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Abstract

Raw data for two new U-Pb zircon dates from the southern Nicola arc are reported here. These dates extend the age and spatial limits of magmatic Nicola Group rocks. Older Nicola Group volcanic strata now span almost the entire known width of exposed Nicola Group at the latitude of Merritt. A CA-TIMs age of 239.99 ±0.16 Ma from Missezula formation (informal) felsic tuffs near Pennask Mountain is now the oldest dated Nicola Group. The new date places these rocks in the early Ladinian (Middle Triassic). This age is similar to those from the central part of the Nicola arc farther west, strengthening stratigraphic ties across the arc. We also obtained a LA-ICPS detrital zircon age of 200.2 ±1.1 Ma from tuff bands in a section of Shrimpton formation (informal) calcareous and argillaceous siltstone near Pothole Lake. Accepting the recent IUGS timescale calibration for the Triassic-Jurassic boundary at 201 Ma, the youngest Nicola magmatism now extends to the earliest Jurassic.

Keywords: Nicola Group, Shrimpton formation, Missezula formation, Aberdeen Ridge formation, Stemwinder Mountain formation, uranium-lead geochronology, detrital zircon, Triassic, Early Jurassic, volcanic tuff, stratigraphy

1. Introduction

Geofile 2020-12 adds to the inventory of geochronological data that have been acquired as part of the Southern Nicola Arc Project (SNAP; Figs. 1, 2). The SNAP is a field-based mapping and sampling program focussed on Middle to Late Triassic rocks of the Nicola Group, especially their magmatic, sedimentary and structural history. Nicola Group rocks are important to British Columbia as they contain large porphyry-style deposits from which copper, gold, silver, and molybdenum have historically been extracted. Extraction from these deposits has been a major economic driver in the province for more than 50 years. The SNAP area is between producing deposits at Copper Mountain (to the south), Highland Valley (to the northwest), and New Afton (to the north, Fig. 2).

The Nicola Group is the most visible part of the Quesnel terrane (Fig. 1; Coney et al., 1980). As a crustal block, it was accreted to the British Columbian segment of North America together with its twin arc terrane, Stikinia, with which it amalgamated in the Middle Jurassic (e.g., Mihalynuk et al., 2004). Sandwiched between the two arc terranes is a ribbon of Cache Creek terrane, including accretionary complex with blueschist and overlap strata (Coney et al., 1980). Collectively, the three terranes comprise the Intermontane Superterrane (Fig. 1; Monger et al., 1982; Wheeler and McFeely, 1987), the largest block of accreted crust in British Columbia, extending the length of the province.

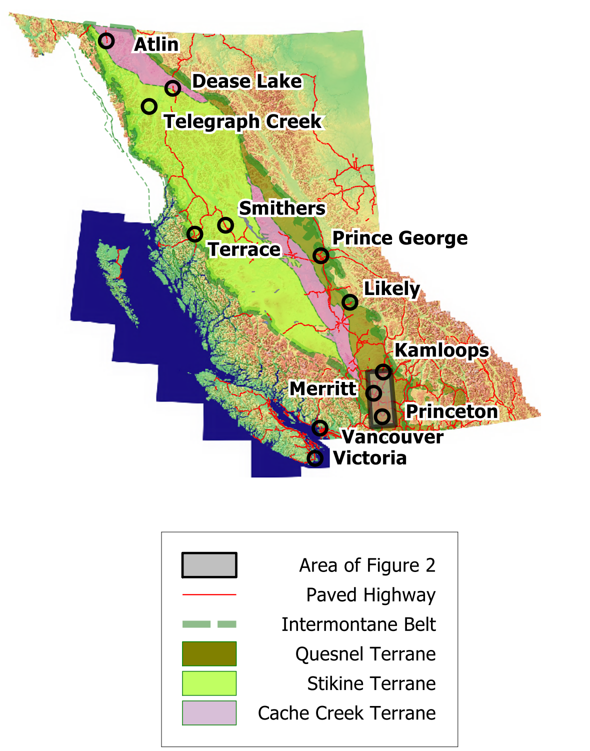
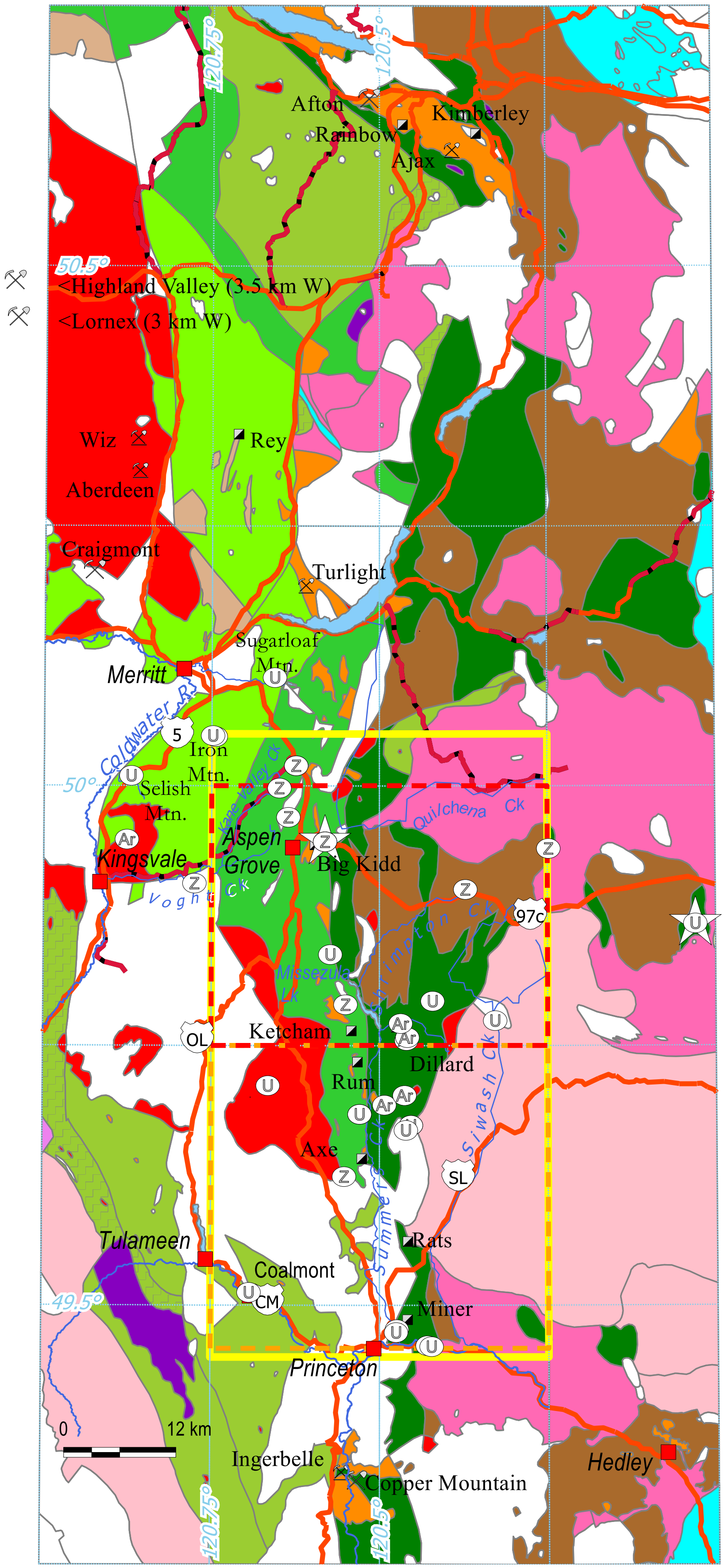


Fig. 1. Location of the project area with respect to tectonostratigraphic terranes (Wheeler et al., 1991) and physiography of British Columbia.



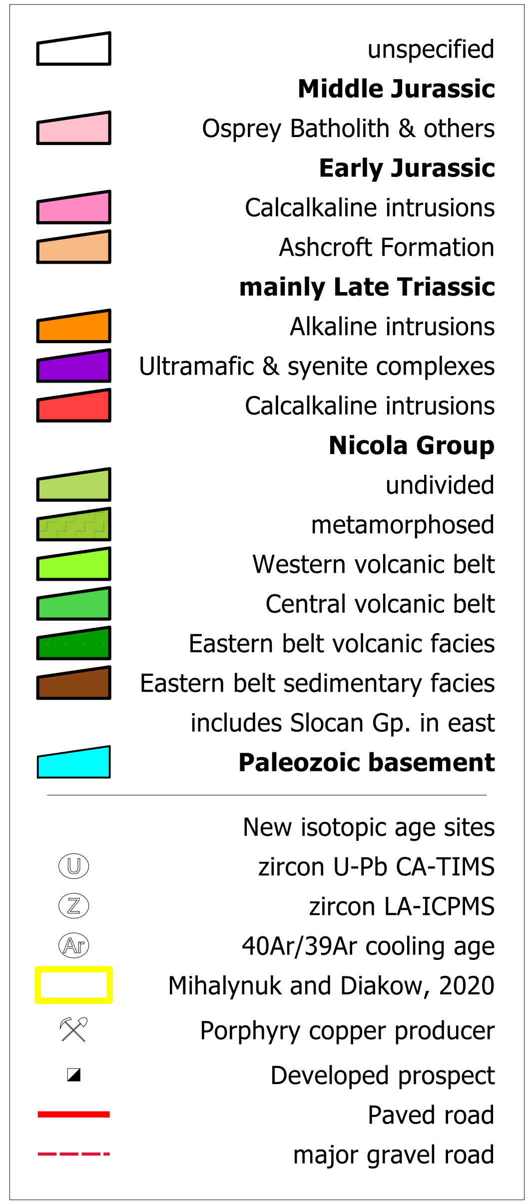


Fig. 2. Regional geological setting of the Southern Nicola Arc Project adapted from British Columbia Geological Survey digital geology (Cui et al., 2017). SNAP map areas are outlined by dashed red and orange, compiled into the area outlined in yellow. Locations of samples discussed here are shown by the stars.

This Geofile contains the results, methods and quality control data from geochronological analyses of two samples collected during fieldwork in 2017 and 2018 (BCGS_GF2020-12.zip). So far, these are the oldest and youngest isotopically dated samples in the southern part of the Nicola Group.

2. Geochronological methods

2.1. U-Pb zircon chemical abrasion thermal ionization mass spectrometry (CA-TIMS)

A synopsis of the CA-TIMS method is presented here. More detailed descriptions are presented in the 'analytical techniques' sheet accompanying the Excel file for sample MMI17-10-1.

CA-TIMS procedures were modified from Mundil et al. (2004), Mattinson (2005) and Scoates and Friedman (2008). Rock samples underwent standard mineral separation procedures, and zircon separates were handpicked in alcohol. The clearest, crack- and inclusion-free grains were selected, photographed, and then annealed at 900˚C for 60 hours. Annealed grains were chemically abraded, spiked with a $^{233-235}U$-^{205}Pb tracer solution (EARTHTIME ET535), and then dissolved. Resulting solutions were dried and loaded onto Re filaments (Gerstenberger and Haase, 1997).

Isotopic ratios were measured by a modified single collector VG-54R or 354S thermal ionization mass spectrometer equipped with analogue Daly photomultipliers. Analytical blanks were 0.2 pg for U and up to 1.0 pg for Pb. U fractionation was determined directly on individual runs using the ET535 mixed $^{233-235}U$-^{205}Pb isotopic tracer. Pb isotopic ratios were corrected for fractionation of 0.25% ±0.04%/amu, based on replicate analyses of NBS-982 reference material and the values recommended by Thirlwall (2000). Data reduction used the Excel-based program of Schmitz and Schoene (2007). Standard concordia diagrams were constructed and regression intercepts and weighted averages calculated with Isoplot (Ludwig, 2003). All errors are quoted at the 2σ or 95% confidence level, unless otherwise noted. Isotopic ages were calculated with the decay constants λ^{238}=1.55125E^{-10} and λ^{235}=9.8485E^{-10} (Jaffey et al, 1971). EARTHTIME U-Pb synthetic solutions were analysed on an ongoing basis to monitor accuracy.

2.2. U-Pb zircon LA – ICPMS

After rock samples underwent standard mineral separation procedures, zircons were handpicked in alcohol and mounted in epoxy, along with reference materials. Grain mounts were then wet ground with carbide abrasive paper and polished with diamond paste. Next, 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/X-Ray 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 a peak count time of 17-27 seconds. After removal of 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 for the investigation of 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 the Pacific Centre for Isotopic and Geochemical Research. A pre-ablation shot was used to ensure that the spot area on the 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 concentrations. 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 ^{90}Zr 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; $^{207}Pb/^{207}Pb$: 1065.4 ±0.3 Ma; $^{206}Pb/^{238}U$ 1062.4 ±0.4 Ma) 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. Final interpretation and plotting of the analytical results employed the ISOPLOT software of Ludwig (2003).

3. Geochronological results

3.1. Sample MMI17-10-1: Missezula formation rhyolitic coarse lapilli tuff, Pennask Mountain: 239.99 ± 0.16 Ma

U-Pb Chemical Abrasion - Thermal Ionization Mass Spectroscopy
Longitude -120.0470° W, Latitude 49.8662°E, N (NAD 83)

Sample MMI17-10-1 was collected from deformed Nicola Group rocks that extend across an area of ~120 km^2 (Fig. 2). These rocks overlie potentially older rocks and are surrounded on all sides by either equigranular tonalite of the Pennask batholith (Early Jurassic, 194 ±1 Ma, Parrish and Monger, 1992; 193.1 ±0.2 Ma, Mihalynuk et al., 2016) or Osprey batholith (Middle to Late Jurassic,166 ±1 Ma, Parrish and Monger, 1992; 162 ±2 Ma, Mihalynuk et al., 2016).

The sample was collected from freshly blasted outcrop near the junction of logging roads, ~5.7 km @113° azimuth from Pennask Mountain summit (Fig. 2). It is a light grey-green weathering, weakly hornfelsed felsic tuff containing off-white, lapilli to block pyroclasts that are commonly flow banded. Dawson and Ray (1988) included this outcrop as part of their 'unit 2', the upper of two subdivisions comprising the informal Peachland Creek formation. This unit is part of the Missezula formation, an informal name introduced by Mihalynuk and Diakow (2020), the oldest dated part of the Nicola Group.

The unit we sampled is unconformably overlain by conglomerates and then by a more extensive unit of argillite and siltstone, correlated with the Stemwinder facies of what Mihalynuk and Diakow (2020) refer to as the Aberdeen Ridge formation of the Slocan Group (replaces the Stemwinder Mountain formation of Dawson and Ray, 1988 and equivalent Stemwinder Formation of Ray and Dawson, 1994; originally, both part of the Nicola Group). These units overthrust younger andesite ash and lapilli tuff to the west that are correlated with the Whistle Formation of the Nicola Group, defined in the Hedley area (Ray and Dawson, 1994; Whistle Creek formation of Dawson and Ray, 1988).

Results from four grains mutually overlap concordia and yield a weighted $^{206}Pb/^{238}U$ age of 239.99 ±0.16 Ma (Fig. 3). Based on the IUGS time scale (Cohen, et al., 2013, rev. 2020) this sample is middle Ladinian. This is consistent with the Ladinian to Norian age of overlying strata as determined from conodonts (M. Orchard, 1990, unpublished). As such, it confirms the speculation of Dawson and Ray (1988) that the upper subdivision of their informal Peachland Creek formation represents the oldest part of the Nicola Group. The lower Peachland Creek formation basaltic tuff subdivision may be significantly older and is provisionally correlated with the Oregon Claims Formation at Hedley (Ray and Dawson, 1994) from which a Late Carboniferous to Early Permian detrital zircon population was acquired by Mortensen et al. (2017).

3.2. Sample MMI18-2-13: Shrimpton formation tuff, Pothole Lake: 200.2 ±1.1 Ma

U-Pb Laser Ablation-Inductively-Coupled Plasma Mass Spectroscopy
Longitude -120.5495° W, Latitude 49.9412° N (NAD 83)

Sample MMI18-2-13 was collected from a well-bedded, moderately west-dipping section of calcareous and argillaceous siltstone containing layers of rhyolitic ash tuff in the Shrimpton formation (an informal name introduced by Mihalynuk and Diakow, 2020). We exhumed clean outcrop along the westbound Highway 97C roadcut (Fig. 2; cover photo) and collected ~15 kg of hand-sorted pieces from tuff bands that attain thicknesses of up to 8 cm within an ~50 cm-thick interval.

All analyzed grains (n=91) are concordant within 2 sigma error, with $^{206}Pb/^{238}U$ dates varying from ca. 215-179 Ma. A weighted mean of $^{206}Pb/^{238}U$ dates at 200.2 ±1.1 Ma (excluding 5 of the youngest and the 2 oldest analyses that were rejected by a 2 sigma filter is considered a reasonable estimate for the age of the tuff (Fig. 4). The tuff age calculator of Isoplot (Ludwig, 2003) yields a similar value of 200.0 + 1.2\-1.0 Ma (n=76, 95% level of confidence). The weighted mean of all $^{206}Pb/^{238}U$ dates gives a value of 199.2 ±1.5 Ma (n=91, MSWD=3.7).

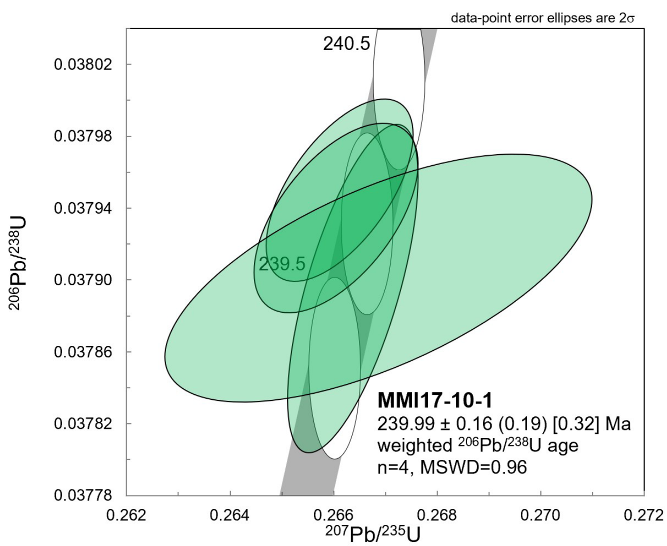


Fig. 3. CA-TIMS results from sample MMI17-10-1. Analyses from four grains mutually overlap concordia to give a relatively precise age of 239.99 ±0.16 Ma; currently the oldest from the southern Nicola arc.

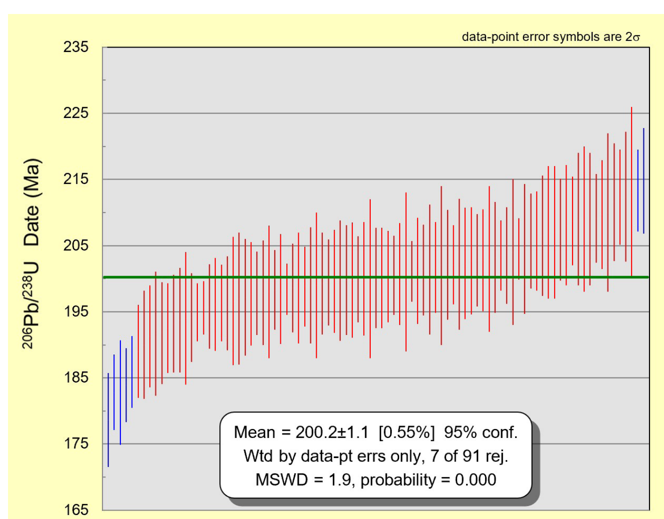


Fig. 4. LA-ICPMS detrital zircon date of sample MMI18-2-13 based on a representative random population of 91 grains from which $^{206}Pb/^{238}U$ dates were obtained. Seven of the data points were rejected to yield an 84-grain population dated at 200.2 ±1.1 Ma.

We consider minor Pb loss as a likely cause for scatter at the young end of the data set, while grains from the old end of the distribution are likely detrital in origin, sourced from slightly older Nicola arc rocks.

Based on our age call and the IUGS time scale (Cohen, et al., 2013, updated 2020), this sample is Hettangian (earliest Jurassic). An Early Jurassic age is supported by our failure to extract conodont elements (jaw parts of eel-like cordates of the class Conodonta, that disappeared at the end of the Triassic; Sweet and Donoghue, 2001) from two samples collected from thin limestone beds within the unit. It is also consistent with the ~202 Ma age from a nearby, underlying felsic tuff marker unit (see Zig volcanic unit in Mihalynuk et al., 2016).

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