

MESOZOIC MAGMATISM AND METALLOGENY OF THE HOTAILUH **BATHOLITH, NORTHWESTERN BRITISH COLUMBIA**

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This report is accompanied by a 1:50,000 scale geology map



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ABSTRACT

A regional-scale reconnaissance bedrock mapping study was conducted in the Hotailuh batholith area, near the town of Dease Lake. The 2275 km² composite Late Triassic to Middle Jurassic batholith occurs within the Stikine terrane of northern British Columbia. The investigation aimed to refine the temporal magmatic and geochemical evolution of the batholith, and specifically focussed on relating mineralization with magmatic events.

This study combines one summer of field bedrock mapping with detailed petrography, geochemistry of both altered/mineralized and unaltered samples, geochronological data and integration with airborne geophysical survey results.

The Late Triassic plutonic suite comprises the Gnat Lake ultramafic to mafic bodies, Cake Hill felsic pluton and Beggerlay Creek ultramafic to mafic pluton. The absence of equivocal crosscutting relationships, lack of absolute crystallization age determinations for the ultramafic to mafic intrusions, and the absence of detailed mineral chemistry data makes it difficult to determine the genetic and temporal relationships between the different Late Triassic intrusions. The Late Triassic intrusions are spatially associated with, and in places intrude, poorly exposed and poorly dated, intermediate-mafic volcanic and sedimentary rocks of the Triassic Stuhini group. The Middle Jurassic Three Sisters pluton comprises at least four phases, namely the fine-grained mafic-intermediate phase, a mafic phase, central felsic phase, and a crosscutting potassic phase. U-Pb zircon crystallization ages and Ar-Ar cooling ages confirm that all phases formed during a relatively short time span in the Middle Jurassic. The northern and eastern margin of the batholith is nonconformably overlain by a succession of Early Jurassic basal sedimentary rocks grading upward into Early-Middle Jurassic volcanic rocks. The volcanic rocks were previously mapped as Triassic Stuhini group, but new geochronological data and mapping suggest they are part of the Jurassic Hazelton group.

Geochronology and geochemistry confirm the presence of at least two discrete magmatic events in the Late Triassic and Middle Jurassic. Both magmatic events have a strong calc-alkaline subduction-modified subcontinental mantle geochemical signature, and formed in a volcanic island arc to continental volcanic arc setting. At least two episodes of mineralization associated with Late Triassic and Middle Jurassic magmatism are found in the area. In addition to the known mineral occurrences within the batholith and its immediate surroundings, this study identified several new mineral occurrences. The intrusion-related magmatic-hydrothermal mineralization comprises predominantly copper, gold, silver, molybdenum and/or tungsten occurrences. Mineral occurrences occur peripheral to the main batholith and along contact zones between different magmatic phases within the batholith. The Gnat Pass ductile to brittle shear zone on the western margin of the batholith appears especially well endowed with mineral occurrences, and includes the newly dated (ca. 216.5 Ma) porphyry copper prospect at Gnat Pass.

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Geology map of the Hotailuh batholith (1:50,000 scale)

INTRODUCTION

This report summarizes the results of a reconnaissance study on the magmatic history and metallogeny of the Hotailuh batholith, and is part of a larger BC Geological Survey Dease Lake Geoscience Project (Logan et al., 2012a). The BCGS project is funded through Geoscience BC's OUEST-Northwest initiative, a program launched in early 2011 to stimulate mineral exploration in the northwestern part of the province along Highway 37. The 2011 Geoscience BC program includes two highairborne magnetic resolution surveys (Simpson, 2012; Aeroquest Airborne, 2012; Geo Data Solutions, 2012), the collection of new regional stream sediment data and reanalysis of stream sediment samples (Jackaman, 2012a, b, c, d), as well as new bedrock mapping (Logan et al., 2012b, c; this report; Moynihan and Logan, 2012; Iverson et al., 2012; Iverson, 2012). provide Collectively, these programs detailed, high quality geoscience data that is intended to enhance metallic mineral exploration in an area of prospective geology adjacent to Highway 37, near Dease Lake, in northwestern British Columbia.

The study area is located within the Stikine terrane of the Canadian Cordillera, an aggregate of Late Paleozoic to Mesozoic magmatic arc successions accreted onto the North American margin during Middle Jurassic time (e.g. Gabrielse, 1991). The Stikine terrane comprises predominantly Triassic to Jurassic volcanic, sedimentary and plutonic rocks. This study focuses on the composite Hotailuh batholith (Figure 1), which has traditionally been subdivided into three plutonic suites of Late Triassic, Early Jurassic and Middle Jurassic age (Anderson, 1983; Gabrielse, 1998). The main objectives of the Hotailuh project were to:

- further refine the temporal magmatic and geochemical evolution of the batholith;
- build a metallogenic framework that relates mineralization to magmatic events; and
- identify prospective areas for mineralized magmatic-hydrothermal systems.

Here, we present the 2011 field results, as well as results from assay analyses of mineralized samples, petrography, lithogeochemistry of least altered samples, geochronology and integration with Geoscience BC's geophysical survey.

The composite Hotailuh batholith is exposed in a 2275 km² area southeast of Dease Lake. Nine weeks of 1:20,000 scale mapping by a two person team in summer 2011 included visits to 331 field stations and collection of 134 samples for laboratory study and analysis. The 2011 study focused on mapping within the Gnat Pass area and seven smaller areas to the east (Figure 1). The field areas were chosen for their mineral occurrences and suitability for understanding the internal geology and external contact relationships for various phases of the batholith. The study areas are covered by the 1:50,000 NTS map sheets 104I/04, 104I/03W, the southernmost part of 104I/05, and northernmost part of 104H/13. The Gnat Pass area is accessible by truck from Highway 37. Except for a section between Upper Gnat Lake and a point 7 km further south, the abandoned BC railroad grade is driveable by truck up to the southern boundary of the study area. The remaining areas were mapped from fly camp



Figure 1: Regional setting of the Hotailuh batholith. (a) Distribution of Triassic and Jurassic intrusive rocks in northwestern B.C. Geology adapted from Massey et al. (2005) using geochronology data from Friedman and Ash (1997), Gabrielse (1998), Scott et al. (2008), Logan et al. (2012c). The QUEST-NW geophysical footprint is shown for reference. (b) Regional geology map of the Hotailuh batholith area, showing main lithologies, faults and the eight study areas.

locations accessed by helicopter chartered from Dease Lake.

The bedrock exposure is poor to moderate (5-10%) in the forested and brush-covered Gnat Pass area, except for exposures along road cuts, abandoned rail cuts and in old exploration trenches. The rock exposure improves dramatically above tree line, at approximately 1500 m. Exposure is best (10-30%) in the topographically higher areas of the Hotailuh batholith, with excellent exposure along alpine ridges, steep valley walls and cirques. However, glacial deposits and colluvium cover many alpine valleys, with only limited exposure in some creeks. Many of the exposures below, and especially above, treeline have an intense lichen cover. A notable exception is the lee side of alpine ridges where the thicker windaccumulated winter snowpack appears to have inhibited lichen growth. These are prime locations for observing complex crosscutting relationships among the intrusive phases of the batholith.

REGIONAL GEOLOGY

The study area is located near the northnortheastern margin of the Stikine terrane of the Canadian Cordillera (Figure 1), a volcanic island-arc complex accreted onto the North American margin during Middle Jurassic time (Gabrielse, 1991; Nelson and Mihalynuk, 1993). The basement of the Stikine terrane is characterized by carbonate and volcanic rocks of the Devonian to Permian Stikine assemblage, overlain by and calc-alkaline volcanic associated sedimentary rocks of the Triassic Stuhini group and Early to Middle Jurassic Hazelton group (Marsden and Thorkelson, 1992; Currie and Parrish, 1997). The Stuhini group volcanic rocks are predominantly mafic to intermediate in composition, whereas the Hazelton group volcanic rocks are

predominantly intermediate in composition with lesser felsic and mafic horizons (Marsden and Thorkelson, 1992).

Late Permian to Middle Triassic tholeiitic volcanism of the Kutcho assemblage formed a proto-arc on the inboard margin of the Stikine terrane, and was the subsequent locus for arc marginal clastic sedimentation in the Early Jurassic (English and Johnston, 2005; Schiarizza, 2011). Sedimentation within this forearc sedimentary basin (Whitehorse trough) comprises proximal conglomerates and more distal sandstones of the Takwahoni and Inklin formations. respectively. Closure of the Cache Creek subsequent collision with the ocean. Whitehorse trough and thrusting overtop the inboard margin of Stikinia occurred in the late Early to earliest Middle Jurassic (Ricketts et al., 1992; Nelson and Mihalynuk, 1993). The rocks of the Cache Creek ocean and Whitehorse trough are currently exposed in a north-northwest striking belt north of Dease Lake (Figure 1), and are found in the hanging wall and footwall of the King Salmon thrust fault. The latter is generally interpreted as a major terrane bounding structure. separating autochthonous rocks of the Stikine terrane to the south from allochthonous rocks of the Cache Creek terrane to the north (e.g. Gabrielse, 1998). The Stikinia - Cache Creek accretionary event was complete by the Middle Jurassic (Bajocian), as indicated by sedimentation of Cache Creek derived chert clasts deposited in the molasse-type Bowser Basin to the south of the study area (Figure 1; Ricketts et al., 1992).

Large granitoid plutons were emplaced during the Late Triassic to Middle Jurassic, and are exposed in an arcuate belt on the northern margin of the Bowser basin. This belt, commonly referred to as the Stikine arch, is centered on the Hotailuh batholith, and includes the Stikine pluton to the southeast and the Hickman batholith to the southwest (Anderson, 1983; Woodsworth *et al.*, 1991). Several smaller Late Jurassic to Cretaceous plutons are present within the Dease Lake area (Anderson and Bevier, 1992; Logan *et al.*, 2012b, c).

Mineralization in the northern Stikine terrane comprises several Late Triassic to earliest Jurassic calc-alkaline porphyry Cu-Mo±Au and alkaline porphyry Cu-Au deposits; notable examples include Galore Creek, Schaft Creek, KSM and GJ to the southwest, Red Chris to the south, and Kemess to the southeast (Ash et al., 1997; Logan et al., 2000; Duuring et al., 2009; Norris et al., 2011). These porphyry copper deposits are roughly located on the southwestern and southeastern apexes of the Stikine magmatic arch. Interestingly, despite the presence of similar rocks in the centre of the arch, no major porphyry copper deposits have yet been found in the immediate area of the Hotailuh batholith. Southwest of the study area, the Au-Ag-enriched Eskay Creek volcanogenic massive sulphide deposit is hosted in felsic volcanic rocks within the Early-Middle Jurassic Hazelton group (Bartsch 1993), and represents a relatively underexplored deposit type elsewhere in the Stikine terrane (Massey et al., 1999).

GEOLOGICAL UNITS

Eight areas were mapped in detailed during this study, and are shown on the accompanying 1:50,000 scale geological map (labelled 'a' to 'h' on Figure 1b). The detailed geological maps incorporate data from Anderson (1983) and Gabrielse (1998), as well as Read and Psutka (1990) and Evenchick and Thorkelson (2005) in the far south. The detailed Gnat Pass compilation map 'a' also incorporates data from Read (1984), Nixon *et al.* (1989; 1997) around the

Gnat Lakes ultramafite, Dircks (1974) around the BCR property, Wetherill (1989; 1990) around the Dalvenie claims, Smith and Garagan (1990) and Page and Scott (2006) around the Gnat Pass prospect, and detrital zircon results from near peak 2096 m (Iverson et al., 2012; Iverson, 2012). The position of geological contacts were refined in areas lacking geological information using the QUEST-Northwest aeromagnetic survey data (Aeroquest Airborne, 2012). U-Pb LA-ICP-MS Additional zircon crystallization ages and Ar-Ar hornblende and biotite cooling ages are reported as part of this study (see 'Geochronology' section).

The regional geological information surrounding the detailed geological maps on the accompanying 1:50,000 scale map are modified from the digital BC geological map compilation of Massey *et al.* (2005) and the above mentioned sources.

Rock classification schemes used throughout this paper follow those developed by the British Geological Survey (Gillespie and Styles, 1999; Hallsworth and Knox, 1999). Notably, the reported crystal size in igneous rocks is the volumetrically dominant size; the mineral qualifying suffixes -bearing and -rich indicate that <5% and >20% of the rock comprises the mineral in question, respectively. In the field, a gabbro has been defined as a rock plotting in the diorite QAPF field, but containing \geq 50% mafic minerals. Elevations for unnamed peaks ("peak ... m") are spot heights from BC's TRIM database. All coordinates are in UTM NAD83 zone 9V.

Magnetic susceptibility values for all rock units were measured in the field with a Terraplus KT-10 hand-held magnetic susceptibility meter. Magnetic susceptibility data is summarized in Figure 2, and shows consistent variability and distinctive ranges for several of the major units.



Figure 2: Graph showing the magnetic susceptibility values and one standard deviation for all major rock units. n = number of measurements, where each measurement represents the average of ten field measurements at one station point.

Rock units encountered in the field are summarized in Table 1, and are described in order from oldest to youngest.

Stratified rocks

Triassic rocks

Rocks in the central and western part of the Gnat Pass valley predominantly comprise massive to foliated augite-phyric coherent rocks with lesser massive fine-grained sedimentary rocks (units T Sv and T Ss in Table 1 respectively), that are assigned to the Triassic Stuhini group (Anderson, 1983; Gabrielse, 1998). The coherent rocks represent either volcanic extrusives and/or sub-volcanic intrusions. The complex map pattern of the volcanic and sedimentary lithologies could be due to a number of factors such as faulting, folding, rapid lateral and vertical facies changes and/or irregular intrusion of augite porphyry into the sedimentary strata. The Stuhini augitephyric rocks are cut by felsic dikes, likely genetically related to the Gnat Lakes ultramafite (unit LT GLf), and appear to be intruded and partially assimilated by the Cake Hill pluton (unit LT CH, 221-218 Ma). The Stuhini group augite-phyric coherent rocks in the Gnat Pass valley north of Lower Gnat Lake are crosscut by the Gnat Pass intrusive (unit LT GP, 216 Ma). These relationships, as well as their foliated nature (discussed below), suggest a pre 221-216 Ma age for these rocks.

South of the Hotailuh batholith (map 'f'), Stuhini group rocks consists of a lower predominantly sedimentary package grading into predominantly coherent rocks exposed at higher elevations (units T Ss and T Sv in Table 1, respectively). The change from laminated and very thinly bedded siltstones and medium-grained sandstones with minor concordant intervals of massive augitephyric coherent rocks to massive augitephyric coherent rocks with rare fine-grained sandstone intervals is well-exposed in a steep gully. Here, laminated to very thinly augite-bearing medium-grained bedded volcaniclastic sandstones to granule-sized volcaniclastic conglomerates (unit T Sv) occur between these two rock units. Unfortunately, poor exposure and lichencovered outcrops dominate the remainder of the area making it difficult to differentiate coarse-grained augite-bearing sediments from augite-phyric coherent rocks. This could explain the apparent lack of augitebearing sediments at other locations near this contact. Way-up criteria were not observed in the area, and although bedding in the southeastern half of the Stuhini succession uniform moderate has а southeasterly dip, structural disturbance appears to have affected rocks in the western half (map 'f'). Based on the presence of augite-bearing volcaniclastic sediments, the augite-phyric coherent rocks most likely are

Table 1a: Stratified rocks

Group	Area	Unit	Aae	Code	Lithology
<u></u>		Undivided	TJ	V	Includes ImJ Hv, ImJ Hsc, ImJ Hs, IJ Hs, T Sv and T Ss; see below
Jurassic Hazelton group	western area	Volcanic rocks	lmJ	Hv	Granule, pebble and cobble-sized volcaniclastic conglomerate and pyroclastic breccia; contains Plag-Aug, Plag, Aug, Plag-Hbl-phyric, amygdaloidal clasts. Volcanic sediments commonly contain Aug crystals
		Coarse-grained sedimentary rocks	lmJ	Hsc	Medium grey, medium bedded, medium- and (very) coarse-grained sandstone. Feldspathic ± lithic arenite. Minor interbedded siltstone; minor interbedded pebble conglomerate
		Fine-grained sedimentary rocks	lmJ	Hs	Dark grey to black, parallel laminated to (very) thinly bedded siltstone and fine-grained sandstone. Often recessive
	North	Coarse-grained quartz-bearing sedimentary rocks	IJ	Hs	Basal unit nonconformably(?) overlies Cake Hill pluton. Very coarse-grained sandstone and pebble-sized conglomerate with granitoid clasts. Includes conglomerate, quartz-bearing feldspathic-arenite, graphitic siltstone and micrite of Anderson (1983), Smith and Garagan (1990)
	_	Volcanic rocks	lmJ	Ηv	Pyroclastic breccia and volcaniclastic pebble-sized conglomerate; contains Hbl(?)-Plag-phyric clasts
	Easterr area	Sedimentary rocks	IJ	Hs	Alternating medium-dark grey (parallel) laminated siltstones, calcareous siltstones, fine- to medium-grained sandstone and rare very thick bedded, likely Qtz-bearing, (very) coarse-grained sandstone and granular conglomerate
Triassic Stuhini group	area	Stuhini volcanic rocks	Т	Sv	Dark green, 1-5 mm euhedral, 20-40% Aug-phyric coherent rocks; rare Plag-Aug-phyric. Local volcanic breccia, volcaniclastic conglomerate and sandstone
	Entire	Stuhini fine-grained sedimentary rocks	Т	Ss	Medium to dark grey, laminated to very thinly bedded siltstone and fine- to medium-grained sandstone. With minor concordant 0.5-1 m intervals of 2-5 mm 30-40% Aug-phyric coherent rocks

Age abbreviations: T = Triassic, J = Jurassic; stratified rocks: I = lower, m = middle, u = upper; intrusive rocks: E = early, M = middle, L = late Mineral abbreviations after Kretz (1983)

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Table 1b: Intrusive rocks

Suite	Pluton	Unit	Age	Code	Lithology
Middle Jurassic Three Sisters plutonic suite		Tees Creek intrusive	≤ MJ	ТС	Altered Hbl-Fsp-porphyritic hypabyssal intrusive
	Б.	Three Sisters potassic phase	MJ	ТЅр	Bt-bearing granite, Qtz-syenite and Qtz-monzonite with Kfs>Plag. Equigranular 1 mm to 4 mm; often 5-20 mm Kfs porphyritic. Includes pink Bt porphyritic dikes
	s pluto	Three Sisters central felsic phase	MJ	TSc	Bt and Hbl-Bt (rare Bt-Hbl) Qtz-monzonite and Qtz-monzodiorite with Plag>Kfs. Equigranular, 2-3mm; 4-5 mm Kfs porphyritic in places; dioritic xenoliths locally present
	Sister	Three Sisters mafic phase	MJ	TSm	Hbl-rich (minor Bt-Cpx Hbl-rich) Qtz-diorite. Acicular Hbl 0.5-4 mm to 2-7mm; equant Hbl 1-2mm to 4-10 mm
	Three	Three Sisters fine- grained mafic-interm. phase	MJ	TSf	Hbl-Bt Qtz-diorite. Equigranular, 1-1.5 mm, often 10 vol.% 1.5-3 mm Plag porphyritic
Early Jurassic	McBride River	McBride River pluton	EJ	MR	Hbl-Bt granodiorite and Qtz-monzodiorite. Equigranular, 1-5 mm; contains abundant rounded, clear to grey Qtz (Anderson, 1983)
ic suite		Gnat Pass intrusive	LT	GP	Plag-porphyritic hypabyssal intrusive (sparse Qtz and/or Hbl porphyritic in places). Inequigranular 2 mm euhedral-subhedral Plag, rarely 2-4 mm Qtz-porphyritic
	creek	Beggerlay Creek potassic dikes	LT	ВСр	Coarse pink Kfs (± Ep) dikes
	erlay C oluton	Beggerlay Creek websterite body	LT	BCw	Serpentinized websterite. Equigranular, 5 mm, massive
	Begge	Beggerlay Creek pluton	LT	BC	Cpx-Hbl-rich to Hbl-Cpx-rich gabbro (BC) to rare Plag-bearing clinopyroxenite (BCc). Equigranular, 3-5 mm, massive to moderately foliated
plutor	Ę	Cake Hill quartz-rich phase	LT	СНq	Hbl monzogranite and granodiorite. Equigranular, 3 to 3-4 mm, with minor ubiquitous 4-7 mm Qtz blebs; tabular Hbl common
Stikine	ll pluto	Cake Hill foliated phase	LT	CHf	Bt(?)-Hbl diorite and Qtz-diorite. Foliated, equigranular, 1-3 mm
Issic S	ake Hi	Cake Hill leucocratic LT CHI phase		CHI	Light-coloured and Ep altered Hbl Qtz-monzodiorite, granodiorite, Qtz-diorite, tonalite(?). Equigranular, 1-2 to 2-3 mm, common tabular Hbl
Late Tria	ö	Cake Hill pluton LT CH		СН	Hbl to lesser Bt-Hbl Qtz-monzodiorite and Qtz-monzonite. Equigranular, 3-4 mm; tabular Hbl bearing, trace Ttn usually ubiquitous; trace Mag in places; massive to moderately foliated
	es te	Gnat Lakes felsic phase	LT	GLf	Hbl granodiorite, monzodiorite and diorite. Equigranular 2 mm
	at Lak ramafi	Gnat Lakes mafic phase	LT	GLm	Cpx Hbl-rich gabbro. Equigranular 1-5 mm Hbl
	Gni	Gnat Lakes ultramafite		GL	Plag-bearing hornblendite to Cpx Hbl-rich gabbro. Equigranular 2-100 mm euhedral-subhedral Hbl, anhedral Plag

extrusive in origin. The volcanosedimentary rocks close to the Beggerlay Creek pluton contact are cut by coarse Kfeldspar dikes that are presumed to be cogenetic with the latter pluton, implying a Late Triassic or older age for this Stuhini succession.

A limited number of Stuhini group xenoliths occur within the Hotailuh batholith. A 0.5-1 km² raft or pendant of Stuhini is present within the Cake Hill leucocratic phase (map 'g') and comprises predominantly volcanic breccia and volcaniclastic conglomerate (unit T Sv). To the north, a much smaller inclusion of augite-phyric coherent rocks (unit T Sv; map 'h') within the Cake Hill quartz-rich phase is intruded and partly assimilated by the Three Sisters mafic phase.

All Stuhini group rocks on the accompanying 1:50,000 map have been assigned a lower-middle Triassic (lmT Ss), middle Triassic (mT Sv) or upper Triassic age (uT Sv) based on Gabrielse's (1998) regional work.

Jurassic rocks

Sedimentary and volcanic rocks of Jurassic age were identified in the northwestern (map 'a') and eastern (map 'h') parts of the Hotailuh batholith.

Northwestern margin of the batholith

A succession of normal-facing Jurassic sedimentary rocks overlies the Cake Hill pluton (map 'a'). It was mapped previously as a Lower Jurassic unit of the Takwahoni formation overthrust by Lower to Upper Triassic Stuhini group (Anderson, 1983; Gabrielse, 1998). However, U-Pb detrital zircon dates suggest the hanging wall rocks are also Jurassic in age (Iverson *et al.*, 2012; Iverson, 2012).

The base of this succession comprises a coarse-grained, quartz-rich sedimentary unit (IJ Hs; Table 1), which was recognized at one outcrop location and in drill core at the Gnat Pass prospect. In outcrop it consists of a granitoid clast-bearing conglomerate and very coarse-grained sandstone (Figure 3). The lower contact lies within ten metres of intrusive rocks and likely represents a nonconformable contact. Fossils from a sandy micrite associated with limey, quartzbearing, feldspathic-arenite located 4.5 km east of Lower Gnat Lake suggest an Early (to Middle?) Jurassic age (Henderson and Perry, 1981; Anderson, 1983, p. 209-214; Gabrielse, 1998, Appendix 2; map 'a'). Conglomerate, quartz-bearing feldspathicarenite and graphitic siltstone intersected in drill core from the Gnat Pass prospect (Smith and Garagan, 1990; this study) appear similar to the rocks described above, and have been included in the basal unit.

The stratigraphically overlying package of rocks can be traced along most of the southfacing slopes of peak 2096 m, and consists of two coarsening-upward sequences of predominantly sedimentary rocks (map 'a'; see also Figure 2, Iverson et al., 2012; Iverson, 2012). Results from three detrital zircon samples show distinct Middle Jurassic and Late Triassic populations (Iverson et al., 2012; Iverson, 2012) and indicate that these rocks must be younger than the Triassic Stuhini group. These sedimentary rock units (ImJ Hs and ImJ Hsc in Table 1) dip moderately to the north, and are stratigraphically overlain by augitephyric volcanic breccias (unit lmJ Hv in Table 1). The coarse-grained quartz-bearing basal unit had traditionally been separated from these overlying, presumed Triassic Stuhini group, rocks by the Hotailuh thrust (Anderson. 1983; Gabrielse, 1998). However, the new detrital zircon results and the stratigraphic continuity between these



11BVA29-207 (454,046E-6,456,056N)



Figure 3: Very coarse-grained sandstone to granule-sized conglomerate with several pebble-sized granitoid clasts (arrow; unit IJ Hs). Altered Cake Hill pluton is exposed 10 m the southeast and suggests to a nonconformable contact. Hammer for scale.

Figure 4: View northwest towards peak 2102 m (on left) showing the contact between grey quartz-rich phase of the Cake Hill pluton on the left (unit LT CHq) and rusty red, stratified sedimentary rocks (unit IJ Hs) on the right. Note light grey breccia body on the southwest face of the central peak.





11BVA11-59 (449,321E-6,449,881N)

Figure 5: Hornblende-bearing granodiorite (Gnat Lake felsic phase, LT GLf) intruding and brecciating the Gnat Lake ultramafite (LT GL). Hammer for scale.

units eliminates the necessity for a thrust fault in this area (map 'a'). A large outcrop of (hornblende)-plagioclase-phyric volcanic breccia is present southwest of peak 2096 m, between the basal quartz-bearing and the overlying fine-grained sedimentary rock succession (map 'a'). It does not appear to extend further east or west. The overlying fine-grained sediments contain two 10 m thick concordant columnar jointed augitephyric coherent rock intervals, either representing fluidal flows or sills. The upper coarse-grained sediments in this unit comprise alternating medium-grained and concordant augite to sandstones plagioclase-augite-phyric coherent rocks. The coherent intervals either represent fluidal flows or sills. These exposures are correlated with similar plagioclase-augitephyric coherent rocks exposed in Gnat Creek. The fine- to coarse-grained stratified sedimentary rocks are overlain by volcanic breccias, and the entire sequence is cut by north-trending sub-vertical faults.

The Jurassic rocks in this area are age equivalent with both the Takwahoni formation and the Hazelton group. Marsden and Thorkelsen's (1992) definition for the Hazelton group includes all Lower to Middle Jurassic volcanic and related sedimentary rocks on Stikinia, including the basinal sedimentary equivalents of the volcanic successions, but excludes distal strata whose origin is generally unrelated to Hazelton volcanism. Following this definition, the entire succession exposed along the northern margin of the Hotailuh area is best assigned to the Hazelton group.

Eastern margin of the batholith

A second succession of Jurassic sediments is present near peaks 2102 and 2214 m (map 'h'). It had been previously correlated with the western succession and mapped as Lower Jurassic Takwahoni formation

overthrust by Upper Triassic Stuhini Group rocks (Anderson, 1983; Gabrielse, 1998). The area around peak 2102 m at the eastern margin of the Hotailuh batholith comprises extensive exposures of reddish sedimentary rocks (map 'h', Figure 4), previously assigned to the Takwahoni formation (Gabrielse, 1998). The rocks comprise alternating medium to dark grey, parallel laminated siltstone, calcareous siltstone, fine- to medium-grained sandstone and rare, very thickly bedded, likely quartz-bearing, coarse-grained sandstone to granule-sized conglomerate (unit IJ Hs in Table 1). The fine-grained sedimentary rocks commonly contain a few percent disseminated and stratiform, very fine-grained (0.05 mm) pyrite and are commonly iron oxide-stained. A sedimentary - intrusive rock contact is exposed in the south-facing headwall of peak 2102 m (map 'h', Figure 4). Sedimentary rocks proximal to the margin of the adjacent Cake Hill intrusion exhibit contact metamorphism (see 'Structure and Metamorphism' section). Fossils collected from this area suggest an Early to possibly Middle Jurassic (Toarcian and possibly Bajocian) age for these rocks (Gabrielse, 1998, Appendix 2).

The exposures northeast of Lower Gnat Lake are part of a semi-continuous band of rocks previously assigned to the Triassic Stuhini group on the north and northeastern margin of the Hotailuh batholith (Figure 1; Anderson, 1983; Gabrielse, 1998). The volcanic rocks in the eastern part of the batholith (map 'h') are presumed to be the easternmost extension of this belt. On the lower southwest ridge of peak 2214 m, black-weathering, hornblende(?)plagioclase-phyric pyroclastic breccia and volcaniclastic pebble-sized conglomerate (unit lmJ Hv in Table 1) stratigraphically contact-metamorphosed, overlie wellstratified fine-grained sedimentary rocks

similar to those exposed on peak 2102 m. No evidence for a thrust fault separating these two units could be found, and if the section is right-way-up, the volcanic rocks are likely Early to Middle Jurassic in age, comparable to the succession northeast of Lower Gnat Lake.

Similar to interpretations for the Jurassic rocks in the northwestern area, the basal Lower (-Middle) Jurassic sedimentary rocks may represent deposition related to the Hazelton group. Further work will need to address whether these rocks, and the entire band of volcanic and sedimentary rocks on the north and northeastern margin of the batholith, are part of the Hazelton group.

Intrusive rocks

Late Triassic plutonic suite

The Late Triassic plutons within the Cry Lake (104I) and Dease Lake (104J) 1:250,000 map sheets comprise the Stikine plutonic suite of Gabrielse (1998). Late Triassic plutonic rocks comprise about twothirds of the Hotailuh batholith, and are exposed mainly in the west, northwest and southern part of the batholith (Figure 1). Here, we will only discuss the Late Triassic plutonic bodies within the main part of the Hotailuh batholith; namely the Cake Hill pluton, Beggerlay Creek pluton and Gnat Lakes ultramafite.

Gnat Lakes ultramafite

The Gnat Lakes ultramafite is a small 2.2 x 0.7 km body exposed both west and east of Highway 37, about three kilometres south of Upper Gnat Lake (Anderson, 1983; map 'a'). It has been described as an Alaskan-type ultramafic body based on the presence of hornblende clinopyroxenite, hornblendite and gabbro lithologies, minor zoning and distinctive whole-rock and mineral chemistry data (Nixon *et al.*, 1989, 1997).

comprises clinopyroxene The body hornblende-rich gabbro and plagioclaseultramafite (predominantly bearing hornblendite; unit LT GL). The cumulateultramafic rock types textured characterized by a cumulus framework of touching hornblende and/or clinopyroxene crystals with intercumulus plagioclase (terminology following Irvine, 1982). The ultramafic body is locally brecciated by coalescing hornblende-bearing irregular dikelets of granodiorite, monzonite and diorite composition (Figure 5). These leucocratic phases (unit LT GLf in Table 1) have not been found outside of the Gnat Lake body, and are tentatively interpreted as cogenetic with the ultramafic body. Hornblende from the body has been dated by Zagorevski et al. (2011) as 223.2±2.0 Ma using the ⁴⁰Ar-³⁹Ar method.

Anderson (1983) interpreted the Cake Hill pluton to predate the Gnat Lakes ultramafite, based on observations southwest of Lower Gnat Lake along the abandoned railroad grade. He reports (p. 85): "Irregular, dun weathering apophyses of hornblende pyroxenite engulf sphene-bearing, wellfoliated hornblende diorite and include rounded xenoliths of it." Upon revisiting these outcrops, we could not confirm these observations but found intimately mixed ultramafic and mafic rock types, both cut by a felsic dike of Cake Hill composition (Figure 6). The mafic rocks exposed at this location are foliated, clinopyroxene hornblende-rich gabbros, which both intrude and are intruded by plagioclase-bearing hornblendite. The mafic rocks are more hornblende and/or clinopyroxene-rich (40-60% mafic minerals) than typical Cake Hill. The felsic dike comprises foliated titanitebearing hornblende diorite, and apart from the relatively low K-feldspar content (0-5% K-feldspar) appears similar to typical Cake Hill. Based on these observations we



MJ TSP MJ TSP

11BVA22-145c (473,331E-6,437,337N)

Figure 6: Titanite-bearing hornblende diorite dike (LT CH) intruding hornblende-rich gabbro to plagioclase-bearing hornblendite (LT GLm, LT GL). Pencil for scale.

Figure 7: Irregular xenolith of acicular hornblende diorite (MJ TSm) within hornblende-biotite quartz-monzodiorite (MJ TSc). Note decrease in grain size within mafic xenolith from core to rim. Pencil for scale.

suggest that the Gnat Lakes body might predate the Cake Hill pluton.

A mineralogically similar, but non-foliated, clinopyroxene hornblende-rich gabbro body is exposed immediately east of the main Gnat Lakes ultramafic body. It also contains a decimetre-scale xenolith of ultramafic material similar to the Gnat Lakes ultramafic body. These relationships suggest a stronger genetic link between the mafic phases and the Gnat Lakes ultramafite than to the Cake Hill pluton. However, the non-foliated nature of this phase suggests it post-dates ductile shear zone development associated with intrusion of the Cake Hill pluton (see 'Structural geology and metamorphism' section) and conflicts with crosscutting relationships southwest of Lower Gnat Lake. It is unlikely that the non-foliated body is Middle Jurassic in age, since it does not contain any quartz, which is common in the hornblende-rich quartz-diorites of the mafic phase of the Three Sisters pluton. We have tentatively reassigned these rocks to a mafic subphase (LT GLm, see Table 1, map 'a') of the Gnat Lakes body. The mafic exposures located immediately east of the Gnat Lakes ultramafite and about 3 km south have been described as augite metagabbro by Read (1984) and Gabrielse (1998). To be consistent, these exposures have also been reassigned to the Gnat Lakes mafic subphase.

Cake Hill pluton

The Cake Hill pluton is the most areally extensive pluton of the Hotailuh batholith (Figure 1). The pluton is relatively homogeneous, xenolith-free, comprises equigranular hornblende quartzmonzodiorite to quartz-monzonite, and contains trace amounts of titanite (LT CH in Table 1). Generally, the Cake Hill can be distinguished from the Three Sisters central felsic phase by the presence of abundant tabular hornblende rather than biotite, presence of trace titanite, rare presence of a moderately developed fabric, and possibly also a lack of fine-grained dioritic xenoliths. A new U-Pb zircon crystallization age of 218.2 ± 1.3 Ma and a new hornblende Ar-Ar cooling age of 220.5 ± 2.2 Ma from the southern part of the Cake Hill pluton determined by this study corroborates the 221 ± 3 Ma age reported by Anderson and Bevier (1992).

light-coloured. epidote-altered, А hornblende quartz-monzodiorite, granodiorite, quartz-diorite to tonalite(?) phase occupies the southeast corner of the batholith (map 'g'). These rocks were mapped as the leucocratic phase of the Three Sisters by Anderson (1983, p. 287), and were reinterpreted as Cake Hill by Gabrielse (1998). The rocks contain tabular, epidote-altered hornblende, appear Kfeldspar-poor in the field, and resemble the main Cake Hill pluton. In addition, the unit several irregular metre-scale contains domains of hornblende quartz-monzonite to quartz-monzodiorite containing tabular hornblende and trace titanite, characteristic of the Cake Hill pluton. We adopt Gabrielse's interpretation, and assign the leucocratic unit to the Cake Hill pluton (unit LT CHl in Table 1).

A foliated, finer-grained biotite(?)hornblende diorite to quartz-diorite is present in the southeast of map 'd', and has been assigned to the Late Triassic Cake Hill pluton due to the presence of hornblende and its foliated nature (LT CHf in Table 1).

An intrusive body originally mapped as the Late Triassic Cake Hill pluton in the southeastern part of the study area (Anderson, 1983; Gabrielse, 1998; map 'h') is composed of massive, equigranular (3-4 mm) hornblende monzogranite and granodiorite that are significantly more quartz-rich than typical Cake Hill, and contain minor but ubiquitous 4-7 mm quartz blebs. We report a new U-Pb zircon crystallization age of 216 ± 1.2 Ma for this intrusive body, and interpret the body as a more quartz-rich phase of the Cake Hill pluton (LT CHq).

The presence of a ~4 km wide WNW-ESE corridor of Cake Hill rocks connecting the south-easternmost exposures with the main pluton has not been confirmed during this study (cf. Figure 1, map 'e'), and remains to be tested. Several <1 km enclaves of hornblende quartz-monzodiorite to quartzmonzonite, presumed to represent Cake Hill, are hosted by the Three Sisters central felsic phase in the southeast (map 'g'). However, gradational contacts complicate distinguishing domains from these surrounding biotite-hornblende to hornblende-biotite quartz-monzodiorite and quartz-monzonite of the Three Sisters central felsic phase. Similar relationships are found in the north-central part of the batholith, where differentiating Cake Hill from the Three Sisters central felsic phase is problematic (map 'c'). In this area, rocks previously mapped as Three Sisters central felsic phase (Anderson et al., 1982; Gabrielse, 1998) are reinterpreted as Cake Hill based on the presence of tabular hornblende and trace titanite. Some of the ambiguity in distinguishing the Cake Hill from the Three Sisters central felsic phase is likely due to the (partial to complete) assimilation of Cake Hill by the Three Sisters central felsic phase pluton.

The presence of Cake Hill rocks in the far southeast and eastern parts of the Hotailuh batholith suggests that this pluton occupied much of eastern half of the batholith before intrusion of the Three Sisters pluton.

Beggerlay Creek pluton

The Beggerlay Creek pluton is confined to the southern part of the Hotailuh batholith, and straddles the boundary between the NTS 104I and 104H map sheets north of the Stikine River. The pluton has been studied previously by Anderson (1983), Read and Psutka (1990), Gabrielse (1998) and Evenchick and Thorkelson (2005). We visited the pluton where it forms the southernmost part of the Hotailuh batholith 'f'). All but the southwestern (map exposures in this area are comprised of clinopyroxene-hornblende-rich gabbro (unit LT BC) with minor plagioclase-bearing clinopyroxenite domains (unit LT BCc). Exposures in the southwest comprise highly serpentinized ultramafic rocks, interpreted as websterite (unit LT BCw in Table 1). A thin section of this unit contains equal proportions of relatively fresh clinopyroxene and completely serpentinized pyroxene, the latter is interpreted to be preferentially The altered orthopyroxene. cumulatetextured ultramafic rock types are characterized by a cumulus framework of touching hornblende and/or clinopyroxene crystals with intercumulus plagioclase (BCc) or a cumulus framework of touching clinopyroxene and orthopyroxene (BCw; terminology following Irvine, 1982). From field observations the nature of the Beggerlay Creek - Cake Hill contact has been reinterpreted, and now includes all clinopyroxene-hornblende-rich gabbro up to an abrupt change (over a 10 m covered interval) to titanite-bearing, hornblende quartz-monzonite of the Cake Hill pluton (map 'f'; cf. Anderson, 1983, p. 84-85, p. 139-140, Appendix 2.3c). Clinopyroxenehornblende-rich gabbro closest to the contact, now assigned to the Beggerlay Creek pluton, is intensely foliated roughly parallel to the trace of the contact.

Minor coarse K-feldspar \pm epidote dikes (unit LT BCp) crosscut the northwestern portions of the Beggerlay Creek pluton, and may be related to a 5 x 1 km biotite metasyenite phase of the Beggerlay Creek pluton mapped about 7 km to the east (Read and Psutka, 1990). Coarse K-feldspar dikes, similar to those within the Beggerlay Creek pluton, also crosscut the augite-phyric coherent rocks of the Stuhini group near the contact with the mafic phases of the Beggerlay Creek intrusion.

Intrusive relationships between the Beggerlay Creek and Cake Hill plutons were not observed, however Anderson (1983, p. 84-85, Appendix 2.3c) reports that in two locations a gabbro dike of suspected Beggerlay Creek affinity intrudes quartzmonzodiorite of the Cake Hill. A new hornblende Ar-Ar date from а clinopyroxene-bearing hornblende-rich gabbro (map 'f') yielded a 210.9 ± 1.6 Ma cooling age. The hornblende in this sample is present within the groundmass and replaces clinopyroxene, clearly confirming that the Ar-Ar age is a minimum age.

Early Jurassic McBride River pluton

The McBride River pluton underlies an 8 x 20 km area at the easternmost margin of the Hotailuh batholith, dissected by the McBride River (Figure 1). The McBride River pluton was not visited during this study, but has been described as an equigranular hornblende-biotite granodiorite and quartz-monzodiorite containing abundant rounded quartz crystals (Anderson, 1983, p. 377). Anderson and Bevier (1992) established a 184 \pm 8 Ma U-Pb zircon age for the pluton.

Middle Jurassic Three Sisters pluton

The Three Sisters pluton comprises about one-third of the Hotailuh batholith. It is predominantly exposed in the eastern half of the batholith and also forms a significant exposure around and west of Highway 37 (Figure 1). The Three Sisters pluton is internally heterogeneous, and has been subdivided into four separate phases by Gabrielse (1998). The four phases studied include the fine-grained mafic-intermediate phase, mafic phase, central felsic phase and potassic phase (Table 1).

Fine-grained mafic-intermediate phase

The Three Sisters fine-grained maficintermediate phase is restricted to an 8 x 2 km body in the southeast of the Hotailuh batholith (map 'g'); it also occurs as centimetre- to decimetre-sized xenoliths within parts of the Three Sisters central felsic phase. The fine-grained maficintermediate phase comprises massive, equigranular sparsely plagioclaseto porphyritic, hornblende-biotite quartzdiorite with a 1-1.5 mm crystal size. Hornblende tonalite dikes intrude the finegrained mafic-intermediate phase. A new hornblende Ar-Ar cooling age of 173.2 ± 1.4 Ma was established in this study.

Mafic phase

The mafic phase comprises a volumetrically small portion of the Three Sisters pluton. Overall, it is fairly uniform compositionally, and comprises massive, equigranular, hornblende-rich quartz-diorite. Texturally, the rocks are varied, and contain either acicular hornblende or equant blebby hornblende, with both types exhibiting wide variations in crystal size (1-20 mm). The mafic phase occurs as small- to mediumsized (<1-2 km²) bodies within the Three Sisters central felsic phase (map 'e'). The central felsic phase intrudes into, as well as assimilates and includes fluidal fragments of the mafic phase. Furthermore, the fluidal domains of mafic phase within central felsic phase rocks often show a decrease in grain size towards the clast edge (Figure 7), interpreted as chilled margins. All evidence suggests that the two phases formed roughly at the same time. Similar mafic plutonic rocks crop out as several small (<0.5 km²) bodies within the Cake Hill pluton close to the contact with the main Three Sisters pluton (map 'c', 'h'). Where the mafic phase is present within these older plutonic rocks, the latter are observed intruding, and often including, the mafic phase rocks. Anderson (1983, p. 86) reports similar observations at these locations, but also reports irregular mafic phase dikelets intruding Cake Hill, features interpreted to reflect remelting and remobilization of felsic rocks by intrusion of hot mafic melts. In the southeast (map 'e'), the mafic phase intrusions form subhorizontal tabular bodies confined to the highest ridge tops. In the north (map 'b'), a body several square kilometres in size forms the margin of the Three Sisters pluton. A new hornblende Ar-Ar cooling age of 171.9 ± 1.7 Ma was established for this phase.

Central felsic phase

The areally most extensive phase occupies the central portion of the Three Sisters pluton. It consists of massive, equigranular (2-3 mm) biotite and lesser hornblendequartz-monzonite biotite and quartzmonzodiorite, locally with K-feldspar phenocrysts. In addition to the internal variation in composition and texture, the central felsic phase encloses several other intrusive phases. For example, an estimated 15 to 50% of the north-south traverses along ridges in maps 'e', 'g' and 'h' comprise either older (partly assimilated?) Cake Hill pluton, roughly coeval Three Sisters mafic phase, or crosscutting Three Sisters potassic

phase. Notably, certain ridges that have been mapped by Anderson (1983) and Gabrielse (1998) as solely central felsic phase (northsouth trending ridge in northwestern part of map 'e'), comprise substantial proportions of other rock types. The age of the central felsic phase was only constrained by K-Ar dates reported in the '70s and early '80s (see compilation in Anderson and Bevier, 1992). A U-Pb zircon crystallization age from a biotite quartz-monzonite exposed along the eastern margin of the Three Sisters pluton yielded a 169.0 ± 1.2 Ma age, identical to a biotite Ar-Ar cooling age of 169.0 ± 1.1 Ma obtained for the same sample (map 'h', this study).

Potassic phase

The Three Sisters potassic phase comprises massive, equigranular (1-4 mm crystal size) to locally K-feldspar porphyritic (5-20 mm crystal size), biotite to biotite-bearing, quartz-syenite granite, and quartzmonzonite. This phase occurs as a large body straddling Highway 37 that appears to be connected to the main part of the Three Sisters pluton through a relatively narrow (~1.5 km wide) corridor occupied by associated potassic phase rocks (Figure 1; Anderson 1983: Gabrielse. 1998) Elsewhere, several medium sized bodies of the potassic phase form the margin of the Three Sisters pluton in the eastern half of the batholith. Several smaller potassic phase bodies crosscut the central felsic phase pluton, and immediately adjacent plutons (maps 'e', 'g', 'h').

A U-Pb zircon crystallization age of 169.1 ± 0.7 Ma (this study) is only slightly younger than a 171 ± 1 Ma date by Anderson and Bevier (1992) for these coarse-grained intrusive rocks. Abundant fine-grained, pink, biotite-phyric dikes, likely related to the potassic phase, cut almost all adjacent plutonic and sedimentary rocks. The

potassic and central felsic phases are distinguished by more quartz, less biotite and more K-feldspar than plagioclase in the potassic phase. In places, the potassic phase can be difficult to distinguish from the central felsic phase. Some areas mapped previously as the potassic phase corridor (Figure 1; Anderson, 1983; Gabrielse, 1998) consist of massive, relatively fine-grained (1-2 mm crystal size), biotite quartz-diorite (maps 'd', 'e'). Further investigations are needed to fully characterize distinctions between these phases. The QUEST-NW geophysical survey (Aeroquest Airborne, 2012) indicates a complex aeromagnetic signature over the area between the BCR showing and newly discovered "BCR north" mineral occurrence (map 'a'). The high aeromagnetic response at BCR north coincides with a high magnetic susceptibility measurement on biotitebearing hornblende svenite $(42 \cdot 10^{-3} \pm 15 \cdot 10^{-3})$ SI units), and appears to represent a different sub-phase of the Three Sisters potassic phase (unit MJ TSpm). The lower aeromagnetic response to the south coincides with more typical biotite-bearing granites (measured magnetic susceptibility of $21 \cdot 10^{-3} \pm 6.8 \cdot 10^{-3}$ SI units).

Other intrusive rocks

In addition to the plutonic rocks described above, several small intrusive bodies and numerous dikes are present throughout the study area. A mineralized intrusive body is the "Gnat Pass intrusive" (unit LT GP in Table 1). Where unaltered, it comprises plagioclase-phyric hypabyssal rocks (with sparse quartz and/or hornblende phenocrysts present in places). The intrusive occupies an area of ~0.1 km² in the "hill zone" (main zone) of the Gnat Pass mineral prospect (Smith and Garagan, 1990). A U-Pb zircon crystallization age from the Gnat Pass intrusive at the hill zone vielded a 216.4 \pm

1.3 Ma age (this study), only slightly younger than the Late Triassic plutons in the area. Similar intrusive bodies and dikes 1-10 m in width, generally also associated with minor sulphides, are found along Gnat Creek downstream of Lower Gnat Lake ("creek zone" of the Gnat Pass prospect) as well as along Highway 37 north of Lower Gnat Lake. In all areas, the intrusive rocks cut Triassic Stuhini group augite-phyric coherent rocks. Interestingly, Asbury (1967) reports a 0.5 x 1 km-size granodiorite intrusion approximately 3.5 km northwest of Lower Gnat Lake. The body is described as "... a medium-grained, granular rock containing grey to pink plagioclase, an estimated 15% free quartz and 1% to 2% mafic minerals." This body is not shown on the regional geological map of Gabrielse (1998), and warrants additional study to determine its spatial extent and possible association with mineralization. In addition, possible cogenetic Fe-carbonate-altered rhyodacite dikes that postdate all other units and are typically associated with sulphide mineralization are reported at the Dalvenie showing (Wetherill, 1990, p.13).

A small intrusion located further south of Gnat Pass is tentatively named the "Tees Creek intrusive". This altered hornblendefeldspar porphyry is exposed along the abandoned railroad about 1.5-3.5 km south of the Gnat Lakes ultramafite; it also occurs as irregular dikes intruding the coarsegrained potassic phase of the Three Sisters pluton. The intrusive is associated with minor pyrite at the "BCR north" mineral occurrence.

Abundant subvertical north to northeast striking 8-10 m wide augite-plagioclaseporphyritic, augite hornblende-rich diabase dikes cut the Cake Hill pluton in the centre of the Hotailuh batholith (map 'd'). Their geochemical petrological, (see

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'Lithogeochemistry' section) characteristics and crosscutting relationships suggest that these hypabyssal dikes are most likely subvolcanic feeders to the Middle Jurassic Hazelton Group volcanics.

STRUCTURAL GEOLOGY AND METAMORPHISM

Whereas the Hotailuh batholith appears to be mostly unaffected by post-intrusion contractional deformation, most surrounding sedimentary and volcanic rocks have been deformed. The area north of the Hotailuh batholith comprises predominantly moderately north-dipping strata, ascribed to result from south-directed thrusting along the King Salmon and Hotailuh faults (Gabrielse, 1998). The Gnat Pass area appears to be a major structural zone with evidence for several north-northeast- to north-northwest-striking ductile to brittle fault zone localized along part of the western margin of the Cake Hill pluton. Faulting and folding is common in Triassic sedimentary and volcanic rocks east of this fault zone (Read, 1984; Gabrielse, 1998). The structural style in the area south and east of the batholith is poorly understood. Two regional-scale faults inferred along the Stikine River include the Beggerlay Rapids Pitman faults (Evenchick and and Thorkelson, 2005).

Anderson (1983, p. 67-76) and Gabrielse (1998, p. 64) described the Cake Hill pluton as pervasively or well-foliated. However, we found the fabric within the Cake Hill pluton to be only moderately-developed to absent, except in a north-northwest-striking zone in the Gnat Pass area where it is welldeveloped. The fabric is defined by alignment of tabular hornblende crystals. Although moderately aligned hornblende is regularly observed in outcrop within the main part of Cake Hill pluton, it is commonly inconsistent over the metre scale. Where present, the orientation of the foliation measured herein is generally similar to the NW-SE striking, sub-vertical orientations reported by Anderson (1983). Except within the Gnat Pass zone (see below), the foliation is likely magmatic in origin.

Gnat Pass fault zone

The Gnat Pass fault has been described as a 25 km long, north-northwest striking, possible dextral strike-slip to east-side-down dip-slip, fault (Gabrielse, 1998, p. 94). According to this author the fault is cut on its southern end by the Three Sisters pluton, occurs on (or near) the western margin of the Cake Hill pluton in the Gnat Pass area, terminates the Hotailuh thrust northwest of Lower Gnat Lake, and is terminated by the King Salmon thrust fault near Dease Lake (Figure 1).

An outcrop immediately south of Upper Gnat Lake shows intensely foliated felsic intrusive rocks containing relict 3-5 mm euhedral augite-crystal porphyroclasts. Augite-phyric coherent rocks up to 250 m east of this location, as well as granitoid rocks of the Cake Hill pluton up to 250 m west of this location, are intensely foliated. Foliation orientations in all rock types are sub-vertical and strike approximately northnorthwest. The foliation in the Stuhini Group augite-phyric coherent rocks comprises newly formed chlorite wrapped around relict augite phenocrysts, indicating greenschist facies metamorphic conditions. In the Cake Hill pluton, the foliation is defined by alignment of tabular hornblende is macroand microscopically that magmatic indistinguishable from hornblende. Outcrops of intensely foliated Stuhini Group and Cake Hill pluton lithologies are found in a up to 1 km wide, generally north-northwest trending zone

coincident with the approximate western edge of the Cake Hill pluton (map 'a'). Based on these observations, we infer the presence of a north-northwest-striking, subvertical, ductile shear zone, roughly situated on the western margin of the Cake Hill pluton. Syn-intrusion shear would explain the relatively narrow band of foliated and metamorphosed country rocks, as well as the presence of a well-developed fabric formed by igneous hornblende in the pluton. The north-northwest-striking belt of foliated rocks continues at least 3 km to the north and 5 km to the south where it appears to be cut by undeformed plutonic rocks of the Three Sisters potassic phase.

A sub-vertical north-northwest striking brittle fault is exposed in a 2 m wide recessive zone in an exposure along the abandoned railroad (map 'a'). The fault separates intensely foliated augite-phyric coherent rocks on the east wall of the fault, with unmetamorphosed, non-foliated, sedimentary rocks on the west wall. Folation in the augite-phyric coherent rocks as well as bedding attitudes in the sedimentary rocks are roughly parallel to the brittle fault. This fault has been interpreted by Gabrielse (1998) as the main Gnat Pass fault.

north-northwest Several trending aeromagnetic lineaments are evident within the Gnat Pass area (Aeroquest Airborne, 2012). All major geophysical lineaments are interpreted here as brittle faults (see map 'a'). An induced polarization survey carried out by Bearclaw Capital Corp. in 2005 (Page and Scott, 2006) indicates a significant north to north-northwest striking sub-vertical resistivity low (< 500 Ω m) between the creek and hill zones of the Gnat Pass prospect. The Gnat Pass shear zone does not show up as a geophysical lineament on the aeromagnetic survey, likely due to the lack magnetite-destructive of alteration

associated with the shear zone. The Gnat Pass shear zone could not be traced beyond the northern margin of the Gnat Lakes mafic phase. This clinopyroxene hornblende-rich gabbro body is not foliated and may postdate formation of the Gnat Pass shear zone.

We interpret the Gnat Pass structural zone as an up to 1 km wide, >10 km long ductile shear zone developed on the western margin of the Cake Hill pluton during Late Triassic time. The ductile shear zone became the locus of brittle faulting during subsequent cooling and/or exhumation. The brittle fault exposed along the abandoned railroad that separates foliated and metamorphosed rocks from non-foliated and unmetamorphosed rocks likely represents such a subsidiary brittle fault. The geophysical lineaments at Upper Gnat Creek, Tees Creek, and at the Gnat Pass showing most likely represent major brittle faults related to the Gnat Pass structural zone.

Hotailuh thrust fault

An exposure of the Hotailuh thrust could not be found during current mapping between Highway 37 and peak 2096 m (map 'a'). Reported evidence for the fault is the presence of presumed Triassic Stuhini rocks overlying Early Jurassic fossil-bearing siliciclastic sedimentary rocks assigned to the Takwahoni formation (Anderson, 1983; Gabrielse, 1998). However, detrital zircon results (Iverson et al., 2012; Iverson, 2012) suggest a Middle Jurassic or younger age for overlying package, leaving the no requirement for the presence of a thrust fault in this particular location. A seismic reflector interpreted as the Hotailuh thrust fault by Evenchick et al. (2005) may just represent the change from Triassic Stuhini and Cake Hill to Jurassic volcanic and sedimentary rock types.

On the eastern margin of the batholith (map 'h'), the Hotailuh thrust has been inferred within steep and largely inaccessible topography surrounding peak 2214 m (Anderson, 1983; Gabrielse, 1998). Study of the lower southwest ridge of peak 2214 m found no evidence for a thrust fault, and if the section is right-way-up, the volcanic rocks previously assigned to the Triassic Stuhini group may be Early to Middle Jurassic in age, comparable to the succession further west that yielded Jurassic detrital zircon populations.

Other structures and metamorphism

The succession Middle of Jurassic sedimentary and volcanic rocks around peak 2096 m is cut by several north-northeast- to north-northwest-trending, sub-vertical faults with stratigraphic offset suggesting a dextral strike-slip and/or east-side-down dip-slip motion. Another important structure is the Dalvenie fault, which hosts the Dalvenie copper-gold-silver prospect (map 'a'). Many roughly parallel topographic lineaments, aeromagnetic lineaments and/or possible faults are present in the immediate area (selected lineaments shown on the 1:50,000 scale map).

At the eastern margin of the Hotailuh batholith, sedimentary rocks with Early (to Middle?) Jurassic fossils (Gabrielse, 1998) exhibit contact-metamorphism adjacent to the 216 Ma hornblende monzogranite to granodiorite of the Cake Hill pluton (map 'h'). Several skarn bodies comprising brown garnet, dark green diopside and/or white fibrous wollastonite occur within about 50 m of the contact with the intrusive, and represent contact-metamorphosed calcareous, fine-grained sedimentary rocks. Three irregular altered felsic intrusive dikes cut the sedimentary rocks. Based on the

geochronological biostratigraphic and constraints, the intrusive to sedimentary contact represents a nonconformity or a fault. We tentatively interpret the calcic exoskarn development to be due to increased fluid flow along the permeable (nonconformable or fault) contact and injection of dikes accompanying intrusion of the nearby Middle Jurassic Three Sisters pluton.

Mafic intrusive rocks of the Beggerlay Creek pluton are intensely foliated in a 500-750 m wide zone adjacent to the Cake Hill contact (map 'f'). The steeply dipping, eastto east-northeast-striking foliation is defined by elongated hornblende and plagioclase, imparting an almost gneissic compositional banding in places.

LITHOGEOCHEMISTRY

Analytical Techniques

A total of 46 least altered lithogeochemical samples were collected from nine different plutonic phases and one mafic dike. The samples were jaw crushed at the Geological Survey sample preparation facilities in Victoria. The crushed samples were further processed at Activation Laboratories in Ancaster (Ontario), pulverized in a mild steel mill to prevent Cr and Ni contamination and analyzed for major and trace elements using a lithium metaborate plus lithium tetraborate fusion technique. At Activation Laboratories, the samples were mixed with a flux of lithium metaborate and lithium tetraborate and fused in an induction furnace at 1150 °C. The melt was immediately poured into a solution of 5% nitric acid, and mixed continuously until completely dissolved. This aggressive fusion technique ensures that the entire sample, including resistate phases, dissolves. The samples were analyzed for major oxides

using an Inductively Coupled Plasma (ICP) technique and trace elements using an Inductively Coupled Plasma - Mass Spectrometry (ICP-MS) technique. Nickel was also analyzed by four acid digestion; beginning with hydrofluoric acid, followed by a mixture of nitric and perchloric acid, and final hydrochloric acid dissolution. Samples were analyzed using an ICP technique. With this near total digestion technique, certain resistate phases (e.g. zircon, monazite, sphene, gahnite, chromite, cassiterite, rutile and barite) may be only partly solubilized. Chromium was analyzed using Instrumental Neutron Activation Analysis (INAA), where samples were irradiated in a nuclear reactor, and following a 7-day decay, gamma rays measured on germanium detectors. Analytical techniques and detection limits for all major oxides and trace elements are listed in Appendix 2. Two blind CANMET standards (see Govindaraju, 1994 for reference values) and two blind duplicates of the jaw crushed material were included in the sample batch (see Appendix 3). Additional Activation Labs' internal quality control duplicate analyses on powdered samples are also listed in Appendix 3.

During sample collection and preparation every effort was taken to avoid sampling altered material. We avoided and/or removed any obvious surface weathering, altered areas, veins and open space fill. A summary of the rock type and intensity of alteration of feldspars and mafic minerals for all lithogeochemistry samples are presented in Appendix 1. Geochemical results presented in Appendix 2 show normal total weight percent values (between 97.5 and 101 wt.%) and loss on ignition values (below 2 wt.%).

Results

Major oxide diagrams (Figure 8a-c) indicate that the bulk of the samples plot within the metaluminous to weakly peraluminous calcalkaline (subalkaline) fields. A small number of samples fall within the alkaline field (Figure 8a). The latter samples likely do not represent original melt compositions, possibly due to crystal addition (phenocrysts accumulation, cumulate origin) and/or minor alteration. The Gnat Lakes and some of the Beggerlay Creek samples are unusually clinopyroxene and/or hornblende-rich (and SiO₂-poor) due to their cumulate origin, which causes them to plot within the alkaline field. All samples define a good calc-alkaline trend on an AFM diagram (Figure 8c), with a clear trend from alkalipoor primitive ultramafic to mafic suites to alkali-enriched intermediate to felsic suites. All intermediate to felsic plutonic rocks plot within the Island Arc Granite (IAG) to Continental Arc Granite (CAG) fields of Maniar and Piccoli (1989). The Middle Jurassic plutonic rocks tend to have a slightly higher Aluminum Saturation Index (ASI, Figure 8b) compared to Late Triassic rocks. Most samples are metaluminous in nature, whereas the Three Sisters potassic phase is weakly peraluminous. Lithogeochemical analyses from the latter phase are corundum normative (based on the CIPW norm, Hutchinson, 1974), indicating that the samples contain more aluminum than can be accommodated in feldspars. agrees well with petrological This observations that show biotite as the dominant mafic phase in these rocks. Trace element tectonic discrimination diagrams of Pearce et al. (1984) indicate a Volcanic Arc Granite (VAG; Figure 8d) affinity for all but one or two rock samples. The Pearce et al. (1984) trace element plot and Frost et al. (2001) ASI classification plot, suggests a subduction-related origin for the magmas



Figure 8: Major and trace element diagrams for different plutonic phases of the Hotailuh batholith. (a) Total Alkali vs. Silica diagram of Le Bas et al. (1986). (b) Aluminum Saturation Index vs. $Al_2O_3/(Na_2O + K_2O)$ diagram of Frost et al. (2001) with granitoid tectonic fields after Maniar and Piccoli (1989). IAG = Island Arc Granite, CAG = Continental Arc Granite, CCG = Continental Collision Granite, PCG = Post-Collision Granite. (c) Alkali – Iron –Magnesium oxide plot of Irvine and Baragar (1971). (d) Y+Nb vs. Rb trace element granite tectonic discrimination plot of Pearce et al. (1984). VAG = Volcanic Arc Granites, ORG = Ocean Ridge Granites, WPG = Within Plate Granites, syn-COLG = syn-Collision Granites.

that formed the Hotailuh batholith. Lastly, the presence of trace magnetite in most rocks and magnetic susceptibility values above $\sim 3.0 \cdot 10^{-3}$ SI (see 'Geological units' section) indicate that the plutonic rocks are part of the relatively oxidized magnetiteseries granitoids of Ishihara (1977; 1981) and Ishihara *et al.* (2000).

The Rare Earth Element (REE) and trace element concentration within the different plutonic suites supports the field and petrographic separation of different intrusive phases (Figure 9, Figure 10). The Gnat Lakes ultramafite has a flat La-Nd Light Rare Earth Element (LREE) pattern, which is distinctly different from other ultramaficmafic-intermediate intrusive phases within the Hotailuh batholith (Figure 9a). The Late Triassic Beggerlay Creek pluton, the Middle Jurassic Three Sisters mafic and fine grained mafic-intermediate phases have broadly similar REE patterns with an increase in REE abundance towards more silicic compositions. The serpentinized websterite (LT BCw) has a flat to slightly irregular with REE pattern verv low REE concentrations (Figure 9a). The REE concentration and negative LREE slope increase from plagioclase-bearing clinopyroxenites (LT BCc) to hornblendeclinopyroxene and clinopyroxenehornblende gabbro (LT BC). There is also an increase in the negative LREE slope from the mafic phase to fine grained maficintermediate phase. The augite-plagioclase basalt dike that cuts the Cake Hill pluton has a similar REE pattern and concentrations as samples from the mafic Beggerlay Creek pluton and the Three Sisters mafic phase and fine grained mafic/intermediate phase. The Late Triassic Cake Hill felsic phases (LT CH, CHl, CHq) and Middle Jurassic Three Sisters central felsic (MJ TSc) and potassic phases (MJ TSp) have overlapping REE concentrations and broadly similar REE

patterns (Figure 9b, c). The Late Triassic Cake Hill quartz-rich phase (LT CHq) is depleted in REE relative to the main Cake Hill pluton (LT CH). The Cake Hill leucocratic phase (LT CH1) shows overlapping, but slightly depleted REE concentrations relative to the main Cake Hill pluton (Figure 9b). The Middle Jurassic Three Sisters central felsic and potassic phases (MJ TSc, TSp) show overlapping REE patterns and moderately negative Eu anomalies (Figure 9d). This indicates that the melt was at one time in equilibrium with now-absent plagioclase, either at the source, or due to removal of plagioclase phenocrysts from the melt. The potassic phase shows steeper negative LREE slopes. and overlapping to lower Heavy Rare Earth Element (HREE) concentrations, relative to the central felsic phase (Figure 9d). One sample from the potassic phase in the Gnat Pass area is highly anomalous and shows very high REE concentrations indicative of a late-stage, incompatible element-enriched melt (Figure 9d). The outcrop also returned much higher magnetic susceptibility readings than measurements on the Three Sisters potassic phase further east, and is associated with a zone of a much higher airborne magnetic response interpreted as a subphase of the potassic phase (MJ TSpm). In addition, a second sample from the potassic phase in the Gnat Pass area has a steeper negative LREE slope than any of the other samples. Relative to N-type Mid Ocean Ridge Basalt (N-MORB), the rock types are all enriched in LREE and contain similar to depleted HREE concentrations (Figure 9e). The HREE pattern suggests that the mantle source for these rocks was similar to, or more depleted than, a typical MORB mantle source region.

Multi-element N-MORB normalized diagrams modelled after Sun and McDonough (1989) are shown in Figure 10.



Figure 9: Chrondrite normalized rare earth element diagram for ultramafic-mafic-intermediate (a,c) and intermediate-felsic (b,d) suites of the Late Triassic (LT) and Middle Jurassic (MJ) plutonic suites within the Hotailuh batholith. Normalization values of Boynton (1984). Ocean Island Basalt (OIB), N-type Mid-Ocean Ridge Basalt (N-MORB) and Primitive Mantle values of Sun and McDonough (1989) plotted for reference in diagram (e).



Figure 10: N-MORB normalized multi-element diagram for ultramafic-mafic-intermediate (a,c) and intermediate-felsic (b,d) suites of the Late Triassic (LT) and Middle Jurassic (MJ) plutonic suites within the Hotailuh batholith. Normalization and ordering scheme of Sun and McDonough (1989). Ocean Island Basalt (OIB) values of Sun and McDonough (1989) plotted for reference in diagram (e).

The elements in the diagram are organized by increasing compatibility towards the right, as shown by typical Ocean Island Basalt (OIB) concentrations (Figure 10e). Notable diversions from a negative sloping trend in Figure 10 include a strong depletion in Nb (a High Field Strength Element; HFSE), and a strong enrichment in hydrous fluid-mobile Large Ion Lithophile Elements (LILE) such as K and Pb. These patterns are typical of subduction-generated magmas where LILE-enriched aqueous fluids derived from dehydration reactions within the downgoing slab induce partial melting in the overlying mantle wedge.

GEOCHRONOLOGY

In this study we used modern radiogenenic isotopic dating techniques to determine the ages of seven different plutons and plutonic phases that comprise the Hotailuh Batholith, as well as one porphyritic hypabyssal intrusion associated with copper mineralization at Gnat Pass. Historical dating of the Hotailuh batholith (Wanless *et al.*, 1972; Stevens *et al.*, 1982) does not reliably constrain crystallization ages or provide adequate coverage of the 2,275 km² area of the batholith.

Five intermediate to felsic intrusive rocks were processed for zircons and subsequently analyzed for U-Pb using a Laser Ablation Inductively Coupled Mass Spectrometer (LA-ICP-MS) at the University of Washington. The U-Pb results presented here supersede preliminary ages presented in van Straaten et al. (2012a, b). In addition, five mafic to intermediate intrusive rocks were processed for hornblende and/or biotite mineral separation, subsequently irradiated and analyzed using the ⁴⁰Ar/³⁹Ar method method at the Pacific Centre for Isotopic and Geochemical Research, University of British

Columbia. Detailed methodologies are described in Appendix 4.

Previous geochronological studies (Wanless *et al.*, 1972; Anderson *et al.*, 1982; Stevens *et al.*, 1982; Anderson and Bevier, 1992) included 29 K-Ar hornblende, biotite and whole rock age dates and three U-Pb zircon dates to estimate the ages of the major plutonic suites within the Hotailuh batholith. More recently Ar-Ar dating on hornblende from the Gnat Lakes ultramafite established a minimum cooling age of 223.2±2.0 Ma for this body (Zagorevski *et al.*, 2011).

Results

All samples analyzed are summarized in Table 2, and shown in detail in Figure 11. Complete datasets are presented in Appendices 5 and 6.

Of the five zircon U-Pb LA-ICP-MS analyses, none suggests the presence of any significant inherited age populations, and only one sample is interpreted to contain a significant number of grains affected by lead loss (Figure 11a-e). Data points were excluded from the U-Pb age determinations based on 1) large degree of discordance in a conventional Tera-Wasserburg diagram (isotopic ratios not corrected for common lead), 2) large 2 standard deviation (SD) errors in the ${}^{206}\text{Pb}/{}^{238}\text{U}$ age, and 3) ²⁰⁶Pb/²³⁸U age values suggesting the data points are outliers with respect to the main population of data points, i.e. data points that plot away from the cumulative relative probability peak. The interpretation of most samples is straightforward; for sample 11BVA31-232 no data points were excluded, and for samples 11BVA38-304 and 11BVA42-333 only 3-4 outliers were excluded for each sample. Inclusion of these grains does not significantly alter the final age determinations. Sample 11JLO32-319 contains a small population (n=3) of older

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UTM N Sample no. Type UTM E Unit Rock description Age (Ma)* Population Statistics 11BVA31-232 U/Pb, Zrn 478,755 6,434,626 MJ TSp MSWD=0.93, Hbl-bearing Bt 169.1±0.8 50/50 grains monzogranite p=0.62 Hbl-bearing Bt Qtz-MSWD=1.12, 11BVA35-276 Ar/Ar, Bt 480,640 6,439,273 MJ TSc 169.0±1.1 13/25 steps, monzonite to p=0.34 54.7% of ³⁹Ar monzogranite 11BVA35-276 U/Pb, Zrn 169.0±1.3 29/49 grains MSWD=0.64, ,, ,, ,, ,, p=0.93 11BVA42-329 Ar/Ar, Hbl 466,997 6,448,398 MJ TSm Acicular Hbl-rich Qtz-171.9±1.7 MSWD=1.13. 6/11 steps, diorite p=0.34 81.6% of ³⁹Ar Fine grained Hbl-Bt Qtz-11BVA42-332 Ar/Ar, Hbl 479,794 6,436,014 MJ TSf 173.2±1.4 4/12 steps, MSWD=0.114, diorite p=0.95 54.2% of ³⁹Ar 11BVA27-199 Ar/Ar, Hbl 462,983 6,427,463 LT BC Cpx-bearing Hbl-rich 210.9±1.6 5/17 steps, MSWD=1.16, gabbro p=0.32 53.3% of ³⁹Ar Plag-porphyritic 11JLO32-319 U/Pb, Zrn 451,832 6,457,090 LT GP 216.5±1.4 MSWD=0.78, 44/49 grains (DDH G-89-8 55.47hypabyssal intrusion p=0.85 60.05 m) 11BVA38-304 U/Pb, Zrn 481,362 6,439,991 LT CHa Hbl-bearing granodiorite 216.2±1.2 45/49 grains MSWD=0.73. to monzogranite p=0.90 11BVA42-333 Hbl Qtz-monzonite MSWD=1.20. Ar/Ar, Hbl 463,692 6,431,161 LT CH 220.5±2.2 6/9 steps, p=0.31 94.2% of ³⁹Ar 218.2±1.3 MSWD=0.76, 11BVA42-333 U/Pb, Zrn 47/50 grains ,, ,, ,, p=0.88

Table 2: Summary of zircon U-Pb and hornblende/biotite Ar-Ar geochronology samples taken from the Hotailuh batholith.

* Crystalization age for U-Pb zircon analyses. Cooling age (plateau age) for Ar-Ar analyses. 2 SD error

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Figure 11: Geochronology plots for samples from the Hotailuh batholith. Graphs (a-e) show U-Pb zircon LA-ICP-MS ages, cumulative relative probability plots and Tera-Wasserburg diagrams (inset). Plotted values are ²⁰⁶Pb/²³⁸U ages, except for yellow data points in samples 11BVA-35-276 and 11JLO32-319 which are common lead-corrected ages. Data points in red, grey and blue are excluded from the age determination based on a high degree of discordance, high error, or outlier nature (respectively). Green data points are included. Error bars represent 2 standard deviations. Graphs (f-j) show Ar-Ar plateau ages for biotite or hornblende crystals. Red heating steps are excluded and green heating steps are included in the age determination. Errors are reported at 2 standard deviations.



Figure 11: (cont.)



Figure 11: (cont.)

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grains interpreted to be inherited from Paleozoic basement rocks, as well as two discordant grains. Sample 11BVA25-276 is complex in nature. The 15 youngest grains excluded from the have been age determination, based on their moderately to highly discordant nature (when not corrected for common lead) and relatively high 2SD errors. The sample contains a relatively robust population of 29 grains with ²⁹⁶Pb/²³⁸U ages ranging from 164 to 177 Ma. The mean of 169.0 (± 1.3) Ma coincides with the main cumulative relative probability function peak, suggesting this represents the crystallization age of this sample. This age is within error of the biotite Ar-Ar age (Figure 11f) from the same sample. This sample would benefit from a follow-up study to determine the validity of the Middle Jurassic age. If the age is correct, it is unclear why about one third of the zircon grains were affected by lead loss, whereas the biotite Ar-Ar cooling age remained unaffected.

One biotite Ar-Ar and four hornblende Ar-Ar cooling ages are shown in Figure 11f-j. Plateau ages are based on 4 to 13 heating steps, and 53 to 94% of released ³⁹Ar.

Sample 11BVA42-333 was analyzed using both U-Pb and Ar-Ar, and the results are the same age within error. Note however, that the cooling age is 2.3 Myr older than the crystallization age. Sample 11BVA35-276 was also analyzed using both U-Pb and Ar-Ar, and has been discussed above. Statistical parameters show no reason for rejection of the U-Pb or Ar-Ar age data (Table 2), with Weighted Mean Squared Deviation (MSWD) values below $1+2(2/(n-1))^{0.5}$ (with n = number of data points; Wendt and Carl, 1991) and Probability (P) values well above 0.05.

MINERALIZATION

Five mineralized prospects and showings in the MINFILE database (BCGS, 2012) have been visited within the Hotailuh study area. Most of these occur in the easily accessible Gnat Pass area where rock exposure is poor to moderate. An additional nine new mineral occurrences were identified, three within the Gnat Pass area, and six on well-exposed ridges within the Hotailuh batholith (see enclosed 1:50,000 scale map).

A total of 20 mineralized (grab) samples were collected from 4 MINFILE locations. as well as 7 from the newly identified mineral occurrences. The samples were jaw crushed and pulverized in a Cr-steel mill at the Geological Survey sample preparation facilities in Victoria and analyzed at AcmeLabs in Vancouver. The samples were dissolved using a four-acid digestion followed by multi-element Inductively Coupled Mass Spectroscopy (ICP-MS) analysis. Gold was analyzed by leadcollection fire assay fusion followed by Inductively Coupled Plasma Emission Spectroscopy (ICP-ES) analysis. Values reported in Table 3 include analysis of one repeat on a jaw crushed reject sample, an external standard, and Acme's internal quality control duplicate samples and standard. The assay results are given in Table 3.

MINFILE prospects and showings

Gnat Pass (MINFILE 104I 001)

The Gnat Pass copper developed prospect is located immediately north to northeast of Lower Gnat Lake (map 'a'), and comprises two different zones. The "hill zone" is about 1.1 km east of the lake outlet and was drilled in 1965 and 1989 (Smith and Garagan, 1990). Indicated resources (non-NI 43-101-

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Table 3: Assay results and coordinates of mineralized rock samples collected during 2011 field work in the Hotailuh area.

.	Element				Au*	Ag	Cu	Мо	w	Sn	Bi	As	Sb	Ва	Pb	Zn	Rb	Sr	Cd	Ni	Co
cur	Units				ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Min OC	Detection limit				2	0.1	0.1	0.1	0.1	0.1	0.1	1	0.1	1	0.1	1	0.1	1	0.1	0.1	0.2
	Station no.	UTM E	UTM N	Unit																	
<u>с</u> .	11BVA5-30	450,034	6,458,207	LT GP	12	0.1	161	<0.1	1.0	0.3	0.9	30	4.2	463	4	5	79	211	<0.1	3	109
nat	11BVA9-48	450,502	6,457,572	LT GP	4	<0.1	34	0.4	0.5	0.6	0.1	7	2.4	598	2	23	66	182	<0.1	2	6
U	11JLO32-319	451,832	6,457,090	LT GP	41	0.6	7221	16.7	0.6	0.6	0.1	5	1.0	510	7	32	134	315	0.2	4	8
<u>></u>	11BVA11-62a	448,489	6,449,977	T Ss	14	<0.1	87	<0.1	29.5	0.9	4.8	535	54.9	53	2	3	64	38	<0.1	230	31
ŏ	11BVA11-62b	448,489	6,449,977	T Ss	570	2	463	0.5	9.8	1.2	61.0	>10000	204.7	36	32	21	38	121	<0.1	53	93
Gnat Cr.	11BVA2-12	451,163	6,451,183	LT CH	1703	81.7	>10000	5.5	<0.1	0.1	482.6	<1	1.4	50	79	125	62	599	0.5	5	18
Ē	11BVA11-57	449,665	6,450,261	T Ss	<2	<0.1	72	1.9	0.3	3.9	0.3	<1	0.3	341	11	33	64	21	<0.1	21	11
, ,	11BVA11-58b	449,472	6,449,706	LT GLf	<2	0.1	87	8.2	0.8	0.9	0.1	5	1.8	1005	8	78	19	689	<0.1	39	22
at I	11BVA11-59	449,321	6,449,882	LT GL	5	0.2	402	3.7	0.2	1.3	0.1	2	1.9	245	4	93	5	424	0.2	30	96
Gn	Acme Dup	,,	,,	,,	4																
at	11BVA26-184	462,220	6,428,961	T Ss	2	0.2	139	7.0	0.4	0.7	<0.1	4	<0.1	27	5	129	2	80	0.4	146	20
ž	11BVA26-187	461,821	6,429,303	T Ss	<2	0.1	133	0.9	0.2	0.6	<0.1	22	0.4	36	73	57	2	272	0.2	63	39
Mat	11BVA25-172	461,904	6,431,947	LT CH	39	9.1	>10000	0.7	0.2	0.2	5.4	<1	0.4	3102	13	86	32	1120	0.1	25	22
Pat	11BVA13-74	470,681	6,449,148	LT CH?	32	1.1	2962	2.2	0.4	1.8	1.0	12	0.7	392	4	24	25	568	<0.1	10	20
< at	11BVA14-82	467,697	6,447,881	MJ TSc	21	0.7	7079	0.1	2.4	1.1	0.6	19	1.3	1083	2	49	117	159	0.2	2	15
<u> </u>	11BVA15-90	466,323	6,447,968	MJ TSp	<2	<0.1	131	2.0	0.1	0.5	<0.1	4	<0.1	1179	4	7	84	461	<0.1	2	8
3 Sis. N	11BVA30-216	480,344	6,438,583	MJ TSc	9	0.2	3645	6.4	>200	3.4	<0.1	3	0.4	130	3	92	19	195	0.2	5	51
<u>s</u> .	11BVA32-241	480,590	6,435,596	MJ TSf	80	<0.1	3520	0.8	6.1	0.7	0.2	<1	0.2	41	2	59	2	270	<0.1	3	15
s s	11BVA32-246	481,249	6,435,903	LT CH	<2	<0.1	144	3.8	3.2	2.7	<0.1	<1	<0.1	188	3	9	4	550	<0.1	2	15
	11BVA33-253	481,447	6,433,699	T Sv	<2	<0.1	55	6.8	1.1	0.8	0.1	5	0.2	40	1	3	2	1028	<0.1	10	124
S S	11BVA33-257	481,525	6,433,380	T Sv	14	0.4	3367	314.3	33.3	3.1	2.4	11	2.7	51	2	58	9	521	<0.1	11	123
Sie	Acme Dup	,,	,,	,,		0.3	3452	331.8	38.9	3.2	2.3	9	2.6	51	2	59	9	537	<0.1	11	122
с С	11BVA33-257Dup	,,	,,	,,	14	0.3	2925	240	31.9	4.6	2.4	8	3.1	50	2	54	7	560	<0.1	12	105
	Standard RU-1	-	-	Standard	238	3.9	7546	10.9	8.5	9.9	18.9	67	0.9	31	380	>10000	9	88	60	32	104
rds	Expected**	-	-	,,	3.10²	7	8.54·10³									2.237 ·10⁴			7·101	7·101	
nda	OREAS45C	-	-	Standard		0.2	595	2.2	1.0	2.8	0.2	11	0.8	279	24	81	23.8	35	0.2	317	100
Star	OREAS45C	-	-	,,		0.1	591	2.6	1.2	3.0	0.2	10	0.8	272	25	79	24.3	39	0.1	302	98
	Expected**	-	-	,,		0.28	620	2.26	1.06	2.9	0.21	10.1	0.79	270	24	83	24	36.4	0.15	333	104

Significant values in yellow, anomalous values in orange, slightly elevated values in blue. Abbreviations used for mineral occurrences: Gnat P. = Gnat Pass, Gnat Cr. = Upper Gnat Creek, Dalv. = Dalvenie, Gnat L. um. = Gnat Lakes ultramafite, 3 Sis. = Three Sisters, W = west, N = north, S = south. For unit abbreviations, see Table 1.

* Analyzed by lead-collection fire assay fusion followed by ICP-ES. All other elements analyzed by four-acid digestion followed by ICP-MS.

** Recommended values for CANMET standard RU-1 in bold (Faye et al., 1977). Expected values for AcmeLabs internal standard.
BC G	Table 3	(cont.)																								
eologi	eral ur.	Element Units	Cr	V ppm	Nb ppm	Y ppm	Zr ppm	Sc ppm	La ppm	Hf ppm	Ta ppm	Ce ppm	Th ppm	U ppm	Li ppm	Be ppm	Mn ppm	Ti %	Al %	Fe %	Mg %	Ca %	Na %	K %	P %	S %
cal	line	Detection limit	1	1	0.1	0.1	0.1	1	0.1	0.1	0.1	1	0.1	0.1	0.1	1	1	0.001	0.01	0.01	0.01	0.01	0.001	0.01	0.001	0.1
Sur	20	Station no.																								
vey	<u>م:</u>	11BVA5-30	63	24	2.0	2	22	1	2	0.9	<0.1	5	0.7	0.8	4	<1	23	0.08	7.7	2.5	0.1	0.1	4.09	1.82	0.01	1.6
-	nat	11BVA9-48	30	39	3.3	3	40	3	5	1.3	0.2	12	1.6	1.0	7	2	103	0.15	7.9	1.5	0.1	0.2	4.53	2.39	0.05	0.2
Dpe	ū	11JLO32-319	32	53	3.7	8	24	4	8	1.0	0.2	16	1.8	1.2	5	<1	221	0.20	7.1	1.3	0.2	0.5	2.10	5.76	0.08	0.5
э П	<u>></u>	11BVA11-62a	769	168	0.3	9	13	23	21	0.5	<0.1	41	0.2	0.4	16	<1	4597	0.22	3.9	3.9	0.7	5.0	0.03	1.75	0.10	0.1
le	Da	11BVA11-62b	299	91	0.4	2	17	10	43	0.5	<0.1	60	0.5	1.3	22	<1	336	0.08	2.9	10.2	0.1	0.0	0.03	1.02	0.04	4.0
2012-	Gnat Cr.	11BVA2-12	17	77	0.2	2	2	<1	6	<0.1	<0.1	6	0.2	7.1	10	<1	815	0.02	4.0	24.8	0.7	1.5	0.03	2.31	0.01	9.7
0	Ė	11BVA11-57	64	22	1.1	4	13	9	7	0.3	<0.1	22	1.0	0.3	17	<1	1088	0.11	3.9	1.3	1.0	0.1	0.10	1.76	0.02	0.4
	э i	11BVA11-58b	60	326	1.9	17	20	31	8	1.0	<0.1	19	0.7	0.4	4	<1	1249	0.65	7.6	6.5	3.6	5.8	3.57	0.84	0.30	0.1
	lat I	11BVA11-59	88	511	1.9	17	31	64	4	1.3	<0.1	13	0.4	0.2	3	<1	1544	1.06	5.8	13.3	6.3	7.9	1.15	0.60	0.06	1.9
	ي ا	Acme Dup																								
	at	11BVA26-184	105	333	6.0	21	24	22	14	0.8	0.4	27	2.9	1.4	2	<1	833	0.47	8.0	4.7	1.1	1.2	7.67	0.12	0.07	1.3
	Σ	11BVA26-187	499	212	1.0	10	17	51	5	0.7	<0.1	12	1.1	0.5	11	<1	1741	0.31	4.8	5.9	6.4	10.4	1.88	0.09	0.18	1.0
	Mat	11BVA25-172	27	107	4.2	6	4	<1	19	0.2	0.3	35	2.0	2.4	27	2	827	0.58	8.6	3.3	2.5	2.0	3.75	1.34	0.13	0.2
36	Pat	11BVA13-74	61	69	3.6	12	8	4	16	0.5	0.2	35	3.5	1.7	8	1	592	0.21	7.2	4.6	0.9	3.5	2.99	0.65	0.06	0.2
	, at	11BVA14-82	52	85	3.7	18	8	9	11	0.5	0.2	26	7.6	6.9	8	<1	811	0.22	6.8	3.3	0.8	0.5	2.23	3.05	0.09	<0.1
	₽S	11BVA15-90	66	18	4.0	12	17	2	20	0.6	0.3	39	7.5	2.5	6	1	162	0.13	7.1	1.6	0.4	1.0	3.63	2.82	0.05	0.5
	3 Sis. N	11BVA30-216	40	244	1.7	24	11	31	11	0.5	0.1	24	4.7	27.5	6	3	1683	0.18	5.1	22.0	2.0	3.2	1.11	0.70	0.07	<0.1
	.s	11BVA32-241	53	99	2.8	15	41	9	14	1.4	0.2	29	4.2	6.2	5	<1	627	0.26	6.6	5.4	1.9	1.6	3.53	0.09	0.07	<0.1
	с С	11BVA32-246	32	54	6.2	19	31	10	70	1.2	0.3	105	3.7	2.9	1	2	310	0.28	7.8	1.8	0.8	3.3	4.38	0.21	0.06	0.6
		11BVA33-253	36	136	5.4	21	55	17	17	1.5	0.3	34	3.8	1.1	2	1	258	0.55	9.6	7.1	2.4	4.9	3.55	0.17	0.16	2.4
	ഗ	11BVA33-257	58	180	4.1	22	57	18	15	1.6	0.2	31	2.4	2.2	5	1	1906	0.43	5.7	16.3	3.5	3.3	0.68	0.20	0.10	1.8
	Si Si	Acme Dup	59	182	4.2	22	61	17	15	1.5	0.2	32	2.5	2.3	5	1	1978	0.44	6.0	15.7	3.6	3.3	0.70	0.20	0.11	1.8
Q	(1)	11BVA33-257Dup	67	182	3.8	23	56	19	17	1.6	0.2	34	2.5	2.5	5	1	1805	0.41	5.8	15.6	3.2	3.7	0.69	0.19	0.10	1.6
soe		Standard RU-1	53	59	1.4	9	34	11	8	1.0	<0.1	17	1.2	0.8	5	<1	778	0.12	3.5	22.9	3.1	2.6	0.40	0.26	0.02	>10.0
cie	Irds	Expected**															1·10³	0.2	4.3	24.40	3.3	2.8	0.8	0.6		21.6
nce	ndê	OREAS45C	934	252	23.1	13	160	59	26	4.1	1.4	49	10.1	2.2	15	<1	1111	1.05	6.9	17.5	0.2	0.5	0.10	0.34	0.05	<0.1
BC	Sta	OREAS45C	925	239	22.9	12	173	58	25	4.2	1.5	52	10.7	2.3	15	<1	1113	1.11	7.2	18.5	0.3	0.5	0.10	0.34	0.05	<0.1
Ľ		Expected**	962	270	23.1	12.9	170	59.0	26.2	4.27	1.43	54	10.2	2.4	15.7		1160	1.131	7.59	18.33	0.25	0.48	0.097	0.36	0.051	0.02

compliant) are 30.4 million tonnes grading 0.389 % copper, including 20 % dilution with wall rock grading 0.15 % copper (Lytton Minerals Ltd., 1972, reported in MINFILE 104I 001; BCGS, 2012). The "creek zone" is exposed along the creek draining Lower Gnat Lake, about 750 m north of the lake outlet, and has not been drill tested.

Apart from minor outcrop at the hill zone and along Gnat Creek, very few exposures are present in the immediate area. Mapping conducted during this study indicates that the area is underlain by predominantly augite-phyric coherent rocks of the Triassic Stuhini group. The augite-phyric rocks are cut at several locations by altered intrusive rocks. These intrusive rocks are plagioclasephyric hypabyssal rocks (with sparse quartz and/or hornblende phenocrysts present in places), termed here the "Gnat Pass intrusive". These intrusive rocks are found both in the hill and creek zones, as well as one small outcrop along Highway 37. A U-Pb zircon crystallization age of 216.5 ± 1.4 Ma was obtained from drill core samples of the Gnat Pass intrusive. The sample was collected from diamond drill hole G-89-8 drilled vertically into the hill zone. This age implies that these intrusive rocks are part of the Late Triassic plutonic suite, and indicate a pre-216.5 Ma age for the augite-phyric coherent rocks. The Stuhini augite-phyric coherent rocks and associated intrusive rocks are overlain by a northeast-dipping sequence of conglomerate, quartz-bearing feldspathic-arenite and graphitic siltstone, as evident in the 1989 drill core (Smith and Garagan, 1990; this study). We have tentatively assigned these rocks to an Early (-Middle) Jurassic coarse-grained quartzrich sedimentary rock unit (IJ Hs, map 'a'). The contact between the Stuhini and siliciclastic rocks is generally brecciated (Smith and Garagan, 1990), and most likely

represents an unconformable contact. Assay results of 1989 drill core (Smith and Garagan, 1990) indicate that mineralization is mostly associated with the Stuhini Group and intrusive rocks; minor copper occurs in the brecciated contact zone, and only trace copper is present within the siliciclastic succession. An Induced Polarization (IP) survey (Page and Scott, 2006) indicates a significant north to north-northwest striking sub-vertical resistivity low between the creek and hill zones, and is interpreted here as a fault. In addition, the IP survey (Page and Scott, 2006) identified a significant chargeability high centred on the hill zone, likely caused by abundant disseminated sulphides in this area. The 12.5mV/V inverted chargeability contour at 40 m depth is shown on the 1:50,000 geological map.

Silicification, tourmaline veining and Fecarbonate-cemented breccias are common in the hill zone. Here, chalcopyrite and pyrite range up to several percent, occur in disseminations or fracture-fillings, and are also found within tourmaline veins and Fecarbonate cement in brecciated zones. A grab sample from subcrop of quartz and plagioclase porphyritic granodiorite on the G-89-8 drill pad returned 0.7% Cu and slightly elevated Au and Mo (sample 11JLO32-319, Table 3). Several percent of pyrite associated with possible K-feldspar alteration is found just north of the creek zone, and pyrite associated with Fecarbonate alteration is found in the small intrusion along Highway 37. Assay samples of altered intrusive rocks from both locations (11BVA09-48, 11BVA05-30) returned no significant mineralization.

Thin section study of the plagioclase±quartz-phyric hypabyssal intrusions near Highway 37 indicate the presence of a few percent disseminated pyrite and selective replacement of

plagioclase by sericite. Samples from the "hill zone" contain disseminated and fracture-hosted chalcopyrite and pyrite in plagioclase-phyric hypabyssal intrusive rocks containing weakly sericite-altered plagioclase and patchy carbonate alteration.

Dalvenie (MINFILE 104I 003)

The Dalvenie gold-copper-silver prospect is located immediately west of the Gnat Lakes ultramafite (map 'a'). The prospect was mapped, trenched and drilled in the 1960's. Results from the program indicated a 1146 m long mineralized shear zone (Dalvenie shear) with short intercepts of up to 1.5 m containing 4.8 g/tonne gold and 3.73% copper (Wetherill, 1990). The report describes a 10-15 m wide, steeply westdipping shear zone that separates the Gnat Lakes ultramafic body on the east from sedimentary and volcanic rocks on the west side of the fault zone. The shear zone contains abundant, weathered grey quartz; 5 massive cm-wide zones of pyrite, chalcopyrite and arsenopyrite; disseminated pyrite and chalcopyrite; and is locally (Wetherill, silicified 1990). Bornite, hematite. siderite. barite. magnetite. pyrrhotite and sphalerite have also been reported (MINFILE 104I 003; BCGS, 2012). A polymictic breccia zone was identified along the trace of the Dalvenie shear, and associated mineralization was sampled (Table 3). Two assay samples were taken about 2 m apart and show the highly variable metal content of the prospect. A sulphide rich sample (11BVA11-62b) returned values of 0.57 g/t Au, > 1% As, anomalous Sb and Bi and slightly elevated Cu and Ag. A pervasively silicified, sericitized and carbonate-altered sample (11BVA11-62a) contained 535 ppm As as well as slightly elevated Sb, Bi and W. Trace fine grained euhedral arsenopyrite, predominantly associated with carbonate,

was identified in a polished thin section taken from the same sample.

BCR (MINFILE 104I 068)

The BCR copper-zinc-lead-molybdenum showing is located along the abandoned BC railway grade, about 12.5 km south of Upper Gnat Lake (map 'a'). It is hosted within biotite granites and quartz-syenites mapped as the potassic phase of the Middle Jurassic Three Sisters pluton. The rocks are reported contain chalcopyrite with minor to sphalerite, galena and molybdenite in northtrending sets of fractures, locally with argillic and quartz-sericite alteration envelopes (MINFILE 104I 068; BCGS, 2012). Fifteen percussion holes with a total length of 437 m were drilled along the BC railway grade and drill roads marked 'BCR' on map 'a', and intersected predominantly granitic rocks (Dircks, 1974). Samples from drill core returned low copper (<112 ppm) and zinc values (<81 ppm; Dircks, 1974). In the current study we examined all outcrops along the BC railroad grade. Sparse outcrop within 1 to 2.5 km north and 1 km south of the drilled area are intensely iron-oxide stained and contain several percent disseminated and fracture-hosted pyrite (marked on map 'a'). Salmon pink Kfeldspar alteration developed along epidote±pyrite-filled fractures is common within the plutonic rocks of the Gnat Pass area, and locally increases in intensity to pervasive K-feldspar alteration at the BCR showing. The southernmost outcrop of granitic rocks visited along the railroad grade (map 'a') shows completely chloritealtered mafic minerals, locally abundant chlorite veins and specular hematite coated fractures. The latter outcrop appears to have suffered significant magnetite-destructive hydrothermal alteration (measured magnetic susceptibility of $0.35 \cdot 10^{-3} \pm 0.12 \cdot 10^{-3}$ SI units), and coincides with an aeromagnetic low (Aeroquest Airborne, 2012). A major

aeromagnetic (and partially, topographic) lineament immediately west of the BCR showing likely indicates the presence of a north-northwest trending brittle fault. Despite discouraging shallow percussion drill results, the large alteration footprint of this showing warrants additional investigation.

Pat (MINFILE 104I 043)

The Pat copper-molybdenum showing is centred on a drift covered valley north of peak 2196 m (map 'c'). In addition to copper \pm molybdenum soil anomalies, several small mineralized outcrops have been described to the south and southeast of the valley (Sadlier-Brown and Chisholm, 1971; Sadlier-Brown and Nevin, 1977). The mineralization reported by these authors comprises disseminations and siliceous veins carrying chalcopyrite and/or molybdenite. One mineralized outcrop identified in this study is characterized by 1-10 mm pyrite + chalcopyrite veins with silicic and potassic altered haloes. An assay sample from this location returned 0.3% Cu and slightly elevated Au and Ag (11BVA13-74 in Table 3). The veins are hosted by biotite-hornblende to hornblende-biotite quartz-monzonite and quartz-monzodiorite, which could be related to the Cake Hill pluton or Three Sisters central felsic phase intrusion. Biotite quartz-monzonite and quartz-monzodiorite, interpreted as the central felsic phase of the Three Sisters pluton, is exposed 100 m to the northeast of this mineral occurrence (map 'c').

Mat (MINFILE 104I 034)

The Mat copper-lead-zinc showings are located in a deeply incised forested valley system on the southern margin of the Cake Hill pluton, several kilometres north of the Stikine River (Figure 1, map 'f'). The area south and southwest of the showing is part

of the Stikine River Provincial Park. Poorly exposed fine-grained, stratified sedimentary rocks are found in the valleys and are overlain by more competent augite-phyric coherent rocks exposed at topographically Both higher levels (map 'f'). the sedimentary and volcanic rocks, as well as surrounding foliated hornblende diorites and gabbros, ultramafic rocks and hornblende quartz-monzonites, have been reported to host copper, lead and/or zinc sulphide occurrences (McAusland, 1971). In addition, a soil survey (McAusland, 1971) indicated moderately elevated values of nickel (>300 ppm) over part of the survey area, likely related to occurrences of ultramafic rocks. We identified several sulphide occurrences in the fine-grained sedimentary rocks, and one within the Cake Hill pluton (see "Mat north" new mineral occurrence). The mineralization within the sedimentary rocks occurs in laminated to very thinly bedded siltstones to medium-grained sandstones, and forms stratiform and more irregularshaped bodies up to 20 m wide. The sulphides occur as fine to very fine-grained disseminations, stratiform horizons and/or within veinlets. Silicification and/or quartzpyrite veins occur locally. No copper oxides, copper sulphides, galena or sphalerite were observed in the field, possibly due to their very fine grain size. Two assay samples returned no significant metal values (11BVA26-184, 187 in Table 3). Trace, very fine grained chalcopyrite inclusions in pyrite were observed in two thin sections of the assay samples.

New mineral occurrences

Nine new mineralized and/or altered zones were discovered within the Hotailuh batholith. Mineralized samples were collected and submitted for base and precious metal assay analysis. The locations have been described as 'mineral occurrences' rather than 'showings', pending their inclusion into the MINFILE database.

Triassic occurrences

Four of the new zones are hosted in probable Late Triassic rocks, and include the "Upper Gnat Creek", "Mat north", "Gnat Lakes ultramafite" and "Three Sisters south" mineral occurrences.

The "Upper Gnat Creek" occurrence is located 1.5 km south of Upper Gnat Lake, on a brush- and forest-covered ridge about 750 m east of the BC railroad grade. The occurrence comprises a 1-10 cm wide vein of massive chalcopyrite (locally widening to a 20 x 20 cm pod) within well-foliated Cake Hill plutonic rocks. The wider mineralized zone is associated with brecciated pink Kfeldspar altered wall-rocks (Figure 12). An assay sample of the massive sulphide breccia returned significant results of 1.7 g/t Au, 82 g/t Ag, >1 % Cu and 483 ppm Bi (11BVA02-12a in Table 3). A thin section of this material shows abundant massive chalcopyrite, with minor replacement by covelite and goethite. Epidote was identified in thin section, and is present within fractures in the host rock and associated with massive chalcopyrite. An outcrop containing copper sulphide-bearing veinlets was found in the same host rock about 140 m further southeast along the ridge. The host rock immediate surrounding the area of the main mineral occurrence, as well as similar intrusive rocks within approximately 1 km, contain mm to cm wide epidote veins, often associated with epidotization of the wall rock and/or iron-oxide staining. Further south in the Gnat Pass area, epidote + pyrite veins with K-feldspar alteration haloes are also found within the potassic phase of the Three Sisters pluton (see BCR showing above). Given the similar vein style, and proximity to intrusions of the potassic phase

of the Three Sisters pluton, the mineralization at "Upper Gnat Creek" may be related to Middle Jurassic intrusive activity.

The "Mat north" mineral occurrence is found on the east face of an alpine ridge, a couple of kilometres north of the Mat showing. It is hosted by the Late Triassic Cake Hill pluton, and comprises decimetresize pods containing about 5% disseminated sulphides (pyrite, bornite; chrysocolla and malachite staining common). One assay sample returned >1 % Cu and slightly elevated Ag, Au and Bi (11BVA25-172 in Table 3). Abundant coarse-grained euhedral biotite immediatelv surrounds the mineralized pods, but is absent further away in the plutonic rocks. A thin section of the assay sample shows bornite with minor chalcopyrite, both partly replaced by chalcocite \pm covelite. Feldspar in the sample is selectively altered to fine grained sericite, whereas biotite is partially altered to chlorite. The occurrence might be similar to undisclosed location described by an McAusland (1971) where bornite is found in epidote stringers within the Cake Hill pluton.

The "Gnat Lakes ultramafite" occurrences occur within, or immediately surrounding, the Gnat Lakes ultramafite. They are significant associated with spatially topographic lineaments, interpreted as faults, and might be genetically related to the Dalvenie prospect. Subcrop of intensely silicified and sericite-altered, fine-grained, Stuhini sedimentary rocks containing several percent disseminated pyrite occurs along strike of a topographic lineament (sample 11BVA11-57 in Table 3). Several ultramafic outcrops contain disseminated pyrite, either directly within ultramafic rocks or associated with later crosscutting felsic dikes (samples 11BVA11-59 and -58b,



Figure 12: Mineralization at "Upper Gnat Creek". Intensely pink-orange K-feldsparaltered and brecciated plutonic rock clasts within massive chalcopyrite matrix. Pencil for scale.



Figure 13: View south towards westernmost peak hosting the Three Sisters fine-grained mafic-intermediate phase, showing orangebrown altered zone of the "Three Sisters" mineral occurrence and small associated copper showings. The orange-brown zone is intensely goethite-stained, contains abundant disseminated pyrite and pyrite in steeply dipping, west-northwest-striking fractures. The Three Sisters central felsic phase (TSc) is exposed along the ridge in the foreground. Light coloured scree below this peak may be an inclusion of the Cake Hill leucocratic phase (CHI). respectively). Thin sections of all three assay samples contain predominantly pyrite and trace (microscopic) chalcopyrite. Only one of three samples assayed (11BVA11-59 in Table 3) returned slightly elevated copper values. Sulphides generally occur interstitially within domains of predominantly mafic minerals. In addition, the easternmost exposures of the ultramafic body contain several percent sulphides where they are associated with another north-trending topographic lineament, possibly part of the Gnat Pass fault system.

The "Three Sisters south" mineral occurrence is hosted in a km-size Stuhini inclusion within the leucocratic phase of the Cake Hill pluton (LT CHl in Table 1, map 'g'). Mineralization consists of several zones with 1-5% pyrite disseminated and in veinlets, locally associated with green actinolite. The linear and recessive nature of the gullies suggests that the <20 m-wide pyritic zones represent NNW to NE-striking sub-vertical faults cutting the Stuhini succession. One of two assay samples (11BVA33-257 in Table 3) returned 0.3 % Cu, 0.03 % Mo and slightly elevated W. Thin sections of the assay samples contain pyrite and trace chalcopyrite (11BVA33-253) or pyrite, minor chalcopyrite and minor possible bornite (11BVA33-257). Actinolite is present as veins or pervasive replacement in both samples, with chlorite and epidote also abundant in the mineralized sample (11BVA33-257).

Middle Jurassic occurrences

The remaining four new zones, the "Pat west", "Three Sisters", "Three Sisters north" and "BCR north" mineral occurrences, are hosted in Middle Jurassic intrusive rocks of the Three Sisters pluton. One new mineral occurrence at "Red Mountain" is hosted in Early-Middle Jurassic fine-grained sediments, and most likely formed by contact metamorphism associated with Middle Jurassic Three Sisters intrusive activity.

The "Pat west" occurrences are sub-vertical, roughly east- to northeast-trending zones hosted in the Three Sisters pluton, and are spread over the entire local map area (map 'b'). A one-metre-wide zone exposed on the easternmost ridge contains quartz + pyrite \pm chalcopyrite veins hosted in biotite quartzmonzonite and quartz-monzodiorite of the central felsic phase, and returned assav values of 0.7% Cu (11BVA14-82). A thin section of this vein material contains trace chalcopyrite. The sample is pervasively potassic altered, feldspars are selectively sericitized, and mafics are completely altered to chlorite. The central and western gossanous exposures are larger in areal extent (30-50 m wide, >200-300 m long), contain disseminated pyrite and/or quartz + pyrite veins, and lack copper sulphides. An assay from the latter location (11BVA15-90) failed to return any anomalous values. A thin section of this material shows pyrite, trace chalcopyrite and only partly chloritized mafic minerals.

The "Three Sisters" occurrences are named after the group of peaks on which the finegrained mafic-intermediate phase of the Three Sisters pluton is exposed (map 'g'). The mineral occurrences are found within the northern margin of the fine-grained mafic-intermediate phase, and within the adjacent central felsic phase and leucocratic Hill pluton. A brown-orange Cake weathering gossan zone, up to 200 m-wide and 2 km-long, is exposed within the Three Sisters central felsic phase close to contact with the fine-grained mafic-intermediate phase (Figure 13). The alteration zone contains abundant WNW-striking and steeply north-dipping goethite-coated fractures after pyrite, and pyrite is also

disseminated throughout the host rock. Three small exposures with quartz + pyrite \pm chalcopyrite \pm epidote veins, locally associated with in-situ brecciation, are found several hundred metres to the south and southwest of this zone and are hosted in the fine-grained mafic-intermediate phase. One assay sample from the latter location (11BVA32-241) returned 0.35% Cu and slightly elevated Au. The sample is cut by early epidote + chlorite veins, and late quartz + chlorite \pm actinolite veins causing local in-situ brecciation. An assay sample from the eastern part of the gossanous pyrite (11BVA32-246) returned zone no anomalous values.

The "Three Sisters north" occurrence is hosted within the Three Sisters central felsic phase. The rocks are intensely veined (roughly 5% veins by volume in a several metre wide interval), with one 10 cm-wide ESE-oriented, steeply north-dipping, epidote + actinolite + magnetite vein. The assay results for this vein indicate 0.36% Cu, >200 ppm W and slightly elevated U (11BVA30-216 in Table 3). A thin section from this vein contains massive magnetite, actinolite, tourmaline and trace apatite.

The "Red Mountain" occurrence is a $>1 \text{ km}^2$ zone with 1-5% very fine grained disseminated and minor stratiform pyrite within Lower (-Middle?) Jurassic siltstones (IJ Hs). The whole area is intensely ironoxide altered. The alteration is centered on the peak located 1 km southeast of Peak 2102 m (map 'h'). One 5 x 30 m NW-SE elongate, steeply SW dipping, grey to white coloured unmineralized breccia body (pipe?) crops out on the upper southwest flank of the above-mentioned peak (see also Figure 4). The breccia body comprises abundant clast-supported, matrixto cm-sized, angular-subround, plagioclase-phyric clasts within a highly silicified matrix. Common, unmineralized, calcic endoskarn bodies are found in Lower-Middle Jurassic calcareous siltstones within about 20 m of the contact with the Late Triassic Cake Hill quartz-rich phase (LT CHq). Given the age relationship implied by geochronology and biostratigraphy, the skarns likely formed by fluid movement along a permeable fault or non-conformable contact, and originated from the underlying intruding Middle Jurassic Three Sisters pluton.

The "BCR north" occurrence is situated on the BC railroad grade 7 km south of Upper Gnat Lake. It is associated with irregular bodies of potassic(?)-altered hornblendefeldspar porphyry (Tees Creek intrusive, see Table 1) intruding a highly magnetic biotitebearing hornblende syenite (representing a sub-phase of the Three Sisters potassic phase, MJ TSpm). Minor pyrite is evident in this location, disseminated in both the fringes of the Tees Creek and adjacent intrusive.

DISCUSSION AND CONCLUSIONS

Geological units

The Hotailuh batholith comprises a number of different plutons and plutonic phases. A compilation of crosscutting relationships and previously published and newly reported zircon U-Pb and Ar-Ar dates is shown in Figure 14. The Hotailuh batholith can be subdivided into three plutonic suites, a Late Triassic Stikine plutonic suite (ca. 225-209 Ma), Early Jurassic McBride pluton (ca. 192-176 Ma) and the Middle Jurassic Three Sisters plutonic suite (ca. 175-168 Ma).

The Late Triassic plutonic suite comprises the Gnat Lake ultramafic to mafic bodies, Cake Hill felsic pluton and Beggerlay Creek ultramafic to mafic pluton. The absence of



Figure 14: Compilation diagram showing all U-Pb and Ar-Ar geochronological data from the Hotailuh batholith.

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equivocal crosscutting relationships, lack of absolute crystallization age determinations for the ultramafic to mafic intrusions, and the absence of detailed mineral chemistry data makes it difficult to determine the genetic and temporal relationships between the different Late Triassic intrusions. The Gnat Lakes ultramafic body lacks orthopyroxene, and can be classified as an Alaskan-type intrusion comprising cumulates derived from a relatively silica undersaturated (alkaline to subalkaline) parental magma (Irvine, 1967; 1974; Nixon et al., 1997). In contrast, the Beggerlay Creek pluton includes a >2 km² websterite body interpreted here as cumulates derived from silica saturated (calc-alkaline) parental magma (Irvine, 1967; 1974; Nixon et al., 1997). The calc-alkaline magma that produced the Beggerlay Creek cumulates by fractional crystallization evolved into more compositions. which felsic may be represented by the Cake Hill pluton.

The Late Triassic plutonic suite is spatially associated with, and in places intrudes, poorly exposed and poorly dated, intermediate-mafic volcanic and sedimentary rocks of the Triassic Stuhini group (Figure 15).

The Early Jurassic plutonic suite comprises the McBride River felsic pluton exposed on the easternmost edge of the batholith, and was not studied here. The McBride pluton has not been dated in this study. It may be related to the Texas Creek plutonic suite exposed further southwest near Stewart and the Iskut River (Anderson and Bevier, 1990; Logan *et al.*, 2000), and remains a highpriority target for future geochronology studies in the area.

The Three Sisters pluton comprises at least four phases, namely the fine-grained maficintermediate phase, a mafic phase, central felsic phase, and a crosscutting potassic phase. U-Pb zircon crystallization ages and Ar-Ar cooling ages confirm that all phases formed during a relatively short time span in the Middle Jurassic (Figure 14).

Northwest of Lower Gnat Lake, a granitoid clast-bearing conglomerate nonconformably overlies the Cake Hill pluton, and is correlated with Lower (-Middle) Jurassic, quartz-bearing. coarse-grained sedimentary rocks reported within the immediate area. The latter are overlain by rocks previously assigned to the Triassic Stuhini group (Anderson, 1983; Gabrielse, 1998) that in light of new U-Pb detrital zircon data are reinterpreted here as Middle Jurassic sedimentary and volcanic rocks (Iverson et al., 2012; Iverson, 2012; Figure 15). Evidence for the presence of the Hotailuh thrust in the present study areas is lacking. The Lower to Middle Jurassic sedimentary and volcanic successions studied herein (maps 'a', 'h') are part of a belt of rocks exposed on the north and northeastern margin of the batholith. The Lower Jurassic rocks have previously been assigned to the Takwahoni formation, a formation predominantly composed of greywacke, siltstone, shale, conglomerate and minor limestone exposed in the footwall of the King Salmon thrust fault (Gabrielse, 1998). However, another important Lower to Middle Jurassic unit in Stikinia is the Hazelton group, a succession of volcanic sedimentary rocks. Following and definitions by Marsden and Thorkelson (1992), and in light of the new U-Pb detrital zircon dates (Iverson et al., 2012; Iverson, 2012), the entire succession of volcanic and sedimentary rocks around peak 2096 m (map 'a') is reassigned to the Hazelton group. In addition, the entire belt of rocks along the north and northeastern margin of the batholith may be part of the Hazelton group.

221±3(Z)

Jurassic Hazelton Group (northwest area)

Volcanic rocks (ImJ Hv)

Coarse-grained sedimentary rocks (ImJ Hsc) Fine-grained sedimentary rocks (ImJ Hs) Coarse-grained sedimentary rocks (ImJ Hsc) Fine-grained sedimentary rocks (ImJ Hs)

Coarse-grained quartz-bearing sedimentary rocks (IJ Hs)

Cake Hill pluton (LT CH)

216±1

Triassic Stuhini Group (all areas)

Augite-phyric coherent rocks (T Sv)

Gnat Pass intrusive (LT GP)

Fine-grained sedimentary rocks (T Ss)

Jurassic Hazelton Group (east area)



 ② U-Pb zircon age (this study; Anderson and Bevier, 1992)
 ③ Detrital U-Pb zircon age (Iverson et al., 2012; Iverson, 2012)
 ⑦ Fossil location (Gabrielse, 1998)

Figure 15: Overview diagram showing all stratified lithologies.

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Mineralization

The Gnat Pass area appears especially well endowed with mineral occurrences. In addition to the mineral occurrences described here, many other showings are present just outside of map area 'a'. Examples are Louise (MINFILE 104I 054), Bell (MINFILE 104I 033), Moss (MINFILE 104I 029), Kay 19, 49 (MINFILES 104I 037, 026), and Crown (MINFILE 104I 046). The latter three comprise the Pliny project that is currently under exploration by West Cirque Resources (2011a). The area is cut by the north-northwest-trending Gnat Pass ductile shear zone and similarly trending brittle faults. The shear zone likely formed during emplacement of the Cake Hill pluton in the Late Triassic and was the locus of subsequent brittle faulting. These structures likely played an important role in the introduction of magmas, fluids and associated mineralization in the Gnat Pass area.

Mineralization hosted in Late Triassic rocks varies widely in host rock, metal tenor and mineralization style and comprises:

- Cu only at the Gnat Pass porphyry-style prospect;
- Au+As±Sb (Cu, Ag reported) hosted in a shear/fault zone at the Dalvenie prospect;
- Cu±Mo pyritic fault zones cutting a roof pendant or inclusion of Stuhini volcanics within the Cake Hill pluton at "Three Sisters south";
- Cu with trace Ag as small bodies within the Cake Hill pluton at "Mat north";
- Cu+Pb+Zn (reported) within stratabound to irregular bodies at the Mat showing;

Two mineral occurrences hosted in Late Triassic rocks that may in fact be related to Middle Jurassic magmatism include:

- Au+Cu+Ag massive chalcopyrite vein in felsic plutonic rocks at the newly discovered "Upper Gnat Creek" mineral occurrence, but similar alteration and mineralization to the BCR showing may indicate a Middle Jurassic age for this mineralizing event; and
- Cu (and Mo reported) at the vein-hosted Pat showing, found within the Late Triassic Cake Hill pluton, but close association with the Three Sisters pluton indicates a possible Middle Jurassic age for this mineralizing event.

Mineralization hosted in the Three Sisters pluton appears less variable, and comprises:

- Cu only at the "Pat west" and "Three Sisters" mineral occurrences;
- Cu±W at the "Three Sisters north" mineral occurrence; and
- Cu+Zn+Pb+Mo reported at the BCR showing.

Possible metal zonation is present in both "Pat west" "Three Sisters" the and occurrences, with relatively large. gossanous, pyrite-dominated zones spatially associated with smaller quartz-vein-hosted, pyrite + copper sulphide occurrences. Assay samples indicate 0.3-0.7% Cu in the coppersulphide-bearing zones, and Cu±W in the possibly related "Three Sisters north" occurrence

Geological history

In this section we will discuss the results of this study in light of the broader geological and tectonic framework of northwestern British Columbia.

The Hotailuh batholith provides a unique example of coincident Mesozoic magmatism formed during multiple magmatic episodes spanning the Late Triassic to Middle Jurassic periods. All investigated intrusive phases have a strong calc-alkaline subduction-modified subcontinental mantle geochemical signature, and formed in a volcanic island arc to continental volcanic arc setting (sensu Maniar and Piccoli, 1989).

The Cake Hill pluton is part of the Late Triassic Stikine plutonic suite, which occurs throughout northern Stikinia (Figure 1a). Several large Late Triassic batholiths occur towards the east (Stikine and Pitman batholiths, Anderson, 1984; Read and Psutka, 1990), west (Moosehorn and Sam batholiths around the Golden Bear deposit, Bradford and Brown, 1993), and southwest (Hickman batholith, Brown et al., 1996). Late Triassic magmatism is generally attributed to westward inboard subduction of the Cache Creek ocean below Stikina (English and Johnston, 2005), but eastward outboard subduction may also have occurred at the same time (Figure 16; MacIntyre et al., 2001).

Latest Triassic intrusive activity in northern Stikinia produced relatively small ca. 210 Ma alkaline feldspathoid-bearing intrusions hosting the Galore Creek Cu-Au porphyry deposit (Mortensen *et al.*, 1995), as well as the slightly younger quartz-absent to quartzbearing 207-204 Ma Groat stock and 205-202 Ma Red stock (host to the GJ and Red Chris Cu-Au porphyry deposits, Ash *et al.*, 1997; Friedman and Ash, 1997; Norris *et al.*, 2011; Hollis, 2011). To date, similar age equivalent rocks have not been identified in the Hotailuh area.

The Early Jurassic McBride River pluton (Anderson and Bevier, 1992) is found on the eastern margin of the Hotailuh batholith. Other Early Jurassic plutons are predominantly found between Stewart and Telegraph Creek, and comprise the Texas Creek and Cone Mountain plutonic suites (Alldrick, 1991; Brown et al., 1996). These intrusions may represent a northern extension of the Coast Mountain plutons (Woodsworth et al., 1991), which formed prior to outboard accretion with the insular terranes (Gehrels, 2001), and a further outboard jump of the subduction zone. Other than the McBride River pluton, only a few Jurassic intrusions have been Early recognized closer to Dease Lake. Notable are the McEwan Creek intrusions east of Iskut (U-Pb zircon age 183.5±0.5 Ma. Evenchick and Thorkelson, 2005 and references therein).

Several Middle Jurassic plutons have been described in northern Stikinia, however most intrusions have only been dated using the technique. Significant older K-Ar geochronological improvements in techniques over the last decades have clearly shown that these earlier-established dates represent minimum age estimates. Notably, the Yeheniko pluton (part of the Hickman batholith to the southwest) was previously interpreted as Middle Jurassic based on several biotite and hornblende K-Ar ages (Brown et al., 1996 and references therein). However, recent U-Pb zircon age dating suggests that the pluton, which is associated with porphyry copper mineralization at Schaft Creek, is Late Triassic in age (Scott et al., 2008). Middle Jurassic plutons are described around the Stikine and Pitman batholiths. but are based on K-Ar biotite/hornblende dates, and need further work to confirm the true crystallization age. During the Middle Jurassic, the Stikine and Quesnel island arc terranes accreted with the



Figure 16: Schematic drawing of possible Late Triassic to Middle Jurassic plate tectonic arrangement, magmatism and associated mineralization. Modified after Mihalynuk et al. (1992), Ricketts et al. (1992), Nelson and Mihalynuk (1993), Mihalynuk et al. (2004), English and Johnston (2005). Abbreviations: ST = Stikinia; CC = Cache Creek; QN = Quesnellia; C-Alk = predominantly calc-alkaline magmatism; Alk = predominantly alkaline magmatism.

North American continent, and enclosed the Cache Creek oceanic terrane (Gabrielse, 1991; Nelson and Mihalynuk, 1993). The completion of the Stikinia - Cache Creek accretionary event (obduction of blueschist metamorphic rocks and intrusion by post tectonic granites) is well constrained as Bajocian (Ricketts et al., 1992; Mihalynuk et al., 1994; 2004). The Three Sisters pluton described here has a similar age and geochemical signature as the Fourth of July pluton that cuts deformed rocks of the Cache Creek terrane (U-Pb zircon ages of 170.4±5.1 Ma, 171.5±3.4 Ma, Mihalynuk et al., 1992), and appear to define a northwest to east-southeast trend of Middle Jurassic. ca. 175-165 Ma, plutons (Figure 1a). Since the Fourth of July pluton is post-kinematic and post-accretion, these plutons formed by eastward outboard subduction below the now-accreted Stikine and Quesnel island arc terranes (Figure 16).

Implications for exploration

The Hotailuh batholith and its environs are highly prospective for intrusion-related magmatic-hydrothermal mineralization, to have formed during at least two magmatic episodes in the Late Triassic and Middle Jurassic. This is indicated by the high known intrusion-related number of MINFILE occurrences and prospects, as well as new mineral occurrences, found peripheral to the main batholith and along contact zones between different magmatic phases within the batholith. The batholith has the same age, chemical composition and tectonic environment as intrusions hosting large precious and base metal deposits within northern Stikinia. The 2275 km² batholith proper is prospective for plutonhosted Cu±Mo±Au deposits associated with late-stage calc-alkaline porphyry intrusions (e.g. similar to Highland Valley), provided the plutons have not been eroded beyond ~3-6 km (Singer et al., 2008). The country rocks are prospective for volcanic and/or sedimentary rock-hosted Cu±Mo±Au deposits associated with high-level calcalkaline porphyry intrusions (e.g. similar to Schaft Creek). Small volume Latest Triassic alkalic (to calc-alkalic) intrusions with potential for porphyry Cu-Au deposits (e.g. similar to Galore Creek, Red Chris, GJ) were not identified during this study, but their relatively small alteration footprint and intermittent presence throughout the Stikine Ouesnel terrane justifies further and attention. Both the Late Triassic and Middle Jurassic magmatic episodes are associated with both pluton- and country rock-hosted copper and/or gold mineral occurrences, which, in many cases are compatible with a porphyry-style deposit type. At Gnat Pass, we dated a plagioclase (±quartz) porphyry stock associated with disseminated, veinand breccia-hosted copper mineralization, yielding a Late Triassic age. The developed prospect has a similar age, geological setting and mineralization style as the Schaft Creek porphyry Cu±Mo±Au deposit (cf. Scott et al., 2008). North of the Hotailuh batholith, West Cirque Resource's (2011b) Tanzilla project comprises a ~7 km long trend of altered and mineralized rocks associated with possible Middle Jurassic (Gabrielse, 1998) porphyry dikes. Both the Gnat Pass and Tanzilla project, as well as the newly described mineral occurrences (this study), confirm the potential for intrusion-related magmatic-hydrothermal mineralization during at least two magmatic episodes of the Hotailuh batholith. The Early Jurassic McBride intrusion was not studied here, but abundant showings located south and east of the intrusion warrant additional investigation regarding the timing and mineralization style of these occurrences.

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APPENDICES

Texture

Foliated Cumulate Cumulate

Cpx-Plag porph.

Cumulate

Cumulate

Fsp porph.

Срх Орх

40 50 50

15

8

5

10

15

5

4

12 12

18

8 4 4

12 12

16 5 11

5 5?

5 5

7 7

60 45

50 42

40 35

30

5

60 60

60 60

4

24

15 15

5

6 12

Bt partly Chl

Fresh Hbl

Trace Chl

(Cpx -> Hbl)

+/- Chl (Cpx -> Hbl)

(Cpx -> Hbl)

+/- Bt partly Chl

+/- Bt partly Chl

+/- Bt mostly Chl

+/- Chl, Ep present (Cpx -> Hbl)

++

-

+/- Bt partly Chl, minor Ep

Ser, turbid

+/- Minor Ser

+/- Minor Ser

++

+

Turbid

Turbid

++ Ser, turbid

++ Ser, turbid

Ser, turbid, Ep?

Some Ser, turbid

+/- Turbid, minor Ser

Sample no		Sample I	ocation		Sample description*	Alte	eration**			Maf	ic mi	neral	vol. %
Geochem.	Original	UTME	UTM N	Unit	Rock type	Fel	dspar	Ма	fic minerals	М	Hbl	Bt	Срх
62187	11BVA-04-24a	449,423	6,446,393	MJ TSp	Bt-bearing Hbl S	+/-	Turbid	-		15	13	2	
62188	11BVA-05-34b	448,764	6,444,221	MJ TSp	Bt-bearing SGr	+/-	Turbid	-		5	1	3.5	
62189	11BVA-06-39	450,377	6,454,968	LT CH	Hbl-Cpx QMz	+/-	Turbid	-	(Cpx -> Hbl)	15	6		9
62190	11BVA-09-52	448,964	6,450,050	LT GL	Plag-bearing hornblendite	+	Ser, turbid	+/-	Locally Chl	80	80		
62191	11BVA-11-60a	449,254	6,449,987	LT GL	Plag-bearing hornblendite	+	Ser, turbid	+/-	Partly Chl	87	87		
62192	11BVA-12-68a	465,787	6,447,921	MJ TSm	Bt=Cpx=Hbl QD	-		-		30	10	10	10
62193	11BVA-14-83	467,589	6,447,538	MJ TSc	Bt-Hbl QMd	+	Ser, turbid	+	Chl	18	10	8	
62194	11BVA-15-84	466,882	6,449,220	LT CH	Hbl QMd	+/-	Turbid	-		12	12		
62195	11BVA-15-89b	466,278	6,448,139	MJ TSp	Bt-bearing SGr	+/-	Turbid	+/-	Minor Chl	6	1	5	
62196	11BVA-16-97	470,019	6,448,963	MJ TSp	Bt-bearing SGr dike (cuts LT CH)	+/-	Turbid	+/-	Partly Chl	3		3	
62198	11BVA-16-97b	470,019	6,448,963	MJ TSm?	Bt-Cpx Hbl-rich QD	+/-	Turbid	+/-	Partly Chl	40	20	8	12
62199	11BVA-16-97c	470,019	6,448,963	LT CH	Bt-bearing Hbl QMd-Md	+	Minor Ser, turbid	+	Chl, some Ep	12	9	3	
62200	11BVA-17-105	470,972	6,448,720	LT CH	Bt-Hbl QMd	+	Ser, turbid	+	Chl	20	14	6	
62201	11BVA-18-112	464,327	6,444,251	≤LT AP dike	Cpx Hbl-rich diabase dike (cuts LT CH)	+/-	Turbid	-	(Cpx -> Hbl)	40	30		10
62202	11BVA-18-114	464,615	6,444,138	LT CH	Hbl QMz	+/-	Turbid	-		17	17		
62203	11BVA-18-117	465,432	6,442,450	MJ TSp	Pink Bt-Fsp porph. dike (cuts LT CH)	++	Turbid	+	Chl	1		1	
62204	11BVA-20-130b	471,886	6,438,030	LT CH	Bt-bearing Hbl QMd	+/-	Turbid	+/-	Bt partly Chl, Hbl fresh	18	16	2	
62205	11BVA-20-131	471,861	6,438,215	MJ TSm	Bt Hbl-rich QD	+	Ser, turbid	-		38	30	8	
62206	11BVA-21-134	472,659	6,436,308	MJ TSc	Cpx-Hbl-bearing Bt QD	+/-	Minor Ser, turbid	-		16	4	8	4
62207	11BVA-22-142	473,559	6,436,426	MJ TSc	Bt-Hbl QMd	-		+/-	Bt mostly Chl, Hbl fresh	20	14	6	
62208,9	11BVA-23-152	472,774	6,435,676	MJ TSp	Hbl-bearing Bt QMz-MGr	+/-	Turbid	+/-	Bt partly Chl, Hbl fresh	15	5	10	
62210	11BVA-24-163	462,745	6,428,368	LT BCc	Plag-bearing clinopyroxenite	+	Ser	+/-	Minor Chl	95			95
62211	11BVA-26-182	462,425	6,428,895	LT BC	Hbl Cpx-rich gabbro	+	Ser	+	Partly Chl	55	10	5	40
62212	11BVA-27-193	460,851	6,429,233	LT BCw	Websterite			++	Opx completely Serp	100			50
62213	11BVA-29-205	454,926	6,455,096	LT CH	Hbl QMz-MGr	+/-	Turbid	-		12	12		
62214	11BVA-30-215	480,345	6,438,923	MJ TSc	Hbl=Bt QMz	+/-	Turbid	+/-	Bt partly Chl, Hbl fresh	18	9	9	
62215	11BVA-30-220	480,067	6,437,062	MJ TSc	Hbl-bearing Bt MGr	+/-	Turbid	-		12	5	7	
62216	11BVA-31-232	478,755	6,434,626	MJ TSp	Hbl-Bt-bearing MGr	+/-	Turbid	+/-	Bt partly Chl	7	3	4	
62217	11BV/A-32-242	480 361	6 435 736	MITSF		+/-	Turbid			22	10	12	

* Abbreviations: D = Diorite, QD = Qtz-Diorite, T = Tonalite, Md = Monzodiorite, QMd = Qtz-Monzodiorite, Gd = Granodiorite, Mz = Monzonite, QMz = Qtz-Monzonite, MGr = Monzogranite, S = Syenite,

QS = Qtz-Syenite, SGr = Syenogranite, porph. = porphyritic, -> = partly replaced by, mineral abbreviations after Kretz (1983) ** Alteration: - unaltered, +/- weakly, + moderately, ++ significantly altered; Turbid = turbid appearance of Fsp in PPL, Ser = Sericitized, Chl = Chloritized, Serp = Serpentinized, Ep = contains epidote

Hbl-Bt QD

Bt=Hbl MGr

Hbl QMd-Gd

Hbl Gd-MGr

Bt-bearing SGr

Bt-bearing SGr

Hbl-rich QD

Hbl-rich D

Hbl=Bt QD

Hbl QMz

Hbl-bearing Bt QMz-MGr

Hbl(?)-bearing Gd

Hbl-bearing Gd-MGr

Cpx Hbl-rich gabbro

Cpx Hbl-rich gabbro

Cpx-bearing Hbl-rich gabbro

Hbl-bearing Cpx-Bt QMd

62218

62220

62221

62222

62223

62224

62225

62226

62229

62230

62231

62232

62233

62234

62235

62236

62227,8

11BVA-32-244-a1

11BVA-34-263

11BVA-34-264

11BVA-35-276

11BVA-35-283

11BVA-38-304

11BVA-38-305

11BVA-27-199

11BVA-42-327

11BVA-42-328

11BVA-42-329

11BVA-42-330

11BVA-42-331

11BVA-42-332

11BVA-42-333

11BVA-40-317-a1

11BVA-40-317-a2

481,062

480,909

480,833

480,640

482,014

481,362

482,467

450,388

450,388

462,983

466,259

466,358

466,997

473,470

473,504

479,794

463,692

6,435,808

6,434,221

6,439,273

6,439,991

6,438,806

6,455,942

6,455,942

6,427,463

6,447,899

6,447,975

6,448,398

6,438,370

6,438,444

6,436,014 MJ TSf

6,431,161 LT CH

6,433,125 LT CHI

6,439,937 LT CHq

MJ TSf

LT CHI

MJ TSc

LT CHq

LT CHq

LT GL

LT BC

MJ TSc

MJ TSp

MJ TSm

MJ TSm

MJ TSp

LT GLm

Appendix 2: Major, minor and trace element data of lithogeochemistry samples

Analuto	symbol	SiO	AL-O		MnO	MaO	C20	Na.O	K.O	TiO.	P.O.	1.01	Total
Analyte	symbol	SIO ₂	AI ₂ O ₃	Fe ₂ O ₃		NIGO	CaO %	Na ₂ O	K2U	11O ₂	P ₂ O ₅	LOI %	10tai
Detectio	n limit	/0	/0 0.01	0 01	/0 0.001	/0	/0	/0	/0 0.01	/0 0.001	/0 0.01	/0	/0
Analytical	mothod*											E-ICP	
Sample no	Unit	1-101	1-101	1-101	1-101	1-101	1-101	1-101	1-101	1-101	1-101	1-101	1-101
62187	MJTSp	61 58	16 77	4 91	0.08	0.73	2 14	4 73	5 69	0.45	0 11	0.66	97 85
62188	MJTSp	74 71	13 41	1 78	0.03	0.34	1 13	3.81	4 77	0.20	0.06	0.40	100.60
62189	LT CH	62.08	18.84	3.40	0.08	0.84	3.75	6.05	3.58	0.36	0.15	0.40	99.55
62190	ITG	37.87	10 75	20.64	0.21	9.94	12 48	1 76	1.03	2 23	1.58	1.56	100.00
62191	LT GL	40.50	9.17	19.57	0.26	10.93	13.51	1.51	0.86	2.07	0.96	0.86	100.20
62192	MJ TSm	55.84	17.37	8.20	0.19	3.33	7.14	3.48	2.20	0.75	0.24	0.70	99.43
62193	MJ TSc	57.02	15.31	7.64	0.17	2.94	5.57	3.31	2.99	0.75	0.26	1.77	97.74
62194	LT CH	65.34	17.26	3.40	0.07	1.21	3.18	5.92	2.43	0.40	0.17	0.50	99.88
62195	MJ TSp	69.98	14.22	2.53	0.03	0.53	1.78	3.79	4.15	0.23	0.09	0.56	97.90
62196	MJ TSp	72.84	14.16	1.83	0.03	0.27	1.76	3.18	4.78	0.19	0.04	0.45	99.54
62198	MJ TSm?	49.50	18.24	11.47	0.22	4.67	9.62	3.49	0.90	0.85	0.14	0.67	99.77
62199	LT CH	57.12	19.39	5.01	0.11	1.50	5.94	4.60	3.02	0.58	0.30	1.19	98.75
62200 #	LT CH	58.75	16.61	6.64	0.13	2.31	5.71	3.68	3.12	0.62	0.22	0.76	98.55
62201	≤LT AP dike	48.86	16.01	11.28	0.21	5.48	10.78	2.60	1.37	0.88	0.20	1.06	98.73
62202	LT CH	64.26	15.99	4.46	0.09	1.68	3.97	4.78	3.21	0.51	0.23	0.56	99.73
62203	MJ TSp	70.80	15.55	2.33	0.04	0.33	0.64	4.71	5.02	0.27	0.06	0.53	100.30
62204	LT CH	60.67	17.01	6.92	0.14	2.15	5.57	3.93	2.72	0.53	0.24	0.58	100.50
62205	MJ TSm	53.99	17.08	8.56	0.15	3.51	7.16	3.20	2.33	0.80	0.24	1.11	98.14
62206 #	MJ TSc	60.11	17.28	6.04	0.15	1.98	4.71	4.13	3.56	0.65	0.29	0.53	99.44
62207	MJ TSc	56.08	18.76	7.64	0.15	2.92	6.09	4.04	2.52	0.71	0.29	1.55	100.80
62208,9 ##	MJ TSp	65.41	16.36	4.53	0.09	1.07	2.59	3.57	5.27	0.53	0.21	1.08	100.70
62210	LT BCc	42.79	7.59	17.93	0.21	10.47	15.46	1.12	0.95	1.10	0.23	1.14	98.99
62211	LT BC	48.99	13.60	10.94	0.21	6.42	10.95	2.59	3.68	0.76	0.71	1.25	100.10
62212	LT BCw	45.14	1.11	8.26	0.13	26.50	11.88	0.09	0.03	0.15	0.03	6.30	99.61
62213	LT CH	67.64	15.70	2.96	0.07	1.08	2.77	4.86	3.50	0.34	0.14	0.45	99.52
62214	MJ TSc	62.05	16.28	5.80	0.12	1.29	3.25	4.11	4.69	0.60	0.29	0.72	99.20
62215	MJ TSc	70.29	14.64	2.76	0.08	0.73	2.35	3.89	4.18	0.28	0.10	0.51	99.81
62216	MJ TSp	70.12	14.49	2.76	0.07	0.62	2.02	3.92	4.01	0.26	0.08	0.60	98.95
62217 #	MJ TSf	62.28	16.32	5.87	0.15	1.95	4.56	4.12	2.96	0.61	0.22	0.80	99.84
62218	MJ TSf	63.57	16.95	5.46	0.14	1.76	4.13	4.09	2.97	0.59	0.22	1.00	100.90
62220	LT CHI	71.21	14.64	2.26	0.03	0.67	2.49	3.57	4.04	0.26	0.09	0.53	99.81
62221 *	LT CHI	64.43	16.77	3.77	0.06	1.29	3.27	5.73	2.76	0.35	0.18	0.61	99.23
62222	MJTSc	67.33	15.18	4.04	0.09	0.73	2.26	3.96	4.97	0.41	0.14	0.60	99.71
62223	LT CHq	69.26	15.95	2.21	0.03	0.31	1.89	5.76	3.20	0.27	0.10	0.45	99.44
62224	LICHQ	/0.//	15.86	2.05	0.04	0.53	1.72	5.94	3.01	0.22	0.08	0.27	100.50
62225	LICHQ	69.38	15.75	2.50	0.04	0.65	2.02	5.59	3.23	0.26	0.10	0.44	99.96
62226		40.55	15.53	15.31	0.25	6.62	12.93	2.16	1.72	1.47	1.23	1.96	99.72
62227,8 ***		40.98	16.30	14.20	0.24	6.18	13.10	2.23	1.65	1.38	1.18	1.68	99.11
62229	LIBC	49.08	18.66	9.30	0.24	3.62	8.74	3.09	3.68	0.78	0.80	2.00	99.97
62230	IVIJ I SC	54.01	16.59	9.17	0.19	3.81	8.16	3.45	1.00	0.88	0.16	0.56	98.64
62231	IVIJ I SP	70.84	14.00	2.70	0.03	0.50	1.//	3.66	4.08	0.24	0.07	0.54	98.42
62232	MUTOW	50.00	16.96	11.81	0.24	5.15	9.81	2.91	1.47	0.99	0.16	0.87	100.40
62233 "	IVIJ I SM	45.94	10.30	15.38	0.17	5.40	9.82	2.92	0.43	1.25	0.15	1.48	99.30
02234	IVIJ I SP	13.21	14.13	1.93	0.02	0.33	1.30	3.09	5.13	0.19	0.04	0.23	100.20
02230		00.30	17.07	0.21	0.14	2.19	4.75	4.27	3.00	0.04	0.24	0.49	99.42
62236	LI CH	64.14	16.87	4.51	0.11	1.//	3.83	5.10	3.24	0.51	0.23	0.61	100.90

* Analytical methods: F-ICP = Fusion ICP; F-MS = Fusion ICP-MS; INAA; TD-ICP = "Total" Digestion ICP #, ## Average value of Activation Labs' duplicate analysis of powdered material, or average value of blind duplicate analysis of jaw crushed material, respectively.

Analyte symbol	Be	Sc	V	Cr	Cr	Mass	Co	Ni	Ni	Cu	Zn	Ga	Ge	As	Rb	Sr	Y	Zr	Nb	Мо	Ag	In	Sn	Sb	Cs
Unit	ppm	ppm	ppm	ppm	ppm	g	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Detection limit	1	1	5	20	5		1	20	1	10	30	1	0.5	5	1	2	0.5	1	0.2	2	0.5	0.1	1	0.2	0.1
Analyt. method*	F-ICP	F-ICP	F-ICP	F-MS	INAA	INAA	F-MS	F-MS	TD-ICP	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-ICP	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS
Sample no.																									
62187	4	12	36	<20	<5	1.46	3	<20	4	20	40	20	1.5	<5	146	175	52.9	653	40.0	18	5.8	<0.1	2	0.8	1.8
62188	3	2	18	<20	<5	1.61	1	<20	2	<10	<30	14	1.7	<5	118	184	15.7	150	23.2	2	1.4	<0.1	<1	<0.2	0.7
62189	2	3	83	<20	9	1.60	4	<20	4	<10	50	21	1.3	<5	67	1504	9.0	89	3.9	<2	0.9	<0.1	<1	0.6	0.7
62190	<1	60	706	40	39	2.02	61	40	43	310	120	19	1.4	<5	9	375	27.3	50	2.1	<2	<0.5	<0.1	2	0.3	0.2
62191	1	68	668	30	37	2.00	62	60	50	130	120	18	1.9	<5	6	355	25.5	51	2.4	<2	<0.5	<0.1	2	1.6	0.2
62192	<1	22	199	<20	10	1.78	16	<20	4	10	70	19	2.0	<5	36	813	17.8	81	2.9	<2	0.7	<0.1	<1	<0.2	0.8
62193	1	21	194	<20	<5	1.79	17	<20	6	100	70	18	2.1	<5	59	577	24.8	186	5.2	<2	1.4	<0.1	1	0.6	0.6
62194	2	5	72	<20	13	1.58	5	<20	1	<10	50	22	1.4	<5	34	1222	14.1	132	5.6	<2	1.0	<0.1	<1	0.6	0.6
62195	2	3	26	<20	<5	1.68	2	<20	2	10	<30	16	1.7	<5	94	358	18.6	168	5.4	<2	1.3	<0.1	1	<0.2	0.6
62196	1	1	26	<20	<5	1.70	2	<20	2	<10	<30	15	1.3	<5	90	520	11.0	109	4.4	<2	0.8	<0.1	<1	0.4	0.9
62198	<1	30	292	<20	<5	1.81	29	<20	8	130	100	20	1.6	<5	15	956	16.6	39	1.1	<2	< 0.5	<0.1	<1	<0.2	0.3
62199	1	9	12	<20	<0 .5	1.60	0	<20	2	20	30	19	1.5	<0 .5	47	939	23.0	222	5.0	< <u>2</u>	1.7	<0.1	1	0.4	0.5
62200	1	15	150	<20	<0	1.72	15	<20	4	20	50	18	1.8	<0 -5	02	040	19.2	184	4.2	<2 -2	1.5	<0.1	< I - 1	0.4	0.8
62201	~1	34	331	50 <20	39	1.01	30	20	25	20	60	19	1.8	<0 <5	29	010	18.3	165	1.8	<2	<0.5	<0.1	<1	2.2	1.3
62202	2	5	92	<20	14	1.09	0	<20	0	20 <10	60 50	20	1.0	<5 <5	00	200	15.0	221	4.2	~2	1.3	<0.1	1	1.5	0.7
62203	2	15	124	~20	~5	1.72	2 11	~20	2	20	50	10	1.0	~5	90 45	200	27.2	201	7. 4 5.5	~2	1.0	<0.1	1	1.5	0.5
62204	1	22	2/2	~20	<5	1.05	20	~20	0	20	60	10	1.9	~5	40	732	23.4	175	3.0	~2	1.9	<0.1	-1	0.3	13
62205	2	15	121	<20	<5	1.75	11	<20	4	40	70	10	1.7	<5	78	578	26.0	168	6.0	<2	1.0	<0.1	1	0.5	1.5
62200	1	10	183	<20	<5	1.78	18	<20	6	60	70	20	1.7	<5	45	798	10.0	121	3.0	<2	1.4	<0.1	<1	0.4	0.7
62207	2	a	71	<20	<5	1.70	8	<20	2	45	30	17	1.0	<5	124	384	25.3	300	8.0	<2	2.5	<0.1	1	0.4	14
62210	1	71	540	70	68	2 19	64	80	73	40	110	16	2.1	<5	18	280	14 1	46	1.3	<2	<0.5	<0.1	1	0.4	0.2
62210	2	32	307	160	140	2.02	37	40	33	230	110	16	1.8	<5	64	1056	15.7	57	2.8	<2	<0.5	<0.1	<1	0.5	0.4
62212	<1	52	75	1320	1080	1.84	84	690	666	60	40	2	2.2	<5	<1	42	2.5	3	<0.2	<2	< 0.5	<0.1	<1	0.3	<0.1
62213	2	4	59	<20	10	1.66	6	<20	7	10	50	21	1.4	<5	98	891	11.8	132	6.3	<2	1.0	<0.1	<1	0.8	1.1
62214	3	11	65	<20	<5	1.63	8	<20	4	40	50	20	1.8	<5	114	435	33.3	372	9.6	<2	2.9	<0.1	2	0.7	1.4
62215	2	5	42	<20	<5	1.84	5	<20	2	70	<30	15	1.7	<5	94	341	18.2	136	5.4	<2	1.2	<0.1	<1	0.2	0.7
62216	2	4	34	<20	<5	1.70	3	<20	2	<10	<30	15	1.8	<5	93	322	15.4	159	4.8	<2	1.3	<0.1	<1	0.3	0.6
62217 #	1	12	123	<20	<5	1.57	11	<20	4	30	70	18	1.9	<5	60	561	20.2	132	4.6	<2	1.2	<0.1	<1	0.6	1.0
62218	2	12	114	<20	6	1.69	9	<20	3	30	60	18	1.7	<5	53	557	20.2	140	4.7	<2	1.0	<0.1	<1	0.7	0.7
62220	1	3	37	<20	6	1.66	2	<20	2	<10	<30	15	1.5	<5	69	416	12.5	158	5.4	<2	1.3	<0.1	<1	0.4	0.4
62221 #	1	5	75	<20	11	1.64	5	<20	7	<10	<30	21	1.3	<5	35	1152	10.5	146	3.5	<2	1.0	<0.1	<1	0.3	0.3
62222	4	7	36	<20	<5	1.84	5	<20	3	10	60	19	1.8	<5	154	241	37.9	341	11.9	<2	2.5	<0.1	1	0.9	2.0
62223	2	3	43	<20	6	1.53	1	<20	3	<10	<30	21	1.4	<5	64	999	7.8	103	3.7	<2	0.7	<0.1	<1	0.8	0.7
62224	2	2	37	<20	7	1.67	2	<20	4	<10	<30	22	0.9	<5	56	986	7.5	109	2.9	<2	0.9	<0.1	<1	0.6	0.5
62225	2	3	44	<20	<5	1.64	3	<20	4	<10	<30	21	1.4	<5	71	888	8.4	118	3.7	<2	0.8	<0.1	<1	0.6	0.6
62226	1	26	423	20	23	2.10	39	20	22	30	140	24	1.7	12	31	1148	25.1	52	3.1	<2	<0.5	<0.1	2	1.7	0.4
62227,8 ***	1	24	392	20	18	1.98	38	20	21	155	145	24	1.7	17	29	1463	23.8	51	3.0	<2	0.6	<0.1	2	0.9	0.6
62229	2	15	281	<20	<5	1.87	28	<20	7	290	120	19	1.5	<5	86	1289	19.3	53	2.4	<2	<0.5	<0.1	<1	0.5	0.7
62230	<1	24	266	<20	9	1.95	24	<20	8	80	90	20	1.8	<5	43	786	16.5	90	3.0	<2	0.7	<0.1	<1	0.5	0.8
62231	2	3	27	<20	<5	1.83	<1	<20	2	<10	<30	15	1.7	<5	88	380	21.7	131	6.7	<2	0.9	<0.1	<1	<0.2	0.7
62232	<1	40	365	<20	<5	1.85	31	<20	7	90	100	19	1.9	<5	23	705	18.5	48	1.3	<2	< 0.5	<0.1	<1	0.3	0.4
62233 *	<1	53	628	<20	<5	1.93	39	30	24	320	40	19	1.7	<5	8	660	13.8	40	1.6	<2	<0.5	< 0.1	1	0.4	0.2
62234	1	3	18	<20	<5	1.//	2	<20	2	<10	<30	12	1.6	<5	87	230	10.7	130	3.3	<2	1.1	< 0.1	<1	<0.2	0.6
62235	1	14	142	<20	<5	1.65	12	<20	5	50	90	17	1.5	<5	53	598	19.3	118	4.4	<2	1.2	<0.1	<1	<0.2	0.9
62236	2	8	95	<20	15	1.76	8	<20	10	10	70	20	1.4	<5	70	862	19.8	161	6.7	<2	1.2	<0.1	1	0.4	1.0

Unit ppm ppm <th>ppm 0.01 F-MS 25.20 3.19 0.98 0.46 0.58 1.48 3.28 1.01 2.57 3.80 0.35 3.13 2.93 0.87</th>	ppm 0.01 F-MS 25.20 3.19 0.98 0.46 0.58 1.48 3.28 1.01 2.57 3.80 0.35 3.13 2.93 0.87
Detection limit 3 0.05 0.05 0.01 0.05 0.01 0.01 0.01 0.01 0.01 0.02 0.1 0.01 0.05 0.01 0.05 5 0.1 0.05 Analyt. method* F-ICP F-MS F-MS <th>25.20 3.19 0.98 0.46 0.58 1.48 3.28 1.01 2.57 3.80 0.35 3.13 2.93 0.87</th>	25.20 3.19 0.98 0.46 0.58 1.48 3.28 1.01 2.57 3.80 0.35 3.13 2.93 0.87
Analyt. method* F-ICP F-MS F-MS <th>F-MS 25.20 3.19 0.98 0.46 0.58 1.48 3.28 1.01 2.57 3.80 0.35 3.13 2.93 0.87</th>	F-MS 25.20 3.19 0.98 0.46 0.58 1.48 3.28 1.01 2.57 3.80 0.35 3.13 2.93 0.87
Sample no. 62187 471 99.0 196.0 22.30 86.7 15.90 0.870 12.50 1.87 10.50 1.98 5.71 0.841 5.77 0.912 16.6 1.97 <0.5 0.17 15 <0.1 98.6 62188 530 37.1 64.4 6.15 20.5 3.31 0.587 2.78 0.42 2.37 0.48 1.56 0.280 2.12 0.393 3.7 2.33 <0.5 0.28 10 <0.1 17.2 62190 390 10.5 28.1 4.39 22.9 6.42 1.930 6.69 1.07 5.71 1.08 2.85 0.384 2.45 0.361 1.9 0.10 <0.5 <0.05 <5 <0.1 0.81 1.27.0 6.30 0.32 0.386 2.00 0.10 <0.5 <0.05 <5 <0.1 0.31 2.51 0.40 <0.5 0.13 <5 <0.1 3.3 0.99	25.20 3.19 0.98 0.46 0.58 1.48 3.28 1.01 2.57 3.80 0.35 3.13 2.93 0.87
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	25.20 3.19 0.98 0.46 0.58 1.48 3.28 1.01 2.57 3.80 0.35 3.13 2.93 0.87
62188 530 37.1 64.4 6.15 20.5 3.31 0.587 2.78 0.42 2.37 0.48 1.56 0.280 2.12 0.393 3.7 2.33 <0.5	3.19 0.98 0.46 0.58 1.48 3.28 1.01 2.57 3.80 0.35 3.13 2.93 0.87
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62200* 988 17.4 35.0 4.0 17.2 3.72 1.100 3.44 0.58 3.23 0.68 2.04 0.44 0.54 0.13 0 <0.17	2.93 0.87
62200 966 17.4 35.0 4.10 17.2 3.72 1.100 3.44 0.56 5.25 0.66 2.03 0.517 2.25 0.505 4.57 0.517 5.05 0.16 7 <0.1	0.87
62201 101 101 24.4 3.21 14.4 3.00 1.20 5.04 0.00 1.54 0.235 1.57 0.51 1.57 0.15 0.16 0.14 0 0.2 1.60 62202 1391 17.5 34.9 4.26 17.5 3.94 1.100 3.00 0.47 2.58 0.51 1.56 0.234 1.57 0.253 4.4 0.26 <0.5	0.07
62203 1504 34.5 63.6 7.23 27.0 5.58 1.070 4.86 0.80 4.32 0.94 2.88 0.468 3.51 0.608 5.6 0.70 <0.5	·2 aa
62204 832 21.1 43.8 5.09 2.06 4.39 3.92 0.66 3.86 0.84 2.52 0.409 2.89 0.483 5.5 0.65 <0.5 0.14 7 <0.1 4.93 62205 822 15.5 33.7 4.29 18.1 4.43 1.230 4.30 0.64 3.55 0.72 2.17 0.321 2.26 0.389 4.0 0.30 <0.5	5.26
62205 822 15.5 33.7 4.29 18.1 4.43 1.230 4.30 0.64 3.55 0.72 2.17 0.321 2.26 0.389 4.0 0.30 <0.5 0.20 <5 <0.1 3.52	2.47
	1.82
62206 # 1206 22.7 47.6 5.72 23.6 5.53 1.340 4.92 0.77 4.31 0.85 2.62 0.400 2.84 0.487 4.6 0.46 <0.5 0.20 10 <0.1 7.79	2.74
62207 1037 17.4 34.6 4.30 18.7 3.93 1.210 3.46 0.60 3.45 0.75 2.23 0.336 2.21 0.379 3.3 0.27 <0.5 0.14 11 <0.1 3.66	1.79
62208,9 #* 1148 25.9 50.7 5.86 22.9 4.95 0.956 4.26 0.67 4.01 0.85 2.68 0.414 3.05 0.537 7.7 0.78 <0.5 0.32 10 <0.1 15.33	7.77
62210 273 8.2 19.0 2.56 12.0 3.53 0.964 3.40 0.54 2.78 0.53 1.44 0.203 1.28 0.202 1.7 0.05 <0.5 <0.05 <5 <0.1 1.17	0.61
62211 675 16.6 33.5 4.28 17.8 4.29 1.210 4.20 0.58 3.00 0.57 1.52 0.216 1.42 0.217 1.4 0.19 <0.5 <0.05 10 <0.1 2.68	1.25
62212 56 0.6 1.9 0.32 1.6 0.56 0.148 0.57 0.10 0.52 0.10 0.29 0.040 0.23 0.034 0.1 <0.01 <0.5 <0.05 <5 <0.1 <0.04	0.01
62213 1408 22.6 36.9 4.25 16.7 3.02 0.846 2.71 0.36 1.92 0.39 1.14 0.172 1.19 0.198 3.4 0.64 <0.5 0.35 14 <0.1 6.09	1.84
62214 1149 37.6 73.1 8.35 32.7 6.92 1.520 6.05 0.95 5.70 1.13 3.68 0.576 4.03 0.729 9.3 0.77 <0.5 0.16 11 <0.1 13.10	3.95
62215 934 20.2 39.0 4.25 16.8 3.33 0.761 2.99 0.48 2.70 0.58 1.92 0.332 2.48 0.396 3.5 0.54 <0.5 0.23 8 <0.1 9.66	3.80
62216 1118 16.6 31.4 3.38 13.0 2.68 0.655 2.42 0.39 2.27 0.52 1.73 0.279 1.93 0.340 4.2 0.47 <0.5 0.22 6 <0.1 10.90	4.11
62217* 1018 21.5 42.1 4.85 20.1 4.37 1.200 3.70 0.61 3.26 0.72 2.06 0.317 2.37 0.406 3.3 0.38 <0.5 0.20 10 <0.1 6.07	2.62
62218 1151 21.8 42.5 4.95 19.1 3.86 1.140 3.92 0.60 3.35 0.71 2.06 0.331 2.37 0.399 3.8 0.43 <0.5 0.15 9 <0.1 6.46	2.44
62220 1382 21.1 36.9 3.72 12.7 2.53 0.536 1.84 0.31 1.90 0.41 1.34 0.228 1.63 0.303 3.8 0.61 <0.5 0.15 <5 <0.1 11.2	3.49
62221 ⁻¹ 1/14 15.0 31.7 3.78 15.0 3.12 0.3220 2.41 0.34 1.75 0.35 1.00 0.150 1.05 0.180 3.0 0.28 <0.5 0.11 9 <0.1 1.53 (0.1 1.53 0.1 1.5 0.5 0.1 1.5	0.69
02222 121 35.0 10.7 6.02 30.4 6.50 0.006 5.94 0.96 5.93 1.26 4.10 0.076 4.79 0.761 9.0 1.00 €0.5 0.20 10 €0.1 16.4 €2223 1620 410 216 2.46 0.9 2.36 0.500 1.500 1.20 0.35 0.72 0.119 0.00 0.169 2.0 0.22 <0.5 0.20 12 <0.1 2.56	4.94
62223 1059 11.9 21.0 2.40 9.0 2.20 0.09 1.09 0.20 1.29 0.20 0.10 0.10 0.90 0.100 2.9 0.22 0.2 0.0 0.20 13 0.1 3.00 62 62 7.0 14 0.1 1.0 10 62 7.0 12 10 10 10 10 10 10 10 10 10 10 10 10 10	1.10
62225 1624 134 255 288 111 214 0.677 179 0.25 148 0.29 0.88 0.143 1.06 0.185 3.3 0.33 <0.5 0.17 10 <0.1 3.60	1.10
62226 656 142 374 557 286 681 1980 688 094 489 094 256 0337 215 0359 23 013 <05 010 <5 <0.1 0.50	0.26
62277 8 ^{##} 783 134 356 512 264 667 1910 648 094 460 0.89 244 0.343 219 0.355 2.3 012 <0.5 0.08 <5 <0.1 0.55	0.23
62229 894 201 413 526 230 498 1610 476 070 362 0.69 189 0268 172 0287 16 017 <0.5 0.08 8 <0.1 2.31	1.12
62230 667 11.4 22.8 2.83 12.8 2.84 1.020 3.06 0.49 2.85 0.58 1.74 0.275 1.87 0.316 2.4 0.26 <0.5 0.17 5 <0.1 3.67	1.65
62231 1153 25.7 46.7 5.22 19.7 3.83 0.645 3.16 0.51 3.20 0.71 2.25 0.389 2.82 0.491 3.7 0.82 <0.5 0.21 <5 <0.1 13.8	3.71
62232 549 8.3 17.8 2.35 11.7 2.99 1.010 3.20 0.54 3.05 0.62 1.87 0.295 1.95 0.324 1.5 0.08 <0.5 0.09 <5 <0.1 1.60	0.81
62233 [#] 211 11.0 21.2 2.59 12.1 2.71 1.030 3.18 0.48 2.63 0.53 1.50 0.216 1.39 0.213 1.4 0.12 1.4 <0.05 <5 0.1 1.32	1.65
62234 941 27.7 50.0 5.08 17.1 2.86 0.606 1.96 0.33 1.88 0.39 1.12 0.181 1.33 0.238 3.5 0.17 <0.5 0.27 5 <0.1 6.67	1.64
62235 1007 20.0 39.4 4.73 19.9 4.18 1.090 3.51 0.55 3.27 0.67 1.97 0.301 1.98 0.343 3.0 0.35 <0.5 0.16 8 <0.1 5.35	2.28
<u>62236</u> 1117 19.4 41.9 5.14 21.9 4.56 1.160 4.16 0.56 3.19 0.65 1.89 0.290 2.05 0.341 4.1 0.39 <0.5 0.24 13 0.1 4.63	2.44

Appendix 3: Quality control data of lithogeochemistry samples

	Analyte symb	lool	SiO ₂	AI_2O_3	Fe ₂ O ₃ ^(T)	MnO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂	P_2O_5	LOI	Total
	Unit		%	%	%	%	%	%	%	%	%	%	%	%
	Detection lim	nit	0.01	0.01	0.01	0.001	0.01	0.01	0.01	0.01	0.001	0.01		0.01
	Analytical meth	nod*	F-ICP	F-ICP	F-ICP	F-ICP	F-ICP	F-ICP	F-ICP	F-ICP	F-ICP	F-ICP	F-ICP	F-ICP
Sample no.#	Orig. sample no.	Unit												
62200 Dup	11BVA-17-105	LT CH	58.56	16.68	6.66	0.13	2.30	5.73	3.66	3.11	0.61	0.22	0.76	98.42
62200 Orig	11BVA-17-105	LT CH	58.93	16.55	6.62	0.13	2.32	5.70	3.69	3.14	0.62	0.22	0.76	98.67
Difference*	11BVA-17-105	LT CH	0.16	0.20	0.15	0.00	0.22	0.13	0.20	0.24	0.33	0.00	0.00	0.06
62206 Dup	11BVA-21-134	MJ TSc												
62206 Orig	11BVA-21-134	MJ TSc												
Difference*	11BVA-21-134	MJ TSc												
62208	11BVA-23-152	MJ TSp	64.79	16.47	4.74	0.09	1.10	2.73	3.49	5.16	0.54	0.21	1.13	100.50
62209	11BVA-23-152-2dupl	MJ TSp	66.03	16.25	4.32	0.08	1.03	2.45	3.65	5.38	0.52	0.20	1.02	100.90
Difference*	11BVA-23-152-2dupl	MJ TSp	0.47	0.34	2.32	2.27	1.64	2.70	1.12	1.04	0.90	1.22	2.56	0.10
62217 Dup	11BVA-32-242	MJ TSf	62.50	16.44	5.86	0.15	1.95	4.52	4.17	2.99	0.61	0.22	0.80	100.20
62217 Orig	11BVA-32-242	MJ TSf	62.06	16.19	5.87	0.15	1.94	4.60	4.07	2.93	0.61	0.23	0.80	99.46
Difference*	11BVA-32-242	MJ TSf	0.18	0.38	0.04	0.33	0.13	0.44	0.61	0.51	0.12	1.11	0.00	0.19
62221 Dup	11BVA-34-264	LT CHI												
62221 Orig	11BVA-34-264	LT CHI												
Difference*	11BVA-34-264	LT CHI												
62227	11BVA-40-317-a2	LT GLm	40.83	16.08	14.22	0.24	6.18	13.18	2.20	1.63	1.37	1.17	1.72	98.81
62228	11BVA-40-317-a2-2dupl	LT GLm	41.13	16.51	14.17	0.24	6.18	13.02	2.26	1.66	1.39	1.19	1.64	99.40
Difference*	11BVA-40-317-a2	LT GLm	0.18	0.66	0.09	0.21	0.00	0.31	0.67	0.46	0.40	0.42	1.19	0.15
62233 Dup	11BVA-42-330	MJ TSm	45.69	16.32	15.41	0.17	5.49	9.82	2.90	0.42	1.25	0.15	1.48	99.09
62233 Orig	11BVA-42-330	MJ TSm	46.18	16.29	15.36	0.17	5.44	9.82	2.95	0.44	1.25	0.15	1.48	99.51
Difference*	11BVA-42-330	MJ TSm	0.27	0.05	0.08	0.00	0.23	0.00	0.43	1.16	0.12	0.00	0.00	0.11
62197	11BVA-50-503blank	Blank	99.78	0.04	0.47	0.00	<0.01	0.01	0.01	<0.01	<0.001	<0.01	0.19	100.50
62250	11DMO50-505blank	Blank	99.89	0.06	0.40	0.00	0.01	0.02	0.02	<0.01	0.00	<0.01	0.08	100.50
Difference*	Blank	Blank	0.03	10.00	4.02	0.00		16.67	16.67				20.37	0.00
62274	MRG1standard	Standard	39.63	8.40	17.32	0.17	13.65	14.77	0.71	0.18	3.79	0.06	1.38	100.10
Expected##	MRG1standard	Standard	39.12	8.47	17.94	0.17	13.55	14.70	0.74	0.18	3.77	0.08	2.23	100.95
Difference*	MRG1standard	Standard	0.32	-0.21	-0.88	-0.45	0.18	0.12	-1.03	0.00	0.16	-7.14	-11.77	-0.21
62275 Dup	SY3standard	Standard	59.24	11.47	6.53	0.32	2.61	8.14	3.98	4.27	0.15	0.55	1.19	98.45
62275 Orig	SY3standard	Standard	59.85	11.67	6.46	0.32	2.61	8.03	4.07	4.39	0.15	0.55	1.19	99.28
Expected##	SY3standard	Standard	59.68	11.76	6.49	0.32	2.67	8.25	4.12	4.23	0.15	0.54	1.31	99.52
Difference*	SY3standard	Standard	-0.18	-0.62	0.15	0.23	-0.57	-0.34	-0.86	0.24	-0.68	0.46	-2.40	-0.27
Difference*	SY3standard	Standard	0.07	-0.19	-0.12	0.00	-0.57	-0.68	-0.31	0.93	-0.17	0.46	-2.40	-0.06

* Difference calculated as follows: $|0.5*100*{(x1-x2)/(x1+x2)}|$

** Analytical methods: F-ICP = Fusion ICP; F-MS = Fusion ICP-MS; INAA = Instrumental Neutron Activation Analysis; TD-ICP = "Total" Digestion ICP

* Analyses with the same sample number are Activation Labs' duplicates of powdered material. Analyses with a different sample number are blind duplicates of jaw crushed material

Recommended values for CANMET standards (Govindaraju, 1994) in bold, proposed values underlined, informational values in normal font

Analyte symbol	Be	Sc	V	Cr	Cr	Mass	Со	Ni	Ni	Cu	Zn	Ga	Ge	As	Rþ	Sr	Y	Zr	Nb	Мо	Aa	In	Sn	Sb	Cs
Unit	ppm	ppm	ppm	ppm	ppm	q	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Detection limit	1	1	5	20	5	0	1	20	1	10	30	1	0.5	5	1	2	0.5	1	0.2	2	0.5	0.1	1	0.2	0.1
Analyt. method*	F-ICP	F-ICP	F-ICP	F-MS	INAA	INAA	F-MS	F-MS	TD-ICP	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-ICP	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS
Sample no.																									
62200 Dup	1	15	151	<20			16	<20		20	50	18	1.8	<5	62	639	19.1	179	4.1	<2	1.5	<0.1	1	0.4	0.8
62200 Orig	1	15	150	<20			14	<20		20	50	18	1.8	<5	62	640	19.4	189	4.3	<2	1.5	<0.1	<1	0.4	0.8
Difference*	0	0	0				3			0	0	0	0.0		0	0	0.4	1	1.2		0.0			0.0	0.0
62206 Dup									4																
62206 Orig									3																
Difference*									7																
62208	2	9	73	<20	<5	1.63	7	<20	2	40	30	17	1.5	<5	120	392	25.9	294	8.9	<2	2.5	<0.1	1	0.4	1.3
62209	2	8	68	<20	<5	1.59	8	<20	2	50	<30	17	1.7	<5	127	375	24.6	305	8.9	<2	2.5	<0.1	1	0.4	1.5
Difference*	0	3	2			0.62	3		0	6		0	3.1		1	1	1.3	1	0.0		0.0		0	0.0	3.6
62217 Dup	1	12	124	<20			10	<20		30	70	17	2.0	<5	60	560	20.0	136	4.4	<2	1.1	<0.1	<1	0.6	1.0
62217 Orig	1	12	123	<20			11	<20		30	70	18	1.8	<5	61	561	20.4	128	4.7	<2	1.2	<0.1	<1	0.6	1.0
Difference*	0	0	0				2			0	0	1	2.6		0	0	0.5	2	1.6		2.2			0.0	0.0
62221 Dup									7																
62221 Orig									7																
Difference*									0																
62227	1	24	392	20	21	1.87	37	<20	21	150	150	24	1.5	17	29	1452	23.5	53	3.0	<2	0.6	<0.1	2	0.9	0.6
62228	1	24	392	20	15	2.09	38	20	21	160	140	24	1.9	16	29	1473	24.0	48	3.0	<2	<0.5	<0.1	2	0.9	0.6
Difference*	0	0	0	0	8	2.78	1		0	2	2	0	5.9	2	0	0	0.5	2	0.0				0	0.0	0.0
62233 Dup	<1	53	626	<20			39	30		310	40	19	1.7	<5	8	660	13.6	38	1.6	<2	<0.5	<0.1	1	0.2	0.3
62233 Orig	<1	53	629	<20			38	30		320	40	19	1.7	<5	8	661	13.9	41	1.6	<2	<0.5	<0.1	1	0.6	0.2
Difference*		0	0				1	0		1	0	0	0.0		0	0	0.5	2	0.0				0	25.0	10.0
62197	<1	<1	<5	<20	10	1.63	<1	<20	2	<10	<30	<1	2.1	<5	<1	<2	<0.5	<1	<0.2	<2	<0.5	<0.1	<1	<0.2	<0.1
62250	<1	<1	<5	<20	11	1.93	<1	<20	<1	<10	<30	<1	1.5	<5	<1	<2	<0.5	<1	<0.2	<2	<0.5	<0.1	<1	<0.2	<0.1
Difference*					2	4.21							8.3												
62274	<1	54	541	430	440	1.67	79	170	179	130	220	19	1.4	<5	7	270	12.1	99	18.1	<2	1.2	<0.1	6	0.7	0.6
Expected [#]	<u>1</u>	55	526	430	430		87	193	193	134	191	17		1	9	266	14.0	108	20.0	1	0.1		4	0.9	0.6
Difference*		0	1	0	1		-2	-3	-2	-1	4	3			-5	0	-3.6	-2	-2.5		41.6		13	-5.1	1.3
62275 Dup	24	8	55	<20			7	<20		20	250	33	2.2	18	195	301	675.0	357	183.0	<2	2.3	<0.1	8	0.2	2.6
62275 Orig	24	8	55	<20			8	<20		10	250	32	2.6	19	198	303	674.0	345	180.0	<2	2.4	<0.1	7	6.4	2.7
Expected [#]	<u>20</u>	<u>7</u>	<u>50</u>	11	11		<u>9</u>	<u>11</u>	<u>11</u>	<u>17</u>	244	27	1.4	<u>19</u>	206	302	718.0	<u>320</u>	148.0	1	1.5		7	0.3	2.5
Difference*	5	4	2				-6			4	1	5	11.1	-1	-1	0	-1.5	3	5.3		10.5		5	-10.8	1.0
Difference*	5	4	2				-2			-13	1	4	15.0	0	-1	0	-1.6	2	4.9		11.5		2	45.4	1.9

Analyte symbol	Ва	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Та	W	TI	Pb	Bi	Th	U
Unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm						
Detection limit	3	0.05	0.05	0.01	0.05	0.01	0.005	0.01	0.01	0.01	0.01	0.01	0.005	0.01	0.002	0.1	0.01	0.5	0.05	5	0.1	0.05	0.01
Analyt. method*	F-ICP	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS	F-MS
Sample no.																							
62200 Dup	984	16.80	34.50	4.02	16.60	3.60	1.100	3.39	0.56	3.21	0.67	1.98	0.306	2.16	0.357	4.5	0.31	<0.5	0.20	8	<0.1	5.61	2.91
62200 Orig	992	18.00	35.60	4.18	17.80	3.84	1.100	3.50	0.60	3.25	0.70	2.08	0.328	2.30	0.372	4.5	0.31	<0.5	0.16	7	<0.1	5.62	2.96
Difference*	0	1.72	0.78	0.98	1.74	1.61	0.000	0.80	1.72	0.31	1.09	1.23	1.735	1.57	1.0	0.0	0.00		5.56	3		0.04	0.43
62206 Dup																							
62206 Orig																							
Difference*																							
62208	1143	26.10	51.50	5.93	23.00	5.08	0.944	4.33	0.66	4.11	0.85	2.67	0.409	3.07	0.529	7.5	0.76	<0.5	0.33	10	<0.1	14.20	7.36
62209	1152	25.70	49.80	5.79	22.80	4.82	0.968	4.18	0.67	3.91	0.85	2.69	0.418	3.03	0.545	7.8	0.80	<0.5	0.30	10	<0.1	16.50	8.17
Difference*	0	0.39	0.84	0.60	0.22	1.31	0.628	0.88	0.38	1.25	0.00	0.19	0.544	0.33	0.7	1.0	1.28		2.38	0		3.75	2.61
62217 Dup	1021	21.40	41.80	4.79	19.40	4.19	1.140	3.74	0.64	3.28	0.72	2.07	0.316	2.40	0.407	3.4	0.37	<0.5	0.20	10	<0.1	6.06	2.58
62217 Orig	1015	21.60	42.40	4.92	20.70	4.55	1.260	3.66	0.58	3.25	0.73	2.04	0.318	2.35	0.405	3.3	0.39	<0.5	0.21	10	<0.1	6.08	2.67
Difference*	0	0.23	0.36	0.67	1.62	2.06	2.500	0.54	2.46	0.23	0.34	0.36	0.158	0.53	0.1	0.7	1.32		1.22	0		0.08	0.86
62221 Dup																							
62221 Orig																							
Difference*																							
62227	779	13.30	35.40	5.01	26.70	6.62	1.970	6.78	0.93	4.57	0.90	2.45	0.332	2.09	0.338	2.3	0.14	<0.5	0.07	<5	<0.1	0.55	0.23
62228	787	13.50	35.70	5.22	26.10	6.72	1.850	6.18	0.94	4.62	0.87	2.43	0.353	2.28	0.372	2.3	0.10	<0.5	0.08	<5	<0.1	0.61	0.22
Difference*	0	0.37	0.21	1.03	0.57	0.37	1.571	2.31	0.27	0.27	0.85	0.20	1.533	2.17	2.4	0.0	8.33		3.33			2.59	1.11
62233 Dup	210	11.10	21.60	2.55	12.00	2.82	1.040	3.22	0.48	2.65	0.52	1.49	0.218	1.39	0.216	1.5	0.12	1.3	<0.05	<5	0.1	1.34	1.64
62233 Orig	211	11.00	20.80	2.63	12.10	2.60	1.020	3.14	0.48	2.60	0.53	1.50	0.213	1.39	0.21	1.4	0.12	1.5	0.05	<5	0.1	1.30	1.66
Difference*	0	0.23	0.94	0.77	0.21	2.03	0.485	0.63	0.00	0.48	0.48	0.17	0.580	0.00	0.7	1.7	0.00	3.6			0.0	0.76	0.30
62197	3	0.16	0.35	0.04	<0.05	0.02	<0.005	0.01	<0.01	<0.01	<0.01	<0.01	<0.005	<0.01	<0.002	<0.1	<0.01	<0.5	<0.05	<5	<0.1	<0.05	<0.01
62250	3	0.34	0.76	0.08	0.32	0.08	0.011	0.06	<0.01	0.02	<0.01	<0.01	<0.005	0.01	0.004	<0.1	<0.01	<0.5	<0.05	<5	<0.1	0.09	0.01
Difference*	0	18.00	18.47	16.67		30.00		35.71															
62274	52	9.21	25.70	3.63	17.20	4.28	1.500	4.13	0.55	2.80	0.51	1.20	0.133	0.77	0.12	3.8	0.87	<0.5	<0.05	9	0.2	0.83	0.30
Expected [#]	61	9.80	26.00	3.40	19.20	4.50	1.390	4.00	0.51	2.90	0.49	1.12	0.110	0.60	0.12	3.76	0.80	0.3	0.06	10	0.13	0.93	0.24
Difference*	-4	-1.55	-0.29	1.64	-2.75	-1.25	1.903	0.80	1.89	-0.88	1.00	1.72	4.733	6.20	0.0	0.3	2.10			-3	10.6	-2.84	5.56
62275 Dup	448	1210	2150	208	688	118	17.000	106.00	19.20	118.00	24.80	77.10	11.300	63.60	8.54	9.8	24.90	<0.5	1.27	372	0.3	984	670
62275 Orig	452	1220	2150	209	691	119	17.000	102.00	19.30	117.00	26.10	78.30	11.300	64.30	8.47	10.6	24.40	<0.5	1.34	415	0.4	999	663
Expected [#]	450	1340	2230	223	670	109	17.000	105.00	18.00	118.00	29.50	68.00	11.600	62.00	7.9	9.7	30.00	1.1	1.50	133	0.8	1003	650
Difference*	0	-2.55	-0.91	-1.74	0.66	1.98	0.000	0.24	1.61	0.00	-4.33	3.14	-0.655	0.64	1.9	0.3	-4.64		-4.15	24	-22.7	-0.48	0.76
Difference*	0	-2.34	-0.91	-1.62	0.77	2.19	0.000	-0.72	1.74	-0.21	-3.06	3.52	-0.655	0.91	1.7	2.2	-5.15		-2.82	26	-16.7	-0.10	0.50

APPENDIX 4: GEOCHRONOLOGY METHODOLOGIES

Zircon U-Pb LA-ICP-MS

Zircons were extracted using standard separation techniques mineral at the laboratories of Apatite To Zircon Inc. (Viola, Idaho, USA). Zircons (both standards and unknowns) were mounted in 1 cm² epoxy wafers, and ground down to expose internal grain surfaces prior to final polishing. The wafers were etched in 5.5N HNO₃ for 20 seconds at 21°C to thoroughly clean the surface of the grains prior to analysis. A representative suite of grains of all sizes and morphologies, and the locations for laser spots on these grains, were selected using transmitted light with an optical microscope at a magnification of 2000x.

Isotopic analyses were performed with a New Wave UP-213 laser ablation system in ThermoFinnigan conjunction with а Element2 single collector double-focusing magnetic sector inductively coupled plasma mass spectrometer (LA-ICP-MS) in the GeoAnalytical Lab at Washington State University (Pullman, WA, USA). For all analyses (both standard and unknown), the diameter of the laser-beam was set at 20 um and the laser frequency was set at 5 Hz, yielding ablation pits approximately 10-15 um deep. He and Ar gas were used to deliver the ablated material into the plasma source of the mass spectrometer. Each analysis of 250 cycles took approximately 30 seconds to complete, and consisted of a 6 second integration on peaks with the laser turned off (for background measurements), followed by a 25 second integration with the laser firing. A delay of up to 30 seconds occurred between analyses in order to purge the previous analysis and prepare for the next. The isotopes measured included ²⁰²Hg, 204 (Hg + Pb), 206 Pb, 207 Pb, 208 Pb, 232 Th, 235 U,

and ²³⁸U. The Element2 detector was set at analog mode for ²³²Th and ²³⁸U, and at pulse counting mode for all other isotopes. Common Pb correction was made by using the measured ²⁰⁴Pb content and assuming an initial Pb composition from Stacey and Kramers (1975).

Interelement fractionation of Pb/U is generally <20%, whereas fractionation of Pb isotopes is generally <5%. At the beginning each LA-ICP-MS session, zircon of standards Tardree (61.23±0.11 Ma) and FC1 (1099 ± 0.6) Ma) were analyzed until fractionation was stable and the variance in the measured ²⁰⁶Pb/²³⁸U and ²⁰⁷Pb/²⁰⁶Pb ratios was at or near 1 percent. In order to monitor interelement fractionation during the session, these standards were generally reanalyzed each 15-25 unknowns. Fractionation also increases with depth into the laser pit. The accepted isotopic ratios were accordingly determined by leastsquares projection through the measured values back to the initial determination.

For each spot, fractionation factor-corrected isotopic ratios and ages were calculated using data collected during scans 70-250 for each analysis. The laser is blocked during the first ca. 50 scans and the laser is fired during the remaining ca. 200 scans. Using the fitted polynomials routine LFIT from Press et al. (1992), the calculated values at the last scan (at scan 40 for a scan range of 20-40) are used as the background values. Fits to individual isotopic signal intensities versus scan number for each spot analyzed (scan number correlating with depth within the ablation pit from which material is derived for ICP analysis) is performed using the sum of multiple Gaussian equations. This approach was adopted because it

description permits the accurate of complicated signal intensity versus scan Complicated isotopic profiles. signal profiles are the rule, not the exception for natural zircon crystals due to chemical zoning. Fitting is performed using the Levenberg-Marquardt method (routine MRQMIN from Press et al., 1992) by chisquared minimization. The standard deviation of each isotopic signal intensity is calculated using routine STEYX from Excel[®] and the quality of fit is assessed by determining the probability of a greater chisquared using routine GAMMQ from Press et al. (1992). Up to 181 individual scans, each yielding isotopic ratios and ages, are used for calculation of isotopic ratios and ages.

Errors for the isotopic ratios and ages are based on the fitting errors of the respective isotopes. Errors are reported at 2σ and using the method outlined above include all analytical and machine errors.

Detailed review of the LA-ICP-MS data identified several issues that caused some spurious age results. This affected a subset of the preliminary age dates reported in van Straaten et al. (2012). Revised age dates are presented here. Two issues that were apparent in the data include 1) switch from pulse to analog mode counting for ²³⁸U during analyses of some samples, causing apparent bimodal age distributions. This has been recovered using the well-measured ²³⁵U to calculate ²³⁸U, using the accepted value for the ${}^{238}U/{}^{235}U$ ratio of 137.88. 2) A marked shift in background signal for ²⁰²Hg, ²⁰⁴(Hg+Pb), and to a lesser extent also ²⁰⁶Pb and ²⁰⁷Pb, after sample 1226-8 was analyzed. Generally, continuous а polynomial function is fitted through the background data of one session (samples 1226-1, 2, 3, 4, 5, 7, 8, 9, 10). The drop in background values during analysis of samples 1226-9 and 1226-10 caused a significant misfit with age standards analyzed near the end of the session. The data has been improved by fitting a separate polynomial function to the background data for the first (samples 1226-1, 2, 3, 4, 5, 7, 8) and last (samples 1226-9, 10) parts of the session.

The weighted average age of a sample is calculated by weighting the selected data points by the inverse-square of their assigned 2 sigma errors. The 2 sigma internal error of the age of a sample is the error propagated from the assigned data point errors alone. Both parameters were calculated using the 'weighted average' subroutine in Isoplot 3.6 (developed by K.R. Ludwig, 2008). In all cases, the 'probability of fit' (the probability that the assigned errors will vield at least the amount of scatter actually observed) was greater than 0.15, validating the use of the 2 sigma internal error.

Hornblende/biotite Ar-Ar

Methodology

The samples were crushed in a ring mill, washed in distilled water and ethanol, and sieved when dry to -40+60mesh. Appropriate mineral grains were picked out of the bulk fraction. Mineral separates were wrapped in aluminum foil and stacked in an irradiation capsule with similar-aged samples and neutron flux monitors (Fish Canyon Tuff sanidine (FCs), 28.03 Ma (Renne et al., 1998).

The samples were irradiated on October 25-26, 2011 at the McMaster Nuclear Reactor in Hamilton, Ontario, Canada, for 45 MWH, with a neutron flux of approximately $6 \cdot 10^{13}$ neutrons/cm²/s. Analyses (n=30) of 10 neutron flux monitor positions produced errors of <0.5% in the J value. The samples were analyzed during November and December 2011 at the Noble Gas Laboratory, Pacific Centre for Isotopic and Geochemical Research, University of British Columbia, Vancouver, BC, Canada. The mineral separates were step-heated at incrementally higher powers in the defocused beam of a 10 W CO₂ laser (New Wave Research MIR10) until fused. The gas evolved from each step was analyzed by a VG5400 mass spectrometer equipped with an ion-counting electron multiplier. All measurements were corrected for total system blank, mass spectrometer sensitivity, mass discrimination, radioactive decay during and subsequent to irradiation, as well interfering Ar from atmospheric as contamination and the irradiation of Ca, Cl production and K (Isotope ratios. $({}^{40}\text{Ar}/{}^{39}\text{Ar})\text{K}$ 0.0302 = ± 0.00006, $({}^{37}\text{Ar}/{}^{39}\text{Ar})\text{Ca} = 1416.4 \pm 0.5, ({}^{36}\text{Ar}/{}^{39}\text{Ar})\text{Ca}$ $= 0.3952 \pm 0.0004$, Ca/K $= 1.83 \pm$ $0.01(^{37}\text{ArCa}/^{39}\text{ArK})).$

Data processing

Details of the analyses, including plateau (spectrum) and inverse correlation ages, are presented in Appendix 6. Initial data entry and calculations were carried out using the software ArArCalc (Koppers, 2002). The plateau and correlation ages were calculated using Isoplot ver.3.09 (Ludwig, 2003). Errors are quoted at the 2-sigma (95% confidence) level and are propagated from all sources except mass spectrometer sensitivity and age of the flux monitor. The best statistically-justified plateau and plateau age were picked based on the following criteria:

- Three or more contiguous steps comprising more than 60% of the 39 Ar;
- Probability of fit of the weighted mean age greater than 5%;

- Slope of the error-weighted line through the plateau ages equals zero at 5% confidence;
- Ages of the two outermost steps on a plateau are not significantly different from the weighted-mean plateau age (at 1.8σ six or more steps only);
- Outermost two steps on either side of a plateau must not have nonzero slopes with the same sign (at 1.8σ nine or more steps only)

The two standard deviation error on all plateau ages includes a J-error of 0.6%.

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Zircon U-Pb LA-ICP-MS data for sample 11JLO32-3'
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Analysis		lso	otopic ratios ¹			Aa	e (Ma) ²
	²³⁸ U/ ²⁰⁶ Pb	± 2σ abs	²⁰⁷ Pb/ ²⁰⁶ Pb	± 2σ abs	Rho	²⁰⁶ Pb/ ²³⁸ U	±2o abs
12265AZ1_1	28.737	0.469	0.05281	0.00356	0.04	220.51	9.29
12265AZ1_2	21.264	0.286	0.05351	0.00291	0.09	296.25	12.24
12265AZ1_3	20.931	0.966	0.23190	0.04177	0.29	251.26	-30.74 +42.23
12265AZ1_4	29.199	0.582	0.05163	0.00186	0.24	217.08	9.70
12265AZ1_5	29.123	0.649	0.05216	0.00336	0.10	217.63	9.77
12265AZ1_6	28.194	0.577	0.05351	0.00380	0.09	224.68	10.08
12265AZ1_7	29.151	0.659	0.05364	0.00399	0.07	217.43	9.76
12265AZ1_8	29.530	0.507	0.05002	0.00206	0.13	214.69	9.19
12265AZ1_9	26.394	0.641	0.05430	0.00405	0.06	239.72	10.90
12265AZ1_10	29.317	0.374	0.05027	0.00162	0.15	216.22	9.19
12265AZ1_11	29.153	0.355	0.05133	0.00163	0.15	217.42	9.18
12265AZ1_12	29.407	2.132	0.05096	0.00491	0.37	215.57	17.59
12265AZ1_13	28.959	1.608	0.05339	0.00397	0.36	218.85	14.69
12265AZ1_15	22.575	1.063	0.05964	0.02906	0.02	279.41	16.69
12265AZ1_16	29.235	0.324	0.05057	0.00154	0.13	216.81	8.92
12265AZ1_17	17.087	0.660	0.32438	0.06790	0.25	<u>230.88</u>	<u>-31.74 +47.00</u>
12265AZ1_18	29.102	0.574	0.05254	0.00426	0.03	217.79	9.57
12265AZ1_19	29.175	0.547	0.05467	0.00395	0.04	217.26	9.64
12265AZ1_20	27.609	0.549	0.05159	0.00213	0.16	229.36	10.26
12265AZ1_21	29.756	0.744	0.05266	0.00369	0.11	213.08	9.94
12265AZ1_22	29.865	1.961	0.05242	0.00409	0.48	212.31	15.99
12265AZ1_23	29.203	0.598	0.05201	0.00344	0.10	217.05	9.57
12265AZ1_24	28.817	0.374	0.05167	0.00249	0.11	219.91	9.16
12265AZ1_25	28.721	0.398	0.05065	0.00219	0.09	220.63	9.32
12265AZ1_26	28.847	0.342	0.05084	0.00214	0.07	219.68	7.53
12265AZ1_27	28.346	0.400	0.05177	0.00248	0.09	223.50	7.90
12265AZ1_28	29.060	0.736	0.05131	0.00251	0.24	218.10	8.96
12265AZ1_29	28.434	0.494	0.05135	0.00175	0.26	222.82	8.30
12265AZ1_30	29.603	0.545	0.05106	0.00255	0.14	214.16	7.89
12265AZ1_31	29.334	0.430	0.04979	0.00183	0.13	216.10	7.61
12265AZ1_32	30.275	0.384	0.05030	0.00153	0.19	209.49	7.33
12265AZ1_33	30.086	0.376	0.05121	0.00181	0.14	210.78	7.44
12265AZ1_34	29.836	0.445	0.05251	0.00334	0.04	212.52	7.50
12265AZ1_35	29.703	0.856	0.05163	0.00177	0.57	213.46	9.19
12265AZ1_36	29.207	0.756	0.05088	0.00263	0.25	217.02	8.85
12265AZ1_37	29.533	1.744	0.05203	0.00362	0.43	214.66	14.30
12265AZ1_38	28.091	1.761	0.05048	0.00424	0.35	225.49	15.63
12265AZ1_39	29.719	0.853	0.05322	0.00346	0.16	213.34	9.05
12265AZ1_40	29.717	0.594	0.05180	0.00320	0.11	213.36	8.13
12265AZ1_41	29.666	0.655	0.05160	0.00417	0.06	213.72	8.24
12265AZ1_42	29.496	0.348	0.05194	0.00225	0.08	214.93	7.50
12265AZ1_43	29.144	0.383	0.05098	0.00180	0.16	217.48	7.61
12265AZ1_44	29.976	0.595	0.05343	0.00360	0.07	211.54	8.09
12265AZ1_45	29.175	0.708	0.05149	0.00305	0.18	217.26	8.72
12265AZ1_46	30.003	0.860	0.05320	0.00303	0.21	211.35	9.03
12265AZ1_47	29.355	1.132	0.05714	0.00564	0.14	215.95	10.65
12265AZ1_48	29.733	0.712	0.05460	0.00462	0.10	213.25	8.51
12265AZ1_49	29.292	0.483	0.05385	0.00332	0.04	216.40	7.88
12265AZ1_50	28.968	0.347	0.05000	0.00215	0.09	218.78	7.60

¹ Data not corrected for common lead

² Data not corrected for common lead, except underlined values

Zircon U-Pb LA-ICP-MS data for sample 11BVA31-232

Analysis		ls	otopic ratios ¹			Age	(Ma) ¹
	²³⁸ U/ ²⁰⁶ Pb	± 2σ abs	²⁰⁷ Pb/ ²⁰⁶ Pb	± 2σ abs	Rho	²⁰⁶ Pb/ ²³⁸ U	±2or abs
12267AZ1 1	38.615	0.495	0.04969	0.00219	0.06	164.82	4.92
12267AZ1_2	37.788	0.482	0.04990	0.00221	0.09	168.38	4.88
12267AZ1_3	37.840	0.456	0.05213	0.00284	0.06	168.15	4.84
12267AZ1_4	37.555	0.644	0.04913	0.00255	0.09	169.41	5.27
12267AZ1_5	38.510	0.525	0.05070	0.00221	0.09	165.26	4.93
12267AZ1_6	37.710	0.514	0.05077	0.00279	0.06	168.72	4.93
12267AZ1_7	38.639	0.630	0.05126	0.00285	0.06	164.71	5.05
12267AZ1_8	37.738	0.720	0.05087	0.00272	0.09	168.59	5.47
12267AZ1 9	37.722	0.541	0.05103	0.00278	0.05	168.67	5.06
12267AZ1 10	37.012	0.556	0.05153	0.00284	0.06	171.86	5.15
12267AZ1 11	38,186	0.534	0.04974	0.00309	0.06	166.64	4.89
12267AZ1 12	38.620	0.596	0.05128	0.00272	0.07	164.79	5.01
12267AZ1_13	36.515	0.446	0.04989	0.00179	0.09	174.17	5.01
12267A71_14	38.651	0.595	0.05202	0.00317	0.07	164.66	5.07
12267AZ1 15	37.549	0.998	0.05104	0.00265	0.23	169.43	6.27
12267A71_16	36.977	0.902	0.05059	0.00198	0.29	172.02	6.16
12267A71 17	37.539	0.730	0.05161	0.00323	0.12	169.48	5.47
12267A71_18	37.878	0.800	0.05171	0.00316	0.12	167.98	5.63
12267A71 19	37 716	0.939	0.05222	0.00344	0.15	168 69	6.06
12267A71_20	37.317	0.843	0.05302	0.00300	0.17	170.47	5.82
12267A71_21	38 160	0.888	0.05231	0.00327	0.15	166 75	5.82
12267AZ1_22	37 181	1 058	0.05152	0.00305	0.10	171 09	6.62
12267A71_23	37 539	0.668	0.04947	0.00188	0.19	169 48	5.38
12267A71_24	37 772	1 100	0.05170	0.00226	0.33	168 45	6.52
12267A71_25	36 740	1 006	0.05369	0.00429	0.00	173 11	6.47
12267A71_26	36 764	0.869	0.05323	0.00364	0.10	173.00	5.82
12267A71_27	37.275	0.798	0.05234	0.00363	0.11	170.66	5.49
12267A71_28	37 658	0 724	0.05256	0.00294	0.13	168.95	5.25
12267A71_29	37.638	0.810	0.05075	0.00323	0.10	169.04	5.53
12267AZ1_30	37 528	1 031	0.05197	0.00408	0.12	169 53	6 15
12267AZ1_31	38 589	0.888	0.05038	0.00179	0.40	164.93	5.60
12267A71_32	37 123	0.649	0.05082	0.00270	0.13	171.35	5.22
12267AZ1_33	37 753	0 724	0.05106	0.00355	0.10	168 53	5.29
12267A71_34	38,270	0.651	0.05171	0.00294	0.09	166.28	4.96
12267AZ1_35	37 262	0 761	0.05347	0.00336	0.13	170 72	5 44
12267AZ1_36	37.308	0.592	0.05078	0.00219	0.19	170.51	4.99
12267A71_37	37 670	0.593	0.04967	0.00248	0.08	168.90	4.96
12267A71_38	38,715	0.644	0.05004	0.00208	0.13	164.40	4.88
12267A71_39	37 441	0.649	0.05061	0.00269	0.10	169.92	5.22
12267A71_40	37.922	1.006	0.04999	0.00200	0.46	167.79	6.07
12267A71 41	37 834	0.527	0.05119	0.00230	0.09	168 17	4 79
12267A71 42	37 418	0.510	0.04984	0.00184	0.19	170.02	4 82
12267A71_43	37.313	0.564	0.05034	0.00197	0.14	170,49	4.97
12267A71 44	37,198	0.568	0.05298	0.00264	0.08	171.01	4.94
12267A71 45	37,773	0.614	0.05181	0.00362	0.04	168.44	4.95
12267A71 46	37 020	0.528	0.05017	0.00214	0.13	171 82	4 94
12267A71 47	36.808	0.574	0.05061	0.00283	0.07	172.80	5.02
12267A71 48	36 413	0 773	0.05033	0.00383	0.07	174 65	5.67
12267A71 49	37,122	0.569	0.05053	0.00215	0.13	171.36	5.01
12267AZ1 50	37.540	0.642	0.05129	0.00297	0.09	169.47	5.06

¹ Data not corrected for common lead
Zircon U-Pb LA-ICP-MS data for sample 11BVA35-276

Analysis		lso		Age (Ma) ²			
	²³⁸ U/ ²⁰⁶ Pb	± 2σ abs	²⁰⁷ Pb/ ²⁰⁶ Pb	± 2σ abs	Rho	²⁰⁶ Pb/ ²³⁸ U	± 2 or abs
12268AZ1_1	36.504	1.117	0.05090	0.00184	0.55	174.22	6.79
12268AZ1_3	35.168	2.170	0.05080	0.00285	0.68	180.75	12.02
12268AZ1_4	37.645	1.297	0.04951	0.00172	0.63	169.01	7.14
12268AZ1_5	35.215	2.929	0.05817	0.00596	0.53	143.68	-30.26 +16.60
12268AZ1_6	37.813	0.971	0.04983	0.00166	0.53	168.27	5.99
12268AZ1_7	37.806	0.826	0.05112	0.00178	0.44	168.30	5.62
12268AZ1_8	41.236	1.869	0.08074	0.00655	0.39	159.11	-29.00 +20.70
12268AZ1_9	39.612	9.731	0.05522	0.01350	0.51	160.72	39.23
12268AZ1_10	42.051	1.162	0.05223	0.00438	0.08	151.51	5.47
12268AZ1_11	38.585	1.381	0.04993	0.00239	0.51	164.94	7.00
12268AZ1_12	40.500	10.981	0.05599	0.02072	0.37	157.24	42.47
12268AZ1_13	37.799	0.786	0.05418	0.00586	0.03	168.33	5.36
12268AZ1_14	43.193	0.486	0.05068	0.00217	0.07	147.55	4.01
12268AZ1_15	43.681	1.982	0.05199	0.00328	0.45	145.92	7.41
12268AZ1_16	36.256	1.229	0.05160	0.00207	0.57	175.40	7.36
12268AZ1_17	40.858	1.984	0.05947	0.00402	0.44	<u>164.36</u>	<u>-23.81 +14.68</u>
12268AZ1_18	41.741	8.057	0.05440	0.01496	0.38	152.62	29.62
12268AZ1_19	37.432	1.197	0.05110	0.00415	0.13	169.96	6.72
12268AZ1_20	40.371	2.611	0.04986	0.00513	0.39	157.73	10.71
12268AZ1_21	37.196	0.812	0.04998	0.00177	0.40	171.02	5.69
12268AZ1_22	36.842	2.837	0.05158	0.00357	0.58	172.64	13.81
12268AZ1_23	54.151	7.018	0.07012	0.01158	0.40	136.04	<u>-49.51 +46.58</u>
12268AZ1_24	33.628	3.385	0.05746	0.00542	0.59	188.91	19.30
12268AZ1_25	38.343	5.256	0.11411	0.01363	0.76	<u>154.99</u>	-55.60 +42.42
12268AZ1_26	37.162	2.152	0.05016	0.00391	0.37	171.18	10.66
12268AZ1_27	36.754	2.909	0.04970	0.00286	0.72	173.05	14.20
12268AZ1_28	36.849	2.839	0.05004	0.00305	0.64	172.61	13.83
12268AZ1_29	48.455	3.856	0.05401	0.00330	0.67	131.69	10.89
12268AZ1_30	35.997	3.140	0.05095	0.00368	0.61	176.64	15.83
12268AZ1_31	36.752	3.046	0.05006	0.00323	0.67	173.06	14.82
12268AZ1_32	35.335	2.078	0.05225	0.00338	0.47	179.90	11.35
12268AZ1_33	36.496	3.395	0.05031	0.00441	0.53	174.26	16.54
12268AZ1_34	37.218	2.309	0.05367	0.00475	0.35	170.92	11.26
12268AZ1_35	38.415	2.686	0.05172	0.00270	0.69	165.66	12.18
12268AZ1_36	36.037	7.223	0.05263	0.00987	0.55	176.44	35.19
12268AZ1_37	38.295	0.554	0.05170	0.00260	0.06	166.18	4.74
12268AZ1_38	37.958	0.743	0.05169	0.00358	0.14	167.63	5.15
12268AZ1_39	41.346	4.905	0.05165	0.00861	0.40	154.06	18.42
12268AZ1_40	37.873	0.763	0.05255	0.00390	0.07	168.00	5.29
12268AZ1_41	37.487	0.726	0.05236	0.00319	0.07	169.71	5.25
12268AZ1_42	50.924	4.389	0.06679	0.00738	0.46	<u>159.90</u>	-29.34 +19.70
12268AZ1_43	38.122	0.558	0.04994	0.00168	0.23	166.92	4.78
12268AZ1_44	38.700	1.807	0.04926	0.00242	0.61	164.46	8.74
12268AZ1_45	38.139	1.387	0.05178	0.00312	0.27	166.85	7.26
12268AZ1_46	30.189	9.138	0.11795	0.15409	0.01	210.07	62.88
12268AZ1_47	36.832	0.522	0.05014	0.00153	0.22	172.69	4.91
12268AZ1_48	37.866	0.624	0.05273	0.00336	0.05	168.04	4.97
12268AZ1_49	38.689	2.396	0.05070	0.00371	0.44	164.51	10.82
12268AZ1_50	37.802	0.821	0.05096	0.00242	0.17	168.31	5.48

¹ Data not corrected for common lead

² Data not corrected for common lead, except underlined values

Zircon U-Pb LA-ICP-MS data for sample 11BVA38-304

Analysis		lse	otopic ratios ¹		Age (Ma) ¹			
	²³⁸ U/ ²⁰⁶ Pb	± 2σ abs	²⁰⁷ Pb/ ²⁰⁶ Pb	± 2σ abs	Rho	²⁰⁶ Pb/ ²³⁸ U	±2or abs	
12269AZ1_1	30.164	0.626	0.05631	0.00520	0.04	210.24	6.58	
12269AZ1_2	30.403	0.664	0.05746	0.00497	0.05	208.62	6.72	
12269AZ1_3	29.644	0.548	0.05464	0.00462	0.05	213.87	6.49	
12269AZ1_4	29.257	0.524	0.05453	0.00403	0.05	216.66	6.49	
12269AZ1_5	29.060	0.550	0.05363	0.00445	0.03	218.10	6.68	
12269AZ1_6	29.431	0.667	0.05485	0.00538	0.03	215.39	7.12	
12269AZ1_7	29.062	0.591	0.05743	0.00561	0.02	218.09	6.86	
12269AZ1_8	30.024	0.675	0.05481	0.00505	0.03	211.21	6.95	
12269AZ1_9	28.638	0.434	0.05286	0.00313	0.05	221.26	6.35	
12269AZ1_10	29.541	0.557	0.05486	0.00521	0.03	214.61	6.55	
12269AZ1_11	30.336	0.559	0.05516	0.00423	0.03	209.07	6.35	
12269AZ1_12	28.185	0.805	0.05782	0.00711	0.02	224.75	8.41	
12269AZ1_13	30.188	1.007	0.05503	0.00508	0.12	210.08	8.61	
12269AZ1 14	29.524	0.783	0.05447	0.00395	0.13	214.73	7.64	
12269AZ1_15	29.943	0.689	0.05234	0.00321	0.14	211.77	7.07	
12269AZ1 16	29.894	0.887	0.05616	0.00570	0.11	212.11	8.06	
12269AZ1_17	29.178	0.901	0.05262	0.00550	0.06	217.23	8.45	
12269AZ1_18	29.562	0.736	0.05343	0.00252	0.23	214.46	7.41	
12269AZ1 19	29.431	0.682	0.05223	0.00345	0.13	215.39	7.20	
12269AZ1_20	28.556	0.746	0.05282	0.00365	0.14	221.88	7.87	
12269AZ1 21	29.994	0.736	0.05468	0.00403	0.13	211.42	7.26	
12269AZ1_22	29.486	0.823	0.05359	0.00427	0.12	215.00	7.86	
12269AZ1_23	29.144	0.882	0.05288	0.00473	0.11	217.49	8.38	
12269AZ1_24	29.250	0.774	0.05487	0.00502	0.08	216.71	7.68	
12269AZ1_25	28.467	0.860	0.05497	0.00449	0.15	222.56	8.56	
12269AZ1_26	28.706	0.808	0.05434	0.00350	0.18	220.75	9.85	
12269AZ1_27	29.516	0.945	0.05704	0.00477	0.15	214.79	10.24	
12269AZ1_28	28.284	0.939	0.05761	0.00550	0.13	223.98	10.70	
12269AZ1_29	29.130	0.674	0.05266	0.00342	0.12	217.59	9.10	
12269AZ1_30	29.435	0.860	0.05515	0.00552	0.08	215.37	9.73	
12269AZ1_31	28.335	1.119	0.05544	0.00591	0.15	223.58	11.73	
12269AZ1_32	29.817	0.824	0.05484	0.00359	0.21	212.66	9.49	
12269AZ1_33	29.198	0.814	0.05624	0.00435	0.16	217.08	9.68	
12269AZ1_34	29.461	0.894	0.05203	0.00295	0.23	215.18	10.04	
12269AZ1_35	29.529	0.984	0.06026	0.00702	0.10	214.69	10.22	
12269AZ1_36	27.844	0.946	0.05378	0.00453	0.14	227.46	11.06	
12269AZ1_37	29.819	1.021	0.05119	0.00277	0.34	212.64	10.59	
12269AZ1_38	29.310	0.951	0.05261	0.00416	0.16	216.27	10.36	
12269AZ1_39	29.509	0.530	0.05410	0.00352	0.07	214.83	8.48	
12269AZ1_40	29.394	0.445	0.05166	0.00269	0.10	215.66	8.36	
12269AZ1_41	29.448	0.553	0.05566	0.00450	0.05	215.27	8.61	
12269AZ1_42	28.807	0.606	0.05530	0.00387	0.09	219.98	9.05	
12269AZ1_43	28.861	0.540	0.05216	0.00386	0.05	219.58	8.73	
12269AZ1_44	28.633	0.394	0.05025	0.00241	0.09	221.30	8.47	
12269AZ1_45	28.711	0.564	0.05471	0.00387	0.09	220.71	9.04	
12269AZ1_46	28.728	0.816	0.05483	0.00393	0.16	220.58	9.89	
12269AZ1_48	29.505	0.987	0.05350	0.00661	0.08	214.86	10.10	
12269AZ1_49	29.613	0.723	0.05153	0.00333	0.14	214.09	9.21	
12269AZ1_50	28.760	0.741	0.05359	0.00441	0.08	220.34	9.57	

¹ Data not corrected for common lead

Zircon U-Pb LA-ICP-MS data for sample 11BVA42-333

Analysis		ls	otopic ratios ¹		Age (Ma) ¹			
	²³⁸ U/ ²⁰⁶ Pb	±2or abs	²⁰⁷ Pb/ ²⁰⁶ Pb	± 2σ abs	Rho	²⁰⁶ Pb/ ²³⁸ U	±2o abs	
122610AZ1_1	27.935	1.296	0.05746	0.00636	0.16	226.73	11.66	
122610AZ1_2	28.027	1.139	0.05637	0.00506	0.20	226.00	10.52	
122610AZ1_3	27.830	0.883	0.05924	0.00650	0.08	227.57	8.91	
122610AZ1_4	28.428	0.851	0.05358	0.00483	0.08	222.86	8.40	
122610AZ1_5	28.240	1.276	0.05955	0.00705	0.15	224.33	11.32	
122610AZ1_6	27.515	1.501	0.05541	0.00548	0.28	230.13	13.49	
122610AZ1 7	28.584	1.097	0.05612	0.00503	0.18	221.67	9.90	
122610AZ1_8	28.359	1.175	0.05152	0.00504	0.17	223.40	10.55	
122610AZ1 9	28.130	1.209	0.05410	0.00551	0.15	225.19	10.97	
122610AZ1 10	28.708	0.939	0.05646	0.00507	0.14	220.73	8.84	
122610AZ1 11	28.388	1.513	0.05729	0.00573	0.24	223.17	12.83	
122610AZ1 12	29.615	0.615	0.05645	0.00444	0.07	214.08	6.72	
122610AZ1 13	29.402	0.617	0.05584	0.00494	0.05	215.60	6.79	
122610AZ1 14	29.049	0.746	0.05573	0.00618	0.05	218.18	7.56	
122610AZ1_15	28.981	1.060	0.05400	0.00506	0.15	218.68	9.46	
122610AZ1_16	28.223	1.034	0.06001	0.00671	0.11	224.46	9.67	
122610AZ1 17	28.888	0.805	0.05547	0.00532	0.08	219.38	8.03	
122610AZ1 18	29.317	0.926	0.05823	0.00587	0.07	216.22	8.44	
122610AZ1_19	29.147	1.220	0.05470	0.00508	0.18	217.46	10.36	
122610AZ1_20	29.312	1.337	0.05378	0.00517	0.19	216.26	11.07	
122610AZ1_21	28.608	1.259	0.05783	0.00692	0.14	221.49	10.94	
122610AZ1_22	29,433	0.885	0.05730	0.00602	0.06	215.38	8.13	
122610AZ1_23	28,748	0.650	0.05329	0.00559	0.05	220.43	7.22	
122610AZ1_24	29.155	1.402	0.05589	0.00610	0.19	217.40	11.52	
122610AZ1_25	29.383	1.457	0.05723	0.00506	0.26	215.74	11.72	
122610AZ1_26	28.648	0.879	0.05534	0.00457	0.12	221.18	8.34	
122610AZ1_27	28.398	1.290	0.05347	0.00559	0.20	223.09	11.13	
122610AZ1_28	29.248	1.461	0.05676	0.00589	0.22	216.72	11.65	
122610AZ1_29	28.909	1.434	0.06002	0.00605	0.22	219.22	11.77	
122610AZ1_30	28.564	1.008	0.05399	0.00425	0.21	221.83	9.16	
122610AZ1_31	28.961	1.568	0.05222	0.00597	0.21	218.83	12.63	
122610AZ1_32	29.762	1.418	0.05455	0.00445	0.28	213.04	11.08	
122610AZ1_33	28,455	1.218	0.05515	0.00722	0.11	222.66	10.60	
122610AZ1_34	29.353	1.026	0.05341	0.00505	0.13	215.96	8.85	
122610AZ1_35	29.735	0.993	0.05473	0.00502	0.15	213.23	8.48	
122610AZ1_36	29.453	1.079	0.05435	0.00476	0.17	215.24	9.14	
122610AZ1_37	29.317	1.026	0.05412	0.00737	0.06	216.22	8.90	
122610AZ1_38	30.534	0.704	0.05352	0.00417	0.07	207.74	6.66	
122610AZ1_39	28.814	0.662	0.05565	0.00572	0.05	219.93	7.05	
122610AZ1_40	30.472	0.447	0.05089	0.00216	0.15	208.16	5.54	
122610AZ1_41	29.629	0.694	0.05261	0.00491	0.06	213.98	6.86	
122610AZ1 42	29.805	0.800	0.05574	0.00558	0.07	212.74	7.36	
122610AZ1 43	29.517	0.939	0.05302	0.00719	0.06	214.78	8.19	
122610AZ1 44	29.109	0.784	0.05861	0.00581	0.06	217.74	7.56	
122610AZ1 45	29.472	0.740	0.05167	0.00416	0.09	215.10	7.30	
122610AZ1 46	28.927	0.767	0.05270	0.00432	0.08	219.09	7.57	
122610AZ1 47	29.732	0.692	0.05509	0.00534	0.06	213.25	6.83	
122610AZ1_48	29,489	0.913	0.05651	0.00656	0.06	214.98	8.08	
122610AZ1 49	29.108	0.643	0.05557	0.00499	0.05	217.75	6.82	
122610AZ1_50	29.193	0.961	0.05826	0.00587	0.08	217.12	8.51	

¹ Data not corrected for common lead

Heating	Laser	Isotope Rat	ios									Age	
step	power(%)	40Ar/39Ar	1σ	37Ar/39Ar	1σ	36Ar/39Ar	1σ	Ca/K	% 40Ar atm	% 39Ar	40Ar*/39ArK	(Ma)	2σ
1	2.40 W	41.20	0.74	2.91	0.08	0.084	0.003	5.34	60.06	0.24	16.488	161.90	17.16
2	2.80 W	11.28	0.13	1.64	0.04	0.008	0.001	3.01	20.89	1.22	8.933	89.51	3.84
3	3.20 W	17.84	0.11	0.96	0.02	0.003	0.000	1.77	4.39	4.66	17.071	167.37	2.03
4	3.60 W	21.44	0.14	1.24	0.02	0.003	0.000	2.27	3.39	6.62	20.730	201.31	2.64
5*	3.80 W	21.85	0.11	1.89	0.03	0.001	0.000	3.46	1.29	9.38	21.594	209.24	2.08
6*	4.00 W	22.04	0.12	2.63	0.04	0.001	0.000	4.82	0.85	13.99	21.896	212.00	2.20
7*	4.10 W	21.76	0.12	2.47	0.04	0.001	0.000	4.53	0.45	7.01	21.704	210.24	2.20
8*	4.30 W	21.97	0.11	2.54	0.04	0.001	0.000	4.66	0.74	11.37	21.848	211.56	2.11
9*	4.50 W	21.94	0.11	2.53	0.04	0.001	0.000	4.64	0.60	11.61	21.845	211.53	2.13
10	4.70 W	21.47	0.11	2.75	0.05	0.001	0.000	5.05	0.50	5.86	21.402	207.48	2.25
11	4.90 W	21.55	0.11	3.06	0.05	0.001	0.000	5.62	0.66	4.80	21.451	207.93	2.67
12	5.10 W	21.23	0.12	3.42	0.06	0.001	0.000	6.27	0.77	6.00	21.114	204.84	2.28
13	5.30 W	20.18	0.13	3.58	0.07	0.002	0.000	6.58	1.49	1.97	19.926	193.91	2.60
14	6.00 W	20.10	0.11	4.48	0.08	0.002	0.000	8.23	1.53	3.56	19.855	193.25	2.23
15	7.00 W	19.97	0.11	5.42	0.09	0.003	0.000	9.97	1.71	4.43	19.705	191.87	2.16
16	8.00 W	20.91	0.11	4.72	0.08	0.002	0.000	8.67	1.46	3.81	20.674	200.80	2.29
17	9.00 W	20.61	0.13	7.66	0.13	0.003	0.000	14.11	2.06	3.46	20.298	197.34	2.49

Hornblende Ar-Ar data for sample 11BVA27-199

Plateau age: 210.9 ± 1.6 Ma (20, including J-error of .6%), MSWD=1.16, p=0.32, includes 53.3% of the 39Ar, steps 5 through 9

Inverse isochron age: 209.4 ± 2.1 Ma, initial 40Ar/36Ar=235 ± 51, MSWD=5.0, p=0, 10 point isochron

* Heating steps used for plateau age calculation

Biotite Ar-Ar data for sample 11BVA35-276

Heating	Laser	Isotope Rat	ios									Age	
step	power(%)	40Ar/39Ar	1σ	37Ar/39Ar	1σ	36Ar/39Ar	1σ	Ca/K	% 40Ar atm	% 39Ar	40Ar*/39ArK	(Ma)	2σ
1	2.40 W	8.50	0.08	0.26	0.01	0.013	0.001	0.47	45.12	0.39	4.666	47.34	3.85
2	2.80 W	10.38	0.06	0.12	0.00	0.008	0.000	0.21	23.54	1.86	7.936	79.80	1.89
3	3.20 W	16.12	0.08	0.04	0.00	0.004	0.000	0.07	6.57	4.72	15.063	148.57	1.57
4	3.30 W	17.41	0.09	0.03	0.00	0.002	0.000	0.05	2.69	3.34	16.941	166.26	1.78
5*	3.40 W	17.64	0.09	0.03	0.00	0.001	0.000	0.06	2.52	2.35	17.194	168.64	1.78
6*	3.50 W	17.39	0.09	0.02	0.00	0.001	0.000	0.04	1.91	3.77	17.060	167.38	1.65
7*	3.60 W	17.55	0.09	0.03	0.00	0.001	0.000	0.06	1.95	3.96	17.204	168.74	1.65
8*	3.70 W	17.65	0.09	0.10	0.00	0.001	0.000	0.19	2.03	5.44	17.288	169.52	1.68
9*	3.80 W	17.57	0.09	0.02	0.00	0.001	0.000	0.04	1.30	3.78	17.347	170.07	1.89
10*	3.90 W	17.49	0.10	0.03	0.00	0.001	0.000	0.05	1.19	3.90	17.282	169.47	1.95
11*	4.00 W	17.61	0.09	0.09	0.00	0.001	0.000	0.17	1.20	4.47	17.400	170.57	1.80
12*	4.10 W	17.53	0.09	0.05	0.00	0.001	0.000	0.09	1.06	3.32	17.340	170.00	1.93
13*	4.20 W	17.46	0.09	0.04	0.00	0.001	0.000	0.07	1.14	4.29	17.265	169.30	1.89
14*	4.30 W	17.48	0.09	0.04	0.00	0.001	0.000	0.07	1.31	4.24	17.252	169.18	1.81
15*	4.40 W	17.45	0.12	0.11	0.00	0.001	0.000	0.20	1.19	2.74	17.244	169.11	2.43
16*	4.60 W	17.38	0.09	0.11	0.00	0.001	0.000	0.20	1.12	5.07	17.185	168.56	1.75
17*	4.80 W	17.29	0.09	0.09	0.00	0.001	0.000	0.17	1.26	7.42	17.072	167.49	1.75
18	5.00 W	17.11	0.10	0.14	0.00	0.001	0.000	0.26	0.96	6.22	16.945	166.30	1.87
19	5.20 W	17.13	0.09	0.16	0.00	0.001	0.000	0.30	1.00	5.16	16.958	166.43	1.76
20	5.40 W	17.11	0.09	0.21	0.00	0.001	0.000	0.38	1.10	3.36	16.921	166.08	1.98
21	5.70 W	17.20	0.09	0.21	0.01	0.000	0.000	0.39	0.80	2.92	17.065	167.43	1.95
22	6.00 W	17.19	0.09	0.22	0.00	0.001	0.000	0.40	0.98	3.49	17.019	167.00	1.85
23	6.50 W	17.13	0.09	0.25	0.00	0.001	0.000	0.46	0.87	7.43	16.981	166.64	1.67
24	7.00 W	17.12	0.09	0.33	0.01	0.001	0.000	0.60	1.03	3.89	16.949	166.34	1.81
25	7.50 W	17.22	0.09	0.41	0.01	0.001	0.000	0.74	1.42	2.48	16.979	166.62	2.07

Plateau age: 169.0 ± 1.1 Ma (2σ , including J-error of .6%), MSWD=1.12, p=0.34, includes 54.7% of the 39Ar, steps 5 through 17

Inverse isochron age: 166.4 ± 1.8 Ma, initial 40Ar/36Ar=476 ± 230, MSWD=2.3, p=0.001, 22 point isochron

* Heating steps used for plateau age calculation

Hornblende Ar-Ar data for sample 11BVA42-329

Heating	Laser	Isotope Rat	ios									Age	
step	power(%)	40Ar/39Ar	1σ	37Ar/39Ar	1σ	36Ar/39Ar	1σ	Ca/K	% 40Ar atm	% 39Ar	40Ar*/39ArK	(Ma)	2σ
1	2.20 W	15.03	18.4	0.58	0.71	0.047	0.061	-1.06	91.96	0.07	1.207	-12.46	128.70
2	2.70 W	165.34	214	5.69	7.37	0.235	0.304	10.47	41.61	0.07	96.928	793.94	1672.2
3	3.70 W	21.51	0.58	2.50	0.08	0.013	0.001	4.59	16.96	3.39	17.891	175.22	9.67
4	4.40 W	17.16	0.30	2.28	0.06	0.003	0.000	4.19	4.19	5.33	16.466	161.87	5.67
5	5.00 W	17.25	0.18	2.86	0.05	0.003	0.000	5.25	3.21	9.73	16.734	164.39	3.46
6*	5.70 W	17.72	0.13	4.42	0.08	0.002	0.000	8.12	1.82	18.30	17.457	171.16	2.59
7*	6.40 W	17.75	0.16	4.60	0.08	0.003	0.000	8.46	2.62	14.22	17.341	170.07	2.94
8*	7.10 W	17.82	0.22	4.71	0.10	0.003	0.000	8.66	2.84	7.83	17.368	170.33	4.26
9*	7.80 W	18.50	0.29	4.42	0.10	0.004	0.000	8.12	5.04	6.11	17.618	172.67	5.39
10*	8.40 W	18.17	0.12	5.38	0.09	0.003	0.000	9.88	2.69	28.99	17.746	173.87	2.23
11*	9.00 W	18.19	0.29	4.55	0.11	0.004	0.000	8.36	4.18	6.10	17.490	171.48	5.65

Inverse isochron age: 168.9 ± 4.7 Ma, initial 40Ar/36Ar=386 ± 210, MSWD=4.7, p=0, 11 point isochron

* Heating steps used for plateau age calculation

Hornblende Ar-Ar data for sample 11BVA42-332

Heating	Laser	Isotope Rat	ios									Age	
step	power(%)	40Ar/39Ar	1σ	37Ar/39Ar	1σ	36Ar/39Ar	1σ	Ca/K	% 40Ar atm	% 39Ar	40Ar*/39ArK	(Ma)	2σ
1	2.20 W	4.71	0.15	0.24	0.01	0.011	0.004	0.44	71.38	0.24	1.349	13.80	21.97
2	2.60 W	6.27	0.05	0.18	0.00	0.006	0.000	0.33	29.35	1.99	4.433	44.96	2.87
3	3.00 W	12.06	0.08	0.08	0.00	0.004	0.000	0.15	9.63	4.17	10.900	108.60	2.03
4	3.60 W	16.68	0.10	0.08	0.00	0.002	0.000	0.14	3.20	15.98	16.144	158.62	1.81
5*	3.80 W	18.02	0.10	0.08	0.00	0.001	0.000	0.15	2.07	14.97	17.652	172.75	1.82
6*	4.00 W	18.11	0.10	0.19	0.00	0.001	0.000	0.34	2.18	9.75	17.715	173.34	1.90
7*	4.30 W	18.00	0.10	0.23	0.00	0.001	0.000	0.41	1.52	11.47	17.728	173.46	1.89
8*	4.80 W	17.95	0.11	0.30	0.01	0.001	0.000	0.55	1.45	18.01	17.692	173.13	1.96
9	5.30 W	17.42	0.09	0.34	0.01	0.001	0.000	0.63	0.94	10.86	17.265	169.14	1.73
10	5.80 W	17.02	0.09	0.46	0.01	0.001	0.000	0.85	1.10	6.33	16.841	165.17	1.90
11	6.30 W	16.81	0.25	0.58	0.01	0.001	0.000	1.07	1.28	3.20	16.603	162.93	4.85
12	7.00 W	16.96	0.09	0.71	0.01	0.001	0.000	1.31	1.24	3.04	16.760	164.41	2.43

Plateau age: 173.2 ± 1.4 Ma (20, including J-error of .6%), MSWD=0.114, p=0.95, includes 54.2% of the 39Ar, steps 5 through 8

Inverse isochron age: 170.1 ± 3.2 Ma, initial 40Ar/36Ar=294.99 ± 0.45, MSWD=14, p=0, 9 point isochron (forced through air argon initial composition)

* Heating steps used for plateau age calculation

Hornblende Ar-Ar data for sample 11BVA42-333

Heating	Laser	Isotope Rat	tios									Age	
step	power(%)	40Ar/39Ar	1σ	37Ar/39Ar	1σ	36Ar/39Ar	1σ	Ca/K	% 40Ar atm	% 39Ar	40Ar*/39ArK	(Ma)	2σ
1*	2.20 W	102.01	22.78	5.11	1.19	0.202	0.121	9.39	58.09	0.03	42.910	394.25	571.29
2*	2.60 W	32.08	1.30	7.73	0.38	0.060	0.017	14.24	53.57	0.22	14.976	147.56	97.01
3*	3.00 W	22.73	0.48	3.00	0.11	0.008	0.007	5.50	8.80	0.48	20.770	201.57	36.59
4*	3.70 W	25.76	0.26	7.38	0.15	0.012	0.001	13.58	10.91	3.24	23.073	222.60	7.83
5*	4.30 W	23.07	0.14	5.72	0.10	0.002	0.000	10.53	0.84	60.81	22.973	221.68	2.55
6*	4.60 W	22.69	0.14	5.27	0.09	0.002	0.000	9.68	0.38	29.47	22.689	219.11	2.60
7	5.00 W	22.18	0.25	5.83	0.15	0.003	0.001	10.72	1.56	2.84	21.920	212.10	7.18
8	5.80 W	21.58	0.20	5.30	0.13	0.002	0.002	9.74	0.57	1.90	21.542	208.64	9.21
9	6.80 W	21.64	0.25	5.18	0.17	0.003	0.006	9.52	1.60	1.02	21.370	207.07	31.43

Plateau age: 220.5 ± 2.2 Ma (2σ , including J-error of .6%), MSWD=1.20, p=0.31, includes 94.2% of the 39Ar, steps 1 through 6

Inverse isochron age: 218.8 ± 3.2 Ma, initial 40Ar/36Ar=365 ± 190, MSWD=2.2, p=0.05, 9 point isochron

* Heating steps used for plateau age calculation