Lower mantle structure and composition: new insights from generalized inversion of sesmic profiles

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Although the precise nature lower mantle structure and composition have been under an intense debate for several decades, various fundamental questions remain without adequate answers. One of them is undoubtly the question of the global average chemical composition. The significant discrepancy in chemical composition between chondrites and natural shallow mantle peridotitic rocks has not been satisfactorily explained. Aside from uncertain radial chemical structure, recent seismological observations revealed significant lateral heterogeneities in the lower mantle, and especially in its lower-most part. These heterogeneous regions may indeed contain hints about the near-surface discrepancies. However their nature has not yet been clearly identified.

A large number of studies have already been dedicated to interpretations of 1-D radial seismological profiles of seismic wave velocities, density, and elastic properties in terms of mantle mineralogy and thermal structure.
First, we review and illustrate some important results of these inversions that provide valuable information on lateraly averaged mantle temperature and chemical composition at various depths. Although no clear consensus has emerged from these studies, several robust conclusions can be drawn.
(1) Average lower mantle compositional models that are not pyrolitic-like in composition are consistent with seismological observations. (2) There are large trade-off's between thermal structure and bulk composition. (3) Regardless of the origin of the 660-km interface, other (chemical) discontinuities may be located at greater depth in the lower mantle. (4) The role of minor elements (such as aliminium, calcium, water) is difficult to constrain.

Second, we show results for lower mantle structure and bulk composition that are obtained by using a generalized inverse technique together with the most recent and accurate values of physical properties (elastic and shear parameters) of adequate lower mantle minerals. We have designed a numerical code that allows us to precisely evaluate the a posteriori uncertainties, correlations and resolution of best matching chemistry and geotherm. We demonstrate that the radial seismic profiles are compatible with a non-adiabatic geotherm and depth-dependent bulk chemistry. We discuss in detail the effect of various sources of uncertainties: we show the effect of experimental uncertainties on the physical properties, of various averaging schemes for the composite mantle material, of different formulations of equation

of state. We compare the results obtained frominversions of density and bulk sound velocity to those obtained from density, seismic velocities Vp and Vs. We show that including the shear properties significantly reduces the a posteriori uncertainties on the resulting geotherm models, and we quantify the correlations between the thermal structure and depth-dependent averaged bulk compostion. We also test the compatibility of radial seismic profiles with the hypothesis of a chemical discontinuity located somewhere in deep lower mantle.