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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 #2

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In this paper, the authors describe a series of direct shear experiments conducted on simulated gouge materials made of crushed Opalinius Claystone. They aim at investigating the mechanical behavior and gas conductivity evolution of caprock penetrating faults. The paper is well organized and written in a clear manner. However, the authors fail to convey the originality of their work and the relevance to real application in my opinion. Moreover, some of the interpretation of the results are not very convincing.

1. Other authors in the literature have already looked at the behavior of clay-rich fault gouge varying the amount of clay content, the normal pressure, etc. and performed permeability tests during the experiments. As stated in the present paper, the results

obtained in these previous studies (e.g. Crawford et al. 2008 or Zhang et al., 1999) are similar to the ones obtained here. Therefore, it is not clear the new information brought by this study.

2. The mechanical behavior of clays is strongly dependent on the presence of water, and it is likely that a fault zone will be saturated in natural conditions. Therefore, the influence of water on the results obtained here and how it should modify what would happen in the field should be addressed by the authors.

3. The authors used an interesting setup to induce flows across or along the experiments. However, the way the samples are prepared should not lead to any anisotropy for the permeability (compressed powder of fine particles). Therefore, the anisotropy they have observed (especially for the initial permeability) appears more as an artifact of the experiment, coming from flow path across the gouge that is more subjected to heterogeneities compared to the flow along the gouge. It makes the comparison with the anisotropy of fault zones not very justified.

4. A mature fault zone presenting a gouge is supposed to have accommodated a large amount of displacements and reach the "critical state" (as defined in the soil mechanics community). At this stage, the material does not change its volume when sheared, so the volume variation observed here and affecting the permeability in the first millimeters of the experiment would presumably not be observed.

5. The fact that the fault zone as a conduit along its shearing direction is mostly due to the damage zone that you are not studying.

6. The interpretation of the evolution of friction with normal stress should be elaborated. The decrease of the friction with increasing effective normal stress is attributed to be an effect of the cohesion, whereas this effect has been extensively studied in Rock mechanics and is related to the change in volumetric behavior. Several models like Hoek-Brown or Cam-clay have been specifically developed to describe this effect. Stick slip coming from slip weakening. . .

7. The observation of stick-slips events during the experiments presented here are quite interesting as the material is velocity-strengthening, but the possible explanation to explain this behavior are not convincing. Argument 1 seem quite difficult to verify and does not seem very likely. Arguments 2 and 3 (lines 405-415) mention some mechanisms that would induce some slip-weakening. If there was any slip weakening it should be observed on the mechanical response of the material. Moreover, slip-weakening leads to a single instability (or stress drop) and cannot create repetitive stick-slip events.

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