Earth and Planetary Science Letters 276 (2008) 226–227

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

journal homepage: www.elsevier.com/locate/epsl

Discussion

# Reply to comment by A. Tommasi and D. Mainprice on Visser et al. (2008), “Probability of radial anisotropy in the deep mantle” [Earth Planet Sci. Lett. 270 (2008) 241–250]

K. Visser [a,b,*], J. Trampert [a], S. Lebedev [c], B.L.N. Kennett [d]

[a] Department of Earth Sciences, Utrecht University , Utrecht 3584 CD, The Netherlands
[b] TNO, Built Environment and Geosciences — former Geological Survey of The Netherlands, Princetonlaan 6, Utrecht 3584 CB, The Netherlands
[c] Dublin Institute for Advanced Studies, School of Cosmic Physics, Dublin, Ireland
[d] Research School of Earth Sciences, The Australian National University, Canberra, Australia

We thank Tommasi and Mainprice (2008) for their interest in our work, the purpose of which was to present new seismological constraints on mantle anisotropy. Our interpretation, a few sentences in the whole manuscript, was intentionally kept short and vague and was only meant as a possible explanation. We agree that it is oversimplified and welcome their three comments which provide additional possibilities.

Point 1: We stated that the absence of significant anisotropy in the lower mantle was likely to be due to a regime of diffusion creep. We were not aware of the work of Mainprice et al. (2008) on perovskite which was published after our paper. We acknowledge that preferred orientation in polycrystals may develop with modest overall anisotropy consistent with our results.

Point 2: We adopted the simple view that a change of sign of anisotropy in the uppermost mantle indicates a change in the flow direction mentioning explicitly the possibility of complications due to the presence of water. Tommasi and Mainprice (2008) refer in their comment to recent experiments at high pressure which also lead to changes in glide systems. These high pressure effects on the olivine system however are still controversial (Karato et al., 2008) which is why we felt they should not be discussed in a seismology paper.

Point 3: We agree that the interpretation of anisotropy requires the use of mineral properties of the actual phases present. It also requires putting the seismological models in the proper context. Seismological models come together with specific resolution properties. While the resolution in the model of Trampert and van Heijst (2002) is clear by construction, vertical average over the whole transition zone and spherical harmonic degree 2 laterally, the model is not necessarily representative of the physical Earth. The Backus–Gilbert modelling indicates that azimuthal anisotropy is required by the data in the transition zone, but the full model does not necessarily fit the data and hence the details of the modelled anisotropy in the transition zone are likely to be different in the actual Earth. Tommasi and Mainprice (2008) correctly state that it is important to know if the anisotropy is in the upper or lower transition zone. We find indeed a peak of probability at 550 km depth, but this depth is distorted by averaging properties of the data. We, for the first time, made a fully non-linear inversion using a model space search. The classical resolution analysis is a linear concept, and does not quantify the averaging properties of our model. It is clear however from the nature of the data, that it is 100 km at best. Significant future work is required for the appraisal of models inferred from non-linear inversion.

Anisotropy is difficult to image and, apart from data, depends on many details of the modelling (crustal correction, linearisation, scaling of parameters etc.), therefore an individual model cannot be interpreted directly. Rather than producing a single model, we solved the non-linear inverse problem using a full model space search. We associated to each model, good ones and bad ones, a probability of how well it fits the data. The obtained probability density functions (pdfs) for each model parameter can therefore be seen as a compact representation of the seismic data themselves and are the most complete constraint on Earth structure from those data. But they also depend on the uncertainty in the measured data, the imperfect data coverage and all prior choices, and hence the most likely model is not necessarily the one which most likely represents the Earth. It is therefore essential that the full pdfs are considered in any interpretation. Other disciplines should similarly make pdfs from their constraints on Earth parameters, and a judicious combination of all pdfs should eventually come to a closer representation of the true Earth.

At present no firm inferences can be made on the causes of seismic anisotropy because of a lack of constraints on actual strain rates in the mantle and their likely effects on the preferred orientation on many mantle minerals at the appropriate pressure and temperature. It is

DOI of original article: 10.1016/j.epsl.2008.07.061.
* Corresponding author. TNO, Built Environment and Geosciences — former Geological Survey of The Netherlands, Princetonlaan 6, Utrecht 3584 CB, The Netherlands. Tel.: +31 30 2564265.
*E-mail address:* karin.visser@tno.nl (K. Visser).

0012-821X/$ – see front matter 
doi:10.1016/j.epsl.2008.09.002

hoped that in the future, seismologists and mineral physicists will jointly try to come closer to likely scenarios.

## References

Karato, S., Jung, H., Katayama, I., Skemer, P., 2008. Geodynamic significance of seismic anisotropy of the upper mantle; new insights from laboratory studies. Annu. Rev. Earth Planet. Sci. 36, 59–95.

Mainprice, D., Tommasi, A., Ferre, D., Carez, P., Cordier, P., 2008. Predicted glide systems and crystal preferred orientations in polycrystalline silicate Mg-perovskite at high pressure: implication for the seismic anisotropy in the lower mantle. Earth Planet. Sci. Lett. 271, 135–144.

Tommasi, A., Mainprice, D., 2008. Comment on "Probability of radial anisotropy in the deep mantle" by Visser et al. (2008). EPSL 270, 241–250.

Trampert, J., van Heijst, H.J., 2002. Global azimuthal anisotropy in the transition zone. Science 296, 1297–1299.