THE ROSSLAND GROUP, NELSON MAP AREA, SOUTHEASTERN BRITISH COLUMBIA (82F/6)

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KEYWORDS: Regional geology, Rossland Group, Ymir Group, Archibald Formation, Elise Formation, shoshonites, Hall Creek syncline, Silver King shear, gold skarn, gold veins, conformable gold.

INTRODUCTION

The Rossland project, begun in 1987, continued during the 1988 season with three months field mapping in the Nelson area (Figure 1-4-1). The project focuses on the Lower Jurassic Rossland Group and the stratigraphic and structural setting of mineral deposits within it. During the 1988 season, approximately 400 square kilometres were mapped at a scale of 1:20 000, essentially covering the distribution of Rossland rocks in the Nelson sheet (82F/6). Work planned for the 1989 season will extend mapping to the south and west, primarily in the Salmo sheet (82F/3), and will eventually extend westward to cover the entire distribution of Rossland Group rocks, including those in the Rossland gold camp. Supporting laboratory work includes trace and whole-rock geochemistry of Rossland volcanic rocks, uranium-lead and potassium-argon isotope geochronology of both intrusive and extrusive rocks, fluid inclusion studies of mineral occurrences, and lead-lead isotope analyses of vein galena.

STRATIGRAPHY

The Rossland Group comprises a basal succession of dominantly fine-grained clastic rocks of the Archibald Formation, volcanic rocks of the Elise Formation and overlying clastic rocks of the Hall Formation. These rocks are Early Jurassic in age, bracketted by Sinemurian fossils in the Archibald (Frebold and Tipper, 1970; Tipper, 1984) and Pliensbachian and Toarcian fossils in the Hall (Frebold and Little, 1962, Tipper, 1984). The Ymir Group underlies the Elise Formation in the Nelson area. Based on lithologic similarity and superposition, the upper part of the Ymir Group is correlated with the Archibald Formation, and its lower part with the Late Triassic Slocan Group exposed on the north side of the Nelson batholith (Little, 1960). The Rossland and Ymir Groups are intruded by numerous small stocks that are probably correlative with the Middle to Late Jurassic Nelson Batholith, by many Tertiary rhyolite an lamprophyre dykes, and by Coryell alkalic intrusions of Eocene age.

YMIR GROUP

The Ymir Group is exposed as a broad arcuate belt of highly deformed, dominantly fine-grained clastic rocks in the east half of the Nelson map area. These rocks have been mapped by McAllister (1951) but complex structural relationships and repetitions have hindered detailed subdivision. Although the base of the Ymir Group is not exposed the sequence has been estimated to be at least a kilometre thick.

The Ymir Group comprises greater than 120 metres of argillaceous quartzite overlain by more than 300 metres of grit, siltstone and argillite with discontinuous bands of massive to thin-bedded, impure limestone (McAllister, 1951). This lower succession is overlain by a fining-upward sequence of grit, siltstone, argillite and argillaceous quartzite over 500 metres thick that terminates with finely laminated argillite, feldspathic wacke and minor limy siltstone (Höy and Andrew, 1988). Augite porphyry sills or thin flows, up to 2 metres thick, also occur near the top of the Ymir Group. The Elise Formation conformably overlies the Ymir Group; the best exposure of the contact is in Ymir Creek.

ROSSLAND GROUP

ARCHIBALD FORMATION

The Archibald Formation, named after its type location in Archibald Creek (82F/3, Frebold and Little, 1962), is the lowermost unit of the Rossland Group. It is exposed in the limbs of an anticline in the Erie Creek area along the west side of the Nelson map area. Previously referred to as "the Sinemurian beds", the Archibald Formation has yielded several macrofossil collections with *Arnioceras* indicating both early and late Sinemurian ages. The exposed thickness of the formation is estimated to be at least 1000 metres; its base is not exposed.

The Archibald Formation generally comprises a fining-upward succession of interbedded siltstones, sandstones and argillites. The lower part of the section is characterized by over 200 metres of interbedded tan siltstone and impure grey sandstone in beds 3 to 4 centimetres thick. These are overlain by a finer grained sequence of rusty weathering, tan siltstones intercalated with grey to black silty argillite and minor black graphitic argillite. A few thin (2 to 10 metres) basaltic andesite flows or sills occur with increasing abundance near the top of the section in both the Erie Creek and Red Mountain areas. This succession of interbedded volcanic and sedimentary rocks correlates with a similar succession at the top of the Ymir Group.

The contact between the Archibald and Elise formations is gradational. It is mapped (Figure 1-4-2) where fine-grained interbedded siltstones and argillites with occasional thin flows give way to massive augite porphyry flows with fine argillaceous partings. The top of the Archibald Formation was previously located at a coquina bed, a few centimetres thick, within an agglomerate overlain by massive augite

British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1988, Paper 1989-1.

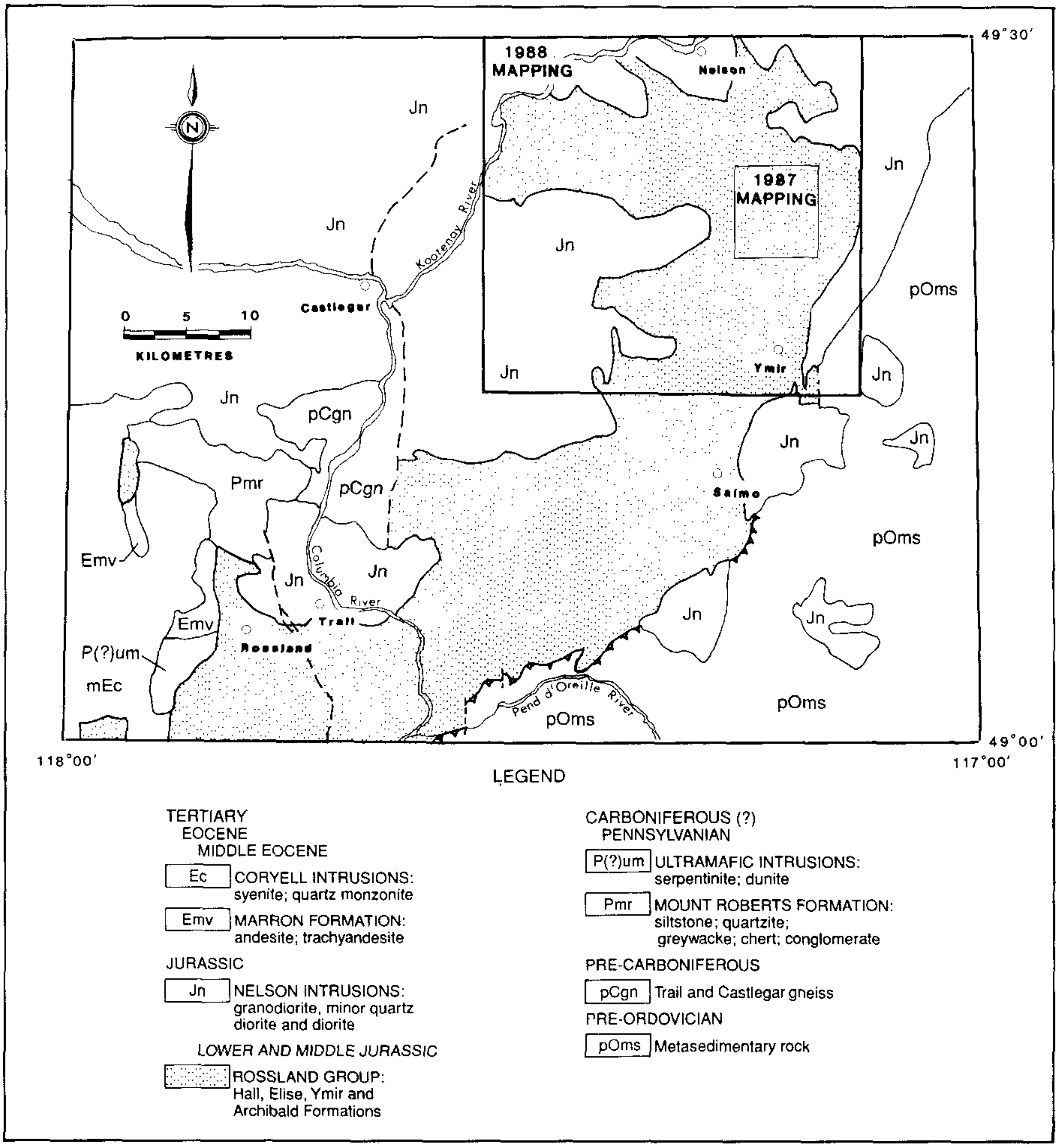

Figure 1-4-1. Map showing distribution of the Rossland Group in southeastern British Columbia and location of 1987 and 1988 map areas. Regional geology after Little (1960, 1964, 1982), Fyles (1984), Simony (1979), Corbett and Simony (1984), and Parrish (1984).

porphyry (Mulligan, 1952); however, this bed was not recognized during the course of our mapping.

Elise Formation

Description

The Elise Formation is characterized by a series of interfingering lenses of massive to brecciated flows, tuffs, subvolcanic porphyries and minor epiclastic deposits. These lenses pinch out laterally and vertically causing facies changes on both outcrop and regional scales. Despite such lithologic variations, the eastern facies of the Elise Formation can be broadly subdivided into a lower and an upper member (Andrew and Höy, 1988). The lower Elise comprises dominantly massive mafic flow-breccias, flows and coarse blocky pyroclastic rocks whereas the upper Elise is predominantly

Plate 1-4-1. Pyroclastic breccia informally referred to as the "Porto Rico tuffs", Cabin Peak area; note clasts are dominantly augite porphyry and augite-plagioclase porphyry in a fine to coarse crystal matrix.

Plate 1-4-2. Well-bedded, mafic to intermediate lapilli, crystal and fine tuff, Cabin Peak area, note numerous structures, including graded or laminated beds, scours, channels and crosslaminations suggestive of subaqueous or base-surge deposition.

intermediate pyroclastic rocks, minor epiclastic rocks and some mafic flows.

The Elise Formation is exposed in the east and west limbs of the Hall Creek syncline. In the eastern limb, the formation is characterized by a lower section of mafic flow breccias and flows up to a kilometre thick, overlain by an upper section of dominantly intermediate volcanic and volcaniclastic rocks nearly 2.5 kilometres thick (Figure 1-1-4, Höy and Andrew, 1988). The flows and flow breccias in the basal member are characterized by augite phenocrysts commonly up to 1 centimetre in diameter, and subordinate finer grained plagioclase. Although the autoclastic fragments in the flow breccias typically include broken calcite and quartz-amygdaloidal pillows, pillow basalt flows are rare.

The upper Elise on the east side of the Hall Creek syncline contains a number of cyclical sequences of pyroclastic rocks that typically grade upward from lapilli tuff to crystal tuff or fine tuff. The tuffs are commonly crystal rich with 5 to 20 per cent plagioclase and several per cent augite crystals. Lapilli tuffs contain subrounded to subangular volcanic clasts of dominantly intermediate composition. The upper Elise is intruded by a number of plagioclase porphyries including the Silver King porphyry. These are intensely deformed and are locally incorporated as fragments in Elise epiclastic rocks, compelling evidence for a comagmatic origin.

The distinction between the upper and lower Elise Formation in the Cabin Peak and Mammoth Peak areas on the west limb of the Hall Creek syncline is less evident. The total thickness of the formation in this area is approximately 1.5 to 2 kilometres. It comprises primarily mafic coarse pyroclastic breccia interlayered with minor augite porphyry flows and prominent sections of waterlain crystal and lapilli tuff (Figure 1-4-3). Pyroclastic breccias and flow breccias of intermediate composition, similar to those that characterize much of the upper Elise east of the Hall Creek syncline (Unit 7, Andrew and Höy, 1988), are uncommon.

The mafic pyroclastic breccias, informally referred to as the "Porto Rico tuffs", mainly comprise clasts of mafic

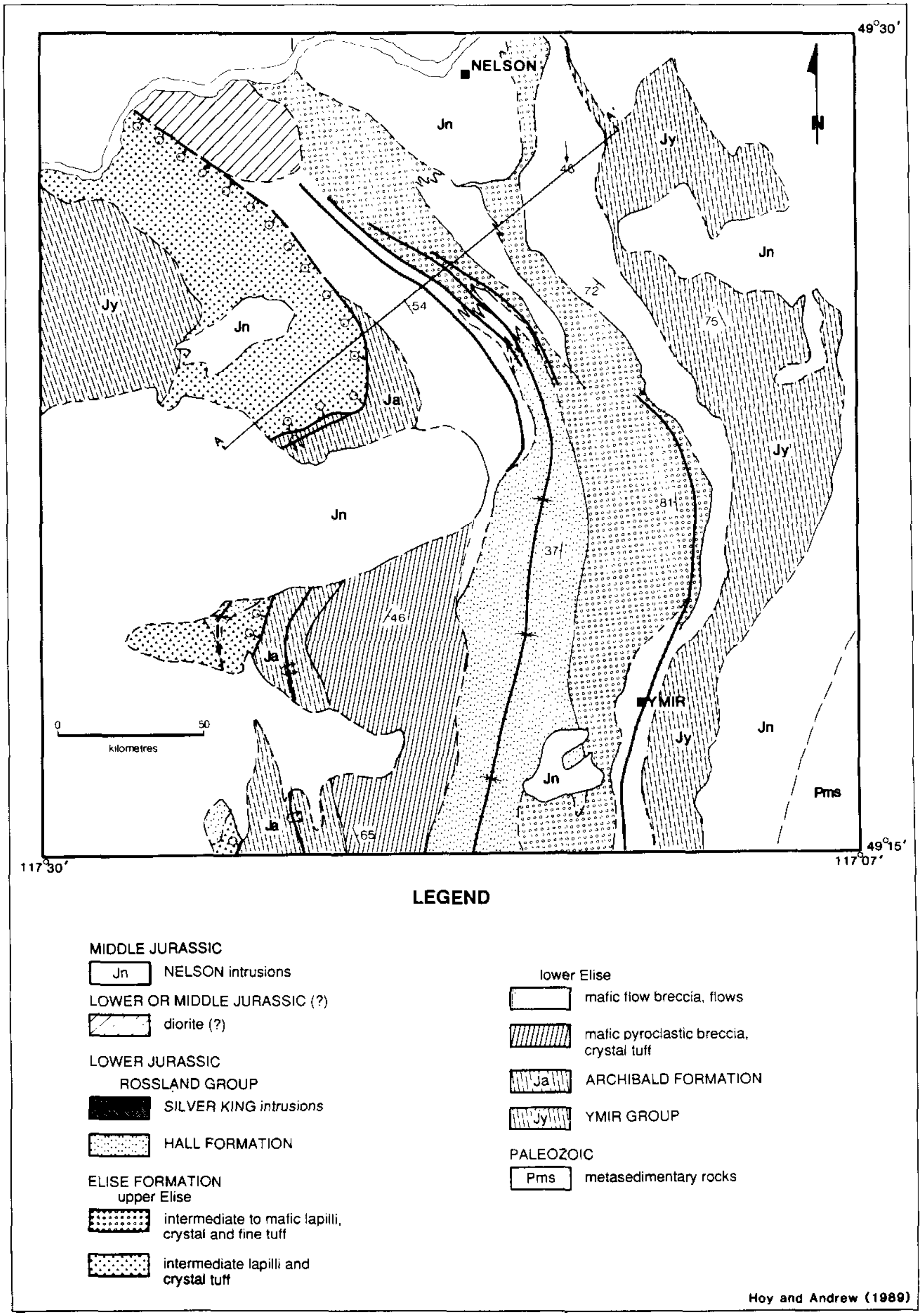

Figure 1-4-2a. Geology of the Nelson map area.

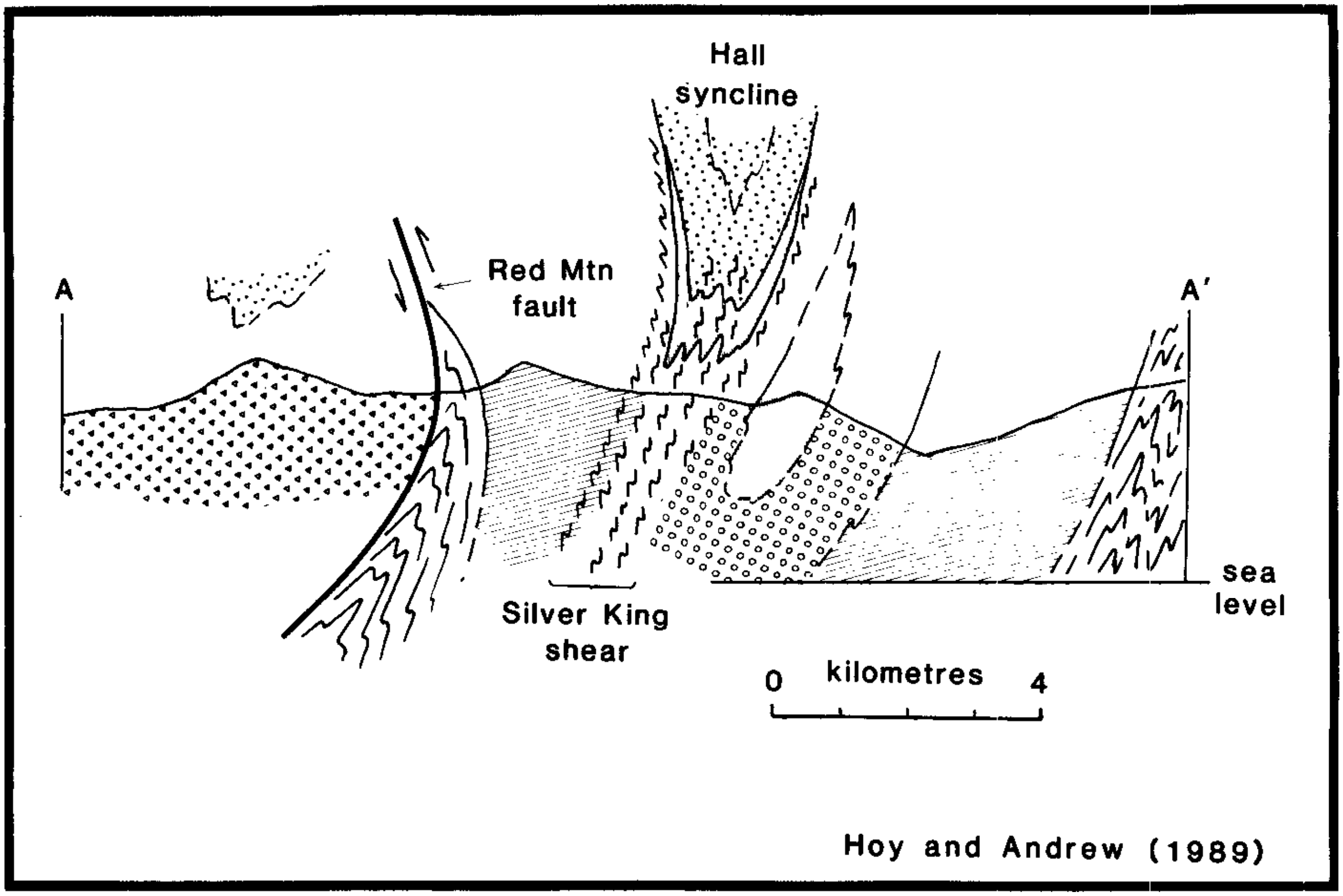

Figure 1-4-2b. Schematic vertical section through the northern part of the Nelson sheet; location is shown on Figure 1-4-2a.

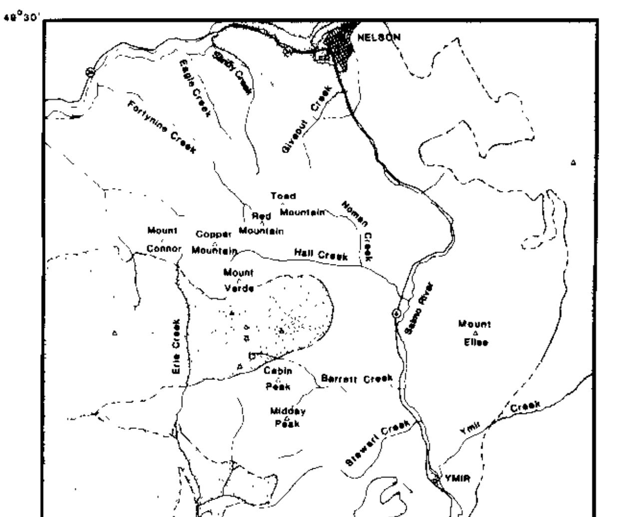

Figure 1-4-2c. Location map.

augite porphyry and minor augite-plagioclase porphyry in a fine to coarse crystal matrix (Plate 1-4-1). They are best exposed in the Cabin Peak area where clasts commonly exceed 20 to 30 centimetres in diameter. The size of pyroclasts decreases to the north and south suggesting the Cabin Peak area is close to an explosive volcanic centre. A prominent mafic intrusion at Cabin Peak may also indicate proximity to a volcanic vent.

The pyroclastic breccias are interbedded with sections dominated by well-bedded, mafic to intermediate lapilli, crystal and fine tuff (Figure 1-4-3). These units are occasionally massive but more commonly contain numerous structures, including graded or laminated beds, scours, channels and crosslaminations suggestive of subaqueous deposition (Plate 1-4-2). Although we interpreted them to be primarily pyroclastic deposits that are reworked into turbidites, it is possible that they also include base-surge deposits; their distribution is areally restricted, unusual for turbidites, and they are closely associated with a proximal vent facies.

Further north, in the Copper Mountain-Fortynine Creek area, the upper Elise typically comprises massive pale grey-green feldspathic tuff, coarse crystal tuff and tuff-breccia. The crystal tuff has prominent white euhedral plagioclase crystals set in a dark tuffaceous matrix such that the rock resembles a subvolcanic intrusive porphyry; however, small lithic fragments and broken crystals indicate a pyroclastic origin. Occasional lenses of tuffaceous conglomerate with clasts of feldspar porphyry, mudstone, chert and mafic volcanic rock occur near the top of the section.

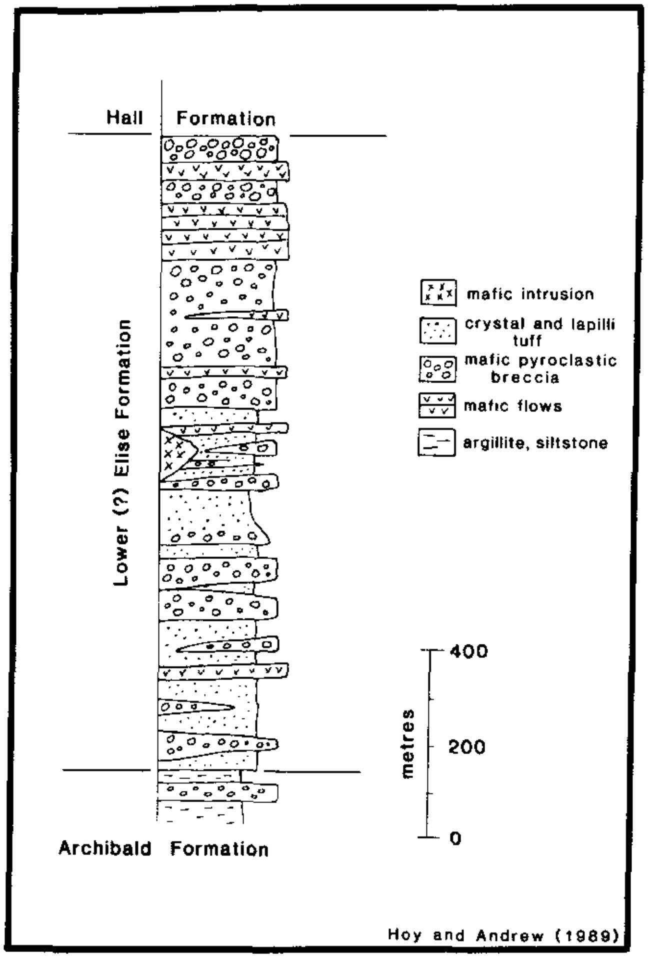

Figure 1-4-3. Composite volcanic succession of the Elise Formation in the Cabin Peak area, west of the Hall Creek syncline.

Geochemistry

The Elise volcanic suite has very high potassium content (Figure 1-4-4) and unusually low titanium content (TiO_2 less than 1 per cent). The volcanic rocks are not significantly metasomatised as most samples plot in the "unaltered" field on an MgO-CaO plot (Höy and Andrew, 1988) from de Rosen-Spence (1976); however, they are locally intensely altered near some mineral deposits.

Most analyses of Elise rocks fall in the alkaline field on the alkali versus silica diagram (Figure 1-4-5), due mainly to the very high potassium content. However, on plots using essentially incompatible trace elements (Figure 1-4-6) they plot as subalkaline andesite and basalt. The contradicting whole-rock and trace-element geochemistry, low titanium contents, high potassium-sodium ratios (Mackenzie and Chappell, 1972) and low titanium-vanadium ratios (Shervais, 1982) support a shoshonitic association for the Elise volcanic rocks, as has been shown by Beddoe-Stephens and Lambert (1981) and de Rosen-Spence (1985). Although tectonic discrimination diagrams are not well defined for shoshonitic rocks, they are interpreted to be formed in volcanic arcs (de Rosen-Spence, 1985).

Summary

The Elise Formation in the Nelson area comprises a pile of mafic augite flows, pyroclastic rocks and minor epiclastic rocks. In the eastern belt, east of the Hall Creek syncline, the formation can be subdivided into a basal member consisting mainly of flows, overlain by an upper member dominated by pyroclastic rocks of a more intermediate composition. In the western belt, the formation is characterized by a thick succession of mafic pyroclastic breccias interbedded with waterlain lapilli and crystal tuffs. Further north, in the Copper Mountain area, pyroclastic rocks are less coarse, dominated by lapilli and feldspathic crystal tuffs. These volcanic facies indicate explosive volcanism initiated Elise volcanism in the Cabin Peak area while effusive eruptions of basaltic magma occurred further to the east.

Southwest of the Nelson map area, the Elise Formation is dominated by sedimentary rocks (Fitzpatrick, 1985). These rocks were undoubtedly derived from active volcanic arcs, such as those in the Nelson area and perhaps in the Rossland area to the west (Fyles, 1984).

Hall Formation

The Hall Formation (Drysdale, 1917) is a succession of clastic sedimentary rocks exposed in the core of the Hall Creek syncline in the Nelson map area. It is the youngest formation of the Rossland Group and has yielded reliable early Pliensbachian and early Toarcian macrofossils in the Salmo, Trail and Rossland areas (Tipper, 1984).

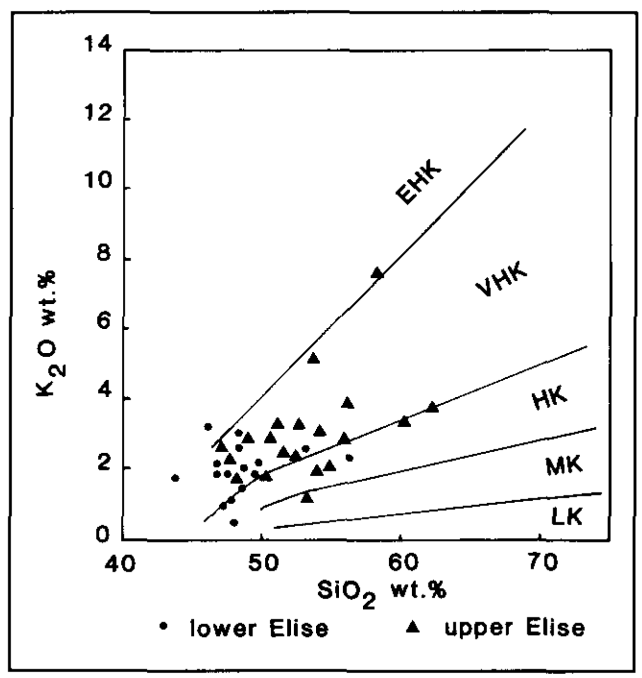

Figure 1-4-4. K_2O/SiO_2 plot demonstrating the consistantly very high K_2O content of Elise Formation volcanic rocks. Low (LK), medium (MK), and high (HK) K_2O domains are from Gill (1981); very high (VHK) and extremely high (EHK) K_2O domains, from de Rosen-Spence (1985).

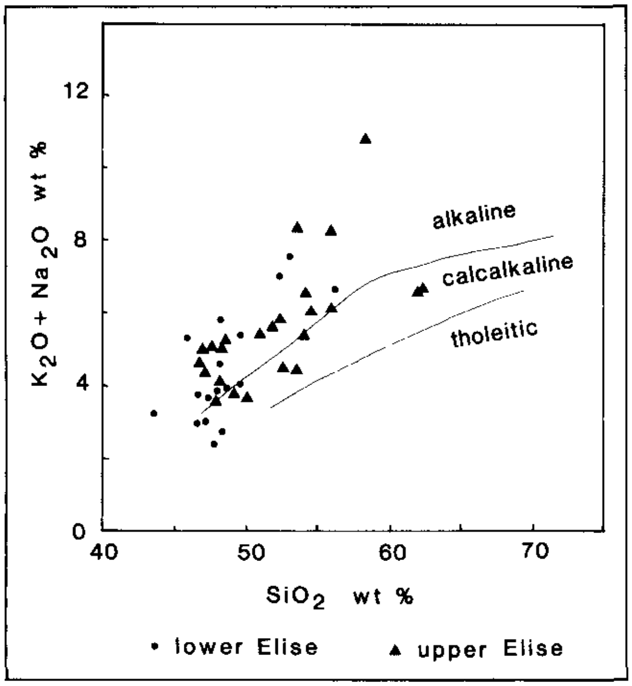

Figure 1-4-5. Alkali-silica plot of Elise Formation volcanic rocks showing the distinct alkaline trend; field boundaries from Kuno (1966).

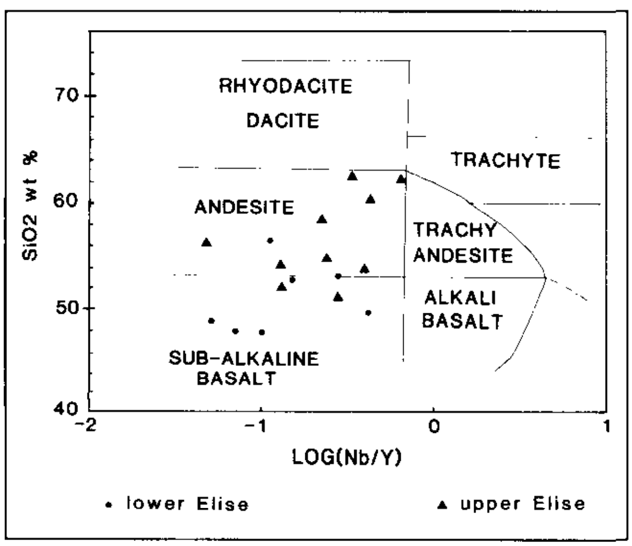

Figure 1-4-6. SiO_2-Nb/Y diagram illustrating the subalkaline nature of Elise volcanic rocks; lower Elise, dominantly basaltic; upper Elise, dominantly andesitic; field boundaries from Winchester and Floyd (1977).

The thickness of the Hall Formation is at least 1400 metres; its top is not exposed. It generally rests conformably on volcanic rocks of the Elise Formation although locally an erosional unconformity, marked by a few metres of conglomerate with pebbles derived from the underlying volcanic rocks, is at the base. In the eastern part of the map area, a number of diorite sills parallel the Hall-Elise contact.

The Hall Formation comprises a lower coarsening-upward sequence of argillites, siltstones, grits and conglomerates overlain by a succession of interbedded siltstone and argillite. The lower part of the sequence is characterized by over 300 metres of black argillite with minor siltstone and rare limy argillaceous layers, overlain by over 200 metres of tan siltstone. These grade upward into over 300 metres of coarse sandstone interlayered with conglomerate, grit and pebble conglomerate, locally with a carbonate cement. The upper part of the section is an interlayered sequence of argillaceous laminated siltstone, silty argillite and argillite. Locally, impure limestones and mud-chip breccias occur near the top of the formation.

STRUCTURE

The structure of the Nelson map area is dominated by northerly trending tight folds and associated shears. The intensity of deformation increases toward the east. The Ymir Group near the eastern edge of the map area is folded into numerous tight to isoclinal west-dipping overturned folds whereas folds in the Archibald and Elise formations in the Copper Mountain and Cabin Peak areas are more open. These structures involve the Silver King intrusive rocks but are truncated by rocks correlative with the Nelson batholith. Small-scale open folds, locally associated with a crenulation cleavage, are superimposed on the early, northerly trending structures.

The Hall Creek syncline is the most prominent fold in the map area. It is a tight, south-plunging, west-dipping overturned fold, cored by the Hall Formation, that extends from west of Nelson to southwest of Ymir (Figure 1-4-2). A pronounced cleavage in clastic rocks of the Hall Formation and a penetrative foliation in the Elise Formation parallel the axial plane of the syncline. Northwest of the closure of the Hall Formation, between the headwaters of Nomar and Giveout creeks, the core of the syncline forms a zone of intense shearing more than a kilometre in width. The shear zone, informally referred to as the Silver King shear, continues northwestward into intrusive rocks and more highly metamorphosed rocks of the Elise Formation near Eagle and Sandy creeks, and appears to die out to the south in rocks at a higher structural level along the limbs of the Hall Creek syncline.

Other zones of intense shearing are recognized in the Elise Formation and Ymir Group east of the Hall Creek syncline. The most prominent follows the western slope of Mount Elise and crosses Highway 6 south and west of Ymir (Figure 1-4-2). It dips to the west, essentially parallel to the prominent foliation, cuts down section to the south, and has an apparent net reverse displacement.

An overturned anticline occurs in the Archibald Formation near the western edge of the map area. It is truncated by apophyses of the Nelson batholith near Erie Creek and appears to be cut by the Red Mountain fault in the Mount Verde–Red Mountain area. The Archibald Formation on the east slope of Red Mountain is an east-facing upright succession on the east limb of the anticline; on the eastern and northern slopes of Mount Verde, a number of small folds verge northward towards the hinge of the anticline. Numer-

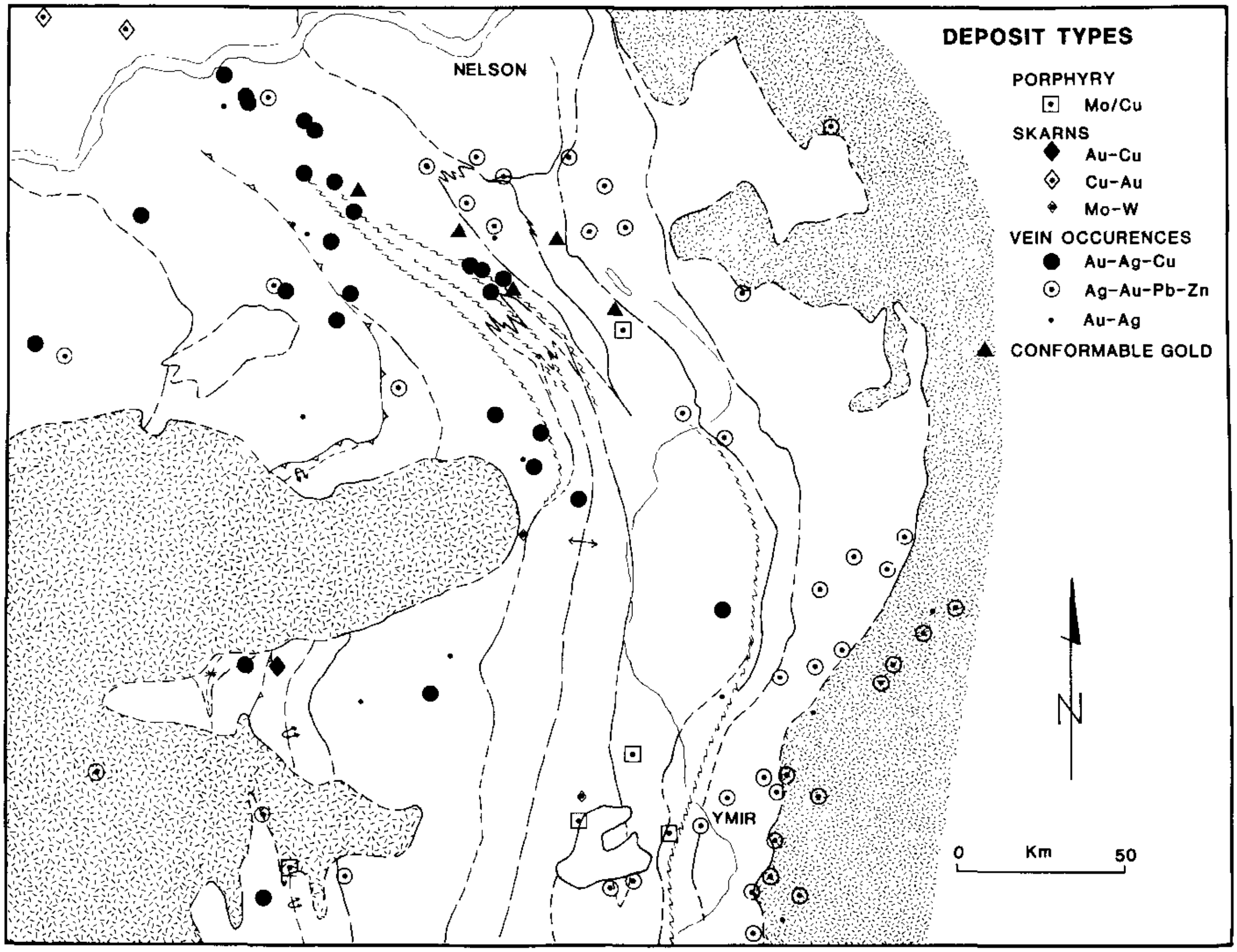

Figure 1-4-7. Metallic mineral deposit types of the Nelson map area.

ous Cretaceous or Tertiary porphyry, aplite and granitic dykes intrude the Archibald Formation in the Erie Creek area.

The Red Mountain fault extends from Fortynine Creek south to Erie Creek. It dips to the north with a normal displacement in the Mount Verde–Copper Mountain area, but is overturned in Fortynine and Erie creeks where its apparent displacement is reverse (*see* cross-section, Figure 1-4-2). It may be a large listric normal fault that juxtaposes upper Elise volcanic rocks in its western hangingwall against more intensely folded Archibald rocks to the east. It is younger than the intense folding and associated shearing, but older than the Nelson granitic rocks.

MINERAL OCCURRENCES

The distribution of metallic mineral occurrences and deposits in the Nelson map area is shown in Figure 1-4-7. These deposits have produced more than 16 750 kilograms of gold and 190 000 kilograms of silver, primarily from vein deposits in the Ymir camp. This compares with more than 84 000 kilograms of gold and 105 000 kilograms of silver recovered from the Rossland Camp, the second largest gold-producing camp in British Columbia.

Mineral occurrences in the Nelson and Ymir areas can be subdivided into four main types:

(1) porphyry or stockwork molybdenum-copper
(2) skarn molybdenum, tungsten, copper, gold
(3) vein gold, silver, copper; gold, silver, lead, zinc
(4) "conformable gold".

Porphyry, skarn and vein occurrences are closely associated with late granitic intrusions, whereas deposits referred to as "conformable gold" are more closely associated with Rossland Group lithologies and early structures.

The most significant porphyry occurrences in the Nelson area are the Stewart and Bobbi prospects just west of Ymir (MINFILE 082FSW229 and 250). These occurrences contain zones of intense alteration and brecciation in a quartz monzonite stock and adjacent rocks of the Elise and Hall formations contain disseminated, vein and stockwork molybdenite, pyrite and minor powellite mineralization.

Three main types of skarn deposits are recognized in the area. These are molybdenum or tungsten skarns, copper skarns and a gold-enriched skarn. The Mammoth showing (MINFILE 082FSW311) is a small molybdenum-copper skarn with minor lead-zinc-silver and trace gold in mafic augite flows of the Elise Formation and hornfelsed argillites of the Hall Formation, adjacent to the Bonnington pluton. Skarn gangue minerals include pyrite, pyrrhotite, quartz, epidote, potassium feldspar, garnet and actinolite. The Arrow Tungsten prospect (MINFILE 082FSW311) is a tungsten-molybdenum-garnet-diopside skarn in Hall Formation metasedimentary rocks on the north side of the intrusive complex that hosts the Stewart deposit. A number of copper skarns, comprising coarse-grained diopside-garnet-quartz-epidote with pyrrhotite, chalcopyrite, magnetite and bornite, occur in the Hall Formation along the margin of the Nelson batholith west of Nelson.

The only deposit that may be classed as a gold-enriched skarn is the Second Relief (MINFILE 082FSW187). It comprises a number of "fissure veins" that carry pyrite, pyrrhotite, chalcopyrite and minor molybdenite in "greenstone" adjacent to a diorite porphyry sill (Cockfield, 1936). Skarn minerals in the country rock include coarse-grained garnet, epidote, biotite, quartz and magnetite. The Second Relief produced 3118 kilograms of gold and 866 kilograms of silver from 1902 to 1959, ranking it as one of the larger gold skarns in British Columbia and one of the few, other than those in the Hedley camp, that produced gold as its primary commodity.

Vein deposits are widely distributed throughout the Elise and Archibald Formations, the Ymir Group and Nelson granitic rocks (Figure 1-4-7). Many of these veins have a preferred orientation parallel to either bedding or foliation, AC jointing, or extension joints (Höy and Andrew, 1988). Vein mineralogy appears to have a lithologic control; veins that carry lead and zinc in addition to gold and silver are preferentially distributed in metasedimentary rocks of the Ymir Group or correlative Archibald Formation and within or adjacent to Nelson granitic rocks, whereas copper-gold-bearing veins are more common in Elise volcanic rocks (Figure 1-4-7). Most copper-gold-bearing veins are within or close to large faults or shear zones such as the Silver King shear. The gangue of the these veins is predominantly quartz, with minor carbonate, chlorite, trace tourmaline and rare scheelite. Sulphides include pyrite, pyrrhotite, chalcopyrite and, in some veins, arsenopyrite and galena.

"Conformable gold" is an informal name applied to a variety of deposits that are conformable with either foliation or bedding in the host Elise Formation. They include the Great Western, Shaft and Cat showings, Kena, some showings in the Star area, and perhaps the Silver King deposits (Figure 1-4-7). In contrast with other deposits, conformable gold deposits are sheared and foliated together with their host rocks. Many appear to be associated with synvolcanic intrusions that range in composition from rhyodacite(?) to diorite, and all have extensive alteration halos.

The Great Western showings, located just southwest of Nelson, were extensively trenched and drilled by Lectus Developments Ltd. in 1987. One of the best mineralized intercepts included approximately 7 metres containing 9.7 grams per tonne gold (DDH 87-10); the highest reported assay was 58 grams per tonne gold over 0.9 metre (DDH 87-3), (George Cross Newsletter, November 17, 1987). The showings consist of a number of elongate zones of intense carbonate-silica-sericite-pyrite alteration up to several metres to several tens of metres thick. A number of the zones include thin lenses of quartz-eye rhyodacite or granular dacite. The zones are hosted by highly sheared mafic tuffs, lapilli tuffs and possible augite flows of the upper Elise Formation.

The Shaft-Cat property, currently being drilled by South Pacific Gold Corporation, is centred on an elongate, fine to medium-grained intrusive diorite complex. The diorite is locally brecciated and extensively altered to a chlorite-epidote-carbonate assemblage that contains magnetite, chalcopyrite and pyrite. Surface grab samples assayed an average of 6.2 grams per tonne gold and 1 per cent copper (O. Janout, personal communication, 1988).

SUMMARY AND DISCUSSION

The Elise Formation exhibits marked facies changes throughout the district. In the eastern part of the Nelson map area, Elise volcanic rocks record an early phase of effusive volcanism followed by eruptions of pyroclastic rocks. Further west, in the Copper Mountain area, explosive volcanism characterizes the entire formation. In contrast, the formation is dominated by sedimentary rocks southwest of Salmo (Fitzpatrick, 1985), that were probably derived from volcanic centres in the Nelson area, and possibly, the Rossland area (Fyles, 1984).

The Rossland Group was subjected to intense compressional deformation, particularly in the east close to its contact with Paleozoic miogeoclinal rocks. This deformation is bracketed by a late Early Jurassic age for the Rossland Group and a post-tectonic, late Middle Jurassic age for the Nelson batholith (Ghosh, 1986; Carr *et al.*, 1987).

The shoshonitic nature of the Elise Formation supports the suggestion that the Rossland Group was deposited in a volcanic arc environment (de Rosen-Spence, 1985; Ray and de Rosen-Spence, 1986). Shoshonitic volcanism appears to be associated with disturbance or steepening of a subduction zone, possibly due to plate collision (Joplin, 1969; Gill, 1970). The Rossland Group shoshonitic rocks may therefore record arc volcanism as a subduction zone was dying just prior to plate collision, possibly involving accretion of Quesnellia in Terrane I (Monger *et al.*, 1982) to the North American craton in Jurassic time. Continued compressional tectonics may have resulted in the intense regional deformation in Rossland Group rocks.

Mineral occurrences and deposits in the Nelson area include gold-silver-copper-lead-zinc veins, a number of porphyry molybdenum-copper deposits, "conformable gold" occurrences and skarn deposits. The recognition of a major gold-enriched skarn deposit within the Nelson area, the Second Relief, considerably increases the exploration potential for gold-bearing skarn deposits in the Rossland Group. The Second Relief produced more than 3100 kilograms of gold, which ranks it as the third largest skarn producer in the province, after the Nickel Plate and Phoenix mines.

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