

Anonymous REFEREE # 1

This is an interesting paper, which combines a review of research related to excavation damage zone characterization and prediction with a presentation of new preliminary results for an ambitious and valuable field experiment. The paper is strong overall, notwithstanding a few technical concerns to be addressed and a need to more clearly articulate the contribution. The writing is generally good, but there are many areas where some minor editing would improve the readability and presentation quality of the work.

We sincerely thank the Anonymous reviewer for the positive and encouraging assessment of our manuscript. We have carefully considered the technical comments and suggestions provided and have revised the manuscript accordingly. We have also made several language improvements throughout the manuscript to improve its readability. In addition, we have further clarified the scientific contribution and objectives of the PRECODE experiment. All the changes are incorporated in the updated text and following are the responses to individual comments.

Specific Major Comments:

- The literature review in the Introduction is appropriate, but the contribution of the paper is not clearly presented in the context of the review. The paragraph from Lines 110-114 is where this would normally happen, but the current version of this paragraph only includes two sentences that are not well-connected, with the second summarizing the study without any reference to the specific contributions.

Thank you for the comment. We modified the ending of the introduction with the contribution of this paper. The updated text is as follows:

.... This paper presents the overview of the PRECODE mine-by experiment and associated laboratory experimental framework at BedrettoLab, a new underground research laboratory (URL) in Switzerland. The PRECODE project combines multidisciplinary in-situ monitoring with controlled excavation methods and laboratory fracture-mechanics testing to investigate the mechanisms governing EDZ formation and evolution in crystalline rock. The resulting multi-scale dataset provides a basis for improving the understanding and prediction of EDZ evolution and its implications for the long-term performance of deep geological repositories.

- Section 4.5: By definition, if imaging is being done using laser scanning (which does not penetrate into the rock), could one not at best be characterizing the HDZ based on visible overbreak? More generally, this raises a question of whether or not the "EDZ growth" that is attributed to time-dependent damage process could instead be attributed to differences in characterization approaches (or, for example, time-dependent transitioning of parts of the EDZ to HDZ without actual EDZ growth). Perhaps these alternative possibilities are not likely for reasons known by the authors, but it should be addressed explicitly either way. I also believe that currently the explicit/direct comparison between the newer results and the older tunnel is made in the abstract (Lines 39-40), but not fully addressed in the discussion within the paper.

Thank you for raising this important point. As appropriately noted, distinguishing between the different damage zones around a tunnel (CDZ, HDZ, and inner and outer EDZ) is not trivial. The transition between these zones is generally gradual rather than defined by distinct boundaries, as reported in previous studies (Perras & Diederichs, 2016). Terrestrial laser scanning (TLS) primarily provides information on the exposed tunnel surface and therefore cannot directly characterize subsurface damage within the EDZ. We have clarified this distinction in Section 4.5 and now refer specifically to visible spalling and overbreak when discussing the TLS results. In the revised version, we have introduced a new "Discussion Section". In Section 7.2, we further discussed the surface expression of damage and the subsurface EDZ and attempted to provide distinction between these two areas.

Regarding the time-dependent growth: In this overview paper, we present only preliminary TLS results, which primarily characterize the surface expression of the CDZ and HDZ. In contrast, the AE monitoring indicates that excavation-induced damage extends deeper into the rock mass, with AE activity suggesting

an EDZ extent of approximately 1.5 m from the tunnel wall. We are currently preparing a separate publication on the evolution of permeability measured using the two MMPS systems installed in the PRECODE tunnel. Preliminary results indicate a time-dependent increase in permeability within the tunnel sidewalls, with the magnitude of the increase varying with distance from the tunnel wall. These observations provide additional evidence for ongoing time-dependent damage evolution, although the contribution of different characterization methods and the progressive transition between damage zones must also be considered. The combined analysis of permeability changes and microcracking will provide a more robust basis for distinguishing the inner and outer EDZ and quantifying their evolution over time. This work will be presented in a separate publication.

Finally, following the reviewer's suggestion, we have also expanded the discussion to provide a more explicit comparison between the newly excavated PRECODE tunnel and the more than 40-year-old Bedretto Tunnel, including the implications for understanding long-term EDZ evolution and permeability.

- The simplified presentation of AE rate over time in Section 6.1 may not be sufficient to understand the trends. I think it is necessary to add a visualization of the accumulation of AE activity relative to the total excavated volume, which is a better representation of changes in the energy balance within the system. In this framing, I actually think that the AE rates may be quite similar between the two excavation methods. Statements like "... indicating a greater degree of excavation-induced damage associated with drill-and-blast excavation" in the conclusions therefore may be misleading (since the total damage per unit-volume excavated, or equivalently per unit length of advance, may be similar).

Thank you for this comment. Following the reviewer's suggestion, we calculated the AE event rate per meter of excavation for both the drill-and-blast (D&B) and soft excavation sections. The calculated AE activity for the D&B section was 72,717 events m^{-1} , compared with 46,664 events m^{-1} for the first part and 48,232 events m^{-1} for the second part of the soft excavation section. These results indicate that the D&B excavation was associated with approximately 50–55% higher AE activity per meter of excavation than the soft excavation method. We have added this quantitative comparison to the revised manuscript.

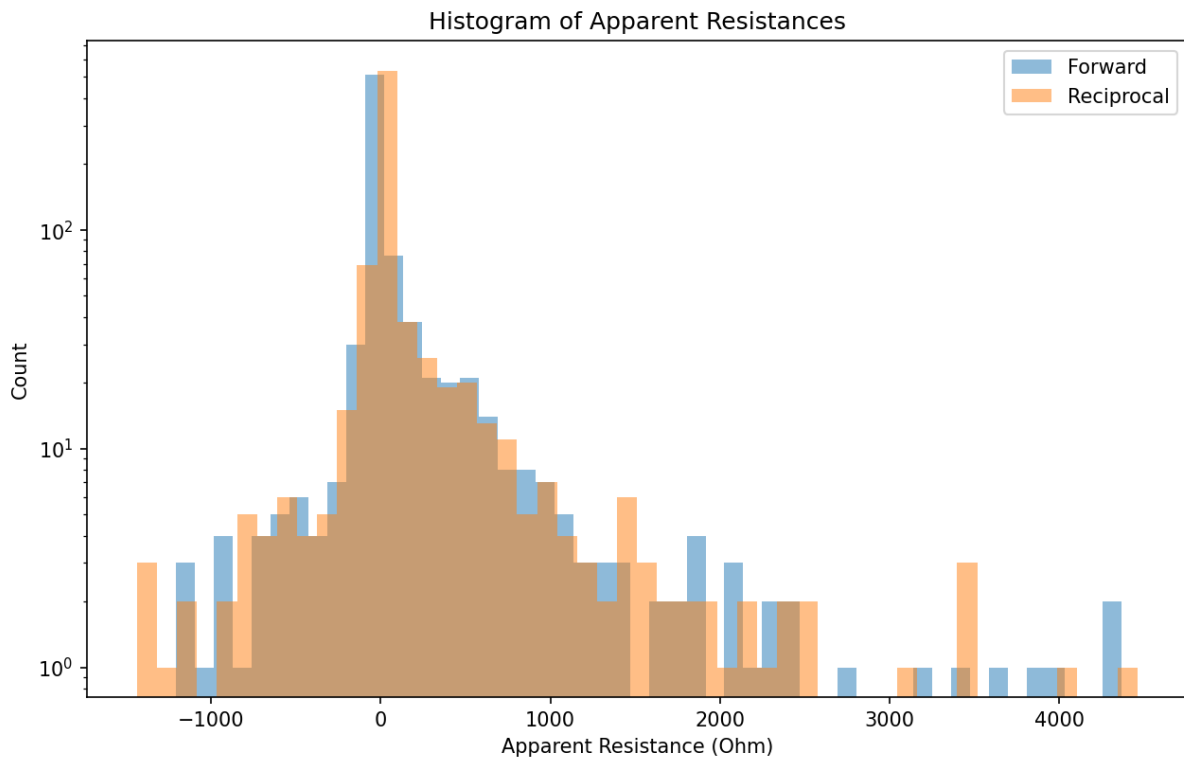
- I would argue that there is a great deal of uncertainty associated with the resistivity results and that there is a risk of overinterpretation. For example, consider the area around (0.8-0.2), which is a prime example of the statement "higher resistivities are observed in the soft excavation region compared to the D&B part". Here, the resistivity varies between the two figure panels from $\sim 2.300 \text{ Ohm.m}$ (left) to $\sim 3.700 \text{ Ohm.m}$. For a quantity that naturally varies over orders of magnitude, such differences are not necessarily particularly large, and well within the range of variability that might be expected to be induced based on propagation of various uncertainties through the inversion process. At the very least, this possibility should be acknowledged (or explicitly refuted). Relatedly, since the rock is so impermeable, why is it a reasonable assumption that one year would be sufficient time for water to enter small (sometimes isolated) cracks within the EDZ?

Thank you very much for pointing this out. On review, we found a plotting error in Figure 14 inversion result: the colorbar was mislabeled as a linear resistivity scale when the underlying values were $\log_{10}$ (resistivity). Correcting this (see updated inversion figure) shows the true resistivity range is larger than originally stated in the manuscript text — roughly 450-2,200 Ohm.m (interquartile range) and 40-24,000 Ohm.m overall (after excluding a handful of poorly-constrained edge cells). Comparing against Fu et al. (2024, Scientific Reports 14, 6120, <https://doi.org/10.1038/s41598-024-56695-x>), who report resistivity of $\sim 2,200$ -5,600 Ohm.m for intact biotite/monzonitic granite core samples, and resistivities as low as $\sim 20 \text{ Ohm.m}$ for water-bearing fractured granite zones: our observed range sits between these two references, consistent with a moderately fractured, somewhat damp excavation damage zone rather than pristine dry granite or a fully saturated fracture zone. This is a physically grounded comparison, and we will cite Fu et al. (2024) in the revised manuscript to support it.

In addition, while addressing the above we also applied the same readability fix requested for Figure 13 to the inversion figure: axis labels, tick labels, colorbar label and annotations increased to 16 pt. We also

corrected the colorbar itself to a proper log-scale axis in Ohm.m, replacing the earlier mislabeled linear $\log_{10}(\text{resistivity})$ axis

Regarding the inversion process, we wish to clarify that our convergence criterion for this deterministic algorithm was that Root Mean Square convergence was reached. We collected both forward and reciprocal measurements for the experiment, to ensure that our measurements are well behaved. Both stacking and reciprocal errors were assessed before inversion, and stacking errors were used as data weights whereas reciprocal errors were used to determine an error model. Therefore, we expect that the convergence of the inversion scheme (in this case, a Newton-Gauss iteration) correctly reflects the data being measured.



Specific Minor Comments:

- The "MS type" is listed as a "Review article", but this article is not really framed as a review, in my opinion.

Thank you for this comment. The first part of the manuscript provides an overview of the current state of knowledge on deep geological repositories (DGRs) in crystalline rocks, with particular emphasis on major in-situ experiments at various URLs, laboratory investigations, and numerical modelling. Based on this review, we identify several knowledge gaps that motivate the PRECODE experimental framework presented in the second part of the manuscript. We therefore, consider "Review article" to be the most appropriate manuscript type among the available categories.

- Lines 70-72: If you are going to mention "A variety of studies", you should cite more than one here, and ideally independent studies (i.e. not just later papers that also cite back to Diederichs, 2007)

It is a valid point. We added more references in the revised manuscript.

- Lines 142-143: This statement is not universally true. It is well-established in the literature that for porous rocks and under confined conditions, CD and volumetric strain reversal are not coincident. A more accurate statement might be something like "Under unconfined compression conditions, low porosity crystalline rocks typically reach the CD threshold at the point where volumetric strain reversal occurs."

The sentence is updated as “In low porosity crystalline rocks under unconfined compression conditions, the CD threshold coincides at the point where volumetric strain reversal occurs”.

- Lines 154-156: A bit strange to only see one reference on relevant studies using DIC when five studies on DSS were provided in the immediately prior sentence.

Thank you for pointing this out. Although DIC can be challenging for capturing abrupt and highly localized brittle fracture, several studies have successfully applied it to brittle rock failure. We have therefore added additional references on DIC applications and revised the relevant text accordingly.

- Table 1: Not something to be addressed in this paper, but it is curious that the dynamic Young's Modulus is lower than the static Young's modulus.

Thank you for the comment. The values of the dynamic Young's and Shear Modulus were indirectly estimated during the P and S wave velocity measurements and were not directly measured. As it was misleading, we decided to remove it from this manuscript.

- Line 602: Wouldn't this represent intact rock properties rather than fracture or rock mass?

That is correct. We updated the text accordingly.

- Line 737: I believe you may mean "point spacing" rather than "pixel spacing"

This is correct. We changed it to the point spacing.

- Lines 740-741: In this comparison, how do you differentiate EDZ (or really, HDZ) development from local structural overbreak?

Thanks for the feedback. In this section, the term EDZ refers specifically to the excavation-induced damage manifested at the exposed tunnel surface and detected by laser scanning, including the observed HDZ and CDZ. We have added a clarification in the revised manuscript to distinguish this surface damage from the subsurface excavation-induced damage within the rock mass, which cannot be directly characterized by TLS.

To differentiate stress-induced damage in intact rock from local structural overbreak, we complemented the TLS measurements with detailed field observations. These observations were used to assess whether the observed damage occurred along pre-existing discontinuities or resulted from newly generated fractures associated with excavation-induced stress concentrations. We have clarified this distinction in the revised manuscript.

- Line 757-761: the distinction between EDZ and CDZ (and the way it is determined) here is getting a bit blurry.

Based on detailed field observations, excluding areas explicitly affected by pre-existing discontinuities, the rock mass between TM 0 and TM 21 shows no significant spatial variation in mechanical characteristics or jointing. We therefore assume that differences in the extent of surface damage (CDZ + HDZ) between the D&B and LDRB sections are primarily related to the excavation method. A similar comparative approach has been adopted in studies at SKB, the Mine-by tunnel in Canada, and the ONKALO facility to evaluate the influence of excavation method on excavation-induced damage around underground repositories. We clarified this in the revised version

- Lines 806-808: why is the number of iterations only known "roughly"? Should this not be a fixed and known number?

We removed the word roughly and mentioned the exact iteration number. Further detail on the regression process is provided above (Specific Major Comments, last comment).

- Lines 853-854: what is meant by "Most AE events"? This is vague. If you're using this metric to delineate the EDZ (at ~1.5 m), you should present a more repeatable criterion (why not 1.4 m or 1.6 m?).

We have modified the sentence to better reflect the observations from the AE monitoring. The results indicate that systematic AE activity is confined to approximately the first 1.5 m from the tunnel wall, whereas no AE events were detected beyond this extent. The transition from active to negligible AE activity occurs gradually, and therefore a distinct boundary cannot be reliably assigned. We have consequently revised the text to describe approximately 1.5 m as the observed extent of systematic AE activity, rather than as a definitive EDZ boundary.

- Lines 847-860: much of this is interpretive and new (i.e. not previously presented in a discussion section). The conclusions should summarize rather than introduce new interpretations.

We have updated the text in the revised version to make sure that the data is presented and discussed earlier in the text. We have also added a dedicated Discussion section to the revised manuscript, which further outlines the key discussion points.

Technical Corrections (Minor Writing Suggestions):

- Please double check the journal's guidelines, but you need to (or wish to) use commas rather than periods to separate thousands in large numbers

Thank you for the comment. We have checked all the text once more to make sure that we follow this guideline.

- Lines 22 and 44: I suggest removing the initial "The" (starting "Brittle damage...")

Text updated

- Line 47: "may or may not to be violent" (typo - erroneous inclusion of "to")

Text updated

- Line 52: I believe "disposals" should be "disposal"

Text updated

- Line 58: I suggest "In-situ observations ... *have* revealed ..."

Text updated

- Line 73: Should the first sentence of this paragraph actually perhaps be the last sentence of the prior paragraph?

Thanks for the suggestion. We updated the text accordingly.

- Line 85: Is the comma after "demonstrated" here appropriate/necessary?

Text updated

- Lines 90-94: I found this sentence a bit awkward/tortuous, and suggest re-wording.

We broke down the long sentence into three shorter sentences. The updated text is as follows:

Deep geological repositories are expected to remain functional for more than 100,000 years. Therefore, understanding the long-term strength of the host rock, in addition to its short-term strength, is crucial. The factors controlling its time-dependent behaviour must also be considered when assessing the integrity of the underground infrastructure from construction through the operational phase.

- Line 106: "... in rock, which impacts the long-term strength."

Text updated

- Lines 134 & 142: "During a compression test..."

Text updated

- Line 149: Suggest removing "More recently,"

Text updated

- Line 214: "are" should be "were"; similarly, "is" should be "was" in the next sentence. The conditions documented by Collins (1997) are not static, and therefore should be referred to in past tense.

Text updated

- Line 215: Start this sentence "Brittle failures ..." (remove "the").

Text updated

- Line 229: "... for the TBM section the EDZ depth was limited to a few centimeters"

Text updated

- Line 230: "... prior to and after excavation ..."

Text updated

- Lines 231-232: "... limited to the EDZ and no enhanced permeability was observed beyond this zone."

Text updated

- Line 239: suggested to remove "a" before "heat transfer"

Text updated

- Line 260: "... and shape of the EDZ"

Text updated

- Line 260: "Using a Hoek-Brown constitutive ..."

Text updated

- Line 291: "Using an FDEM approach ..."

Text updated

- Lines 306-312: I know you need to touch on this here, but this is longer than it needs to be and feels repetitive, repeating some earlier text almost verbatim.

Thank you for the suggestion. We shortened the text more.

- Line 356: "Even a massive rock mass ..."

Text updated

- Line 359: "... around underground openings strongly interact with ..."

Text updated

- Line 360: The repetitive use of "and" reads awkwardly here

Text updated

- Lines 362-363: "... tips of microcracks ..."

Text updated

- Line 431: "... of the field stress tensor"

Text updated

- Line 433: Here "in situ" is not hyphenated, while it is elsewhere. I prefer "in-situ", but I suppose the most important thing is that it is consistent throughout the document either way.

Text updated.

Line 462: "shows" should be "show"

Text updated

- Lines 465-456: can specific citations be added?

Reference added

- Line 522: "... from the Bedretto Tunnel, which has an azimuth of ..."

Text updated

- Line 539: there appears to be a run-on sentence here that could be solved by adding a semi-colon between "sensors" and "after"

Text updated

- Line 540: maybe "slower" rather than "more time-demanding"?

Text updated

- Line 567: suggest replacing "post" with "after" for better parallelism with "during"

Text updated

- Line 623: I believe "system" should be "systems"

Text updated

- Lines 653-654: "The objective of the geophysical monitoring is to collect time lapse data to track EDZ evolution and allow for comparison of the shape and extent of the EDZ between areas with different excavation methods."

Text updated

- Line 657: repeated with what frequency?

The GPR and OPTV/ATV were carried out after each round of excavation. We updated the text to reflect that.

- Line 666: remove "up"

Text updated

- Line 670: suggest replacing "however," with "but"

Text updated

- Line 671: "... and each electrode is connected to takeout cables ..."

Text updated

- Lines 735-736: "... a number of laser scanning and outbreak mapping activities were conducted ..."

Text updated

- Line 736: "... characteristics of the EDZ ..."

Text updated

- Line 739: "... the cloud-to-cloud distance algorithm ..."

Text updated

- Line 747: suggest removing "the" before "normal"

Text updated

- Line 748: suggest a comma before "with"

Text updated

- Line 751: should "location" be "locations"?

Text updated

- Line 774: "... we expect that saturation had taken place ..."

Text updated

- Line 785: "Regarding the latter, ..."

Text updated

- Lines 806-808: this sentence switches from past tense ("was run") to present tense ("is reached")

Text updated

Dr. Jon Engström REFEREE # 2

The manuscript submitted to SE, emphasis a relevant topic to study regarding nuclear safety for a repository in a crystalline environment. The Introduction and the State-of-the-art sections are in general comprehensive and summarize earlier research well and the open-science question parts raises some important research to consider. However, the latter part of the manuscript still needs some work. Now this reads more as report description of project and does not define clearly what is the aim of the manuscript and how the research has been done to answer these open questions. The experiments are well described, and research environment is world class but the background information for a scientist not familiar with the site is thin.

Especially, the geological setting needs to be expanded since this kind of research is dependent on a clear definition of the geological framework where research is done. Bedrock is defined as granite, but this must be more defined with photos and thin sections. Geological structures are mentioned that are found but how they affect the research environment is not clear. One example found in the manuscript is the following: “The rock is considered to be massive to moderately fractured”. Please evolve and define this clearer. The results from all experiments are defined by the existing geology. This vague statement of geology that affects the experiments does give the impression that the geological setting has been overlooked while doing the research. I understand that this manuscript is more focused on different geophysical methods and that this research is work in progress, but nevertheless the geological environment is important.

In the research project there are defined some primary objectives within this PRECODE project in section 5.1. However, some of these objectives are not explored in the manuscript thus could be omitted and focus more on the results and aim of this study and manuscript. Some of the figures are also very generic and would benefit with some scales to define the extent of things. Another major issue with manuscript is the abstract stating research of the study that are not clearly shown in results and that the manuscript is totally lacking a discussion part to define what is the outcome of this study and how is this advancing the research that has been performed earlier.

Still, I find the research interesting and worth publishing, especially if the aims and the result parts are highlighted with clear connection and further discussed with earlier research.

General comment: Thank you for the constructive feedback. In this paper, we aimed to maintain a balance between the extensive body of literature on deep geological repositories in crystalline rocks, including in situ observations, laboratory experiments, and numerical modelling, and the presentation of our in-situ research programme within the PRECODE project and its preliminary results. This required us to remain concise in some aspects of the review and to provide relevant references for readers interested in specific topics in greater detail. It is important to emphasize that the primary objective of this overview paper is to present the overall experimental framework and detailed components of the PRECODE project, with particular emphasis on its multidisciplinary in situ instrumentation and monitoring programme. The presented preliminary results provide an initial overview of the data and demonstrate the potential of the integrated approach. Detailed analyses and interpretations of the individual datasets and monitoring techniques are currently being developed as separate scientific publications. These studies will provide a more comprehensive analysis and discussion of the individual methods and their results. We have clarified this scope in the revised manuscript to better distinguish the objectives of this overview paper from those of the subsequent individual studies. Following the reviewer's suggestions, we have revised the manuscript (in track changes), below are the responses to the individual comments.

Geological and Structural Setting: The authors agree with the reviewer that there is room to expand the description of the geological and structural setting of the project and acknowledge the important role of geological conditions in influencing the observed behaviour. As mentioned above, given the broad range of topics covered in this paper, we aimed to keep individual sections concise. Following the reviewer's suggestion, we have expanded Section 4.2, “Geological and Structural Setting”, to provide a more detailed description of the geological and structural conditions at the project site. We have also referred readers to

two recently published articles for further details on the geological and tectonic setting of BedrettoLab. The corresponding changes are highlighted in the revised manuscript and are excerpted below:

.... Geological structures including fracture sets and fault zones with various persistence and thickness ranging from sub-meters to tens of meters are frequently observed along the tunnel. Extensive surface and subsurface mapping of the geological structures has recently been conducted to analyze the geometrical and geomechanical characteristics of the structures in the study area (Lützenkirchen, 2002; Lützenkirchen & Loew, 2011; Jordan, 2019; Achziger-Zupančič et al., 2024; Ceccato et al., 2024). Achziger-Zupančič et al. (2024) identified three main sets of lineaments with different characteristics e.g., orientation, spatial distribution, persistence and intensity. They include: 1) NE-SW to ENE-WSW-striking lineaments with lateral persistence up to several hundreds of meters, 2) N-S striking structures with limited lateral persistency, and 3) WNW-ESE to NW-SE trending lineaments, with limited intensity and lateral persistency. Achziger-Zupančič et al. (2024) further studied the chronology between the identified lineament sets, and identified a complex series of brittle, ductile and ductile-to-brittle shear zones that have imposed within the Rotondo granite. Further details on the geological and tectonic setting of the Bedretto Valley are provided in recent publications on BedrettoLab (Ceccato et al., 2024, 2026).

Preliminary Results and Interpretations and Discussion Section: Thank you for comment. In response to the reviewer's suggestion, we have added a dedicated Discussion section to the revised manuscript. The revised paper therefore includes both a "Preliminary Results and Interpretation" section and a "Discussion" section. We have also explicitly outlined the contribution of this paper and the outline for future publications from the PRECODE project where we provide a more comprehensive analysis and discussion of the individual methods and their results.

Formatting and Graphs: With reference to the suggestion above, we have modified Figures to better clarity and added scales where appropriate.

Dr. Giacomo Medici Community Comment 1

General comments

Very good interdisciplinary research. Please, follow my specific comments to increase the impact and the readability.

Specific comments

Line 100. Fracture or matrix porosity? Maybe, you refer to the low permeability intergranular matrix.

Thank you for the comment. Here, we refer to the matrix porosity. We modified the text to reflect that.

Line 114. You need to describe the specific objectives of your research by using numbers (e.g., i, ii, and iii) at the end of your introduction.

That for the valid comment. It was also brought to our attention by one of the reviewers. We have added a new paragraph to describe the specific objectives of our research. The updated text is added at the end of the Introduction Section.

Lines 200-219. I would incorporate studies in the framework of the planned Sellafield nuclear waste repository with igneous-metamorphic basement, hydraulic tests performed and discussion on radionuclides. See below relevant literature on this topic for integration:

- Morris, K., Butterworth, J.C. and Livens, F.R., 2000. Evidence for the remobilization of Sellafield waste radionuclides in an intertidal salt marsh, West Cumbria, UK. *Estuarine, Coastal and Shelf Science*, 51(5), pp.613-625.

- Medici, G., West, L.J. and Mountney, N.P., 2018. Characterization of a fluvial aquifer at a range of depths and scales: the Triassic St Bees Sandstone Formation, Cumbria, UK. *Hydrogeology Journal*, 26(2), pp.565-591.

Thank you for the suggestion. We agree that the cited papers are relevant to radionuclide migration and provide valuable insights into this topic. However, we found it difficult to identify an appropriate place to incorporate these references within the scope of our manuscript. The suggested studies primarily focus on sedimentary rocks, whereas our literature review is specifically focused on deep geological repositories in crystalline rocks.

Line 400. Please, provide more information on non-fault related fracture sets. Type of faults? Thrusts and normal faults?

Thank you for the suggestion. We added a summary of the information related to the dominant structures and fracture sets as well as the type of the faults in the revised version. Further detail can be found in the following reference:

Achtziger-Zupančič, P., Ceccato, A., Zappone, A. S., Pozzi, G., Shakas, A., Amann, F., Behr, W. M., Escallon Botero, D., Giardini, D., Hertrich, M., Jalali, M., Ma, X., Meier, M.-A., Osten, J., Wiemer, S., & Cocco, M. (2024). Selection and Characterisation of the Target Fault for Fluid-Induced Activation and Earthquake Rupture Experiments. *EGU sphere*, 1–38. <https://doi.org/10.5194/egusphere-2024-586>

Line 421. “Fracture toughness”. Better stiffness?

The term “fracture toughness” is a standard nomenclature in the fracture mechanics testing and is therefore used in this section.

Figures and tables

Figure 2. You need a spatial scale.

This is a conceptual image. the depth of failure is dependent on various parameters. Adding a scale here may be misleading. We therefore decided to leave it without scale to avoid misinterpretation. We have added scale in other figures, where appropriate.

Figure 3a. The legend on the right cannot be read. Please, improve readability.

The size of the legend is increased for readability.

Figure 3b. There is room to make the geological cross-section larger.

The size of the geological cross-section is increased.

Figure 13. Graphs are difficult to read. Increase the font size.

Addressed. Axis labels and tick labels in both panels of Figure 13 have been increased.

Figure 13. Add the equation with R2 for the regression line of the upper graph.

Addressed. A power-law regression fit was computed in log-log space for the forward vs. reciprocal resistance panel:

$$y = 1.05 x^{0.95}$$

$$R^2 = 0.859$$

The fit (red line) closely tracks the ideal 1:1 relationship (black dashed line), confirming high repeatability between forward and reciprocal measurements.

Figure 13. Do you need a regression line for the lower graph?

We propose not to add a regression line to the reciprocal-error vs. average-resistance panel. The reciprocal error spans nearly four orders of magnitude at a given resistance value, so the relationship is not well described by a single fitted curve (power-law or otherwise). The panel is intended to be diagnostic, with the purpose of showing that error decreases as measured resistance increases, and motivating the 10% reciprocal-error cutoff used for filtering. A regression line would imply a level of precision the data do not support.