Solid Earth Discussions

Solid Earth Discuss., referee comment RC2
https://doi.org/10.5194/se-2021-114-RC2, 2021

Comment on se-2021-114

Anonymous Referee #2

Referee comment on "Creep of CarbFix basalt: influence of rock–fluid interaction" by Tiange Xing et al., Solid Earth Discuss., https://doi.org/10.5194/se-2021-114-RC2, 2021

This is a review for "Creep of CarbFix Basalt: Influence of Rock-fluid Interaction" by Xing et al. This manuscript presents the results of deformation experiments on tholeiite samples from the CarbFix CO2 storage site under different pore fluid compositions. The goal of the study is to better understand the role of fluid composition, and CO2 in particular, on deformation of basalt. The authors used a stress stepping technique to evaluate brittle creep processes. Experiments that investigate fluid composition are few and far between, so this is a welcome study and approach. The rather large sample size used by the authors is also welcome.

I think that this data should be published, but I have several concerns with the analysis as described below. The results indicate that there are clearly differences in the mechanical behavior at different testing conditions, and I think the strongest link is between AE results, crack geometries, and stress-strain rate data. However, there are some issues with data interpretation that are detracting from this bigger picture in the present draft and some more detail on the chemistry of the system is needed.

- I think some of the confusion can be reduced by simplifying the analysis of the mechanical data to only what is critical to understanding the end goal. The problem also needs to be framed a bit more precisely which would help with this; while stress stepping experiments are very useful, they also provide a very specific kind of data and it is not clear why the authors chose these tests. I recommend presenting either a hypothesis or description of expected/anticipated results and the meaning of those results.
- The rock composition is likely very important to the results presented and I think better compositional data is necessary to understand the results. First, the mineralogy is not clear from what is written. With the imaging tools available, it seems like it would be reasonable to estimate the modal mineralogy (also I think it should be mentioned if olivine is not present since it is involved in a potentially important reaction in some basalts). Beyond modal mineralogy, I strongly recommend using the resources available at MIT to determine the chemistry of the phases either qualitatively or quantitatively (what are the 'iron ore' and 'phyllosilicate phases?).

- More detail about the experimental procedure is needed to really understand what was done and how best to analyze the results.
  - What is the fluid composition in these experiments and how was is created/controlled? More information is needed about how the fluids are mixed and what the resulting composition is. For instance, what is the partial pressure of CO2? Is this the same during the open and closed experiments?
  - I am unclear about why/how experiments were terminated. In at least some of the experiments it seems that the samples failed because the authors refer to 'ultimate strength', but that is not clearly explained and data demonstrating that is not shown (and no plot shown indicates anything that looks like failure to me). The dry test seems to have been terminated for other reasons, but that is not clear either. Understanding this would help to understand what is comparable between the samples.

- Interpretation of the data.
  - The authors refer to `ultimate strength' which they bever describe. Usually this term is used during constant strain rate tests. In these experiments, it is not clear what the significance of this value is, since failure in brittle creep is largely controlled by the amount of strain that is accommodated the rate of which is dependent on stress. If a sample fails at a lower stress when similar stress steps have been followed, as I think is being presented here, then that is probably a reflection of differences in the rate of processes, but that is not clearly explained or developed. The authors should clarify the meaning and significance of 'ultimate strength' and I recommend using a different term such as failure strength.
  - It looks like the authors are using the change from net compaction to net dilation to identify the onset of dilatancy (C') (Figure 5). This is not correct. The onset is identified as the diff stress at which the stress-vol strain curing deviates from the elastic hydrostat. Which is a lower stress that how it is identified by the authors. Without a hydrostatic loading curve it is very difficult to identify this transition. C' is generally thought to reflect the onset of microcracking, so it seems the authors have reached it in their experiments or they would have no results. Either way, they don't seem to have enough information to identify C' and the discussion in lines 337 to 348 need to be edited to reflect that.
  - The negative correlation between creep rate and differential stress in the dry test seems largely controlled by the highest differential stress. I recommend emphasizing that most of the data indicates stress-neutral behavior.
  - Tertiary creep (the acceleration in strain that occurs before failure) is typically avoided as it does not have a steady state strain rate. How was that dealt with in these experiments? Is it possible that the high strain rates and AE rates at the highest stresses actually represent tertiary creep?
  - I hesitate to ask for more experiments, but because of how the authors have chosen to interpret the data (with respect to C' and ultimate strength) hydrostatic and constant displacement rate tests under different conditions are an obvious way to clear up some of the issues. Another option is to avoid these concepts.
  - There is almost no mention or description of carbonation products in these samples or their abundance. This is seems like a huge oversight given the goals of this project. There are before and after pictures in Figure 10, but no mention of what look like (figure is too small) some chemical changes. Some descriptions are necessary and important to understanding the data. The reactions likely affect

deformation. Also, L438: I am confused about this paragraph. How so the results imply the supply of cations are rate-limiting? Are you saying the reaction was slower when there was less Mg and Ca? It seems the carbonation tends to be limited by HCO3 (equation 6) to me? Please explain the reasoning here.

- L 366-378 There is no localization in the dry experiment (no failure) so I do not understand how these results are consistent the previous studies cited? Which specifically looked at localization associated with failure? Figure 11a shows very little localization. (L384 – If that is true, then why didn't the sample localize and fail?)
- L433 I think it makes more sense to say that dissolution weakens the rock, rather than the dissolution strengthens the rock (it is not stronger than dry, that we know).

Minor Comments:

Line 187-188: Describing the phases as rapidly or slowly evolving and varying does not explain what is evolving. Strain? Strain rate?

In many figures the fonts and images are too small and I cannot easy read or process what is being presented. 1, 3, 7, 8, 11 (also the black background in not very helpful)

Figure 4: The data here is presented in a way that is hard to follow and I am not convinced it adds much to the analysis.

Figure 6: I recommend plotting permeability in SI units (m^2)

Figure 9: I cannot tell the different greens apart

L 223: compressive is a stress term not a strain term

L340: C' is often as low as 50 % of failure strength, although I agree 11% is low. I would argue that your definition of failure strength is not comparable to previous studies since they are defining based on constant strain rate tests. I would be careful about how this is worded because differences in how this is being defined are not clear.

L354: Is this stress effect on amplitude only for fluid saturated conditions (not clear)? As wing cracks can also grow longer at higher differential stress and that can lead to coalescence, both of which might reflect larger events.

L361: I have never heard bulging referred to as a dilational feature. I am pretty sure it occurs during cataclastic pore collapse. Reference?

L415: I don’t understand how the relationship between the stress and total strain accommodated during phase 2 can be independent of fluid conditions if the strain rate is dependent on fluid conditions.