Stratigraphic Classification and Geochronology Within the Hazelton Group, Stewart Mining Camp, Northwestern British Columbia (Parts of NTS 104A, B)

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Introduction

The Stewart mining camp is a prolific historical region within the 'Golden Triangle', a mineral district in northwestern British Columbia (BC; Figure 1). Zinc-silver-lead–bearing volcanogenic massive-sulphide (VMS) deposits such as the BA occurrence and the Mountain Boy epithermal silver-copper-gold occurrence (K.M. Powers, K.E.L. Rubingh and S.L.L. Barker, unpublished poster, 2023), both properties owned and operated by MTB Metals Corp., and structurally controlled gold deposits (Scottie Resources Corp.) in the Stewart mining camp, are hosted within the Hazelton Group. The Hazelton Group is a package of volcanic, volcaniclastic and cogenetic sedimentary rocks of Jurassic age, which in regions remains relatively broadly lumped together as packages of undifferentiated volcanic rocks. A large part of the information gap is due to the rugged and remote nature of northwestern BC. Detailed geological descriptions of the volcanic rocks in the camp, as defined by previous researchers, are mafic to felsic intrusions, flows, pyroclastic and volcaniclastic rocks, as well as various clastic sediments ranging from mudstones to limestone, to boulder conglomerates (Marsden and Thorkelson, 1992; Alldrick, 1993; Gordee, 2006; Gagnon et al., 2012; Nelson and Kyba, 2014; Barresi et al., 2015; Nelson et al., 2022). Past work focused on the western portion of the camp, centring on larger past-producing mines such as the Premier mine that produced 56.7 million g Au and 1300 million g Ag; the Granduc mine that produced 190 million kg Cu, 124 million g Ag and 2 million g Au; and the Scottie Gold mine that yielded 3 million g Au (MINFILE 104B 021, BC Geological Survey, 2023b; Alldrick, 1993; Bird et al., 2020). The largest operating of these is the Premier Gold project, with an indicated resource of 28 million g Au (Bird et al., 2020). Fieldwork in 2023 focused on Hazelton Group stratigraphy, away from previously described regions.

The objective of this study is to refine the Hazelton Group stratigraphy and to place within that stratigraphy the BA Zn-Ag-Pb VMS and Mountain Boy epithermal Ag-Cu-Zn occurrences (Figure 2). Of added interest is the stratigraphic variability between these two deposits, which are hosted in rocks that are broadly recognized as belonging to the Hazelton Group. Five lithostratigraphic sections were selected due to their excellent outcrop exposure along vertical cliff sections that could be studied, from the oldest to the youngest unit, along a 17 km strike that is perpendicular to the dip of the bedding. These sections were mapped at the 1:1000 scale (Figure 2), with the goal of collecting representative rock samples for geochemical and geochronological analyses from a broad section of the stratigraphic column. The stratigraphic sections were completed to help better define textural and chemical changes through detailed mapping across major contacts in the Hazelton Group. In previous regional mapping, such as the map at 1:50 000 scale of Alldrick (1994) or the maps at 1:250 000 scale and 1:100 000 scale of Grove (1973), these rocks were recognized as rocks of the Hazelton Group or were designated 'undivided volcanic rocks'. Refinement within the stratigraphy will also allow for comparison of the host formation of the BA Zn-Ag-Pb VMS occurrence to that of the Eskay Creek Au-Ag-Zn-Cu-Pb VMS occurrence, which has been extensively studied and dated within the Iskut River formation, and is regionally equivalent to the Quock Formation of the upper Hazelton Group.

This study is part of a larger project focusing on improving the understanding of the Hazelton Group in the Golden Triangle through lithostratigraphy, geochemistry and geochronology to refine the relationship between volcanic stratigraphy and mineralization within the region. Three

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[1] *The lead author is a 2023 Geoscience BC Scholarship recipient.*

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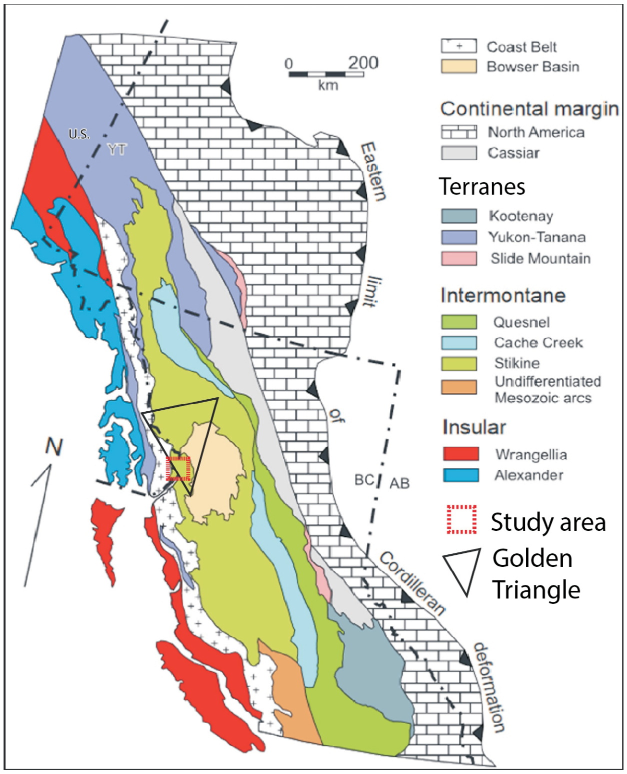

Figure 1. Major terranes of British Columbia and Yukon (modified from Gagnon et al., 2012). The red box indicates the location of the study area shown in Figure 2.

measured sections and the preliminary interpretations of the observed rock units, as well as their relationships to each other and to published literature, are presented in this paper.

Background

Regional Geology

The Stikine terrane of northwestern North America (Figure 1) makes up a portion of the Intermontane terranes that formed during the accretion of an outboard island arc onto the western margin of Laurentia in the Early to Late Jurassic (Anderson and Thorkelson, 1990). Stikine is one of three Intermontane terranes of western Laurentia, the others being the Quesnel and Cache Creek terranes (Gagnon et al., 2012). Stikinia has a tapered shape, with a width of less than 100 km at its northern boundary in the Yukon as well as at its southern boundary, just north of the border between Canada and the United States. Its maximum width is over 500 km in northern BC at the location of the Golden Triangle (Figure 1; Marsden and Thorkelson, 1992; Alldrick, 1993; Gordee, 2006; Gagnon et al., 2012; Nelson and Kyba, 2014; Barresi et al., 2015; Nelson et al., 2022). Three volcanic successions composed of volcanic rocks, volcaniclastic rocks and clastic sedimentary rocks make up Stikinia, with each succession separated by an unconformity. The oldest consists of Devonian to Permian arc-related volcanic and plutonic units and accompanying sedimentary strata, which make up the Stikine assemblage and Asitka Group. The next succession comprises arc-related magmatic units and accompanying sedimentary rocks of the Middle to Late Triassic Stuhini and Takla groups. The last succession, capping the Stikine terrane, is the Jurassic Hazelton Group (Alldrick, 1993; Nelson and Kyba, 2014). In the Stewart mining camp and further north (Figure 2), economically important mineral deposits, such as Scottie Gold and Premier, are hosted in the volcanic strata of the lower Hazelton Group, whereas deposits such as Eskay Creek are hosted within the volcano-sedimentary strata of the upper Hazelton Group (Mortensen et al., 2004).

Hazelton Group Stratigraphy

The following section is a description of the Hazelton Group stratigraphy (Figure 3), from the oldest to the youngest unit, as defined by Marsden and Thorkelson (1992), Alldrick (1993), Gordee (2006), Gagnon et al. (2012), Nelson and Kyba (2014), Barresi et al. (2015), Nelson et al. (2018), Brueckner et al. (2021) and Nelson et al. (2022).

Jack Formation 205.5–201 Ma

The Jack Formation was first described as a 'transitional unit' (Anderson and Thorkelson, 1990) and is a largely sedimentary unit. This formation unconformably to disconformably overlies arc volcanism of the earlier Triassic Stuhini Group (Henderson et al., 1992). The Jack Formation, was originally defined as a purely siliciclastic unit composed of cobble to boulder conglomerates (Anderson and Thorkelson, 1990). More recently, Nelson and Kyba (2014) described quartz-bearing arkosic sandstone, granulestone, and thinly bedded siltstone and mudstone, along with andesitic volcaniclastic rocks, in direct gradational contact with identical siliciclastic strata above and below in sections in the Bruce glacier and Treaty glacier areas, which lie 110 km to the north of Stewart (Figure 1).

Betty Creek Formation 201–181.5 Ma

The lower members (Figure 3) constitute a volcaniclastic sequence of massive to well-bedded ash tuffs, turbidites, dust, lapilli and breccia tuffs, with varying abundances of plagioclase and hornblende. The upper tuffs in this succession, which has been referred to as the Unuk River andesite member, include fragmental units that contain lithic fragments and pumice, as well as crystal fragments. Overlying this package, most prominently within the Stewart mining camp area, are extrusive, locally coarse-grained flows and tuffs of the Premier porphyry intrusions (194 ±2 Ma), as well as cogenetic intrusive units (Alldrick, 1985, 1993; Anderson and Thorkelson, 1990). These intrusive rocks are both economically and stratigraphically significant as they host the gold-rich Premier mine and are a distinctive marker unit in the region, respectively. (Alldrick, 1989, 1993; Anderson and Thorkelson, 1990; Marsden and Thor-

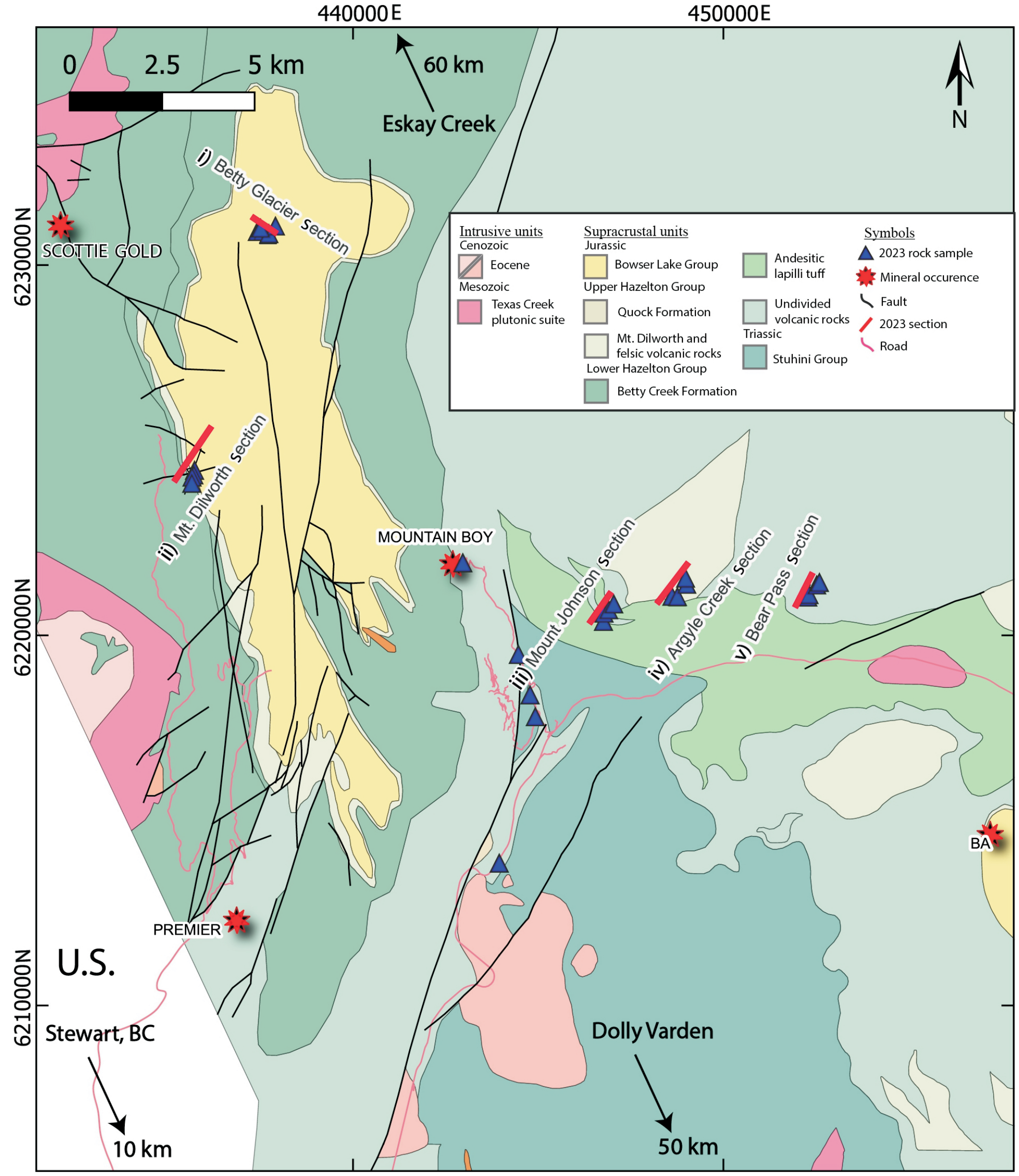

Figure 2. Regional geology of the Stewart mining camp study area (modified from BC Geological Survey, 2023a). The five sections studied are: i) Betty Glacier, ii) Mount Dilworth, iii) Mount Johnson, iv) Argyle Creek and v) Bear Pass (labelled parallel to their length). Additional sample sites located outside of these sections are shown at the Mountain Boy silver prospect, as well as along roads. The distance between the Betty Glacier section and the Bear Pass section is 17 km. All co-ordinates are in UTM Zone 9, NAD 83.

kelson, 1992; Lewis et al., 2001; Gordee, 2006; Gagnon et al., 2012).

The upper members (Figure 3), which are distinguishable from the Unuk River andesite, can be divided into various mafic volcanic flows that may directly overlie the Jack Formation or the Premier porphyry intrusions of the Unuk River andesite. These flows consist of interbedded ‘dust’, lapilli, feldspar crystal tuffs and porphyritic felsic lava flows (Alldrick et al., 1993) overlain by pyroclastic flows consisting of pumice-rich rocks. Interbedded among these flows are volcaniclastic rocks characterized by way-up features such as load casts, ball-and-pillow structures, flame structures, graded bedding, as well as centimetre-scale growth faults (Anderson and Thorkelson, 1990). Another sedimentary sequence caps the package; this sequence is distinctive due to its variably altered, brightly maroon and green sedimentary rocks that range from mudstone to coarse boulder conglomerate.

Mount Dilworth Formation 181.5–177 Ma

The contact with the underlying Betty Creek Formation (Figure 3) varies throughout the Golden Triangle and is either marked by limestone and chert beds or by the stratigraphic position where felsic volcanic lithofacies predominate

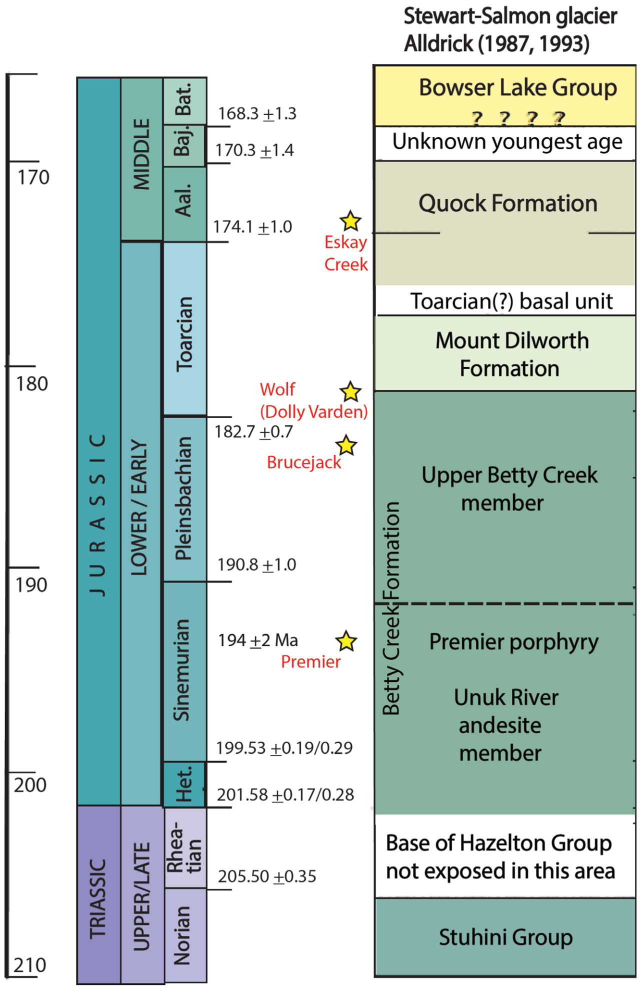

Figure 3. Generalized stratigraphy of the lower and upper units of the Hazelton Group in the Stewart mining camp (modified from Nelson et al., 2018 and Brueckner et al., 2021). Yellow stars indicate the U-Pb ages of major deposits in the Stewart camp and further north, such as at Brucejack and Eskay Creek. Premier U-Pb age from Alldrick (1985); Wolf U-Pb age (Dolly Varden) from Hunter and van Straaten (2020). Abbreviations: Aal., Aalenian; Baj., Bajocian; Bath., Bathonian; Het., Hettangian.

over more distal and intermediate compositions of the Betty Creek Formation (Alldrick, 1989, 1993; Anderson and Thorkelson, 1990; Marsden and Thorkelson, 1992; Lewis et al., 2001; Gordee, 2006; Gagnon, 2012). Anderson and Thorkelson (1990) described the variability within the Mount Dilworth Formation as characterized by felsic white, maroon or green flow-layered tuff, tuff breccia and dust tuff. These rock types show varying degrees of pumice welding and texturally range from aphyric to plagioclase-phyric.

Quock Formation 177–170 Ma

The sedimentary rocks of the Quock Formation conformably to unconformably overlie the Mount Dilworth Formation (Figure 3). The Quock Formation is regionally extensive and consists of basal, limey, belemnite-rich sandstone and carbonate-cemented grit with limestone nodules (Anderson and Thorkelson, 1990; Marsden and Thorkelson, 1992; Alldrick, 1993). Overlying this are ‘pyjama beds’, described by Tipper and Richards (1976) as thinly bedded siliceous mudstones and tuffs, which are distinctive due to their rhythmic beige and brown bands. In the Eskay mining camp, the Quock Formation is equivalent to the Iskut River formation, which overlies a series of rhyolite flow-dome complexes dated at 175 ±2 Ma. Here the Quock Formation (Iskut River formation) hosts the prolific Eskay Creek VMS deposit (Gagnon et al., 2012).

Methodology

During the 2023 field season, detailed volcano-stratigraphic mapping was carried out along five vertical sections of Hazelton Group rocks (Figure 2). These sections were chosen due to their orientation perpendicular to bedding, which allowed mapping of individual lithofacies and lateral facies changes along strike; the sections were also chosen as they cover a large lateral map extent, with 17 km separating the easternmost from the westernmost section. Details on the map were recorded at the 1:1000 scale to effectively record major changes in the depositional environment, lithology and key field relationships between volcanic facies. The sections ranged in vertical thickness from 100 to >375 m.

Along with the mapping of these continuous outcrop sections, samples were strategically collected from key stratigraphic units. Three types of sample were collected during fieldwork: representative rocks, as well as samples for whole-rock geochemical and for geochronological analyses (sample locations shown in Figure 2). Representative samples will be used primarily as polished rock samples or to create petrographic thin sections, if more detailed descriptions of mineralogy are deemed necessary. The analysis results of the outcrop samples collected for whole-rock geochemistry will aid in the correlation of texturally similar rocks observed throughout the study area. The samples for whole-rock analyses were collected only from the visually least altered, most homogeneous and representative portions of the outcrop, thus reducing the risk of potential chemical contamination and increasing the level of confidence in geochemical correlations established within the stratigraphy. Different types of outcrop samples were collected for U-Pb geochronological analysis. The first type was collected from coherent volcanic flows, where the textural and field evidence allowed their classification as such. These samples will help determine the crystallization age of zircons within coherent sections of the Hazelton Group stratigraphy (Figure 3). The second type of U-Pb geochronological sample consists of detrital zircons. The results of the analyses of these samples selected from sandy layers within clastic units at the base of the Quock Formation will aid in confirming both the formation and the erosional period that this unconformity represents. To aid in the correlation of studied sections, other samples for U-Pb detrital zircon radiometric dating were collected from sandy/silty layers of volcaniclastic sediments of the lower and upper Hazelton volcanic pile, which occur throughout the stratigraphy.

Stratigraphic Sections

Three of the five studied sections shown on Figure 2 are described here in detail. These sections were chosen as representative of the lower through upper Hazelton Group stratigraphy that is present within the Stewart mining camp along a strike of 17 km. The sections are referred to on the map in Figure 2 as 'Mount Johnson section' (Figure 4), 'Bear Pass section' (Figure 5) and 'Betty Glacier section' (Figure 6).

Mount Johnson Section

The Mount Johnson section (Figure 4) was chosen as the westernmost vertical section within the east- trending Bear River valley. The stratigraphy at this location has a general strike of 300° and dips moderately between 30 and 40°; there are flame structures in the fine sediments that show clear evidence of way-up features, with units identified as being upright.

Volcaniclastic and Clastic Sediments

The base of the measured section is dominated by a heterolithic volcaniclastic conglomerate. This unit weathers beige in outcrop and is green to grey on fresh surfaces. Aphanitic, matrix-supported, subangular to subrounded clasts make up 30% of the rock and range from 1 to 5 cm in size. These clasts (Figure 4a) consist of a mixture of light-coloured, pumice-rich felsic units and darker plagioclase-phyric mafic clasts. Interbedded within this massively bedded unit are sequences of coarse sand, one of which was sampled for U-Pb geochronology. The conglomerate unit grades into finely interbedded silt and sandstone. This unit has well-defined bedding and way-up-defining flame structures at the interface between the sand and silt layers.

Pumice-Rich Sediments

Conformably overlying the sedimentary package is a gradational transition into interbedded pumice and very coarse-grained sandstone (Figure 4b). Bedding within the darker bands of this package is defined by densely packed, clast-supported, flattened pumice that ranges from 0.1 to 1 cm in size. The lighter bands are beds of very coarse-grained, heterolithic, arkosic arenite sandstone containing clasts consisting of rounded volcanic granules with rare jasper. A geochronological sample was collected from a 10 m thick bed of this very coarse-grained sandstone, whereas a geochemical sample was collected from a pumice-rich bed and a massive section of sandy limestone. Topping this interbedded pumice and sandstone is a thin unit of monolithic conglomerate comprising pebble-sized mudstone clasts (1–2 cm), which fines upward over 2 m. The upper 25 m of this member marks a distinct increase in the presence of sandy limestone, including a succession 5 m thick locally showing deformation defined by tight folding of the less competent limestone that caps the unit.

Pillow Basalts

The lime-rich sediments are disrupted sharply by 50 m of pillowed flows, which include pillow breccias. The best example of these pillowed flows and disaggregated breccias is in Figure 4c, where pillow lobes are draped by the same sand-rich limestone as below. Pillows are vesicle-rich, orbicular in shape and, on average, 30 cm in diameter. At the top of this pillow sequence are reworked pillows that show alignment with bedding supported by a limey mudstone and coarse-grained clastic sandstone. Within this outcrop, the density of pillows varies, with zones of densely stacked pillows interbedded with rubble zones of angular clasts of clastic and volcanic rocks. A pillow 30 cm in size was collected as a sample for whole-rock geochemistry.

Crystal-Rich Tuff

Overlaying the pillow rubble is a normally graded, pumice-rich conglomerate. At the base is a thin limestone and volcaniclastic matrix-supported angular boulder conglomerate 2 m thick, with clasts that reach up to 70 cm in size. Figure 4d shows the grading in bedding-aligned pumice that transitions from densely packed 20 cm clasts through to trace 1 cm flattened clasts over a 15 m vertical section. Capping the measured section is a white-weathering unit of crystal tuff that shows massive bedding for the first 15 m, then transitions into fine 1 cm laminations of coarse crystals. The rock consists of 20% plagioclase, 5% amphibole and 5% quartz, with a fine lithic groundmass. This unit is interpreted in field observations as a felsic crystal tuff that appears to continue at least another 50 m upsection to a point at which the mountain flattens out.

Bear Pass Section

The Bear Pass section is located 5.5 km to the east of, and topographically above, the Mount Johnson section. Measurements in this area indicate bedding striking 265° and dipping 45°. As a result, just as at Mount Johnson, stratigraphy can be followed perpendicularly by walking uphill for a measured vertical section of 375 m. The observed stratigraphy, from bottom to top, is outlined below.

Volcaniclastic and Clastic Sediments

The base of this measured section generally constitutes the first half of the observed outcrop. It is primarily composed of interbedded sandstone and conglomerate units of varying thicknesses. The conglomerate consists of angular to subangular, aphanitic, matrix-supported heterolithic clasts (1–5 cm) of red vesicular volcanic rocks (20%), and

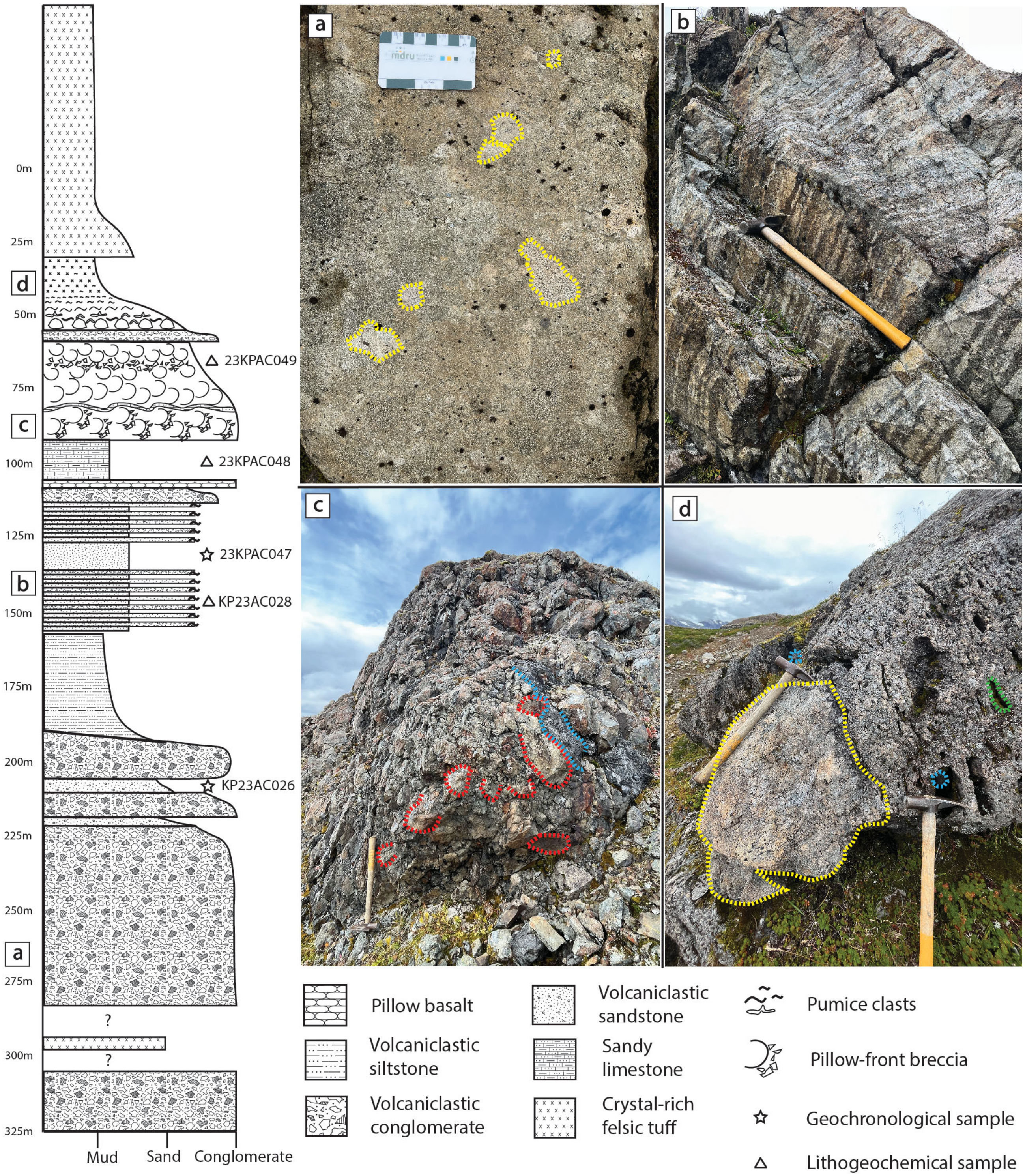

Figure 4. Stratigraphy of the Mount Johnson section, with corresponding field photographs of units showing **a)** clasts (outlined in yellow) supported in an aphanitic groundmass forming a massively bedded unit within the interpreted Betty Creek Formation; **b)** interbedded pumice-rich layers (dark) and lighter-coloured, coarse-grained volcaniclastic sandstone; **c)** pillows (outlined in red) cut in cross-section with spalling brecciation textures, draped by in situ sandy limestone (outlined in blue); **d)** large basal boulders (outlined in yellow) and in situ sandy limestone (outlined in blue) at the base of a coarse-grained, pumice-rich succession (outlined in green) that fines upward into fine pumice and ash.

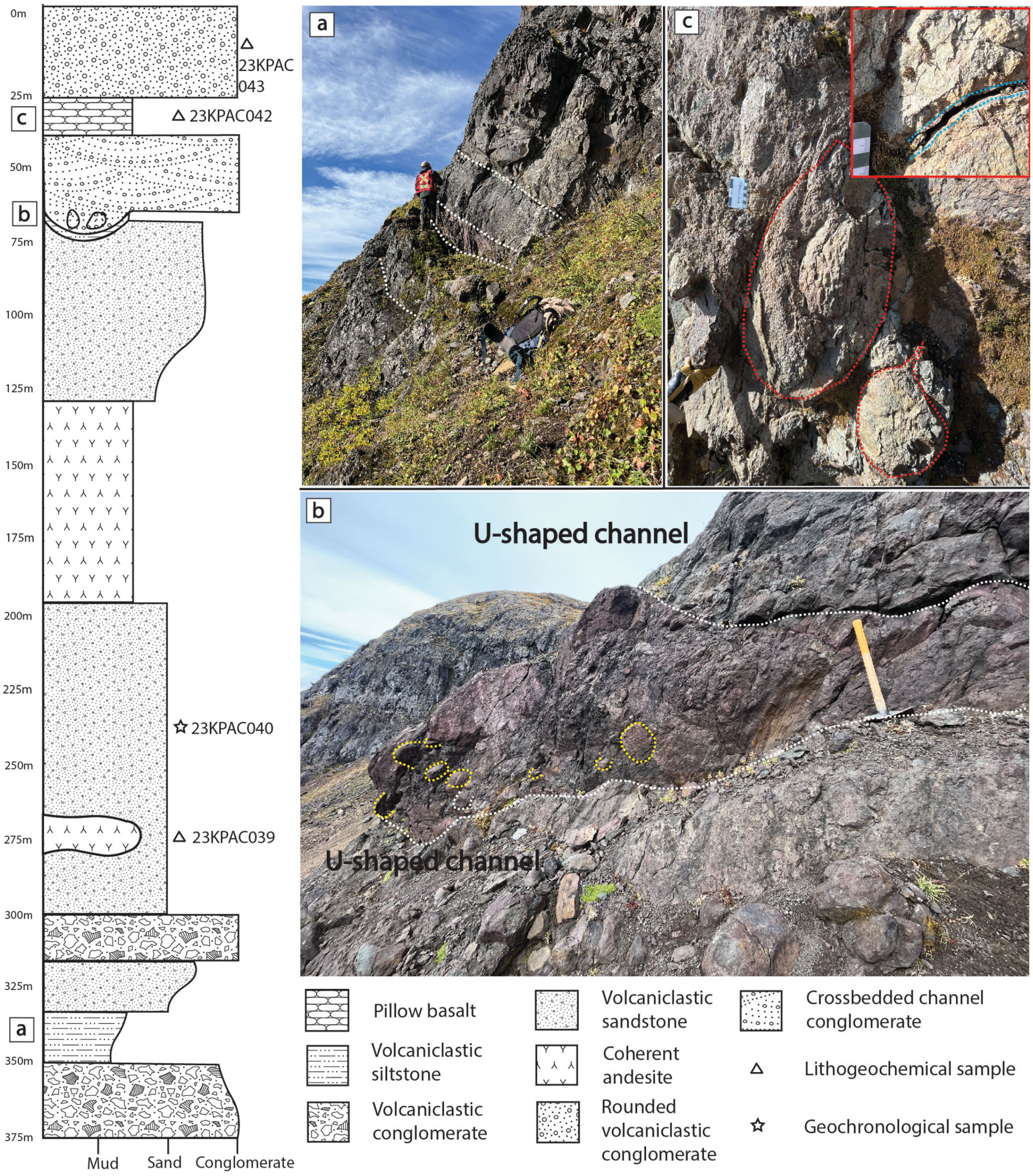

Figure 5. Stratigraphy of the Bear Pass section, with corresponding field photographs of units showing **a)** representative bedding dip within the lowermost 300 m of the measured section, in which the middle unit (indicated by dashed lines) is a fine volcaniclastic sandstone that has been disproportionately sheared; **b)** two stacked channel-cut deposits (lower limits outlined in white) displaying grading, with the largest rounded clasts (yellow) occupying the deepest portion of the channel and the fining, well-rounded clasts observed away from the channel base; and **c)** pillow-basalt lobes (outlined in red) that make up a narrow package (<10 m), with the glassy, weathered-out pillow-rind boundaries (outlined in blue) shown in the inset.

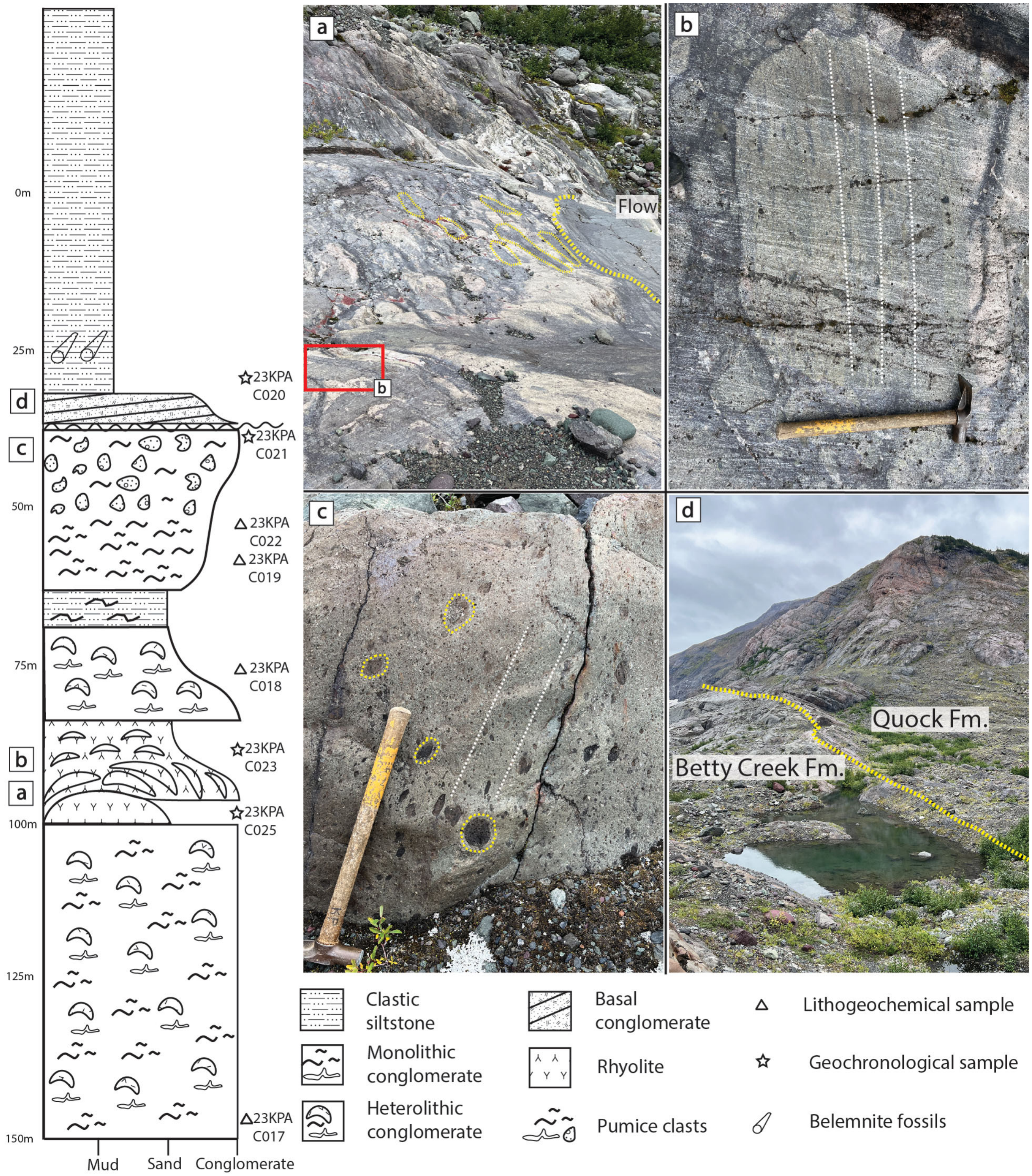

Figure 6. Stratigraphy of the Betty Glacier section, with corresponding field photographs of units showing **a)** a rhyolite flow with flow lobes and distinctive flow banding terminating initially in a jigsaw-fit monomictic breccia that transitions into rotated blocks of the same flow-banded rhyolite, the matrix of which is strongly altered to albite(?) that appears white in outcrop; **b)** a rotated clast of flow-banded (white) rhyolite; **c)** pumice clasts (outlined in yellow) and their alignment, roughly outlining bedding (dashed white lines), that are representative of most of the measured section; and **d)** the unconformable contact (dashed yellow line) between the Betty Creek Formation (lower Hazelton Group) and the Quock Formation (upper Hazelton Group), marking the transition between primarily volcanic rocks and clastic rocks.

pale-beige and green porphyritic volcanic rocks (80%). The massively bedded sandstone unit consists of coarse or granule-sized sand, comprising thick sections as well as finer (<1 m) interbeds within the conglomerate (Figure 5a). A small outcrop of coherent andesite was observed further upsection within the clastic sequence; the contacts defining this unit could not be observed in the outcrop. A section of coarse-grained sandstone was sampled for detrital zircon U-Pb geochronology.

Coherent Andesite

This cliff-forming, coherent unit shows patches of intense hydrothermal brecciation, which consists of angular clasts of porphyritic andesite, with a carbonate matrix that weathers distinctively. The unit is plagioclase- and hornblende-phyric, with millimetre-sized chlorite-filled amygdules set in a maroon groundmass. The andesite sits within the volcaniclastic/clastic sediments, where they are observed to continue upsection. This unit was sampled for whole-rock geochemistry analyses from a small outcrop of andesite hosted within the previously described sandstone unit shown on the stratigraphic column in Figure 5.

Channel Sediments

A distinctive set of channel deposits cut U-shaped erosional contacts into the underlying coarse sand and conglomerate unit, which is 3 m thick (Figure 5b). This unit is defined by a bed 10 cm thick of finely laminated, coarse sand that transitions sharply into a conglomerate, with well-rounded boulders and a lesser amount of subangular boulders; the largest of the rounded boulders are concentrated in the deepest part of the U shape. The upper contact of the coarse sand and conglomerate unit is cut by the erosional U-shaped contact of another channel deposit that has the same textures as the basal channel. The boulder conglomerate fines into a medium- to coarse-grained sandstone, which shows extensive crossbedding on the centimetre scale; this crossbedding shows that the units are facing upward.

Pillow Basalt

A narrow lens (10 m) of pillowed flows is observed in contact with the crossbedded sandstone. These pillows show porphyritic textures, the plagioclase phenocrysts (20%) and mafic crystals (20%) having been selectively altered to chlorite in a porphyritic groundmass (Figure 5c). The pillows lack obvious vesicles, but thin (2–3 mm) rinds can be observed rimming pillows 20–30 cm in size. A pillow was sampled for whole-rock geochemistry.

Rounded Conglomerate

The succession is capped by an outcrop of conglomerate weathered beige, which forms the plateau of the mountain. The conglomerate is matrix-supported and contains subrounded to rounded, pebble-sized clasts of felsic volcanic rocks. This unit was sampled for whole-rock geochemistry.

Betty Glacier Section

The Betty Glacier section was selected in a location close to the type section of the Betty Creek Formation. Defining the stratigraphy and collecting both whole-rock geochemical and geochronological samples in this location allows for comparison with samples collected from outside the type area, such as those collected in the Mount Johnson and Bear Pass sections described above. Here again, stratigraphy was walked perpendicular to strike, allowing for a vertical section of 150 m to be described. The observed stratigraphy, from bottom to top, is outlined below.

Heterolithic Conglomerate

The base of the observed outcrop at the Betty Glacier section consists of a dark grey to black unit of heterolithic clasts of both unflattened pumice and rounded to subrounded porphyritic volcanic clasts between 0.1 and 5 cm in size. The alteration within this unit is patchy, ranging from pervasive chlorite to magnetite veining and flooding. Sorting and clast density vary through the 75 m section, ranging from domains of large (>20 cm) clasts of pumice to finer centimetre-sized lithic-dominated domains. The unit is consistently matrix-supported. Four samples were collected for whole rock geochemistry from this unit, covering the variability of the rock.

Rhyolite Dome

Hosted within the heterolithic conglomerate portion of the stratigraphy is a distinctive flow-banded felsic flow lobe. The lobe is cut parallel, or close to parallel, to its flow direction, which made it possible to describe its autobrecciated flow front. This breccia is characterized by its jigsaw fit immediately adjacent to the flow front, which then transitions into a mosaic of rotated flow-banded blocks cemented by an aphanitic, matrix-altered to pervasive, hard and white mineral, which is potentially albite, and bright red jasper (Figure 6a, b). A clast of this rhyolite within the autobreccia as well as a portion of the flow lobe itself were sampled for geochronological analyses.

Pumice Conglomerate

Overlying the heterolithic conglomerate unit, lithic clasts become fewer as pumice now dominates the unit. The pumice clasts show moderate flattening (Figure 6c) and increase in average size from 5 cm at the base of the unit to 30 cm at the top. Two whole-rock geochemical samples and one geochronological sample were collected from portions of this unit. The geochronological sample at the upper limit of the unit corresponds to the unconformity between the felsic volcanism of the Betty Creek Formation and the clastic sediments of the overlying Quock Formation of the upper Hazelton Group (Figure 6d).

Clastic Sediments

The base of this unit is defined by a basal pebble conglomerate of rounded lithic clasts 1 m thick. This is overlain by a thick succession of rhythmically interbedded 'pyjama beds' consisting of medium-grained sand to mudstone. Within sandy interbeds, trace belemnites can be found. A detrital zircon geochronological sample was collected near the base of this unit.

Discussion

The three stratigraphic sections described above are separated by a minimum of 5.5 km (Mount Johnson and Bear Pass sections) and a maximum of 17 km, between Betty Glacier and the Bear Pass sections. This large distance between sections allows for a broad correlation with observed facies and also allows for speculation about their potential depositional environment, with respect to their proximity to volcanic centres and paleoposition within the topography.

Stratigraphic Units

Volcaniclastic and Clastic Sediments

All three sections (Figures 4–6) describing the 17 km distance along strike show a package of volcaniclastic rocks that is at least 200 m thick. This unit can be described as a volcaniclastic conglomerate that consistently contained clasts of pumice, with consistent clast size, matrix composition and percentage of the whole rock throughout the sections. Locally, pumice showed varying degrees of flattening, along with variable lithic-fragment content and frequency of sandstone interbeds. Units matching this textural description correspond to either the lower or upper members of the Betty Creek Formation. Of the units observed during the 2023 field mapping, this volcaniclastic conglomerate unit is the most ambiguous, as the various ways in which it is described in reports of most of the members of the Hazelton Group make it difficult to clearly distinguish in the field. Samples collected for both whole-rock geochemical and geochronological analyses will aid in correlating this unit, as it is broadly described in the literature.

Pumice-Rich Volcaniclastic Rocks

The distinctly pumice-rich units present within the two western sections, 12 km apart, are either thinly bedded (Mount Johnson section, Figure 4b) or massively bedded (Betty Glacier section, Figure 6c). Across the 12 km, these units vary in thickness from 80 m at the Mount Johnson section to 55 m at the Betty Glacier section. The difference between the two units lies in their textural and field relationships with their respective overlying units. The easternmost section, Bear Pass (Figure 5), shows rare to no pumice within its volcaniclastic rocks. This can be explained as either due to a change in the lateral facies or by the location of that section vertically within the stratigraphy; geochronological and geochemical analyses will aid in answering this question.

The pumice-rich layers of the Mount Johnson section are consistent with descriptions from Gordee (2006) about similar layers from the upper Betty Creek Formation, referring to features such as pumice-rich pyroclastic units and flame structures in finely bedded sediments. The other key feature observed in the field is the increasing frequency in the occurrence of limestone, which has been described in the literature as occurring at the interface between the Betty Creek and Mount Dilworth formations (Alldrick, 1993).

The Betty Glacier section (Figure 6) appears to be consistent with the Mount Dilworth section as it consists of "white, maroon, or green, flow-layered, tuff that can be welded or unwelded" (Alldrick, 1993) and is also in contact with overlying sediments of the Quock Formation. Therefore, the Betty Glacier section may be interpreted as the upper limits of the Mount Dilworth Formation.

Pillow Basalt

Pillow basalt at the Mount Johnson section (Figure 4) is intimately associated with the above-mentioned limestone units observed at the transition between the Betty Creek and Mount Dilworth formations. When this is considered in conjunction with the overlying crystal-rich, well-bedded felsic tuff that caps the section, it can be interpreted that these limestone-hosted pillowed flows are occurring at the contact between the Betty Creek and Mount Dilworth formations. These flows are texturally different than those observed further east at the Bear Pass section (Figure 5), where they are hosted within a volcanic, fine-grained porphyritic matrix, the upper contact of which is a continuation of volcaniclastic conglomerate units. The lack of sandy limestone that appears to mark the transition between the Betty Creek and Mount Dilworth formations, suggests the pillows seen at the Bear Pass section may occur stratigraphically deeper within the Betty Creek Formation, away from this observed contact relationship.

Upper Hazelton Unconformity

The unconformity observed between the pumice-rich felsic volcanic rocks and the overlying rhythmically bedded clastic sediments at the Betty Glacier section (Figure 6) shares the same basal conglomerate, consisting of rounded pebbles grading into fossiliferous sandstone and mudstone, as the unconformity observed at the Zn-Ag-Pb VMS occurrence of the BA property (Figure 3; K.M. Powers, K.E.L. Rubingh and S.L.L. Barker, unpublished poster, 2023). Both show a unit of rounded pebble basal conglomerate <1 m thick along an irregular erosional contact, followed by fossiliferous beds of sandstone and siltstone. The significance of this correlation lies in the potential erosion of the upper portions of the VMS sulphides at BA, which occur right up to the unconformity. Both of these unconformities have been sampled for geochronological and whole-rock geochemical analyses, the results of which will allow the reconstruction of differences in erosional history between the two sections along the top of this volcanic unit, thus establishing whether it is associated with the Betty Creek Formation or the younger Mount Dilworth Formation (K.M. Powers, K.E.L. Rubingh and S.L.L. Barker, unpublished poster, 2023).

Placement of Sections into Regional Stratigraphy

The textural descriptions of outcrops and the field relationships between these outcrops are outlined below. The sections described in this study occur within the Betty Creek Formation of the lower Hazelton Group through to the Quock Formation of the upper Hazelton Group (Figure 7).

The Bear Pass section (Figure 5) represents the oldest of the measured sections, with the rocks primarily being classified as mafic, heterolithic, volcaniclastic or clastic conglomerates, characterized by the presence of minor mafic pillowed volcanic rocks and an overall lack of felsic pyroclastic units. The lack of felsic volcanic or volcaniclastic rocks places this section below the contact with the Mount Dilworth Formation, where a distinct increase in felsic content is observed. The Mount Johnson section (Figure 4) encompasses that transition zone between the Betty Creek volcaniclastic and clastic units and the basal limestone, felsic pumice-rich rocks and crystal-rich tuffs of the Mount Dilworth Formation. Lastly, the section measured in the Betty glacier area (Figure 6) represents the youngest of the sections. At this section, a rhyolite dome with flow-top breccias is observed, followed by a sequence of interbedded felsic pumice-rich conglomerate and tuff, which ulti-

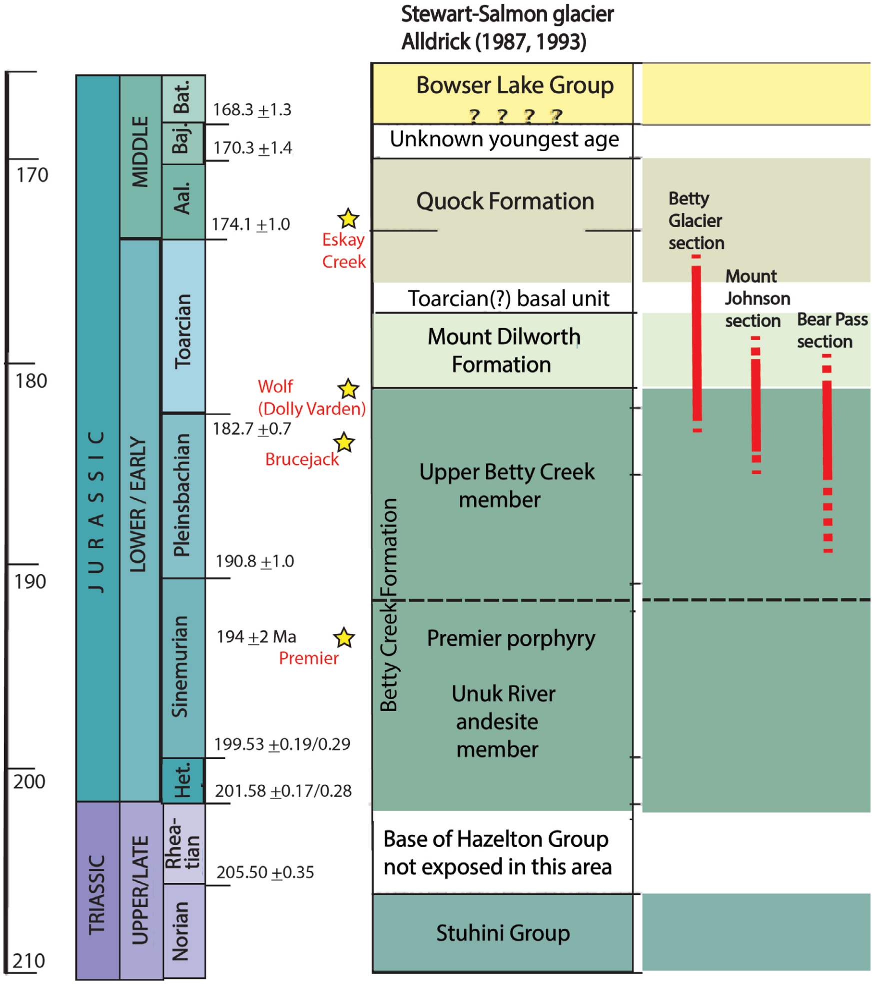

Figure 7. Generalized stratigraphy of the lower and upper units of the Hazelton Group in the Stewart mining camp (modified from Nelson et al., 2018 and Brueckner et al., 2021). Yellow stars indicate the U-Pb ages of major deposits in the Stewart camp and further north, such as at Brucejack and Eskay Creek. Premier U-Pb age from Alldrick (1985); Wolf U-Pb age (Dolly Varden) from Hunter and van Straaten (2020). The dashed lines showing the locations of the Bear Pass, Mount Johnson and Betty Glacier sections in the study area are indicative of interpreted continuation of the sections based on overlapping units observed during fieldwork. Abbreviations: Aal., Aalenian; Baj., Bajocian; Bath., Bathonian; Het., Hettangian.

mately terminates at the unconformity with sediments of the overlying clastic Quock Formation.

Future Work

The work outlined in this paper represents one aspect of the work being conducted in this study. Paralleling the research being done on volcanic stratigraphy are studies investigating and classifying the mineralization at the BA Zn-Ag-Pb VMS and the Mountain Boy epithermal Ag deposits. Uranium-lead geochronological analysis of the samples collected during the 2023 season will aid in placing these deposits within the stratigraphic column and in reconstructing the local volcanic-arc environment. To properly define the mineralized units of this area, the following work will be undertaken:

- U-Pb geochronology, to determine both crystallization and detrital ages. The results will be processed through the 2023–2024 winter months, along with corresponding results from whole-rock geochemistry.
- Detailed petrographic descriptions of fine-grained and aphanitic volcanic and volcaniclastic rocks, to aid in further classifying the alteration, the mineralogy and, potentially, the origin of these rocks.
- Micro X-ray fluorescence analysis of representative samples that were collected from mineralized zones within the study area. These studies will focus on metal deportment, origin and geochemistry of the ore-hosting units.
- Further mapping of the region, with potential step-out fieldwork in the direction of the Dolly Varden silver deposit, where mineralization appears to draw some parallels to that observed within the study area.

Conclusion

The Hazleton Group stratigraphy within the Stewart mining camp, and elsewhere within the Stikine terrane is highly variable and in regions units remain relatively broadly lumped together and described as packages of undifferentiated volcanic rocks. A wide range of textural and field-relationship descriptions apply to the Betty Creek Formation in particular; as a consequence, regional correlation of the members within the formation will benefit from geochemical and geochronological analyses undertaken in conjunction with descriptions recorded during fieldwork. This preliminary summary of field observations in 2023 makes it possible to tentatively place three stratigraphic sections (Figures 2, 4–6) within the Hazelton Group stratigraphy (Figure 7). The study sections have been interpreted to include rocks of the aforementioned Betty Creek and Mount Dilworth formations, as well as from the base of the Quock Formation, which represents potentially 18 m.y. of volcanic succession.

The three sections have laterally continuous units that share textural and field relationships, such as the extent and thickness (<200 m) of the units studied as well as volcaniclastic and clastic sediments, which appear to extend beyond this 17 km distance along strike. The sections, in particular the Bear Pass section, show distinct differences in both unit composition and depositional environment, which will be defined with the help of future geochemical and geochronological results. The oldest rocks (Figure 7), as determined from field relationships during 2023 mapping, are in the Bear Pass section (Figure 5), barring any unrecorded major fault displacement. In the Bear Pass section, volcanically derived conglomerate, sandstone-interfingered andesitic flows, channel deposits with clear U-shaped submarine erosional contacts (Figure 5b) and crossbedded sand, and finally pillowed basalts (Figure 5c) are primarily observed. These units, in combination with their field relationships, place the Bear Pass section within the Betty Creek Formation. The Mount Johnson section (Figure 4) is located both stratigraphically and geographically in the middle (Figure 6). In this section, there is a transition from lithic-rich conglomerate, and interbedded sand and pumice (Figure 4b) of the upper Betty Creek Formation to limestone-hosted pillow-basalt breccias (Figure 4c) at its upper contact. This transition from mafic volcanic rocks to felsic volcanic lithofacies and the presence of limestone units is consistent with previous descriptions of the Mount Dilworth Formation. Capping this section is a porphyritic, crystal-rich felsic tuff. Lastly, the youngest section (Figure 7) is the Betty Glacier section (Figure 6), which is located 17 km northwest of the Bear Pass section (Figure 2). In this section, the aforementioned laterally extensive volcaniclastic conglomerate, primarily felsic pumice-rich sediments (Figure 6c), a rhyolite dome (Figure 6b) and the unconformable contact with the clastic Quock Formation (Figure 6d) are observed. The majority of these, with the exception of the conglomerate at the base of the section and the Quock Formation, are consistent with earlier descriptions of the Mount Dilworth Formation.

The relationship between these areas will be fine-tuned and further defined based on the results from geochemical and geochronological analyses. The stratigraphic difference between the Mount Johnson (Figure 4) and Bear Pass sections (Figure 5) will require further work, as they are at the same elevation and share a similar strike and dip. These differences are likely a result of the combination of distance from the volcanic centre, structure and paleotopography at the time of deposition. Understanding the framework of depositional environments within the eastern Stewart mining camp will provide additional data to future explorers targeting known prospective stratigraphic intervals in the region.

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