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Solid Earth
Discussions

Interactive comment on "Anisotropic transport and frictional properties of simulated clay-rich fault gouges" *by* Elisenda Bakker and Johannes H. P. de Bresser

Anonymous Referee #1

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The paper by Bakkers and de Bresser presents new experimental data on the influence of pressure and slip on permeability (and permeability anisotropy) of clay-rich gouge. The new data are certainly valuable, and those experiments are not easy to conduct. The paper is framed heavily around CO2 storage problems, which is just one of the many possible applications of the work; this is somewhat distracting, since a lot of space is devoted (in the introduction and discussion) on the link with CO2 storage, which can only be addressed very generically here, at the expense of more physical/microstructural discussions about the processes that generate changes in permeability.

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Discussion paper

My main concern with the paper is twofold. Firstly, it is not clear at all if the data are useable, since the author repeatedly mention that they could not achieve a proper correction for the Klinkenberg effect. This should be clarified. Secondly, the data interpretation in terms of mechanisms (in absence of other measurements, such as pore volume, or microstructures, or modelling attempts) are very vague and rely almost entirely on comparison and analogies with published literature.

In that sense, the paper remains very technical and descriptive. One key question that is not really addressed, for instance, is the role of pre-compaction: if permeability is anisotropic to start with, it means that normal compaction of the layer already produces a texture, which is then altered by shear. But how is this initial texture formed? Is it visible in the microstructure? Is this an experimental artefact or something that we should expect in nature?

One thing that could help put the results in perspective with literature data is the make systematic comparison between the permeability anisotropy data obtained here and the other existing datasets. Is there anything general that can be established? What is the order of magnitude of anisotropy that we should expect across the range of materials tested?

Detailed comments:

l.29: permeable -> permeability

l.56: not sure that dilation and compaction (i.e., porosity change) can be so easily linked to increase of decrease in permeability. Maybe moderate the statement?

l.66: one recent reference that is relevant here is Rutter and Mecklenburgh, JGR 2018, where systematic characterisation of shear and normal stress effects on permeability anisotropy was conducted. Also, Okazaki, Katayma and Noda, GRL, 2013, specifically studied along-fault permeability vs slip in a phyllosilicate gouge.

l.81: by "transport", it seems that the authors mean "permeability". (Transport is more vague and could refer to hydraulic diffusivity)

l.175: does "dynamic permeability" refer to "syn-deformation permeability"? the word "dynamic" means different things to different people, and some clarity would bring everyone on the same page.

l.177: maybe reword as "... a dynamic permeability measurement was conducted"

l.209: the symbol on the lhs seems to be "proportional to" instead of "alpha".

l.217: is there a way to estimate the potential error produced by this assumption? I don't think it will be huge, but a rough estimate could be helpful, since compaction might lead to artificial increase in permeability (reduction in A).

l.243: just say "... a rapid decrease"?

l.255: remove first "it"

l.270: I do not really understand what was done here, and what was the conclusion. Should we trust the data or not?

l.350: is the reduction in k with increasing sigma_n reversible? how much of that is elastic closure of pathways vs. permanent collapse?

l.370: I understand that the measurement of volumetric strain (or pore volume change) was not possible in the experiments. Would there be a way to back the statements in the discussion using some indirect observations (say, microstructures, or anything else), rather than just relying on literature data (on other rocks!)?

l.375: What exactly is the problem here? I am not I follow what is stated.

l.389: I do not understand the sentence; rephrase?

l.397-415: I am not convinced that such small anomalies deserve to be discussed at such great length, especially since no real explanation is given beyond speculation. Is the stick-slip behaviour reproducible under those conditions?

l.430: this conclusion strongly depends on the state of consolidation of the gouge layer. How do the laboratory condition reflect the in-situ conditions of natural faults? In nature, faults might be overconsolidated or chemically sealed, which would lead to dilation (not compaction) upon slip.

l.455: I am not sure what it means to show "uncorrected" values. They may not be meaningful at all, unless some reasonable error bars can be provided. Are the results upper or lower bounds for the actual permeability? In addition, if CO_2 is the focus, the interesting permeability value is that relevant to (possibly gaseous) CO_2, which then implies another Klinkenberg effect.

l.459: foliation is mentioned but not shown? here again, microstructures would be important to support this point.

l.470: I sense that this point, as stated, could be made independently from the data shown in the paper. I am not convinced this is a solid conclusion that is drawn from the new dataset, rather than a generic point about permeability.

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