Late Early to Middle Jurassic Hazelton Group volcanism and its tectonic setting, McBride River area, northwest British Columbia

Bram I. van Straaten[1, a] and Sebastian Bichlmaier[1]

[1] British Columbia Geological Survey, Ministry of Energy, Mines and Petroleum Resources, Victoria, BC, V8W 9N3
[a] corresponding author: Bram.vanStraaten@gov.bc.ca

Recommended citation: van Straaten, B.I., and Bichlmaier, S., 2018. Late Early to Middle Jurassic Hazelton Group volcanism and its tectonic setting, McBride River area, northwest British Columbia. In: Geological Fieldwork 2017, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2018-1, pp. 39-66.

Abstract

Continued mapping and geochronologic studies on the northeast margin of Stikinia east of Dease Lake indicate that Late Triassic plutonic rocks of the Cake Hill pluton are unconformably overlain by late Early to Middle Jurassic rocks in the upper part of the Hazelton Group. The unconformity, which has been traced laterally for 50 km, spans at least 30 m.y. and represents one of the few examples of unroofed Stuhini arc in northern Stikinia. The unconformity is overlain by sedimentary rocks of the Spatsizi Formation (up to 0.2 km thick, Toarcian) and volcanic rocks of the Horn Mountain Formation (at least 3.5 km thick, Aalenian-Bajocian). The recently-defined Horn Mountain Formation is unusual because it postdates typical Late Triassic to Early Jurassic arc volcanism in northern Stikinia, and was deposited during accretion of the Stikine and Cache Creek terranes. In the lower part of the Horn Mountain Formation, partly or wholly subaqueous, massive green augite-plagioclase-phyric volcanic breccia pass upward to a subaerial volcanic edifice composed of interlayered maroon augite-plagioclase-phyric flows, volcanic breccia and tuff. Felsic volcanic rocks cap the succession. The Horn Mountain Formation is cut by the Three Sisters pluton (ca. 173-169 Ma, Aalenian-Bajocian) and McBride River pluton. The McBride River granodiorite has hitherto been interpreted as Early Jurassic (ca. 184 Ma), but based on crosscutting relationships we suggest a Middle Jurassic or younger age to be more plausible. The Bowser Lake Group (Bajocian) conformably overlies the Horn Mountain Formation; it records initiation of erosion from the Stikinia-Cache Creek tectonic welt. Chert and limestone clast-bearing pebble to cobble conglomerate (>330 m thick) is interpreted to have formed close to range front faults along the building orogen. The coarse clastic facies transitions to interbedded subaerial siltstone, sandstone, chert clast-bearing conglomerate, and mafic flows (>430 m thick) farther south. In the northern part of the study area, the Horn Mountain Formation and Bowser Lake Group are structurally overlain by rocks of the Whitehorse trough, juxtaposed along the Kehlechoa thrust fault (south vergent). In the hanging wall, Sinwa Formation limestones (Upper Triassic) are unconformably overlain by Takwahoni Formation sedimentary rocks (Lower Jurassic). The Takwahoni Formation succession comprises a lithologically variable unit of fine-grained siliciclastic rocks, polymictic conglomerate and volcanic rocks (Sinemurian?) that appears to grade upward to a thick unit of interbedded sandstone and siltstone (Pliensbachian). In the northernmost part of the map area, rocks of the Whitehorse trough are structurally overlain by rocks of the Cache Creek terrane along the King Salmon thrust fault (south vergent).

At Tanzilla and McBride, northwest of the study area, the Horn Mountain Formation hosts large advanced argillic alteration systems. However in the present area, evidence of alteration and mineralization is more modest. Four grab samples from two intrusion-related hydrothermal alteration zones west and southeast of the McBride River returned no anomalous metal values. Several Cu-Ag mineral occurrences with limited alteration footprints are hosted in the middle and upper part of the Horn Mountain Formation in the southeast part of the map area. Polymetallic veins near the Kehlechoa and King Salmon thrust faults locally contain significant gold and silver.

Keywords: Horn Mountain Formation, Spatsizi Formation, Hazelton Group, Bowser Lake Group, Stuhini Group, Cake Hill pluton, Three Sisters pluton, McBride River pluton, Hotailuh batholith, Takwahoni Formation, Sinwa Formation, Kehlechoa fault, Jurassic, McBride River, Tanzilla, Stikine terrane

1. Introduction

This paper presents the results of the third year of a mapping project focussed on an unusual volcano-sedimentary succession southeast of Dease Lake (northern Stikinia; Fig. 1). Before this project, the succession was poorly understood. Part of it was assigned to the Takwahoni Formation (Lower Jurassic), part to the Stuhini Group (Triassic), and part to Triassic-Jurassic volcanic rocks that could correlate with either the Stuhini Group or the Hazelton Group (Gabrielse, 1998). Detailed mapping by van Straaten and Nelson (2016) directed at understanding the host rocks of large hydrothermal alteration zones at Tanzilla (Fig. 2), identified a sedimentary succession (up to 1 km thick) overlain by a volcanic succession (ca. 5.4 km thick). They found the units to be late Early to Middle Jurassic, and defined the volcanic unit as the Horn Mountain Formation (part of the upper Hazelton Group). Mapping in 2016 extended the along-strike length of this succession from Gnat Pass to the McBride River (Fig. 2; van Straaten and Gibson, 2017; van Straaten et al., 2017). The Horn Mountain Formation is unusual because it postdates typical Late Triassic to Early Jurassic

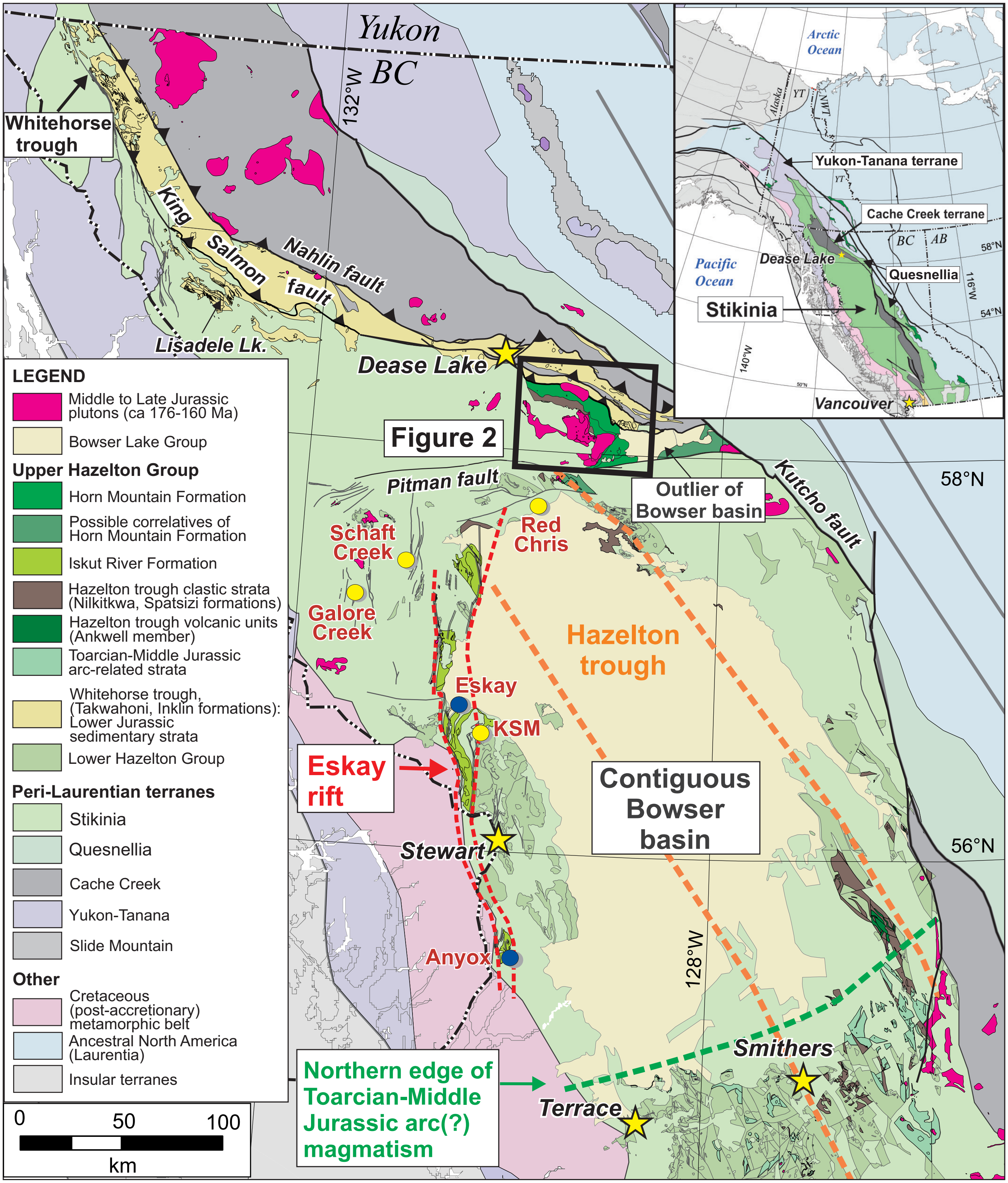

Fig. 1. Geology of northern Stikinia with emphasis on Middle to Late Jurassic geology and tectonic elements. Boundary of Hazelton trough from Marsden and Thorkelsen (1992); boundary of Eskay rift from Gagnon et al. (2012). Modified from van Straaten and Nelson (2016).

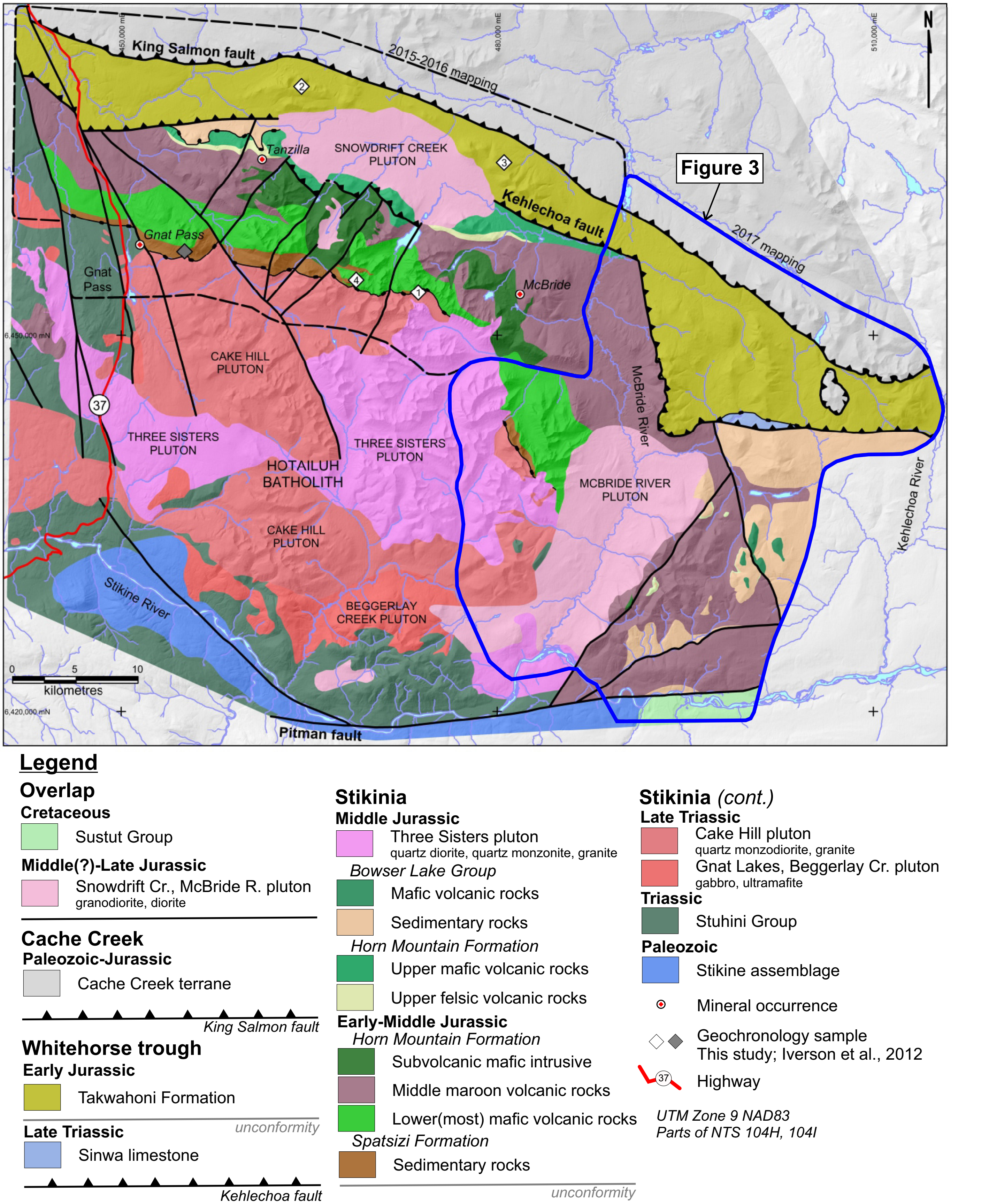

Fig. 2. Regional geology. Modified after Read and Psutka (1990), Gabrielse (1998), van Straaten et al. (2012, 2017). See Figure 1 for location.

volcanic arc successions in northern Stikinia, formed during accretion of the Stikine and Cache Creek terranes, and occupies a position adjacent to their suture (van Straaten and Nelson, 2016). Between the Tanzilla gossan and the McBride River, the Horn Mountain Formation hosts several porphyry- and epithermal-style mineral occurrences attributed to a Middle Jurassic magmatic-hydrothermal event. The syncollisional Middle Jurassic magmatic event represents a potential new metallogenic epoch for the Canadian Cordillera and is prospective for porphyry- and epithermal-style mineralization (van Straaten and Nelson, 2016).

Herein we present the results of two months of 1:20,000-scale mapping carried out by two field teams along the McBride River, representing an eastward continuation of work carried out in 2015 and 2016 (Fig. 3). We demonstrate continuity of the Spatsizi and Horn Mountain formations to a strike length of at least 80 km. We show the Horn Mountain volcanic rocks to be conformably overlain by largely subaerial synorogenic siliciclastic strata of the Bowser Lake Group. This contact records the interaction between Middle Jurassic (Bajocian) volcanism and initial debris shed from the Stikinia-Cache Creek tectonic welt, and provides further evidence for the syncollisional nature of the volcanic rocks.

2. Geological setting

The study area is in the Intermontane belt of the Canadian Cordillera, near the northeastern margin of the Stikine terrane (Stikinia; Fig. 1). Stikinia represents a multi-episodic volcanic island arc complex that accreted to ancestral North America during the Middle Jurassic (Nelson and Mihalynuk, 1993; Mihalynuk et al., 1994; Evenchick et al., 2007; Nelson et al., 2013). Volcanic and sedimentary rocks of the Stikine assemblage (Devonian to Permian), basement to Stikinia, are overlain by volcanic and related sedimentary rocks of the Stuhini Group (Triassic) and the Hazelton Group (Early to Middle Jurassic; Tipper and Richards, 1976; Marsden and Thorkelson, 1992). Also in the Intermontane belt, the Quesnel terrane (Quesnellia), is a volcanic island arc with a similar Devonian to Early Jurassic history. The two volcanic arcs are separated by the Cache Creek terrane, an accretionary complex of oceanic crustal rocks, primitive arc ophiolites, pelagic rocks, carbonate rocks, and blueschists (Fig. 1). The northeastern margin of Stikinia and adjacent Cache Creek terrane are covered by Lower Jurassic siliciclastic rocks of the Whitehorse trough (Fig. 1; Colpron et al., 2015). Accretion of Stikinia to the Cache Creek terrane, Quesnellia, and ancestral North America is recorded by deposition of Bowser Lake Group siliciclastic rocks (Middle Jurassic) in a foreland basin atop Stikinia (Evenchick et al., 2007). Combined, Stikinia and Quesnellia host most of the porphyry copper deposits in the Canadian Cordillera (Logan and Mihalynuk, 2014).

In the present study area (Figs. 2, 3), we recognize two successions in the upper part of the Hazelton Group that extend southeast from areas mapped by van Straaten and Nelson (2016) and van Straaten and Gibson (2017); the Spatsizi Formation, a predominantly sedimentary unit and the Horn Mountain Formation, a predominantly volcanic unit conformably above the Spatsizi Formation. These units form a westerly trending belt, about 80 km long and 10 km wide, north and east of the Hotailuh batholith, along the northeastern edge of Stikinia (Figs. 1, 2). Both units unconformably overlie Late Triassic rocks of the Cake Hill pluton. Prior to this project, the sedimentary rocks were mapped as the Takwahoni Formation (Lower Jurassic), structurally overlain by volcanic rocks of the Stuhini Group (Triassic) and an undivided Triassic-Jurassic unit above an inferred thrust (Hotailuh fault; Anderson, 1983; Gabrielse, 1998). The area east of the McBride River was previously interpreted as undivided Triassic-Jurassic and Lower Jurassic volcanic rocks (Gabrielse, 1998); the latter based on a four-point Rb-Sr whole rock isochron age of 191 ±9 Ma from rocks near Mount Sister Mary (Erdman, 1978). However, rocks previously mapped as part of the Takwahoni Formation contain an Early to Middle Jurassic detrital zircon population (ca. 176 Ma peak; Iverson et al., 2012) and the contact between the Spatsizi Formation and the overlying volcanic rocks is conformable, not structural (van Straaten et al., 2012; van Straaten and Nelson, 2016), thus removing the need for the putative Hotailuh thrust (Fig. 2). These Hazelton Group units are bounded to the north by the Kehlechoa thrust fault, which separates it from rocks of the Whitehorse trough (Takwahoni Formation), to the west by the Gnat Pass fault, and to the east by overlying siliciclastic strata of the Bowser Lake Group. Farther north, Cache Creek terrane rocks in the hanging wall of the south-verging King Salmon thrust structurally overlie the Takwahoni Formation (Fig. 2).

3. Lithostratigraphic units

Rocks in the study area lie within three tectonostratigraphic domains that are separated by two north-dipping thrust faults; the Kehlechoa fault in the south and the King Salmon fault in the north. Stratigraphic units in the footwall of the Kehlechoa fault are part of Stikinia; those in between the Kehlechoa and King Salmon faults are part of the Whitehorse trough; those in the hanging wall of the King Salmon fault are part of the Cache Creek terrane (Figs. 3, 4; Table 1). In the following descriptions we use classifications for sedimentary rocks from Hallsworth and Knox, (1999) and for igneous rocks from Gillespie and Styles (1999).

3.1. Stikinia

3.1.1. Stikine assemblage (Paleozoic)

Dark green phyllitic greenstone and light green phyllite assigned to the Stikine assemblage are exposed south of the Pitman fault (Fig. 3; Read and Psutka, 1990).

3.1.2. Stuhini Group (Triassic)

A 0.5 km block or roof pendant of dark green augite-plagioclase porphyry and mafic volcanic breccia is enclosed within the Cake Hill pluton in the southwest part of the map area (Fig. 3; van Straaten et al., 2012). A body of mafic volcanic

Table 1. Summary of volcano-sedimentary units on Stikinia and within the Whitehorse trough, excluding overlap assemblages. Mineral abbreviations after Kretz (1983).

Age	Unit		Description	Position
Early Jurassic	Laberge Group	Takwahoni Formation	**Greywacke (lJT*gw*).** Alternating medium to thick beds of fine- to medium-grained feldspathic wacke to feldspathic arenite (70-100%) and thin to medium beds of internally massive to locally laminated siltstone (0-30%). Sandstone contains 20-70% subangular to euhedral Pl, 5-10% round to subround Qtz, and occasional argillite rip-up clasts. Moderately resistant, grey to orange weathering. Contains early Pliensbachian, late Pliensbachian fossils (Gabrielse, 1998), late Sinemurian-early Pliensbachian and possibly early Pliensbachian fossils (T. Poulton, pers. comm., 2017).	Whitehorse trough
			Lower unit; ~3000 m thick. Contains 8 (late) Sinemurian, 1 late Pliensbachian, 1 late Pliensbachian-early Toarcian and 5 Toarcian fossil collections (Gabrielse, 1998). **Argillite, siltstone and sandstone facies (lJT*Ls*):** Laminated to thin-bedded argillite, siltstone and very fine- to fine-grained sandstone. Rare medium-grained feldspathic arenite. Very recessive, mostly observed as dark grey weathering angular scree. **Volcaniclastic sandstone facies (lJT*Lsv*):** Interbedded fine- to medium-grained volcaniclastic sandstone, very fine- to medium-grained sandstone and siltstone. Volcaniclastic sandstone is moderately sorted and contains very fine-, fine- and medium-grained sand-sized subangular to euhedral Pl (80%), black mafic grains (15%), Qtz (5%) and locally minor microphenocrystic volcanic clasts. Lesser crystal tuff, lapilli-tuff and lapillistone with subangular volcanic clasts containing 40-60% equant Pl (0.5-3 mm) and 20% equant and elongate black mafic crystals (0.5-2 mm). Rare pebble conglomerate with limestone, volcanic and/or Qtz clasts. Rare coarse- to very coarse-grained sandstone. Locally common mud- to siltstone rip-up clasts. Recessive to locally moderately resistant, dark grey weathering. **Mafic volcanic facies (lJT*Lv*):** Massive lapillistone, lapilli-tuff and tuff breccia with subangular volcanic clasts containing 30-50% euhedral equant Pl (3-5 mm) and 20% equant to elongate black mafic crystals (Aug and possibly Hbl; 1-3 mm). Interbedded with siltstone, very fine- to fine-grained sandstone and fine- to medium-grained volcaniclastic sandstone. Latter contains predominantly subangular to euhedral Pl, minor mafic grains and rare Qtz. Rare polymictic conglomerate with volcanic and limestone clasts. Resistant, orangey-grey weathering. **Conglomerate facies (lJT*Lcg*):** Polymictic pebble to cobble to rare boulder conglomerate with light grey limestone clasts (locally up to 1 m), (sub)volcanic clasts (35-40%, 2-20 mm, euhedral equant Pl; 15%, 1-3 mm equant to elongate mafic crystals), plutonic clasts (equigranular, 1-4 mm, leucocratic tonalite (?); equigranular, 1-2 mm, Hbl diorite; Qtz-porphyritic, 3-4 mm, Hbl Qtz diorite) and white to light grey Qtz clasts. Lesser poorly sorted sandstone, granule conglomerate and monomictic (limestone) pebble to boulder conglomerate. Interbedded with argillite, siltstone and very fine- to fine-grained sandstone. Minor lapilli-tuff, lapillistone and tuff breccia (similar to lJTLv). Conglomerate weathers in positive relief relative to enclosing fine-grained rocks. Mostly resistant, orangey grey to dark grey to light grey weathering.	
Late Triassic		Sinwa Fm.	**Limestone (uTrS*ls*); ≥400 m thick.** Massive recrystallized limestone; where less recrystallized the protolith is a wackestone to packstone with abundant fossil fragments (0.1-2 cm) in a lime mud matrix. Resistant, light grey weathering. Contains upper Norian conodonts (Gabrielse, 1998).	
Middle Jurassic	Bowser Lake Group		**Undivided sedimentary unit (mJBL*s*).** **Sedimentary facies 1; >430 m thick.** Interbedded 1) recessive, maroon to greenish-grey laminated to thin-bedded siltstone to fine-grained sandstone, 2) recessive to moderately resistant, thin- to thick-bedded, internally massive to cross-bedded, maroon, light greenish grey to dark grey, medium- to very coarse-grained lithic arenite with abundant chert grains, 3) resistant, green-grey to orange-brown very thick-bedded chert pebble (to cobble) conglomerate with predominantly subrounded to rounded grey, white, reddish, greenish, brown, black radiolarian chert clasts and lesser (0-5%) medium grey limestone clasts in a medium-grained sand- to granule-sized matrix. Rare <1 m-thick maroon lapilli-tuff beds. Intercalated mafic flows (mJBLv) and lustrous black organic detritus (up to 1-4 cm) suggests subaerial deposition. Brown-grey very thinly laminated limestone bed (5-40 cm thick) near the base of the facies in the southwest. **Sedimentary facies 2.** "interbedded marine shale and greenish breccia, siltstone, and tuffaceous shale" (Gabrielse, 1998). Contains early Bajocian ammonites (Gabrielse, 1998). **Conglomerate facies; >330 m thick.** Medium to very thick, internally massive to locally fining upward beds of pebble (to cobble) conglomerate, interbedded with minor very thin to thin beds of medium-grained sandstone to granule conglomerate. Contains 50-95% rounded to subrounded light to dark grey, green and red radiolarian chert pebbles and 5-50% subrounded to rounded light grey limestone pebbles to cobbles. Contains woody fragments (Gabrielse, 1998). Resistant, orangey-grey knobbly weathering.	Stikinia

Table 1. Continued.

Age	Unit		Description	Position
Middle Jurassic	Bowser Lake Group		**Mafic volcanic rocks (mJBL*v*); ≤60 m thick.** Coherent rocks with 10-15% commonly brownish or reddish altered Aug (0.1-1 mm) and 30-50% Pl (0.1-0.2 mm). Generally found as 10-30 m thick stratiform units, commonly with narrow (20-30 cm thick) brecciated bottoms and tops, indicating they are flows. Locally, the base has moderately well-developed columnar joints (0.5-0.75 m wide). Laminated, well-sorted tuff to lapillistone (clast-supported; with up to 3-4 mm volcanic clasts, generally with a matrix-deficient open framework) commonly underlies flows. In one location a flow is directly underlain and overlain by siltstone and sandstone (mJBLs). Minor lapilli-tuff and lapillistone with grey, green and reddish Aug-Pl-phyric clasts and chert granules to pebbles. Resistant; orangey-brown weathering (flows) to recessive, brownish-grey weathering (tuff, lapilli-tuff, lapillistone).	Stikinia
Middle Jurassic	upper part of Hazelton Group	Horn Mountain Formation	**Upper felsic volcanic rocks (mJHM*Uvf*); 0-100 m thick.** Crudely to well-stratified felsic tuff, lapilli-tuff, lapillistone, tuff breccia and breccia. Contains maroon, creamy orange, light grey, white, creamy green and brick red Pl-phyric and lesser aphyric clasts; common flow-banded and rare spherulitic clasts. Stratiform maroon to cream, flow banded, Pl-phyric coherent intervals (~5-50 m thick) are generally directly underlain and overlain by lapillistone, tuff breccia and breccia with clasts that have identical textures, suggesting these coherent intervals represent felsic flows. Rare welded lapilli-tuff. Clasts and coherent rocks contain 10-25% equant to rectangular Pl (0.5-2 mm). Rarely contains minor grey limestone clasts. Moderately resistant; weathers light grey, maroon, pale green.	
Early-Middle Jurassic			**Middle maroon volcanic rocks (lmJHM*Mv*); >1500 m thick.** Interlayered flows, volcanic breccia, tuff breccia, lapillistone, lapilli-tuff and tuff. Aug-Pl-phyric flows (maroon to maroonish-grey to greyish-green, 5-20 m thick) transition to monomictic autoclastic breccia. Flows are locally amygdaloidal; their texture and composition ranges from 1) fine-crystalline with 25-30% lath-shaped Pl (0.5 x 2 mm) and 5-15% equant Aug (0.5 mm), to 2) medium-crystalline with 20-35% stubby Pl (1-2 mm x 2-4 mm), 5-10 % equant to rare elongate Aug (?; 1 mm), and up to 7% microdiorite xenoliths, to 3) rare coarse-crystalline with 40% Pl (1-2 mm) and 30% Aug (2-10 mm). Crudely stratified maroon to brick red tuff, crystal tuff, lapilli-tuff. Maroon lapillistone, tuff breccia, breccia contains varicoloured (maroon, green, grey, brick red) subangular Aug-Pl-phyric clasts and lesser aphyric clasts in a matrix with abundant angular to euhedral Pl. Minor well-stratified volcaniclastic siltstone to very fine- to coarse-grained volcaniclastic sandstone (with common angular to euhedral Pl) interbedded with tuff and lapilli-tuff. Minor felsic tuff, lapilli-tuff, lapillistone, volcanic breccia and a felsic flow. Rare welded lapilli-tuff. Resistant, dark grey, maroonish grey to brick red weathering.	
			Lower mafic volcanic rocks (lmJHM*Lvm*); ≥2000 m thick. Massive, monomictic volcanic breccia to tuff breccia; predominantly clast supported. Subangular grey, greyish green and green clasts (0.5-100 cm) contain 15-25% Aug (0.5-7 mm) and 20-60% equant to lath-shaped Pl (0.2-2.5 mm). Rare tuff, crystal tuff, and volcaniclastic sandstone beds. Locally, the base of the unit contains Aug-Pl-phyric coherent rocks, commonly with <5 mm wide very fine-grained dark grey irregular to wispy bands and minor in-situ brecciated domains grading into volcanic breccia; these may represent local flows and flow-margin autobreccias. Very resistant and cliff-forming; greenish grey weathering. **Lower volcaniclastic sandstone (lmJHM*Lvs*); 0-60 m thick.** Thin- to medium-bedded (commonly wavy) volcaniclastic sandstone (locally calcite-cemented), laminated siltstone, and crystal tuff. Sandstone contains abundant angular to subangular Pl grains. Fairly recessive, tannish grey weathering. **Lower felsic volcanic rocks (lmJHM*Lvf*); 0-20 m thick.** Felsic lapillistone, lapilli-tuff and lesser tuff, tuff breccia and breccia. Contains predominantly angular to subangular white, cream to greenish-grey aphanitic to Pl-phyric felsic clasts, locally subordinate mafic volcanic clasts, and rare Qtz-phyric or flow-banded felsic clasts. Resistant, yellowish grey weathering.	
		Spatsizi Formation	**Argillite, siltstone and sandstone (lmJSP*s*); ~0.2 km thick.** Interbedded laminated siltstone and thin- to medium-bedded fine- to medium-grained sandstone. Fining upward, internally massive to locally laminated sandstone beds with scoured bases generally grade upward into parallel laminated siltstone. Generally silicified. Local small-scale syn-sedimentary faults. Thick- to very thick-bedded, medium- to coarse-grained feldspathic arenite with abundant Pl, 10-20% Qtz and ~5% mafic grains; locally contains minor white felsic (?) clasts. Rare mafic tuff and tuff breccia with Aug-Pl-phyric volcanic clasts. Recessive to moderately resistant, rusty brown weathering. Contains Toarcian fossils (Gabrielse, 1998).	
			Basal sandstone and conglomerate (lmJSP*cg*); 20-50 m thick. Thin- to medium-bedded, medium- to very coarse-grained feldspathic arenite (locally calcite-cemented) with 20-40% Qtz grains; Qtz-rich granule conglomerate with granitic pebbles. Moderately resistant, light grey weathering.	

rocks 2 km to the southeast is interpreted as Stuhini Group (after Gabrielse, 1998), but could also be part of the Horn Mountain Formation.

3.1.3. Hazelton Group (Lower to Middle Jurassic)

Volcano-sedimentary rocks in the upper part of the Hazelton Group are exposed on both sides of the McBride River (Fig. 3). We divide them into a lower sedimentary succession (Spatsizi Formation; up to 0.2 km thick), and a conformably overlying, mainly volcanic succession (Horn Mountain Formation; at least 3.5 km thick; Fig. 4). On the west flank of Peak 2102 m, the Spatsizi Formation unconformably overlies the Cake Hill pluton (Late Triassic); southeast of the peak, the Horn Mountain Formation unconformably overlies the Cake Hill pluton. Elsewhere in the western part of the map area, the stratigraphic level occupied by the unconformity, Spatsizi Formation and lower part of the Horn Mountain Formation is cut by the Three Sisters pluton (Middle Jurassic). In the eastern part of the map area, the middle and upper part of the Horn Mountain Formation is conformably overlain by the Bowser Lake Group

3.1.3.1. Spatsizi Formation

The Spatsizi Formation (defined by Thomson et al., 1986 and modified by Evenchick and Thorkelson, 2005 and Gagnon et al., 2012) is exposed in a 0.6 by 5 km area centered on Peak 2102 m in the western part of the map area (Fig. 3). It unconformably overlies the quartz-rich phase of the Cake Hill pluton (Late Triassic; Section 4.1.), and is conformably overlain by volcanic rocks of the Horn Mountain Formation. In the present map area, we recognize a basal sandstone and conglomerate unit (20-50 m thick), and an overlying argillite, siltstone, and sandstone unit (~0.2 km thick; Table 1), similar to subdivisions along strike to the northwest in the adjoining map area (van Straaten and Gibson, 2017).

The unconformity above hornblende granodiorite of the Cake Hill pluton is defined on the west flank of Peak 2102 m. After a covered interval of 1.5 m, coarse- to very coarse-grained quartz-rich feldspathic arenite and granule conglomerate with granitic pebbles (Fig. 5a) appear. Calcic exoskarn is commonly observed in calcareous sandstone near the contact, and locally adjacent to felsic dikes that cut the Spatsizi argillite, siltstone and sandstone unit. The skarn consists of brown garnet and green diopside bands alternating with cream-coloured bands containing minor epidote. Late Early to Middle Jurassic felsic intrusions (unit EMJf or MJTSgr, see Sections 4.2., 4.3.) were likely responsible for skarn development and we speculate that the flow of metasomatic fluids may have focussed along the anisotropy provided by the unconformity. Geochronological results from the hornblende granodiorite (216.2 ±1.2 Ma, van Straaten et al., 2012), and ammonite collections from the Spatsizi Formation in the map area (Toarcian, Gabrielse, 1998) and fossils along strike to the west-northwest (late Pliensbachian to Toarcian, van Straaten et al., 2017) indicate a significant hiatus across the unconformity. Consistent with the interpretation of an unconformity, grain size in the granodiorite does not decrease towards the contact, granodiorite dikes are lacking in the Spatsizi Formation, and the contact lacks evidence of a fault.

Crudely bedded medium- to very coarse-grained quartz-rich feldspathic arenite and granule conglomerate with granitic pebbles in the basal unit (Fig. 5a) grade upward to a unit of argillite, siltstone, and sandstone (Fig. 5b). Abundant incomplete Bouma-like sequences include fining upward, internally massive to locally laminated sandstone beds with scoured bases that generally grade upward into parallel laminated siltstone. These sandstone-siltstone couplets are interpreted as subaqueous mass flow deposits. Interbedded argillite, siltstone and very fine- to medium-grained sandstone are generally strongly silicified and contain 5-10% disseminated pyrite (Section 7.1.). The unit also includes thick to very thick feldspathic arenite beds, and rare mafic volcanic rocks.

The base of the Spatsizi Formation marks the change from latest Triassic - Early Jurassic uplift and erosion of northern Stikinia to late Early Jurassic subsidence and sedimentation. The basal unconformity represents one of the few well-documented examples of the pre-late Early Jurassic unroofing of a Triassic pluton in northern Stikinia. The associated hiatus spans at least 30 m.y. (Fig. 4), a period of time that saw widespread lower Hazelton Group volcanism and the latest Triassic and Early Jurassic porphyry copper metallogenic epochs farther south (e.g., Galore Creek, Red Chris, KSM; Logan and Mihalynuk, 2014). The unconformity in the Dease Lake area contrasts with the latest Triassic sub-Hazelton Group unconformity in the south, which spans <5 m.y. (Nelson et al., 2018). Regionally, the Spatsizi Formation is correlated with the predominantly siliciclastic Nilkitkwa Formation east and northeast of Smithers (Marsden and Thorkelson, 1992). The north-northwest trend of the Spatsizi and Nilkitkwa formations records Pliensbachian to Toarcian marine sedimentation in a back-arc or intra-arc depression (Hazelton trough, Fig. 1; Tipper and Richards, 1976; Marsden and Thorkelson, 1992; Gagnon et al., 2012).

3.1.3.2. Horn Mountain Formation

Herein, we significantly expand the known along-strike extent of the Horn Mountain Formation (defined by van Straaten and Nelson, 2016) to 80 km. This predominantly volcanic succession displays relatively consistent stratigraphy and lithological characteristics along its strike length. In the McBride River study area, we recognize three subdivisions that are similar to those in the adjoining map area to the northwest (van Straaten and Gibson, 2017); the lower mafic volcanic unit, the middle maroon volcanic unit and the upper felsic volcanic unit (Fig. 4, Table 1). The lowermost volcanic units and the upper mafic volcanic unit of van Straaten and Gibson (2017) were not observed in the study area.

West of the McBride River, moderately northeast-dipping volcanic rocks of the Horn Mountain Formation conformably overlie the Spatsizi Formation. Here, the Horn Mountain lower mafic volcanic unit is overlain by the middle maroon volcanic

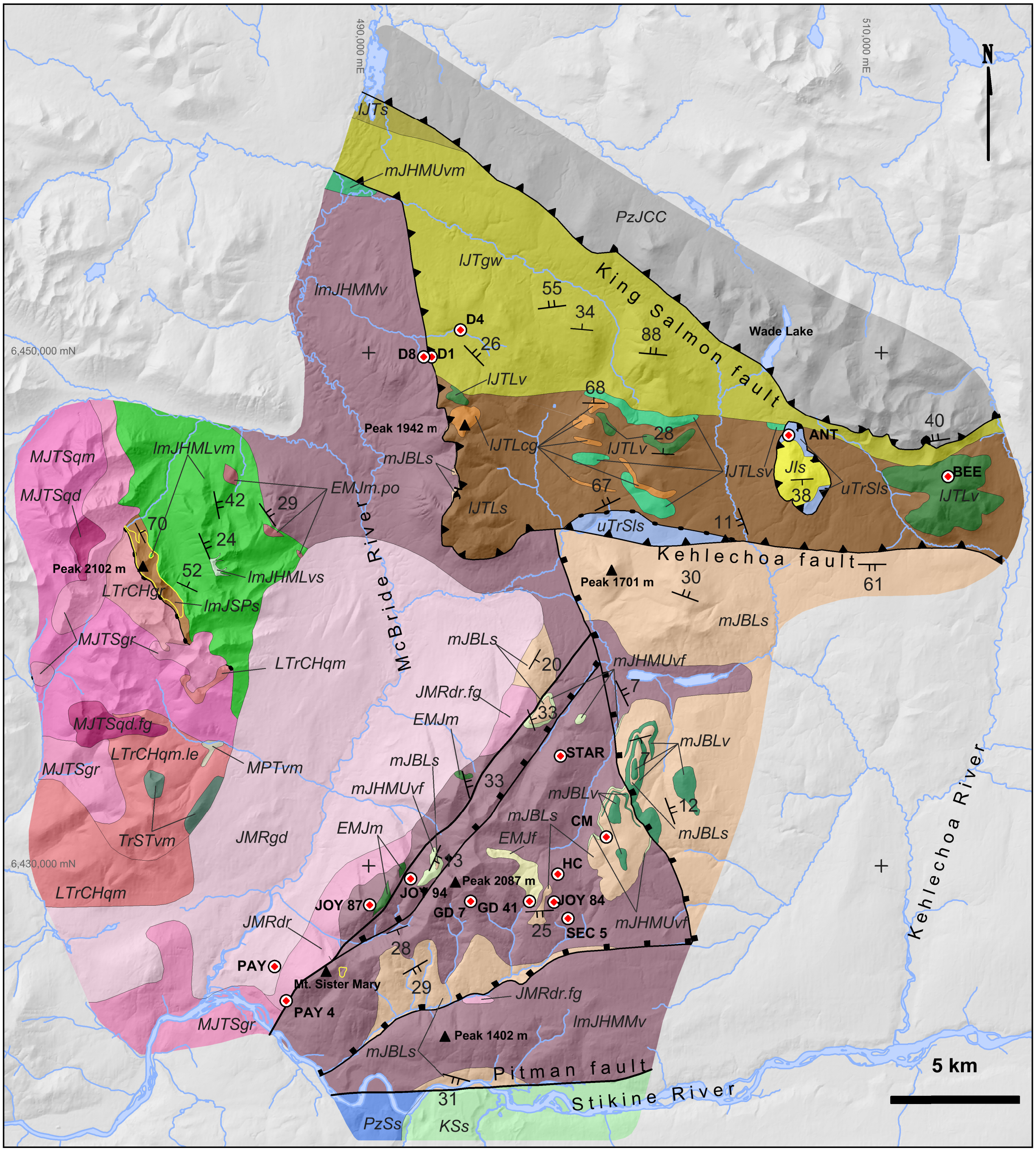

Fig. 3. Geologic map of field area. See Figure 2 for location.

unit with an apparent conformable contact. Along the McBride River, the Horn Mountain Formation is cut by the McBride River pluton (Middle Jurassic or younger, Section 4.4.). East of the McBride River, the Horn Mountain Formation is moderately to gently southeast-, east- and northeast-dipping to subhorizontal, and cut by north-northeast to north-northwest trending faults (Section 5.1.). Here, the formation comprises the middle maroon volcanic unit, which is generally overlain by the upper felsic volcanic unit; both are conformably overlain by sedimentary rocks of the Bowser Lake Group in the north, east and south (Fig. 3).

Stratified rocks

Overlap assemblages

Miocene-Pleistocene, Tuya Formation

MPTvm — Olivine basalt

Cretaceous, Sustut Group

KSs — Undivided

Stikinia

Middle Jurassic, Bowser Lake Group

mJBLs — Sandstone, conglomerate and shale

mJBLv — Mafic volcanic rocks

Lower to Middle Jurassic, upper Hazelton Group

Middle Jurassic, Horn Mountain Formation

mJHMUvm — Upper mafic volcanic rocks

mJHMUvf — Upper felsic volcanic rocks

Lower to Middle Jurassic, Horn Mountain Formation

lmJHMMv — Middle maroon volcanic rocks

lmJHMLvm — Lower mafic volcanic rocks

lmJHMLvs — Lower volcaniclastic sandstone

Lower to Middle Jurassic, Spatsizi Formation

lmJSPs — Argillite, siltstone and sandstone

Triassic, Stuhini Group

TrSTvm — Mafic volcanic rocks

Paleozoic, Stikine assemblage

PzSs — Undivided

Whitehorse Trough

Lower Jurassic, Laberge Group

Lower Jurassic, Takwahoni Formation

lJTs — Siltstone

lJTgw — Greywacke

Lower unit

lJTLsv — Volcaniclastic sandstone

lJTLv — Mafic volcanic rocks

lJTLs — Argillite and siltstone

lJTLcg — Conglomerate

Cache Creek

Paleozoic to Jurassic

PzJCC — Undivided

Jurassic, Inklin Formation

Jls — Sandstone and siltstone

Upper Triassic, Sinwa Formation

uTrSls — Limestone

Intrusive rocks

Jurassic, McBride River pluton

JMRgd — Hornblende-biotite granodiorite

JMRdr — Hornblende-clinopyroxene(?) diorite

Middle Jurassic, Three Sisters pluton

MJTSgr — Biotite monzogranite

MJTSqm — Biotite quartz monzonite

MJTSqd — Hornblende quartz diorite

Early to Middle Jurassic, Horn Mountain intrusions

EMJf — Felsic intrusive

EMJm.po — Platy plagioclase porphyry

EMJm — Mafic intrusive

Late Triassic, Cake Hill pluton

LTrCHgr — Hornblende monzogranite

LTrCHqm — Hornblende quartz monzodiorite

Bedding, tops known, right-way up

Bedding, tops unknown

Contact

Unconformity

Fault

Reverse fault

Normal fault

Altered or gossanous rocks

Peak

MINFILE/mineral occurrence

UTM Zone 9 NAD83
Parts of NTS 104H/14, 15;
104I/02, 03, 06, 07

Fig. 3. Continued.

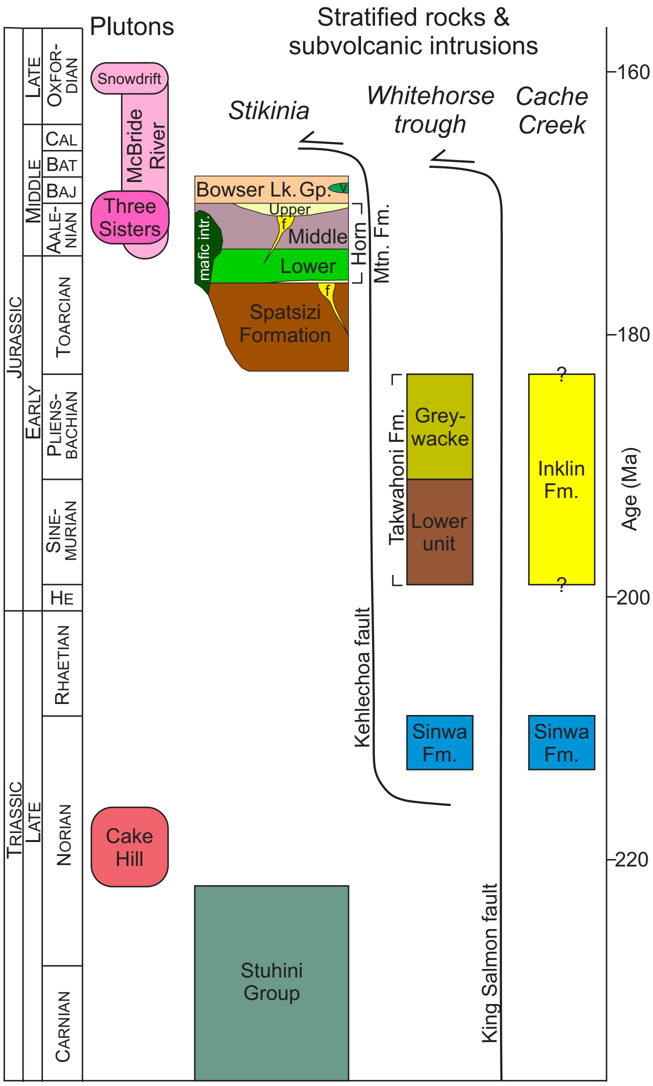

Fig. 4. Schematic stratigraphic, plutonic, and structural relationships for Triassic to Jurassic rocks in the map area. Abbreviations: felsic intrusive (f), Bowser Lake mafic volcanic rocks (v), Hettangian (He), Bajocian (Baj), Bathonian (Bat), Callovian (Cal). Chronostratigraphic ages from Cohen et al. (2013, updated February 2017).

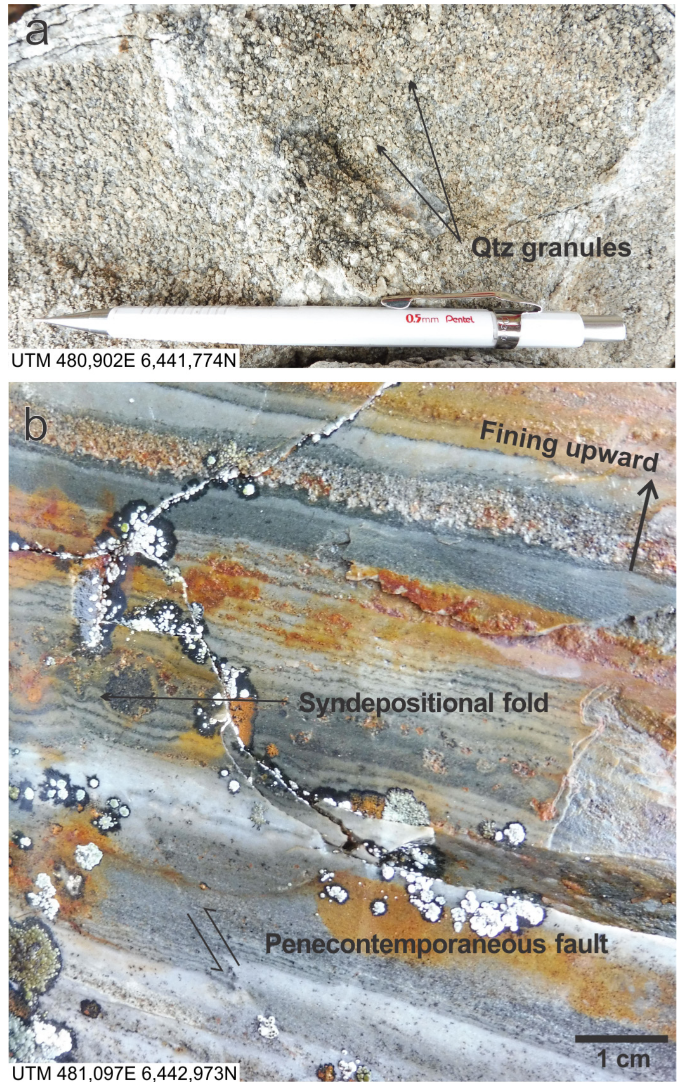

Fig. 5. Spatsizi Formation. **a)** Basal conglomerate unit (lmJSPcg). Granule conglomerate with quartz fragments in a very coarse sandstone matrix. **b)** Argillite, siltstone and sandstone unit (lmJSPs). Strongly silicified thinly laminated to thinly bedded siltstone and fine-grained sandstone.

The lower mafic volcanic unit is at least 2 km thick and consists predominantly of massive greenish-grey monomictic volcanic breccia to tuff breccia with augite-plagioclase-phyric clasts (Fig. 6a; Table 1). In most locations, the base of the unit is marked by a felsic volcanic subunit (up to 20 m thick; Fig. 6b). The lower contact of the unit is conformable, displaying gradational to locally sharp relationships with rocks in the upper part of the Spatsizi Formation. On the northwest ridge of Peak 2102 m, a ~5 m-thick gradational contact shows interfingering siltstone, sandstone and felsic volcanic rocks. In the valley east of Peak 2102 m, stratified sedimentary rocks (locally with m-scale intraclasts) were observed immediately below and above the felsic volcanic subunit. We consider that the unit was deposited subaqueously because similar lower Horn Mountain Formation units along strike to the northwest locally contain pillows and interfinger with sedimentary rocks interpreted as submarine (van Straaten and Gibson, 2017). A mafic volcanic breccia with minor granitic clasts outcrops 5.3 km southeast of Peak 2102 m, ~400 m from the Cake Hill pluton. The contact was not observed, but it is likely unconformable. In the adjoining map area to the northwest, similar Horn Mountain granitic clast-bearing mafic volcanic breccias rest directly on the Cake Hill pluton (van Straaten and Gibson, 2017). Within the lower mafic unit, a volcaniclastic sandstone subunit (up to 60 m thick) was mapped 2.8 km east of Peak 2102 m; it is inferred to pinch out along a short distance.

The middle maroon volcanic unit contains interlayered mafic to intermediate lapilli-tuff, tuff, flows, lapillistone, tuff breccia and breccia (Fig. 7, Table 1). Clasts are augite-plagioclase-phyric, plagioclase-phyric and aphyric. The

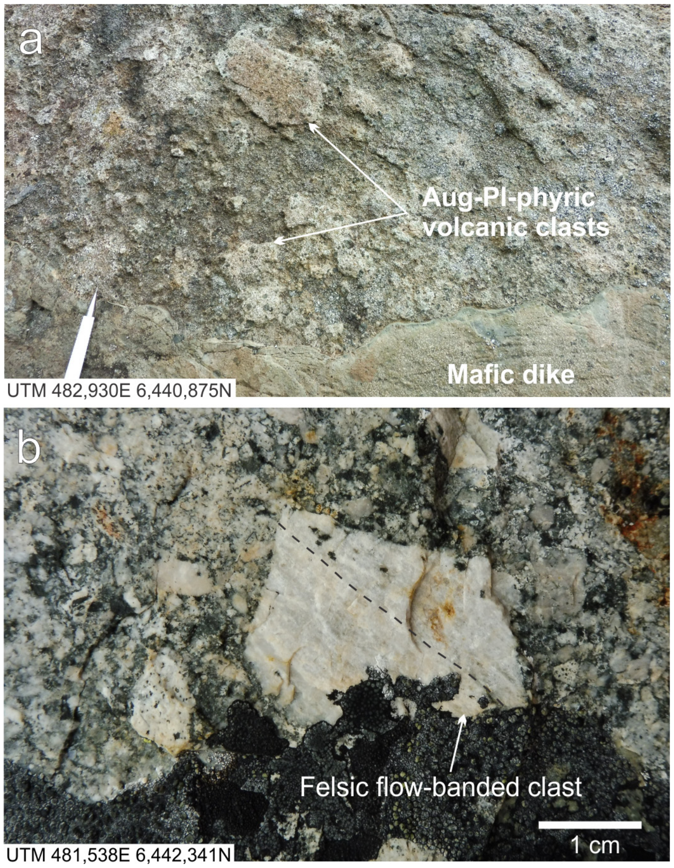

Fig. 6. Horn Mountain Formation. **a)** Lower mafic volcanic unit (lmJHMLvm). Massive monomictic augite-plagioclase-phyric volcanic breccia to tuff breccia cut by a metre-scale subvolcanic mafic dike (EMJm). **b)** Lower felsic volcanic subunit (lmJHMLvf). Tuff breccia with felsic flow-banded clasts.

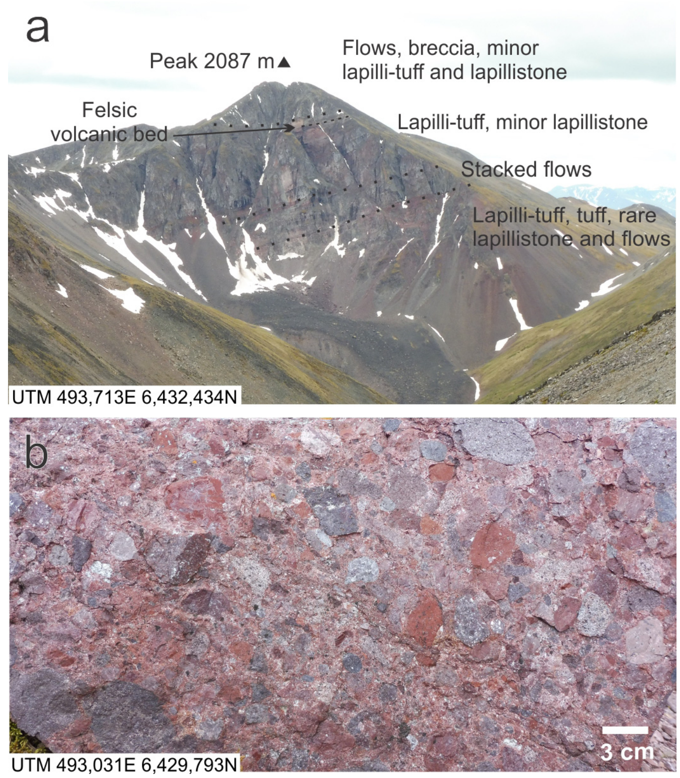

Fig. 7. Horn Mountain Formation, middle maroon volcanic unit (lmJHMMv). **a)** View of interlayered lapilli-tuff, tuff, flows, lapillistone, tuff breccia, breccia and rare felsic volcanic rocks on the north face of Peak 2087 m. **b)** Massive, clast-supported maroon lapillistone.

thickness of the unit is difficult to estimate due to a lack of marker units, truncation by the McBride River pluton, and poorly constrained offset along faults. It is at least 1.5 km thick, but may be significantly thicker. We interpret the bedding-parallel coherent intervals as flows because they 1) overlie and underlie breccias interpreted as flow-marginal autobreccias; 2) overlie red baked tuffs; and 3) gradationally overlie spatter deposits with rare cow-pat-shaped vesicular clasts. Delicate pumiceous clasts and welded lapilli-tuff suggest subaerial deposition. The unit contains minor 0.1-20 m-thick felsic volcanic intervals composed of tuff, lapilli-tuff, lapillistone and volcanic breccia. A 70 m-thick interval of felsic volcanic rocks, including a spherulitic to flow-banded felsic coherent rock interpreted as a flow, are 1.7 km north-northeast of Peak 2087 m. In one location near the base of the northwest ridge of Peak 2087 m we observed abundant limestone clasts in brick red tuff and lapilli-tuff. The broad ridge incorporating Peak 1402 m north of the Stikine River exposes a succession of rusty brown to maroon augite-plagioclase-phyric coherent rocks, brown weathering lapilli-tuff to lapillistone with plagioclase-phyric lapilli and local intervals (probable intrusions) of coarse platy plagioclase porphyry. We include this unit, designated as mJgv and mJvp by Read and Psutka (1990), within the middle maroon volcanic unit. The lower contact of the middle maroon volcanic unit was not observed, but the presence of maroon lapilli-tuff to crystal tuff in the top of the lower mafic volcanic unit suggests that the contact is gradational.

The upper felsic volcanic unit is up to 100 m thick, and contains felsic tuff, lapillistone, tuff breccia, breccia and flows. Clasts are plagioclase-phyric to aphyric and commonly flow banded (Fig. 8). The unit thins to 2-4 m in the southwest, and is either absent or thin and recessive in the south and southeast. The lower contact is gradational based on the following

Fig. 8. Horn Mountain Formation, upper felsic volcanic unit (mJHMUvf). Tuff breccia with angular flow-banded felsic clasts.

observations. 1) On a ridge 2.9 km north-northeast of Peak 2087 m, maroon augite-plagioclase-phyric flows (middle maroon volcanic unit) are conformably overlain by felsic lapillistone with flattened pumices grading up to purple and white felsic tuff breccia with flow-banded clasts (upper felsic volcanic unit). 2) Two kilometres north-northeast of the CM prospect, maroon crystal tuff and tuff (middle maroon volcanic unit) are overlain by felsic tuff breccia and a flow-banded felsic flow (upper felsic volcanic unit). 3) At the CM prospect, maroon to brick red crystal tuff and lapilli-tuff (middle maroon volcanic unit) are overlain by a 50 m-thick flow-banded purple and white felsic coherent rock (upper felsic volcanic unit).

3.1.4. Bowser Lake Group (Middle Jurassic)

Bowser Lake Group sedimentary rocks conformably overlie the Horn Mountain Formation east of the McBride River. We distinguish two sedimentary, one conglomerate and one volcanic facies (Table 1).

Sedimentary facies 1 (Table 1) is the most common in the map area, and comprises maroon to greenish-grey siltstone and sandstone (Fig. 9) with lesser chert clast-bearing conglomerate.

Fig. 9. Bowser Lake Group (mJBLs), sedimentary facies 1. Maroon laminated to thinly-bedded siltstone and fine-grained sandstone with local cross bedding.

Organic detritus and interbedded volcanic flows (see below) attest to subaerial deposition.

Minor volcanic rocks (mJBLv, Table 1) are found within sedimentary facies 1. They include augite-plagioclase-phyric coherent rocks (Fig. 10a) and subordinate mafic tuff, lapilli-tuff and lapillistone. In many instances the coherent rocks show brecciated lower and upper contacts, suggesting they are extrusive (Fig. 10b). These coherent rocks can be distinguished from mafic feeder dikes of the Horn Mountain Formation (EMJm, Table 2) by their smaller grain size and orangey-brown weathering colour. Laminated, very well-sorted tuff to lapillistone commonly underlie the flows and likely represent airfall deposits that preceded the effusive stage. In one location, we observed possible adhesion warts (Fig. 10c), which form by wind drifting sand across a damp surface (e.g., Olsen et al., 1989).

Gabrielse (1998) described “interbedded marine shale and greenish breccia, siltstone, and tuffaceous shale” containing early Bajocian ammonites on Peak 1701 m. Based on the predominantly fine-grained siliciclastic nature and submarine depositional environment, we assign these rocks to sedimentary facies 2 (Table 1). The facies likely includes poorly exposed fine-grained siliciclastic rocks in the northeast part of the map area near the Kehlechoa fault.

The conglomerate facies (Table 1) is exposed 3.5 km southeast of Peak 1701 m. It comprises a succession, at least 330 m thick, of chert ±limestone clast-bearing conglomerate with minor sandstone interbeds.

Light brown weathering chert clast-bearing pebble conglomerate and recessive, dark grey-to cream-weathering, laminated to very thinly bedded siltstone and very fine-grained sandstone is exposed along the north bank of the Stikine River. It is tentatively assigned to the Bowser Lake Group, but could also be part of the Sustut Group mapped by Read and Psutka (1990) across the Pitman fault to the south.

The lower contact of the Bowser Lake Group is conformable based on observations at six locations. 1) Three-and-a-half kilometres southwest of Peak 2087 m, the top of the Horn Mountain middle maroon volcanic unit contains maroon tuff to lapilli-tuff with rare chert clasts, indicating interfingering with Bowser Lake Group chert clast-bearing conglomerates. It is overlain by a light green felsic lapillistone bed (2-4 m thick) with rare limestone clasts (Horn Mountain upper felsic volcanic unit) and maroon to greenish-grey laminated to thinly-bedded siltstone to fine-grained sandstone with rare 5-40 cm-thick internally laminated limestone beds and very thick chert clast-bearing pebble conglomerate beds (Bowser Lake Group). 2) One kilometre northwest of Peak 2087 m, felsic lapillistone grades into stratified crystal tuff (Horn Mountain upper felsic volcanic unit) and is conformably overlain by an internally laminated limestone bed and maroon to sea-green siltstone to fine-grained sandstone (Bowser Lake Group). 3) Six-and-a-half kilometres south-southwest of Peak 1701 m, maroon lapilli-tuff with flow-banded felsic clasts fines upward into very thickly-bedded maroon crystal tuff (Horn Mountain upper

Table 2. Summary of intrusive units. Mineral abbreviations after Kretz (1983).

Age	Phase	Description	Relationships to adjacent units	Geochronology
Jurassic	McBride River pluton	**Hbl-Bt granodiorite (JMR*gd*).** Massive, equigranular (2-5 mm). Contains 15-30% mafic minerals; euhedral Bt books (2-6 mm) and euhedral, prismatic Hbl (<1 cm long) in approximately equal proportions. Common dark grey dioritic xenoliths. Recessive, medium grey weathering.	Cuts Horn Mountain lower mafic volcanic unit and mafic intrusive unit.	U-Pb zircon: 184±8 Ma[4] (see Section 4.4.)
		Hbl-Cpx(?) diorite to Qtz diorite (JMR*dr*). Equigranular (1-3 mm) to Pl porphyritic (2-4 mm). Includes Hbl diorite (JTSdi)[5]. Moderately recessive, medium to dark grey weathering.	Cuts Horn Mountain middle maroon volcanic unit and felsic intrusive unit.	
		Fine-grained mafic-rich microdiorite (JMR*dr.fg*). Massive, equigranular (0.1-0.5 mm) microdiorite with 50-70% lath-shaped to anhedral Pl and 30-40% vaguely elongate to anhedral black mafic minerals. Moderately recessive, blocky, medium grey weathering. Includes green-grey meta diabase (mJd)[5].	Cuts Bowser Lake Group sedimentary rocks, which also display features of contact metamorphism.	
		Hbl-Cpx-Pl porphyry dikes (J*dr*). Hbl-Pl, Cpx-Pl and Hbl-Cpx-Pl-porphyritic dikes. Aphyric to microdioritic groundmass, locally contains acicular Hbl.	Cuts Takwahoni lower unit, Horn Mountain middle maroon volcanic unit, Bowser Lake Group. Follows north-trending Kehlechoa fault.	
Middle Jurassic	Three Sisters pluton	**Potassic phase (MJTS*gr*).** Bt and lesser Hbl-Bt monzogranite to rare Qtz syenite. Massive, equigranular (1-3 mm). Rare Qtz eyes (4-5 mm). Moderately recessive, orange-pinkish weathering. Includes Hbl-Bt granite (JTSg)[5].	Cuts Cake Hill Qtz-rich phase, Three Sisters mafic and central felsic phase. Cuts and includes pendants of platy Pl porphyry.	U-Pb zircon: 171±1 Ma[4], 169.1±0.8 Ma[3], 168.57±0.54 Ma[2]
		Central felsic phase (MJTS*qm*). Bt Qtz monzonite. Massive, equigranular (1-4 mm) to locally Pl and Kfs porphyritic. Contains cm- to dm-scale, sub-angular, equigranular (0.1-2 mm) dioritic xenoliths. Resistant, medium grey weathering.	Intrudes, brecciates, and includes xenoliths of Three Sisters mafic phase.	U-Pb zircon: 177.13±0.59 Ma[2], 172.75±0.87 Ma[2], 169.0±1.3 Ma[3]
		Mafic phase (MJTS*qd*). Hbl-rich (minor Bt-Cpx Hbl-rich) Qtz diorite[3]. Includes a Hbl-Cpx diorite body with platy Pl (1-3 x 5-20 mm) and euhedral Cpx and Hbl (1-3 mm) set in an equigranular (0.1 mm) groundmass with lath-shaped to anhedral Pl (40-70%) and equant black mafic minerals (<30%). Locally contains platy Pl porphyritic melanocratic xenoliths. Resistant, brownish dark grey to black weathering.		Ar-Ar Hbl: 171.9±1.7 Ma[3]
		Fine-grained mafic-intermediate phase (MJTS*qd.fg*)[3]. Hbl-Bt Qtz diorite. Equigranular (1-1.5 mm) to sparsely Pl porphyritic (1.5-3 mm).		Ar-Ar Hbl: 173.2±Ma[3]

Table 2. Continued.

Age	Phase	Description	Relationships to adjacent units	Geochronology
late Early-Middle Jurassic	Horn Mountain-related subvolcanic intrusions	**Felsic intrusive (EMJ*f*).** Creamy white, green-grey, pale yellow to maroon dikes, sills and other intrusive bodies. Generally flow banded, locally spherulitic. Generally contains 5-20% white to orange stubby to lath-shaped Pl (1-3 mm) and very rare minor Qtz (<0.5 mm). Resistant, yellowish weathering.	Cuts Spatsizi Formation, Horn Mountain middle maroon volcanic rocks and base of Bowser Lake Group.	
		Platy Pl porphyry (EMJ*m.po*). Platy Pl-phyric dikes, sills and other intrusive bodies. Contains 30-50% platy Pl (0.5-3 cm) and locally <5% Aug (5 mm) in a dark grey aphanitic to microdioritic groundmass.	Cuts Spatsizi Formation; Horn Mountain lower mafic volcanic unit and middle maroon volcanic unit.	
		Mafic intrusive (EMJ*m*). Aug-Pl-phyric dikes, sills and other intrusive bodies. Contains 15-40% Pl laths (0.1-1 mm) and 10-15% dark green/black equant Aug (0.5-1 cm). Resistant, dark greenish grey weathering.	Cuts Cake Hill quartz-rich phase; Horn Mountain lower mafic volcanic unit, lower volcaniclastic sandstone unit, middle maroon volcanic unit and upper felsic volcanic unit.	
Late Triassic	Cake Hill pluton	**Cake Hill Qtz-rich phase (LTrCH*gr*).** Hbl granodiorite to monzogranite. Massive, equigranular (2-4 mm) with minor ubiquitous Qtz eyes (5-7 mm). Contains tabular Hbl and lacks xenoliths. Moderately resistant, light-medium grey weathering.	Unconformably overlain by Spatsizi basal sandstone and conglomerate unit.	U-Pb zircon: 217.91±0.24 Ma, 216.2±1.2 Ma[3]
		Cake Hill pluton (LTrCH*qm*)[3]. Euigranular (3-4 mm) Hbl to lesser Bt-Hbl Qtz monzodiorite and Qtz monzonite. Tabular Hbl bearing, trace Ttn usually ubiquitous; trace Mag in places. Moderately resistant, light-medium grey weathering. **Leucocratic phase (LTrCH*qm.le*)[3].** Equigranular (1-3 mm), light-coloured and Ep altered Hbl Qtz monzodiorite, granodiorite, Qtz diorite, tonalite(?)	Interpreted to be unconformably overlain by Horn Mountain lower mafic volcanic unit.	U-Pb zircon: 221±3 Ma[4], 218.2±1.3 Ma[3]

Note: [1] van Straaten and Nelson (2016); [2] Takaichi (2013a; b); [3] van Straaten et al. (2012); [4] Anderson and Bevier (1992); [5] Read and Psutka (1990).

Fig. 10. Bowser Lake Group, mafic volcanic rocks (mJBLv). **a)** Close up of fine-grained augite-plagioclase-phyric coherent rock with characteristic reddish altered augite. **b)** Red tuff overlain by brecciated lower contact of fine-grained augite-plagioclase-phyric flow. **c)** Possible adhesion warts in crudely laminated crystal tuff. Weak alignment and asymmetry may indicate incipient adhesion ripples.

felsic volcanic unit) and grades into laminated to thinly-bedded siltstone to fine-grained sandstone (Bowser Lake Group). 4) Two kilometres north-northeast of the CM prospect, a 15-m-thick flow-banded felsic flow is overlain by cream-coloured tuff breccia with flow-banded clasts that grades upward into maroon crystal tuff and tuff (Horn Mountain upper felsic volcanic unit) and laminated maroon siltstone (Bowser Lake Group). 5) Half a kilometre west of the CM prospect, the top of the Horn Mountain middle maroon volcanic unit contains green chert-grain bearing lapillistone indicating interfingering with Bowser Lake Group. It is overlain by a 50 m-thick purple and white flow-banded felsic coherent rock (Horn Mountain upper felsic volcanic unit), maroon and green-grey sandstone and chert clast-bearing pebble conglomerate (Bowser Lake Group). 6) The immediate footwall of the north-trending Kehlechoa fault exposes a narrow strip of chert clast-bearing pebble to granule conglomerate and sandstone that interfingers with, and ultimately overlies, the Horn Mountain middle maroon volcanic unit (Fig. 19; van Straaten and Nelson, 2016).

Regionally, deposition of Cache Creek-derived chert clast-bearing conglomerate of the Bowser Lake Group records the onset of erosion from the Stikinia - Cache Creek tectonic welt (Evenchick et al., 2007). Bowser Lake Group strata in the map area are on the western margin of a northern outlier of the Bowser basin (Fig. 1) and contain early Bajocian ammonites on Peak 1701 m (Fig. 3; Tipper, 1978; Gabrielse, 1998). The biostratigraphic age is similar to a preliminary detrital zircon maximum depositional age (ca. 170 Ma) for Bowser Lake strata overlying Horn Mountain volcanic rocks in the Tanzilla area (van Straaten and Gibson, 2017). Together with early Bajocian fossils from chert-clast bearing granule conglomerate overlying a Whitehorse trough succession in the Lisadele Lake area (Fig. 1; Mihalynuk et al., 1999; Sirmohammad et al., 2011), these occurrences represent the oldest documented rocks in the Bowser Lake Group. Rocks at the base of the Bower Lake Group get progressively younger towards the south. Basal strata in the northern part of the contiguous Bowser basin (Fig. 1) are Bathonian; in the centre and south they are Callovian to Oxfordian (Evenchick et al., 2010). Within the contiguous Bowser basin, the Bowser Lake Group (Middle Jurassic to Cretaceous) comprises a shallowing-upward succession deposited in submarine fan, submarine slope, shallow-marine shelf to deltaic environments (Evenchick and Thorkelson, 2005). The oldest (Bathonian) strata in the northern and northeastern part of the contiguous Bowser basin were deposited in submarine fan to submarine slope environments, followed by deposition in shallow-marine shelf and deltaic environments by the early Oxfordian (Evenchick and Thorkelson, 2005; Evenchick et al., 2010).

In the present map area, the conglomerate facies likely formed in alluvial fans or braided river systems close to range front faults along the building orogen, with limestone cobbles to boulders derived from Sinwa Formation rocks in the hanging wall of thrust ramps. Interbedded fine-grained siliciclastic rocks and lesser chert clast-bearing conglomerate beds (sedimentary facies 1), and minor mafic volcanic flows (volcanic facies) were likely deposited in a more distal subaerial setting. We correlate the sedimentary facies 2 in the map area with coeval strata in the Tanzilla area (Fig. 2) where Bowser Lake conglomerate, sandstone and siltstone unconformably overlie the Horn Mountain Formation; clasts are locally-derived and the succession contains marine fossils (van Straaten and Nelson, 2016). The sedimentary rocks may have formed an elongate marine basin on the northern margin (present coordinates) of waning Horn Mountain volcanic centres.

3.2. Whitehorse trough

Strata of the Whitehorse trough are exposed in a west-northwest to east-southeast trending fault panel bounded by the Kehlechoa and King Salmon thrust faults; the belt abruptly narrows from ~13 km in the north central part of the map area to ~3-5 km in the west (Figs. 2, 3). Limestones of the Sinwa Formation are exposed in the immediate hanging wall of the Kehlechoa fault, and are overlain by siliciclastic rocks, polymictic conglomerates, and volcanic rocks of the Takwahoni Formation (Laberge Group; Table 1).

3.2.1. Sinwa Formation (Upper Triassic)

Light to medium grey Sinwa Formation limestones (Table 1; Late Norian, Gabrielse, 1998) form the basement to the Whitehorse trough succession. The Sinwa Formation-Takwahoni contact is hidden by a 35 m-long covered interval. The lowest Takwahoni Formation rocks exposed are fine- to medium-grained sandstones (this study), which yielded Sinemurian fossils along strike (Gabrielse, 1998). Based on the apparent time gap, the contact is likely an unconformity.

3.2.2. Takwahoni Formation (Lower Jurassic)

3.2.2.1. Lower unit

The southern portion of the Kehlechoa-King Salmon fault panel exposes a right-way-up, moderately north-dipping and lithologically-variable sequence. Within this sequence we distinguish four facies: argillite, siltstone and sandstone (Fig. 11); volcaniclastic sandstone; volcanic (Fig. 12); and conglomerate (Fig. 13, Table 1). The conglomerate and volcanic facies are exposed mainly on ridges, and detailed mapping suggests they form laterally discontinuous 100 m- to 3 km-scale bodies in argillite, siltstone and very fine- to fine-grained sandstone (Fig. 3). This map pattern is mimicked on a smaller scale, where we found several 0.1-50 m bulbous conglomerate bodies enveloped by fine-grained siliciclastic rocks (Fig. 13a). The conglomerate is predominantly polymictic and contains limestone, (sub)volcanic and lesser plutonic clasts (Fig. 13b). The (sub)volcanic clasts in the conglomerate facies and volcanic clasts in the volcanic facies are compositionally and texturally similar, except for the greater size range and larger average size of plagioclase phenocrysts in clasts in the conglomerate (Table 1). Several ~10-15 m limestone olistoliths are present within the conglomerate and volcaniclastic sandstone facies.

The lower unit has yielded fossil collections with Sinemurian and Toarcian ages (Gabrielse, 1998; Table 1). This has led Gabrielse (1998) and van Straaten and Nelson (2016) to infer several thrust faults separating Sinemurian and Toarcian rocks. During our mapping we observed identical lithologies within areas previously interpreted as Sinemurian and Toarcian, and found no evidence for major thrust faults. Based on these observations, and an apparent conformable contact with the overlying greywacke unit (Pliensbachian; see below), we suggest the lower unit may be an internally conformable succession and largely Sinemurian.

Fig. 11. Takwahoni Formation lower unit, argillite, siltstone and sandstone facies (lJTLs). Interbedded laminated to medium-bedded siltstone and medium-grained sandstone.

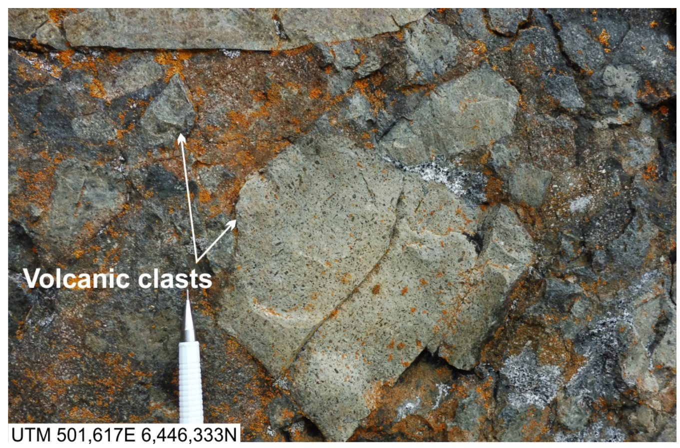

Fig. 12. Takwahoni Formation lower unit, mafic volcanic facies (lJTLv). Massive, clast-supported volcanic breccia.

Rocks beneath a klippe of Sinwa limestone and Inklin Formation south of Wade Lake are very poorly exposed. They have been tentatively interpreted as Takwahoni lower argillite, siltstone and sandstone facies (south) and Takwahoni greywacke unit (north). The main outcrops on the rounded peak west of the Kehlechoa River and north of the Kehlechoa

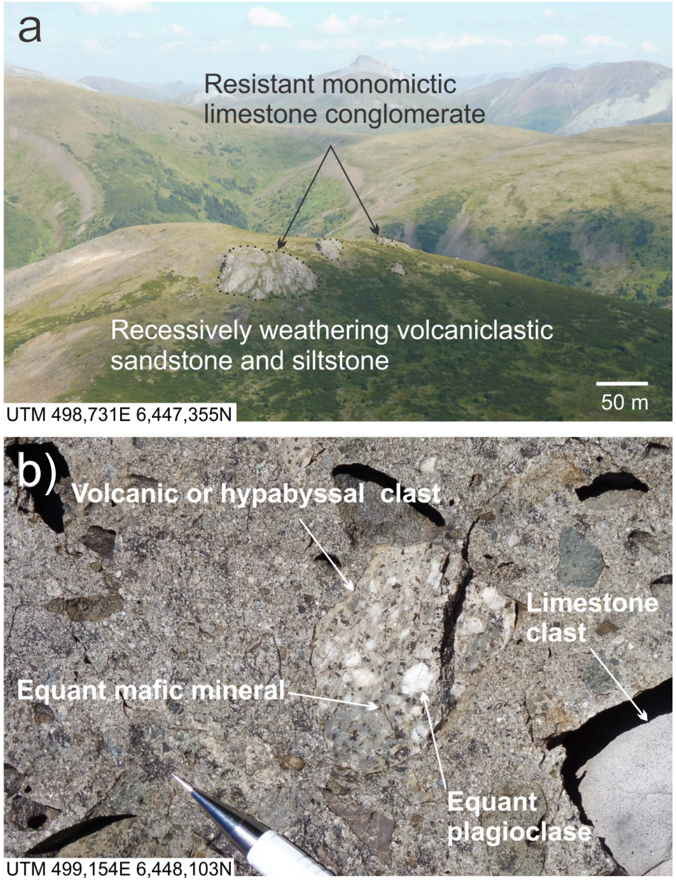

Fig. 13. Takwahoni Formation lower unit. **a)** Resistant bulbous bodies of monomictic limestone clast-bearing conglomerate within recessively weathering siltstone and volcaniclastic sandstone (lJTLsv). View northeast. **b)** Close up of polymictic conglomerate (lJTLcg) with limestone and (sub)volcanic clasts. Volcanic or hypabyssal clasts contain distinct coarse plagioclase and equant mafic minerals.

fault were not visited. They were previously grouped with an undivided unit of maroon-weathering plagioclase-phyric flows, volcanic conglomerate, volcanic breccia, and tuff (Upper Triassic to Lower Jurassic; unit TrJv of Gabrielse, 1998). This undivided volcanic unit included rocks north of the Cake Hill pluton that are now re-interpreted as the Horn Mountain maroon volcanic unit (Fig. 2; van Straaten and Nelson, 2016; van Straaten and Gibson, 2017). Along its ~100 km strike length, the Kehlechoa fault carries only Sinwa limestone (Upper Triassic) and Takwahoni Formation (Lower Jurassic) in its hanging wall. We consider it unlikely that the volcanic rocks in the hanging wall of the Kehlechoa fault are part of the Horn Mountain Formation, and tentatively re-interpret the exposures as a laterally discontinuous, several square kilometre-sized body of Takwahoni volcanic rocks (lJTLv; Fig. 3).

3.2.2.2. Greywacke unit

The northern half of the Kehlechoa-King Salmon fault panel exposes a right-way-up, moderately north-dipping succession of interbedded feldspathic wacke, feldspathic arenite and siltstone. Medium- to coarse-grained feldspathic wacke with volcanic clasts (top of the Takwahoni lower unit) grade into interbedded fine- to medium-grained sandstone and siltstone (base of the Takwahoni greywacke unit) across a distance of ~100 m. The lack of evidence for large-scale faulting and the subtle change in rock type suggest the contact is gradational. Ammonites collected near the base of the unit returned late Sinemurian-early Pliensbachian and possible early Pliensbachian ages (T. Poulton, pers. comm., 2017), in accordance with several early and late Pliensbachian fossil collections reported by Gabrielse (1998).

3.3. Cache Creek terrane

3.3.1. Sinwa Formation (Upper Triassic)

Distinctly light grey weathering Sinwa Formation limestone is commonly exposed in the immediate hanging wall of the King Salmon fault. It is massive to rarely medium- to thickly-bedded, generally recrystallized and fractured. Following Gabrielse (1998), limestone exposures on the north and south side of a rounded knob 4.5 km south of Wade Lake are interpreted as a klippe of Cache Creek terrane (Fig. 3).

Within the Cache Creek terrane east-northeast of the study area, Sinwa limestone overlies the Kutcho assemblage, a Late Permian to Middle Triassic primitive intra-oceanic volcanic arc succession (Schiarizza, 2012) accreted to Stikinia in the Late Triassic (Logan and Mihalynuk, 2014). The Sinwa Formation therefore represents a common unit between the Whitehorse through and parts of the Cache Creek terrane.

3.3.2. Inklin Formation (Jurassic)

Recessively weathering thinly-bedded feldspathic wacke, laminated siltstone and phyllite appear to overlie Sinwa limestone on a rounded knob 4.5 km south of Wade Lake. Fine- to medium-grained and minor coarse-grained sandstone contains rare quartz grains and fine-grained sandstone rip-up clasts. Following Gabrielse (1998) it is interpreted as Inklin Formation above the inferred King Salmon thrust fault. The age of the Inklin Formation is poorly constrained within the Dease Lake area. However, a detailed study in the Atlin Lake area suggests it is early Sinemurian to late Pliensbachian (Johannson et al., 1997).

3.4. Overlap units

3.4.1. Sustut Group (Cretaceous)

Sandstone, siltstone, and mudstone (locally muscovite-bearing) with chert-clast bearing conglomerate interbeds are found south of the Pitman fault (Read and Psutka, 1990), and are assigned to the Tango Creek Formation (Sustut Group).

3.4.2. Tuya Formation (Miocene to Pleistocene)

A small basaltic volcanic centre was mapped by Gabrielse (1998) in the southwestern part of the study area.

4. Intrusive units

4.1. Late Triassic: Cake Hill pluton

The map area includes the eastern part of the Hotailuh batholith, a composite body that extends for 2275 km^2 (Fig. 2). Hornblende quartz monzodiorite to quartz monzonite of the Cake Hill pluton (Late Triassic; Table 2) represents one of the oldest phases of the batholith, and is exposed in the southwestern part of the map area (Fig. 3; van Straaten et al., 2012). A minor leucocratic phase was recognized by van Straaten et al. (2012).

The quartz-rich phase of the Cake Hill pluton forms a 6 km^2 body in the western part of the map area. The hornblende granodiorite to monzogranite (Fig. 14) is unconformably overlain by Spatsizi Formation sedimentary rocks (Section 3.1.3.1.). A U-Pb zircon sample from this phase returned a 216.2 ±1.2 Ma age (van Straaten et al., 2012), slightly younger than 217.91 ±0.24 Ma from a hornblende monzogranite body in the adjacent map area to the northwest (Fig. 2; Section 6.1.). This unit represents the youngest and most evolved phase of the Cake Hill pluton.

4.2. Early to Middle Jurassic subvolcanic intrusions

Augite-plagioclase-phyric mafic intrusions (EMJm, Table 2) form 1 m- to 1 km-scale dikes and intrusive bodies (Fig. 6a). Several north-northeast-trending bodies cut the Horn Mountain middle maroon volcanic unit east of the McBride River (Fig. 3). The intrusions are texturally and mineralogically similar to volcanic clasts within the Horn Mountain lower mafic and middle maroon volcanic units; they likely represent feeder dikes.

Decimetre- to 1 km-scale dikes, sills and other intrusive bodies of coarse platy plagioclase porphyry (EMJm.po, Table 2) cut the Spatsizi Formation and the Horn Mountain lower mafic volcanic unit and middle maroon volcanic unit. Rare coarse platy plagioclase-phyric clasts within the Horn Mountain middle maroon volcanic unit indicate that the intrusions are subvolcanic feeders.

We distinguish at least two felsic intrusive episodes (EMJf, Table 2). West of the McBride River near Peak 2102 m, the Spatsizi Formation is commonly cut by felsic dikes and other intrusive bodies; intrusive felsic breccias are exposed at two locations (van Straaten et al., 2012; this study). Felsic intrusions are notably absent in the Horn Mountain Formation west of the McBride River, suggesting they represent feeders to the Horn Mountain lower felsic volcanic subunit (Section 3.1.3.2.). East of the McBride River, the Horn Mountain middle maroon volcanic unit is commonly cut by m-scale flow-banded felsic dikes and intrusive bodies up to 1.5 km^2 in size (Fig. 15). One flow-banded felsic dike cuts basal Bowser Lake sedimentary rocks 3.5 km southwest of Peak 2087 m. The distribution, dimension, and stratigraphic level of these intrusions suggest that they are the roots of felsic volcanic centres that fed the Horn Mountain upper felsic volcanic unit.

4.3. Middle Jurassic: Three Sisters pluton

The Three Sisters pluton (Middle Jurassic) represents the youngest documented phase of the Hotailuh batholith. Extensive exposures of the pluton are limited to the southwestern part of the map area (Fig. 3). The pluton has been divided into four phases: mafic; fine-grained mafic-intermediate; central felsic; and marginal potassic (Anderson, 1983; van Straaten et al., 2012; Table 2).

The mafic phase forms several relatively small (<1-2 km^2) medium-grained hornblende quartz diorite bodies (van Straaten et al., 2012). A 1.5 km^2 mafic intrusive body 2 km west of Peak 2102 m contains similar coarse platy plagioclase (Fig. 16) as the platy plagioclase porphyry (EMJm.po, Table 2). However, we assign it to the mafic phase because it is fine to medium grained and mafic rich. It may indicate a common magma source for the mafic phase of the Three Sisters pluton and Horn Mountain (sub)volcanic rocks. A fine-grained hornblende-biotite quartz diorite body in the southwest part of the map area is the type locality for the fine-grained mafic-intermediate phase (van Straaten et al., 2012).

Fig. 14. Cake Hill pluton, quartz-rich phase (LTrCHgr). Massive, equigranular, hornblende granodiorite (LTrCHgr) cut by pink dikelets (Three Sisters potassic phase, MJTSgr).

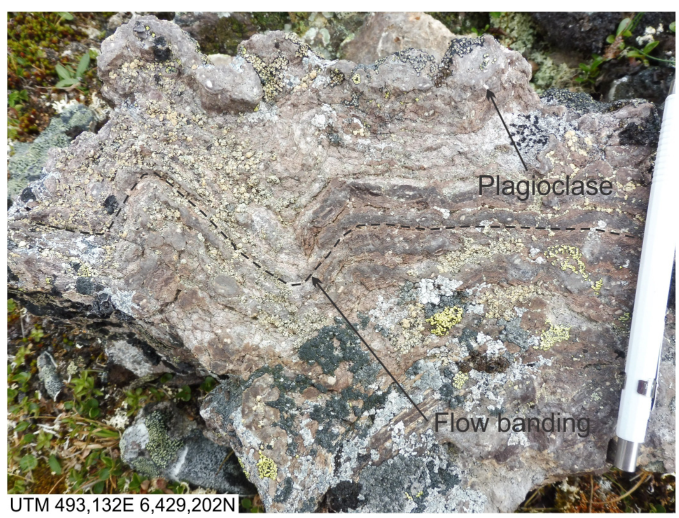

Fig. 15. Felsic intrusive, (EMJf). Folded flow banding in plagioclase-phyric felsic intrusive body.

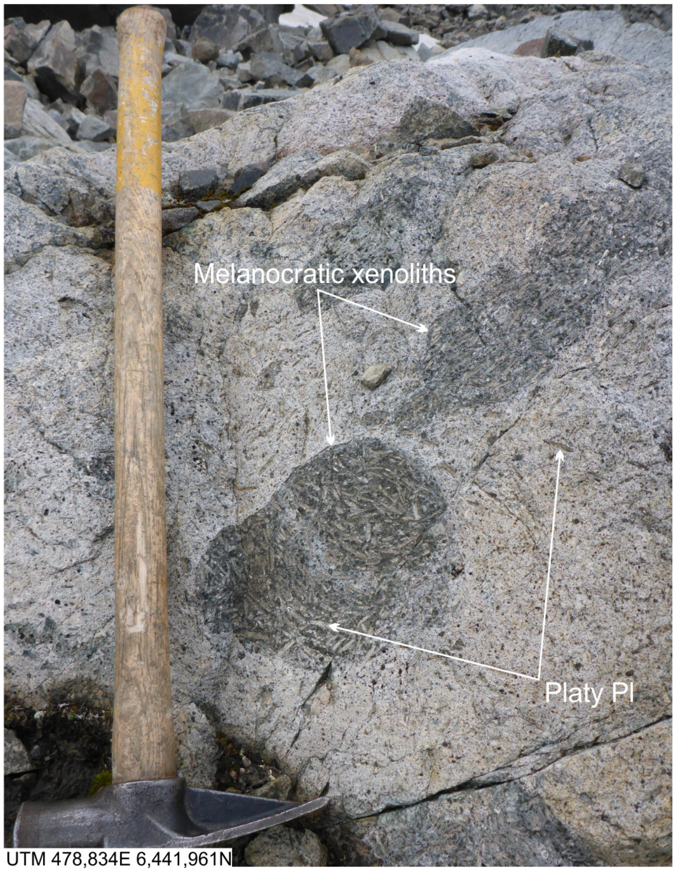

Fig. 16. Three Sisters pluton, mafic phase (MJTSqd). Hornblende-clinopyroxene diorite with melanocratic xenoliths; both contain coarse platy plagioclase.

Fig. 17. Three Sisters pluton, central felsic phase (MJTSqm). Massive, equigranular quartz monzodiorite containing a fine-grained dioritic xenolith.

Fig. 18. McBride River pluton (JMRgd). **a)** Massive, equigranular hornblende-biotite granodiorite containing a dioritic xenolith. **b)** Massive, equigranular, hornblende-biotite granodiorite dike intruding massive volcanic breccia with augite-plagioclase-phyric volcanic clasts (Horn Mountain lower mafic volcanic unit, lmJHMLvm).

The central felsic phase is the most extensive unit of the Three Sisters pluton. It is typically resistant and forms numerous ridges and peaks in the western part of the map area (Fig. 3). It consists primarily of biotite quartz monzonite, and contains common fine-grained dioritic xenoliths (Fig. 17). The central felsic phase cuts and includes xenoliths of the mafic phase.

The marginal potassic phase is the youngest unit of the Three Sisters pluton. It varies from fine to medium grained, and ranges in composition from biotite to hornblende-biotite monzogranite to quartz syenite (Table 2). Dikes of the potassic phase cut the Cake Hill quartz-rich phase (Fig. 14), the platy plagioclase porphyry (EMJm.po), and the Three Sisters mafic and central felsic phases.

4.4. Middle Jurassic (or younger): McBride River pluton

The McBride River pluton forms a 150 km^2 body in the southern half of the map area where it is interpreted to underlie the lower McBride River valley and adjacent forested slopes. Where exposed at or above treeline it consists mainly of medium-grained hornblende-biotite granodiorite (Fig. 18a). Along its western margin, the pluton cuts the Horn Mountain lower mafic volcanic unit. At the interface of the two units, granodiorite dikes and dikelets cut medium-grey weathering augite-plagioclase-phyric volcanic breccia (Fig. 18b). Along its eastern margin the pluton cuts a mafic intrusive body (EMJm, Fig. 3) which, based on nearby mafic dikes, appears to cut the Horn Mountain middle maroon volcanic unit.

The McBride River pluton was previously assigned an Early Jurassic age, based on a 184 ±8 Ma weighted $^{207}Pb/^{206}Pb$ age for three multigrain abraded zircon fractions interpreted to have undergone Pb loss (Anderson and Bevier, 1992) and a 186 ±13 Ma K-Ar hornblende age (Stevens et al., 1982). An earlier analysis of this sample yielded a 166 ±8 Ma upper concordia intercept based on a line forced through the origin and three nearly concordant zircon fractions (Anderson et al., 1982). The earlier U-Pb zircon results were dismissed by Anderson and Bevier (1992) based on systematic errors resulting from the inaccurate estimation of the common Pb composition. However, the ca. 184 Ma age is difficult to reconcile with crosscutting relationships and new age determinations. The pluton unequivocally crosscuts the Horn Mountain Formation lower mafic volcanic unit and mafic intrusions, and likely crosscuts the Horn Mountain middle maroon volcanic unit. Underlying the Horn Mountain Formation, the Spatsizi Formation contains Toarcian fossils (Henderson and Perry, 1981; Gabrielse, 1998) and a ca. 176 Ma detrital zircon population (Iverson et al., 2012). Rocks at the top of the Horn Mountain Formation are ca. 173-170 Ma (van Straaten and Gibson, 2017). Given that coarse-grained phaneritic rocks such as the McBride River pluton require emplacement depths of a few kilometres, it seems unlikely that the pluton is significantly older than ca. 173-170 Ma. The McBride River pluton shares some characteristics with the central felsic phase of the Three Sisters pluton (Middle Jurassic) in that it contains biotite and common fine-grained xenoliths. However, the pluton is most similar to the Snowdrift Creek pluton, a mostly recessive-weathering Late Jurassic biotite-hornblende granodiorite with common mafic xenoliths exposed in the adjacent map area to the northwest (Fig. 2; van Straaten and Gibson, 2007). Awaiting results from a sample submitted for U-Pb zircon analysis, we tentatively suggest that the ca. 184 age of Anderson and Bevier (1992) is incorrect and that the McBride River pluton is Middle Jurassic or younger.

Three dioritic intrusions outcrop east of the McBride River pluton (Fig. 3). Medium-grained hornblende diorite to quartz diorite (unit JMRdr, Table 2) is exposed for approximately 9 km^2 southeast of the McBride River pluton, but contacts with the pluton were not observed. Dikes and dikelets of the diorite cut the Horn Mountain middle maroon volcanic unit and the felsic intrusive unit. Our observations corroborate mapping by Read and Psutka (1990), who recognized a hornblende diorite and gabbro unit (their unit JTSdi) in the same area. A 3 km^2 body of fine-grained diorite (unit JMRdr.fg, Table 2) outcrops along a ridge northeast of the McBride River pluton (Fig. 3); again, contacts with the pluton were not exposed. To the north, and across a fault to the east, the fine-grained diorite cuts laminated to thin-bedded siltstone and sandstone of the Bowser Lake Group. At both locations, the sedimentary rocks are silicified, likely from contact metamorphism. A small meta-diabase body (unit mJd of Read and Psutka, 1990) is tentatively assigned to the same unit. The dioritic intrusions resemble the Three Sisters mafic phase and fine-grained mafic-intermediate phase (see above; Table 2). However, the Three Sisters mafic phase and fine-grained mafic-intermediate phase (ca. 172-173 Ma cooling ages, Table 2) are slightly older than-and have never before been observed cutting-the Bowser Lake Group (ca. 170 Ma; Table 1, van Straaten and Gibson, 2017).

Common clinopyroxene-hornblende-plagioclase porphyry dikes cut and follow the Kehlechoa fault 3.5 km south of Peak 1942 m (unit Jdr, Table 2). Their crosscutting relationship suggests a Late Jurassic age, similar to the Snowdrift Creek pluton and related diorite dikes observed in the adjacent map area to the northwest (van Straaten and Nelson, 2016).

5. Structure

We divide the map area into three tectonostratigraphic domains, separated by the Kehlechoa and King Salmon thrust faults (Fig. 2). The southern domain comprises Spatsizi sedimentary rocks overlain by Horn Mountain volcanic rocks and Bowser Lake sedimentary rocks of Stikinia. The central domain includes mostly sedimentary strata of the Whitehorse trough between the Kehlechoa and King Salmon faults. The northern domain includes rocks assigned to the Cache Creek terrane in the hanging wall of the King Salmon fault.

On Stikinia, Hazelton Group stratified rocks northwest and north of the McBride River pluton form a homoclinal, right-way-up, northeast-dipping sequence; bedding attitudes flatten towards the northeast (Fig. 3). An outlier of the Horn Mountain lower mafic volcanic unit is on the northeast ridge of Peak 2102 m (Fig. 3); the outcrop pattern is caused by an approximately 150 m-wide s-fold with moderately to steeply northeast-dipping long limbs and a gently southwest-dipping short limb. In the southeastern part of the map area, a sequence of Horn Mountain Formation and Bowser Lake Group is right-way-up and defines an approximate dome shape. In the centre, Horn Mountain middle maroon volcanic rocks predominate, with Horn Mountain upper felsic volcanic rocks exposed on some ridge tops. Bowser Lake Group sedimentary rocks overlie the succession along the margins of the dome in the south, east and north (Fig. 3).

The central structural domain comprises Sinwa limestone (Upper Triassic) unconformably overlain by a right-way-up, moderately north-dipping predominantly sedimentary sequence of the Takwahoni Formation (Lower Jurassic). Local variations in bedding attitudes in the Takwahoni Formation may be related to syn-sedimentary deformation and/or minor folds and faults. One 10 m-scale chevron fold with a north-dipping axial plane was observed in the footwall of the King Salmon thrust fault. In contrast to the Takwahoni Formation in the adjacent map area to the west (van Straaten and Gibson, 2017; van Straaten et al., 2017), we did not find any evidence for large-scale folding.

5.1. Major faults

We mapped two sets of faults and lineaments in the study area. The older set includes southwest- and north-northwest-striking normal/strike-slip faults that cut the Bowser Lake

Group and older units of Stikinia. Younger, generally west- to northwest-striking thrust faults (including the King Salmon and Kehlechoa faults) juxtapose the Cache Creek terrane to the north with Whitehorse trough strata and, in turn, Stikinia. They also appear to truncate faults of the older set (Fig. 3).

5.1.1. Early normal/strike-slip faults

Several southwest-trending normal/strike-slip faults are in the southeast part of the map area. East of the McBride River, the more westerly of two subparallel south-southwest-trending faults forms a well-defined topographic and aeromagnetic lineament. In two saddles, we found highly altered and veined subcrop with common slickensides. The movement on this fault is equivocal. In the north, the base of northeast-dipping Bowser Lake Group rocks is at higher topographic elevations east of the fault, suggesting west-side down or sinistral movement. However, in the centre, the fault juxtaposes Horn Mountain middle maroon volcanic rocks (west) against Horn Mountain upper felsic volcanic rocks (east), suggesting east-side down movement. Some of the stratigraphic differences across the fault may also be caused by relatively abrupt lateral facies changes. The eastern fault forms a well-defined topographic and moderately defined aeromagnetic lineament. Stratigraphic differences across the fault suggest west-side-down or sinistral movement. Farther south, the location of the two faults is poorly constrained. Similarly south-southwest trending topographic and aeromagnetic lineaments cut the McBride River pluton (Aeroquest Airborne, 2012; van Straaten et al., 2012), but no significant offset is apparent. A south-southwest-striking fault with an approximately 10 m west-side-down movement was observed at the CM prospect. A west-southwest-striking fault is inferred north of the Stikine River. Offset of the south-dipping Horn Mountain Formation-Bowser Lake Group contact (Sections 3.1.3.2., 3.1.4.) suggests a north-side-down movement. The latest movement along these faults is Middle Jurassic or younger.

Two north-northwest-striking normal faults are east of the McBride River. One of these faults is interpreted to cut subhorizontal strata east of the CM prospect, and is inferred to cut the south-southwest-trending faults south of Peak 1701 m (Fig. 3). West of the fault, Horn Mountain volcanic rocks are present from the valley bottom to 1610 m elevation, and are overlain by the Bowser Lake Group. To the east, rocks from valley bottom to the ridge top are all part of the Bowser Lake Group. An approximately 300 m east-side-down movement is inferred, but some of the apparent offset could be due to rapid lateral facies changes. Two outcrops west of the fault trace (1.4 km northeast of the CM prospect) show unusual, moderately to steeply southwest-dipping bedding attitudes that may reflect minor reactivation with a top-to-the-southwest reverse sense, similar to the north-northwest-trending segment of the Kehlechoa fault (see below). The immediate footwall of the north-northwest-striking segment of the Kehlechoa fault (see below) exposes an approximately 80 m-wide strip of Bowser Lake chert clast-bearing conglomerates south of Peak 1942 m (Figs. 3, 19; van Straaten and Nelson, 2016). These rocks are in fault contact with the Horn Mountain Formation along north-trending and subvertical to steeply east-dipping recessive zones interpreted as east-side-down normal faults (Fig. 19).

5.1.2. Late thrust faults

The Kehlechoa and King Salmon thrust faults (Fig. 2; Gabrielse, 1998) formed as south-vergent structures in a regime

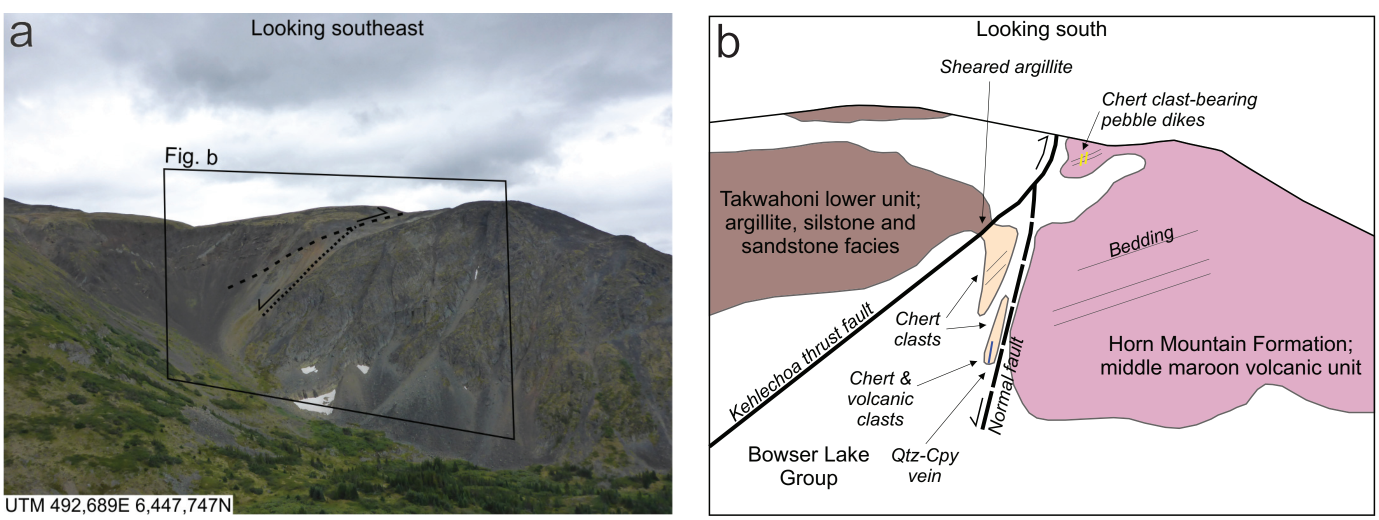

Fig. 19. North-northeast-trending Kehlechoa thrust fault, 750 m southwest of Peak 1942 m. **a)** Oblique view to the southeast. **b)** Diagram looking south. Fine-grained siliciclastic rocks of the Takwahoni lower unit (lJTLs) in the hanging wall of the Kehlechoa fault. The footwall comprises Horn Mountain middle maroon volcanic unit rocks (lmJHMMv) cut by chert-bearing pebble dikes (Fig. 9 in van Straaten and Nelson, 2016), and down-dropped Bowser Lake Group (mJBLs) conglomerates in which volcanic and chert clasts at the base (Fig. 10 in van Straaten and Nelson, 2016) grade to chert clasts at the top. The bottom of the down-dropped Bowser Lake succession is cut by a 10-20 cm-wide vertical quartz-chalcopyrite vein that returned >1% Cu and 0.391 g/t Au (sample 15BvS-25-11, Table 3).

of north-south to north-northeast to south-southwest shortening during accretion of the Quesnel, Cache Creek and Stikine terranes (Mihalynuk et al., 2004). Auriferous polymetallic quartz veins may have formed as extensional veins related to these thrusts (Section 7.3.).

The Kehlechoa thrust fault separates the Sinwa and Takwahoni formations to the north from the Horn Mountain Formation and Bowser Lake Group to the south. The west-trending segment of the fault is not exposed. It places older rocks (Late Triassic to Early Jurassic) above younger rocks (late Early Jurassic to Middle Jurassic), suggesting south-directed reverse movement similar to that on the King Salmon fault. Along its north-northwest-trending segment, the location and nature of the Kehlechoa fault is better constrained. Outcrop patterns suggest that it is subvertical to moderately east-dipping. At one exposure, sheared argillaceous rocks separate a hanging wall containing fine-grained siliciclastic rocks of the Takwahoni lower unit (lJTLs) from a footwall of Horn Mountain middle maroon volcanic rocks and a narrow down-dropped block of Bowser Lake Group (Fig. 19; van Straaten and Nelson, 2016). We interpret this zone as an east-side-down normal fault in the underlying Stikinia panel, reactivated as a dextral-reverse lateral ramp or tear fault. Movement on the Kehlechoa fault is bracketed by fossils in Bowser Lake sedimentary rocks in the footwall (early Bajocian, ca. 170 Ma using the Cohen et al., 2013 scale), and the stitching Snowdrift Creek pluton in the adjacent map area to the northwest (160.43 ±0.16 Ma, van Straaten and Gibson, 2017).

The King Salmon thrust fault separates sedimentary rocks of the Takwahoni Formation (footwall) from fine-grained siliciclastic, carbonate, and ultramafic rocks of the Cache Creek terrane (hanging wall). It is interpreted as a north-dipping, south-verging thrust with Sinwa limestone commonly in the immediate hanging wall of the fault (Gabrielse, 1998). A rounded knob 4.5 km south of Wade Lake is interpreted as a klippe, carrying Sinwa Formation limestone (Upper Triassic) and Inklin Formation (Jurassic).

5.1.3. Other faults

The Pitman fault is a poorly exposed east-trending regional structure with a strike length of at least 200 km. The south side of the fault exposes Stikine assemblage unconformably overlain by Sustut Group (Fig. 3; Read and Psutka, 1990). Significant differences in stratigraphy across the fault suggest a long-lived history. To the east, the fault is interpreted to cause 3 km of sinistral offset of the Kutcho and Thudaka terrane-bounding faults (Gabrielse, 1985; Evenchick and Thorkelson, 2005).

6. Geochronology

Below we report the preliminary results from four U-Pb zircon samples collected during the 2016 field season in the adjacent Tanzilla - McBride field area to the northwest (Fig. 2); detailed methods and final results will be reported elsewhere. U-Pb zircon analyses were carried out at the Pacific Centre for Isotopic and Geochemical Research (University of British Columbia). Preliminary maximum depositional ages are calculated for laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) detrital zircon analyses using the weighted mean age of the youngest zircon population (excluding discordant grains and outliers). Future work will use zircon trace element data and methods of Ludwig (2012) and Dickinson and Gehrels (2009) to further constrain maximum depositional ages.

6.1. Cake Hill pluton, quartz-rich phase

A sample of equigranular hornblende monzogranite from the quartz-rich phase of the Cake Hill pluton (Sample 1, Fig. 2) returned a preliminary age of 217.91 ±0.24 Ma (Fig. 20). The sample was processed using a chemical abrasion thermal ionization mass spectrometry (CA-TIMS) technique, which is assumed to fully mitigate Pb loss in grains. The youngest concordant grouping is represented by the youngest grain (Fig. 20); we interpret the slightly older grains as autocrystic zircon crystallization in the cooling magma (e.g., Samperton et al., 2015). The age is somewhat older than a 216.2 ±1.2 Ma LA-ICP-MS age for the quartz-rich phase of the Cake Hill pluton in the map area (van Straaten et al., 2012).

6.2. Horn Mountain Formation

A sample of a felsic lapilli-tuff bed with abundant aphyric to plagioclase-phyric clasts from the Horn Mountain lowermost mafic volcanic unit (sample 16BvS-15-111a; sample 4, Fig. 2) returned a unimodal zircon peak at 215.0 ±1.4 Ma (Fig. 21a). A fine felsic tuff bed from the same location (16BvS-15-111b; van Straaten et al., 2017) was not analyzed further. The age overlaps with a maximum depositional age of 214.8 ±1.5 Ma for a Spatsizi basal conglomerate (van Straaten and Gibson,

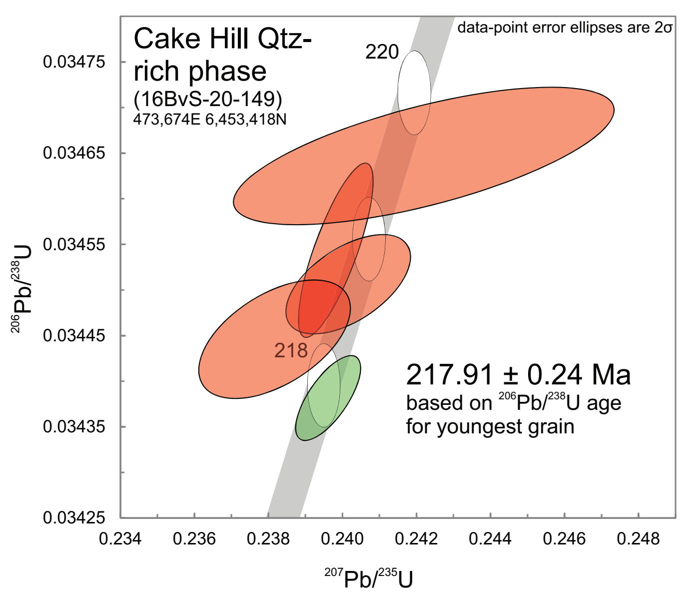

Fig. 20. Uranium-lead zircon concordia diagram showing chemical abrasion thermal ionization mass spectrometry results from the Cake Hill pluton quartz-rich phase (LTrCHgr).

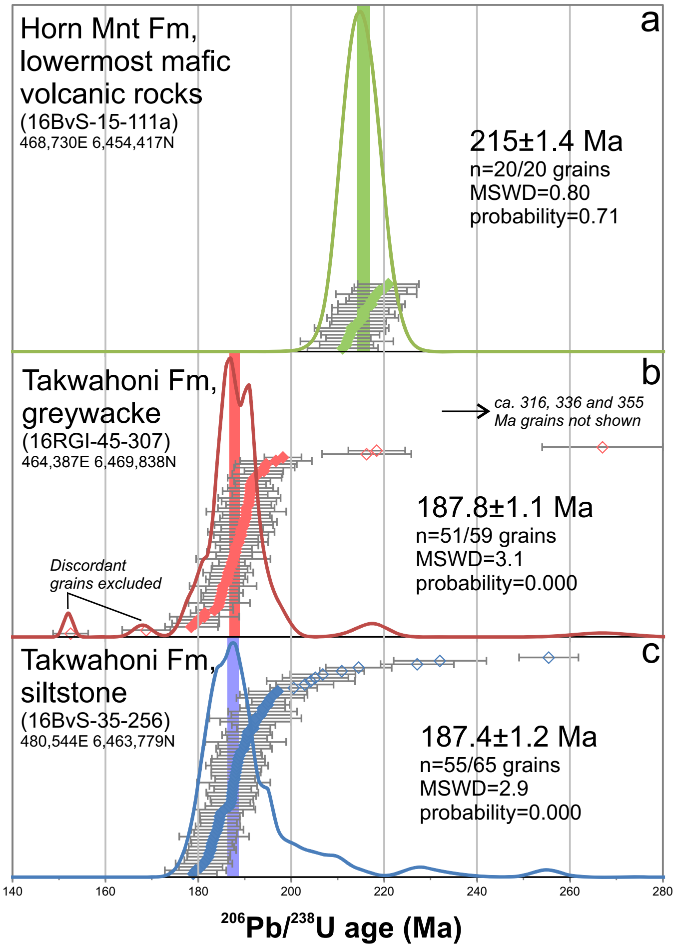

Fig. 21. Detrital zircon $^{206}Pb/^{238}U$ age distribution plots, probability curves, and preliminary maximum depositional ages. **a)** Felsic lapilli-tuff bed in Horn Mountain Formation lowermost mafic volcanic unit (lmJHMLMvm). **b)** Takwahoni Formation greywacke unit (lJTgw). **c)** Takwahoni Formation siltstone unit (lJTs). Ages are marked with coloured diamonds (open symbols are discordant grains and outliers excluded from age calculation) with two standard deviation analytical error represented by grey bars. The probability distribution is plotted with bold coloured lines and the preliminary maximum depositional age listed on the plots is represented by a coloured vertical line.

2017) and the quartz-rich phase of the Cake Hill pluton (see above). Based on the presence of Early Jurassic fossils and zircon populations along strike (Gabrielse, 1998; Iverson et al., 2012) we interpret these zircons as having been derived from erosion of the underlying Cake Hill pluton (Late Triassic). The lack of penecontemporaneous zircons within the Spatsizi and lower Horn Mountain formations (this study; van Straaten and Gibson, 2017) suggests the source magmas to the alkaline mafic and felsic volcanic products did not crystallize zircon.

6.3. Takwahoni Formation

A coarse-grained, moderately-sorted feldspathic arenite from the Takwahoni greywacke unit (lJTgw; sample 16RGI-45-307; Sample 2, Fig. 2) yielded predominantly Early Jurassic zircons (Fig. 21b). The preliminary maximum depositional age has a larger Mean Square Weighted Deviation (MSWD=3.1) than expected for such a population (target MSWD=1.4). This indicates that the scatter is greater than expected based on the precision of individual measurements, suggesting that: 1) all grains are not of the same true age, or 2) uncertainty is underestimated. We tentatively attribute the spread in ages due to the presence of overlapping Early Jurassic zircon populations. In addition to Early Jurassic zircons, the sample contains two Late Triassic and four Paleozoic grains.

Two thick beds of medium-grained, moderately-sorted feldspathic arenite in a section of predominantly siltstone (Takwahoni siltstone unit, lJTs; sample 16BvS-35-256; sample 3, Fig. 2) returned predominantly Early Jurassic zircons (Fig. 21c). Similar to the sample above, the preliminary maximum depositional age has a larger MSWD (2.9) than expected for such a population, likely resulting from overlapping Early Jurassic zircon populations. This sample also contains seven latest Triassic to earliest Jurassic, one Late Triassic, two early Late Triassic, and one Late Permian grain.

The preliminary maximum depositional age from both samples agree with Pliensbachian biostratigraphic constraints in Gabielse (1998). The samples returned only three grains (ca. 215-218 Ma) that overlap with the Stikine plutonic suite (ca. 216-222 Ma, Table 2), suggesting that Whitehorse trough rocks in the study area were not sourced from the Cake Hill and related plutons. Possible sources for the Pliensbachian zircons include distal felsic ash fall or erosional products from lower Hazelton volcanic centres in the Stewart - Iskut area (e.g., Brucejack Lake felsic unit; Nelson et al., 2018), Nordenskiöld volcanic centres in the Whitehorse trough in southern Yukon (Colpron et al., 2015), and extrusive equivalents and/or erosion of the Aishihik and Long Lake plutonic suites along the BC-Yukon border (ca. 192-178 Ma, Mihalynuk, 1999; Colpron et al., 2016).

7. Mineral occurrences

We divide mineral occurrences in the map area (Fig. 3) according to mineralization characteristics, alteration style, alteration footprint, and host rock. Two sizeable intrusion-related gossans are west and southeast of the McBride River. Several volcanic rock-hosted Cu-Ag mineral occurrences, generally with limited alteration footprints, are hosted by the Horn Mountain Formation in the southeast part of the map area. A number of (locally auriferous) polymetallic veins are near the Kehlechoa and King Salmon thrust faults.

Preliminary assay data from eight altered and/or mineralized rock samples collected in 2015 and 2017 are presented in Table 3. Samples were jaw crushed and pulverized at the British Columbia Geological Survey, and analyzed at Bureau Veritas in Vancouver. The samples were dissolved using an aqua regia digestion before being analyzed by inductively coupled plasma-emission spectroscopy/mass spectrometry (ICP-ES/MS). Results of external standards and duplicates were monitored to ensure analytical reproducibility and accuracy. Detailed methods and complete results will be reported elsewhere.

Table 3. Assay results and coordinates of mineralized and altered rock samples.

Sample	Location	Easting	Northing	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As	Au	Cd	Sb	Bi	W	S
			unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppb	ppm	ppm	ppm	ppm	%
			DL	0.1	0.1	0.1	1	0.1	0.1	0.1	1	0.01	0.5	0.5	0.1	0.1	0.1	0.1	0.05
15BvS-25-11	3 km S D1	493040	6447048	8.0	>1%	10.2	46	22.0	3.8	4.8	161	5.07	11.2	391.4	1.1	0.6	2.6	0.1	0.33
17BvS-12-90	0.6 km E MSM	488954	6425909	4.5	43.2	9.4	11	0.1	2.1	2.2	26	1.53	1.5	<0.5	<0.1	0.2	0.9	<0.1	0.86
17BvS-2-11	Pk2102	481116	6441759	4.7	350.5	2.3	13	0.2	13.5	5.6	87	1.74	7.2	1.3	<0.1	0.3	0.3	0.3	0.91
17BvS-16-134	Pk2102	481595	6442112	4.4	35.1	5.6	52	<0.1	11.1	15.9	202	4.65	36.9	<0.5	0.2	0.3	0.3	0.1	2.55
17BvS-17-139	Pk2102	482194	6440885	0.3	155.7	7.4	19	0.3	5.0	61.5	165	11.96	5.3	5.1	<0.1	<0.1	1.6	0.1	6.59
17BvS-28-270	1 km NW Star	496771	6435397	0.1	>1%	13.0	41	22.7	2.4	3.7	339	1.22	5.4	60.5	1.1	1.2	0.9	<0.1	<0.05
17SBI-37-300	CM	499170	6431066	0.4	>1%	3.4	21	23.5	0.9	1.3	358	1.02	6.7	2.8	0.5	7.6	<0.1	0.3	<0.05
17SBI-41-361	5 km SE Pk2102	484610	6437844	0.2	10.3	21.3	26	<0.1	1.5	0.9	205	0.45	7.5	<0.5	0.1	0.1	<0.1	0.2	<0.05
External standards and duplicates																			
17SBI-41-361dup				0.3	42.5	21.3	31	<0.1	1.6	0.8	220	0.45	5.8	<0.5	<0.1	0.1	<0.1	0.3	<0.05
BCGS Till 2013 STD				0.7	170.1	225.9	399	1.8	212.2	50.0	1644	7.63	64.3	22.9	1.1	6.4	0.3	<0.1	<0.05
Expected*				0.8	170.0	240.0	410	2.2	250.0	60.0	1780	8.94	70.0	31.0	1.0	16.4	0.2	2.3	<0.01

Coordinates in NAD83, Zone 9 north
Aqua regia digestion followed by ICP-ES/MS analysis
Abbreviations: DL-detection limit, MSM-Mount Sister Mary, Pk2102-Peak 2102 m, N-north, E-east, S-south, W-west
* BCGS Till 2013 expected values from A. Rukhlov, pers. comm. (2016)

7.1. Intrusion-related gossans

Two sizeable gossans are west and southeast of the McBride River. They likely formed by magmatic-hydrothermal activity related to Jurassic intrusions. Rusty red-brown weathering gossanous rocks are exposed in a zone (~0.5 by 4 km) centred on Peak 2102 m. The alteration is strongly controlled by lithology (Fig. 3). The Spatsizi Formation basal sandstone and conglomerate unit generally lacks sulphides, and instead displays common calcic skarn mineral assemblages. The strongest alteration is in interbedded argillite, siltstone, and fine-grained sandstone of the Spatsizi argillite, siltstone and sandstone unit, where strong silicification is accompanied by 5-10% (locally up to 20%) disseminated pyrite. Iron-oxide coated fracture sets likely represent oxidized pyrite veinlets, with vein densities up to one percent (Fig. 22). Thickly to very thickly bedded sandstone packages and rare mafic volcanic rocks within the Spatsizi argillite, siltstone and sandstone unit are generally less altered. Alteration in the overlying Horn Mountain lower mafic volcanic unit is limited to the lower contact, which contains oxidized pyrite and rare oxidized quartz-pyrite veinlets. The gossan is cut by relatively abundant altered felsic dikes (unit EMJf, Table 2); they likely represent feeders to the Horn Mountain lower felsic volcanic subunit (Section 4.2.). The Three Sisters pluton (Middle Jurassic) is exposed less than 1.5 km to west. It is likely that one of these felsic intrusive phases is responsible for the formation of this gossan. Grab samples returned no anomalous metal values (17BvS-2-11, 17BvS-16-134 and 17BvS-17-139, Table 3). A felsic dike near the Cake Hill pluton - Horn Mountain lower mafic volcanic unit contact (5.1 km southeast of Peak 2102 m) contains 2% disseminated pyrite; a grab sample yielded no anomalous metal values (17SBI-41-361, Table 3).

A prominent gossan (approximately 0.4 by 0.3 km) is exposed on a subalpine saddle 0.6 km east of Mount Sister Mary (Fig. 3); the southern portion is within the Stikine River

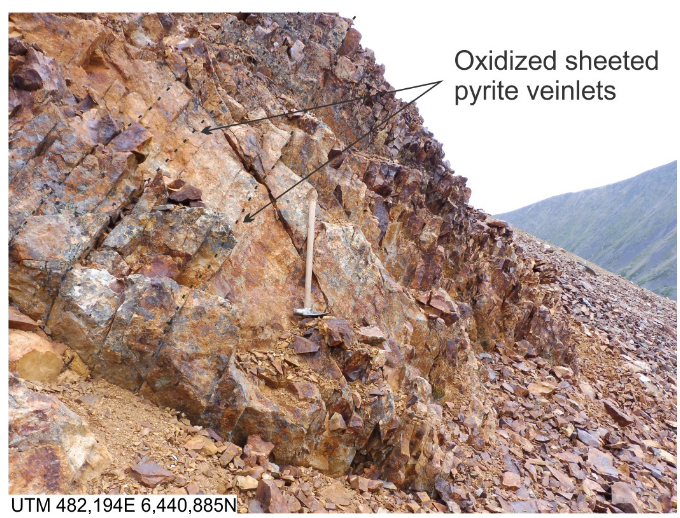

Fig. 22. Strongly silicified Spatsizi Formation sedimentary rocks (lmJSPs) with 5-10% disseminated pyrite and common iron oxide-coated fracture sets, likely representing sheeted pyrite veinlets.

Provincial Park. Within the gossan, strong silicification and bleaching are accompanied by 5-10% disseminated pyrite. The protolith is a uniformly-textured plagioclase-phyric rock, similar to flows in the Horn Mountain middle maroon volcanic unit. A grab sample returned no anomalous metal values (17BvS-12-90, Table 3). The altered and gossanous rocks are cut by late- to post-mineral chalky white-altered fine-grained diorite intrusions (JMRdr.fg, Table 2) that lack sulphides. Two showings within the Stikine River Provincial Park (Pay, MINFILE 104H 007; Pay 4, MINFILE 104H 027) are approximately 2.5 km west of the gossan.

Three additional mineral occurrences are hosted in the Hotailuh batholith in the southwestern part of the map area, and are described in van Straaten et al. (2012).

7.2. Volcanic rock-hosted Cu-Ag mineral occurrences

Several Cu-Ag mineral occurrences are hosted in Horn Mountain volcanic rocks, subvolcanic felsic intrusions, and faults in the southeastern part of the map area. Mineralization generally comprises chalcocite, chalcopyrite, bornite and/or native copper; obvious widespread hydrothermal alteration footprints are lacking. The occurrences have been variably classified as epigenetic veins and volcanic redbed copper in the MINFILE database (British Columbia Geological Survey, 2017). However, their presence in or close to felsic (sub) volcanic rocks may suggest a relatively low-temperature epithermal origin. Trenching and drilling at the CM prospect (MINFILE 104I 016, Fig. 3) intersected fine disseminations and stringers of chalcocite, bornite, and copper oxides accompanied by pervasive kaolinization, K-feldspar alteration, and local quartz-carbonate stringers in a vertical northeast-striking fault; a 6.1 m drill interval assayed 0.39% Cu and 8.57 g/t Ag (Chisholm, 1971). Chip samples across the zone averaged 1.94% Cu and 35.7 g/t Ag over 10 m (Yeager and Ikona, 1984). The trench exposes chalcocite and copper oxide stringers and local massive to vuggy quartz-calcite-chalcocite-copper oxide veinlets (Fig. 23). The mineralization is hosted in a cream to purple-grey, flow-banded plagioclase porphyry (likely a flow) of the Horn Mountain upper felsic volcanic unit, where it is cut by a south-southwest-striking fault with an approximately 10 metre west-side-down movement. A grab sample returned >1% Cu and 23.5 g/t Ag (17SBI-37-300, Table 3).

A light grey, bleached and silicified flow-banded plagioclase porphyry contains common copper oxides and locally abundant quartz-sulphide-copper oxide veinlets 1.3 km northwest of the Star showing (MINFILE 104I 027). The host rock is a felsic intrusion, and a grab sample returned >1% Cu, 22.7 g/t Ag and trace Au (17BvS-28-270, Table 3). At the nearby Star showing, local chalcocite and malachite are in north-trending subvertical brittle fault zones that cut gently dipping to subhorizontal strata of the Horn Mountain middle maroon volcanic unit. A historic grab sample returned 4.5% Cu (Mann and Reynolds, 1969).

We noted two gossanous outcrops with ~2% percent disseminated pyrite hosted in felsic intrusions and adjacent Horn Mountain middle maroon volcanic rocks in the valley below the Joy 94 showing (MINFILE 104I 021). A nearby cirque to the southwest hosts the Joy 87 showing (MINFILE 104H 009). Gifford (1969) reported several chalcopyrite and malachite fractures that returned assay results up to 2.01% Cu, 6.9 g/t Ag, 1.37 g/t Au (Joy 87) and 5.7% Cu, 17 g/t Ag, trace Au (Joy 94).

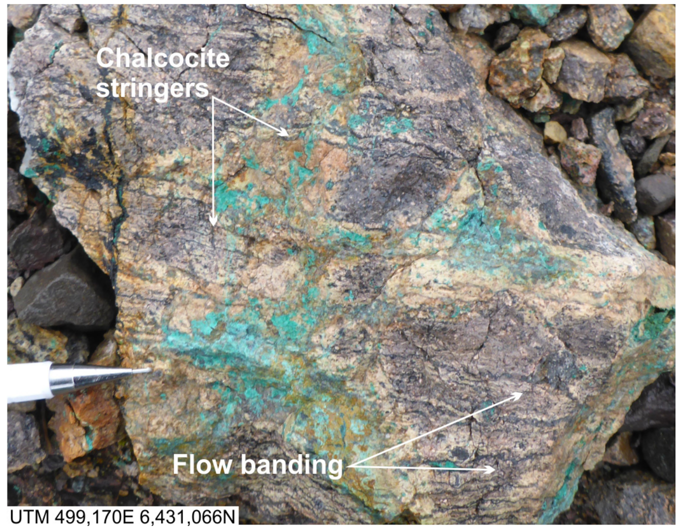

Fig. 23. Chalcocite and copper oxide stringers parallel to flow banding in felsic coherent rock (Horn Mountain upper felsic volcanic unit, mJHMUvf).

Five additional copper and copper-silver mineral occurrences are east of Peak 2087 m (MINFILES 104H 010, 028, 029, 030 and 104I 015); descriptions refer to chalcocite, bornite and/or native copper as disseminations, in fractures or fault zones. Historic samples returned 0.21% Cu from a trench at Joy 84 (MINFILE 104H 010; Gifford, 1969) and 0.2% Cu and trace Ag from a 30 cm-long drill interval at HC (MINFILE 104I 015; Chisholm, 1971).

7.3. Polymetallic veins

Several polymetallic and locally auriferous quartz±carbonate veins are near the Kehlechoa and King Salmon thrust faults. A grab sample of quartz-chalcopyrite-malachite vein 2.8 km south of the D8 showing returned >1% Cu, 0.39 g/t Au and 22 g/t Ag (15BvS-25-11, Table 3). The vertical vein strikes 020 degrees and is 10-20 cm wide. The quartz vein cuts chert and volcanic clast-bearing conglomerate of the Bowser Lake Group, and is in the footwall of the Kehlechoa thrust fault (Fig. 19). Quartz and quartz-carbonate veins with chalcopyrite, bornite, galena, sphalerite and/or arsenopyrite locally contain high gold, silver, copper, lead and zinc values at the nearby D1, D4 and D8 showings (MINFILES 104I 093, 100, 101). A subvertical northwest-striking quartz-calcite vein at the D1 showing returned 116 g/t Au and 590 g/t Ag over 25 cm (Yeager and Ikona, 1982; 1985).

Quartz-calcite-chalcopyrite veins are in an east-northeast trending probable shear zone that cuts Sinwa Formation limestone at the ANT showing (MINFILE 104I 009; Hampton, 1962a). Chalcopyrite in quartz stringers and fracture fillings have been noted at the BEE showing (MINFILE 104I 010; Hampton, 1962b); the sulphides are hosted in Takwahoni Formation volcanic rocks.

8. Discussion: Regional extent and significance of the Horn Mountain Formation

Work on this project has identified the Horn Mountain Formation as a distinct late Early to Middle Jurassic volcanic unit. It extends along the northeastern edge of Stikinia for at least 80 km; evaluation of the regional literature indicates that it likely continues for at least 120 km (Fig. 1; van Straaten and Nelson, 2016). The Horn Mountain Formation represents an unusual volcanic sequence in the upper part of the Hazelton Group. It is coeval with accretion of the Stikine and Cache Creek terranes, as indicated by conformable contacts with rocks of the Bowser Lake Group, and-so far-similar volcanic successions have not been documented elsewhere in northern Stikinia. The Horn Mountain Formation postdates widespread arc volcanism recorded in the lower part of the Hazelton Group. In northern Stikinia, the upper part of the Hazelton Group consists mainly of Pliensbachian and younger sedimentary rocks assigned to the Spatsizi Formation in the north and the Nilkitkwa and Smithers formations in the south; both are succeeded by mudstone and minor tuff of the Quock Formation (Gagnon et al, 2012). Volcanic rocks are mainly in a narrow, north-south oriented belt of tholeiitic pillow basalts, sedimentary rocks, and minor rhyolites assigned to the Iskut River Formation (Gagnon et al., 2012; Barresi et al., 2015). This Middle Jurassic (Aalenian to Bajocian) succession is interpreted to have formed in a series of sub-basins that define the Eskay rift (Barresi et al., 2015; Fig. 1). The Iskut River Formation contrasts markedly with the Horn Mountain Formation in lithology, depositional style, structural setting, and lithogeochemistry (van Straaten and Nelson, 2016). As discussed elsewhere (van Straaten and Nelson, 2016), timing relationships with respect to subduction-related volcanic deposits elsewhere in the Hazelton Group and timing of Stikinia - Cache Creek collision suggest that the Horn Mountain Formation does not record normal subduction-related arc magmatism. Instead we speculate that volcanism was generated by re-melting of subduction-modified lithosphere during collision between the Stikine and Quesnel terranes, well after cessation of subduction in the Late Triassic.

9. Conclusions

This paper presents the results of the third year of a mapping project focussed on the Horn Mountain Formation (late Early to Middle Jurassic), a predominantly volcanic unit in the upper part of the Hazelton Group that regionally hosts advanced argillic alteration zones with potential for porphyry-style systems at depth. The Horn Mountain Formation is unusual because it is younger than any known volcanic succession of arc affinity in northern Stikinia.

The oldest rocks in the field area are part of the Cake Hill pluton. New U-Pb zircon data for the youngest hornblende granodiorite to monzogranite phase yield a preliminary age of 217.91 ±0.24 Ma, slightly older than a previous determination of 216.2 ±1.2 Ma reported by van Straaten et al. (2012). The pluton is cut by an unconformity that extends laterally for at least 50 km and represents one of the few well-documented examples of unroofed Stuhini arc in northern Stikinia. The unconformity marks an hiatus of ~30 m.y. Detrital zircons in the overlying volcano-sedimentary succession are mostly derived from the Cake Hill pluton, and suggest that Late Triassic igneous activity in the area continued until ca. 215 Ma.

The unconformity is overlain by rocks in the upper part of the Hazelton Group in which the Spatsizi Formation (a sedimentary sequence up to 0.2 km thick) is conformably overlain by the Horn Mountain Formation (a volcanic succession at least 3.5 km thick). The volcanic rocks are unusual within northern Stikinia as they postdate widespread arc volcanism of the lower part of the Hazelton Group, are coeval with deposition of predominantly sedimentary rocks in the upper part of the Hazelton Group, and are concurrent with accretion of the Stikine and Cache Creek terranes. Sedimentary rocks of the Spatsizi Formation (Toarcian) grade into mafic volcanic breccia of the lower part of the Horn Mountain Formation. They were, at least in part, deposited in a subaqueous environment. Increasingly higher volume volcanism led to the formation of a subaerial volcanic edifice and deposition of interlayered flows, volcanic breccia and tuff of the middle maroon volcanic unit. Lower and middle units are cut by cogenetic mafic feeder dikes and intrusions. An upper felsic volcanic unit caps the succession.

The Horn Mountain Formation is cut by the Three Sisters pluton (ca. 173-169 Ma) and the McBride River pluton. The McBride River granodiorite has hitherto been interpreted as Early Jurassic (ca. 184 Ma), but this age is difficult to reconcile with the unequivocal crosscutting relationships observed in the field and we suggest that a Middle Jurassic or younger age is more plausible.

The Bowser Lake Group (Bajocian) conformably overlies the Horn Mountain Formation, and records the onset of erosion from the Stikinia - Cache Creek tectonic welt. Chert and limestone clast-bearing pebble to cobble conglomerate (>330 m thick) is interpreted to have formed close to range front faults along the building orogen. The coarse clastic facies transitions to interbedded subaerial siltstone, sandstone, chert clast-bearing conglomerate and mafic flows (>430 m thick) farther south.

The Kehlechoa thrust fault places rocks of the Whitehorse trough above the Horn Mountain Formation and Bowser Lake Group. The hanging wall panel contains Sinwa Formation limestone (Upper Triassic) unconformably overlain by Takwahoni Formation sedimentary rocks (Early Jurassic). The Takwahoni Formation comprises a lithologically variable package of fine-grained siliciclastic rocks, polymictic conglomerate, and volcanic rocks (Sinemurian?) that appears to grade upward into a thick unit of interbedded sandstone and siltstone (Pliensbachian). Two detrital zircon samples from the upper unit returned a largely unimodal ca. 187-188 Ma

(Pliensbachian) population; significant Late Triassic zircons are lacking. The detrital zircon data are compatible with derivation from local Stikinia sources or axial transport from sources within or adjacent to the Whitehorse trough in southern Yukon, and suggest that the Cake Hill and related plutons were not significant sources.

Two intrusion-related hydrothermal alteration zones are west and southeast of the McBride River; limited sampling returned no anomalous metal values. Several Cu-Ag mineral occurrences with restricted alteration footprints are hosted in the middle and upper part of the Horn Mountain Formation in the southeast part of the map area. Polymetallic veins are near the Kehlechoa and King Salmon thrust faults; some have returned significant gold and silver values.

The Horn Mountain Formation represents a rare example of syncollisional volcanism that is coeval with accretion of the Stikine and Quesnel island arcs. Continuing study of its nature and relationships to adjacent terranes will aid in the understanding of collisional tectonics of the northern Canadian Cordillera.

Acknowledgments

We thank Marc Beaton and Rachel Gavin for their capable and enthusiastic assistance during the field season, and Tundra Helicopters for safe flying. Thanks to JoAnne Nelson for constructive commentary that significantly improved the manuscript. We also thank Terry Poulton (Geological Survey of Canada, Calgary) for providing preliminary macrofossil age determinations and Richard Friedman (University of British Columbia, Vancouver) for providing preliminary U-Pb zircon geochronology results.

References cited

Aeroquest Airborne, 2012. Report on a helicopter-borne magnetic survey (Aeroquest Job #11-046) for Geoscience BC. Geoscience BC Report 2012-2, 11 p.

Anderson, R.G., 1983. Geology of the Hotailuh batholith and surrounding volcanic and sedimentary rocks, north-central British Columbia. Unpublished Ph.D. thesis, Carleton University, Ottawa, Ontario, Canada, 669 p.

Anderson, R.G., and Bevier, M.L., 1992. New late Triassic and early Jurassic U-Pb zircon ages from the Hotailuh Batholith, Cry Lake map area, North - Central British Columbia. In: Radiogenic age and isotopic studies: Report 6, Geological Survey of Canada Paper 92-02, pp. 145-152.

Anderson, R.G., Loveridge, W.D., and Sullivan, R.W., 1982. U-Pb isotopic ages of zircon from the Jurassic plutonic suite, Hotailuh Batholith, north-central British Columbia. Current Research, Part C, Rb-Sr and U-Pb isotopic age studies, Report 5 Paper 82-1C, Geological Survey of Canada.

Barresi, T., Nelson, J.L., and Dostal, J., 2015. Geochemical constraints on magmatic and metallogenic processes: Iskut River Formation, volcanogenic massive sulfide-hosting basalts, NW British Columbia, Canada. Canadian Journal of Earth Sciences, 52, 1-20.

British Columbia Geological Survey, 2017. MINFILE-British Columbia mineral inventory database. Available from http://minfile.gov.bc.ca/.

Chisholm, E., 1971. Progress Report - McBride River Project. British Columbia Ministry of Energy and Mines, Assessment Report 3237, 32 p.

Cohen, K.M., Finney, S.C., Gibbard, P.L., and Fan, J.-X., 2013. The ICS International Chronostratigraphic Chart. Episodes, 36, 199-204. Updated version (February, 2017) available from http://www.stratigraphy.org/.

Colpron, M., Crowley, J.L., Gehrels, G., Long, D.G.F., Murphy, D.C., Beranek, L., and Bickerton, L., 2015. Birth of the northern Cordilleran orogen, as recorded by detrital zircons in Jurassic synorogenic strata and regional exhumation in Yukon. Lithosphere, 7, 541-562.

Colpron, M., Israel, S., and Friend, M., 2016. Yukon plutonic suites. Yukon Geological Survey, Open File 2016-37, 1:750,000 scale.

Dickinson, W.R., and Gehrels, G.E., 2009. Use of U-Pb ages of detrital zircons to infer maximum depositional ages of strata: A test against a Colorado Plateau Mesozoic database. Earth and Planetary Science Letters, 288, 115-125.

Erdman, L.R., 1978. Petrology, geochronology and geochemistry of Jurassic volcanic and granitic rocks of the Cry Lake and Spatsizi map sheets, north-central British Columbia. Unpublished B.Sc. thesis, The University of British Columbia, Vancouver, B.C., Canada, 63 p.

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., 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. Geological Society of America Special Papers, 433, 117-145.

Evenchick, C.A., Poulton, T.P., and McNicoll, V.J., 2010. Nature and significance of the diachronous contact between the Hazelton and Bowser Lake groups (Jurassic), north-central British Columbia. Bulletin of Canadian Petroleum Geology, 58, 235-267.

Gabrielse, H., 1985. Major dextral transcurrent displacements along the Northern Rocky Mountain Trench and related lineaments in north-central British Columbia. Geological Society of America Bulletin, 96, 1-14.

Gabrielse, H., 1998. Geology of Cry Lake and Dease Lake map areas, North-Central British Columbia. Geological Survey of Canada Bulletin 504, 147 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.

Gifford, R., 1969. Bowser Resources Ltd., McBride River Project, British Columbia. British Columbia Ministry of Energy and Mines, Property Files 019716, 019720, 019721 and 019723.

Gillespie, M.R., and Styles, M.T., 1999. BGS rock classification scheme. Volume 1. Classification of igneous rocks. British Geological Survey Research Report RR99-06, 52 p.

Hallsworth, C.R., and Knox, R.W.O., 1999. BGS rock classification scheme. Volume 3. Classification of sediments and sedimentary rocks. British Geological Survey Research Report RR99-03, 44 p.

Hampton, M., 1962a. Geological Report on the ANT Mineral Claim Group. British Columbia Ministry of Energy and Mines, Assessment Report 437, 9 p.

Hampton, M., 1962b. Geological Report on the BEE Mineral Claim Group. British Columbia Ministry of Energy and Mines, Assessment Report 438, 10 p.

Henderson, C.M., and Perry, D.G., 1981. A Lower Jurassic heteroporid bryozoan and associated biota, Turnagain Lake, British Columbia. Canadian Journal of Earth Sciences, 18, 457-468.

Iverson, O., Mahoney, J.B., and Logan, J.M., 2012. Dease Lake geoscience project, part IV: Tsaybahe group: Lithological and geochemical characterization of Middle Triassic volcanism in the Stikine arch, north-central British Columbia. In: Geological Fieldwork 2011, British Columbia Ministry of Energy, Mines and Natural Gas, British Columbia Geological Survey Paper 2012-1, pp. 17-22.

Johannson, G.G., Smith, P.L., and Gordey, S.P., 1997. Early Jurassic evolution of the northern Stikinian arc: evidence from the Laberge Group, northwestern British Columbia. Canadian Journal of Earth Sciences, 34, 1030-1057.

Kretz, R., 1983. Symbols for rock-forming minerals. American Mineralogist, 68, 227-279.

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.

Ludwig, K.R., 2012. Isoplot 3.75. A Geochronological Toolkit for Microsoft Excel. Special Publication No. 5, Berkley Geochronology Center.

Mann, D., and Reynolds, N.W., 1969. Geological report on the STAR claims. British Columbia Ministry of Energy and Mines, Assessment Report 2154, 15 p.

Marsden, H., and Thorkelson, D.J., 1992. Geology of the Hazelton Volcanic Belt in British Columbia: Implications for the Early to Middle Jurassic evolution of Stikinia. Tectonics, 11, pp. 1266-1287.

Mihalynuk, M.G., 1999. Geology and Mineral Resources of the Tagish Lake Area, (NTS 104M/8,9,10E, 15 and 104N/12W), Northwestern British Columbia. British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Bulletin 105, 202 p.

Mihalynuk, M.G., Erdmer, P., Ghent, E.D., Archibald, D.A., Friedman, R.M., Cordey, F., Johannson, G.G., and Beanish, J., 1999. Age constraints for emplacement of the northern Cache Creek terrane and implications of blueschist metamorphism. In: Geological Fieldwork 1998, British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper 1999-1, pp. 127-141.

Mihalynuk, M.G., Erdmer, P., Ghent, E.D., Cordey, F., Archibald, D.A., Friedman, R.M., and Johannson, G.G., 2004. Coherent French Range blueschist: Subduction to exhumation in <2.5 m.y.? Geological Society of America Bulletin, 116, 910.

Mihalynuk, M.G., Nelson, J., and Diakow, L.J., 1994. Cache Creek terrane entrapment: Oroclinal paradox within the Canadian Cordillera. Tectonics, 13, 575-595.

Nelson, J., and Mihalynuk, M., 1993. Cache Creek ocean: Closure or enclosure? Geology, 21, 173-176.

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 and regional digital map representation of the Hazelton Group in the Iskut River region, northwestern British Columbia. In: Geological Fieldwork 2018, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2018-1, pp. 15-38.

Olsen, H., Due, P.H., and Clemmensen, L.B., 1989. Morphology and genesis of asymmetric adhesion warts - a new adhesion surface structure. Sedimentary Geology, 61, 277-285.

Read, P.B., and Psutka, J.F., 1990. Geology of Ealue Lake East-half (104H/13E) and Cullivan Creek (104H/14) map areas, British Columbia. Geological Survey of Canada Open File 2241, Geological Survey of Canada.

Samperton, K.M., Schoene, B., Cottle, J.M., Brenhin Keller, C., Crowley, J.L., and Schmitz, M.D., 2015. Magma emplacement, differentiation and cooling in the middle crust: Integrated zircon geochronological-geochemical constraints from the Bergell Intrusion, Central Alps. Chemical Geology, 417, 322-340.

Schiarizza, P., 2012. Geology of the Kutcho assemblage between the Kehlechoa and Tucho Rivers, northern British Columbia (NTS 104I/01, 02). In: Geological Fieldwork 2011, British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper 2012-1, pp. 75-98.

Shirmohammad, F., Smith, P.L., Anderson, R.G., and McNicoll, V.J., 2011. The Jurassic succession at Lisadele Lake (Tulsequah map area, British Columbia, Canada) and its bearing on the tectonic evolution of the Stikine terrane. Volumina Jurassica, 9, 43-60.

Stevens, R.D., DeLabio, R.N., and Lachance, G.R., 1982. Age determinations and geological studies. In: K-Ar isotopic ages, report 16, Geological Survey of Canada Paper 82-2, pp. 5-11.

van Straaten, B.I., and Gibson, R., 2017. Late Early to Middle Jurassic Hazelton Group volcanism and mineral occurrences in the McBride-Tanzilla area, northwest British Columbia. In: Geological Fieldwork 2016, British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper 2017-1, pp. 83-115.

van Straaten, B.I., and Nelson, J.L., 2016. Syncollisional late Early to early Late Jurassic volcanism, plutonism, and porphyry-style alteration on the northeastern margin of Stikinia. In: Geological Fieldwork 2015, British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper 2016-1, pp. 113-143.

van Straaten, B.I., Gibson, R., and Nelson, J.L., 2017. Preliminary bedrock geology of the Tanzilla and McBride area (NTS 104I/03, 04, 05, 06). British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Open File 2017-9, 1:50,000 scale.

van Straaten, B.I., Logan, J.M., and Diakow, L.J., 2012. Mesozoic magmatism and metallogeny of the Hotailuh Batholith, northwestern British Columbia. British Columbia Ministry of Energy, Mines and Natural Gas, British Columbia Geological Survey Open File 2012-6, 58 p.

Takaichi, M., 2013a. Assessment Report on the 2012 Geological, Geochemical, Program at the McBride Property, BC, Canada. British Columbia Ministry of Energy and Mines, Assessment Report 34265, 17 p.

Takaichi, M., 2013b. Assessment Report on the 2012 Geological, Geochemical, and Geophysical Program at the Eagle Property, BC, Canada. British Columbia Ministry of Energy and Mines, Assessment Report 34266, 22 p.

Thomson, R.C., Smith, P.L., and Tipper, H.W., 1986. Lower to Middle Jurassic (Pliensbachian to Bajocian) stratigraphy of the northern Spatsizi area, north-central British Columbia. Canadian Journal of Earth Sciences, 23, 1963-1973.

Tipper, H.W., 1978. Jurassic biostratigraphy, Cry Lake map-area, British Columbia. In: Current Research, Part A, Geological Survey of Canada Paper 78-1A, pp. 25-27.

Tipper, H.W., and Richards, T.A., 1976. Jurassic stratigraphy and history of north-central British Columbia. Geological Survey of Canada Bulletin 270, Geological Survey of Canada, 82 p.

Yeager, D.A., and Ikona, C.K., 1982. Report on the D1 Mineral Claim. British Columbia Ministry of Energy and Mines, Assessment Report 10699, 30 p.

Yeager, D.A., and Ikona, C.K., 1984. Geochemical and geological report on the Mt. Sister Mary Property. British Columbia Ministry of Energy and Mines, Assessment Report 12292, 40 p.

Yeager, D.A., and Ikona, C.K., 1985. Report on the D1, D3, D4, D6, D8, and D9 Mineral Claims. British Columbia Ministry of Energy and Mines, Assessment Report 14004, 27 p.