Interactive comment on "Relationship between microstructures and resistance in mafic assemblages that deform and transform" *by* Nicolas Mansard et al.

Nicolas Mansard et al.

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Author's response to comments from Reviewer 1 (J.L.)

General comments Rev.1: In this manuscript the authors describe shear deformation experiments performed on mafic rocks with four different compositions. The authors infer that if reaction and nucleation rates in the assemblages are fast, the experiments show no peak stress and deform at lower stresses than experiments where the nucleation rates are slower. A faster nucleation of reaction products is assumed to be caused by the presence of water inside the minerals of the starting material. When the reaction products form fine-grained interconnected layers the experiments show

a strain weakening. In contrast, when the reaction products are coarser grained and have a poor connectivity the experiments show a steady-state or a strain hardening. The experiments highlight the importance of reactions during deformation. The results indicate that the ability of minerals to react will determine where the strain is localized. With ongoing strain, the grain size and connectivity of the reaction products will determine if a large weakening occurs. The manuscript is well-written and of excellent scientific quality. The results, discussion and conclusion are presented in a clear, concise and structured way. The quality of the figures are high. I have some minor comments below, and I suggest the manuscript is accepted with minor revisions. I hope the comments are useful.

Authors: We would like to thank you for the suggestions to improve the manuscript and greatly appreciate the comments and suggestions of the manuscript.

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Rev.1: Line 175: Why did you do experiments on the Mg-rich assemblages with a long and a short run-in time? In the results you mention that the experiments with a longer run-in show systematic weakening after peak stress. I guess this is because the assemblages have a longer time to react? This is later not mentioned in the discussion.

Authors: These experiments have been carried out in order to be able to compare experiments reaching similar shear strain with different total durations. We document that the longer run-in periods cause reaction products to nucleate before deformation starts, whereas shorter run-in periods cause reaction products to form only during deformation. Thus, carrying out these experiments allows us to study the relationship between the amount of reaction products over time and the effect of deformation. This has been documented in our recently accepted article (Mansard et al., 2020), and we have added a sentence to explain the situation (lines 183-184).

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Rev.1: Line 489-490: did you compare the experiments of Fe-rich and Mg-rich assemblages at low shear strain to see if indeed the Fe-rich samples contain more reaction products at the beginning of the experiment? This would strengthen your argument that the lack of peak stress and initial lower stresses in the Fe-rich samples is due to the faster nucleation rate in these samples. Related to this comment: can the initial lower stresses in the Fe-rich assemblages not be due just to the higher water content inside the starting minerals compared to the dry minerals in the Mg-rich assemblages?

Authors: The reviewer is right, a comparison of samples at low strain would contribute to clarify whether reaction progress at the early stages affects the strength. We do not have samples with the same low shear strain, but some approximate comparison is possible. We have added a sentence explaining the difference in the text (lines 501-503). Considering that the rheological behavior is strongly controlled by the reaction products, the Fe-rich opx + plag assemblages initially deform at lower stresses than the Mg-rich opx + plag assemblages because in the Fe-rich assemblages reaction products nucleate faster than in the Mg-rich assemblages at early stages of the experiment. The explanation of a lower strength due to different H2O content does not work because deformation is not accommodated by crystal plasticity in these samples. We have added a sentence explaining this fact, too (lines 513-514).

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Rev.1: Line 216-217: you talk here about the amph rich shear bands in the Fe-rich opx + plag assemblage but then refer to figure 3c which is belonging to the amph + plag assemblage.

Authors: The reviewer is right. We have changed the sentence to refer to the right figure (lines 226-227).

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Rev.1: Line 478: how did you estimate the amphibole content in the samples? This is

not mentioned in the methods.

Authors: We have added a description of the method to the text (lines 161-168): In order to estimate the proportion of phases we used SEM/BSE images to produce manually digitized grain maps with the illustrator software, when it was possible to distinguish the grain boundaries (e.g. Fe-rich opx + plag assemblages). From these phase maps we could separate the phases with the ImageJ software and estimate their proportion. This is how the amount of amphibole in the Fe-rich opx + plag assemblages is estimated. When it was impossible to distinguish the grains individually, we drew areas that corresponded either to a set of grains of the same phase or to several phases that could not be separated. Some grains are too small to be separated with enough confidence from other grains. For this reason, we have included all reaction products together, and have not separated the amphibole from the plagioclase2 and the pyroxene2 in the Mg-rich opx + plag assemblages. Section 2.3 has been modified to clarify that the proportion of phases is estimated from the manually digitized grain maps by using the software ImageJ.

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Rev.1: Line 481: for completion it would be nice to have a number of the amphibole content in the Mg-opx + plag assemblage. In Fig 5b, d and f it seems to be quite an amount. Fig. 11: How did you measure the opx2+plag2+amph grain sizes in the Mg-rich opx + plag samples? Did you use EBSD maps as well for this, in the methods you mentioned you only use EBSD maps to determine the amph grain size. When I look at fig 10a it is not clear to me how you can determine the grain size from these BSE images. The same for the cpx in the amph + plag and pure amph samples.

Authors: The reviewer is right, it would be nice to have number of the amphibole content in the Mg-rich opx + plag assemblages. However, we cannot be more precise because these phases are difficult to threshold on a large scale (cf. previous comment). Although locally we are able to distinguish individual grains, this is still on a small scale

(Fig. 5b-d). This is why it may be noticed that throughout this manuscript, especially in Figure 11, we group the amphibole with pyroxene (opx2) when we are attempting to estimate proportions of reaction products in the Mg-rich opx + plag assemblages. Regarding the amphibole grain size, we can easily estimate it with our manually digitized grain maps in the Fe-rich opx + plag assemblages. On the other hand, as mentioned, we need to use EBSD maps to determine the amphibole grain size when it is not too small. To give an example, the grain sizes in Figure 13 are too small to be analyzed at EBSD. Only rigorous observation at the SEM and rigorous segmentation of the grains can then allow estimation of the grain size (e.g. Heilbronner and Barrett, 2005 – Image Analysis in Earth Sciences).