Regional and District Mapping

STRUCTURE AND TECTONIC SETTING OF THE ROSSLAND GROUP, MOUNT KELLY – HELLROARING CREEK AREA, SOUTHEASTERN BRITISH COLUMBIA (82F/3W)

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KEYWORDS: Regional geology, Rossland Group, Archibald Formation, Elise Formation, Hall Formation, Mount Kelly syncline, Hellroaring Creek syncline, Waneta fault, shear-related gold deposits, vein deposits.

INTRODUCTION

The Mount Kelly–Hellroaring Creek area is situated in the Salmo map area south of the Nelson sheet (Little, 1960; Höy and Andrew, 1989a) and east of the Rossland–Trail sheet (Little, 1982; Andrew *et al.*, 1990a, b). The area (Figure 1-1-1) has been mapped at 1:50 000 scale by Little (1964) and formed the basis of a structural-stratigraphic thesis by Fitzpatrick (1985). This report focuses on a new structural interpretation of the area and on subdivision and interpretation of the Archibald and Elise formations of the Rossland Group. Regional correlations of the Rossland Group and tectonostratigraphic models are detailed in Andrew *et al* *(op. cit.)*. A number of mineral occurrences in the area and favorable exploration results in Rossland Group rocks both to the north and in the Rossland camp have resulted in a considerable increase in the level of exploration, with the

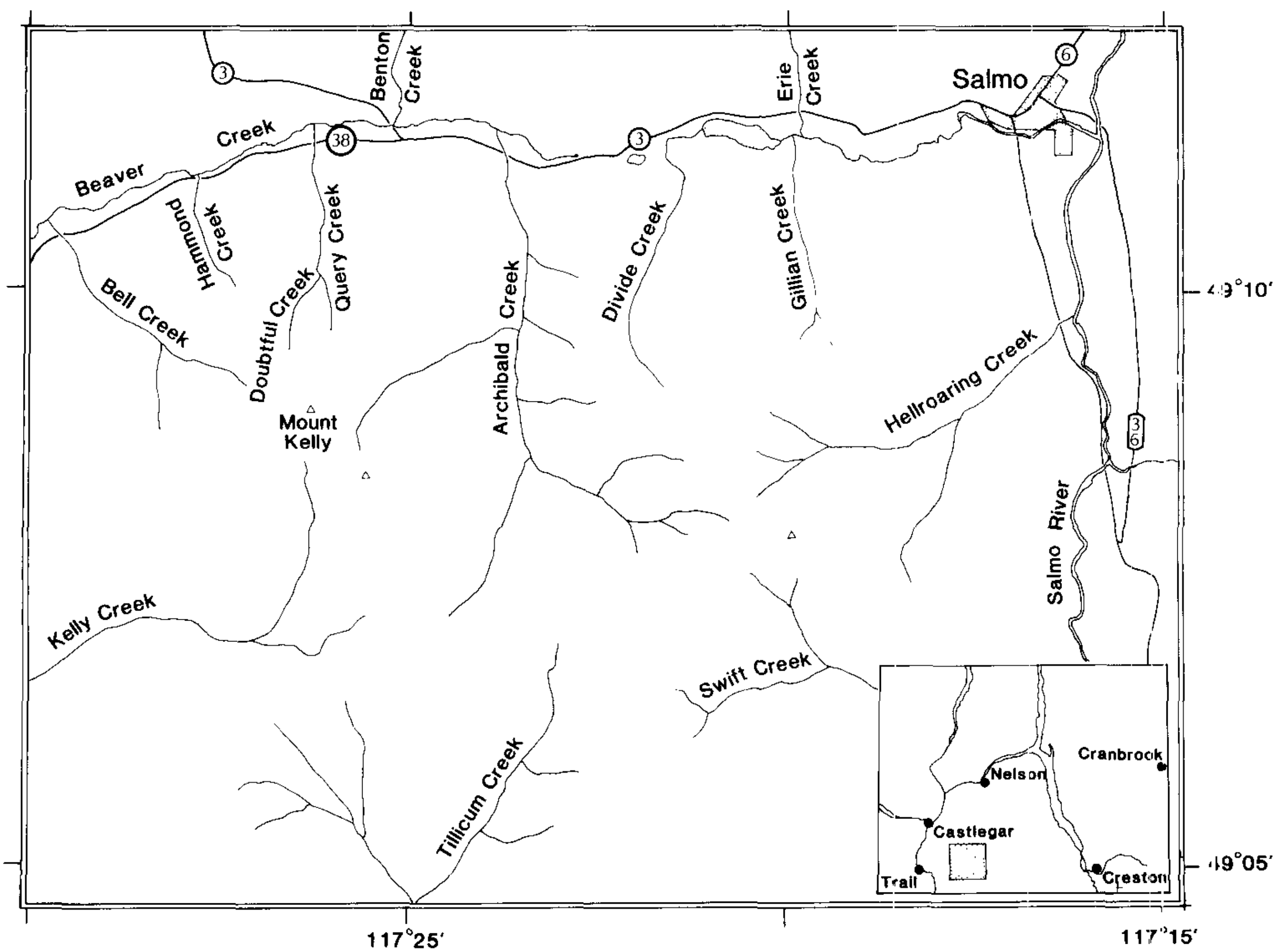


Figure 1-1-1. Location map showing physiographic features of the Mount Kelly–Hellroaring Creek area.

primary target being shear-related gold and copper mineralization.

ROSSLAND GROUP

The Lower Jurassic Rossland Group comprises dominantly clastic rocks of the Archibald Formation, overlain by a succession of volcanic rocks of the Elise Formation and clastic rocks of the Hall Formation. The base of the Rossland Group is not exposed in the Salmo map area. To the southeast, it is in contact along the Waneta fault with Paleozoic rocks of the Kootenay arc. To the north, in the Nelson map area, the Elise Formation is underlain by non-fossiliferous, fine-grained clastic rocks of the Ymir Group, which are correlative with the Archibald Formation. In the Rossland area, the Archibald Formation is missing (Fyles, 1984; Little, 1982) and Elise volcanic rocks unconformably overlie late Paleozoic rocks of the Mount Roberts Formation.

ARCHIBALD FORMATION

The Archibald Formation is exposed in a panel in the Divide Creek area east of Archibald Creek (Figure 1-1-2). Numerous bedding-cleavage intersections and sedimentary structures indicate that this panel is a homoclinal, west-facing succession. The base of the formation, exposed in the headwaters of the east fork of Archibald Creek, comprises dominantly argillite with thin interbeds of siltstone (Ja1). To the northeast, exposures are limited to scattered outcrops of altered argillite and siltstone near the faulted contact with the Elise Formation. The upper part of the Archibald comprises interbedded siltstone, argillite and minor conglomerate (Ja2). A prominent layer of plagioclase-rich lapilli and crystal tuff in the Archibald Formation (Jav) has been traced from the slopes south of Erie Lake in the northeast to the upper reaches of Archibald Creek in the central part of the map area (Figure 1-1-1).

A detailed section of the Archibald Formation, exposed in the hinge of the Mount Kelly syncline, is illustrated in Andrew *et al.* (1990a, this volume). It comprises essentially a basal succession of dominantly argillite, overlain by well-layered siltstone and wacke beds which are interpreted to have been deposited from turbidity currents. Farther west, near the western edge of the map area (Figure 1-1-2), conglomerates are prominent at a number of stratigraphic levels in the upper part of the Archibald Formation.

ELISE FORMATION

The Elise Formation comprises a thick succession of augite-phyric flows, tuffs, some epiclastic deposits and minor interbedded siltstone and argillite sequences. South of Nelson, on the east limb of the Hall Creek syncline, the formation is readily subdivided into a basal unit of mafic flows and flow breccias overlain by a thick accumulation of intermediate pyroclastic rocks (Andrew and Höy, 1988). On the west limb of the Hall Creek syncline, the distinction between the lower and and upper Elise is less evident (Höy and Andrew, 1989a). Here, the formation comprises primarily coarse, mafic pyroclastic breccia interlayered with minor flows and waterlain crystal tuff.

The distinction between the upper and lower Elise in the Salmo map area is apparent only in the east limb and hinge zone of the Mount Kelly syncline. Near the headwaters of Tillicum Creek, a thick succession of amygdaloidal, massive to pillowed augite porphyry flows and flow breccias (Je1) immediately overlies siltstones of the Archibald Formation. Locally, heterolithic lapilli tuff occurs near the base. The basal Elise is overlain by several hundred metres of interbedded argillite, siltstone, grit and polymictic pebble conglomerate (Je10), exposed on the switchbacks on the Tillicum Creek road.

The lower Elise at Mount Kelly (Je1) comprises mafic, locally pillowed flows (Plate 1-1-1), overlain by a succession of interlayered mafic tephra, tuffites (comprising mixed pyroclastic and epiclastic fragments) and epiclastic deposits. Chemical analyses of similar mafic volcanic rocks in the Nelson area indicate they are predominantly shoshonites (Höy and Andrew, 1989b; Beddoe-Stephens and Lambert, 1981). Pyroclastic deposits include well-bedded, commonly graded sequences of waterlain pyroclastic breccia, lapilli tuff and crystal tuff. Tuffaceous conglomerate and sandstone, locally with a calcareous cement, are prominent near the peak of Mount Kelly. Lahars, comprising poorly sorted, subrounded augite porphyry and plagioclase porphyry fragments, occur locally.

The upper Elise in the Mount Kelly syncline (Je8), comprises predominantly heterolithic lapillistone, lapilli tuff and pyroclastic breccia. The pyroclastic rocks contain subrounded to subangular clasts of plagioclase-rich volcanic and intrusive fragments and lesser augite porphyry in a fine tuffaceous to crystal-rich matrix.

In the Hellroaring Creek area, mafic flows and tuffaceous rocks are prominent in the upper part of the Elise, in contact with argillite and siltstone of the Hall Formation (Figure 1-1-2). However, considerable shearing occurs in these rocks and therefore their stratigraphic position is not exactly known. Structurally beneath this succession, northwest of Hellroaring Creek, are mixed mafic (augite-phyric) and intermediate (plagioclase-phyric) lapilli tuff, minor crystal tuff and some mafic flows. The structurally lowest succession, adjacent to the faulted Archibald contact, comprises predominantly intermediate tuffs (Je8) more typical of upper Elise rocks.

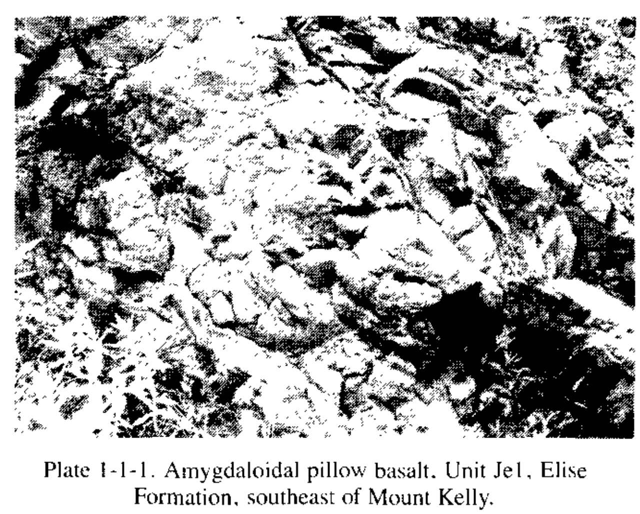
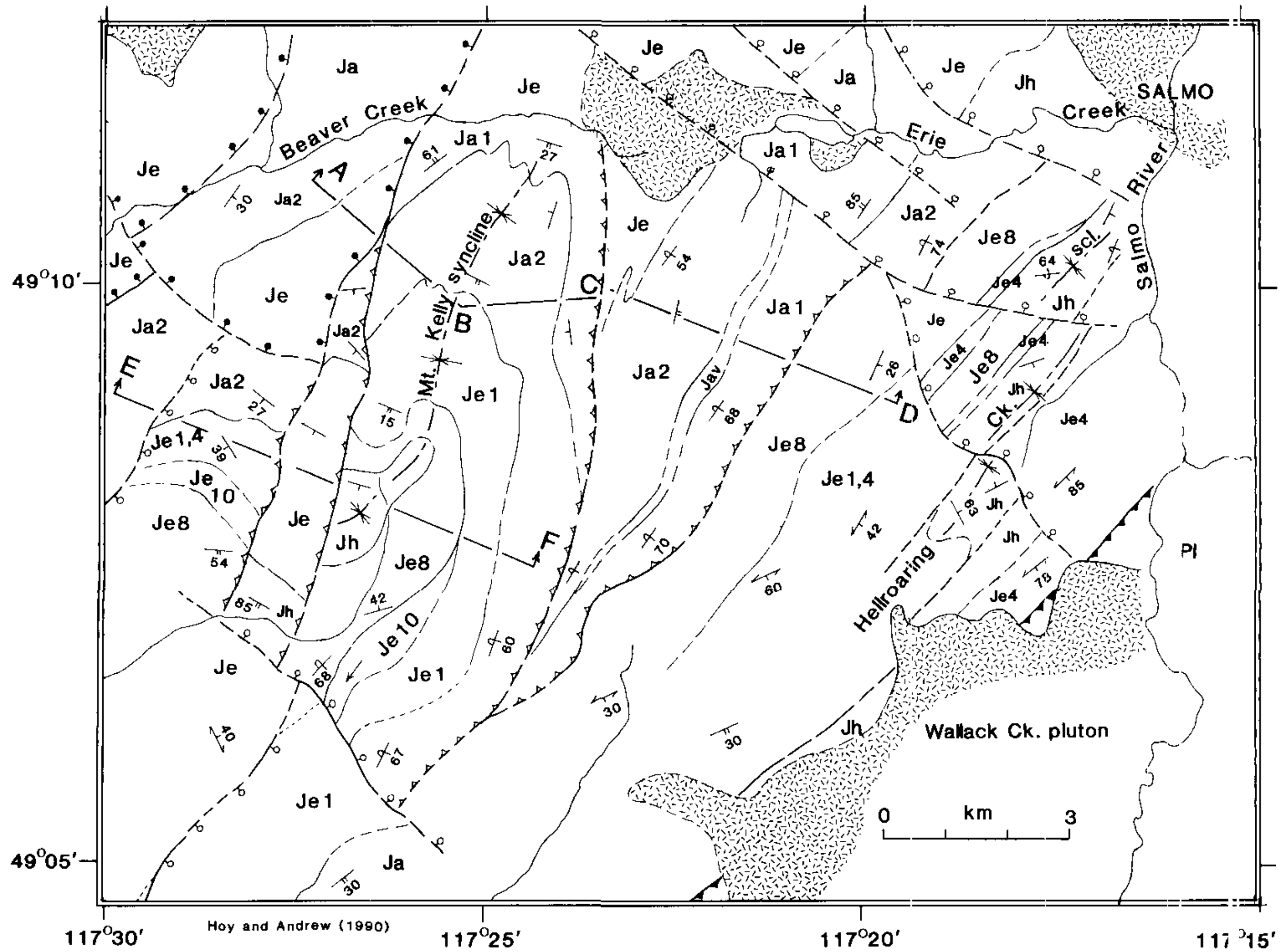


Plate 1-1-1. Amygdaloidal pillow basalt, Unit Je1, Elise Formation, southeast of Mount Kelly.



LEGEND

JURASSIC - CRETACEOUS

granite, granodiorite

LOWER JURASSIC

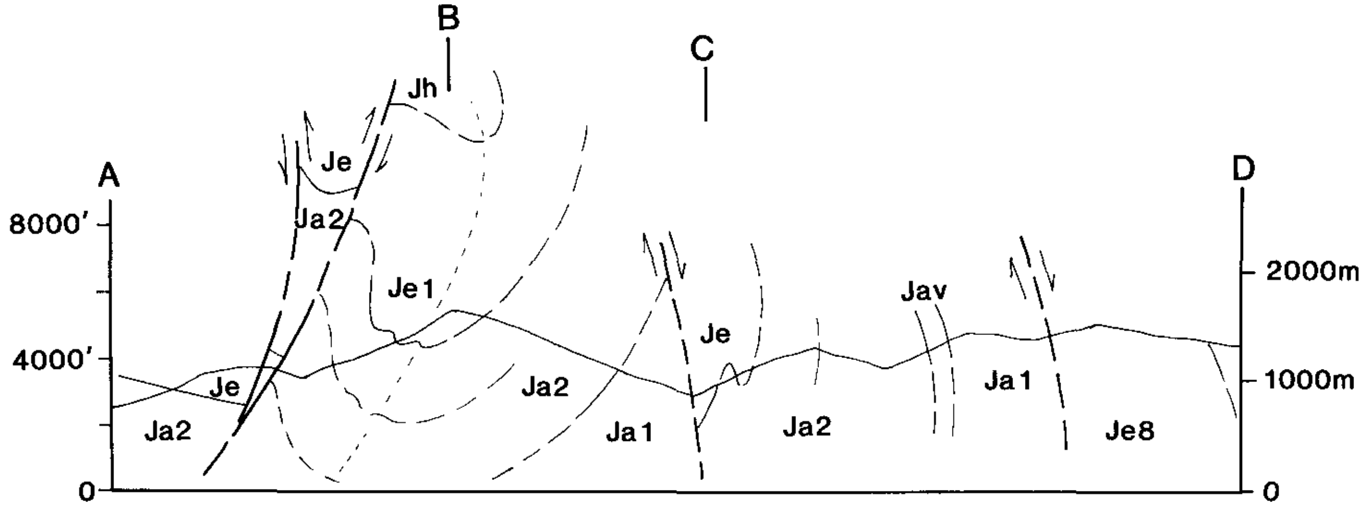
ROSSLAND GROUP

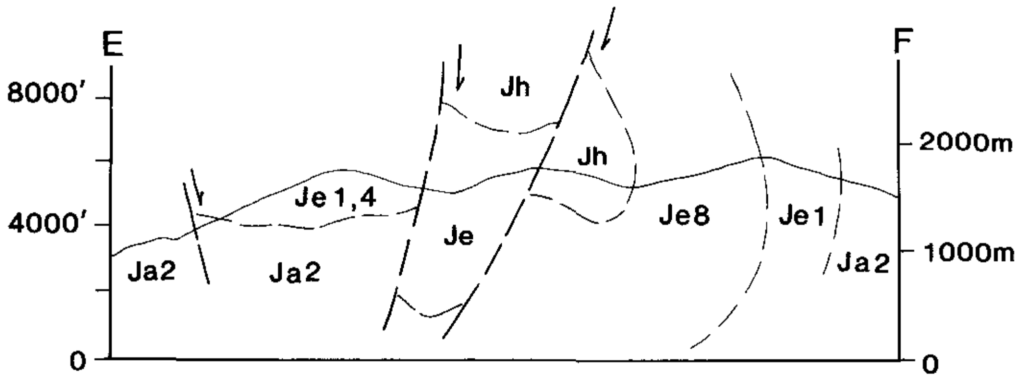
Jh	HALL FORMATION: argillite, siltstone
Je	ELISE FORMATION
Je10	siltstone, argillite
Je8	intermediate to mafic tuff
Je1,4	mafic flows, tuff
Ja	ARCHIBALD FORMATION
Ja2	Siltstone, conglomerate
Ja1	Argillite, siltstone
Jav	Lapilli tuff

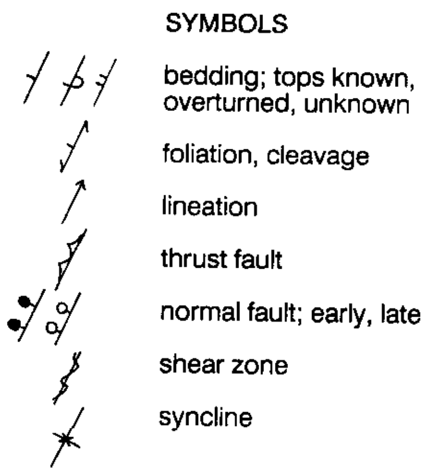
PALEOZOIC

Pl	LAIB FORMATION (?)

Figure 1-1-2. Geological map of the Mount Kelly–Hellroaring Creek area, Salmo map sheet, southeastern British Columbia (after Höy and Andrew, 1990; Fitzpatrick, 1985 and Little, 1964).







In summary, marked facies changes in the Elise Formation, similar to those recognized in the Nelson area to the north, characterize the Elise Formation in the Mount Kelly–Hellroaring Creek area. In the Mount Kelly area, as in the eastern part of the Nelson area, Elise rocks record inital effusive mafic volcanism followed by eruptions of mafic then more intermediate pyroclastic deposits. Northwest of Mount Kelly, and in the Hellroaring Creek area, intermixed mafic and intermediate pyroclastic deposits characterize much of the Elise succession. Epiclastic deposits near the middle of the formation comprise dominantly siltstone and argillite and record a hiatus in volcanic activity.

HALL FORMATION

The Hall Formation (Jh) is exposed in the cores of synclines in the Hellroaring Creek and Mount Kelly areas. Exposures in Hellroaring Creek comprise black, fissile, locally graphitic argillite with only minor thin siltstone laminations. Similar exposures occur in the Mount Kelly syncline. However, southwest of Mount Kelly, a fault-bounded structural panel of Hall rocks comprises a basal black argillite succession overlain by a succession of grit, arenite and wacke, siltstone and only minor argillite.

STRUCTURE

The earliest structures recognized in the Hellroaring Creek–Mount Kelly area are tight folds, locally associated with a penetrative mineral foliation and intense shearing and thrusting. In general, the intensity of this compressive strain increases to the southeast. The Waneta fault, near the southeast edge of the map area, is a steeply dipping, west-verging thrust fault that marks the boundary of Quesnellia with North American rocks. A number of essentially layer-parallel faults or shear zones in the vicinity of the Waneta fault are associated locally with an intense penetrative foliation. An overturned, east-dipping syncline with Hall Formation in its core and sheared Elise Formation in its limbs is exposed in the footwall of the Waneta fault. It is possible that this syncline, referred to as the Hellroaring Creek syncline, is the continuation of the Hall Creek syncline in the Nelson map area. The Hall succession on its eastern limb is locally overturned, dipping toward the southeast. Only a few stratigraphic tops were determined in the southeast-dipping Elise panel west of the syncline and these indicate that this panel is right-way-up. It is in contact with a west-facing Archibald succession in Gillian creek, necessitating a fault between the Elise and Archibald formations (Figure 1-1-2).

A large upright to overturned, south-plunging syncline, the Mount Kelly syncline (Fitzpatrick, 1985), is exposed in the Mount Kelly area (Section A-D, Figure 1-1-2). Archibald Formation in its hinge zone is gently to tightly folded and locally thickened (*see* Mt. Kelly ridge, northeast section; Andrew *et al.*, 1990a, this volume). The more competent Elise Formation rocks are concentrically folded and the Hall Formation in the core is strongly cleaved. The Mount Kelly syncline is cut by a steep west-dipping thrust fault that merges with a west-side-down fault to the north.

At least four generations of faulting are recognized. Intense shearing, particularly along the limbs of the Hellroaring Creek syncline and southeastward towards the Waneta fault, may be related to movement along the Waneta fault. This faulting predates intrusion of the Wallack Creek pluton; locally, however, mylonitic zones parallel to the Waneta fault, and associated shears developed in the pluton, indicate some post-intrusive movement.

North-trending, easterly verging thrust faults may be associated with development of more open folds such as the Mount Kelly syncline. These are later than shearing along the Waneta fault but are older than the intrusion of Late Jurassic plutons and normal faulting. They include the two thrust faults southwest of Mount Kelly and a fault in the Archibald Creek valley. The Archibald Creek thrust dips steeply to the west and places the west-facing Archibald succession on the east limb of the Mount Kelly syncline on an overturned succession to the east. A splay of the Archibald Creek thrust trends northeasterly towards Gillian Creek, juxtaposing exposures of the lower Archibald Formation (Ja1) against the Elise Formation (Je8). This eastern splay dips steeply to the east, perhaps due to overturning at higher structural levels or to regional tilting related to Eocene extensional tectonics (T.E. Irving, personal communication, 1989).

A number of north to northeast-trending, west-dipping normal faults occur northwest of Mount Kelly. They cut the early folds and faults but are cut and sealed by Late Jurassic intrusions. They may be southern extensions of the Red Mountain fault in the Nelson area (Höy and Andrew, 1989a). The most prominent, along Doubtful and Query creeks (Figure 1-1-1), follows the locus of an earlier thrust fault and juxtaposes Elise Formation on the west with Archibald Formation in Query Creek. It has a rectilinear shape, swinging sharply northwestward in Bell Creek, thus forming a down-dropped angular block. To the northwest in the Beaver Creek valley, a northeast-trending, west-side-down normal fault is inferred with folded Archibald Formation (Ja2) in the eastern footwall and Elise Formation (Je) in its hangingwall.

A complex array of late normal faults cuts all earlier structures. They offset intrusive rocks and some may be related to Eocene extensional tectonics documented to the northwest (Parrish *et al.*, 1988; Corbett and Simony, 1984). Steeply dipping, northwest-trending faults, down-dropped to the northeast, are prominent southwest of Salmo (Figure 1-1-2).

In summary, the earliest recognised structures in the Mount Kelly–Hellroaring Creek area involve west-verging thrusts, shears and tight folds along the Waneta fault, the tectonic boundary between Quesnellia and ancestral North America. Farther west, in the Mount Kelly and Archibald Creek areas, more open folds and east-verging thrusts are prominent. West-side-down normal faults that locally follow the trace of earlier thrusts, record extensional tectonics prior to the intrusion of Late Jurassic plutons. Late, post-intrusive, east and northeast-dipping normal faulting may be related to an Eocene extensional tectonic event.

MINERAL OCCURRENCES

Metallic mineral occurrences in the map area include shear-related conformable gold-copper zones and gold-silver-lead-zinc, gold-silver-copper and molybdenum veins (Table 1-1-1). Conformable gold occurrences, those where mineralization is conformable with either foliation or bedding, are closely associated with Rossland Group lithologies and early structures. Vein occurrences are post-tectonic and formed during intrusion of Middle Jurassic granites (Höy and Andrew, 1988).

The shear-related conformable gold-copper zones are characterized by intense carbonate-sericite-chlorite alteration in mafic flows and flow breccias. They occur southwest of Salmo in a zone of intense shearing more than a kilometre in width and extending from the headwaters of Tillicum Creek to the west fork of Hellroaring Creek (Figure 1-1-2). These alteration zones are 5 to 10 metres wide, over 20 metres long and are often cored by 1 to 2-metre sericite-silica altered felsic intrusions (or volcanics). Examples of these zones include the Gus and Jim showings in the headwaters of Hellroaring and Swift Creeks. Their structural and stratigraphic position, in the sheared limbs of a syncline cored by the Hall Formation (Figure 1-2-2), is a similar environment to conformable gold mineralization at the Great Western–Star property south of Nelson (Höy and Andrew, 1989c).

Vein occurrences are distributed throughout the Rossland Group and Middle Jurassic granitic intrusions. With the exception of the carbonate-hosted Silver Dollar (MINFILE 082FSW207), the veins are quartz-rich. Accessory silicate minerals include epidote, muscovite and tourmaline. Common sulphide minerals include pyrite, chalcopyrite, sphalerite and galena; molybdenum and minor tungsten occur at the Meadows showing (MINFILE 082FSW268) and arsenopyrite and stibnite at the Armstrong showing (MINFILE 082FSW267). The tenor of veins seems to have a lithologic control; precious metal rich veins that carry lead and zinc occur preferentially in sedimentary rocks of the Archibald or Hall Formations, copper-bearing veins are more

TABLE 1
MINERAL PROPERTIES WITH PAST PRODUCTION OR EXTENSIVE DEVELOPMENT, MOUNT KELLY-HELLROARING CREEK AREA

MINFILE No.	Name	Commodities	Type	Host	Status
82FSW207	Silver Dollar	Au,Ag,Pb,Zn	Vein	Jh	Past producer
82FSW267	Armstrong	Au,Ag,Pb,Zn	Vein	Jn	Past producer
82FSW268	Meadows	Mo	Vein	Jn	Showing
82FSW283	Allouez	Au,Ag,Cu	Vein	Je1	Showing
82FSW290	Jim	Au,Cu	Shear-related	Je1	Showing
82FSW291	Gus	Au,Cu	Shear-related	Je1	Showing

common in Elise Formation volcanic rocks and molybdenum-tungsten veins are restricted to late granitic intrusions.

EXPLORATION ACTIVITY

Ground underlain by the Rossland Group has had a steady increase in claims staked since the onset of the Rossland Project in 1987 (Figure 1-1-3). The area covered by claims on the Salmo west-half sheet alone has increased from 56 to 83 per cent. Exploration targets include conformable gold (shear-related and alkaline porphyry gold-copper), gold skarn and gold-silver-lead-zinc vein deposits. Although much of the staking may be due to increased activity generated by flow-through-share financing, re-evaluation and reinterpretation of classical vein and shear zone deposits has led to the development of new exploration models for past producers.

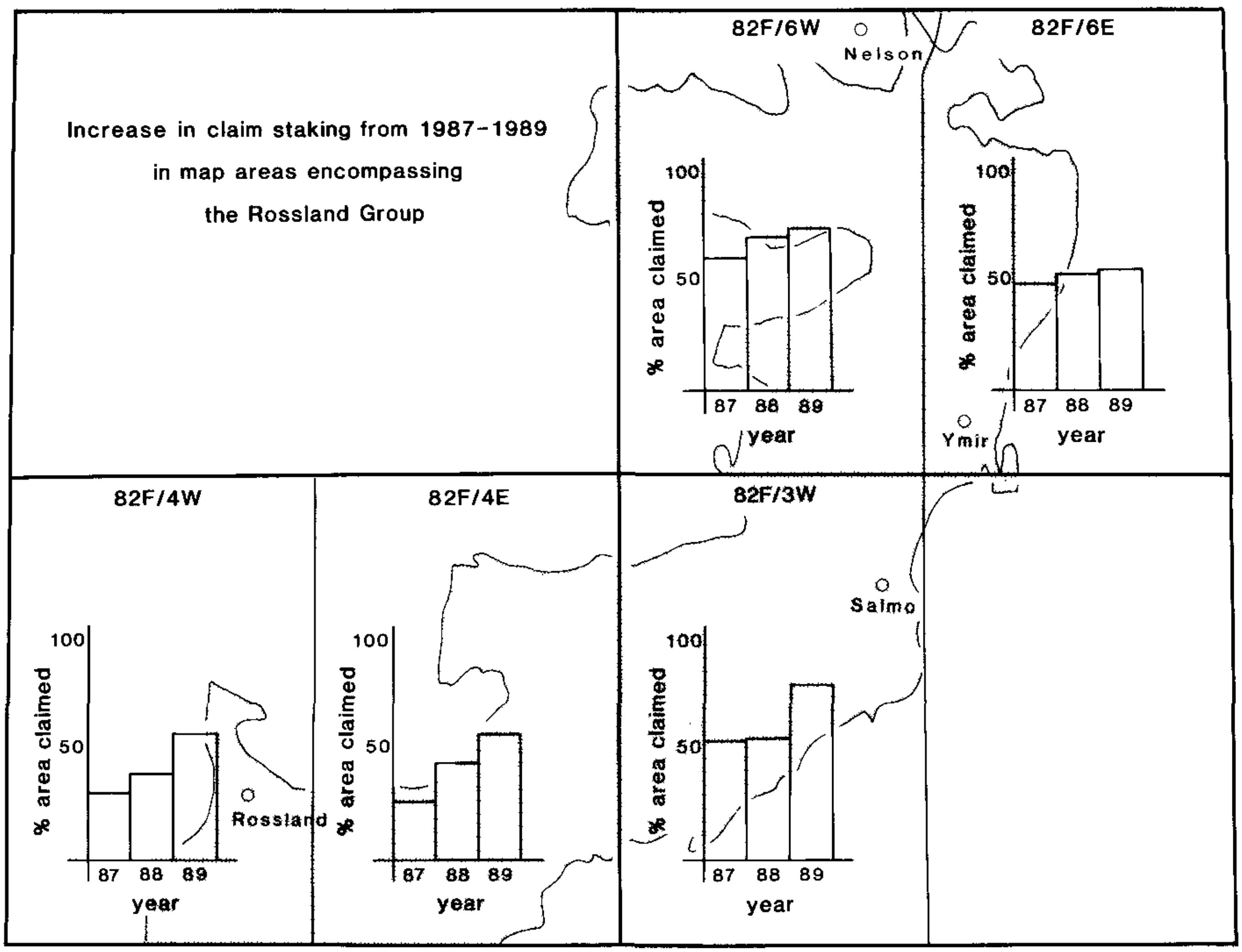


Figure 1-1-3. Map and graphs showing the increased level of staking in areas underlain by the Rossland Group, southeastern British Columbia, 1987 to 1989.

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