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Solid Earth Discussions

Interactive comment on "Flexible parallel implicit modelling of coupled Thermal-Hydraulic-Mechanical processes in fractured rocks" *by* Mauro Cacace and Antoine B. Jacquey

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General comment: My sincere apologies for the extremely late comment. I have read the manuscript with great interest and I think it does fit the scope of the journal and should be published following some minor to moderate revisions.

Answer to the general comment: We would like to thank the reviewer for his comments. We have systematically addressed all of his points, as explained below. When we did believe the comments from Reviewer #1 required changes

in the manuscript, we have followed his suggestions and implemented those changes accordingly (these are all marked in the revised version, see the file cacace_jacquey_solid_earth_tracked_changes.pdf). We have provided detailed answers for those comments that either we did not agree with the reviewer's point of view or we did not consider requiring any change to the manuscript.

Point 1: My main comment concerns the presentation of the mechanical model, with the detailed emphasis given in the algorithmic implementation of the plasticity algorithm without being used at all in this manuscript. This confuses the reader who expects to see an application using the return map described in detail without delivering it. I would recommend the authors to remove the discussion about plasticity, keep the model elastic and put more emphasis in the excellent geothermal example of paragraph 4.5. In its present form, the paper is weak in the sense that most of the benchmarks described already exist in the tensor mechanics module of MOOSE and as such they do not really deserve to be in the main text of a novel contribution. The geothermal example however, is novel and impressive and deserves its own section and some more detail to be added.

Answer to Point 1: We acknowledge the point raised by the reviewer, though we would like to add a short discussion on some aspects on Reviewer#1. First of all, concerning his main comment on the abswence in the manuscript on a practical example of the return map procedure we should add that we did present an application dealing with the plasticity (and the return mapping algorithm we implemented in our simulator) and we validated our implementation against an analytical solution derived in details in the Appendix. We nevertheless acknowledge the point from Reviewer#1 in the sense that in its present form, the organization of the results in the current manuscript might have read a bit confusing and we have re-organized the results part according to his suggestions, and by also taking into consideration the suggestions from Reviewer#2. Now we have provided a clear distinction between benchmark test cases which we make use to compare the reliability and reproducibility of the simulator against existing

analytical solutions in addressing specific coupling (as commonly done in the modelling community) and reservoir applications. For each case we have highlighted the processes targeted to ease the understanding of each example. All changes can be found in the revised manuscript accordingly. With respect to the second aspect of Reviewer#1 comment, we would like to add that we could not fully agree with Reviewer#1 in saying that the test cases presented are already part of the benchmark suite of the MOOSE framework. Indeed, while they can be considered as commonly adopted test cases, they have not been taken from the framework itself. This is why we did spend some time in the appendix to derive the analytical solution for the oedometer benchmark while using a Drucker-Prager plastic model. Specifically with respect to the applications focusing on the elastic and inelastic processes, we once again followed Reviewer#1 suggestions, and also take into account the comments from Reviewer#2, and we add an additional study case which increases the level of complexity of the reference oedometer test by additionally considering the hydromechanical response under undrained condition with poroelastoplastic coupling in the revised version. Following the reviewer's suggestions we have decided to dedicate a separate paragraph to the applied (reservoir) applications, both the hydrothermal multi-fractured and the thermo-hydro-mechanical applications. As a closing comment to our answer so far, we would like to spend some more words on the reason why we did consider important to maintain the description of the elastoplastic constitutive laws and their integration in the revised manuscript. The scope of the manuscript is to describe the full capability of the simulator we have developed. As stated in the introduction, attention was mainly focused on capturing the details of the non-linear feedbacks between thermal, hydraulic (pore pressure) and mechanical processes as of relevance in the context of reservoir applications in the presence of discrete fractures and/or major fault zones. In this regard, the latter component entail to systematically address and integrate the effect related to the (poro and thermo) elastic behaviour of the porous material, but also the irreversible one, e.g. inelastic processes. To implement inelastic behaviour in the context of porous media application requires to develop specific algorithmic features (in

our case the return map algorithm for non-associated plasticity) that are generally non trivial. This is the main reason we spent some efforts in, briefly explained how such algorithms have been integrated in our current numerical framework, in a way that would be reproducible by other scientists who might follow the same route. In this regard, the reviewer might be right in saying that the discussion provided might read long, but this has likely to do with him being familiar with the topic (in the context of numerical implementation). Indeed, we have already been contacted by other colleagues who were specifically interested to learn more details (than those provided in the manuscript) on our implementation of the inelastic routines. For this reason, we consider important to maintain the description of the algorithm in the manuscript (leaving it off would also hindered the reader and potential user of the numerical framework to fully appreciate the capability of Golem).

Point 2: On a minor note, it would be nice to acknowledge other modules that are doing fully coupled THMC with thermo-hydro-chemically sensitive plasticity, like REDBACK. We have just released the first works that I think deserve to be mentioned in the literature review section of this contribution.

Answer to Point 2: We acknowledge the comment from Reviewer#1, and would like to apologise for our lack of referencing other works and had the expected reference in the revised version of the paper (see introduction in the revised version).

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