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Interactive comment on “Petrophysical constraints on the seismic properties of the Kaapvaal craton mantle root” *by* V. Baptiste and A. Tommasi

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Revisions for the manuscript “sed-5-963-2013” entitled “Petrophysical constraints on the seismic properties of the Kaapvaal craton mantle root” by V. Baptiste and A. Tommasi for publication in Solid Earth.

We thank the two anonymous reviewers for their helpful contribution to improve our manuscript. In the following, the comments and questions are addressed one by one.

Comments and reply to anonymous Referee #2

Sample set

1. How were the xenoliths chosen and why?

We have studied peridotites from 9 pipes (Kimberley, Jagersfontein, Monastery, Lentseng, De Beers, Finsch, Kamfersdam, Premier, and Mothae) to allow sampling possible lateral variations. The analyses of a larger number of samples from Jagersfontein and Kimberley allowed studying vertical variations at these locations.

2. How is the maximum representativeness for the present-day lithosphere ensured? It is said on page 967 that the age of kimberlite pipes ranges from 1200 to 87 My. It is quite substantial range and it would be good to give the ages for individual pipes. I wonder if there could be a possible bias resulting from assessing together rocks sampled at so different phases of the lithosphere’s evolution.

A table giving the ages of the kimberlite pipes is given in the first article published on these xenoliths (Baptiste et al., 2012). We have added the reference to the main text. All the pipes have eruption ages ranging between 120 and 86 Ma, except for Premier, which is associated with the Bushveld intrusion. The peridotites from Premier only represent 6% of the total sample set. Most studied samples record therefore the state of the mantle lithosphere at 120-86 Ma, that is after the last major geodynamic episode in this region, which was the eruption of the Karoo basalts at 180 Ma.

3. This is not mentioned in sections 4.3 to 5.2 dealing with large-scale seismic model constructed from this xenolith dataset. Is it assumed that there was no evolution in the Kaapvaal lithosphere since 1.2 By? This might be true for olivine CPO and hence the seismic anisotropy but how about the metasomatic processes and resulting isotropic seismic properties? The problem is four-dimensional and this would deserve some paragraph in Discussion.

The Kaapvaal craton records no major evolution since Karoo times (∼180 Ma) and kimberlite eruptions (mainly between 120 and 80 Ma) (Begg et al., 2009). All the pipes we sampled have eruption ages ranging between 120 and 86 Ma, except for Premier (see answer to comment 2). Therefore, we believe that we can compare our xenolith data set to present seismic study.

4. Fig. 1 is a bit confusing since the tomographic section at 150 km depth is presented at a depth of 0 km of the sampling columns - the 3D view does not help much here. Furthermore, I suggest to add to this figure a simple schematic map of the region with coordinates.

We have added a map with the geographical coordinates to Figure 1.

Textures and EBSD

5. At least the range of grain size could be given so that we know how coarse the "coarse-grained“ peridoties are (e.g., page 968, line 1).

A grain size range has been added to the main text.

6. How often the lineation was observed in the samples and how is it defined? (referred to on page 971, line 12 and elsewhere).

The lineation is defined as the direction of elongation of the minerals. It could not be observed in most coarse-grained peridotites except for the coarse-porphyroclastic samples (5 out of 30 coarse-grained peridotites). However, it could always be distinguished in the 12 sheared peridotites.

7. But most of all it is necessary to give more methodical details on the EBSD setting and results so that we can asses how good the description of preferred orientation can be (EBSD performed on single thin section for each sample? Or multiple sections were used for coarse-grained types? How many grains were measured per each phase? Manual or automatic indexing? How the pseudosymmetry of olivine EBSP was dealt with? How successful was the indexing of pyroxenes?...)

We used one thin section for most samples. However, we did measure two sections for two very coarse-grained peridotites. The number of olivine grains indexed varies from more than 80 grains in coarse-grained peridotites, to more than 20 000 grains in some

sheared peridotites. Because most samples are harzburgites, the number of pyroxenes is usually lower, from less than 40 grains in coarse-grained peridotites, to more than 10 000 grains in some sheared peridotites. Olivine pseudosymmetry was corrected by careful post-acquisition data treatment. The indexing of orthopyroxene was good, except in few samples, where it was sometimes misindexed for clinopyroxene. All the methodical details on the EBSD are given in the first paper published on these xenoliths (Baptiste et al., 2012). We have added the reference in the main text for clarity.

Densities and elastic constants

8. It is not clear to me how the sample densities were obtained. Was it by measurement or by modeling based on modal mineralogy? In either case the method should be described.

The density was calculated based on modal mineralogy. The main text has been corrected for clarity.

9. In the latter case it should be taken into account that mineral compositions of pyroxenes vary strongly in peridotites and so do their densities. How was this solved?

The variation of orthopyroxene composition was not taken into account in our calculation, since olivine is the main phase in these rocks. Additionally, among all samples, the variation of orthopyroxene Mg# does not exceed 7%.

10. And the same problem might be with the elastic constants used. How close were the pyroxene compositions in the present samples to those at which the elastic constants were measured? How well the effects of chemical variations in pyroxenes on their seismic properties are known anyway? The mineral chemistry will also reflect the equilibration pT conditions, so this effect, if not taken into account, might lead to systematic depth-dependent bias in isotropic seismic properties. Perhaps these factors will not have dramatic effect, but this should all be discussed and an estimate of effective errors in seismic properties should be given, taking into account all potentially

important uncertainties.

The pyroxene composition at which the elastic constants of Chai et al. (1997) were measured are a Mg# of 0.91, 5 wt.% Al2O3, and 1 wt.% CaO. The pyroxenes from the Kaapvaal craton xenoliths are significantly less aluminous (0.2-3.0 wt%) and have similar CaO contents (0.1-2.0%). Their Mg# varies between 0.88 and 0.95. In Kaapvaal peridotites, orthopyroxene contents vary between 5 and 39%. One can expect that variations in orthopyroxene composition will have a greater effect on the seimic properties of samples with the higher orthopyroxene contents. However, these effects are difficult to quantify. Because, Chai et al. (1997) pyroxenes are more aluminous, it is to be expected that the density of Kaapvaal pyroxene is slightly overestimated and that the resulting velocities are slightly overestimated too (a few weight percent Al2O3 content increases a mineral seismic velocities by several percent according to Chai et al. 1997). Lower Mg#, meaning higher Fe contents will increase the orthopyroxene density. However, the effect of these compositional changes on the elastic constants may be more important to the seismic velocities then the change in density and we lack experimental data on a large range of orthopyroxene compositions to constrain them. In addition to the Chai et al (1997) dataset, there is only another set of measurements by Jackson et al (2007) on enstatite with (En 0.994 Fe 0.002 Al 0.004). In conclusion, although the variation in orthopyroxene composition may affect the calculated seismic velocities, we do not have the experimental data needed to calculate this effect.

11. It is written on page 969, lines 1-3, that elastic constant tensors for fayalite, forsterite and olivine of three compositions were used. But it is not clear in which cases the end-members were used and why in other cases the Mg-Fe olivine was used instead?

The fayalite, forsterite, and olivine of three compositions were used to calculate the elastic tensors of olivine with intermediate Mg#. The text has been modified for sake of clarity.

12. It is not clear how the isotropic Vp and Vs are defined (page 975, line 20). Is it calculated by D. Mainprice's careware using isotropic elastic constants as input?

See the answer to referee 1, comment 7.

13. What are G and P in equation 1? Some eigenvalues?

See reply to referee 1, comment 3.

Other items

14. page 969, line 20: ...properties of six 20km-deep sections... | perhaps 20km-thick would sound better

The text has been corrected.

15. page 970, line 13: ...J indexes varies...

The text has been corrected.

16. page 970: M- indices are now used by significant part of the community. It might be useful to calculate these as well.

The study is focused on the xenoliths seismic properties, not on their fabrics, which have been carefully analyzed in another article (Baptiste et al., 2012). M-indices and J-indexes are just different ways to quantify the same thing: the strength of the fabric. Both have the same bias; they depend on the bandwidth used in the calculation of the ODF (or MODF). Therefore, we do not think that calculating M-indices would provide any additional information. Moreover, we took care to use a fixed 10° bandwidth, which is the one most commonly used to analyze the CPO of naturally deformed peridotites, to calculate the J-index for all samples.

17. page 972, line 7: ...anisotropy is observed between to the Y...

The text has been corrected.

18. page 974, line 25: ...garnet content may attain up to 15% | There is 18% in Tab. 1

and Fig. 4.

The text has been corrected.

19. page 981, lines 27/28 ...anisotropy of the individual samples seismic anisotropy... | I am not sure whether this is grammatically correct.

In the main text, it is written “Analysis of the individual samples seismic anisotropy…”, which is grammatically correct.

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