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Solid Earth Discussions

Interactive comment on "Fault sealing and caprock integrity for CO_2 storage: an in-situ injection experiment" *by* Alba Zappone et al.

Anonymous Referee #1

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General comments

In this paper, the experimental concept and initial results of a CO2 injection experiment at the scale of a rock laboratory are presented. It is the CS-D experiment within the Mont Terri Rock Laboratory which has a complex and comprehensive layout which are described in detail in the paper. Results are presented from the initial experimental phase, mainly focusing on the characterization of the fault system into which CO2 injection is carried out. The paper is overall well written with some minor technical issues I will list below.

The scientific background, including further related experiments and the current gap of knowledge (between lab scale and full size scale of a real storage site) are comprehensively described. Many technical details of the injection experiment and the monitoring

setup are given and presented with the support of well organized figures.

One striking issue is that in the discussion, the authors are claiming to provide conclusions which are valid for large scale storage. This aspect is, in my opinion, a bit over-estimated here. The main results of the experiment, to date, provide some very interesting insight into detailed process understanding related to leakage into fault zone, basically scale independant. The results especially of long-term injection into the fault will be highly interesting for the safety assessment of full scale storage sites, but these results are yet to come.

Also, a direct transfer of monitoring approaches from such small scale experiments to the full scale of large storage sites is problematic. The direct geophysical imaging of leaking CO2 within the caprock will probably not be aimed at by operators due to the very high resolution needed at relatively large depth. The assessment of containment will rather be performed indirectly by potentially monitoring indicator horizons, such as aquifers right above the first caprock where leaking CO2 may be accumulating. I would suggest to sharpen the statements in the general discussion a bit in this sense.

Specific comments:

1. Line 669 and ff.: "If the active seismic analysis and the electrical resistivity tomography will not be able to detect variation in the long-term injection, it could mean that the flow is confined in tiny fracture or that exsolution of the CO2 is not strong, implying then that those additional monitoring techniques should be employed in combination at large scale storage sites."

Maybe I am missing something here but I cannot follow this logic. If seismic and ERT do not detect variation, they should be applied at large scale storage sites?

I guess you want to stress the recommendation to combine seismic and ERT because of their complementary sensitivity. That would enhance the chance to detect variations and to actually image a CO2 related signature.

2. Line 700 and ff.: "The seismic characterization successfully highlights the fault zone as a region of low velocity anomaly, probably due to different seismic velocity anisotropy in and outside the fault.“

Why do you argue with different anisotropy here. I think this is not necessary. It is reasonable to assume that the fault zone is mechanically weaker than the surrounding rock mass and thus seismic velocities are lower here. Anisotropy may be an additional factor, but not necessarily.

3. Seismic Tomography: Data processing: As the first step, you indicate that a median filter has been applied. What has been the purpose of this filter at this point? Removing secondary (linear) tube waves? Events before the P-wave first arrivals? Could this median filter affect the exact picking of traveltimes (time-shift as a processing artefact)?

Technical comments:

Line 17: confinement → containment Line 23: think → thick Line 99: delete one of the two ", ," Line 115: "pressure conditions exceeding the rupture of the fault“ what does this mean? You mean pressure conditions causing fault rupture? Line 116: extent Line 125: by a synchronized... Line 169 f: Better write as a complete sentence: The CS-D experiment focuses on.... and addresses.... Line 172: ...it simulates... Line 177: north-wester (use identical spelling in the paper (northwester, north-wester)) Line 183: ...properties of a pristine claystone.... Line 187: that Based → of which, based . . ., three main Line 430: "still performed in interval Q4“ - this means "still ongoing“? maybe better indicate the actual period to which you are referring to, e.g, "still ongoing as of Sept. 2020“ (just as an example). This paper will probably be read in the future when the experiment is not active anymore. Or do you mean "also“? Line 431: showed → shows Line 438: affected Line 449: ˆ(-12) Line 470: stabilized Line 539: if → of Line 660 and ff. There are some grammar issues. Figure 4d: colour scale ranging from 0 to 1, but brine distribution in %. Should the colour scale range from 0 to 100 % ? Figure 9: M1 and M5 in a, but M4 in b and in text. M5 should read M4? This is at least what

the reader may think while reading. Please clarify. Figure 13: Please explain shortly the meaning of A – F in the figure caption.

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