Solid Earth Discuss.,
https://doi.org/10.5194/se-2018-84-RC2, 2018

Solid Earth Discussions
Open Access
EGU

Interactive comment on "Advecting heating by hot fluids of an Alpine fissure in Lauzière Granite (Belledonne massif, Western Alps)" *by* Emilie Janots et al.

Anonymous Referee #2

Received and published: 9 October 2018

A) General comments:

This study uses a multi-method approach in order to investigate the timing and effect of fluid-flow through the upper crust within an Alpine cleft. A large number of microthermometric data on quartz and monazite crystals along with new results from zircon fission-track dating (ZFT) is presented. The most intriguing result is that the fluid responsible for mineral formation in the cleft is significantly hotter (150–250 °C) compared to the surrounding host rock.

I very much like the multi-method approach the authors use in order to tackle such a complicated problem and how the temperatures and times obtained from the different

Printer-friendly version

Discussion paper

methods are combined. The outcomes of this study contribute to an improved understanding of the effects of fluids migrating through the middle – upper crust. Due to my lack of knowledge for microthermometry I can't judge in detail the results obtained from this method (maybe another reviewer is able to do this). Nonetheless, the interpretation of the microthermometry data seems logically and valid to me. Where I see a bit of a shortcoming of the manuscript is in the interpretation of the presented ZFT data and the drawn conclusions for the duration of fluid flow and the effect on exhumation (see detailed comments below). However, these concerns/questions should be easy to address by the authors.

In general, this work presents interesting and new results on a topic that is relevant for a broad audience within the geoscience community and hence the manuscript is worth publishing in Solid Earth, pending the authors address the comments below.

B) Specific comments:

(1) Introduction: If the authors restructure the introduction a little bit it might be more clearer to readers, which questions are actually addressed in the paper and how the new data aids in better understanding the general problem. I suggest splitting it into four paragraphs (see also technical comments below).

Then in the third paragraph (currently extending on page 2 from line 21 to 33), the authors should rephrase how they setup the main questions. E.g. it took me a while to figure out the two scenarios currently considered for monazite growth ("fast" precipitation from hot fluid vs. "slow" precipitation during exhumation?). So maybe start by just stating that similar ZFT and monazite ages lead to two hypotheses for monazite formation, but that constraints on the temperatures of the fluid in the vein and the surrounding host-rock are absent.

Then in the fourth paragraph you can explain how you tackle this problem in the current work by providing constraints from microthermometry (fluid temperature) and ZFT (information about host rock), which leads to a better understanding of the migration

of fluids. Be sure to indicate, what data used in your interpretation is from this study (microthermometry, ZFT) and already published (Monazite age). Also give a quick overview of your main outcomes, e.g. the unusually hot fluid and localized heating of the country rocks.

(2) ZFT data: For the three considered samples only a small number of zircon grains could be dated (7, 10 and 12 grains, respectively) and the $\chi 2$ values are very low (<0.26). In general for application of fission track dating around 20 grains should be dated to have good statistics on the reported sample ages (due to the high uncertainties on the single grain ages). However, this seems not to be possible with the current samples, due to analytical issues. The low $\chi 2$ values show that for each sample the dated grains do not belong to a single age peak, which might indicate that the samples are only partially reset (but again due to the small number of grains, this is difficult to assess). So the obtained central age and the associated uncertainty should be viewed with some caution.

I believe to interpret the young ZFT age of sample R1 as a result of (partial?) reseting of the ZFT system due to hot fluids is a valid assumption, but I would not put too much confidence into the actual date. So the calculated duration of fluid flow of 1–3 Myr by combing ZFT age and monazite age (which is very robustly constrained) should be viewed with caution.

For the manuscript I suggest to include a paragraph with a more thorough discussion/elaboration on the limitations of the presented ZFT ages (regarding the above mentioned points). A data table containing the results for the single grain analyses (number of counted induced/spontaneous tracks, Uranium content . . .) should also be included (could go to a supplement file).

(3) Sample coordinates: Detailed information on the location of the samples from this work seems to be missing. So indicate the coordinates of one sampled outcrop, either in the text or in the caption of Figure 1.

Printer-friendly version

Discussion paper

(4) Impact of advective heating: As stated by the authors, the impact of advective heating of fluids circulating in the cleft is only small, given that ZFT ages 30 m and 100 m away from the cleft still record the “background” cooling which occurred at 14–16 Ma. Having a look at other ZFT and Th-Pb monazite ages presented in Figure 1 supports only a local scale overprint (e.g. ZFT ages to the south of the Lauzière Granite are significantly older than the monazite ages next to them).

So in the paper the authors could put more emphasis on the fact, that even if fluids are significantly hotter compared to the surrounding country rock, the impact of advective heating is limited to the vicinity of an Alpine cleft (but of course it still depends on the duration and amount of fluid circulation).

In the conclusion the authors try to assess the impact on exhumation rates (p. 9 line 26 – 27). Strictly speaking, circulating fluids do not directly affect exhumation rates (i.e. rock uplift and denudation leading to exhumation are not affected by circulating fluids). The fluids locally perturb the geotherm, resulting in younger thermochronometer ages. This in turn suggests seemingly faster exhumation rates, if cooling ages are inverted for exhumation rates. However, as indicated above this effect should only be local and should not affect exhumation rates obtained from cooling ages on a larger area.

C) Line comments

Title: Could be rephrased to “Effects of advective heating by hot fluids . . ..”

Page 1, Line 30 – 31: As indicated above I would view the calculated duration with caution and also the possible effect on calculated exhumation rates should only be local.

Page 2, Line 5–6: This sentence requires a citation.

Page 2, Line 11: Should be the end of the first paragraph of the introduction, insert a return after exhumation rates.

Page 2, Line 21: End of second paragraph, insert a return after numerical modeling.

Page 2, Line 26–27: Indicate the respective ZFT and monazite ages in the text.

Page 2, Line 27–33: As indicated in comment (1), I would rephrase this paragraph. And there is no (direct) feedback between exhumation rates and fluid flow.

Page 3, Line 1–5: This would be the fourth paragraph of the introduction. Could be rephrased a bit as indicated above in comment (1).

Page 3, Line 10: Maybe not all readers are familiar with Alpine tectonics and the terms "internal/ external" domains so maybe quickly describe what these are/comprise.

Page 3, Line 25: What exactly do the authors mean by " . . . close from tectonic accident to the south"? Do they mean not far away from the main thrust? Please rephrase. The term "tectonic accident" also appears at another part of the manuscript (Page 9, Line 18).

Page 3, Line 30–31: Is white mica not the evidence of retrogression? Currently it sounds like retrogression occurs in the white mica.

Page 4, Line 1: What do the authors mean by "plurimetric", that height and length are variable?

Page 4, Line 17–23: The authors could consider to put this paragraph before the section describing the details of the cleft. Then the structure would be more logical, but some sentences would need to be rephrased then. Also indicate a reference to Figure 2a at line 16/17.

Page 8, Line 7–12: The authors state that the Lauzière Granite cooled below 240–280 °C at 14–16 Ma. This refers to the closure temperature of ZFT, but this is not really explained in this section (although the concept of closure temperatures is briefly outlined in the introduction). So to aid the reader where this temperature range comes from, the authors should include a short explanation about the concept behind a closure temperature (e.g. why it's a range of temperatures, depending on the actual cooling rate and radiation damage in zircon etc.) together with citations for this. This could then also be

used to explain, that advective heating due to the fluids caused the cleft hanging-wall to experience temperatures above the closure temperature, leading to the observed resetting of ZFT.

Page 8, Line 25–26: Please give a citation for the onset of exhumation.

Page 8, Line 26–27: Make sure to introduce the reader to the ZFT closure temperature (comment above), before mentioning the 240–280 °C temperature range. Usually cooling ages only give constraints on temperatures, but not necessarily the depth. If the authors use a depth (<10 km), they should also indicate the geothermal gradient, this calculation is based on.

Page 8, Line 32: Are there maybe studies estimating values for the geothermal gradient at that time? Otherwise at least state the geotherm used in the calculations.

Page 9, Line 3–7: As indicated in comment (2) I'm a bit skeptical about the calculated duration of fluid flow, or at least the authors should discuss this duration also considering the limitations of their ZFT age.

Figure 1: In general add tick marks of a coordinate system to both subpanels, this aids readers for orienting. In subpanel B add a tag/arrow to the star, saying something like "sample area". The reported ages of ZFT/monazite are very difficult to read, because the boxes of the symbols overlap with the text, so consider increasing the size. There are also typos in the legend, check that Crystalline Massif is written correctly. Are all monazite ages from Alpine clefts? If so you could indicate this in the figure caption.

Figure 2: In panel A the text is difficult to read, consider changing the font color to white or placing a white background behind the text. In panel B consider indicating the foliation of the mylonite (it is only mentioned in the caption). There's also a typo ("Mezosoic cover").

Figure 4: Indicate the number of analyzed fluid inclusions for the different minerals/populations.

Table 2: Is there a typo in the column with the Na concentration, because all rows show the same value? Maybe add columns with the Na/K and Na/Li ratios, since these values are later on plotted.

D) Technical/editorial comments

Page 1, Line 28: Use “resetting” instead of “rejuvenation”.

Page 1, Line 30: “advective heating” instead of “advecting heating”.

Page 2, Line 3: Use “assess” instead of “appreciate”.

Page 2, Line 9–10: “with ages based . . .” instead of “with age based . . .”.

Page 2, Line 11: Delete “efficiently”.

Page 2, Line 20: Use “rarely” instead of “seldom”.

Page 2, Line 23–26: Make two sentences out of the long one: “ . . . partly filled by hydrothermally grown mineral). This provides precise constraints . . .”.

Page 2, Line 25: Use “precipitation” instead of “precipitations”.

Page 2, Line 26: Add a “the” after “general overlap of”.

Page 2, Line 26: Use “crystallization ages” instead of “crystallization age”.

Page 3, Line 12: Replace “the values” with “metamorphic conditions”.

Page 4, Line 1: “minerals” instead of “mineral”.

Page 4, Line 21: “areas” instead of “area”.

Page 4, Line 22: “has a” instead of “show”.

Page 4, Line 23: “ . . . taken further away from the cleft” instead of “ . . . take at different distances of the cleft”.

Page 4, Line 31: add “analyses” after LA-ICP-MS.

Page 5, Line 12: “Fission-tracks” instead of “Fission track”.

Page 5, Line 18: insert “aligned” before “along trails”.

Page 5, Line 20: “shapes” instead of “shape”.

Page 5, Line 20: “microstructures” instead of “microstructure”.

Page 6, Line 1: “temperatures” instead of “temperature”.

Page 6, Line 6: “inclusions” instead of “inclusion”.

Page 6, Line 28: insert an “a” before “relatively high”.

Page 6, Line 30: “fission-tracks” instead of “fissions track”.

Page 7, Line 5: add a “of” after “range”.

Page 7, Line 8: “petrographic” instead of “petrologogical”.

Page 7, Line 23: “indicate that main quartz growth occurred at . . .” instead of “indicate for a main quartz growth at around ...”.

Page 7, Line 29: Add an “occurred” after “major exhumation”.

Page 7, Line 29: “Myr” instead of “My”.

Page 7, Line 32: Insert an “a” after document.

Page 8, Line 4: “clefts” instead of “cleft”.

Page 8, Line 7: Insert “ages” after ZFT.

Page 8, Line 8: “indicates” instead of “indicate”.

Page 8, Line 9: Delete “down”.

Page 8, Line 9: delete one of the “in the”.

Page 8, Line 15: “growth in the cleft” instead of “growth in cleft”.

Page 8, Line 17: Replace “as evidenced in the Mont Blanc . . .” with “as shown in the Mont Blanc . . .”.

Page 8, Line 22: “constituted of” instead of “constituted by”.

Page 8, Line 23: Replace “ . . . and then exhumed to form today some of the highest alpine relief (>4000 m high peaks)” with “ . . . and then exhumed to form some of the highest relief observed in the Alps today (>4000 m high peaks)”.

Page 8, Line 24: “ . . . granite the metamorphic peak . . .” instead of “. . . granite, metamorphic peak . . .”.

Page 8, Line 27: “exhumed to” instead of “exhumed at”.

Page 8, Line 28: delete the “for”.

Page 9, Line 3: “dextral transpression” instead of “dextral transpressive regime”.

Page 9, Line 7: Delete “interval”.

Page 9, Line 7: “Myr” instead of “My”.

Page 9, Line 10: “regimes” instead of “regime” and “inclusions” instead of “inclusion”.

Page 9, Line 13: “could have” instead of “could be”.

Page 9, Line 14–15: Replace “Fluid channelization required here is expected . . .” with “The required fluid channelization is expected . . . “.

Page 9, Line 17: Delete “migrating”.

Page 9, Line 18: “features” instead of “accidents”.

Page 9, Line 26: “circulation” instead of “circulations”.

Interactive comment on Solid Earth Discuss., https://doi.org/10.5194/se-2018-84, 2018.