Solid Earth Discussions

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Comment on se-2021-83

Anonymous Referee #2

Referee comment on "Biotite supports long-range diffusive transport in dissolution–precipitation creep in halite through small porosity fluctuations" by Berit Schwichtenberg et al., Solid Earth Discuss., https://doi.org/10.5194/se-2021-83-RC3, 2021

The paper by Schwichtenberg et al describes a set of 3 long-term compaction experiments on pure NaCl, a layered sample of pure NaCl and a mixed NaCl/biotite layer, and a layered sample of pure NaCl, mixed NaCl/biotite and pure NaCl. It addresses the question of the role of biotite in pressure solution creep, which is a process relevant to the understanding of deformation processes in the Earth crust. It is not exactly clear how this paper differs in approach and conclusions from earlier work done by Macente et al in 2017 and 2018. The paper concludes that with the type of biotite used, the earlier indicated reinforcing effect of phyllosilicates on pressure solution creep has not been found. The methods and assumptions are valid, and results are probably sufficient to support interpretations and conclusions, provided the two major comments are fixed. Otherwise, the organization of the paper and details of the manuscript are mostly of appropriately high quality, though some edits (see specific and technical comments) are needed to fix what is currently not clear.

Apart from the apparent similarity to Macente et al 2017 and 2018, I have two major comments concerning the potential validity of this study.

Major comment 1 is related to the technical capacity of the DVC. How well can automatic processing, such as DVC cope, with material literally moving, or jumping, from one place to another? it is written for small amounts of lateral deformation and shape change of particles, so if material moves from one place to another, which the 2D analyses indicate, is DVC then capable of picking it up? The main part of the argument in paragraph 4.3.3 seems to be based on the fact that the code ran and indicated no massive problems, and therefore the answers are correct. This is not necessarily the case. A smaller part of the argument is that the interiors of the grains don’t change. But what if new grains are created with a similar shape and size? And what if grains are completely dissolved? In the latter case, a correlation can be made with the neighboring NaCl grain, which looks otherwise quite similar, due to similar initial grain size.

The second major comment is related to the starting porosity, a critical element for compaction experiments, and a notoriously difficult one to control. The initial compaction was 9 to 18%, but the starting porosity of the samples is quite different (Figure 12). In the mixed samples this porosity is not homogenously distributed. Since pressure solution is heavily affected by porosity, how does this affect the rates and results you indicate? and on this note, the term steady state compaction is misleading, since the compaction rate should continuously decrease (see references in the manuscript). It is also not entirely clear how porosity is determined: is this like Macente et al from a 400^3 voxel subvolume in the CT scan? If so, include in the method section. Is the determination of the 2D porosity and 2D presence of NaCl per slice, but for the full sample, and for the 3D volumetrics on subvolumes only?

Specific comments:

Line 15: this is the only place where the length scale is actually quantified, whereas it would make sense to include it in the discussion paragraph 4.1.

Line 73: please add a clarification on the different aspect ratio of the biotite flakes. Which dimension is 200-500 microns?

Line 76: dry NaCl?

Line 80: simple insertion of the piston, or already with a specific applied force?

Line 86-91: out of curiosity, why is there a difference between SBS and SB samples in the design of the pumping system? Is there a different brine used? Or is it just one of those things that happens when experiments progress?

Line 92: what was the fluid pressure? Was this the same for all three experiments?

Line 98: why is there a difference between the constant effective load for SBS (6.64 MPa) for SB + S1 (10.5 MPa)? What is the load during the experiments? Please add here.

Line 142: is for this type of microtomograph the gray scale belonging to 100% NaCl density always the same, regardless of scanning conditions? Because in some CT scanners the grey signal “floats”, and in some scanners it is fixed. How is that for this scanner?

Line 155-157: I do not understand the size of the 3rd dimension for the 3D NaCl subvolume.

Line 176: How do SPAM and TomoWarp deal with grains which change shape themselves? They do not only rotate and rearrange, but can also change shape due to dissolution and precipitation (major comment 1).

Line 186-187: all samples were under a constant and similar effective vertical load during this compaction time? This doesn't become clear from the preceding sections. What is the starting porosity of the sample? Is it homogeneous throughout the sample? Does each sample have the same starting porosity? (major comment 2)

Figure 3 and line 198-206: why the smooth connection between datapoints in Figure 3a? What is the highest resolution in vertical strain rate you can obtain with your measurement method? The fact that a plateau is reached can also mean you have reached the measurement capacity of the setup. In principle, in a pressure solution type of process, based on theory (citations in the manuscript), one would expect a continuously decrease in strain rate with porosity. In other words, it is a steady state in the length of the experiment, but if you could measure indefinitely, the rate would continue to decrease. So is it really a 2 stage process, or is it actually a visual artefact caused by measurement resolution and experiment duration?

Line 225/Figure 7: as Figure 3 and line 198-206: is it caused by steady state or measurement resolution?

Figure 7: this is z-displacement rate. In the NaCl-biotite-NaCl sample both NaCl layers have a different thickness than the mixed layer, where in the NaCl-biotite sample they are of similar thickness. If you would plot strain rate instead of z-displacement rate, would the trend then change?

Figure 8-9-10: why did you not do the DVC for all time steps? How certain are you that the time steps shown are representative?

Line 229-245: please be more precise in your description, and in labeling if you are looking at compactive or dilative strain maximum in this paragraph. In Figure 8 (SBS), I see deviatoric strain maxima in the center of the sample, correlating with positive volumetric strain (dilatation), and overall more activity in the bottom half of the sample. In Figure 9 (SB) I see similar high deviatoric strain in the center, but more activity in the top half of the sample. There is barely any dilatation. In Figure 10 (S1), there are high deviatoric strains in the center, and both dilation and compaction, with more activity in the bottom half of the sample. Moreover, what would be the minimum strain needed to be measurable? The samples overall do look blue, but how blue does it need to be to be

sufficiently away from zero?

Table 2: in all three figures, there are three plots for the DVC, but only two data entries for each sample in this table.

Line 236: I would consider the use of the word "trend" with only two data-points per sample too strong.

Line 243: "deviatoric strain maxima corresponded to the location of biotite grains as well as open pore space and pure NaCl clusters" – in other words, there is no correlation between the location of the deviaotric strain maxima?

Line 247: the correlation is not absolute: the maximum loss of porosity in the SB sample (1932 hr) is from slice 500-925 or so, and the biotite layer ends at slice 1000. For the SBS sample, the maximum loss (1932 hr) is from slice 800 to slice 1550, and the biotite layer is from slice 750 to 1350. How does the location of the maxima compare to the data from the DVC?

Figure 12: the starting porosity is quite different for the samples. How would this affect the average compaction curves of Figure 3?

Line 254-259: how did you determine the NaCl distribution? 100% minus porosity minus biotite? Or did you also segment the NaCl grains individually? What is part of the NaCl remains in solution as supersaturation, as indicated in the discussion as a potential part of the process?

Line 260-264: Unclear phrasing: if the assumption is made that biotite is an insoluble internal standard (line 261), it makes sense that the analyses show the biotite content to be standard… And can you show somewhere in a Figure where the subvolume is taken (this would also solve line 155-157)?

Line 273-275: it is not clear to me why this is interpreted a change in deformation mode, instead of it being a continuous log-linear decrease in rate (same comment as in the description of the results).

Line 278: This needs more careful phrasing, since even the current description of results indicates that strain maxima occurred mainly within the biotite part of the sample (line 233).

Line 294: unless one takes it that the patterns of Fig 8, 9 and 10 do show there is more strain localization in the biotite… Or that the DVC actually doesn't cope very well with the material transport (major comment 1).

Line 329: This wasn't clear to me in the results on the DVC, though the concentration of deformation was mentioned in Figure 12 and 13. Perhaps it would help to add arrows or boundaries to Figs 8-9?

Line 333: I do not understand how figure 5 demonstrates the efficiency of this process

Line 334: ah, that's what the Lambert plots did (technical comment line 180)! But if there is no significant rotation, then why is the deviatoric strain so high in the biotite layers? Another reason could be that many of them are already fairly horizontal, so that might also be why there is no strong realignment.

Line 345: can you add here that Macente reported a first order effect (i.e. why would you expect a first order effect), and which observations showed there is no first order effect?

Line 367: why/how does Figure 11 show that local maxima correspond to sites of precipitation?

Technical comments

Line 62: "which are described in Macente (2017)": Since the description is actually below, this phrasing is slightly misleading

Line 105: for clarity, it would be nice to add if the samples were compacting in the same building (I assume so), or if they were transported by car throughout Edinburgh or the UK or even from France (looking at the affiliations of the authors). Given the composition of the author team I imagine the transport between CT scans and compaction location was done carefully, but the explicit mention of the location of the tomography instrument somehow gives the impression that the scans were done somewhere far, far away… Which would have consequences for their validity.

Line 106-107: how many scans and compaction time for the S1 sample?

Section 2.5: this section would be easier to read if there was a flow diagram that briefly labels all the steps and different softwares

Line 136: please mention your figures in order of appearance. Fig 12 now follows Fig 2. Fig. 12 doesn't contain the error, though that is suggested by this part of the text. Idem for Fig 13 and Fig 14

Line 159: given the name (digital *volume* correlation) I assume this approach is only valid for the 3D volumes, correct? Please add.

Line 160: can you indicate in 1-2 lines which operations or calculations are performed by SPAM and which by TomoWarp2?

Line 180: this is my own ignorance: how does one read a Lambert projection? As the reader, what would it tell me? Can you add a reference here so the non-knowledgeable reader can read up on the importance of these plots?

Figures 4 and 5: why did you choose this specific vertical slice? Where is it located in the 3D sample? Would we see the same if you choose any other slice?

Figure 5: can you add the red markers to all 5 panels? It would help guide the eye. The lower biotie grain seems to also change curvature between the panels, or is that simply due to the unfocused visualization?

Figure 5: Why do you not have panels also to show if similar things happen in the SB and SI samples?

Figure 6: to my non-Lambert-trained eye, figures a and b look very similar… Why could you measure so much more grains for a versus b? Is that because there were more grains in b to keep the layers of equal thickness?

Line 229-234: For readability, please treat the descriptions in the same order as the figures are shown for clarity, and in Figure 8 9 and 10 please add the sample name in the caption or in the figure. This could be improved throughout the paper: sometimes the pure salt sample is described first, and sometimes the salt-biotite-salt sample.

Figure 8 9 10: compaction in rock mechanics experiments is often denoted positive, whereas here the negative values are compaction (line 234/second-last line of caption).

Figure 9: typo: “cumulative”

Paragraph 4.1: the title of the paragraph, combined with the question of the introduction, gives the reader the impression the length scale will be quantified, whereas this is actually a more qualitative interpretation.

Line 374 – 388: OK, but how can you then be sure for the rest of your sample that the values are correct? You probably can I’m sure, but I don’t see it straight away. What am I missing?

Given the length of appendix A2 and how crucial the terms are, I suggest to move this definition to the method section.