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Interactive Comment

Interactive comment on "Short wavelength undulatory extinction in quartz recording coseismic deformation in the middle crust – an experimental study" *by* C. A. Trepmann and B. Stöckhert

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Dear Authors, dear Editor, This manuscript reports the results of deformation experiments on natural vein quartz performed in a Griggs-type solid medium apparatus, and an accurate investigation of the resulting microstructures. The paper explores the preservation potential of microstructures formed during high-stress experiments ("kick" experiments), overprinted during subsequent creep experiments at lower stress. The experiments presented in this manuscript are complementary to those discussed in Trepmann et al. (2007, on quartz) and Druiventak et al. (2011, 2012, on olivine).

Overall, the main goal of this set of experiments is to document diagnostic deformation microstructures for non-steady state high T deformation in the context of the seismic cycle (i.e. coseismic deformation followed by post-seismic stress relaxation near the tip of a seismogenic fault). This is an important and innovative research line in the field of structural geology and rock deformation, pointing out the feedbacks between brittle and plastic deformation processes under P, T conditions typically considered representative of the broad field of ductile deformation. The most important novel contribution of the present manuscript is the possibility that short wavelength undulatory extinction (SWUE) represents a stable microstructure indicative of a stage of high-stress deformation experienced by quartz prior to a subsequent creep deformation stage. The Authors suggest that SWUE might be indicative of stress cycles related to large earthquakes. SWUE lamellae show many similarities to the enigmatic deformation lamellae, and these findings provide yet another interesting explanation for their origin. The results are presented in a clear and well-structured way, and support the main conclusions drawn by the Authors.

I refer to the Solid Earth manuscript evaluation criteria as follows: Scientific significance: 1 – excellent. Identification of the dominant deformation processes through experimental rock deformation and quantitative microstructural analysis is essential for our understanding of lithosphere rheology and strength. Scientific quality: 1 – excellent. The experimental strategy and analytical methods are sound and well presented. Presentation quality: 2 – good. The paper is well written, concise and easy to read. The figures are all necessary, but require some clarifications and improvements (see minor comments). Based on this evaluation and on my comments listed below, I recommend the manuscript for publication on Solid Earth after minor revision.

Major comments Crystal plastic deformation at high stress as an indicator of past seismic activity. The whole set of experiments performed by the Authors' group in the recent past is motivated by the idea of tracking the cyclic stress history at the schizosphere-plastosphere transition and below, which is associated with the occurrence of large earthquakes. This is an excellent and innovative idea, and the sound experimental and microstructural data produced by the Authors (as well as observations from naturally deformed rocks) are certainly interpretable in these terms. However, high stress deformation under high T conditions is not necessarily the result of seismic activity, and this is particularly true for quartz. An alternative interpretation, which is not in conflict with the Authors' believe, is based upon the effect of water on the creep strength of quartz, and I invite the Authors to consider mentioning it in the discussion. It has been known for decades that water has the potential to reduce creep strength dramatically, by enhancing crystal plasticity in nominally anhydrous minerals even if only present as a few parts per million (ppm) (Kronenberg Tullis 1984; Mackwell et al. 1998). On the contrary, extremely dry conditions result in very high creep strength of minerals. "Dry" quartz is well known for being extremely strong and for showing very high plastic yield strength in the lab, on the order of 2.0–3.0 GPa even at temperatures of 1000°C (e.g., Griggs and Blacic, 1965; Blacic and Christie, 1984; Kronenberg et al., 1986). Under these conditions, quartz shows high stress (or low T) deformation microstructures, as shown in Menegon et al. (2011). High stress can lead to local fracturing, fluid infiltration (if available), dynamic recrystallization/grain size reduction, and substantial weakening. In other words, there is the alternative possibility that the sequence of microstructures documented in the present manuscript as the result of "kickcreep" experiments could be indicative also of dehydration/hydration cycles experienced by quartz at lower crustal conditions, without necessarily invoking seismic activity. But as stated before, these two interpretations are not mutually exclusive (e.g. pseudotachylytes in dry lower crustal rocks: Austrheim and Boundy, 1994).

Deformation bands – recrystallization bands. The microstructure of deformation bands parallel to prism planes and to rhomboedral planes looks very similar in Figs. 6a, b, thus suggesting a similar origin. In particular, there is no evidence for progressive and systematic rotation of the crystal lattice when approaching the prism-parallel deformation band (Fig. 6d), so that the recrystallization mechanism in the deformation bands was probably not subgrain rotation recrystallization. This is also suggested by the mi-

SED
5, C185–C189, 2013
Interactive Comment

crostructure in Fig. 5b, showing large recrystallized grains with a rectangular shape locally "protruding" into the more highly strained quartz host grain. This could indicate grain boundary migration and growth from strain-free nuclei along fractures, driven by the reduction in strain- and surface energy, or alternatively precipitation/growth from aqueous fluids (e.g. Vernooij et al. 2006). Is there the possibility that also these deformation bands have exploited (micro)fractures formed during the kick experiments? Or perhaps healed microfractures (decorated by fluid inclusions trails?) originally present in the starting material?

Minor comments Page 282, line 5: A corresponding. . . Page 283, line 15: van Daalen et al., 1999 Page 289, line 10: A second set Page 289, line 23: refer only to Fig. 7a, as Fig. 7b shows pole figures and not microstructures Page 289, line 28: refer to Fig. 7c rather than 7b-d Page 290, line 15: Fig. 8f does not exist; the rose diagram is an insert in Fig. 8c Page 295, line 10: Preserved large original portions Page 306, Fig. 3: Please indicate also r and z in addition to the Miller indices in (a), as r and z are frequently used in the text and in the figure caption. The arrays of microcracks and lamellae parallel to z are not clearly evident in (a), I would recommend enlarging this picture. The misorientation profile in (d) is dominated by the noise; I would rather omit the profile and enlarge fig. 3a instead. The oscillating change in crystallographic orientation is nicely shown in the map in (b) and the profile does not add anything to that. Caption: There is no yellow rectangle in (a). Please indicate what the yellow rectangle in (c) is. Page 307, Figure 4: It is really hard to see on these photos the details pointed out by the arrows. It would be nice if the Authors could specify here (or even better in the text) the meaning of cellular structure. Page 308, Fig. 5: What is the yellow rectangle in (c)? I would show the traces of misorientation profiles in (c) rather than in (d), because the oscillating change in misorientation is evident in (b). Page 309, Fig. 6: in the caption of (b) replace red line with yellow line. Specify what the great circles in (c) indicate. Page 310, Fig. 10: What are the grey clusters of data points on the pole figures in (b) (particularly in the pole figure of r)? Is (c) colour-coded according to the Euler angles? Page 314, Fig. 11: in the caption of (b) the Authors probably intend to refer to Fig. 10 rather than to Fig. 8.

Plymouth, 23rd May 2013 Luca Menegon

Interactive comment on Solid Earth Discuss., 5, 281, 2013.

SED

5, C185–C189, 2013

Interactive Comment