Solid Earth Discuss.,
https://doi.org/10.5194/se-2019-159-RC1, 2019


Solid Earth
Discussions

# *Interactive comment on* "Influence of reservoir geology on seismic response during decameter scale hydraulic stimulations in crystalline rock" *by* Linus Villiger et al.

**Anonymous Referee #1**

Received and published: 29 November 2019

The manuscript describes the in-situ injection experiments at the Grimsel Underground laboratory in detail with emphasis on the seismic response and its relation the the fracturing treatments. In particular, the authors compare the seismic responses of hydroshear and hydraulic fracturing treatments. The subject is introduced very comprehensively and with attention to detail, the paper is very well written, the figures are of great quality and all analysis steps are well thought out and executed. Hence, I only have some minor comments for improvements of the paper.

The biggest question I have left after reading the manuscript is concerned with the (lack of) difference of the HS and HF stimulation responses. It seems the experiment was set



up to tease out the differences in seismic behavior between the two different stimulation treatments. Looking at the structures that were activated seismically I wonder if the result really were ANY different. It seems that the same structures were activated and the variation among the 4 tests of each treatment was at least as large as the variation between HF and HS treatments. Although the differences of HF and HS tests are discussed in some length, I am missing a clear statement regarding this negative finding.

To support this I would like to encourage the authors to rework Fig. 4 as the pressure information cannot be discerned from that. Please add a second axis for pressure and scale it such that it uses the full range of the subfigure.

The last major comment is regarding the references in the text, many of which are missing in the list of references. I did not do a full check, but urge the authors to do so. Some missing references are McClure&Horne, 2013; Secor & pollard, 1975; Schoenball et al., 2019; Kwiatek et al., 2018; Goodfellow & Young, 2014, Brixel et al., in review; Villiger et al., 2019; Jung, 2013b;

Minor comments: L. 115: I would not say that alternative approaches to McGarr are more conservative, but rather say that the assumptions of McGarr may not be valid. We now have ample of data to discard the McGarr hypothesis.

L. 261: It is unclear what "a possibly unperturbed stress state" should mean.

l. 537f: Do you have an idea why so many events were detected after shut-in in this test? Any indications from the structures that were active. How about b-value, etc.? Is that something we should worry about for a full-scale test?

Fig. 6: Would be helpful to remind what gray events represent

l. 655: You substitute t by the injected volume for Shapiro's diffusivity estimation (SBRC). This addresses and important criticism of the SBRC method, namely that it disregards fluid injection rate (e.g. Schoenball et al., 2010, GJI). I believe this deserves

to be discussed in some more detail here.

l. 694 & 696: -0.1%, -0.5%

l. 772ff: Not quite clear. Do you mean the moment of all events combined into a single event?

l. 956ff: Nice discussion, important observation!

l. 991ff: In this whole discussion I am missing some statements whether the activated structures actually are hydraulic fractures. Based on the Schmitt plots and the seismicity plots it seems that most structures could be hydraulic fractures just as well.

Section 5.3: Given the data presented in this manuscript this entire discussion is rather speculative. I can see that this point may well be made using complementary data discussed in some of the "in prep" manuscripts referenced throughout but it may not fit well in this manuscript.

l. 1089ff: This is an interesting discussion. However, there should be a limit to this given by the total volume per stage or the size of the activated rock volume. Let's call this elementary rock volume (ERV) for now. Once you break out of this ERV, your likelihood of activating a structure from a neighboring ERV with different seismogenic index grows very fast. So unless you are activating only the near-wellbore region of your ERV there may be limits to the zonal isolation approach.

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