Solid Earth Discuss.,
https://doi.org/10.5194/se-2020-100-RC2, 2020

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 #2

Received and published: 5 October 2020

General comments

This manuscript describes an experiment of induced CO2 migration along a fault at an original scale, between the laboratory and the field scale. Instrumented with various hydraulic, geophysical and geochemical tools, this experiment is an important step in the development of the CCS technology for its commercial deployment and public acceptance. It will provide an amazing set of data and allow a better understanding of faults systems, CO2 leak's risk, coupled hydro-chemo-mechanical processes and ways of monitoring CO2 leaks in the subsurface. My comments and remarques are hence more related to the manuscript itself, its organization and writing, than the experimental work, which is an impressive piece of work. Generally, the text could have been shortened and written in a more concise way. For example, some sections, like

the monitoring systems, are introduced several times (e.g. l.120 to l.128; l.146 to l.159) before being actually presented in details (l.330 to 378). An important part of the manuscript is also about the planned experiments (phases 2 and 3), again introduced at several locations before being detailed in the methodology section and discussed in section 5. The manuscript would have gained in clarity by i) focusing more on presenting and analyzing the main findings of the characterization phase 1, ii) then describing the instrumentation planned for the actual in-situ experiments, and what questions this experimental work will allow to clarify, iii) but without spending so much time discussing potential results and outcomes of these in-situ experiment and monitoring.

The second comment relates to the geochemical aspects of the work. It would help to add a few more details or explanations in some places. The first one is on the initial content of CO2 in the injected fluid: it is not clear in the text how and how much of CO2 is mixed: i.e. are pCO2, alkalinity (and thus pH) constant and constrained in the injected fluid? I would guess so, but this is not clear l.290 to l.294. A second point relates to monitoring the CO2 leak by a 'CO2 breakthrough' using the miniRuedi mass spectrometer. Again, all is fine with the methodology used, but it would help to add one sentence stating that this mass spectrometer will measure, both partial pressure of dissolved CO2 and CO2 gas (gas being produced by the fact that the pressure at that depth becomes smaller than the initial pCO2). Also, by talking about CO2 breakthrough we could take it as 'breakthrough of (pure, here gas) CO2, which I think is not the case and the authors aims at detecting the dissolved CO2 from the injected CO2-rich water.

Specific comments

l.68 to l.70: the studies described in the given references are not on fault reactivation per se, though they are still relevant to appear in this manuscript. I suggest replacing with a sentence similar to: 'The coupling between chemical and mechanical processes have been studied in the laboratory (Le Guen [. . .]).'

l.84 to l.88: there is actually a second field scale experiment in Australia at the CO2

Otway Research Facility. This is an ongoing experiment, for which, similarly to what is described in this paper, the site characterization and the design of the monitoring have been completed so far and the actual 'shallow release of CO2' experiment will happen next year. There are only a few conference abstracts and proceedings publicly available as of now, but several papers are on preparation. Below are the references available and the links to the project description:

Feitz et al., 2018, The CO2CRC Otway shallow CO2 controlled release experiment: Preparation for Phase 2, Energy Procedia, Volume 154, Pages 145-150, doi: 10.1016/j.egypro.2018.11.024

Feitz et al., 2018, The CO2CRC Otway shallow CO2 controlled release experiment: Geological model and CO2 migration simulations, GHGT-14, 21st - 25th October 2018, Melbourne, Australia.

Tenthorey et al., 2019, The CO2CRC Otway Controlled CO2 Release Experiment in a Fault: Geomechanical Characterisation Pre-Injection, Conference Proceedings, Fifth International Conference on Fault and Top Seals, Volume 2019, p.1 – 5, doi:10.3997/2214-4609.201902321

https://www.ga.gov.au/about/projects/resources/geological-storage-co2
https://co2crc.com.au/co2research/srd3-3/

I would suggest also to add the following review papers

Migration and leakage of CO2 from deep Geological Storage sites by Bush and Kampman published in the AGU monograph Geological Carbon Storage: Subsurface seals and caprock integrity DOI: 10.1002/9781119118657.ch14

Fluid-rock interactions in Clay-rich seals: impact on transport and mechanical properties by Skurtveit et al. in that same monograph

l.219 to 226: the tense used in this section makes us confused about whether this phase is still under planning or has already been performed. Both present and future

tenses are used, however it is stated that this phase started in June 2019 for 12 months, which is thus something that should be now finished.

l.292: injection water: that would be better to mention here what is this injection water instead of later l.302 to l.304

l.293: It would be useful for the readers to briefly explain why Kr is used here

l.343: 'the circulation prevents chemical precipitation in the interval'. This is not clear to me at all why, it may prevent deposition of precipitated minerals but not necessarily their formation if the fluid is supersaturated with respect to these minerals

l.409 to l.411: do you mean that these labs have performed experiments on that topic in a general context, or do they have specifically studied the rocks of this study? In any case references should be added

Technical comments

The manuscript is generally well written but there are a few sentences throughout the text that are grammatically incorrect, or difficult to understand. e.g. l.116 to l.117; l.171 to l.173

There are also some words missing, errors in verb constructions, spelling mistakes or use of inappropriate words. I encourage the authors to carefully read and edit the text e.g. (this is not an exhaustive list)

l.96. and after: 'transport/migration' -> transport and migration

l.168: 'large volume injection' -> large volumes of injection or large injection volumes

l.169: 'role of CO2' -> role of CO2-rich water

l.170: 'behaviour of clay to several months of' -> behaviour of lays exposed to several months of

l.172: 'it stimulate' -> it stimulates

l.187: ‘is sequence of shales, that Based on’ -> is a sequence of shales that is based on

l.210: ’the fault suddenly show’ -> the fault suddenly shows

l.227: ‘we will repeat characterization’ -> we will repeat the characterization’

l.230: ‘petrophysical and geo-mechanical, and’ -> petrophysical, geo-mechanical, and

l.233: sections instead of chapters

l.257: ‘less permeable than as indicated’ -> less permeable than the value found

l.259: ‘the case of permeability 5.10ˆ-20 mˆ2’ -> the case of a permeability of 5.10ˆ-20 mˆ2

l.260: ‘up to 8m distance’: please rephrase

l.270: ‘in a way which’ -> in a way that

l.272: ‘are oriented normal to bedding planes’ -> are (oriented) normal to the bedding planes l.303: ‘depleted of’ -> depleted from

l.353: ‘fluid remobilization’ -> remobilized fluid

l.406: ‘drilling induced features’ -> no drilling-induced features’

l.422: ‘(BCS-D1), which’ -> (BCS-D1), and which

l.467: ‘increased of’ -> increased by

l.539 to l.541: please rephrase because the sense of this sentence is not clear

l.541: ‘comprises gouge’ -> comprises a gouge

l.554: ‘if this observation were’ please fix the singular/plural

l.556: ‘the poroelasticity is negligible’ -> the poroelasticity response is negligible’

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