Response to referee comments RC1 Solid Earth se-2018-81

General comment: Particular, the relationship between cracking and recrystallization or low temperature plasticity and recrystallization as presented in the text contain some virtually contradictory or at least inconsistent statements.

As the sequence of associated microcracking and dislocation glide of albite (low-temperature plasticity) followed by growth (by strain-induced grain boundary migration and overgrowth parallel to the extensional direction) is one of the major points of this study, we will phrase this sequence more carefully to avoid misunderstandings (see comment to points 32, 35).

1. Abstract, line 10: Better: "…replacement is interpreted to take place by…"

We will change this.

line 10: Better: "chemical metastability" instead of "solubility difference", as that term is more general

We will follow the suggestions by rephrasing the sentences accordingly when revising the manuscript.

2. Line 11: omit "in contrast"

We will omit "in contrast".

3. line 15: "dislocation glide and strain-induced grain boundary migration" – see general comments and comments below concerning this term

See general comment and response to points 32 and 35.

4. p.3, line 16: Fig. 1 e,g do not exist, only Fig. 1

This was a typesetting error, the e.g. introduces the cited references: (Fig. 1; e.g., Hofmann et al., 1983; …).

5. p.3, line 28: What is the connection of tertiary ages with the rest of this text?

Tertiary ages are mentioned in the geologic context. They reveal that the rocks north of the DAV were deformed during alpine metamorphism, in contrast to rocks south of the DAV.

6. p.4, line 11: insert commas after "argued" and "studies"

We will add the commas.

7. p.4, line 14: insert "and" after comma

We will insert "and" after comma.

8. p.4, line 15. "mineral" instead of "mineralogical"

We agree.

9. p.5, line 10: Are the grain sizes given as diameters of equivalent spheres or circles? Mean or mode of the grain size distribution? Please state more details of the grain size analysis.

We were referring to the diameter of a circle with equivalent diameter. We will now describe the area normalized grain size as requested by referee#2 (see comments to RC2, point 12). We will describe the grain size analysis in more detail in the revised manuscript.

10. p.5, line 16: omit the sentence: "Feldspar…". This is a repetition, the situation is better explained below in the text.

We omit this sentence in the revised text.

11. p.5, line 17: better: "…and rarely shows perthitic…"

We will rephrase this sentence accordingly.

12. p.5, line 18: better: "…with Ab95-86 is present and in these grains zoisite…"

We will rephrase this sentence accordingly.

13. p.5, line 25: Omit "In contrast" at beginning of sentence

We agree and will omit "in contrast".

14. p.5, line 27: "affected" instead of "influenced"

We will rephrase this sentence accordingly.

15. p.6, line 5: better: "…are irregular and rather…"

We will rephrase this sentence accordingly.

16. p.6, lines 7-8: I think that there is some indication for host control for the upper left hand quadrant (compare Fig. 4d with 4f). Many of the new grains have an orientation which is vaguely similar to the clast, whereas this is clearly not the case of the other pole figures (4e, g).

We will describe this observation more specifically in the revised manuscript.

17. p.6, line 18: The term "sawtooth-shaped" is not very good. Sawtooth usually implies some asymmetry in the teeth shape, like "monoclinic" shapes. Perhaps it is better to use "cuspate-lobate" or just "lobate" as a descriptive term for these microstructures.

We adopted this term from Norberg et al. (2011). However, we agree that the term might be problematic, especially as there is no host-control on the dissolution and reprecipitation, which could lead to asymmetric "teeth". The term "lobate" might rather associate to roundish / smoothly curved boundaries, which is not the case here. Therefore, we will use the suggested term "cuspate".

18. p.6, line 19: "into" instead of "through" K-feldspar.

We will rephrase this sentence accordingly.

19. p.6, line 19: "lobate" instead of "curved" grain boundaries

We will use "lobate" accordingly.

20. p.6, line 24: What do you mean by this sentence? That the cracks terminate at the albite grains or that the albite grains are separated from the host clast? Please explain this better.

We mean that microcracks terminate at new albite grains, which suggests that the albite grains formed after the cracks. We will rephrase this sentence to describe this observation more clearly.

21. p.6, line 28: "aggregate" instead of "aggregates"

We will correct this mistake.

22. p.7, line 3-4: better: "…that they represent healed cracks … misorientation rather than subgrains (Fig. 8a)."

We will rephrase this sentence accordingly.

23. p.7, line7: "… (Fig. 8e), particularly for correlated grain boundaries."

We will add this specification.

24. p.7, line 17: space after "compositional" and "which" instead of "whis"

We will correct these typos.

25. p.7, line 19: omit "which is"

We will omit "which is".

26. p.7, line 24: "elongated" instead of "lens shaped" (lens is a 3-D term)

We rephrase the sentence accordingly.

27. p.8, line 23: "of" instead of "on"

We will correct this.

28. p.8, lines 22-23: The apatite inclusions are interesting. It is difficult to see the apatite inclusions in the K-spar in the images of Fig. 6, but they seem to be there in some cases. Is it possible that the apatite inclusions are also present in the K-spar and can be used to mark the former clast outline of the K-spar grains?

Indeed, the apatite inclusions can be traced into the K-feldspar. This indicates that not only albite replaced K-feldspar, but there was also precipitation of K-feldspar. We will add this observation in the revised manuscript. Whether the apatite inclusions can be used to outline the original shape of the K-feldspar is, however, from our point of view too vague.

29. p.8, line 24: o.k, the replacement is not directly related to strain, but the stresses will be highest at the grain boundary, so that in a deforming aggregate, the K-spar will be replaced at the highest stress sites. In addition, it is, generally speaking, the higher free energy state of K-spar than albite. Of course, the higher free energy state will result in a higher solubility, but to express it as solubility is a bit unusual as the solubility depends, among other factors, on the fluid composition, which is unknown here.

With the term solubility difference, we want to stress not only the driving force for dissolution of the K-fsp, but also the formation of albite. The higher free energy state depends on many unknown factors as well.

30. p.8, lines 29-31. The fact that there are albite grains at the boundary of the K-spar clasts (clear replacement structures, Fig. 5b) and that there are K-spar clasts inside the fractures (Fig. 5d), it is obvious that K-spar is replaced by albite. It may be possible that, in addition to the replacement, some albite might also precipitate from a fluid, but it is not necessarily "more likely" (as expressed in the text) than the replacement, for which there is clear evidence.

We will rephrase the text accordingly.

31. p.9, lines 2-3: The bending may well be results of microcracking, as outlined in Tullis & Yund 1987. So, it is not necessarily the result of plasticity.

In bent albite grains we did not find evidence of microcracks at light-optical scale and SEM-scales, yet some influence of microcracking can certainly not be excluded. However, to explain the observation of a continuously bent crystal solely by brittle deformation would be from our point of view too speculative. See also comments to points 34 and referee #2. We will discuss this when revising the manuscript more comprehensively.

32. p.9, line 9: Dislocation glide combined with recrystallization (e.g. strain induced grain boundary migration) constitutes, by definition, dislocation creep. Phrased in the way it is written here, the statement is neither correct nor what you want to say. It should be made clear (also in the following discussion section) that the two events (e.g. cracking or glide of dislocations and the replacement/re- or neocrystallization) are different events or episodic processes, otherwise the combined processes would constitute dislocation creep.

We fully agree, we mean a sequence of events, i.e. fracturing and dislocation glide followed by growth (e.g. strain-induced grain boundary migration or overgrowth parallel to the extensional direction). Indeed, this is one of our main point. We will carefully rephrase the text to make our main point more clearly. Please see general comment and point 35.

33. p.9, lines 10-12: I agree with this statement, and you are showing in Fig 11 and 13 that there are chemical differences in grains and overgrowth rims. So, chemical effects will be part of the driving potential.

We agree.

34. p.9, 12-14: As pointed out above, the bending may be the result of microcracking. In addition, the discrete boundaries of misorientation are visible in Fig. 7a (lower arrow marks a discrete misorientation boundary), and in Fig. 8a (many sharp boundaries between dark and light blue). Furthermore, the fragmentation of the albite clast is clearly visible in the Figs. 7 and 8). The brittle deformation induces defects, too. So, certainly low temperature glide processes may occur, but the evidence shown documents primarily cracking processes.

We agree that cracking is clearly documented by the albite microstructures, as described in chapter 4.3 and 5.2. Plagioclase is showing characteristically a mixture of new grains (strain-free) and fragments (twinned, bent, see Fig. 7 and 8) along boundaries perpendicular to the finite shortening direction. Microcracking can produce dislocations but also dislocation glide can cause micro fracturing. Pile up of dislocations during dislocation glide with ineffective dislocation climb (and thus ineffective recovery) causes strain hardening finally leading to brittle fracturing. The relative role of microcracking versus dislocation glide is clearly difficult to assess from our “post-mortem” approach. Yet, qualitatively, bent and twinned grains without any evidence of microcracks on the light-optical and SEM-scales (as observed here for plagioclase) would indicate that dislocation glide plays a more important role than indicated by healed and sealed intragranular microcracks at low angle to the shortening direction of the finite strain ellipsoid visible on both light-optical and SEM scales (as observed here for K-feldspar, Fig. 5). We will stress this point in our discussion throughout the manuscript and especially in the discussion (Chapters 5.2 and 5.3).

35. p.9, line 28-30: Strain induced grain boundary migration is a recovery or recrystallization mechanism and thus would be part of dislocation creep. Again, as pointed out above, one has to stress the fact that the processes do not occur simultaneously or are not coupled, because dislocation creep is excluded here (for good reasons).

We fully agree and will sharpen and stress our arguments for this sequence of microfracturing and associated dislocation glide followed by grain boundary migration. Please see general comment and point 32.

36. p.9, line 32: The “micro-crush zones” point to an important term in this context: “semibrittle“ deformation. I think that this term is perfectly applicable and includes the cracking and replacement/recrystallization aspects.

We agree.

37. p.10, line 5: omit “in contrast” – this is the start of a new chapter.

We will omit “in contrast”.

38. p.10, lines 16-18: Myrmekitization typically does not occur below 550C, because an intermediate plagioclase composition is required for that.

We agree.

39. p.10, line21-23: Why only precipitation and not partly replacement? The albite replacing Kspar forms randomly oriented grains (Fig. 5).

We agree that replacement might occur also in strain shadows. Yet, the (micro-)fabrics indicate shortening perpendicular to the foliation and dilation parallel to the stretching lineation of the finite strain ellipsoid. The polyphase aggregates in strain shadows are taken to indicate precipitation of material that has been dissolved from areas at high angle to the shortening direction, and thus resulting in dilation. Yet, replacement probably occurs as well, which will be mentioned now in addition in the revised manuscript.

40. p.10, lines 28-31: Do you refer to phase mixing by grain boundary sliding? This mechanism is not very effective in producing mixing, and nucleation is far more efficient for that. As you have precipitation (including nucleation?), the mixing in the polyphase material may well be produced by this process.

We fully agree, as stated in the text: "In the mylonitic pegmatites reported here, however, no indication of active "phase mixing" is observed and we attribute the occurrence of a polyphase matrix to precipitation." Precipitation includes nucleation, i.e. not only replacement. We refer to Fliervoet (1995), who describes mechanical phase-mixing, though this author does not present a clear explanation of the process. Yet, we argue that we here do not see evidence of any active phase-mixing.

The question is: why is the monophase albite aggregate a single phase material?

The next sentence: "Also, the highest strain in the mylonitic pegmatites is associated not with a polyphase matrix but with the monophase quartz and feldspar layers." is used as connecting passage to discuss the monophase albite aggregates in the following Chapter 5.5.

42. p.11, lines 28: It seems necessary to include at least a short discussion about what may cause the difference between type A and B microstructures. As everything is documented carefully and in detail, the reader is left without a conclusion concerning these differences.

Type A: isometric fine-grained albite correlated with coarse quartz grains are interpreted to indicate lower strain.

Type B: elongate shape of albite grains are explained by growth parallel to the extensional direction during deformation (i.e. the stretching lineation of the finite strain ellipsoid), i.e. overgrowth at sites of dilation and together with fine-grained quartz interpreted to indicate overall higher strain.

We will discuss this difference more comprehensively.

43. p.12, lines1-2: What is the difference between "strain-induced replacement of albite with granular flow" and "dissolution precipitation creep"? The old albite (or K-spar) has to be dissolved in some way, and the replacement corresponds to a precipitation. So, given the fact that chemical changes are involved, it still is a type of dissolution precipitation creep process.

The difference can be expressed as follows:

"Dissolution precipitation creep" refers to dissolution at areas at high angle to the shortening direction and precipitation with nucleation at areas at high angle to the extensional direction (stretching lineation of the finite strain ellipsoid), which usually results in polyphase aggregates in strain shadows.

“Strain-induced replacement of albite” refers to fracturing and dislocation glide in areas at high angle to the shortening direction followed by growth by strain-induced grain boundary and involving precipitation to form grains with high aspect ratio with the long axes parallel to the stretching lineation. The results are monophase aggregates.

Because of the characteristically different microstructures and the characteristic sequence for “Strain-induced replacement of albite” (see points 32, 35, 36) with fracturing and dislocation glide followed by growth involving precipitation (including chemical driving forces in addition to strain) we feel that this difference is important. We will strengthen this difference when revising the manuscript, as this is one of our main points.