U-Pb geochronology of the Hazelton Group in the McTagg anticlinorium, Iskut River area, northwestern British Columbia

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Abstract

Early to Middle Jurassic rocks of the Hazelton Group are extensively mineralized, including the precious metal-rich Eskay Creek deposit that is hosted by bimodal volcanic successions in the Eskay rift. In this study, we present U-Pb zircon ages of seven Hazelton Group volcanic, epiclastic and hypabyssal rocks to establish the absolute ages of Hazelton Group units in the McTagg anticlinorium, east of the Eskay Creek deposit. A felsic volcaniclastic sample from the Brucejack Lake member (Betty Creek Formation) yielded a 187.1±1.9 Ma U-Pb crystallization age that is consistent with previous fossil and U-Pb age determinations. Six samples from the Bruce Glacier member (Iskut River/Salmon River Formation) yielded U-Pb crystallization ages of 178.5±1.8, 174.6±1.8, 174.4±1.7, 174.7±1.8, 173.6±1.7, and 173.3±1.8 Ma. These ages indicate that volcanic rocks coeval with the Eskay member occur in the McTagg anticlinorium, as far south as Mt. Dilworth.

Keywords: Hazelton Group, Eskay Rift, Betty Creek Formation, Iskut River Formation, Salmon River Formation, Bruce Glacier, Treaty Ridge, geochronology

1. Introduction

The Canadian Cordillera is endowed with abundant and diverse mineral deposits. Mineralization includes Cu±Au±Mo porphyry, volcanogenic massive sulphide, gold stockwork, shear-hosted vein, hydrothermal breccia, and replacement deposits that range in age from Devono-Mississippian to Eocene (Nelson and Colpron, 2007; Nelson et al., 2013). Most prospects and deposits in northwestern British Columbia are hosted by Triassic to Middle Jurassic volcano-sedimentary and plutonic rocks of the Stikine terrane (Fig. 1). The nature of Triassic to Middle Jurassic magmatism in the northern Stikine terrane changed over time, resulting in episodic emplacement of calc-alkaline, alkaline, and tholeiitic magmas (e.g., Souther, 1972; Anderson, 1993; Logan et al., 2000). The late Early Jurassic transition from calc-alkaline to tholeiitic magmatism in the Hazelton Group (Lower to Middle Jurassic) is perhaps one of the most profound changes in magmatic character (Alldrick et al., 2005 and references therein). This change was caused by rifting of the Hazelton arc complex, which led to development of the Eskay rift (Fig. 2; Anderson and Thorkelson, 1990). It also represents a change to predominantly submarine volcanism and sedimentation and a change from porphyry and epithermal to volcanogenic massive sulphide mineralization. Constraining the age and tectonic significance of this change is critical for understanding the tectonics of the northwestern Cordillera and the distribution of Mesozoic mineral deposits.

The Hazelton Group (Tipper and Richards, 1976) hosts epithermal deposits in Lower Jurassic units and volcanogenic massive sulphides in Middle Jurassic units, including the

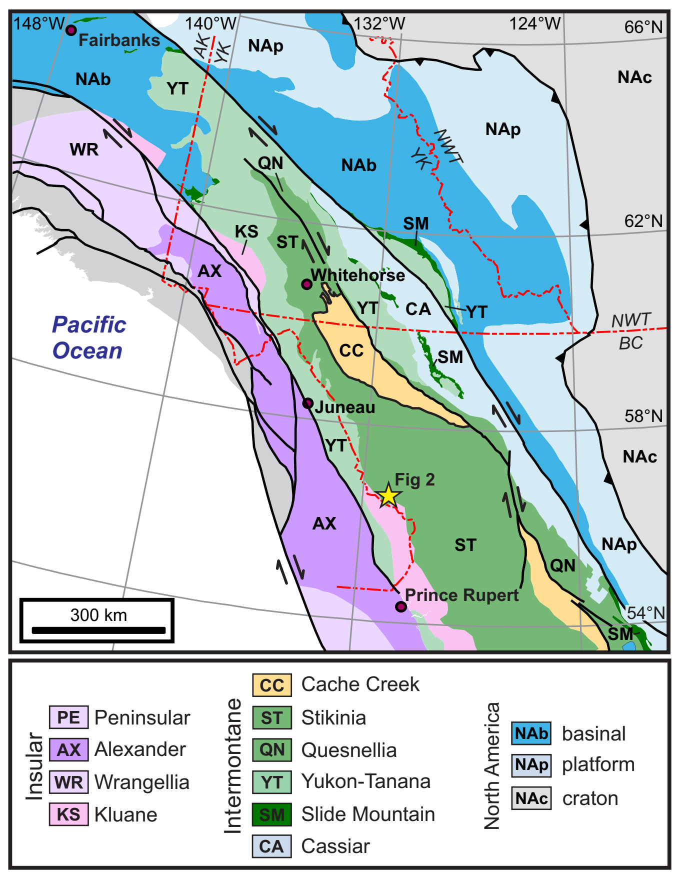

Fig. 1. Terranes of the northern Cordillera (after Colpron and Nelson, 2011). Iskut River area (star) is in the Stikine terrane (Paleozoic to Mesozoic).

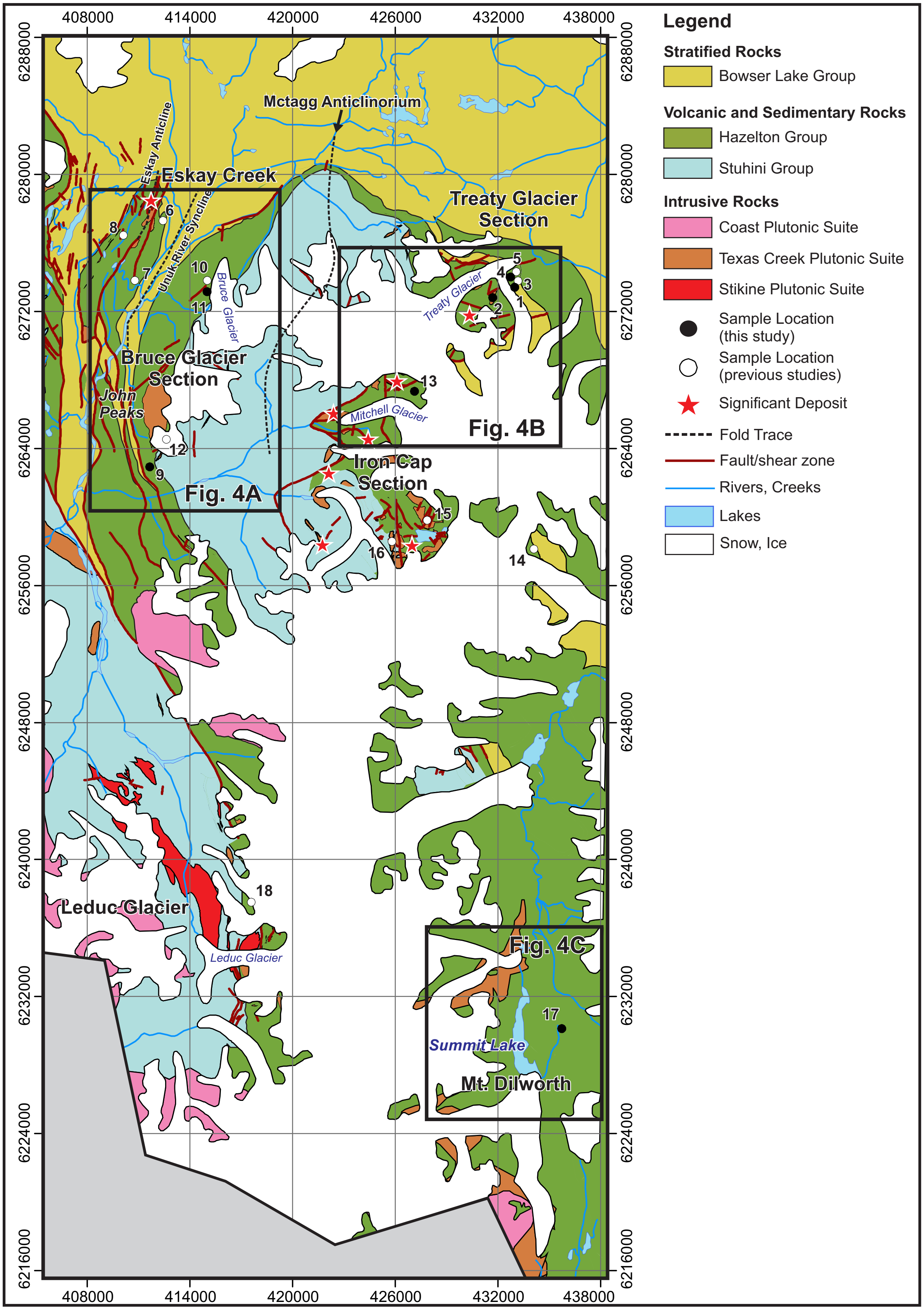

Fig. 2. Simplified geological map of the Iskut River area (modified from Lewis 2013). Numbers refer to ages of volcanic and hypabyssal rocks summarized in Table 1. UTM zone 9, NAD 83.

Au-rich Eskay Creek volcanogenic massive sulphide deposit (Roth et al., 1999 and references therein) and the Iron Cap, Mitchell, Sulphurets, Kerr, Snowfields, and Valley of Kings Cu-Au porphyry deposits (Nelson and Kyba, 2014). The rift stratigraphy of the Hazelton Group forms a northerly trend (Anderson and Thorkelson, 1990). Understanding the regional distribution of this stratigraphy and the underlying regional-scale controls on mineralization has been hampered by a lack of geochronological data from outside of known deposit areas. Herein, we present Sensitive High Resolution Ion Microprobe II (SHRIMP II) data on volcanic, epiclastic, and hypabyssal samples from the Hazelton Group on the limbs of the McTagg anticlinorium, east of the Eskay Creek deposit (Fig. 2; Roth et al., 1999; Nelson and Kyba, 2014, and references therein). Our main goal is to better understand the stratigraphy and timing of the key volcano-sedimentary Hazelton Group units with potential to host economic deposits. We integrate these data into the compilation map of Lewis (2013) and extend definitive occurrences of rocks around the McTagg anticlinorium that are coeval with the Eskay member.

2. Regional geology

The study area is in the Stikine terrane (Paleozoic to Mesozoic) of northwestern British Columbia (Figs. 1, 2). The oldest rocks in the Stikine terrane are included in the Stikine assemblage (Devonian to Permian, Monger, 1977). The Stikine assemblage comprises predominantly Mississippian arc and backarc volcanic, epiclastic, and plutonic rocks that are overlain by Pennsylvanian to Permian limestone and chert (e.g., Brown et al., 1991; Logan et al., 2000; Mihalynuk et al., 2012). The Stikine assemblage is unconformably overlain by Triassic rocks of the Stuhini Group and intruded by the Stikine and Copper Mountain plutonic suites (e.g., Brown et al., 1991; Logan et al., 2000; Mihalynuk et al., 2012). The Stuhini Group comprises characteristic augite-phyric volcanic and volcaniclastic rocks, sedimentary rocks, and minor felsic volcanic rocks. Stuhini Group volcanic rocks and related intrusions have yielded ca. 223 to 213 Ma crystallization ages (U-Pb zircon; Lewis et al., 2001; Logan et al., 2000) and Carnian-Norian fossil collections (Logan et al., 2000). Overall, the Stuhini Group and related plutonic suites have been interpreted to have formed in an intra-oceanic arc setting; however, Upper Triassic alkalic magmatism with Precambrian inheritance (Bevier and Anderson, 1991) suggests a more complex tectonic setting. Stuhini Group magmatism ended in the Late Triassic and was followed by erosion, exhumation of plutonic complexes, development of a regional angular unconformity (Brown et al., 1996; Logan et al., 2000; Lewis, 2013; Kyba and Nelson, 2015), initiation of Labarge Group deposition to the north (Gabrielse, 1998), and initiation of Hazelton Group deposition and consanguineous plutonism in northwestern British Columbia (Anderson, 1993; Thorkelson et al., 1995; Brown et al., 1996; Logan et al., 2000; Mihalynuk et al., 2012; Nelson and Kyba, 2014).

2.1. Hazelton Group

The Hazelton Group is aerially extensive in the Stikine terrane of northwestern British Columbia, from the Smithers-Hazelton area in the south, through the Iskut region of central-northern Stikinia and extending north into southern Yukon (e.g. Tipper and Richards, 1976; Thorkelson et al. 1995, Hart, 1997; Lowey, 2004). Regionally, it consists of a lower and upper part. The lower Hazelton Group is arc-related, whereas the upper Hazelton Group records arc demise, regional subsidence, and local development of the Eskay rift (Gagnon et al., 2012).

The following summary of the Iskut area is from Lewis (2013) and Nelson and Kyba (2014). The Hazelton Group is exposed in a series of north-northeast trending anticlines and synclines (Fig. 2). The lower Hazelton Group is divided into the Jack and Betty Creek formations (Lewis 2013), although the divisions are not universally agreed upon (Fig. 3; see Table 1 in Nelson and Kyba, 2014). Unconformably overlying Stuhini Group rocks, the Jack Formation consists of conglomerate, sandstone, and siltstone with limey interbeds. Fossil collections from the Jack Formation yielded ammonites that are diagnostic of Upper Hettangian to Lower Sinemurian age (Lewis, 2013). The overlying Betty Creek Formation includes predominantly volcanic and volcaniclastic strata of the Unuk River member (andesitic), the Brucejack Lake member (dacitic to rhyolitic), and predominantly siliciclastic and carbonate rocks of the Treaty Ridge member (Lewis, 2013). The Unuk River and Brucejack Lake members may be, in part, laterally equivalent and have yielded ca. 194-185 Ma U-Pb ages (Table 1, Fig. 3; Lewis, 2013). The overlying Treaty Ridge member yielded Upper Pliensbachian to Upper Aalenian fossil collections, suggesting a significant gap in magmatism prior to onset of upper Hazelton Group magmatism (Lewis, 2013). Nelson and Kyba (2014) include the Treaty Ridge member in the upper Hazelton Group.

The upper Hazelton Group comprises bimodal volcanic rocks that overlie the Treaty Ridge member (Fig. 3). These rocks were assigned to the Salmon River Formation by Lewis (2013) and Iskut River Formation by Gagnon et al. (2012) and Nelson and Kyba (2014). Gagnon et al. (2012) proposed that the term 'Salmon River Formation' be formally abandoned because it was inaccurately defined in its type area and confused with the Bowser Lake Group. For clarity however, we retain the term here so that our samples can be readily cross referenced with units on the Lewis (2013) compilation. The Salmon River Formation (Figs. 4, 5) is divided into the Bruce Glacier member (predominantly felsic volcanic rocks), the Troy Ridge member (predominantly tuffs and other sedimentary rocks), the John Peak member (predominantly mafic volcanic rocks) and the Eskay member (predominantly felsic volcanic rocks). The Bruce Glacier member is distinguished geochemically from the Eskay member on the basis of Al-Ti-Zr ratios (Childe, 1996; Roth et al., 1999; Lewis, 2013). Nelson and Kyba (2014) retained these members, but followed Gagnon et al. (2012) and included the Bruce Glacier, John Peaks, and Eskay members in the Iskut River Formation of the upper Hazelton Group.

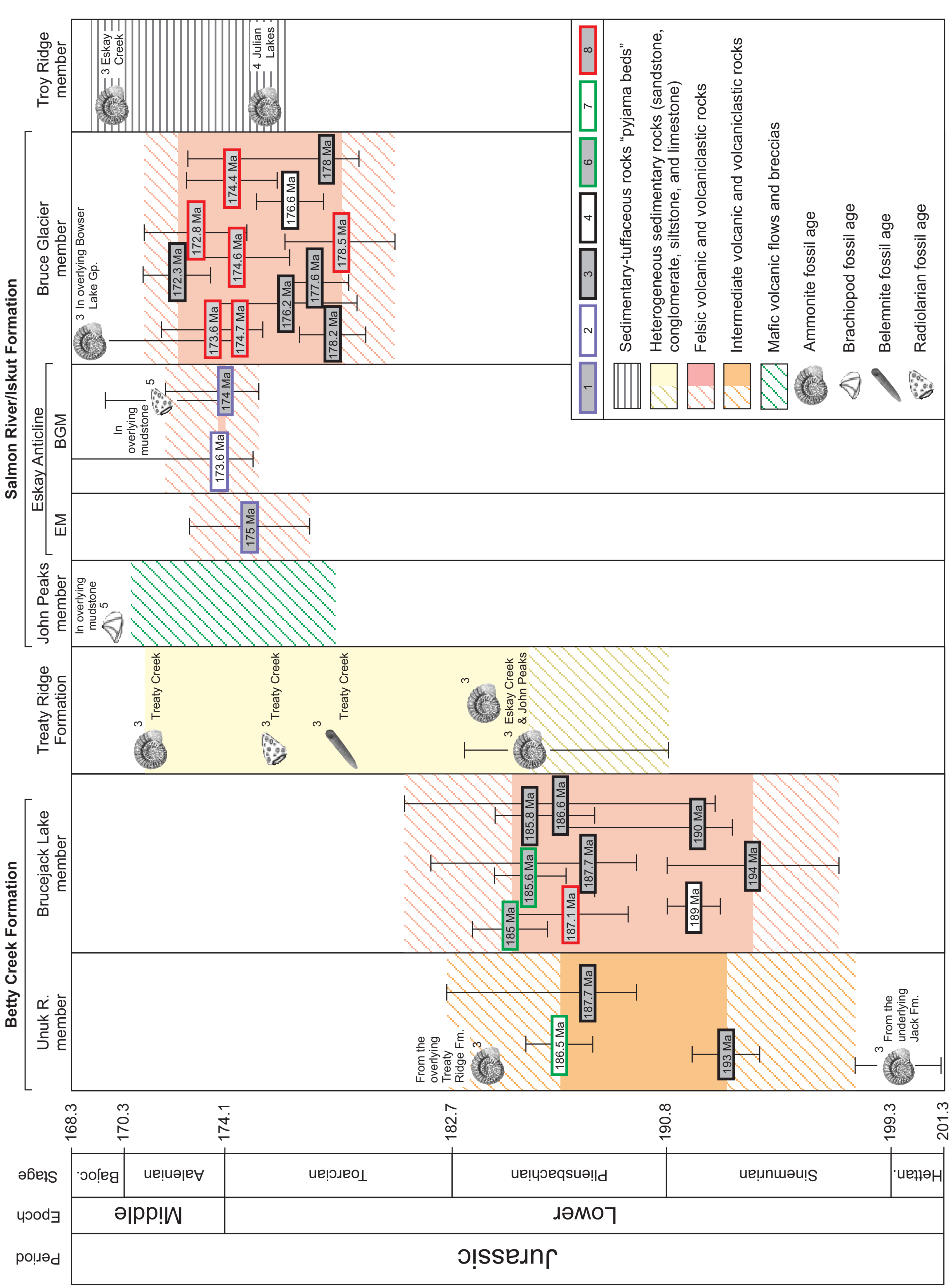

Fig. 3. U-Pb and fossil ages from the Hazelton Group in the Iskut River area summarized from 1 – Childe, 1994; 2 – Childe, 1996; 3 – Lewis et al., 2001; 4 – Evenchick et al., 2001; 5 – Gagnon et al., 2012; 6 – Macdonald, 1993; 7 – Macdonald et al., 1996; 8 – This study. EM = Eskay member, BGM = Bruce Glacier member. Stage boundaries are from Cohen et al. (2013).

Table 1. Geochronology data for volcanic and hypabyssal rocks in the Iskut River area.

	#	Unit	Rock Type	Age (Ma)	Reference
Bruce Glacier Section					
	9	Bruce Glacier member	Felsic volcaniclastic	174.6 ± 1.8	This Study
	10	Bruce Glacier member	Dacite flow	176.2 ± 2.2	Lewis et al. 2001
	11	Bruce Glacier member	Spherulitic rhyolite	178.5 ± 1.8	This Study
	12	Brucejack Lake member	Felsic crystal tuff	190 +5/-1	Lewis et al. 2001
Iron Cap Section					
	13	Bruce Glacier member	Felsic volcaniclastic	173.3 ± 1.8	This Study
	14	Bruce Glacier member	Dacite to rhyolite flow	178 +5/-1	Lewis et al. 2001
	15	Brucejack Lake member	Kspar megacrystic flow	187.7 +5.8/-1.5	Lewis et al. 2001
	16	Brucejack Lake member	Rhyolite flow	194 ± 3	Lewis et al. 2001
Treaty Glacier Section					
	1	Bruce Glacier member	Feldspar-phyric rhyolite	173.3 ± 1.8	This Study
	2	Bruce Glacier member	Hypabyssal flowbanded rhyolite	174.4 ± 1.7	This Study
	3	Bruce Glacier member	Dacite-rhyolite pyroclastic flow	177.6 ± 1.0	Lewis et al. 2001
	4	Brucejack Lake member	Alkali-feldspar porphyritic volcaniclastic	187.1 ± 1.9	This Study
	5	Unuk member	Andesite-dacite pyroclastic flow	187.7 +5.3/-1.5	Lewis et al. 2001
Mt. Dilworth					
	17	Bruce Glacier member	Felsic volcaniclastic	173.6 ± 1.7	This Study
Eskay Creek					
	6	Bruce Glacier member	Dacite flow	173.6 +5.6/-0.5	Childe 1994
	7	Eskay Rhyolite member	Rhyolite breccia and tuffs	174 +2/-1	Childe 1996
	8	Bruce Glacier member	Flow-banded rhyolite	175 ± 2	Childe 1996
Leduc Glacier					
	17	Brucejack Lake member	Dacite breccia	186.6 ± 5.6	Lewis et al. 2001

These upper Hazelton units have yielded 178-172 Ma U-Pb ages and Upper Toarcian to Bajocian fossils (Table 1, Fig. 3; Lewis, 2013). The Hazelton Group is conformably overlain by siliciclastic cover rocks of the Bowser Lake Group (Evenchick et al., 2010; Gagnon et al., 2012).

3. U-Pb Geochronology

Seven samples were collected and analyzed from the Bruce Glacier, Iron Cap, Treaty Ridge, and Mt. Dilworth areas of the McTagg anticlinorium (Fig. 2), including at or near the type sections of Hazelton Group members (see Lewis 2013 and Nelson and Kyba 2014). The upper Hazelton Group samples analyzed herein display low Al/Ti ratios (Anderson, unpublished data) indicating affinity with the Bruce Glacier member rather than the Eskay member (e.g., Childe, 1996; Roth et al., 1999). U-Pb SHRIMP data are presented in Table 2 and Figure 6.

3.1. Analytical procedures

SHRIMP II (Sensitive High Resolution Ion MicroProbe) analyses were conducted at the Geological Survey of Canada using analytical procedures described by Stern (1997), with standards and U-Pb calibration methods following Stern and Amelin (2003). Heavy mineral concentrates were prepared from the samples using standard mineral separation techniques, including: crushing, grinding, hydrogravimetric Wilfley™ table, and heavy liquid separation. This was followed by final separation of the zircon grains by magnetic susceptibility using a Frantz™ isodynamic separator and hand-picking. Zircons from the samples and fragments of the GSC laboratory zircon standard (z6266 zircon, with $^{206}Pb/^{238}U$ age = 559 Ma) and a secondary zircon standard (Temora 2) were cast in an epoxy grain mount (see Table 2 for GSC mount number), polished with diamond compound to reveal the grain centers, and photographed in transmitted light. Internal features of the zircons (such as zoning, structures, and alteration) were characterized in back-scattered electron (BSE) and cathodoluminescence (CL) modes using a Zeiss Evo 50 scanning electron microscrope (SEM). Mount surfaces were evaporatively coated with 10 nm of high purity Au. Analyses were conducted using an O^- primary beam, projected onto the zircons with an elliptical 17µm x 23µm spot (K120). The count rates of ten masses including background were sequentially measured over 6 scans with a single electron multiplier and a pulse counting system with deadtime of 23 ns. Off-line data processing used customized in-house software. The SHRIMP analytical data are presented in Table 2, where

Table 2. U/Pb SHRIMP Analytical Data.

Spot name	U (ppm)	Th (ppm)	Th/U	Pb (ppm)	^{204}Pb (ppb)	^{204}Pb/^{206}Pb	f206	^{208}Pb/^{206}Pb	±^{208}Pb/^{206}Pb	^{207}Pb/^{235}U	±^{207}Pb/^{235}U	^{206}Pb/^{238}U	±^{206}Pb/^{238}U	Corr Coeff	^{207}Pb/^{206}Pb	±^{207}Pb/^{206}Pb	Ages (Ma) ± 1σ[1] ^{206}Pb/^{238}U	Ages (Ma) ± 1σ[1] ±^{206}Pb/^{238}U	Ages (Ma) ± 1σ[2] ^{206}Pb/^{238}U	Ages (Ma) ± 1σ[2] ±^{206}Pb/^{238}U
04-ATSK-106-L01 (z8335): spherulitic rhyolite, Bruce Glacier member (GSC grain mount IP345[3])																				
8335-5.1	418	156	0.39	12	1	0.0001129	0.00196	0.130	0.006	0.2014	0.0100	0.0283	0.0004	0.366	0.0516	0.0024	180	2	180	2
8335-11.1	1230	325	0.27	34	0	0.0000100	0.00017	0.091	0.003	0.1950	0.0046	0.0279	0.0004	0.659	0.0506	0.0009	178	2	177	2
8335-31.1	1816	608	0.35	50	0	0.0000100	0.00017	0.108	0.002	0.1929	0.0028	0.0279	0.0003	0.799	0.0502	0.0005	177	2	177	2
8335-32.1	1454	440	0.31	41	2	0.0000495	0.00086	0.096	0.002	0.1918	0.0051	0.0283	0.0003	0.535	0.0492	0.0011	180	2	180	2
8335-33.1	1273	432	0.35	37	3	0.0001010	0.00175	0.099	0.002	0.1939	0.0047	0.0292	0.0004	0.707	0.0482	0.0008	185	3	186	3
8335-34.1	1186	400	0.35	33	0	0.0000100	0.00017	0.107	0.003	0.1958	0.0034	0.0283	0.0003	0.752	0.0502	0.0006	180	2	180	2
8335-36.1	1112	333	0.31	31	0	0.0000100	0.00017	0.099	0.002	0.1975	0.0035	0.0281	0.0004	0.797	0.0509	0.0006	179	2	178	2
8335-37.1	1059	292	0.28	29	5	0.0002031	0.00352	0.101	0.004	0.1992	0.0072	0.0276	0.0004	0.476	0.0523	0.0017	176	2	175	2
8335-40.1	678	188	0.29	18	3	0.0002017	0.00350	0.087	0.004	0.1845	0.0074	0.0275	0.0003	0.397	0.0487	0.0018	175	2	175	2
8335-41.1	960	367	0.39	26	1	0.0000406	0.00070	0.069	0.275	0.1901	0.0110	0.0281	0.0003	0.316	0.0491	0.0027	179	2	179	2
8335-42.1	1064	332	0.32	29	4	0.0001617	0.00280	0.097	0.004	0.1891	0.0070	0.0281	0.0003	0.432	0.0489	0.0016	179	2	179	2
8335-44.1	1137	354	0.32	32	3	0.0001189	0.00206	0.097	0.003	0.1895	0.0058	0.0283	0.0003	0.475	0.0487	0.0013	180	2	180	2
8335-46.1	790	244	0.32	21	4	0.0001949	0.00338	0.101	0.003	0.1858	0.0051	0.0274	0.0003	0.511	0.0491	0.0012	174	2	174	2
8335-47.1	1313	421	0.33	37	2	0.0000623	0.00108	0.107	0.002	0.1955	0.0051	0.0283	0.0004	0.586	0.0500	0.0011	180	2	180	2
8335-51.1	1327	367	0.29	37	1	0.0000457	0.00079	0.091	0.004	0.1916	0.0067	0.0283	0.0006	0.651	0.0491	0.0013	180	3	180	3
8335-55.1	1203	315	0.27	33	1	0.0000245	0.00042	0.083	0.004	0.2001	0.0042	0.0285	0.0003	0.636	0.0510	0.0008	181	2	181	2
8335-56.1	1311	325	0.26	36	6	0.0001957	0.00339	0.084	0.004	0.1837	0.0050	0.0285	0.0003	0.506	0.0467	0.0011	181	2	182	2
04-ATSL-042-L01 (z8337): felsic volcaniclastic rock, Bruce Glacier member (GSC grain mount IP345[3])																				
8337-1.1	196	74	0.39	6	1	0.0002095	0.00363	0.138	0.015	0.2025	0.0247	0.0286	0.0005	0.263	0.0514	0.0061	182	3	181	3
8337-4.1	1499	443	0.31	42	3	0.0000698	0.00121	0.097	0.002	0.1931	0.0048	0.0281	0.0003	0.555	0.0499	0.0011	179	2	178	2
8337-5.1	294	87	0.31	8	2	0.0002825	0.00490	0.096	0.014	0.1896	0.0209	0.0274	0.0004	0.252	0.0502	0.0054	174	2	174	2
8337-13.1	155	35	0.23	4	1	0.0001456	0.00252	0.098	0.019	0.2107	0.0316	0.0274	0.0004	0.229	0.0558	0.0082	174	3	173	2
8337-18.1	255	59	0.24	7	1	0.0001264	0.00219	0.089	0.009	0.2095	0.0159	0.0271	0.0003	0.286	0.0562	0.0041	172	2	171	2
8337-21.1	96	36	0.39	3	2	0.0008253	0.01430	0.154	0.026	0.2735	0.0504	0.0337	0.0006	0.217	0.0589	0.0107	213	4	213	4
8337-40.1	207	62	0.31	6	2	0.0004803	0.00832	0.109	0.011	0.1916	0.0173	0.0272	0.0004	0.277	0.0511	0.0045	173	2	173	2
8337-41.1	346	116	0.35	10	0	0.0000415	0.00072	0.117	0.013	0.2178	0.0199	0.0276	0.0004	0.284	0.0574	0.0051	175	3	173	2
8337-42.1	208	52	0.26	6	2	0.0003621	0.00628	0.092	0.015	0.2027	0.0235	0.0276	0.0004	0.236	0.0532	0.0061	176	2	175	2
8337-43.1	171	35	0.21	4	4	0.0008921	0.01546	0.064	0.011	0.1845	0.0179	0.0271	0.0004	0.264	0.0494	0.0047	172	2	172	2
8337-44.1	706	224	0.33	19	4	0.0002201	0.00381	0.106	0.004	0.1852	0.0070	0.0274	0.0003	0.403	0.0490	0.0017	174	2	175	2
8337-46.1	665	236	0.37	18	6	0.0003551	0.00615	0.110	0.008	0.1908	0.0103	0.0279	0.0003	0.319	0.0496	0.0026	177	2	177	2
8337-62.1	297	102	0.35	8	5	0.0007427	0.01287	0.114	0.011	0.1874	0.0143	0.0274	0.0004	0.294	0.0496	0.0036	174	2	174	2
8337-63.1	174	41	0.24	5	3	0.0007368	0.01277	0.083	0.012	0.2004	0.0201	0.0278	0.0004	0.258	0.0523	0.0051	177	2	176	2
8337-64.1	921	238	0.27	25	7	0.0003068	0.00532	0.085	0.004	0.1861	0.0069	0.0280	0.0004	0.476	0.0482	0.0016	178	2	178	2
8337-65.1	339	93	0.28	9	1	0.0001183	0.00205	0.111	0.010	0.2257	0.0162	0.0274	0.0003	0.294	0.0597	0.0041	175	2	172	2
04-AT0-1001-L01 (z8567): lapilli tuff, Bruce Glacier member (GSC grain mount IP357[3])																				
8567-3.1	308	138	0.46	9	3	0.0004428	0.00767	0.157	0.012	0.1973	0.0195	0.0273	0.0004	0.251	0.0524	0.0051	174	2	173	2
8567-5.1	180	82	0.47	5	6	0.0013849	0.02400	0.135	0.020	0.1688	0.0276	0.0270	0.0004	0.221	0.0453	0.0073	172	3	173	2
8567-7.1	122	32	0.28	3	0	0.0000100	0.00017	0.141	0.014	0.2528	0.0091	0.0275	0.0004	0.512	0.0668	0.0021	175	3	171	3
8567-8.1	179	52	0.30	5	0	0.0000100	0.00017	0.117	0.008	0.2138	0.0074	0.0269	0.0005	0.622	0.0577	0.0016	171	3	169	3
8567-10.1	458	158	0.36	13	2	0.0001864	0.00323	0.119	0.007	0.2069	0.0109	0.0282	0.0004	0.351	0.0532	0.0026	179	2	179	2
8567-14.1	187	56	0.31	5	5	0.0011380	0.01972	0.067	0.021	0.1559	0.0306	0.0271	0.0004	0.206	0.0418	0.0081	172	3	174	2
8567-15.1	459	147	0.33	12	3	0.0003248	0.00563	0.102	0.009	0.1783	0.0121	0.0273	0.0004	0.308	0.0475	0.0031	173	2	174	2
8567-17.1	144	48	0.34	4	3	0.0009831	0.01704	0.110	0.024	0.1815	0.0327	0.0270	0.0006	0.236	0.0487	0.0086	172	3	172	3
8567-20.1	218	70	0.33	6	2	0.0003296	0.00571	0.113	0.012	0.1972	0.0169	0.0272	0.0004	0.304	0.0526	0.0043	173	3	172	3
8567-21.1	245	123	0.52	7	5	0.0008801	0.01525	0.156	0.016	0.1676	0.0178	0.0270	0.0004	0.256	0.0450	0.0046	172	2	173	2
8567-22.1	176	54	0.32	5	4	0.0008616	0.01493	0.099	0.014	0.1819	0.0208	0.0271	0.0004	0.264	0.0488	0.0054	172	3	172	3
8567-70.1	192	112	0.60	5	0	0.0000080	0.00014	0.223	0.016	0.2251	0.0243	0.0270	0.0004	0.262	0.0604	0.0063	172	3	170	2
8567-71.1	257	106	0.42	7	6	0.0009742	0.01688	0.138	0.012	0.1767	0.0206	0.0271	0.0004	0.242	0.0474	0.0054	172	2	172	2
8567-82.1	238	91	0.40	7	2	0.0004197	0.00727	0.137	0.019	0.2110	0.0275	0.0286	0.0005	0.243	0.0535	0.0068	182	3	181	2

Table 2. Continued.

Spot name	U (ppm)	Th (ppm)	Th/U	Pb (ppm)	^{204}Pb (ppb)	^{204}Pb/^{206}Pb	f206	^{208}Pb/^{206}Pb	±^{208}Pb/^{206}Pb	^{207}Pb/^{235}U	±^{207}Pb/^{235}U	^{206}Pb/^{238}U	±^{206}Pb/^{238}U	Corr Coeff	^{207}Pb/^{206}Pb	±^{207}Pb/^{206}Pb	Ages (Ma) ± 1σ[1] ^{206}Pb/^{238}U	Ages (Ma) ± 1σ[1] ±^{206}Pb/^{238}U	Ages (Ma) ± 1σ[2] ^{206}Pb/^{238}U	Ages (Ma) ± 1σ[2] ±^{206}Pb/^{238}U
04-ATSK-026-L02 (z8391): flow-banded rhyolite, feeder to Bruce Glacier member? (GSC grain mount IP345[3])																				
8391-1.1	158	114	0.75	5	0	0.0001203	0.00208	0.277	0.022	0.2322	0.0339	0.0274	0.0005	0.235	0.0614	0.0088	174	3	172	2
8391-11.1	228	139	0.63	7	3	0.0004856	0.00842	0.220	0.014	0.2045	0.0173	0.0270	0.0004	0.280	0.0550	0.0045	171	2	170	2
8391-22.1	373	417	1.16	13	4	0.0004215	0.00731	0.382	0.009	0.1977	0.0128	0.0276	0.0003	0.301	0.0520	0.0032	175	2	175	2
8391-23.1	326	255	0.81	10	5	0.0006007	0.01041	0.265	0.016	0.2090	0.0244	0.0274	0.0004	0.244	0.0552	0.0063	175	2	173	2
8391-29.1	315	257	0.84	10	7	0.0008926	0.01547	0.264	0.015	0.1660	0.0216	0.0275	0.0004	0.235	0.0437	0.0056	175	3	176	2
8391-30.1	262	255	1.01	9	0	0.0000100	0.00017	0.338	0.010	0.2011	0.0054	0.0278	0.0003	0.554	0.0525	0.0012	177	2	176	2
8391-37.1	235	188	0.83	7	5	0.0009239	0.01601	0.284	0.019	0.2020	0.0281	0.0276	0.0004	0.228	0.0531	0.0073	175	3	174	2
8391-38.1	808	1022	1.31	28	9	0.0004811	0.00834	0.416	0.006	0.1767	0.0076	0.0278	0.0003	0.375	0.0460	0.0018	177	2	178	2
8391-39.1	362	342	0.98	11	6	0.0007573	0.01312	0.280	0.012	0.1551	0.0172	0.0272	0.0003	0.236	0.0414	0.0045	173	2	175	2
8391-42.1	275	257	0.96	8	8	0.0012210	0.02116	0.282	0.012	0.1439	0.0195	0.0270	0.0003	0.217	0.0387	0.0052	172	2	174	2
8391-44.1	264	237	0.93	8	6	0.0009912	0.01718	0.291	0.017	0.1718	0.0206	0.0271	0.0004	0.241	0.0459	0.0054	173	2	173	2
8391-47.1	348	278	0.83	10	9	0.0010600	0.01837	0.244	0.015	0.1430	0.0201	0.0270	0.0004	0.216	0.0384	0.0053	172	2	174	2
8391-48.1	360	407	1.17	12	6	0.0007043	0.01221	0.358	0.012	0.1666	0.0158	0.0275	0.0003	0.246	0.0440	0.0041	175	2	176	2
04-ATSK-020-L01 (z8457): felsic volcaniclastic rock, Brucejack Lake member (GSC grain mount IP350[3])																				
8457-23.1	1120	575	0.53	35	4	0.0001316	0.00228	0.169	0.004	0.2147	0.0074	0.0299	0.0004	0.448	0.0522	0.0016	190	2	189	2
8457-24.1	832	290	0.36	25	4	0.0001943	0.00337	0.117	0.004	0.2143	0.0074	0.0298	0.0004	0.477	0.0522	0.0016	189	2	189	2
8457-25.1	815	418	0.53	25	9	0.0004330	0.00750	0.165	0.005	0.1976	0.0080	0.0296	0.0004	0.408	0.0485	0.0018	188	2	188	2
8457-44.1	234	129	0.57	7	9	0.0015005	0.02601	0.157	0.019	0.1720	0.0302	0.0287	0.0005	0.214	0.0435	0.0075	182	3	183	2
8457-45.1	1210	518	0.44	37	5	0.0001627	0.00282	0.140	0.005	0.2062	0.0056	0.0297	0.0003	0.526	0.0503	0.0012	189	2	189	2
8457-48.1	465	158	0.35	14	4	0.0003449	0.00598	0.116	0.006	0.2031	0.0100	0.0291	0.0004	0.382	0.0506	0.0023	185	2	185	2
8457-49.1	699	348	0.51	21	2	0.0001090	0.00189	0.167	0.004	0.2054	0.0076	0.0293	0.0004	0.460	0.0508	0.0017	186	2	186	2
8457-50.1	644	304	0.49	20	3	0.0001611	0.00279	0.164	0.006	0.2065	0.0100	0.0293	0.0005	0.431	0.0511	0.0023	186	3	186	3
8457-54.1	731	365	0.52	23	6	0.0003333	0.00578	0.158	0.005	0.2023	0.0074	0.0296	0.0003	0.419	0.0495	0.0017	188	2	188	2
8457-55.1	686	225	0.34	20	4	0.0002052	0.00356	0.110	0.004	0.2066	0.0074	0.0291	0.0004	0.524	0.0516	0.0016	185	3	184	3
8457-58.1	712	299	0.43	21	4	0.0002214	0.00384	0.143	0.007	0.2095	0.0098	0.0294	0.0004	0.402	0.0518	0.0022	186	2	186	2
8457-59.1	506	210	0.43	15	4	0.0003099	0.00537	0.140	0.006	0.2064	0.0097	0.0290	0.0004	0.415	0.0517	0.0022	184	3	184	3
8457-60.1	735	318	0.45	22	5	0.0002469	0.00428	0.141	0.005	0.2020	0.0079	0.0296	0.0004	0.432	0.0496	0.0018	188	2	188	2
8457-71.1	1861	1252	0.69	61	6	0.0001242	0.00215	0.218	0.002	0.2085	0.0038	0.0301	0.0003	0.673	0.0502	0.0007	191	2	191	2

Table 2. Continued.

Spot name	U (ppm)	Th (ppm)	Th/U	Pb (ppm)	^{204}Pb (ppb)	^{204}Pb/^{206}Pb	f206	^{208}Pb/^{206}Pb	±^{208}Pb/^{206}Pb	^{207}Pb/^{235}U	±^{207}Pb/^{235}U	^{206}Pb/^{238}U	±^{206}Pb/^{238}U	Corr Coeff	^{207}Pb/^{206}Pb	±^{207}Pb/^{206}Pb	Ages (Ma) ± 1σ[1]		Ages (Ma) ± 1σ[2]	
																	^{206}Pb/^{238}U	±^{206}Pb/^{238}U	^{206}Pb/^{238}U	±^{206}Pb/^{238}U
04-ATSK-008-L01 (z8336): spherulitic rhyolite, Bruce Glacier member (GSC grain mount IP345[3])																				
8336-2.1	132	54	0.42	4	1	0.0003259	0.00565	0.146	0.015	0.2225	0.0282	0.0317	0.0006	0.259	0.0509	0.0063	201	3	201	3
8336-3.1	401	89	0.23	10	4	0.0004007	0.00694	0.065	0.006	0.1697	0.0097	0.0271	0.0003	0.325	0.0454	0.0025	173	2	173	2
8336-4.1	293	56	0.20	7	42	0.0056797	0.09844	-0.022	0.032	0.0783	0.0558	0.0265	0.0005	0.152	0.0215	0.0152	168	3	173	3
8336-5.1	309	61	0.20	8	2	0.0003403	0.00590	0.064	0.010	0.1819	0.0157	0.0274	0.0004	0.275	0.0481	0.0040	174	2	175	2
8336-6.1	335	68	0.21	9	2	0.0002844	0.00493	0.065	0.007	0.1840	0.0120	0.0274	0.0004	0.323	0.0486	0.0030	175	2	175	2
8336-7.1	458	113	0.26	12	2	0.0002156	0.00374	0.081	0.005	0.1930	0.0091	0.0280	0.0004	0.393	0.0500	0.0022	178	2	178	2
8336-8.1	662	274	0.43	21	0	0.0000100	0.00017	0.150	0.003	0.2208	0.0052	0.0306	0.0004	0.657	0.0523	0.0009	194	3	194	3
8336-9.1	270	52	0.20	7	0	0.0000100	0.00017	0.074	0.003	0.2072	0.0070	0.0273	0.0004	0.581	0.0551	0.0015	173	3	172	3
8336-12.1	723	193	0.28	20	2	0.0001336	0.00232	0.094	0.006	0.1942	0.0171	0.0281	0.0016	0.736	0.0500	0.0030	179	10	179	10
8336-13.1	277	57	0.21	7	1	0.0001702	0.00295	0.073	0.012	0.1867	0.0201	0.0276	0.0004	0.267	0.0490	0.0051	176	3	176	3
8336-17.1	310	58	0.19	8	3	0.0003484	0.00604	0.059	0.008	0.1877	0.0117	0.0278	0.0004	0.369	0.0489	0.0029	177	3	177	3
8336-18.1	221	41	0.19	6	2	0.0003788	0.00657	0.062	0.013	0.1989	0.0223	0.0280	0.0005	0.279	0.0515	0.0056	178	3	178	3
8336-21.1	275	54	0.20	7	1	0.0001585	0.00275	0.068	0.008	0.1867	0.0115	0.0271	0.0003	0.311	0.0500	0.0029	172	2	172	2
8336-23.1	165	99	0.62	6	2	0.0003107	0.00538	0.203	0.016	0.2564	0.0299	0.0344	0.0006	0.275	0.0541	0.0061	218	4	217	4
8336-26.1	320	66	0.21	8	2	0.0002649	0.00459	0.070	0.012	0.1897	0.0180	0.0274	0.0004	0.257	0.0503	0.0047	174	2	174	2
8336-33.1	305	62	0.21	8	0	0.0000548	0.00095	0.073	0.008	0.1943	0.0135	0.0273	0.0003	0.293	0.0516	0.0035	174	2	173	2
8336-35.1	268	51	0.20	7	3	0.0005335	0.00925	0.050	0.011	0.1784	0.0162	0.0278	0.0004	0.270	0.0465	0.0041	177	2	178	2
8336-36.1	430	117	0.28	12	0	0.0000100	0.00017	0.097	0.005	0.2024	0.0125	0.0284	0.0010	0.673	0.0517	0.0024	181	6	180	6
04-ATSK-004-L01 (z8392): felsic volcaniclastic rock, Bruce Glacier member (GSC grain mount IP345[3])																				
8392-5.1	309	131	0.44	9	3	0.0004185	0.00725	0.149	0.010	0.2109	0.0163	0.0289	0.0004	0.302	0.0529	0.0039	184	3	183	2
8392-12.1	854	352	0.43	24	6	0.0002789	0.00483	0.135	0.005	0.1872	0.0078	0.0279	0.0003	0.376	0.0486	0.0019	178	2	178	2
8392-15.1	337	119	0.36	9	3	0.0003418	0.00592	0.129	0.009	0.2057	0.0120	0.0277	0.0004	0.334	0.0539	0.0030	176	2	175	2
8392-16.1	236	70	0.31	6	5	0.0009088	0.01575	0.107	0.015	0.2003	0.0234	0.0270	0.0004	0.252	0.0539	0.0061	172	3	171	2
8392-21.1	394	124	0.33	11	4	0.0004587	0.00795	0.106	0.007	0.1895	0.0113	0.0273	0.0004	0.332	0.0504	0.0029	173	2	173	2
8392-22.1	539	168	0.32	14	4	0.0003206	0.00556	0.107	0.007	0.1831	0.0102	0.0266	0.0003	0.323	0.0499	0.0027	169	2	169	2
8392-23.1	385	115	0.31	10	4	0.0004966	0.00861	0.094	0.009	0.1862	0.0124	0.0271	0.0003	0.296	0.0499	0.0032	172	2	172	2
8392-24.1	782	265	0.35	21	6	0.0003409	0.00591	0.111	0.005	0.1845	0.0076	0.0274	0.0003	0.392	0.0489	0.0019	174	2	174	2
8392-26.1	173	50	0.30	4	5	0.0013426	0.02327	0.080	0.017	0.1814	0.0259	0.0268	0.0004	0.232	0.0491	0.0069	171	3	170	2
8392-27.1	327	108	0.34	9	3	0.0003550	0.00615	0.117	0.007	0.2008	0.0117	0.0272	0.0004	0.352	0.0536	0.0030	173	2	172	2
8392-28.1	483	138	0.30	13	4	0.0003766	0.00653	0.101	0.006	0.1919	0.0093	0.0273	0.0003	0.348	0.0510	0.0023	174	2	173	2
8392-29.1	255	70	0.28	7	7	0.0011725	0.02032	0.086	0.011	0.1694	0.0177	0.0270	0.0004	0.257	0.0455	0.0046	172	2	172	2
8392-30.1	222	53	0.25	6	5	0.0009356	0.01621	0.070	0.020	0.1941	0.0322	0.0282	0.0004	0.218	0.0499	0.0082	179	3	179	2
8392-31.1	1009	127	0.13	28	6	0.0002423	0.00420	0.040	0.005	0.2015	0.0087	0.0297	0.0003	0.380	0.0492	0.0020	189	2	189	2
8392-43.1	635	212	0.34	18	2	0.0001266	0.00219	0.112	0.007	0.2044	0.0113	0.0277	0.0003	0.317	0.0536	0.0028	176	2	175	2
8392-47.1	606	202	0.35	17	6	0.0004075	0.00706	0.108	0.006	0.1914	0.0111	0.0279	0.0003	0.327	0.0498	0.0028	177	2	177	2

Notes:
Spot name follows the convention x-y.z; where x = lab number, y = grain number, z = spot number
Uncertainties reported at one sigma and are calculated by numerical propagation of all known sources of error (Stern, 1997).
f206 refers to mole fraction of total ^{206}Pb that is due to common Pb based on ^{204}Pb; data have been corrected for common Pb according to procedures outlined in Stern (1997).
[1] 204-corrected ages; [2] 207-corrected ages (Stern 1997)
[3] GSC grain mounts IP345, IP350, and IP357: spot size - 17μm x 23μm (K120); calibration error = 1.0%

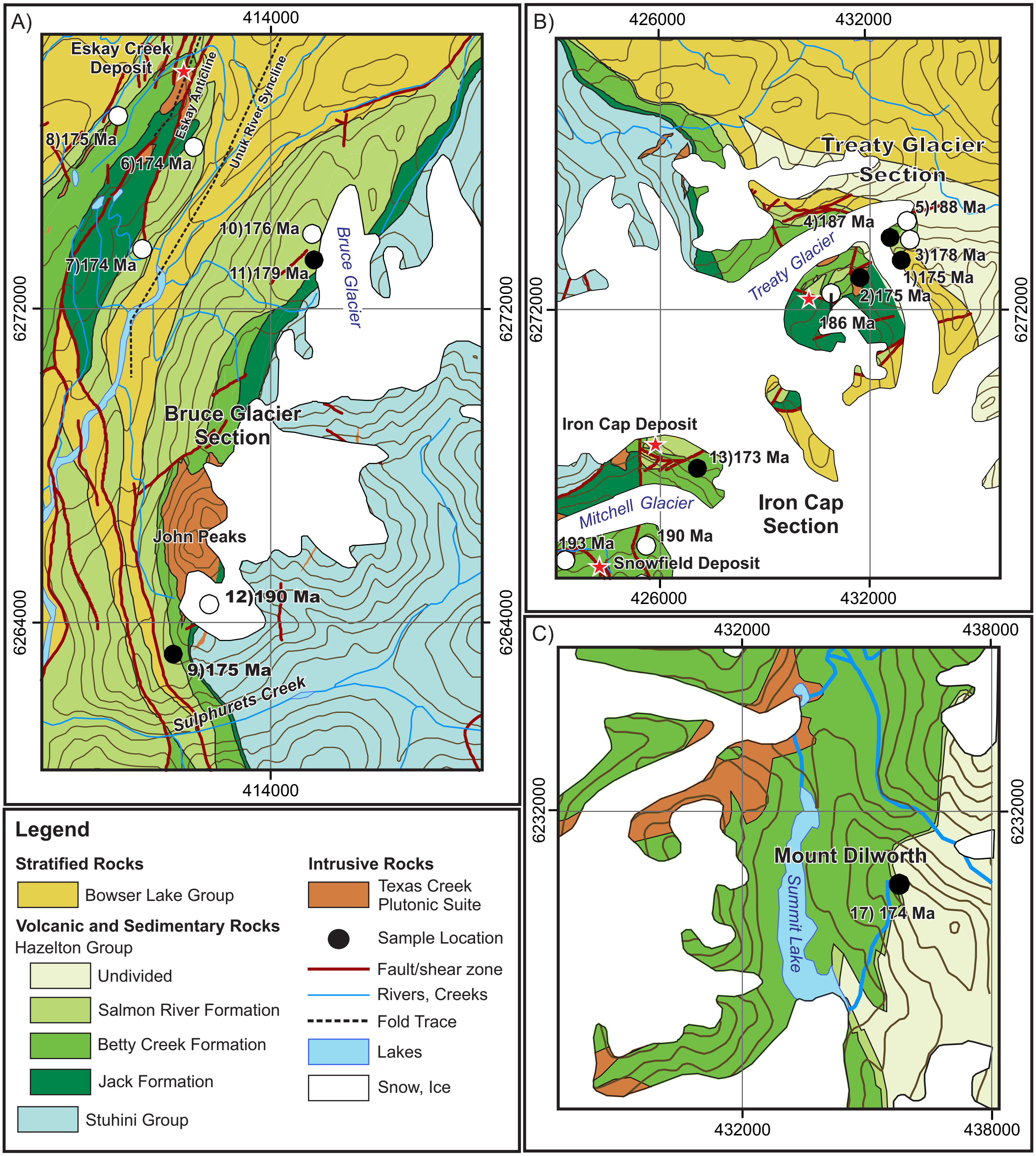

Fig. 4. Simplified geological maps (modified from Lewis, 2013). **a)** Bruce Glacier area. **b)** Iron Cap-Treaty Glacier area. **c)** Mt. Dilworth area. Numbers refer to ages of volcanic and hypabyssal rocks in the Iskut River area (Table 1). UTM zone 9, NAD 83.

the 1σ external errors of $^{206}Pb/^{238}U$ ratios incorporate a 1.0% error in calibrating the standard zircon (Stern and Amelin, 2003). A fractionation correction was not applied to the Pb-isotope data; common Pb correction used the Pb composition of the surface blank (Stern, 1997). The 207-corrected $^{206}Pb/^{238}U$ ages of analyses overlapping concordia were used to calculate weighted means and construct cumulative probability plots (Fig. 6). Weighted means were calculated using Isoplot v.

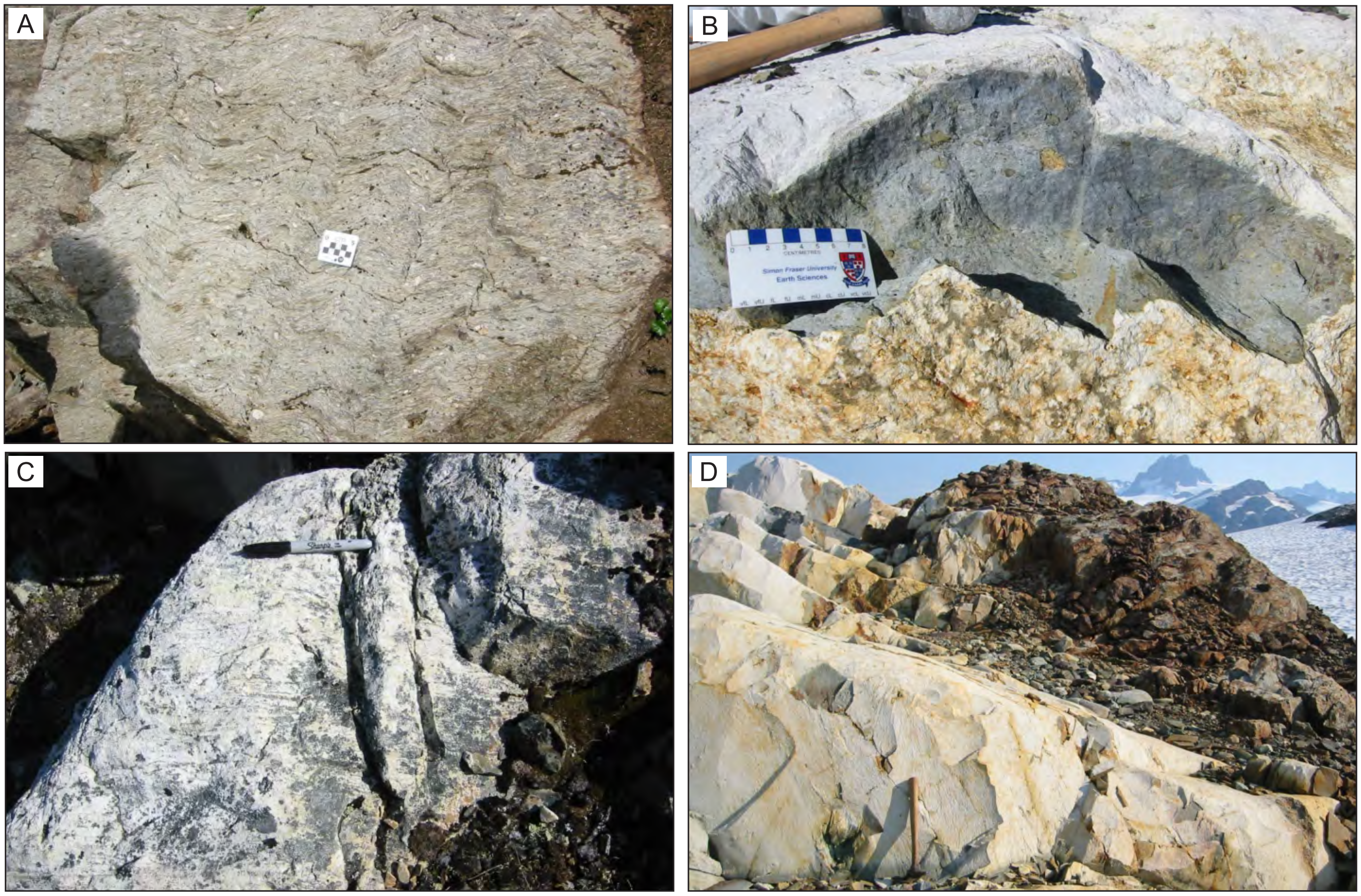

Fig. 5. Representative photographs of analyzed samples. **a)** Thick unit of foliated and crenulated, monolithic, felsic lapilli tuff of the Bruce Glacier member (Sample 04-ATSL-042-L01; z8337). **b)** Felsic lapilli tuff in the Iron Cap area (Sample 04-AT-1001-L01; z8567). **c)** Spherulitic, flow-banded rhyolite from Treaty Ridge (Sample 04-ATSK-008-L01; z8336). **d)** Felsic tuff in the Mt. Dilworth area (Sample 04-ATSK-004-L01; z8392).

3.0 (Ludwig, 2003) with errors on the ages quoted at the 2σ level and cumulative probability plots were constructed using AGEDISPLAY (Sircombe, 2004).

3.2. Bruce Glacier area

3.2.1. 04-ATSK-106-L01 (z8335): Spherulitic rhyolite, Bruce Glacier member

In the Bruce Glacier section (Fig. 4a), the Stuhini Group is unconformably overlain by the Jack Formation, which is in turn unconformably overlain by the Bruce Glacier member (Lewis 2013; see also Fig. 3 in Nelson and Kyba 2014). West of the McTagg anticlinorium, the base of the Bruce Glacier member is an angular unconformity that cuts through the Treaty Ridge and Unuk River members (Lewis 2013). We collected a sample of spherulitic rhyolite considered to be typical of the Bruce Glacier member along Bruce Glacier, northeast of John Peaks and east of Unuk River (Fig. 4a). The sample yielded two size populations of zircon. One consists of clear, colourless, euhedral prism tips ~150 µm long, with abundant fractures, rare inclusions, and faint to strong oscillatory growth zoning typical of magmatic zircons. The second consists of clear, colourless, euhedral prismatic crystals, prism tips and tabular grains ~100 µm long, lacking visible fractures or inclusions. These grains display faint oscillatory growth and sector zoning, both typical of magmatic zircons (Fig. 6a). Excluding one analysis interpreted to be inherited (analysis 8335-33.1, Table 2), sixteen analyses from both populations yielded a mean $^{206}Pb/^{238}U$ age of 178.5±1.2 (MSWD = 1.2). Taking into account the error associated with the zircon standards, the crystallization age of the rhyolite is interpreted as 178.5±1.8 Ma (Fig. 6a).

3.2.2. 04-ATSL-042-L01 (z8337): Felsic volcaniclastic rock, Bruce Glacier member

South of John Peaks, the Stuhini Group is overlain by the Jack Formation at a well-exposed, sharp, angular unconformity (Fig. 4a; Lewis 2013). The Jack Formation is in turn overlain by the Brucejack, Unuk River and Treaty Ridge members of the Betty Creek Formation. Bruce Glacier member felsic volcanic rocks overlie the Betty Creek Formation above an angular unconformity (Fig. 4a; Lewis 2013). We collected a sample of monolithic, felsic lapilli tuff from the Bruce Glacier member (Fig. 5a). The sample yielded two size populations of zircon. The first population comprises 50-100 µm, clear, colourless, subhedral prismatic grains and prism fragments with rounded

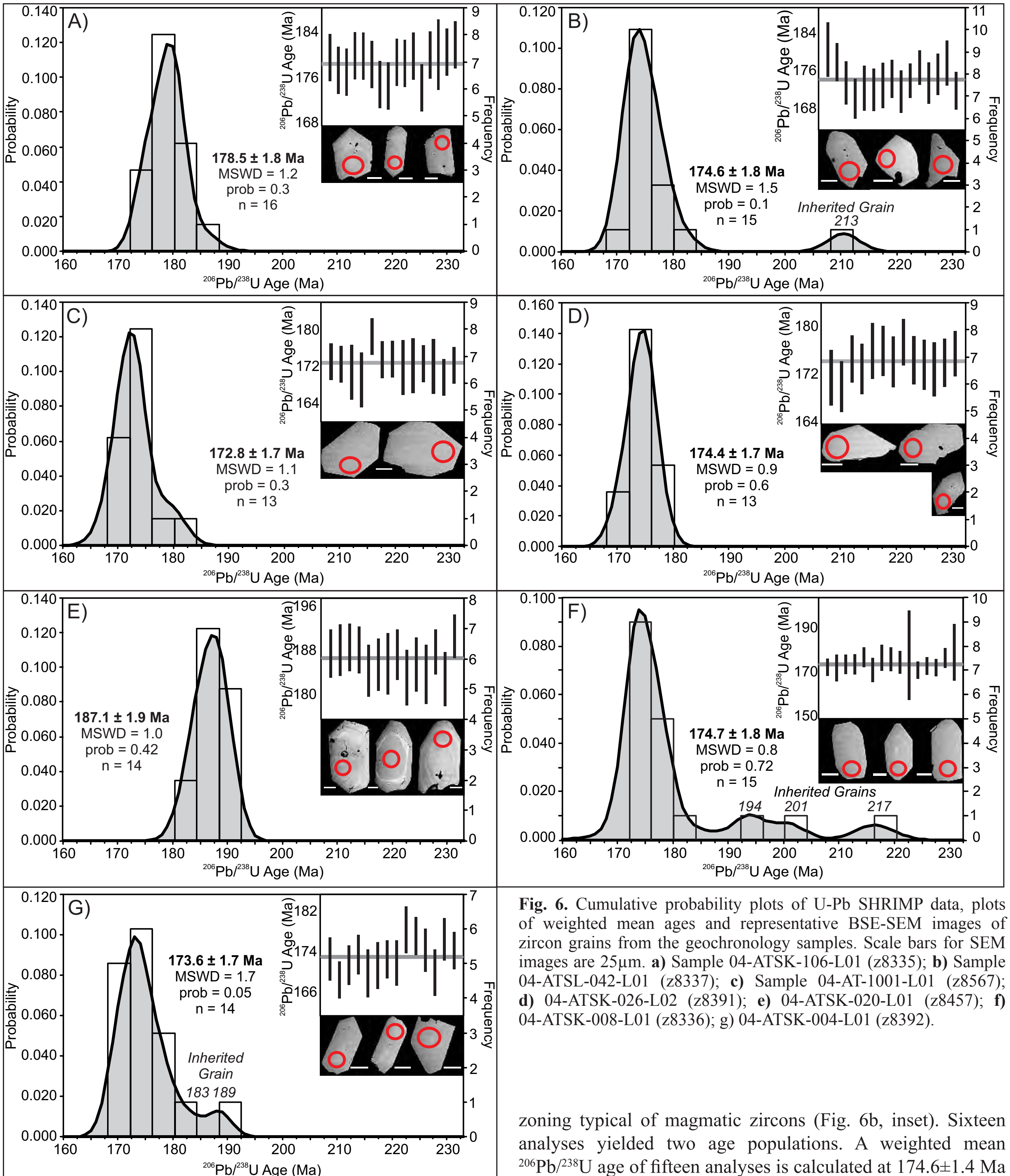

Fig. 6. Cumulative probability plots of U-Pb SHRIMP data, plots of weighted mean ages and representative BSE-SEM images of zircon grains from the geochronology samples. Scale bars for SEM images are 25µm. **a)** Sample 04-ATSK-106-L01 (z8335); **b)** Sample 04-ATSL-042-L01 (z8337); **c)** Sample 04-AT-1001-L01 (z8567); **d)** 04-ATSK-026-L02 (z8391); **e)** 04-ATSK-020-L01 (z8457); **f)** 04-ATSK-008-L01 (z8336); g) 04-ATSK-004-L01 (z8392).

tips, and rare to abundant fractures. The second comprises 150-200 µm, clear, colourless, euhedral to subhedral prismatic grains with rare fractures and inclusions. Both populations lack zoning typical of magmatic zircons (Fig. 6b, inset). Sixteen analyses yielded two age populations. A weighted mean ^{206}Pb/^{238}U age of fifteen analyses is calculated at 174.6±1.4 Ma (MSWD=1.5). Taking into consideration the error associated with the zircon standards, the crystallization age of the felsic tuff is interpreted as 174.6±1.8 Ma (Fig. 6b). A single unzoned prism fragment (analysis 8337-21.0, Table 2) yielded ca. 213 Ma age and is interpreted to be inherited (Fig. 6b).

3.3. Iron Cap area
3.3.1. 04-AT-1001-L01 (z8567): Lapilli tuff, Bruce Glacier member

The ca. 195 Ma Iron Cap intrusion and related volcaniclastic rocks that host the Iron Cap porphyry Cu-Au deposit (Kirkham and Margolis, 1995) are unconformably overlain by the Treaty Ridge member (Middle Jurassic; Lewis et al., 2001) west of the Brucejack fault (Fig. 4b; see Fig. 5 in Nelson and Kyba, 2014). East of the Brucejack fault, the Treaty Ridge member is absent and Unuk River member andesitic rocks are unconformably overlain by the Bruce Glacier member (Fig. 4b). A sample from a unit of flow-banded felsic lapilli tuff was collected to test its correlation with the Bruce Glacier member (Fig. 5b). The sample yielded abundant zircon grains ranging in size from 50-100 µm with variable morphologies, including euhedral to subhedral prismatic grains and prism fragments and sparse euhedral to subhedral, tabular grains. Some grains display oscillatory growth zoning typical of magmatic zircons (Fig. 6c). Excluding one analysis interpreted to be xenocrystic (analysis 8567-82.1, Table 2), thirteen analyses yielded a weighted mean $^{206}Pb/^{238}U$ age of 172.8±1.2 Ma (MSWD = 1.1). Taking into account the error associated with the zircon standards, the crystallization age of the lapilli tuff is interpreted as 172.8±1.7 Ma (Fig. 6c).

3.4. Treaty Glacier area
3.4.1. 04-ATSK-026-L02 (z8391): Flow-banded rhyolite, feeder to Bruce Glacier member?

Southeast of the Treaty Glacier, on the Treaty Nunatak, hypabyssal felsic dykes and stocks, assigned by Lewis (2013) to the Texas Creek plutonic suite, intrude a southeast-younging succession of sedimentary rocks and pillow basalts interpreted as the Treaty Ridge and John Peaks members (Fig. 4b; Lewis, 2013). A sample of hypabyssal flow-banded rhyolite was collected to establish the age of these intrusive rocks and to provide a minimum age for the volcano-sedimentary rocks that are assigned to the Treaty Ridge member. The sample yielded abundant zircon grains that are clear, colourless, stubby, prismatic crystals 75-100 µm long, with rare fractures and inclusions. Some grains display oscillatory growth zoning typical of magmatic zircons (Fig. 6d), and some have possible inherited cores that were not analyzed. Thirteen analyses yielded a weighted mean $^{206}Pb/^{238}U$ age of 174.4±1.1 Ma (MSWD = 0.9). Taking into consideration the error associated with the zircon standards, the crystallization age of the rhyolite and related felsic stocks is interpreted as 174.4±1.7 Ma (Fig. 6d). It is significantly younger than the Texas Creek suite, and corresponds to ages of nearby felsic rocks of the Bruce Glacier member.

3.4.2. 04-ATSK-020-L01 (z8457): Felsic volcaniclastic rock, Brucejack Lake member

The base of Treaty Ridge, south of Treaty Creek, exposes volcanic rocks of the lower Hazelton Group that were included in the Unuk River member by Lewis (2013). These rocks are overlain by the Treaty Ridge, John Peaks, and Bruce Glacier members (Fig. 4b). A sample of alkali feldspar-phyric felsic volcaniclastic rock was collected from near the base of exposed section. The sample yielded abundant zircon grains including clear, colourless subhedral to euhedral, tabular prismatic crystals and prism fragments, 50-100µm long, that contain many fractures and inclusions. These grains are either unzoned or display oscillatory growth zoning typical of magmatic zircons (Fig. 6e). A weighted mean of the $^{206}Pb/^{238}U$ ages of fourteen analyses is calculated at 187.1±1.2 Ma (MSWD=1.0). Taking into account the error associated with the zircon standards, the crystallization age of the felsic volcanic is interpreted as 187.1±1.9 Ma (Fig. 6e).

3.4.3. 04-ATSK-008-L01 (z8336): Spherulitic rhyolite, Bruce Glacier member

We collected a sample of fine-grained, feldspar-phyric, spherulitic rhyolite from the Bruce Glacier member upsection from sample 04-ATSK-020-L01 (see above, Fig. 5c). The sample yielded abundant zircon grains that are 50-100µm long and include clear, colourless, euhedral to subhedral tabular prisms, with rare fractures and local inclusions. Some grains display strong oscillatory growth zoning typical of magmatic zircons (Fig. 6f). Fifteen analyses yielded a weighted mean $^{206}Pb/^{238}U$ age of 174.7±1.2 Ma (MSWD=0.8). Taking into account the error associated with the zircon standards, the crystallization age of the rhyolite is taken to be 174.7±1.8 Ma (Fig. 6f). Three zircon grains yielded significantly older ages, which are interpreted to be inherited. Inherited analyses of ca. 194 and 200 Ma ages (analyses 8336-8.1 and 8336-23.1) were from euhedral to subhedral prismatic grains lacking evidence of inherited cores. A rounded grain with a possible older core yielded an age of ca. 218 Ma (analysis 8336-2.1; Fig. 6f).

3.5. Mt. Dilworth area
3.5.1. 04-ATSK-004-L01 (z8392): Felsic volcaniclastic rock, Bruce Glacier Member

North of Mt. Dilworth and east of Summit Lake, the Betty Creek Formation is overlain by a continuous unit of dacitic volcaniclastic rocks that extends over 20 kilometres along strike (Fig. 4c). This unit was assigned to the Mt. Dilworth Formation by Alldrick (1991, 1993). Its age was poorly constrained by a single Toarcian macrofossil collection from an overlying limestone unit (Alldrick, 1993), and a ca. 178 Ma U-Pb age with complicated systematics (ATP-Troy Ridge, in Lewis et al., 2001). As evidence began to emerge of the Middle Jurassic (ca. 174-176 Ma) age of the Eskay and Bruce Glacier members, Lewis (2001) considered that the Mt. Dilworth Formation was significantly older than originally defined and discontinued use of the term in the Iskut area. A sample of a volcaniclastic rock (Fig. 5d) was collected to determine the age of magmatism in the Mt. Dilworth area and to test its correlation with other felsic units of the Hazelton Group (i.e. Brucejack and Bruce Glacier members). The sample yielded abundant zircon grains that are 50-100 µm long and include clear, colourless, euhedral prismatic crystals and prism fragments with rounded tips, no fractures and few inclusions, and elongate prisms up to 150 µm long. Some grains display oscillatory growth zoning typical of magmatic zircons (Fig. 6g). Fourteen analyses yielded a weighted mean $^{206}Pb/^{238}U$ age of 173.6±1.7 Ma (MSWD=1.7), which is interpreted as the crystallization age of the felsic volcanic rock (Fig. 6g). Two inherited zircon analyses include a core of a subhedral rounded grain (analysis 8392-5.1: Table 2) with an age of ca. 183 Ma and an oscillatory growth zoned euhedral prism (analysis 8392-31.1: Table 2) with an age of ca. 189 Ma.

4. Discussion

In this study, we present U-Pb zircon data from seven Hazelton Group samples to establish the absolute ages of volcano-sedimentary units in the McTagg anticlinorium, east of the Eskay Creek deposit (Tables 1, 3). One sample of felsic volcaniclastic rock documents the age of the Brucejack Lake member of the Betty Creek Formation at Treaty Ridge. Six samples limit the spatial and temporal extent of the Bruce Glacier member of the Iskut River Formation.

4.1. Brucejack Lake Member

The Treaty Ridge section exposes a continuous stratigraphic sequence from the Unuk River member to the Treaty Ridge, John Peaks and Bruce Glacier members (Fig. 3b). Alkali feldspar porphyritic felsic volcaniclastic rock from near the base of the exposed section yielded a 187.1±1.9 Ma crystallization age (Table 2) confirming Brucejack Lake member epiclastic units, which may interfinger with andesites of the Unuk River member. This age closely agrees with the ca. 188 Ma age from this section reported by Lewis et al. (2001). Elsewhere, the Brucejack Lake and Unuk River members and their hypabyssal equivalents yielded ca. 194 to 185 Ma U-Pb zircon crystallization ages (Macdonald, 1993; Lewis et al. 2001), indicating that magmatism spanned ca. 5 to 10 m.y. (Fig. 3).

The underlying Jack Formation yielded Hettangian ammonites (Lewis et al. 2001) consistent with ca. 194 to 185 Ma U-Pb ages from the overlying Betty Creek Formation. However, there appears to be a several m.y. hiatus prior to onset of Unuk and Brucejack Lake member volcanism (Fig. 3). Pliensbachian ammonites in the overlying Treaty Ridge Member (Fig. 3) suggest either that Treaty Ridge sedimentation immediately followed cessation of Sinemurian to Pliensbachian Betty Creek Formation magmatism or that Treaty Ridge deposition occurred in an area that was isolated from the products of Betty Creek Formation volcanism.

4.2. Bruce Glacier Member

Bruce Glacier member felsic volcanic and epiclastic rocks are exposed along the east limb of the Eskay anticline and on both limbs of the McTagg anticlinorium (Fig. 2). Samples from the type locality at Bruce Glacier yielded 178.5±1.8 Ma and 174.6±1.8 Ma ages (Table 2, Fig. 3a) indicating that magmatism spanned ca. 1 to 7 m.y. Bruce Glacier member volcanic and hypabyssal rocks in the Iron Cap, Treaty Glacier, and Mt. Dilworth areas yielded ca. 175 to 173 Ma ages (Table 2; Figures 3b,c). Older Bruce Glacier member felsic rocks appear to be more commonly dacitic whereas younger rocks tend to be rhyolitic. Previous samples of the Bruce Glacier member volcanic and hypabyssal rocks equivalents have yielded ca. 178 to 173 Ma U-Pb zircon crystallization ages (Fig. 3; Macdonald, 1993; Lewis et al., 2001). Both our results and previous ages indicate magmatism either spanned ca. 5 to 9 m.y. or occurred in several discrete pulses.

Based on zircon inheritance and Sm-Nd isotopic data, Childe (1996) suggested that underlying Mesozoic and Paleozoic arcs

Table 3. Sample summary.

Sample Number	Lab Number	UTM E	UTM N	Unit Name	Rock Description	Interpreted Age	Inherited Ages
Bruce Glacier area							
04-ATSK-106-L01	8335	415112	6273249	Bruce Glacier member	Spherulitic rhyolite	178.5 ± 1.8 Ma	ca. 186 Ma
04-ATSL-042-L01	8337	411626	6263187	Bruce Glacier member	Felsic volcaniclastic rock	174.6 ± 1.8 Ma	ca. 213 Ma
Iron Cap area							
04-AT-1001-L01	8567	427059	6267454	Bruce Glacier member	Felsic volcaniclastic rock	173.3 ± 1.8 Ma	ca. 181 Ma
Treaty Glacier area							
04-ATSK-026-L02	8391	431695	6272917	Bruce Glacier member	Hypabyssal flowbanded rhyolite	174.4 ± 1.7 Ma	
04-ATSK-020-L01	8457	432437	6274000	Brucejack Lake member	Alkali feldspar porphyritic volcaniclastic rock	187.1 ± 1.9 Ma	
04-ATSK-008-L01	8336	432873	6273418	Bruce Glacier member	Feldspar-phyric rhyolite	174.7 ± 1.8 Ma	ca. 194 Ma, ca. 200 Ma, ca. 217 Ma
Mt. Dilworth area							
04-ATSK-004-L01	8392	435770	6230257	Bruce Glacier member	Felsic volcaniclastic rock	173.6 ± 1.7 Ma	ca. 183 Ma, ca. 189 Ma

influenced petrogenesis of Bruce Glacier member rhyolites. Data presented herein confirms Mesozoic inherited zircon in Bruce Glacier member felsic volcanic rocks (Table 2). Circa 200-183 Ma xenocrystic zircons were likely derived from the underlying Betty Creek Formation (Fig. 3) or related Texas Creek plutonic suite rocks (e.g., Logan et al. 2000 and references therein). Circa 218-213 Ma inheritance is consistent with derivation from the underlying Stuhini Group and related Stikine plutonic suite (ca. 225-210 Ma: Logan et al., 2000 and references therein).

U-Pb ages from the Bruce Glacier member agree with limits provided by the Aalenian radiolaria and Bajocian ammonites and brachiopods in overlying strata (Lewis et al., 2001). However, deposition of the Treaty Ridge member, which is characterized by non-volcanic strata, appears to partially overlap Bruce Glacier member volcanism. This suggests that either the Treaty Ridge Formation was deposited in a coeval basin that was somehow isolated from Betty Creek and Iskut River formations volcanic products, or that Treaty Ridge Formation needs to be re-examined in more detail (cf. Lewis et al., 2001).

5. Conclusion

Rhyolitic rocks from the Eskay member are discriminated from broadly coeval Bruce Glacier member volcanic rocks (Fig. 3) on the basis of Al-Ti-Zr ratios (Childe, 1996; Roth et al., 1999; Lewis, 2013). Previous studies in the Eskay anticline demonstrated that the Eskay member is only exposed on the western limb of the anticline, whereas the eastern limb comprises Bruce Glacier member, which displays Al/Ti ratios of <100. The samples that we dated have low Al/Ti ratios (Anderson, unpublished data), suggesting that the Bruce Glacier member is widespread in the MacTagg anticlinorium (Fig. 2). Although definitive Eskay member rocks have not been identified outside of the Eskay anticline, age-equivalent submarine felsic volcanic rocks are aerially extensive and locally voluminous in the MacTagg anticlinorium (Fig. 2; Lewis, 2013) and adjacent areas (Evenchick et al., 2004; Evenchick and McNicoll, 2002; Alldrick et al., 2005). Age-equivalent rocks also host volcanogenic massive sulphide deposits in the Anyox Pendant (Evenchick and McNicoll, 2002) and north of Eskay Creek mine (Alldrick et al., 2005). The presence of known VMS mineralization outside of the Eskay area indicates that much of the Upper Hazelton Group remains prospective for mineralization.

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