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Interactive comment on "Micro- and nano-porosity of the active Alpine Fault zone, New Zealand" *by* Martina Kirilova et al.

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Dear Michel Bestmann,

We are grateful for your review and your positive feedback. Below we have copy pasted your comments and responded to each one in turn.

General comments: 1. Portion/fraction of weak minerals related to fluid overpressure in relation to pre- existent weak minerals (clay minerals in gouge zone / fault zone) - Abstract (line 25-29) and chapter 5.3 line 245-261: You analyses gouge material, especialy clay minerals. In chapter 2. you mentioned that the gouge material is a re-worked product probably as a result of ultracomminution due to multiple shear events under brittle conditions. The local presence of authigenic smectite clays (Schleicher et

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al., 2015) and calcite and/or chlorite mineralization within sealed fractures and in the gouge matrix (Williams et al, 2017) indicate that mineral reactions are restricted to an alteration zone within the fault core. You conclude that due to fluid overpressure a weak mineral phase was introduced into the fault zone. My Question: What portion/fraction of the gouge material is related to the fluid overpressure and what part related to former events, e.g. ultracomminu- tion together with fluid mobility/sealing, without fluid overpressure. Because when you already deal with a weak clay-rich rock and afterwards another weak phase in fluid- overpressurized pores is precipitated (e.g. clay, graphite), than the influence of this minor third weak phase (volume weighted with respect to the existing surrounding weak fault rock) on the already existent rheology is relatively low. Please clarify this point.

Response: Thank you for this comment. Before answering your question we would like to clarify two points: (i) the conclusion that mineral phases were introduced was documented by previous studies on these rocks (i.e. Schleicher et al., 2015 and Williams et al., 2017), our data only confirm the conclusions made in those studies; and (ii) in lines 25-29 and 245-261, we don't state that fluid overpressure caused the precipitation of weak mineral phases. Instead, we suggest that fluid-filled pores are favourable environment for mineral precipitation, which could further reduce the already extremely low total porosities in these rocks, and thus lead to fluid overpressure. In this way, the addition of only small amount of new material phases could have a dramatic effect on the mechanical behaviour of the fault. Furthermore, if the newly precipitated material is with low frictional properties, the likelihood of a fault slip would be even higher.

2. Analytical detection of 1 μm-sized pores line 185-187: On figure 8b pores have sizes comparable to the small range of pores segmented on XCT images (> 1.3 μm in diameter), and thus we conclude that both nano- and micro pores within the Alpine Fault core are distributed on grain and phase boundaries, especially of clay minerals (Fig. 8). MB-comment: In Fig. 8b the pores are extremely flattened /elongated and only the long g axis show a value > 1 μm. I am not sure if you can measure with

synchrotron and a voxel size resolution of 1.3 μm such elongates pores where the calculated diameter is <1.3 μm. Please clarify this point.

Response: We do not imply we have measured the exact same pores shown on the TEM images. We only state we observe pores with comparable (but not the same) size, which allows us to suggest that the distribution of pores in these rocks is focused along grain boundaries. In response to the review by James Gilgannon, we uploaded a screenshot from Avizo that demonstrates similar distribution of pores in the micro-scale as well.

Following points are minor comments: Line 136: High resolution TEM images MB-comment: Actually, your TEM images are not High Resolution images. The defini- tion of high resolution TEM imaging means that you work with an Angstrom resolution in order make visible the atomic structure and that is not the case for your microstructures

Response: We will omit referring to the TEM images as high-resolution images.

line 200-201: To address this possibility more data for systematic analyses of pore orientations are needed MB-comment: Please compare your observations/data with published papers, which contain similar TEM porosity analysis in clay-rich rocks.

Response: Our TEM observations are comparable with previous porosity studies in clay-rich rocks from the San Andreas Fault core (Janssen et. al., 2011) and Nojima Fault (Surma et al., 2003) zone. Both studies document grain boundary pores, that appear with irregular and/or elongated shapes. We demonstrate such pores on Fig. 8a, b and c. In the San Andreas fault rocks pores identified as inter-clay and fracture porosity were also documented and interpreted as in-situ pores (i.e. not induced by coring or mechanical damage) whenever pores are associated with newly formed clay minerals. We show pores with similar shape characteristics and mineral associations on fig. 8b and d. However, those studies focus on pore morphology and do not discusses pore orientations.

line 229-231: Thus, the comparatively lower porosity estimates of the Alpine Fault core than other active faults (e.g. the Nojima Fault, Surma et al., 2003, and the San Andreas Fault, Blackburn et al., 2009) can be attributed to the fact that the Alpine Fault is late in its seismic cycle (Cochran et al., 2017). MB-comment: Do you refer to the latest seismic event in the year 1717 and the average seismic cycle of 291 23 years? please clarify this - because maybe the reader already forgot that you have mentioned this point at the begin of the paper.

Response: Yes, we did refer to the last seismic event in 1717, and this information was provided in lines 55, 56. However, we can repeat this here to make the manuscript easier to follow.

Figure 1 Line 403 (Figure 1): MB-comment: Please provide GPS data of the drilling site Figure 8 (a)

Response: GPS coordinates will be added to the caption of figure 1.

MB-comment: I presume the dark structures are the pores - please point directly with arrow-tip onto the structures. Otherwise it is a little bit confusing, especially for readers who are not familiar in reading TEM images

Response: Figures 8a and 8c are bright-field images, where porosity appears as bright contrast areas. Figures 8b and 8d are high- angle annular dark field images, where pores appear as dark contrasts areas. The arrows are positioned on the figure accordingly. However, we will add this additional information to the caption.

Figure 8 (c) MB-comment: where are the quartz/feldspar grains with the strain shadow? Is it the grain in the middle of the image? Than please shift the text "Ellipsoidal pores" to an area in the image where it does not cover an essential part of the image.

Response: We will modify the figure.

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