

Response to referee #2 David Prior:

This remains an excellent contribution. I'm pleased to see that a lot of comments from all reviewers (official and not) have been taken on board and the paper is much improved because of this. There are a lot of minor errors in the English in the revised version and a few places where the text needs greater clarity. The conclusions are disappointing as they fail to summarise some of the key observations related the CPO with increasing strain ($M1, M2$, $\langle a \rangle$ and $\langle m \rangle$).

We thank the referee for the in-depth review initially provided that helped a lot the quality of the manuscript.

We added some details and a bullet point in the conclusions to underline better the key observations related to the evolution of the CPO with strain.

Some comments on responses to reviewers:

Scientific Discussion 2: The new supplementary material is all very useful. Could you add bigger and better resolution photo and drawing of the apparatus. The words on this slide can take up less space.

We reorganized the supplementary material to address this comment.

11. What you say here is not correct. It's possible to have a sublimation condition in a cold room where air and sample are at the same temperature and the partial pressure of water in the air can be below the pressure that is in equilibrium with the ice. This is pretty much impossible if the ice is cold (even if only -20C) and the room at ~-20C, even if the room is de-humidified or (as in our case) has a constant flow of nitrogen. You might not see the frost and it only needs a few tens of nm to be a problem. I'm sure that your frost goes when you pump down the chamber. So rather than arguing about this just include what temperature the sample is at when it is put into the SEM. This means others can reproduce (sort of) what you have done. If the sample is warmer than ~-80 it is highly likely to sublime during the pump down to high vacuum (pressure cycling).

We changed the phrasing in the corresponding section of the manuscript to just specify the loading temperature at -60°C.

Comments/ corrections for the manuscript: in page/ line number order.

Page 1. Line 1-2. "... reproduce simple shear conditions close to those encountered in ice streams and ..". This phrasing is misleading as it can imply all conditions (T, strain rate etc). I would rephrase with something that relates specifically to the kinematics "to reproduce the simple shear kinematics that are believed to dominate in ice streams and .."

Done.

Page 1. Line 6. “in natural setups” is not great English. How about “in naturally deformed ice”
Done.

Page 1. Line 7. Electron BackScattering Diffraction is not a common full version for EBSD. Most literature and books use Electron Backscatter Diffraction.
Done.

Page 1. Line 9. Add the word “an” to make “...form under torsion of an initially ...”
Done.

Page 2. Line 11. references should be plural.
Done.

Page 2. Line 34. As you are referring to the pioneering studies that show this for the first time you should include Kamb 1972 in this list. This is the first substantial and easily available piece of work.
Done.

Page 3 Line 21-24. Not quite as simple as this. The double maximum is there in the Llorens et al models (see discussion in Qi et al 2019). None of the models really produce the interlocking grains (including the Etchecopar model: it can't really). The later discussion on models now has a much better and more scientific tone than the original. This section effectively picks out one model to point out some problems that are common to many models. That's not very helpful. Reducing this paragraph to say simply that we need good constraints to test models, without pointing out specific problems is better. Not that interlocking grains is a high temperature/ low strain rate thing. You don't get that at lower T or fast rates (e.g. the -20,-30 experiments in Qi et al).

We rephrase this part of the manuscript to address this comment.

Page 4. Line 23. Replace “Supplementary” with “Supplementary material”.
Done.

Page 4. Line 20. Add Li et al 2000 to the Swift 1947 citation. Li et al relates directly to ice.
Done.

Page 5 Line 18. PETERNELL in caps?
Fixed.

Page 5 Line 19. “were operated” is not good English as the object of the sentence is the measurments not the machine. “All optical CPO measurements were conducted at -7...” is better.
Done.

Page 5 Line 27. Replace “Supplementary” with “Supplementary material”.
Done.

Page 5 around Line 30. Please add what temperature (or range of temperatures) the ice is when it is put in the SEM. See my comment to your response about sublimation later.

Done.

Page 6 Line 3. Just say at approximately -60C. It is more complicated than your statement makes out as the pressure of interest is the partial pressure of H₂O in the SEM chamber rather than the vacuum pressure, which is the addition of the partial pressures of the gasses involved (nitrogen and water).

Done.

Page 7 Line 23. Replace “..less than 25 per radii.” With “..fewer than 25 grains per radii.”

Done.

Page 10 Line 22. Replace “The CPO seems not modified..” with “The CPO does not seem to be modified..”

Done.

Page 10 Line 30. “Its almost disappearance” is poor English. How about : “The nearly complete disappearance of M2 correlates...”

Done.

Caption to fig 3 (and elsewhere). I presume the J index here relates just the c-axes; what Dave Mainprice’s old software called pfJ (pole figure J). As such it is not identical to most peoples understanding of the J index (for full crystallographic orientations). It would be good to make this clear.

We added details at several place in the manuscript to make clear that we are referring to the c-axis J index.

Page 11 Line 5. “allows to perform” is poor English. This sentence could be: “The access to the full crystallographic orientations enables more complete grain segmentation based on misorientation data.”

Done.

Page 11 Line 10. J index- see above (caption to fig 3).

Done.

Fig 4b. <a> and <m> axes. Why not use the colour scale for <a> and <m> as applied for The gamma 1.96 sample for all of the samples. Then one can see how these evolve? The current formatting of this figure is very confusing for the reader.

Done.

Fig 4b. Rotated view of gamma 1.96 sample. The rotation is not correct. In the left hand reference frame x is between the two <c> sub-maxima of the elongated overall maximum. In the right hand reference frame x lies on one of the sub-maxima. The y axis is differently aligned

relative to the $\langle a \rangle$ and $\langle m \rangle$ sub maxima in the right and left hand reference frames. It looks like the data on the right hand side needs rotating about 20 degrees around x followed by ~ 20 degrees around y?

We thank the reviewer to have spotted this, this was a mistake where some rotation on the X axis was applied. The new version has only 90° rotation on the Y axis.

Page 13 Line 7. “allows to” is poor English. How about “WBV analysis allows calculation of GNDs and definition of the relative...”

Done.

Page 14 Line 14. “almost no-sub-grain boundaries”. This wording does not reflect the truth- it’s rather misleading. This is what I see. “Both the undeformed sample and the annealed sample have much lower low angle boundary densities than the other samples. The undeformed sample map shows low angle boundaries very close to high angle boundaries and as unconnected pixels and small segments within grains. These are best explained as low angle misindexing errors. Most grains in the annealed sample contain no low angle boundaries. There are ~ 4 grains that contain low angle boundaries that are similar to the more extensive low angle boundaries observed in the deformed but not annealed samples.”

We rephrase this part of the manuscript including the wording of the referee. We thank him for the helpful comment.

Page 14 Line 15. The sentence that starts on this line is really difficult to understand. I think if you remove “with a significant $||WBV||$ ” from line 15 it is much clearer.

We rephrase this part of the manuscript to address this comment.

Page 14 Line 18. Replace “lower statistics” with “smaller sample size”.

Done.

Page 14 Line 24. Replace “poor statistics” with “the small sample size”.

Done.

Page 15 Line 2-4. This says nothing. Just remove these three lines.

Done.

Page 15 Line 8. Replace “apparition” (means a ghost or a miracle!) with “appearance”.

Done.

Page 17 Line 7. Replace “apparition” with “appearance”.

Done.

Page 17 Line 15. “suggest” should be “suggests”

Done.

Page 17 Line 17. I'm not sure there is any evidence that bulging gives closer orientations to parents. If the "break off" mechanisms is subgrain rotation then the two mechanisms will give the same relationship.

As it is stated in the manuscript, this is just an hypothesis we are making in our interpretation of the results. We are conscious that this not a solved issue, and we feel that this is clear for the reader in the current version of the manuscript.

Page 17 Line 35. Replace "amount" with "number".

Done.

Page 18 Line 6. The Urai et al reference is wrong here and in the list. Probably the reference in citation software is wrong. Full reference should be:

Urai, J. L., Means, W. D., and Lister, G. S., 1986, Dynamic recrystallization of Minerals, in Hobbs, B. E., and Heard, H. C., eds., Mineral and Rock Deformation (Laboratory Studies), Volume 36, p. 161-200.

Another key ref here that I had forgotton about is:

Stipp, M., and Kunze, K., 2008, Dynamic recrystallization near the brittle-plastic transition in naturally and experimentally deformed quartz aggregates: Tectonophysics, v. 448, no. 1-4, p. 77-97.

Done.

Page 18 Line 15 to Page 19 line 10. You have reverted to using the term texture rather than CPO here. Probably elsewhere in the manuscript as well. Do a search to ensure terminology is the same in the bulk of the paper.

We corrected this in the new version of the manuscript.

Page 18 Line 17. Etchecopar does not use the term polygonazation and does not allude to this process. He talks about grains breaking. You should make it clear that thinking of this as polygonization is a reasonable extension of the Etchecopar idea. You could extend the phrase in brackets to "(Etchecopar defines this as grain breaking but grain polygonization would have the same kinematic effect)".

Done.

Page 19 Line 18. Replace "M2 CPO" with "M2 maximum".

Done.