U-Pb zircon date for Eocene volcanic rocks on Mount Timothy, south-central British Columbia

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Recommended citation: Schiarizza, P., and Friedman, R.M., 2021. U-Pb zircon date for Eocene volcanic rocks on Mount Timothy, south-central British Columbia. In: Geological Fieldwork 2020, British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey Paper 2021-01, pp. 15-21.

Abstract

Mount Timothy, near the eastern edge of the Fraser Plateau in south-central British Columbia, is in a belt of Late Triassic-Early Jurassic volcanic, sedimentary, and plutonic rocks belonging to Quesnel terrane. The mountain is also in a belt of Eocene volcanic rocks that unconformably overlie rocks of Quesnel terrane. Volcanic rocks on Mount Timothy have previously been assigned to either the Nicola Group (Triassic, Quesnel terrane) or the Skull Hill Formation (Eocene). In order to resolve this uncertainty, a sample of plagioclase-hornblende-pyroxene-phyric andesite collected from the south slope of the mountain was dated using the U-Pb zircon chemical abrasion thermal ionization mass spectrometry method (CA-TIMS). Five zircon grains yield a weighted mean $^{206}Pb/^{238}U$ date of 50.84 ±0.04 Ma, interpreted as the crystallization age of the andesite. This date shows that the volcanic rocks are part of the Skull Hill Formation and, together with the few K-Ar dates obtained elsewhere in the region, indicates a predominantly early Eocene age for the unit.

Keywords: Eocene, Skull Hill Formation, Kamloops Group, Mount Timothy, U-Pb, zircon, CA-TIMS

1. Introduction

Mount Timothy is near the eastern edge of the Fraser Plateau, 18 km northeast of the community of Lac La Hache and Highway 97, within the traditional territories of the Secwepemc and Esk'etemc First Nations. It is in a belt of Triassic and Early Jurassic volcanic, sedimentary and plutonic rocks included in Quesnel terrane, and also in a younger belt of Eocene volcanic rocks that overlies Quesnel terrane and extends northwestward into the Chilcotin and Nechako plateaus, where it overlies Cache Creek and Stikine terranes (Fig. 1). Volcanic and volcaniclastic rocks near Mount Timothy were included in the Nicola Group (Triassic) by Campbell and Tipper (1971) but were assigned to the Skull Hill Formation (Eocene) by Schiarizza and Bligh (2008). However, Schiarizza (2016) questioned the Eocene assignment because a distinctive plagioclase-phyric andesite in the upper part of the volcanic package is lithologically similar to Late Triassic andesite (U-Pb zircon date of 203.9 ±0.4 Ma) in the upper part of the Nicola Group near Woodjam Creek, 36 km north of Mount Timothy (Schiarizza et al., 2013). To resolve this uncertainty, a sample from the Mount Timothy andesite, collected in 2015, was dated using the U-Pb zircon CA-TIMS method. The crystallization age of 50.84 ±0.04 Ma that we report herein demonstrates that the andesite from Mount Timothy is early Eocene and part of the Skull Hill Formation, as inferred by Schiarizza and Bligh (2008).

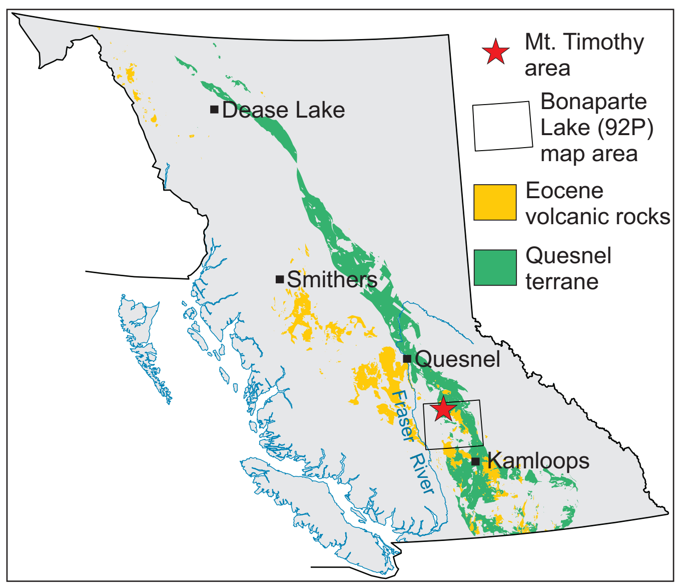

Fig. 1. Location of the Mount Timothy area; main exposures of Quesnel terrane rocks and the belt of Eocene volcanic rocks that cuts across Quesnel terrane. Lower Eocene volcanic rocks east of the Fraser River are in the Kamloops, Princeton and Penticton groups, those to the west are mainly in the Ootsa Lake and Endako groups.

2. Geology of the Mount Timothy area

The Mount Timothy area is underlain by Late Triassic and Early Jurassic sedimentary, volcanic and plutonic rocks of

Quesnel terrane, and unconformably overlying Eocene volcanic rocks. The youngest rocks are Pleistocene basalts, commonly with mantle-derived xenoliths of spinel lherzolite, that locally overlie the Mesozoic and Eocene rocks (Fig. 2).

The oldest rocks of Quesnel terrane are sedimentary and volcanic rocks of the Nicola Group, which includes two separate units. The oldest Nicola unit is exposed in the southern part of the area and is separated from adjacent rocks by east- and north-trending faults. This unit (assemblage two of Schiarizza, 2019) consists mainly of green to grey volcanic sandstone and conglomerate, dated regionally as Carnian and lower Norian. The second Nicola unit (assemblage four of Schiarizza, 2019) is exposed mainly north of Mount Timothy. It consists of red, purple and green polymictic conglomerate and feldspathic sandstone, but also includes a mappable body of pyroxene-plagioclase-phyric basalt and basalt breccia (Fig. 2). Assemblage four (mainly late Norian and Rhaetian) is the uppermost component of the Nicola Group in the region and is separated from older parts of the group by an unconformity or disconformity (Schiarizza, 2019).

Plutonic rocks of Quesnel terrane include several small stocks of Late Triassic monzodiorite and diorite that cut assemblage four of the Nicola Group, mainly north of Mount Timothy, and a large body of Early Jurassic hornblende-biotite granodiorite, which forms part of the western margin of the Takomkane batholith, in the eastern part of the area (Schiarizza et al., 2013).

Campbell and Tipper (1971) applied the name Skull Hill Formation (originally defined by Uglow, 1922) to Eocene volcanic rocks in the Mount Timothy area, considering the unit as part of the Kamloops Group. The Skull Hill Formation, as mapped by Schiarizza and Bligh (2008) and confirmed by the U-Pb zircon date of the present study, covers a large area near Mount Timothy, where it overlies the Nicola Group and the adjacent Takomkane batholith; it also forms several small outliers that overlie the Nicola Group farther north (Fig. 2). The formation consists mainly of andesitic to basaltic flows, but also includes volcanic breccias and minor amounts of arkosic wacke. Basalt flows are dark grey, massive, and commonly include sparse to abundant phenocrysts of pyroxene±plagioclase. Andesitic flows are grey to brown, commonly friable, and characterized by phenocryst assemblages of plagioclase-hornblende-pyroxene or plagioclase-hornblende-biotite. These flows, in part, form a mappable unit on the south and east flanks of Mount Timothy that contains abundant large (5-12 mm) plagioclase phenocrysts, commonly accompanied by smaller and less abundant hornblende and pyroxene phenocrysts. Volcanic breccias of uncertain origin are mainly near the top of Mount Timothy; together with basaltic and andesitic flows, these breccias are beneath the mappable coarse plagioclase-phyric andesite unit. The breccias comprise purple, green and grey volcanic fragments (1-10 cm, with various combinations of plagioclase, hornblende and pyroxene phenocrysts) in a friable matrix that contains abundant plagioclase grains.

Grey, fine- to medium-grained, equigranular diorite forms two small plugs that intrude volcanic flows and breccias of the Skull Hill Formation on the east flank of Mount Timothy. The diorite consists of plagioclase, traces of K-feldspar, and 25 to 35% mafic minerals that include hornblende, clinopyroxene and biotite. This composition is very similar to that of Late Triassic monzodiorite-diorite stocks that intrude the Nicola Group north of Mount Timothy. Nevertheless, Schiarizza and Bligh (2008) considered them Eocene or younger because they intrude rocks that they mapped as Skull Hill Formation. The early Eocene U-Pb zircon date presented here confirms this interpretation.

3. Geochronology

Here we present U-Pb zircon isotopic dating results obtained by the chemical abrasion thermal ionization mass spectrometry method (CA-TIMS) for a sample collected from the coarse plagioclase-phyric andesite unit that is exposed on the south and east flanks of Mount Timothy. Sample preparation and analytical work was conducted at the Pacific Centre for Isotopic and Geochemical Research (PCIGR), the Department of Earth, Ocean and Atmospheric Sciences, the University of British Columbia.

3.1. Analytical procedures

CA-TIMS procedures described here are modified from Mundil et al. (2004), Mattinson (2005) and Scoates and Friedman (2008). After the rock sample underwent standard mineral separation procedures, zircons were handpicked in alcohol. The clearest, crack- and inclusion-free grains were selected, photographed and then annealed in quartz glass crucibles at 900°C for 60 hours. Annealed grains were transferred into 3.5 mL PFA screwtop beakers, ultrapure HF (up to 50% strength, 500 µL) and HNO_3 (up to 14 N, 50 µL) were added and caps were closed finger tight. The beakers were placed in 125 mL PTFE liners (up to four per liner) and about 2 mL HF and 0.2 mL HNO_3, of the same strength as the acid in the beakers containing the samples, were added to the liners. The liners were then slid into stainless steel Parr™ high-pressure dissolution devices, which were sealed and brought to a maximum of 200°C for 8-16 hours (typically 175°C for 12 hours). Beakers were removed from the liners and zircon was separated from the leachate. Zircons were rinsed with >18 MΩ.cm water and subboiled acetone. Then 2 mL of subboiled 6N HCl was added and beakers were set on a hotplate at 80-130°C for 30 minutes and again rinsed with water and acetone. Masses were estimated from the dimensions (volumes) of grains. Single grains were transferred into clean 300 µL PFA microcapsules (crucibles), and 50 µL 50% HF and 5 µL 14 N HNO_3 were added. Each was spiked with a $^{233\text{-}235}U\text{-}^{205}Pb$ tracer solution (EARTHTIME ET535), capped and again placed in a Parr liner (8-15 microcapsules per liner). HF and nitric acids, in a 10:1 ratio, were added to the liner, which was then placed in a Parr high-pressure device and dissolution was achieved at 240°C for 40 hours. The resulting solutions were dried on a hotplate at 130°C, 50 µL 6N HCl was added to microcapsules and fluorides were dissolved in high-pressure

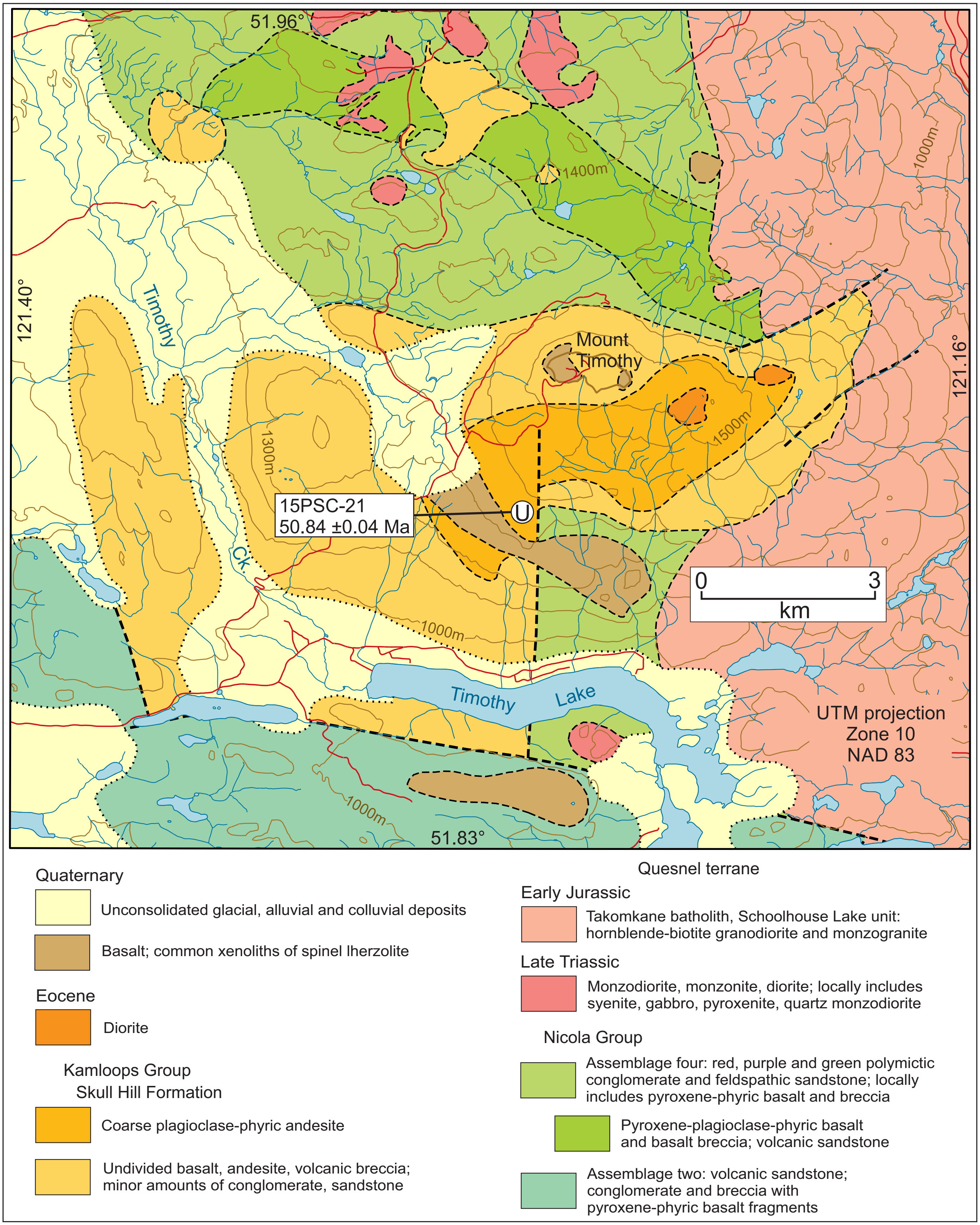

Fig. 2. Geology of the Mount Timothy area showing the location of sample 15PSC-21. Geology modified from Schiarizza et al. (2013), with Nicola subdivisions from Schiarizza (2019).

Parr devices for 12 hours at 210°C. HCl solutions were transferred into clean 7 mL PFA beakers and dried with 2 μL of 0.5 N H_3PO_4. Samples were loaded onto degassed, zone-refined Re filaments in 2 μL of silicic acid emitter (Gerstenberger and Haase, 1997).

Isotopic ratios were measured by a modified single collector VG-54R or 354S (with Sector 54 electronics) thermal ionization mass spectrometer equipped with analogue Daly photomultipliers. Analytical blanks were 0.2 pg for U and up to 1 pg for Pb. U fractionation was determined directly on individual runs using the EARTHTIME ET535 mixed $^{233\text{-}235}$U-^{205}Pb isotopic tracer. Pb isotopic ratios were corrected for fractionation of 0.25 ±0.03%/amu, based on replicate analyses of NBS-982 reference material and the values recommended by Thirlwall (2000). Data reduction employed 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). Unless otherwise noted all errors are quoted at the 2 sigma or 95% level of confidence. Isotopic dates are 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 analyzed on an on-going basis to monitor the accuracy of results.

3.2. U-Pb zircon CA-TIMS results for sample 15PSC-21

Sample 15PSC-21 was collected from an exposure along an abandoned logging road (618939E, 5749330N, UTM Zone 10, NAD 83), 2.6 km south-southwest of Mount Timothy (Fig. 2). It is a grey andesite with abundant large plagioclase phenocrysts, and smaller and less abundant hornblende and pyroxene phenocrysts (Fig. 3). A moderate quantity of anhedral and subhedral zircon grains were extracted from the sample (Fig. 4), and five of these were selected for CA-TIMS processing and analysis (Table 1). Results for the five grains are mutually overlapping on concordia, with a weighted mean ^{206}Pb/^{238}U date of 50.84 ±0.04 Ma (MSWD=1.35), interpreted as the crystallization age of the andesite (Fig. 5).

Fig. 3. Plagioclase-hornblende-pyroxene-phyric andesite of sample 15PSC-21, collected 2.6 km south-southwest of Mount Timothy.

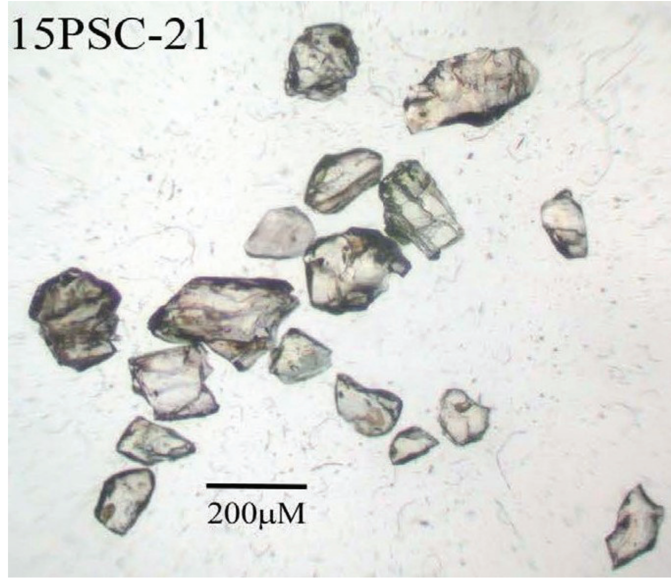

Fig. 4. Zircon grains extracted from sample 15PSC-21.

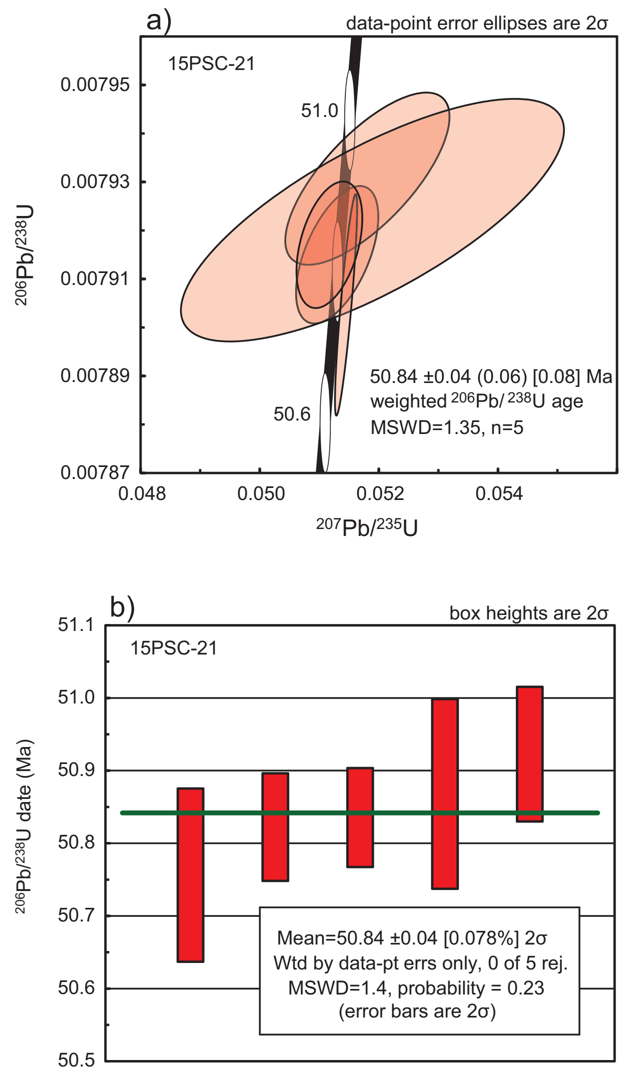

Fig. 5. a) Concordia plot of zircons analyzed from sample 15PSC-21. **b)** ^{206}Pb/^{238}U ages and calculated weighted mean age.

Table 1. U-Th-Pb analytical results for sample 15PSC-21.

	Compositional Parameters									Radiogenic Isotope Ratios								Isotopic Ages					
Sample (a)	Wt. mg (b)	U ppm (c)	Pb ppm (c)	Th/U (d)	$^{206}Pb^*$ $x10^{-13}$ mol (e)	mol % $^{206}Pb^*$ (e)	Pb^*/Pb_c (e)	Pb_c (pg) (e)	$^{206}Pb/^{204}Pb$ (f)	$^{208}Pb/^{206}Pb$ (g)	$^{207}Pb/^{206}Pb$ (g)	% err (h)	$^{207}Pb/^{235}U$ (g)	% err (h)	$^{206}Pb/^{238}U$ (g)	% err (h)	corr. coef.	$^{207}Pb/^{206}Pb$ (i)	± (h)	$^{207}Pb/^{235}U$ (i)	± (h)	$^{206}Pb/^{238}U$ (i)	± (h)
15PSC-21																							
A	0.0042	466	4.6	0.934	0.6522	97.34%	12	1.46	696	0.299	0.047005	1.027	0.051297	1.101	0.007915	0.147	0.554	49.46	24.51	50.79	0.55	50.82	0.07
B	0.0033	383	3.8	0.522	0.4196	94.23%	5	2.11	321	0.169	0.047376	2.048	0.051805	2.176	0.007931	0.183	0.719	68.22	48.70	51.28	1.09	50.92	0.09
G	0.0029	79	0.8	0.415	0.0760	91.53%	3	0.57	218	0.134	0.047505	4.880	0.051889	5.069	0.007922	0.258	0.744	74.68	115.9	51.37	2.54	50.87	0.13
H	0.0127	796	7.0	0.765	3.3346	99.76%	135	0.66	7681	0.246	0.047203	0.146	0.051446	0.296	0.007905	0.236	0.872	59.51	3.49	50.94	0.15	50.76	0.12
I	0.0046	280	2.4	0.524	0.4290	98.44%	19	0.55	1189	0.168	0.046873	0.836	0.051166	0.883	0.007917	0.135	0.417	42.74	19.97	50.67	0.44	50.84	0.07

(a) A, B etc. are labels for fractions composed of single zircon grains or fragments; all fractions annealed and chemically abraded after Mattinson (2005) and Scoates and Friedman (2008).
(b) Nominal fraction weights estimated from photomicrographic grain dimensions, adjusted for partial dissolution during chemical abrasion.
(c) Nominal U and total Pb concentrations subject to uncertainty in photomicrographic estimation of weight and partial dissolution during chemical abrasion.
(d) Model Th/U ratio calculated from radiogenic $^{208}Pb/^{206}Pb$ ratio and $^{207}Pb/^{235}U$ age.
(e) Pb* and Pbc represent radiogenic and common Pb, respectively; mol % $^{206}Pb^*$ with respect to radiogenic, blank and initial common Pb.
(f) Measured ratio corrected for spike and fractionation only. Mass discrimination of 0.25±0.03%/amu based on analysis of NBS-982; all Daly analyses.
(g) Corrected for fractionation, spike, and common Pb; up to 2.1 pg of common Pb was assumed to be procedural blank: $^{206}Pb/^{204}Pb = 18.50 \pm 1.0\%$; $^{207}Pb/^{204}Pb = 15.50 \pm 1.0\%$; $^{208}Pb/^{204}Pb = 38.40 \pm 1.0\%$ (all uncertainties 1-sigma).
(h) Errors are 2-sigma, propagated using the algorithms of Schmitz and Schoene (2007) and Crowley et al. (2007).
(i) Calculations are based on the decay constants of Jaffey et al. (1971). $^{206}Pb/^{238}U$ and $^{207}Pb/^{206}Pb$ ages corrected for initial disequilibrium in $^{230}Th/^{238}U$ using Th/U [magma] = 3.

4. Discussion

Campbell and Tipper (1971) mapped the rocks near Mount Timothy as Nicola Group (Triassic), but mapped volcanic rocks farther west, on the ridge west of Timothy Creek, as Skull Hill Formation (Eocene). Schiarizza and Bligh (2008) inferred that the Eocene rocks were much more extensive, and that they continued eastward from Timothy Creek beyond Mount Timothy, where they overlapped the contact between the Nicola Group and the Takomkane batholith (as shown on Fig. 2). Schiarizza (2016) subdivided the Nicola Group regionally into four assemblages and assigned the Nicola rocks north of Mount Timothy to the uppermost part of the group (assemblage four). He suggested that the volcanic rocks on and south of Mount Timothy, mapped as Eocene by Schiarizza and Bligh (2008), were also part of assemblage four because: 1) the plagioclase-phyric andesite unit exposed south and east of Mount Timothy is lithologically similar to Late Triassic andesite in assemblage four near Woodjam Creek, 36 km north of Mount Timothy (Schiarizza et al., 2013); and 2) the two small diorite plugs that intrude the plagioclase-phyric andesite unit east of Mount Timothy are markedly similar to the Late Triassic monzodiorite stocks that intrude assemblage four north of Mount Timothy, and might likewise be Late Triassic. The 50.84 ±0.04 Ma date obtained for the Mount Timothy andesite in this study confirms the Eocene interpretation of Schiarizza and Bligh (2008) and allows us to reject the Triassic interpretation proposed by Schiarizza (2016).

Uglow (1922) introduced the name Skull Hill Formation for undated volcanic rocks of suspected Tertiary age along the North Thompson River valley, and Campbell and Tipper (1971) adopted the name for volcanic rocks of probable Eocene age across the entire Bonaparte Lake map area (Fig. 1). Campbell and Tipper (1971) assigned the formation to the Kamloops Group, a term applied to Tertiary rocks in the Kamloops area by Drysdale (1914) and Cockfield (1948), and later redefined to include only Lower and Middle Eocene rocks (Mathews, 1964; Ewing, 1981). Before the present study, an early Eocene age for the Skull Hill Formation had been confirmed by only a few scattered K-Ar age determinations, including whole rock K-Ar dates of 52.1 ±1.8 Ma and 50.9 ±1.8 Ma for two separate basalt flows north of the Bonaparte River, 74 km south of Mount Timothy (Read, 2000), and a K-Ar date of 52.2 ±1.8 Ma on biotite separated from a trachyandesite flow near Antoine Lake, 56 km north-northwest of Mount Timothy (Panteleyev et al., 1996). The 50.84 ±0.04 Ma date obtained for the Mount Timothy andesite in this study corroborates these K-Ar dates and confirms that the Skull Hill Formation is, at least in part, early Eocene.

5. Conclusions

Plagioclase-hornblende-pyroxene-phyric andesite exposed on the south and east slopes of Mount Timothy was dated with the U-Pb zircon CA-TIMS method and yields a weighted mean $^{206}Pb/^{238}U$ date of 50.84 ±0.04 Ma, interpreted as the crystallization age of the andesite. This date confirms that the volcanic succession on Mount Timothy is part of the Skull Hill Formation, as proposed by Schiarizza and Bligh (2008). It shows that the Skull Hill Formation is, at least in part, early Eocene, as also indicated by the few K-Ar dates obtained elsewhere in the region.

Acknowledgments

Jessica Norris helped collect sample 15PSC-21 (and correctly inferred its Eocene age). H. Lin, T. Ockerman, C. Wall, and N. Moerhius assisted with mineral separation, sample preparation and mass spectrometry at PCIGR. Lawrence Aspler reviewed the paper and made suggestions that improved it.

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