Stratigraphic and tectonic framework of the Khyber-Sericite-Pins mineralized trend, lower Iskut River, northwest British Columbia

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Recommended citation: Kyba, J. and Nelson, J.L., 2015. Stratigraphic and tectonic framework of the Khyber-Sericite-Pins mineralized trend, lower Iskut River, northwest British Columbia. In: Geological Fieldwork 2014, British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper 2015-1, pp. 41-58.

Abstract

The Khyber-Sericite-Pins trend is part of the 'Bronson corridor', a belt of mineralization in northwest Stikinia that extends southeast from the past-producing Snip and Johnny Mountain gold mines. Within the mineralized belt, a series of Early Jurassic (195-190 Ma) plutons, stocks and dikes of the Lehto plutonic suite cut stratified Stuhini Group and Hazelton Group rocks. Large quartz-sericite-pyrite (QSP) alteration zones and precious-metal veins and stockworks are spatially associated with the intrusive suite. The corridor is bounded to the southwest by the Sky fault system, a 20 kilometre-long set of normal faults and reactivated post-mineral reverse faults. Notable among the latter is the Khyber reverse fault, which forms the immediate hanging wall to intense QSP alteration and mineralization at the Khyber-Inel prospects. Previous workers distinguished between the Stuhini and Hazelton groups on chronostratigraphic grounds, placing the contact at the Triassic-Jurassic boundary (201 Ma). In contrast, we use lithostratigraphic criteria, and place the base of the Hazelton Group at an angular unconformity cut into Stuhini Group volcaniclastic rocks that is overlain by a distinctive Upper Norian conglomerate-bearing siliciclastic unit, herein referred to as the Snippaker unit. The Snippaker unit consists of polymictic conglomerate, arkose, and siltstone. It is compositionally mature relative to Stuhini Group strata beneath the unconformity. Coeval with Late Triassic porphyry deposits of Stikinia such as Red Chris, the unit records the termination of Stuhini arc volcaniclastic sedimentation and erosional unroofing of the Stuhini Group. Very coarse, immature lower Hazelton Group conglomerates near the Sky fault zone south of Mt. Johnny indicate steep local slopes and clast contributions from a variety of nearby sources. Previously brecciated hypabyssal intrusive clasts in one of the deposits suggest deposition proximal to a penecontemporaneous fault. The structural and stratigraphic setting of the Khyber-Sericite -Pins trend closely resembles that of the Kerr-Sulphurets-Mitchell-Brucejack porphyry-epithermal camp. The Sky fault system appears to have played a similar role to that of the Sulphurets thrust and its precursor basin-bounding faults, in localizing Early Jurassic intrusion and mineralization. The Khyber reverse fault, with its highly QSP-altered footwall, is a close analogue to the Sulphurets thrust fault. In both cases, Cretaceous thrust reactivation was facilitated by mechanically weak, highly altered, clay-sericite-rich rocks.

Keywords: Bronson corridor, KSP trend, Iskut River area, Stikinia, Cu-Au porphyries, Snippaker unit, Hazelton Group, Early Jurassic

1. Introduction

The Khyber-Sericite-Pins mineralized trend of northwest Stikinia is on the south side of the Iskut River, southeast of the past-producing Snip and Johnny Mountain gold mines (Figs. 1, 2). It is part of the northwest-trending 'Bronson corridor' (Metcalfe and Moors, 1992), in which an unusual concentration of intrusion-related mineral occurrences and broad alteration zones are spatially associated with a belt of plutons, stocks, and dikes of the Lehto suite (Fig. 3; Early Jurassic, ca 195-190 Ma, U-Pb zircon, Lewis et al., 2001). Investigations by Nelson and Kyba (2014) in the KSM-Brucejack camp, about 40 km to the east (Fig. 2), documented details of the Hazelton Group and allied intrusive host rocks. We focused on basal units in the Hazelton Group and the sub-Hazelton unconformity, and recognized reactivated basin structures, particularly the Sulphurets fault. Herein we continue our analysis of the lower Hazelton Group and structural controls on mineralization, emphasizing the unconformity between the Stuhini Group (Upper Triassic) and the Hazelton Group (Upper Triassic to Lower Jurassic) and a system of faults on the southwest flank of the Bronson corridor.

2. Mineralization in the Bronson corridor

Of the 58 known MINFILE occurrences in the Bronson corridor, most are precious metal-rich polymetallic and intrusion-related veins and skarns. Combined past gold production from Snip and Johnny Mountain totalled over one million (1,106,163) ounces from 712,990 tonnes between 1989 and 1999. The best-known porphyry prospect in the area is the Red Bluff stock, which has been genetically linked to the Snip vein (Fig. 3; Rhys, 1995). The concentration of intrusion-related mineralization linked to Early Jurassic plutons, which are coeval with, and texturally and compositionally similar to, intrusions at the Stewart camp (Mitchell porphyry suite at Kerr-Sulphurets-Mitchell or KSM, and 'Premier Porphyry'), suggests that undiscovered porphyry deposits may exist in the Bronson corridor. Other indications include broad, intense quartz-sericite-pyrite alteration zones (Alldrick et al., 1990; Fig. 3) and regionally elevated gold and copper values in stream sediments (British Columbia Geological Survey Regional

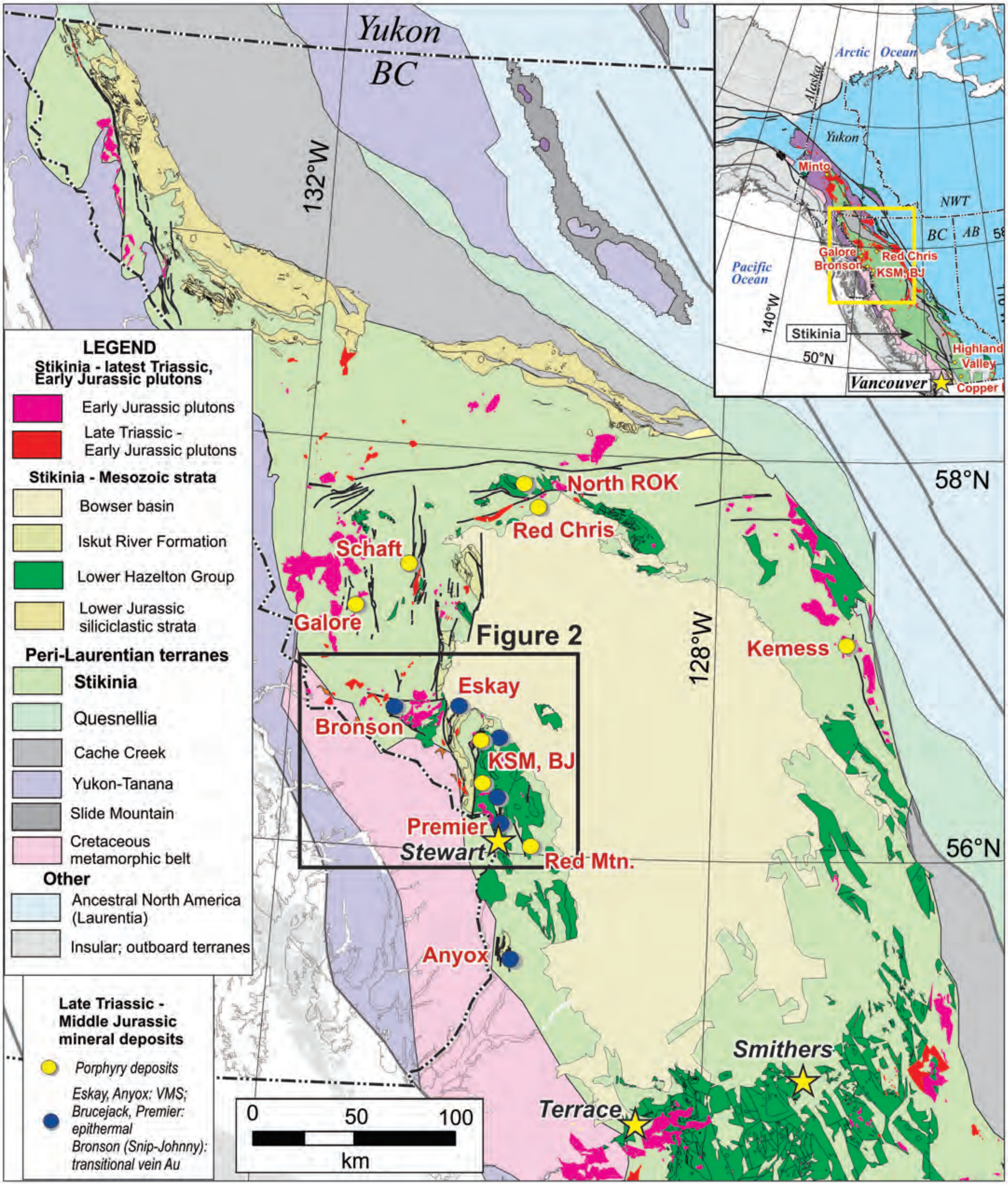

Fig. 1. Triassic and Jurassic geology and major mineral occurrences of northern Stikinia.

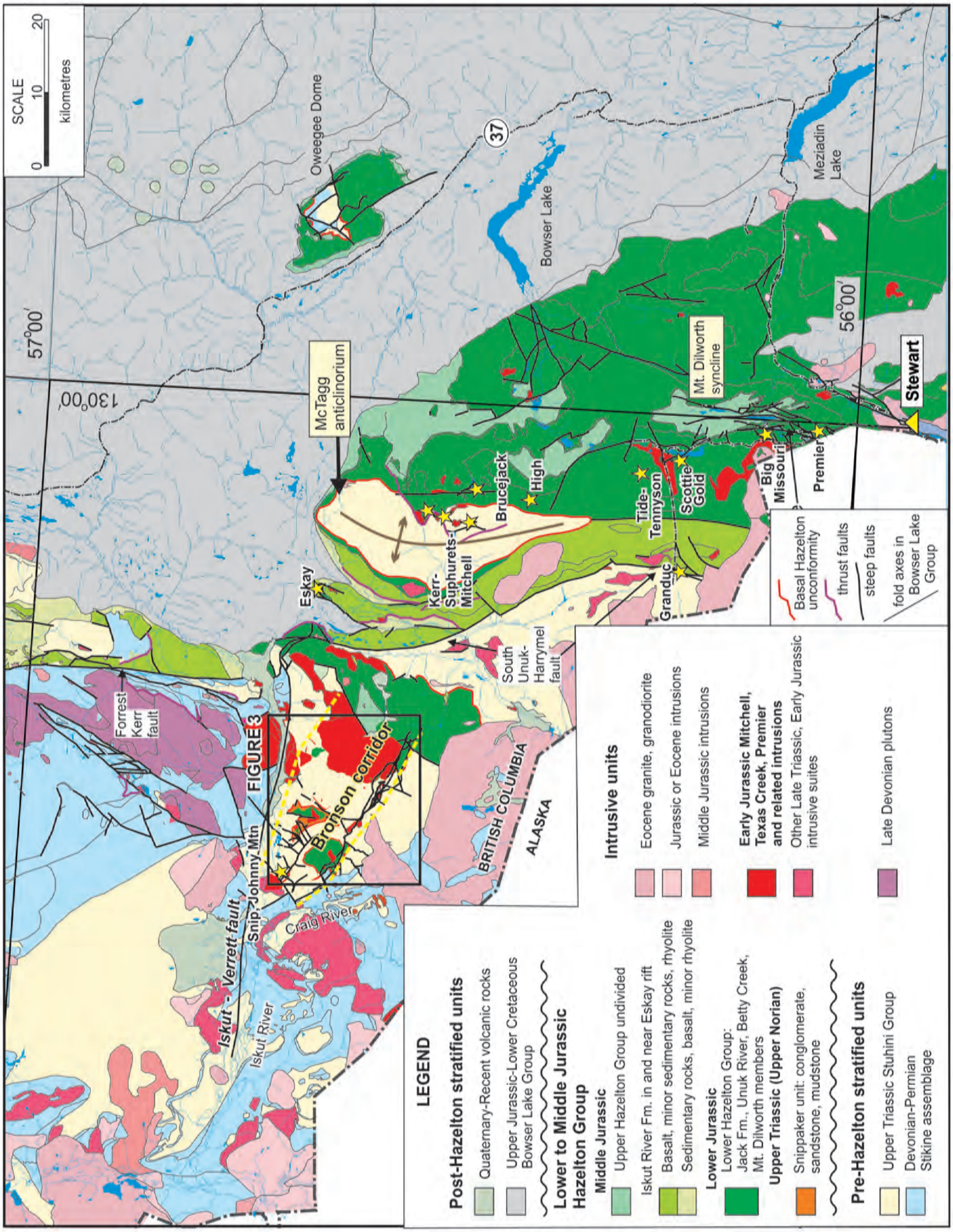

Fig. 2. Geology of lower Iskut River area and Bronson corridor, western Stikinia.

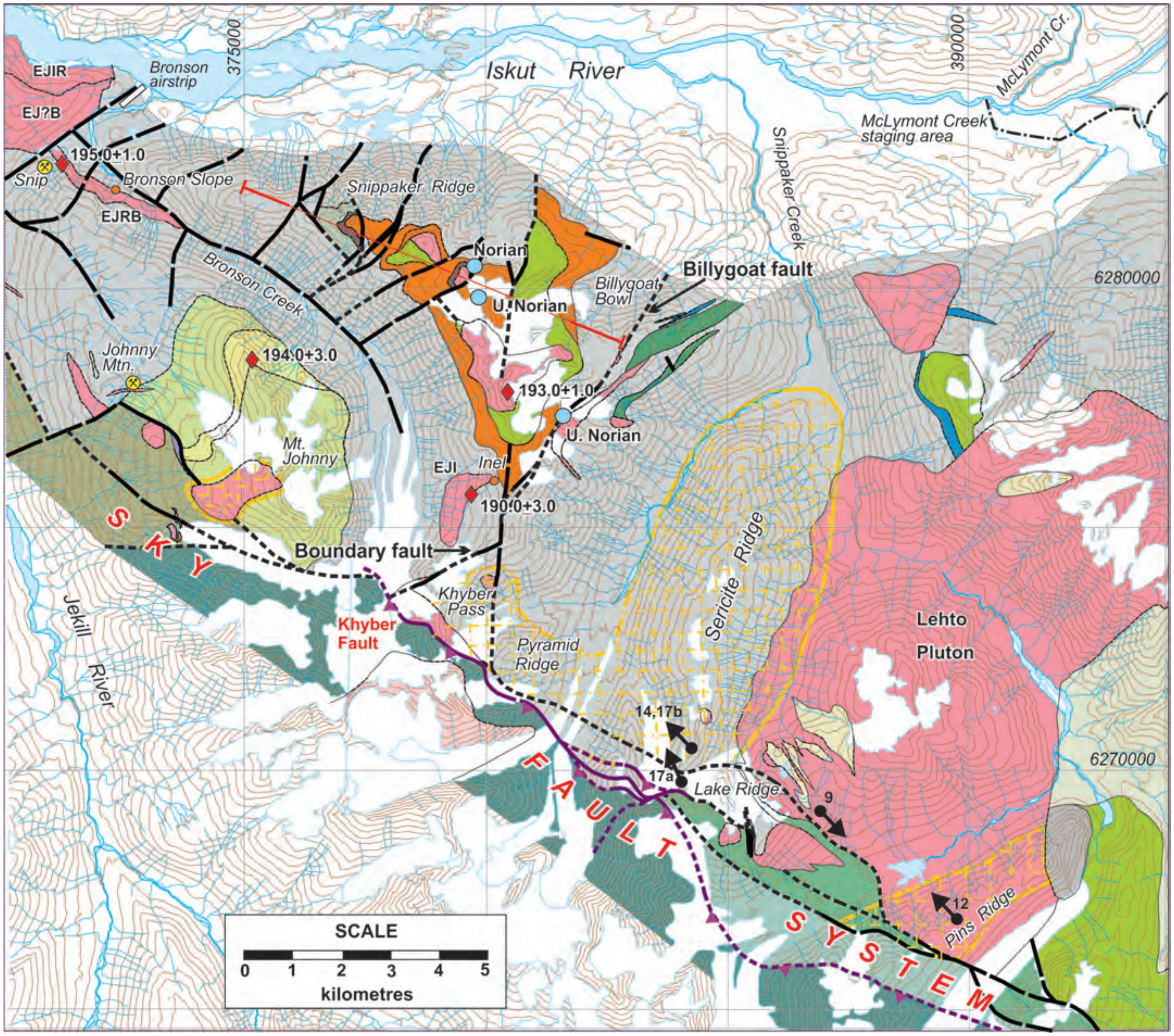

Fig. 3. Geology of the Bronson corridor and Khyber-Sericite Ridge-Pins trend. Mapping by J. Kyba and J.L. Nelson, 2014; other contacts compiled from Lewis (2013), with some subdivisions of Stuhini Group omitted for clarity. UTM Zone 9V, NAD 83.

Geochemical Survey). In 2014, Colorado Resources conducted district-scale exploration including geologic, geochemical, and geophysical surveys followed by drilling that tested for porphyry copper-gold and related precious metal prospects. Convenient helicopter access to the area is now possible from a staging area at the newly commissioned Alta Gas McLymont power project, 17 km east of the Bronson airstrip (Fig. 3).

3. Stratigraphy of the Stuhini and Hazelton groups; Lehto plutonic suite

The study area is underlain mainly by stratified rocks of the Stuhini Group (Upper Triassic) and Hazelton Group (Upper Triassic to Lower Jurassic) and by Early Jurassic plutons and smaller bodies that are considered comagmatic with Hazelton Group volcanic units. Epiclastic and volcaniclastic rocks of the Stuhini Group are unconformably overlain by siliciclastic, volcanic, and volcaniclastic rocks of the Hazelton Group (Fig. 4). In contrast to previous studies (Alldrick et al., 1990; Metcalfe and Moors, 1993; Lewis 2013), we assign a siliciclastic unit immediately above the unconformity, which contains Norian and Upper Norian fossils (Nadaraju and Smith 1992; Nadaraju and Lewis, 2001), to the Hazelton Group, introducing the informal name 'Snippaker unit'. The Snippaker unit is overlain by the 'volcaniclastic unit', which locally cuts through the Snippaker section to lie directly on Stuhini Group rocks. Lewis et al. (2001) reported a U-Pb zircon age of ca. 193 Ma for this volcaniclastic unit.

Stuhini and Hazelton strata along the Bronson corridor are

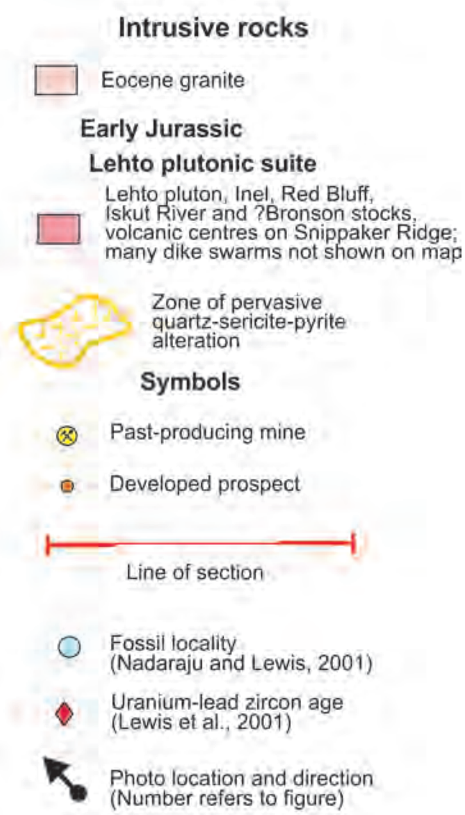

Fig. 3. Continued.

cut by diorite, quartz diorite, and monzodiorite plutons, plugs and dikes of the Lehto suite (Fig. 3; Early Jurassic, ca 190-195 Ma, U-Pb zrcon, Lewis et al., 2001). It includes the main Lehto pluton, a northeast-trending body 5 kilometres wide and 10 kilometres long, and the Inel, Red Bluff, and Iskut River stocks.

Snippaker Ridge (Fig. 4a) provides the best exposed and most easily accessed stratigraphic section across the contact between the Stuhini Group and overlying rocks of the Hazelton Group. In general, units are gently dipping, as shown by major contacts that follow topographic contours, interrupted by minor, steep, northeast-striking faults (Fig. 3).

3.1. Stuhini Group

Stuhini Group rocks at the base of the Snippaker Ridge section (Fig. 5) consist of laminated to thick-bedded greywacke, argillite, siltstone, sandstone, crystal tuff, and rare fossiliferous limestone. Most common are grey-green, fine-grained, locally graded, tuffaceous volcanic wackes containing subhedral to anhedral plagioclase feldspar and up to 10% mafic minerals (replaced by chlorite) and rare detrital quartz. This unit coarsens upward to a 60 m-thick succession of interbedded polymictic conglomerate and greywacke (Fig. 5a). Rounded to subangular clasts, up to several decimetres in long dimension and supported by a siltstone-sandstone matrix, include microdiorite, plagioclase-phyric felsic intrusive rocks, fine-grained mafic volcanic rocks, carbonate rocks, quartz-sericite-pyrite (QSP) altered fragments, vein quartz, and minor chert. Conglomerate beds are locally graded and up to 5 meters thick.

At the Khyber Pass prospect (Fig. 3), coarse-grained rocks in the upper part of the Stuhini Group include a 125-150 m thick unit of framework-intact monomictic conglomerate, which

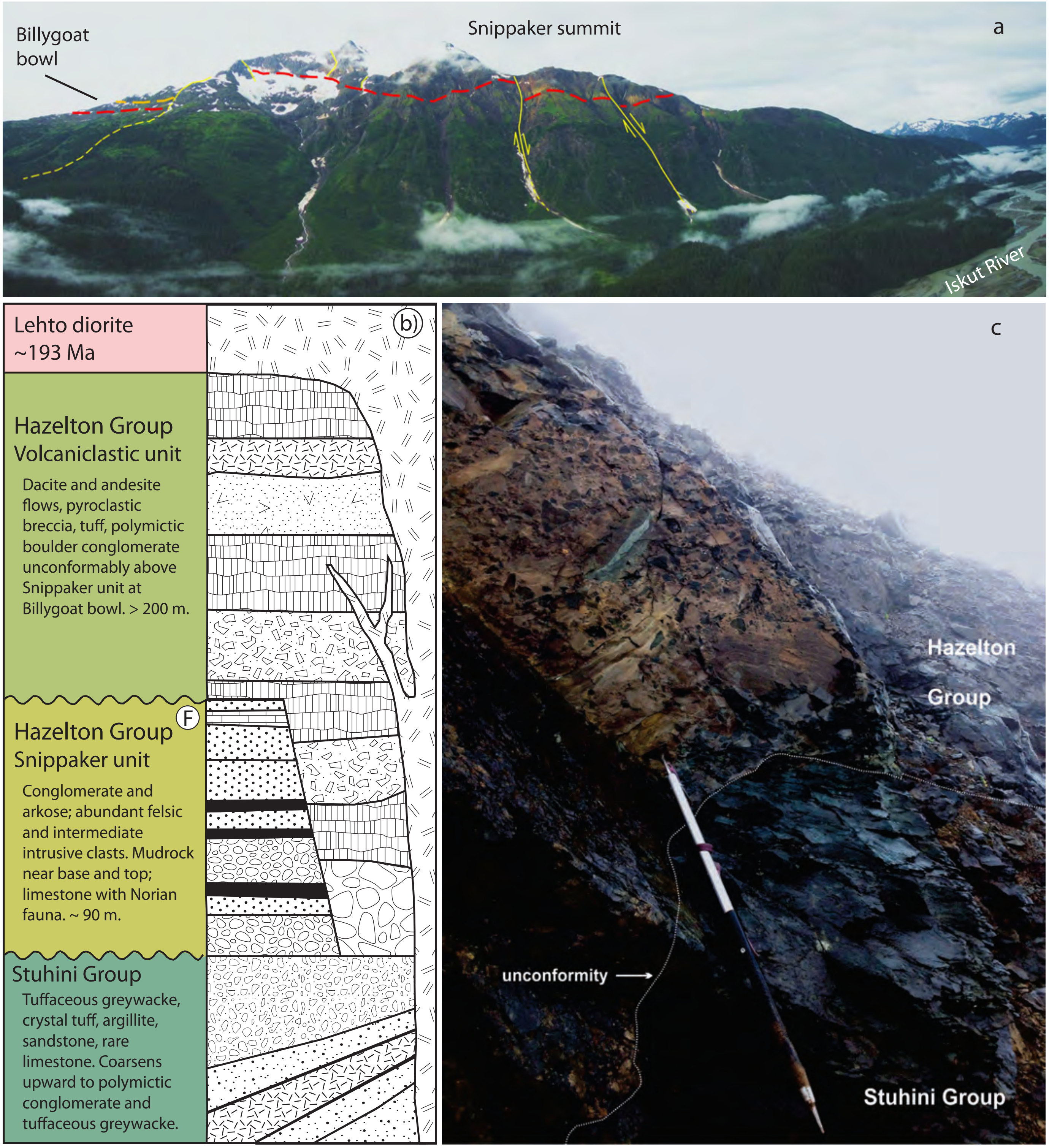

Fig. 4. Snippaker Ridge stratigraphy. **a)** Snippaker Ridge looking toward southwest. Elevation difference from valley floor to summit is ca. 2000 m. Dashed red line marks unconformity between Stuhini Group and overlying Hazelton Group. **b)** Schematic section. **c)** Angular unconformity between Stuhini Group mafic tuff and overlying matrix-supported conglomerate of the Hazelton Group, Billygoat bowl. Angular fragments of the immediately subjacent, weakly foliated, dark green Stuhini mafic tuff are incorporated in the conglomerate together with greywacke and laminated volcanic mudstone clasts from elsewhere in the Stuhini Group. 381979 E, 6278421 N.

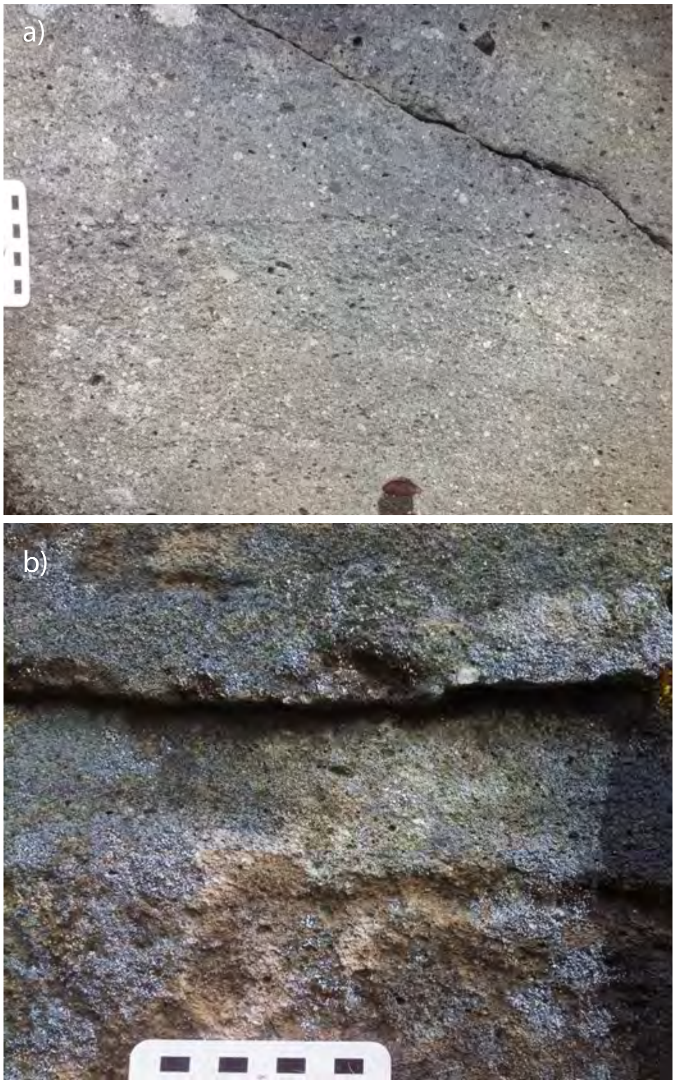

Fig. 5. Stuhini Group. **a)** Uppermost Stuhini polymictic pebbly granulestone, western Snippaker Ridge. Most pale-coloured clasts are of high-level intrusive origin. Dark clasts are basalt. 376110 E, 6281460 N. **b)** Tuffaceous greywacke. Scale in cm.

contains well-rounded pyroxene-bearing clasts, that transitions to a unit of conglomerate in which diverse clast types float in a volcanic wacke matrix. The base of this epiclastic succession is an important local exploration guide, because gold-silver and zinc mineralization tends to focus along it (Jim Oliver personal communication, 2014).

3.2. Hazelton Group

3.2.1. Snippaker unit (new informal name)

In previous studies, siliciclastic rocks of Upper Norian age at high elevations on Snippaker Ridge were assigned to the Stuhini Group, based on the concept that the Stuhini-Hazelton contact should be placed at the Triassic-Jurassic (ca. 201 Ma; International Commission on Stratigraphy, 2014) boundary (Tipper and Richards, 1976). A revision is suggested here, because these strata lie unconformably above the Stuhini Group and display a different sedimentary style. We consider them to be the lowest unit of the Hazelton Group, and introduce the name 'Snippaker unit' to differentiate them from volcaniclastic rocks higher in the Hazelton section. The base of the Snippaker unit is a mildly angular unconformable surface that forms a slight bench in the cliffs on the north side of the ridge and corresponds to a distinct colour change, from dull-toned Stuhini Group rocks to bright orange rocks of the Snippaker unit (Fig. 4a). Bedding in the underlying Stuhini Group is truncated along the unconformity,

The Snippaker unit is a siliclastic succession, approximately 90 m thick, that includes conglomerate, arkose, siltstone, laminated argillite and locally, limestone with Upper Norian fauna (Fig. 4b). Iron carbonate cement weathers orange, in strong contrast to the grey-green of the underlying volcanosedimentary Stuhini Group. The thickest and most distinctive beds of the unit are polymictic conglomerates containing decimetre- to metre-scale arkosic sandstone lenses and beds. (Fig. 6). The conglomerates contain well-rounded clasts (30-80%) in an arkosic matrix. Clast types include felsic and intermediate plagioclase-phyric intrusive rocks, aphanitic quartz, grey and dark grey chert, weak to moderate QSP-replaced tonalite, argillite, fossiliferous limestone, and rare woody debris. A fossiliferous limestone olistolith containing Upper Norian corals, brachiopods, gastropods, sponges, and ammonites occurs within the conglomerate. Mudstone-siltstone intervals with minor interbedded iron carbonate-cemented sandstone and conglomerate occur near the base and top of the Snippaker unit. Minor crystal ash tuff and at least one basalt breccia also occur within this unit; they share the typical orange-weathering iron carbonate cement.

3.2.2. Lower Jurassic volcaniclastic unit

The sub-volcaniclastic unit (ca. 193 Ma, Lewis et al., 2001) unconformity bevels into the Snippaker unit (Fig. 3), although locally the contact is paraconformable. At Billygoat bowl six kilometers southeast of Snippaker Ridge (Fig. 3), the basal conglomerate of the volcaniclastic unit lies in direct contact with Stuhini group rocks, above an angular unconformity (Fig. 4c). At the Inel prospect (Fig. 3), mafic crystal tuffs and fragmental rocks overlie Stuhini Group rocks along an unconformity that is locally marked by a zone of ankerite-rich alteration (Jim Oliver, personal communication, 2014).

At Snippaker Peak, the volcaniclastic unit consists of dacite and andesite flows and related pyroclastic breccias. Two kilometers east of Snippaker Peak, it comprises polymictic boulder, cobble and pebble conglomerate, interbedded polylithic tuff breccias, and greywacke. Conglomerate units contain 70% rounded to angular clasts including fine-grained mafic and intermediate volcanic rocks and intermediate to felsic crowded plagioclase-phyric intrusive rocks in a litharenite matrix (Figs. 7, 8). Above the basal conglomerate at Billygoat bowl, the sequence consists mainly of pale maroon ash-lapilli tuffs with sparse clasts of intermediate intrusive rocks, aphanitic quartz, and fine-grained mafic volcanic rocks.

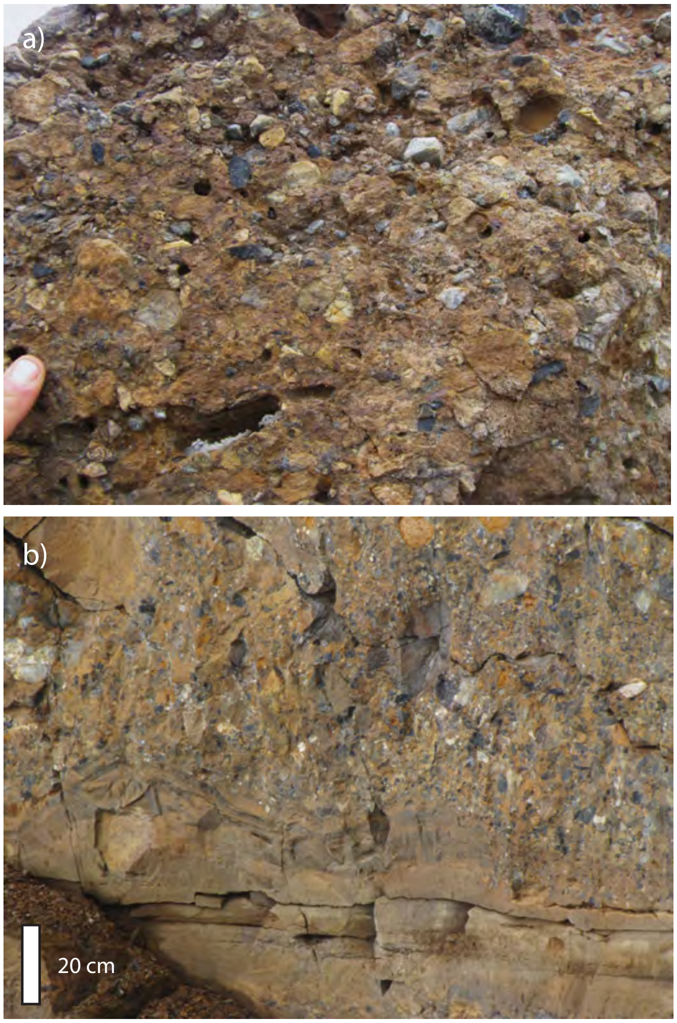

Fig. 6. Hazelton Group, Snippaker unit. **a)** Polymictic framework-intact conglomerate. Light clasts are felsic to intermediate high-level intrusive and silicified rocks; dark clasts are chert. Weathered-out clasts are limestone. 377358 E, 6281369 N. **b)** Polymictic pebbly conglomerate layer, with local ankeritic cement, cut into underlying sandstones.

3.2.3. Lehto plutonic suite on Snippaker Ridge

Most of the peaks on Snippaker Ridge are underlain by small elliptical hypabyssal intrusive bodies, with long axes less than 0.5 km, of coherent diorite, quartz diorite and monzodiorite (Fig. 3). The bodies are generally porphyritic, and contain plagioclase, hornblende and lesser potassium feldspar phenocrysts. Intrusive phases intermingle with surrounding volcaniclastic units: contacts are locally defined by transition zones in which coherent, crowded plagioclase-phyric intrusions pass into mixed zones where they are cut by, and grade into, intrusive breccias, and then into polymictic, crudely bedded breccias that appear to be volcaniclastic. Dikes up to 3 m wide intrude the surrounding Hazelton volcanic units. Due to their shapes and contact relationships, the elliptical bodies are interpreted to be the remains of volcanic pipes that fed the volcaniclastic unit on Snippaker Ridge. They are part of the Lehto suite, and represent the highest subvolcanic level of intrusion.

Fig. 7. Hazelton Group volcaniclastic unit polymictic pebble-cobble conglomerate, Billygoat bowl. The pinkish felsic intrusive clasts are texturally similar to the small plugs on top of Snippaker Ridge, which are interpreted as feeders to the volcaniclastic sequence. 381430 E, 6280469 N.

Fig. 8. Hazelton Group volcaniclasitic unit at Billygoat bowl. Interbedded polymictic conglomerate and pebbly sandstone with local carbonate cement.

3.2.4. Hazelton Group stratigraphy and synvolcanic intrusion on Mt. Johnny

3.2.4.1. Basal conglomerate south of Mt. Johnny

A remarkable section of coarse conglomeratic rocks is exposed in extensive, recently deglaciated outcrops in the valley below the south side of Mt. Johnny (Fig. 3). The unit has an observed thickness of over 200 m near the toe of the glacier, and probably extends many hundreds of metres on Mt. Johnny above and below treeline to the west. It consists mainly of sharp-based boulder-cobble conglomerate and breccia in beds 5-25 m thick. Sorting is poor, and angular to subangular clasts float in a matrix of sand, mud and locally, minor carbonate. Some beds show crude grading. The unit also includes rare thin lenses of framework-intact pebble-cobble conglomerates containing rounded clasts (Fig. 9a), and sandstones with local

Fig. 9. Hazelton conglomeratic unit south of Mt. Johnny. **a)** Polymictic conglomerate containing andesite, hypabyssal intrusive, chert and minor limestone clasts. **b)** Coral-head clast in monomictic breccia of fossiliferous limestone. 373839 E, 6275103 N.

cross stratification.

Nested coarse conglomeratic lenses contain markedly different clast populations. Clast types include felsic to intermediate hypabyssal intrusive rocks, andesite, basalt, limestone, coral, vein quartz, chert, intraformational sandstone and siltstone, QSP-altered rocks, and brecciated intrusive rock. Most beds contain a diverse clast suite, but some consist mostly of one clast type. A striking example is a conglomerate containing wispy-shaped coral fragments that are supported in a micritic matrix (Fig. 9b); clast shapes imply fragmentation before complete induration. This bed lies between layers of polymictic, matrix-supported boulder conglomerate containing andesite and hypabyssal intrusive clasts and a single green (Paleozoic?) chert block three metres across.

Thirty metres downsection from the coral clast-bearing conglomerate is a nearly monomictic, matrix-supported boulder conglomerate that contains clasts up to 3 m in diameter that were derived from a brecciated plagioclase-phyric diorite. Internal breccia textures vary from clasts with a jig-saw-fit, to clasts that are slightly rotated, to clasts that are isolated; hairline fractures and breccia fragments are cemented by grey cryptocrystalline silica with clay and silt impurities (Fig. 10). White quartz veins cut across the both fragments and cement in one breccia clast (Fig. 10b) indicating that the breccia from which the clast was derived was indurated sufficiently to maintain fractures. However, some clasts display jagged rentrants (Fig. 10a), and some of the larger clasts are surrounded by swarms of small fragments in zones that transition from intact breccia to a clast-dense periphery to trains of centimeter-scale angular fragments, suggesting that induration was inadequate in some of the source breccia to prevent clasts from dismembering during transport. We interpret that the clasts were derived from variably cemented fault breccias that originated due to movement along a shallow-level brittle fault. Angular, metre-scale, matrix-supported clasts consisting almost entirely of probable fault breccia imply that the unit records near-source mass flow sedimentation, likely from collapse of a syndepositional fault scarp.

A bifurcating polymictic clastic dike, 10 cm to >1 m wide, with subrounded clasts floating in a mudstone matrix, cuts sharply through a ca.15 m thick layer of clast-poor, matrix-supported andesite block breccia (Fig. 11). Its clast population differs from the surrounding unit in that it contains both volcanic and laminated sandstone-siltstone intraclasts. The excess pore pressures that lead to fluidization of unconsolidated sediment and injection of conglomeratic dikes are most commonly generated by seismic events (e.g., Jolly and Lonergan, 2002) consistent with the idea of synsedimentary faulting.

In summary, the Mount Johnny conglomerates record repeated mass flows that were derived from diverse sources, including high-level intrusive bodies, carbonate bodies, chert, volcanic rocks and, significantly, fault breccia. The thickness of the conglomeratic section (200 m minimum), the thickness of individual depositional units (5-25 m), and extremely large (up to 3 m) angular clasts point to near-source sedimentation and significant relief. This relief was likely generated and maintained by syndepositional faulting, such as is evident in the beds containing clasts of fault-brecciated diorite. It remains unclear if the Mount Johnny conglomerates are equivalent to the Snippaker unit or to the basal conglomerates at the Billygoat bowl section. We collected samples for detrital zircon geochronology to determine the maximum age of deposition.

3.2.4.2. Lower Jurassic Hazelton volcanic sequence and pluton, upper Mt. Johnny

The upper slopes of Mt. Johnny are underlain by a felsic volcaniclastic sequence of lapilli tuffs and tuff breccias, with one thick bed of coherent rhyolite or dacite that has yielded a ca. 194 Ma U-Pb zircon age (Fig. 3; Lewis et al., 2001). The tuffs contain a range of felsic clast types, including angular white coherent dacite and green lithic fragments, flattened lapilli, and crowded feldspar-phyric hypabyssal intrusive and propylitically altered rocks, in a fine crystal-ash matrix. On the upper southern slope of Mt. Johnny the felsic volcaniclastic section is cut by a strongly altered microtonalite body 1 by 2 kilometres across

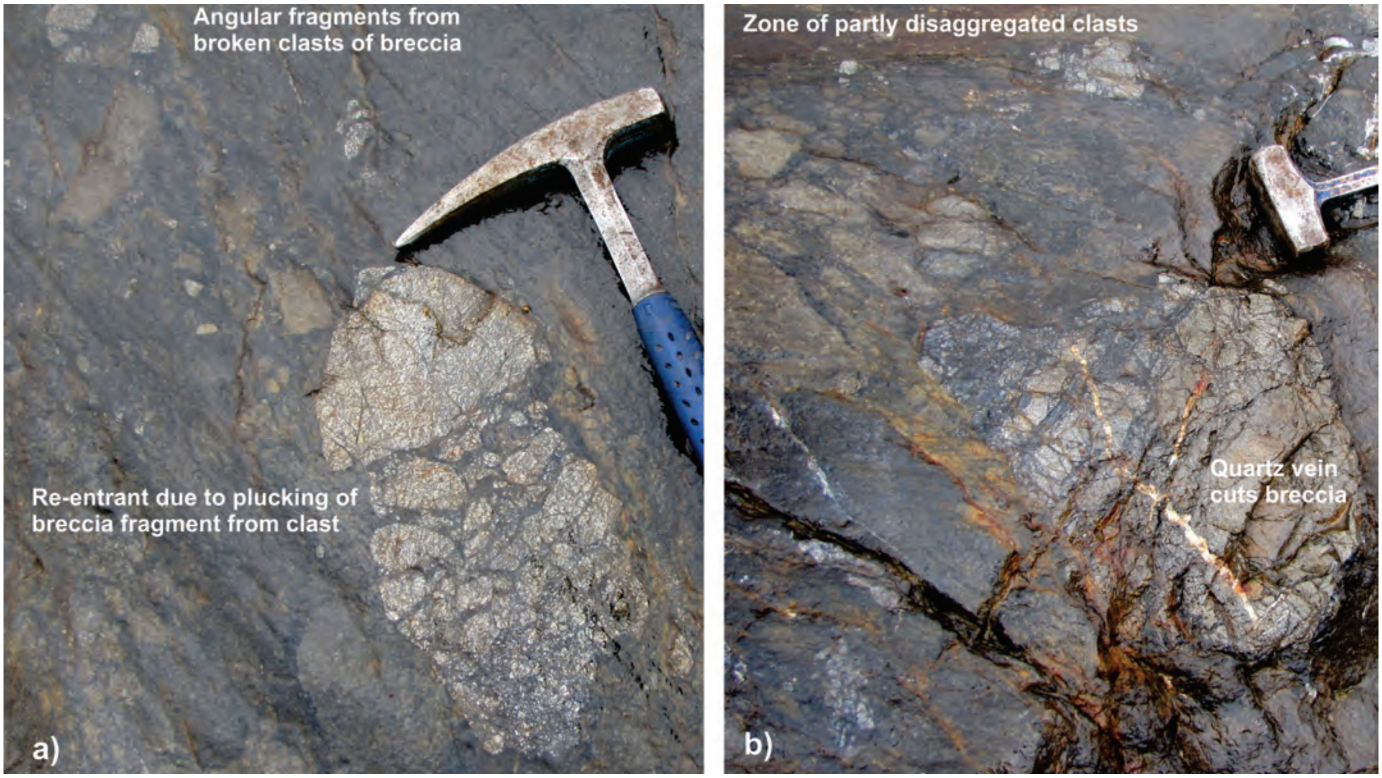

Fig. 10. a) Clast of cataclastically brecciated porphyritic diorite, healed with dark silica. **b)** Clast of brecciated porphyritic diorite, with post-brecciation but pre-sedimentation quartz veins. Note irregular shape of clast; stronger unbrecciated diorite resists mechanical breakage. Top centre shows incipient breakage of breccia clasts. 373844 E, 6275046 N.

Fig. 11. Margin of polymictic pebble dike in foreground cutting brown-weathering conglomerate. Note sandstone-siltstone intraclast. 373801 E, 6275016 N.

that has not been recognized in previous mapping (Fig. 3). Moderate to strong QSP alteration is pervasive. Hydrothermal and intrusive breccias in and around the body host broad areas of silicification and quartz stockwork veins that contain rare fine-grained visible gold and a show weak, patchy malachite stains on fractures. This body may have been an intrusive feeder to the surrounding felsic volcaniclastic edifice, given the presence of hypabyssal and altered clasts in some of the units. It may be coeval with a ca. 192 Ma plagioclase-phyric dike near the Johnny Mtn. mine portal, which is interpreted as a subvolcanic equivalent to the volcaniclastics and flows (Lewis et al., 2001).

South of Mt. Johnny, the volcaniclastic sequence is underlain by coarse conglomerates. Although contact relationships are obscured by deformation and thick vegetation cover, interlayering of rocks with diagnostic volcaniclastic textures and conglomerates indicate a transitional, albeit faulted, boundary. North and west of the Johnny Mtn. mine, the conglomeratic unit is missing and the felsic volcaniclastic unit directly overlies thinly-bedded mudstone and greywacke of the Stuhini Group.

4. The Sky fault system

Our structural study focused on the southwestern margin of intense quartz-sericite-pyrite alteration, intrusion, and mineralization along the Bronson corridor (Fig. 2, Alldrick et al., 1990). We refer to this margin as the Sky fault system, following informal usage for strands near Mt. Johnny (Fig. 3; Rhys, 1995). The system includes significant normal and reverse structures. Near its southeastern extent, on Pins Ridge (Fig. 3), most strands show normal-sense motion except for one short reverse section (Fig. 12). To the northwest, between Sericite Ridge and Khyber Pass, reverse strands become more important.

Fig. 12. View of the Sky fault system cutting Stuhini Group rocks on Pins Ridge, looking southeast from Lake Ridge (see Fig. 3 for location). Steeply northeast-dipping normal-sense shear zones (yellow) on higher part of the ridge separate panels with low-angle normal shear zones. A single thrust fault (red) forms the hanging wall of strong quartz-sericite-pyrite alteration in 'Pins bowl'.

4.1. Pins Ridge

The Pins Ridge segment of the Sky fault system is over 1 km wide (Figs. 3, 12). On its southwest margin, a normal fault cuts upper greenschist facies-grade Stuhini Group volcanic breccias in which pyroxenes are replaced by coarse crystalline actinolite. To the northeast, within the fault zone, consistent C-S kinematic indicators on chlorite shears document normal-sense, northeast-side-down displacement. The absence of actinolite neoblasts may indicate that the shearing occurred during retrograde, lower-temperature metamorphism. A plagioclase-phyric dike crosscuts the shear fabric along an argillite-basalt breccia contact, but is locally sheared along its margins, indicating that it was emplaced late in the shearing event (Figs. 13a, b). It has been sampled for uranium-lead zircon geochronology. The concentration of Lehto suite intrusive rocks increases toward the northeast, with accompanying hornfelsing of Stuhini volcaniclastic rocks. Locally, epidote fills veins and replaces phenocrysts in Lehto suite rocks, including hornblende diorite dikes with epidote-replaced megacrysts of euhedral plagioclase up to 4 cm long and 2 cm wide (Fig. 14). This 'pistachio diorite' also occurs farther west as part of the main Lehto pluton on the Lake Ridge and as dikes on Sericite Ridge. Both quartz-sericite-pyrite alteration zones and normal faults are cut by a late reverse fault of small interpreted displacement that forms the hanging wall of alteration in 'Pins bowl' (Fig. 12).

4.2. Lake Ridge

Northwest of Pins Ridge, reverse faults begin to become more prominent. At Lake Ridge, the Sky fault system narrows to about 700 m (Figs. 3, 15). A reverse fault bounds the southwestern flank of this segment, but the northeast fault block displays C-S fabrics indicating normal movement. Strain is distributed; gently dipping zones of intense fabrics are separated by 100 metre-scale panels of less deformed rock. The zones of strong flattening focus pyrite-epidote and lesser quartz-sericite-pyrite alteration and dike emplacement. This demonstrates that the normal-sense distributed shear system was in existence prior to, and at least in part controlled, intrusion of the Lehto suite and accompanying mineralization.

4.3. Sericite Ridge

At Sericite Ridge, the Sky fault system narrows to less than 400 m (Fig. 3). Reverse faults overprint earlier normal structures and fabrics. This is the most southeasterly occurrence of a north-vergent reverse fault in the immediate hanging wall of strong quartz-sericite-pyrite alteration. The hanging wall of the gently southwest-dipping (123/20°) reverse fault is marked by strong chlorite-silica-pyrite-replaced volcaniclastic rock (Fig. 16). Approximately 100 m into the footwall, hornblende diorite, plagioclase porphyry diorite and aplite dikes are cut by curviplanar brittle shears of widely varying orientations with slickenfibres and zones of cataclasite. These features mark a distributed brittle fault zone that post-dates intrusion and alteration. Farther to the northeast, normal-sense fabrics are preserved locally in QSP-chlorite-replaced Stuhini volcaniclastic rocks. A swarm of intersecting west-northwesterly dikes of Lehto suite 'pistachio diorite' and other plagioclase-phyric phases cuts QSP- and propylitically altered rock. North of the Sky fault system, the remainder of the northeast-trending Sericite Ridge shows strong pervasive QSP

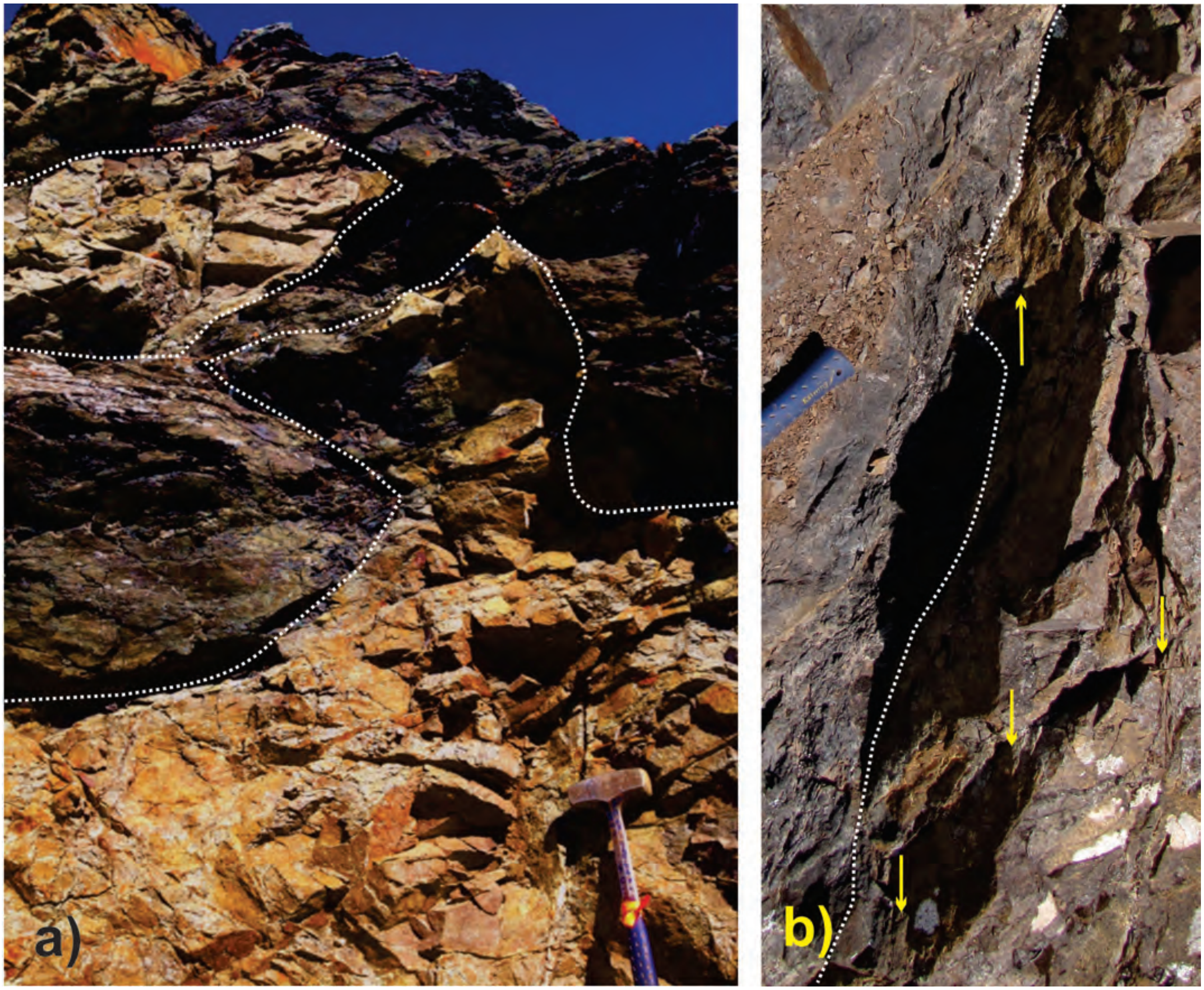

Fig. 13. a) Plagioclase-phyric dike intruding normal-sense shear zone that separates argillite from volcaniclastic protolith, Stuhini Group, upper Pins Ridge. Dike apophyses cut across hanging wall and foot wall. **b)** Close-up of dike margin to show internal weak, sporadic shear fabric (arrows). 388175 E, 6265759 N.

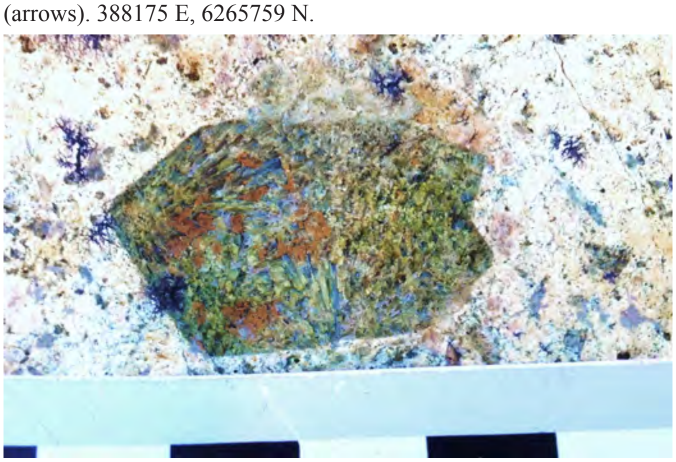

Fig. 14. Plagioclase megacryst replaced by radiating crystalline epidote, the 'pistachio diorite' phase of the Lehto pluton, Pins Ridge. Identical textures also occur in the main body of the pluton on Lake Ridge, and on Sericite Ridge and Pyramid. Scale in cm. 389715 E, 6266563 N.

alteration (Fig. 3). This zone parallels the northwestern contact of the main Lehto pluton.

4.4. Pyramid Ridge

At Pyramid Ridge, northwest of Sericite Ridge, the Sky fault system further narrows to about 200 m. The Khyber reverse fault (143/70°) outcrops as a planar surface separating strongly QSP-replaced rock in the footwall from hornfelsed, siliceous volcanic rocks and meta-chert in the hanging wall (Fig. 17). The hanging wall rocks are unlike any others observed in the area. They display strong pervasive silica replacement and patchy red-brown biotite hornfels, and likely represent volcaniclastic protoliths overprinted by regional and contact metamorphism. Unlike other zones of hornfelsed volcanic rocks, primary features beyond centimeter-scale layering are lacking. The most distinctive textural variant is a matrix-supported breccia with angular clasts of aphanitic quartz (Fig. 18). These hanging

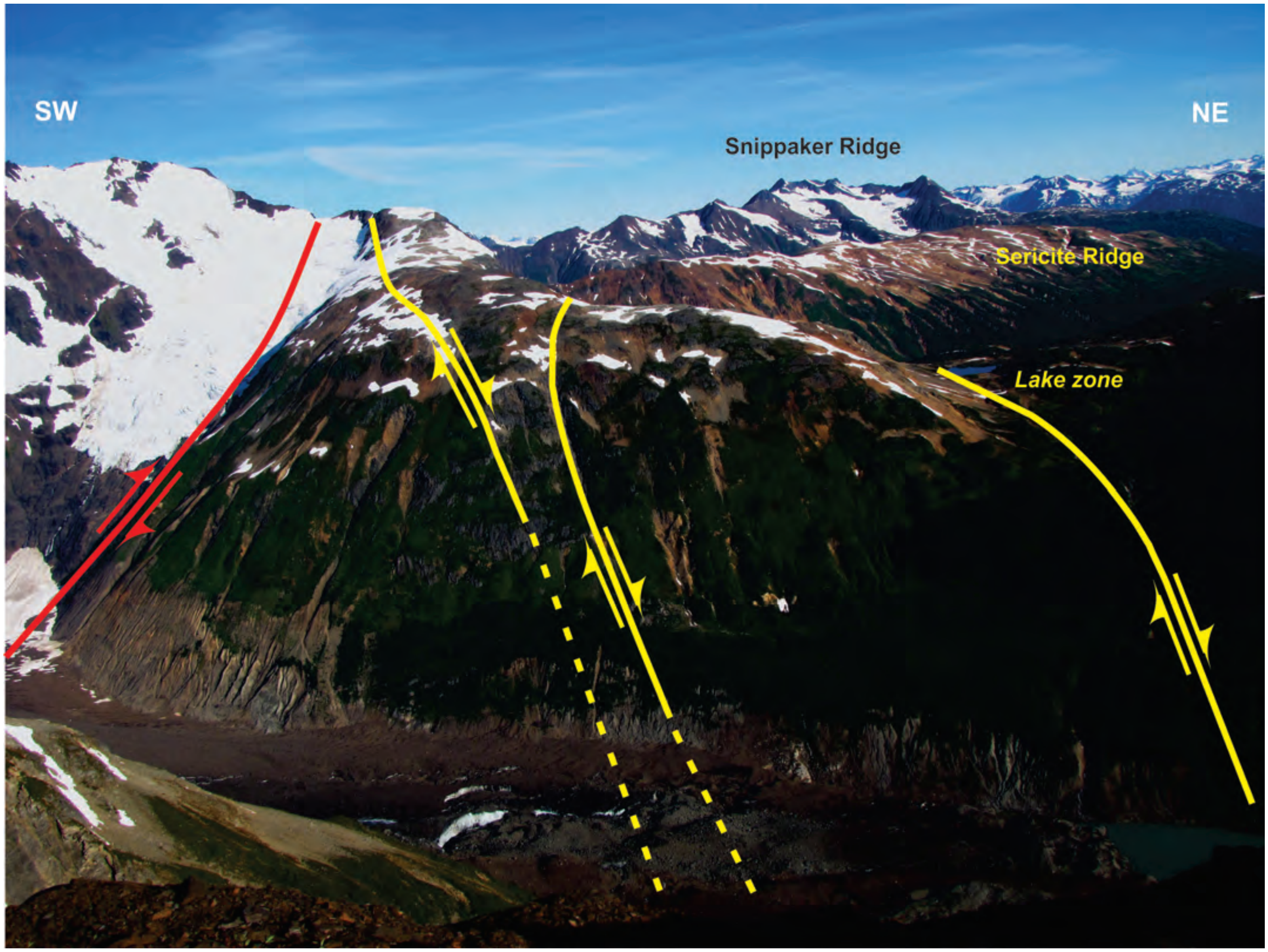

Fig. 15. Lake Ridge area, looking northwest from Pins Ridge (see Fig. 3 for location). Inferred thrust fault through glacier joins Khyber fault to west. Sericite Ridge in background.

Fig. 16. Sheared, chlorite-sericite-quartz-pyrite-altered rock in Khyber fault zone, Sericite Ridge. Scale in cm. 384023 E, 6269865 N.

wall rocks may have been derived from the Stuhini Group or the Stikine assemblage (Paleozoic).

4.5. Khyber Pass, Inel and the Boundary-Billygoat fault system

At Khyber Pass, about 1.5 km to the northwest, the Khyber fault (140/40°) truncates the northeast-trending (045-060°), southeast-dipping (75-85°) Boundary-Billygoat fault (Fig. 3; Jim Oliver personal communication, 2014). This fault divides the Khyber from the Inel prospects and appears to have exerted control on intrusion and mineralization. The Boundary fault zone hosts a concentration of fine-grained mafic sills and dikes, and dense quartz-chlorite-sulphide stockworks and sheeted veins with gold-silver-zinc mineralization. The number and volume of intrusive bodies and the intensity of alteration and mineralization increase toward the Sky fault system and Khyber reverse fault (Jim Oliver personal communication, 2014). Dikes in the immediate footwall of the Sky fault system are sub-parallel to it. Many intrusive rocks are strongly altered and occur with strong copper and gold mineralized zones. Gold is commonly identified along the margins of orthoclase-phyric dikes and in sheeted quartz veins in larger dioritic intrusions.

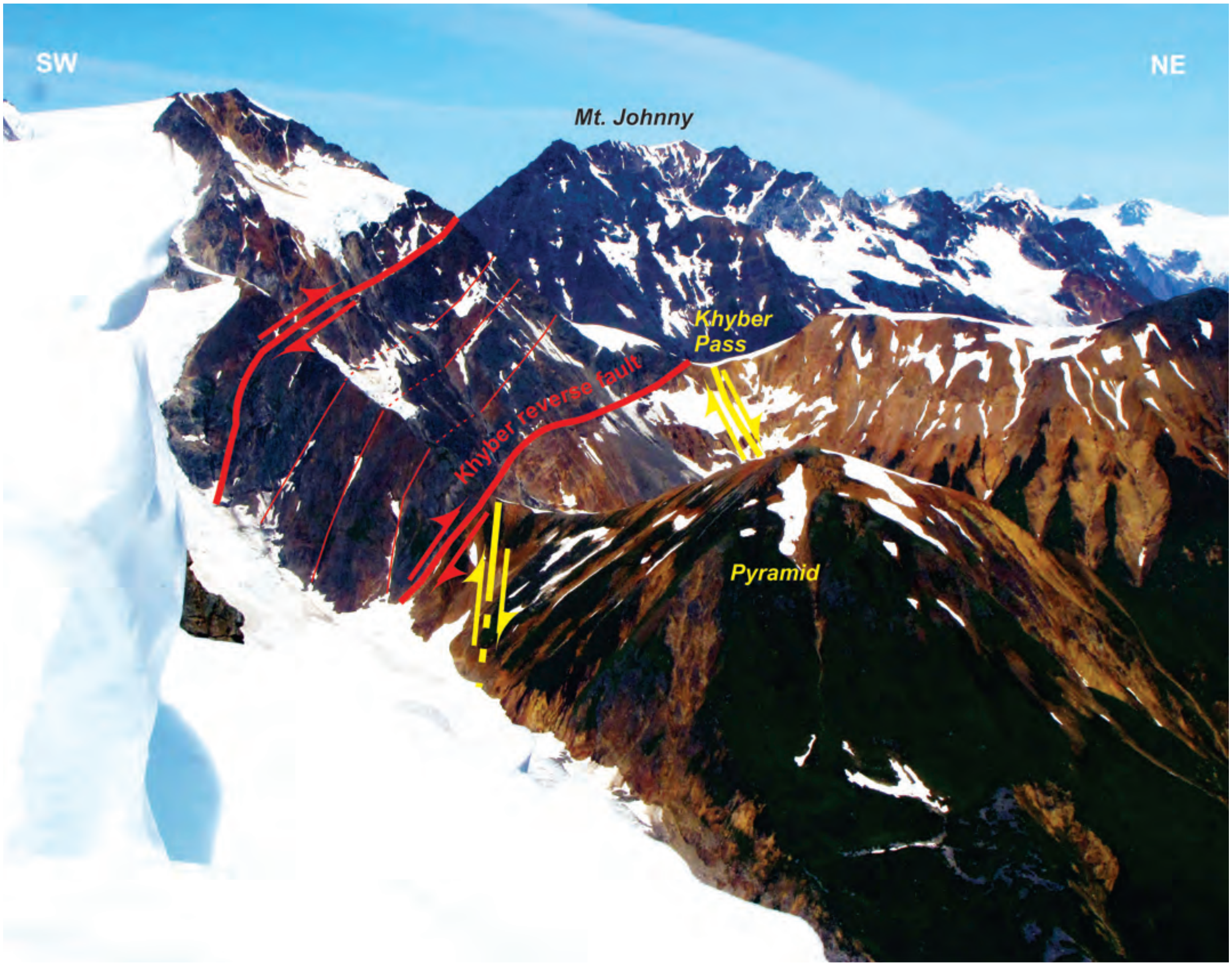

Fig. 17. The Sky fault system in the Pyramid-Khyber Pass area from the southeast (see Fig. 3 for location). The Khyber reverse fault marks the hanging wall of strong quartz-sericite-pyrite alteration. Structural form lines are shown in the hanging wall. Normal-sense faults in the footwall are truncated by the Khyber fault.

Fig. 18. Breccia with aphanitic quartz clasts in the hanging wall of the Khyber fault at Pyramid Ridge. Scale in cm. 379818 E, 6272105 N.

The Boundary fault is offset by the Inel fault, and continues as a well-defined structure, the Billygoat fault, at least 8 kilometres to the northeast. On the ridge south of Billygoat bowl, the fault zone is occupied by a swarm of Lehto dikes, gabbros, monzonites, 'pistachio diorites' and aplites. Stuhini Group wall rocks are propylitically altered with patchy epidote and pyrite. The structural block immediately southeast of the fault has been tilted to a steep, northeasterly orientation parallel to the fault trace, as shown by the distribution of Stuhini layered units (Fig. 3 and Lewis, 2013). Presence of Lehto-suite dikes indicates that the Boundary-Billygoat faults, like the Sky fault, were active in Early Jurassic time.

4.6. South of Mt. Johnny

The Sky fault system is well exposed at recently deglaciated outcrops on the south side of Mt. Johnny (Fig. 3), where it is expressed as a 400 m wide zone of penetrative foliation and anastomosing mylonites developed in coarse conglomerates of the lower Hazelton Group. In one instance, a dextral sense of shear on a foliation of 315/64° is shown in deformed conglomerate (Fig. 19a). The conglomerates also display down-dip stretching lineations but lack macroscopic kinematic indicators. Nearby, a set of sigmoidal quartz veins indicates dextral displacement toward 280°. Alteration intensity is greatest in the most strained rocks. Most pervasive replacements include well-foliated red-brown, fine-grained biotite and green chlorite, and clots of pyrite. Alteration styles include matrix replacement, clast replacement, vein selvages, and fracture fills. Quartz ± carbonate ± pyrite veins up to 5 cm wide are common throughout; they have been affected by both ductile and brittle deformation.

Several plagioclase-phyric dikes up to 3 m wide crosscut and also intrude along the shear-related fabrics. Dike margins are typically irregular on centimeter as well as metre scales (Fig. 19b). One dike displays a weak subsolidus fabric defined by foliated chlorite, suggesting late synkinematic emplacement. We collected a geochronological sample of this dike to establish the time of faulting.

The felsic volcanic units on upper Johnny Mountain contain a gently dipping penetrative flattening fabric that parallels compositional layering and the basal contact of the sequence. Lineations plunge gently to the WNW; they are parallel to the axes of upright folds mapped in the underlying Stuhini Group (Lewis, 2013). The origin of the layer-parallel fabric is unclear, given that faults and fabrics elsewhere tend to be steep. Kinematic indicators were not recognized.

Fig. 19. a) Mylonitic zone in conglomerate, sigma porphyroclasts show dextral sense of shear; one possible delta clast indicated. 373851 E / 6275019 N; **b)** Quartz-feldspar porphyry dike (bottom) cutting well-foliated conglomerate. Note irregular, non-planar margin indicated by white arrow. 373530 E, 6274904 N.

5. Discussion

5.1. Hazelton Group stratigraphy and Hazelton-Stuhini relationships

The sedimentary succession at Snippaker Ridge records the termination of volcaniclastic sedimentation related to the Stuhini arc, erosional unroofing of Stuhini Group rocks, and subsequent Hazelton arc volcanism. We place the sub-Hazelton Group unconformity beneath the Snippaker unit, which includes Upper Norian fauna, in contrast to Tipper and Richards (1976) who separated the Stuhini and Hazelton groups chronostratigraphically, at the ca. 201 Ma Jurassic-Triassic boundary. This revision is consistent with examples of Late Triassic lower Hazelton rocks elsewhere in Stikinia. The oldest Hazelton unit in the Spatzizi area is the ca. 206 Ma Griffith Creek volcanics, which overlie a conglomerate containing Triassic and Permian limestone clasts (Thorkelson et al., 1995). Upper Norian fossil fauna were reported from above the basal Hazelton unconformity at Kinskuch Lake near Kitsault (Cordey et al., 1992), and near Terrace, the base of the Telkwa Formation is ca. 205 Ma old (Barresi et al., in press). The onset of deposition of basal Hazelton rocks above the unconformity seems to have varied not only across western Stikinia, but also on a more local scale. On the flanks of the McTagg anticlinorium about 40 km east of the Bronson area (Fig. 2), Lower Jurassic (201-191 Ma; Hettangian-Sinemurian) conglomeratic rocks of the Jack Formation unconformably overlie the Stuhini Group (Nelson and Kyba, 2014). Cessation of Stuhini volcanism was followed by the creation of a landscape of highlands and basins. Onset of Hazelton deposition and volcanism varied throughout the terrane, in response to local topography and magma sources.

The second unconformity observed at Billygoat bowl and elsewhere on Snippaker Ridge indicates the onset of Early Jurassic volcanism. This episode is likely co-magmatic with the ca. 193 Ma Lehto plutonic suite and coeval with the nearby copper-gold porphyry intrusions at Kerr-Sulphurets-Mitchell-Iron Cap (Fig. 2). The Lehto plutonic suite appears to have been the thermal driver for mineralization observed in the Bronson corridor, as indicated by the close spatial association of intrusions, alteration zones and mineralization; the occurrence of intrusive-hosted veins at Inel; the Red Bluff porphyry occurrence; and an Early Jurassic lead isotopic model age

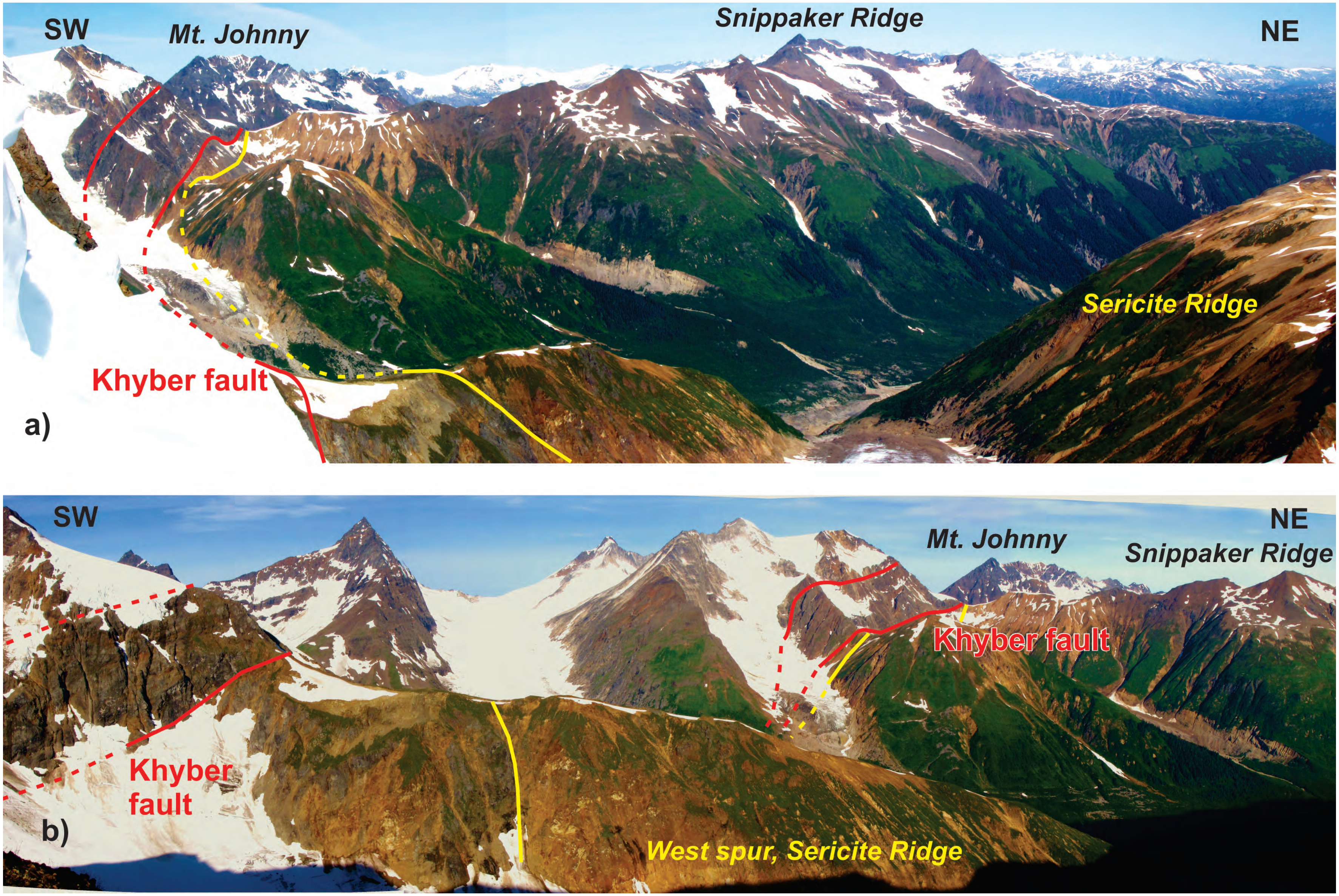

Fig. 20. a) View of Sky fault and Snippaker Ridge from Sericite Ridge (See Fig. 3 for location); **b)** Looking northwest from top of Sericite Ridge along Sky fault toward Pyramid and Khyber Pass. Shows continuity of Khyber fault from Khyber Pass to Sericite Ridge.

from the Snip mine (Rhys, 1995). The configuration of nested unconformities and related intrusive systems is analogous to that observed at the porphyry-hosting Tampakan stratavolcanic complex in the Philippines (Rohrlach, 2002).

5.2. The Sky fault system: influence on Early Jurassic intrusion, alteration and mineralization

Our analysis of the Sky fault system suggests that the Bronson corridor of alteration and mineralization (Metcalfe and Moors, 1992) was controlled by regional structures. Normal faulting, emplacement of Lehto intrusive rocks, and alteration appear to be genetically related, as indicated by synkinematic dikes (Fig. 13) and the increased intensity of QSP alteration, polymetallic mineralization, and dike density at the Inel and Khyber prospects toward the Sky fault system. South of Mt. Johnny, the coarse mass-flow conglomerate section of the basal Hazelton Group coincides with the Sky fault trace. It reflects local steep topography; the presence of healed fault-breccia fragments as predominant clasts in one of the deposits suggests relief along penecontemporaneous fault scarps.

In this study, we have observed many instances of normal-sense motion on strands of the Sky fault system. However, the stress regime during the Early Jurassic may not have been purely extensional. There is limited evidence of dextral-sense motion on the Sky fault south of Mt. Johnny. Detailed underground structural study of the Snip vein showed that it formed during normal-oblique (dextral) motion on the minor west-northwesterly, southeast-dipping fault zone that hosts it (Rhys, 1995). Northeasterly faults and trends of intrusions and alteration zones are an important feature of the Bronson corridor. These include the Boundary-Billygoat fault, the Lehto pluton, and the 4 kilometre-wide zone of QSP alteration on Sericite Ridge that parallels the western margin of the pluton for 10 kilometres. All are truncated against the Sky fault system. The exploitation of northeasterly structures by intrusions is consistent with Early Jurassic northwest-southeast extension along the axis of the Bronson trend coeval with faulting along its southern margin. Thus, there may have been a transcurrent component in the fault regime.

Part of the Sky fault system was reactivated as a set of reverse faults after emplacement of the Lehto plutonic suite and associated alteration. Reverse fault movement increases in importance along strike from southeast to northwest. At Pins and Lake ridges, reverse faulting is limited, but northwest of Sericite Ridge, displacement on the Khyber reverse strand increases. At Pyramid and Khyber Pass the Khyber fault is a single southwesterly, steeply-dipping surface that separates strongly QSP altered rocks in the footwall from greenschist grade rocks in the hanging wall (Figs. 20a, b). The southeastern tip-line of the Khyber reverse fault is close to Sericite Ridge and the southeastern limit of broad-scale QSP alteration that extends from Sericite Ridge through Pyramid and Khyber Pass (Fig. 3). We consider that the mechanically weakened, clay-sericite-rich altered rocks provided convenient glide surfaces for thrust reactivation during regional shortening. The only limit we have on the timing of thrust reactivation is that it was post-Early Jurassic. Nonetheless, the style of deformation corresponds closely to the Skeena fold and thrust belt in the KSM-Brucejack area. In particular, the Khyber reverse fault closely resembles the Sulphurets thrust fault, with strongly QSP-altered Early Jurassic and older rocks in its footwall and weakly altered Triassic and older strata in its hanging wall (Nelson and Kyba, 2014).

6. Conclusions

The Bronson corridor is prospective for porphyry and related precious metal mineralization as indicated by past production and recent (2014) discoveries. Late Triassic siliciclastic rocks of the Snippaker unit record uplift and erosional unroofing of the Stuhini arc before the main episode of Hazelton Group volcanism. The Lehto pluton, as shown in the Lewis (2013) compilation, is a large, northeast-trending, uniform intrusive body. More detailed observations show a wider diversity of phases, and distribution of Lehto plutonic rocks throughout the belt in small, high-level intrusive centers (e.g., Snippaker Ridge and Mt. Johnny) and as dikes near the Sky fault system. Analysis of the Sky fault system indicates that early normal faults, likely genetically related to alteration, mineralization, and Lehto plutonism, reactivated in a thrust sense during post-Early Jurassic regional shortening. The Sky fault system likely formed close to the boundary of a rift-type basin and enhanced circulation of hydrothermal fluids generated during Lehto suite plutonism to form the deposits of the Bronson corridor. The coeval Early Jurassic Mitchell intrusions, responsible for the KSM deposits, occupy a similar structural position in a basin now in the immediate footwall of the Sulphurets Fault (Nelson and Kyba, 2014).

Acknowledgments

Our understanding of the Khyber-Sericite Ridge-Pins Ridge area benefitted greatly from field interaction with the Colorado Resources exploration team, particularly Jim Oliver, who contributed descriptions of the Khyber Pass-Inel area to this paper. Colorado Resources and Seabridge Resources aided in field logistics. Wes Luck of Fireweed Helicopters provided superb piloting in difficult conditions. We are grateful for Pete Kossey's hospitality at his camp on Bronson strip.

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