

## **Vezinet et al., Supplementary Information - Outline**

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# 1 Apatite laser-ablation split stream (LASS) analyses

Apatite U–Pb/Sm–Nd isotopes LASS analyses were conducted at the Arctic Resource Lab, University of Alberta (Canada).

## 1.1 Metadata for LASS U–Th–Pb/Sm–Nd analyses

Table S1 shows the main analytical parameters used to conduct the LASS U–Th–Pb/Sm–Nd isotopes analyses.

**Table S1:** Metadata for the laser-ablation split-stream analyses performed during this study

Laboratory & Sample Preparation	
Laboratory name	Arctic Resource Lab, University of Alberta (Canada)
Sample type/mineral	Apatite $\text{Ca}_5(\text{PO}_4)_3(\text{F}, \text{OH}, \text{Cl})$
Sample preparation	Conventional mineral separation, polished 1 inch resin mount,
Imaging	CL & BSE (Gemini supra 55 VP Zeiss; EVO MA15 Zeiss; JEOL JSM-5910 LV)
Laser ablation system	
Make, Model & type	RESOLution ArF excimer
Ablation cell	Laurin Technic S-155
Laser wavelength	193 nm
Pulse width	20 ns
Fluence	5.5 J.cm <sup>-2</sup> (energy set: 120 mJ)
Repetition rate	6 Hz
Ablation/Washout duration	50 secs / 50 secs
Ablation rate	0.125 cm.pulse <sup>-1</sup> with the <i>ca.</i> 6.5 J.cm <sup>-2</sup> setting (measured on zircon)
Spot diameter nominal	130 $\mu\text{m}$
Sampling mode / pattern	Static spot ablation
Carrier gas	100% He in the cell, Ar and N <sub>2</sub> make-up gas combined using a Y-piece 50% along the sample transport line to the torch.
Cell carrier gas flow	0.8- 0.9 l.min <sup>-1</sup>
SC-ICP-MS Instrument	
U–Th–Pb isotopes	
Make, Model & type	Thermo Fisher Scientific, Element XR, SC-SF-ICP-MS
Sample introduction	Ablation aerosol introduced through Tygon tubing
RF power	1200W
Make-up gas flow (l/min)	Total gas is made of ~ 1.6 L.min <sup>-1</sup> of Ar, ~ 800 mL.min <sup>-1</sup> of He and ~ 14 mL.min <sup>-1</sup> of N <sub>2</sub> . This total gas is divided between both ICP-MS at a ~ 50-50 rate.
Detection system	202, 208, 232 in triple mode. 206 and 238 in analogue mode.

	204 and 207 in counting mode 235 is calculated using canonical value. No Faraday cup used.
Masses measured	202, 204, 206, 207, 208, 232, 238
Integration time per peak/ dwell times	30 ms on 202, 204, 208 and 232; 60 ms on 206, 207 and 238
Total integration time	300 ms for each output datapoint
IC Dead time	20 ns

**Table S1:** (continued)

MC-ICP-MS Instrument								
Sm-Nd isotopes								
Make, Model & type	Thermo Fisher Scientific, Neptune Plus, MC-SF-ICP-MS							
Sample introduction	Ablation aerosol introduced tygon tubing. Ni-Jet Sample cone and X-Skimmer cone.							
RF power	1200 W							
Make-up gas flow (l/min)	Total gas is made of ~ 1.6 L.min <sup>-1</sup> of Ar, ~ 800 mL.min <sup>-1</sup> of He and ~ 14 mL.min <sup>-1</sup> of N <sub>2</sub> . This total gas is divided between both ICP-MS at a ~ 50-50 rate.							
Detection system	Static Faraday (attached to 10 <sup>11</sup> Ω amplifier) measurement							
Masses measured	143, 144, 145, 146, 147, 148, 149, 150							
Integration time per output datapoint	1.049 secs							
Cup configuration	L3	L2	L1	Axial	H1	H2	H3	H4
	143	144	145	146	147	148	149	150
Data Processing								
Gas blank	30 second on-peak zero subtracted both for U-Pb and Lu-Hf measurements							
Calibration strategy	<b>Bancroft apatite</b> was used as primary (calibration) reference material for both U-Pb and Sm-Nd isotope analyses. <b>Durango and Mud Tank</b> were used as secondary (validation) for both U-Pb and Sm-Nd isotope analyses.							
Reference Material info	Bancroft: [1] Durango and Mud Tank: [1,2]							
Data processing package used / Correction for LIEF	Iolite v3 software package [3-5] using the following DRS: “ <i>U_Pb Geochron 4</i> ” for U-Th-Pb isotopes analyses and “ <i>SmNd_downhole</i> ” for Sm-Nd isotopes. LIEF correction assumes matrix match between reference material and samples.							
Mass discrimination	Standard-sample bracketing with <sup>207</sup> Pb/ <sup>206</sup> Pb and <sup>206</sup> Pb/ <sup>238</sup> U normalized to primary reference material.							
Common-Pb correction, composition and uncertainty	No common-Pb correction applied to the data							

Nd mass bias coefficient ( $\beta^{Nb}$ )	Calculated using $^{146}\text{Nd}/^{144}\text{Nd}$ ratio of 0.7219 and the exponential law of [6].
Isobaric interferences on $^{144}\text{Nd}$	Monitored with invariant Nd ratios: $^{145}\text{Nd}/^{144}\text{Nd}$ , $^{148}\text{Nd}/^{144}\text{Nd}$ and $^{150}\text{Nd}/^{144}\text{Nd}$ , used to assess the quality of the analysis, and its relative inaccuracy due to isobaric interferences from Sm on masses 144, 148, and 150 [1].
Uncertainty level & propagation	Ages are quoted at a coverage factor of 2 absolute ( <i>ca.</i> 95% confidence interval). No propagation of systematic uncertainty is made on single data points, only on weighted mean or discordia intercepts. Propagation is by quadratic addition. Reproducibility and age uncertainty of reference material uncertainty are propagated where appropriate.
Quality control / Validation	Results of LASS analyses on validation reference material are reported in Table S1.

## 1.2 Iolite data reduction

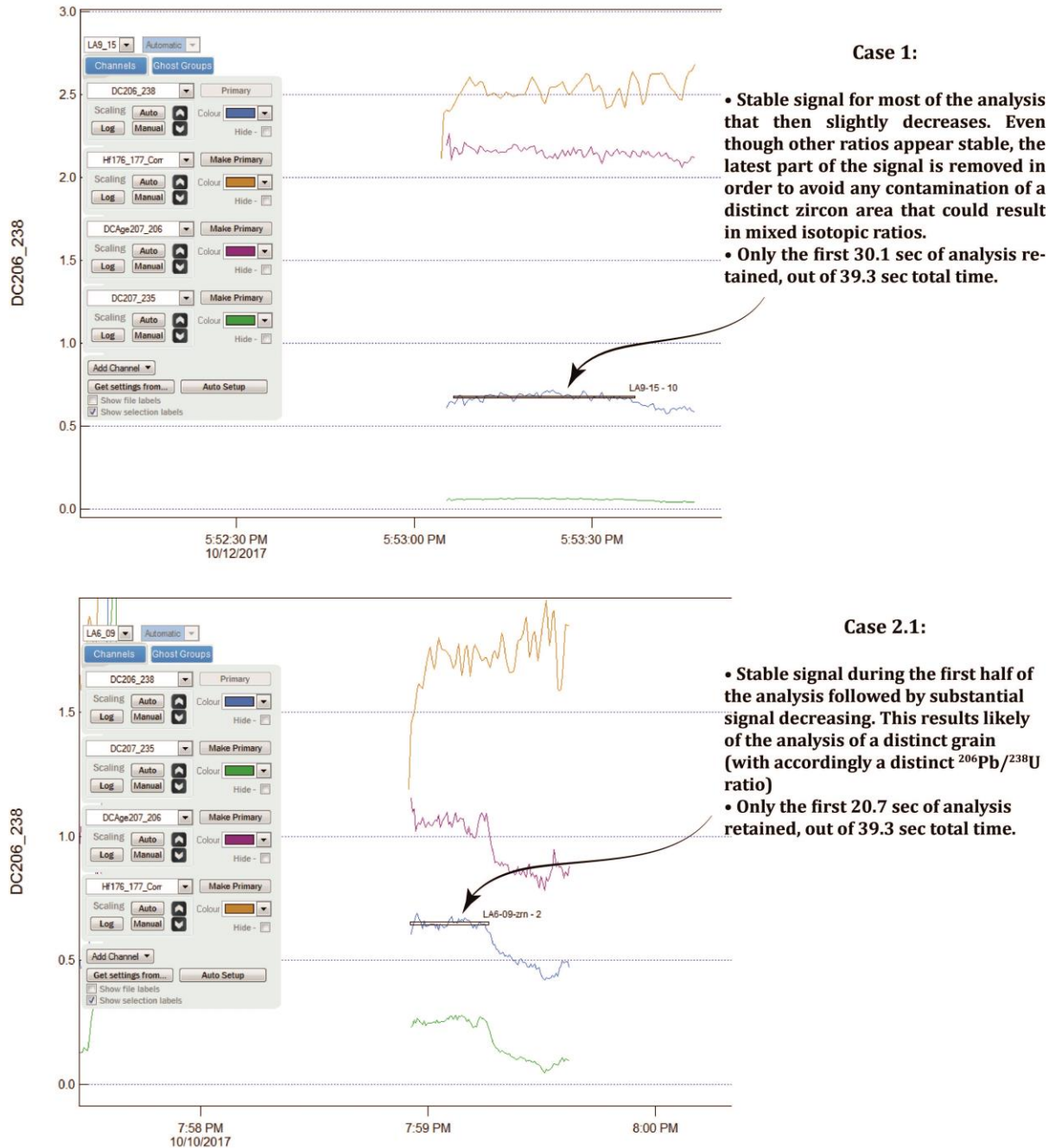
LASS analyses were processed offline using the Data Reduction Scheme (DRS) supplied by Iolite v3 software [3,4]. Isotope measurements from both the SC-SF-ICP-MS (U–Th–Pb isotope measurements) and the MC-SF-ICP-MS (Sm–Nd isotope measurements) were processed simultaneously through the “Run in Multiple DRS mode” option of the Iolite v3 software. This option implies that for each LASS analysis the integration time of the U–Th–Pb isotope analysis and the integration time Sm–Nd isotope analysis are identical. Moreover, as demonstrated in Figure S1, the integration time is manually determined for each single analysis in order to best represent the area of the grain selected prior LASS analysis, and reject obvious spurious parts of the signal.

## 1.3 Identification of common-Pb during apatite U–Pb isotope analyses

In addition to the masses 206, 207 and 208, we also measured the intensity on mass 204 to constrain the amount of common lead during the U–Pb analyses. To limit mercury (Hg) contamination and isobaric interferences in lead measurement, we used 3 Hg traps (VICI® Metronics Hg trap) positioned on the Ar line, the He line and the N<sub>2</sub> line. As the mass resolution power used in this study ( $M/\Delta M=300$ ) is not sufficient to separate <sup>204</sup>Pb ( $m=203.973044$ ) and <sup>204</sup>Hg ( $m=203.973494$ ) – that requires a  $M/\Delta M$  of *ca.* 408,000 – the signal obtained during scanning the 204-mass represents the combination of both isotopes. The potential contamination that would persist after the Hg-trapping step was thus quantified measuring mass 202, which is an interference-free mass of the <sup>202</sup>Hg. Using the measured <sup>202</sup>Hg value and the natural ratio of <sup>202</sup>Hg/<sup>204</sup>Hg (=29.74/6.82), we calculated the proportion of the 204-mass signal attributable to <sup>204</sup>Hg and hence the 204-mass signal attributable to <sup>204</sup>Pb. The <sup>204</sup>Pb value was then used to calculate the <sup>206</sup>Pb/<sup>204</sup>Pb ratio and, with reference to the model values of [7], to yield the  $f^{206}\text{Pb}_c$  reported in the Supplementary Table using the following equation:

$$f^{206}\text{Pb}_c(\%) = \frac{(^{206}\text{Pb}/^{204}\text{Pb})_{\text{Stacey \& Kramers, 1975}}}{(^{206}\text{Pb}/^{204}\text{Pb})_{\text{measured}}} \cdot 100$$

We emphasise that no common-Pb correction was applied to our apatite U–Pb isotope data.



**Figure S1. Time-resolved signal obtained in the course of LASS analysis.** These diagrams are drawn from the Iolite main Windows and based on zircon U–Pb/Hf analyses. The X-axis represents the time, the Y-axis represents the intensity of the selected wave. The horizontal black stroke rectangle represents the selected integration time. On every image, the grey panel located on the left reports the name of the displayed waves. DC206\_208 = Down-hole Corrected  $^{206}\text{Pb}/^{238}\text{U}$  isotopic ratio; DC207\_235 = Down-hole Corrected  $^{207}\text{Pb}/^{235}\text{U}$  ratio; DCAge207\_206 = Down-hole Corrected  $^{207}\text{Pb}/^{206}\text{Pb}$  isotopic age; Hf176\_177\_corr =  $^{176}\text{Hf}/^{177}\text{Hf}$  isotopic ratio corrected from mass bias fractionation. On every diagram, DC206\_208 is the selected wave.

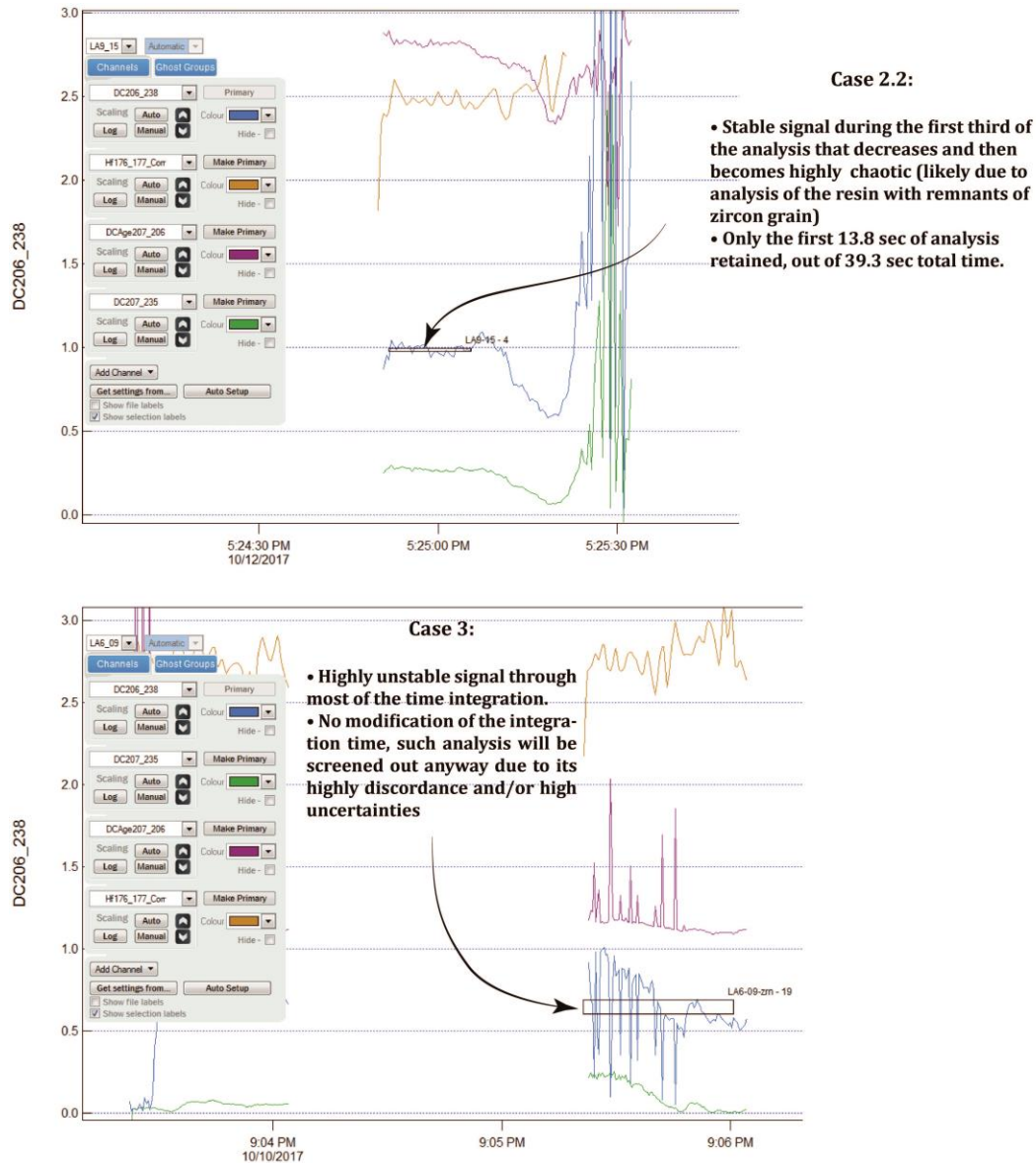


Figure S1. (continued)

## 2 Uncertainty propagation workflow

### 2.1 Uncertainty in U–Th–Pb isotope ratios and dates

Uncertainties in U–Th–Pb isotope ratios are those produced by the uncertainty propagation workflow built into Iolite software [3]. Systematic (external) uncertainties are reported where relevant, calculation from IsoplotR [8]. Uncertainties are reported at 95% confidence interval unless stated otherwise.

## **2.2 Uncertainty in Sm–Nd isotopes ratios**

Uncertainty in Sm–Nd isotope ratios are those produced by the uncertainty propagation workflow built into Iolite software. The “SmNd\_downhole” DRS of Iolite v3 used for this study does not include the “pseudo-secondary standard” pooling method implemented for U–Th–Pb analyses [3]. Thus, uncertainty in Sm–Nd isotopic ratios are measured uncertainties. No excess variance has however been detected in the analytical run.

## **3 Methodology for the determination of whole-rock major- and trace-elements composition**

Whole-rock chemical composition of the investigated rock was determined at the Service d’Analyse de Roches et Minéraux (SARM). A thorough description of the methodology is reported in [9]. The only difference with [9] is the mass-spectrometer devices used at the present day. The SARM is currently using iCap6500 and iCapQ (both ThermoFisher instruments) as ICP-AES and ICP-MS devices respectively.



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