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Interactive comment on "Constraints on the rheology of lower crust in a strike-slip plate boundary: Evidence from the San Quintin xenoliths, Baja California, Mexico" *by* Thomas van der Werf et al.

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This paper uses uppermost lower crustal and upper mantle xenoliths from the San Quintin volcanic field in Baja California to provide constraints in the rheology of a strike-slip plate boundary. Mineral chemistry, geothermometry, and phase equilibria were used to estimate granulite equilibration conditions of T = 750–890 °C and P = 400–580 MPa, and a geotherm of 40 °C/km for the upper 20 km of the crust. Near isothermal

conditions in the deeper lower crust (20–30 km) are inferred from the similarity of the equilibration temperatures between the lower crustal and upper mantle xenoliths.

Microstructural evidence is used to infer that the granulite and peridotite samples deformed primarily by processes transitional between grain-size sensitive and grain-size insensitive creep, with convincing microstructural evidence for grain-boundary sliding. Recrystallized grain size paleopiezometry in the granulite and peridotite rocks yields similar differential stresses in both the uppermost lower crust and upper mantle (12–33 MPa versus 17 MPa, respectively). Dry-plagioclase and dry-olivine flow laws were used to estimate the viscosity of the lower crust and upper mantle (∼ 10ˆ18 Pa s versus ∼10ˆ20 Pa s). Given the inferred isothermal conditions in the lower crust, it is suggested that a zone of lower-crustal flow facilitates transfer of displacement from the mantle to the upper crust.

Using these constraints on the viscosity structure of the lithosphere with results from post-seismic relaxation studies from western US, it is suggested that the lower crust is stronger during transient deformation (immediate post-seismic relaxation period) while the upper mantle is stronger during long term deformation (e.g., interseismic period).

This paper is well written and illustrated, and the discussion, interpretations, and conclusions are all consistent with the data presented. The paper does a very good job with the literature, though I have a couple of suggested readings below. If I wanted to quibble I might ask a few questions such as: (1) how might the paleopiezometry estimates have been affected by grain growth at relatively high temperature (the abundance of triple-junctions speaks to at least some grain-boundary area-driven coarsening)?; (2) how well do existing flow laws really reflect the deformation mechanisms dominating polymineralic rocks deformed in Earth time frames?; (3) (4) what are the errors on the quantitative estimates presented in this paper? Errors on temperature estimates feed back exponentially on rheology and viscosity estimates. If the authors wanted to briefly address any of these question, it might be helpful to the reader, but it is not essential. Detailed treatment of any one of these questions would add a lot of writing to what is already a fairly long paper (but I like fairly long papers because they give a more complete story).

I think Fig. S6 might be good in the published paper if there is room. The near-random, random-pair orientation distributions are important 1st-order evidence for processes other than dislocation creep (in particular grain boundary sliding), despite the evidence in the finer-grained fraction for subgrain rotation recrystallization. In addition, the M-Index would be a superb way to quantify the fabric strength in this particular instance as it would really go well with the random-pair misorientation data.

Question – the paleopiezometers give differential stress. How did you go from differential stress to shear stress in Section 5.3 and Fig. 11? Maybe I misunderstand?

Here are a few papers that the authors may or may not find useful in support of your work:

Rolandone, F., Bürgmann, R. and Nadeau, R.M. (2004). The evolution of the seismic-aseismic transition during the earthquake cycle: Constraints from the time-dependent depth distribution of aftershocks. Geophysical Research Letters 31: doi: 10.1029/2004GL021379. issn: 0094-8276.

Moore et al., (2017). Imaging the distribution of transient viscosity after the 2016 Mw 7.1 Kumamoto earthquake. Science 356, 163–167.

Tate, M.C. and Johnson, S.E., 2000. Subvolcanic and deep-crustal tonalite genesis beneath the Méxican Peninsular Ranges. Journal of Geology, 108, 721-728.

Johnson, S.E., Tate, M.C. and Fanning, C.M., 1999. New geological and SHRIMP U-Pb zircon data in the Peninsular Ranges batholith, Baja California, México: Evidence for a suture? Geology, 27, 743-746.

Tate, M.C., Norman, M.D., Johnson, S.E., Anderson, J.L. and Fanning, C.M., 1999. Generation of tonalite and trondhjemite by subvolcanic fractionation and partial melting in the Zarza Intrusive Complex, western Peninsular Ranges batholith, northwestern

México. Journal of Petrology, 40, 983-1010.

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