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GEOLOGY OF THE ROSSLAND GROUP IN THE ERIE LAKE AREA, WITH EMPHASIS ON STRATIGRAPHY AND STRUCTURE OF THE HALL FORMATION, SOUTHEASTERN BRITISH COLUMBIA (82F/3W)

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KEYWORDS: Regional geology, Rossland Group, Hall Formation, Elise Formation, Archibald Formation, Hall syncline, Erie Creek fault, Beaver Creek fault, Keystone deposit, Arlington mine, Clubine deposit.

INTRODUCTION

Regional mapping and mineral deposit studies have been carried out in the Rossland Group since 1987. The aim of the project is to develop a better understanding of the stratigraphic and structural setting of the Rossland Group and to assess controls on mineralization within it. The project includes systematic whole-rock and trace element analyses of volcanic rocks, uranium-lead dating of intrusive rocks and Elise volcanic rocks, and fluid inclusion, stable and radiogenic isotope studies of mineral occurrences.

During the 1990 field season, 1:20 000-scale regional mapping was completed in both the Salmo and Rossland map areas (Figure 1-1-1). The Salmo mapping ties together previous work in the Nelson map area to the north (Höy and Andrew, 1989b) and in the Mount Kelly – Hellroaring Creek and Beaver Creek areas to the south (Höy and Andrew, 1990b, Andrew *et al.*, 1990a, b). Previous to this study, the structural tie between the Nelson and Salmo map sheets was unresolved. Special emphasis is given to the distribution, facies changes and contact relationships of the Hall Formation in both the Salmo and Nelson map areas.

Previous regional mapping of the Rossland Group in the Erie Lake area has been by Little (1960, 1965), Fitzpatrick (1985), Mulligan (1951, 1952) and Walker (1934). Petrologic and geochemical studies of the Elise Formation have been undertaken by Beddoe-Stephens and Lambert (1981) and Beddoe-Stephens (1982).

STRATIGRAPHY

The Rossland Group is divided into a lower sequence of predominantly fine-grained clastic rocks of the Archibald Formation, a thick accumulation of mafic flows and pyroclastic and epiclastic rocks of the Elise Formation, and generally less intensely deformed clastic rocks of the overlying Hall Formation. The upper part of the Ymir Group, a fine-grained, strongly deformed clastic and carbonate package which underlies the Elise Formation in the Nelson area, is correlated with the Archibald Formation (Little 1960, 1965; Frebold, 1959; Höy and Andrew, 1989a). The age of the Elise Formation is bracketed by Sinemurian fossils in the Archibald Formation and Toarcian fossils in the overlying Hall Formation (Frebold and Tipper, 1970; Tipper, 1984); no fossils have been found in the Ymir Group.

Plagioclase porphyry and diorite plutons that intrude the Rossland Group are locally intensely sheared and conformable. These include the Silver King porphyry southwest of Nelson, the 'Shaft monzodiorite', and numerous other small alkaline intrusions. They have been interpreted to be coeval subvolcanic intrusions (Höy and Andrew, 1988, 1989a; Andrew and Höy, 1989); however, uranium-lead dating of the Silver King porphyry indicates a Middle Jurassic age of 178.1±1.4 Ma. This age is between that of the Rossland Group (187 to 204 Ma), defined by macrofossil collections, and the Nelson batholith and related plutons, dated at 165 Ma. Other, more mafic intrusions, including the Shaft and Mammoth bodies are, however, still considered to be coeval with the Elise Formation.

Several granite to granodiorite stocks and plutons in the Erie Lake area are probably correlative with either the Middle to Late Jurassic Bonnington pluton or the Nelson batholith. Small biotite-rich monzonite stocks (Coryell intrusions) and quartz rhyolite dikes crosscut the Jurassic units and are of Eocene age (Little, 1960).

ARCHIBALD FORMATION

The Archibald Formation is the lowermost unit of the Rossland Group and is correlative with the upper part of the Ymir Group. The total exposed thickness of the formation varies from 825 to 2550 metres (Andrew *et al.*, 1990a); its base is not seen because it is either cut by faults or by Middle Jurassic intrusions. The contact between the Archibald and Elise formations is gradational, mapped where fine-grained interbedded siltstones and argillites with occasional thin flows give way to massive augite porphyry flows (Höy and Andrew, 1989a). In the Erie Lake area (Figure 1-1-2a), the Archibald Formation is exposed in the limbs of an anticline that parallels Erie Creek, in fault-bounded blocks west of the town of Salmo, in the Beaver Creek valley and on the northeast slopes of Mount Kelly.

The oldest rocks in the formation are massive to finely laminated, dark grey to black, rusty weathering argillite. These crop out on the northeastern slopes of Mount Kelly. This lower argillite unit is often either missing, not exposed or replaced by a coarser facies (Andrew *et al.*, 1990b). The lower argillite is overlain by an upper turbidite sequence of interbedded graded wacke, siltstone and silty argillite. This sequence generally coarsens upwards with over 400 metres of poorly lithified, matrix-supported conglomerate near the top. The conglomerate is best exposed in highway cuts in the Beaver Creek valley just west of the Crowsnest Highway cut-off. It contains approximately 10 per cent limestone and siltstone clasts; the limestone clasts contain Permian

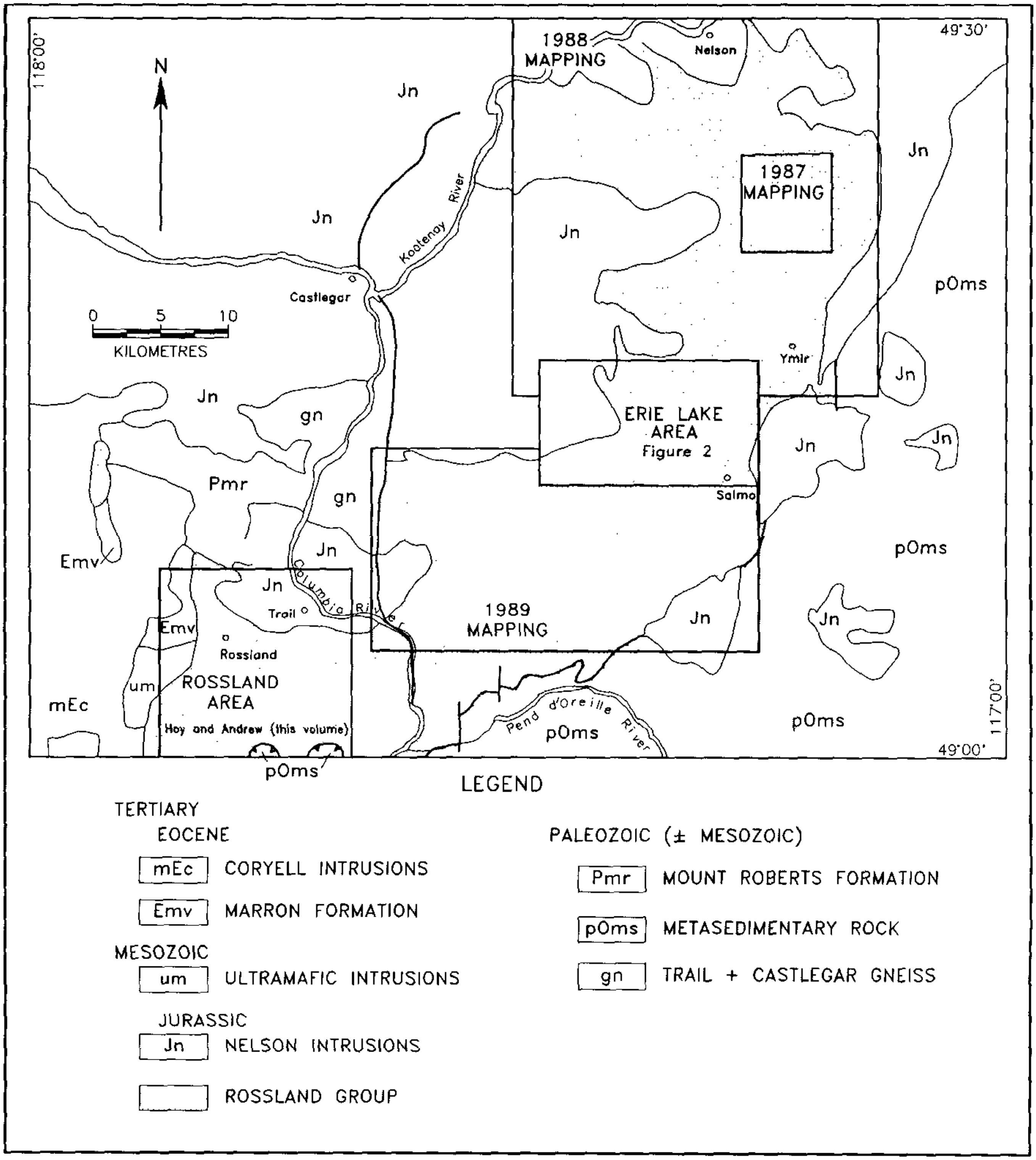


Figure 1-1-1. Location map and main physiographic and geologic features, Erie Lake area, southeastern British Columbia.

fossils probably derived from the Mount Roberts Formation (Little, 1982b). Augite porphyry sills, locally up to 50 metres thick, occur near the top of the succession in Erie Creek, on Bell Ridge and on the northeast ridge of Mount Kelly. In the Beaver Falls area (Andrew *et al.*, 1990b), the formation is capped by 100 metres of maroon siltstone and lithic wacke.

Elise Formation

The Elise Formation occurs within fault-bounded blocks east of Hudu Creek, in the vicinity of Erie Mountain, on the northern slopes of Mount Kelly, northwest of Hellroaring Creek and as east and west-facing homoclinal panels on the limbs of the Hall Creek syncline. Interfingering lenses of massive to brecciated flows as well as pyroclastic, tuffite and epiclastic deposits characterise the formation. The total exposed thickness of the formation varies from 600 metres near Champion Lakes to 5100 metres in the Erie-Stewart Creek area (Andrew *et al.*, 1990a; Höy and Andrew, 1989a; Figure 1-1-3).

The basic subdivision of the Elise Formation in the Nelson area into a lower succession of mafic flows or pyroclastic breccias and an upper section of more intermediate pyroclastic and tuffite rocks, epiclastic deposits and minor fine sedimentary rocks, is not apparent in the Salmo area. This may be due to lack of outcrop in the Erie and Keystone Mountain areas or to structural complications.

The basal part of the Elise Formation shows rapid lateral facies changes. North of Beaver Creek, on the west limb of the Hall Creek syncline, the lower Elise comprises mafic pyroclastic breccia whereas south of Beaver Creek and near Ymir, mafic flows predominate. The top of the formation is poorly exposed in the limbs of the Hall syncline (Figure 1-1-2a). It includes intermediate lapilli and crystal tuff in the limbs of the Hellroaring Creek syncline south of Salmo. Elsewhere, the top of the formation is faulted out.

The thickest section of the Elise Formation is exposed in the Erie and Stewart Creeks areas. It comprises dominantly mafic lapilli tuff and pyroclastic breccia as well as more intermediate crystal tuff, tuffaceous conglomerate and 500 metres of finely laminated siltstone. It is possible that this siltstone succession, included as part of the Elise Formation (Figure 1-1-2a), may be the upper part of the Archibald Formation as mapped by Little (1960; 1982a).

Hall Formation

The 'Hall Series', from which the Hall Formation was named, was defined by Drysdale in 1917. It was renamed the Hall Group by Little in 1950 and subsequently referred to as the Hall Formation (Mulligan, 1952). The formation consists of conglomerate, lithic wacke, sandstone, siltstone and argillite with minor intercalated crystal tuffs. It is exposed in a belt extending from the headwaters of Noman Creek, just east of Toad Mountain in the Nelson area, southward to the town of Salmo, around Hellroaring Creek south of Salmo, near the head of Kelly Creek and in the Fruitvale area (Figure 1-1-4). The Hall Formation contains early Pleinsbachian and early Toarcian ammonites (Tipper, 1984). A plant fragment and pelecypods were also collected from the formation (Little, 1950).

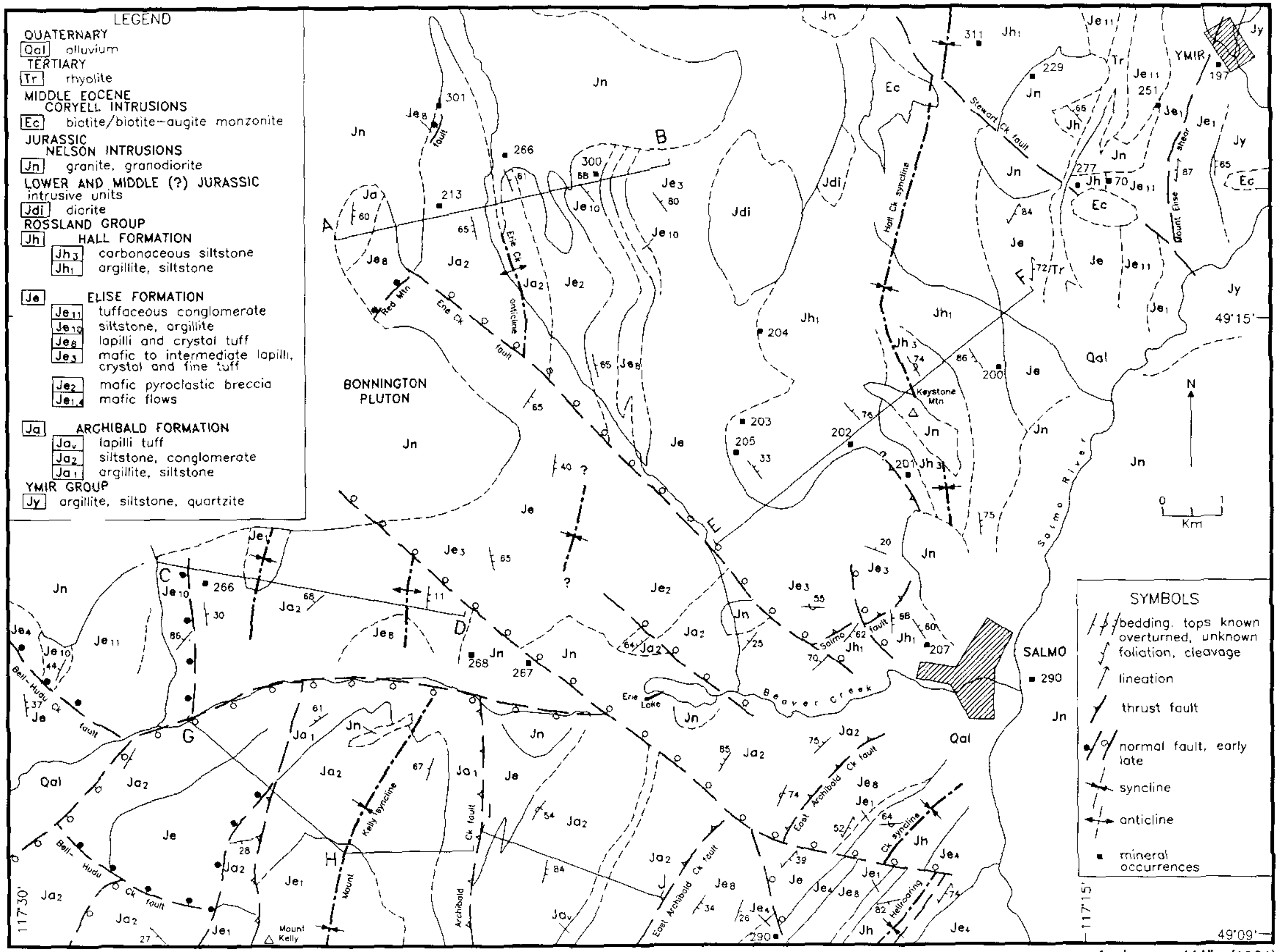
The exposed thickness of the Hall Formation (Figure 1-1-5) varies from at least 350 metres near Fruitvale, 550 metres near Kelly Creek, 1650 metres in Hellroaring Creek, 1700 metres on Keystone Mountain, 2100 metres in the Stewart Creek area and 1150 metres south of Hall Creek (Little, 1985; the type section of Drysdale, 1917). These are minimum estimates; the top of the Hall is not seen because the formation is either exposed in a syncline or faulted out (Figure 1-1-4).

Generally, the Hall Formation conformably overlies the Elise Formation; however, in the Salmo River valley, near Hall Creek, an erosional unconformity with development of basal conglomerates separates the two formations (Figure 1-1-6). The conglomerate varies in thickness from 10 to 20 metres and comprises subrounded clasts of augite porphyry and plagioclase lapilli and crystal tuff of the Elise Formation incorporated in a poorly consolidated muddy matrix. Elsewhere, as in highway cuts just south of Salmo and in Hellroaring Creek (Figure 1-1-4), moderate to intense shearing is exposed at the contact. Kinematic indicators, including c-s fabrics, kink bands and tension gashes, indicate a general right-lateral movement on the east side of the syncline and left-oblique dip-slip movement on the west side.

The Hall Formation can be subdivided into three broadly defined units: a lower, rusty black siltstone and argillite succession, a coarse sandstone and conglomerate succession and, locally, an upper carbonaceous siltstone unit (Figure 1-1-5). The base of the lower Hall is either conformable or marked by an erosional unconformity. Argillites within the lower Hall are rusted due to weathering of disseminated pyrite (Plate 1-1-1). Interbedded quartzitic siltstone and argillite, also typical of the lower part of the formation (Figure 1-1-6), are well exposed in Hall Creek (Plate 1-1-2). Although primary small-scale structures such as graded beds are absent or poorly developed in these rocks, rip-up clasts and flame structures are occasionally seen and can be used for top determinations (Plate 1-1-3). This unit hosts most of the vein deposits in the area (Figure 1-1-2a).

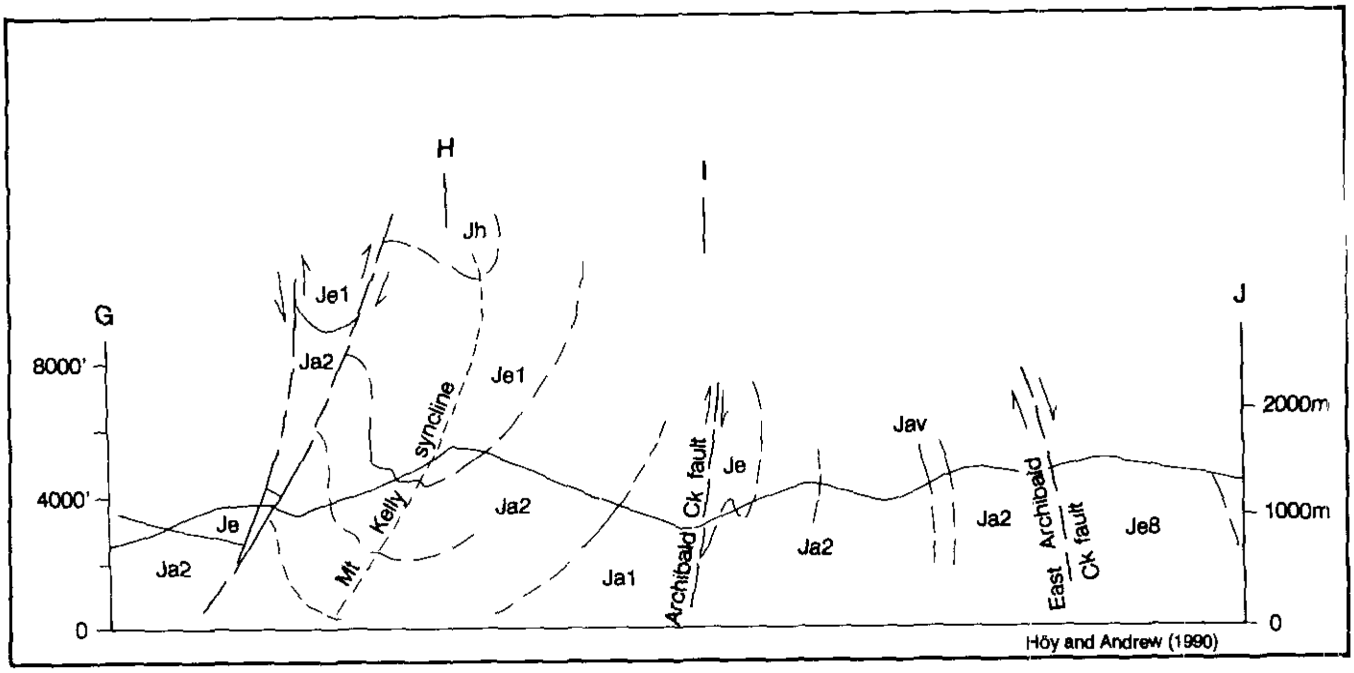
The middle unit of the Hall varies from a coarse polymict pebble conglomerate to lithic wacke and minor silty argillite. The conglomerate is characterised by elongate, subangular mudstone fragments 5 to 10 centimetres in diameter (Plate 1-1-4) and is probably the same unit described as 'intraformational' conglomerate by Mulligan (1952). The lithic wacke contains from 10 to 50 per cent quartz, feldspar, ferromagnesian minerals and angular rock fragments. The upper part of the Hall is characterised by massive fine-grained carbonaceous siltstone in the Keystone Mountain area (Figure 1-1-6).

Thickness and facies changes in the Hall Formation are summarized in the stratigraphic columns of Figure 1-1-5. The formation is absent in the Rossland area where Elise volcanic rocks are unconformably overlain by either late Cretaceous conglomerates of the Sophie Mountain Formation or Eocene volcanic rocks of the Marron Formation



Andrew and Höy (1991)

Figure 1-1-2a. Geology of the Erie lake area after Höy and Andrew, 1989; 1990b; Little, 1960, 1965; Mulligan 1951, 1952; Fitzpatrick, 1985.



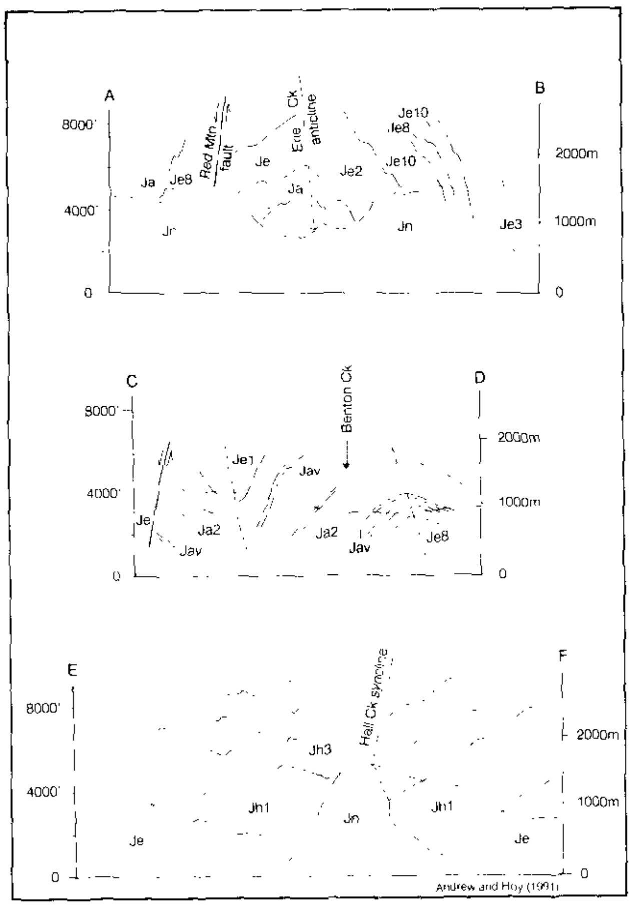


Figure 1-1-2b. Vertical structural sections, Erie Lake map area. Section locations are identified on Figure 1-1-2a.

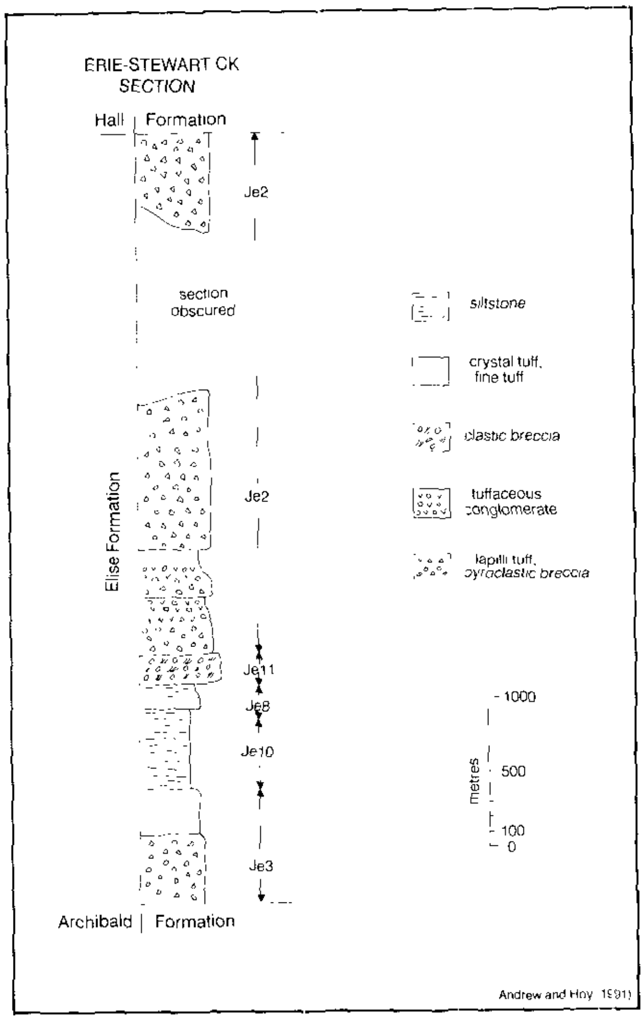


Figure 1-1-3. Composite stratigraphic section of the Elise Formation, Erie – Stewart Creek area.

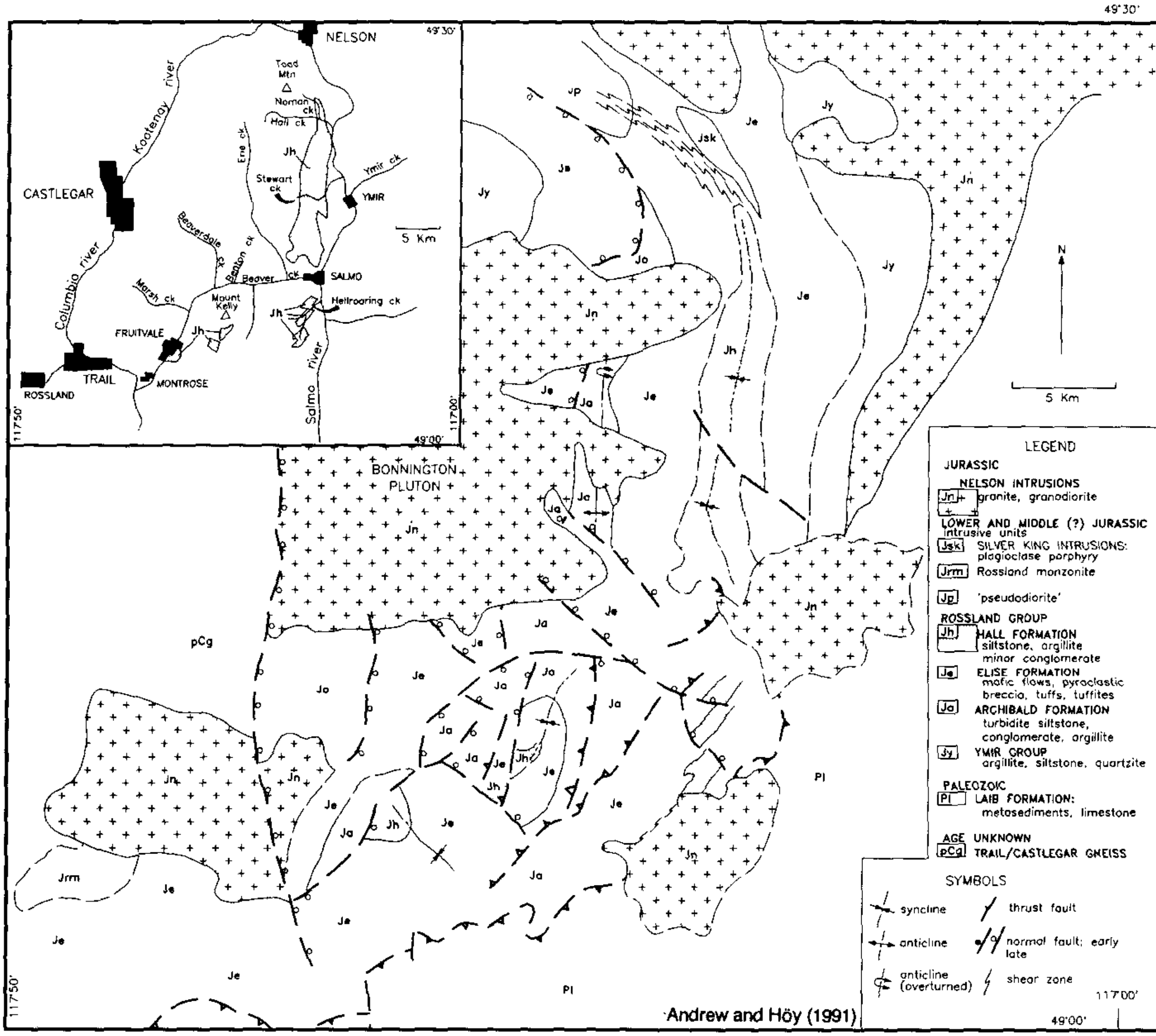


Figure 1-1-4. Distribution of the Hall Formation and main geologic and physiographic features in the Nelson (W1/2) southwest portion (82F/SW).

(Höy and Andrew, 1991a, this volume). To the east, in the Fruitvale area, the Hall Formation forms a wedge of fine-grained clastic beds that thicken and coarsen eastward (Figure 1-1-5). Farther east, in the Hall Creek and Stewart Creek areas, conglomerates are more predominant. The fine-grained, carbonaceous clastic units that occur at the top of the formation in the Keystone Mountain area appear to be laterally discontinuous; they are not recognized in the upper Hall to the west or north.

Based on sedimentary rock types and the abundance of marine fossils, the Hall Formation has been interpreted to have been deposited in a littoral to offshore environment (Little, 1950; Mulligan, 1951). Local development of a basal unconformity and, elsewhere, conformable deposition of laminated argillite above the Elise, suggests that the Hall developed on an irregular paleosurface. Fanglomerates and clastic-wedge deposits within the Hall suggest deposition may have been modified by local fault scarps. In summary, the Hall Formation is interpreted to have been deposited in a shallow-marine structural basin at the end of a period of explosive pyroclastic volcanism.

STRUCTURE

The structure of the Salmo area is dominated by a complex pattern of rectilinear faults, superposed on an earlier thrust and fold terrain. Four phases of deformation are identified: intense shearing and development of a penetrative mineral foliation, north-trending folds associated with east-directed thrust faults, normal faulting prior to intrusion of Nelson batholithic rocks, and Eocene normal faulting.

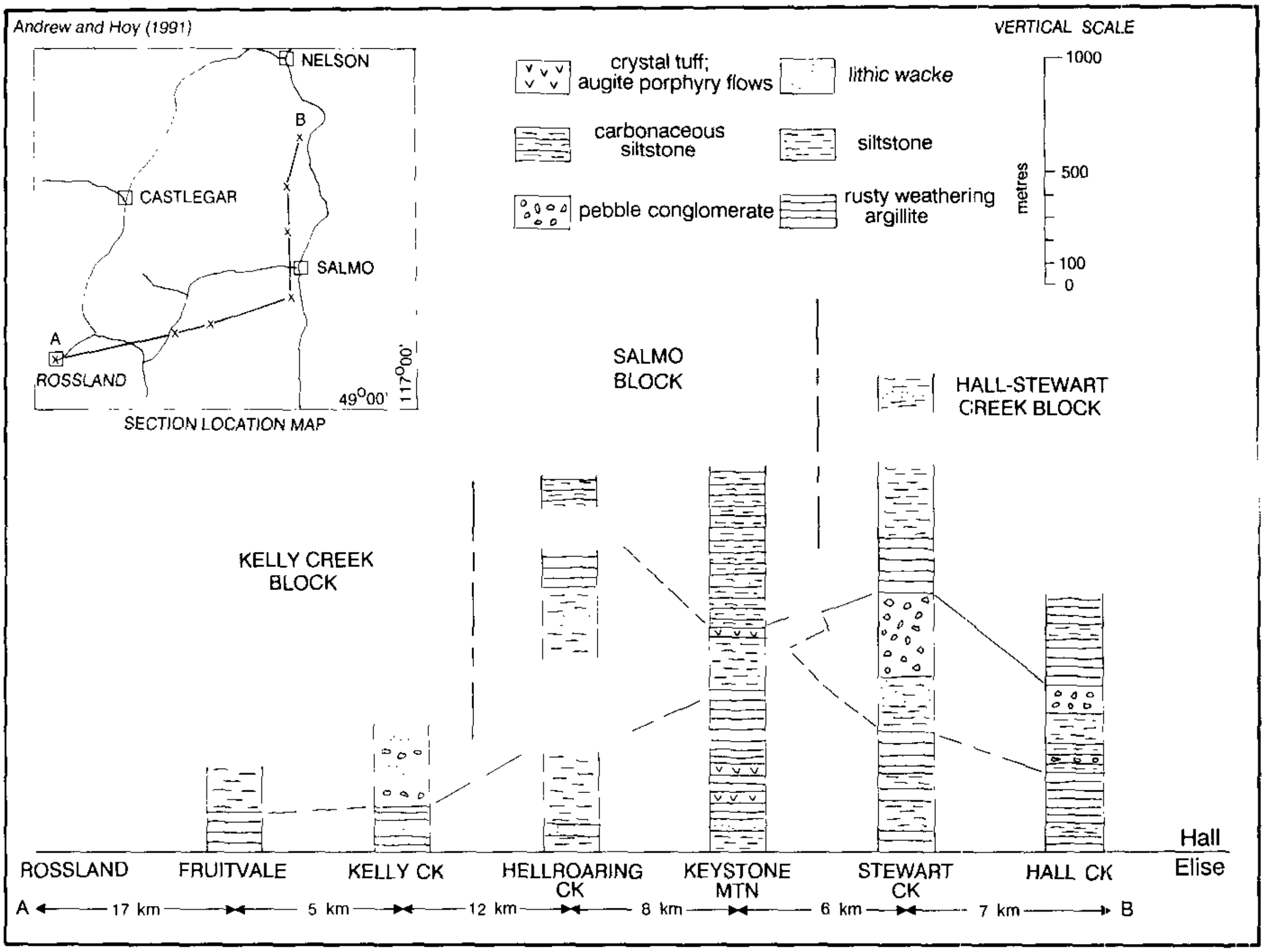


Figure 1-1-5. Correlation chart of the Hall Formation showing main lithologic and thickness changes.

Intense shearing along the eastern edge of exposed Rossland Group rocks, particularly in the Ymir Group northeast of Ymir and in the vicinity of the Hellroaring Creek syncline south of Salmo (Figure 1-1-2a; Höy and Andrew, 1989a), may result from collisional tectonics along the eastern margin of Quesnellia. With continued compressional tectonics, east-directed thrusts and east-verging to upright folds developed. The Hellroaring Creek syncline, the faulted continuation of the Hall Creek syncline north of Salmo (Höy and Andrew, 1990a), is an overturned, east-dipping syncline with Hall Formation in its core (*see* sections, Figure 1-1-2b). A number of layer-parallel faults or shear zones associated with intense penetrative deformation in Elise volcanic rocks parallel the margins of this syncline.

Farther west, folds are more upright, more open and appear to be associated with thrust faults. The Archibald Creek, East Archibald Creek and Salmo thrusts (Figure 1-1-2a) postdate early shearing and possibly related tight folds in the Hellroaring Creek area. The Salmo fault dips steeply to the northwest and places a west-facing lower Elise succession (Je3) on east-facing Hall Formation (Jh1, Figure 1-1-2a). Southwest of Salmo, the East Archibald Creek thrust juxtaposes west-facing Archibald Formation (Ja2) in its hangingwall with east-facing upper Elise Formation (Je8). The Erie Creek anticline, mapped as slightly overturned to the east in the Nelson area (Höy and Andrew, 1989b), is upright and open south of the Bonnington pluton (section G-J, Figure 1-1-2b).

West and northeast-dipping normal faults that predate intrusion of Middle to Late Jurassic granitic plutons occur northwest of Mount Kelly; they may record similar extensional tectonics as the Red Mountain fault in the Nelson area (Höy and Andrew, 1989a, 1990a). The Hudu – Bell Creek fault has a rectilinear shape just northwest of Mount Kelly (Andrew and Höy, 1991b). It follows in part the locus of an earlier thrust fault (Figure 1-1-2a). The fault forms a down-dropped block which is then offset to the north by the Beaver Creek fault. The extension of the Red Mountain fault is seen farther north near Erie Creek (Figure 1-1-2a; Höy and Andrew, 1989a).

East and northeast-dipping normal faults cut all earlier structures. The Beaver Creek fault postdates the Archibald Creek thrust, downdrops earlier west-side-down normal faults and offsets Middle to Late Jurassic intrusive rocks. The Erie Creek fault and associated normal faults near Erie Mountain and Salmo downdrop strata to the northeast (Fig-

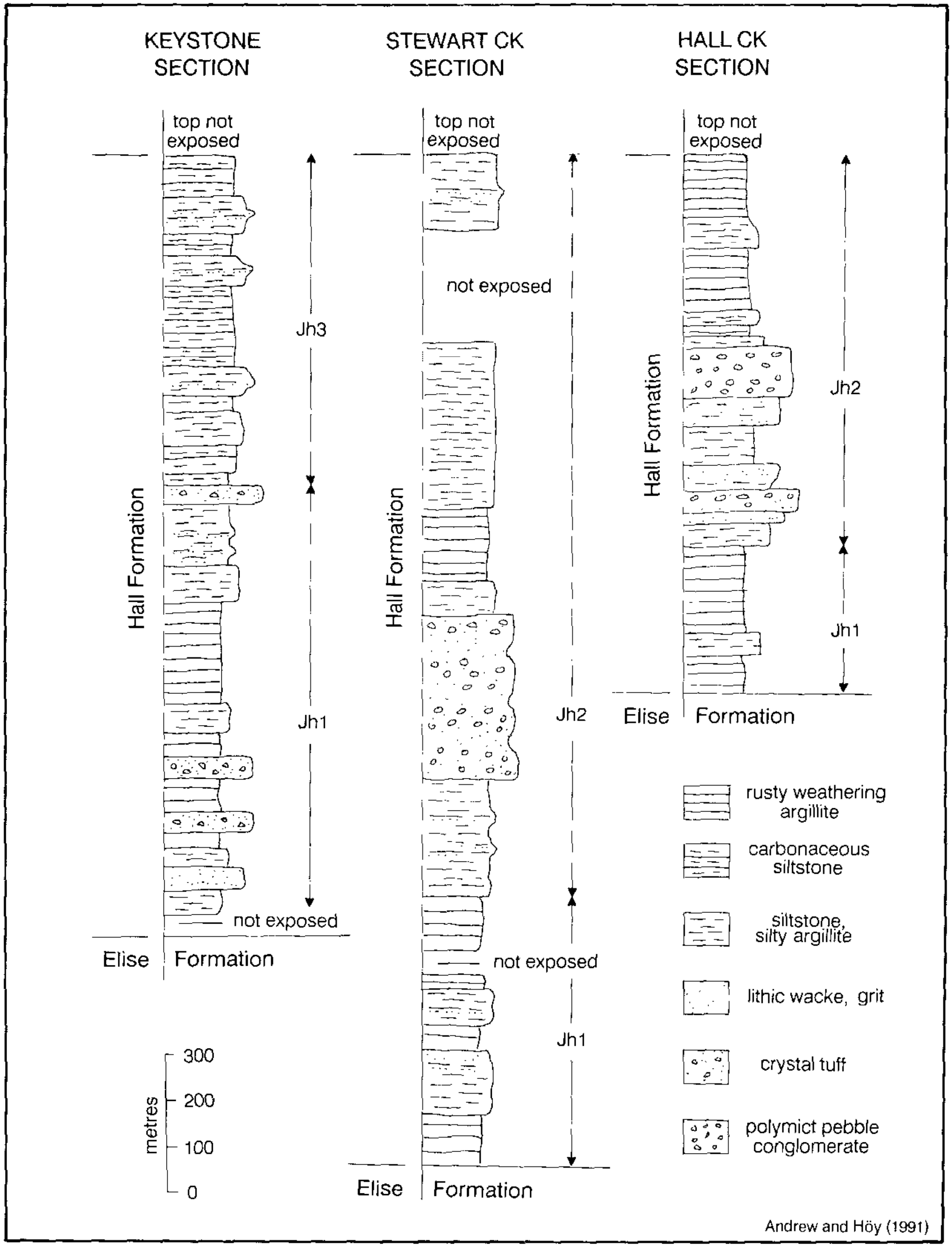


Figure 1-1-6. Stratigraphic sections of the Hall Formation, Keystone Mountain, Stewart Creek and Hall Creek areas.

Plate 1-1-1. Weathering of disseminated pyrite in siltstone of the Hall Formation, Hall Creek.

Plate 1-1-2. Interbedded quartzitic siltstone and argillite typical of the lower Hall Formation, Hall Creek type section.

ure 1-1-2a). The Stewart Creek fault (Höy and Andrew, 1989b) may also be a late east-dipping normal fault. These faults may be the same generation as the normal east-side-down Champion Lake and Slocan Lake faults which are part of an Eocene extensional event in southeastern British Columbia (Little, 1962; Simony, 1979; Parrish, 1984; Corbett and Simony, 1984; Parrish *et al.*, 1988).

Plate 1-1-3. Rip-up clasts and flame structures in interbedded siltstone and sandstone beds, Stewart Creek area.

Plate 1-1-4. Pebble conglomerate of the middle Hall Formation with 5 to 10-centimetre subangular mudstone fragments, south of Hall Creek.

In summary, the tectonic evolution of the Erie Lake area west of Salmo involved early compressive strain, with development of intense shearing, a penetrative mineral foliation and possible tight folds. This strain is concentrated along the eastern edge of Quesnellia and resulted from collision with cratonic North America in early Middle Jurassic time. Continued compressive strain spread westward, producing more open folds and associated east-verging thrust faults. Intrusion of the syntectonic Silver King suite of plutonic rocks (*ca* 178 Ma) records a magmatic event associated with this deformation.

Extensional tectonics produced large high-angle normal faults in the western part of the area. These faults are earlier than the late Middle Jurassic Nelson batholith (*ca* 165 Ma). Eocene extensional faults, associated with a suite of north-trending dikes, are the latest structures in the area.

MINERAL OCCURRENCES

Mineral occurrences in the Salmo area are shown on Figure 1-1-2a and listed in Table 1-1-1. These can be separated into:

TABLE 1-1-1
MINERAL PROPERTIES IN THE ERIE LAKE AREA

MINFILE No.	Name	Commodities	Type	Host	Status
82FSW070	May Blossom	Au,Pb,Zn,Mo,W	Vein	Je11	Showing
82FSW197	Myrtle	Au,Ag,Pb,Zn	Vein	Je1,4	Past producer
82FSW200	Clubine	Au,Ag,Pb,Zn	Vein	Jh1	Past producer
82FSW201	Second Chance	Au,Ag	Vein	Jh1	Past producer
82FSW202	Keystone	Au,Ag,Pb,Zn,Cu	Vein	Jh1	Past producer
82FSW203	Canadian King	Au,Ag,Pb	Vein	Jh1	Past producer
82FSW204	Gold Hill	Au,Ag	Vein	Jh1	Past producer
82FSW205	Arlington	Au,Ag,Pb,Zn	Vein	Jh1	Past producer
82FSW207	Silver Dollar	Au,Ag,Pb,Zn	Vein	Jh	Past producer
82FSW213	Drum Lummon	Au,Ag,Pb,Zn,Cu,W	Vein	Ja2	Showing
82FSW220	Curlett	Mo	Porphyry	Jn,e	Showing
82FSW226	Hattie	Mo,W,Cu,Ag	Porphyry	Jn	Showing
82FSW229	Stewart	Au,Mo,W	Porphyry	Jn	Developed prospect
82FSW251	Fresno	Mo	Porphyry	Jn	Showing
82FSW266	Rely	Au,Ag,Pb,Zn	Skarn	Ja2	Past producer
82FSW267	Armstrong	Au,Ag,Pb,Zn	Vein	Jn	Past producer
82FSW268	Meadows	Mo	Vein	Jn	Showing
82FSW277	Free Silver	Ag,Pb	Vein	Jh	Showing
82FSW283	Allouez	Au,Ag,Cu	Vein	Jn	Showing
82FSW290	Katie	Au,Cu	Shear-related	Je1,4	Showing
82FSW300	Ben Hassen	Au,Ag,Pb,Zn,Cu	Vein	Je10	Prospect
82FSW311	Arrow Tungsten	W,Mo	Skarn	Jh	Prospect

- pre and syntectonic types, which occur in the Elise Formation and are associated with tight folds and intense shearing (MINFILE 082FSW290); Andrew and Höy, 1989, 1990; Höy and Andrew, 1989c);
- intrusive-related types such as tungsten skarns and molybdenum porphyries, associated with Nelson or Coryell intrusions (MINFILE 082FSW311, 082FSW299, 082FSW268, 082FSW226); and,
- vein deposits associated with west-side-down, pre-Nelson normal faults (MINFILE 082FSW301, 082FSW266), east-side-down post-Nelson normal faults (MINFILE 082FSW70, 082FSW277), and the Hall-Elise contact (MINFILE 082FSW200-205).

A number of vein occurrences are hosted by the basal part of the Hall Formation, close to the Hall-Elise contact. They are characterised by generally north-trending shear-controlled quartz veins from about 0.5 to 1.5 metres wide with variable amounts of galena, pyrite, chalcopyrite and minor sphalerite, tetrahedrite and pyrrhotite. Arsenopyrite has been identified at the Gold Hill prospect (MINFILE 082FSW204).

The Clubine property (MINFILE 082FSW200) has recorded production from 1937 to 1939 of 2322 tonnes containing 28.8 grams per tonne gold and 42.6 grams per tonne silver. Trenching and drilling in new zones near the old Clubine-Comstock workings has been undertaken by Yellow Jack Resources Ltd. with return of high silver and lead assays (K. Murray, personnal communication, 1990). On the Maggie zone, quartz veins 3 to 15 centimetres wide occur within shear zones 5 to 10 metres wide in the lower Hall Formation. Argillite and siltstone beds are contorted, displaying kink banding and crenulation cleavage. A distinctive yellow-green alteration envelope, 5 to 10 centimetres wide, that surrounds some of the veins, may be chrome mica and iron-rich carbonate.

The Arlington mine (MINFILE 082FSW205) produced over 765 kilograms of gold from approximately 64 000 tonnes of ore between 1899 and 1970. In 1988, a small tonnage was mined by Rimrock Gold Corporation and South Kootenay Goldfields Inc. (George Cross Newsletter, No. 6, 10 Jan. 1989) The Canadian King prospect occurs just north of the Arlington mine and is considered to be part of the Arlington vein system (MINFILE). This system is characterised by brecciated, milky white quartz with irregular patches of pyrite, galena, sphalerite and carbonaceous siltstone. The Keystone deposit may be the up-dip extension of the Arlington ore zone. Intermittent production of 1664 tonnes from 1901 to 1981 returned an average grade of about 50 grams per tonne gold and 100 grams per tonne silver (MINFILE). The results of detailed mapping and study of the Arlington and Clubine properties will be released in future editions of *Exploration in British Columbia*.

Drilling in 1990 on the Silver Dollar property northwest of Salmo was undertaken to explore for extensions of the Lucky Boy and Silver Dollar veins; these produced 52 kilograms of gold and 787 kilograms of silver between 1899 and 1970. Ore minerals include sphalerite, galena and minor chalcopyrite in a gangue of calcite, ankerite(?) and brecciated argillite (Walker, 1934).

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