Editorial comments

I generally agree with Reviewer A in that having a paper that outlines this impressive experiment, its aims, the set-up, and early results is very useful for the community, and I therefore support publication in Seismica. However, I also agree with reviewer B in that it reads more like a proposal than a paper. I also think the manuscript reads quite repetitive and could benefit from significant shortening.

The suggestions from Reviewer A are very constructive and will both place the manuscript better within the literature, and improve the reading and figures. I like the idea of a summary table - which could also facilitate shortening the text. In addition to following these suggestions (and the editorial annotations from Reviewer B), I would like to see some additional focus, and removal of repetition. In a paper, as opposed to a proposal, you can focus on what has been done and early results, and keep the aims more focused. I think Section 1 is currently too detailed, and can be shortened significantly to focus on specifically how the experiments will improve current knowledge, considering also the reference suggestions from Reviewer A. Section 3 is largely repetition and while I support outlining future aims, this can be done more concisely. For example, because Section 3 is not really a discussion in the sense of interpreting results, it may be better renamed something like 'Summary and Future Plans' and shortened significantly to outline the potential of the project with some less 'proposal speak'. Section 2 is the meat of the paper, and while it can be more concise in places (and made easier to follow with a summary table), it is already very good.

Ake Fagereng

Reviewer A:

Earthquake nucleation, propagation, and arrest are outstanding topics in the Earth sciences. Although laboratory experiments and numerical simulations can reproduce some of these processes, there is a lack of sufficiently precise near-fault earthquake data to enable better predictions. This paper describes the construction of a natural laboratory — a highly instrumented tunnel in the Swiss Alps — where magnitude-one earthquakes could be induced by pumping water into a preexisting fault. If successful, the data acquired will represent a major advance in earthquake mechanics.

The article reviews the current state of the operations that have led to the construction of this unique site and present some first results. It is a useful article that could be cited in following studies. I consider that it could be accepted pending the following revisions.

Major points.

- A table is missing that lists all the equipment installed in the FEAR tunnel, with their specifications (logging rate, resolution, date of installation, provider, and other relevant information). I suggest adding such a table so that the reader can better understand the breadth of data acquired in the FEAR tunnel.
- Another point is that the introduction could refer to several recent publications on field experiments studying induced seismicity in geothermal contexts. For example, the Helsinki experiment showed that a comparison between the near-real-time evolution of seismic moment and seismic efficiency relative to injected fluid volume can indicate the reservoir’s state of criticality. This concept has also been discussed

retrospectively using data from several other geothermal projects: many showed a stable evolution, while others did not, and such differences could be detected early through near-real-time monitoring. The following references may be useful to discuss in the Introduction.

Ader et al., 2020, J Seismol, 24:991–24:1014, https://doi.org/10.1007/s10950-019-09853-y

Bentz, S.,et al., 2020, Geophysical Research Letters, 47, e2019GL086185. https://doi.org/10.1029/2019GL086185.

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Minor points

- Some figures appear like screenshots of computer softwares and lack some informations. Examples are:
    1. Figure 1: increase the font size of small texts on the figure. Add a graphical scale bar that shows a length-scale for the FEAR tunnel and add a vertical scale bar on the cross-section. Label the panels a), b, c).
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    7. Figure 7: This is a low quality screenshot. The font size is too small.
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- References: Check carefully in the text how references are called. For example lines 103-104 J. Rice and J. R. should be Rice, line 159 D. A. Lockner should be Lockner, etc
- Typos, small changes
    1. Line 176: replace “heat” by “energy”
    2. Line 190: insitu -> in situ
    3. On Figure 5: Gasgeochemical -> Gas geochemical
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- Acronyms: Most acronyms used in the article should be replaced by the original name. This includes LSBB (line 216), GTB (lines 357, 795), ETB (line 360 and everywhere), FBG (line 455), TLS (line 823),
- Several references include papers in preparation and this point should be solved before publication. For example, the authors could refer to pre-prints of these articles deposited in an open repository with a DOI number. Alternatively, some of these works may refer to presentations to conferences (e.g., upcoming EGU), where DOI numbers will be available.
- Line 331: Please expand a bit more what are the arguments to describe the fault as "immature". Is there some information on the total displacement along this fault? Is it a purely strike-slip fault or is there also a normal component?
- Line 374: An additional figure that would show some microstructures of fault gouge and fault material could be a nice addition to the paper.
- The DOI link provided line 946 to access data should be made active at the time of publication.

Reviewer B:

This paper is well written. I marked just minor editorial suggestions on the PDF, many simply second-guessing the placement of commas, which I recognize is somewhat arbitrary, and the use of "that" vs "which".

The main issue with this paper is that it is precisely in the form of a proposal rather than replete with new science results. Maybe that is the purpose of Seismica, I am not familiar with the range of submissions that are published. So I tentatively recommended acceptance, but am mentioning that there is no new science here, in case that is a show stopper.

Specifically, there are many pages of review of the science of earthquake rupture, pages about science questions one would address with future work, pages about the experiment implementation, and pages repeating future plans and hoped for extensions of this somewhat natural laboratory. I could go into 4 or 5 details of the science mentioned in passing while referring to the results of other papers about this experiment, but those are not really what a reader would be trying to understand in this paper.

So if a detailed snapshot of an impressively audacious experiment, its history and its hopes are appropriate for Seismica, this is a fine paper.

John Vidale

Zurich, 11 December 2025, ETH Zurich

Response to reviewers for FEAR Project Concept Paper

Dear editor,

after a careful revision of our manuscript on our *"impressively audacious experiment"* (quote from Reviewer B), we are happy to re-submit the FEAR Project Concept Paper for your reconsideration. The comments from you and from both reviewers helped a lot to streamline and improve both text and figures. The feedback we get in this form on our project is very encouraging, and we are excited to have the prospect of presenting our work to the science community via SEISMICA.

With respect to the first submitted version, we have implemented the following more major changes, which we describe in more detail below. We have streamlined the introduction section, shortened most segments, and added a brief additional paragraph on relevant induced seismicity experiments and literature, as requested by you and by Reviewer A. We have refined all figures, and addressed all corresponding, specific comments that we received from the reviewers. Furthermore, we added an additional figure (now Figure 4) on fault zone microstructures. We followed the suggestion of Reviewer A to add a sensor overview table (now Table 1) and, of course, implemented the grammar changes suggested by Reviewer B.

With these changes, we are confident that the manuscript is in good shape. We are curious to hear your response, and we look forward to hearing back from you.

Yours sincerely,
for the large team of co-authors,
Men-Andrin Meier

Editor

I generally agree with Reviewer A in that having a paper that outlines this impressive experiment, its aims, the set-up, and early results is very useful for the community, and I therefore support publication in Seismica. However, I also agree with reviewer B in that it reads more like a proposal than a paper. I also think the manuscript reads quite repetitive and could benefit from significant shortening.

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Thank you. We agree that there had been some redundancy. We have removed repetitions, and passages that did not directly relate to the experiments themselves. We were able to streamline many statements in the introduction and discussion sections, and also sharpen descriptions in Section 2. The comments, and also a bit of distance from the text, greatly helped for this. As a consequence, Section 3 is now substantially shorter, so that the focus of the reader is more brought to Section 2, which, we agree, is the core part of the paper. We do think that Section 3 is indeed a 'Discussion', rather than a summary or outlook (the latter is at the end of Section 2.4), and so we would prefer to keep that section title if we may.

Reviewer A

- A table is missing that lists all the equipment installed in the FEAR tunnel, with their specifications (logging rate, resolution, date of installation, provider, and other relevant information). I suggest adding such a table so that the reader can better understand the breadth of data acquired in the FEAR tunnel.

Great idea. We have added what is now Table 1. This gives an overview and impression of the wide range of instrumentation we are describing in more detail in the text.

- Another point is that the introduction could refer to several recent publications on field experiments studying induced seismicity in geothermal contexts. For example, the Helsinki experiment showed that a comparison between the near-real-time evolution of seismic moment and seismic efficiency relative to injected fluid volume can indicate the reservoir's state of criticality. This concept has also been discussed retrospectively using data from several other geothermal projects: many showed a stable evolution, while others did not, and such differences could be detected early through near-real-time monitoring. The following references may be useful to discuss in the Introduction.

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Leonhardt, M. et al., 2021, Solid Earth, 12, 581–594, https://doi.org/10.5194/se-12-581-2021, 2021

We thank the reviewer for this comment. We agree that a summary of induced seismicity at the field scale could help to better frame the context and scope of our work. Given this, we have added a new segment to the manuscript in the introduction, under the heading "Induced seismicity at the field scale". There we cover a general introduction to induced seismicity, highlight some of the seminal works from the past decade, and then go onto describe the fundamental problems and observational gaps inherent with these studies, and how our in situ experimentation approach can potentially alleviate the challenges.

Minor points

- Some figures appear like screenshots of computer softwares and lack some informations. Examples are:
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  7. Figure 7: This is a low quality screenshot. The font size is too small.
  8. Figure 8: Here the reviewer did not understand the data shown in panel b). Please explain a bit more details in the main text how these data were acquired and what they show.

Thank you. These comments helped us make virtually all figures clearer and more informative.

Figure 1: we have implemented all these changes, improved the colour selection and various other aspects to improve clarity and organisation.

Figure 2: Done. We have also added a coordinate system for spatial orientation.

Figure 3: We have improved not just the font sizes but also added a much higher resolution fault outcrop photograph. Furthermore, we have added a rotated close-up view inlet that shows the main fault strand in greater detail, adapted the caption, and added more detail on the structural immaturity of the fault zone in the text. Also see reply to later comment by same reviewer on the topic.

Figure 4 (now Figure 5): We have replaced this figure with an improved, higher-resolution version.

Figure 5 (now Figure 6): We have increased font sizes and improved the organisation of the figure.

Figure 6 (now Figure 7): Thank you; we are quite excited about this. We have improved font sizes and relative sizes of sub-figures.

Figure 7 (now Figure 8): Apologies for this mistake. I had erroneously inserted a low-resolution version of the figure. It is now high resolution and crips.

- References: Check carefully in the text how references are called. For example lines 103-104 J. Rice and J. R. should be Rice, line 159 D. A. Lockner should be Lockner, etc

Thank you for spotting this. We have carefully revised all references in the text and in the bibliography.

- Typos, small changes
  1. Line 176: replace “heat” by “energy”
  2. Line 190: insitu -> in situ
  3. On Figure 5: Gasgeochemical -> Gas geochemical
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  7. Check everywhere if “e.g.” should be always followed by “,” or not. Please ensure consistency on this choice.

1. This statement has been removed in the process of streamlining the introduction.

2. Done; thank you for catching this. We have made sure that 'in situ' and other commonly used terms are spelled consistently throughout the document.

3. Done.

4. Thank you for catching this.

5. Done; agreed, much better.

6. Corrected.

7. Done. Apologies for this mistake. This is the sort of thing we should have already taken care upon before the first submission. Thank you for pointing this out.

- Acronyms: Most acronyms used in the article should be replaced by the original name. This includes LSBB (line 216), GTB (lines 357, 795), ETB (line 360 and everywhere), FBG (line 455), TLS (line 823),

Thank you for pointing this out. We have replaced all listed acronyms in the text with their full name.

- Several references include papers in preparation and this point should be solved before publication. For example, the authors could refer to pre-prints of these articles deposited in an open repository with a DOI number. Alternatively, some of these works may refer to presentations to conferences (e.g., upcoming EGU), where DOI numbers will be available.

We have replaced the corresponding references with citable conference contributions wherever possible.

- Line 331: Please expand a bit more what are the arguments to describe the fault as “immature”. Is there some information on the total displacement along this fault? Is it a purely strike-slip fault or is there also a normal component?

In the revised version we have added a dedicated paragraph to this topic, because we agree that this is important, first order information that the reader should know:

*The fault is classified as immature, as it is characterized by a simple slip surface defined by a centimetre-thick fault core and lacking a well-developed damage zone at the metre scale. This suggests high degrees of strain localisation within the main fault strand #48.1. This strand presents far larger fluid outflow than the fracture network, and thus it may be acting as a channelised conduit (Caine et al., 1996). The fault core and slip plane are lined by an up to 5 cm thick, discontinuous layer of gouge and cataclasite (**Figure 4**), which represent the natural fine-grained product of brittle shearing through cataclasis of the fractured host rock (Volpe et al., 2023). The geological evolution of the fault includes an initial activation under high-temperature, ductile deformation conditions with a thrust–reverse shear sense (Ceccato et al., 2024), followed by strike-slip reactivation at shallow crustal levels, as indicated by sub-horizontal slickenlines and grooves on the fault plane. Although direct field constraints on the total displacement are lacking, the fault core thickness of ~0.01–0.1 m suggests a cumulative displacement on the order of ~1 m during the shallow faulting activity, based on scaling laws for similar faults in granitic rocks (Shipton et al., 2006; Torabi and Berg, 2011). The spatial distribution and prevalence of gouge layers and bare-rock contacts across the fault zone are not yet known, and it is currently unclear if the gouge layers dictate the frictional stability of the fault zone, or if they are merely a passive result of localised fault deformation.*

We have also updated the caption to Figure 3, which relates to this paragraph:

***Figure 3**: Target fault zone of the FEAR project. (a) Conceptual fault zone model with 5 distinct facies, and (b) expected, qualitative fluid permeability. (c) Photograph of the intersection of the target fault zone with the Bedretto tunnel (bottom); rotated close-up view of the main strand (#48.1, top) which hosts the gouge material studied in Volpe et al., 2023 and across which a DORSA strain probe is installed; and stereonet (top right) of the main strand (black & white lines) and secondary structures (fine coloured lines). The shear indications on strand #48.1 reflect the deformation sense during the early stages of fault zone evolution (see text), rather than the expected shear sense in the current stress field. (d) Acoustic televiewer logging image of the target fault zone in two fault-crossing boreholes (BFE_A05 and BFE_A07) across the first 100m of the borehole (bottom), and close-up views where the borehole intersects the target fault zone.*

- Line 374: An additional figure that would show some microstructures of fault gouge and fault material could be a nice addition to the paper.

Excellent suggestion. We have added what is now Figure 4, and refer to it in the text that discusses fault zone genesis and its immature nature (see previous answer).

- The DOI link provided line 946 to access data should be made active at the time of publication.

We were planning to open access to this repository with a dedicated overview paper on the FEAR-1 experiment, which is in preparation. This is in accordance with the BedrettoLab publication policy. That paper, which we hope to publish by April 2026, will provide much more detailed information that is necessary to understand and use the very complex, multi-disciplinary data set that we have collected, with the >20 (!) different sensor types. The information provided in the very brief summary paragraph we include in this paper is likely not enough to use the data. However, if open access to this data set is a hard condition from SEISMICA, than we should be able to accommodate that and open access already now.

Reviewer B

This paper is well written. I marked just minor editorial suggestions on the PDF, many simply second-guessing the placement of commas, which I recognize is somewhat arbitrary, and the use of "that" vs "which".

Thank you very much. We appreciate the comments, and have implemented the numerous editorial suggestions in the pdf file. In many places they simplify the language, and therefore make it clearer.

> The main issue with this paper is that it is precisely in the form of a proposal rather than replete with new science results. Maybe that is the purpose of Seismica, I am not familiar with the range of submissions that are published. So I tentatively recommended acceptance, but am mentioning that there is no new science here, in case that is a show stopper.

Thank you. In response to this comment and to similar statements by the editor, we have changed and sometimes removed parts of the text in Section 3, and to a lesser extent also in Section 1, in order to have less 'proposal speak', and to focus on the main contributions of this manuscript. See also answer to editor comments at the beginning of this document.

> Specifically, there are many pages of review of the science of earthquake rupture, pages about science questions one would address with future work, pages about the experiment implementation, and pages repeating future plans and hoped for extensions of this somewhat natural laboratory. I could go into 4 or 5 details of the science mentioned in passing while referring to the results of other papers about this experiment, but those are not really what a reader would be trying to understand in this paper.

> So if a detailed snapshot of an impressively audacious experiment, its history and its hopes are appropriate for Seismica, this is a fine paper.

> Recommendation: Accept Submission

Thank you for this assessment. As we are carrying out the described experiments, we are working hard on dedicated publications for each experiment and science aspects, which is why we had a number of 'in prep.' references in the first submitted version. In this paper, we indeed want to provide a bigger picture overview, that will be an important reference for the much more detailed science papers that will follow. We therefore much appreciate the SEISMICA Reports format.

By the way, the "impressively audacious experiment" comment is rapidly becoming a common expression in the BedrettoLab :)