Update on bedrock mapping in the Kitsault River area, northwestern British Columbia

Emily A. Miller[1, a], Bram I. van Straaten[1], and Rebecca C. Hunter[1, 2]

[1] British Columbia Geological Survey, Ministry of Energy, Mines and Low Carbon Innovation, Victoria, BC, V8W 9N3
[2] Now at: Forum Energy Metals Corp., Suite 615, 800 West Pender Street, Vancouver, BC, V6C 2V6
[a] corresponding author: Emily.X.Miller@gov.bc.ca

Recommended citation: Miller, E.A., van Straaten, B.I., and Hunter, R.C., 2023. Update on bedrock mapping in the Kitsault River area, northwestern British Columbia. In: Geological Fieldwork 2022, British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey Paper 2023-01, pp. 23-32.

Abstract

The Kitsault River area in northwestern British Columbia hosts Ag-rich volcanogenic massive sulphide (VMS), Au-rich epithermal, and Cu-Au porphyry systems. Resolving the distribution, age, and affinity of prospective Stuhini and Hazelton Group host rocks is key to understanding the metallogeny and mineral potential of the area. Geological mapping of the northeastern portion of the Kitsault River area shows that mafic volcanic and sedimentary rocks of the Stuhini Group (Upper Triassic) are conformably overlain by Hazelton Group rocks (uppermost Triassic to Middle Jurassic). The lower part of the Hazelton Group consists mainly of intermediate volcanic rocks, lesser sedimentary rocks, and rare felsic volcanic rocks of the Betty Creek Formation (uppermost Triassic to Lower Jurassic). In the centre of the map area, the basal Hazelton Group comprises conglomerate and megaconglomerate (with clasts up to 120 m) of the Kinskuch unit (Rhaetian), which record deposition in a local syndepositional fault-bounded basin. The Kinskuch unit is overlain by intermediate volcanic rocks of the Betty Creek Formation. The Kinskuch unit and basal Betty Creek Formation are cut by the Big Bulk stock (latest Triassic), which hosts the coeval Big Bulk porphyry Cu-Au prospect. The upper part of the Hazelton Group (Lower to Middle Jurassic) consists of thin Spatsizi Formation sedimentary rocks that are overlain by intermediate, mafic, and felsic volcanic rocks of the Kitsault unit, which host the Dolly Varden Ag-rich VMS deposits. The Kitsault unit is only found in the northern part of the map area and appears to transition eastward to an unnamed sedimentary unit with common tuff beds. Within northwestern British Columbia, the Kitsault unit is prospective for Dolly Varden-style Ag-rich VMS mineralization.

Keywords: Kitsault River, Stikinia, Hazelton Group, Stuhini Group, Kinskuch unit, Betty Creek Formation, Spatsizi Formation, Kitsault unit, Quock Formation, Bowser Lake Group, Late Triassic, Jurassic, porphyry, VMS, Golden Triangle, silver, gold, copper

1. Introduction

Northwestern British Columbia is host to significant porphyry, epithermal, and volcanogenic massive sulphide (VMS) precious and base metal deposits (Figs. 1, 2), including Schaft Creek, Galore Creek, Red Chris, KSM, Red Mountain, Premier, Snip and Bronson slope. Particularly significant in the metallogeny of the region are latest Triassic to Jurassic volcano-sedimentary rocks of the Hazelton Group and coeval plutonic rocks (Nelson et al., 2013; Logan and Mihalynuk, 2014). Most of the Mesozoic VMS mineralization in Stikinia, including the Eskay Creek and Anyox deposits, is hosted in rift-related rocks of the Iskut River Formation (Lower to Middle Jurassic) in the upper part of the Hazelton Group (Gagnon et al., 2012; Nelson et al., 2013, 2018). Recent geochronological studies in the Kitsault River area have shown that rocks hosting the Dolly Varden VMS deposits are in the upper part of the Hazelton Group and coeval with volcanism in the Eskay rift (Hunter and van Straaten, 2020; Hunter et al., 2022).

As part of a multi-year project, ongoing detailed bedrock mapping in the Kitsault River area is directed at resolving the age and affinity of latest Triassic to Middle Jurassic Hazelton Group rocks and testing regional Hazelton Group correlations. Establishing the stratigraphic, magmatic, structural, and

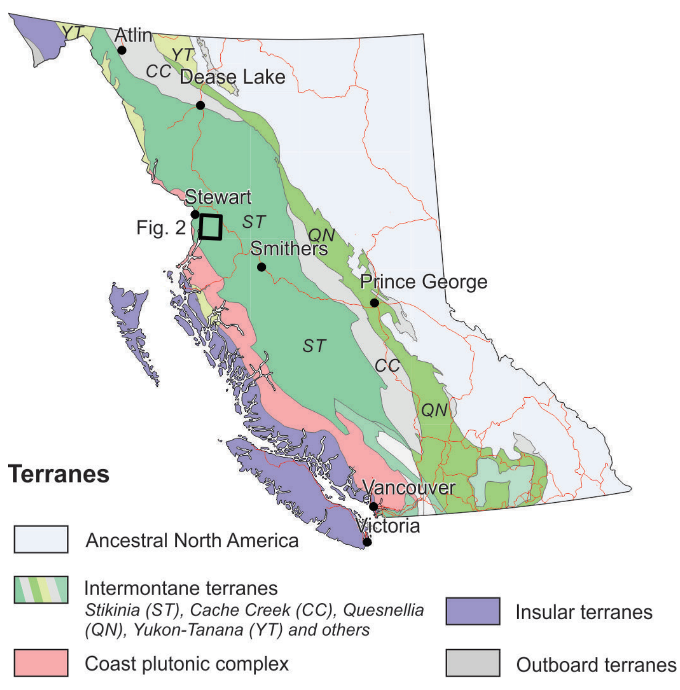

Fig. 1. Location of the Kitsault River area with respect to terranes of British Columbia (after Colpron and Nelson, 2011).

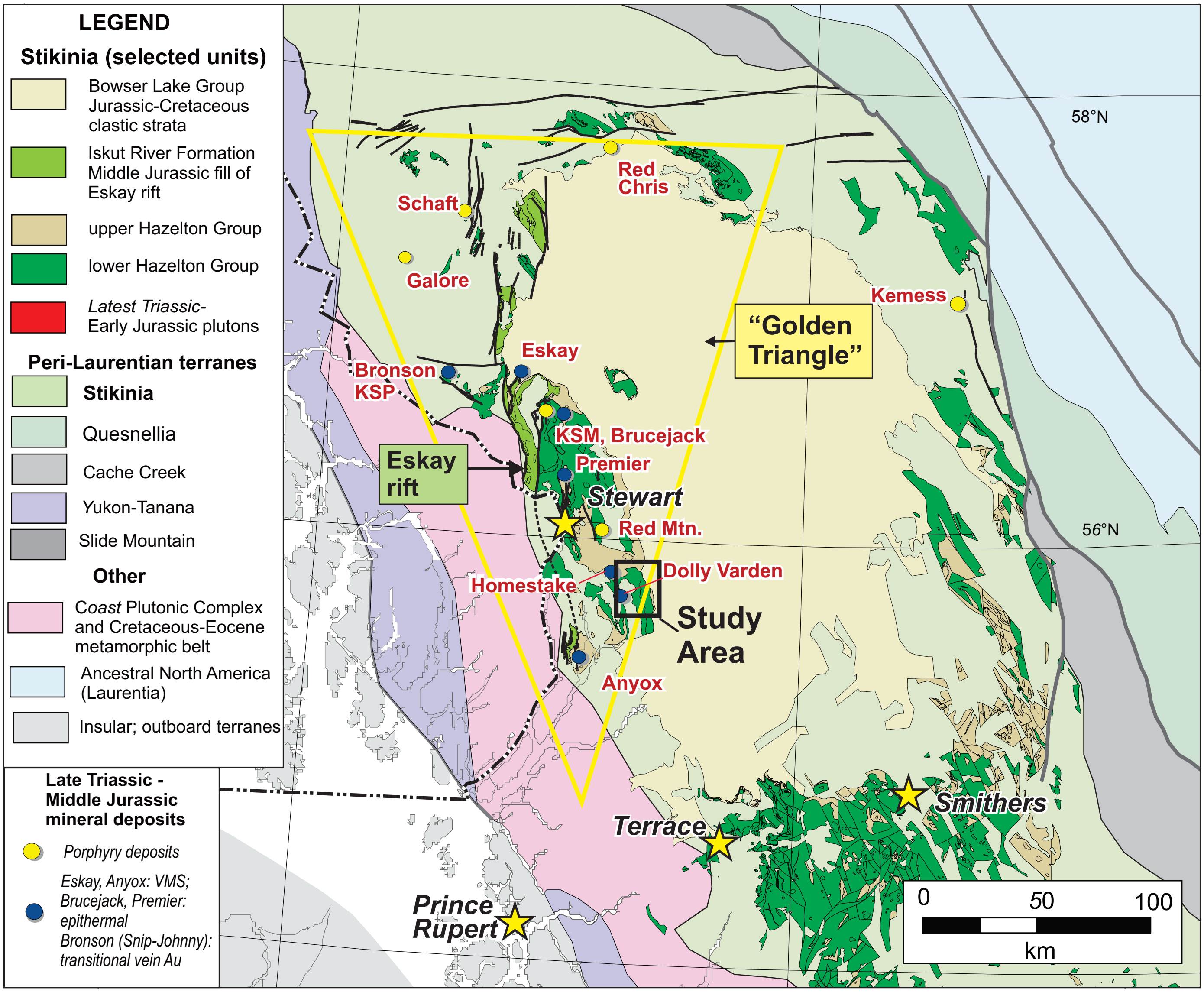

Fig. 2. Regional geological setting (after Alldrick et al., 1986; Greig, 1992; and Colpron and Nelson, 2011), with selected mineral deposits (red dots). After Nelson et al., 2022.

chronological framework of rocks in the Kitsault River area will help in better understanding the distribution of mineral deposits in northwestern British Columbia. Based on fieldwork in 2022, we present a new preliminary map and extended legend of the northeastern part of the Kitsault River area that builds on and incorporates historical mapping by Alldrick et al. (1986), Devlin (1987), Greig et al. (1994), and Evenchick et al. (2008), our previous work (Hunter and van Straaten, 2020; Hunter et al., 2022a, b), detailed mapping of the Kinskuch Lake area (Miller et al., 2020), and property-scale mapping by Dolly Varden Silver Corporation (unpublished data). We recognize a conformable contact between Stuhini Group and overlying Hazelton Group, record the lithological variation in the Hazelton Group, and show that the upper part of the Hazelton Group comprises a local volcanic unit that is prospective for Ag-rich VMS systems.

2. Regional geological and metallogenic setting

The Kitsault River area is along the west-central margin of the Stikine terrane (Stikinia), in the Intermontane belt of the Canadian Cordillera (Fig. 1), in the traditional lands of the Nisga'a, Gitanyow, Tsetsaut Skii Km Lax Ha, and Metlakatla First Nations. It is at the southern end of a region popularly referred to as the 'Golden Triangle', which is a loosely defined area that includes most of the major gold, copper, and silver deposits in west central Stikinia (Fig. 2). The region is underlain primarily by arc-related volcano-sedimentary rocks of the Stuhini Group (Late Triassic) and Hazelton Group (Jurassic), which are overlain by the Bowser Lake Group (Middle Jurassic) in the east and bounded by Eocene intrusions of the Coast Plutonic complex (Nelson et al., 2013) in the west.

The Stuhini Group comprises augite-phyric mafic volcanic rocks and sedimentary rocks that are generally unconformably overlain by the Hazelton Group (e.g., Kyba and Nelson, 2014; Nelson et al., 2018), although in parts of the Kitsault River area the Stuhini to Hazelton Group transition is gradational (see below). Basal rocks in the lower part of the Hazelton Group include sandstones and conglomerates including those of the Jack Formation (Rhaetian to Sinemurian; Nelson et al., 2018) that display evidence of sedimentation controlled by syndepositional faulting (Nelson and Kyba, 2014; Febbo et al., 2019; Miller et al., 2020). These sedimentary rocks are overlain by intermediate volcanic, lesser felsic volcanic and volcanic-derived sedimentary rocks (Rhaetian to Pliensbachian; Betty Creek and Klastline formations; Nelson et al., 2018). The regionally developed Texas Creek plutonic suite (latest Triassic to Early Jurassic) is coeval and comagmatic with volcanic units in the lower part of the Hazelton Group (Nelson et al., 2018). This magmatism is associated with significant latest Triassic to Early Jurassic porphyry copper-gold and related epithermal gold deposits (Fig. 2) including: Red Chris, Red Mountain, Premier, Kerr-Sulphurets-Mitchell-Snowfield-Iron cap and Brucejack. In the Kitsault River map area, the Homestake Ridge deposit (MINFILE 103P 216) is a tabular vein and breccia-hosted Au-Ag-Cu system hosted in Stuhini and Hazelton Group rocks. Mineralization at Homestake Ridge may be coeval with monzonite dikes found to the west of the deposit which returned a 191.71 ±0.20 Ma U-Pb zircon age (Hunter and van Straaten, 2020).

The upper part of the Hazelton Group (Pliensbachian to Bajocian) contains predominantly post-arc sedimentary rocks of the Spatsizi and Quock formations, felsic volcanic rocks of the Mount Dilworth Formation and local bimodal rift-related volcanic and sedimentary rocks of the Iskut River Formation (Gagnon et al., 2012; Nelson et al., 2018). Bimodal rift related rocks have not been reported in the Kitsault River study area, but felsic tuffs of roughly equivalent age to the Mount Dilworth Formation (173.6 ±1.7 Ma; Cutts et al., 2015) and Iskut River Formation (ca. 179-173 Ma; Nelson et al., 2018 and references therein) have been identified in the Kitsault River valley. The Iskut River Formation is host to several mineral deposits such as VMS-type mineralization at the Au-Ag-rich Eskay Creek and Cu-rich Anyox deposits in the Eskay rift (Fig. 2; Barrett and Sherlock, 1996; Childe, 1996; MacDonald et al., 1996; Roth et al., 1997; Evenchick and McNicoll, 2002). Middle Jurassic to mid-Cretaceous sedimentary rocks of the Bowser Lake Group overlie the Hazelton Group (Evenchick and Thorkelson, 2005; Nelson et al., 2018).

Significant shortening in the Cretaceous resulted in the development of the thin-skinned Skeena fold and thrust belt, which was first recognized and described within the rocks of the Bowser basin (Evenchick, 1991). Northwest- and northeast-trending Skeena folds and thrusts, which display a wide variety of geometries as a function of competency contrast, define the structural style of northern Stikinia (Evenchick, 1991; Evenchick et al., 2007). Initiating in the Late Cretaceous and continuing into the Eocene, significant dextral offset accumulated along large-scale faults that appear to have reactivated pre-existing orogen-parallel structures (Nelson and Kyba, 2014).

3. A new geological map of the northeastern Kitsault River area

The oldest rocks exposed in the map area (Fig. 3; Table 1) are part of the Stuhini Group (Upper Triassic). These rocks include

Table 1. Summary of U-Pb zircon geochronological data from the northeastern part of the Kitsault River area. See Figure 3 for locations. LA-ICP-MS, laser-ablation inductively coupled plasma mass spectrometry; CA-TIMS, chemical abrasion thermal ionization mass spectrometry; and ID-TIMS, isotope dilution thermal ionization mass spectrometry. References: [1] Mortensen and Kirkham (1992); [2] Greig and Gehrels (1995); [3] Hunter and van Straaten (2020); [4] Miller et al. (2020); and [5] Hunter et al. (2022a, b).

Sample	Age (Ma)	Type	Lithostratigraphic Unit
1	154.3 ± 0.9[5]	LA-ICP-MS (detrital)	Bowser Lake Group (muJBs)
2	168.9 ± 2.2[3]	LA-ICP-MS (detrital)	Quock Formation (mJHs)
3	178.1 ± 2.2[3]	LA-ICP-MS	Kitsault unit (lmJHva)
4	187.3 ± 0.8[5]	LA-ICP-MS (detrital)	Spatsizi Formation (lmJHs)
5	188.1 ± 0.6[5]	LA-ICP-MS (detrital)	Spatsizi Formation (lmJHs)
6	193.5 ± 0.4[1]	ID-TIMS	Betty Creek Formation (lJHvf)
7	193.93 ± 0.11[5]	CA-TIMS	Betty Creek Formation (lJHva.xor)
8	193.98 ± 0.11[5]	CA-TIMS	Betty Creek Formation (lJHva.xor)
9	196 +5/-1[2]	ID-TIMS	Betty Creek Formation (lJHvf)
10	198 +4/-3[2]	ID-TIMS	Betty Creek Formation (lJHva.xor)
11	198 +8/-7[2]	ID-TIMS	Betty Creek Formation (lJHva)
12	200.85 ± 0.15[5]	CA-TIMS	Betty Creek Formation (uTrlJHsv)
13	204.61 ± 0.18[4]	CA-TIMS	Texas Creek Plutonic Suite (LTrEJmd)
14	206.7 ± 1.9[3]	LA-ICP-MS (detrital)	Betty Creek Formation (uTrlJHva)
15	228.4 ± 1.4[3]	LA-ICP-MS (detrital)	Betty Creek Formation (uTrlJHsv)

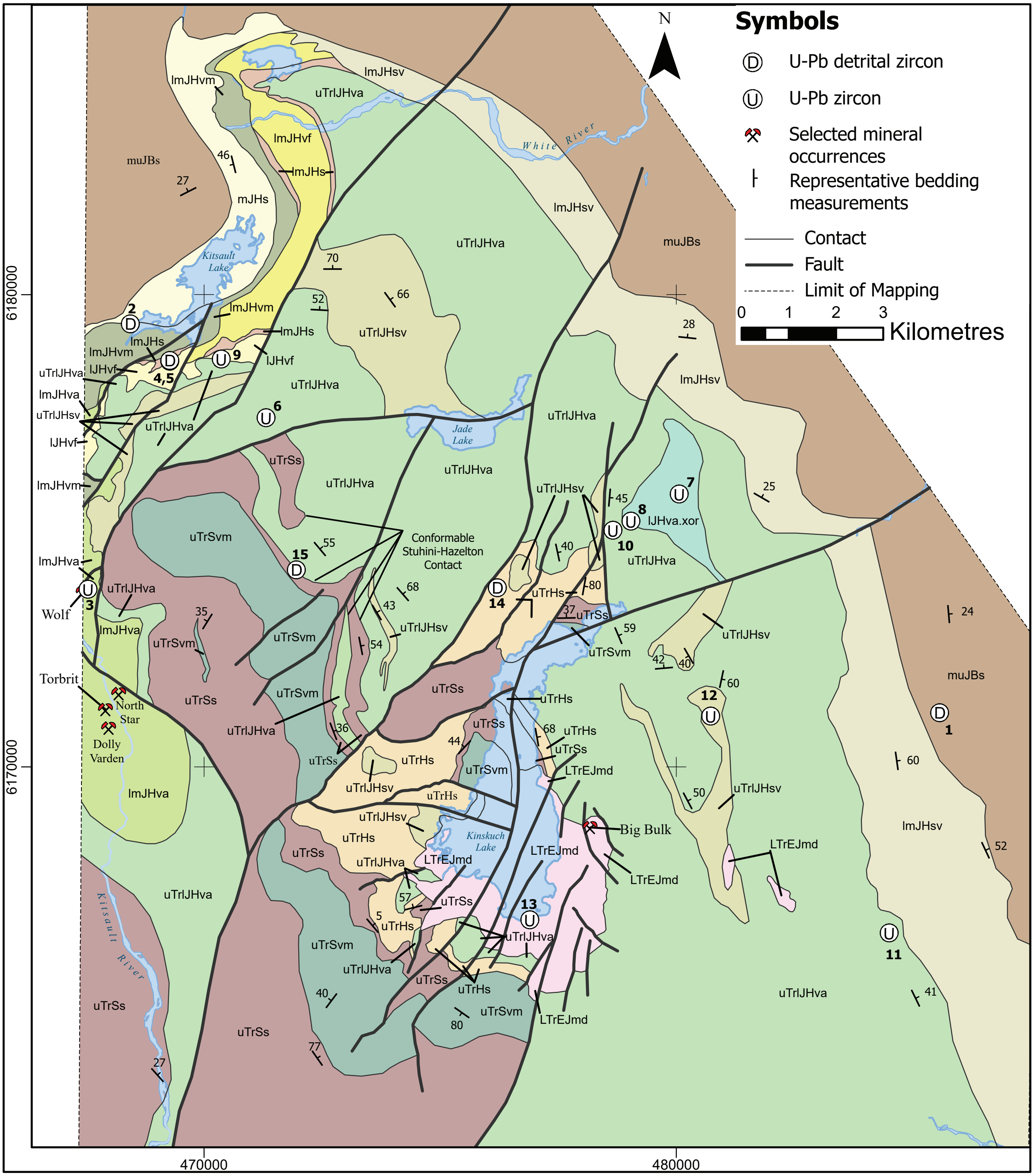

Fig. 3. a) Preliminary geology map of the northeastern part of the Kitsault River area, with locations of geochronological samples listed in Table 1.

Bowser Lake Group (Middle to Upper Jurassic)

muJBs — Grey to brown, well-stratified feldspathic wacke, siltstone and mudstone. Common load casts, flame structures, and mudstone intraclasts. Lesser very thick conglomerate beds locally containing chert granules and pebbles in a coarse sandstone matrix (154.3+/-0.9 Ma U-Pb detrital zircon MDA, Hunter et al., 2022a,b).

Hazelton Group
upper Hazelton Group
Quock Formation (Middle Jurassic)

mJHs — Well-stratified dark grey mudstone and siltstone (commonly siliceous) and minor pale-toned tuff laminae. The base of this unit consists of a sandstone interval several m thick containing belemnite casts with 168.9±2.2 Ma U-Pb detrital zircon MDA (Hunter and van Straaten, 2020).

Unassigned unit (Lower to Middle Jurassic)

lmJHsv — Mudstone, siltstone, feldspathic wacke, limestone, and fine tuff to lapilli-tuff. Mudstone is commonly siliceous and locally graphitic or carbonaceous. Predominantly laminated to thinly bedded. Locally light brown weathering fine tuff to lapilli-tuff layers, 3-20 cm thick. Rare limestone, sandstone, and conglomerate near the base of the unit in the east.

Kitsault unit (Lower to Middle Jurassic)

lmJHvf — Felsic to lesser intermediate volcanic rocks including pale greenish, grey to cream tuff breccia, lapilli-tuff, lapillistone, and crystal tuff. Commonly with plagioclase-phyric volcanic clasts and/or plagioclase crystal-bearing matrix. Locally foliated or with elongate volcanic clasts.

lmJHvm — Mafic volcanic rocks including lapilli-tuff, tuff breccia, and coherent rocks. Volcanic clasts and coherent rocks are augite-plagioclase-phyric. Interstratified with lesser limestone, siltstone, and feldspathic wacke.

lmJHva — Intermediate volcanic rocks including tuff, lapilli-tuff, crystal tuff, and local tuff breccia. Interstratified with volcanic-derived sandstone, reworked tuff, and pebble conglomerate with volcanic and sedimentary clasts Rare felsic volcanic rocks similar to lmJHvf yielded a 178.1+/-2.2 Ma U-Pb zircon age (Hunter and van Straaten, 2020).

Spatsizi Formation (Lower to Middle Jurassic)

lmJHs — Fine- to coarse-grained feldspathic sandstone, pebble wacke, siltstone, and local thin limestone beds (187.3±0.8 and 188.1±0.6 Ma U-Pb detrital zircon MDA, Hunter et al., 2022a, b).

lower Hazelton Group
Betty Creek Formation (Lower Jurassic)

lJHvf — Light green to grey to maroon-grey felsic lapilli-tuff, crystal tuff and tuff. Locally with quartz, biotite, and K feldspar crystals; rare elongate volcanic clasts or possible fiamme up to 2 mm (193.5+/-0.4 Ma U-Pb zircon, Mortensen and Kirkham, 1992; 196+5/-1 Ma U-Pb zircon, Greig and Gehrels, 1995)

lJHva.xor — K feldspar-hornblende-plagioclase-phyric intermediate coherent rocks and K feldspar hornblende plagioclase crystal tuff. K feldspar phenocrysts are commonly aligned along bedding. Interstratified with 100 m-thick lapilli-tuff to tuff breccia intervals with hornblende-plagioclase-phyric volcanic clasts, similar to unit uTrlJHva. Local lenticular and discontinuous beds of brown weathering, coarse- to very coarse-grained sandstone (193.93+/-0.11 Ma and 193.98+/-0.11 Ma U-Pb zircon, Hunter et al., 2022a,b; 198+4/-3 Ma, U-Pb zircon; Greig and Gehrels, 1995).

Texas Creek plutonic suite (Late Triassic to Early Jurassic)
Big Bulk stock

LTrEJd — Hornblende diorite and lesser biotite-hornblende monzodiorite to monzonite stocks and dikes. Hornblende plagioclase porphyritic (1-2 mm) to equigranular (1-5 mm) (204.61+/-0.18 Ma U-Pb zircon, Miller et al., 2020).

Lower Hazelton Group
Betty Creek Formation (Upper Triassic to Lower Jurassic)

uTrlJHsv — Sedimentary and intermediate volcanic rocks. Well-stratified to locally massive coarse- to fine-grained feldspathic sandstone, siltstone, limestone, and lesser pebble conglomerate. Conglomerate clasts include chert, limestone, and augite-phyric basalt. Intercalated with pale-weathering, well-stratified to locally massive, lapilli-tuff, lapillistone, and tuff breccia with hornblende-plagioclase-phyric volcanic clasts (228.4±1.4 Ma U-Pb detrital zircon MDA; Hunter and van Straaten, 2020; 200.85+/-0.15 Ma U-Pb zircon age, Hunter et al., 2022a, b).

uTrlJHva — Intermediate volcanic and coherent rocks. Massive to very thickly bedded (5-100 m) lapilli-tuff, lapillistone, tuff breccia and lesser crystal tuff. With angular to subrounded hornblende-plagioclase-phyric or less common biotite-plagioclase-phyric juvenile volcanic clasts, locally with minor sandstone, limestone, argillite and rare augite-phyric volcanic accessory clasts. Rare, discontinuous, coarse-grained sandstone channels (206.7±1.9 Ma U-Pb detrital zircon MDA from base of unit, Hunter and van Straaten, 2020; 198+8/-7 Ma U-Pb zircon age, Greig and Gehrels, 1995)

Kinskuch unit (Upper Triassic)

uTrHs — Massive to poorly stratified conglomerate with rounded to angular pebbles to boulders and local megaclasts (up to at least 120 m). Clast types include sandstone, mudstone, limestone, chert, augite-phyric mafic volcanic, and hornblende-feldspar-phyric intermediate volcanic rock. Locally interstratified with coarse-grained feldspathic sandstone and pebbly sandstone (Constrained to the Rhaetian by cross-cutting Big Bulk stock and conodonts from a limestone megaclast originally assigned a Late Norian age, now considered Rhaetian; Cordey et al., 1992; Golding, pers. comm. 2021.)

Stuhini Group (Upper Triassic)

uTrSs — Well-stratified argillite, mudstone, siltstone, wacke, and feldspathic sandstone. Detrital quartz is absent in all rock types. Local graphitic mudstone. Rare conglomerate, pebbly sandstone, and calcite-rich sandstone. Very rare thin limestone and chert beds.

uTrSvm — Mafic coherent rocks and mafic volcanic breccia, coherent rocks and volcanic clasts are augite-phyric, and locally amygdaloidal. Intercalated with lesser well-stratified, monomictic mafic volcanic clast-bearing conglomerate to volcanic-derived sandstone.

Fig. 3b. Legend.

coherent and fragmental augite-phyric mafic volcanic rocks (uTrSvm) and well-stratified siltstone, mudstone, feldspathic wacke, and rare conglomerate (uTrSs). The Stuhini Group is overlain by diverse rock types in the lower part of the Hazelton Group; all are assigned to the Betty Creek Formation except for the Kinskuch unit (Fig. 3, Table 2). Approximately 4 km southwest of Jade Lake, intermediate volcanic rocks of the Betty Creek Formation (uTrlJHva) conformably overlie Stuhini Group sedimentary rocks (uTrSs). Slightly farther southeast, intermediate volcanic rocks of the Betty Creek Formation (uTrlJHva) interfinger with Stuhini Group sedimentary rocks (uTrSs; Figs. 3, 4). These conformable and gradational transitions are in marked contrast to the unconformity between the Stuhini Group and Hazelton Group observed elsewhere in the region (e.g., Greig, 2014; Nelson and Kyba, 2014; Nelson et al., 2018). Close to Kinskuch Lake, basal Hazelton Group strata consist of conglomerates and local megaclast-bearing conglomerates of the Kinskuch unit (uTrHs, Rhaetian; Fig. 5) that are overlain by intermediate volcanic rocks of the Betty Creek Formation (uTrlJHva). The Kinskuch unit is considered to represent the fill of a local fault-bounded basin (Miller et al., 2020). The Betty Creek Formation includes intermediate volcanic rocks with hornblende-plagioclase-phyric or biotite-plagioclase-phyric clasts (uTrlJHva; 206.7 ±1.9 Ma U-Pb detrital zircon maximum depositional age (MDA) from base of unit, 198 +8/-7 Ma; U-Pb zircon age from higher up the section; Table 1) that are locally interstratified with medium- to fine-grained feldspathic sandstone, siltstone, lesser mudstone, and rare conglomerate and limestone (uTrlJHsv; 228.4 ±1.4 Ma U-Pb detrital zircon MDA; 200.85 ±0.15 Ma U-Pb zircon age; Table 1; Fig. 6). Approximately 3 km northeast of Kinskuch Lake is a distinctive unit of limited areal extent consisting of K-feldspar-phyric volcanic rocks (lJHva.xor; 198 +4/-3 Ma, 193.98 ±0.11 Ma, 193.93 ±0.11 Ma U-Pb zircon ages; Table 1). South of Kitsault Lake a felsic volcanic rock package (lJHvf; 193.5 ±0.4 Ma, 196 +5/-1 Ma U-Pb zircon ages; Table 1) is at the top of the lower part of the Hazelton Group.

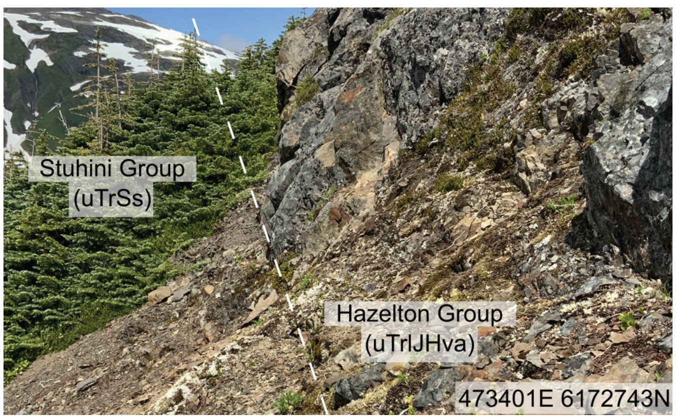

Fig. 4. Conformable Stuhini Group-Hazelton Group contact. Stuhini Group (unit uTrSs) consists of recessive-weathering laminated black siltstone with rare reworked plagioclase crystal tuff beds. Hazelton Group (Betty Creek Formation unit uTrlJHva) consists of hornblende-plagioclase crystal tuff that grades up into lapilli tuff with hornblende-plagioclase phyric clasts (473401E, 6172743N, UTM NAD83, Zone 9; looking northeast).

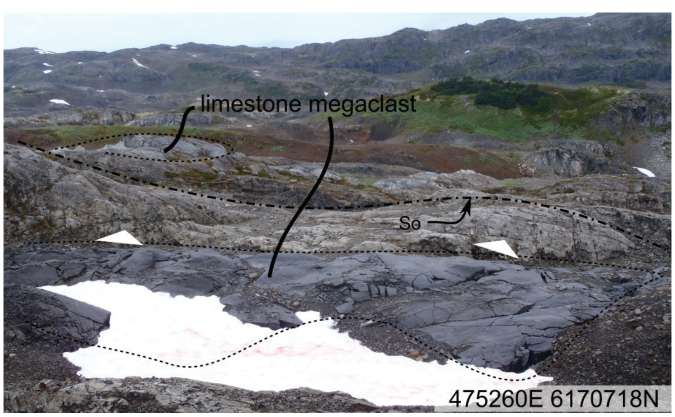

Fig. 5. Kinskuch unit (uTrHs) megaclast-bearing conglomerate near the base of the lower part of the Hazelton Group (S_0=bedding) (475260E, 6170718N, UTM NAD83 Zone 9N; looking northwest).

Units in the upper part of the Hazelton Group (Lower to Middle Jurassic) vary significantly from west to east across the map area. In the west and northwest, near Kitsault Lake, the base comprises well-bedded to massive sedimentary rocks of the Spatsizi Formation (lmJHs), including fine- to coarse-grained feldspathic sandstone, pebbly wacke, siltstone, and local thin limestone beds (187.3 ±0.8 Ma and 188.1 ±0.6 Ma U-Pb detrital zircon MDA; Table 1). The several million year age gap between the lower and upper parts of the Hazelton Group may suggest the presence of an unconformity, similar to elsewhere in the region (e.g., Gagnon et al., 2012; Nelson et al., 2018). The Spatsizi Formation is overlain by interbedded volcanic rocks, volcanic-derived sandstone, pebble conglomerate, and rare

Fig. 6. Betty Creek Formation (uTrlJHsv), interbedded pebbly sandstone with limestone and minor plagioclase-phyric volcanic clasts (top of photo, grey), reworked calcareous crystal tuff, and pale buff siltstone (473514E, 6173208N, UTM NAD83 Zone 9N; looking northeast).

Table 2. Comparison of the lithostratigraphic subdivisions used in this study to those used in previous work.

Group	Formation	Hunter et al., 2022	This Study
Bowser Lake Group		Bowser Lake Group	muJBs
upper Hazelton Group	**Quock Formation**	Facies 6	mJHs
	Unassigned unit	Facies 6	lmJHsv
	Kitsault unit	Facies 5 (Kitsault unit)	lmJHvf
			lmJHvm
			lmJHva
	Spatsizi Formation		lmJHs
lower Hazelton Group	**Betty Creek Formation**		lJHvf
		Facies 4a	lJHva.xor
		Facies 2 and 3	uTrlJHsv
		Facies 2, 3 and 4	uTrlJHva
	Kinskuch unit	Facies 1	uTrHs
Stuhini Group			uTrSs
			uTrSvm

coherent volcanic or subvolcanic rocks of the Kitsault unit. The Kitsault unit contains intermediate volcanic facies (lmJHva; 178.1 ±2.2 Ma U-Pb zircon age; Table 1), mafic volcanic facies (lmJHvm; Fig. 7), and felsic volcanic facies (lmJHvf; Figs. 3, 8). The intermediate volcanic rocks in the Kitsault unit (lmJHva) can be difficult to differentiate from compositionally similar rocks in the Betty Creek Formation (uTrlJHva), particularly in areas where no intervening sedimentary rocks of the Spatsizi Formation (lmJHs) have been identified. The Kitsault unit hosts stratabound to locally vein-hosted Ag-Zn-Pb VMS deposits at Dolly Varden (MINFILE 103P 188), North Star (MINFILE 103P 189), Torbrit (MINFILE 103P 191), and Wolf (MINFILE 103P 198; Hanson, 1922; Black, 1951; Campbell, 1959; Dawson and Alldrick, 1986; Devlin and Godwin, 1986; Devlin, 1987; Pinsent, 2001; Dunne and Pinsent, 2002; Higgs, 2015; McCuaig and Sebert, 2017; Hunter and van Straaten, 2020; Hunter et al., 2022a; Fig. 3). The Kitsault unit is overlain by mudstone and siltstone (commonly siliceous) interbedded with felsic tuff laminae of the Quock Formation (mJHs; 168.9 ±2.2 Ma U-Pb zircon MDA at base; Table 1).

Fig. 7. Kitsault unit (lmJHvm, upper part of Hazelton Group) mafic tuff breccia with augite-plagioclase phyric clasts (470583E, 6183982N, UTM NAD83 Zone 9N; looking northwest).

Fig. 8. Kitsault unit (lmJHvf, upper part of Hazelton Group) foliated felsic tuff breccia to lapilli tuff with medium green plagioclase-phyric clasts (471908E, 6183396N, UTM NAD83 Zone 9N; looking north).

In the eastern and northeastern parts of the map area, the upper part of the Hazelton Group consists of well-stratified mudstone, siltstone, sandstone, and limestone with fine tuff to lapilli-tuff beds (unit lmJHsv). This unit was mapped as the Surprise Creek facies of the Salmon River Formation by Evenchick et al. (2008); the formation name was abandoned by Gagnon et al. (2012). Hunter et al. (2022a) tentatively assigned this unit to the Quock Formation but based on the significantly coarser nature of the siliciclastic and volcanic strata, and a current lack of age constraints, we revert to an unassigned unit (lmJHsv). It may represent the lateral equivalent of the Kitsault unit and correlate regionally with the Spatsizi Formation.

The Quock Formation (in the north) and an unassigned unit (in the northeast and east; Figs. 3, 9) in the upper part of the Hazelton Group are overlain by well-stratified siliciclastic sedimentary rocks of the Bowser Lake Group (muJBs; 154.3 ±0.9 Ma U-Pb detrital zircon MDA; Table 1). The contact appears to be gradational and conformable and is marked by the disappearance of tuff to lapilli-tuff and appearance of chert clast-bearing pebble conglomerate (Hunter et al., 2022a).

Fig. 9. Unassigned unit, (lmJHsv, upper part of Hazelton Group) well-stratified sandstone to siltstone with a white-weathering 10 cm thick tuff layer; younging upright to the east from cross bedding (485093E, 6166413N, UTM NAD83 Zone 9N; looking east).

4. Discussion

Continued mapping combined with geochronological results in the Kitsault River area permit preliminary interpretations that will guide future work and have implications for understanding the geological evolution and metallogeny of the area.

The study area records the early timing (206.7 ±1.9 Ma U-Pb detrital zircon MDA; Hunter and van Straaten, 2020) of Hazelton Group volcanism and overlaps with latest Triassic to Early Jurassic ages for the onset of Hazelton Group volcanism (e.g., Nelson et al., 2018). The conformable Stuhini to Hazelton Group contact in the Kitsault River area is in contrast with the sub-Hazelton Group angular unconformity found elsewhere in the region (e.g., Nelson et al., 2018). Relative to areas farther north, the Kitsault River area preserves a more continuous record from Stuhini Group sedimentation to Hazelton Group volcanism and may have been outside of the area affected by latest Triassic contractional strain (e.g., Nelson and Kyba, 2014; Nelson et al., 2018) recorded regionally. Rocks in the Kitsault River area likely represent a Late Triassic marine back arc (Nelson and van Straaten, 2020) with the Kinskuch unit (Rhaetian; Miller et al., 2020) deposited in a fault bounded pull-apart basin. In the Kinskuch Lake area, these basin-related faults may have exerted control on the emplacement of the Big Bulk porphyry stock, which hosts the Big Bulk Cu-Au porphyry system (Rhaetian; 204.61 ±0.18 Ma U-Pb zircon; Fig. 3; Miller et al., 2020; MINFILE 103P 016).

Preliminary geochronological data from the upper Hazelton Group in the Kitsault River area ranges from ca. <188 Ma to 178 Ma (Hunter and van Straaten, 2021; Hunter et al., 2022a) suggesting that VMS type mineralization in the Kitsault River area may be the same age or slightly older than VMS mineralization in the Eskay rift (ca. 174-176 Ma; Childe, 1996; Evenchick et al., 2004; Alldrick et al., 2005; Barresi et al., 2015). Hunter et al. (2022a) noted that the volcanic to epiclastic strata in the upper part of the Hazelton Group in the study area differ significantly from the typical Iskut River Formation and thus introduced the Kitsault unit, which represents deposition outside of the main Eskay rift. The VMS-prospective Kitsault unit was only observed on the northwest side of the map area and appears to transition laterally into an unassigned sedimentary unit found in the northeastern and eastern parts. The Kitsault unit likely formed in local extensional basins much like the broadly coeval Iskut River Formation (Barresi et al., 2005, 2015; Nelson et al., 2018) but without developing into a rift. The unassigned, predominantly sedimentary unit to the east may represent its lateral equivalent, with thin tuff interlayers representing distal volcanic input.

5. Conclusions

Stuhini Group rocks in the Kitsault River area were likely deposited in a Late Triassic marine back arc (Nelson and van Straaten, 2020). In contrast to the sub-Hazelton Group unconformity observed elsewhere in the region, our current mapping in the area suggests a continuous or near-continuous record across the transition from Stuhini Group sedimentation to the onset of Hazelton Group volcanism in the latest Triassic. Therefore, the Kitsault River area may allow for precise determination of the onset of Hazelton Group volcanism, which is significant because coeval and comagmatic intrusions are responsible for the emplacement of most of the porphyry Cu-Au deposits in the region. The Kinskuch unit (Rhaetian; Miller et al., 2020), locally at the base of the Hazelton Group, was deposited in a fault bounded pull-apart basin. The basin-related faults likely exerted control on the emplacement of the Big Bulk porphyry stock, which hosts the Big Bulk Cu-Au porphyry system (Rhaetian; 204.61 ±0.18 Ma U-Pb zircon; Fig. 3; Miller et al., 2020).

In the study area, volcanic rocks of the Kitsault unit (upper part of the Hazelton Group) host several Ag-rich VMS deposits. The Kitsault unit is distinct from the Iskut River Formation within the Eskay rift, lacking the latter's characteristic bimodal volcanism (Hunter and van Straaten, 2020). The Kitsault unit is interpreted to record local volcanism of a similar or slightly older age than the Iskut River Formation. The volcanic rocks of the Kitsault unit are notably absent in the eastern half of the map area. Here, thin tuff interlayers in a predominantly sedimentary unit may represent distal volcanic input. Future work will focus on better defining the lower contact of the upper part of the Hazelton Group, determine the extent of the Kitsault unit and its relationship to broadly coeval sedimentary rocks, which will be a key step in assessing prospectivity of VMS-style mineralization throughout the region.

Acknowledgments

We thank Dolly Varden Silver Corporation, in particular Chris Sebert, Rob van Egmond, and Charlie Fleenor for logistical support, their hospitality while staying in the Alice Arm camp, and their generosity in sharing property-scale geological maps and data. Summit Helicopters and their pilots transported us safely throughout the summer. Fantastic field assistance and sample preparation was provided by Ben Coats, Cameron Fielding, and Shannon Murtonen. A thoughtful and insightful review by JoAnne Nelson significantly improved the manuscript.

References cited

Alldrick, D.J., Dawson, G.L., Bosher, J.A., and Webster, I.C.L., 1986. Geology of the Kitsault River area (NTS 103P). British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 1986-02, 1:50,000 scale.

Alldrick, D.J., Nelson, J.L., and Barresi, T., 2005. Geology and mineral occurrences of the upper Iskut River area: Tracking the Eskay rift through northern British Columbia. In: Geological Fieldwork 2004, British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper 2005-1, pp. 1-30.

Barresi, T., Nelson, J.L., Alldrick, D.J., and Dostal, J., 2005. Pillow basalt ridge facies; Detailed mapping of Eskay Creek-equivalent stratigraphy in northwestern British Columbia. In: Geological Fieldwork 2004, British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper 2005-1, pp. 31-38.

Barresi, T., Nelson, J.L., Dostal, J., and Friedman, R., 2015. Evolution of the Hazelton arc near Terrace, British Columbia: Stratigraphic, geochronological, and geochemical constraints on a Late Triassic-Early Jurassic arc and Cu-Au porphyry belt. Canadian Journal of Earth Sciences, 52, 466-494. doi: 10.1139/cjes-2014-0155.

Barrett, T.J., and Sherlock, R.L., 1996. Geology, lithogeochemistry and volcanic setting of the Eskay Creek Au-Ag-Cu-Zn deposit, northwestern British Columbia. Exploration and Mining Geology, 5, 339-368.

Black, J.M., 1951. Geology and mineral occurrences of the Upper Kitsault Valley. In: British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Annual Report, pp. A76-A83.

Campbell, F.A., 1959. The geology of Torbrit Silver Mine British Columbia. Economic Geology, 54, 1461-1495. doi: 10.2113/gsecongeo.54.8.1461.

Childe, F., 1996. U-Pb geochronology and Nd and Pb isotope characteristics of the Au-Ag-rich Eskay Creek volcanogenic massive sulfide deposit, British Columbia. Economic Geology, 91, 1209-1224. doi: 10.2113/gsecongeo.91.7.1209.

Cordey, F., Greig, C.J., and Orchard, M.J., 1992. Permian, Triassic, and Middle Jurassic microfaunal associations, Stikine terrane, Owegee and Kinskuch areas, northwestern British Columbia. In: Current Research Part E, Geological Survey of Canada Paper 92-1E, pp. 107-116.

Cutts, J.A., McNicoll, V.J., Zagorevski, A., Anderson, R.G., and Martin, K., 2015. U-Pb geochronology of the Hazelton Group in the McTagg anticlinorium, Iskut River area, northwest British Columbia. In: Geological Fieldwork 2014, British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper 2015-1, pp. 87-101.

Dawson, G.L., and Alldrick, D.J., 1986. Geology and mineral deposits of the Kitsault Valley. In: Geological Fieldwork 1985, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 1986-1, pp. 219-224.

Devlin, B.D., 1987. Geology and genesis of the Dolly Varden silver camp, Alice Arm area, northwestern British Columbia. M.Sc. thesis, University of British Columbia, Vancouver, B.C., Canada. <https://open.library.ubc.ca/cIRcle/collections/ubctheses/831/items/1.0052815 (last accessed November 5, 2015).

Devlin, B.D., and Godwin, C.I., 1986. Geology of the Dolly Varden camp, Alice Arm area. In: Geological Fieldwork 1985, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 1986-1, pp. 327-330.

Dunne, K.P.E., and Pinsent, R.H., 2002. Depositional setting of silver-rich quartz-sulphate-carbonate deposits of the upper Kitsault River area, northwest British Columbia. In: Geological Fieldwork 2001, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2002-01, pp. 177-196.

Evenchick, C.A., 1991. Geometry, evolution, and tectonic framework of the Skeena Fold Belt, north-central British Columbia. Tectonics, 10, 527-546. doi: 10.1029/90TC02680.

Evenchick, C.A., 2001. Northeast-trending folds in the western Skeena Fold Belt, northern Canadian Cordillera: A record of Early Cretaceous sinistral plate convergence. Journal of Structural Geology, 23, 1123-1140. doi: 10.1016/S0191-8141(00)00178-4.

Evenchick, C.A., and McNicoll, V.J., 2002. Stratigraphy, structure, and geochronology of the Anyox Pendant, northwest British Columbia, and implications for mineral exploration. Canadian Journal of Earth Sciences, 39, 1313-1332. doi: 10.1139/e02-036.

Evenchick, C.A., and Thorkelson, D.J., 2005. Geology of the Spatsizi River map area, north-central British Columbia. Geological Survey of Canada Bulletin 577, 276 p.

Evenchick, C.A., McNicoll, V.J., and Snyder, L.D., 2004. Stratigraphy, geochronology, and geochemistry of the Georgie River area, northwest British Columbia, and implications for mineral exploration. Canadian Journal of Earth Sciences, 41, 199-216. doi: 10.1139/e03-091.

Evenchick, C.A., McMechan, M.E., McNicoll, V.J., and Carr, S.D., 2007. A synthesis of the Jurassic-Cretaceous tectonic evolution of the central and southeastern Canadian Cordillera: Exploring links across the orogen. In: Sears, J.W., Harms, T.A. and Evenchick, C.A., (Eds.), Whence the mountains? Inquiries in the Evolution of Orogenic Systems: A volume in honor or Raymond A. Price, Geological Society of America Special Paper 433, pp. 117-145.

Evenchick, C.A., Mustard, P.S., Greig, C.J., McMechan, M.E., Ritcey, D.H., Smith, G.T., and Ferri, F., 2008. Geology, Nass

River, British Columbia. Geological Survey of Canada Open File 5705, 1:125,000 scale.
Febbo, G.E., Friedman, R.M., Kennedy, L.A., and Nelson, J.L., 2019. U-Pb geochronology of the Mitchell deposit, northwestern British Columbia. British Columbia Ministry of Energy, Mines and Petroleum Resources, GeoFile 2019-03, 8 p.
Gagnon, J.-F., Barresi, T., Waldron, J.W.F., Nelson, J.L., Poulton, T.P., and Cordey, F., 2012. Stratigraphy of the upper Hazelton Group and the Jurassic evolution of the Stikine terrane, British Columbia. Canadian Journal of Earth Sciences, 49, 1027-1052. doi: 10.1139/e2012-042.
Greig, C.J., 1992. Fieldwork in the Oweegee and Snowslide ranges and Kinskuch Lake area, northwestern British Columbia. In: Current Research, Part A, Geological Survey of Canada, Current Research 92-1A, pp. 145-155.
Greig, C.J., 2014. Latest Triassic-earliest Jurassic contractional deformation, uplift and erosion in Stikinia, NW B.C. Geological Society of America Abstracts with Programs, 46, p. 588.
Greig, C.J., and Gehrels, G.E., 1995. U-Pb zircon geochronology of Lower Jurassic and Paleozoic Stikinian strata and Tertiary intrusions, northwestern British Columbia. Canadian Journal of Earth Sciences, 32, 1155-1171. doi: 10.1139/e95-095.
Greig, C.J., Anderson, R.G., Daubeny, P.H., and Bull, K.F., 1994. Geology of the Cambria Icefield: Stewart (103P/13), Bear River (104A/4), and parts of Meziadin Lake (104A/3) and Paw Lake (103P/12) map areas, northwestern British Columbia. Geological Survey of Canada Open File, 2931, 1:50,000 scale.
Hanson, G., 1922. Upper Kitsault Valley, British Columbia. In: Geological Survey of Canada, Summary Report Part A, pp. 7-21.
Higgs, A.A., 2015. 2015 Technical Report for the Dolly Varden Property, Skeena Mining Division (NTS 103P/11, 12, 13, and 14), 133 p. <https://www.dollyvardensilver.com/site/assets/fi les/1326/dv-2015-04-16-43-101-technical-report.pdf> (last accessed December 2019).
Hunter, R.C., and van Straaten, B.I., 2020. Preliminary stratigraphy and geochronology of the Hazelton Group, Kitsault River area, Stikine terrane, northwest British Columbia. In: Geological Fieldwork 2019, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2020-02, pp. 101-118.
Hunter, R.C., Sebert, C.F.B., Friedman, R., and Wall, C., 2022a. Revised stratigraphy and geochronology of the Hazelton Group, host rocks for volcanogenic mineralization in the Kitsault River area, northwest British Columbia. In: Geological Fieldwork 2021, British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey Paper 2022-01, pp. 63-81.
Hunter, R.C., Sebert, C.F.B., Friedman, R., and Wall, C., 2022b. Geochronologic data from the Kitsault River area, northwest British Columbia. Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey GeoFile 2022-13, 4 p.
Logan, J.M., and Mihalynuk, M.G., 2014. Tectonic controls on Early Mesozoic paired alkaline porphyry deposit belts (Cu-Au+/-Ag-Pt-Pd-Mo) within the Canadian Cordillera. Economic Geology, 109, 827-858. doi: 10.2113/econgeo.109.4.827.
Macdonald, A.J., Lewis, P.D., Thompson, J.F.H., Nadaraju, G., Bartsch, R., Bridge, D.J., Rhys, D.A., Roth, T., Kaip, A., Godwin, C.I., and Sinclair, A.J., 1996. Metallogeny of an Early to Middle Jurassic arc, Iskut River area, northwestern British Columbia. Economic Geology, 91, 1098-1114. doi: 10.2113/gsecongeo.91.6.1098.
McCuaig, M., and Sebert, C., 2017. 2016 Technical Report for the Dolly Varden Property, Skeena Mining Division. British Columbia Ministry of Energy, Mines and Petroleum Resources, Assessment Report 36934.
Miller, E.A., Kennedy, L.A., and van Straaten, B.I., 2020. Geology of the Kinskuch Lake area and Big Bulk porphyry prospect: Syndepositional faulting and local basin formation during the Rhaetian (latest Triassic) transition from the Stuhini to the Hazelton Group. In: Geological Fieldwork 2019, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2020-02, pp. 77-100.
Mortensen, J.K., and Kirkham, R.V., 1992. A U-Pb zircon age for host rocks of a syngenetic strontium(-zinc) occurrence in the Kitsault Lake area, west-central British Columnia. In: Radiogeneic Age and Isotopic Studies: Report 5, Geological Survey of Canada Paper 91-2, pp. 181-185.
Nelson, J.L., and Kyba, J., 2014. Structural and stratigraphic control of porphyry and related mineralization in the Treaty Glacier-KSM-Brucejack-Stewart trend of western Stikinia. In: Geological Fieldwork 2013, British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper 2014-1, pp. 111-140.
Nelson, J.L., and van Straaten, B., 2020. Recurrent syn- to post-subduction mineralization along deep crustal corridors in the Iskut-Stewart-Kitsault region of western Stikinia, northwestern British Columbia. In: Sharman, E.R., Lang, J.R., and Chapman, J.B., (Eds.), Porphyry Deposits of the Northwestern Cordillera of North America: A 25-Year Update. Canadian Institute of Mining and Metallurgy Special Volume 57, pp. 194-211.
Nelson, J., Colpron, M., and Israel, S., 2013. The Cordillera of British Columbia, Yukon and Alaska: tectonics and metallogeny. In: Colpron, M., Bissig, T., Rusk, B., and Thompson, J.F.H., (Eds.), Tectonics, Metallogeny and Discovery: The North American Cordillera and Similar Accretionary Settings. Society of Economic Geologists, Special Publication 17, pp. 53-109.
Nelson, J.L., Waldron, J., van Straaten, B.I., Zagorevski, A., and Rees, C., 2018. Revised stratigraphy of the Hazelton Group in the Iskut River region, northwestern British Columbia. In: Geological Fieldwork 2017, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2018-1, pp. 15-38.
Nelson, J.L., van Straaten, B., and Friedman, R., 2022. Latest Triassic-Early Jurassic Stikine-Yukon-Tanana terrane collision and the onset of accretion in the Canadian Cordillera: Insights from Hazelton Group detrital zircon provenance and arc-back-arc configuration. Geosphere, 18, 670-696. doi: 10.1130/GES02444.1.
Pinsent, R.H., 2001. Mineral deposits of the upper Kitsault River area, British Columbia. In: Geological Fieldwork 2000, British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper 2001-1, pp. 313-326.
Roth, T., Thompson, J.F.H., and Barrett, T.J., 1997. The precious metal-rich Eskay Creek deposit, northwestern British Columbia. In: Barrie, C.T., Hannington, M.D., (Eds.), Volcanic Associated Massive Sulfide Deposits: Processes and Examples in Modern and Ancient Settings, Reviews in Economic Geology 8, p.0. doi: 10.5382/Rev.08.15.