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Interactive comment on "Cataclastic deformation of triaxially deformed, cemented mudrock (Callovo Oxfordian Clay): an experimental study at the micro/nano scale using BIB-SEM" *by* Guillaume Desbois et al.

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Review of SE manuscript Cataclastic deformation of triaxially deformed, cemented mudrock (Callovo Oxfordian Clay): an experimental study at the micro/nano scale using BIB-SEM by Guillaume Desbois, Nadine Höhne, Janos L. Urai, Pierre Bésuelle, and Gioacchino Viggiani.

The manuscript contains a detailed microstructural analysis of Bure clay samples that were previously subjected to different mechanical tests at confining pressures of 2 and 10 MPa. Sample deformation was recorded in situ using DIC and X-ray tomography,

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Discussion paper

respectively. Samples for the microstructure analysis presented here were carefully chosen with reference to the recorded deformation, and the analytical techniques used for this analysis are state of the art. The paper is generally well written and organized and could be published with minor revision. I have just a few comments listed below:

1. Section 3: Samples were extracted with a diamond saw and surfaces first polished using SiC paper and then BIB polished. Is this procedure sufficient to erase potential surface damage introduced during sawing and SiC polishing?

→ After extraction of sub-samples by sawing, we pre-polished manually sub-samples with SiC grinding paper down to a grade of P4000 (i.e. a median grain size of 2.5 μm), removing damage from sawing. Subsequently, we used BIB milling to prepare high quality polished cross-section. The BIB cross-sectioner removes about 100 μm of the SiC milled surface. Therefore, BIB cross sectioning erases all potential surface damage introduced during SiC polishing. This information is now specified in the reviewed version of the manuscript (Lines 287 to 288 in the revised version).

2. Section 4.1: It did not become clear to what extent and by which arguments the mode I fractures in either sample could be attributed to deformation or rather to unloading, drying etc. The authors refer to Figure 4d,e to illustrate the rather dramatic changes in the microstructure that occured over time. Should one not expect that most of the fractures that initially formed during deformation experienced some later overprint?

→ We agree with the reviewer: some fractures were initially formed during deformation (Fig. 4.d) and later overprinted by drying (Fig. 4.e). Here, drying tends to make the aperture of syn-deformation fractures larger. Unfortunately, BIB-SEM images (performed on dried samples) do not provide direct information to know if the visible fractures and cracks developed during deformation (and subsequently overprinted by drying) or only by drying. However, as presented in the second part of the Section 5.1, indirect evidences argue that the fractures in the fragments between the arrays of antithetic fractures and the antithetic fractures of Type I and of Type II developed during deformation. In the reviewed version of the manuscript, we updated the Section 5.1 (in discussion) to make it clearer.

3. Section 4.2 and Discussion: Type II fractures show damage zones that are suggested to be wider in samples deformed at 10 MPa although porosity there is supressed by shear-enhanced compaction. I would encourage the authors to elaborate on the micromechanisms forming the damage zones and involving cataclasis and pore collapse.

→ In the revised version of the manuscript we added a new section (Section 5.3, in Discussion) titled " Conceptual model of microstructure development in triaxially deformed COX".

4. Section 4.2.2: Figure 8 is really busy and some arguments of the authors illustrated by this figure are hard to follow. For example, I find many chipped/angular non clay minerals also in the undeformed matrix (Figure 5, Figure 12a).

→ We find that Figure 8 is not too busy but we can split it into 2 figures if the editor thinks it is necessary. There are chipped/angular non-clay minerals also in the undeformed matrix. This is true but not "many" as suggested by the reviewer. In comparison, the damage zone is built with "many" of broken grains/fragments (e.g. Figure 12). In the revised version of the manuscript, we reworded slightly the section 4.2.2 to clarify this above.

5. Figure 10: The epoxy impregnation indicating a damage zone is hard to see in this figure. Also, this is an image of a sample deformed at 10 MPa where porosity was suggested to be significantly reduced due to compaction. That would make it difficult for the epoxy to preferentially impregnate the damage zone, I would think.

→ We think that the reviewer refers to the lines 233-234 in the original version of the manuscript. In this case, we fully agree about the comments above. The reference to the Figure 10 in lines 233-234 is a mistake. We deleted the reference to the figure 10 in lines 233-234 in the revised version of the manuscript.

6. Section 5.2: The authors consider the dominance of cataclastic deformation in these samples surprising. Why? Differential stresses exceed the confining pressures by a factor of 3-15, which would suggest empirically that dilatatant fracturing prevails over other mechanisms (e.g. Kohlstedt et al., 1995).

→ Reviewer has right, cataclastic deformation is not "surprising". Therefore we updated the first paragraph of the section 5.2 as following:

"In our experiments, differential stresses exceed the confining pressure by a factor of 3-15, which would suggest that dilatant fracturing prevails over other mechanisms (e.g. Kohlstedt et al., 1995). This is partly corroborated from the stress-strain measurements that show major stress drops after peaks of stress (Figures 2 and 3). In agreement with this, at micro-scale the first conclusion based on the microstructural observations above is the dominantly cataclastic deformation in Callovo-Oxfordian Clay at confining pressures up to 10 MPa. Microfracturing, producing fragments at a range of scales and reworking into a phyllosilicate-rich cataclastic gouge during frictional flow are the main processes in both samples. This is accompanied by dilatancy and by microfracturing of the original fabric, but also by progressive decrease of porosity and pore size in the gouge with the non-clay particles embedded in reworked clay. The structure of macro-scale fracture in the samples compares well with Ishii et al., (2011, 2016). "

I hope my comments are useful to the authors. Sincerely

Georg Dresen

Please also note the supplement to this comment:
http://www.solid-earth-discuss.net/se-2016-131/se-2016-131-AC2-supplement.pdf

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