Geology and Mineral Potential of the Grand Forks Map Sheet (082E/01), Southeastern British Columbia

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INTRODUCTION

The Grand Forks map sheet (082E/01) in southern British Columbia lies between the Rossland area in the east and the Greenwood area in the west (Fig. 1). The sheet was proposed as a Rocks to Riches mapping/compilation project due to its potential for discovery of gold mineralization, particularly epithermal gold. Exploration in the Republic District of northern Washington, southwest of the Grand Forks sheet, has led to the discovery of several epithermal gold deposits, and recent prospecting northeast of the Grand Forks sheet has also identified several epithermal gold targets that appear to be related to Eocene Coryell intrusive rocks. Both the Rossland and Greenwood camps are historical gold producers that are currently undergoing renewed interest and exploration, as is the Franklin gold camp north of Grand Forks. Some recent exploration has also focused in the Grand Forks map sheet, in part due to the similarities in styles of mineralization, lithologies and structures that characterize the Rossland and Greenwood camps, and the Republic district. This report, and the newly released 1:50,000 geological map (Höy and Jackaman, 2005) will hopefully spur and direct future exploration in the Grand Forks-Christina Lake area.

The Grand Forks area is part of the Kettle River (east-half) sheet, mapped at a scale of one inch to four miles (1:253,440) by Little (1957). It is included in the 1:250,000 scale compilation by Tempelman-Kluit (1989). This latter work stressed the importance of extensional tectonics throughout southern British Columbia and, within the Grand Forks area, supported a model proposed by Preto (1970) that recognized a Proterozoic core complex between extensional normal faults. Preto's detailed mapping clearly defined the limits of these inferred Proterozoic rocks, and outlined lithologic and structural units within the complex.

Several other more detailed studies include parts of the Grand Forks map sheet. The western edge of the sheet is part of the Greenwood camp that has been mapped by Fyles (1990) and Church (1986). A thesis by Laberge (Laberge *et al*., 2004) focused on the western edge of the complex, and in particular on the Granby fault. Acton *et al*. (2002) studied the area east of Christina Lake, focusing on the nature of late Paleozoic basement rocks and several previously unrecognized mafic intrusive complexes.

This study has compiled and reinterpreted all previously published geological maps of the area, including considerable data that has been released in industry assessment reports. Approximately one month was spent in the field, mainly focusing on the southeastern part of the map sheet as this area had not been previously mapped at a detailed (1:50,000) scale.

All geological data has been compiled on 1:20,000 trim maps. These have been combined and will be released as a 1:50,000 map in both digital and hardcopy format (Höy and Jackaman, 2005). An update of BC MINFILE data is also in progress and will be released at a later date.

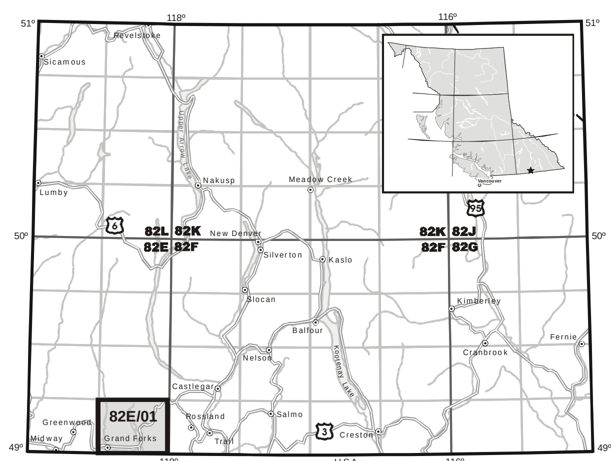

Figure 1: Map showing the location of the Grand Forks map sheet.

[1] *2450 Dixon Road, Sooke, BC, V0S 1N0*
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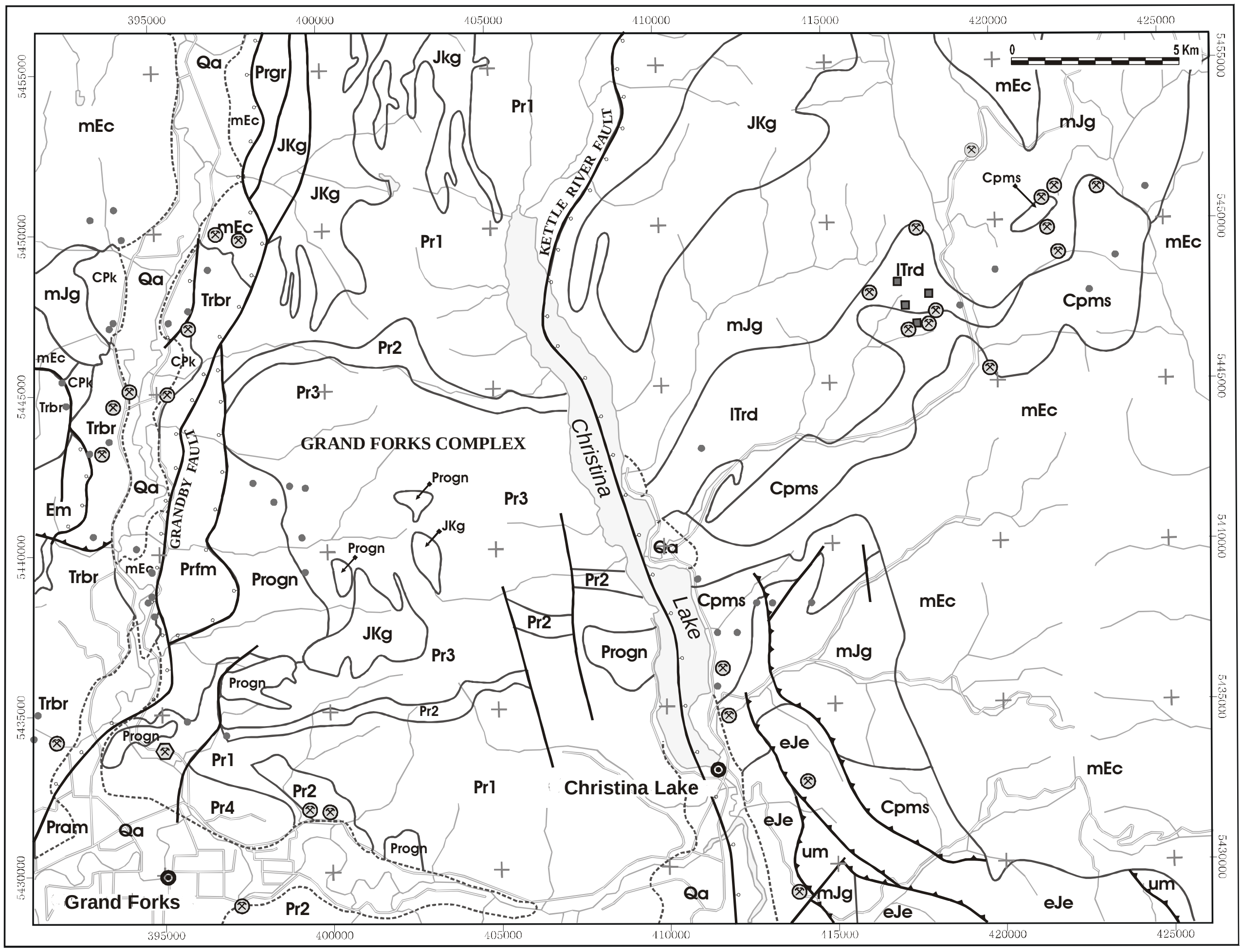

Figure 2: Geological map of the Grand Forks area (*see* text for sources of mapping).

REGIONAL GEOLOGY

The Grand Forks complex is one of several metamorphic complexes in the southern Omineca that appears to be related to Eocene extension, faulting and denudation (Parrish *et al*., 1988). It is bounded on the west by the Granby fault, a west-dipping normal fault, and on the east by the east-dipping Kettle River fault (Fig. 2). Within the complex are a suite of mainly high-grade metasedimentary rocks that are intruded by a variety of mainly felsic stocks and dikes.

Hangingwall Assemblages, Granby Fault

An interfolded and faulted succession of late Paleozoic oceanic rocks of the Knob Hill and Anarchist groups, and mainly middle Triassic volcaniclastic rocks of the Brooklyn Formation, Nicola Group (Fyles, 1990; Preto, 1970; Laberge *et al*., 2003) occur in the hangingwall of the Granby fault, along the western edge of the map area (Fig. 2).

The bounding Granby fault dips variably to the west, placing these mainly low-grade rocks of Quesnellia and Slide Mountain against the higher grade rocks of the Grand Forks complex. The fault is marked by a zone of brittle shearing and brecciation, typically a few hundred metres wide. It appears to truncate and shear Coryell syenites of the Granby pluton (Preto, 1970). The Granby pluton is dated at 51.1 ± 0.5 Ma, U/Pb zircon (Carr and Parkinson, 1989) and therefore normal movement on the fault must have occurred during or post middle Eocene time. Wingate and Irving (1994), based on geomagnetic data, present a model of Eocene tilting of hangingwall rocks (mean tilt of approximately 30° east) due to normal movement on the west-dipping, listric Granby fault. Assuming synchronous metamorphism and a similar geothermal gradient across the fault, Laberge *et al*. (2003) estimate a minimum vertical displacement of 4 km across the Granby fault.

Hangingwall Assemblages, Kettle River fault

Hangingwall rocks of the Kettle River fault, exposed east of Christina Lake (Fig. 2), include mainly syenites and monzonites of the Eocene Coryell batholith and granites and granodiorites of the Middle Jurassic Nelson plutonic suite. A granodiorite of probable

Legend (Figure 1)

CENOZOIC	
Qa	alluvium; sand, gravel, silt, till
mEc	Coryell plutonic rocks: syenite, monzonite
MESOZOIC	
Kgd	granodiorite
JKg	biotite granodiorite and granite
mJg	Nelson plutonic rocks: granite, granodiorite
eJe	Elise Formation: mafic volcaniclastic rocks
Trd	Josh Creek diorite
Trbr	Brooklyn Formation: mafic volcaniclastics, limestone
PALEOZOIC	
CPk	Knob Hill Group: greenstone, chert, amphibolite, metasediments
Cpa	Anarchist Group: greenstone, amphibolite, serpentinite
um	serpentinite (correlation unknown)
CPms	schist, siltstone, calcsilicate, marble; includes Mollie Creek assemblage
PROTEROZOIC to PALEOZOIC? Grand Forks Complex: (from Preto, 1970)	
Prfm	leucogranodiorite, mylonitic, sheared
Prog	granodiorite orthogneiss
Pr4	amphibolite, amphibolite gneiss
Pr3	schist, quartzite, marble, pegmatite
Pr2	quartzite
Pr1	sillimanite paragneiss, schist, amphibolite
	contact
	fault
	normal fault
	thrust fault
	mineral deposit (past producer, prod, dev. prospect, showing)

Cretaceous age intrudes the Nelson granodiorite near the northeast end of Christina Lake. Acton *et al*. (2002) also recognized and mapped a large diorite body, referred to as the Josh Creek diorite, which intruded Paleozoic metasedimentary rocks of the "Mollie Creek assemblage". The Josh Creek diorite is intruded by Nelson and Coryell age plutons, and has been deformed along with host metasedimentary rocks. A lower intercept U/Pb zircon date of 215.9 ± 1.4 Ma suggests a late Triassic age of emplacement and hence correlation with Quesnel Terrane.

These intrusive rocks cut rocks correlated with the Early Jurassic Elise Formation and with an older Paleozoic metasedimentary succession of siltstone, calcsilicate schists and marbles.

The metasedimentary succession is exposed in two main areas: along the southern margin of the Josh Creek diorite (the Mollie Creek assemblage) and in the southeastern part of the Grand Forks map sheet (Fig. 2). The age of these rocks is not known, but they are similar to parts of the Carboniferous-Permian Mount Roberts Formation, exposed in the Rossland area to the east (Höy and Dunne, 1997) and are, therefore, tentatively correlated with these rocks. Alternatively, as indicated by Tempelman-Kluit (1989), they may be Ordovician to Devonian in age, and may possibly correlate with Lardeau Group rocks of the Kootenay Terrane.

Rocks correlated with the Elise Formation of the Rossland Group are exposed in two structural panels, separated by a thrust fault, in the southeastern part of the map area. They include mainly mafic volcaniclastic units, minor massive "greenstone" and minor argillite. They are structurally overlain by the late Paleozoic metasedimentary succession. In the Rossland area, the Elise Formation unconformably overlies the Mount Roberts Formation, and it is probable that in the Christina Lake area as well this stratigraphic relationship occurred prior to thrust faulting.

Acton *et al*. (2002) recognized at least two phases of deformation in the Mollie Creek assemblage. The dominant Phase 2 deformation produced tight to isoclinal folds with steeply dipping axial planes. These folds trend northeasterly in southwestern exposures of the Mollie Creek assemblage and swing more northerly in northeastern exposures. The age of this folding is bracketed between the age of the deformed Josh Creek diorite and a post-kinematic diorite exposed along the abandoned railway line at Fife just north of the town of Christina Lake (Acton *et al., op. cit.*). As noted above, the Josh Creek diorite is interpreted to have an emplacement age of *ca*. 216 Ma, and the Fife diorite, based on U-Pb zircon dating, an age of 197-181 Ma.

Thrust faults in the more southern exposures of the Rossland Group and metasedimentary succession trend northerly and verge to the west. They are recognized by zones of intense shearing or brecciation, structural emplacement of ultramafic rocks, and offsets of lithologic units. It is probable that they extend northward into the Mollie Creek assemblage but due to lack of offset of marker units, were not recognized there. The age of thrust faulting clearly postdates the intense Phase 2 folding that is recognized in these rocks, and also appears to postdate intrusion of middle Jurassic Nelson intrusive rocks. A granodiorite just east the town of Christina Lake, inferred to be part of the Nelson suite, is cut and offset by two of the thrust faults, and a small granitic plug just north of the Washington border, also correlated with the Nelson suite, appears to be truncated by two splays of the southern thrust fault. The thrust faults are generally truncated by Eocene Coryell intrusive rocks, providing an upper age limit to faulting. However, in the very southeastern part of the map area, the most eastern thrust fault produces minor shearing and alteration in the Coryell batholith. As offset of the Coryell was not noted, it is probable that this represents only minor reactivation along the older thrust fault.

The Kettle River fault is not well exposed in the study area. Throughout most of its length its trace is beneath Christina Lake or covered in overburden south of the town of Christina Lake (Fig. 2). Farther south in northern Washington, the fault separates amphibolite-grade rocks of the Kettle complex (the southern extension of the Grand Forks complex) from lower metamorphic grade rocks to the east (Cheney, 1980). Northeast of Christina Lake, Preto (1970) placed the fault at the contact of high grade gneissic rocks (unit Pr1, Fig. 2) with Nelson granitic rocks. However, Parrish *et al*. (1988) place the fault farther east, thereby including foliated and metamorphosed rocks that are correlated with the Nelson granite in the Grand Forks Complex.

Grand Forks Complex

The Grand Forks complex is bounded by Eocene-age normal faults. It is structurally similar to several other metamorphic complexes in the southern Omineca belt that typically expose penetratively deformed and highly metamorphosed mid-Proterozoic to mid-Paleozoic rocks. These are interpreted to correlate with ancestral North America or with marginal miogeoclinal rocks of the Kootenay terrane.

Details of the geology of the Grand Forks complex, as schematically illustrated in Figure 2, are taken mainly from Preto (1970). The complex includes a lower succession of highly deformed sillimanite paragneiss and schist, amphibolite, calcsilicates and marbles of unit Pr1. They are intruded by abundant pegmatite and, locally, granodiorite orthogneisses in the form of stocks and sills (unit Progn).

A succession of quartzites (Pr2), locally interlayered with white marble, structurally overlies the older? paragneiss complex. These are in turn structurally overlain by garnet-biotite-sillimanite schists, marbles and calcsilicates of unit Pr3 (unit III, Preto, *op. cit.*). As in underlying units, pegmatites are locally abundant, and in places comprise more than 25 % of the succession. Unit Pr3 is exposed in the central part of the complex, within a large synformal structure that is bounded to the north and south by the quartzites of Pr2 (Fig. 2). Amphibolites and amphibole gneisses of Pr4 are exposed in the southern part of the complex, as well as in stratabound lenses in Pr3. Their structural position, mainly above unit Pr3, implies a younger age, although this is not known with certainty.

A variety of deformed and locally differentiated intrusive units occur throughout the Grand Forks complex. Only the largest of these orthogneisses or foliated granitic rocks are shown on Figure 2, and are collectively included in unit Progn. As well, many post-kinematic intrusions, correlated with Jurassic-Cretaceous granodiorites, are exposed in the complex.

The age of paragneisses and schists of the Grand Forks complex is not known, although most workers have suggested correlations with Proterozoic to Paleozoic (?) rocks exposed in the Monashee complex farther north. Detailed mapping of Monashee complex rocks in both the Thor-Odin and Frenchman cap domes south and north of Revelstoke have established a fairly well constrained stratigraphy as shown in Hoy (1987). This succession includes a core gneiss complex comprising intercalated paragneiss and orthogneiss, unconformably overlain by a cover sequence comprising a basal quartzite succession and overlying paragneisses, schists, calcsilicates, marbles and amphibolites (*see* Summary and References in Höy, 2001). A regionally extensive carbonatite tuff and several large stratabound lead-zinc-silver deposits occur in the cover succession. Several of these have been compared to the Broken Hill-type deposit (Höy, 2001).

Comparison of the Grand Forks succession with that in the Monashee complex shows a general similarity (Fig. 3), with the structurally lowest unit, Pr1, correlating with the core gneisses of the Monashee complex, the quartzitic sequence, Pr2, with the basal quartzites of the cover succession, and overlying dominantly paragneisses, schists, amphibolites and marble with the similar overlying cover sequence in the

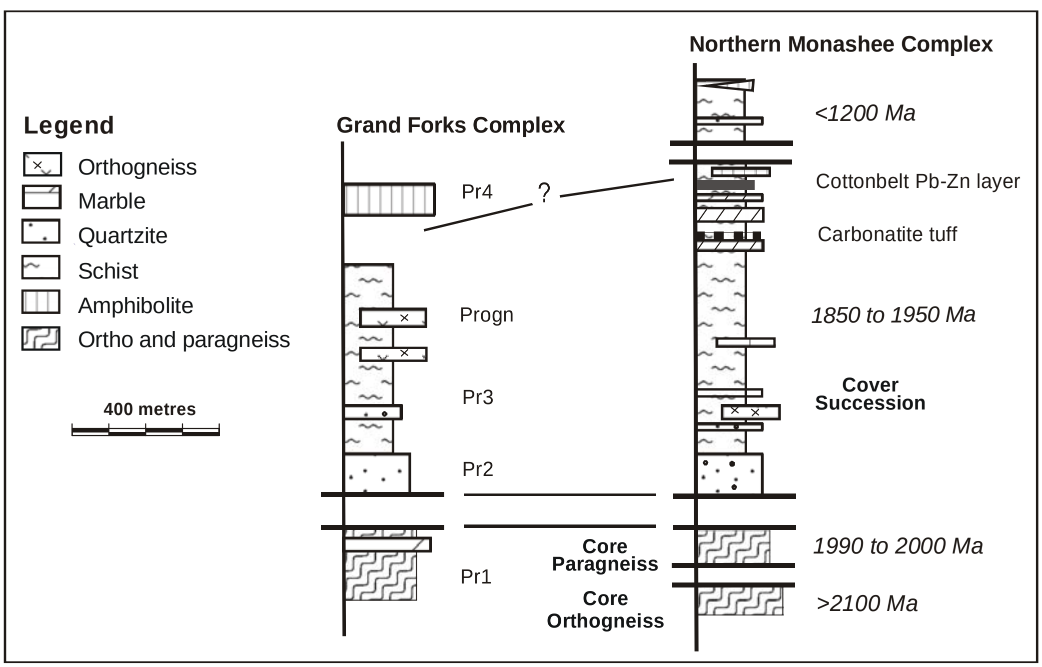

Figure 3: Correlation of main lithologic units of the Grand Forks complex with those of the Monashee Complex; data modified from Preto (1970) and Höy (2001).

Monashee complex. Furthermore, this correlation, if valid, implies that the quartzitic unit (Pr2) may define an unconformity separating early Proterozoic basement (Pr1) from an overlying Middle Proterozoic stratigraphic succession.

MINERAL POTENTIAL

A variety of mineral deposit types occur throughout the Grand Forks map sheet, including several types of gold veins, numerous gold, molybdenite and copper skarns, rare-earth pegmatites and industrial minerals. This diversity and abundance of deposits reflect both the structural complexity of the area and the variety of host rock types.

Some recent exploration, particularly north and east of the Grand Forks map sheet, has focused on epithermal-style mineralization. This is due, in part, to the successful exploitation by Echo Bay Mines (now Kinross Gold Corp.) of the K-2 gold deposit in the Republic Graben in northern Washington State and to the recent successful drill results from the Emanual Creek deposit. These are structurally controlled low-sulphidation epithermal gold deposits that appear to be related to an unconformity at the top of the Eocene Sanpoil Formation.

Similar north-trending structures extend into southern British Columbia and have been the focus of considerable exploration. Epithermal style gold mineralization is recognized in the Franklin gold camp, located along the Granby Fault north of the Grand Forks map sheet. Farther west, the Dusty Mac and Vault deposits, both low-sulphidation epithermal deposits, are within the White Lake basin along the north-trending Okanagan fault system. North of Christina Lake, in the Lower Arrow Lake area, prospecting has focused on north-trending structures and on Eocene age intrusive and volcanic rocks and has led to the discovery of several new occurrences with characteristics typical of epithermal gold mineralization.

A new thrust belt has been identified in the southeastern part of the Grand Forks sheet, east of Christina Lake, that is probably related to thrust faulting that has been documented at the Rossland (Höy and Dunne, 2001) and Greenwood camps (Fyles, 1990). The thrust faults in the Christina Lake area locally extend through Eocene Coryell rocks resulting in zones of widespread sericite-silica alteration and dispersed pyrite mineralization. This Eocene reactivation of earlier faults, associated hydrothermal activity, and Coryell host has similarities to epithermal mineralization that is currently being investigated at Lower Arrow Lake (Kootenay Gold Corp.). Hence, it is suggested that the large exposures of Coryell intrusive rock to the north, generally considered a barrern host for mineralization, warrant further prospecting and exploration.

A number of other exploration targets in the eastern part of the Grand Forks map sheet have been identified. Preliminary work on several north- and northeast-trending shear zones in Middle Jurassic intrusive rocks located just northeast of the map area have identified anomalous gold (Kootenay Gold Corp.). Mapping (this study and Acton *et al*., 2002) has identified a number of other similar shears that cut unit mJg just east of Christina Lake and in the northeast part of the map area. Pyrite and variable high-level alteration assemblages along these shears, including sericite and quartz, suggest potential for gold mineralization.

Several massive sulphide occurrences in metasediments just north of Sunderland Creek, east of Christina Lake, have similarities to the massive sulphide veins at Rossland. Preliminary investigation of these suggests that they are structurally controlled and related to a mafic intrusion, and have skarn envelopes and a mineralogy dominated by pyrrhotite, chalcopyrite and magnetite. The recognition of several structural panels of Elise metavolcanic rocks in the southeast part of the map sheet (Fig. 2), similar to host rocks of many of the Rossland veins, enhances the potential for Rossland-type veins in the southern part of the Grand Forks sheet.

These discoveries, the considerable exposure of under-explored Eocene-age rocks, and recognition of several mineralized faults underscore the potential for discovery of epithermal gold mineralization in the Grand Forks map sheet. As well, recognition of a thrust belt that has been traced for more than 15 km in Elise Formation metavolcanic rocks, and massive sulphide mineralization related to mafic intrusive activity, also indicates potential for Rossland-type gold-copper mineralization.

SUMMARY

The Grand Forks map sheet includes highly deformed and metamorphosed Proterozoic paragneiss and orthogneiss exposed in the core of the Grand Forks complex. These rocks appear to correlate with lithologically similar rocks of the Monashee complex farther north. The Grand Forks complex is bounded by extensional normal faults, the Granby fault along the western margin and the Kettle River fault along the eastern.

Hangingwall rocks above the Granby fault, exposed along the western edge of the map sheet, include mainly lower metamorphic grade rocks of Quesnellia that are intruded by Jurassic-Cretaceous and Eocene Coryell rocks. Farther west in the Greenwood area, Quesnel rocks and probable Slide Mountain Terrane mafic and ultramafic rocks are repeated by a series of apparent southwest-verging thrust faults.

Hangingwall rocks of the Kettle River fault, exposed east of Christina Lake, include metavolcanic rocks of the Early Jurassic Rossland Group and a metasedimentary succession that is tentatively correlated with the Carboniferous-Permian Mount Roberts Formation, both part of Quesnel Terrane. These are repeated by several high angle thrust faults, locally marked by serpentinites that may be remnants of Slide Mountain terrane lithologies.

There is considerable potential for discovery of new gold occurrences in the Grand Forks and Christina Lake areas. Important new exploration targets include Rossland-type intrusive-related gold-copper veins in Early Jurassic Elise Formation rocks east of Christina Lake and epithermal gold mineralization in late structures that cut Coryell intrusive rocks farther north.

The Grand Forks project has involved mapping and compilation of geology of the Grand Forks map sheet. This map will be released in digital format and 1:50,000 hard copy format early in 2005.

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