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Interactive comment on "Hierarchical creep cavity formation in an ultramylonite and implications for phase mixing" *by* James Gilgannon et al.

L. Morales (Referee)

luiz.morales@scopem.ethz.ch

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In this paper the authors performed a detailed microstructural analysis of a sample of quartz-feldsphatic ultramylonite from a shear zone in Central Australia in order to understand the origin of creep cavities ubiquitously observed in the studied sample. For that the authors have used multi-technique workflow combining techniques of electron microscopy and x-ray nanotomography. Through these different approaches the authors were able to visualize not only where the porosity is concentrate in the studied sample, but also determine the orientation and shape of these pores. I liked the idea of a "two" step cavity formation and the role of creep cavitation on the transition from grain insensitive to grain sensitive rheology in this ultramylonite example. The paper is very well written, easy to follow, the figures are really good and the paper is in a good

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shape to be published. Nevertheless the authors may want to consider the comments below before publication:

1) Although I like the idea of Zener-Stroh cracking mechanism to explain the initial porosity in the quartz rich bands, the evidence provided is not totally convincing because of the lack of TEM analyses in the studied sample. The TEM imaging in this case is really necessary because one has to be able to see the dislocations aligned against some sort of "barrier" (a grain boundary, or particular slip plane), where they would piled up and eventually coalesce to form voids and cracks. This is obviously not very easy but would be a more convincing evidence for the activation of this mechanism during the deformation of the quartz bands and the cavities. The authors also have to keep in mind that in quartz one will be never sure if the dislocations pile up to form the porosity of if the porosity (and the stress concentration around it) will be the place where the dislocations are nucleated, because we cannot see dislocations moving. Another possible way to tackle better this problem would evolve, for instance, the detailed EBSD mapping around the pores to see if there any evidence of more distorted lattice around the voids or somewhere in the grains;

2) The authors mentioned that roughly the porosity is generated in grain boundaries aligned with the YZ plane of finite strain. From the graphics of Fig. 3, the predominant porosity shape is rather irregular, and although there is a predominance of porosity long axes parallel to Z (Fig. 3a), I did not understand the relation to Y, considering that the analyses were performed in the XZ section. Maybe there is some piece of information missing about the calculation of the Y-axis (for instance, as a cross-product of the long and short axes extracted from the maps). Or maybe the authors should include analysis in an orthogonal section?

3) In the section 4.5 the authors say that they have clear evidence for "subgrains and lattice distortions", but this is not evident in the figures. For instance the misorientation angle histogram in the Figs. 8a and 8b do not show a low angle misorientation peak as one would expect when quartz is deformed in the crystal plasticity field. I guess this is

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related to the cut off misorientation angle chosen for the grain calculations in MTEX, so the authors have to provide new histograms where these peaks are more clear. This is also necessary because the EBSD map in the supplementary material does not show abundant subgrain boundaries.

4) A very interesting feature in these misorientation histograms is the lack of a misorientation peak at 60°, related to Dauphine twinning. Do the authors "cleaned" the twinning or the lack of twins is a real feature in this sample. If the later is the case, this should be discussed in the paper, as this is not very common in quartz EBSD data;

Some minor comments include:

Page 2, line 3-4 – I would briefly discuss these three different models like in two sentences each, that allows a quick comparison between models;

Page 3, line 4 – substitute "We present a highresolution map of porosity distribution on the mm scale in an ultramylonite and" by "Through this work flow we demonstrate. . .";

Line 16 – is there any temperature estimation for the deformation?

Line 20 – remove "?"

Page 4, equation 1 (and the others) – is there any reference for these equations, like Heilbronner's book?

Page 5, line 6 – please add where the EBSD data was acquired (Bern?);

Line 10 – Mainprice et al. is not the correct reference for MTEX, the correct is Hielscher & Schaeben 2008 - A novel pole figure inversion method: specification of the MTEX algorithm, J. of Appl. Cryst., 41(6), 2008.

Line 11 – please specify the parameters for the ODF calculations (halfwidth, etc). This is given in the figures but should be included here

Line 23 – what do you mean by thin section wafer?

Line 23 – “ion beam techniques”;

Page 6, line 12 – please refer to the figures;

Line 20 – how calcic is the plagioclase? Please give an estimative of An content

Page 7, line 6 – please briefly explain how the hexbin statistic works;

Line 15 – how do you define high and low beta angles?

4.2.4 – the numerical definitions in the figure are different from the ones presented in the text

Line 17 – the authors mentioned 3 clusters, but I only see one, maybe the authors should indicate them in the figures;

Page 9. Line 6 – Fig. 6c

Line 8 – the authors mentioned that the dentrites are Si-rich. Looking at their Fig. 6, it is clear that the dentrites have a maximum of few 100’s of nanometers in thickness. If the EDS was done with 20 kV as mentioned in the paper, the volume of interaction in quartz would be around 1 μm, meaning that the Si X-ray signal the authors detected may come from the quartz underneath. Did the authors performed low kV EDS analyses for better spatial resolution (less interaction volume)?

Page 10, line 6 – remove the two sentences between brackets, no need to call the questions here

Page 11, line 30 – dominant slip. . .plane? Direction?

Page 12, line 8 – how do you do EBSD on cavities? âŸž

Line 26 – remove “systematic”

Line 13, line 9-10 – in the way is written, it reads as if the fluids could induce pinning

Figures

General comment – either rotate all the pictures to have foliation E-W compatible with the pole figures in Fig. 8 (and the standard tectonic reference frame with foliation/lineation E-W) or rotate the pole figures from figure 8 to have the foliation N-S

Figure 1 – you should separate A, and C from the big picture B, and also write B on the big picture. You should also consider making A and C bigger, in the printed version the features are really small (consider also increasing the font size)

Figure 2 & 3 – I would make all the pictures bigger

Figure 4 – The authors mentioned in the caption that the largest pores have high beta values (with long axes parallel to X) but this is not clear from the Fig. 4b, there are only 7 or 9 points with blue colors (indicating larger pores) with high beta values, is this number relevant, considering that for intermediate size pores (yellow) you have much more points covering a full range of beta values?

Figure 5 – please make the scale for A & C and B & D the same, for easier comparison

Figure 6 – in the picture D you point to “incipient precipitates” (I imagine you are referring to the brig tiny spots), but the tip of your arrow points to an artefact caused by the grains from the coating, you should move the arrow to point exactly one of the bright spots or make a circle around the whole area

Figure 7 – Is there a colorcode for the 3D model of porosity? And is it possible to have the same orientation as X-Y-Z as in the 2D figures?

Figure 8 – your contoured pole figures are missing the primitive circle of the stereonet. The arrows pointing to quartz grain dispersion and quartz domain width should be more separate and the font larger. The font needs to be larger in the pole figure legend and in the histograms. Pleas also write [0001] instead of (0001).

Luiz F. G. Morales

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