Solid Earth Discuss.,
https://doi.org/10.5194/se-2017-123-RC1, 2017

Solid Earth
Discussions

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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Received and published: 21 November 2017

Review: Pseudotachylyte as field evidence for lower crustal earthquakes during the intracontinental Petermann Orogeny (Musgrave Block, Central Australia) By Friedrich Hawemann et al.

This paper for Solid Earth describes lower crustal, intra-continental pseudotachylytes developed at high-grade metamorphic conditions from the Musgrave Block in Australia. These rocks have been described and discussed in several previous papers (which are

adequately referred to in the manuscript). After reading this new manuscript I am still in doubt about why the pseudotachylytes (PST) are there, how they are related to the co-facial mylonitic shear zones and how they were formed. The main conclusion of the authors of this manuscript is that: "Repeated episodes of brittle failure and ductile creep represent recurring earthquake cycles and a strong variation of stress in a water deficient lower crust". You have not shown that they are cyclic, to me the changes from brittle to ductile and back again seem random (not cyclic). How these repeated 'strong variations' in stresses are formed, and the causal link between stress variations and the formation of shear zones vs. co-seismic faulting is not discussed or explained in detail in the manuscript. So, for new readers including me, their presence is still 'mysterious'. The authors reject both dehydration embrittlement, fluid infiltration weakening and 'shear-heating runaway' as weakening mechanisms to trigger co-seismic faulting. In the end, we have no real explanation for the observed phenomenon. Self-localised-thermal runaway (SLTR) following John et al (2009) is plainly rejected as a weakening mechanism in this manuscript because the authors have not found ductile precursors to any of the studied faults. I wonder if they have looked well enough? because there is no detailed description or illustration of fault veins in their figures included here. The deep crustal PST examples I have detailed knowledge from (in Corsica and Norway) we have spent a long time looking and dedicated sampled fault veins (not the nice big injection veins) to observe what happens with wall-rocks during co-seismic faults. Particularly the smallest fault veins (see Andersen et al 2008, Deseta et al. 2014) provide the best examples of ductile wall-rock damage zones. The evidence for crystal-plastic and ductile deformation is not easily found because the high heat tends to melt and destroy the evidence for the ductile wall-rock precursor as well as most of the inclusions of the wall rocks. Therefore, only a few examples provide macroscopic evidence for pre-fault (PST) ductile fabrics, one is from the Kråkeneset gabbro described in John et al. (2009) and I enclose a field photo of this for your inspection, where shear fabrics are preserved along a small fault next to a PST where they are mostly melted away on the same fault. Evidence from minor fault in thin section are more common.Therefore, if you still find no evidence of shearing after new inspection of wall-rock damage zones in you fault veins, you are at least be able to say with confidence that evidence of SLTR is not found after careful inspection! Otherwise, perhaps you should keep an open mind to SLTR as an option until you can document that there is no crystal plasticity or ductility anywhere in the wall-rock damage zones along your fault veins.

The message of this manuscript is therefore a mainly a further documentation of the high- grade PSTs. It presents a somewhat improved determination of the metamorphic conditions during their formation by characterising the quench-mineralogy by using pseudosections and the Matlab toolbox XMapTools to calculate bulk compositions from small regions within the PSTs from wavelength dispersive spectrometer (WDS) maps. This useful and may give better constraints than bulk-rock analyses, but are also hampered by the selective masking of some minerals and mineral inclusions from the calculations. In the PST in Holsnøy described by Austrheim and co-workers, mineral inclusions in for example garnet is very commonly associated with the shock-type deformation (partial pulverisation of wall-rocks) of minerals during the co-seismic faulting, and should therefore perhaps be included? On the other hand, there may be very local grain-scale disequilibrium due to the isolation of inclusions inside minerals from the matrix.

Figures! In this part of my review with general comments I suggest that you improve most of your figures or at least the explanation in the figure text. If you discuss more in text I want you to specify where this can be found in the main text. I also want to see micrograph of fault-veins and I want better (in fact much improved) text to most of the figures. In many cases texts are very short and do not explain well enough what we see particularly in the photo figures. There are also some errors for examples in Fig 8b where the pressure unit is written as GPa but probably given in numbers as kbar? A regional geological map (Fig. 2) should normally have a regional cross-section as well. In Fig. 3 you have some nice PST images, but again the explanations in the fig-text is very short and inadequate. I miss a much better explanation of what I see

in fig 3a and 3c, and a discussion/explanation of how rotation of clasts in 3a occurred, and if there is a PST fault vein along the contact with the amphibolite dolerite and the duplex-like structure in 3b. This can be done better! And I want image(s) fault-vein contacts with wall-rocks. In figure 4 there is an inset backscatter image of an obliquely foliated injection vein? Explain what we see and why is there a foliation there. Is this flow foliation or some post PST deformation phenomenon? See comments in the manuscript text on figure 5!

Concluding remarks: My conclusions are that I would like to see this research published but that you need to improve the text and the figures and perhaps add more illustrations of what you have observed from these impressive and enigmatic PSTs. You have demonstrated beyond doubt that the co-seismic faulting took place at depth in the lower crust! The runaway weakening mechanism is, however, still not explained but you can obviously provide more information and discuss this in more detail, and perhaps use some of the papers mentioned above that you have not referred to. (The Austrheim 2013 paper is missing from the ref list.)

Comments in the Manuscript pdf file: I have made a number of comments in the manuscript-pdf and to the figures (in red). I have also highlighted some of parts of the text and figures in yellow, mostly for my own reading, but some of the red comments are directly related to the yellow highlighted text, so take a good look at these parts and see if improvements are needed.

As a conclusion, I would like to see this manuscript published but only after some careful revision; where at least some of the points I have raised are improved. I therefore recommend a thorough revision before the paper is published.

Best regards, Torgeir B. Andersen

Please also note the supplement to this comment:
https://www.solid-earth-discuss.net/se-2017-123/se-2017-123-RC1-supplement.pdf

Interactive comment on Solid Earth Discuss., https://doi.org/10.5194/se-2017-123, 2017.