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U-Pb zircon geochronology from a Late Triassic pluton in the Mount Nansen area

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Introduction

This report presents the geochronology results for one sample from a Late Triassic Pyroxene Mountain pluton collected in the Mount Nansen area and analyzed for U-Pb zircon dating at Boise State University. These data complement the large dataset released in the Atlas of Sack *et al.* (2020).

Pyroxene Mountain pluton in the Mount Nansen area

A series of small Late Triassic plutons assigned to the Pyroxene Mountain suite intrude the Yukon-Tanana terrane in the Mount Nansen area, approximately 55 km west of Carmacks, central Yukon (*see* Fig. 1-2 in Sack *et al.*, 2020). The largest (~5 km²) Late Triassic pluton in the area is found on the southern flank of Mount Nansen (Fig. 1). This pluton was previously dated by Klöcking *et al.* (2016; their sample LM370) who reported LA-ICPMS $^{206}Pb/^{238}U$ zircon dates ranging from 214.3 ± 2.0 to 208.8 ± 1.6 Ma and a weighted mean age of 211.1 ± 0.9 Ma (*see* also Sack *et al.*, 2020, p. 51–56). We collected sample 20PS122-1 approximately 250 m SSE of the previously dated rock (N 62.069711, W 137.363691) for more precise U-Pb analysis at Boise State University using a combination of LA-ICPMS and CA-TIMS methods as described in detail below.

Sample 20PS122-1 is a medium-grained, foliated hornblende diorite to quartz diorite (Fig. 2) that intrudes amphibolite and schist of the Devonian to Mississippian Finlayson assemblage and locally quartzite and quartz-mica schist of the Snowcap assemblage of the Yukon-Tanana terrane (Klöcking *et al.*, 2016; Ryan *et al.*, 2016). The Late Triassic plutons in the Mount Nansen area are foliated and fabrics have similar attitude as the dominant foliation in the Paleozoic country rocks (Ryan *et al.*, 2016; Sack *et al.*, 2021). The northern margin of the Mount Nansen pluton is unconformably overlain by andesitic volcanic rocks of the mid-Cretaceous Mount Nansen Group and intruded by high-level porphyritic rocks of the Late Cretaceous Casino suite (Fig. 1).

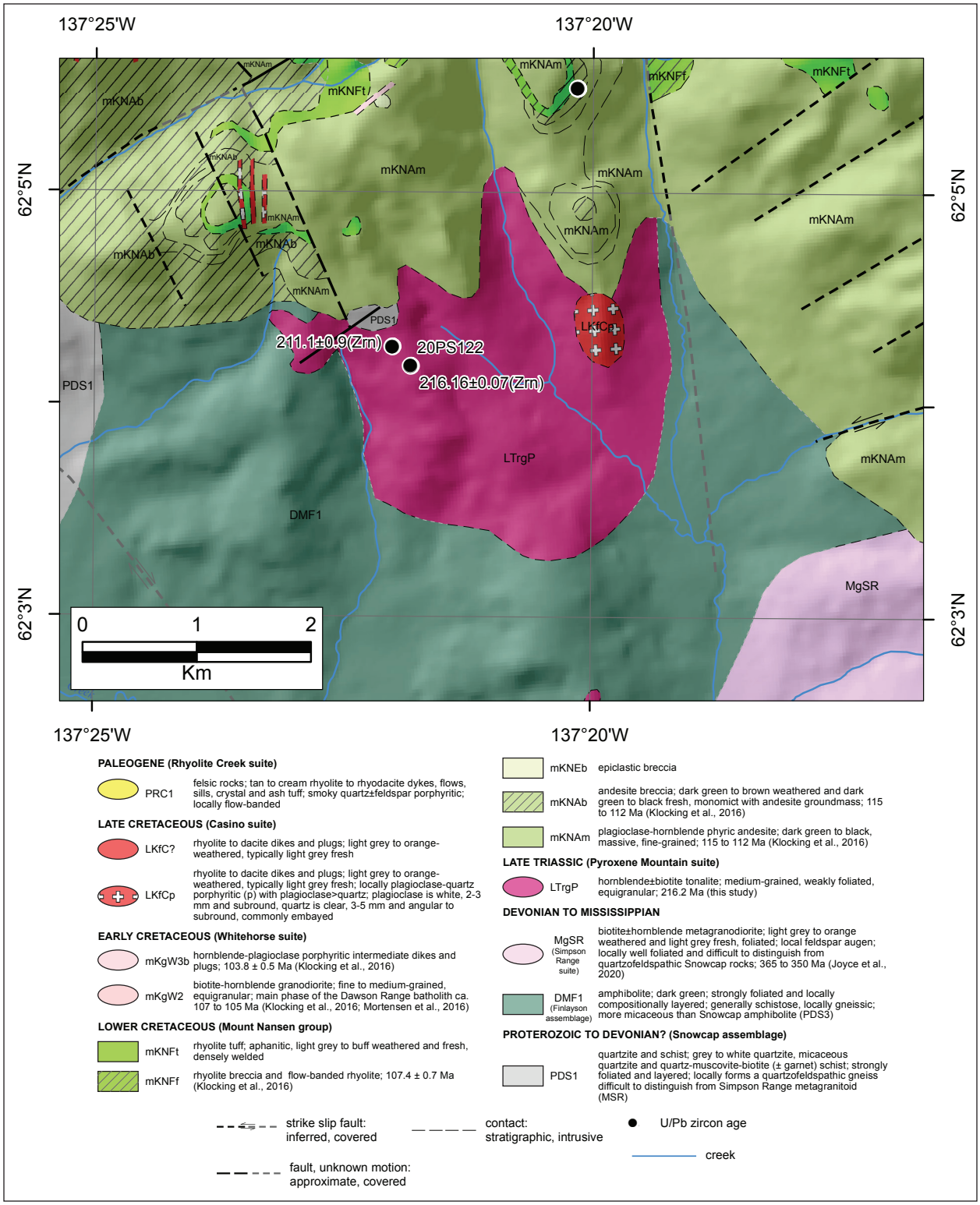

Figure 1. *Simplified geological map of the Mount Nansen area, modified after Sack et al. (2021).*

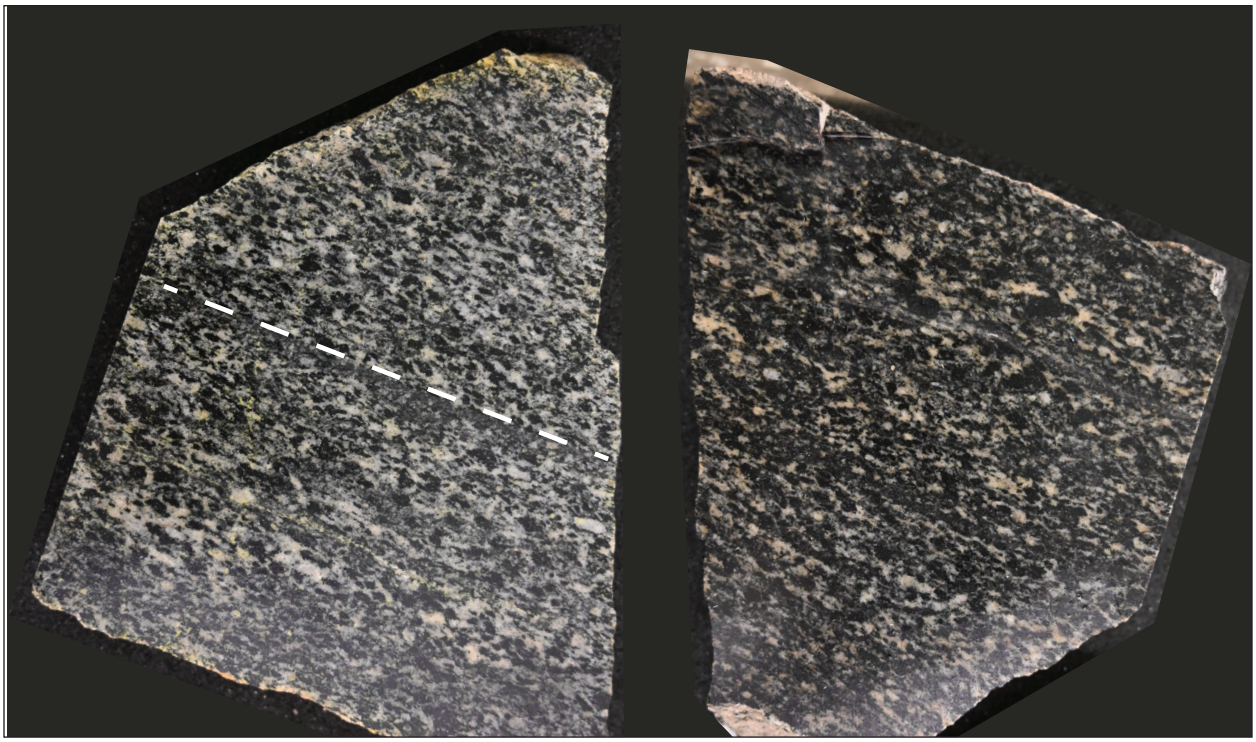

Figure 2. *Representative samples of foliated medium-grained hornblende diorite from the southern flank of Mount Nansen, sample 20PS122-1. Fresh polished surface (left) and a cobaltinitrite-stained cut surface (right); yellow-stained mineral is K-feldspar. Dashed white line in photograph at right shows foliation trace.*

Analytical methods

LA-ICPMS methods

Zircon grains were separated from rocks using standard techniques, annealed at 900°C for 60 hours in a muffle furnace, and mounted in epoxy and polished until their centers were exposed. Cathodoluminescence (CL) images were obtained with a JEOL JSM-300 scanning electron microscope and Gatan MiniCL. Zircon was analyzed by laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) using an iCAP RQ Quadrupole ICP-MS and Teledyne Photon Machines Analyte Excite+ 193 nm excimer laser ablation system with HelEx II Active two-volume ablation cell. In-house analytical protocols, standard materials, and data reduction software were used for acquisition and calibration of U-Pb dates and a suite of high field strength elements (HFSE) and rare earth elements (REE). Zircon was ablated with a laser spot of 20 µm wide using fluence and pulse rates of 3 J/cm^2 and 10 Hz, respectively, during a 35 second analysis (15 sec gas blank, 20 sec ablation) that excavated a pit ~8 µm deep. Ablated material was carried by a 0.5 L/min He gas stream in the inner cell and a 1.1 L/min He gas stream in the outer cell. Dwell times were 10 ms for Si, 1 ms for Zr, 5 ms for Hf, 200 ms for ^{49}Ti and ^{207}Pb, 100 ms for ^{206}Pb, 20 ms for ^{202}Hg and ^{204}Pb, 10 ms for ^{238}U, and 10 ms for all other HFSE and REE. Background count rates for each analyte were obtained prior to each spot analysis and subtracted from the raw count rate for each analyte. Ablations pits that appear to have intersected glass or mineral inclusions were identified based on Ti and P. U-Pb dates from these analyses are considered valid if the U-Pb ratios appear to have been unaffected by the inclusions. Analyses that appear contaminated by common Pb were rejected based on mass 204 being above baseline. For concentration calculations,

background-subtracted count rates for each analyte were internally normalized to ^{29}Si and calibrated with respect to NIST SRM-610 and -612 glasses as the primary standards. Temperature was calculated from the Ti-in-zircon thermometer (Watson *et al.*, 2006). Because there are no constraints on the activity of TiO_2, an average value in crustal rocks of 0.6 was used.

Data were obtained in one experiment in June 2021. For U-Pb and $^{207}Pb/^{206}Pb$ dates, instrumental fractionation of the background-subtracted ratios was corrected and dates were calibrated with respect to interspersed measurements of zircon standards and reference materials. The primary standard Plešovice zircon (Sláma *et al.*, 2008) was used to monitor time-dependent instrumental fractionation based on two analyses for every 12 analyses of unknown zircon. A secondary correction to the $^{206}Pb/^{238}U$ dates was made based on results from the zircon standards Seiland (531 Ma, unpublished data, Boise State University) and 91500 (1065 Ma, Wiedenbeck *et al.*, 1995), which were treated as unknowns and measured once for every 12 analyses of unknown zircon. These results showed a linear age bias of several percent that is related to the ^{206}Pb count rate. The secondary correction is thought to mitigate matrix-dependent variations due to contrasting compositions and ablation characteristics between the Plešovice zircon and other standards (and unknowns).

Radiogenic isotope ratio and age error propagation for all analyses includes uncertainty contributions from counting statistics and background subtraction. Errors without and with the standard calibration uncertainty are shown in the data table (Appendix 1). This uncertainty is the local standard deviation of the polynomial fit to the interspersed primary standard measurements versus time for the time-dependent, relatively larger U/Pb fractionation factor, and the standard error of the mean of the consistently time-invariant and smaller $^{207}Pb/^{206}Pb$ fractionation factor. These uncertainties are 1.2% (2σ) for $^{206}Pb/^{238}U$ and 0.6% (2σ) for $^{207}Pb/^{206}Pb$. For groups of analyses that are collectively interpreted from a weighted mean date, a weighted mean date is first calculated from equivalent dates (probability of fit >0.05) using Isoplot 3.0 (Ludwig, 2003) with errors on individual dates that do not include a standard calibration uncertainty. A standard calibration uncertainty is then propagated into the error on the date. Errors on single analyses without the standard calibration uncertainty are given below. Age interpretations are based on $^{206}Pb/^{238}U$ dates. Errors are at 2σ.

CA-TIMS U-Pb geochronology methods

U-Pb dates were obtained by the chemical abrasion isotope dilution thermal ionization mass spectrometry (CA-TIMS) method from analyses composed of single zircon grains (Appendix 2), modified after Mattinson (2005). Zircon was removed from the epoxy mounts for dating based on CL images.

Zircon was put into 3 ml Teflon PFA beakers and loaded into 300 µl Teflon PFA microcapsules. Fifteen microcapsules were placed in a large-capacity Parr vessel and the zircon partially dissolved in 120 µl of 29 M HF for 12 hours at 190°C. Zircon was returned to 3 ml Teflon PFA beakers, HF was removed, and zircon was immersed in 3.5 M HNO_3, ultrasonically cleaned for an hour, and fluxed on a hotplate at 80°C for an hour. The HNO_3 was removed and zircon was rinsed twice in ultrapure H_2O before being reloaded into the 300 µl Teflon PFA microcapsules (rinsed and fluxed in 6 M HCl during sonication and washing of the zircon) and spiked with the Boise State University mixed ^{233}U-^{235}U-^{205}Pb tracer solution (BSU-1B). Zircon was 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 hours, dried to fluorides, and re-dissolved in 6 M HCl at 180°C overnight. U and Pb were separated from the zircon matrix using an HCl-based anion-exchange chromatographic procedure (Krogh, 1973), eluted together 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 made on a GV Isoprobe-T multicollector thermal ionization mass spectrometer equipped with an ion-counting Daly detector. Pb isotopes were measured by peak-jumping all isotopes on the Daly detector for 160 cycles, and corrected for 0.16 ± 0.03%/a.m.u. (1σ) mass fractionation. Transitory isobaric interferences due to high-molecular weight organics, particularly on ^{204}Pb and ^{207}Pb, disappeared within approximately 60 cycles, while ionization efficiency averaged 10^4 cps/pg of each Pb isotope. Linearity (to ≥1.4×10^6 cps) and the associated deadtime correction of the Daly detector were determined by analysis of NBS982. Uranium was analyzed as UO_2^+ ions in static Faraday mode on 10^{12} ohm resistors for 300 cycles, and corrected for isobaric interference of $^{233}U^{18}O^{16}O$ on $^{235}U^{16}O^{16}O$ with an $^{18}O/^{16}O$ of 0.00206. Ionization efficiency averaged 20 mV/ng of each U isotope. U mass fractionation was corrected using the known $^{233}U/^{235}U$ ratio of the Boise State University tracer solution.

U-Pb dates and uncertainties were calculated using the algorithms of Schmitz and Schoene (2007), calibration of BSU-1B tracer solution of $^{235}U/^{205}Pb$ of 77.93 and $^{233}U/^{235}U$ of 1.007066 for, U decay constants recommended by Jaffey *et al.* (1971), and $^{238}U/^{235}U$ of 137.818 (Hiess *et al.*, 2012). $^{206}Pb/^{238}U$ ratios and dates were corrected for initial ^{230}Th disequilibrium using $D_{Th/U} = 0.20 \pm 0.05$ (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 are calculated from equivalent dates (probability of fit >0.05) using Isoplot 3.0 (Ludwig, 2003). Errors on weighted mean dates are given as ± x / y / z, where x is the internal error based on analytical uncertainties only, including counting statistics, subtraction of tracer solution, and blank and initial common Pb subtraction, y includes the tracer calibration uncertainty propagated in quadrature, and z includes the ^{238}U decay constant uncertainty propagated in quadrature. Internal errors should be considered when comparing our dates with $^{206}Pb/^{238}U$ dates from other laboratories that used the same tracer solution or a tracer solution that was cross-calibrated using EARTHTIME gravimetric standards. Errors including the uncertainty in the tracer calibration should be considered when comparing our dates with those derived from other geochronological methods using the U-Pb decay scheme (*e.g.*, laser ablation ICPMS). Errors including uncertainties in the tracer calibration and ^{238}U decay constant (Jaffey *et al.*, 1971) should be considered when comparing our dates with those derived from other decay schemes (*e.g.*, $^{40}Ar/^{39}Ar$, ^{187}Re-^{187}Os). Errors are 2σ.

Geochronology

Sample 20PS122-1 yielded prismatic zircons with an aspect ratio of 2:1, concentric igneous zoning (Fig. 3a). Forty-eight LA-ICPMS spots were analyzed and yielded $^{206}Pb/^{238}U$ dates between 231 ± 11 and 203 ± 5 Ma, with a weighted mean of 214.4 ± 2.9 Ma for 46 of 48 analyses (Fig. 3b; Appendix 1). Five zircons were analyzed using the CA-TIMS method (Appendix 2); a sixth grain was initially selected but was found to have very low radiogenic Pb and was not analyzed. The five grains analyzed yielded concordant analyses ranging from 216.23 ± 0.15 to 216.10 ± 0.15 Ma with a weighted mean age of 216.16 ± 0.07 Ma (MSWD = 0.40, n = 5; Fig. 3c). This weighted mean age is interpreted to represent the crystallization age of the rock.

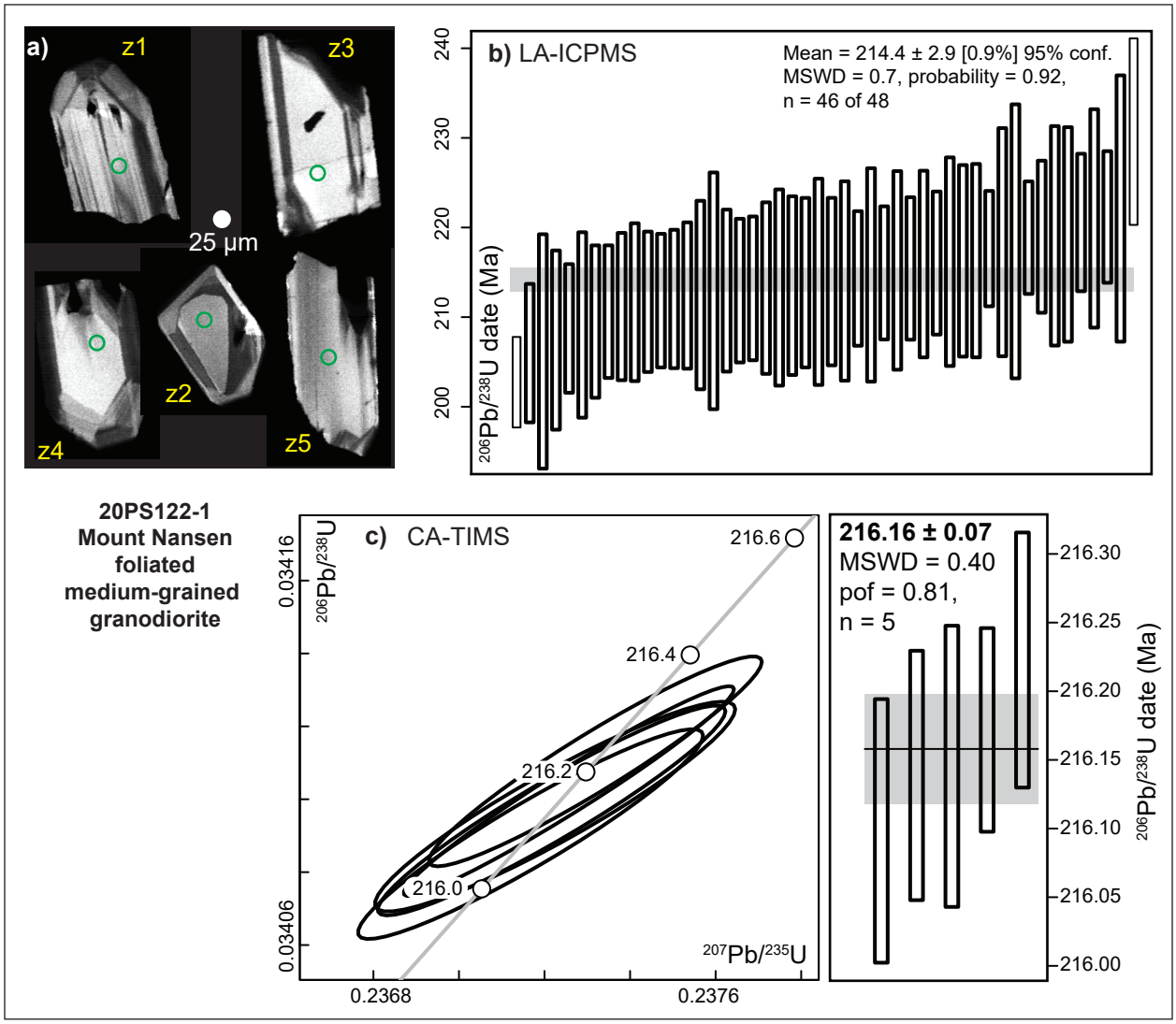

Figure 3. U-Pb zircon geochronology results for 20PS122-1. **a)** *Cathodoluminescence images of zircon analyzed by CA-TIMS, with analyses labelled; green circle indicates approximate location of 20 µm spot LA-ICPMS analysis.* **b)** *Ranked plot of $^{206}Pb/^{238}U$ dates determined by LA-ICPMS.* **c)** *Concordia plot of CA-TIMS dates. Analyses included in CA-TIMS weighted mean date calculation are shown by bold ellipses; ellipses with thin lines are not used in calculation. Ranked $^{206}Pb/^{238}U$ date plot is to the right of the concordia plot, with the weighted mean date shown by the grey band. Line-type designations are the same as the concordia plot. Errors in all plots are at 2σ; LA-ICPMS errors include the standard calibration uncertainty. MSWD = mean squared weighted deviation, pof = probability of fit, n = number of analyses included in age calculation.*

References

Crowley, J.L., Schoene, B. and Bowring, S.A., 2007. U-Pb dating of zircon in the Bishop Tuff at the millennial scale. Geology, vol. 35, p. 1123–1126.

Gerstenberger, H. and Haase, G., 1997. A highly effective emitter substance for mass spectrometric Pb isotope ratio determinations. Chemical Geology, vol. 136, p. 309–312.

Hiess, J., Condon, D.J., McLean, N. and Noble, S.R., 2012. $^{238}U/^{235}U$ systematics in terrestrial uranium-bearing minerals. Science, vol. 335, p. 1610–1614.

Jaffey, A.H., Flynn, K.F., Glendenin, L.E., Bentley, W.C. and Essling, A.M., 1971. Precision measurements of half-lives and specific activities of ^{235}U and ^{238}U, Physical Review C, vol. 4, p. 1889–1906.

Klöcking, M., Mills, L., Mortensen, J.K. and Roots, C.F., 2016. Geology of mid-Cretaceous volcanic rocks at Mount Nansen, central Yukon, and their relationship to the Dawson Range batholith. Yukon Geological Survey, Open File 2016-25, 37 p.

Krogh, T.E., 1973. A low contamination method for hydrothermal decomposition of zircon and extraction of U and Pb for isotopic age determination. Geochimica et Cosmochimica Acta, vol. 37, p. 485–494.

Ludwig, K.R., 2003. User's Manual for Isoplot 3.00. Berkeley Geochronology Center, Berkeley, CA.

Mattinson, J.M., 2005. Zircon U-Pb chemical abrasion ("CA-TIMS") method: combined annealing and multi-step partial dissolution analysis for improved precision and accuracy of zircon ages. Chemical Geology, vol. 220, p. 47–66.

Ryan, J.J., Westberg, E.E., Williams, S.P. and Chapman, J.B., 2016. Geology, Mount Nansen - Nisling River area, Yukon. Geological Survey of Canada, Canadian Geoscience Map 292.

Sack, P.J., Colpron, M., Crowley, J.L., Ryan, J.J., Allan, M.M., Beranek, L.P. and Joyce, N.L., 2020. Atlas of Late Triassic to Jurassic plutons in the Intermontane terranes of Yukon. Yukon Geological Survey, Open File 2020-1, 365 p.

Sack, P.J., Eriks, N. and van Loon, S., 2021. Revised geological map of the Mount Nansen area (NTS 115I/3 and part of 115I/2). Yukon Geological Survey, Open File 2021-2.

Schmitz, M.D. and Schoene, B., 2007. Derivation of isotope ratios, errors and error correlations for U-Pb geochronology using ^{205}Pb-^{235}U-(^{233}U)-spiked isotope dilution thermal ionization mass spectrometric data. Geochemistry, Geophysics, Geosystems (G^3), vol. 8, Q08006, doi:10.1029/2006GC001492.

Sláma, J., Košler, J., Condon, D.J., Crowley, J.L., Gerdes, A., Hanchar, J.M., Horstwood, M.S.A., Morris, G.A., Nasdala, L., Norberg, N., Schaltegger, U., Schoene, B. Tubrett, M.N and Whitehouse, M.J., 2008. Plešovice zircon — A new natural reference material for U–Pb and Hf isotopic microanalysis. Chemical Geology, vol. 249, p. 1–35.

Watson, E.B., Wark, D.A. and Thomas, J.B., 2006. Crystallization thermometers for zircon and rutile. Contributions to Mineralogy and Petrology, vol. 151, p. 413–433.

Wiedenbeck, M., Alle, P., Corfu, F., Griffin, W., Meier, M., Oberli, F., Quadt, A.V., Roddick, J. and Spiegel, W., 1995. Three natural zircon standards for U-Th-Pb, Lu-Hf, trace element and REE Analyses. Geostandards Newsletter, vol. 19, p. 1–23.

Appendices (digital)

Appendix 1: LA-ICPMS zircon and trace element data (Appendix 1_LA-ICPMS data.xls)

Appendix 2: CA-TIMS zircon data (Appendix 2_CA-TIMS data.xls)