

## Final Response: SE-2021-118

### Anonymous Referee #2

Thank you for reviewing our manuscript. In accordance with your comments, we have enhanced and extended in particular the discussion section. Please find below some more detailed responses to your comments.

*The study presents data on fracturing of intrusives considered as analogs of buried structures relevant for geothermal exploration. Technically speaking, the ms is well done and text well presented.*

*My overall concern is the lack of novelty of this work (and similar studies). There is no real innovation from a technical or methodological point of view (tools adopted are presently accessible to numerous groups) and the conclusions are so dependent on the assumptions and on parameters different from the subsurface that they are of little use.*

Answer: In the presented study we investigate the fracture network in a greenfield area. For this reason, it is important to use established methods in order to have a benchmark against previous studies. The novelty of the study consists mainly in the investigation of the specific outcrop analog, which has been poorly explored until now. In addition, such a combination of structural geological and geophysical methods has not previously been applied to characterize a potential fractured reservoir formation. The comprehensive data set is thus unique for the crystalline basement.

The data and interpretations are valuable for different geothermal applications in the crystalline basement, from EGS projects to medium-deep heat storages, as their efficiency largely depends on the architecture of the fracture network. In addition, the results are of high value to the GeoLaB underground research laboratory that is potentially to be constructed in the study area. To highlight this fact, an additional paragraph has been included in the discussion.

We are aware that not all questions regarding the fracture network and the hydrogeological properties of the crystalline basement can be answered in the manuscript. Nevertheless, the study represents an important step forward and provides indications of where, for example, additional exploration measures are necessary.

Except for in Section 3.1.3 "DFN Modeling," no significant assumptions are made (and even these assumptions are based on published observations of other sites, see additional comment below)

*In addition, one could even argue that in those intrusives there are so many fractures that flow will take place anyway.*

Answer: While this may be true in the near-surface part of the pluton, the hydrogeological properties change considerably at depth (Manning und Ingebritsen 1999; Stober und Bucher 2007). On the one hand, this is due to the stress-induced closure of most fractures and, on the other hand, to the mineralization of the fractures. As a result, permeability at depths of some hundred meters can already be one or more orders of magnitude lower (Achtziger-Zupančič et al. 2017):

- Achtziger-Zupančič P, Loew S, Mariéthoz G. A new global database to improve predictions of permeability distribution in crystalline rocks at site scale. *J. Geophys. Res.* 2017;122(5):3513–39. doi:10.1002/2017JB014106.
- Manning CE, Ingebritsen SE. Permeability of the continental crust: Implications of geothermal data and metamorphic systems. *Rev. Geophys.* 1999;37(1):127–50. doi:10.1029/1998RG900002.
- Stober I, Bucher K. Hydraulic properties of the crystalline basement. *Hydrogeol J.* 2007;15(2):213–24. doi:10.1007/s10040-006-0094-4.

*- i have huge problems with the definition of sets in plots such as the ones in fig. 4: there are simply faults/fractures in most directions*

Answer: This fact is acknowledged in the manuscript: “The strike directions of the lineaments from the high-resolution DEM show nearly an equal distribution”. The text was adjusted to make this clearer.

*- it is unclear to me what the role of gravity and radon studies; i did not see a link with the fractures. Even the gravity, radon and faults are less correlated than pretended*

Answer: The introduction and discussion of the radon and gravity measurements was revised to emphasize the link between geophysical and structural data. We added a more thorough description of the uncertainties associated with this approach.

*- i miss a sensitivity analysis and cannot therefore judge how robust are the conclusions*

Answer: In section 4.1.4 the effect of various parameters on the hydrogeological properties were systematically analyzed, as presented in the manuscript. A more detailed sensitivity analysis would mean a disproportionate additional effort, as the DFN is very time consuming and cannot be automatized. Hence, we added references to other sensitivity studies on this topic that are supporting our interpretations.

*- i also miss information on the outcrops: are they vertical? horizontal? in between?*

Answer: The information was added to the text.

*What to do? Either the authors can substantially highlight innovative and useful results, or it remains a technically interesting study with little impact.*

Answer: We are somewhat surprised that the results are considered to be not useful. Please see the first comment above where we emphasize the importance of the study. We have revised the introduction, discussion, and conclusions to enhance the impact of the manuscript.

Interpretation of data from outcrop analog studies with respect to deep reservoir properties are always subject to uncertainties. However, with very little well data available (see introduction), this approach is the only possibility for gaining new insight into the structural/hydrogeologic/geophysical properties of the basement without drilling cost-intensive new wells.