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Interactive comment on "Pseudotachylyte as field evidence for lower crustal earthquakes during the intracontinental Petermann Orogeny (Musgrave Block, Central Australia)" *by* Friedrich Hawemann et al.

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RC (referee comment): The petrographic observations of the host rocks are little and sometimes not clear but these have strong relation to the conclusion AC (author's changes to the manuscript): The petrographic descriptions of the host rock have been added and additional references provided, including a recent one by Wex et al (2017) from the same research group where the host rock conditions are considered in more detail..

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RC: Are there any remnants of previous, possibly ultra-mylonitic, deformations? AR: This was already addressed in the manuscript by clearly separating the pseudotachylytes into three categories with respect to ductile shearing– so yes, there are examples where the pseudotachylyte post-dates strong shearing. However, as visible in Fig. 3c, there are also examples of pseudotachylytes that can be found in undeformed host rocks.

RC: Are the pst concentrated in special layers of the protolithe, e-.g. involving more (OH) - bearing phases? AR: The OH-bearing minerals are mostly limited to late- to post Musgravian intrusions. There is no affinity of pseudotachylytes to these lithologies. AC: This has been added to the field observations.

RC: In the description of the dolerite, as a protolith, there is no given mineral assemblage (does it include grt or hbl as a (OH)-bearing phase?). AR: The assemblage of the dolerites is “dry”. AC: The description of the paragenesis has been added to the description of sample S5.

RC: Is there any thin-section or SEM image of the mylonites adjacent to the pst (e.g. a prolongation of Fig 4). AR: The sample of Fig. 4 is a pseudotachylyte breccia in an undeformed host rock. Examples for the ductile shearing can be found in Fig. A2 and Fig. 5a.

RC: Is the brittle deformation a direct consequence of the ductile deformation ?, e.g. same layers, or discordant after changing the stress system? AR: Pseudotachylytes emplaced in mylonites often show localization on foliation planes, as seen for example in Fig. 3b, new Fig. 5 and Fig. A2 and in the Fig 1 of the short comment. However, the opposite can also be found as late stage pseudotachylytes crosscut the mylonitic foliation and have a somewhat random orientation. AC: This was clarified in section 3.

RC: The reader is not informed if the minerals described are “magmatic”, i.e. crystallized directly from the melt or if these are formed (overprinted) by the crustal metamorphism. In the deep crustal environment this is not easy to distinguish but has a strong

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impact on the interpretation. We know from some places, that kyanite can crystallize from the melt and, as it is described, the garnet with cauliflower structures are a clear evidence for rapid cooling, i.e. crystallizing directly from the melt. AR: In the samples we used to derive the metamorphic conditions, the minerals are thought to form during dynamic recrystallization of the pseudotachylyte. In sample F44, for example, generation 1 remains unsheared and the minerals might well have crystallized directly from the melt or represent a static overgrowth of the former melt. However, the cauliflower garnet in Fig. 4 overgrows a planar foliation resulting from ductile shearing. We therefore argue that in this case the cauliflower garnet is not crystallized directly from the melt. The cauliflower garnets in the Fig. 5c however, can well be the result of direct crystallization from the melt, as they are hosted in an unsheared pseudotachylyte. AC: Fig. 4 was extended to clearly emphasize the difference between the pseudotachylyte generations. The text was modified to clearly state whether the minerals grew from the melt, statically or by dynamic recrystallization.

RC: And how can we know, that kyanite is formed in the sample, not sillmanite? They are probably too small to distinguish by the used methods, XRD is need to confirm this, not pseudosections. AR: Pseudosections had not been used to identify minerals in the thin sections. Kyanite was distinguished from sillimanite by using Raman spectroscopy and EBSD. AC: This information has been added to the text.

RC: A point of interest is also: which minerals from the protolithe are consumed and which are stable. I think biotite will directly melt, producing some (OH). AR: In the example of sample F68, biotite is slightly enriched in the pseudotachylyte. However, the amount of OH produced is small, as no new OH-bearing phases are found in the pseudotachylyte assemblage. Garnet is also readily molten, as it never appears as clasts in the pseudotachylytes. Quartz is commonly found as clasts, for example visible in Fig. 5a, where whole ribbons of quartz “survive” the melt formation. In the example of F6, most clasts are made up of plagioclase. AC: This information was integrated into the manuscript.

RC: The descriptions of some important figures like Fig 4 is too short-and do not describe the four generations of pst sufficiently. AC: The description of figures where enlarged, Fig. 4 was augmented with further backscatter images for all generations of pseudotachylytes.

RC: Some simple ideas have no base, if it is written, two generations of pst overprinted by ductile deformation are an indicator of cyclic brittle and ductile deformation. It is only an evidence for two phases of brittle deformation followed by ductile deformation. AC: A new Figure 6 was added, to demonstrate the switch from brittle to ductile deformation and back to brittle. It is true, that this only represents one cycle, from brittle to ductile and back to brittle, but the chances of preservation of multiple cycles are low. In the new version of the manuscript, we avoid the use of the word “cyclic” and restrict the use of the word to the discussion part.

RC: What is the PT-conditions of the ductile deformation-any evidence? Is it possible, that the ductile event is part of the retrograde exhumation? AR: The ductile deformation in the Davenport Shear Zone is described in detail Camacho et al. (1997), as stated in the text. As the mylonites host the sub-eclogitic assemblage, we can exclude a ductile retrograde overprint.

RC: Some parts are clearly described but not well thought: a pst in a gabbro is containing Kfs clasts - gabbros should not contain Kfs. AR: There are no clasts of Kfs, but Pl-clasts are overgrown by Kfs. AC: This error has been corrected in the text.

RC: I agree with the used method of pseudosections. However, is there any further indication for the deep crustal evolution, like high Al2O3 concentration in the newly formed pyroxenes, what is the composition of the melt-derived garnets-there are experimental data on the P-conditions of garnets formed from magmatic melts. AR: The pseudotachylyte-melt derived minerals are for sure interesting in many ways, but the study of those would be beyond the scope of this publication. As garnets crystallize from the pseudotachylyte melt, they probably record the temperature of the melt, which

is much higher than the ambient conditions. Al-rich pyroxenes have been described from pseudotachylytes in the Musgrave Ranges by Wenk and Weiss (1982), and the applied barometers return pressures of about 3 GPa, thought to represent dynamic pressures, rather than lithostatic. AC: The comment about the pyroxenes have been added to section 4.1.

RC: Therefore, please write if in the described examples recrystallization is crystallization from the melt (e.g. grt) or recrystallized under metamorphic conditions during later times from the fine-grained matrix? AC: This has been clarified in the text.

RC: You can calculate by your data also the geothermal gradient - it is only ca 20 °/km. AC: This information has been added to the results.

RC: However, I am wondering, that the classical paper of Handy & Bruhn (2004, EPSL,223), thinking about the cyclicity and "Stress– strain evolution for a volume of rock undergoing deformation to frictional sliding or creep at a constant slip or strain rate" is not cited. AC: The work of Handy and Brun is now cited.

RC: The interpretations in the manuscript are not satisfying, but maybe there is no simple answer. AR: The model of downward propagation of seismic stresses from the upper crust is favoured by many authors in recent publications, and is physically feasible but in our opinion there is no unequivocal geological evidence in previous publications that exclusively support this model. We therefore wanted to critically evaluate this model in the current study and to show the contradictions. This highlights rather than "solves" the problem and if anything provides an impetus for future studies.

RC: Is there any correlation with the drastic change in shear direction from sinsitral to dextral? AR: The change from sinistral to dextral sense of shear is more likely the result of slight variation in orientation of the shear zones, as described in the text, as this change is lateral in space and not temporal. In some cases, shear zones do show a change in sense of shear, but no consistent change can be documented.

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RC2_supplement: RC: Nice maps, but a map of the local geology, where the samples are taken from would be of interest, too. AR: The geological background is kept concise, therefore we did not include a geological map or profile. The geophysical maps provide a direct insight through the cover, and help to identify the main shear zones as well as the difference in metamorphic grade. AC: We modified the text to indicate better where a geological map and cross section can be found.

RC: I would add the beautiful BSE image A 1 from the Appendix with the flow folds, which is not described in the text, yet. AC:. We integrated the beautiful image A1 into figure 5 along with a better description.

RC2_supplement: Other comments, if not already addressed above, have been integrated in text and figures.

RC: why is it sheared? Give an evidence- AR: There is an internal foliation visible, which is defined by garnet and biotite. This is stated in the text.

RC: And the red box is to boarder of the red box are too thin-better to do this in white AC: The outline of the red box is now thicker.

All other comments from the supplement are discussed above. Figure captions have been enhanced to provide better insight.

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