Regional and District Mapping

PRELIMINARY GEOLOGY AND GEOCHEMISTRY OF THE ELISE FORMATION, ROSSLAND GROUP, BETWEEN NELSON AND YMIR, SOUTHEASTERN BRITISH COLUMBIA (82F/06)

By Trygve Höy and Kathryn Andrew

KEYWORDS: Regional geology, Rossland Group, Elise Formation, Nelson batholith, Ymir Group, Archibald Formation, Hall Formation, gold-bearing veins, volcanic centres.

INTRODUCTION

The Rossland project was initiated in 1987 in order to develop a better understanding of the structural and stratigraphic controls of gold and silver vein mineralization in Rossland Group rocks. The Rossland Group has been a major producer of precious metals, with over 84 000 kilograms of gold and 105 000 kilograms of silver recovered from the Rossland camp, ranking it second in the province in gold production (Panteleyev and Schroeter, 1986). Exploration continues to be active in the camp and throughout the length of exposures of Rossland Group rocks, particularly with the recent discovery of significant gold mineralization at the Willa property in a roof pendant within the Nelson batholith.

The 1987 field project included regional mapping, at a scale of 1:20 000, on an area centred on Highway 6A approximately 10 kilometres south of the town of Nelson (Figure 1-1-1). The mapping focused on the Elise Formation, the central volcanic part of the Rossland Group, and subdivided the formation into a number of distinct and mappable units. Work planned for the 1988 season will extend the mapping to include all exposures of Rossland Group rocks south to Salmo and west to the Nelson batholith. The area is within the Selkirk Mountains, with relief varying from 900 metres in the valley floors to greater than 3500 metres on the higher ridges. Exposure is variable, from 10 to 20 per cent on the heavily wooded lower slopes to almost 100 per cent on the ridges.

The results of the 1987 mapping will be released as an open file map early in 1988. Work begun this winter includes trace and major element geochemistry of volcanic rocks of the Elise Formation, uranium-lead and potassium-argon isotope geochronology of both intrusive and extrusive rocks, fluid inclusion studies of vein occurrences, and lead-lead isotope analyses of vein galena.

REGIONAL GEOLOGY

The Rossland Group is exposed in a broad arcuate belt in southeastern British Columbia, bounded to the east, north and west by granitic rocks of the lower Cretaceous Nelson batholith, and in fault contact with lower Paleozoic rocks of the Kootenay arc on the south (Figure 1-1-1). It is intruded by numerous small, irregular stocks, probably correlative with the Nelson batholith (Little, 1964), by apophyses of the Nelson batholith and, in the south near the town of Rossland, by Coryell alkalic intrusions of Eocene age.

The Rossland Group is subdivided into a lower, generally highly deformed sequence of predominantly fine-grained clastic rocks of the Ymir Group and Archibald Formation, a thick accumulation of pyroclastic and epiclastic volcanic rocks of the Elise Formation, and overlying, generally less intensely deformed clastic rocks of the Hall Formation (Table 1-1-1). The age of the Elise Formation is bracketed by Sinemurian macrofossils in the Archibald Formation and Toarcian fossils in the overlying Hall Formation; no fossils have been found in the Ymir Group.

A variety of gold, silver, copper, lead and zinc vein deposits as well as molybdenite deposits occurs within the Rossland Group or in intrusions cutting these rocks. These deposits are concentrated in the more northern exposures southwest of Nelson (Mulligan, 1952; Little, 1982), east and northeast of Ymir (Cockfield, 1936; McAllister, 1951), and in the Rossland camp itself (Fyles, 1984).

STRUCTURE

The map area is at the southwestern extension of the Kootenay arc, tectonically emplaced on highly deformed lower and middle Paleozoic rocks to the south and east, and intruded by granitic rocks of the Nelson batholith on the west. The northern part of the belt of Rossland Group rocks has been folded into broad north-trending and east-verging folds that repeat formations. The Ymir Group is exposed along the eastern margin of the belt and is correlative with the Archibald Formation in an anticline on the west, and the Elise Formation is repeated on both limbs of an intervening syncline cored by the Hall Formation.

The structure of the area is not complex. Numerous top indicators and bedding-cleavage intersections indicate that the Elise and Hall Formations form a right-way-up structural panel on the east limb of the syncline. A prominent mineral foliation trends north to northwesterly and dips to the west, parallel to the axial plane of the syncline. Mineral lineations are variable, but generally plunge south at 10 to 20 degrees.

Structures within the underlying Ymir Group are, however, considerably more complex. Reversals of top in-

British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1987, Paper 1988-1.

dicators and fold vergence indicate that, locally, tight to isoclinal intrafolial folds occur in these less competent rocks. These folds and related shears repeat parts of the Ymir Group. In general, the Ymir Group faces west with the oldest rocks exposed in more eastern outcrops.

STRATIGRAPHY

YMIR GROUP

The Ymir Group is a sequence of fine-grained clastic and carbonate rocks at least 1500 metres thick. The base of the Ymir has been cut off by Nelson intrusions and is not exposed in the map area.

A Ymir section was examined in detail from exposures on the Apex Creek road (Figure 1-1-2). Although structural repetitions are recognized in this section, it nevertheless represents an approximate stratigraphic sequence through the upper part of the Ymir Group. The structural base is dominated by over 300 metres of massive to impure limestone beds interlayered with grits, siltstone and argillite. It is overlain by a fining-upward succession of grits, siltstone and argillite and finally interbedded argillite and chert at least 500 metres thick. The top of the Ymir Group is characterized by finely laminated argillite interbedded with feldspathic wacke and minor limy siltstone beds.

ELISE FORMATION

The Elise Formation is differentiated into units on the basis of the following criteria: (1) textures, either massive or fragmental; (2) per cent pyroclastic, epiclastic and autoclastic fragments; (3) average clast size; and (4) phenocryst assemblage, size and abundance. Facies changes are distinguished by separating units of the same composition into massive and fragmental components. Original textures and primary phenocryst assemblages are used to describe units regardless of the degree of metamorphism or alteration.

A basal augite porphyry succession (Units 1, 2, and minor 3 and 4) lies with apparent conformity on sedimentary rocks

TABLE 1-1-1
REGIONAL CORRELATION OF THE ROSSLAND GROUP, SOUTHEASTERN BRITISH COLUMBIA

AGE			ROSSLAND AREA		NELSON AREA		SLOCAN AREA	
PERIOD	EPOCH	AGE	GROUP	FORMATION	GROUP	FORMATION	GROUP	FORMATION
JURASSIC	L		? NELSON INTRUSIONS		? NELSON INTRUSIONS			
	M		?	?	?	?		
	E	TOARCIAN		HALL		HALL		
		PLIENSBACHIAN	ROSSLAND	ELISE	ROSSLAND	ELISE		
		SINEMURIAN		ARCHIBALD		YMIR		
		HETTANGIAN						
TRIASSIC	L		?	?	?	?	SLOCAN	
	M							
	E							
PERMIAN							KASLO	
CARBONIFEROUS							MILFORD	
DEVONIAN							LARDEAU	
CAMBRIAN								BADSHOT
								MOHICAN
								HAMILL

of the Ymir Group; argillite beds persist through the lower part of the Elise Formation. The upper Elise section is characterized by mafic to intermediate volcanic and volcaniclastic rocks (Units 3 to 10). Feldspar porphyry intrusions, including the Silver King porphyry, are interpreted to be coeval with the Elise Formation and hence are also described in this section. The principal lithologic units are shown in Figures 1-1-2 and 1-1-3, outlined in Table 1-1-2, and described in detail following.

Basal Section

The lower part of the Elise Formation (predominantly Units 1 and 2) is a sequence of dominantly mafic flows and

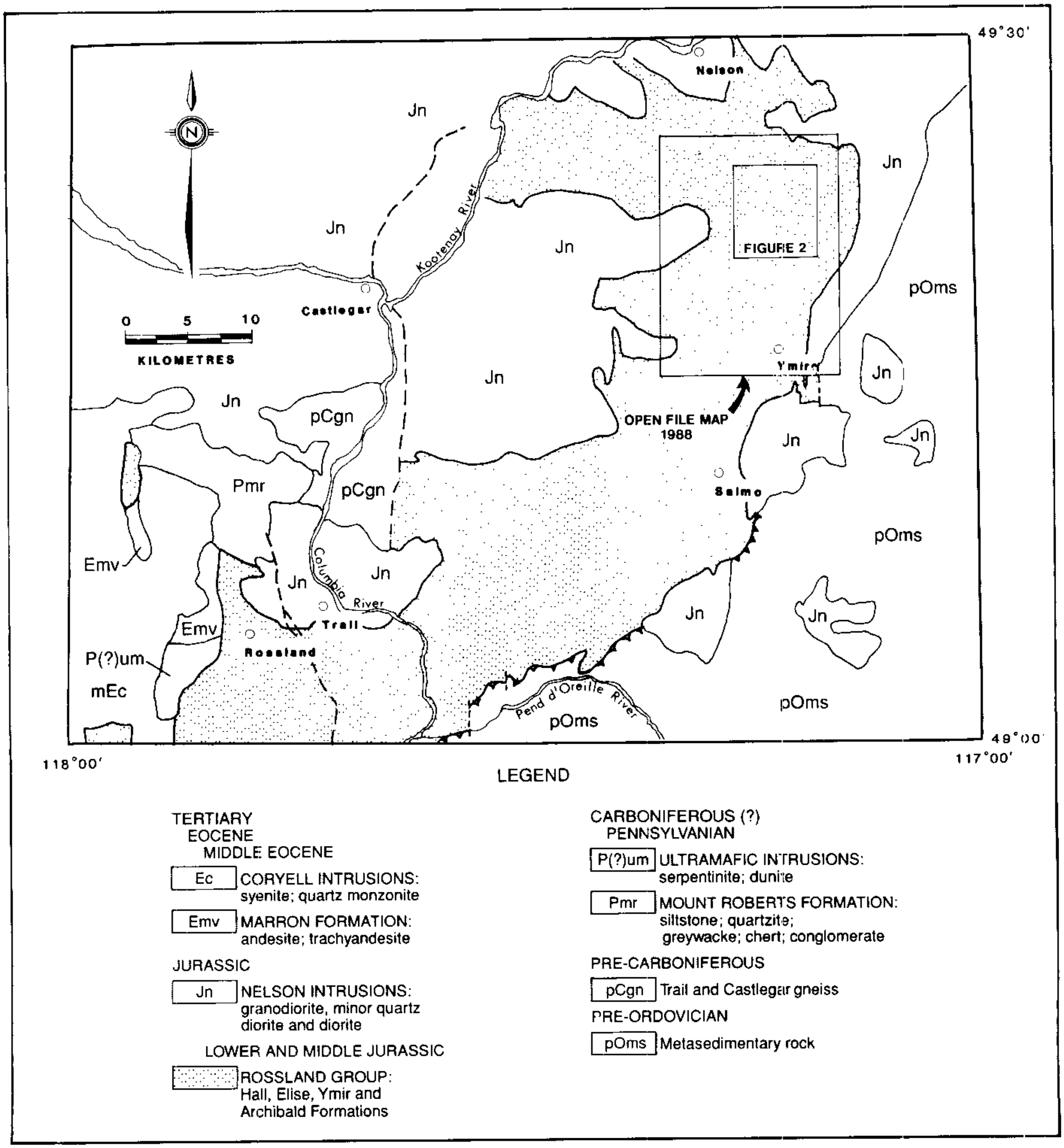


Figure 1-1-1. Map showing distribution of Rossland Group in southeastern British Columbia and location of Figure 1-1-2 and Open File map. Regional geology after Little (1960, 1964, 1982), Fyles (1984), Simony (1979), Corbett and Simony (1984), and Parrish (1984).

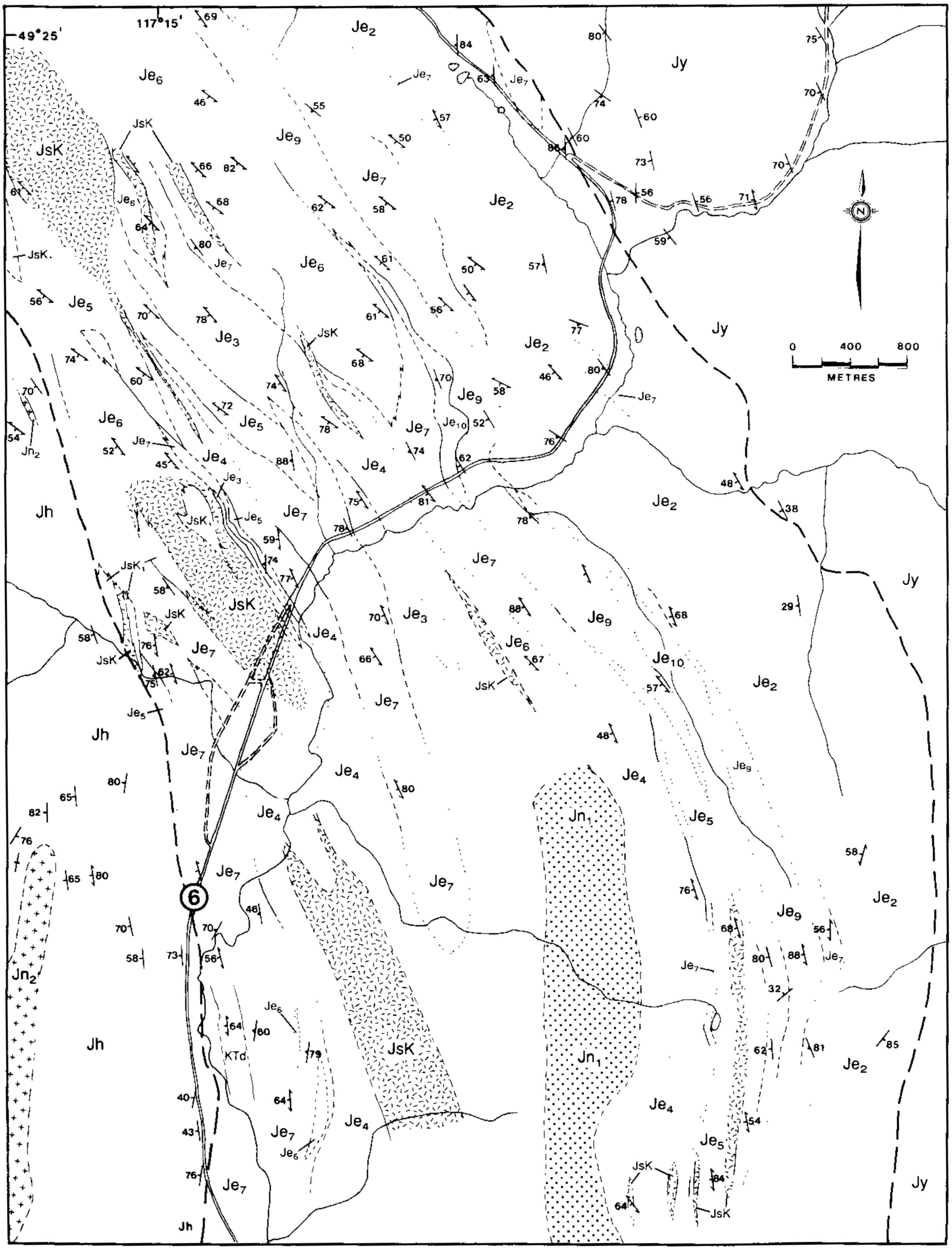


Figure 1-1-2. Geological map of the Hall Creek--Apex Creek area south of Nelson; *see* Figure 1-1-3 for legend.

TABLE 1-1-2
UNITS OF THE ELISE FORMATION

Unit No.	Unit Name	Texture	Fragments	Phenocrysts
Je_1	Coarse-grained augite porphyry flows	Massive	—	Augite, 20-40% (10 mm)
Je_2	Coarse-grained augite porphyry flow breccias	Fragmental	Autoclastic	Augite, 20-40% (10 mm)
Je_3	Medium-grained augite porphyry flows	Massive	—	Augite, 20-30%m (5 mm)
Je_4	Medium-grained augite porphyry flow breccias	Fragmental	Autoclastic, 20-30% (2-5 cm)	Augite, 20-30% (5 mm)
Je_5	Mafic ash tuff	Fragmental	Pyroclastic, 20-80% (<1 mm)	Augite, <5% (2-5 mm) Biotite, 10-15% (1-4 mm)
Je_6	Plagioclase augite crystal tuff	Massive	Pyroclastic, 20-80% (2-64 mm)	Augite, <5% (2-5 mm) Plagioclase, 10-20% (1-2 mm)
Je_7	Plagioclase lapilli tuff	Fragmental	Pyroclastic, 5-20% (2 mm-10 mm)	Augite, <5% (2-5 mm) Augite, <5% (2-5 mm)
Je_8	Plagioclase-porphyritic flows	Massive	—	Augite, <2% (<2 mm) Plagioclase, 15-30% (<3 mm)
Je_9	Tuffaceous siltstone	Fragmental	Epiclastic 90% (<2 mm)	—
Je_{10}	Tuffaceous conglomerate	Fragmental	Epiclastic 15-30% (2 mm-10 mm)	—
Je_{11}	Plagioclase porphyry	Porphyritic	—	Plagioclase, 20-30% (10 mm)

Plate 1-1-1. Massive and brecciated flows of Unit Je_1, Highway 6, 2 kilometres west of Apex Creek. Note thin mud selvages between flows.

flow breccias, minor lahars and tuffs, up to 1 kilometre thick. Near its base it is interbedded with argillite of the Ymir Group. Autoclastic fragments, including broken amygdaloidal pillows, characterize the section and are incorporated in flows 0.5 to 1 metre thick. Such textures are indicative of fragmentation by mechanical friction or gaseous explosion during lava flow movement, or gravity crumbling of spines and domes.

Despite regional greenschist facies metamorphism, primary euhedral augite phenocrysts are occasionally preserved. They are partially altered to an assemblage of actinolite, biotite, epidote and chlorite. More commonly, the augite phenocrysts are totally replaced. Plagioclase phenocrysts are less common in the basal units and are generally partially saussuritized. The phenocrysts are set in a fine-grained matrix of secondary plagioclase, biotite, chlorite, epidote and carbonate.

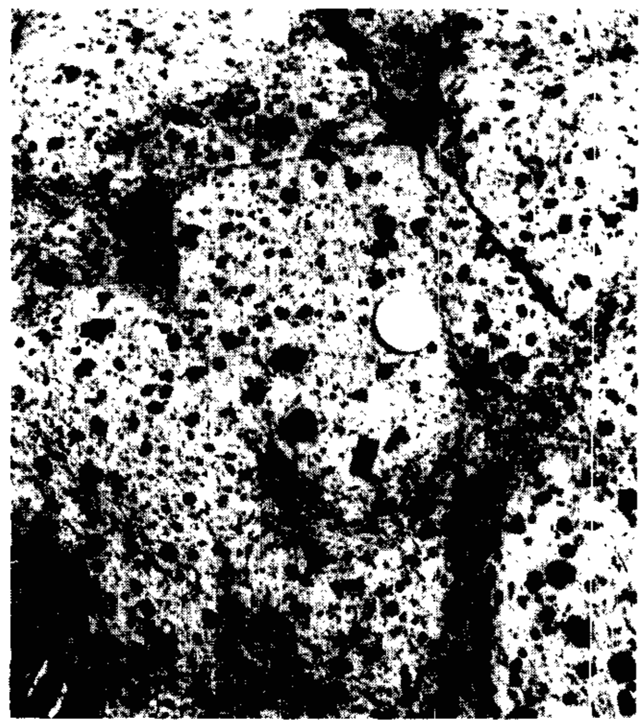
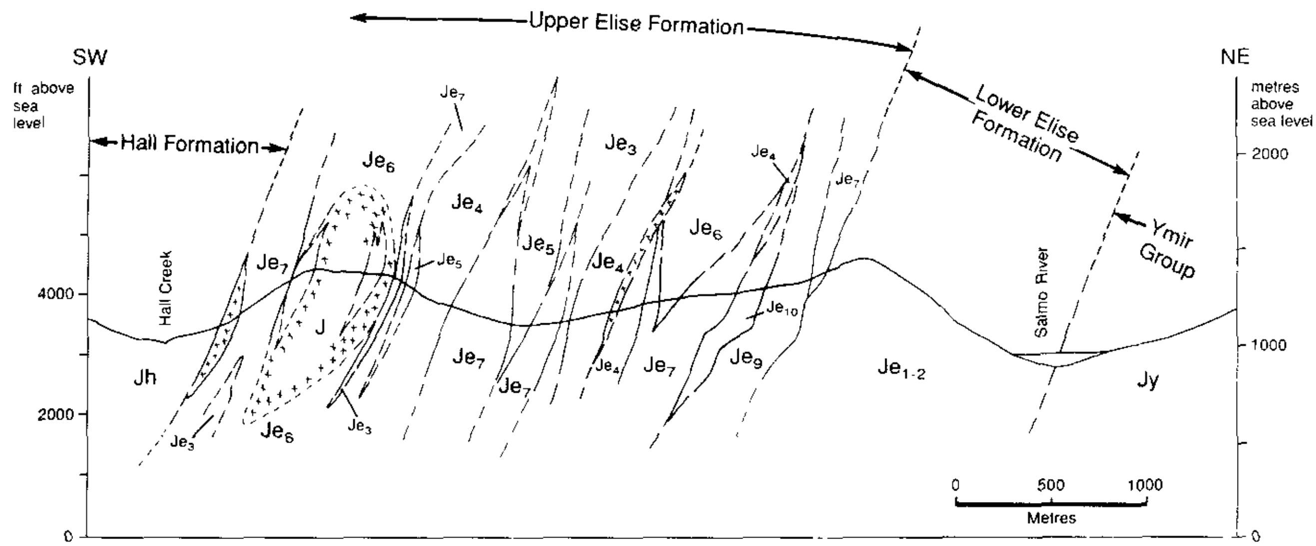


Plate 1-1-2. Coarse-grained augite porphyry flow breccia of Unit Je_2; note large augite phenocrysts in both matrix and fragments.

Coarse-grained Augite Porphyry Flows (Je_1)

Dark green, massive, compound flows (0.5 to 1 metre thick) typify this unit. The flows are characterized by 20 to 40 per cent augite phenocrysts commonly up to 1 centimetre in diameter and virtually no plagioclase phenocrysts. Truly massive flows are subordinate to those with autoclastic fragments and are not differentiated at this map scale.



LEGEND

CRETACEOUS AND/OR TERTIARY

KTd	Diorite dykes

JURASSIC

Jn	Nelson intrusions

LOWER AND MIDDLE JURASSIC

Jh	Hall Formation

Grit, sandstone, conglomerate, argillite

Je	Elise Formation
Je_1	Coarse-grained augite-porphyry flows
Je_2	Coarse-grained augite-porphyry flow breccias
Je_3	Medium-grained augite-porphyry flows
Je_4	Medium-grained augite-porphyry flow breccias
Je_5	Mafic ash tuff
Je_6	Plagioclase augite crystal tuff
Je_7	Plagioclase augite lapilli tuff
Je_8	Plagioclase-porphyritic flows
Je_9	Tuffaceous siltstone
Je_{10}	Tuffaceous conglomerate
Je_{11}	Plagioclase porphyry intrusion
Jy	Ymir Group

Argillite, limey siltstone; minor wacke, limestone

Figure 1-1-3. Vertical cross-section through the Hall Creek–Apex Creek area; *see* Figure 1-1-2 for location of section.

Way-up structures include amygdaloidal pillows and flowtop breccia. Thin (1 to 5 centimetres) mud selvages, often seen between flows, mark short periods of quiescence (Plate 1-1-1).

Coarse-grained Augite Porphyry Flow Breccia (Je_2)

This autoclastic unit is volumetrically more extensive than Unit Je_1 and is its fragmental counterpart. Monolithic fragments of the same composition as Je_1 are broken or quenched *in situ* (Plate 1-1-2). As a result, the size, shape and abundance of clasts are widely variable. Most often, flow breccias are matrix supported with subrounded clasts ranging from 2 to 10 centimetres in diameter.

Due to the similarity in fragment and matrix composition, the autoclastic nature of Unit Je_2 is often difficult to confirm. Generally, fragments are finer grained, are more felsic, and tend to have more augite phenocrysts and calcite amygdules from broken pillows. In places fragments are cemented by an impure brown carbonate.

UPPER SECTION

The upper Elise Formation (Units 3 through 10) is a sequence of mafic to intermediate flows, tuffs and subvolcanic intrusions with minor epiclastic deposits. This section is up to 2.5 kilometres thick in the map area. Pyroclastic and epiclastic deposits are distinguished on the basis of their pyroclastic fragment content (Fisher and Schminke, 1984).

Medium-grained Augite-Porphyry Flows (Je_3)

These massive medium-grained flows outcrop throughout the upper section but are subordinate to coarser grained units in the basal section (Je_1 and Je_2) and thus not differentiated there at this scale of mapping. The unit is characterized by 20 to 30 per cent augite phenocrysts, generally less than 0.5 centimetre in diameter and virtually no plagioclase phenocrysts. Microphenocrysts of titaniferous magnetite (Beddoe-Stephens and Lambert, 1980) have also been identified in thin section.

Individual flows range in thickness from 1 to 4 metres and are typically massive and rarely pillowed. Compound flows are unusual. In outcrop, pillows (up to 1 metre in diameter) are amygdaloidal with glassy rinds (Plate 1-1-3).

Medium-grained Augite Porphyry Flow Breccia (Je_4)

Unit Je_4 is compositionally similar to Unit Je_3, but is its fragmental counterpart. This relationship is parallel to that between Units Je_2 and Je_1. Flow breccias of this unit are intimately associated with rocks of Unit Je_3 in outcrop but

Plate 1-1-3. Stretched amygdaloidal pillows of Unit 3, station R33-13, on Highway 6, north of Ymir (*see* section, Figure 1-1-7).

distinguished from them by their fragmental nature. The unit is characterized by mafic, angular, monolithic fragments (2 to 5 centimetres in diameter) hosted in a matrix of similar composition.

Ash Tuff (Je_5)

This unit occurs as dark green fine-grained lenses (less than 100 metres thick) closely associated with medium-grained augite porphyry units (Je_3 and Je_4). Several per cent broken, commonly saussuritized plagioclase phenocrysts (An_{55-65}) less than 1 millimetre in diameter, and rare quartz crystals (0.5 millimetre in diameter) are the only primary textures preserved in the tuff.

A conspicuous biotite mineral foliation imparts a slabby parting in outcrop. The elongate biotite (up to 4 millimetres in diameter) comprises 15 per cent of the rock and is its most distinguishing feature. In thin section, the groundmass is seen to be metamorphosed to predominantly epidote, secondary plagioclase and minor calcite.

Plagioclase Augite Crystal Tuffs (Je_6)

Crystal tuffs of Unit Je_6 are characterized by a significant plagioclase component in the phenocryst assemblage and are interpreted to be of andesitic composition. Phenocrysts are dominantly 10 to 20 per cent euhedral plagioclase (An_{60-80}) laths (1 to 2 millimetres in diameter) and less than 5 per cent subhedral augite crystals (2 to 5 millimetres in diameter). Several per cent microphenocrysts of magnetite are evident in thin section.

Plagioclase Augite Lapilli Tuff (Je_7)

Unit Je_7 is typified by 5 to 20 per cent subrounded cognate pyroclasts ranging from 2 millimetres up to 6 centimetres in diameter. Fragments are the same composition as Je_6 and generally darker in colour than their matrix. This marked colour contrast is due to the preferential alteration of the fine-grained matrix to calcite, epidote and secondary plagioclase.

Plagioclase-Porphyritic Flows (Je_8)

The most distinguishing feature of these massive flows is the abundance of euhedral plagioclase laths. The flows are

Plate 1-1-4. Cross-bedded volcanic sandstone and minor siltstone of Unit Je_9. Note graded bed above siltstone layer.

typically 1 to 2 metres thick and occur in scattered outcrops of more mafic composition. Phenocrysts are mainly 15 to 30 per cent plagioclase (An_{50-70}) up to 3 millimetres in length, and minor augite up to 2 millimetres in diameter. The groundmass is a finely interwoven network of plagioclase microlites which have been altered to sericite, calcite and epidote.

Tuffaceous Siltstone (Je_9)

This unit is typified by mixed pyroclastic and epiclastic fragments with average clast size less than 1 millimetre. Pale green volcanic siltstone is interbedded with coarser tuffaceous plagioclase-rich beds that contain small lithic fragments. The siltstone is thinly (0.5 to 2 centimetres) bedded and finely laminated with well-defined graded beds, basal scours, crossbeds and channels (Plate 1-1-4). The tuffaceous and reworked material was probably emplaced in a high-energy shallow-marine environment.

Tuffaceous Conglomerate (Je_{10})

This unit is an interbedded sequence of conglomerate, grit, sandstone and siltstone of predominantly volcanic or subvolcanic provenance. It underlies Unit Je_9 and hence forms the basal part of a thick fining-upward succession. It comprises a series of fining-upward clastic cycles, generally, a few to several tens of metres thick, that are coarser near the base of the succession and finer at the top. Hence, cycles near the base grade from coarse conglomerates (Plate 1-1-5) to grits whereas those at the top typically grade upward from sandstone to siltstone. As in Unit Je_9, crossbeds, scours and channels are common throughout the unit.

The most abundant clasts are subrounded boulders and cobbles of feldspar porphyry that are similar in texture and composition to the Silver King porphyry (Plate 1-1-6). These clasts provide the most compelling evidence that the suite of Silver King porphyries are high-level subvolcanic intrusions. Other clasts include chert fragments, less commonly mafic volcanic fragments and rarely felsic volcanics with fiammé textures.

Units Je_9 and Je_{10} are epiclastic deposits formed by weathering of a more felsic volcanic centre and an exposed subvolcanic intrusion. Je_9 is overlain abruptly by coarse fragmentals of Unit Je_7.

Plagioclase Porphyry (Je_{11}) Including the Silver King Intrusions

This unit occurs as subvolcanic intrusions up to 400 metres thick that conform to stratigraphy. The porphyry is characterized by 20 to 30 per cent euhedral plagioclase phenocrysts (An_{56-60}), up to 1 centimetre across, and less than 5 per cent hornblende laths. Textural evidence for the subvolcanic origin of these plutons includes several per cent resorbed quartz phenocrysts. Highly sheared zones within and along the margins of the porphyries are evidence of considerable strain within the Elise Formation.

GEOCHEMISTRY

Considerable rock and mineral chemical analyses of Rossland volcanic rocks have been undertaken by Beddoe-Stephens and Lambert (1981). Whole-rock analyses of a few samples of various units of the Elise Formation, collected in 1986, are presented in Table 1-1-3.

Our analyses indicate that Elise volcanic rocks include dominantly undersaturated basic volcanics of mainly alkaline affinity (Figure 1-1-5). The volcanics are chemically classified as tephrite basanite, trachybasalt and basalt based on the total alkali-silica diagram of LeBas *et al.* (1986). Samples are neither sodic, $(Na_2O-4)>K_2O$, nor potassic, $Na_2O<K_2O$, and do not plot as shoshonites. The total alkali-silica diagram (TAS) is considered reliable despite low-grade metamorphism that has affected the Rossland Group; these samples plot in the "unaltered" field on an MgO-CaO plot from de Rosen-Spence (1976) (Figure 1-1-6).

Beddoe-Stephens and Lambert (1981) propose that Rossland volcanics have an alkalic, shoshonitic association based on the presence of ankaramitic rocks, amphibole-bearing basalts, and trace element abundances. However, they also show that tectonic discrimination diagrams indicate a calcalkaline affinity. They conclude that the Rossland volcanics are not typically calcalkaline in character but formed in the late stages of island arc development when tensional

Plate 1-1-5. Boulder conglomerate near the base of Unit Je_{10}.

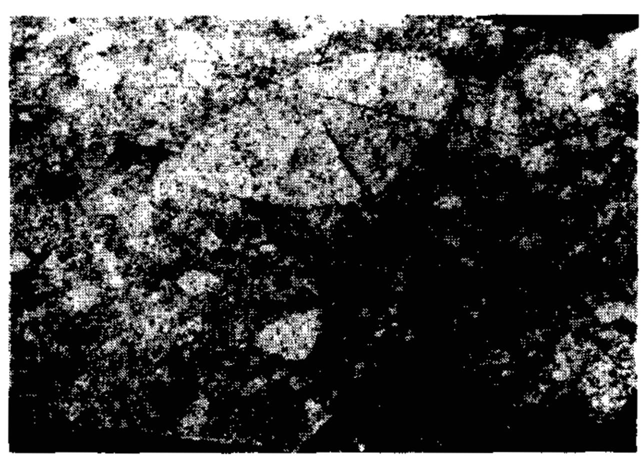


Plate 1-1-6. Boulder conglomerate containing abundant subrounded clasts of intrusive feldspar porphyry, Unit Je_{10}.

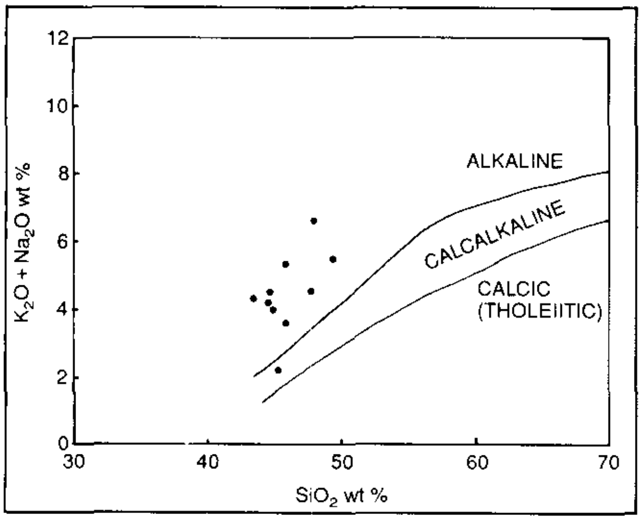


Figure 1-1-5. Alkali-silica plot of Elise Formation volcanic rocks; the field boundaries are modified from Kuno by Spence (1985).

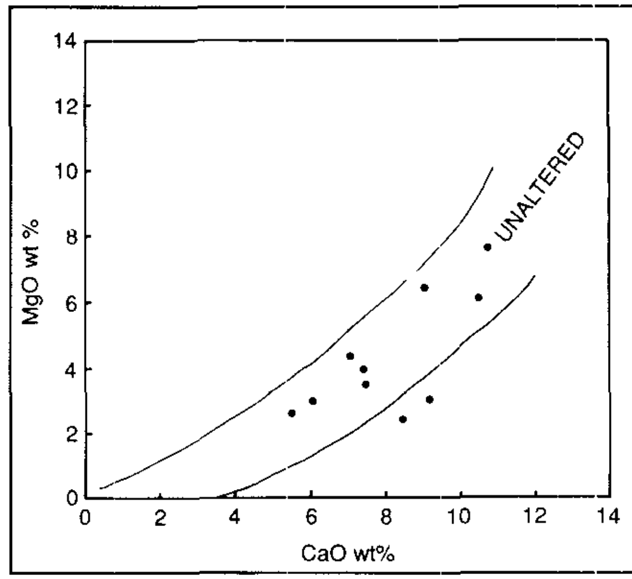


Figure 1-1-6. MgO/CaO plot designed to screen altered rocks (from de Rosen-Spence, 1976; Ray and Spence, 1986).

regimes begin to predominate. The variety of lithologies recognized in this study, and the variability in chemical composition indicates, however, that the tectonic setting of Rossland volcanic rocks is considerably more complex than previously recognized.

SUMMARY AND DISCUSSION

The Elise Formation is dominated by a series of interfingering lenses of massive to brecciated flows and tuffs of variable composition. The basal succession comprises

TABLE 1-1-3
WHOLE-ROCK CHEMICAL ANALYSES OF ELISE FORMATION VOLCANIC ROCKS

Sample Number	31833	31834	31835	31836	31837	31838	31839	31840	31841	31842
Unit Number	Je$_9$	Je$_7$	Je$_3$	Je$_3$	Je$_8$	Je$_6$	KTd	Je$_9$	Je$_7$	Je$_7$
Oxides as Determined										
SiO_2	47.81	47.78	47.64	47.41	48.60	52.38	45.85	49.70	46.83	50.64
TiO_2	0.76	0.76	0.78	0.81	0.64	0.68	1.08	0.75	0.97	0.77
Al_2O_3	15.70	16.94	14.51	14.89	16.50	16.96	16.00	18.53	17.14	17.57
Fe_2O_3*	10.77	9.98	12.38	11.86	9.33	8.50	9.17	9.33	11.52	8.48
MnO	0.16	0.18	0.20	0.21	0.15	0.12	0.16	0.16	0.17	0.16
MgO	4.98	4.21	6.75	6.25	3.18	2.78	7.92	3.75	2.59	3.09
CaO	7.69	7.89	9.87	10.83	9.76	5.87	10.62	7.87	9.33	6.46
Na_2O	2.21	3.37	1.33	1.79	3.09	3.55	2.75	2.19	1.95	4.20
K_2O	2.25	1.64	1.09	1.89	2.52	2.27	1.42	2.59	2.62	2.81
P_2O_5	0.29	0.29	0.24	0.31	0.31	0.29	1.29	0.37	0.32	0.34
L.O.I.	6.99	6.64	5.33	3.30	5.72	6.75	3.15	4.15	6.93	5.67
Total	99.61	99.68	100.12	99.55	99.80	99.47	99.41	99.39	100.37	100.19
Oxides Recalculated Volatile-Free										
SiO_2	44.47	44.61	45.10	45.85	45.82	49.20	44.41	47.64	43.58	47.77
TiO_2	0.71	0.71	0.74	0.78	0.60	0.64	1.05	0.72	0.90	0.73
Al_2O_3	14.60	15.82	13.74	14.40	15.56	15.93	15.50	17.76	15.95	16.57
Fe_2O_3*	10.02	9.32	11.72	11.47	8.80	7.98	8.88	8.94	10.72	8.00
MnO	0.15	0.17	0.19	0.20	0.14	0.11	0.15	0.15	0.16	0.15
MgO	4.63	3.93	6.39	6.04	3.00	2.61	7.67	3.59	2.41	2.91
CaO	7.15	7.37	9.34	10.47	9.20	5.51	10.29	7.54	8.68	6.09
Na_2O	2.06	3.15	1.26	1.73	2.91	3.33	2.66	2.10	1.81	3.96
K_2O	2.09	1.53	1.03	1.83	2.38	2.13	1.38	2.48	2.44	2.65
P_2O_5	0.27	0.27	0.23	0.30	0.29	0.27	1.25	0.35	0.30	0.32
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Analyses by X-ray fluorescene, Analytical Laboratory, B.C. Ministry of Energy, Mines and Petroleum Resources.

* Total iron is reported as Fe_2O_3.

mainly massive flows and flow breccias of probable alkali basalt composition. It is overlain in the upper Elise by a number of cyclical sequences that typically comprise lapilli tuff and blocky tephra overlain by crystal tuff and ash tuff (*see* Figure 1-1-4). These volcanic cycles have variable composition, but in general, the upper Elise Formation is dominated by "intermediate" flows and tuffs at the base and top with a sequence of more mafic volcanics near the centre. The mafic volcanics are similar to those in the lower Elise; they are lavas and flow breccias that are overlain by dominantly ash tuff. These units interfinger extensively and, in detail, several units may be represented in a single outcrop (Figure 1-1-7); hence units in Figure 1-1-2 are named according to the dominant lithology.

The Silver King porphyry and other similar intrusive lenses are interpreted to be subvolcanic intrusions of similar age to the host Elise volcanics. They are sheared and foliated, generally conformable, and appear to be areally restricted to the Elise Formation. The most compelling evidence for a subvolcanic origin is the presence of feldspar porphyry clasts, megascopically similar to the Silver King porphyry, within Unit Je_{10}.

HALL FORMATION

The Hall Formation is a sequence of interbedded conglomerate, grit, siltstone and argillite exposed in the southwest part of the map area; this is the type locality of the Hall Formation as defined by Drysdale (1917). A disconformable relationship between the Hall and Elise formations is proposed by Little (1982) on the basis of pebbles resembling Elise lavas within Hall conglomerate. The top of the Hall is not seen because the formation is exposed in a syncline; however, the section is at least 1400 metres thick.

Cursory examination of the Hall section was undertaken in 1987. The basal Hall is dominated by coarse grits which fine upwards within 100 metres into interbedded graphitic argillite and sandstone with minor limy argillaceous layers. Several small (less than 50 metres) coarsening-upward sequences of argillite, sandstone and grit culminate in a clastic succession of pebble conglomerates that is up to 200 metres thick. Siltstone, silty argillite and argillite characterize the top of the Hall and are invariably interbedded with minor impure limestone layers.

PLUTONIC ROCKS

Small plutons similar to the Jurassic Nelson batholith intrude the Elise and Hall formations in the southern half of the map area. These plutons are subdivided compositionally into east and west intrusive equivalents. The more easterly intrusions are characterized by a nonporphyritic medium-grained equigranular texture. On the basis of modal analyses [60 per cent plagioclase (An_{90-92}), 5 per cent quartz, 15 per

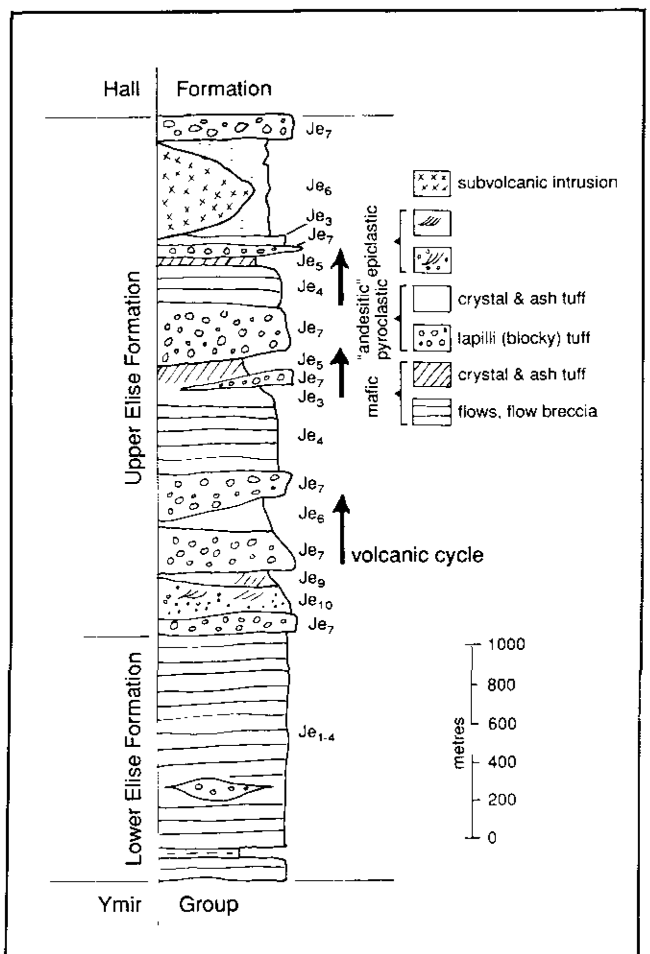


Figure 1-1-4. Composite volcanic succession, Elise Formation.

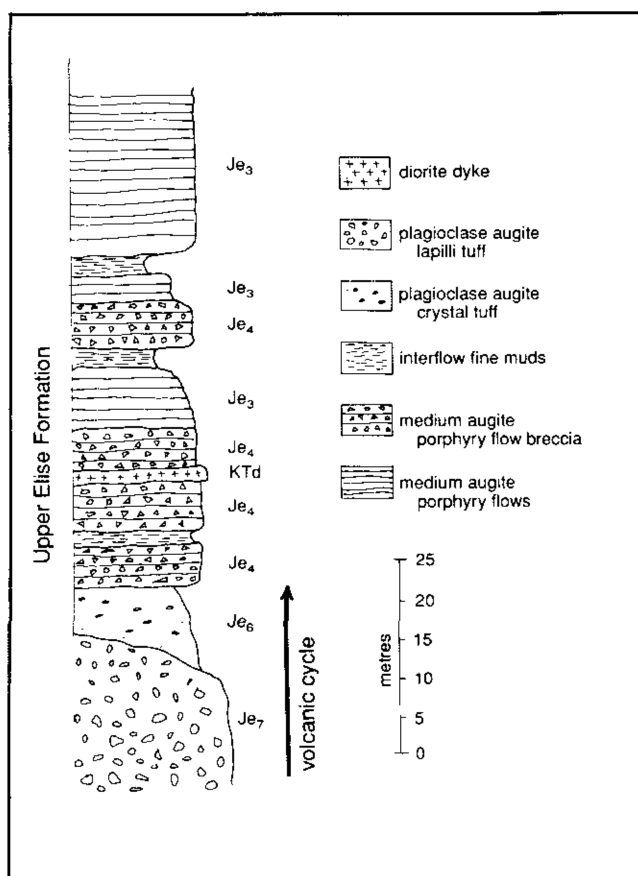


Figure 1-1-7. A detailed stratigraphic section in the upper Elise, station R33-13, on Highway 6, 6 kilometres north of Ymir.

TABLE 1-1-4
MINERAL PROPERTIES WITH PAST PRODUCTION OR EXTENSIVE DEVELOPMENT, HALL CREEK–APEX CREEK AREA

Map No.	MINFILE No.	Name	Commodities	Status	Reference
1	—	—	(Au, Pb, Zn)	Showing (adit)	—
2	—	—	(Cu, Au, Ag)	Showing (adit)	Little, 1964
3	—	—		Showing (adit)	
79	82FSW-079	Gold Cup	Au, Ag, Cu	Past producer	MINFILE
185	82FSW-185	Golden Age	Au, Ag, W, Pb, Zn	Past producer	MINFILE
186	82FSW-186	Euphrates	Au, Ag, Pb, Zn	Past producer	MINFILE
4	—	Lost Cabin	(Au, Ag, Cu)	Past producer?	Drysdale, 1917
237	82FSW-237	Kena	Cu, Au	Showing (diamond drilling)	MINFILE
5	—	Jennie Bell	Au, Ag, Pb	Past producer	Drysdale, 1917

cent orthoclase, 10 per cent biotite, 5 per cent hornblende and 3 per cent opaques], these intrusions are compositionally classified as granodiorites. Western intrusions are referred to as diorite porphyries by Little (1982). These fine-grained diorites are characterized by plagioclase (An_{66-84}) and hornblende phenocrysts.

Lamprophyric and dioritic dykes of probable Cretaceous or Tertiary age crosscut all map units. Several lamprophyric dykes crop out within the Ymir Group in the northeastern part of the map area. Diorite dykes striking north-northeast, approximately parallel to stratigraphy, form a subparallel swarm which straddles the Elise/Hall contact in the southwestern part of the map area. The diorite is typically medium grained with distinctive glomerocrysts of plagioclase variably replaced by calcite and epidote.

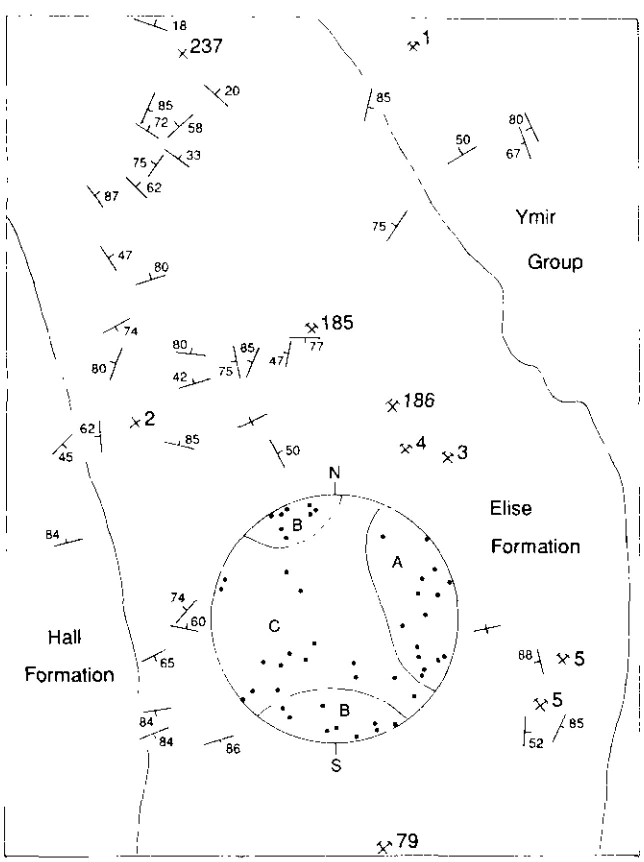


Figure 1-1-8. Map showing orientations of veins and location of mineral deposits, Hall Creek–Apex Creek area. Stereonet plots poles to quartz veins in the area. Deposits are listed in Table 1-1-3.

MINERALIZATION

Mineral occurrences in the map area include auriferous quartz veins and, on the Kena claims, conformable silicified zones carrying copper and gold. These occurrences (Table 1-1-4), as well as numerous other quartz veins, are plotted in Figure 1-1-8.

Quartz veins vary from massive white bull-quartz to quartz-carbonate. Accessory silicate minerals include plagioclase, tourmaline, epidote, chlorite, muscovite, actinolite and axinite. Common sulphide minerals include pyrite and chalcopyrite; in veins that have had some development work, covellite, bornite, tetrahedrite, galena and sphalerite are also recognized. Scheelite occurs with tourmaline and axinite in a quartz-carbonate vein on the Golden Age property.

Although the veins appear to be highly variable in strike and dip, a number of preferred orientations are apparent. A large number (set A, stereonet in Figure 1-1-8) trend north-northwest and dip variably toward the west, essentially parallel to bedding or the prominent regional foliation. A second set (B) is perpendicular to the gentle south to north-plunging lineation, parallel to prominant AC jointing. Most other veins (C) are parallel to extension joints, striking northwest but dipping to the east at a high angle to bedding. These orientations indicate that the veins are structurally controlled. However, their spatial distribution on a regional scale, near the margins of large intrusions, and the general lack of tectonic fabric within them suggest that they are post-tectonic and formed during intrusion of the Nelson batholith and related rocks. Their orientations are at least partially controlled by a pre-intrusive structural fabric. Lead-lead isotope analyses of galenas, detailed geochemistry and fluid inclusion studies will further clarify the controls of vein emplacement in Rossland rocks.

CONCLUSIONS

The central part of the Rossland Group, the Elise Formation, is readily subdivided into a number of distinct and mappable units. Mafic augite porphyry flows and flow breccias dominate the lower Elise and probably record a period of tectonic extension, perhaps in a back-arc basin, prior to more explosive volcanism typical of the upper Elise.

The upper Elise comprises dominantly thick accumulations of lapilli tuff and blocky tephra that grade laterally and vertically to crystal tuff and ash tuff. These cyclical sequences interfinger extensively, indicating the presence of distinct and separate explosive vent areas. Less abundant in the upper Elise are mafic flows similar to those in the lower Elise; these may grade laterally and vertically to mafic ash tuffs.

Conformable, locally sheared plagioclase porphyry bodies in the upper Elise, including the Silver King porphyry, are interpreted to be coeval subvolcanic intrusions. A dominantly epiclastic unit near the base of the upper Elise is composed largely of clasts of intrusive plagioclase porphyry. It hosts a number of vein deposits (Figure 1-1-8) emphasizing a genetic link between comagmatic intrusions and mineralization.

The presence of at least two volcanic centres in the Rossland Group here, and in the Rossland mining camp (Fyles, 1984), extensive epiclastic deposits west of Salmo (Fitzpatrick, 1985), and variable chemistry and lithology indicate a complex tectonic setting for Rossland Group rocks, probably including both arc development and rifting.

ACKNOWLEDGMENTS

We wish to thank Mike Fournier and Mike Holmes for their capable and cheerful assistance during field mapping. Field trips with Jim Fyles and Philip Simony contributed greatly to our understanding of the regional geology of Rossland Group. Discussions with these geologists and with Vic Preto, Bill McMillan, Richard Lambert, Colin Godwin, and Don MacIntyre were helpful and stimulating. Knowledge of mineral occurrences in the map area was considerably improved through discussions with George Addie, Bob Bourden, Otto Janout, and Eric Denny. The manuscript was improved by the editorial comments of John Newell.

REFERENCES

Beddoe-Stephens, B. and Lambert, R. St. J. (1981): Geochemical, Mineralogical, and Isotopic Data Relating to the Origin and Tectonic Setting of the Rossland Volcanic Rocks, Southern British Columbia, *Canadian Journal of Earth Sciences*, Volume 18, pages 858-868.

Cockfield, W.E., (1936): Lode Gold Deposits of Ymir-Nelson Area, British Columbia, *Geological Survey of Canada*, Memoir 191, 78 pages.

Corbett, C.R. and Simony, P.S. (1984): The Champion Lake Fault in the Trail-Castlegar Area of Southeastern British Columbia, *in* Current Research, Part A, *Geological Survey of Canada*, Paper 841A, pages 103-104.

de Rosen-Spence, A.F. (1976): Stratigraphy, Development and Petrogenesis of the Central Noranda Volcanic Pile, Noranda, Quebec, Unpublished Ph.D Thesis, *University of Toronto*.

Drysdale, C.W. (1917): Ymir Mining Camp, British Columbia, *Geological Survey of Canada*, Memoir 94, 185 pages.

Fisher, R.V. and Schmincke, H.-U. (1984): Pyroclastic Rocks, *Springer-Verlag*, New York, 472 pages.

Fitzpatrick, Mark (1985): The Geology of the Rossland Group in the Beaver Valley Area, Southeastern British Columbia, Unpublished M.Sc. Thesis, *University of Calgary*, 150 pages.

Fyles, J.T. (1984): Geological Setting of the Rossland Mining Camp, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Bulletin 74, 61 pages.

LeBas, M.J., LeMaitre, R.W., Streckeisen, A, Zanettin, B. (1986): A Chemical Classification of Volcanic Rocks Based on the Total Alkali-silica Diagram, *Journal of Petrology*, Volume 27, Part 3, pages 745-750.

Little, H.W. (1960): Nelson Map-area, West-Half, British Columbia, *Geological Survey of Canada*, Memoir 308, 205 pages.

——— (1964): Ymir Map Area, British Columbia, *Geological Survey of Canada*, Map 1144A.

——— (1982): Geology, Bonnington Map-area, British Columbia, *Geological Survey of Canada*, Map 1571A.

——— (1982): Geology, Rossland-Trail Map-area, British Columbia, *Geological Survey of Canada*, Paper 79-26, 38 pages.

McAllister, A.L. (1951): Ymir Map-area, British Columbia, *Geological Survey of Canada*, Paper 51-4, 58 pages.

Mulligan, R. (1952): Bonnington Map-area, British Columbia, *Geological Survey of Canada*, Paper 52-13, 37 pages.

Panteleyev, A. and Schroeter, T.G. (1986): Gold in British Columbia, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Preliminary Map 64.

Parrish, R. (1984): Slocan Lake Fault: A Low Angle Fault Zone Bounding the Valhalla Gneiss Complex, Nelson Map-area, Southern British Columbia, *in* Current Research, Part A, *Geological Survey of Canada*, Paper 84-1A, pages 323-330.

Ray, G.E. and Spence A. (1986): The Potassium-Rich Volcanic Rocks at Tillicum Mountain – Their Geochemistry, Origin, and Regional Significance, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork, 1985, Paper 1986-1, pages 45-49.

Simony, P.S. (1979): Pre-Carboniferous Basement near Trail, British Columbia, *Canadian Journal of Earth Sciences*, Volume 16, Number 1, pages 1-11.

Spence, A. (1985): Shoshonites and Associated Rocks of Central British Columbia, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork, 1984, Paper 1985-1, pages 426-442.