in subhedral crystals some of which are more than 0.5 millimetre long, apatite in euhdral crystals 0.1 millimetre across, magnetite, pyrite
ALTERATION: Very minor

R70-2 ROSSLAND MONZONITE

NAME: Hornblende diorite
TEXTURE: Medium-grained allotriomorphic with ragged mafic minerals
ANDESINE (An_{48}) (45%): Irregular lath-shaped grains about a millimetre long with patchy twinning and scattered sericite
HORNBLENDE (30%): Pale green clusters and feathery individual grains up to 1.5 millimetres across, some with cores of augite
BIOTITE (10%): Ragged flakes 0.3 millimetre across and clusters of grains about one-tenth this size, intimately associated with hornblende, altered commonly to chlorite and epidote (?)
AUGITE (10%): Subhedral grains commonly altered to hornblende, contains crystals of plagioclase, rarely biotite
ORTHOCLASE: Few small grains associated with the plagioclase
ACCESSORIES: Sphene and apatite as subhedral grains up to 0.2 millimetre, magnetite, pyrite
ALTERATION (extensive): Fine fractures contain biotite and chlorite and about half the biotite is altered to chlorite; progressive alteration of augite to hornblende, to biotite, to chlorite

R70-3 SPOKANE DYKE

NAME: Lamprophyre (odinite)
TEXTURE: Porphyritic with hypidiomorphic grains and fluxion structure
LABRADORITE (An_{65}) (50%): Slightly zoned laths in the matrix and scattered large crystals, large crystals commonly altered to sericite
HORNBLENDE (25%): Red-brown to tan-coloured euhedral crystals in the matrix and rounded resorbed phenocrysts
BIOTITE (5%): Fine flakes in the matrix and a few large phenocrysts, red-brown to straw yellow

ACCESSORIES: Apatite in euhedral crystals, some forming rounded phenocrysts; magnetite — very fine 'dust' and one large grain
ALTERATION (minor): Serpentine (20%) probably resulting from the alteration of olivine, none of which remains; carbonate, sericite in plagioclase

R70-4 CONGLOMERATE DYKE

NAME: Lamprophyre (spessartite)
TEXTURE: Porphyritic with subhedral phenocrysts up to 5 millimetres across in a fine-grained matrix
ANDESINE (50%): As phenocrysts and matrix as irregular laths and plates, partly altered to sericite
AUGITE (25%): Zoned subhedral crystals with cores or layers of inclusions, notably biotite
OLIVINE (15%): No olivine left — abundant serpentine as large pseudomorphs of olivine phenocrysts and scattered through the matrix
BIOTITE (5%): As small ragged grains mainly in the matrix interstitial and intimately interlocked with the feldspar
ORTHOCLASE (less than 5%): A few clear subhedral phenocrysts and possibly as obscure grains in the matrix
ACCESSORIES: Apatite, magnetite
ALTERATION (extensive): Epidote, sericite, serpentine

R70-5 CORYELL MONZONITE

NAME: Augite-biotite monzonite
TEXTURE: Medium-grained allotriomorphic
ORTHOCLASE MICROPERTHITE (45%): Irregular grains up to 5 millimetres across enclosing laths of plagioclase, rare patches of myrmekite
AUGITE (20%): As subhedral twinned and zoned crystals partly altered to hornblende
BIOTITE (20%): Dark brown to straw yellow with rare pennine between the cleavages; minor amounts of biotite associated with hornblende and probably derived from it is green to colourless
ANDESINE (An_{50}) (10%): Small twinned and slightly zoned crystals mainly in orthoclase microperthite
HORNBLENDE (5%): Pale green surrounding and along fractures in augite, partly altered to green biotite
ACCESSORIES: Apatite - small euhedral grains, carbonate, magnetite, pyrite
ALTERATION: Very minor sericite and pennine

R70-6 ROSSLAND MONZONITE

NAME: Monzonite
TEXTURE: Medium-grained allotriomorphic
ANDESINE (An_{48}) (45%): Poorly zoned laths with sutured edges and patchy twinning, mostly less than 1 millimetre long
ORTHOCLASE MICROPERTHITE (25%): Interstitial grains
AUGITE (15%): Subhedral grains with a sieve texture up to 4 millimetres across commonly containing biotite and plagioclase, rimmed by green hornblende
BIOTITE (10%): Fresh anhedral flakes up to 1.5 millimetres across
HORNBLENDE (less than 5%): Light green to colourless aggregates of fine-grained hornblende surrounding and replacing augite
ACCESSORIES: Apatite — euhedral crystals less than 0.1 millimetre, magnetite
ALTERATION: Minor

R70-7 MAYFLOWER DYKE

NAME: Lamprophyre (minette)
TEXTURE: Medium-grained hypidiomorphic, bent biotite grains
ANDESINE (An_{48}) (25%): Anhedral interlocking grains, slightly zoned
HORNBLENDE (25%): Light green to colourless grains and aggregates replacing augite
AUGITE (20%): Subhedral grains replaced by hornblende
BIOTITE (20%): Brown to almost colourless subhedral grains, not altered
CARBONATE (10%): Interstitial grains
ACCESSORIES: Apatite, epidote, magnetite
ALTERATION (minor): Sericite, carbonate — difficult to distinguish alteration and crystallization effects

R70-9 NICKEL PLATE DYKE

NAME: Lamprophyre (minette)
TEXTURE: Medium-grained hypidiomorphic
BIOTITE (30%): Red-brown, brown, and locally green, some plates bent
AUGITE (30%): Subhedral grains with a sieve texture and partly replaced by hornblende
ORTHOCLASE MICROPERTHITE (25%): Interstitial grains with patches of indeterminate plagioclase
OLIVINE (10%): Mostly altered to serpentine
HORNBLENDE (5%): Colourless to pale green grains and rims to augite crystals
ACCESSORIES: Apatite, magnetite
ALTERATION (moderate): Serpentine, sericite

R70-11 MICA PERIDOTITE

NAME: Mica peridotite
TEXTURE: Medium-grained allotriomorphic, grains up to 5 millimetres across
BIOTITE (35%): Red-brown to almost colourless, as irregular, locally bent plates, some intergrown amphibole
OLIVINE (30%): Partly altered to serpentine
TREMOLITE (25%): Colourless to very pale green, bladed crystals and clusters of grains
ANDESINE (10%): About An_{50} in composition but difficult to determine in one thin section
ACCESSORIES: Apatite, magnetite
ALTERATION (minor): Serpentine, carbonate, sericite

R70-12 DIORITE DYKE

NAME: Hornblende gabbro
TEXTURE: Fine-grained allotriomorphic ragged biotite up to 1 millimetre across
LABRADORITE (An_{55}) (65%): Interlocking plates overprinted with fine biotite and sericite
HORNBLENDE (20%): Green to light brown ragged grains and clusters of fine grains
BIOTITE (15%): Brown to straw yellow, as phenocrysts and clusters of fine grains, also scattered fine grains
ACCESSORIES: Apatite, sphene, magnetite
ALTERATION (minor): Sericite and secondary (?) biotite, hornblende

R70-13 HEADWALL DYKE A PIT

NAME: Lamprophyre (minette)
TEXTURE: Porphyritic, panidiomorphic, phenocrysts up to 2 millimetres across in fine-grained matrix
BIOTITE (40%): Dark red-brown to straw-coloured euhedral plates as phenocrysts and matrix
OLIVINE (20%): Some fresh, some completely altered to serpentine, euhedral phenocrysts
AUGITE (15%): Euhedral phenocrysts
FELDSPAR (?) (20%): As indeterminate grains in the matrix crowded with sericite
APATITE (5%): Euhedral crystals up to 1 millimetre across
ACCESSORIES: Apatite, carbonate, pyrite
ALTERATION (minor): Serpentine, sericite (?)

R70-14 BIOTITE HORNFELS

NAME: Biotite hornfels
TEXTURE: Aphanitic — equant grains of quartz about 0.1 millimetre across and finer flakes of biotite
QUARTZ (80%): Equant angular recrystallized grains locally in clusters and veinlets
BIOTITE (20%): Red-brown to straw yellow minor green flakes, poorly oriented
ACCESSORIES: Apatite
ALTERATION (none): Chlorite and muscovite in veinlets with quartz

R70-15 RAINY DAY PLUTON

NAME: Pyroxene quartz diorite
TEXTURE: Medium-grained allotriomorphic
ANDESINE (An_{45}) (45%): Zoned and twinned grains with sutured margins, up to 5 millimetres across, scattered sericite
ORTHOCLASE MICROPERTHITE (15%): Interstitial grains
QUARTZ (15%): Fine equant grains between feldspars, not strained, one veinlet of coarse quartz
BIOTITE (5%): Clusters of irregular grains generally a millimetre across, brown to light brown, rarely altered to chlorite
AUGITE (5%): Anhedral grains about 0.5 millimetre across, in clusters, partly replaced by hornblende
HORNBLENDE (5%): Pale green to yellowish green
ACCESSORIES: Apatite, sphene, epidote
ALTERATION (minor): Sericite, pennine

R70-16 TRAIL PLUTON

NAME: Granodiorite
TEXTURE: Medium-grained allotriomorphic
ANDESINE (An_{48}) (45%): Strongly zoned, twinned, subhedral grains up to 5 millimetres across
ORTHOCLASE MICROPERTHITE (20%): Relatively small grains, a few with plaid (microcline) twinning
QUARTZ (20%)
HORNBLENDE (10%): Subhedral green to yellow-green crystals
BIOTITE (5%): Dark greenish brown to straw yellow, minor alteration plus inclusions of apatite

ACCESSORIES: Apatite, sphene — few subhedral crystals 1 millimetre across
ALTERATION (minor): Pennine in biotite, sericite in plagioclase particularly in the cores of crystals, epidote in plagioclase

R70-17 TRAIL PLUTON

NAME: Granodiorite
TEXTURE: Medium-grained allotriomorphic, grain size about 4 millimetres maximum
ANDESINE (An_{42}) (45%): Zoned, twinned crystals with sutured margins, scattered sericite
ORTHOCLASE MICROPERTHITE (20%): Interstitial large grains, some with myrmekitic contacts with andesine
QUARTZ (20%)
HORNBLENDE (10%): Subhedral, green to yellowish green, inclusions of apatite, biotite
BIOTITE (5%): Dark brown to straw coloured, minor pennine, epidote along cleavage
ACCESSORIES: Apatite, sphene — both as small euhedral crystals
ALTERATION (minor): Chlorite, sericite, epidote

R70-18 CORYELL SYENITE

NAME: Syenite
TEXTURE: Medium to coarse-grained allotriomorphic
ORTHOCLASE MICROPERTHITE (75%): Large plates with exsolved albite in grains up to 0.1 millimetre across
BIOTITE (5%): Mainly orange-brown to golden yellow plates, some clusters of very fine crystals
HORNBLENDE (5%): Green-yellow green, rare cores of pyroxene, commonly hornblende altered to biotite
QUARTZ (5%): Small grains between the feldspars
ACCESSORIES: Mainly clustered with the mafic minerals — sphene, zircon, apatite, allanite
ALTERATION (very minor): Sericite

R71-1 ROSSLAND MONZONITE

NAME: Monzonite
TEXTURE: Medium-grained allotriomorphic
ANDESINE (An_{44}) (50%): Subhedral interlocking poorly zoned lath-shaped grains
ORTHOCLASE MICROPERTHITE (20%): Anhedral interstitial grains commonly enclosing andesine
AUGITE (15%): Anhedral grains partly altered to hornblende
BIOTITE (10%): Anhedral grains straw yellow to brown
HORNBLENDE (5%): Light green ragged grains associated with augite
ACCESSORIES: Apatite, magnetite
ALTERATION: Minor sericite and chlorite

F9-203 O.K. VOLCANIC GROUP

NAME: Porphyritic trachyte
TEXTURE: Porphyritic with subhedral phenocrysts up to 1 millimetre across in an aphanitic to vitreous matrix
MATRIX (50%): Mainly microspherulitic with a fluidal structure

LABRADORITE (An_{50}) (35%): Subhedral and angular broken crystals, slightly zoned and partly corroded by the matrix
BIOTITE (5%): Subhedral bent grains, straw yellow to dark brown
AUGITE (5%): Subhedral grains partly converted to hornblende
HORNBLENDE (5%): As small subhedral crystals
ACCESSORIES: Magnetite, apatite
ALTERATION: Slight alteration of biotite and hornblende to chlorite, plagioclase to epidote

TP81-4 TRAIL PLUTON

NAME: Granodiorite
TEXTURE: Medium grained
OLIGOCLASE ANDESINE (An_{38}-An_{23}) (50%): Zoned twinned subhedral crystals with sutured margins and minor sericite alteration
ORTHOCLASE MICROPERTHITE (15%): As interstitial large grains
QUARTZ (15%)
HORNBLENDE (8%): Green to straw yellow small subhedral crystals
BIOTITE (8%): Ragged crystals, partly altered to chlorite
ACCESSORIES: Apatite, sphene, allanite
ALTERATION: Sericite, epidote, chlorite

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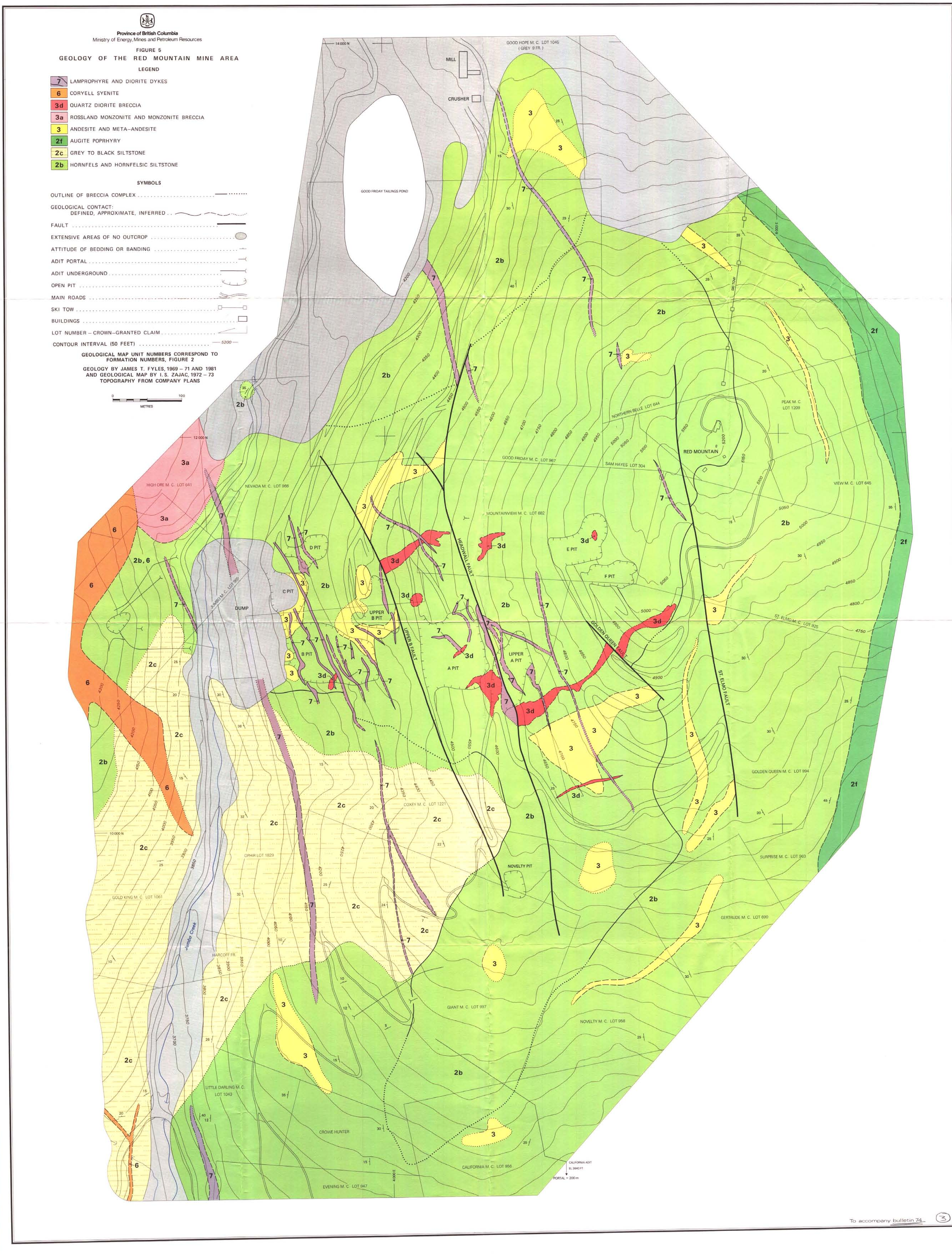
Victoria, 1984


Province of British Columbia
Ministry of Energy, Mines and Petroleum Resources
FIGURE 2
GEOLOGICAL MAP OF THE ROSSLAND AREA
SCALE 0 1000 METRES
LEGEND
6 CORYELL INTRUSIONS: SYENITE AND MONZONITE
5 MARRON FORMATION: TRACHYANDESITE FLOWS AND RELATED VOLCANICLASTIC ROCKS
4 SERPENTINITE
3c RAINY DAY PLUTON: QUARTZ MONZONITE
3b TRAIL PLUTON: GRANODIORITE
3a ROSSLAND MONZONITE
ROSSLAND GROUP
2f AUGITE PORPHYRY (ROSSLAND SILL AND RELATED INTRUSIONS)
2e GREEN VOLCANIC CONGLOMERATE, BRECCIA, AND SANDSTONE
2d GREENSTONE
2c GREY TO BLACK SILTSTONE
2b BANDED HORNFELS
2a BRECCIA COMPLEX
MOUNT ROBERTS FORMATION
1c DARK GREY SILTSTONE
1b GREEN TO GREY SANDSTONE
1a GREEN BRECCIA
AREAS OF LITTLE OR NO OUTCROP
SYMBOLS
GEOLOGICAL CONTACT: DEFINED, APPROXIMATE, ASSUMED
FAULT: DEFINED, APPROXIMATE, ASSUMED
ATTITUDE OF BEDDING, SCHISTOSITY
ATTITUDE OF MINERALIZED FRACTURES
LOCATION AND NUMBER OF SAMPLE USED FOR AGE DETERMINATION
DIAMOND-DRILL HOLE
LINE OF CROSS-SECTION
TAILINGS POND
ADIT PORTAL
SURFACE MINE WORKING
PROSPECT
TRIANGULATION STATION
ROAD: HARD TOP, GRAVEL
RAILWAY GRADE
CONTOURS AND ELEVATIONS IN FEET 5200
POWER LINE
BUILDINGS
PIPELINE
SKI LIFT
GEOLOGY BY JAMES T. FYLES
1967 – 1971 AND 1981
ROSSLAND
RED MTN.
MONTE CRISTO MTN.
COLUMBIA KOOTENAY MTN.
ROSSLAND MINING SCHOOL PIT
BLACK JACK MTN.
MT. ROBERTS
GRANITE MTN.
GREY MTN.
MT. KIRKUP
O.K. MTN.
DEER PARK HILL
BALDY MTN.
O.K. FAULT
SNOWDROP FAULT
JUMBO FAULT
117° 50'
49° 05'
To accompany bulletin 74

Province of British Columbia
Ministry of Energy, Mines and Petroleum Resources
FIGURE 3
SURVEYED MINERAL CLAIMS, VEINS AND SELECTED UNDERGROUND WORKINGS
0 1000
SCALE ~ METRES
LEGEND
CLAIM NAME AND LOT NUMBER IN KOOTENAY LAND DISTRICT
K. 954 SUNSET
ATTITUDE OF MINERALIZED FRACTURES AND VEINS
ADIT PORTAL
UNDERGROUND WORKINGS WITH ELEVATION ABOVE SEA LEVEL
2962 FT.
PROSPECT
OPEN PIT
SCALE AND COORDINATES ARE THE SAME AS FIGURE 2
CLAIMS COMPILED BY BRITISH COLUMBIA DEPARTMENT OF LANDS AND WATER RESOURCES 1970
SNOWDROP MINE
LE ROI 1650 (2300 FT.)
JOSIE 4 (2962 FT.)
WAR EAGLE 6 (3378 FT.)
WAR EAGLE 18 (1650 FT.)
LE ROI 1200 (2675 FT.)
FALAISE LAKE (3045 FT.)
City of Rossland
215,000
210,000
205,000
200,000
195,000
190,000

To accompany bulletin 74 (2)



Province of British Columbia
Ministry of Energy, Mines and Petroleum Resources
FIGURE 5
GEOLOGY OF THE RED MOUNTAIN MINE AREA
LEGEND
7 LAMPROPHYRE AND DIORITE DYKES
6 CORYELL SYENITE
3d QUARTZ DIORITE BRECCIA
3a ROSSLAND MONZONITE AND MONZONITE BRECCIA
3 ANDESITE AND META-ANDESITE
2f AUGITE POPRHYRY
2c GREY TO BLACK SILTSTONE
2b HORNFELS AND HORNFELSIC SILTSTONE
SYMBOLS
OUTLINE OF BRECCIA COMPLEX
GEOLOGICAL CONTACT: DEFINED, APPROXIMATE, INFERRED
FAULT
EXTENSIVE AREAS OF NO OUTCROP
ATTITUDE OF BEDDING OR BANDING
ADIT PORTAL
ADIT UNDERGROUND
OPEN PIT
MAIN ROADS
SKI TOW
BUILDINGS
LOT NUMBER – CROWN-GRANTED CLAIM
CONTOUR INTERVAL (50 FEET)
GEOLOGICAL MAP UNIT NUMBERS CORRESPOND TO FORMATION NUMBERS, FIGURE 2
GEOLOGY BY JAMES T. FYLES, 1969 – 71 AND 1981 AND GEOLOGICAL MAP BY I. S. ZAJAC, 1972 – 73
TOPOGRAPHY FROM COMPANY PLANS
METRES
MILL
CRUSHER
GOOD FRIDAY TAILINGS POND
GOOD HOPE M. C. LOT 1046 (GREY 9 FR.)
HIGH ORE M. C. LOT 641
NEVADA M. C. LOT 966
GOOD FRIDAY M. C. LOT 967
NORTHERN BELLE LOT 644
SAM HAYES LOT 304
RED MOUNTAIN
PEAK M. C. LOT 1209
VIEW M. C. LOT 646
MOUNTAINVIEW M. C. LOT 682
D PIT
C PIT
DUMP
UPPER B PIT
B PIT
A PIT
UPPER A PIT
E PIT
F PIT
HEADWALL FAULT
UPPER B FAULT
GOLDEN QUEEN FAULT
ST. ELMO FAULT
ST. ELMO M. C. LOT 925
GOLDEN QUEEN M. C. LOT 994
SURPRISE M. C. LOT 983
COXEY M. C. LOT 1221
NOVELTY PIT
OPHIR LOT 1829
GOLD KING M. C. LOT 1061
Jumbo Creek
HARCOFF FR.
GERTRUDE M. C. LOT 690
GIANT M. C. LOT 997
NOVELTY M. C. LOT 958
LITTLE DARLING M. C. LOT 1043
CROWE HUNTER
CALIFORNIA M. C. LOT 856
EVENING M. C. LOT 947
CALIFORNIA ADIT
PORTAL – 200 m
To accompany bulletin 74