Revised stratigraphy of the Hazelton Group in the Iskut River region, northwestern British Columbia

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Abstract

The Iskut River region hosts many significant porphyry, precious-metal vein and volcanogenic massive sulphide deposits. Most of these deposits are related to the Hazelton Group (latest Triassic to Middle Jurassic) and affiliated intrusions. Current knowledge of the Hazelton Group is the outcome of piecemeal, local mapping contributions over many years by different workers at different scales, resulting in inconsistencies and errors in stratigraphic nomenclature. Given that exploration interest in the region remains high, and that considerable work has recently been done in the region, a reappraisal of this nomenclature, applying provisions in the North American Stratigraphic Code is required. In our new stratigraphic framework, newly recognized units are given local geographic names; others are correlated with previously established units. Two newly defined lowermost Hazelton units, the Klastline formation (new informal name) and the Snippaker unit, are latest Triassic, showing that earliest Hazelton volcanism and sedimentation were coeval with formation of the Red Chris porphyry deposit. These, along with siliciclastic rocks of the Jack Formation (Lower Jurassic) and mainly andesite successions such as the Betty Creek Formation, comprise the lower Hazelton Group. The upper Hazelton Group includes the Iskut River Formation (mainly Aalenian-Bajocian) comprising the bimodal volcanic-sedimentary succession within the Eskay rift that hosts the Eskay volcanogenic massive sulphide deposit; mainly sedimentary units such as the Spatsizi Formation and Quock Formation that occur throughout central Stikinia; the Mount Dilworth Formation, a stratified Middle Jurassic felsic volcanic unit that occurs outside but near the Eskay rift; and the Eddontenajon formation (new informal name), an unusual Pleinsbachian-Toarcian bimodal volcanic-sedimentary sequence that outcrops near the hamlet of Iskut.

Keywords: Iskut, Stewart, Golden Triangle, Hazelton Group, Iskut River Formation, Betty Creek Formation, Snippaker unit, Klastline formation, Eddontenajon formation, Unuk River andesite unit, Brucejack Lake felsic unit, Johnny Mountain dacite unit, Willow Ridge mafic unit, Bruce Glacier felsic unit, Mount Madge sedimentary unit, Downpour Creek siliciclastic unit, Palmiere dacite-mudstone unit, Mount Dilworth Formation, Spatsizi Formation, Quock Formation, Triassic, Jurassic, Stikinia

1. Introduction

The Iskut River region, between Stewart and Iskut (Fig. 1), hosts many significant porphyry, precious-metal vein and volcanogenic massive sulphide (VMS) deposits. Mining commenced at the Red Chris porphyry Cu-Au deposit in 2015, and at the Brucejack (Valley of the Kings) gold deposit in 2017. Deposits comparable to the past-producing Eskay Creek precious-metal VMS orebody remain targets of exploration interest. Past-producing gold mines at Premier, Snip, and Johnny Mountain are currently being reassessed for additional resources (Fig. 2). Significant developed prospects include the Kerr-Sulphurets-Mitchell-Iron Cap (KSM) porphyry Cu-Au, the GJ porphyry, and porphyry and precious metal targets in the Snippaker Mountain-Johnny Mountain area (Fig. 2).

Most deposits in the Iskut region are related to the Hazelton Group (latest Triassic-Middle Jurassic) and affiliated intrusions. The Hazelton Group represents the final arc construction phase in Stikinia before and during the onset of collision with Laurentia (Nelson et al., 2013). It is distributed throughout the region (Figs. 1, 3; Ash et al., 1997a; Lewis 2001, 2013; Alldrick et al., 2006); coeval and cogenetic intrusions of the Texas Creek plutonic suite (ca. 195-186 Ma; Anderson, 1993) are also widely distributed . The Hazelton Group includes all volcanic and sedimentary strata that lie above the Stuhini Group (Upper Triassic) and below Upper Jurassic to Lower Cretaceous synorogenic siliciclastic rocks of the Bowser Lake Group. Tipper and Richards (1976) defined the Hazelton Group from work near Smithers, and subdivided it into formations based on the relative abundance of volcanic and non-volcanic rocks, and subaerial and submarine facies. Since then, significant advances in our understanding of the Hazelton Group have been made through detailed mapping, geochronology, and biochronology. For example, Tipper and Richards (1976) considered that the Hazelton Group is entirely Early Jurassic,

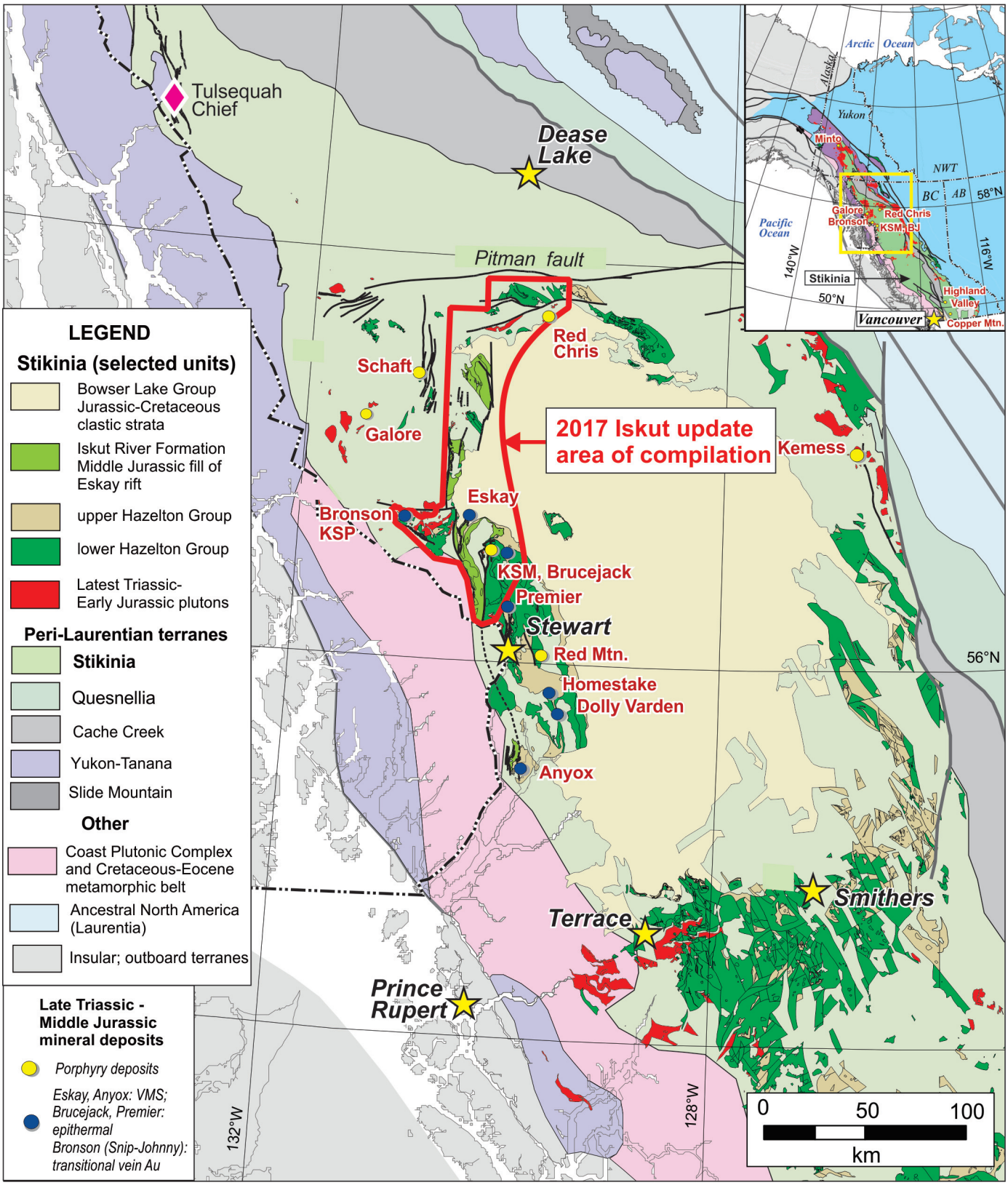

Fig. 1. Regional setting of the Iskut River study area.

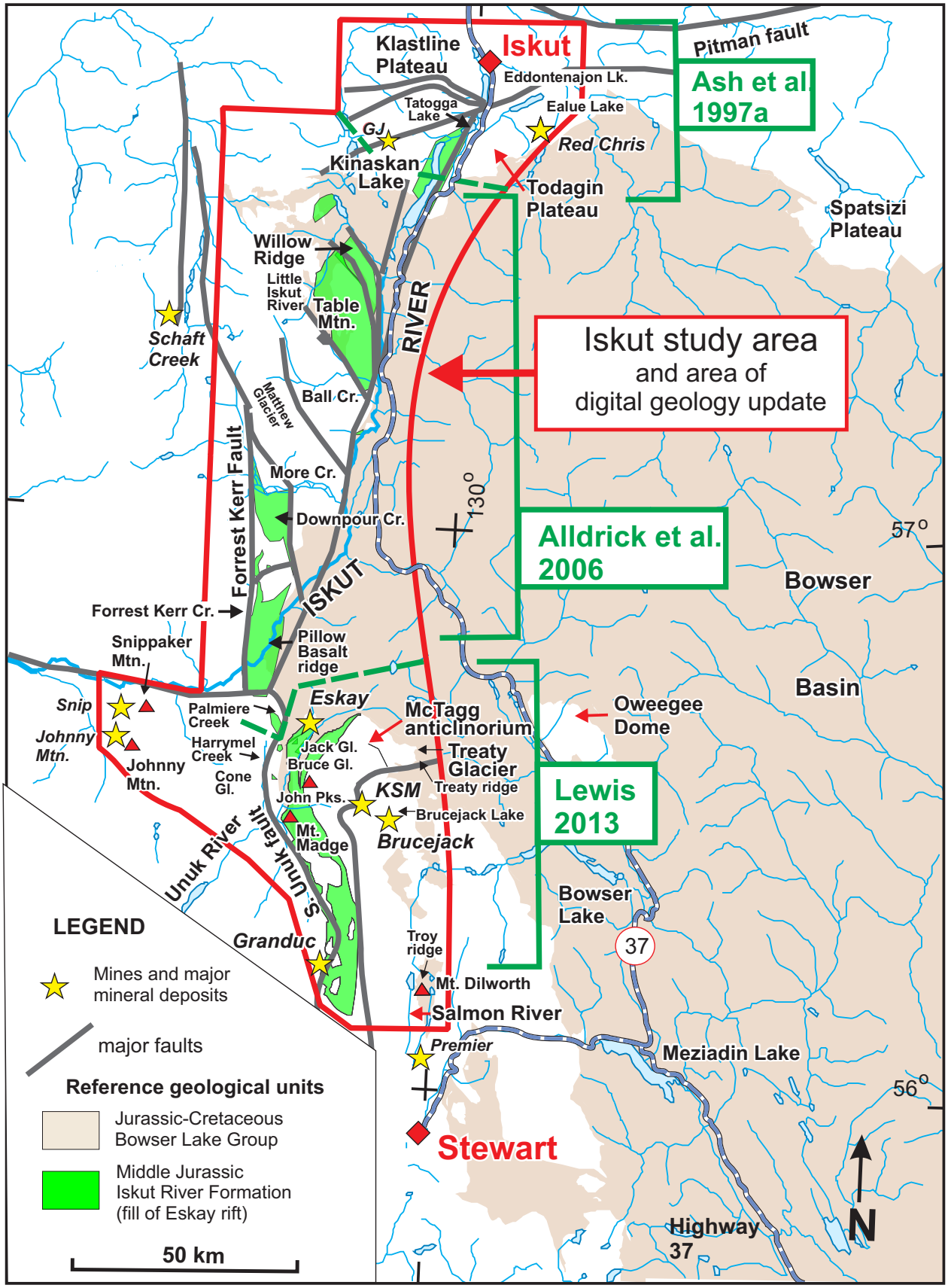

Fig. 2. Geography of the Iskut River region, showing mines, major projects, and key geological features. Areas covered by principal existing geological sources (Lewis, 2013; Alldrick et al., 2006; Ash et al., 1997a, b) are shown for reference.

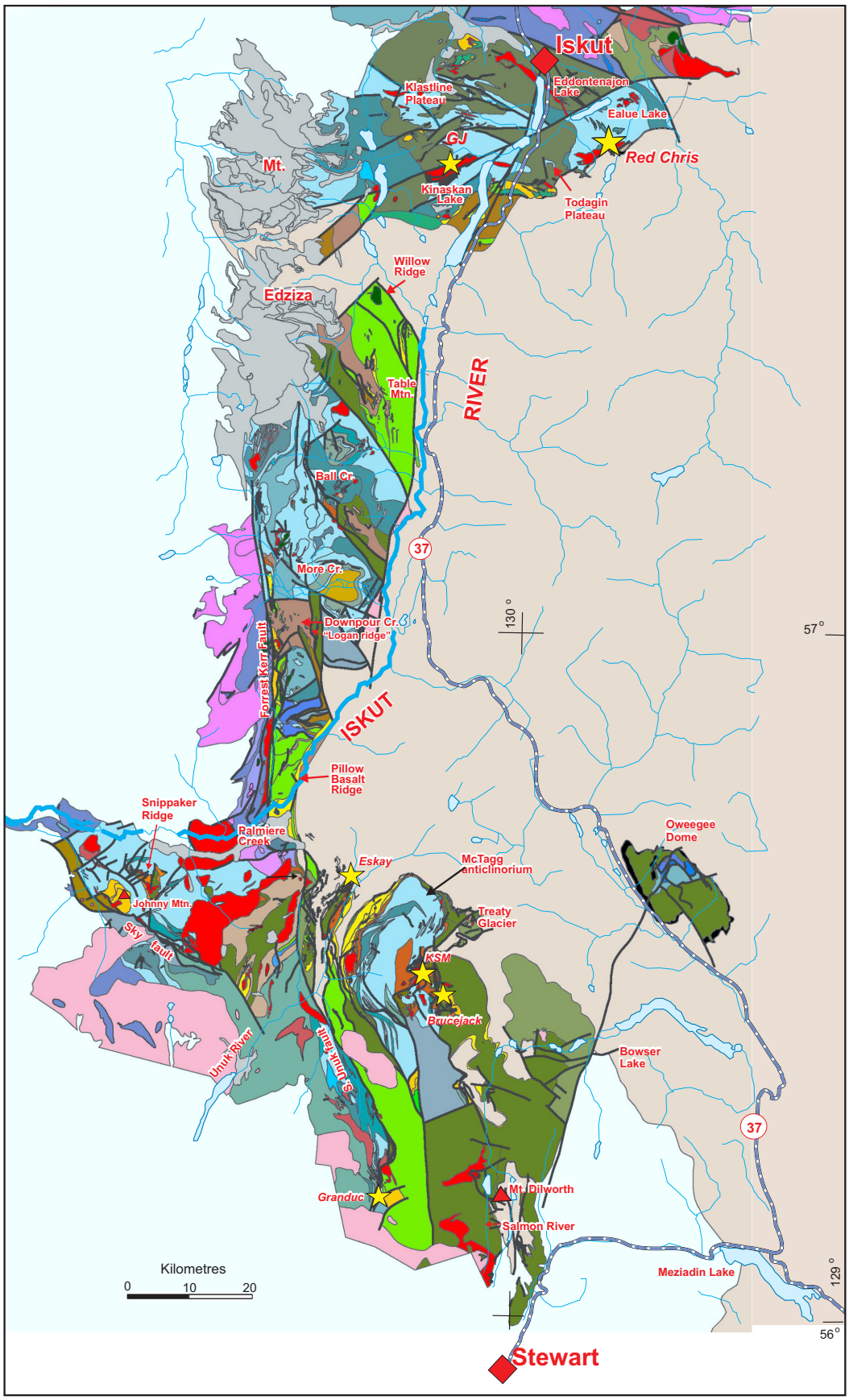

Fig. 3. **a)** Preliminary compiled geology for the Iskut River region, **b)** legend.

Fig. 3. **b)** Legend.

but recent work by Barresi et al. (2015) showed that basal volcanic rocks near Terrace are ca. 205 Ma, within the Rhaetian stage (Gradstein et al., 2012; Cohen et al., 2013) of the Upper Triassic. In the 1990s, detailed studies of the Hazelton Group stratigraphy, spurred by the discovery and development of the Eskay Creek deposit, identified a heterogeneous succession of Middle Jurassic bimodal volcanic and sedimentary strata in the upper Hazelton Group that differ in age and character from older, predominantly andesitic units in the lower Hazelton Group (Anderson and Thorkelsen, 1990, Lewis et al., 2001a). Recently, Gagnon et al. (2012) developed a stratigraphic schema for the Hazelton Group throughout Stikinia, based on detailed studies by Gagnon (2010) and Barresi (2015). They proposed that it consists of two divisions. The lower Hazelton Group includes basal siliciclastic units (where present) and andesitic to variable volcanic successions. The upper Hazelton Group includes the Iskut River Formation, a distinctive unit of bimodal volcanic and interbedded sedimentary rocks that occupies a fault-bounded belt in western Stikinia (Fig. 1), and mainly sedimentary strata that immediately underlie the Bowser Lake Group throughout central and northern Stikinia. We follow their system of nomenclature in this paper.

As is commonly the case when different areas within a region are studied by different workers at different scales over many years, errors and inconsistencies, which constitute conceptual barriers, have been introduced into the stratigraphic nomenclature of the Hazelton Group. Because exploration interest in this mineral-rich area is high, and because new published and unpublished data are currently being integrated into the province-wide geology database (see Cui et al., 2017), a regionally consistent and stable stratigraphic scheme is required. In this paper we review key aspects of Hazelton Group lithostratigraphy, evaluate stratigraphic terms in the light of recent work and current understanding, and introduce a new stratigraphic framework for the Iskut River region. Our scheme retains some long-standing terms, abandons some obsolete or ill-conceived terms, and introduces new terms following procedures outlined in the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 2005). Because the Hazelton Group displays significant longitudinal variation in the region, we present our analysis along a south-to-north transect, providing details from three areas: 1) Stewart-McTagg anticlinorium-Snippaker Mountain; 2) Forrest Kerr-Ball Creek-Table Mountain, and 3) Kinaskan Plateau-Klastline Plateau-Todagin Plateau.

2. Stewart-McTagg anticlinorium-Snippaker Mountain area

This area extends north from the Stewart mineral camp and includes the Unuk River drainage, Treaty Glacier, Snippaker Mountain, and Johnny Mountain (Fig. 2). It centres on the McTagg anticlinorium (Fig. 3), a regional structural culmination cored by Stuhini Group strata and flanked by Hazelton Group rocks. Eskay rift rocks form extensive exposures in the Unuk River valley, bounded on the west by the South Unuk fault. Below we track the evolution of Hazelton nomenclature in the area (Fig. 4). For the most part, we follow stratigraphic assignments in Lewis et al. (2001a) and Lewis (2013) but with revisions as described below (Figs. 4, 5).

2.1. Basal Hazelton Group: Jack Formation; introduction of Snippaker unit

Along the margins of the McTagg anticlinorium, the Stuhini Group-Hazelton Group contact is an angular unconformity that is overlain by a basal conglomeratic unit (Lewis et al., 2001a, Lewis, 2013; Nelson and Kyba, 2014; Kyba and Nelson, 2015). This basal siliciclastic unit is named the Jack Formation after exposures near the Jack Glacier (Fig. 3; Henderson et al., 1992; Lewis et al., 2001a). It was originally defined as a wholly siliciclastic unit, identified primarily by cobble to boulder granitoid-clast conglomerate (Fig. 6a). Quartz-bearing arkosic sandstone, granulestone, and thinly bedded siltstones and mudstones are also present (Fig. 6b; Nelson and Kyba, 2014). Jack Formation sections at Bruce Glacier and Treaty Glacier contain andesitic volcaniclastic rocks that are in gradational contact with identical siliciclastic strata above and below (Fig. 6c; Nelson and Kyba, 2014). Near Treaty Glacier, ammonite collections from above the andesitic volcaniclastic layer are Late Hettangian to Early Sinemurian (Nadaraju and Lewis, 2001). Although Lewis et al. (2001a) assigned these andesitic volcaniclastic rocks to the overlying Unuk River unit, evidence of interfingering or continuity between the two is lacking, and we consider them part of the Jack Formation. Febbo et al. (2015) and Febbo (2016) identified similar andesitic pyroclastic units in the Jack Formation in the KSM deposit area.

The base of the Jack Formation is broadly latest Triassic to Early Jurassic. In the Atkins Glacier area (north of Treaty Glacier), a fossil collection from near the Stuhini Group-Jack Formation contact is considered Late Norian (Crickmayi zone; collection 93-ATP-7, Lewis, 2013) based on the ammonite *Choristoceras*(?). However, this ammonite is presently considered as Rhaetian (Ogg, 2012). Further work is needed to establish a more precise age and to determine if the unit sampled is part of the Stuhini Group rather than the Hazelton Group. A tuffaceous sandstone from the Jack Formation 2 km northwest of Brucejack Lake yielded ca. 197 Ma detrital zircons, and a volcanic conglomerate in the overlying Betty Creek Formation contains a ca. 196 Ma leucodiorite clast (Figs. 4, 5; J. Nelson, unpublished, 2017). These ages suggest that the top of the Jack Formation is mid-Sinemurian, at least locally (Fig. 5). Other samples of the Jack Formation contain mainly 220-226 Ma and minor Paleozoic detrital zircon populations (J. Nelson, unpublished, 2017). Together with the abundance of coarse-grained plutonic clasts, these distinctly older populations indicate that Jack Formation deposition represents a significant break from Stuhini Group volcanic and volcaniclastic accumulation, recording deep erosion into the Paleozoic section and Triassic Stikine suite plutons.

On Snippaker Mountain, the uppermost layer of the Stuhini

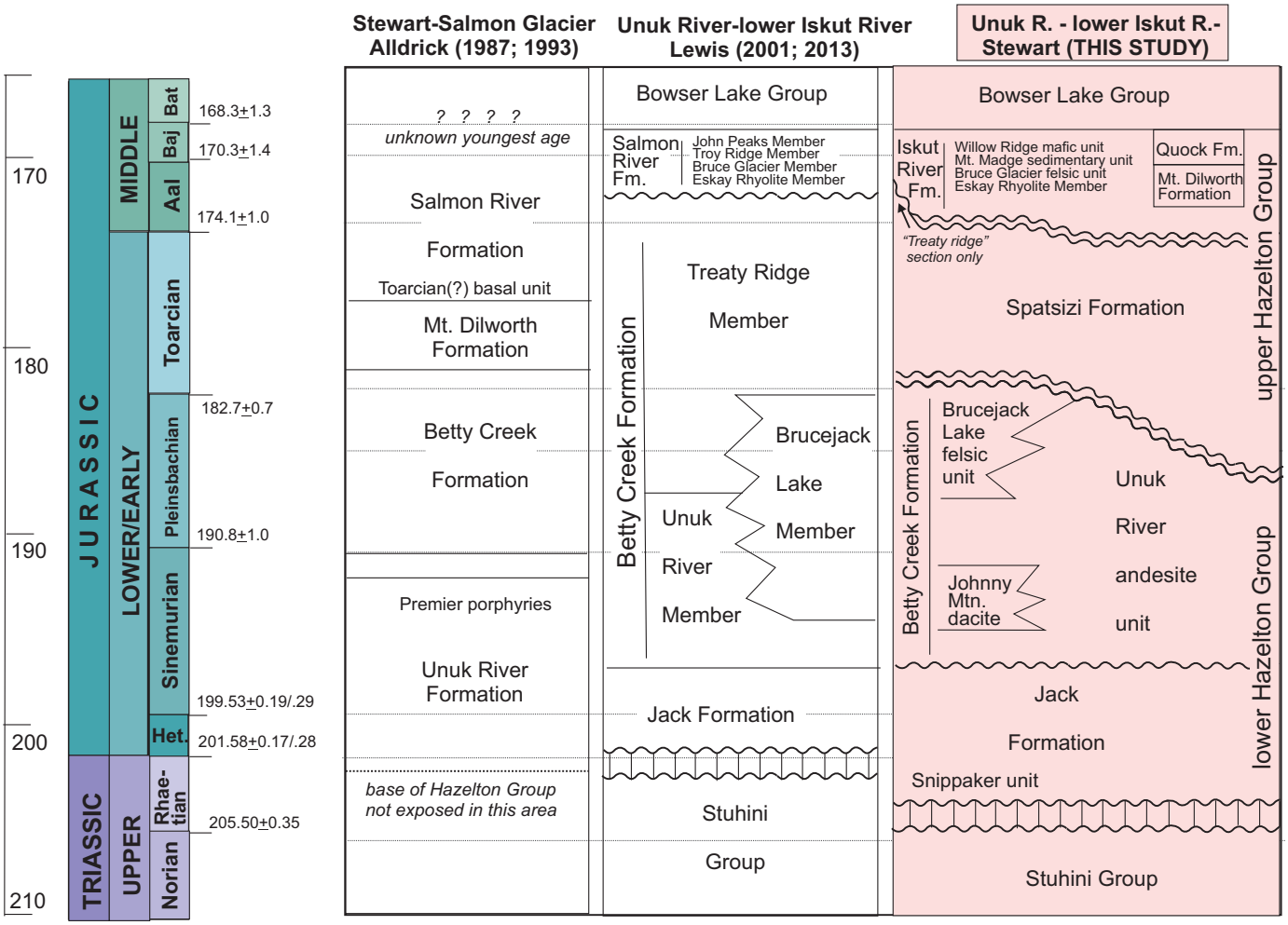

Fig. 4. Evolution of Hazelton Group stratigraphic nomenclature in the Stewart-McTagg-Snip area, southern Iskut River region.

Group consists of dull green greywacke in which pebbles of hypabyssal diorite increase in abundance up-section (Kyba and Nelson, 2015). This layer is unconformably overlain by a succession of orange-weathering sandstone, polymictic conglomerate, siltstone, and mudstone (Figs. 6d, e). Clasts in the conglomerate are well rounded and include granitoid rocks, chert, and volcanic rocks. Because the unit contains Late Triassic faunal assemblages (Nadaraju, 1993) it was previously included in the Stuhini Group (unit TrSs8, Lewis, 2013). However, because it unconformably overlies the Stuhini Group, physically resembles Jack Formation conglomerates (Kyba and Nelson, 2015), and contains detrital zircon populations identical to those in the Jack Formation (see below), we recommend that these siliciclastic rocks be included as an informal unit in the Jack Formation, and call it the Snippaker unit.

Small (tens of metres) rafts of highly fossiliferous limestone and clasts of individual fossils occur within the conglomerate (Fig. 6f). Fossil collections from these contain *Nevadathalamia* sp., *Placites* sp., *Rhacophyllites* sp., *Cladiscites* sp.; *Myophoria* sp., *Pinna* sp., *Weyla* sp., *Trigonia* sp., *Gryphae* sp., *Thamnastrea* sp., and *Thecosmilia* sp. (Nadaraju, 1993), which were originally assigned to the Amoenum-Crickmayi zone, considered to be Upper Norian (Tozer, 1979). However, these faunal zones are now considered to be Rhaetian (Orchard and Tozer 1997; Grădinaru and Sobolev, 2010). An additional maximum age constraint for the Snippaker unit comes from the main population of detrital zircons in the underlying uppermost Stuhini pebble greywacke at ca. 203 Ma (J. Nelson, unpub. data). Main detrital zircon populations from the Snippaker unit at ca. 220-226 Ma are similar to main peaks in the Jack Formation (J. Nelson, unpub. data, 2017). It also contains late Paleozoic grains, and a ca. 212 Ma population. As with the main part of the Jack Formation, the appearance of distinctly older zircons is evidence of regional exhumation.

2.2. Betty Creek Formation: Replacement of Unuk River 'Member' by Unuk River andesite unit; replacement of Brucejack Lake 'Member' by Brucejack Lake felsic unit; introduction of Johnny Mountain dacite unit; and abandonment of Treaty Ridge 'Member'

We follow Lewis et al. (2001a) in assigning most lower Hazelton volcanogenic strata to the Betty Creek Formation.

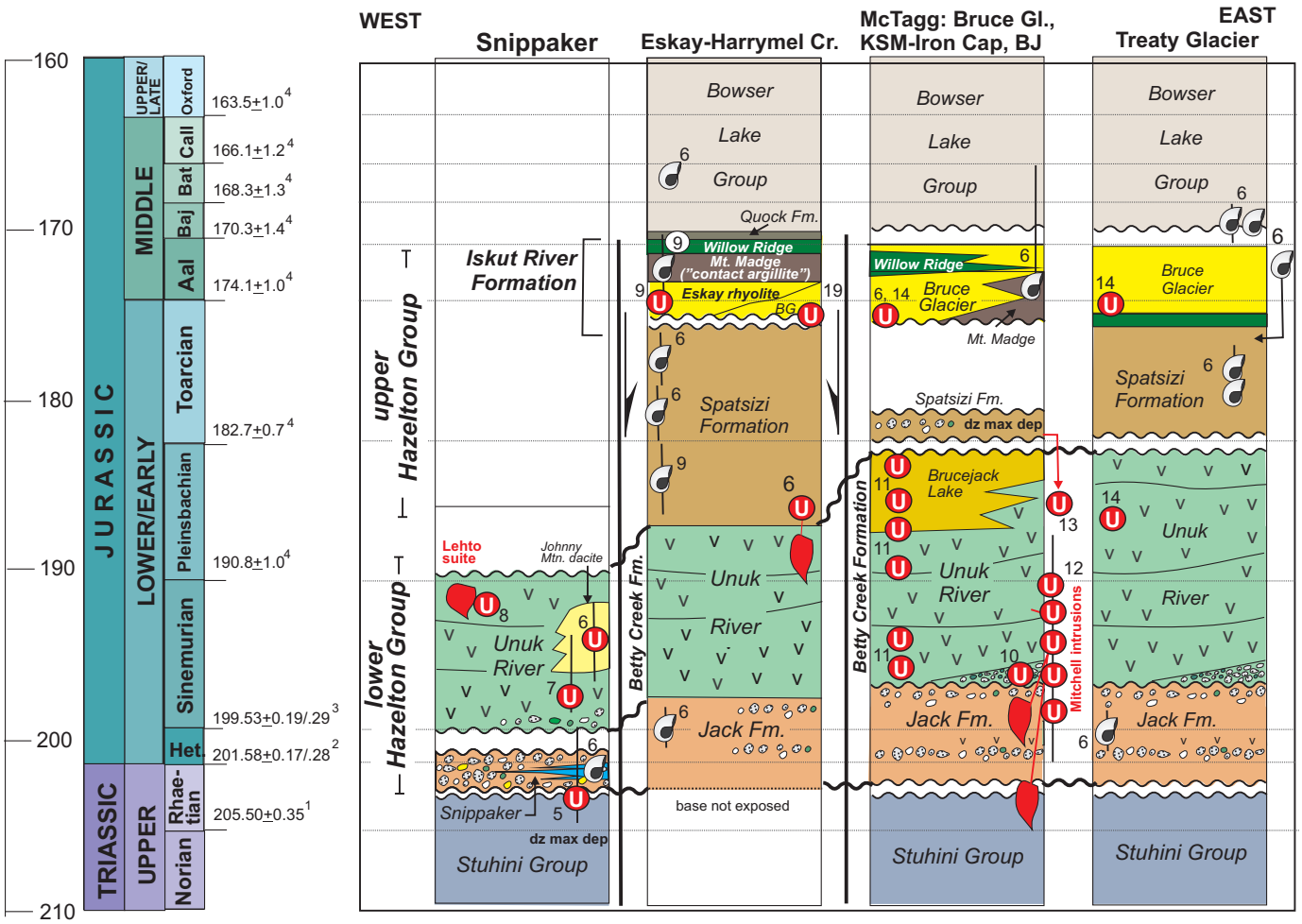

Fig. 5. Stratigraphic columns representing the Hazelton Group in the Stewart-McTagg-Snip area, southern Iskut River region. Numbers reference sources for fossil and radiometric ages. **1.** Norian-Rhaetian boundary (Wotzlaw et al., 2014); **2.** Rhaetian-Hettangian boundary (Schaltegger et al., 2008); **3.** Hettangian-Sinemurian boundary (Schaltegger et al., 2008); **4.** Cohen et al. (2013); **5.** ca. 203.4 Ma youngest detrital population (J. Nelson, unpublished data, 2017); **6.** biochronologic and geochronologic compilations of Lewis et al. (2013) based on Nadaraju (1993); Nadaraju and Lewis (2001); Lewis et al. (2001b); **7.** ca. 198 Ma youngest detrital population (J. Nelson, unpublished data); **8.** ca. 192 Ma U-Pb zr (J. Nelson, unpublished data, 2017); **9.** Childe, 1996; **10**. ca. 197 Ma, U-Pb zr (J. Nelson, unpublished data, 2017); **11.** Greig (2013); MacDonald (1993); **12.** 198-189 Ma U-Pb zr (Febbo, 2016); **13**. ca. 186 Ma youngest detrital zircon population (J. Nelson, unpublished data, 2017); **14.** Cutts et al. (2015).

Alldrick (1987, 1993) referred to the lowest exposed Hazelton Group unit near the Salmon River, consisting of interbedded green andesitic volcaniclastic and sedimentary strata, as the Unuk River Formation. The name Unuk River was derived from earlier assignment of volcanic rocks in the Unuk River valley farther north and west by Grove (1971, 1986). Overlying maroon and green, mostly epiclastic andesitic units were assigned to the Betty Creek Formation (Alldrick, 1987, 1993). Noting that the distinction between these two units was mainly based on colour and not regionally significant, Lewis et al. (2001a) reassigned andesitic rocks of the Unuk River 'Formation' to the Betty Creek Formation, giving it a 'Member' status (Fig. 4). Other proposed members of the Betty Creek Formation were the felsic Brucejack Lake Member and sedimentary Treaty Ridge Member.

We consider subdivision of the Betty Creek Formation into formal members (Lewis et al., 2001a; Lewis, 2013) to be problematic. In formal stratigraphic nomenclature (see North American Commission on Stratigraphic Nomenclature, 2005) a member is defined as a single unit with a defined bottom and top. In the Betty Creek Formation, volcanic lithotypes do not form discrete unrepeated layers but multiple bodies at different stratigraphic levels. Thus we abandon the formal term 'Member' for subdivisions of the Betty Creek Formation in this area and instead propose that it be divided into three informal subdivisions (Fig. 4): the Unuk River andesite unit, the Johnny Mountain dacite unit (ca. 194 Ma, Lewis et al., 2001b), and the Brucejack Lake felsic unit (ca. 185-178 Ma; Lewis et al., 2001b). As described further below (see section 2.3) Lewis et al. (2001a) considered the succession of mainly sedimentary rocks above these volcanogenic units as part of the Betty Creek Formation and referred to them as the Treaty Ridge Member

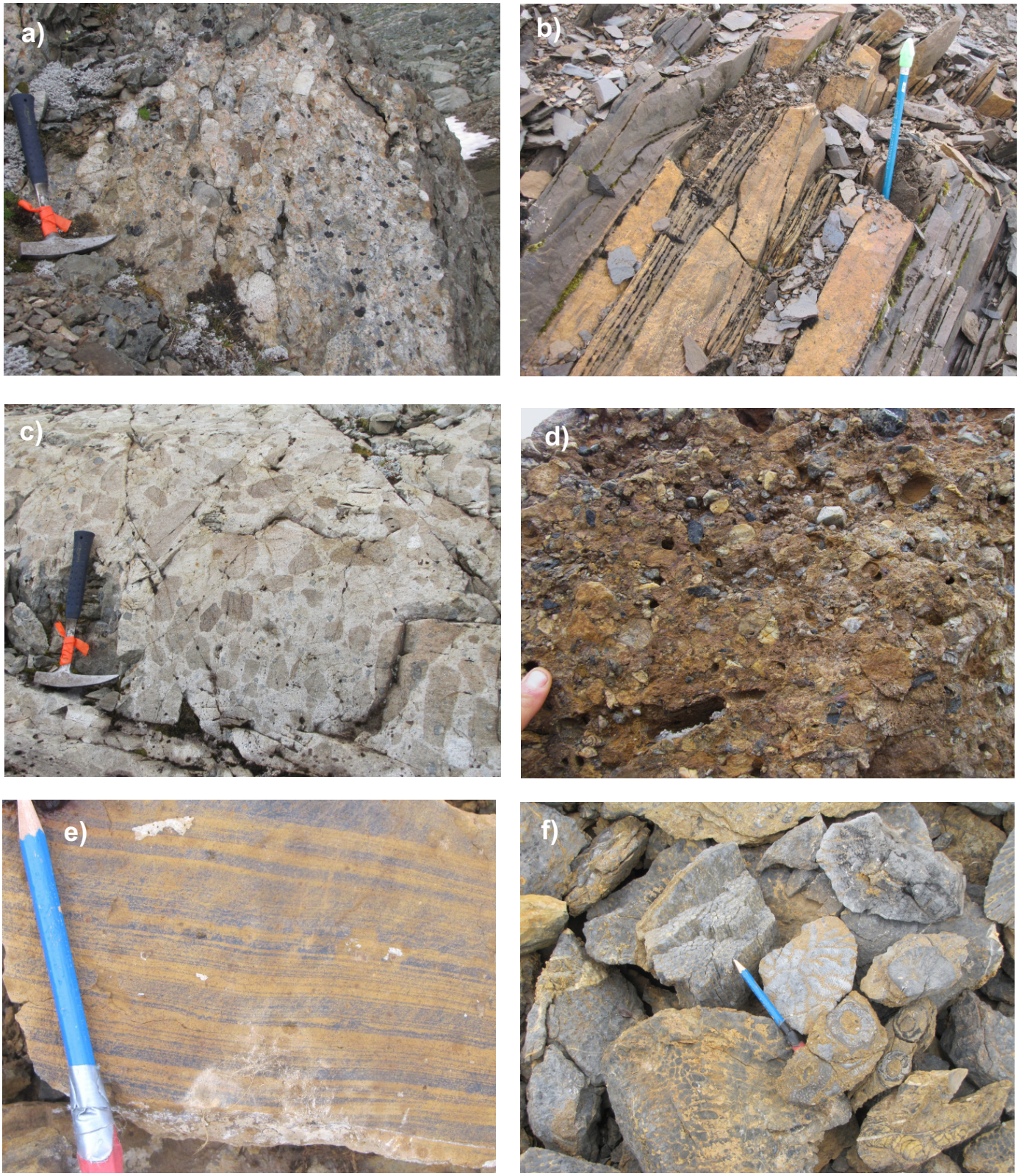

Fig. 6. Representative photos of the Jack Formation and Snippaker clastic unit. **a)** Basal polymictic conglomerate, Jack Formation near Jack Glacier (413850 E, 6269040 N). **b)** Thinly bedded calcareous siltstone, fine-grained sandstone, and carbonaceous mudstone; Jack Formation mudstone±sandstone and siltsone facies, near Jack Glacier (413557 E, 627708 N). **c)** Andesite block breccia; Jack Formation middle volcaniclastic facies (413278 E, 6270599 N). **d)** Snippaker unit polymictic conglomerate. Light clasts are felsic to intermediate high-level intrusive rocks and silicified rocks; dark clasts are chert. Weathered-out clasts are limestone (377358 E, 6281369 N). **e)** Snippaker unit, thinly bedded sandstone and mudstone (376848 E, 6281354 N). **f)** Corals from partly dismembered boundstone raft, Snippaker unit (379725 E, 6279752 N).

(Fig. 4). However, this succession displays the same lithological characteristics, age and stratigraphic position as the Spatsizi Formation in the upper Hazelton Group elsewhere (Gagnon et al., 2012), and Treaty ridge is an informal topographic term. Thus we reassign the succession to the Spatsizi Formation and propose that the term 'Treaty Ridge Member' be abandoned (Figs. 4, 5).

2.2.1. Unuk River andesite unit

We agree with the decision of Lewis et al. (2001a) to include all lower Hazelton Group andesites previously referred to as the Unuk River Formation (Alldrick, 1987) in the Betty Creek Formation. They include both pyroclastic (Fig. 7a) and epiclastic (Fig. 7b) deposits. In general, subaerial and epiclastic deposits increase up-section in the andesitic unit, but a simple transition is not traceable throughout the region (cf. Alldrick, 1987, 1993). For example, in the section 2 km northwest of Brucejack Lake, maroon and green volcanic clast-bearing conglomerate is at the base of the Betty Creek Formation, lying directly on the Jack Formation (Fig. **7**c; Nelson and Kyba, 2014). Facies distinctions can be usefully documented locally, for example on the Brucejack property where increasing oxidation upwards may have exerted chemical control on mineralization (W. Board, pers. comm., 2013; S. Flasha, pers. comm., 2017), but cannot be used regionally.

The base of the Unuk River andesite unit above the Jack Formation is sharp and ranges from paraconformable to unconformable. It represents an abrupt transition from siliciclastic sedimentation to mixed, predominantly andesitic pyroclastic and epiclastic accumulation. Near the Iron Cap deposit, a volcanic breccia lies at the base of the unit. It contains irregular, angular dark green andesite and lesser pinkish felsic clasts, overlain in part by a pillowed mafic flow (Nelson and Kyba, 2014). North of Treaty Glacier, the basal bed is a coarse, matrix-supported, polymictic volcanic-hypabyssal clast conglomerate, overlain by monomictic andesite pyroclastic breccia (Nelson and Kyba, 2014). Northwest of Brucejack Lake, the polymictic basal volcanic conglomerate contains a ca. 196 Ma porphyritic diorite block (J. Nelson unpublished, 2017) along with mostly andesite cobbles. On Snippaker Mountain, the base of the Unuk River andesite unit cuts down through the Snippaker unit into the underlying Stuhini Group (Kyba and Nelson, 2015). A matrix-supported basal conglomerate includes both volcanic blocks derived from the underlying Stuhini Group and intraformational sedimentary clasts. A detrital zircon sample of this conglomerate contains a youngest population at ca. 198 Ma, along with older Late Triassic populations derived from the Stuhini Group and comagmatic intrusions (J. Nelson unpublished, 2017). In summary, U-Pb ages place the base of the Unuk River andesite unit in the mid-Sinemurian (ca. 197 Ma), slightly younger than the Jack Formation, indicating abrupt onset of voluminous andesitic volcanism. Youngest U-Pb ages, obtained from minor felsic rocks in the Unuk River andesite unit, are ca. 187 Ma (Cutts et al., 2015). U-Pb ages of Texas Creek suite intermediate porphyritic intrusions, notably the Mitchell suite at KSM (Febbo et al., 2015; Febbo, 2016) and the Lehto suite in the Snippaker area (Kyba and Nelson, 2015), overlap those of the Unuk River andesite unit (Fig. 5). We consider them intrusive and extrusive equivalents.

2.2.2. Johnny Mountain dacite unit

Johnny Mountain (Fig. 2) is underlain by a succession of bedded dacite lapilli tuff and breccia (Fig. 7d) that unconformably overlies the Stuhini Group (Kyba and Nelson, 2015). It was previously assigned to the Brucejack Lake Member (Lewis et al., 2001a), and mapped, probably in error, as felsic and mafic Salmon River Formation (Lewis, 2013). A U-Pb age from this unit is ca. 194 Ma (Lewis et al., 2001b; Lewis, 2013). Given that the unit is markedly older than the rocks at the Brucejack Lake type locality (ca. 183-188 Ma; Lewis et al., 2001b; Lewis, 2013; Greig, 2013) and given its geographic distance from Brucejack Lake, we suggest that the succession forms a distinct unit and propose the name Johnny Mountain dacite unit. It is coeval with nearby porphyry bodies such as at Red Bluff and Inel (Kyba and Nelson, 2015) and probably represents an extrusive equivalent.

2.2.3. Brucejack Lake felsic unit

Near Brucejack Lake, the Unuk River andesite unit is overlain by a felsic unit including potassium feldspar-, plagioclase- and hornblende-phyric flows, breccias, and bedded welded to non-welded felsic tuffs (Fig. 7e) that are intruded by a flow-banded coherent plagioclase-phyric body, which grades upwards into flows (MacDonald, 1993). MacDonald (1993) interpreted this unit, which we refer to as the Brucejack Lake felsic unit (cf. 'Member' of Lewis, et al., 2001a; Lewis, 2013, Fig. 4) as a flow-dome complex, representing the extrusive and high-level intrusive products of a local magmatic centre. The intrusive and extrusive rocks of the unit have yielded ca. 183-188 Ma U-Pb ages (Lewis et al., 2001b; Lewis, 2013; Greig, 2013). Polymictic conglomerates with well-rounded cobbles to boulders at the base of the unit 2 km northwest of Brucejack Lake (Fig. 7f) suggest that the lower contact of the unit is an unconformity. Felsic rocks of similar age also occur in the Unuk River drainage and are included in the unit.

2.3. Spatsizi Formation and abandonment of 'Treaty Ridge Member' for basal rocks in the upper Hazelton Group

Examining stratigraphic relationships across Stikinia, Gagnon et al. (2012) recognized that the Hazelton Group consists of two parts, separated by a diachronous contact. In the Iskut River region, the lower part includes the Rhaetian to Sinemurian basal sedimentary units (Jack Formation) and overlying voluminous volcanogenic strata (Betty Creek Formation) described above. Regionally, the basal unit of the upper Hazelton Group is the Spatsizi Formation, defined on the Spatsizi Plateau of north-central Stikinia (Fig. 2) as a Pleinsbachian through Aalenian siliciclastic sequence with minor volcanic components (Figs. 8, 9; Spatsizi Group of

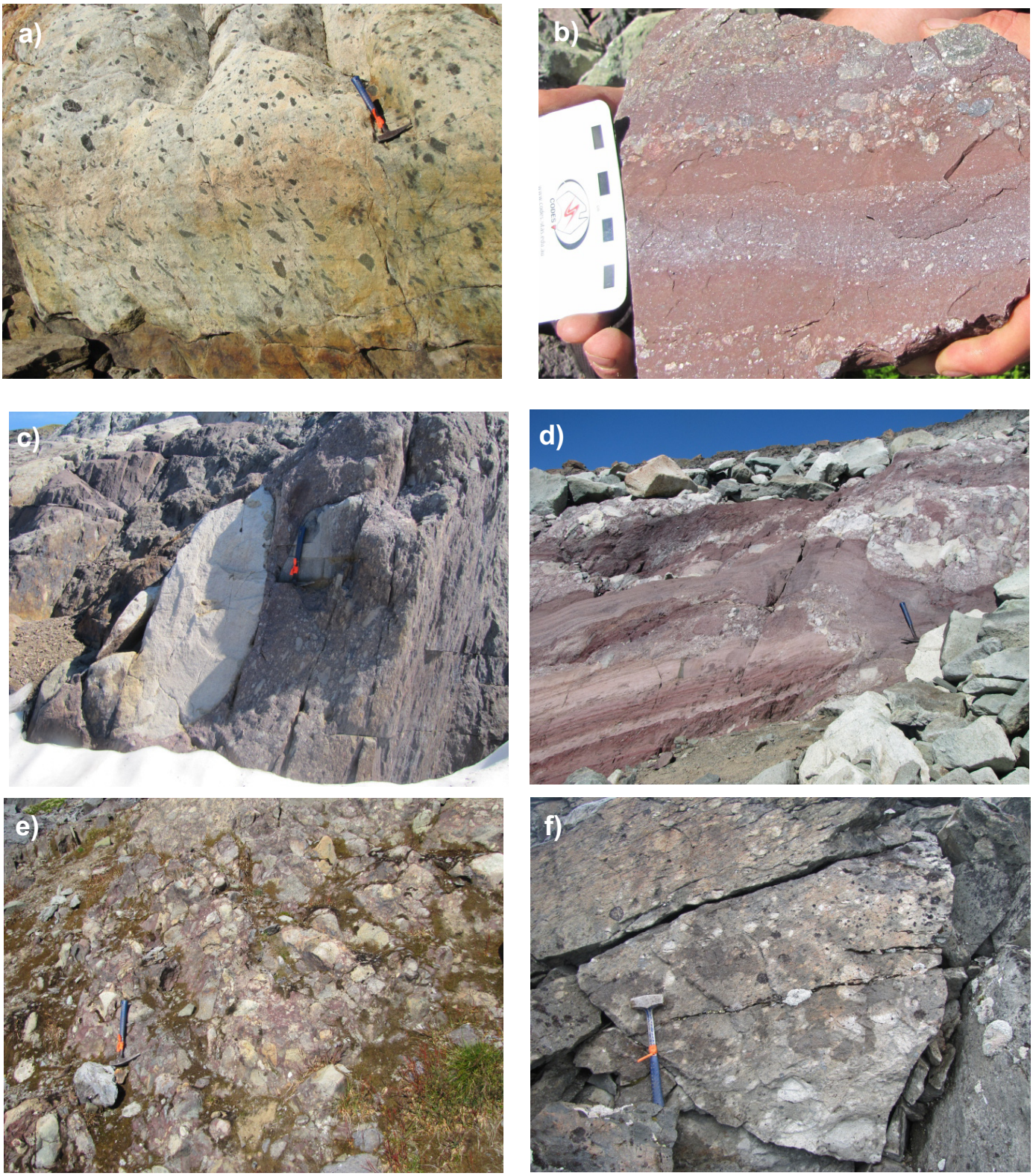

Fig. 7. Representative photos of the Betty Creek Formation. **a)** Sparse clasts in andesite lapilli tuff, Unuk River andesite unit 2 km northwest of Brucejack Lake (426273 E, 6260107 N). **b)** Interbedded pebble conglomerate with volcanic clasts and tuff; Unuk River andesite unit, Treaty Glacier (427578 E, 6272959 N). **c)** Tabular crowded plagioclase-phyric boulder (light-toned left foreground) in basal Unuk River andesite unit (425715 E, 6260099 N); U-Pb zircon age ca. 197 Ma (J. Nelson, unpub. data). **d)** Felsic-clast breccia, Johnny Mountain dacite unit (374608 E, 6276356 N). **e)** Welded tuff and pyroclastic breccia, Brucejack Lake felsic unit (426343 E, 6261610 N). **f)** Local conglomerate at the base of the Brucejack Lake felsic unit (426101 E, 6260852 N).

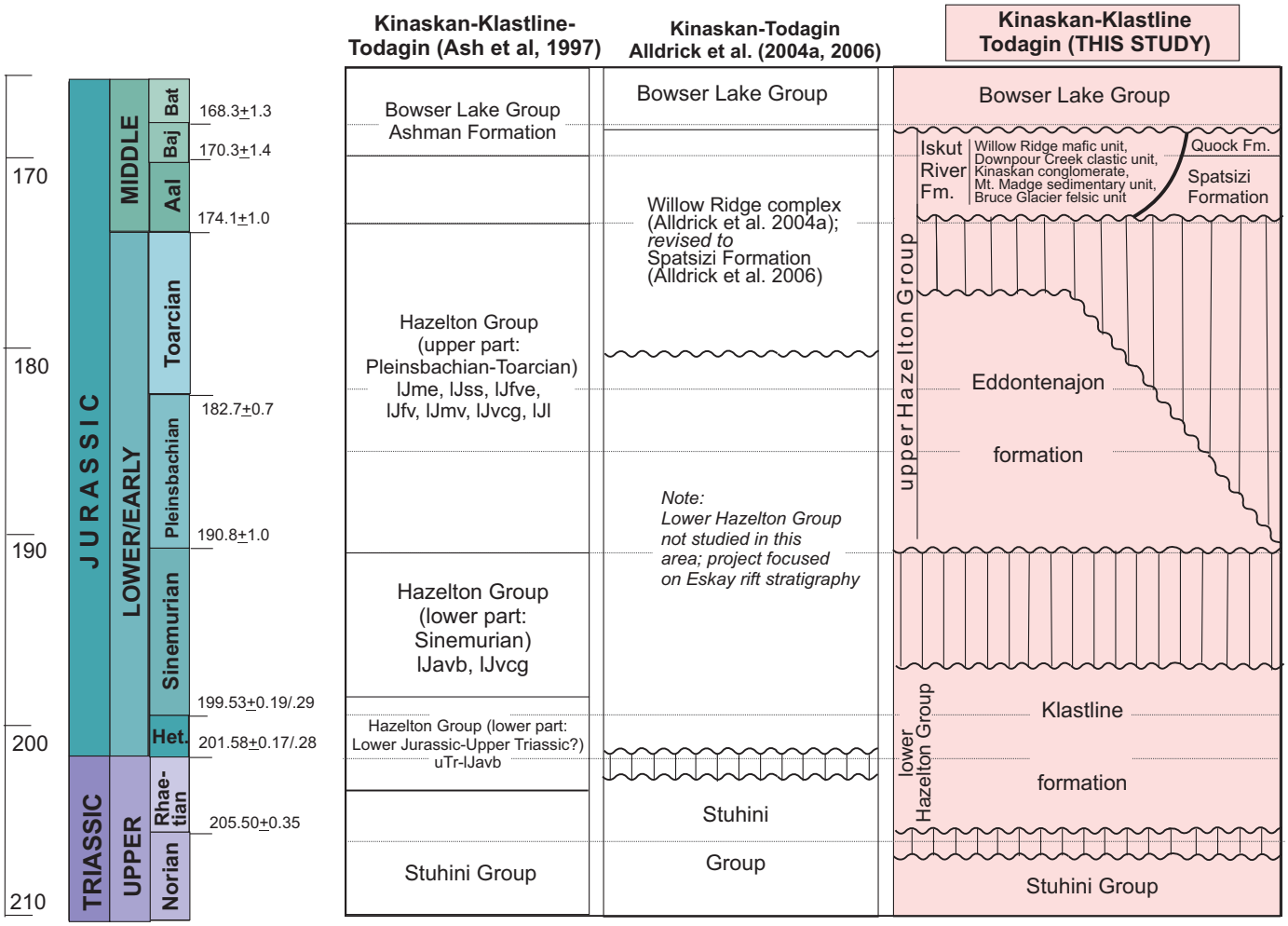

Fig. 8. Evolution of Hazelton Group stratigraphic nomenclature in the Kinaskan-Klastline-Todagin area, northern of Iskut River region.

Thomson et al., 1986; revised to Spatsizi Formation within the Hazelton Group by Evenchick and Thorkelson (2005) and Gagnon et al., 2012). In its type area, the Spatsizi Formation is divided into four members based on proportions of sandstone vs. shale and siltstone, interpreted as the result of cycles of transgression and regression (Fig. 9; Thomson et al., 1986). In the Iskut region, we use the first appearance of similar rocks above the Unuk River andesite unit to define the base of the upper Hazelton Group.

Near Treaty Glacier, the sedimentary succession consists of volcanic sandstone, conglomerate, and local bioclastic sandy limestone, mudstone-siltstone rhythmites, and limestone. It overlies the Unuk River andesite unit, which includes a ca. 187 Ma U-Pb felsic unit (Cutts et al., 2015). Two ammonite collections from a single locality near the top of the sedimentary section are Late Aalenian (PDL-886 and GJ-099; Nadaraju 1993; Lewis, 2013). Similar sedimentary rocks are also exposed within the Eskay anticline, near John Peaks-Bruce Glacier, and in the Cone Glacier-Julian Creek area west of the Unuk River. These sedimentary sections contain abundant Upper Pleinsbachian to Upper Toarcian macrofossils (Nadaraju, 1993).

Although Lewis et al. (2001a) and Lewis (2013) referred to this succession as Treaty Ridge Member of the Betty Creek Formation, the lithologic character, fossil age, and stratigraphic position of the unit are similar to those of the Spatsizi Formation in its type area (Figs. 5, 9). We recommend that these strata be included in the upper Hazelton Group and be referred to as the Spatsizi Formation. Because Treaty ridge is an informal and poorly described location, we further recommend that the term 'Treaty Ridge Member' be abandoned.

2.4. The Eskay rift, the Iskut River Formation, and abandonment of 'Salmon River Formation'

A several kilometre-thick succession of interlayered basalt, rhyolite, and sedimentary rocks in the upper Hazelton Group occupies a narrow, elongate north-trending belt, extending from Kinaskan Lake in the north to Anyox in the south (Figs. 1-3; Anderson, 1993; Lewis, 2001, 2013; Lewis et al., 2001a; Alldrick et al., 2005b; Gagnon et al., 2012; Barresi, 2015). This narrow, fault-bounded zone has been referred to as the Eskay rift (e.g., Evenchick and McNicoll, 2002;

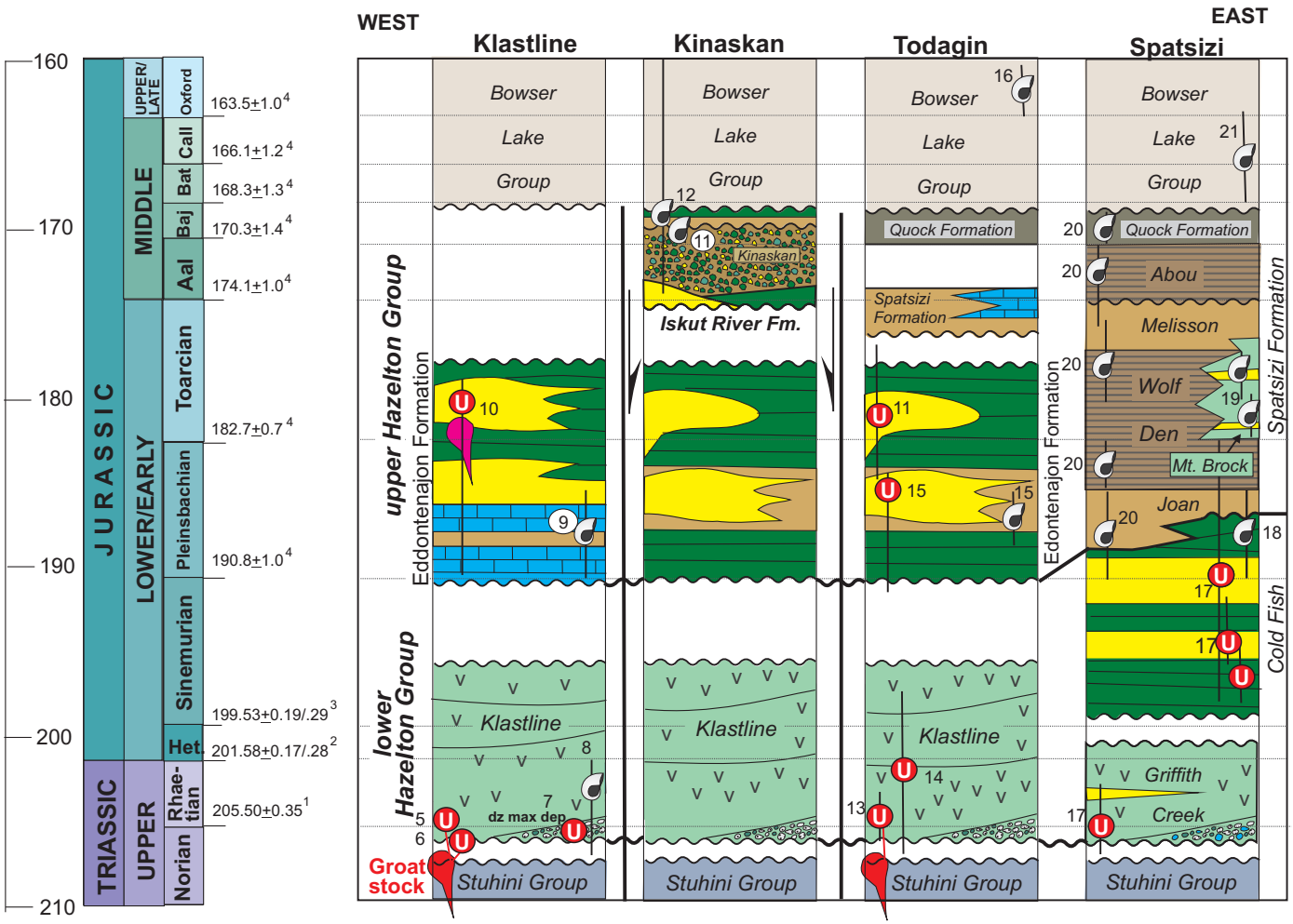

Fig. 9. Stratigraphic columns representing the Hazelton Group in the Kinaskan-Klastline-Todagin area, northern Iskut River region. Numbers reference sources for fossil and radiometric ages. **1.** Norian-Rhaetian boundary (Wotzlaw et al., 2014); **2.** Rhaetian-Hettangian boundary (Schaltegger et al., 2008); **3.** Hettangian-Sinemurian boundary (Schaltegger et al., 2008); **4.** Cohen et al. (2013); **5.** Groat stock 205-207 Ma (Peatfield et al., 2016); **6.** Groat stock 205.1 ±0.8 (Ash et al., 1997b); **7.** A. Zagorevski, unpub. Dz 10ZE-176. Main population 205.7 ±0.8 Ma; **8.** Upper Triassic, Suessi zone (Late Norian-Rhaetian, collections 32781, 32767, 40482; Souther, 1972); **9.** Early Jurassic (collection 32786; Souther, 1972); contains pectinid similar to P. *bodenbenderi behr* similar to Weyla in Joan Member (Early Pleinsbachian; see Gagnon et al., 2012); **10**. Felsite intrusions 182-186 Ma (Ash et al., 1997a); **11.** D. Alldrick and J. Nelson, unpub. data, 2017; **12.** Possibly middle-Upper Jurassic macrofossils (collection 32834, Souther, 1972); **13.** Red stock 203.8 ±1.3 Ma (Ash et al., 1997b); **14.** Trachyte north of Ealue Lk, 202.1 ±4.2 Ma (Ash et al., 1997b); 1**5.** 185.6 +6.1-0.6 Ma, Freboldi zone (Lower Pleinsbachian; Palfy et. al., 2000); **16**. Early Oxfordian (collection 32778, Souther, 1972); **17.** Thorkelson et al. (1995); **18**. Early Pleinsbachian fossils in Cold Fish volcanics (Evenchick, 1986); **19.** Toarcian fossils in Mt. Brock volcanics **(**Read and Psutka, 1990); **20.** Thomson et al. (1986); **21**. Bathonian-Callovian fossils in Bowser Lake Group (Evenchick, 1986).

Alldrick et al., 2005b). Gagnon et al. (2012) proposed the name Iskut River Formation for this succession in the Iskut River region and elsewhere in western Stikinia. Previously, Lewis et al. (2001a) and Lewis (2013) used the term 'Salmon River Formation' for these rocks. However, as originally defined on Mount Dilworth by Grove (1971, 1986) and Alldrick (1987), the 'Salmon River Formation' is not a bimodal-volcanic rock and sedimentary succession but rather comprises a <10 m thick basal layer of Toarcian(?) calcareous grit overlain by 50-100 m of thinly bedded siltstone, shale, tuff and radiolarian chert, and then more than 1000 m of siliciclastic strata (Alldrick 1993). Furthermore, Gagnon and Waldron (2011) recognized that the siliciclastic rocks on Mount Dilworth are part of the Bowser Lake Group, which unconformably overlies the Hazelton Group (Fig. 4).Thus, because the term 'Salmon River Formation' was appropriated for an entirely different succession of rocks (in contradiction to the North American Stratigraphic Code), and because, as originally defined, the Salmon River Formation, was miscorrelated, Gagnon et al. (2012) proposed that the term 'Salmon River Formation' be abandoned, a recommendation that we follow.

The Iskut River Formation is laterally equivalent to the upper parts of the Hazelton Group elsewhere, but it is much thicker than correlative units, displays distinct volcanic-rich, locally variable facies, and occupies a unique tectonic setting. It has yielded uppermost Toarcian, Aalenian to Early Bajocian fossils

and ca. 179-173 Ma U-Pb zircon ages (Childe, 1996; Cutts et al., 2015; J. Nelson and D. Alldrick, unpublished, 2017). The base of the unit in the Treaty Glacier area is constrained by Late Aalenian fossils at the top of the underlying Spatsizi Formation (Nadaraju, 1993).

The Iskut River Formation is a highly variable succession in which mafic and felsic volcanic and sedimentary units occur in differing stratigraphic sequences, with multiple stratigraphic repetitions in some areas. Similar to subdivisions of the Betty Creek Formation, most of these units do not lend themselves to formal member status. In the following we: abandon the John Peaks Member (Lewis et al., 2001a; Lewis, 2013) and replace it with Willow Ridge mafic unit; downgrade the Bruce Glacier Member (Lewis et al., 2001a; Lewis, 2013) to an informal unit; retain the 'Eskay Rhyolite Member' (Lewis et al., 2001a; Lewis 2013); and introduce the Mount Madge sedimentary unit for the Troy Ridge Member, which we abandon (Fig. 4).

2.4.1. Willow Ridge mafic unit

Basalt is the most voluminous rock type in the Iskut River Formation throughout its extent. It is abundant in the Unuk River valley (Lewis, 2013; Fig. 3), where it was called the John Peaks Member (Lewis et al., 2001a). However, the John Peaks massif is underlain by an Early Jurassic pluton, which Lewis (2013) named the John Peaks pluton. Because John Peaks do not expose the basalts and because the same name is used for two different rock bodies, we propose that the term 'John Peaks Member' be abandoned. Alldrick et al. (2004b) proposed Willow Ridge as a type section of basalt typical of the Iskut River Formation. This locality, between Table Mountain and Kinaskan Lake (Figs. 2, 3), displays typical variations within the unit and is road accessible. We recommend the term Willow Ridge mafic unit for these rocks.

2.4.2. Bruce Glacier felsic unit

Non-welded to welded lapilli tuff (Fig. 10), felsic volcanic breccia and coherent flows, and volcanic conglomerates occur extensively around the periphery of the McTagg anticlinorium, where they form the local basal unit of the Iskut River Formation (Fig. 3). This unit also occurs in the Eskay anticline, in the footwall of the Eskay deposit, and overlying Betty Creek strata west of Harrymel Creek (Lewis, 2013). In the Bruce Glacier area, it unconformably overlies the Jack, Betty Creek and Spatsizi formations. Similar felsic rocks also occur at higher stratigraphic levels, such as at the top of the Iskut River Formation on Treaty ridge and above pillow basalts of the Willow Ridge mafic unit on Pillow Basalt ridge and Table Mountain (see below). Because of this repetition, we refer to these felsic rocks as the Bruce Glacier felsic unit, rather than retaining the formal 'Member' status used by Lewis et al. (2001a). Six SHRIMP U-Pb zircon ages from the unit range from 178.5 ±1.8 to 173.3 ±1.8 Ma (Cutts et al., 2015). These ages agree well with the multigrain TIMS ages presented in Lewis (2013), and support the Middle Jurassic age of the Iskut River Formation.

Fig. 10. Bruce Glacier felsic unit, welded lapilli tuff (412848 E, 6270707 N).

2.4.3. Eskay Rhyolite Member

The Eskay Rhyolite Member (Lewis et al., 2001a) forms the immediate footwall of the Eskay deposit at the northern end of the Eskay anticline (Fig. 5) where it was rigorously defined by mapping and core logging as a single, linear flow-dome complex of coherent to brecciated flows that show peperitic contacts with the overlying argillite, which is the host for massive sulphide mineralization (Bartsch, 2001; Barrett and Sherlock, 1996; Childe, 1996). Childe (1996) obtained a U-Pb zircon age of 175 ±2 Ma from the Eskay rhyolite, identical within error to ages in the Bruce Glacier felsic unit. Geochemistry of the rhyolite (Al/Ti>100) also distinguishes it from other felsic bodies in the area, although this does not constitute a lithostratigraphic criterion.

2.4.4. Mount Madge sedimentary unit

The Eskay Rhyolite Member is overlain by thinly bedded black argillaceous mudstone and felsic tuff. This unit hosts most of the mineralization at Eskay Creek where it is referred to as the Contact argillite (Barrett and Sherlock, 1996). Elsewhere in the Iskut River Formation, tuff-argillite units occur as thin, discontinuous lenses enclosed within volcanic rocks. They were included in the Troy Ridge Member as defined by Lewis et al. (2001a) because of their similarity to siliceous strata at the type locality on Troy ridge. However, the rocks on Troy ridge are now assigned to the regionally extensive Quock Formation (see section 2.6. below). We suggest that Mount Madge (Fig. 2) be the type locality for isolated occurrences in the Iskut River Formation, because Lewis (2001, 2013) has documented two prominent layers on its higher slopes. Other examples occur north of the McTagg anticlinorium, at the head of Treaty Glacier, and near Granduc (Lewis, 2001, 2013).

2.5. Mount Dilworth Formation

Dacite and rhyolite form laterally continuous exposures on Mount Dilworth and Troy ridge in the Salmon River

area, above the Betty Creek Formation and below the Quock Formation (see below). They constitute the Mount Dilworth Formation as originally defined by Alldrick (1987). A U-Pb zircon SHRIMP age of 173.6 ±1.7 Ma from the northern ridge of Mount Dilworth (Cutts et al., 2015) shows that these rocks are coeval with the Bruce Glacier felsic unit of the Iskut River Formation. We suggest that the Mount Dilworth Formation be retained as part of the upper Hazelton Group, distinguished from felsic units in the Iskut River Formation by its tabular geometry, regional extent, and lack of interfingering with mafic units. It indicates widespread Aalenian felsic activity proximal to, but outside of, the Eskay rift.

2.6. Quock Formation

The highest unit of the Hazelton Group regionally is the Quock Formation, which ranges from Bajocian in the Spatsizi Plateau area (Fig. 9) to Callovian near Terrace (Gagnon et al., 2012). It comprises 50-100 m of thinly bedded, dark grey siliceous argillite with pale felsic tuff laminae, and radiolarian chert. The dark and light striping led to the unit being informally but unforgettably termed 'pyjama beds' by Howard Tipper of the Geological Survey of Canada. It is at least in part a facies equivalent of the Iskut River Formation.

The Quock Formation forms a thin but regionally continuous layer on Mount Dilworth and Troy ridge, above the Mount Dilworth Formation and below the Bowser Lake Group. It was previously called the Troy ridge facies of the Salmon River Formation (Anderson and Thorkelson 1990), and later the Troy Ridge Member of the Salmon River Formation (Lewis et al., 2001a; Lewis, 2013). Because Troy ridge is an informal locality, we favour the usage of Gagnon et al. (2012) and propose that these rocks be included in the Quock Formation, which forms a thin but areally extensive layer at the top of the Hazelton Group throughout Stikinia, outside of the Eskay rift.

3. Ball Creek-Forrest Kerr Creek-Table Mountain (central) area

This area extends north from the confluence of Forrest Kerr Creek and the Iskut River and includes the Downpour Creek, More Creek, and Ball Creek drainages, Table Mountain, and Willow Ridge (Fig. 2). Rocks of the Iskut River Formation are exposed in northerly, fault-bounded graben in contact with older units of the Stuhini Group and Paleozoic stratified and intrusive bodies.

Souther (1972) mapped the area at a 1:250,000 scale, providing a broad bedrock framework and important age constraints from macrofossil collections (Fig. 11). Subsequent 1:50,000-scale mapping was supported by macrofossil and microfossil collections and sparse U-Pb geochronology (Read et al., 1989; Logan et al., 2000). Alldrick et al. (2004a, b; 2005, a, b; 2006) mapped from Forrest Kerr Creek to Kinaskan Lake (Fig. 2), identifying a series of geographically named sub-basins in the Eskay rift, each with a distinct stratigraphy, and used unique codes for each lithotype in each sub-basin (see list of sub-basin names on Fig. 11, which correspond to major legend subdivisions in Alldrick et al., 2006). In the following, we apply Hazelton Group terminology developed above for the Stewart-McTagg anticlinorium-Snippaker Mountain area to previously unnamed units. We also propose new informal names for rocks in the Iskut River Formation that do not occur farther south: Kinaskan conglomerate unit, Downpour Creek siliciclastic unit, and Palmiere dacite-mudstone unit.

3.1. Units in the lower Hazelton Group

3.1.1. Jack Formation(?)

At two localities along a southern tributary to Ball Creek, east of the Matthew Glacier (Figs. 2, 12), a siliciclastic sedimentary-volcanic succession (unit 13 of Souther, 1972) yielded Hettangian ammonites (*Psiloceras canadense* Frebold). These rocks overlie the Stuhini Group in the hinge zone of a syncline (Souther, 1972). Although lacking the characteristic conglomerates, these rocks are coeval with the Jack Formation elsewhere and, like Jack Formation equivalents, form the basal unit of the Hazelton Group in this area.

3.1.2. Betty Creek Formation

Isolated occurrences of Lower Jurassic andesites between Downpour Creek and the Little Iskut River are herein assigned to the Unuk River andesite unit. Felsic units near Downpour Creek (Logan et al., 2000; Alldrick et al., 2005b) and Ball Creek (Alldrick et al., 2004a, b) are designated as unnamed rhyolites in the Betty Creek Formation (Fig. 12). The unit near Downpour Creek is Sinemurian based on a conodont collection in overlying strata (Logan et al., 2000). The rhyolites near Ball Creek occur in a succession containing Pleinsbachian ammonites (Souther, 1972).

3.2. Units in the upper Hazelton Group

The Iskut River Formation was first defined based on stratigraphic sections in this area (Gagnon et al., 2012). Below we assign previously unnamed basaltic sequences to the Willow Ridge mafic unit, rhyolites to the Bruce Glacier felsic unit, and fine-grained siliceous sequences to the Mount Madge sedimentary unit, as described from the southern area. The area also contains units not seen in the southern sub-area (Fig. 12). Sections many hundreds of metres thick of mainly medium-grained siliciclastic beds near Downpour Creek and on Table Mountain are assigned to the Downpour Creek siliciclastic unit (new name). Conglomerates south of Downpour Creek and on western Table Mountain are assigned to the Kinaskan conglomerate (new name). Also not recognized in the south, the Palmiere unit (new name) is a unique felsic volcaniclastic-mudstone succession that occurs on both sides of the Iskut River near Palmiere Creek (Fig. 2).

3.2.1. Willow Ridge mafic unit

As is the case elsewhere in the region, basalt and pillow basalt are the most widespread and thickest Iskut River Formation rock types. They form particularly thick, km-scale sections on the eponymous Pillow Basalt ridge (Fig. 13a), and on Table

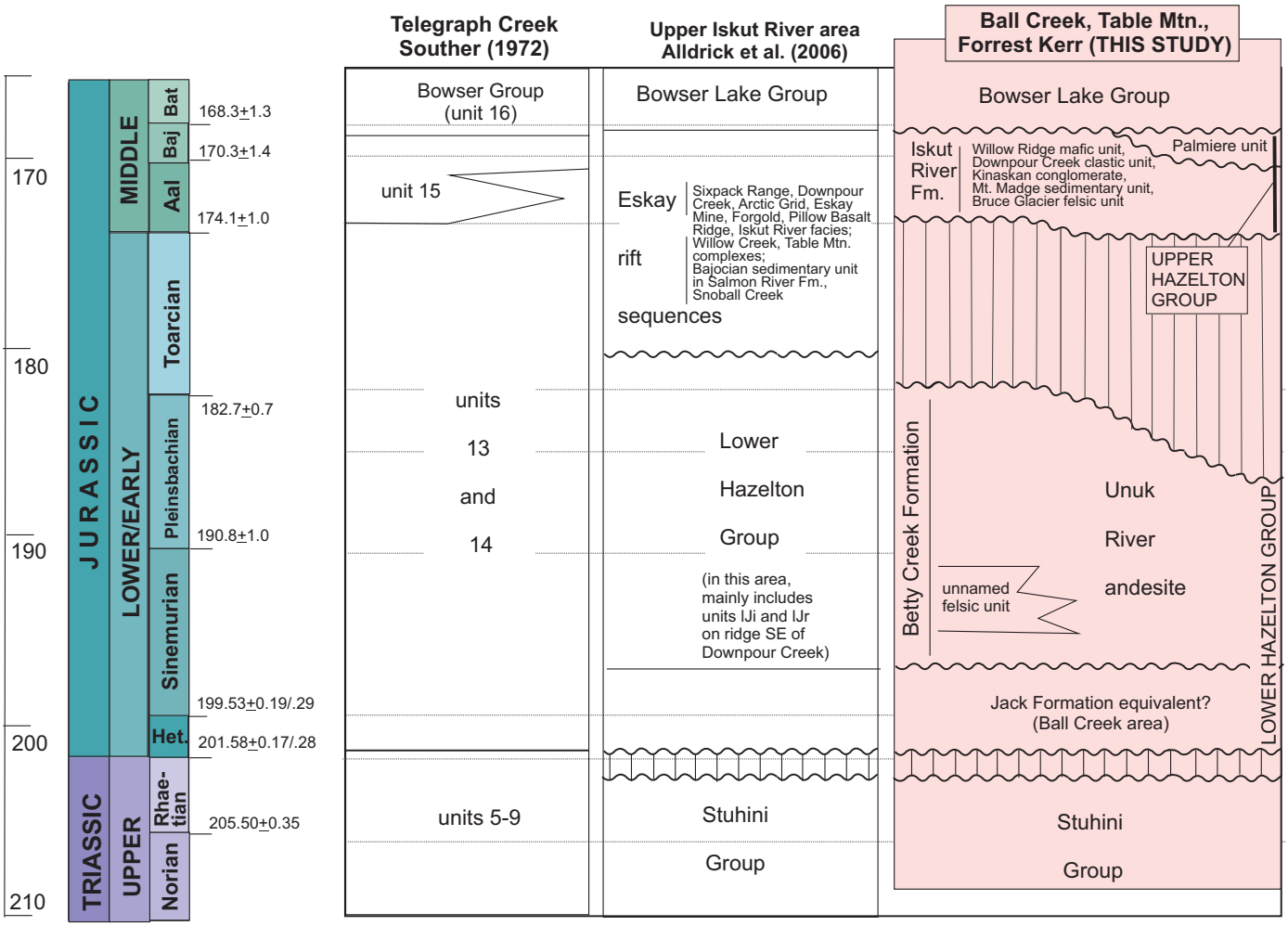

Fig. 11. Evolution of Hazelton Group stratigraphic nomenclature in the Forrest Kerr-Ball Creek-Table Mountain area, central Iskut River region.

Mountain and adjacent Willow Ridge south of Kinaskan Lake. On Pillow Basalt ridge, a small rhyolite in a sedimentary inlier yielded a U-Pb TIMS age of ca. 174 Ma (J. Nelson and D. Alldrick, unpublished data, 2017). Voluminous feeder dikes and sills form part of the unit. Basalts are of non-arc, tholeiitic character, variably contaminated by incorporation of older arc crust (Barresi et al., 2015b).

3.2.2. Bruce Glacier felsic unit

Small domes and cryptodomes with peperitic margins occur on Pillow Basalt ridge, near Forrest Kerr Creek (Figs. 2, 13b), on Table Mountain, and on Willow Ridge, most commonly surrounded by sedimentary facies, but also enclosed within basalts (Alldrick et al., 2004b, 2005b). Felsic volcaniclastic and coherent bodies also occur near Kinaskan Lake.

3.2.3. Mount Madge sedimentary unit

Two discontinuous intervals of thinly bedded to laminated, fine-grained, siliceous argillite and felsic tuff occur on Pillow Basalt ridge (Fig. 13c). One of these encloses a small rhyolite dome or cryptodome that has yielded a U-Pb age of 174.07 ±0.2 Ma (J. Nelson and D. Alldrick, unpublished, 2017), coeval within error with the Eskay Rhyolite and the Bruce Glacier felsic unit (Childe, 1996; Cutts et al., 2015).

3.2.4. Kinaskan conglomerate unit (new name)

Conglomeratic deposits interfinger with Willow Ridge basalts along the southern shores of Kinaskan Lake, on Table Mountain, and between Downpour Creek and Pillow Basalt ridge. Clasts are both intraformational basalts and rhyolites and extrabasinal, derived from adjacent older Hazelton, Stuhini, and Paleozoic stratified units and intrusive bodies (Figs. 13d, e). They transition across short distances from monomictic breccias to polymictic conglomerates; clast roundness increases with clast diversity. On western Table Mountain, the base of the unit consists of breccias that are interpreted to be paleotalus derived from underlying fault-brecciated lower Hazelton volcanic rocks (Alldrick et al., 2004b). They grade upward into polymictic conglomerates with a sandstone matrix that contain rounded rhyolite and basalt clasts derived from the Iskut River Formation. A suite of monomictic sedimentary breccias north of Pillow Basalt ridge consists of individual deposits derived

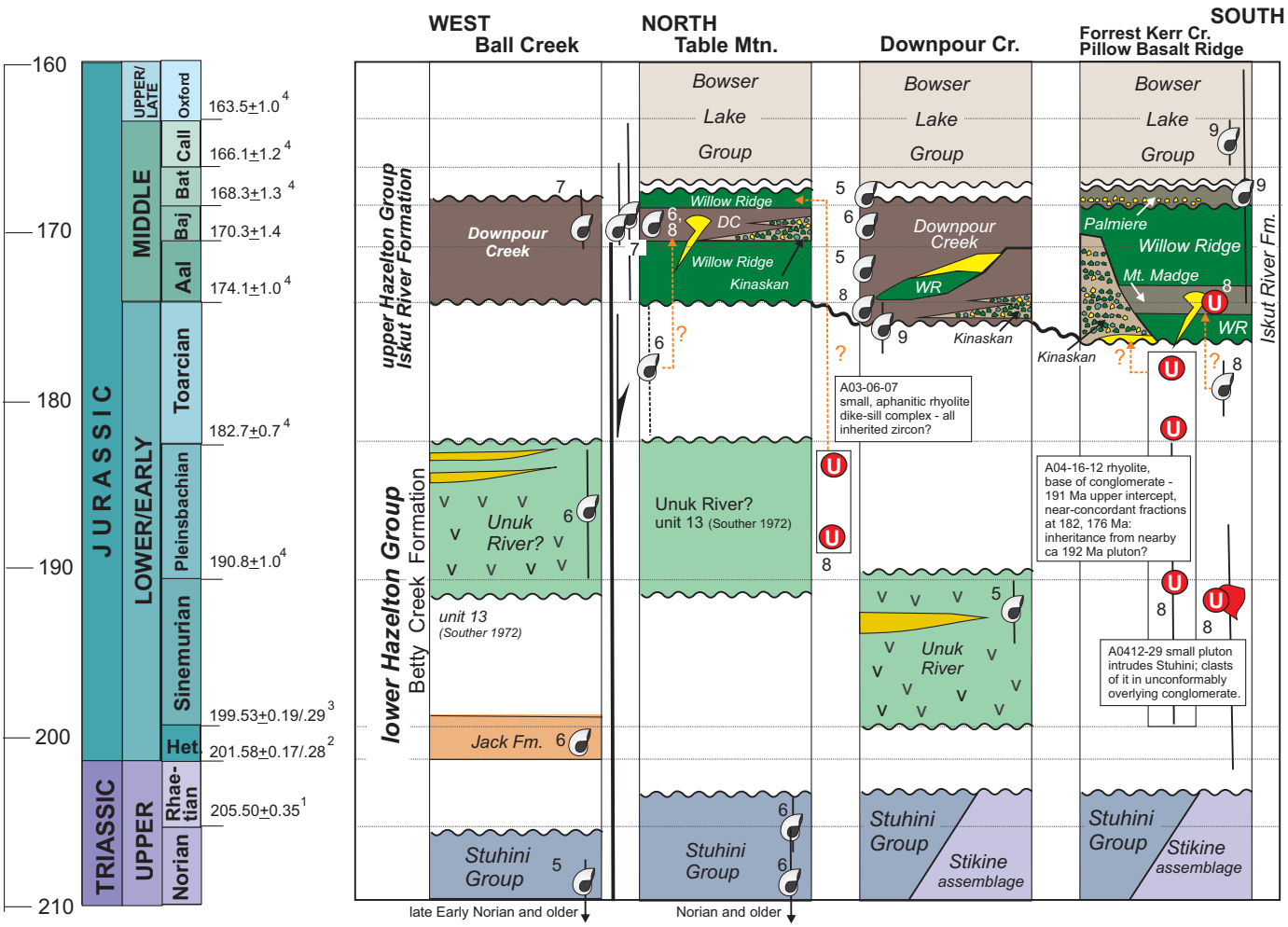

Fig. 12. Stratigraphic columns representing the Hazelton Group in the Forrest Kerr-Ball Creek-Table Mountain area, central Iskut region. Numbers reference sources for fossil and radiometric ages. **1.** Norian-Rhaetian boundary (Wotzlaw et al., 2014); **2.** Rhaetian-Hettangian boundary (Schaltegger et al., 2008); **3.** Hettangian-Sinemurian boundary (Schaltegger et al., 2008); **4.** Cohen et al. (2013); **5.** Logan et al. (2000); **6.** Souther (1972); **7.** Evenchick et al. (2001); **8.** D. Alldrick and J. Nelson, unpub. data (2017); **9.** Read et al. (1989).

from diverse volcanic and intrusive sources that interfinger on a scale of less than a hundred metres (Alldrick et al., 2005b). These units are localized next to probable syn-sedimentary faults, some of which were later remobilized as thrust faults (Alldrick et al., 2004b, 2005b).

3.2.5. Downpour Creek siliciclastic unit (new name)

The Kinaskan conglomerate unit grades upsection and laterally into a succession of sandstone, siltstone and mudstone that we refer to as the Downpour Creek siliciclastic unit, after exposures near Downpour Creek (Fig. 2). The Downpour Creek siliciclastic unit yielded Late Toarcian to Bajocian and perhaps Bathonian macrofossils (Souther, 1972; Logan et al., 2000). A key collection from a small outlier in a synclinal keel overlying lower Hazelton Group rocks yielded abundant, diverse latest Toarcian shelly fauna (J. Nelson and D. Alldrick, unpublished, 2017), which best constrains the age of the base of the Iskut River Formation in this area.

Table Mountain is underlain by two basaltic units separated by interbedded sandstone, siltstone and mudstone assigned to the Downpour Creek siliciclastic unit (Fig. 13f). Small bodies of rhyolite and basalt occur within it. Rare beds of fine-grained siliceous argillite resemble the Mount Madge sedimentary unit, but they are not separated in regional mapping. The unit grades laterally into a narrow zone near the western bounding fault of coarse clastic deposits (Alldrick et al., 2004b) that we assign to the Kinaskan conglomerate unit. This sequence has yielded Late Toarcian, Early Bajocian, and Middle Bajocian macrofossil assemblages (Souther, 1972; J. Nelson and D. Alldrick, unpublished data, 2017).

3.2.6. Palmiere dacite-mudstone unit (new name)

The southern end and southeastern slopes of Pillow Basalt ridge are underlain by a distinctive unit of dacite-clast volcanic breccia, dacite-clast conglomerate, arkosic sandstone, and dark grey to black silty argillite and mudstone (Alldrick et al.,

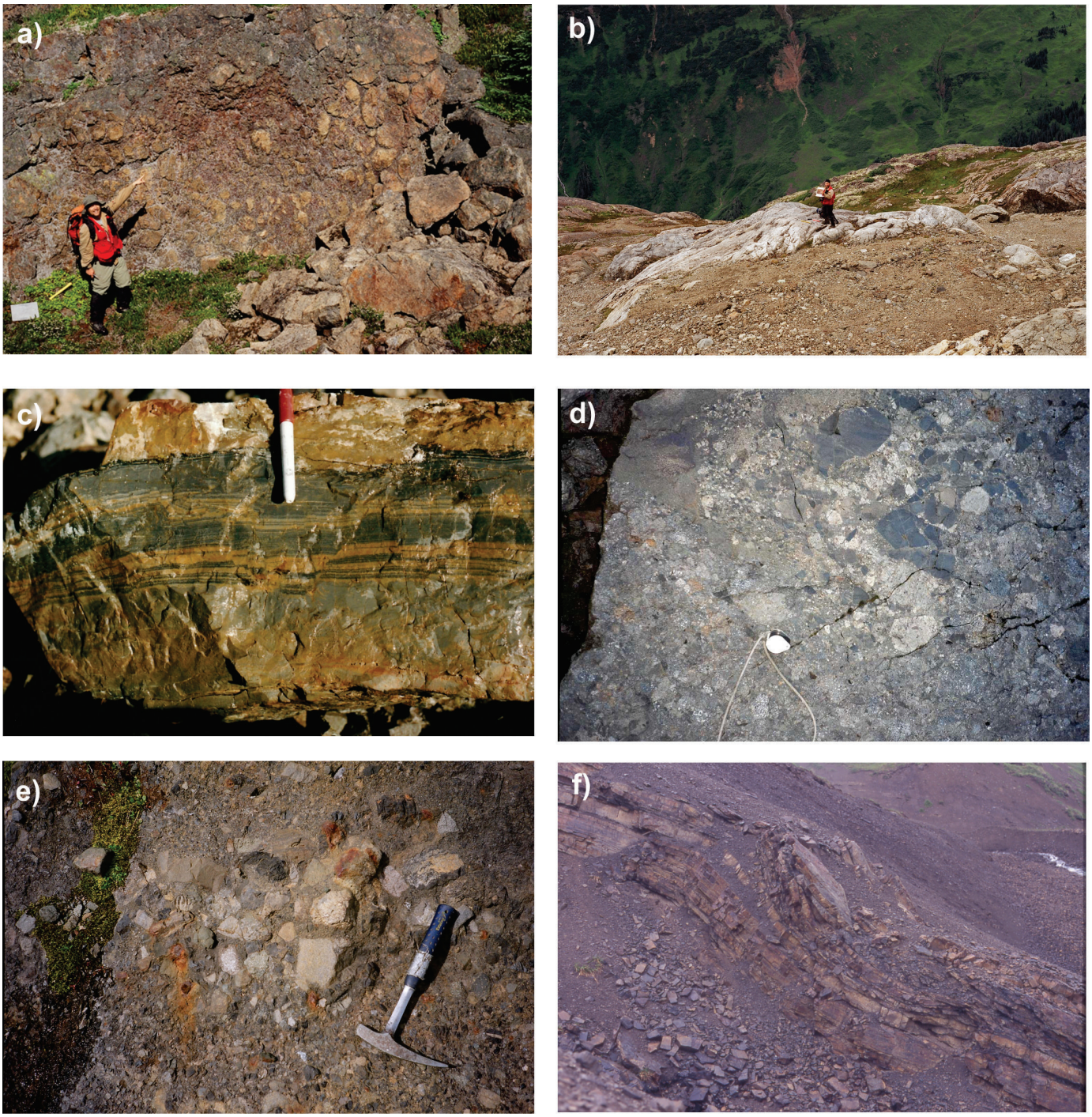

Fig. 13. Representative photographs of the Iskut River Formation. **a)** Willow Ridge mafic unit, pillow basalt, Pillow Basalt ridge (401436 E, 6298614 N). **b)** Bruce Glacier felsic unit, small rhyolite dome-cryptodome complex, 'Four Corners' area (401000 E, 6307500 N). **c)** Mt. Madge sedimentary unit, laminated siliceous argillite and pale felsic tuff offset by small synsedimentary (?) faults, Pillow Basalt ridge (403000 E, 6301000 N). **d)** Kinaskan conglomerate unit, breccia, Sixpack ridge (405608 E, 630318 N). **e)** Kinaskan conglomerate unit, polymictic conglomerate, Sixpack ridge (405424 E, 6303410 N). **f)** Downpour Creek clastic unit interbedded sandstone and siltstone, Table Mountain (415000 E, 6360000 N). Monocline typical of mild deformation seen in these strata.

2005a, b). Correlative felsic breccia and argillite occur on the ridge northeast of Palmiere Creek, south of the Iskut River. Relationships on Pillow Basalt ridge suggest that the Palmiere unit onlaps all older Iskut River units as well as thrust faults that imbricate them (Alldrick et al., 2005a, 2006). The Palmiere dacite-mudstone unit is overlain by the Bowser Lake Group. On the southern end of Pillow Basalt ridge, dacite breccias show incipient fragmentation textures. Large olistoliths of

limestone are scattered within it. One has yielded Early Permian conodonts (F129, Read et al., 1989). A macrofossil collection from the unit is Middle or possibly early Late Jurassic (F141, Read et al., 1989).

The Palmiere unit appears to be the youngest unit in the Iskut River Formation. Its suggested unconformable relationship to other Iskut River units and structures should be further investigated, and more precise ages obtained. The Palmiere unit could provide constraints on episodes of transtension and transpression, or transfer from releasing to restraining bends, within the overall Eskay rift (Alldrick et al., 2005b).

4. Kinaskan Plateau-Klastline Plateau-Todagin Plateau area

This area was initially mapped at 1:250,000 scale by Souther (1972). The Klastline and Todagin plateau areas were subsequently mapped at 1:50,000 scale (Ash et al., 1996, 1997a, b). In their study of the Stuhini, Hazelton, and Bowser Lake groups in the Spatsizi Plateau area, Evenchick and Thorkelson (2005) overlapped the eastern limit of the present study near Ealue Lake and included a partial re-interpretation of mapping by Ash et al. (1997a) on the Todagin Plateau (Evenchick and Green, 2004). To constrain the northern termination of the Eskay rift, Alldrick et al. (2004a, 2006) extended mapping to Kinaskan Lake and southern Todagin Plateau.

In the following, we replace the codes that were used for two new Hazelton map units recognized in the area by Ash et al. (1997a) with informal stratigraphic names, and substitute units within the Iskut River Formation for unit codes used in Alldrick et al. (2004a, 2006; Figs. 8, 9). Uppermost Triassic (to lowermost Jurassic?) andesites in the lower Hazelton Group are included in the Klastline formation and Lower Jurassic (partly or wholly Pleinsbachian to Toarcian) bimodal volcanic and sedimentary strata in the upper Hazelton Group are included in the Eddontenajon formation. Also, we correlate a siliciclastic-limestone unit in the upper Hazelton Group with the redefined Spatsizi Formation of Gagnon et al. (2012), and an overlying thinly bedded siliceous unit with the Quock Formation. Conglomerates and sedimentary breccias, basalt and felsic volcanic rocks near Kinaskan Lake are considered part of the Iskut River Formation, and named accordingly.

4.1. The lower Hazelton Group

4.1.1. Klastline formation (new name)

Ash et al. (1996, 1997a, b) recognized extensive andesitic volcaniclastic deposits and lesser flows unconformably above the Stuhini Group on the Klastline and Todagin plateaus (Fig. 14a) and referred to them using informal map code designations (units TrJavb and lJavb in Ash et al., 1997a). Pending detailed study, we propose the informal name Klastline formation for these rocks.

The andesites contain plagioclase phenocrysts accompanied by either pyroxene or hornblende. They unconformably overlie steeply dipping greywacke-argillite and pyroxene-phyric basalt of the Stuhini Group (Ash et al., 1996, 1997a; C. Rees, unpublished, 2017). Mapping of the Todagin Plateau near the Red Chris mine (Rees et al., 2015; C. Rees, unpublished, 2017) confirmed the existence of the lower Hazelton volcanic unit, and at one locale documented a conglomerate at its base above the Stuhini Group. The basal conglomerate contains intrusive and chert clasts (Fig. 14b). Its matrix, quartz-bearing arkose with orange-weathering carbonate cement, physically resembles the Snippaker unit. Detrital zircon peaks at 225 and 330-355 Ma indicate regional exhumation of the Stuhini Group and its Paleozoic basement (J. Nelson and B. van Straaten unpublished 2017). A detrital zircon sample from basal volcanogenic sandstone on the Klastline Plateau displays a major peak of ca. 205.4 Ma (A. Zagorevski, unpublished, 2017). This maximum depositional age likely approximates the actual age of the sandstone because the preservation of microlites suggests a proximal volcanic source. Klastline andesites have been interpreted as the volcanic equivalents of the ca. 206 Ma Red and Groat stocks (Friedman and Ash, 1997; Hollis, 2011), which intrude the underlying Stuhini Group. We suggest that this be named the Tatogga intrusive suite, after Tatogga Lake. The Klastline formation is intruded by numerous smaller undated bodies of the same suite.

North of Ealue Lake, a trachyte from the Klastline formation yielded a ca. 202 Ma U-Pb zircon age (Ash et al., 1997b). Farther north and at higher elevation on the tableland, a linear body of fossiliferous limestone and limestone breccia is intercalated with the plagioclase-phyric volcanic breccias. The limestone contains Late Triassic conodonts (Ash et al., 1997b). Because of its age, the limestone was previously considered to be a small inlier of the Stuhini Group below the volcanic pile (Ash et al., 1997a). However, limestone breccia contains volcanic matrix, and volcanic clasts occur within limestone (Fig. 14c; J. Nelson, unpublished, 2014), suggesting that this limestone represents small bank deposits on the Klastline volcanic edifice.

On Klastline Plateau, small bodies of limestone and fossil hash with a volcaniclastic matrix occur within the andesitic succession. They were described by Ash et al. (1997a, b) as olistoliths. One of these occurrences is an andesite breccia containing small colonial corals, brachiopods, and gastropods, which appear to have been incorporated as individuals in a volcanic mass flow deposit (Fig. 14d; J. Nelson, unpublished, 2014). Fossils from three collections include Paleocardita, Myophoria, Pinna, and *Plicatula perimbricata* Gabb; assigned a Late Norian (Suessi zone) age (E.T. Tozer in Souther, 1972). Some of these genera are also recognized in the Rhaetian of Europe (Hallam and Wignall, 1997). The base of the Rhaetian is now placed between ca. 205.5 Ma and its top at ca. 201.58 Ma (Ogg, 2012). Given its current age constraints, the Klastline formation is latest Triassic (Rhaetian), with possible range into earliest Jurassic. It is coeval with the Griffith Creek volcanics in the Spatsizi area (Fig. 9; Thorkelsen et al., 1995) and with the Snippaker unit to the south (Fig. 5). It is physically isolated from, and older than, the Betty Creek Formation, and represents a separate, earlier episode of Hazelton andesitic volcanism.

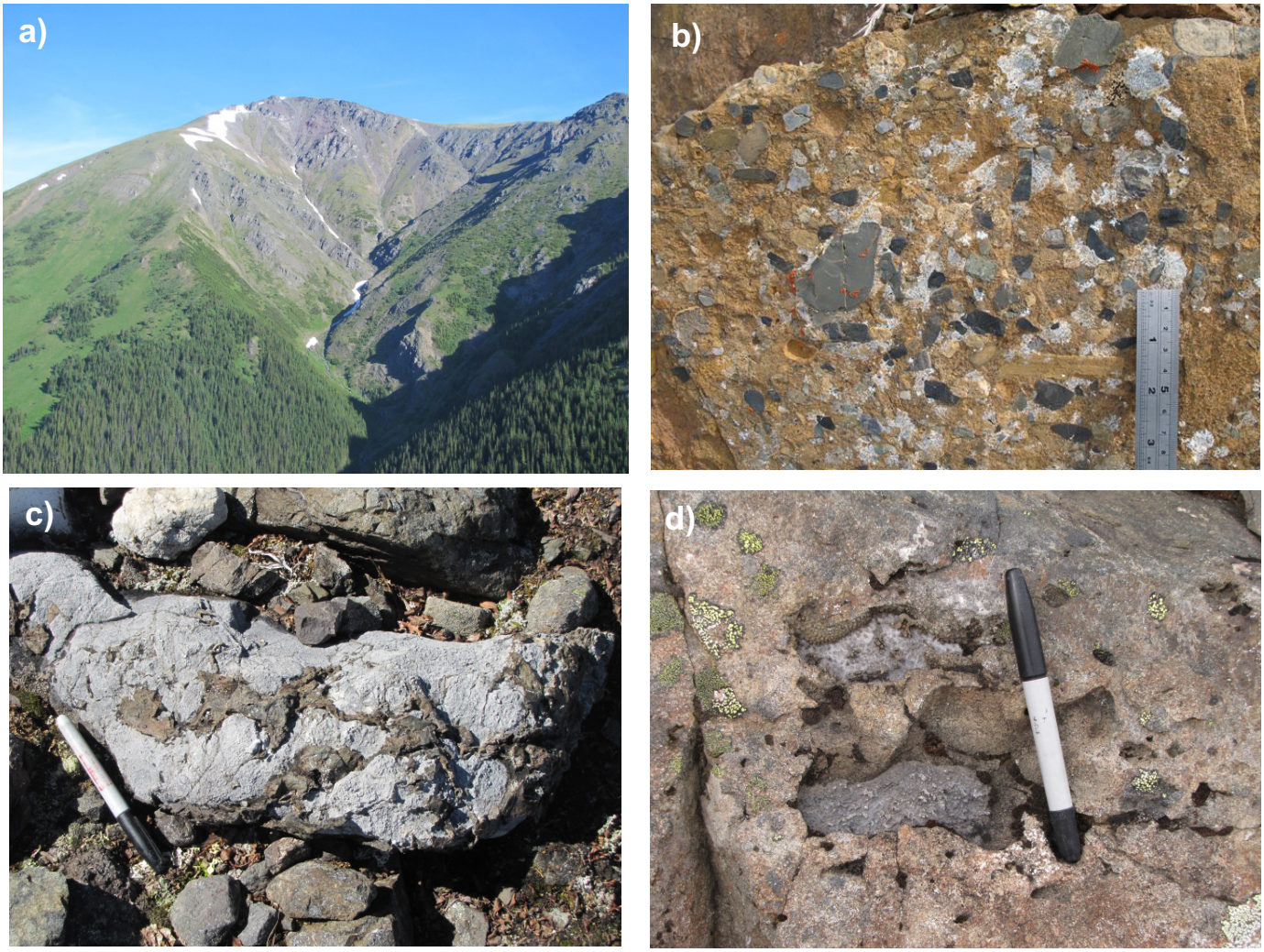

Fig. 14. Representative photographs of Klastline formation. **a)** Andesite breccia forms mountains west of Tatogga Lake. **b)** Basal conglomerate west of Red Chris (446000 E, 6394000 N). **c)** Limestone with andesitic tuff inclusions displaying embayed and flame-like boundaries, north of Ealue Lake (448290 E, 6406500 N). **d)** Coral clasts in andesite breccia, Klastline Plateau (429680 E, 6402520 N).

4.2. Units in the upper Hazelton Group

4.2.1. Eddontenajon formation (new name)

Pleinsbachian to Toarcian basalt, pillow basalt, rhyolite and interbedded limestone, calcareous sandstone and shale occur on southern Todagin Plateau and as scattered outliers on Klastline Plateau, unconformably overlying Klastline formation andesites (Figs. 3, 9). These rocks were designated as lJmv (mafic volcanic rocks), lJfv (felsic volcanic rocks) and lJl (limestone) by Ash at al. (1997a). Ash et al. (1997b) reported a ca. 180 Ma age from a rhyolite on Todagin Plateau. At the Todagin section, a rhyolite (U-Pb zircon, 185.6 +6.1-0.6 Ma) is interbedded with sandstone from which a late Early Pleinsbachian ammonite fauna was collected (Palfy et al., 2000). Another rhyolite in this area yielded a 181 ±4 Ma U-Pb zircon age (J. Nelson and D. Alldrick, unpublished, 2017). Souther (1972) reported Early Jurassic fossils from one locality on Klastline Plateau.

The sedimentary components of this unit resemble the Spatsizi Formation in age and character. However the bimodal volcanic rocks physically resemble those of the Iskut River Formation. A local name for this unit is appropriate, leaving potential correlations and interpretations for future work. We consider it part of the upper Hazelton Group because of its age and unconformable relationship to the Klastline formation.

4.2.2.Spatsizi Formation

A thin equivalent of the Spatsizi Formation outcrops along the southern edge of the Todagin Plateau, unconformably overlying the Stuhini Group and Klastline formation (Rees et al., 2015; C. Rees, unpublished mapping, 2017) and probably the Eddontenajon formation farther west. It includes bioclastic calcarenite that grades into fine-grained limestone, and feldspathic-lithic sandstone.

4.2.3. Quock Formation

Chert and siliceous argillite with pale felsic tuff laminae occur on the southern Todagin Plateau as a thin, continuous unit above the Spatsizi Formation and immediately below the

basal beds of the Bowser Lake Group (Rees et al., 2015; Fig. 9).

4.2.4. Iskut River Formation

The northernmost outcrops of possible Iskut River Formation lie west and east of southern Kinaskan Lake (Fig. 3). They include immature, poorly bedded conglomerates and sedimentary breccias of the Kinaskan conglomerate unit (see above; Alldrick et al., 2004b), interfingering with basalt and felsic volcanic rocks. The conglomerate contains macrofossils considered Bajocian and younger (Souther, 1972; D. Alldrick and J. Nelson, unpublished). This succession abuts the Eddontenajon formation at the western edge of Todagin Plateau. Although different in age (Middle Jurassic vs. Pleinsbachian-Toarcian), the two units have similar characteristics, i.e., basalt and rhyolite with interlayered siliciclastic beds. The contact between them is mostly covered and interpreted to be structural. Further mapping and geochronological work in this area is required to establish their relationship.

5. Discussion

Integration of mapping studies conducted in the Iskut region of western Stikinia has brought new understanding of the Hazelton Group, and provides a stratigraphic framework for related intrusions and mineral deposits. Newly defined uppermost Triassic (to lowermost Jurassic?) basal Hazelton units include the Klastline formation near the hamlet of Iskut and the Snippaker unit in the lower Iskut River area. Detrital zircon and fossil ages in these units indicate deposition in the Rhaetian (ca. 206-203 Ma) coeval with the emplacement of the Tatogga intrusive suite and porphyry mineralization at Red Chris and GJ. Close association of the Klastline formation and Tatogga intrusive suite suggests a temporal and probably causative link between the local onset of Hazelton volcanism and porphyry intrusion and mineralization. The abrupt appearance of older detrital zircon populations in basal Hazelton conglomerates attests to tectonically-induced denudation immediately preceding the onset of Hazelton deposition.

The Hazelton magmatic axis apparently shifted southwards by nearly a hundred kilometres between latest Triassic and Early Jurassic time, to the lower Iskut-McTagg region. Early Betty Creek volcanism coincided with emplacement of Texas Creek plutons. Of these, the Mitchell suite gave rise to the Kerr, Sulphurets, Mitchell and Iron Cap porphyry systems, and plutons of the Lehto suite caused porphyry and related gold mineralization in the Snip-Johnny Mountain-Inel-KSP camp. Epithermal gold mineralization at Valley of the Kings was formed during the waning stages of the magmatic episode, overlapping ages of felsic volcanic and intrusive rocks of the Brucejack Lake felsic unit.

All Middle Jurassic upper Hazelton Group units that fill the Eskay rift are included in the Iskut River Formation, as recommended by Gagnon et al. (2012). This supersedes the abandoned term Salmon River Formation. The Iskut River Formation is divided into seven informal, lithostratigraphic units: the Willow Ridge mafic unit, Bruce Glacier felsic unit, Mount Madge sedimentary unit, Kinaskan conglomerate, Downpour Creek siliciclastic unit, and Palmiere unit; and one formal member, the Eskay Rhyolite Member. The informal terms are applicable throughout the northern part of the Eskay rift, and probably beyond.

The Eskay rift opened as a post-arc extensional to mildly transtensional, terrane-scale feature in response to the collision of Stikinia with adjacent terranes (Nelson et al., 2013). Mainly andesite volcanism in the lower Hazelton Group was succeeded by bimodal basalt-rhyolite volcanism in the rift, which provided the setting for volcanogenic massive sulphide deposits such as Eskay Creek and Anyox. In detail, the Eskay deposit lies in an interval of fine-grained sedimentary strata immediately above footwall rhyolite (Childe, 1996). The association of thin Mount Madge siliceous sedimentary units with rhyolite is thus an important exploration criterion in the Iskut River Formation. This critical association has been observed on Pillow Basalt ridge and to the north in the "Four Corners" area (Alldrick et al., 2005b). Dark siliceous mudstone beds in the middle sedimentary unit on Table Mountain (Downpour Creek unit) host laminated syngenetic pyrite (Alldrick et al., 2004b).

Work with the existing set of geological maps and supporting data has identified a number of knowledge gaps in the area that will benefit from future studies. First, the newly defined Klastline formation needs detailed documentation through mapping and construction of reference sections. Its absolute age is currently based on a few unpublished U-Pb ages. Its internal and external unit relationships require re-examination, in particular its unconformable contacts with the Stuhini Group. Comparison of ages and geochemistry with the many small plutons of the Tatogga intrusive suite will test the degree of consanguinuity between intrusive and extrusive magmatism. Porphyry mineralization of the Castle occurrence (BC MINFILE 104G 076) and newly discovered epithermal veins in the Saddle zone have yet to be studied in this context.

Second, the Eddontenajon formation also requires further study. Structural and stratigraphic relationships between the Eddontenajon formation (Lower Jurassic) and Iskut River Formation (Middle Jurassic) on the western margin of the Todagin Plateau need clarification. This will result in greater understanding of the apparent northern termination of the Eskay rift. Was it simply a propagating rift tip? Or did the north-trending rift terminate against nearly orthogonal faults of the Pitman system (Fig. 1)? Did bimodal Eddontenajon volcanism evolve into that of the Iskut River Formation? How do their trace-element chemistries compare?

Third, an age from the Bruce Glacier unit on the east limb of the Eskay anticline (174.10 +0.68/-0.72 Ma; Childe, 1996), is currently the sole radiometric age used to establish the absolute age of the Aalenian in the 2012 Geological Time Scale (Schmitz, 2012). Near the sample locality, it is overlain by sedimentary strata that contain Late Aalenian fauna (Nadaraju and Lewis, 2001). The Treaty ridge section offers an excellent opportunity to improve understanding of Aalenian stage boundaries via combined fossil zonation and absolute ages.

This section contains Late Aalenian fossils at the top of the Spatsizi Formation (formerly Treaty Ridge Member; Nadaraju, 1993; Lewis, 2013), overlain by basalt and rhyolite of the Iskut River Formation. The rhyolite has yielded a concordant, U-Pb age of 174.7 ±1.4 Ma (Cutts et al., 2015). The current age pick for the base of the Aalenian, 174.1 ±1.0 Ma (Ogg and Hinnov, 2012), thus probably requires downward revision. The fossiliferous strata contain thin felsic tuff beds (P. Lewis, personal communication, 2017), offering an opportunity for establishing additional absolute age constraints in this important section.

6. Conclusions

A revised stratigraphic framework for the Hazelton Group in the Iskut River region sets it in the context of Stikinia-wide recommendations (Gagnon et al., 2012), highlights the importance of basal units within the uppermost Triassic, and offers a technically correct terminological scheme that meets the requirements of the North American Stratigraphic Code.

- The Hazelton Group is divided into upper and lower parts. The lower Hazelton Group comprises basal siliciclastic units (Jack Formation, Snippaker unit), and andesite and minor felsic volcanogenic accumulations (Klastline formation, Betty Creek Formation). The upper Hazelton Group comprises the Spatsizi, Mount Dilworth and Quock formations regionally, the Eddontenajon formation locally and, within the Eskay rift, the Iskut River Formation.
- The Klastline formation and Snippaker unit are of Rhaetian, latest Triassic age, coeval with the Griffith Creek volcanics in the Spatsizi Plateau (Thorkelsen et al., 1995) and the lower Telkwa Formation near Terrace (Barresi et al., 2015a).
- Lithostratigraphic subdivisions of the Betty Creek and Iskut River formations are recast as informal units, with the exception of the Eskay Rhyolite Member.

Stratigraphic names recommended here will be applied to map units in the upcoming revision of Iskut geology in the digital geological map of British Columbia, to be released this year.

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