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

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General: The manuscript put forward by Kovaleva presents data on the deformation of zircon in shear zones from two different metamorphic terranes, namely an amphibolite facies and a granulite facies shearzone. The presented data adds to the growing data on zircon deformation. One of the most important outcomes of this work is to show that small zircon grains can be crystal plastically deformed, and that only a percentage of zircon grains exhibit crystal-plastic deformation with respect to the full population of zircons. Overall, the data presentation is well done. However, in places results and interpretation are mixed. The authors make a case that it is important to assess zircon deformation in the light of neighbourhood (i.e. what are the phases adjacent to the zircons). Also, some more information on this neighbourhood should be given

and tabulated, it is in places hard for the reader to follow. In the interpretation section, a lot of speculation is made, several sections can be cut out or must be significantly improved, the model as given in the current version is not convincing and needs to be reassessed and improved. In many places, referencing is very poor, it seems that most is based on one textbook (Rannalli, 1995), which is a very good book, but original references should be used.

Still, all in all, this work should be published after major revisions.

Below are comments, questions and suggestions given to help improve this manuscript.

General comments that need to be addressed: 1) Please provide a tabulated list of samples/grains and the metamorphic grade. It is difficult for the reader to follow your manuscript if you do not give this basic information.

2) Extra data: It would be very instructive to show statistically the neighbourhood versus deformation type – is the neighbourhood more important than the metamorphic grade? This is not clear. (incorporate into the tabulated list (comment1)

3) Neighbourhood: The use of “decoupling” of the zircon grain from surrounding grains – How do you know, normally one would expect, if there is decoupling – you mean brittle failure between the phases, then one would see for example qtz infill in these areas. This is not documented. The whole notion of “coupling” and “decoupling” is not clear. It needs to be clarified.

4) A graph showing the metamorphic grade versus type of structure would be also useful in the light of the comment 2

5) According to comments above: Provide table with shear zone no., metamorphic grade, grain size range of zircons, grain name, size, deformation type, neighbourhood.

6) I wonder if you can look for more trends, at the moment it is very hard to assess and at the end of the manuscript the reader is left without knowing if the deformation

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structures in zircon can be taken as a proxy for strain (can I look at the frequency of deformed grains and get a number for strain (i.e. do you know the finite strain from your different samples?)) or for metamorphic grade?.

7) In the light of comment No. 6: provide for each sample the complete statistical data: % of deformed grains (split into brittle versus crystal plastic, and crystal plastic into type I, II, III). Also a grain size distribution of the zircon grains should be provided. It would be probably the best to show for each sample one bigger figure, with this statistics and examples of the deformation types given.

8) For the figures: it is unclear if each one of these are in the same reference frame with regard to the macroscopic strain/ stress. Please clarify. Further, in the figure caption please identify for each presented grain which dislocation structure you are classifying it into. Having 5 subcategories for the type III structures does not really help as then you nearly give each grain its own category which is counter productive to the message of this manuscript.

9) BH12-02_45 does not show unsystematic scattering, there is still a crystallographic relationship between grains, they still cluster – no random orientation. So, still causal relationship – are these fragments that rotated just a little? Is this similar to Rimsa et al. 2010?

10) You refer to CPO development for a whole population of zircons, however the data is not shown, please provide, at present it cannot be assessed and should not be discussed.

11) Literature referencing has to be improved significantly. In the specific comments improvement is suggested, however the authors should do their own literature search especially in places where they at the moment cite Ranalli (1995)

12) Discussion needs to be improved according to specific comments.

Specific comments: 1) Last sentence of abstract: Is not at all justified as from data and

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discussion this conclusion cannot be made Section 1.3 l.23: Reddy et al. 2007 were not the first ones to describe dislocation walls, go into the material science literature e.g. Sellars 1978; Urai et al.1986; McQueen & Evangelista 1988; Humphreys & Hatherly 2004

2) Section 1.4.: Subgrain versus grain boundary: The change from one to the other is a significant energy and behaviour change, TEM studies are needed to see this change in structure, for different mineral it is different, e.g. qtz 10 degrees (studies by White, 1980). Go to original literature. You do not need a whole new section for this, can be incorporated into EBSD method description.

3) Throughout text: e.g. sect.1.5. "metamorphic recrystallization" – what is that? Be specific

4) Restructure section 2: Geological background and sample localities combine for each area the overall geological background and the sample localities into one joint section. In the heading of the section the metamorphic grade should be given. Identify what you later use as shear zone I, II , III

5) Section 3.1: l.2 – The mafic dyke .. wording: 'extremely" – use strongly,"highly foliated" use "strongly". Please be specific and tell the reader where exactly the samples are from. You have several samples I think please specify

6) Section 4.1 line 15 ff – is there a size relationship between brittle and crystal plastic de formation, give statistics. Fig. 8 does not show what promised here in text.

7) Spelling: sect. 4.3, line 26: "brittlely" (is that really a word – rephrase)

8) Section 5.3 line 21: Reddy did not invent orientation contrast imaging, cite Trimby, P.W. and Prior, D.J. (1999) Microstructural imaging techniques: a comparison of optical and scanning electron microscopy in the study of deformed rocks. Tectonophysics, 303, 71–81. & Prior et al. 1999

9) EBSD section: you go overboard here, not that much detail on the technique is

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needed (bands etc.) there is a lot of EBSD data on zircon, so we do not need that much technical detail. However, some crucial pieces of information are not given: What is the raw indexing percentage, how many zero solutions did you get? What filtering, noise reduction did you use? In the figures, zircon is always 100% indexed, I do not believe that this is the raw data.

10) Section 6: The structure of the section needs to be changed – introduce the different microstructural types and then show examples for each type. The problem currently is that it nearly seems random which grains you show or not show, but there must have been a selection process for showing these specific grains. At the moment it seems like a "data dump", structure it for the reader, it is difficult to follow in the present format. Regarding data representation for the pole figures – do you always show the data for the whole grain or selected areas, this is not clear.

11) Section 7.2.2. this needs discussion with respect to the "indentor" interpretation of Piazolo et al. 2012, as you interpret these differently . . .

12) Section 7.2.3: This section can be shortened significantly. I do not think it is necessary to give 5 extra groupings. Keep to type III and show the variability, they all have subgrains – now importantly, give the statistics of the subgrain size, subgrain size has been suggested as a good indicator for differential stress (e.g. for salt) – so is important to report. The whole decoupling interpretation is not convincing as you do not show how you decide when a grain is decoupled or not. Unclear, needs significant rewriting and clarification, and shortening.

13) Last section of section 7.2.3. Delete – you do not show the CPO data, so do not discuss, alternatively add CPO data

14) Section 7 belongs into the Discussion if you keep it as it is written now. In this section, you put a lot of interpretation. Best would be to keep this section in the results, but shorten significantly describing the data alone. This would shorten this section significantly. Then restructure discussion accordingly.

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15) Section 8: A lot of general knowledge is given here and not even related to the data presented. E.g. section 8.1., not once you related it to your data. Can you show that a specific microstructure is only seen at a specific temperature, if yes, then this section needs to state it. Shorten and combine with stress, strain rate, to a new section: Influence of deformation conditions on zircon deformation: Be sure that you refer to your data (having a table and more stats will be essential for this). Major rewriting is needed.

16) Delete section 8.5 and 8.6. – 8.5 you have no quantitative data to discuss this (you can add a sentence in the new suggested section (see comment No. 16), 8.6 is not robust enough, delete, no need for this manuscript.

17) Section 8.7. No you have not shown any decoupling features at present. If you want to keep this interpretation, you need to move a lot from section 7, into this and argue better, not convincing at the moment. Maybe a schematic diagram can help? Actually this is mostly about the host environment, combine with Section 8.4. shorten, very repetitive.

18) Section 8.4. Can be kept, but combined with section 8.7 and section 8.8. note that much of the differential stress is also part of your host environment, please combine. At the moment you have a lot of repetition.

19) Zircon deformation model There are several misconceptions that hamper the validity of the proposed model. The strain does not truly decrease from type I to type III. In type III you have a more recovered microstructure, but if you look at the energy including subgrain boundary energy, the strain energy is actually quite similar in these grains. It would be interesting to check what the internal misorientation range of each distortion type would be – can you see a clear trend (again the data is not there . . .). Many statements are very general and not connected to the data that you have e.g. lines 24 ff, Referencing is missing significantly, all the relationships you write about have been recognize before e.g. Urai et al. 1990 (rotational recrystallization), a lot has been done

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on this over the last 20 years on qtz (many experiments) Please check literature. You finished the section by saying that temperature and differential stress matter, however your diagram is stress versus strain – not consistent. This section needs a major re-think and rewrite. If it is temperature that matters, then the granulite facies shearzone should have significantly different distortion patterns – however, as far as I can gather, this is not the case (or only to a limited extend).

20) Conclusions need to be reassessed after changes made, new statistics given.

Best regards, Sandra Piazolo

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