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Interactive comment on "The microstructural record of porphyroclasts and matrix of serpentinite mylonites – from brittle and crystal-plastic deformation to dissolution-precipitation creep" *by* J. Bial and C. A. Trepmann

Anonymous Referee #2

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This manuscript "The microstructural record of porphyroclasts and matrix of serpentinite mylonites – from brittle and crystal-plastic deformation to dissolution-precipitation creep" by J. Bial and C. A. Trepmann show microstructural observations and textural analysis with EBSD on serpentinite mylonites fron the Voltri Massif (Italy). While the title and the abstract of this manuscript explain clearly the aim of this study, the microstructures of the samples and the interpretation in terms of deformation mechanisms are not sufficiently described and documented through the paper. The conclusions on the successive deformation regimes through geological history are mostly based on general statements. The authors should describe more precisely and clearly their results and analysis using existing literature to support their conclusions. I address some points in some parts of the manuscript and recommend a major revision of the paper.

General comment The aim of this study - clearly enunciated in the title and in the abstract - is to show the difference in the microstructural records in serpentinite mylonite samples from the Voltri Massif (Italy) and relate them to independent successive episodes of deformation during geodynamical history. I was then expecting a detailed description of the microstructures linked to appropriate literature. Because of this too short microstructural description and lack of references to previous studies, the conclusions are not always supported by the results. The transition between deformation regimes suggested in the title of the article is not clearly demonstrated. In the case of antigorite microstructures the presented data do not support the conclusion largely based on general assumptions that are not documented in the text.

Introduction:The introduction describes very shortly the context of the study and the Erro-Tobbio Unit. The title and the abstract of the paper suggest that microstructures and EBSD textures were used to determine the processes (mechanisms and deformation regimes) that have taken place during the successive episodes of deformation as well as the associated stress-states (from rheological laws). However, no reference of previous works on the use of deformation microstructure as P, T and stress gauge for olivine, pyroxenes and serpentines are reported. I was expecting a large part of the introduction on these aspects.

4. Sample description and microfabrics This part describes the microstructures in olivine and diopside porphyroclats and in antigorite. In the discussion these microstructures are used to infer the geological history. Then I expect a clear and more detailed description of microstructures in the samples.

From page 369 line 24 to page 370 line 22: This part consist of a description of olivine porphyroclast in terms of microstructures and chemical composition. This paragraph refers to five figures composed of more than 15 images and pole figures. As a reader I would have appreciate some help inserted directly on the images to show what you want me to see.

Page 370 line 20 : Whereas the SPO is associated with a crystallographic preferred orientation (CPO) for antigorite with the (001) basal plane in the foliation plane, olivine grains show no marked CPO (Fig. 6c, e). There is no measurement of CPO in antigorite in the sample so the authors suppose (which is reasonable) that basal planes are in the foliation plane?

From Page 370 line 23 to page 371 line 3: It is not clear for me on the images and pole figure whether diopside deformed in the plastic regime by kinking and (100) mechanical twining, which is dominant in this temperature range, or by dislocation glide, which is dominant above 800 °C or in some sample deformed at low stress below 800°C (e.g. Raleigh & Talbot, 1967; Ave Lallemant, 1978; Kolle & Blacic 1982; Kirby & Kronenberg, 1984; Ingrin et al.,1992)?

Page 371 Line 12: The pronounced SPO of antigorite corresponds to a CPO with the (001) basal plane in the foliation plane (Fig. 8). How the authors can be sure that the SPO of antigorite corresponds to a CPO with basal plane in the foliation plane?

5. Discussion 5.1 Deformation of olivine and diopside porphyroclasts

Page 371 line 17: The deformed diopside porphyroclasts (Fig. 7) record brittle and crystal-plastic deformation by dislocation glide. The bent (100) plane, the common rotation axis and kink band axis parallel to [010] indicate that the glide system (100)[001] was active. Could the authors explain if this glide system is common in diopside? Is the activation of the dominant (100)[001] glide system permits to precise the P-T conditions or the stress-state during deformation? Is this result different from previous microstructural observations in clinopyroxenes porphyroclasts? I expect a comparison with previous studies on both experimental and petrological aspects.

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Page 371 line 25: Both observations suggest subgrain rotation recrystallisation in the regime of dislocation creep, where the new grains inherit a crystallographic orientation similar to that of the replaced original grain. Dynamic recrystallization has taken place during deformation by dislocation glide. If so, maybe the extrapolation of the rheological law determined in the dislocation creep regime (Chopra & Paterson, 1981) to infer the stress-state needs to be done with some precautions?

Page 372 line 18: A temperature above 600°C is also in accord with the general assumption that dynamic recrystallisation of olivine in the regime of dislocation creep at reasonable strain rates of 10-13 – 10-15s-1 requires temperatures considerably higher than 600°C as based on observations from natural systems (e.g. Skrotzki et al., 1990; Altenberger, 1995; Jin et al., 1998) and the extrapolation from experimentally derived flow laws (Fig. 9, Chopra and Paterson, 1981; Hirth and Kohlstedt, 2003). I am not sure to understand this part. The extrapolation of the rheological law by Chopra and Paterson (1981) is used: i) to conclude that the temperature was higher than 600°C or ii) to conclude that the stress was below 250 MPa ?

Page 372 line 24: The recrystallisation grain size paleopiezometers of Van der Wal et al. (1993) for the observed recrystallised grain sizes of 10–50 μm would indicate differential stresses on the order 70–250 MPa. Assuming that an extrapolation of the experimentally derived flow law to relevant strain rates of 10-13 – 10-15s-1 is valid and that the grain size paleopiezometer is applicable, temperature conditions of 650–800°C are thus indicated for dynamic recrystallisation. Other experimental piezometers at different temperatures and for different water contents have been proposed for olivine since Van der Wall study (e.g. Zhang et al, 2000; Jung & Karato, 2001; Jung et al., 2006), can we expect a large variation in stresses with the use of other paleopiezometers?

5.2 Deformation of serpentinite

P 374 line 3: In monomineralic antigorite aggregates, a characteristic grain size variation with fine-grained antigorite at sites of stress concentrations showing a marked

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CPO around porphyroclasts and sutured grain boundaries (Fig. 8c, d) point to deformation by dislocation creep. The conclusion of antigorite deformation by dislocation creep is not supported by the presented data. In serpentine minerals a marked CPO (not presented for monomineralic antigorite in this study) do not mean that deformation was controlled by dislocation glide. This is a highly debated subject (Hilairet et al., 2007; Chernak & Hirth, 2010; Auzende et al., 2011). At a high stress-state (laboratory strain-rates), the fine-grained regions formed by grain size reduction in antigorite result mainly by activation of glide along basal planes and kink-band formation. But at tectonic strain-rates, dissolution-precipitation could play a major role (e.g. Andreani et al., 2005; Wassmann et al., 2011). I expect a more substantiated interpretation of microstructures in antigorite with detailed references.

6 Implications

Page 375 Line 13: The observed secondary olivine and enstatite crystals occurring in strain shadows of diopside and olivine porphyroclasts (Fig. 6) as well as olivine in foliated antigorite aggregates (Fig. 8a, b) are assumed to have formed by these reactions and during deformation by dissolution-precipitation creep during alpine subduction and exhumation. How the authors relate enstatite and olivine in the samples with the dehydration reactions of antigorite?

Some references on the deformation microstructures in olivine, pyroxenes and serpentines Andréani, M., Boullier, A.-M. a.-M., Gratier, J.-P., & Andreani, M. (2005). Development of schistosity by dissolution–crystallization in a Californian serpentinite gouge. Journal of Structural Geology, 27(12), 2256–2267. Auzende et al., 2011, Microstructures of antigorite serpentinites deformed at high pressure and high temperature American Geophysical Union, Fall Meeting 2011, abstract #MR11B-2163 Avé Lallemant, H. (1978). Experimental deformation of diopside and websterite. Tectonophysics, 48, 1–27. Chernak, L. J., & Hirth, G. (2010). Deformation of antigorite serpentinite at high temperature and pressure. Earth And Planetary Science Letters, 296(1-2), 23–33. Ingrin, J., Doukhan, N., & Doukhan, J. (1992). Dislocation glide systems in diopside single crystals deformed at 800-900°C. European Journal of Mineralogy, 4, 1291–1302. Jung, H. & Karato, S., 2001. Water-induced fabric transitions in olivine,Science, 293 (5534), 1460–1463. Jung, H., Katayama, I., Jiang, Z., Hiraga, I., & Karato, S. (2006). Effect of water and stress on the lattice-preferred orientation of olivine. Tectonophysics, 421(1-2), 1–22. Kirby, S. H. H., & Christie, J. M. (1977). Mechanical twinning in diopside Ca(Mg, Fe)Si2O6: structural mechanism and associated crystal defects. Physics and Chemistry of Minerals, 1, 137–163. Kollé, J. J., & Blacic, J. D. (1982). Deformation of Single-Crystal Clinopyroxenes: 1- Mechanical Twinning in Diopside and Hedenbergite. Journal Of Geophysical Research, 87, 4019–4034. Raleigh, C. B., & Talbot, J. L. (1967). Mechanical twinning in naturally and experimentally deformed diopside. American Journal of Science, 265, 151–165. Zhang, S., Karato, S.-I., FitzGerald, J., U.Faul, & Zhou, Y., 2000. Simple shear deformation of olivine aggregates, tectonophysics ,316, 133–152.

Interactive comment on Solid Earth Discuss., 5, 365, 2013.