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Solid Earth Discussions

Interactive comment on "Unprecedented quiescence in resource development area allows detection of long-lived latent seismicity" *by* Rebecca O. Salvage and David W. Eaton

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1 General Comment

This paper documents the detection and analysis of earthquake activity within a normally-active region of hydraulic fracturing during the cessation of activity due to lockdowns associated with the COVID-19 pandemic. This study has an interesting and unique position in being able to assess changes in earthquake rate due to a change in hydraulic fracturing activity, alongside changes in earthquake detectability due to the reduction in background seismic noise. The authors find that seismicity during the

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lockdown does not display the high-rate, temporally clustered sequences otherwise observed associated with reservoir stimulation, however, they do observe consistent seismicity within previously stimulated regions.

The authors provide good analysis of possible causes of this non-stimulated seismicity, including discussion of triggering from large regional earthquakes, the impact of pore-pressure, and longer-lasting fluid diffusion and poroelastic effects. The authors finally interpret this "latent" seismicity as being due to an altered stress-state within the previously stimulated regions due to trapped fluids, and infer that these earthquakes are driven by aseismic slip. I would like to see more discussion of the interplay between the purported stress-changes, and the strength of the fractures within the reservoir: I wonder if the change in stress is actually the dominant effect, or instead a reduction in fault strength due to prior fracturing would dominate the failure criterion? I'm also curious about how the purported high-pressures are sustained alongside the interconnectedness of the fracture network?

Overall I think this is a good, well-written paper documenting an interesting case of reservoir stimulation shutdown. I think it might be relevant to point out the further uniqueness of this study in that most other shutdowns occur either after a large event, which would in itself alter the stress state, or when a reservoir is depleted. I have some specific comments below and some minor technical corrections to the manuscript.

2 Specific Comments

1. Is there any indication of long-lasting changes in the stress-field? e.g. do you observe changes in the stress-ratio or rotation in the principal stress axes associated with the initiation of reservoir stimulation, and is this sustained throughout the background seismicity? I imagine that the seismicity might be too sparse prior to the field becoming active to provide background state, but there may be

stress-field data from borehole-breakouts prior to stimulation? I'm also curious about the likely magnitude to stress-variation due to hydraulic fracturing.

2. Is there any other evidence of aseismic creep? I am not familiar with the paper by Eyre (2020), but I wonder if they found any characteristic temporal evolution of seismicity that they associated with aseismic slip? I'm also curious about why an aseismic driver is required? It is not generally assumed that background seismicity requires an aseismic driver, could this not just be the "new-normal" background seismicity after fractures were weakened due to hydraulic fracturing?

3. It would be great to have some well-stimulation data to confirm your suspicions in Line 125. I imagine that this is hard to come by, and if so, can you add a note around line 125 to say that well-data were not available.

4. Around line 267 the authors argue that upwards of 70

5. I am surprised that your magnitude of completeness appears to have gone up during the shutdown and I'm curious to hear why you think this is? It would also be useful to state what method was used to compute the magnitude of completeness.

3 Technical Comments

Below I have listed my technical comments starting with the relevant line number:

- 23: Change "on such" to "of such"
- 64: Change "Z-component" to "vertical-component"

- Lines 89-95: While the detection methods are not the key topic of this paper, and it only really matters that the detection method is consistent throughout the study, it would be good to have a little more detail and cite relevant papers - ideally citing another paper using the same methodology would be useful here.
- 134: What was the magnitude of completeness for these precursory events? Saying “A total” suggests absolute completeness.
- 175: Remove trailing “a” at the end of the line
- 218: “Data is” should be changed to “Data are” – it also isn’t clear which data are being referred to here.
- 258: I suggest changing “non-existent” to “undetectable” given the limitations of the seismic networks available.
- 314: “Stress field would likely diminish”: I suggest rephrasing this, it is hard to imagine the entire stress field diminishing, but there certainly might be a change in orientation and magnitude of principal stress axes. This statement could also do with a citation.
- 320: I don’t know the paper cited here, but aseismic slip has long been associated with seismicity, so I assume that this paper talks specifically about aseismic slip in hydraulic fracturing environments: It would be good to make that clear in this statement.
- 365: Change “always” to “since Oil and Gas production started” or similar.
- Figure 2(b): The inset and key are not needed as far as I can tell because they repeat from 2(a) – happy to have them left in, but if you do, can you add in the white box on the inset map showing the main figure location – I saw this in 2(a), but not 2(b).

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