Geology of the Latham and Pallen Creek area, northwestern British Columbia: Distinguishing the Tsaybahe group, Stuhini Group, and Hazelton Group, and the onset of Triassic arc volcanism in northern Stikinia

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Abstract

The oldest units in the Latham Creek and Pallen Creek area are penetratively deformed meta-sedimentary and volcanic rocks and limestones of the Stikine assemblage (upper Paleozoic). These rocks are overlain (likely unconformably) by a volcano-sedimentary sequence informally referred to as the Tsaybahe group (Lower-Middle Triassic), which is succeeded by the Stuhini Group (Upper Triassic). We subdivide the Tsaybahe group into a sedimentary unit of fine-grained siliciclastic rocks and minor chert, and a volcanic unit of monomictic tuff breccia with plagioclase-augite-phyric volcanic clasts. Tsaybahe volcanic rocks appear texturally similar to the overlying Stuhini Group, but are separated based on their stratigraphic position atop of the Stikine assemblage, rare Middle Triassic biostratigraphic ages, low magnetic susceptibility, and low response on regional aeromagnetic surveys. Stuhini Group volcanic rocks include massive monomictic tuff breccia and lapilli-tuff with augite-plagioclase-phyric volcanic clasts, have a high magnetic susceptibility, and display a high and variable response on regional aeromagnetic surveys. Triassic and older stratified rocks are cut by Late Triassic stocks and plutons ranging from ultramafic to gabbro, hornblende-rich quartz diorite and hornblende quartz monzonite in composition. Triassic units generally lack penetrative tectonic fabrics and are deformed into map-scale open folds. An outlier of volcano-sedimentary rocks assigned to the upper part of the Hazelton Group is inferred to unconformably overlie the Triassic rocks. The succession (~500 m thick) includes two sedimentary units that are overlain by a maroon volcanic unit, which is capped by a felsic volcanic unit. Based on lithological and stratigraphic criteria, the sedimentary units are assigned to the Spatsizi Formation and the volcanic units to the Horn Mountain Formation. Three Middle Jurassic plutons are exposed in the area, ranging in composition from biotite-hornblende quartz diorite to biotite monzogranite. Developed within or adjacent to these plutons are zones of alteration and mineralization containing locally elevated copper, gold, silver and/or molybdenum in fractures, veins, skarns, and gossans.

Augite-phyric mafic volcanic units in each of the Tsaybahe group, Stuhini Group, and Horn Mountain Formation, although temporally distinct, are texturally similar. Compared to widespread exposures of mafic volcanic rocks of the Stuhini Group in northern Stikinia, occurrences of the Tsaybahe group and its correlatives are rare. However, owing to a lack of age constraints, we consider that Tsaybahe group exposures may have been included in the Stuhini Group and suggest that the unit is more extensive than currently recognized. The Tsaybahe group may represent nascent Middle Triassic arc volcanism before widespread Upper Triassic Stuhini arc activity.

Keywords: Stikine assemblage, Tsaybahe group, Stuhini Group, Spatsizi Formation, Horn Mountain Formation, Hazelton Group, Latham Creek pluton, Cake Hill pluton, Three Sisters pluton, Pallen Creek pluton, Tanzilla pluton, Hotailuh batholith, Paleozoic, Permian, Triassic, Jurassic, Stikine terrane.

1. Introduction

Mapping near Dease Lake (Figs. 1, 2) has highlighted temporally distinct, but texturally similar augite-phyric mafic volcanic units in each of the Tsaybahe group (Lower-Middle Triassic; Read, 1983; 1984), Stuhini Group (Upper Triassic; Logan et al., 2012a) and Horn Mountain Formation (Lower to Middle Jurassic; van Straaten and Nelson, 2016; van Straaten and Gibson, 2017; van Straaten and Bichlmaier, 2018a). Continuing as part of a multi-year program, two field teams spent six weeks mapping at a 1:20,000 scale in the Latham Creek and Pallen Creek area, south of Dease Lake (Fig. 2; NTS 104J/01 and parts of 104I/04, 05; 104J/08). Because access was limited by wildfires, the geology of the south central and southwestern parts of the study area (Fig. 2) is interpreted from previous mapping by Read (1983; 1984) and Gabrielse (1998), and an aeromagnetic survey by Aeroquest Airborne (2012).

Our study confirms the presence of Read's (1984) Tsaybahe group (Lower-Middle Triassic). It can be distinguished from younger units based on its stratigraphic position, presence of a lithologically characteristic sedimentary unit, presence of Lower-Middle Triassic microfossils (Read, 1983; 1984; Gabrielse, 1998; Golding et al., 2017), and low magnetic susceptibility values and a low response on Aeroquest Airborne's (2012) aeromagnetic survey. We use these criteria to

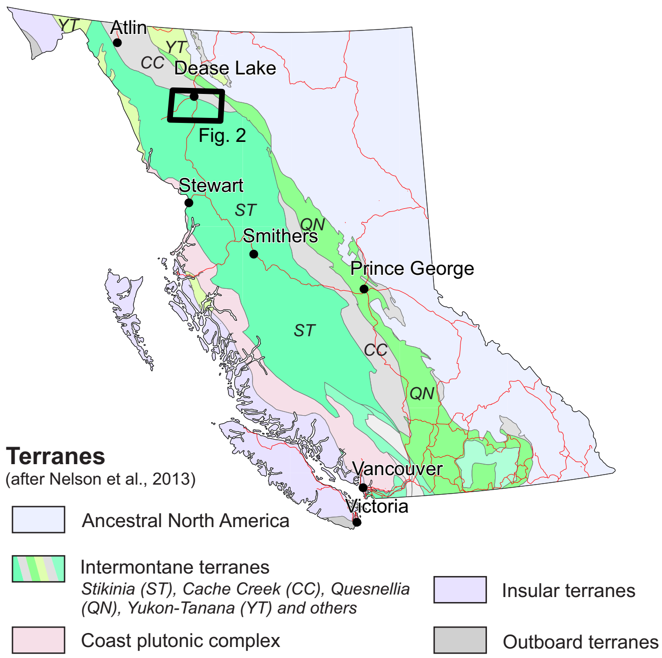

Fig. 1. Location of study area, modified after Nelson et al. (2013).

reinterpret Triassic stratigraphic assignments in the study area and consider if the Tsaybahe group and its equivalents are more extensive in northern Stikinia than previously appreciated.

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 is a multi-episodic volcanic island arc terrane 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 (Lower 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 (Fig. 1), an accretionary complex of oceanic crustal rocks, primitive arc ophiolites, pelagic rocks, carbonate rocks, and blueschists. The northeastern margin of Stikinia and adjacent Cache Creek terrane are covered by Lower Jurassic siliciclastic rocks of the Whitehorse trough (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).

3. Lithostratigraphic units

In the study area, Paleozoic to Middle Jurassic lithostratigraphic units of Stikinia are overlain by Cretaceous and younger overlap units (Figs. 2, 3; Table 1). The oldest rocks are part of the Stikine assemblage (Devonian-Permian). These basement rocks are overlain by three temporally distinct, but texturally similar, augite-phyric mafic volcanic and related sedimentary successions. The oldest succession, informally referred to as the Tsaybahe group by Read (1984), is Early-Middle Triassic, and is recognized only locally in northern Stikinia. The second succession comprises Late Triassic mafic volcanic and sedimentary rocks of the Stuhini Group. These rocks are widespread throughout northern Stikinia. In the northwestern part of the map area is an outlier of sedimentary and volcanic rocks of the Spatsizi and Horn Mountain formations (upper part of the Hazelton Group) as defined by van Straaten and Nelson (2016), van Straaten and Gibson (2017) and van Straaten and Bichlmaier (2018a).

Within the study area, low magnetic susceptibility values (Fig. 4) and a low response on Aeroquest Airborne's (2012) aeromagnetic survey characterize all Triassic rocks lying immediately above the Stikine assemblage, all units containing accurately located Lower-Middle Triassic fossil collections (Read, 1983; Read, 1984; Gabrielse, 1998; Golding et al., 2017) and all Triassic fine-grained sedimentary rock units. In contrast, high magnetic susceptibility values and a high and variable aeromagnetic response characterize stratigraphically higher Triassic strata that contain rare Upper Triassic conodonts (Read, 1984; Gabrielse, 1998; Logan et al., 2012b; Golding et al., 2017). We used this observation to reinterpret Triassic stratigraphic assignments east of the Plateau fault (Fig. 2).

In the following 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 (Devonian-Permian)

Stikine assemblage rocks are exposed in the northwestern and southeastern parts of the map area (Fig. 2); observations presented herein are based mainly on work in the northwestern part. We recognize a meta-sedimentary unit (DPS*s*), a volcanic unit (DPS*v*) and a limestone unit (DPS*ls*; Table 1). These units are folded and generally show a well-developed phyllitic foliation. Although way-up indicators were not observed, the limestone unit seems to overlie the meta-sedimentary unit (see Section 5.1.). The volcanic unit forms a lens in the meta-sedimentary unit (Figs. 2, 3). Contacts between units are not exposed. Direct age constraints are only available for the limestone unit; it contains Early-Middle Permian fossils (Table 1).

3.1.2. Tsaybahe group (Lower-Middle Triassic)

Based on mapping near the Stikine River that overlaps with our study area (Fig. 2b), Read (1984) introduced the Tsaybahe group as an informal name for a section of Lower-Middle

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

Age	Unit		Description
Lower-Middle Jurassic	upper part of Hazelton Gp.	Horn Mnt. Fm.	**Middle felsic volcanic rocks (lmJHM*Mvf*).** Massive to locally crudely stratified felsic tuff, lapilli-tuff and minor tuff breccia; matrix-supported to lesser clast-supported. Generally contains angular to very angular light-coloured aphanitic to Pl-phyric volcanic clasts, rare flow-banded clasts, very rare quartz-phyric and spherulitic clasts. Unit includes lesser coherent Pl-phyric, commonly flow-banded, rhyolitic rock with 5-20% subhedral equant to lath-shaped Pl (0.3-1.5 mm). Fairly resistant, light-medium grey weathering.
			Middle maroon volcanic rocks (lmJHM*Mv*). Generally crudely stratified maroon volcanic breccia, tuff breccia, lapillistone, lapilli-tuff and tuff; matrix- to clast-supported. Contains generally subangular volcanic clasts with 20% euhedral lath-shaped to equant Pl (1-3 mm) and 15% euhedral equant Aug (1-3 mm), typically set in a Pl and Aug crystal and fine ash matrix. Aug-Pl and Pl-phyric coherent rocks; may represent flows or subvolcanic intrusions. Local monomictic clast-supported volcanic breccia with a matrix-deficient open framework (likely flow-margin autobreccia). One internally laminated limestone bed observed. Resistant, dark grey to maroonish weathering.
		Spatsizi Fm.	**Volcaniclastic sandstone (lmJSP*sv*).** Medium- to very thickly bedded, medium-grained (lesser fine-, rare coarse-grained) volcaniclastic feldspathic arenite with angular and lesser euhedral Pl and Aug grains. Interstratified with siltstone and fine-grained feldspathic wacke. Lesser medium-grained calcareous feldspathic arenite. Minor crystal tuff with subordinate Aug-Pl-phyric volcanic clasts. Very rare limestone and volcaniclastic feldspathic arenite with limestone pebbles. Fairly recessive, light-medium grey weathering.
			Sedimentary rocks (lmJSP*s*). Laminated to thinly bedded siltstone, very fine- to medium-grained sandstone. Strongly silicified with abundant disseminated pyrite. Grades upward to interbedded volcaniclastic siltstone, volcaniclastic sandstone, tuff, crystal tuff, and lesser lapilli-tuff with abundant euhedral Pl, minor altered mafic crystals and up to 15% aphanitic to Pl-phyric grey to green volcanic clasts. Fairly recessive, rusty weathering.
Upper Triassic	Stuhini Gp.		**Volcanic rocks (uTrST*vm*).** Monomictic tuff breccia, lapilli-tuff, lesser volcanic breccia and lapillistone; massive to very rarely crudely thin to very thick bedded, clast- to matrix-supported. Subangular clasts contain 20-50% euhedral platy Pl (aspect ratio 1:4:4, 0.2-2 mm) and 15-40% euhedral equant Aug (0.5-3 mm) and 0-10% round to irregular-shaped amygdules (0.5-3 mm) set in a Pl and Aug crystal and fine ash matrix. Aug-Pl-phyric coherent rocks contain 15-30% subhedral equant Aug (0.5-3.0 mm) and 15-30% subhedral equant Pl (0.3-2 mm), and may represent subvolcanic intrusions or flows. Mean magnetic susceptibility 23 x 10^{-3} SI units. Resistant, dark grey weathering. Contains early Carnian conodonts (Read, 1984; Golding et al., 2017).
			Sedimentary rocks (uTrST*sv*). Laminated to medium-bedded interstratified fine- to medium-grained (lesser very fine-, rare coarse-grained) volcaniclastic feldspathic arenite, lesser feldspathic wacke and siltstone. Sandstone is generally planar- to cross- to trough cross-stratified, poorly sorted, and contains 80% angular to subangular Pl, 20% equant mafic grains. Moderately recessive, dark grey to orangey grey weathering. Contains late Carnian conodonts in adjacent map area to the north (Logan et al., 2012b; Golding et al., 2017).
Lower-Middle Triassic	Tsaybahe gp.		**Volcanic rocks (lmTrT*vm*).** Massive monomictic tuff breccia and lesser lapilli-tuff; clast- to matrix-supported. Contains subangular to subround, lesser angular and minor irregular-shaped volcanic clasts with 15-35% euhedral rectangular Pl (0.2-1.5 mm), 15-32% euhedral equant Aug (0.5-7 mm) and commonly 10-20% round-ovoid amygdules (0.5-2.5 mm) in an Aug and Pl crystal and fine ash matrix. Mean magnetic susceptibility 0.88 x 10^{-3} SI units. Resistant, dark grey weathering.
			Sedimentary rocks (lmTrT*s*). Laminated to thinly-bedded interstratified dark grey argillite, siliceous argillite, siltstone, dark-medium grey, greenish grey very fine- to fine-grained (rare medium-grained) sandstone and minor dark grey, black, green chert. Sandstone is generally planar- to ripple cross-stratified, contains predominantly Pl and lesser mafic grains, and varies from feldspathic arenite, feldspathic wacke to lesser lithic arenite. Commonly cut by Pl-Aug-phyric sills and dikes. Recessive, dark grey to locally rusty weathering. Contains Early-Middle Triassic fossils (Read, 1983; 1984; Gabrielse, 1998; Golding et al., 2017).
Devonian-Permian	Stikine assemblage		**Limestone (DPS*ls*).** Pale, medium to dark grey and rare rusty orange laminated lime mudstone and thin to medium bedded fossiliferous wackestone and packstone. Planar, wavey planar to lensoidal stratified. Commonly interstratified with medium to dark grey chert laminae, cherty limestone laminae and chert beds. Commonly foliated, with 0.5-1 mm pressure solution cleavage and local boudinaged chert beds. Locally slightly fetid. Resistant, light grey to yellowish-grey weathering. Contains Early-Middle Permian and Artinskian-Kungurian fossils (Read, 1983; Gabrielse, 1998; Logan et al., 2012b; Golding et al., 2017).
			Volcanic rocks (DPS*v*). Grey, greenish grey to maroon tuff, crystal tuff and lapillistone. Contains 3-60% euhedral Pl (0.1-4 mm), up to 5% altered mafic crystals (0.5 mm), and 2-70% pale greenish grey, maroon, brick red, medium to dark grey and medium green aphanitic to microphenocrystic volcanic clasts (0.1-15 mm). Generally has a well-developed phyllitic foliation. Fairly recessive, grey weathering.
			Meta-sedimentary rocks (DPS*s*). Pale, medium to dark grey, minor pale to medium green, rare orange, rare maroonish, very fine- to fine-grained (rare medium-grained) meta-sandstone and phyllite. Minor meta-volcaniclastic sandstone or tuff with euhedral Pl grains and dark green possible mafic grains. Rare medium grey laminated to massive recrystallized limestone beds or boudins. Generally has a well-developed phyllitic foliation. Rare dark grey to black argillite, siliceous argillite, siltstone and chert. Recessive, grey weathering.

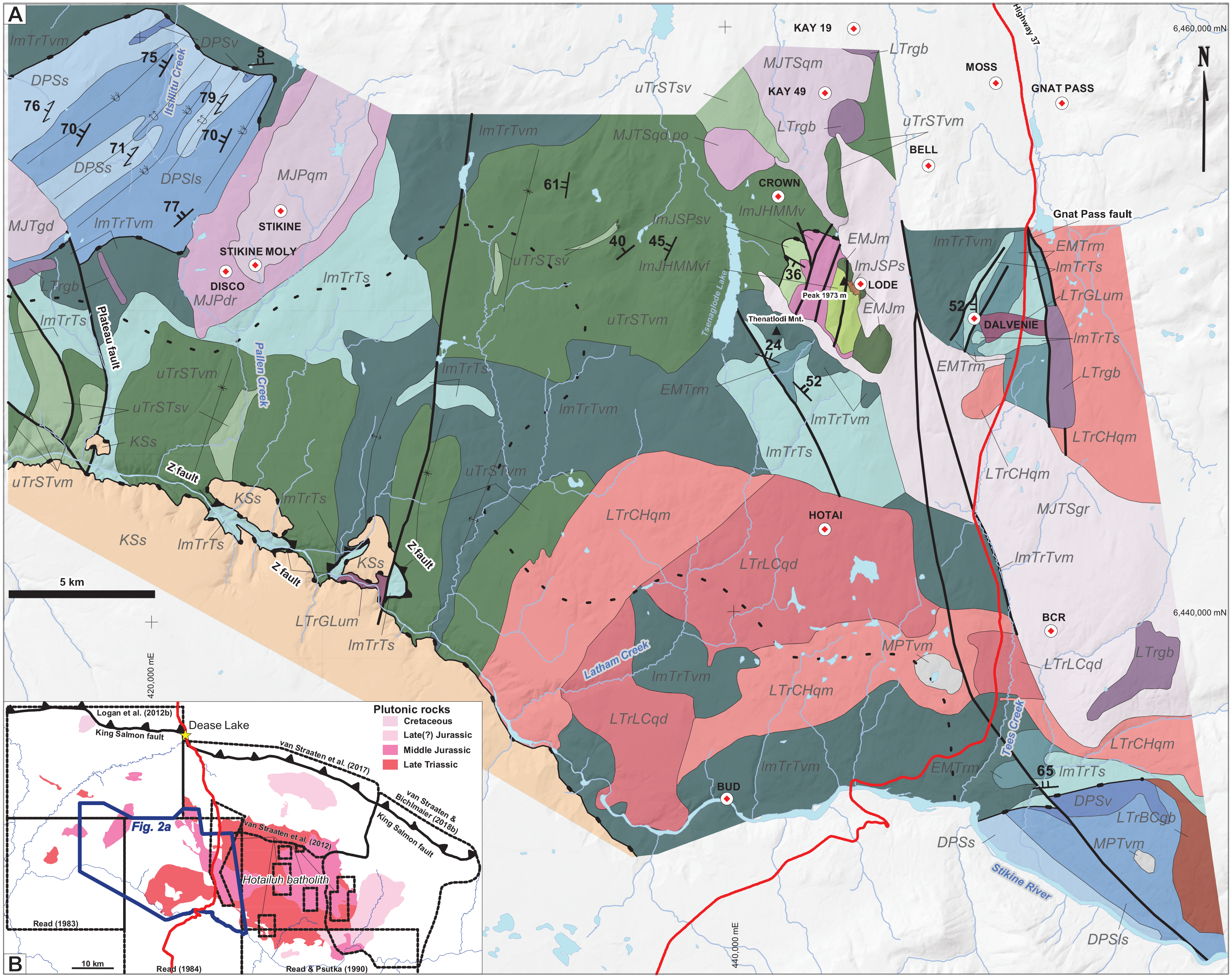

Fig. 2. a) Generalized geology of the Latham Creek and Pallen Creek area, incorporating data from Read (1983, 1984), Gabrielse (1998) and Logan et al. (2012b). The study area is mainly below treeline, with only 5-15% outcrop; exposure is better in alpine areas (~50%). **b)** Location of the Latham Creek and Pallen Creek area in the context of previous mapping in the Dease Lake region.

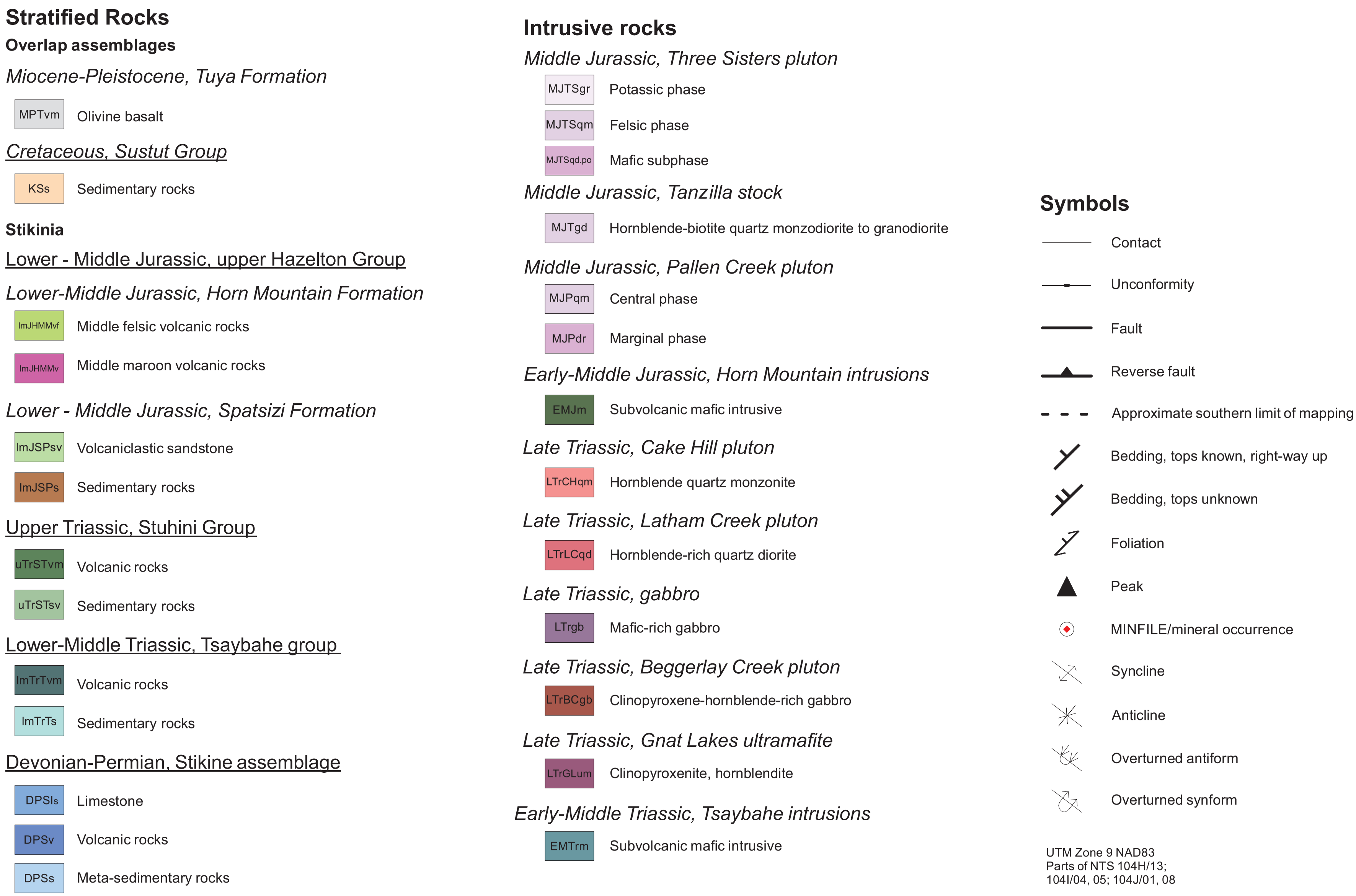

Fig. 2. Continued.

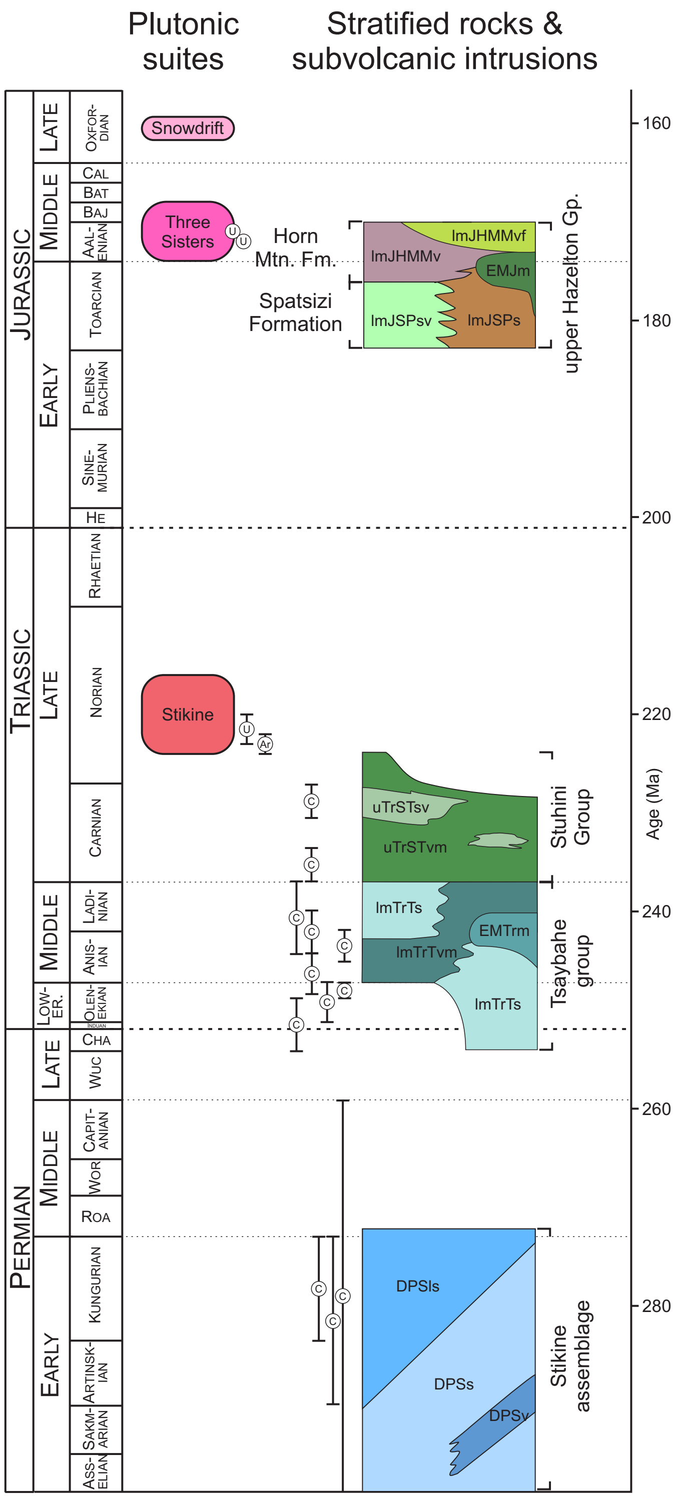

Fig. 3. Schematic stratigraphic and plutonic relationships for Permian to Jurassic rocks in the map area. References for geochronological and biostratigraphic age constraints listed in Tables 1 and 2. Chronostratigraphic ages from Cohen et al. (2013, updated August 2018).

Triassic sedimentary and mafic volcanic rocks. He subdivided the group into four units (basal sedimentary, lower volcanic, middle sedimentary, upper volcanic), and interpreted that they underlie most of the current study area. Both sedimentary units yielded Middle (and rare Lower) Triassic conodonts (Read, 1983; 1984). The lower and upper volcanic units comprise texturally similar mafic volcanic rocks (Read, 1983; 1984). Based on the difficulty of separating Read's lower and upper volcanic units on a regional scale, particularly where intervening sedimentary rocks are not exposed, Gabrielse (1998) discontinued the use of Tsaybahe group. Instead Gabrielse (1998) assigned all of Read's units to the Stuhini Group, which he mapped as undivided Triassic. In this study we retain the Tsaybahe group to include all Early to Middle Triassic volcano-sedimentary rocks, and subdivide it into a volcanic unit and a sedimentary unit (Table 1). Following Gabrielse (1998), we generally include Read's (1983; 1984) upper volcanic unit in the Stuhini Group (Table 1), but based on studies throughout northern Stikinia (e.g., Souther, 1971; Logan and Koyanagi, 1994; Brown et al., 1996; Mihalynuk, 1999) we consider that the Stuhini Group formed entirely in the Late Triassic.

The Tsaybahe group sedimentary unit we mapped (lmTrT*s*, Table 1) comprises fine-grained siliciclastic rocks (Fig. 5) and minor chert. It includes Read's (1983; 1984) basal sedimentary unit and most exposures of his middle sedimentary unit. It can generally be distinguished from Stuhini Group sedimentary rocks (Table 1) based on the presence of minor chert and a greater abundance of argillite, siltstone, and fine-grained sandstone relative to medium- to coarse-grained volcaniclastic sandstone. The Tsaybahe group volcanic unit (lmTrT*vm*, Table 1) contains massive monomictic tuff breccia with plagioclase-augite-phyric volcanic clasts. It appears texturally similar to Stuhini Group volcanic rocks, but has magnetic susceptibility values that are more than one order of magnitude lower (Fig. 4). It includes occurrences of Read's (1983; 1984) lower and upper volcanic unit displaying a low magnetic susceptibility and a low response on aeromagnetic surveys.

Contacts between the Tsaybahe group and underlying Stikine assemblage are not exposed, but the lack of widespread tight, north-northeast trending folds and accompanying phyllitic foliation in Triassic and younger rocks (see Section 5.2.), bedding in basal Tsaybahe units that dips away from Stikine assemblage exposures (Fig. 2; Read, 1983; 1984; Logan et al., 2012b; this study) and an apparent ca. 20 m.y. gap in biostratigraphic ages (Fig. 3) suggest an unconformable relationship. We note significant lateral variation in the character of basal Tsaybahe strata; Stikine assemblage rocks in the west of the map area are overlain by Tsaybahe volcanic rocks, whereas in the east they are overlain by Tsaybahe sedimentary rocks (Fig. 2; Read, 1983; 1984; Logan et al., 2012b; this study). The contact between the Tsaybahe sedimentary and volcanic unit is exposed immediately south of Thenatlodi Mountain, where interbedded siliceous argillite and fine sandstone are conformably overlain by lapillistone with plagioclase-augite-phyric volcanic and minor chert clasts.

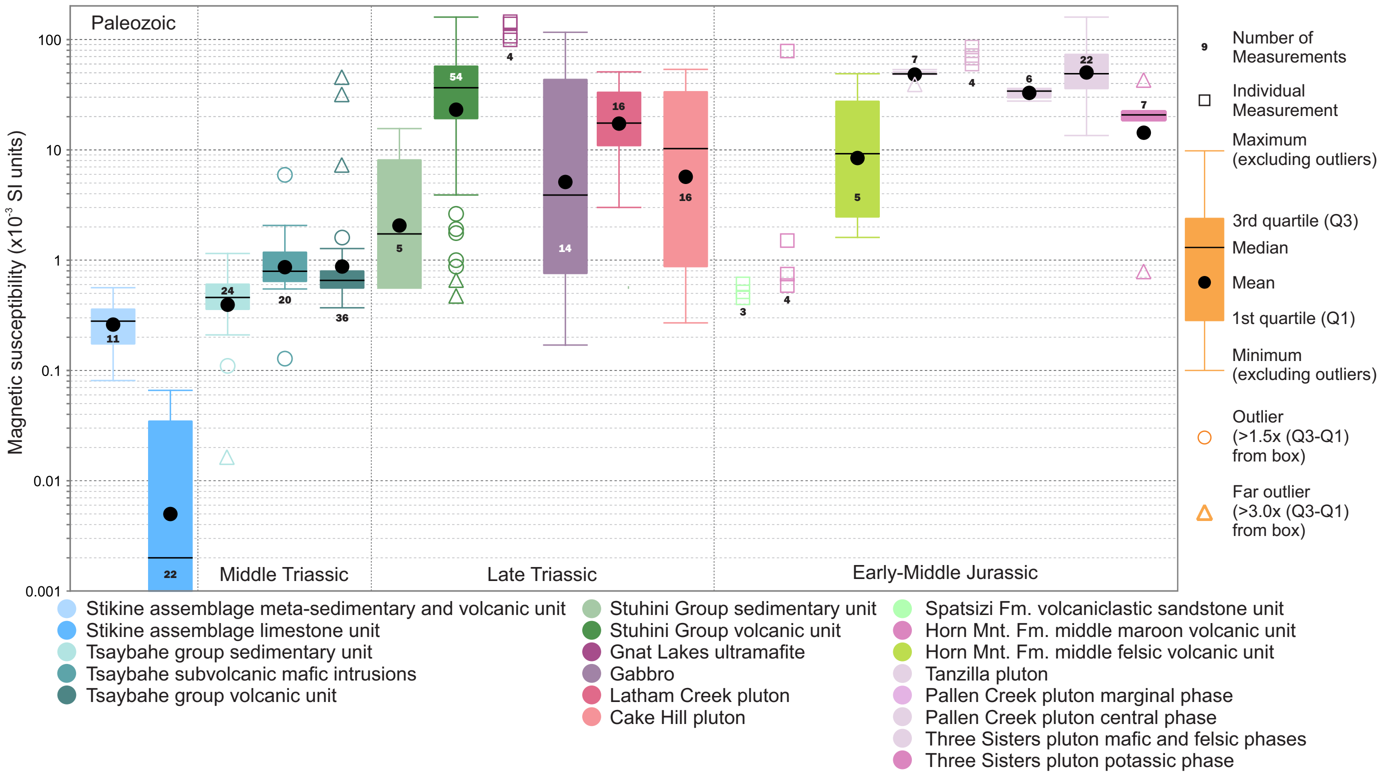

Fig. 4. Box and whisker plots showing magnetic susceptibility values for stratified and intrusive units, ordered from old (left) to young (right). Each magnetic susceptibility value represents the average of ten measurements at one field station. Where less than five data points per unit, individual measurements are shown.

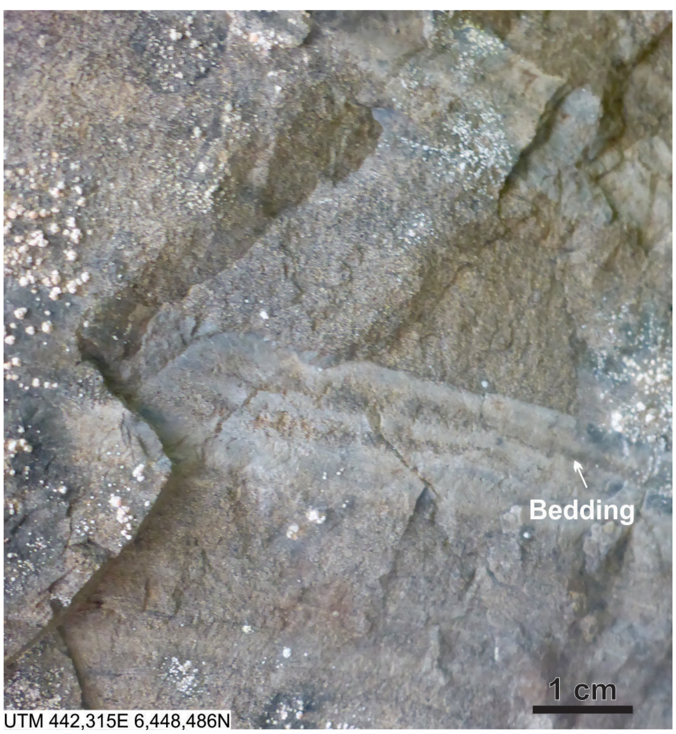

Fig. 5. Tsaybahe Group sedimentary unit (lmTrTs). Interstratified fine-grained sandstone and siliceous argillite.

3.1.3. Stuhini Group (Upper Triassic)

The Stuhini Group crops out in the southwestern, central and northwestern parts of the map area (Fig. 2) and comprises volcanic and minor sedimentary rocks. The volcanic unit contains massive monomictic tuff breccia and lapilli-tuff with augite-plagioclase-phyric volcanic clasts (uTrST*vm*, Table 1; Fig. 6). It locally includes significant proportions of augite-plagioclase-phyric coherent rocks that may represent subvolcanic intrusions or flows. The unit has high magnetic susceptibility values (Fig. 4) and returned one early Carnian conodont collection (Read, 1984; Gabrielse, 1998; revised by Golding et al., 2017). A sedimentary unit, mostly fine- to medium-grained volcaniclastic feldspathic arenite (uTrSTsv, Table 1), forms <140 m-thick intervals within the Stuhini volcanic unit in the centre of the map area. Due to a lack of exposures we were unable to observe the contact between the Tsaybahe and Stuhini groups.

3.1.4. Upper part of the Hazelton Group (Lower-Middle Jurassic)

Peak 1979 m and the surrounding high ground expose maroon volcanic and felsic volcanic rocks that are distinct from surrounding Triassic rocks (Fig. 2). Read (1984) assigned the sequence to the Toodoggone volcanics (Lower Jurassic), whereas Gabrielse (1998) interpreted them as an undifferentiated Triassic-Jurassic volcanic unit. We recognize two lower sedimentary and two upper volcanic units, and expand the areal extent of Jurassic rocks. We assign the sedimentary units to the Spatsizi Formation and the volcanic units to the Horn Mountain Formation (both late Early to Middle Jurassic and in the upper part of the Hazelton Group), based

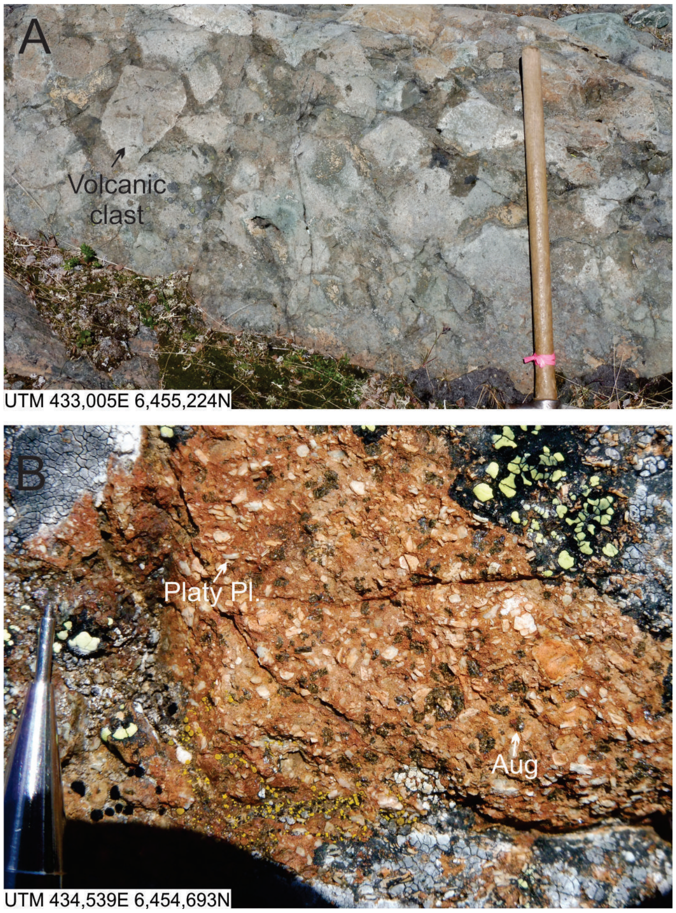

Fig. 6. Stuhini Group volcanic unit (uTrSTvm). **a)** Volcanic breccia with clast-supported subangular augite-plagioclase-phyric volcanic clasts. **b)** Close-up of volcanic clast with platy plagioclase and augite phenocrysts.

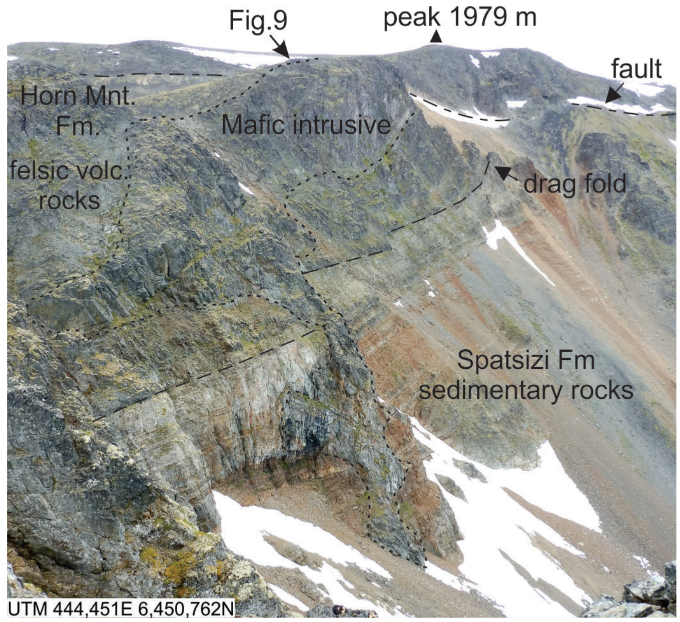

Fig. 7. Hazelton Group volcano-sedimentary rocks. Stratified rusty weathering Spatsizi Formation sedimentary rocks (lmJSP*s*) overlain by Horn Mountain Formation middle felsic volcanic unit (lmJHM*Mvf*); both units are cut by mafic intrusive (EMJ*m*). Megascopic drag fold suggests east-side-down normal movement along north-trending fault. View to west.

on similarities to rocks on the northern to eastern margin of the Hotailuh batholith as described by van Straaten and Nelson (2016), van Straaten and Gibson (2017) and van Straaten and Bichlmaier (2018a). The change in character of sedimentary rocks from west to east, and absence of one of the volcanic units in a stratigraphic section in the northeast may be related to syn-depositional north-trending faults (Section 5.3.). Based on mapping north and east of the Hotailuh batholith, we assume that the Stuhini Group and Hazelton Group in the map area are separated by an unconformity. Locally, the contact between these rocks is cut by the Three Sisters pluton (Middle Jurassic, see Section 4.4.).

3.1.4.1. Spatsizi Formation

We recognize two Spatsizi Formation sedimentary units. Exposed in the cirque east of Peak 1979 m (Fig. 2) is a unit of interstratified siltstone and very fine- to medium-grained sandstone (lmJSP*s*, Table 1). It grades conformably up to Horn Mountain Formation felsic volcanic rocks (Fig. 7). It is similar to a discontinuous 48 km-long belt of Spatsizi Formation sedimentary rocks along the northern to northeastern margin of the Hotailuh batholith described by van Straaten and Nelson (2016), van Straaten and Gibson (2017) and van Straaten and Bichlmaier (2018a).

About 1-2 km west of Peak 1979 m is a unit of medium-grained volcaniclastic feldspathic arenite (lmJSP*sv*, Table 1; Fig. 2) that was previously interpreted as Middle Triassic (Read, 1984). We reinterpret these rocks as Spatsizi Formation because: 1) they resemble Spatsizi Formation rocks on the northern margin of the Hotailuh batholith, 2) they appear to grade upward into maroon volcanic rocks interpreted as Horn Mountain Formation, and 3) they contain limestone beds that are similar to those within Horn Mountain middle maroon volcanic rocks, and both limestone beds failed to yield conodonts (Read, 1984). Two sandstone samples from this unit were processed for U-Pb geochronology but yielded no zircons (Iverson et al., 2012).

3.1.4.2. Horn Mountain Formation

We subdivide the Jurassic volcanic rocks near Peak 1979 m into a maroon volcanic unit and an overlying felsic volcanic unit (Fig. 2). The first unit includes crudely stratified maroon volcanic breccia, flows, tuff breccia, lapillistone, lapilli-tuff and tuff; coherent rocks and volcanic clasts are augite-plagioclase-phyric (lmJHM*Mv*, Table 1; Fig. 8). The unit is similar to an 80 km-long belt of Horn Mountain maroon volcanic rocks along the northern to eastern margin of the Hotailuh batholith.

The second volcanic unit comprises felsic tuff, lapilli-tuff, and minor tuff breccia with light-coloured, aphanitic to plagioclase-phyric volcanic clasts (lmJHM*Mvf*, Table 1; Fig. 9). Although we correlate this unit with felsic rocks in

Fig. 8. Horn Mountain Formation middle maroon volcanic unit (lmJHM*Mv*). Interstratified cream coarse crystal tuff and maroon tuff.

Fig. 9. Horn Mountain Formation middle felsic volcanic unit (lmJHM*Mvf*); lapilli-tuff with angular cream-coloured plagioclase-phyric to aphyric felsic clasts.

the Horn Mountain middle maroon volcanic unit (late Early to Middle Jurassic) exposed east of the Hotailuh batholith (van Straaten and Bichlmaier, 2018a), it could also be equivalent to the Horn Mountain upper felsic volcanic unit (Middle Jurassic) of van Straaten and Nelson (2016), van Straaten and Gibson (2017) and van Straaten and Bichlmaier (2018a). West and south of Peak 1979 m, maroon volcanic rocks appear to be stratigraphically overlain by felsic volcanic rocks (Fig. 2). In the cirque east of Peak 1979, the sedimentary unit of the Spatsizi Formation grades directly to the felsic volcanic unit of the Horn Mountain Formation without intervening maroon volcanic rocks (Fig. 7).

The Hazelton Group in the present map area differs from exposures along the northern to eastern margin of the Hotailuh batholith. First, the exposed stratigraphic thickness (<0.5 km) is significantly less than farther east, where the section is up to 6.4 km thick. Second, units display abrupt lateral facies and thickness changes in contrast to farther east where units display significant lateral continuity. Third, the lower volcanic unit of the Horn Mountain Formation is absent in the present map area.

3.2. Overlap units

3.2.1. Sustut Group (Cretaceous)

Sedimentary rocks of the Sustut Group (Cretaceous) unconformably overlie Stikinia rocks along the Stikine River (Fig. 2). The Sustut Group includes feldspathic and lithic sandstone (locally muscovite-bearing), siltstone, shale, carbonaceous shale, chert clast-bearing pebble to lesser cobble conglomerate and thin zeolitized tuff beds (Read, 1983; 1984).

3.2.2. Tuya Formation (Miocene-Pleistocene)

Several 0.2-1.7 km-wide olivine basalt volcanic centres were mapped by Read (1983; 1984) and Gabrielse (1998) in the southeastern part of the study area.

4. Intrusive units

Plutonic rocks in the map area can be grouped with the Stikine plutonic suite (Late Triassic) and Three Sisters plutonic suite (Middle Jurassic). We recognize two subvolcanic intrusive units, one related to Tsaybahe group volcanic rocks (Early-Middle Triassic) and another related to Horn Mountain volcanic rocks (Early-Middle Jurassic; Fig. 3; Table 2).

4.1. Early-Middle Triassic subvolcanic intrusions

Plagioclase-augite- to augite-phyric sills, dikes, and subvolcanic intrusive complexes (EMTr*m*, Table 2; Fig. 10) up to 1-3 km^2 in size are exposed in the eastern part of the map area (Fig. 2). Mafic intrusions cut, and include xenoliths of, Tsaybahe group sedimentary rocks (lmTrT*s*, Table 1). The intrusions have low magnetic susceptibility values (Fig. 4) and are texturally and mineralogically similar to clasts in the Tsaybahe volcanic unit (lmTrT*vm*). Thus we consider them as feeder dikes.

4.2. Late Triassic plutonic rocks

We recognize four Late Triassic plutonic units in the map area: the Gnat Lakes ultramafite, an unnamed gabbro unit,

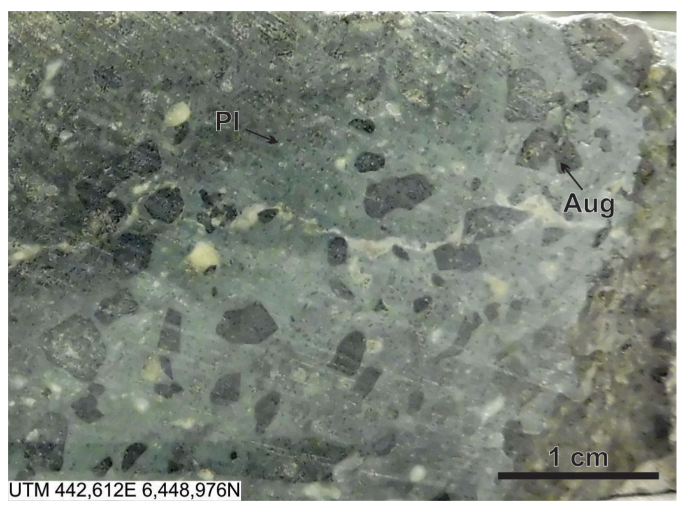

Fig. 10. Subvolcanic Tsaybahe mafic intrusive (EMTr*m*) with euhedral augite and dispersed fine stubby plagioclase; striae are saw cut marks.

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

Age	Phase	Description	Relationships to adjacent units	Geochronology
Middle Jurassic	Three Sisters pluton	**Potassic phase (MJTS*gr*).** Bt-Hbl Qtz monzonite to Bt (-bearing) monzogranite. Massive, equigranular (1-4 mm) to Bt, Pl and/or Kfs porphyritic (3-5 mm). Contains 25-70% equant Kfs, 25-40% equant Pl, 5-25% Qtz, 5-25% mafic minerals, up to 4% Mag and fine-grained xenoliths. Moderately recessive, light grey to pinkish weathering.	Cuts Tsaybahe group volcanic rocks, Stuhini Group volcanic rocks, Horn Mountain middle maroon volcanic rocks. Adjacent Spatsizi Formation sedimentary unit (lmJSP*s*) displays features of contact metamorphism.	U-Pb zircon: 171±1 Ma[4]
		Felsic phase (MJTS*qm*). Hbl-Bt to Bt-Hbl Qtz monzodiorite. Massive, equigranular (0.2-3.5 mm). Contains 35-60% equant Pl, 10-35% equant Kfs, 5-20% Hbl, 4-20% Bt, 3-20% Qtz, and up to 4% Mag. Resistant, weathers pink to cream.		
		Mafic phase (MJTS*qd*). Bt-Cpx-Hbl Qtz diorite. Massive, equigranular (0.5-3 mm). Contains 55-75% euhedral blocky to rectangular Pl, 20-30% green altered mafic minerals (predominantly Hbl, with possible Cpx and Bt), 0-20% anhedral Qtz, 0-15% possible Kfs. Resistant, weathers light grey to greenish grey. **(MJTS*qd.po*).** Bt-bearing Hbl-Cpx diorite with 60-70% platy Pl (0.3-7 mm), 30-40% equant mafic minerals (0.2-1.5 mm) and possibly 2-5% Bt. Resistant, orange to tan weathering.		
	Pallen Creek pluton	**Central phase (MJP*qm*).** Bt to Hbl-Bt Qtz monzonite, lesser Qtz monzodiorite, rare Bt monzogranite. Massive, Kfs porphyritic (4-10 mm) to equigranular (1-3 mm), and contains trace Mag. Moderately recessive, weathers grey to pinkish.	Apophyses cut Pallen Creek marginal phase.	U-Pb zircon: 172±1 Ma[2]
		Marginal phase (MJP*dr*). Hbl-Bt, Bt-Hbl to Hbl-rich diorite, Qtz diorite and lesser Qtz monzodiorite. Massive to rarely foliated, equigranular (0.5-2 mm) to rarely Bt-Hbl porphyritic (5-10 mm). Contains 42-55% blocky to rectangular Pl (0.5-1.5 mm), 10-50% rectangular Hbl (0.5-2 mm), 0-20% green altered Bt (1-3 mm), 3-10% Qtz (0.5-1 mm), 0-20% Kfs and trace Mag. Locally contains Bt Hbl-rich microdiorite xenoliths. Moderately recessive, pinkish cream to orange cream weathering.	Dike cuts Stikine assemblage limestone unit. Includes xenoliths of Tsaybahe group volcanic unit. Adjacent Tsaybahe group volcanic unit and Stikine assemblage limestone unit display features of contact metamorphism.	
	Tanzilla pluton	**Tanzilla pluton (MJT*gd*)**. Bt-bearing Hbl-rich to Hbl Bt-rich Qtz monzodiorite and Bt-Hbl to Bt Hbl-rich granodiorite. Massive, equigranular (0.5-2 mm). Contains 35-65% rectangular Pl, 10-30% elongate to rectangular Hbl, 5-30% equant Bt, 10-20% Qtz and 5-10% blocky Kfs. Resistant, white to grey blue with some pinkish weathering.	Adjacent Stikine assemblage limestone unit displays features of contact metamorphism.	K-Ar Hbl: 171±14 Ma[6] K-Ar Bt: 188±4 Ma[6]

Table 2. Continued.

Age	Phase	Description	Relationships to adjacent units	Geochronology
Early-Middle Jurassic	Horn Mountain-related subvolcanic intrusions	**Platy Pl porphyry (EMJ*m.po*).** Aug-Plag-phyric dikes. Contains 35% platy Pl (0.5-1 cm) and 20% Aug (1-4 mm) in a pale grey groundmass.	Cuts Gnat Lakes ultramafite, Tsaybahe group sedimentary unit and mafic intrusive unit (EMTr*m*).	
		Mafic intrusive (EMJ*m*). Aug-Pl-phyric to Pl-phyric coherent rocks interpreted as sills, dikes and intrusions. Contains 25-40% rectangular to lath-shaped Pl (0.1-2 mm) and 0-20% equant to hexagonal Aug (0.5-10 mm). Resistant, dark grey weathering.	Cuts Spatsizi Fm. sedimentary unit and Horn Mountain middle maroon felsic volcanic unit. Interpreted to cut Horn Mountain middle maroon volcanic unit.	
Late Triassic	Cake Hill pluton	**Cake Hill pluton (LTrCH*qm*)**. Hbl Qtz monzonite and rare Hbl (-rich) monzonite to monzogranite. Massive, equigranular (0.5-3 mm). Contains 10-35% blocky to tabular Hbl, 30-55% blocky Pl, 20-30% blocky to rectangular Kfs, and 5-30% Qtz. Moderately resistant, pinkish to white weathering.	Cuts Stuhini Group volcanic unit. Adjacent Stuhini Group volcanic unit displays features of contact metamorphism.	U-Pb zircon: 221±3 Ma[4] K-Ar Hbl: 212±7 Ma[5] ca. 222 Ma[5]
	Latham Creek pluton	**Latham Creek pluton (LTrLC*qd*).** Hbl-rich Qtz diorite. Commonly foliated, equigranular (0.5-4 mm). Contains 35-55% blocky to rectangular Hbl, 45-63% rectangular to blocky Pl, and 0-10% Qtz (0.5-1.5 mm). Moderately resistant, black and white weathering.		
	Gabbro	**Gabbro (LTr*gb*).** Mafic-rich gabbro. Massive, typically equigranular (0.3-4 mm). Contains 30-85% mafic minerals (probably Cpx and Hbl) and 15-70% rectangular Pl. Resistant, medium grey to greenish weathering.	Locally contains xenoliths similar to Gnat Lakes ultramafite.	
	Gnat Lakes ultramafite	**Gnat Lakes ultramafite (LTrGL*um*)**. Hbl clinopyroxenite, hornblendite and gabbro [3]. Resistant, dark grey to dark greenish grey weathering.	Adjacent Tsaybahe group sedimentary unit and mafic intrusive unit (EMTr*m*) display features of contact metamorphism.	Ar-Ar Hbl: 223.3±2.0 Ma[1]
Early-Middle Triassic	Tsaybahe-related subvolcanic intrusions	**Mafic intrusive (EMTr*m*).** Pl-Aug- to Aug-phyric coherent rocks, interpreted as dikes, sills and intrusions. Contains 25-45% equant Aug (0.5-4 mm), 0-30% blocky to platy Pl (0.2-2 mm), set in a fine-grained dark sea-green groundmass. Median magnetic susceptibility 0.79 x 10^{-3} SI units. Resistant, dark grey to dark green weathering.	Cuts and includes xenoliths of Tsaybahe group sedimentary rocks.	

Note: [1] Zagorevski (unpublished data); [2] Logan et al. (2012b); [3] Nixon et al. (1997; 1989); [4] Anderson and Bevier (1992); [5] Read (1984); [6] Stevens et al. (1982).

the Latham Creek pluton, and the Cake Hill pluton. The Gnat Lakes ultramafite is a 4.7 km^2 body exposed along Highway 37 (Fig. 2). It has been described as an Alaskan-type intrusion based on the presence of hornblende clinopyroxenite, hornblendite and gabbro, minor zoning, and distinctive whole-rock and mineral chemistry data (LTrGL*um*, Table 2; Nixon et al., 1989; 1997). An Ar-Ar hornblende analysis returned a 223.3 ±2.0 Ma cooling age (A. Zagorevski, unpublished data). The adjacent Tsaybahe group sedimentary unit (lmTrT*s*) and mafic intrusive unit (EMTr*m*) are strongly silicified and contain common disseminated pyrite as a result of contact metamorphism.

Small (<4 km^2) mafic-rich gabbro bodies are exposed in the eastern, northeastern, and northwestern parts of the map area (LTr*gb,* Table 2; Fig. 2). In the northeast, a 1.3 km^2 compositionally zoned gabbro body displays a central zone containing up to 80% clinopyroxene and a marginal zone to the north with 25-30% clinopyroxene. A significantly larger gabbroic pluton is exposed west of the map area (Caribou Meadows pluton; Read, 1983).

The Latham Creek pluton forms three separate bodies (up to 44 km^2 in size) in the southeastern part of the map area (Fig. 2) and consists of hornblende-rich quartz diorite that is commonly foliated (LTrLC*qd,* Table 2; Fig. 11).

The Cake Hill pluton is exposed in the eastern part of the map area (Fig. 2). It consists mainly of hornblende quartz monzonite and lacks xenoliths (LTrCH*qm,* Table 2). Decimetre-scale dikes of Cake Hill composition cut Stuhini Group augite-phyric coherent rocks (uTrST*vm*) along the pluton's western margin. A sample from the adjacent map area to the east returned a U-Pb zircon age of 221 ±3 Ma (Anderson and Bevier, 1992).

4.3. Early-Middle Jurassic subvolcanic intrusions

Augite-plagioclase-phyric and plagioclase-phyric coherent rocks (EMJ*m*, Table 2; Fig. 12) form relatively small (<1.5 km^2) bodies in the eastern part of the map area. The intrusions are texturally and mineralogically similar to volcanic clasts within the Horn Mountain middle maroon volcanic unit (lmJHM*Mv*); they likely represent feeder dikes. Rare augite- and coarse platy plagioclase-phyric dikes (EMJ*m.po*, Table 2) cut Early-Middle Triassic mafic intrusive rocks and Tsaybahe sedimentary rocks in the eastern part of the map area. These dikes are texturally similar to platy plagioclase-phyric intrusions that are cogenetic with Horn Mountain volcanism in the adjacent map area to the northwest (e.g., van Straaten and Gibson, 2017).

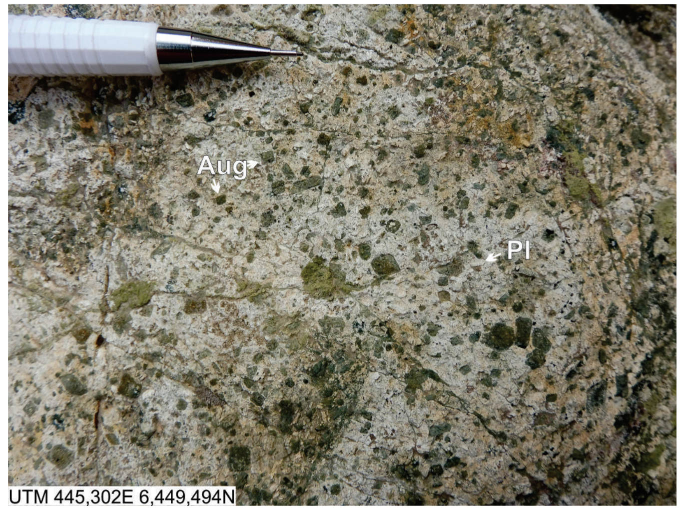

Fig. 12. Subvolcanic Horn Mountain mafic intrusive (EMJ*m*) with hexagonal chloritized and epidote-altered augite and plagioclase.

4.4. Middle Jurassic plutonic rocks

We mapped three Middle Jurassic plutonic bodies in the field area, the Three Sisters, Pallen Creek, and Tanzilla plutons (Fig. 2, Table 2). The Three Sisters pluton is exposed in the eastern part of the map area. The pluton is subdivided into a mafic phase (MJTS*qd*), a felsic phase (MJTS*qm*), and a potassic phase (MJTS*gr*). Several small (<1 km) mafic to mafic-rich quartz diorite bodies of the mafic phase are enclosed within the felsic phase in the northeastern part of the map area. A 3.5 km^2 coarse platy plagioclase porphyritic diorite body of a mafic subphase (MJTS*qd.po*; Fig. 13) is exposed in the northeastern part of the study area. It is texturally and compositionally similar to a hornblende-clinopyroxene diorite body with platy plagioclase described by van Straaten and Bichlmaier (2018a) on the eastern margin of the Three Sisters pluton. The felsic

Fig. 11. Latham Creek pluton (LTrLC*qd*). Foliated hornblende-rich quartz diorite.

Fig. 13. Three Sisters pluton plagioclase porphyritic mafic subphase (MJTS*qm.po*). Mafic-rich diorite with coarse platy plagioclase set in a fine-crystalline plagioclase-rich groundmass.

phase, exposed in the northeastern part of the map area, consists of hornblende-biotite quartz monzodiorite. The potassic phase extends along the eastern side of the map area, and consists of biotite-hornblende quartz monzonite to biotite monzogranite. A sample of the potassic phase returned a U-Pb zircon age of 171 ±1 Ma (Anderson and Bevier, 1992).

The Pallen Creek pluton forms a 30 km^2 body in the northwestern part of the map area. We identify a marginal phase (MJP*dr*) and a central phase (MJP*qm*; Table 2), corroborating previous work by Downing (1980). The marginal phase comprises biotite-hornblende quartz diorite, is locally foliated and contains minor fine-grained dioritic xenoliths (Fig. 14). The central phase of the Pallen Creek pluton consists of (hornblende-) biotite quartz monzonite to monzodiorite. A sample from the adjacent map sheet to the north returned a U-Pb zircon age of 172 ±1 Ma (Logan et al., 2012b).

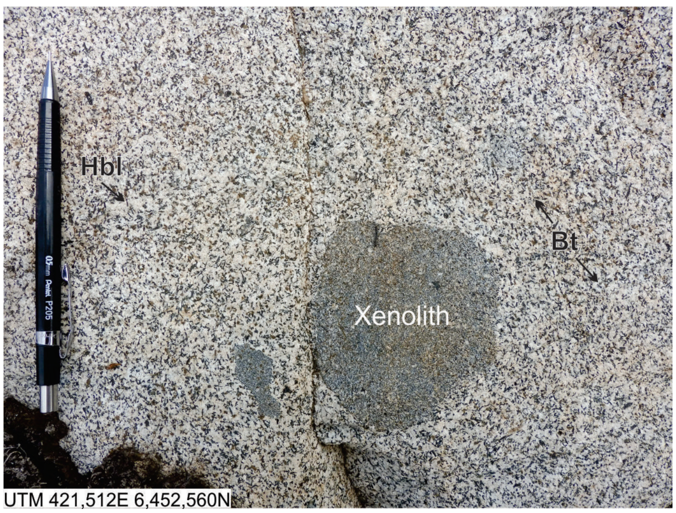

Fig. 14. Marginal phase of the Pallen Creek pluton (MJP*dr*). Biotite-hornblende quartz diorite with hornblende-rich microdiorite xenoliths.

The Tanzilla pluton forms a 15 km^2 body in the western part of the map area. It consists mainly of biotite-hornblende quartz monzodiorite to granodiorite (MJT*gd*, Table 2; Fig. 15). Although K-Ar biotite and hornblende analyses returned Early to Middle Jurassic cooling ages (Stevens et al., 1982), textural and mineralogical similarity to the Three Sisters and Pallen Creek plutons suggests it is most likely part of the Middle Jurassic plutonic suite.

5. Structure

Within the field area, penetrative deformation is limited to Stikine assemblage rocks. Triassic and Jurassic rocks generally lack penetrative fabrics.

5.1. Devonian-Permian rocks

Kilometre-scale tight folds are outlined by Stikine assemblage rocks in the northwestern part of the map area (Fig. 2). Rocks generally display a penetrative northwest-dipping phyllitic foliation and the folds display subhorizontal to gently northeast to southwest plunging axes (Fig. 16a). Bedding is commonly

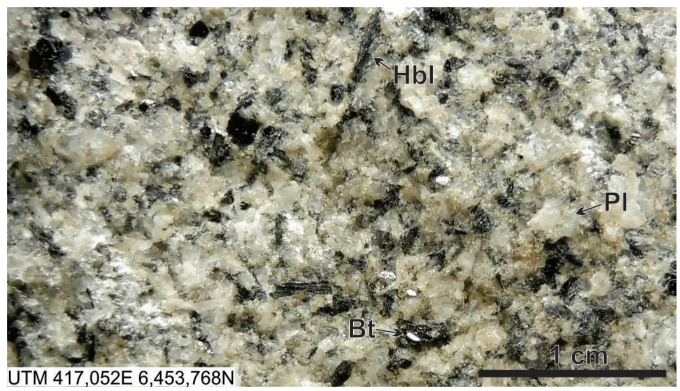

Fig. 15. Tanzilla pluton (MJT*gd*). Massive, biotite-hornblende quartz monzodiorite.

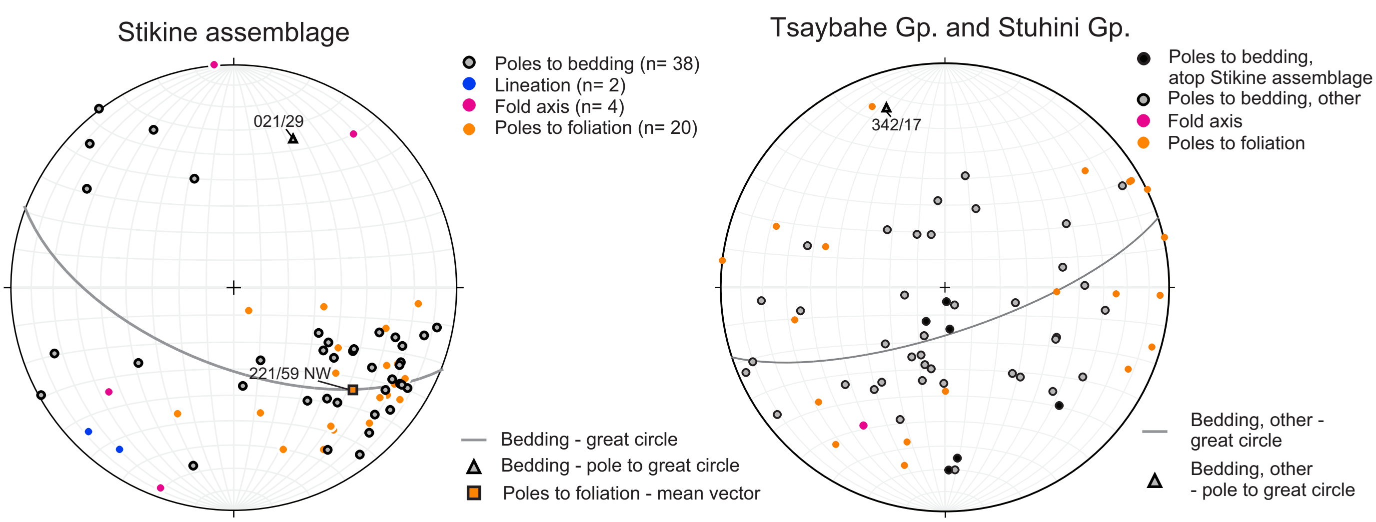

Fig. 16. Equal area lower hemisphere stereonet projections of structural data for **a)** Stikine assemblage (Devonian-Permian) rocks and **b)** Tsaybahe group and Stuhini Group (Triassic) rocks. In a), lineations include a bedding/cleavage intersection and a stretching lineation. Structural data from Logan et al., (2012a; b) and this study.

parallel to foliation (Fig. 16a). Although way-up indicators are lacking we infer the folds have one overturned limb. On the limb of the easternmost antiform along Itsillitu Creek, both bedding and foliation dip to the northwest, but bedding dips more shallowly, indicating that the limb is right-way-up and that the limestone unit overlies the meta-sedimentary unit.

The absence of penetrative deformation in unconformably overlying Tsaybahe and Stuhini groups suggests deformation postdates Stikine assemblage limestone formation (Early Permian) and predates Tsaybahe group deposition (Early Triassic). It correlates with the Tahltanian orogeny recognized throughout most of the Intermontane terranes (e.g., Wheeler, 1967; Logan and Koyanagi, 1994).

5.2. Triassic rocks

Triassic Tsaybahe and Stuhini Group rocks are only rarely foliated, and no outcrop-scale folds were observed. Bedding in basal Tsaybahe group generally dips away from Stikine assemblage basement (Fig. 2). Stereonet analysis of bedding variations within the Tsaybahe and Stuhini groups suggest they are folded about gently northerly plunging fold axes (Fig. 16b). The reinterpreted distribution of Tsaybahe and Stuhini units, particularly within 6 km north of the Stikine River (Fig. 2), could be most easily explained by gently southerly plunging map-scale folds. Inferred fold axes in the map area appear continuous with map-scale north-plunging folds noted by Logan et al. (2012a; b) in the adjacent map area to the north. The absence of north-south trending folds in late Early-Middle Jurassic strata (e.g., van Straaten and Gibson, 2017) may suggest deformation occurred in the latest Triassic to Early Jurassic. The change in fold plunge may be explained by north-south shortening during mid-Jurassic terrane accretion. Structures resulting from south-vergent fold and thrust belt development are widespread north of the King Salmon fault and moderately developed in footwall Whitehorse trough strata (e.g., Logan et al., 2012a; b; van Straaten and Gibson, 2017).

Northerly trending structures including the Gnat Pass shear zone (see van Straaten et al., 2012) and shear zones west of the Gnat Lakes ultramafite (Fig. 2) display a well-developed shear zone-parallel phyllitic foliation.

Read (1983; 1984) mapped the low-angle folded ‘Z-fault’ along Stikine River (Fig. 2). Erosion of the fault along the Stikine River exposes two windows of Tsaybahe sedimentary rocks containing Early to Middle Triassic fossils, cut by a hornblendite to gabbro body (Fig. 2). Read (1983; 1984) interpreted the structure as a gently dipping detachment fault along which Tsaybahe and Stuhini rocks in the hanging wall moved north to northeast. The fault was subsequently folded about a northeasterly axis; faulting and folding predates deposition of the Sustut Group (Cretaceous, Read, 1983; 1984).

5.3. Jurassic rocks

Bedding in the Hazelton Group mainly dips moderately to the southwest. Several northerly trending lineaments and faults cut the succession, with adjacent fault blocks showing moderate differences in bedding attitude, character of sedimentary rocks, and stratigraphic superposition. The change in character of sedimentary rocks from west to east, and absence of one of the volcanic units in a stratigraphic section in the northeast may be related to syn-depositional fault movement. Megascopic drag folding on the east wall of the easternmost fault (Fig. 7) suggests an east-side-down normal movement.

6. Mineral occurrences

A number of intrusion-related mineral occurrences lie within the field area. One is hosted in Late Triassic plutonic rocks, and five are likely related to Middle Jurassic intrusions. Several additional mineral occurrences near Highway 37 (e.g., Gnat Pass, Moss, Dalvenie and BCR; Fig. 2) are described in van Straaten et al. (2012) and van Straaten and Gibson (2016).

6.1. Late Triassic intrusion-hosted mineral occurrences

Hotai is a donut-shaped aeromagnetic anomaly in the Latham Creek pluton (Fig. 2). A soil geochemical survey indicated no anomalous metal values, an induced polarization survey showed a chargeability high coincident with part of the aeromagnetic high, and a grab sample from a bornite vein in weakly chlorite-altered hornblende diorite returned 0.56% Cu (sample 966971, Andrzjewski and Bui, 2012).

6.2. Middle Jurassic intrusion-related mineral occurrences

Geochemical sampling in the 1970s discovered molybdenum in the Pallen Creek pluton (Downing, 1980). We observed 1-3 vol.% fractures (1-3 mm wide) with pyrite and minor chalcopyrite with or without molybdenite in small pits at the Disco and Stikine showings (MINFILE 104J 019, 46); plutonic host rocks appear unaltered. At the Stikine Moly showing (MINFILE 104J 034) up to 4-6% disseminated and fracture-hosted pyrite is accompanied by minor molybdenite and chalcopyrite. A 1.5 m chip sample from Disco returned 0.30% Cu and 0.8 ppm Mo (sample 975162, Andrzjewski and Bui, 2012). Exploration by Quartz Mountain Resources Ltd. in 2012 did not generate significant soil geochemistry anomalies that correlate with induced polarization chargeability highs (Andrzjewski and Bui, 2012).

The Crown copper showing (MINFILE 104I 046) is 3.5 km northwest of Peak 1979 m (Fig. 2). A pyritic gossan and disseminated and vein-hosted chalcopyrite with K-feldspar and skarn alteration is hosted in Triassic volcanic rocks adjacent to a granodiorite to monzonite intrusion (BC Department of Mines and Petroleum Resources, 1972, p. 44; 1973, p. 538). Geophysical surveys, geochemical sampling, and two diamond drill holes were completed in the 1970s, but only geophysical results were reported (Fominoff and Adamson, 1971). We mapped nearby plutonic rocks as the felsic phase of the Three Sisters pluton. Work carried out by West Cirque Resources Ltd. in 2011 and 2012 identified an induced polarization chargeability and copper in soil anomalies (Luckman and Kuttai, 2012; Luckman, 2013).

The Kay 49 showing (MINFILE 104I 026) is in the northwestern part of the map area (Fig. 2). Exploration activities by Tanzilla Explorations Ltd. in the late 1960s and early 1970s identified a 27 m-wide altered and mineralized meta-volcanic outcrop that returned 0.04% Cu and 1.37 g/t Ag. The meta-volcanic rocks are bordered by extensive outcrops of unmineralized intrusive rocks to the southeast (Scott, 1970). The showing is in the felsic phase of the Three Sisters pluton, and possibly in a Stuhini Group pendant. At the nearby Kay 19 showing (MINFILE 104I 037) three drill holes intersected up to 0.09% Cu and 3.4 g/t Ag over 1 m, and a grab sample of nearby exposures returned 0.25% Cu (Aikins, 1971).

The Lode occurrence is in the cirque immediately east of Peak 1979 m. Anomalous silver in a stream-sediment sample (Andrzjewski et al., 2012) led to prospecting and soil geochemistry and induced polarization surveys (Andrzjewski and Bui, 2012). The surveys showed a moderate chargeability feature and coincident multi-element soil geochemical anomaly. We observed rusty weathering and strongly silicified Spatsizi Formation sedimentary rocks (Fig. 7) containing abundant disseminated pyrite and local arsenopyrite. Locally, calcareous sedimentary rocks contain garnet-diopside-epidote skarn assemblages. Alteration and mineralization are likely related to intrusion of the adjacent potassic phase of the Three Sisters pluton (Fig. 2). Significant copper and elevated gold and silver values were reported in several rock samples, including two grab samples that returned 1.05% Cu, 68 ppb Au, 5.9 g/t Ag (sample 975215), 13.0% Cu and 1012 ppb Au and 70.2 ppb Ag (sample 975233, Andrzjewski and Bui, 2012).

7. Discussion

7.1. Regional extent and significance of Tsaybahe group

Although the Triassic history of northern Stikinia is recorded mainly by Upper Triassic volcanic and related sedimentary rocks of the Stuhini Group (British Columbia) and Lewes River Group (Yukon), local remnants of Lower to Middle Triassic sedimentary and volcanic rocks are scattered across the region.

Approximately 100 km west-southwest of our study area and north of the Chutine River, Brown et al. (1996) mapped chert, ribbon chert, siliceous siltstone and tuff containing Early Permian and Middle Triassic radiolaria and conodonts. Contact relationships with underlying Lower Permian limestones are equivocal, and the succession that contains Middle Triassic conodonts “appears to grade abruptly upward into tuffaceous wacke of the Stuhini Group” (Brown et al., 1996). In the same area, Brown et al. (1996) documented a limestone block with Early Triassic conodonts in Upper Triassic volcaniclastic sandstone. About 55 kilometres farther southwest, at the toe of the Scud Glacier, Late Permian limestone, maroon tuff, and chert (Stikine assemblage) is either conformably or paraconformably overlain by an undated tuffaceous wacke and tuff unit correlated with either the Tsaybahe or Stuhini Group (Brown et al., 1996). Approximately 130 km to the southwest of the study area, and north and east of the Galore Creek Cu-Au porphyry deposit, Souther (1972) and Logan and Koyanagi (1994) described a Lower to Middle Triassic siliceous siltstone, limy siltstone and carbonaceous silty shale unit that paraconformably overlies Lower Permian limestone. Volcanic-bearing successions of Early to Middle Triassic age are even rarer than purely sedimentary units. Approximately 165 km to the south-southwest of the study area and near the lower Iskut River, Read et al (1989) mapped a Middle Triassic sedimentary unit containing sedimentary and volcanic breccia, sandstone, and argillite that interfingers with mafic volcanic breccia and tuff; he noted that the volcanic rocks are similar to extensive Middle Triassic augite-phyric volcanic rocks found near the Stikine River.

We suggest that the scattered occurrences summarized above, and coeval sedimentary rocks within the study area, may represent the rare remnants of an Early-Middle Triassic marine basin. Based on textural and compositional similarity between Tsaybahe and Stuhini volcanic rocks and a volcanic arc geochemical signature for both successions (Logan and Iverson, 2013) we further suggest that Middle Triassic volcanism may represent the onset of arc volcanism before the Late Triassic Stuhini-Lewes River arc was fully established. The onset of Tsaybahe group volcanism appears to coincide with the end of Permo-Triassic mafic and bimodal primitive intra-oceanic arc volcanism in the northern Cache Creek terrane (ca. 261-242 Ma, Childe and Thompson, 1997; Childe et al., 1998, Mihalynuk et al., 2003; English et al., 2010; Schiarizza, 2011; 2012a; b; Bickerton, 2014; Zagorevski et al., 2015; 2016; McGoldrick et al., 2018; Bordet, in press; Bordet et al., in press). It may indicate an inboard jump of the subduction zone resulting in termination of subduction below intra-oceanic volcanic arc segments within the Cache Creek terrane and initiation of subduction below Stikinia.

Lacking biostratigraphic and geochronologic constraints, Paleozoic, Jurassic and Eocene augite-phyric volcanic rocks throughout northwest British Columbia have inadvertently been included in the Stuhini Group (e.g., Mihalynuk et al., 1995; Mihalynuk, 1999; van Straaten and Nelson, 2016). Given its remarkable similarity to the Stuhini Group, we conclude that the Tsaybahe group is probably more extensive than currently recognized.

7.2. Criteria to distinguish Triassic-Jurassic volcano-sedimentary successions

Mapping by the British Columbia Geological Survey in the Dease Lake area during the last decade has largely focussed on separating three temporally distinct, but texturally similar, mafic volcanic successions: the Tsaybahe group (Lower-Middle Triassic), the Stuhini Group (Upper Triassic), and the upper part of the Hazelton Group (Lower to Middle Jurassic). In Table 3 we summarize key criteria that can be used to distinguish these three successions.

8. Conclusions

New 1:20,000-scale mapping in the Latham and Pallen Creek area, part of a multi-year project devoted to examining the geologic history and metallogeny of Stikine terrane near

Table 3. Summary of criteria to distinguish Triassic-Jurassic mafic volcanic successions in the Dease Lake area.

	Tsaybahe group *(Early to Middle Triassic)*	**Stuhini Group** *(Late Triassic)*	**upper part of Hazelton Group** *(late Early to Middle Jurassic)*
Volcanic rocks	Predominantly dark green Pl-Aug-phyric mafic volcanic rocks; no felsic rocks reported	Predominantly dark green Pl-Aug-phyric mafic volcanic rocks dominate; no felsic rocks reported	Dark green Pl-Aug-phyric mafic volcanic rocks common; maroon to medium grey Pl-Aug- to (coarse platy) Pl-phyric mafic to intermediate volcanic rocks common; felsic volcanic rocks subordinate (Horn Mnt. Fm.)
Sedimentary rocks	Argillite, siltstone, sandstone, rare chert	Volcaniclastic sandstone	Argillite, siltstone, (volcaniclastic) sandstone, rare conglomerate with granitic clasts (Spatsizi Fm.)
Lower contact	Unconformably above Stikine assemblage	Unknown contact relationships with Tsaybahe group	Unconformably atop Stikine plutonic suite and Stuhini Group
Upper contact	Unknown contact relationships with Stuhini Group	Unconformably overlain by Hazelton Group	Generally conformably overlain by Bowser Lk. Gp. sedimentary rocks
Relationship to plutonic rocks	Cut by Stikine plutonic suite and younger intrusions	Cut by Stikine plutonic suite and younger intrusions	Cut by Three Sisters plutonic suite and younger intrusions
Magnetic susceptibility	Low (0.88 x 10^{-3} SI units for volcanic unit)	High (23 x 10^{-3} SI units for volcanic unit)	Variable
Aeromagnetic signature	Low	High, variable	Variable
Structure	Open map-scale folds, no outcrop-scale folds observed	Open map-scale folds, no outcrop-scale folds observed	Homoclinal to subhorizontal
Metamorphic grade	Lower greenschist	Lower greenschist	Possibly no higher than prehnite-pumpellyite
Age	Anisian-Ladinian, basal sedimentary rocks as old as Olenekian	Carnian	Toarcian to Bajocian
Tectonic interpretation	Early volcanic arc (?)	Volcanic arc	Syncollisional volcanism

Dease Lake, focussed on separating three temporally distinct, but texturally similar, mafic volcanic successions: the Tsaybahe group (Early-Middle Triassic), the Stuhini Group (Late Triassic) and the upper part of the Hazelton Group (late Early to Middle Jurassic). We separate Tsaybahe volcanic rocks from those of the Stuhini Group, based on their stratigraphic position atop the Stikine assemblage (upper Paleozoic), rare Middle Triassic biostratigraphic ages, low magnetic susceptibility and low response on regional aeromagnetic surveys. In contrast, Stuhini Group rocks have a high magnetic susceptibility and display a high and variable response on regional aeromagnetic surveys.

The Tsaybahe group is unusual in northern Stikinia because it is older than most Triassic volcanic successions. Throughout northern Stikinia, augite-phyric mafic volcanic rocks have largely been assigned to the Stuhini Group where sparse biostratigraphic data suggest a mostly Late Triassic age. However, large tracts mapped as Stuhini Group lack age constraints. Rare documented Early-Middle Triassic exposures throughout northern Stikinia contain mainly fine-grained siliciclastic rocks which, in the Dease Lake area, are overlain by significant accumulations of Middle Triassic mafic volcanic rocks. These scattered occurrences of sedimentary rocks may represent rare remnants of an Early-Middle Triassic marine basin, followed by localized, or perhaps largely unrecognized, Middle Triassic volcanism representing the onset of arc volcanism before widespread Upper Triassic Stuhini arc activity. The onset of Tsaybahe group volcanism appears to coincide with the end of mafic and bimodal intra-oceanic arc volcanism in the Cache Creek terrane, and may suggest initiation of subduction below Stikinia resulting from an inboard jump of the subduction zone.

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