

Reviewer #2 (Rachel E. Bernard)

Major and specific comments

Section 5.2: I would have liked to see more of a discussion of the difference in temperatures calculated using the two geothermometers. Is there a geological explanation for this? Should we believe one method over another?

In the manuscript, we used two geothermometric methods: the Opx-Cpx equilibrium thermometer of Brey and Köhler (1990) and the empirical Opx thermometer of Witt-Eickschen and Seck (1991). The decoupling between the different geothermometric results is often observed in mantle rocks that record various degrees of disequilibrium. This disequilibrium is typically kinetic due to different diffusion of Ca and Al in pyroxenes.

In the Oran mantle xenoliths, clinopyroxene and orthopyroxene major element compositions provide a relatively wide range of temperatures along with decoupling between the results of different thermometers. This is observed less frequently in xenoliths than in massif peridotites. We consider that the decoupling is due to the melt-rock reaction, which resulted in disequilibrium of pyroxenes in some xenoliths. Although the disequilibrium involves uncertainties in the calculated temperatures in these samples, this is the only way to estimate the potential range of temperature in the rocks. Therefore, we think that the detected differences do not reflect the reliability of one thermometer over the other but, rather, highlight that the chemical equilibrium has been perturbed during the melt-rock reaction. We added a brief explanation to the Geothermometry chapter but a more detailed discussion is beyond the scope of the manuscript: “... *We observe a weak match of the two geothermometric methods only in a few coarse-grained rocks, typically in the range of ca. 920-1050 °C, which potentially reflects chemical disequilibrium between the pyroxenes...*”

References cited in the answer:

Brey, G. P., and Köhler, T.: Geothermobarometry in four-phase lherzolites. II. New thermobarometers, and practical assessment of existing thermobarometers, *Journal of Petrology*, 31, 1353-1378, 1990.

Witt-Eickschen, G., and Seck, H. A.: Solubility of Ca and Al in orthopyroxene from spinel peridotite - an improved version of an empirical geothermometer, *Contributions to Mineralogy and Petrology*, 106, 431-439, 1991.

Section 6.1: (page 11, lines 28-30): I was a bit confused by the terminology of “second phase particles,” but maybe I’m just unfamiliar with this term. Does it always refer to the phase doing the “pinning”? (Also, there is a misplaced comma in line 29 after the hyphen)

Second phase particle is a terminology of material sciences background and, to our best knowledge, its use is also common in Earth Sciences. The term is often associated with the pinning effect of these textural elements but it is not exclusively used in this context everywhere. In fact, a second phase particle can refer to any secondary phases that are present in a polymineralic assemblage but the pinning effect largely depends on the size and distribution of

such phases in the texture (grain boundaries vs. inclusions, crystal aggregates vs. dispersed crystals in the fabric). This is the analysis that we carried out in Fig. 8 of the manuscript.

We deleted the comma in line 29.

(page 12, lines 8-9): Something is odd about this sentence. As is, it doesn't make sense grammatically, particularly in this part: "relatively cold and then stiffer and high stress: : :"

We clarified the sentence in the revised version: "...Grain size reduction in mantle xenoliths is symptomatic of increasing strain localization in relatively cold, stiff and high stress domains of the mantle lithosphere (e.g., Drury et al., 1991; Karato, 2008; Linckens et al., 2011b; Vauchez et al., 2012; Tommasi and Vauchez, 2015)..."

Section 6.1.2 (page 13, lines 24-27): This is a more general comment, but is there a reason why the authors chose not to estimate stress magnitude from recrystallized or subgrain size? It seemed odd to me that this was missing, especially because all the authors would have to do is use the already obtained EBSD maps to calculate the average grain size, apply a correction factor, and use a paleopiezometer (e.g., Van der Wal et al. 1993). The authors note how the fine grain sizes of some samples are consistent with high-stress deformation, but don't put a number on this. People might be interested in this value both from a regional deformation perspective but also to address whether or not higher stresses are associated with their [100]-fiber CPO samples vs. orthorhombic CPOs, as is commonly assumed (e.g., Karato et al. 2008, review).

The main reason for not including paleopiezometry in the manuscript is that this method only works for dynamically recrystallized grain sizes. Considering grains other than those of dynamic recrystallization origin would certainly return erroneous stress values in the paleopiezometric estimations. In the Oran mantle xenoliths, olivine and pyroxene grain sizes are largely influenced by melt-rock reaction, and we have no tools to differentiate dynamically recrystallized grains from those produced during the melt-rock reaction. This issue is critical in the fine-grained rocks but cannot be disregarded in the coarse-grained xenoliths either, where at least a fraction of small orthopyroxene is of reactional origin. Consequently, we decided not to use paleopiezometry in the revised manuscript either.

(page 14, lines 16-17): Was there any microstructural evidence (other than weakened CPO) for a switch to diffusion-assisted grain boundary sliding? As an example, were there any 4-grain junctions?

The switch in the deformation mechanism is supported by the observations listed in the paragraph and we have not found any further microstructural evidence for the presence of melts.

Figure 3: You should specify whether the maps shown are the entire EBSD area mapped for each sample or just a portion of it. If so, if doesn't appear that there would be enough opx or cpx grains in 3B for a reliable bulk CPO.

The images have been cropped for aesthetic purposes in the figure but the data behind the analyses are considered for the entire analyzed area. We have clarified this in the revised figure caption: "...Note that images in the figure are cropped out from EBSD maps; see supplementary Fig. S1 for the entire maps..."

Figure 9: It is hard to read the yellow text, even with the black outlines.

We updated the figure to enhance legibility:

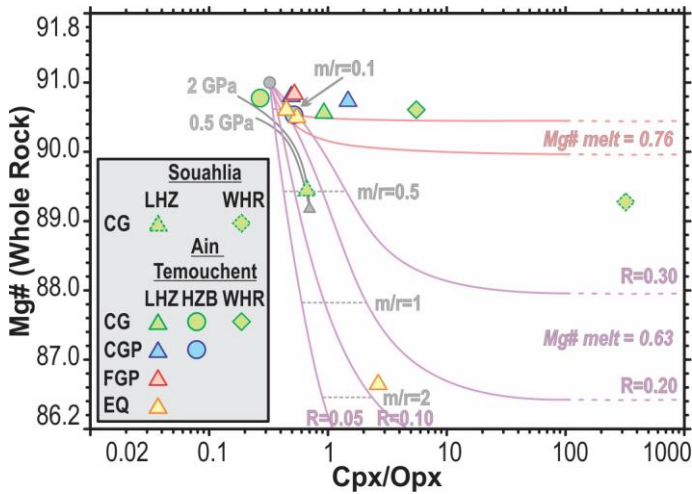


Figure 10: It is hard to see the tiny volcanoes on the surface. Perhaps just make them one color (and bigger). It is also difficult to read the text associated with those volcanoes (in red and blue). It might help to have a white box behind each of them.

We increased the size of the volcanoes and we added a white box in the background, but the blue and red colors reflect geochemistry of the igneous rocks, thus we consider this information important.

