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Front cover:
In foreground, mafic tuff breccia, Betty Creek Formation, lower Hazelton Group. In background, ridge exposing section of (in ascending order), lower Hazelton Group, unconformity, upper Hazelton Group, Bowser Lake Group. Top of ridge west of the Kitsault Glacier, looking southeast across Homestake Creek. **Photo by Leonie Ebert.**

Back cover:
In foreground, intermediate hornblende-feldspar phyric lapilli tuff, interstratified with volcanic-derived coarse-grained sandstone, Betty Creek Formation, lower Hazelton Group. Looking northeast towards Mt. Klayduc. **Photo by Matteo Ferri.**

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Abstract
This release provides the full data, detailed methods, and interpreted ages for 14 high-precision CA-TIMS igneous U-Pb zircon ages, four LA-ICP-MS detrital U-Pb zircon ages, and three Re-Os molybdenite hydrothermal mineralization ages from samples collected in the Kitsault River area of northwestern British Columbia. The CA-TIMS ages are interpreted as recording times of crystallization and include samples from the Hyder intrusive suite (Hyder pluton; Eocene; one sample), Alice Arm intrusive suite (Ajax and Lime Creek stocks; Eocene; three samples), the upper part of the Hazelton Group (Upper Jurassic; two samples), the Texas Creek intrusive suite (Bulldog Creek pluton; Lower Jurassic; one sample), and the lower part of the Hazelton Group (Betty Creek Formation; Upper Triassic to Lower Jurassic; seven samples). LA-ICP-MS U-Pb detrital zircon ages represent maximum depositional ages and include those from the Bowser Lake Group (upper Jurassic; one sample), upper Hazelton Group (Middle to Upper Jurassic; two samples), and Stuhini Group (Upper Triassic; one sample). The three Re-Os molybdenite ages are hydrothermal mineralization ages from Eocene Mo-porphyry systems using molybdenite recovered from veins that cut the Lime Creek stock (Alice Arm intrusive suite) of the past-producing Kitsault mine (MINFILE 103P 120; two samples) and veins that cut Stuhini Group rocks at the Ajax deposit (MINFILE 103P 223; one sample).

Keywords: Kitsault River, Stikinia, Triassic, Jurassic, Eocene, Stuhini Group, Hazelton Group, Kinskuch unit, Betty Creek Formation, Kitsault unit, Smithers Formation, Bowser Lake Group, Texas Creek plutonic suite, Hyder plutonic suite, Alice Arm plutonic suite, detrital zircon geochronology, igneous zircon geochronology, U-Pb zircon geochronology, Re-Os geochronology, Golden Triangle, Kitsault molybdenum porphyry

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1. Summary

The Stikine terrane (Stikinia) of northwest British Columbia hosts significant porphyry, epithermal, and volcanogenic massive sulphide (VMS) precious and base metal deposits, including Schaft Creek, Galore Creek, Red Chris, KSM, Red Mountain, Premier, Snip and Bronson Slope. Particularly significant in the metallogeny of the region are volcano-sedimentary rocks of the Hazelton Group and coeval plutonic rocks (latest Triassic to Middle Jurassic; Alldrick et al., 1986; Gagnon et al., 2012; Nelson et al., 2013; Logan and Mihalynuk, 2014; Nelson et al., 2018; Nelson and van Straaten, 2020). The latest Triassic to Jurassic volcano-sedimentary successions are cut by intrusive rocks of the Hyder plutonic suite (Eocene, part of the Coast Plutonic complex), which define the western boundary of the Kitsault River map area, and the Alice Arm plutonic suite (Eocene), which hosts molybdenum porphyry deposits including the past-producing Kitsault mine (LeBel, 1988; Giroux and L'Heureux, 2007; Evenchick et al., 2008; Orovan et al., 2024).

In this geochronologic data release (BCGS_GF2025-21.zip), Appendix 1 contains sample descriptions and metadata, Appendix 2 contains LA-ICP-MS data for detrital zircons (U-Pb and trace element), Appendix 3 contains CA-TIMS data for igneous zircons (U-Pb), Appendix 4 contains Re-OS molybdenite data, Appendix 5 contains concordia and weighted mean plots for igneous zircon CA-TIMS analyses, Appendix 6 contains concordia, probability density, and weighted mean plots for detrital zircon LA-ICP-MS analyses, and Appendix 7 contains cathodoluminescence (CL) imagery. Supporting conclusions presented in Miller et al. (2025), these data are part of a larger study to better resolve the ages of the Stuhini, Hazelton, and Bowser Lake groups, the Texas Creek, Hyder, and Alice Arm intrusive suites, and mineralization in molybdenum porphyry systems in the Kitsault River area. The data presented herein (Table 1) include 14 ages presented in Miller et al. (2025) and seven previously unreleased ages. Samples were collected in 2022 and 2023 by E. Miller, R. Hunter, B. van Straaten, M. Ferri, and E. Orovan.

2. Methods

2.1. LA-ICP-MS methods

Zircons were handpicked in alcohol from rock samples that underwent standard mineral separation procedures. The entire zircon separate was placed in a muffle furnace at 900°C for 60 hours in quartz beakers to anneal minor radiation damage; annealing enhances cathodoluminescence (CL) emission and promotes more reproducible inter-element fractionation during laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). Following annealing, individual grains from all samples were handpicked based on morphology, clarity, and the absence of inclusions and mounted in epoxy for imaging, along with reference materials. Grain mounts were wet ground with carbide abrasive paper and polished with diamond paste. Cathodoluminescence (CL) imaging was carried out on a Philips XL-30 scanning electron microscope (SEM) equipped with a Bruker Quanta 200 energy-dispersion X-ray microanalysis system at the Electron Microbeam/Xray Diffraction Facility (EMXDF) at the University of British Columbia. An operating voltage of 15 kV was used, with a spot diameter of 6 µm and peak count time of 17-27 seconds. After removing the carbon coat, the grain mount surface was washed with mild soap and rinsed with high-purity water. Before analysis, the grain mount surface was cleaned with 3 N HNO_3 acid and again rinsed with high-purity water to remove any surficial Pb contamination that could interfere with the early portions of the spot analyses.

Analyses were conducted using a Resonetics RESOlution M-50-LR, which contains a Class I laser device equipped with a UV excimer laser source (Coherent COMPex Pro 110, 193 nm, pulse width of 4 ns) and a two-volume cell designed and developed by Laurin Technic Pty. Ltd. (Australia). This sample chamber allowed investigating several grain mounts in one analytical session. The laser path was fluxed by N_2 to ensure better stability. Ablation was carried out in a cell with a volume of approximately 20 cm^3 and a He gas stream that ensured better signal stability and lower U-Pb fractionation (Eggins et al., 1998). The laser cell was connected via a Teflon squid to an Agilent 7700x quadrupole ICP-MS housed at PCIGR. A pre-ablation shot was used to ensure that the spot area on grain surface was contamination-free. Samples and reference materials were analyzed for 36 isotopes: ^{7}Li, ^{29}Si, ^{31}P, ^{43}Ca, ^{45}Sc, ^{49}Ti, Fe (^{56}Fe, ^{57}Fe), ^{89}Y, ^{91}Zr, ^{93}Nb, ^{95}Mo, ^{98}Mo, ^{139}La, ^{140}Ce, ^{141}Pr, ^{146}Nd, ^{147}Sm, ^{153}Eu, ^{157}Gd, ^{159}Tb, ^{163}Dy, ^{165}Ho, ^{166}Er, ^{169}Tm, ^{172}Lu, ^{177}Hf, ^{181}Ta, ^{202}Hg, Pb (^{204}Pb, ^{206}Pb, ^{207}Pb, ^{208}Pb), ^{232}Th, and U (^{235}U, ^{238}U) with a dwell time of 0.02 seconds for each isotope. Pb/U and Pb/Pb ratios were determined on the same spots along with trace element concentration determinations. These isotopes were selected based on their relatively high natural abundances and absence of interferences. The settings for the laser were: spot size of 34 µm with a total ablation time of 30 seconds, frequency of 5 Hz, fluence of 5 J/cm^2, power of 7.8 mJ after attenuation, pit depths of approximately 15 µm, He flow rate of 800 mL/min, N_2 flow rate of 2 mL/min, and a carrier gas (Ar) flow rate of 0.57 L/min.

Reference materials were analyzed throughout the sequence to allow for drift correction and to characterize downhole fractionation for Pb/U and Pb/Pb isotopic ratios. For trace elements, NIST 612 glass was used for both drift correction and trace element calibration, with sample spacing between every five to eight unknowns, and 90Zr was used as the internal standard assuming stoichiometric values for zircon. NIST 610 glass was analyzed after each NIST 612 analysis and used as a monitor reference material for trace elements. For U-Pb analyses, natural zircon reference materials were used, including Plešovice (Sláma et al., 2008; 337.13 ±0.33 Ma) or 91500 (Wiedenbeck et al., 1995; 2004; 1062.4 ±0.4 Ma, 206Pb/238U date) as the internal reference material, and both Temora2 (Black et al., 2004; 416.78 ±0.33 Ma) and Plešovice and/or 91500 as monitoring reference materials; the zircon reference materials were placed between the unknowns in a similar fashion as the NIST glasses. Raw data were reduced using the Iolite 3.4 extension (Paton et al., 2011) for Igor Pro™ yielding concentration values, Pb/U and Pb/Pb dates, and their respective propagated uncertainties. For all LA-ICPMS analyses, we excluded individual grain ages with <0.05 probability of concordance (calculated using IsoplotR, Vermeesch, 2018). We calculated the following maximum depositional ages: youngest graphical probability peak (YPP; Dickinson and Gehrels, 2009) formed by 3 or more concordant grains in a probability density plot (PDP) constructed in Isoplot (Ludwig, 2012); Youngest Statistical Population (YSP; Coutts et al., 2019), and Maximum Likelihood Age (MLA, Vermeesch, 2021).

2.2. CA-TIMS methods

Chemical Abrasion Isotope Dilution Thermal Ionization Mass Spectrometry (CA-TIMS) procedures described here are modified from Mundil et al. (2004), Mattinson (2005), and Scoates and Friedman (2008). After preliminary analysis by LA-ICPMS, individual zircon grains were selected for CA-TIMS analysis to generate results with better precision. The grains were transferred into clean 300 mL PFA microcapsules (crucibles) and ultrapure HF (up to 50% strength, 500 mL) and HNO_3 (up to 14 N, 50 mL) were added for chemical abrasion leaching step. The grains were then placed in 125 mL PTFE liners (up to 15 per liner) and about 2 mL HF and 0.2 mL 3.5 N HNO_3 of the same strength as acid in beakers containing samples were added to the liners. The liners were then slid into stainless steel Parr™ high-pressure dissolution devices,

Table 1. Summary of geochronological ages.

Sample	Age (Ma)	Type	Lithostratigraphic unit	Longitude*	Latitude*
S23MFE-94-a	51.895 ±0.0099	CA-TIMS U-Pb zircon[1]	Hyder intrusive suite (Hyder pluton)	-129.691138	55.609981
S23EMI-78-a	55.473 ±0.0096	CA-TIMS U-Pb zircon[1]	Alice Arm intrusive suite (Ajax stock)	-129.409013	55.585978
D23EOR-32-14	55.705 ±0.225	Re-Os molybdenite[2]	Alice Arm intrusive suite (Lime Creek stock)	-129.421006	55.418555
D23EOR-31-4	55.975 ±0.231	Re-Os molybdenite[2]	Alice Arm intrusive suite (Lime Creek stock)	-129.429264	55.422480
D23EOR-36-1	55.0752 ±0.0087	CA-TIMS U-Pb zircon[1]	Alice Arm intrusive suite (Lime Creek stock)	-129.419161	55.423324
D23EOR-42-6	55.128 ±0.01	CA-TIMS U-Pb zircon[1]	Alice Arm intrusive suite (Lime Creek stock)	-129.419953	55.423501
S23EMI-178-1	56.09 ±0.23	Re-Os molybdenite[2]	Stuhini Group (sedimentary unit)	129.407324	55.587047
S23MFE-77-a	143.9 ±3.4	LA-ICPMS U-Pb detrital zircon[3]	Bowser Lake Group	-129.201456	55.525400
22RHU-42b	157.7 ±1.1	LA-ICPMS U-Pb detrital zircon[3]	Hazelton Group (upper)	-129.255097	55.695461
S23EMI-134-a	157.850 ±0.033	CA-TIMS U-Pb zircon[1]	Hazelton Group (upper)	-129.214045	55.587519
S23EMI-67-a	159.901 ±0.049	CA-TIMS U-Pb zircon[1]	Hazelton Group (upper)	-129.581395	55.775841
S23BVA-54-a	160.5 ±1.3	LA-ICPMS U-Pb detrital zircon[3]	Hazelton Group (upper)	-129.651902	55.619321
S23BVA-4-a	190.036 ±0.032	CA-TIMS U-Pb zircon[1]	Hazelton Group (lower, Betty Creek Formation)	-129.603287	55.780983
22EMI-002/ DV20-228-290m	190.524 ±0.037	CA-TIMS U-Pb zircon[1]	Hazelton Group (lower, Betty Creek Formation)	-129.540176	55.698519
S23BVA-81-a	190.776 ±0.030	CA-TIMS U-Pb zircon[1]	Hazelton Group (lower, Betty Creek Formation)	-129.592312	55.761304
S23EMI-1-a	192.079 ±0.030	CA-TIMS U-Pb zircon[1]	Hazelton Group (lower, Betty Creek Formation)	-129.580598	55.766697
22RHU-077b	192.491 ±0.034	CA-TIMS U-Pb zircon[1]	Hazelton Group (lower, Betty Creek Formation)	-129.334361	55.615201
22EMI-001/ DV20-216-139m	193.297 ±0.035	CA-TIMS U-Pb zircon[1]	Hazelton Group (lower, Betty Creek Formation)	-129.505119	55.688245
S23API-84-a	193.820 ±0.027	CA-TIMS U-Pb zircon[1]	Texas Creek intrusive suite (Bulldog Creek pluton)	-129.688536	55.688184
22BvS-90b	204.526 ±0.037	CA-TIMS U-Pb zircon[1]	Hazelton Group (lower, Betty Creek Formation)	-129.250803	55.642161
22RHU-061a	205.3 ±1.5	LA-ICPMS U-Pb detrital zircon[3]	Stuhini Group	-129.471621	55.703207

[1] igneous crystallization age; [2] hydrothermal mineralization age; [3] maximum age of deposition; * Datum used for all coordinates: WGS 1984

which were sealed and brought up to a maximum of 190°C for 8-16 hours (typically 175°C for 12 hours). Beakers were removed from liners and zircons were separated from leachate. Zircons were rinsed with >18 $M\Omega$.cm water and 3.5 N HNO_3. Then 200 µL of sub-boiled 6N HCl was added and beakers were set on a hotplate at 80-130°C for 30 minutes and again rinsed with water. For full dissolution in same microcapsules (crucibles), about 50 µL 50% HF and 5 µL 14 N HNO_3 were added and each was spiked with a $^{233-235}U$-^{205}Pb tracer solution (EARTHTIME ET535), capped and again placed in a Parr liner (up to 15 microcapsules per liner). Zircons were dissolved in Parr vessels in 120 µL of 29 M HF with a trace of 3.5 M HNO_3 at 220°C for 48 h, dried to fluorides, and re-dissolved in 6 M HCl at 180°C overnight. Solutions were subsequently dried down and redissolved in 60 µL of 3 M HCl to convert to $PbCl_3$-, UO_2Cl_3-, and UCl_6-ions. U and Pb were separated from the zircon matrix using an HCl-based anion-exchange chromatographic procedure. Pb was eluted with 200 µL of 6 M HCl and U with 250 µL of MQ-H_2O into the same beaker and dried with 2 µL of 0.05 N H_3PO_4.

Pb and U were loaded on a single outgassed Re filament in 5 µL of a silica gel-phosphoric acid mixture (Gerstenberger and Haase, 1997), and U and Pb isotopic measurements were made on a Nu Instruments thermal ionization mass spectrometer equipped with an ion-counting Daly detector. Pb isotopes were measured in static mode for all isotopes on 150 cycles on 10 second intervals on $10^{13}\,\Omega$ resistors for masses 208-205 with mass 204 measured on the Daly detector. Mass fractionation was determined using repeat measurements of standard material NBS-981 solution that has equal atom ^{208}Pb and ^{206}Pb and thus measures fractionation directly and was 0.16±0.03 %amu^{-1} for the analytical sessions reported here. Transitory isobaric interferences due to high-molecular-weight organics, particularly on ^{204}Pb and ^{207}Pb, disappeared within approximately 20 cycles, whereas ionization efficiency averaged 10 mVpg^{-1} of each Pb isotope. Linearity (to cps) and the associated deadtime correction of the Daly detector were monitored by repeated analyses of NBS981. Uranium was analyzed as UO ions in static Faraday mode on $10^{13}\,\Omega$ resistors for 200 cycles and corrected for isobaric interference of $^{233}U^{18}O^{16}O$ on $^{235}U^{16}O^{16}O$ with an $^{18}O/^{16}O$ ratio of 0.00206. Ionization efficiency averaged 20 mVng^{-1} of each U isotope. U mass fractionation was corrected using the known $^{233}U/^{235}U$ ratio of the tracer solution.

U-Pb dates and uncertainties were calculated using the algorithms of Schmitz and Schoene (2007); calibration of ET535 tracer solution (Condon et al., 2015) of $^{235}U/^{205}Pb = 100.233$, $^{233}U/^{205}Pb = 0.99506$, and $^{205}Pb/^{204}Pb = 11268$; U decay constants recommended by Jaffey et al. (1971); and of $^{238}U/^{235}U = 137.818$ (Hiess et al., 2012). The $^{206}Pb/^{238}U$ ratios and dates were corrected for initial ^{230}Th disequilibrium using DTh/U = 0.20±0.05 (1σ) and the algorithms of Crowley et al. (2007), resulting in an increase in the $^{206}Pb/^{238}U$ dates of ~0.09 Ma. All common Pb in analyses was attributed to laboratory blank and subtracted based on the measured laboratory Pb isotopic composition and associated uncertainty. U blanks are estimated at 0.013 pg.

Weighted mean $^{206}Pb/^{238}U$ dates were calculated from equivalent dates (probability of fit >0.05) using Isoplot 3.0 (Ludwig, 2003). Errors on the weighted mean dates are given as X (Y) [Z]. X is the internal error based on analytical uncertainties only, including counting statistics, subtraction of tracer solution, and blank and initial common Pb subtraction, and Y errors include the uncertainty in the tracer calibration propagated in quadrature. Internal errors should be considered when comparing these CA-TIMS dates with those derived from other geochronological methods using the U–Pb decay scheme (e.g., LA-ICPMS). Z errors include uncertainties in the tracer calibration and ^{238}U decay constant (Jaffey et al., 1971) and should be considered when comparing our dates with those derived from other decay schemes (e.g., $^{40}Ar/^{39}Ar$, ^{187}Re-^{187}Os).

2.3. Re-Os methods

Methods used for molybdenite Re-Os analysis are described in detail by Selby and Creaser (2004). Areas of each sample with visible molybdenite were selected, and preparation of a molybdenite mineral separate was made by metal-free crushing and sieving followed by magnetic and gravity concentration. The ^{187}Re and ^{187}Os concentrations in molybdenite were determined by isotope dilution mass spectrometry using Carius-tube, solvent extraction, anion chromatography, and negative thermal ionization mass spectrometry techniques. For this work, a mixed, double-Os spike containing known amounts of isotopically enriched ^{185}Re, ^{190}Os, and ^{188}Os analysis was used (Markey et al., 2007). Isotopic analysis used a ThermoScientific Triton mass spectrometer by Faraday collector. Total procedural blanks for Re and Os are less than <3 picograms and <0.5 picograms, respectively, which are insignificant in comparison to the Re and Os concentrations in molybdenite. The Reference Material 8599 Henderson molybdenite (Markey et al., 2007) is routinely analyzed as a standard, and during the past 2 years returned an average Re-Os date of 27.83 ± 0.09 Ma (n=14), indistinguishable within uncertainty from the Reference Age Value of 27.66 ± 0.1 Ma (Wise and Watters, 2011). The ^{187}Re decay constant used is 1.666×10^{-11} a^{-1} (Smoliar et al, 1996).

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