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Interactive
Comment

Interactive comment on "Finite lattice distortion patterns in plastically deformed zircon grains" *by* E. Kovaleva et al.

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General Comments

This manuscript reports EBSD and CL data from zircon grains from rocks of the Western Tauern Window in the Eastern Alps and the Ivrea Zone in the Southern Alps, deformed at amphibolite facies and granulite facies conditions, respectively. The authors demonstrate that grains preserve cumulative misorientations of up to 40deg. The authors classify the microstructures into three types, depending on the low-angle boundary microstructure. They report crystallographic dispersions around <001> and <100>, interpreted to be a consequence of <100>{001}, <100>{010} and <001>{100} dislocation slip accommodated by tilt and twist boundaries. Finally, the authors discuss deformation coupling and viscosity ratios with adjacent phases, and the anisotropy of

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elastic properties of zircon.

The article is valuable in that it adds to the growing body of evidence that natural zircon can deform by crystal-plastic processes in a range of conditions and settings. Generally, the manuscript is well written, with well prepared figures, and the description of the methods and results are excellent. However, the introductory sections contain several misleading statements and/or inappropriate or incomplete references – these will need to be rectified – see technical corrections section. Other issues are contained within the discussion, and relate to reconciliation of the use of various rheological terms, assessment of the elastic anisotropy of zircon and its role in crystal-plasticity, and interpretations of the key controls on microstructural style (i.e., stress, strain, temperature and type I, II, III microstructures).

Specific Comments

P1835: Section 8.6 Crystal Anisotropy: This section could be useful, except for several key points: (1) P-wave velocity is not relevant for crystal-plastic behavior! The stiffness and compliance tensors are derived from the elastic moduli, and so the geometry of the P-wave anisotropy is dominated by Young's Modulus anisotropy, E. References to the P-wave anisotropy should be deleted from this manuscript. (2) The form of the Young's modulus and P-wave anisotropy is incorrect (see Timms et al. 2012, MAPS). This is quite a serious point because it means that the way that MTEX (the program from which the plots were automatically generated) has calculated the forth order tensors is incorrect. I might contact Dave Mainprice directly to see if he agrees and/or can fix any issues! Also the units are incorrect for Young's Modulus – they should be in GPa! I have double-checked this with my co-author David Healy. He has been very careful to benchmark his MATLAB code against materials for which elastic anisotropy is well known (e.g., copper), and so is confident that the plots on Fig. 14 are incorrect. The geometry of Young's modulus presented in Timms et al. 2012 MAPS is correct. This key point changes the whole nature of this section of the discussion. I suggest that you remove Fig 14, refer to Timms et al., 2012, and modify the text accordingly. (3) As

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well as young modulus, the shear modulus (G) and Poisson's ratio will also have key relationships with crystal-plasticity. The authors should show the anisotropy for these parameters for a thorough discussion. If this is not possible, then I suggest removing this section from the discussion completely.

Also, the authors need to reconcile usage of various rheological terminology and concepts. For example, their inference about elastic controls (Young's Modulus) on a crystal-plastic process (dislocation creep) while referring to viscosity ratios between zircon and the surrounding phases. So which is it - is the deformation viscous? Elastic? Elastic-plastic? And what actual evidence is available to support your chosen rheological model(s)?

Figures 2-7: Many of the intragrain boundaries and are either concentric (e.g., Figs 2-3) or define 'sectors' with grain boundary normal interfaces (e.g., Figs 4-6). How do you know that the intragrain boundaries are not growth-related rather than deformation-related (see Pearce et al., 2013, CMP for examples from carbonates).

P1861: Figure 15: Wouldn't temperature have a greater effect on the mobility of GNDs? If so, this diagram isn't strictly accurate. As a thought experiment, could you plot a similar diagram for strain and temperature?

Technical Corrections

P1801 Lines 11-12: These are completely inappropriate references to support the previous statement.

Lines 12-13: This statement is too general and doesn't hold much meaning. There are a wide variety of trace elements that can be incorporated into zircon, and their diffusion characteristics are highly variable (see extensive work by Cherniak and Watson). Also, you need to justify the use of 'Relatively' – relative to what?

Lines 23-25: This list should also contain Nemchin et al. 2009 Nature Geoscience; Timms et al. 2006 Geochem Trans.; Timms et al. 2012b J. Struct. Geol.; Erickson

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et al. 2013 Am. Min.; Erickson et al. 2013 GCA.; Schwartz et al. 2010 Chem Geol.; Grange et al. 2013 GCA; Kaczmarek et al., 2011 Lithos.

P1802 Lines 6-8: This statement is incorrect. The aforementioned articles provide a lot of in depth discussion on the mechanisms of fast-diffusion and which microstructures are important for resetting: particularly see Reddy et al. 2007; Timms et al., 2011; 2012b (JSG) and Grange et al., 2013.

Lines15-17: This statement is simply not true. Zircon grains from these studies span a wide variety of rock types, settings, and sizes (including 10-50 micron grains). Even a quick scan through the titles of the articles gives this impression. The opening statement to this section needs to be modified to reflect this fact.

Lines 19-23: Indeed, but there are a growing number of studies that detail deformed zircons in situ: see Kaczmarek et al., 2011; McDonald et al. 2013; Timms et al., 2011; and all of the lunar zircon studies. Please reconsider the wording of this sentence? Given this fact, the words ‘In contrast with previous studies,’ also need to be removed from line 28 of this page.

P1803 Line 7: ‘micron’ should be ‘micrometer’

P1804 Line 21: Intragranular brittle cracks most commonly have either no misorientation or <2 degrees of misorientation associated with them, simply because larger block rotations are difficult to accommodate without significant fragmentation. Therefore, intragrain crack-related high-angle boundaries are unlikely. Note: an exception to this seems to be grains deformed in impact environments (e.g., Vredefort – see Moser et al., 2011; Timms et al., 2012; Erickson et al., 2013a; 2013b), where dislocations arrest against (i.e., cannot glide across) planar factures and planar deformation features.

P1805 Lines 6-7: Difficult to see how one would test the ‘rheology’ of zircon from finite strain resolved by EBSD mapping! Rheology would necessarily require deformation experiments.

P1809 Line 3: ‘a few microns-thin K-feldspar veins’ should be ‘K-feldspar veins a few micrometers thick’.

Line 8: ‘wherefrom’ should be ‘and’.

P1814 Line 10: insert ‘minimum’ prior to ‘misorientation’ (see Wheeler et al., 2001, CMP).

P1822 Line 17: insert hyphen between ‘low’ and ‘angle’.

Line 17: spell out zircon instead of Zrn

P1829 Line 17: insert commas before and after ‘therefore’.

P1833: Section 8.4: This is a great finding, and a key point of the paper!

P1834: Section 8.5: Hydrolitic (and not ‘hydrolithic’, as the authors state on line 19) weakening significantly affects the behavior of quartz. However, there is no evidence to suggest that zircon is affected in similar ways!

P1835-1836: Section 8.6 Grain Shape: These findings ought to be discussed with respect to the findings of, for example, Kaczmarek et al., 2011 and Reddy et al., 2009.

P1838-1839: Section 9 Conclusions: Move point 1 to after current point 2. Also see my comments above for the use of viscous in point 6.

Regards, Nick Timms (Curtin University)

Interactive comment on Solid Earth Discuss., 6, 1799, 2014.