Upper Hazelton Group stratigraphy along the Stikine arch, northwestern British Columbia

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Abstract

This paper presents new stratigraphic studies of the upper Hazelton Group (late Early to Middle Jurassic) along the Stikine arch, part of the Stikine terrane in northwestern British Columbia. Detailed maps, composite stratigraphic sections, lithological descriptions, contact relationships, and preliminary geochronological data are presented for four areas along the Stikine arch (Stikine batholith, Mount Blair, Spatsizi, and Yehiniko Lake areas), and compared to recent studies in the Dease Lake area.

The upper Hazelton Group unconformably overlies Late Triassic volcano-plutonic centres of the Stuhini arc. The unconformity spans at least 30 m.y. and indicates a prolonged period of uplift and erosion of the Stuhini arc that followed cessation of subduction and termination of arc activity in the latest Triassic. Thick (1-5 km) successions of upper Hazelton Group rocks extend for at least ~275 km along the Stikine arch. We apply uniform stratigraphic nomenclature to these rock units, which include basal sedimentary rocks of the Spatsizi Formation, and overlying volcanic rocks of the Horn Mountain Formation. Volcano-sedimentary units are lithologically similar along the entire length of the belt, and typically include basal granitoid clast-bearing conglomerates, overlain by marine siliciclastic sedimentary rocks that grade upward into subaqueous green mafic fragmental volcanic to reworked volcanic rocks. Thick overlying successions of maroon to grey, mafic to intermediate flows and fragmental volcanic rocks are found in all study areas and indicate the formation of subaerial volcanic centres. Preserved parts of the uppermost succession include subaerial felsic volcanic rocks, locally overlain by mafic volcanic rocks. The thickest successions are in the centre of the belt (>4.8 km), with thinner successions in the west and east (>0.7-1 km). The onset of sedimentary deposition atop the basal unconformity is constrained by late Pliensbachian to early Toarcian fossils, with the start of voluminous volcanism constrained by modern high-precision U-Pb zircon geochronology to ca. 185 Ma (latest Pliensbachian) in the southwest, ca. 175 Ma (latest Toarcian) in the centre, and before ca. 172 Ma (Aalenian) in the east. The general pattern is permissive of an eastward younging trend in the onset of upper Hazelton Group deposition atop the Stuhini arc. Horn Mountain volcanism in the southwest continued until at least the end of the Toarcian, but a lack of modern age dates and faulted or eroded top contacts preclude a confident interpretation. The end of Horn Mountain volcanism in the centre of the belt is well-constrained at ca. 171 Ma (latest Aalenian). Upper Hazelton Group volcanism occurred during accretion of the Quesnel, Cache Creek, and Stikine terranes to Ancestral North America, and was probably generated by re-melting of subduction-modified lithosphere during accretion.

The upper Hazelton Group is overlain by the Bowser Lake Group, where marine siliciclastic sedimentary rocks in the western and central parts of the Stikine arch (early Bajocian and younger) give way eastward to interstratified subaerial mafic volcanic and siliciclastic rocks of the newly defined Mount Blair Formation (ca. 171 Ma and younger). These successions represent the oldest preserved Bowser Lake Group and mark the onset of deposition of erosional products from the Stikinia-Cache Creek tectonic welt.

Keywords: Stratigraphy, upper Hazelton Group, Bowser Lake Group, Spatsizi Formation, Horn Mountain Formation, Mount Blair Formation, Stikine plutonic suite, Stuhini Group, Triassic, Jurassic, Stikinia, Stikine arch, Stuhini arc, Stikine batholith area, Mount Blair area, Spatsizi area, Yehiniko Lake area

1. Introduction

This paper focuses on arc-like volcanic successions in the upper Hazelton Group along the Stikine arch (Stikine terrane), in northwestern British Columbia on the traditional lands of the Tahltan First Nation (Fig. 1). Within Stikine terrane, upper Hazelton Group successions have previously been described as predominantly sedimentary (Gagnon et al., 2012). However, recent studies suggest that significant arc-like volcanic rocks are in the Dease Lake area of the Stikine arch (Fig. 2; van Straaten et al., 2022b, and references therein). Presented herein are stratigraphic studies of the upper Hazelton Group from four additional locations along the Stikine arch (Figs. 1, 2) that were carried out during a total of three weeks of fieldwork between 2016 and 2019. The field studies and preliminary geochronology data show that thick (1-4 km) arc-like volcanic successions extend for at least ~275 km along the Stikine arch. The latest Pliensbachian to Aalenian (ca. 185-171 Ma) mafic to intermediate, and rare felsic volcanic rocks show remarkably similar rock types and facies along the entire Stikine arch. We interpret these successions to have formed during collision of Stikinia and intervening Intermontane terranes with Ancestral North America.

2. Geological setting

The Stikine arch is in the multi-episodic Stikine island arc terrane (Stikinia), in which volcano-sedimentary rocks of the

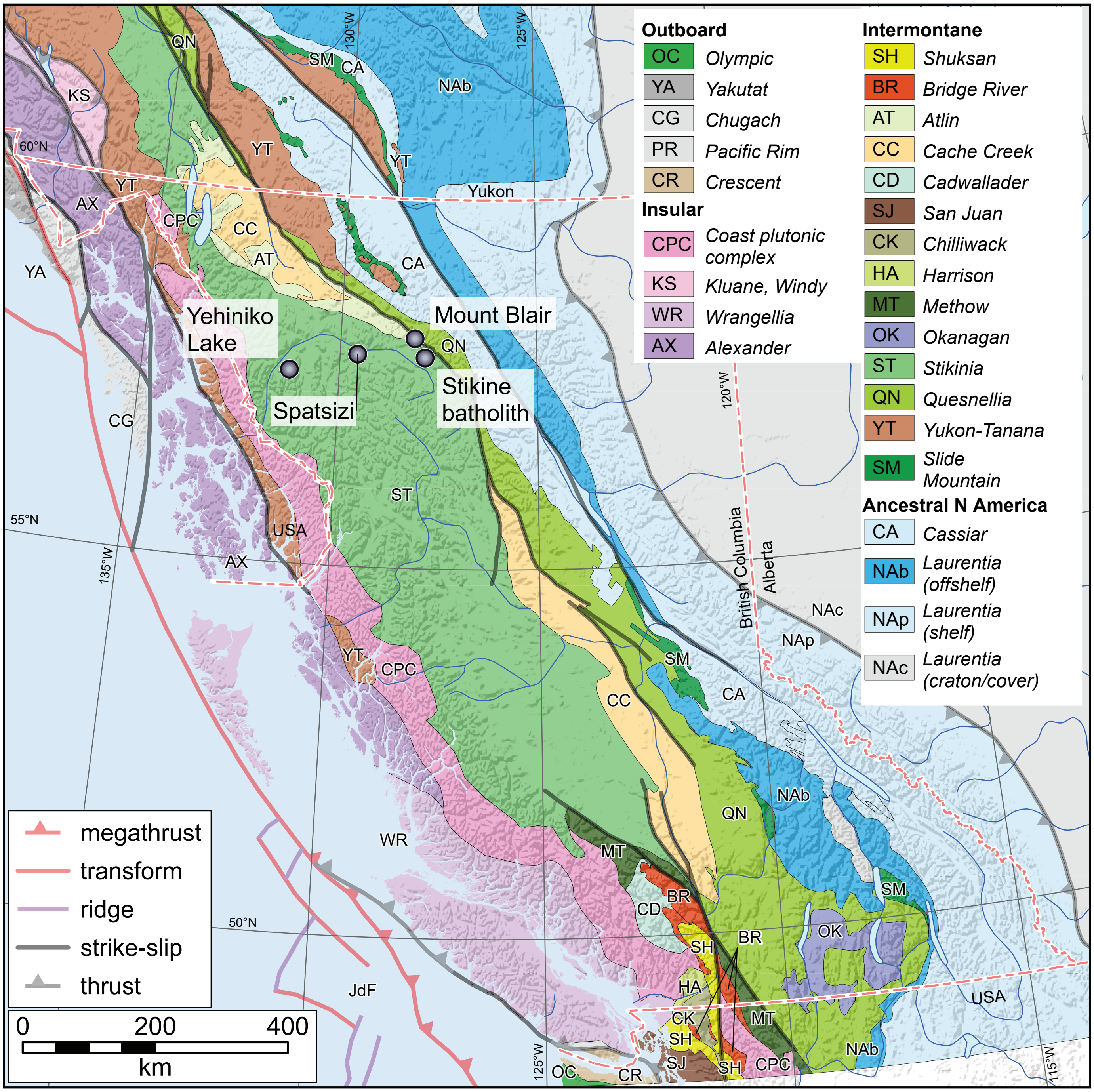


Fig. 1. Location of Stikine batholith, Mount Blair, Dease Lake, Spatsizi, and Yehiniko Lake areas in Stikine terrane. Terranes modified from Colpron (2020).

Stikine assemblage (Devonian to Permian) are overlain by the Stuhini Group (Upper Triassic) and the Hazelton Group (uppermost Triassic to Middle Jurassic). These successions are bounded by regional unconformities that mark significant deformation including: 1) poorly characterized Permo-Triassic deformation that affects Paleozoic rocks (Logan and Koyanagi, 1994); 2) latest Triassic deformation that affects Stuhini Group and older strata throughout northwestern British Columbia, and has been attributed to collision between the Yukon-Tanana and Stikine terranes (Nelson et al., 2022); and 3) a Middle to early Late Jurassic fold-and-thrust belt along the northeastern margin of Stikinia, formed due to accretion of Stikinia and intervening Intermontane terranes to Ancestral North America (Mihalynuk et al., 1994; Nelson et al., 2013; van Straaten et al., 2022b). Accretion of Stikinia to inboard terranes and the Ancestral North American margin is recorded by deposition of Bowser Lake Group siliciclastic rocks (Middle Jurassic to mid-Cretaceous) in a foreland basin atop

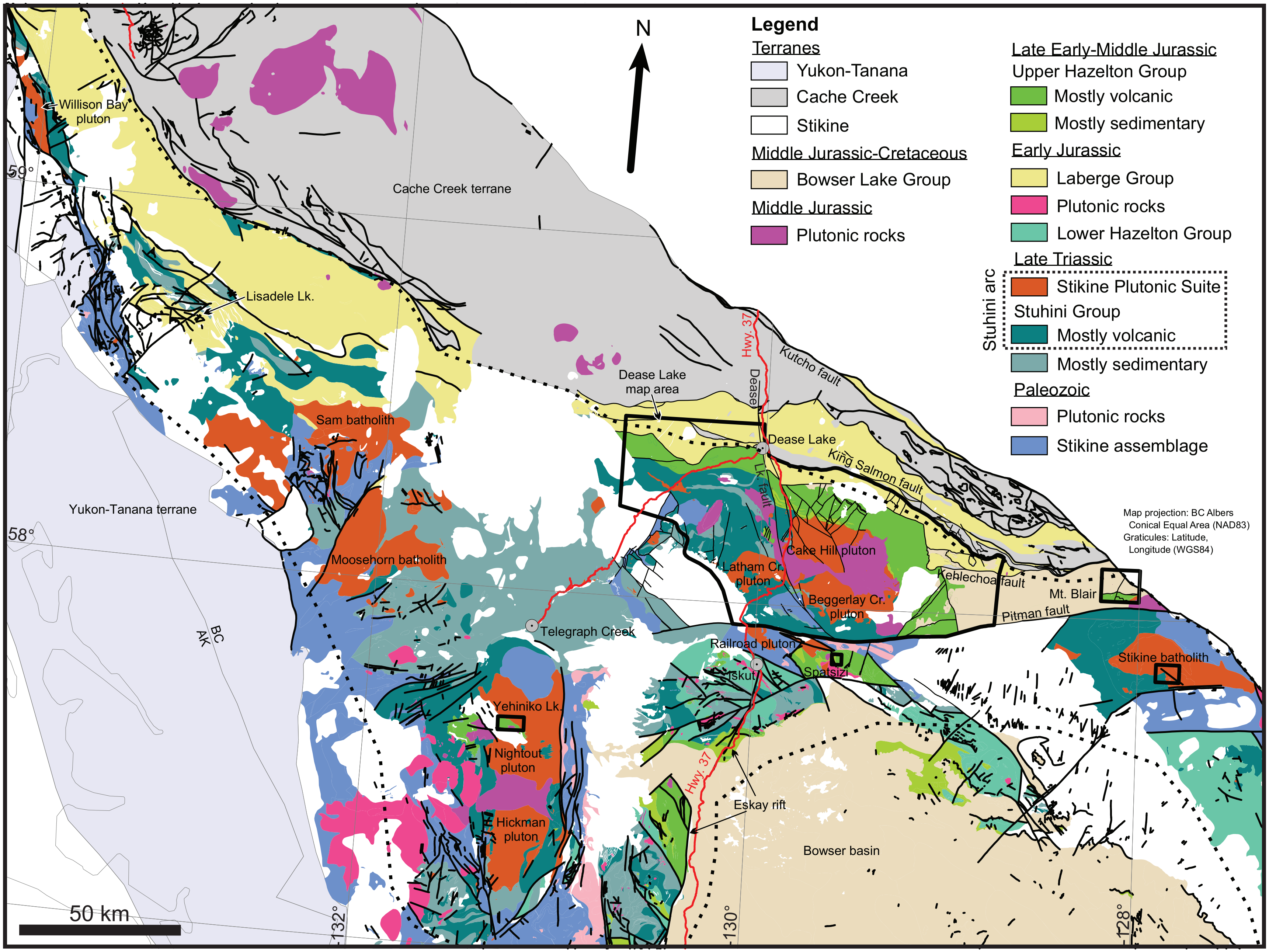


Fig. 2. Geological map of northwestern British Columbia, showing four study areas discussed herein, and outline of Dease Lake area map by van Straaten et al. (2020b). The map shows Paleozoic to Jurassic units of Stikinia, and Whitehorse trough overlap assemblage and post-accretionary plutons (latest Triassic to Middle Jurassic) in Cache Creek terrane. Younger units, and units on other terranes, are omitted. Modified from Cui et al. (2017).

Stikinia (Evenchick et al., 2007). Bowser Lake Group and older rocks are deformed by Cretaceous Skeena fold-and-thrust belt deformation linked to continued convergence between accreted terranes and Ancestral North America (Evenchick et al., 2007). The Stikine arch is a loosely defined area that exposes Triassic and older rocks of Stikinia between the Coast Plutonic complex, Cache Creek terrane, and the northern margin of the contiguous Bowser basin (e.g., Souther, 1971). It is characterized by Stikine plutonic suite intrusions (Late Triassic) and older rocks that were topographically elevated in the Early Jurassic (Gabrielse, 1998).

The main axis of Late Triassic magmatism in Stikinia (hereafter referred to as the Stuhini arc) is defined by thick accumulations of predominantly mafic volcanic strata assigned to the Lewes River Group in Yukon, Stuhini Group in northwestern and central British Columbia, and Takla Group in north-central British Columbia. These strata are accompanied by ca. 229-216 Ma Stikine plutonic suite intrusions. These volcanic and intrusive rocks extend for at least ~1300 km along the eastern margin and northern part of Stikinia and have been interpreted to have formed as an east-facing arc (Nelson and van Straaten, 2020; van Straaten et al., 2023).

Stuhini arc activity terminated in latest Triassic by a collision between northern Stikinia and the Yukon-Tanana terrane. This collision is expressed by: 1) the latest dated Stuhini arc magmatism at ca. 216 Ma (van Straaten et al., 2022b); 2) latest Triassic shortening of the Stuhini Group and older strata throughout northwestern British Columbia (Henderson et al., 1992; Rhys, 1993; Brown et al., 1996; Nelson et al., 2018); 3) a regional-scale unconformity between the Stuhini and Hazelton groups (Nelson et al., 2018; Nelson et al., 2022); 4) a ca. 9-12 m.y. magmatic gap south of the Stikine arch in the Kitsault, Stewart to Iskut corridor (ca. 216 to 207-204 Ma; Hollis and Bailey, 2013; Miller et al., 2023; Campbell, 2021); 5) an at least 30 m.y. magmatic gap along the Stikine arch (ca. 216 to 185-175 Ma; Brown et al., 1996; van Straaten et al., 2022b); 6) crustal thickening and burial of Yukon-Tanana terrane to amphibolite facies in southern Yukon, and coincident ca. 205-194 Ma mid- to lower-crustal magmatism along the Yukon-Tanana-Stikinia suture in southern Yukon (Colpron et al., 2022); and 7) deposition of siliciclastic sedimentary strata of the Laberge Group (Early Jurassic) in the syn-collisional Whitehorse trough (Colpron et al., 2015, 2022; van Drecht et al., 2022).

Within the Kitsault, Stewart to Iskut corridor, the Stuhini Group is overlain by intermediate and rare felsic volcanic rocks of the lower Hazelton Group (Rhaetian to Pliensbachian; Nelson et al., 2018). The Tatogga and Texas Creek plutonic suites (latest Triassic to Early Jurassic) are coeval and comagmatic with the lower Hazelton Group and are responsible for the formation of numerous porphyry Cu-Au and epithermal Au-Ag deposits (Nelson and van Straaten, 2020).

The upper Hazelton Group in the Kitsault, Stewart to Iskut corridor comprises sedimentary rocks of the Spatsizi and Quock formations (Gagnon et al., 2012), local bimodal volcanic and sedimentary rocks of the Iskut River Formation within the Eskay rift (Nelson et al., 2018), and minor volcanic rocks of the Eddontenajon formation (Nelson et al., 2018), Mount Dilworth Formation (Alldrick, 1993), and Kitsault unit (Miller et al., 2023). Recent studies in the Dease Lake area of the Stikine arch have identified thick successions of arc-like volcanic rocks of the Horn Mountain Formation (van Straaten et al., 2022b, and references therein). Similar rocks elsewhere along the Stikine arch are the subject of this study.

3. Field results

Below I describe volcano-sedimentary successions in the upper Hazelton Group from four areas along the Stikine arch: Stikine batholith, Mount Blair, Spatsizi, and Yehiniko Lake (Fig. 2). All areas expose Spatsizi Formation sedimentary rocks and/or Horn Mountain Formation volcanic rocks, both part of the upper Hazelton Group (van Straaten et al., 2022b).

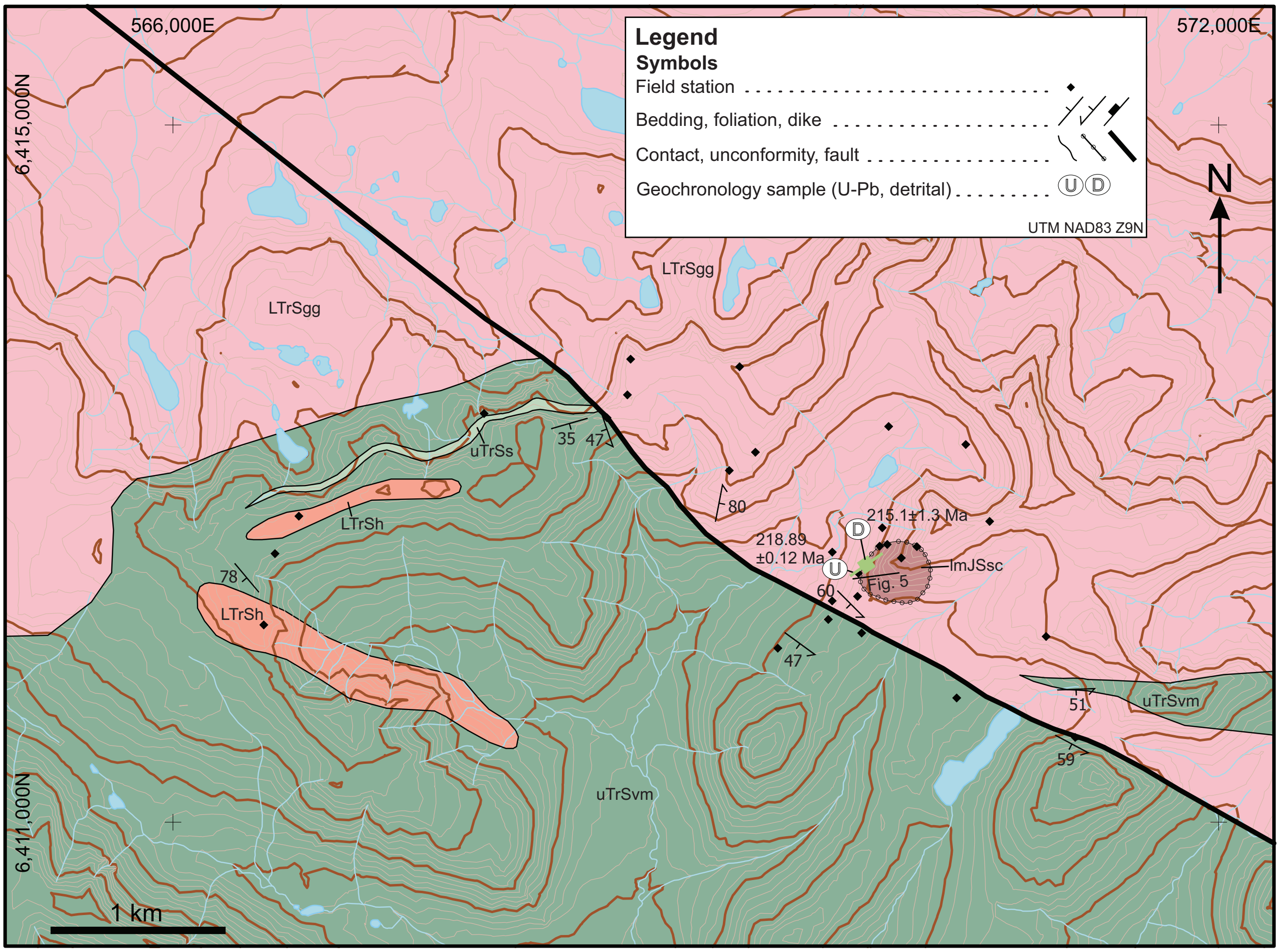
3.1. Stikine batholith area

The Stikine batholith area is approximately 145 km southeast of Dease Lake (Fig. 2). Regional 1:250,000-scale mapping identified an approximately 400 km^2 plutonic body cutting volcanic rocks of the Stuhini Group (Gabrielse et al., 1977; Cui et al., 2017), and a granitoid clast-bearing conglomerate of unknown age that locally rests unconformably above the plutonic rocks (Anderson, 1984). The plutonic body was named the Stikine batholith by Anderson (1984) and interpreted as Late Triassic based on ca. 222-213 K-Ar hornblende cooling ages, ca. 215-204 Ma K-Ar biotite cooling ages (Wanless et al., 1979; Hunt and Roddick, 1987), and lithological similarities to better constrained Late Triassic plutons elsewhere along the Stikine arch (Anderson, 1984).

New mapping in the south-central portion of the Stikine batholith (Fig. 3) indicates that the area is cut by a northwest-trending fault, marked by an at least 200 m-wide foliated zone. Fabrics dip steeply towards the southwest and rarely steeply to the northeast. This fault separates mafic volcanic rocks of the Stuhini Group (Upper Triassic) to the southwest from granitoids of the Stikine batholith (Late Triassic) to the northeast. The circular outlier of conglomerate and sandstone that rests above the Stikine batholith is assigned to the Spatsizi Formation, and mafic dikes that cut the conglomerate are inferred to be related to the Horn Mountain Formation.

3.1.1. Stuhini Group

The southern half of the map area exposes mafic volcanic rocks (unit uTrSvm) and minor intercalated sedimentary rocks (unit uTrSs) of the Stuhini Group (Upper Triassic; Fig. 3). In the west these strata dip moderately to steeply to the south-southeast to southwest. The mafic volcanic rocks are phyllitic adjacent to the northwest-trending fault, locally with the foliation wrapping around volcanic clasts or augite porphyroclasts.



LATE EARLY TO MIDDLE JURASSIC

Upper Hazelton Group

Horn Mountain Formation

EMJhm — **Horn Mountain intrusions: Mafic subvolcanic dikes;** medium green; contain 20% augite (0.1 mm) and 15-20% plagioclase (0.5-2 mm, locally up to 3-4 mm) phenocrysts in a very fine-grained plagioclase lath-rich groundmass (35-60% plagioclase, 0.1 to rarely 0.2-2 mm in size); 0.5-5 metre-wide dikes; interpreted as subvolcanic feeders to the Horn Mountain Formation.

Spatsizi Formation

lmJSsc — **Conglomerate and sandstone;** rare breccia; greenish- to brownish-grey; pebble to boulder, lesser granule conglomerate, clast- to lesser matrix-supported, polymictic to rarely monomictic; coarse- to very coarse-, rare fine- to medium-grained feldspathic arenite; matrix-poor breccia with angular metre-sized monomictic monzogranite clasts; subround to angular clasts (up to 2 m) dominated by monzogranite similar to subjacent pluton, minor green mafic volcanic clasts with 15% plagioclase phenocrysts (0.5-2 mm) and possible mafic minerals (0.1 mm) in a very fine-grained plagioclase-rich groundmass (0.1 mm), rare green phyllitic mafic volcanic clasts, mafic-rich monzodiorite, diorite to quartz diorite clasts, foliated plutonic clasts, and laminated sandstone/mudstone clasts; conglomerate matrix and sandstone contain abundant angular feldspar and quartz grains; locally stratified; resistive; ca. 215 Ma U-Pb detrital zircon maximum depositional age.

— — — — unconformity — — — —

LATE TRIASSIC

Stikine Plutonic Suite

LTrSh — **Hypabyssal intrusions;** plagioclase, locally hornblende, rare quartz, possible clinopyroxene porphyritic; with 40-50% equant plagioclase (3-10 mm); Late Triassic or possibly younger.

LTrSgg — **Monzogranite;** rare quartz monzonite; light pink to light orange; medium grained, K-feldspar and quartz porphyritic to rarely equigranular; hornblende and/or biotite; massive, flow foliated (defined by aligned elongate mafic minerals and quartz) to tectonically foliated (defined by flattened mafic minerals and bands with significantly reduced grain size); resistive; 218.89 ±0.12 Ma U-Pb zircon age.

— — — — intrusive contact — — — —

Stuhini Group

uTrSvm — **Mafic flows and/or subvolcanic intrusions, volcanic breccia, and tuff breccia;** dark green to grey; coherent rocks and clasts contain 10-30% augite (1-3 mm, locally up to 5 mm); locally with well-developed phyllitic foliation; resistive to moderately resistive.

uTrSs — **Mudstone, siltstone, and very fine-grained sandstone;** laminated to thinly bedded; recessive.

Fig. 3. Geological map of the Stikine batholith area, incorporating data from Gabrielse et al. (1977), Anderson (1984), Cui et al. (2017), and this study.

3.1.2. Stikine plutonic suite

The Stikine plutonic suite is represented mainly by granitic rocks of the Stikine batholith (unit LTrSgg), but also includes plagioclase porphyritic hypabyssal intrusions of presumed Late Triassic age (unit LTrSh) that cut mafic volcanic rocks of the Stuhini Group in the western part of the map area (Fig. 3). The Stikine batholith is a porphyritic (rarely equigranular) monzogranite and locally displays a flow foliation. Tectonic foliation adjacent to the northwest-trending fault is defined by flattened quartz and mafic minerals, and local cm-wide planar bands of significantly reduced grain size (Fig. 4); subparallel tectonic fabrics are locally developed elsewhere in the batholith. A sample from a quartz and K-feldspar porphyritic monzogranite returned a CA-TIMS U-Pb zircon age of 218.89 ±0.12 Ma (sample 17BvS-33-320; B. van Straaten and R. Friedman, unpublished data). The Late Triassic plutonic rocks of the Stikine batholith have been described to locally intrude the mafic volcanic rocks of the Stuhini Group (Anderson, 1984).

Fig. 4. Planar tectonic fabric defined by zones of significantly reduced grain size in monzogranite (unit LTrSgg) of the Stikine batholith.

3.1.3. Spatsizi Formation

A circular outlier of conglomerate and sandstone in the centre of the map area (unit lmJSsc, Figs. 3, 5, 6), about 375 m in diameter, is inferred to unconformably overlie the Stikine batholith. The unit is assigned to the Spatsizi Formation. Along the western margin of the outlier, a 2 m covered interval separates monzogranite from conglomerate and sandstone beds (Figs. 5, 7a, b) that dip 77° to 60° to the southeast. In the north, intact granitoid country rock transitions to highly fractured granitoid and then into polymictic cobble-boulder conglomerate. The sedimentary rocks are interpreted to post-date the granitoid, based on the presence of predominantly monzogranite clasts similar to the adjacent granitoid and a lack of evidence for a faulted or intrusive contact. The conglomerate contains subordinate angular to subangular, green mafic volcanic clasts, locally with lobate margins (Fig. 7c), suggesting

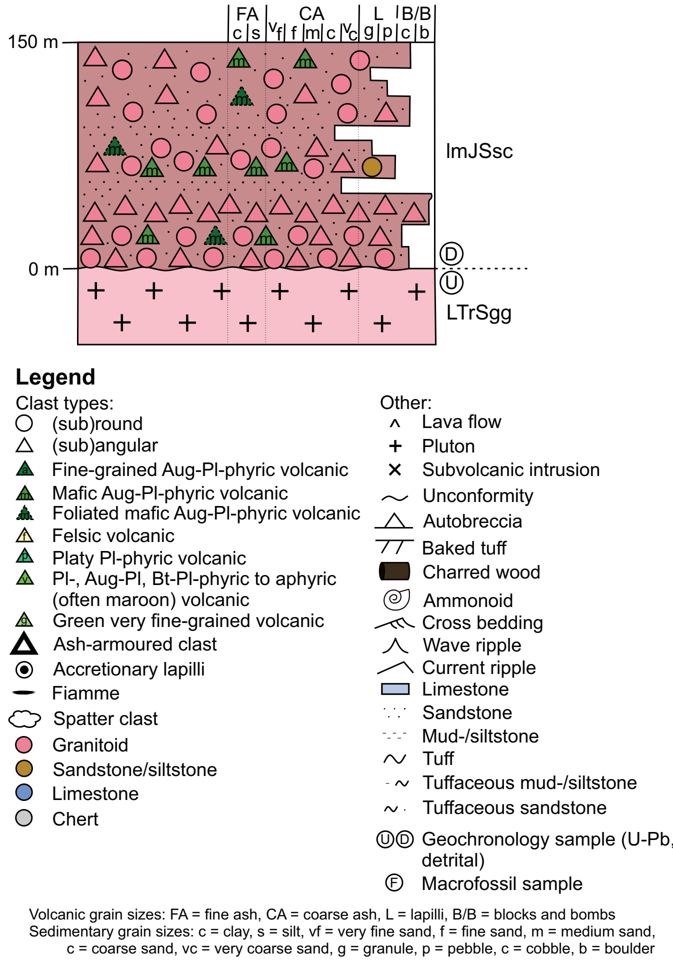


Fig. 5. Schematic stratigraphic section for the Stikine batholith area. See Figure 3 for location of stratigraphic section.

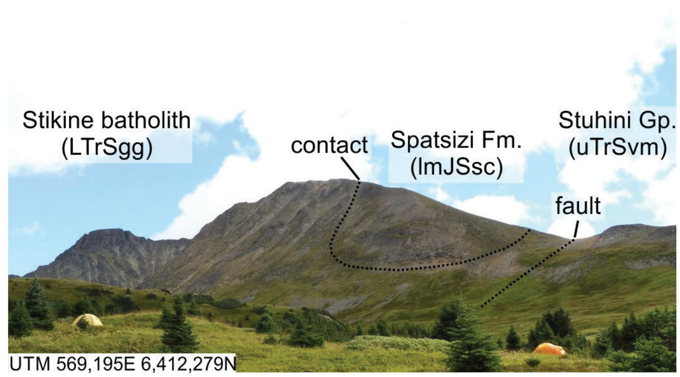


Fig. 6. Panoramic view of the Spatsizi Formation conglomerate and sandstone unit (lmJSsc) unconformably atop of monzogranite of the Stikine batholith (LTrSgg), faulted against Stuhini Group mafic volcanic rocks (unit uTrSvm). View towards the northeast. Stikine batholith area.

coeval volcanic activity. However, one 1.5 m angular clast is a plutonic rock cut by a green mafic dike, suggesting that at least some of the mafic clasts may have been derived from erosion of mafic dikes. Clasts appear largely locally derived, and the presence of minor phyllitic mafic volcanic and foliated

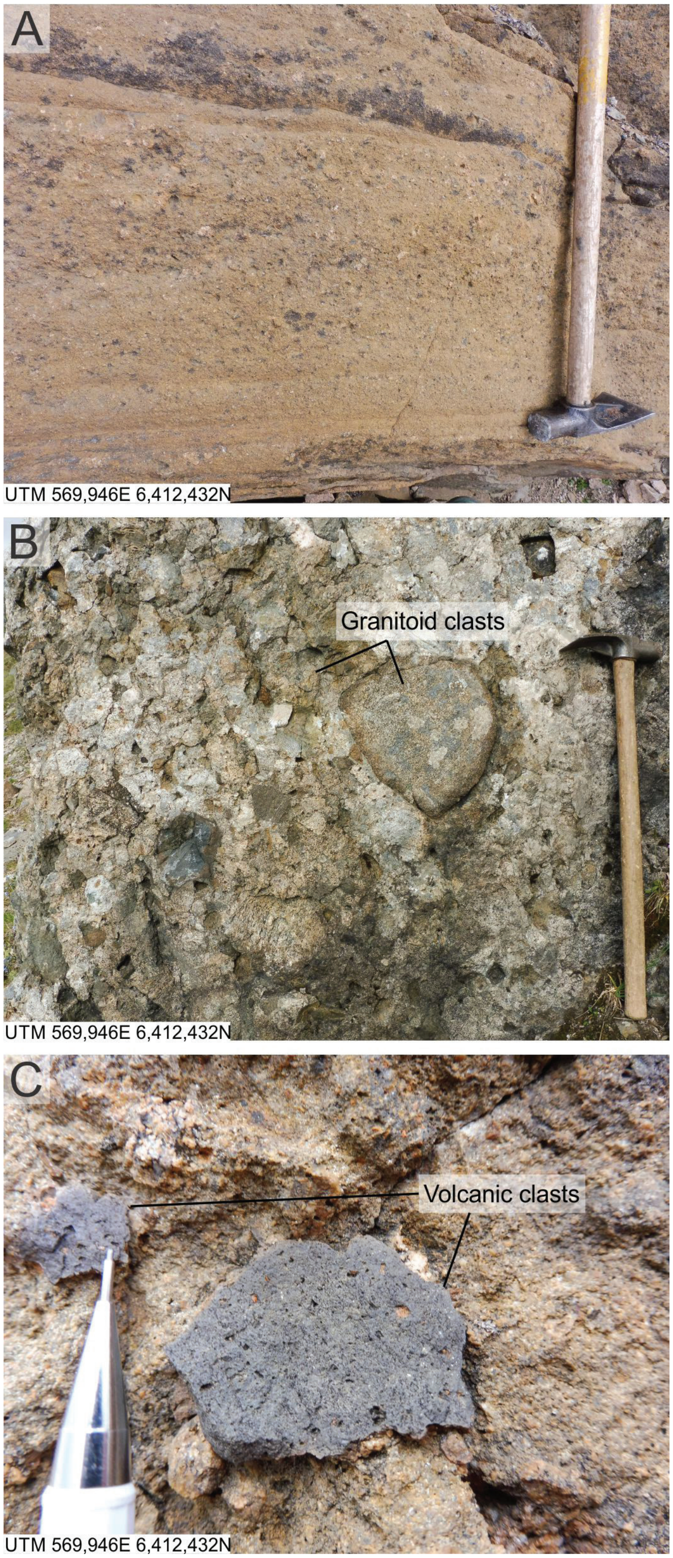


Fig. 7. Spatsizi Formation conglomerate and sandstone unit (lmJSsc). **a)** Stratified pebbly sandstone. **b)** Conglomerate with predominantly granitoid clasts. **c)** Mafic volcanic clasts with lobate margins in conglomerate. Stikine batholith area.

plutonic clasts suggests deformation pre-dates deposition of the conglomerate. A sandstone sample returned a ca. 215 Ma LA-ICP-MS U-Pb detrital zircon maximum depositional age (Fig. 3; sample 17BvS-33-317c; B. van Straaten and R. Friedman, unpublished data). Correlation with the Spatsizi Formation (Lower to Middle Jurassic, upper Hazelton Group) is based on a strong similarity to basal Spatsizi Formation granitoid clast-bearing conglomerate unconformably atop the Stikine plutonic suite in the Dease Lake map area (see van Straaten et al., 2022b).

3.1.4. Horn Mountain Formation dikes

Green augite-plagioclase-phyric mafic dikes (unit EMJhm, Fig. 3) locally cut the Spatsizi Formation. Potentially similar clinopyroxene-hornblende porphyry dikes crosscut the Stikine batholith (Anderson, 1984). Petrographic studies and lithogeochemical data show that they are similar to mafic subvolcanic feeders to the upper Hazelton Group in the Dease Lake map area (van Straaten et al., 2022a, b). The dikes are therefore inferred to be mafic subvolcanic intrusions related to the Horn Mountain Formation. Mafic dike clasts and mafic volcanic clasts in the Spatsizi Formation conglomerate (see above) are lithologically and geochemically similar to the mafic dikes and suggest that upper Hazelton Group mafic volcanism occurred before, during and after deposition of the conglomerate.

3.2. Mount Blair area

The Mount Blair area is 120 km east-southeast of Dease Lake, north of the Pitman fault and west of the terrane-bounding Kutcho fault (Fig. 2). The region was previously mapped at 1:250,000 scale by Gabrielse (1998; 2003), who distinguished a volcanic unit and a sedimentary unit both assigned to the Bowser Lake Group. A compositionally variable intrusive body in the southeastern part of the map area (Fig. 8) was previously mapped as syenite, monzonite, diorite, quartz monzonite, and granodiorite (Erdman, 1978; Gabrielse, 1998; Gabrielse, 2003). The intrusion was considered Middle to Late Jurassic based on a 162 ±12 Ma K-Ar hornblende cooling age from a biotite-bearing hornblende diorite (Erdman, 1978; recalculated using IUGS decay constants by Breitsprecher and Mortensen, 2004).

Based on the current work and following nomenclature in van Straaten et al. (2022b), the volcano-sedimentary rocks in the southern part of the area are reassigned to the Spatsizi Formation and Horn Mountain Formation of the upper Hazelton Group (Lower to Middle Jurassic), and volcano-sedimentary rocks in the northern part of the map are assigned to the Mount Blair Formation (new formation, see below) of the Bowser Lake Group (Middle to Upper Jurassic). The northeastern granodioritic portion of the compositionally variable intrusive body is here interpreted as part of the Stikine plutonic suite (Late Triassic), the central part as intermediate subvolcanic intrusions that fed Horn Mountain Formation volcanic rocks (Early to Middle Jurassic) and the southeastern part as a younger dioritic pluton (Middle to Late Jurassic).

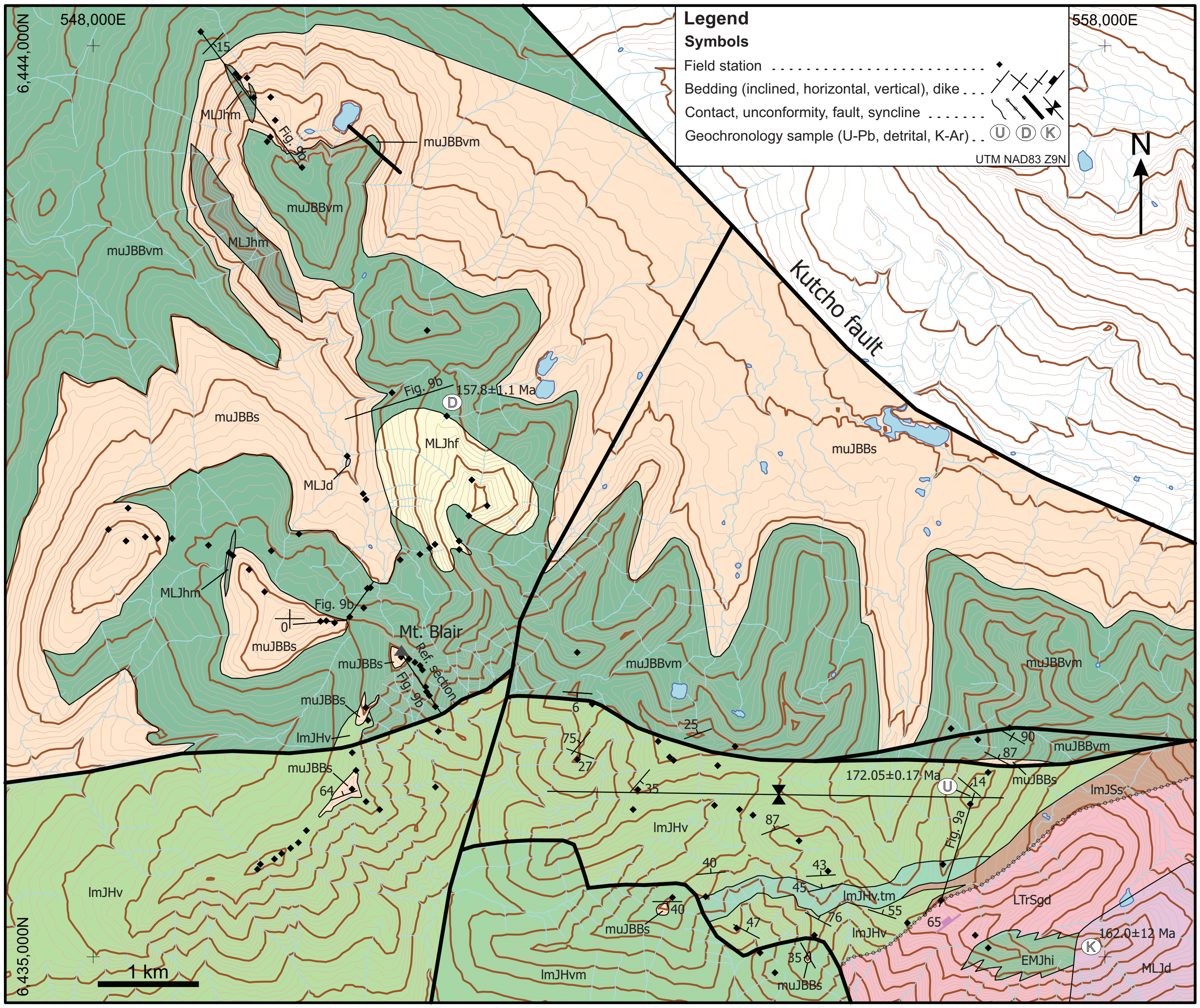


Fig. 8. Geological map of the Mount Blair area, incorporating data from Erdman (1978), Gabrielse (1998; 2003), Cui et al. (2017), and this study.

The revised geological map of the Mount Blair area (Fig. 8) shows the area is transected by several faults. The southern part of the map area exposes a subvertical west-striking fault that separates subhorizontal volcano-sedimentary rocks of the Bowser Lake Group (north) from sedimentary and volcanic rocks of the upper Hazelton Group (south). In the central part of the map area, this fault has a minor apparent dextral offset across a northerly-trending fault and continues east where it is inferred to bifurcate and enclose a lens of unusually steeply dipping Bowser Lake Group strata. The west-striking fault may represent a north-side-down normal fault, based on the steep to subvertical attitude and younger rocks on its northern side. It is similar in orientation and inferred kinematics to a west-southwest-trending normal fault in the southeastern portion of the Dease Lake map area (van Straaten et al., 2022b). In the southeast part of the map area is an inferred fault with a moderate south-southwest dip. Hanging wall strata dip to the southwest and comprise mafic volcanic rocks of the Horn Mountain Formation (unit lmJHvm; see below) that are locally capped by sedimentary rocks of the Bowser Lake Group (Fig. 8). Footwall mafic to intermediate volcanic strata of the Horn Mountain Formation (unit lmJHv) are folded in a km-scale open syncline. Bedding attitudes in the southwestern fault block are subhorizontal in the north to unknown in the south.

3.2.1. Stikine plutonic suite

A biotite-bearing granodiorite pluton is exposed in the southeastern part of the Mount Blair area (unit LTrSgd, Fig. 8). It was previously interpreted as part of a compositionally variable Middle to Late Jurassic intrusive body, but is reassigned here to the Stikine plutonic suite (Late Triassic) based on unconformable relationships with overlying upper

MIDDLE TO LATE JURASSIC

MLJd — **Diorite,** rare quartz monzodiorite and quartz monzonite; medium grained; biotite and/or hornblende; resistive; 162 ±12 Ma K-Ar hornblende cooling age.

— — — — intrusive contact — — — —

Bowser Lake Group

Mount Blair Formation

MLJhf — **Felsic subvolcanic intrusions;** yellow to orangey; aphanitic to plagioclase-phyric; often flow banded; rare marginal autobreccia; moderately resistant; interpreted as subvolcanic feeders to the Mount Blair Formation.

MLJhm — **Mafic subvolcanic dikes;** intrusions contain 20-25% augite (0.2-2 mm) and 40-55% plagioclase (0.05-4 mm) phenocrysts; resistant; interpreted as subvolcanic feeders to the Mount Blair Formation.

muJBBs — **Siltstone, sandstone, and conglomerate;** grey, yellowish grey, maroon, sea green; common very fine- to fine-grained sandstone, rare medium- to very coarse-grained sandstone with common black lustrous organic material; pebble to granule conglomerate contains chert and rare limestone clasts; very rare, laminated limestone bed near base; resistant knobbly-weathering conglomerate beds form distinct bands in hillside; largely subaerial depositional environment.

muJBBvm — **Mafic flows and lapillistone;** lesser mafic lapilli-tuff, tuff, tuff breccia and siltstone; rare reworked volcanic rocks; very rare limestone; orangey to medium grey, green, maroon; flows and clasts contain 15-25% augite (0.1-1 mm) and 15-55% plagioclase (0.1-0.2, rarely up to 1.5 mm) phenocrysts, and up to 5% amygdules (0.1-2 cm); locally minor felsic volcanic clasts; rare chert clasts; well-stratified; 5-40 m thick bedding parallel coherent intervals interpreted as flows based on common autobrecciated lower (rarely, upper) contact, and rare underlying brick red baked tuff; resistant flows form distinct bands in hillside; ca. 158 Ma U-Pb detrital zircon maximum depositional age; largely subaerial depositional environment.

LATE EARLY TO MIDDLE JURASSIC

Upper Hazelton Group

Horn Mountain Formation

EMJhi — **Horn Mountain intrusions: Intermediate subvolcanic intrusions;** contain 20% plagioclase (1-4 mm) phenocrysts in an often pink-coloured aphanitic groundmass; resistive; interpreted as subvolcanic feeders to the Horn Mountain Formation.

lmJHvm — **Glacial Mountain unit: Lapilli-tuff;** medium to light grey; contains predominantly medium-grey clasts with 25-30% plagioclase (1-5 mm) and 10% augite (0.5-1 mm) phenocrysts, subordinate lighter grey clasts with finer-grained plagioclase and augite phenocrysts, and pink fine-grained to aphanitic clasts; set in a matrix with abundant plagioclase crystals, lesser augite crystals, and fine ash; massive; resistive.

lmJHv.tm — **Cariboo unit: Intermediate coherent flows and/or subvolcanic intrusions, tuff breccia,** rare crystal tuff and sandstone; coherent rocks and clasts contain 35% platy plagioclase (0.5-1.5 cm) phenocrysts; massive; resistive.

lmJHv — **Sister Mary unit: Mafic to intermediate lapilli-tuff, crystal tuff, tuff and lapillistone;** lesser coherent flows and/or subvolcanic intrusions; rare felsic lapilli-tuff; very rare limestone; maroon, greenish grey, brick red; volcanic clasts are plagioclase-phyric, biotite-plagioclase-phyric, augite-plagioclase-phyric to aphyric; subordinate pink biotite-bearing possible (quartz) monzonite clasts, rare limestone clasts; coherent rocks are augite-plagioclase-phyric or biotite-plagioclase-phyric; unit includes subordinate fine-grained augite-plagioclase-phyric volcanic rocks (resembling unit muJBBvm); felsic lapilli-tuff contains plagioclase-phyric to aphyric volcanic clasts, and is locally welded; crudely stratified; resistive to moderately resistive; felsic volcanic rocks returned 172.05 ±0.17 Ma U-Pb zircon age; predominantly subaerial depositional environment.

Spatsizi Formation

lmJSs — **Sandstone and basal conglomerate;** dark brown to grey; basal pebble to cobble conglomerate with subround to subangular granitoid clasts set in a matrix with granule- to sand-sized granitoid-derived grains; conglomerate unconformably overlies granodiorite pluton; very fine- to fine-grained sandstone; stratified; recessive and poorly exposed.

— — — — unconformity — — — —

LATE TRIASSIC

Stikine Plutonic Suite

LTrSgd — **Granodiorite,** rare quartz monzodiorite and quartz monzonite; medium grained, equigranular; biotite-bearing; moderately resistive.

Fig. 8. Continued. Legend.

Hazelton Group strata (Lower to Middle Jurassic) and lithological similarity to hornblende and/or biotite granodiorite and monzogranite of the Stikine plutonic suite elsewhere along the Stikine arch (e.g., Stikine batholith, unit LTrSgg, see Section 3.1.2.; Cake Hill pluton, unit LTrSgg, van Straaten et al., 2022b; Nightout pluton, unit LTrSgd, see Section 3.4.1.; Hickman pluton, Brown et al., 1996).

3.2.2. Spatsizi Formation

A sedimentary unit assigned to the Spatsizi Formation (Early to Middle Jurassic, unit lmJSs) unconformably overlies granodiorite of the Stikine plutonic suite in the southeast part of the map area (Figs. 8, 9a). The unconformity is exposed at 556,379E-6,435,556N (UTM NAD83 zone 9 north). As the contact is approached, the plutonic rocks become increasingly more weathered and recessive. At the contact, the pluton is overlain by a thin (<5 m) conglomerate unit with granitoid clasts (Fig. 10), which grades up into recessive and poorly exposed sandstone. The section above the unconformity includes a 55 m-thick interval of fragmental volcanic rocks that we assign to the Horn Mountain Formation (Fig. 9a; unit lmJHv, see below), reflecting interfingering relationships between the two units.

3.2.3. Horn Mountain Formation

The upper Hazelton Group in the southern part of the Mount Blair area is represented mainly by volcanic rocks of the Horn Mountain Formation. Most rocks of the formation are assigned

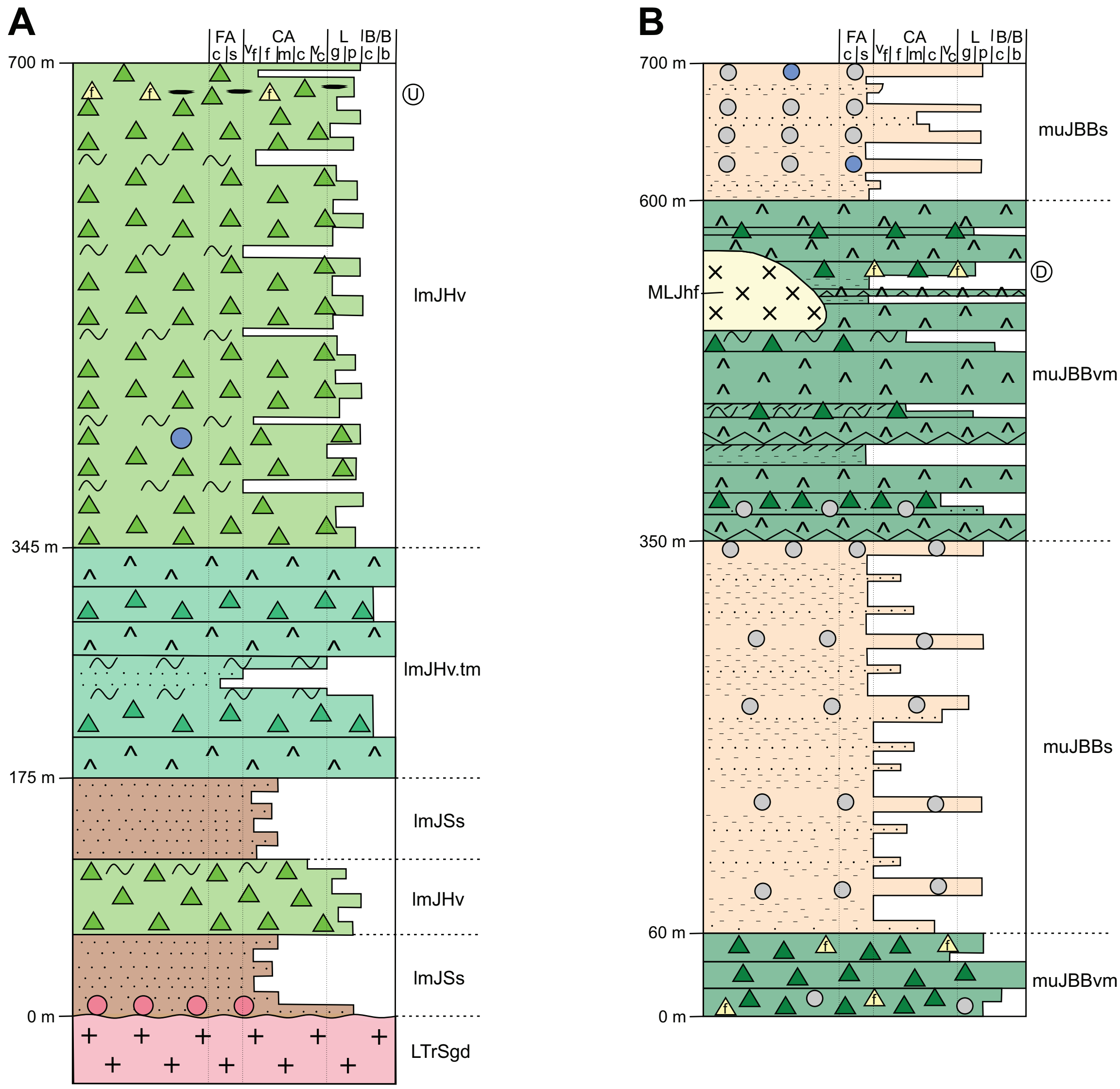


Fig. 9. Schematic stratigraphic sections for the Mount Blair area. **a)** Upper Hazelton Group. **b)** Bowser Lake Group composite stratigraphy based on sections exposed at four sites. See Figure 5 for legend, and Figure 8 for location of sections.

to unit lmJHv, which is well-represented by a section more than 350 m thick that unconformably overlies the granodiorite pluton (unit LTrSgd), and gradationally overlies and interfingers with sedimentary rocks of the Spatsizi Formation (see above). The unit comprises mafic to intermediate and rare felsic fragmental volcanic rocks (Fig. 11); subordinate mafic to intermediate coherent rocks may represent subvolcanic intrusions or flows. Volcanic clasts and coherent rocks are plagioclase-phyric, biotite-plagioclase-phyric, augite-plagioclase-phyric, and aphyric, with phenocryst-bearing clasts and units typically containing 0.5-5 mm plagioclase crystals. The upper portion of the succession (above unit lmJHv.tm, see below) is interpreted as largely primary volcaniclastic and subaerial based on the presence of welding textures (fiamme) observed at two locations, and the absence of substantially reworked volcanic rocks. The presence of limestone in one location may suggest local subaqueous deposition in a standing body of water. A sample from a felsic lapilli tuff returned a 172.05 ±0.17 Ma CA-TIMS U-Pb zircon age (Fig. 8; sample 19BvS-3-21, B. van Straaten and R. Friedman, unpublished data). Based on lithological, textural, mineralogical and compositional similarities we correlate unit lmJHv with the Sister Mary unit of the Horn Mountain Formation in the Dease Lake map area (van Straaten et al., 2022b) although, in the Mount Blair area, biotite phenocrysts are more common, the proportion of fragmental volcanic rocks is greater, and lava flows appear less numerous. Fine-grained coherent and very rare fragmental mafic volcanic rocks, texturally resembling mafic volcanic rocks in the Bowser Lake Group (unit muJBBvm, see below), occur locally within the Sister Mary unit. These rocks might be subvolcanic sills or intrusions related to the overlying Mount Blair Formation volcanic rocks (unit MLJhm, see below), represent unusual Horn Mountain Formation volcanic rocks, or perhaps reflect that the two units are partly coeval.

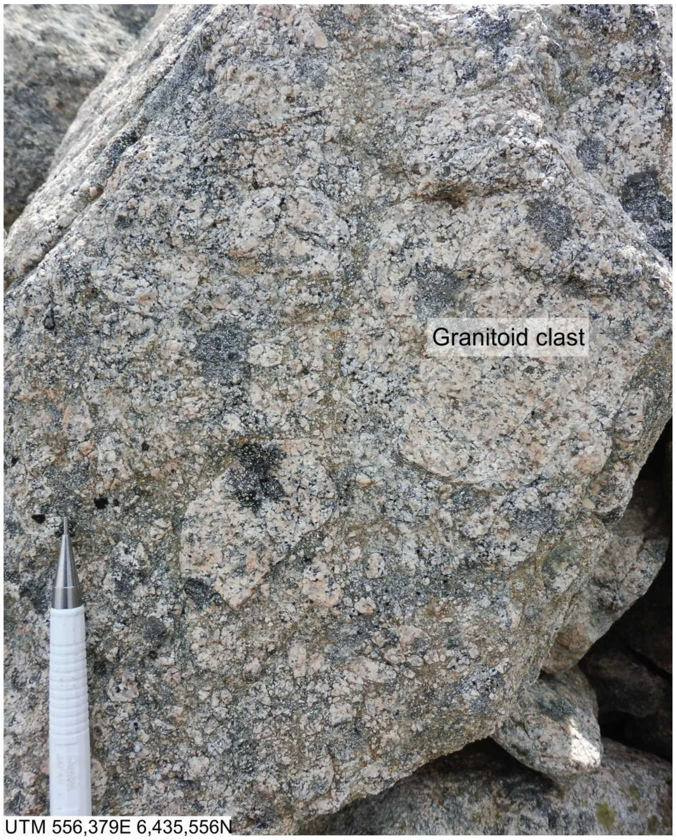


Fig. 10. Basal granitoid clast-bearing conglomerate of the Spatsizi Formation (unit lmJSs) unconformably above granodiorite (LTrSgd). Mount Blair area.

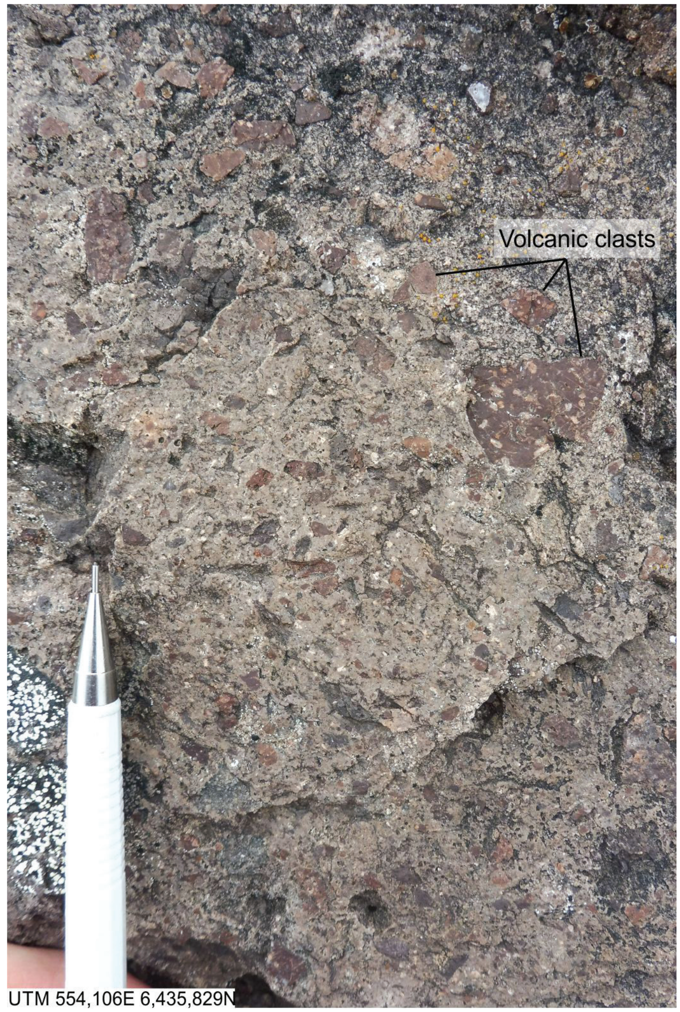


Fig. 11. Horn Mountain Formation, Sister Mary mafic to intermediate volcanic unit (lmJHv). Lapilli-tuff with pinkish maroon to grey plagioclase-phyric volcanic clasts. Mount Blair area.

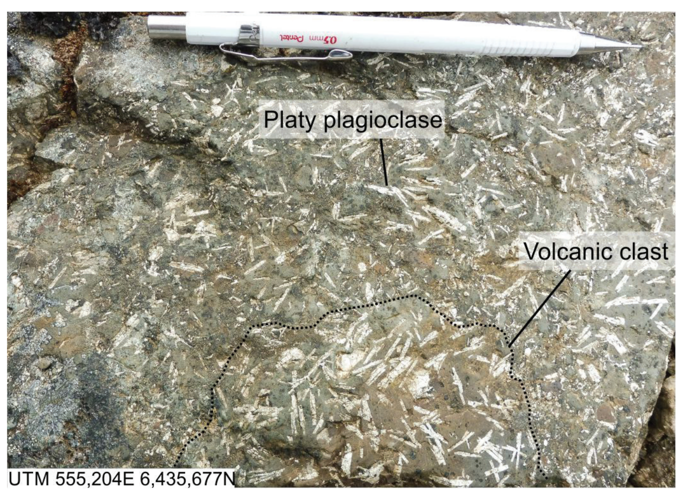


Fig. 12. Horn Mountain Formation, Cariboo intermediate volcanic unit (lmJHv.tm). Tuff breccia with platy plagioclase-phyric volcanic clasts. Mount Blair area.

In the southeastern part of the map area, an approximately 170 m-thick volcanic unit with distinct cm-sized platy plagioclase phenocrysts (unit lmJHv.tm) is near the base of the Sister Mary unit (Figs. 8, 9a, 12). It is correlated with the Cariboo unit of the Horn Mountain Formation in the Dease Lake map area (van Straaten et al., 2022b).

The south-southwest-dipping fault panel in the south-central part of the map area contains grey weathering mafic lapilli-tuff with abundant plagioclase and lesser augite crystals (unit lmJHvm; Figs. 8, 13). These rocks are correlated with the Glacial Mountain unit of the Horn Mountain Formation in the Dease Lake map area (van Straaten et al., 2022b).

A plagioclase-phyric subvolcanic intrusion (unit EMJhi), commonly with a pinkish groundmass, and locally epidote-chlorite-sericite or silica altered, is inferred to cut granodiorite of the Stikine plutonic suite in the southeastern part of the map area. These rocks are lithologically similar to those of the Sister Mary unit, and likely represent subvolcanic feeders to the Horn Mountain Formation. We postulate that these rocks are similar to syenite, monzonite and feldspar porphyritic rocks described by Erdman (1978) and Gabrielse (1998; 2003).

3.2.4. Mount Blair Formation (new formal unit)

The rocks on the north side of the prominent west-striking fault, making up the northern two-thirds of the map

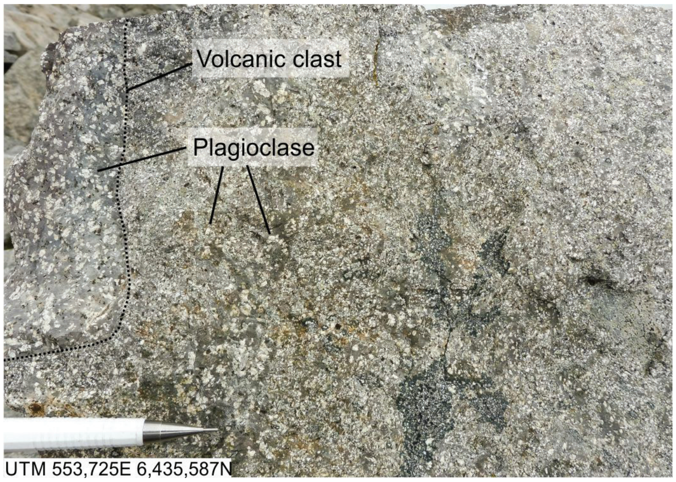


Fig. 13. Horn Mountain Formation, Glacial Mountain mafic volcanic unit (lmJHvm). Lapilli-tuff with abundant plagioclase crystals. Mount Blair area.

area (Fig. 8), comprise an at least 700 m-thick predominantly flat-lying succession of sedimentary rocks (unit muJBBs) and mafic volcanic rocks (unit muJBBvm) of the Bowser Lake Group. These rocks are defined herein as a new formation (Mount Blair Formation; Table 1), and correlate to rocks mapped as the informal 'Mount Blair unit' in the Dease Lake map area (van Straaten et al., 2022b). The formation comprises a mafic volcanic succession exposed near the lowest elevations of the map area, an overlying sedimentary succession that is succeeded by a second mafic volcanic succession, and an upper sedimentary succession exposed at the top of the highest ridges (Figs. 8, 9b, 14). Contacts between these alternating mafic volcanic and sedimentary successions are conformable.

The sedimentary unit (muJBBs) of the Mount Blair Formation comprises maroon to sea green siltstone, yellowish grey very fine- to fine-grained sandstone, and grey chert clast-bearing conglomerate (Fig. 9b). A largely subaerial setting is suggested by their intercalation with subaerial mafic volcanic rocks.

Table 1. Definition of the Mount Blair Formation. Coordinates in UTM NAD83 Zone 9 north.

Mount Blair Formation	
Category, rank	Lithostratigraphic unit with the rank of formation. Part of the Bowser Lake Group.
Name	Named for Mount Blair, a prominent peak at the top of a reference section.
Description of unit	Interbedded siltstone, sandstone, conglomerate, mafic flows, mafic fragmental volcanic rocks, rare felsic fragmental volcanic rocks (van Straaten and Bichlmaier, 2018; van Straaten et al., 2022b; this study). Siltstone is generally maroon to sea green. Conglomerate contains predominantly chert and lesser limestone granules to pebbles, and local cobbles. Mafic flows and volcanic clasts contain 10-25% augite (0.1-1 mm) and 15-55% plagioclase (0.1-0.2 mm) phenocrysts. Flows are 5-40 m thick, commonly have autobrecciated contacts, and are locally underlain by brick red baked tuff. Rare basal laminated limestone bed (<0.5 m thick). The presence of flows and common black organic material suggest a subaerial depositional environment. The succession is cut by mafic and felsic dikes and intrusions. The intrusions are likely coeval with the volcanic rocks based on similar texture and mineralogy. In regional studies, these intrusions could be included in the formation. The non-marine succession is lithologically distinct from mainly marine units in the Bowser Lake Group to the south (Evenchick and Thorkelson, 2005).
Geometry, thickness	The unit extends for at least ~70 km in a west to east trending belt between the McBride River, Pitman fault, Kutcho fault, and the King Salmon fault or Kehlechoa fault. The unit is at least 430 m thick east of the McBride River, and at least 700 m thick in the Mount Blair area (Fig. 9b).
Lower contact	Conformable and gradational contact above volcanic rocks of the Horn Mountain Formation (upper Hazelton Group). Lower boundary defined where sedimentary rocks are more abundant (>50%) than volcanic strata (type section: UTM 499,528 E-6,433,031N). The base of the reference section is a fault (UTM 551,426E-6,437,390N).
Upper contact	The top contact is not exposed. The top of the type section is at UTM 499,646E-6,432,733N. The top of the reference section is at the summit of Mount Blair (UTM 551,038E-6,437,997N).
Age	Middle Jurassic (Bajocian) to Upper Jurassic (Oxfordian), possibly younger. A high-precision CA-TIMS U-Pb zircon crystallization age on immediately underlying Horn Mountain Formation felsic volcanic rocks east of the McBride River constrains the onset of Bowser Lake Group sedimentation to 170.99 ±0.13 Ma (van Straaten et al., 2022b), and shows that these units are the oldest known Bowser Lake Group strata in Stikinia.

Coordinates are in UTM NAD 83 zone 9 north.

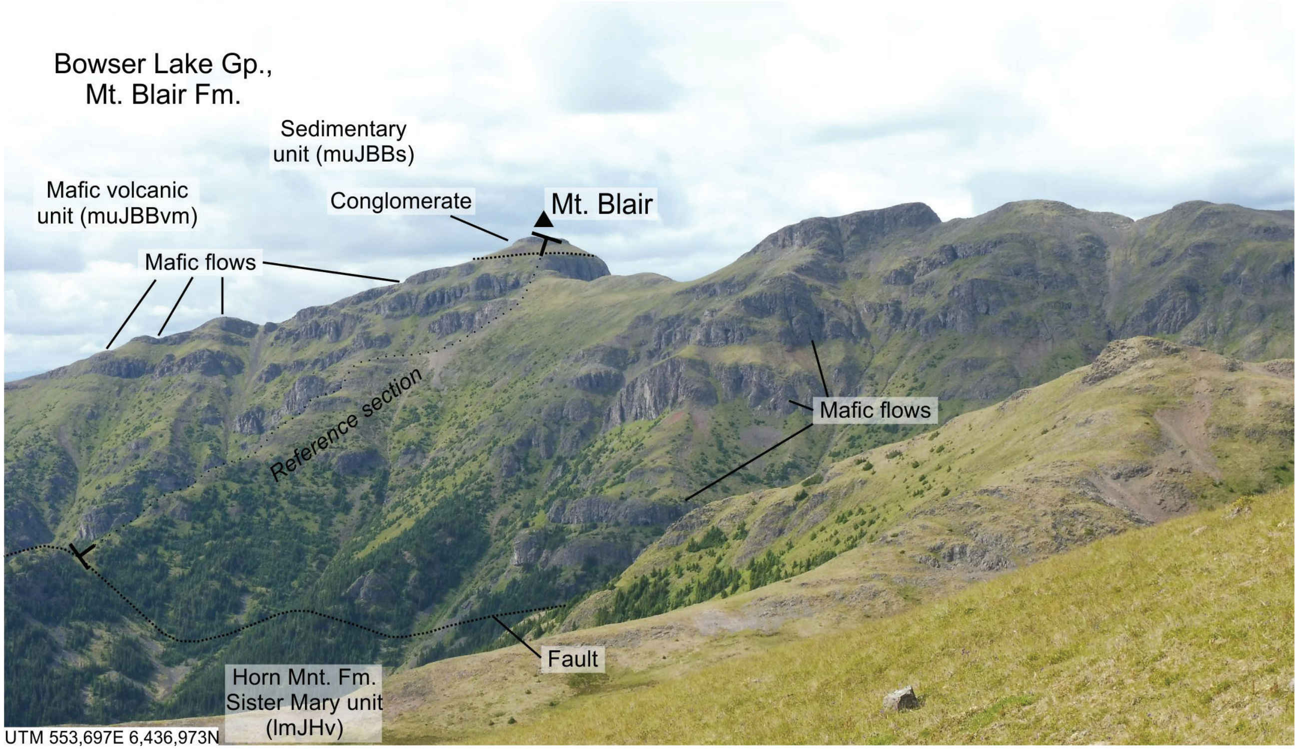


Fig. 14. Reference section, Mount Blair Formation (new unit), Bowser Lake Group. Resistant mafic flows and interbedded recessive fragmental volcanic rocks and siltstones (muJBBvm) overlain at the top of Mount Blair by recessive siltstone, sandstone, and resistant conglomerate (muJBBs). In the foreground a west-trending fault separates the Mount Blair Formation from volcanic rocks of the Horn Mountain Formation (unit lmJHv). View towards the northwest.

Lithologically similar sedimentary rocks of the Mount Blair Formation are in the Dease Lake map area, where intercalated mafic flows and adhesion warts provide evidence for a subaerial setting (van Straaten and Bichlmaier, 2018; van Straaten et al., 2022b). An outlier of the sedimentary unit in the southwestern part of the area gradationally overlies volcanic rocks of the Sister Mary unit (lmJHv). Here, a laminated limestone bed near the base of the unit likely represents short-lived subaqueous deposition following Horn Mountain volcanism, analogous to limestone observed at the same stratigraphic level in the Dease Lake map area (van Straaten and Bichlmaier, 2018). Small outliers of sedimentary rocks also occur in the southeast, at approximately 1700-1800 metres elevation, where the unit gradationally overlies volcanic rocks of the Glacial Mountain unit (lmJHvm).

The mafic volcanic unit of the Mount Blair Formation (muJBBvm) comprises interbedded mafic flows, mafic fragmental volcanic rocks, and siltstone. Flows commonly display autobrecciated margins and are locally underlain by brick red baked tuff (Fig. 15a). Mafic flows contain fine-grained augite and plagioclase phenocrysts (<1-1.5 mm; Fig. 15b), distinctly finer grained than volcanic rocks in the Horn Mountain Formation. Lapillistone is commonly well-sorted, clast-supported, and ash-poor, suggesting a probable origin as air fall deposits (Fig. 15c). A mafic lapillistone with subordinate felsic volcanic clasts yielded a 157.77 ±1.1 Ma LA-ICP-MS U-Pb detrital zircon maximum depositional age (Figs. 8, 9c; sample 18BvS-31-307, B. van Straaten and R. Friedman, unpublished data). The presence of mafic flows with autobrecciated margins, baked tuff, and air fall deposits suggests a predominantly subaerial setting.

In the eastern part of the map area, a fault block bounded by splays of the prominent west-trending fault contains steeply dipping sedimentary rocks overlain by mafic volcanic rocks of the Mount Blair Formation. The volcanic succession contains rare limestone beds, and a lapilli-tuff interbed similar to those within the Horn Mountain Formation (unit lmJHv). The presence of limestone (locally common near the base of the Mount Blair Formation) and volcanic rocks similar to those in the Horn Mountain Formation may suggest that the fault block represents part of a gradational contact between the Horn Mountain and Mount Blair formations. In the west-central part of the map area, immediately north of the major west-trending fault, volcanic rocks of the Horn Mountain Formation (unit lmJHv) appear to interfinger with Mount Blair Formation volcano-sedimentary rocks (Fig. 8).

Mafic subvolcanic dikes (unit MLJhm) are present throughout the area (Fig. 8). They are 3-300 metres wide and cut Mount Blair sedimentary and volcanic units. Some dikes are texturally similar to mafic flows within the Mount Blair Formation, others contain coarser grained (0.5-4 mm) augite and plagioclase phenocrysts.

A 1.5 km by 1.5 km body of felsic coherent rock (unit MLJhf) occurs within the mafic volcanic unit of the Mount

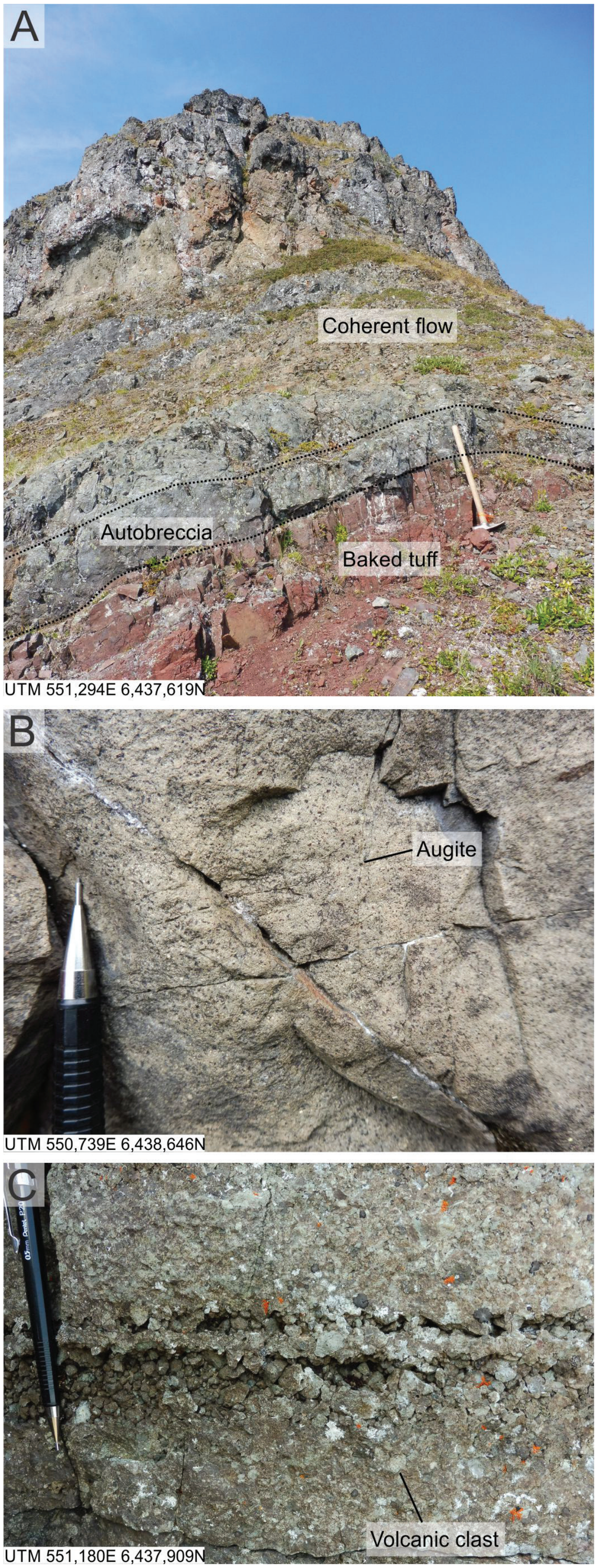


Fig. 15. Bowser Lake Group, Mount Blair Formation mafic volcanic unit (muJBBvm). **a)** Baked red tuff overlain by basal autobreccia grading upward into coherent mafic flow. **b)** Fine-grained augite-plagioclase-phyric mafic flow. **c)** Well-sorted, crudely stratified lapillistone. Mount Blair area.

Blair Formation in the central part of the map area (Fig. 8). The margins vary from sharp and intrusive (east) to autobrecciated (west), and the body is compositionally and texturally similar to felsic clasts in the adjacent mafic volcanic unit (Fig. 9b). These observations suggest it may be a felsic dome, and broadly coeval with Mount Blair volcanism. Metre-wide felsic dikes with a similar composition were locally observed in the map area.

3.2.5. Diorite intrusions (Middle-Late Jurassic)

A diorite body (Middle-Late Jurassic; unit MLJd) is inferred in the far southeast of the map area, following Erdman (1978), who reported a 162 ±12 Ma K-Ar hornblende cooling age from a hornblende diorite. A vesicular microdioritic dike that cuts Late Triassic granodiorite 1.5 km to the west (Fig. 8) may be related. A very small hornblende diorite intrusion is also mapped about 1.8 km north of Mount Blair (Fig. 8), where it cuts and contact metamorphoses sedimentary rocks of the Mount Blair Formation. If all these intrusions are of the same generation, the K-Ar date and maximum depositional age for the Mount Blair volcanic rocks suggest a latest Jurassic age for their emplacement.

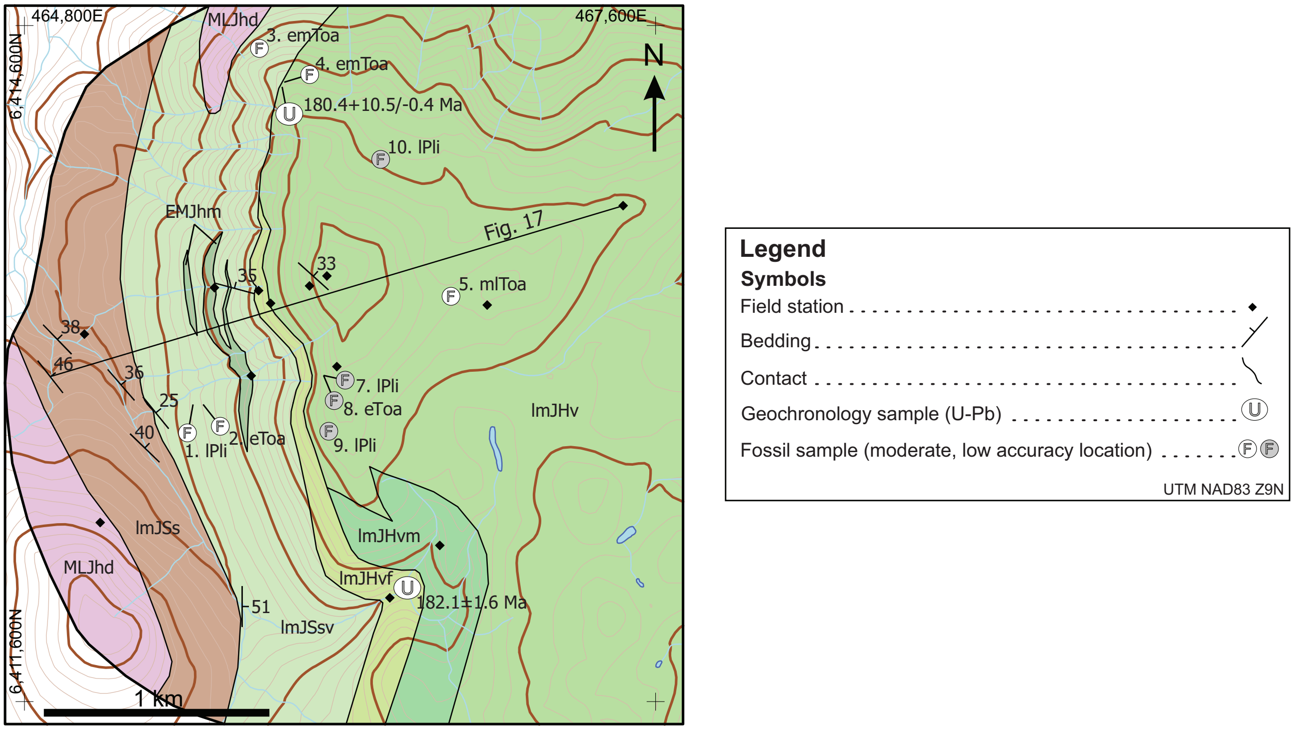
3.3. Spatsizi area

The Spatsizi area is 24 km east of the town of Iskut (Fig. 2). Geological mapping (Read and Psutka, 1990; Thorkelson, 1992; Evenchick and Thorkelson, 2005) and stratigraphic studies (Smith et al., 1984; Thomson et al., 1986; Pálfy et al., 2000) identified sedimentary strata of the Spatsizi Formation overlain by mafic, intermediate, and felsic volcanic rocks of the informal '(Mount) Brock volcanics'.

New mapping shows a right-way-up, moderately northeast dipping homocline (Fig. 16). The lower volcano-sedimentary succession is part of the Spatsizi Formation; the overlying volcanic rocks, originally assigned to the informal '(Mount) Brock volcanics' (Read and Psutka, 1990; Thorkelson, 1992; Evenchick and Thorkelson, 2005), are reassigned here to the Horn Mountain Formation based on similar lithology and late Early to Middle(?) Jurassic age.

3.3.1. Spatsizi Formation

The oldest map unit in the Spatsizi study area is a sedimentary unit (lmJSs) consisting of interbedded siltstone, feldspathic arenite, mudstone, siliceous mudstone, and minor limestone (Figs.16-18). The unit was previously referred to as part of the informal 'Spatsizi sediments' (Smith et al., 1984), later formally defined as the Spatsizi Group (Thomson et al., 1986), and subsequently demoted to Spatsizi Formation (within the Hazelton Group; Evenchick and Thorkelson, 2005). Common soft-sediment deformation structures, mud rip-up clasts, scours, current ripples, rare crossbedding, very rare oscillatory ripples, and ammonoids were observed, with ammonoids suggesting a marine setting. At the top of this unit is a conglomerate to breccia with limestone, mafic(?) volcanic and rare chert clasts (Fig. 17). Smith et al. (1984) and Read and



MIDDLE-LATE JURASSIC (?)

MLJhd — **Microdiorite;** greenish grey; fine grained, equigranular; mafic-rich; Middle to Late Jurassic or possibly younger.

— — — — intrusive contact — — — —

LATE EARLY TO MIDDLE JURASSIC

Upper Hazelton Group

Horn Mountain Formation (formerly 'Mount Brock volcanics')

EMJhm — **Horn Mountain intrusions: Mafic subvolcanic intrusions;** grey; contain 50-60% plagioclase (2-4 mm) and 10-30% augite (0.5-3 mm) phenocrysts in an aphanitic groundmass; Interpreted as subvolcanic feeders to the Horn Mountain Formation.

lmJHv — **Sister Mary unit: Mafic to intermediate flows, volcanic breccia, lapillistone, lapilli-tuff, and tuff;** maroon, green to greenish grey; flows contain 25-50% medium-grained (1-4 mm) to fine-grained (0.1-0.5 mm) plagioclase laths, 0-15% equant augite (0.3-2 mm) phenocrysts, and often vesicular bottom and top; fragmental rocks are predominantly clast-supported and contain maroon, red, green, and grey volcanic clasts that are non-vesicular to vesicular, plagioclase-phyric to aphyric to plagioclase-augite-phyric, and include irregular-shaped vesicular spatter clasts; interstratified flows (4-35 m thick) and fragmental volcanic rocks; rare Toarcian (and younger?) ammonoids, bivalves, brachiopods, and belemnites; predominantly subaerial depositional environment.

lmJHvm — **Glacial Mountain unit: Mafic flows, volcanic breccia;** minor siltstone, mudstone, sandstone; flows and volcanic clasts are augite-plagioclase-phyric; laminated mudstone, siltstone, and fine-grained feldspathic wacke (locally fossiliferous) with common soft-sediment deformation structures are overlain by mafic volcanic breccia in mud matrix, which is in turn overlain by either mafic volcanic breccia with a crystal-rich clastic matrix or mafic coherent rocks; subaqueous depositional environment.

lmJHvf — **Felsic lapillistone,** rare welded lapilli-tuff; greyish to greenish buff; contains cream white plagioclase-phyric felsic volcanic clasts, green fine-grained volcanic clasts, common equant plagioclase crystals, and rare charred wood fragments in a fine ash matrix; 182.1 ±1.6 and 180.4 +10.5/-0.4 Ma U-Pb zircon ages; predominantly subaerial depositional environment.

Spatsizi Formation

lmJSsv — **Tuffaceous siltstone, tuff, tuffaceous sandstone, lapilli-tuff, lapillistone;** rare conglomerate, siltstone; maroon to green; volcanic rocks contain green fine-grained volcanic clasts, local ash-armoured volcanic clasts, and accretionary lapilli; very fine- to fine-grained, rare medium- to coarse-grained tuffaceous feldspathic wacke to rare tuffaceous feldspathic arenite, with common quartz grains and locally organic detritus; conglomerate contains predominantly chert pebbles, granules and rare cobbles; moderately stratified; rare lower Pliensbachian to middle Toarcian ammonoids; subaerial to submarine depositional environment.

lmJSs — **Siltstone, feldspathic arenite, mudstone, siliceous mudstone, minor limestone;** rare conglomerate and breccia; very fine- to medium-grained, rare coarse-grained feldspathic arenite with 75-85% feldspar, 10-25% lithics (including hornblende) and 0-10% quartz grains; conglomerate contains rounded to subangular chert granules and pebbles; breccia contains angular to subrounded clasts (0.2-7 cm) of limestone, mafic(?) volcanic, and rare chert clasts; planar to wavy parallel laminated mudstone and siltstone; very thinly to very thickly bedded feldspathic arenite; common soft-sediment deformation structures, mud rip-up clasts, scours, current ripples, rare cross-bedding, and very rare oscillatory ripples; very rare ammonoids; marine depositional environment.

Fig. 16. Geological map of the Spatsizi area, incorporating data from Read and Psutka (1990), Evenchick and Thorkelson (2005), and this study. See Table 2 for fossil ages.

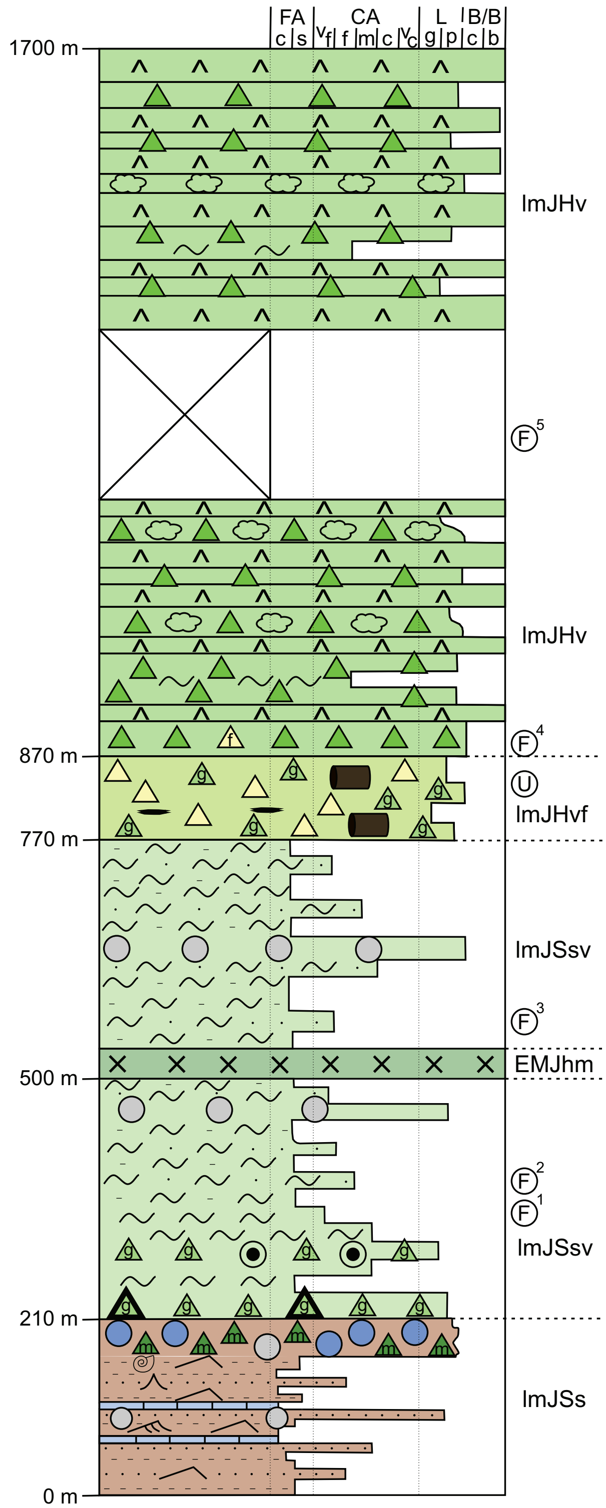


Fig. 17. Schematic stratigraphic section for the Spatsizi area. See Figure 5 for legend, Figure 16 for location of stratigraphic section, and Table 2 for fossil ages.

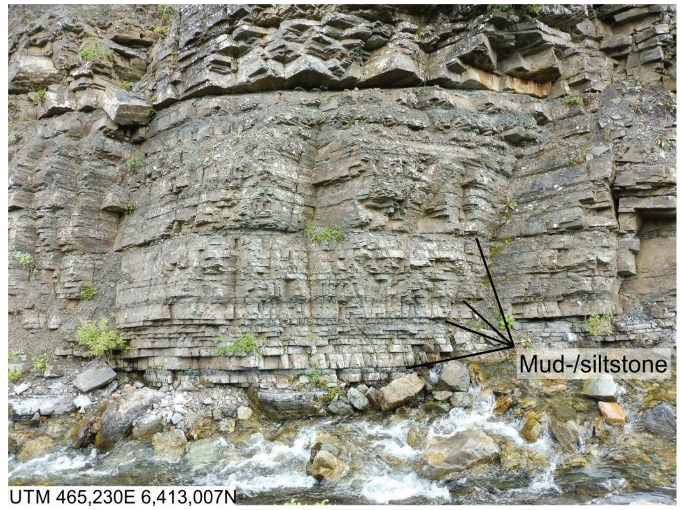


Fig. 18. Spatsizi Formation, sedimentary unit (lmJSs). Interstratified fine- to medium-grained feldspathic arenite, siltstone, and mudstone. Spatsizi area.

Psutka (1990) reported that the unit unconformably overlies diorite to monzodiorite of the Railroad pluton (Stikine plutonic suite, Late Triassic) along the valley bottom, however, we only encountered near-continuous outcrop of sedimentary rocks where plutonic rocks were mapped previously.

The sedimentary unit (lmJSs) is overlain by a tuffaceous sedimentary to volcanic unit (lmJSsv) that, following previous studies, is also included in the Spatsizi Formation (Figs. 16, 17). The base of the unit includes interbedded lapilli-tuff, lapillistone and tuff with common accretionary lapilli and ash-armoured volcanic clasts (Fig. 19), indicating subaerial deposition. Higher up in the section, the unit includes recessive maroon to green tuffaceous siltstone to fine tuff, tuffaceous sandstone to crystal tuff, rare chert-clast bearing conglomerate, and dark grey siltstone. Rare ammonoids suggest a late Pliensbachian to middle Toarcian age (Table 2) and, at least locally, a submarine setting for the middle and upper parts of the unit.

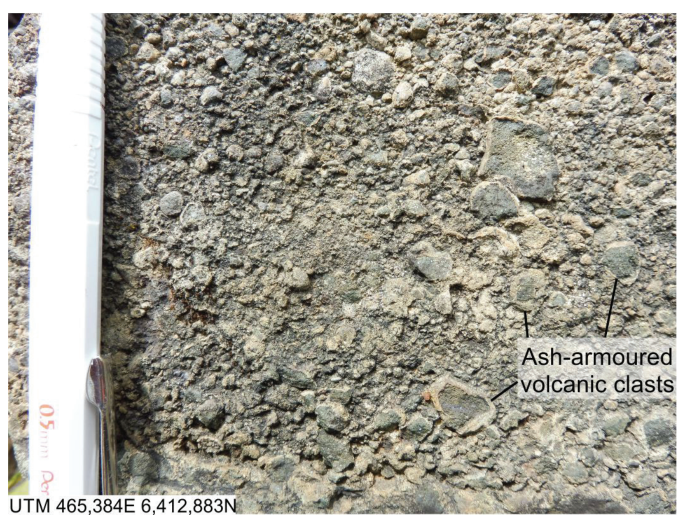


Fig. 19. Spatsizi Formation, tuffaceous sedimentary to volcanic unit (lmJSsv). Ash-armoured volcanic clasts in lapillistone. Spatsizi area.

Table 2. Compilation of fossil data for the Spatsizi area. Numbers 1-5 and 7-10 in first column correspond to fossil labels on Figures 16 and 17.

	GSC no.	Easting	Northing	Loc. acc.	Unit	Age	Fossil description	Identified by	Source	Loc. source
1	C-103177	465548	6412919	mod.	lmJS	lPli	Ammonoid (*Lioceratoides propinquum* (Whiteaves, 1884), *Protogrammoceras* sp.)	H.W. Tipper	1 (6)	6[+]
2	C-103182	465593	6412919	mod.	lmJS	eToa	Macrofossil	H.W. Tipper	1 (6)	6
3	C-087250	465843	6414499	mod.	lmJS	emToa	Ammonoid (*Dactylioceras* cf. *D. kanense* McLearn, *Dactylioceras* sp. indet., harpoceratinae gen. et sp. indet.)	G.K. Jakobs	2 (1,6)	6
4	C-090698	465953	6414349	mod.	lmJH	emToa (K-P)	Ammonoid (*Dactylioceras* cf. *D. kanense* McLearn, *Dactylioceras* cf. *D. commune* (Sowerby), harpoceratinae gen. et sp. indet.), Bivalve (*Weyla alata* (Buch), *Weyla* cf. *W. bodenbenderi* (Behrendsen), pectinid bivalves, bivalves), rhynchonellid brachiopods, terebratulid brachiopods	G.K. Jakobs	2 (1,4,6)	6
5	C-103428	466693	6413399	mod.	lmJH	mlToa	Ammonoid (*Polyplectus* sp. indet.), trigonid bivalves, bivalves	G.K. Jakobs	2 (1,6)	6
6	C-090732	469050	6413750	mod.	lmJH	Toa-?	True belemnite	H.W. Tipper	1 (6)	6*
7	C-103174	466125	6413050	low	lmJ	lPli (C)	Ammonoid (*Tiltoniceras propinquum*, *Protogrammoceras* spp.)	P.L. Smith	5 (1)	5
8	C-103152, C-103153, C-103154, C-103188	466125	6413050	low	lmJS?	eToa (K)	Ammonoid (C-103152: *Dactylioceras* cf. *D. kanense* McLearn; C-103153: *Dactylioceras* cf. D. *simplex* Fucini, *Dactylioceras* cf. *D. kanense* McLearn; C-103154: *Dactylioceras* cf. *D. kanense* McLearn, harpoceratinae gen. et sp. indet.; C-103188: *Dactylioceras* cf. *D. kanense* McLearn)	G.K. Jakobs	2	2
9	C-103171, C-103173, C-103175, C-103179	466150	6412800	low	lmJ	lPli	Ammonoid (C-103171: *Lioceratoides propinquum*, ?*Protogrammoceras paltum*; C-103173: *Lioceratoides propinquum*, *Protogrammoceras* sp.; C-103175: *Lioceratoides propinquum*, *Protogrammoceras paltum*; C-103179: *Protogrammoceras paltum*)	H.W. Tipper	7	7
10	C-210959	466381	6414007	low	lmJS?	lPli (C)	Bivalve (*Posidonotis semiplicata*)	M. Aberhan	3	3

Coordinates in UTM NAD83 Zone 9 north.

Age: e, m, l = early, middle, late; Pli = Pliensbachian, Toa = Toarcian; C = Carlottense Zone (latest Pliensbachian), K = Kanense Zone (early Toarcian), P = Planulata Zone (early middle Toarcian).

Location accuracy (Loc. acc.): mod. = moderate - converted from tabulated coordinates in UTM NAD27 on map, and matching fossil location shown on 1:50,000 scale map (Read and Psutka, 1990); low - converted from latitude-longitude with poor or no accompanying location description.

Source, Location source (Loc. source): 1. Evenchick and Thorkelson (2005); 2. Jakobs (1997); 3. Aberhan and Pálfy (1996). 4. Jakobs et al. (1994); 5. Thomson and Smith (1992); 6. Read and Psutka (1990); 7. Tipper (1986); () = other source, often with superseded age determination; [+] = location slightly adjusted to correct elevation; * = location digitized from map.

3.3.2. Horn Mountain Formation

The Spatsizi Formation is conformably overlain by volcanic rocks of the Horn Mountain Formation, which is subdivided into three map units (Figs. 16, 17). At the base is a felsic volcanic unit (lmJHvf; Fig. 20) that includes welded lapilli-tuff indicating subaerial deposition. A sample of felsic volcanic breccia from the southern part of the map area, where the unit is about 150 m thick, returned a 182.1 ±1.6 Ma LA-ICP-MS U-Pb zircon age (sample 16BvS-39-284, B. van Straaten and R. Friedman, unpublished data). The unit thins northward, becoming about 100 m thick in the centre of the map area, and ceasing to be a mappable unit farther north. It may, however, continue into the north part of the area and be represented by a 1.5 m thick felsic non-welded waterlain feldspar-phyric crystal tuff that returned a 180.4 +10.5/-0.4 Ma U-Pb zircon age (Fig. 16; Pálfy et al., 2000).

In the southern part of the map area the felsic volcanic unit is overlain by a mafic volcanic unit (lmJHvm) of the Horn Mountain Formation (Fig. 16). Based on lithological similarity, we correlate it with the Glacial Mountain unit of the Horn Mountain Formation in the Dease Lake map area (van Straaten et al., 2022b). The presence of intercalated mudstone, siltstone and sandstone suggests transport and deposition by water such as in a subaqueous or fluvial setting.

Most of the Horn Mountain Formation in the Spatsizi area is composed of a mafic to intermediate volcanic unit (lmJHv; Figs. 16, 17), which overlies the felsic volcanic unit (lmJHvf), and overlies and interfingers with the mafic volcanic unit (lmJHvm). This unit comprises interbedded flows and fragmental volcanic rocks (Fig. 21a), locally with amoeboid vesicular spatter clasts (Fig. 21b). Based on lithological similarity, we correlate it with the Sister Mary unit of the Horn Mountain Formation in the Dease Lake map area (van Straaten et al., 2022b). Rare reports of ammonoids, bivalves, and brachiopods suggest a Toarcian age (Table 2). Vesicular flows and spatter clasts suggest a predominantly subaerial setting although rare marine macrofossils indicate periodic flooding by seawater.

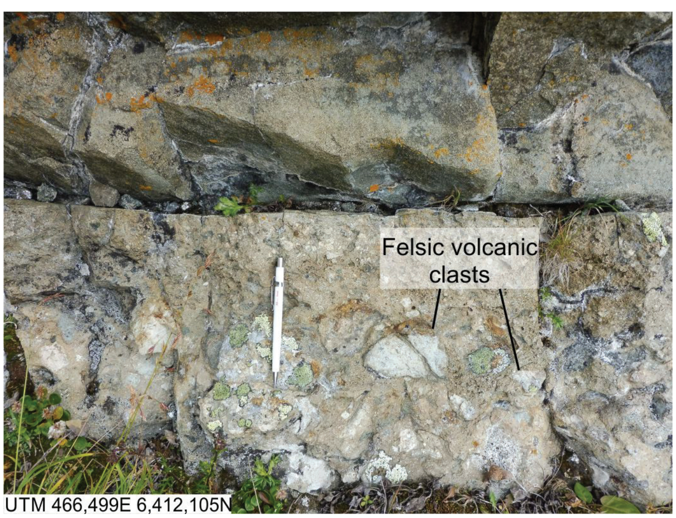


Fig. 20. Horn Mountain Formation, felsic volcanic unit (lmJHvf). Felsic volcanic breccia overlain by felsic crystal tuff. Spatsizi area.

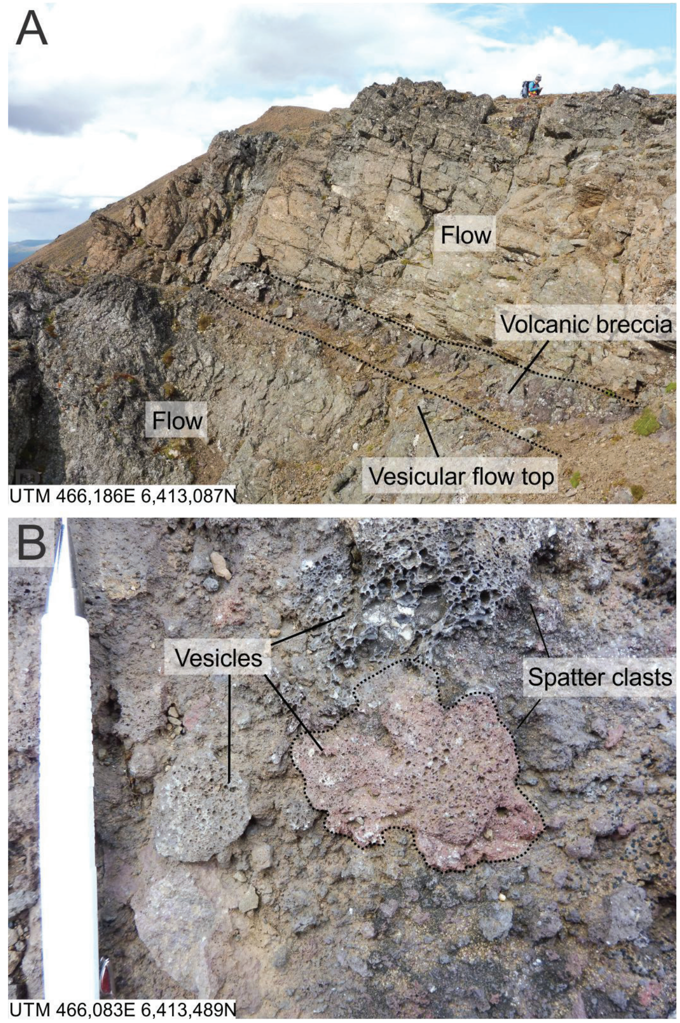


Fig. 21. Horn Mountain Formation, Sister Mary mafic to intermediate volcanic unit (lmJHv). **a)** At base, augite-plagioclase-phyric flow with highly vesicular top overlain by 1 m-thick bed of volcanic breccia with common spatter clasts, overlain by 4 m-thick augite-plagioclase-phyric flow. **b)** Lapillistone from 75 cm thick bed, with amoeboid, highly vesicular, brick red, maroon, and dark grey plagioclase-phyric spatter clasts. Spatsizi area.

Mafic subvolcanic sills and intrusions (unit EMJhm) cut the tuffaceous sedimentary and volcanic unit (lmJSsv) of the Spatsizi Formation (Fig. 16). Based on textural and compositional similarity they are interpreted as subvolcanic feeders to the Horn Mountain Formation.

3.3.3. Microdiorite (Middle-Late Jurassic)

A mafic-rich microdiorite (unit MLJhd) occurs in the southwest corner of the of the map area where it is inferred to cut sedimentary rocks of the Spatsizi Formation (Fig. 16). It is interpreted as Middle to Late Jurassic or possibly younger.

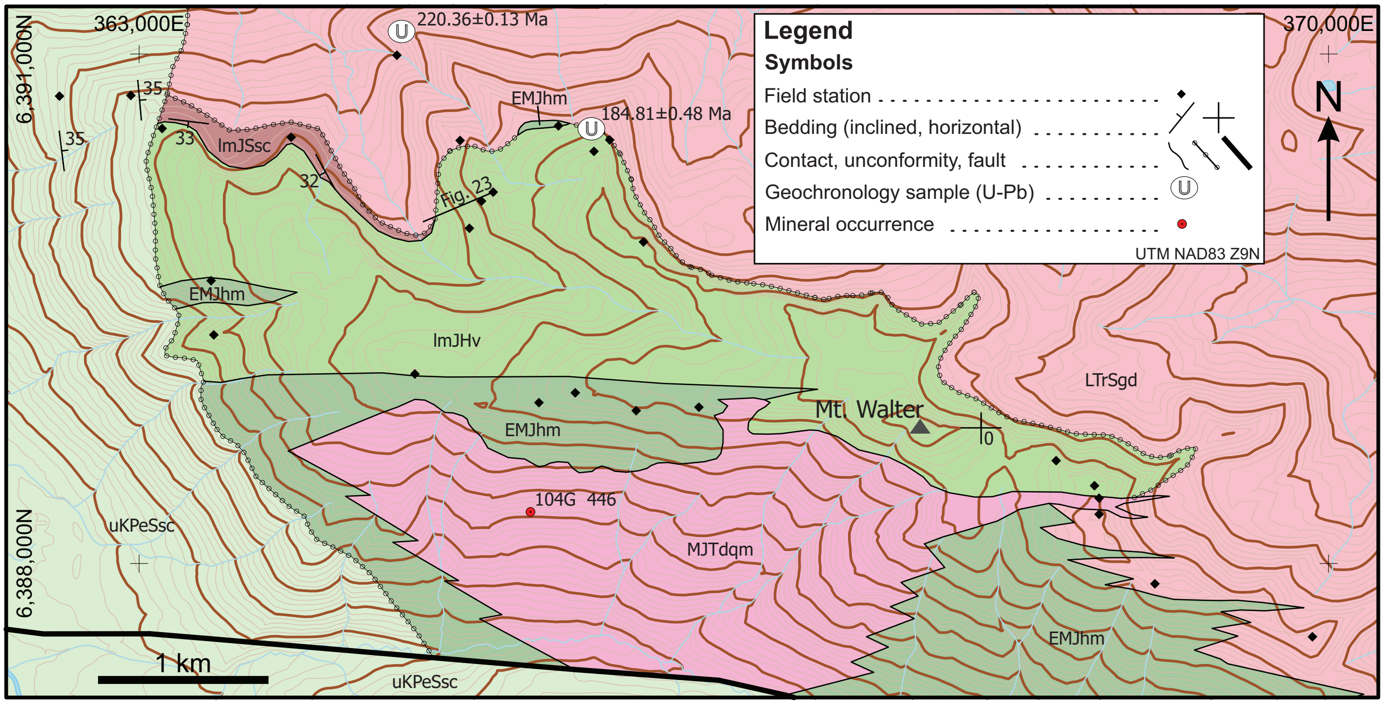
3.4. Yehiniko Lake area

The Yehiniko Lake area is 31 km south of Telegraph Creek (Fig. 2). The area was previously mapped at 1:250,000 scale by Souther (1972); the western portion was mapped at

1:50,000 scale by Brown et al. (1996). A revised geological map (Fig. 22) shows a granodiorite pluton (part of the Stikine plutonic suite, Late Triassic) unconformably overlain by subhorizontal sedimentary and volcanic rocks (Fig. 23). The sedimentary rocks are assigned to the Spatsizi Formation and the volcanic rocks, previously mapped as undivided Hazelton Group (Lower to Middle Jurassic; Brown et al., 1996), are assigned to the Horn Mountain Formation.

3.4.1. Nightout pluton (Stikine plutonic suite)

The northern part of the Yehiniko Lake map area is underlain by granodiorite (unit LTrSgd) of the Nightout pluton, which extends across 544 km^2 and was previously considered Middle to Late Triassic based on a number of K-Ar, Rb-Sr and U-Pb radiometric age determinations (Holbek, 1988; Brown et al., 1996; Logan et al., 2000; Breitsprecher and Mortensen, 2004). A sample of quartz porphyritic biotite-hornblende granodiorite



LATE CRETACEOUS TO PALEOCENE

Sustut Group

Brothers Peak Formation

uKPeSsc — **Conglomerate, lesser sandstone, siltstone,** rare shale, felsic tuff, lapilli-tuff and flows, very rare basalt and andesite flows and breccia; brick red, brown, and grey; poorly indurated; 85.6 ±6.0 Ma K-Ar biotite cooling age, rare Early Paleocene palynomorphs; terrestrial depositional environment.

— — — — unconformity — — — —

MIDDLE JURASSIC (?)

Three Sisters Plutonic Suite (?)

MJTdqm — **Quartz monzonite, feldspar porphyry intrusions;** pink; fine- to coarse-grained, equigranular to feldspar porphyritic; biotite-hornblende, biotite; Middle Jurassic, or possibly younger.

— — — — intrusive contact — — — —

EARLY TO MIDDLE JURASSIC

Upper Hazelton Group

Horn Mountain Formation

EMJhm — **Horn Mountain intrusions: Mafic subvolcanic intrusions;** dark grey; contain 25-35% plagioclase (0.5-4 mm) and 10-15% augite (0.5-1.5 mm) phenocrysts in a very fine-grained groundmass; interpreted as subvolcanic feeders to the Horn Mountain Formation.

lmJHv — **Sister Mary unit: Mafic to intermediate flows, lapillistone, tuff, volcanic breccia;** rare felsic lapillistone; maroon to grey; flows contain 15-30% plagioclase (0.2-4 mm) and 10-15% augite (0.1-0.5 mm) phenocrysts; fragmental volcanic rocks contain augite-plagioclase-phyric, plagioclase-phyric and aphyric volcanic clasts; crudely stratified; 184.81 ±0.48 Ma U-Pb zircon age from basal felsic volcanic rocks; subaerial depositional environment.

Spatsizi Formation

lmJSsc — **Sandstone and conglomerate;** coarse- to very coarse-grained quartz-rich feldspathic arenite; conglomerate with granitoid granules and rare pebbles; unconformably overlies Nightout pluton; crudely stratified.

— — — — unconformity — — — —

LATE TRIASSIC

Stikine Plutonic Suite

Nightout pluton

LTrSgd — **Granodiorite;** medium-grained, quartz to K-feldspar-quartz porphyritic; biotite-hornblende; moderately resistant; 220.36 ±0.13 Ma U-Pb zircon age.

Fig. 22. Geological map of the Yehiniko Lake area, incorporating data from Souther (1972), Brown et al. (1966), Cui et al. (2017), and this study.

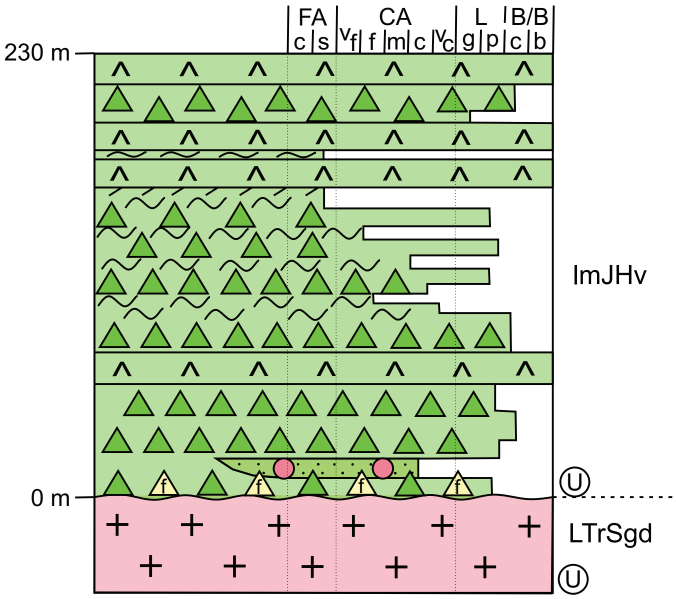


Fig. 23. Schematic stratigraphic section for the Yehiniko Lake area. See Figure 5 for legend, and Figure 22 for location.

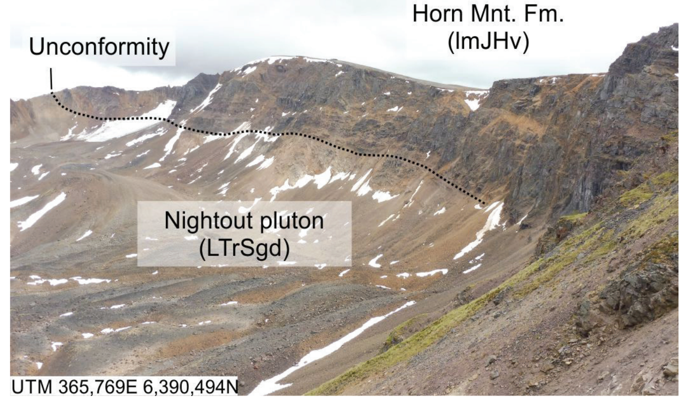


Fig. 24. Unconformity between flat-lying upper Hazelton Group volcanic rocks (Horn Mountain Formation, lmJHv) and subjacent Nightout pluton (LTrSgd) northeast of Yehiniko Lake. View towards the southeast.

from the northwestern part of the area (Fig. 22) returned a 220.36 ±0.13 Ma CA-TIMS U-Pb zircon age (sample 18BvS-12-97; B. van Straaten and R. Friedman, unpublished data) confirming that it is Late Triassic and part of the Stikine plutonic suite.

3.4.2. Spatsizi and Horn Mountain formations

Within the study area, the Nightout pluton is unconformably overlain by flat-lying volcano-sedimentary rocks of the upper Hazelton Group. In the west, an eastward-thinning wedge of sandstone and conglomerate (unit lmJSsc) directly overlies the pluton. In the centre and east, a succession of maroon to grey volcanic rocks (unit lmJHv) directly overlies the pluton; in the west, the volcanic unit overlies the sandstone and conglomerate unit (Fig. 22). Based on similar lithology and age we assign the sedimentary rocks (lmJSsc) to the Spatsizi Formation, and the volcanic rocks (lmJHv) to the Horn Mountain Formation. The unconformity is well-exposed along the northern edge of the Mount Walter ridge system (Fig. 24) and was studied 2.4 km west-northwest of Mount Walter. Here, a 5-m covered interval separates granodiorite of the Nightout pluton from maroon to grey volcanic rocks. The lowest volcanic exposures comprise felsic lapillistone with aphyric volcanic, very fine-grained volcanic, and flow-banded volcanic clasts set in an ash matrix with common detrital quartz grains (2-3 mm). The felsic lapillistone returned a U-Pb CA-TIMS zircon age of 184.81 ±0.48 Ma (sample 18BvS-12-99, B. van Straaten and R. Friedman, unpublished data), and constrains the onset of upper Hazelton Group volcanism in the area. The Early Jurassic age is based on five zircon grain analyses, and three older grains (ca. 224.1-219.4 Ma, B. van Straaten and R. Friedman, unpublished data) indicate that detrital material was derived from the subjacent Nightout pluton. At this locality, basal volcanic rocks are locally interbedded with medium- to very coarse-grained quartz-rich feldspathic arenite and granular conglomerate (Fig. 25a). To the north of the map area, a relatively flat-topped plateau incised by creeks likely outlines the continuation of the subhorizontal erosional surface atop the Nightout pluton. It is similar in attitude to a largely flat-lying unconformity at the base of a larger outlier of Hazelton Group rocks to the west (Brown et al., 1996).

The volcanic unit (lmJHv) consists mainly of interbedded mafic to intermediate flows and fragmental volcanic rocks (Figs. 25b, 25c), which we assign to the Sister Mary unit of the Horn Mountain Formation (van Straaten et al., 2022b). Flows are generally 15 m thick, are locally underlain by red baked tuff, and locally grade upward into a vesicular flow top directly overlain by tuff breccia lacking interclast-matrix (interpreted as flow-marginal autobreccia; Fig. 25c). The succession is interpreted as subaerial.

Subvertical east-west trending mafic subvolcanic dikes and intrusions (unit EMJhm) cut broadly contemporaneous volcano-sedimentary rocks of the upper Hazelton Group and older rocks of the Nightout pluton (Fig. 22). The presence of different textural varieties of mafic subvolcanic intrusions, local sharp internal intrusive contacts, and rare screens of probable volcanic rocks, suggest the southern slopes of Mount Walter may represent an intrusive complex that fed Horn Mountain volcanism. This unit was mapped along the alpine ridges near Mount Walter; its presence on the lower southern slopes of Mount Walter is inferred based on regional mapping by Souther (1972).

3.4.3. Intrusions (Middle Jurassic)

A quartz monzonitic intrusive body was mapped by Souther (1972) in the southern part of the study area

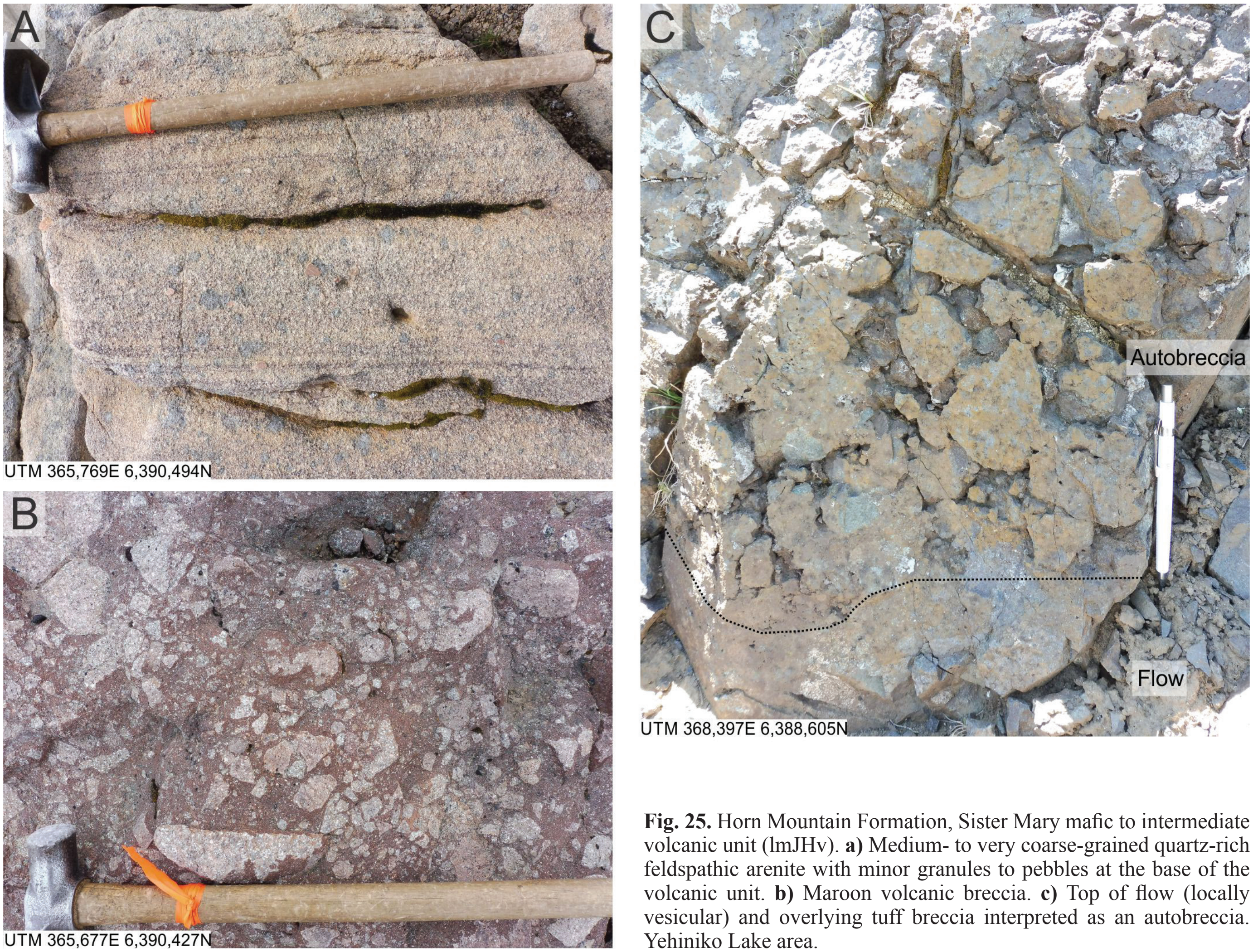


Fig. 25. Horn Mountain Formation, Sister Mary mafic to intermediate volcanic unit (lmJHv). **a)** Medium- to very coarse-grained quartz-rich feldspathic arenite with minor granules to pebbles at the base of the volcanic unit. **b)** Maroon volcanic breccia. **c)** Top of flow (locally vesicular) and overlying tuff breccia interpreted as an autobreccia. Yehiniko Lake area.

(Fig. 22; unit MJTdqm). The lithology, geometry, and age of this intrusion are poorly constrained. It is tentatively assigned to the Three Sisters plutonic suite (Middle Jurassic) based on lithological similarity to the nearby Yehiniko and Saffron plutons described by Brown et al. (1996). Pink feldspar to quartz-biotite-feldspar porphyritic dikes that cut Horn Mountain volcanic rocks throughout the study area are probably related. On the southern slopes of Mount Walter, the intrusive body and its wall rocks are commonly gossanous and host the Boomerang showing (MINFILE 104G 446).

3.4.4. Sustut Group

Exposures in the westernmost part of the study area include interbedded coarse- to very coarse-grained quartz-bearing feldspathic arenite, very fine- to medium-grained maroon to grey sandstone with minor pinkish (hematite-altered?) mica grains, and conglomerate with granitoid pebbles and granules. We tentatively correlate these with exposures of the Sustut Group described by Brown et al. (1996) in the valleys to the west and south of our study area, who assigned it an Upper Cretaceous to Paleocene age based on an 85.6 ±6.0 Ma K-Ar biotite cooling age and one Early Paleocene palynomorph collection.

4. Discussion

Below we discuss the spatial variation of upper Hazelton Group and coeval strata (Pliensbachian to Aalenian) and Bowser Lake Group (Bajocian and younger) atop the Stuhini arc.

4.1. Spatial variation of upper Hazelton Group and coeval strata (Pliensbachian to Aalenian) atop the Stuhini arc

This study shows that thick (1-4 km) upper Hazelton Group volcanic successions are present along most of the Stikine arch. The following considers the variation in thickness, depositional setting, preserved areal extent (Fig. 26), and age (Fig. 27) of upper Hazelton Group and broadly coeval strata. The successions unconformably overlie Late Triassic rocks of the Stuhini arc (see Section 2) separated by a ca. 30 m.y. hiatus, except in the Spatsizi area where the lower contact was

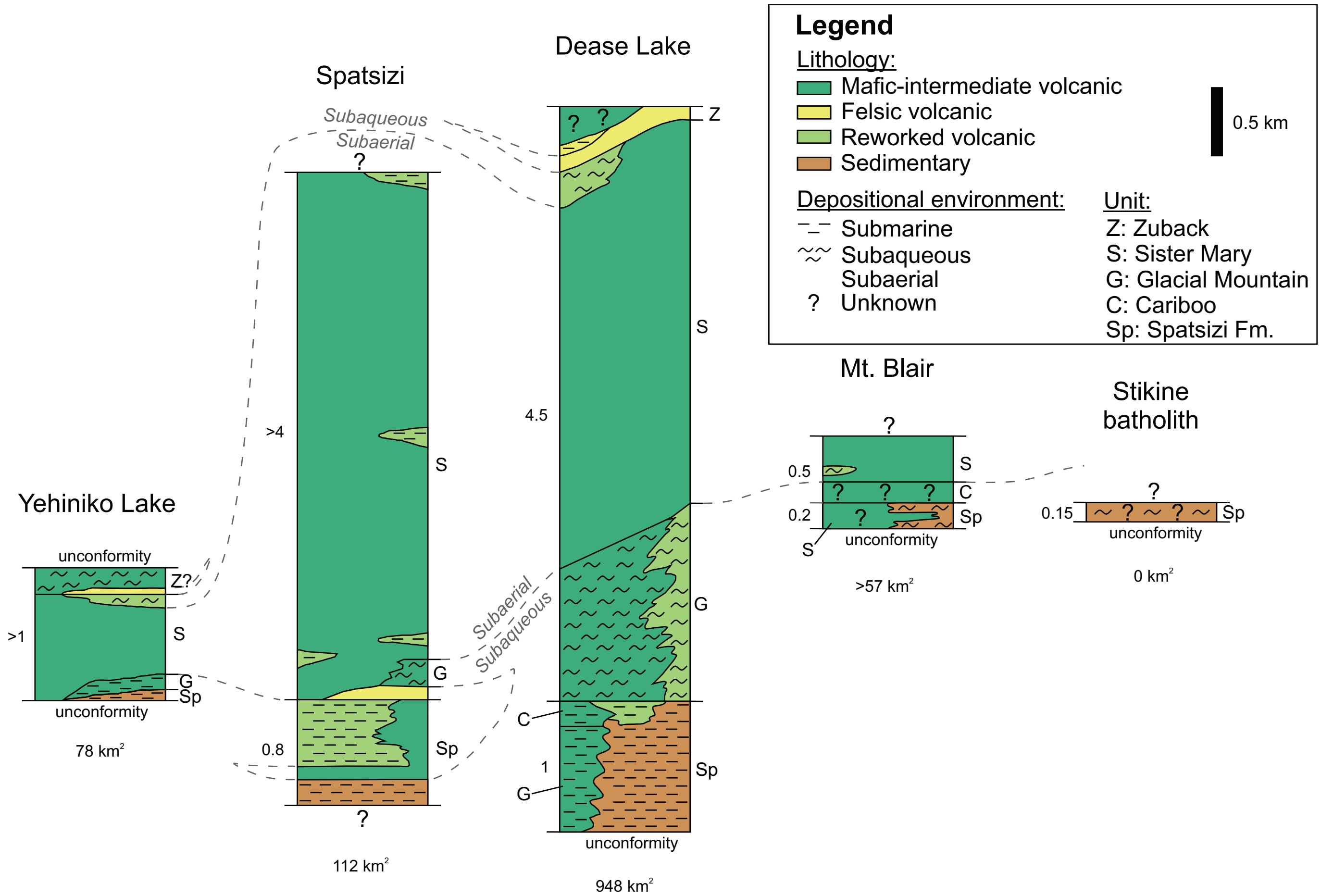


Fig. 26. Schematic representation of the variation in thickness, lithology, and depositional environment of upper Hazelton Group strata along the Stikine arch. Values at the bottom of each stratigraphic column represent the preserved areal extent of the Horn Mountain Formation in each area. Data from Read and Psutka (1990), Brown et al. (1996), Gabrielse (1998; 2003), Evenchick and Thorkelson (2005), Cui et al. (2017), van Straaten et al. (2022b), and this study.

not observed. Farther northwest along the Stikine arch, in the Sam batholith, Lisadele Lake, and Willison Bay areas (Fig. 2), broadly coeval sedimentary rocks of the Laberge Group (Lower Jurassic) unconformably overlie the Stuhini arc.

4.1.1. Stikine batholith and Mount Blair areas

The Stikine batholith and Mount Blair areas represent the easternmost occurrences of upper Hazelton Group strata documented in this study. In the Stikine batholith area, Spatsizi Formation granitoid clast-bearing conglomerate and sandstone unconformably overlie the Stikine batholith (Late Triassic). A sandstone sample returned a ca. 215 Ma U-Pb detrital zircon maximum depositional age, confirming derivation from Late Triassic plutonic rocks. Based on a similar lithology to elsewhere along the arch, the succession is likely late Pliensbachian to Toarcian. The unit contains mafic dike clasts, mafic volcanic clasts, and cross-cutting mafic dikes (all with similar lithology), suggesting mafic magmatism may have an overlapping, but broader, age range than the preserved sedimentary unit. Based on a similar lithology, composition, and post-Late Triassic age, the mafic subvolcanic to volcanic activity is correlated with Horn Mountain volcanism (Early to Middle Jurassic). These observations suggest active Horn Mountain volcanism in the eastern part of the Stikine arch. The absence of volcanic rocks indicates that volcanism was relatively minor, and/or the volcanic strata have been eroded.

In the Mount Blair area, volcano-sedimentary rocks of the upper Hazelton Group unconformably overlie a granodiorite pluton with an inferred Late Triassic age. A section about 0.7 km thick is preserved in the eastern half of the study area, and felsic strata from near the top of the section returned a 172.05 ±0.17 Ma CA-TIMS U-Pb zircon age. In the east, the upper part of the section is cut out by a fault. In the southeast and southwest, the contact between the Horn Mountain Formation and overlying Mount Blair Formation is conformable. The preserved areal extent of the Horn Mountain Formation is a minimum estimate because these strata likely extend west of the Tucho River. Poorly exposed basal conglomerate and sandstone of the Spatsizi Formation were likely transported and deposited by water and the depositional setting for the volcanic

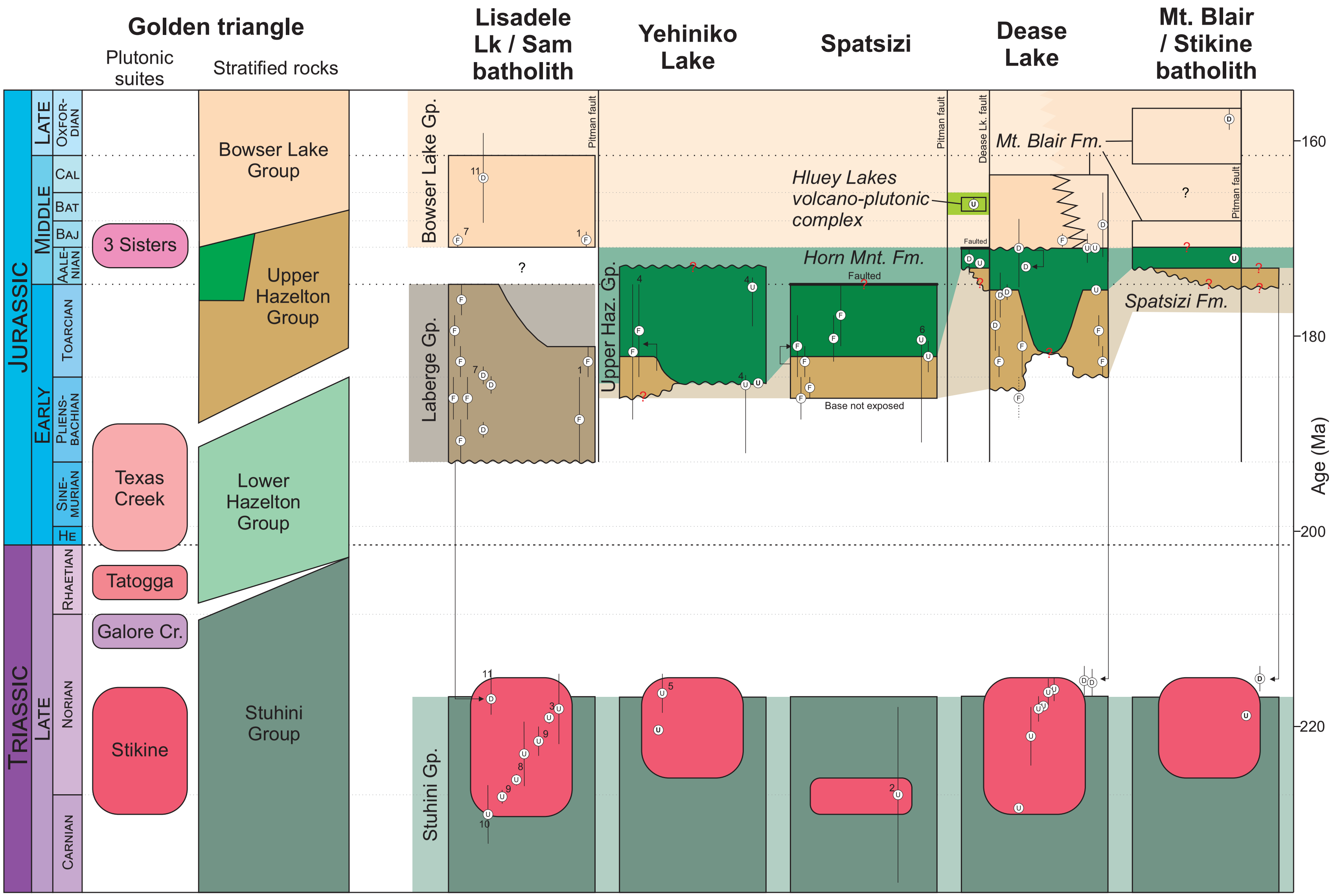


Fig. 27. Late Triassic to Jurassic stratigraphic framework for upper Hazelton Group and coeval strata atop the Stuhini arc in northwestern British Columbia. References for stratigraphic columns, fossil (F), U-Pb zircon (U) and U-Pb detrital zircon (D) ages: 1. Souther (1971), 2. Read and Psutka (1990), 3. Oliver and Gabites (1993), 4. Brown et al. (1966), 5. Logan et al. (2000), 6. Pálfy et al. (2000), 7. Shirmohammad et al. (2011), 8. Takaichi and Johnson (2012), 9. Takaichi (2013), 10. Mihalynuk et al. (2016), 11. Kellett and Iraheta Muniz (2019). Stratigraphic column, fossil ages, and geochronological constraints for the Dease Lake area are from van Straaten et al. (2022b); fossil ages for the Spatsizi area are from Table 2; all other unlabelled geochronological ages are from this study. Red question marks denote poorly constrained age. The Golden triangle plutonic and stratigraphic framework is modified from Nelson et al. (2018) and Nelson and van Straaten (2020). Triassic and Jurassic time scale after Cohen et al. (2013). U-Pb detrital zircon maximum depositional ages for all samples were calculated by excluding individual grain ages with a probability of discordance <0.05, and using either the Youngest Statistical Population method of Coutts et al. (2019) or TuffZirc routine of Ludwig (2012), depending on which age is closest to the youngest graphical peak formed by three or more grains on an age-probability plot constructed using Isoplot (Ludwig, 2012).

rocks in the remainder of the lower half of the stratigraphic section is poorly constrained. The upper volcanic succession was largely deposited in a subaerial setting.

4.1.2. Dease Lake area

Along the Stikine arch, the thickest, most complete, and largest preserved areal extent of upper Hazelton Group strata are in the Dease Lake area (Fig. 26; van Straaten et al., 2022b). The best exposures are in a 70 km-long arcuate belt extending east to southeast from Highway 37 to the Pitman fault (Fig. 2). Here, a 5.5 km-thick volcano-sedimentary succession unconformably overlies the Cake Hill pluton (Late Triassic). In the west and east of the belt, basal strata are represented by sedimentary rocks of the Spatsizi Formation; in the centre of the belt, basal strata consist of Horn Mountain Formation volcanic rocks. The onset of deposition atop the basal upper Hazelton Group unconformity is constrained by late Pliensbachian(?) to early Toarcian fossils near the base of the Spatsizi Formation (Fig. 27; van Straaten et al., 2022b). The thickness variation within the Spatsizi Formation suggests that deposition was controlled by penecontemporaneous growth faults (van Straaten and Nelson, 2016; van Straaten and Gibson, 2017), where rapid basin deepening resulted in a change from subaerial erosion of granitoids and formation of grus, to granitoid clast-bearing conglomerates and fossiliferous sandstone deposited in a shallow-marine setting, to deeper marine interstratified argillite and siltstone (Henderson and Perry, 1981; van Straaten and Gibson, 2017). In the centre of the belt, subaqueous volcanic rocks of the Horn Mountain Formation rest directly on the basal upper Hazelton Group unconformity. They include mafic volcanic rocks of the Glacial Mountain unit overlain by distinct coarse platy plagioclase-phyric volcanic rocks of the Cariboo unit (lowermost unit of van Straaten and Gibson, 2017; van Straaten et al., 2022b). These volcanic rocks grade laterally into Spatsizi Formation sedimentary rocks containing late Pliensbachian(?) and early-middle Toarcian marine fossils, suggesting that the base of the Horn Mountain Formation is locally younger than ca. 175 Ma (Fig. 27; see below). This area may have been a topographic high or horst centred on the Cake Hill pluton (Late Triassic) during initial Spatsizi Formation sedimentation. In the west and east of the belt, sedimentary rocks of the Spatsizi Formation are overlain by volcanic rocks of the Horn Mountain Formation; in the centre of the belt, mafic volcanic rocks of the Glacial Mountain unit overlie coarse platy plagioclase-phyric volcanic rocks of the Cariboo unit. The age of this contact, which marks the onset of voluminous Horn Mountain volcanism, is well-constrained to ca. 175 Ma by a CA-TIMS U-Pb zircon age for basal felsic volcanic rocks and LA-ICP-MS U-Pb detrital zircon maximum depositional ages for immediately underlying sedimentary rocks of the Spatsizi Formation. The overlying Horn Mountain Formation is characterized by subaqueous mafic volcanic rocks of the Glacial Mountain unit, which transitions upward into maroon and grey subaerial mafic to intermediate volcanic rocks of the Sister Mary unit. In the west of the belt, a thick succession of maroon subaerial volcanic rocks is overlain by reworked maroon epiclastic rocks (both of the Sister Mary unit), in turn overlain by subaerial felsic volcanic rocks with submarine strata locally reported near the top of the felsic unit (Zuback unit), and capped by mafic volcanic rocks with an unknown depositional setting (Zuback unit; Fig. 26). Here, the volcanic strata are unconformably overlain by marine sedimentary rocks of the Bowser Lake Group (van Straaten and Nelson, 2016; van Straaten and Gibson, 2017). Strong hydrothermal alteration along the Sister Mary-Zuback unit contact renders protolith identification locally challenging. In the east of the belt, maroon volcanic rocks of the Sister Mary unit are overlain by felsic volcanic rocks of the Zuback unit (Horn Mountain Formation, upper Hazelton Group), and interstratified sedimentary and volcanic rocks of the Mount Blair Formation (Bowser Lake Group; van Straaten and Bichlmaier, 2018; van Straaten et al., 2022b). The succession is conformable, and entirely subaerial. A high-precision CA-TIMS U-Pb zircon crystallization age on immediately underlying Horn Mountain Formation felsic volcanic rocks constrains the onset of Bowser Lake Group sedimentation to 170.99 ±0.13 Ma. This age is based on the two youngest zircon grains, with three older antecrystic to xenocrystic grains showing 171.9, 172.1, and 173.7 Ma $^{206}Pb/^{238}U$ ages (B. van Straaten and R. Friedman, unpublished data), indicating significant inheritance. These observations suggest a nearly complete to completely preserved upper Hazelton Group stratigraphic section in this area.

From approximately 4 km east of Highway 37 to the Dease Lake fault, the Glacial Mountain unit shows a westward increase in the proportion of reworked volcanic strata. Here, the unit transitions from unconformably overlying the Cake Hill pluton (Late Triassic) to unconformably overlying the Stuhini Group (Upper Triassic; van Straaten et al., 2022b).

West of the Dease Lake fault, the upper Hazelton Group succession unconformably overlies the Stuhini Group (Upper Triassic) and is approximately 4 km thick. The succession has an approximately 30 km strike length, is poorly to moderately exposed, contains mainly reworked volcanic rocks, and returned a 172.1 +1.6/-1.0 Ma LA-ICP-MS U-Pb detrital zircon maximum depositional age. This unit conforms to a westward trend of increasing reworked volcanic strata described above. The top contact is the Kehlechoa fault. Farther west, a poorly to moderately exposed fault-bound succession of volcanic rocks (Glacial Mountain unit) with an approximately 10 km strike length may represent a separate Horn Mountain volcanic centre.

An outlier of upper Hazelton Group strata 27 km south of Dease Lake shows subaqueous sedimentary rocks of the Spatsizi Formation grading up into possibly subaerial volcanic rocks. Abrupt facies changes across north-trending faults may be related to syn-depositional faulting. The succession is 0.5 km thick, and the lower and upper contacts are not exposed. A 172.54 ±0.11 Ma CA-TIMS U-Pb zircon age from the base of the volcanic rocks shows volcanism in this area started relatively late.

4.1.3. Spatsizi area

The Spatsizi area exposes the second largest preserved areal extent and second thickest succession of upper Hazelton Group along the Stikine arch. In the Spatsizi area, the base and top of the succession are not exposed. Here, volcano-sedimentary strata of the Spatsizi Formation are overlain by volcanic rocks of the Horn Mountain Formation. The Spatsizi Formation is at least 0.8 km thick (Figs. 17, 26) and contains late Pliensbachian, early Toarcian, and early-middle Toarcian fossils (Table 2). Latest Pliensbachian (Carlottense Zone) ammonoid collections with low accuracy locations (Table 2) were likely sampled from the Spatsizi Formation. A marine siliciclastic sedimentary unit (lmJSs) transitions upward into subaerial volcanic and subaqueous tuffaceous sedimentary rocks (unit lmJSsv; Fig. 26). Based on fossil evidence, volcanism within the Spatsizi Formation probably started in the latest Pliensbachian. The base of the overlying Horn Mountain Formation is constrained with a new 182.1 ±1.6 Ma LA-ICP-MS U-Pb zircon age (Fig. 27), which matches an age with larger error reported by Pálfy et al. (2000). The Horn Mountain Formation comprises predominantly subaerial volcanic rocks (Evenchick and Thorkelson, 2005; this study) which we assign to the Sister Mary unit. The succession is at least 4 km thick (Read and Psutka, 1990), and contains rare early-middle Toarcian, middle-late Toarcian, Toarcian, probable Toarcian, and Early Jurassic fossils (Table 2; Read and Psutka, 1990; Evenchick and Thorkelson, 2005).

The volcanic unit has previously been interpreted as entirely Toarcian based on paleontological data and cross-cutting relationships with the McEwan Creek pluton (Evenchick and Thorkelson, 2005). However, the top of the volcanic unit is not exposed, and its uppermost strata in the north and east are bound by faults (Read and Psutka, 1990; Evenchick and Thorkelson, 2005). The paleontological evidence hinges on two localities near the top of the succession from which bivalves and belemnites with an Early Jurassic or probable Toarcian age were recovered (C-116297 and C-116299 in Read and Psutka, 1990; Evenchick and Thorkelson, 2005). To the immediate south of our study area the volcanic succession was described as being cut by leucogranite to quartz monzonite of the McEwan Creek pluton (Thorkelson, 1992; Evenchick and Thorkelson, 2005). A sample from the northwestern part of the pluton returned a 183.5 ±0.5 Ma U-Pb zircon and 183.0 ±0.5 Ma U-Pb titanite age (Evenchick and McNicoll, 1993). However, these ages were derived from one air abraded multi-grain zircon fraction and two unabraded multi-grain titanite fractions (Evenchick and McNicoll, 1993). As the pluton was mapped cutting the upper Hazelton Group volcano-sedimentary succession, the isotopic ages were proposed as a potential constraint for the Pliensbachian-Toarcian stage boundary (Evenchick and McNicoll, 1993; Pálfy, 1997). This interpretation is difficult to reconcile with the 182.1 ±1.6 Ma LA-ICP-MS U-Pb zircon age (this study) for the base of the >4 km thick volcanic succession, a middle-late Toarcian fossil call for the volcanic strata (Table 2), the lack of detailed presentation on crosscutting relationships between the pluton and the upper Hazelton Group volcano-sedimentary rocks, the several kilometre distance between the geochronological sample site and the location where the pluton is mapped in contact with upper Hazelton Group rocks, the use of a single air abraded zircon fraction for isotopic age determination, and the complexity and multi-episodic nature of many of the plutonic bodies along the Stikine arch (e.g., van Straaten et al., 2022b). Volcanism started significantly earlier in the Spatsizi area than in the nearby Dease Lake area, and, based on limited data, volcanic strata may be predominantly older than similar strata in the Dease Lake area (Fig. 27). Further geochronological and paleontological studies to constrain the age of the upper part of the succession are warranted.

4.1.4. Yehiniko Lake area

West of Yehiniko Lake, an outlier of relatively flat-lying Hazelton Group volcanic strata unconformably overlies the Stuhini Group (Brown et al., 1996). Individual stratigraphic sections show thicknesses ranging from 300 to 825 m, with a total thickness estimated at more than 1 km (Brown et al., 1996). In this outlier, the base is locally formed by a dacite flow or sill, locally overlain by a thin (<75 m) limy wacke unit with late Pliensbachian and Toarcian fossils; the sedimentary rocks are correlated here with the Spatsizi Formation. These units are overlain by andesitic breccias, flows and tuffs; these also form the base in the remainder of this outlier. An andesite flow breccia near the base of this unit returned a 185 +7/-1 Ma U-Pb zircon age (Brown et al., 1992), comparable to our more precise CA-TIMS U-Pb zircon age. The unit is lithologically similar to exposures near Yehiniko Lake described herein. The unit is interpreted as largely subaerial, except for rare thin marine volcanic rocks locally near the base, and we correlate it with the Sister Mary unit of the Horn Mountain Formation. Near the top of the andesitic unit are local epiclastic beds (Fig. 26), and they are locally overlain by a subaerial pink flow-banded rhyolite flow that returned a 175 +4/-1 Ma U-Pb zircon age (Brown et al., 1996). The age is based on a single strongly air abraded zircon fraction, all other unabraded fractions are discordant (interpreted to result from Pb loss; Brown et al., 1992). The felsic unit is in turn overlain by an up to 200 m thick unit of basalt flows and pillow basalt breccia, largely interpreted to be deposited subaqueously. The upper felsic and mafic units west of Yehiniko Lake are lithologically similar and have a similar stratigraphic position as felsic and overlying mafic volcanic rocks of the Zuback unit in the Dease Lake map area, albeit the former returned an older multi-grain U-Pb zircon age. Because inheritance is common in rhyolite of the upper Hazelton Group (e.g., Nelson et al., 2018; this study, see Section 4.1.2.), further geochronological analysis is warranted. The volcanic rocks are unconformably overlain by polymictic conglomerate and sandstone of unknown age, assigned by Brown et al. (1996) to the Sustut Group (Upper Cretaceous to Lower Paleocene). The unconformity is inferred to span >75 m.y. and may indicate a significant period of erosion; as a result, the upper Hazelton Group thickness estimate for this area is considered a minimum.

4.1.5. Lisadele Lake and Sam batholith areas

Several large Stikine plutonic suite (Late Triassic) intrusions mark the continuation of the Stuhini arc towards the northwest (Fig. 2). They include the Sam, Moosehorn, and other satellite stocks (Souther, 1971; Bradford and Brown, 1993) which returned ca. 229-217 Ma U-Pb zircon ages (Oliver and Gabites, 1993; Takaichi and Johnson, 2012; Takaichi, 2013; Zagorevski et al., 2015; Mihalynuk et al., 2016). Souther (1971) described at least 3.3 km of sedimentary rocks of the Takwahoni Formation (Laberge Group) unconformably atop Late Triassic rocks, and reported Pliensbachian, early Toarcian, and middle Bajocian fossils. It should be noted that in 1980 the early Bajocian was formally changed to the Aalenian stage, and the middle Bajocian to early Bajocian. Detailed stratigraphic studies in the Lisadele Lake area show nearly 3 km of sedimentary strata unconformably overlying the Stuhini Group; the sedimentary rocks contain early Pliensbachian, late Pliensbachian, early, middle and late Toarcian, and early Bajocian fossils (Mihalynuk et al., 1995; Mihalynuk et al., 2004; Shirmohammad et al., 2011). The basal 150 m of the succession did not yield fossils, and its age is unconstrained. Previously the entire succession was assigned to the Takwahoni Formation (Laberge Group). However, Shirmohammad et al. (2011) reassigned the uppermost chert-pebble conglomerate and immediately underlying 100 m of black mudstone (early Bajocian) to the Bowser Lake Group, a reassignment that is followed here for all other Bajocian strata in the region. U-Pb detrital zircon samples from the Laberge Group (Shirmohammad et al., 2011; Kellett and Iraheta Muniz, 2019) yielded Late Triassic, and Pliensbachian to early Toarcian maximum depositional ages (Fig. 27), with Late Triassic peaks likely reflecting derivation from erosion of Stikine plutonic suite intrusions. A U-Pb detrital zircon sample from the overlying Bowser Lake Group (Kellett and Iraheta Muniz, 2019) shows a Callovian maximum depositional age (Fig. 27). Farther northwest, the Willison Bay pluton (Stikine plutonic suite, Late Triassic; Fig. 2) is unconformably overlain by conglomerate and sandstone (Mihalynuk, 1999), with a sandstone sample returning a Jurassic U-Pb detrital zircon maximum depositional age, suggesting correlation with the Laberge Group (Zagorevski et al., 2015).

4.2. Spatial variation of Bowser Lake Group strata (Bajocian and younger) atop the Stuhini arc

In the Mount Blair and eastern Dease Lake map area, the Horn Mountain Formation (upper Hazelton Group) is conformably overlain by the newly defined Mount Blair Formation (Middle-Upper Jurassic, Bowser Lake Group). The Mount Blair Formation represents a unique subaerial unit of siltstone, sandstone, chert clast-bearing conglomerate, mafic flows, and mafic fragmental volcanic rocks. A precise 170.99 ±0.13 Ma CA-TIMS U-Pb zircon age on immediately underlying volcanic rocks (van Straaten et al., 2022b) constrains the onset of deposition of erosional products from the Stikinia-Cache Creek tectonic welt. A thick succession of chert and limestone clast-bearing pebble to cobble conglomerate in the Dease Lake map area is interpreted to have formed close to range-front faults along the building orogen. This coarse facies transitions southward to interbedded subaerial siltstone, sandstone, chert clast-bearing conglomerate and mafic volcanic rocks (van Straaten and Bichlmaier, 2018).

Bajocian and younger marine sedimentary rocks of the Bowser Lake Group are recorded in the centre and rarely east of the Dease Lake map area (van Straaten and Nelson, 2016; van Straaten and Bichlmaier, 2018; van Straaten et al., 2022b), and at Lisadele Lake (Shirmohammad et al., 2011). Together with the Mount Blair Formation, these occurrences represent the oldest documented rocks in the Bowser Lake Group. Farther south within the contiguous Bowser basin (Fig. 2), rocks at the base of the Bower Lake Group get progressively younger from north to south. Basal strata in the northern part of the contiguous Bowser basin 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).

5. Conclusions

Stratigraphic studies presented here focus on Late Triassic to Jurassic strata in four study areas along the Stikine arch and compare them to well-studied successions in the Dease Lake area. The oldest units investigated in this study include Stuhini Group mafic volcanic rocks (Upper Triassic) cut by Stikine plutonic suite intrusions (Late Triassic). I provide two new ca. 220.36 ±0.13 and 218.89 ±0.12 Ma CA-TIMS U-Pb zircon ages for the Stikine plutonic suite, which conform to a previously established ca. 229-216 Ma age range. These units define major volcano-plutonic centres that make up the east-facing Stuhini arc.

Stuhini arc rocks are unconformably overlain by late Early to Middle Jurassic volcano-sedimentary strata of the upper Hazelton Group and coeval strata. The unconformity spans at least 30 m.y. and indicates a prolonged period of uplift and erosion of the Stuhini arc that followed cessation of subduction and termination of arc activity in the latest Triassic.

This study shows that thick (1-5 km) successions of upper Hazelton Group rocks extend for at least ~275 km along the Stikine arch. A uniform stratigraphic nomenclature for these successions includes basal sedimentary rocks of the Spatsizi Formation and overlying volcanic rocks of the Horn Mountain Formation. Volcano-sedimentary units are lithologically similar along the entire length of the belt, typically showing a transition from early submarine volcano-sedimentary facies to overlying subaerial volcanic facies. Where preserved, uppermost volcanic facies range from subaqueous to subaerial. The thickest successions are in the Spatsizi and Dease Lake areas (>4.8 km), with thinner successions in the Yehiniko Lake and Mount Blair areas (>0.7-1 km). In the Yehiniko Lake and Dease Lake areas, the onset of sedimentary deposition atop the basal unconformity is constrained to late Pliensbachian to early Toarcian. New geochronological results show that Horn Mountain volcanism started ca. 185 Ma in the Yehiniko area, and the latest Pliensbachian to ca. 182 Ma in the Spatsizi area. Horn Mountain volcanism in the Yehiniko Lake and Spatsizi areas continued until at least the end of the Toarcian. Minor Horn Mountain volcanic activity in the Dease Lake area probably started as early as late Pliensbachian to middle Toarcian. However, voluminous and extensive volcanism occurred from ca. 175-171 Ma (Aalenian); this represents a significantly later onset of main-stage volcanism compared to the Yehiniko Lake and Spatsizi areas. Volcanic activity in the Dease Lake area is centred on a Late Triassic pluton, with primary volcanic strata giving way westward to reworked volcanic strata. In the Mount Blair area, volcanism may have started later than in the eastern Dease Lake area but shows similarities to exposures in the western Dease Lake area. The general pattern is permissive of an eastward younging trend in the onset of upper Hazelton Group deposition atop the Stuhini arc.

Horn Mountain volcanism does not record normal subduction-related arc magmatism, because it formed well after cessation of subduction in the latest Triassic. Instead, upper Hazelton Group volcanism occurred during accretion of the Quesnel, Cache Creek, and Stikine terranes to Ancestral North America, and was possibly generated by re-melting of subduction-modified lithosphere during accretion (van Straaten and Nelson, 2016). The upper Hazelton Group successions are coincident with major Late Triassic volcano-plutonic centres, suggesting that earlier arc magmatic reservoirs may have been tapped.

Farther northwest along the Stikine arch, the Stuhini arc is unconformably overlain by thick (~3 km) Pliensbachian to Toarcian marine siliciclastic rocks of the Laberge Group, part of the Whitehorse trough. It represents a syn-collisional depositional basin, formed as a result of collision between Stikinia and Yukon-Tanana (Colpron et al., 2022).

In the Lisadele Lake and parts of the Dease Lake area, upper Hazelton Group and coeval Laberge Group strata are overlain by marine siliciclastic rocks of the Bowser Lake Group. In the eastern part of the Dease Lake area and in the Mount Blair area, the upper Hazelton Group is conformably overlain by terrestrial siliciclastic and subaerial mafic volcanic rocks of the Mount Blair Formation (newly defined herein, part of the Bowser Lake Group). These successions represent the oldest preserved Bowser Lake Group and indicate the onset of deposition of erosional products from the Stikinia-Cache Creek tectonic welt.

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References cited

Aberhan, M., and Pálfy, J., 1996. A low oxygen tolerant East Pacific flat clam (Posidonotis semiplicata) from the Lower Jurassic of the Canadian Cordillera. Canadian Journal of Earth Sciences, 33, 993-1006. <https://doi.org/10.1139/e96-075>

Alldrick, D.J., 1993. Geology and metallogeny of the Stewart mining camp, northwestern British Columbia. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey, Bulletin 85, 105 p.

Anderson, R.G., 1984. Late Triassic and Jurassic magmatism along the Stikine Arch and the geology of the Stikine batholith, north-central British Columbia. In: Current Research, Part A, Geological Survey of Canada Paper 84-1A, pp. 67-73.

Bradford, J.A., and Brown, D.A., 1993. Geology, Mineral Occurrences and Geochemistry of the Bearskin and Tatsamenie Lakes Area, Northwestern B.C. British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Open File 1993-01,1:50,000 scale.

Breitsprecher, K., and Mortensen, J.K., 2004. BC age 2004A-1: A database of isotopic age determinations for rock units from British Columbia. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2004-03.

Brown, D.A., Greig, C.J., Bevier, M.L., and McClelland, W.C., 1992. U-Pb zircon ages for the Hazelton Group and Cone Mountain and Limpoke plutonis, Telegraph Creek map area, northwestern British Columbia: age constraints on volcanism and deformation. In: Radiogenic Age and Isotopic Studies: Report 6, Geological Survey of Canada, Paper 92-2, pp. 153-162.

Brown, D.A., Gunning, M.H., and Greig, C.J., 1996. The Stikine project: Geology of western Telegraph Creek map area, northwestern British Columbia. British Columbia Ministry of Employment and Investment, British Columbia Geological Survey Bulletin 95, 130 p.

Campbell, M.E., 2021. The geology and geochemistry of the Sulphurets district porphyry Au-Cu-Mo deposits, British Columbia, Canada: Insights from a long-lived, gold-enriched porphyry district. Unpublished Ph.D. thesis, Oregon State University, 238 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 September, 2023). <https://stratigraphy.org/ICSchart/ChronostratChart2023-09.pdf>

Colpron, M., 2020. Yukon terranes-A digital atlas of terranes for the northern Cordillera. Yukon Geological Survey. <https://data.geology.gov.yk.ca/Compilation/2#InfoTab>

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. <https://doi.org/10.1130/L451.1>

Colpron, M., Sack, P.J., Crowley, J.L., Beranek, L.P., and Allan, M.M., 2022. Late Triassic to Jurassic magmatic and tectonic evolution of the Intermontane terranes in Yukon, Northern Canadian Cordillera: Transition from arc to syn-collisional magmatism and post-collisional lithospheric delamination. Tectonics, 41, article e2021tc007060. <https://doi.org/10.1029/2021TC007060>

Coutts, D.S., Matthews, W.A., and Hubbard, S.M., 2019. Assessment of widely used methods to derive depositional ages from detrital zircon populations. Geoscience Frontiers, 10, 1421-1435. <https://doi.org/10.1016/j.gsf.2018.11.002>

Cui, Y., Hickin, A.S., Schiarizza, P., and Diakow, L.J., 2017. British Columbia digital geology. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2017-08, 9 p.

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 McNicoll, V.J., 1993. U-Pb age for the Jurassic McEwan Creek pluton, north-central British Columbia: regional setting and implications for the Toarcian stage boundary. In: Radiogenic age and isotopic studies: Report 7, Geological Survey of Canada Paper 93-2, pp. 91-97.

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. In: Sears, J.W., Harms, T.A., and Evenchick, C.A., (Eds.), Whence the Mountains? Inquiries into the Evolution of Orogenic Systems: A Volume in Honor of Raymond A. Price. Geological Society of America Special Paper 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. <https://doi.org/10.2113/gscpgbull.58.3.235>

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

Gabrielse, H., 2003. Geology, Kechika River, British Columbia. Geological Survey of Canada, Open File 1633, 1:250,000 scale.

Gabrielse, H., Doods, C.J., Mansy, J.L., and Eisenbacher, G.H., 1977. Geology of Toodoggone and Ware map areas, British Columbia. Geological Survey of Canada, Open File 483, 1:250,000 scale.

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. <https://doi.org/10.1139/e2012-042>

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. <https://doi.org/10.1139/e81-040>

Henderson, J.R., Kirkham, R.V., Henderson, M.N., Payne, J.G., Wright, T.O., and Wright, R.L., 1992. Stratigraphy and structure of the Sulphurets area, British Columbia. In: Current Research, Part A, Cordillera and Pacific Margin, Geological Survey of Canada, Paper 92-1A, pp. 323-332.

Holbek, P.M., 1988. Geology and mineralization of the Stikine assemblage, Mess Creek area, northwestern British Columbia. Unpublished M.Sc. thesis, University of British Columbia, 175 p. <https://doi.org/10.14288/1.0052696>

Hollis, L., and Bailey, L., 2013. Assessment report on drilling, geological, geochemical and geophysical work conducted during 2012 at the GJ/Kinaskan copper-gold porphyry project. British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Assessment Report 33815, 60 p.

Hunt, P.A., and Roddick, J.C., 1987. A compilation of K-Ar ages, Report 17. In: Radiogenic age and isotopic studies: Report 1, Geological Survey of Canada Paper 87-2, pp. 143-210.

Jakobs, G., 1997. Toarcian (Early Jurassic) ammonoids from western North America. Geological Survey of Canada Bulletin 428, 144 p.

Jakobs, G.K., Smith, P.L., and Tipper, H.W., 1994. An ammonite zonation for the Toarcian (Lower Jurassic) of the North American Cordillera. Canadian Journal of Earth Sciences, 31, 919-942. <https://doi.org/10.1139/e94-083>

Kellett, D.A., and Iraheta Muniz, P., 2019. Detrital U-Pb zircon and ^{40}Ar/^{39}Ar muscovite geochronology of the Whitehorse trough, and surrounding rocks, Yukon and British Columbia. Geological Survey of Canada, Open File 8565, 33 p.

Logan, J.M., and Koyanagi, V.M., 1994. Geology and mineral deposits of the Galore Creek area. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey, Bulletin 92, 102 p.

Logan, J.M., Drobe, J.R., and McClelland, W.C., 2000. Geology of the Forrest Kerr-Mess Creek area, northwestern British Columbia. British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Bulletin 104, 132 p.

Ludwig, K.R., 2012. Isoplot 3.75. A geochronological toolkit for Microsoft Excel. Berkley Geochronology Center, Special Publication 5, 75 p.

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., Nelson, J., and Diakow, L.J., 1994. Cache Creek terrane entrapment: Oroclinal paradox within the Canadian Cordillera. Tectonics, 13, 575-595. <https://doi.org/10.1029/93TC03492>

Mihalynuk, M.G., Meldrum, D., Sears, S., and Johannson, G., 1995. Geology and mineralization of the Stuhini Creek area (104K/11). In: Geological Fieldwork 1994, British Columbia MInistry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 1995-01, pp. 321-342.

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, 910-922. <https://doi.org/10.1130/B25393.1>

Mihalynuk, M.G., Zagorevski, A., Joyce, N.L., and Creaser, R.A., 2016. Age of magmatism and mineralization at the Star (Sheslay, Copper Creek) copper porphyry prospect: Inception of the Late Triassic mineralized arc. In: Geological Fieldwork 2015, British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Paper 2016-1, pp. 65-75.

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

Nelson, J.L., and van Straaten, B.I., 2020. Recurrent syn- to post-subduction mineralization along deep crustal corridors in the Iskut-Stewart-Kitsault region of western Stikinia, northwestern British Columbia. In: Sharman, E. R., Lang, J. R., and Chapman, J.B., (Eds.), Porphyry Deposits of the Northwestern Cordillera of North America: A 25-Year Update, CIM Special Volume 57, pp. 149-211.

Nelson, J.L., Colpron, M., and Israel, S., 2013. The Cordillera of British Columbia, Yukon and Alaska: Tectonics and metallogeny.

In: Colpron, M., Bissig, T., Rusk, B. G., and Thompson, J. (Eds.), Tectonics, Metallogeny and Discovery: The North American Cordillera and Similar Accretionary Settings, Society of Economic Geologists Special Publication 17, pp. 53-110.

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 2017, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2018-1, pp. 15-38.

Nelson, J.L., van Straaten, B., and Friedman, R., 2022. Latest Triassic-Early Jurassic Stikine-Yukon-Tanana terrane collision and the onset of accretion in the Canadian Cordillera: Insights from Hazelton Group detrital zircon provenance and arc-back-arc configuration. Geosphere, 18, 670-696. <https://doi.org/10.1130/GES02444.1>

Oliver, J., and Gabites, J., 1993. Geochronology of rocks and polyphase deformation, Bearskin (Muddy) and Tatsamenie lakes district, northwestern British Columbia (104K/8, 1). In: Geological Fieldwork 1992, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 1993-1, pp. 177-188.

Pálfy, J., 1997. Calibration of the Jurassic time scale. Unpublished Ph.D. thesis, University of British Columbia, 170 p. <https://doi.org/10.14288/1.0052486>

Pálfy, J., Mortensen, J.K., Smith, P.L., Friedman, R.M., McNicoll, V., and Villeneuve, M., 2000. New U-Pb zircon ages integrated with ammonite biochronology from the Jurassic of the Canadian Cordillera. Canadian Journal of Earth Sciences, 37, 549-567. <https://doi.org/10.1139/e99-115>

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, 1:50,000 scale.

Rhys, D.A., 1993. Geology of the Snip Mine, and its relationship to the magmatic and deformational history of the Johnny Mountain area, northwestern British Columbia. Unpublished M.Sc. thesis, The University of British Columbia, Vancouver, B.C., Canada. <https://circle.ubc.ca/handle/2429/2173> (accessed April 12, 2012).

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. <https://doi.org/10.5604/17313708 .1114171>

Smith, P.L., Thomson, R.C., and Tipper, H.W., 1984. Lower and Middle Jurassic sediments and volcanics of the Spatsizi area, British Columbia. In: Current Research, Part A, Geological Survey of Canada Paper 84-1A, pp. 117-120.

Souther, J.G., 1971. Geology and mineral deposits of Tulsequah map area, British Columbia (104K). Geological Survey of Canada, Memoir 362, 84 p.

Souther, J.G., 1972. Telegraph Creek map-area, British Columbia (104G). Geological Survey of Canada, Paper 71-44 and Map 11-1971, 36 p.

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

Takaichi, M., and Johnson, C., 2012. Assessment Report on the 2011/2012 Geological, Geochemical, and Geophysical program at the Eagle Property, BC, Canada. British Columbia Ministry of Energy and Mines, British Columbia Geological Survey Assessment Report 33330, 27 p.

Thomson, R.C., and Smith, P.L., 1992. Pliensbachian (Lower Jurassic) biostratigraphy and ammonite fauna of the Spatsizi area, north-central British Columbia. Geological Survey of Canada Bulletin 437, 87 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. <https://doi.org/10.1139/e86-182>

Thorkelson, D.J., 1992. Volcanic and tectonic evolution of the Hazelton group in Spatsizi River (104H) map-area, north-central British Columbia. Unpublished Ph.D. thesis, Carleton University, Ottawa, Ontario, Canada, 281 p.

Tipper, H.W., 1986. Report on Pliensbachian fossils collected in the Spatsizi map area 104H collected between 1975 and 1985 and submitted for identification in November 1985. Geological Survey of Canada, Paleontological Report J19-1986-HWT.

van Drecht, L.H., Beranek, L.P., Colpron, M., and Wiest, A.C., 2022. Development of the Whitehorse trough as a strike-slip basin during Early to Middle Jurassic arc-continent collision in the Canadian Cordillera. Geosphere, 18, 1538-1562. <https://doi.org/10.1130/GES02510.1>

van Straaten, B.I., and Bichlmaier, S.J., 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 and Mines, British Columbia Geological Survey Paper 2018-1, pp. 39-66.

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 Mines and Petroleum Resources, 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., Logan, J.M., Hunter, R.C., Nelson, J.L., and Miller, E.A., 2022a. Igneous lithogeochemistry data for the Dease Lake, Kitsault River, Galore Creek, Telegraph Creek, Foremore, and other areas in northwestern British Columbia. British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey GeoFile 2022-12, 14 p.

van Straaten, B.I., Logan, J.M., Nelson, J.L., Moynihan, D.P., Diakow, L.J., Gibson, R., Bichlmaier, S.J., Wearmouth, C.D., Friedman, R.M., Golding, M.L., Miller, E.A., and Poulton, T.P., 2022b. Bedrock geology of the Dease Lake area. British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey Geoscience Map 2022-01, 1:100,000 scale.

van Straaten, B.I., Friedman, R.M., and Camacho, A., 2023. Stratigraphy of the Stuhini Group (Upper Triassic) in the Galore Creek area, northwestern British Columbia. In: Geological Fieldwork 2022, British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey Paper 2023-01, pp. 33-49.

Wanless, R.K., Stevens, R.D., Lachance, G.R., and DeLabio, R.N., 1979. Age determinations and geological studies: K-Ar isotopic ages, report 14. Geological Survey of Canada Paper 79-2, 67 p.

Zagorevski, A., Mihalynuk, M.G., Joyce, N., Kellett, D.A., and Milidragovic, D., 2015. Characterization of volcanic and intrusive rocks across the British Columbia-Yukon border, GEM 2 Cordillera. Geological Survey of Canada, Open File 7956, 13 p.