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The nature of the lithospheric and sub-lithospheric upper mantle: recent views from interdisciplinary studies and their limitations

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There have been significant advances over the past decade in the determination of the thermal and compositional structure of the upper mantle. The improvement and integration of geophysical, petrological, mineral physics, and geochemical data into self-consistent models have opened new promising approaches to study the interaction between the lithospheric and sub-lithospheric upper mantle.

Here we present the advances and limitations brought up by these interdisciplinary studies. Firstly, we evaluate recent seismological models and their capability to distinguish thermal vs compositional signatures. For this, we present the results of a systematic exploration of the effects of thermal and compositional heterogeneities in seismic velocities applying 1) both thermodynamically self-consistent and hybrid methods, 2) the latest mineral physics databases, and 3) recent anelasticity measurements on olivine aggregates at seismic frequencies.

Secondly, we present results from forward and dynamic models based on a self-consistent combination of petrological, mineral physics, and geophysical information. The final result is a lithospheric/sublithospheric thermal and compositional model that simultaneously fits all available geophysical and petrological observables, and consequently reduces the uncertainties associated with the modelling of these observables alone or in pairs, as commonly done in the literature.

Thirdly, we focus on inverse methodologies based on gravity anomalies and topography which yield estimations of the effective elastic thickness of the lithosphere, T_e. We present a new approach to estimate lithospheric thickness and lithospheric mantle viscosity based on T_e and estimates of the geotherm resulting from forward modelling. Uncertainties and lateral resolution of these estimates are assessed using a Monte-Carlo approach.

Finally, we discuss some technical and observational advances that will be required in the future to expand our understanding of the lithosphere-sublithospheric upper mantle system.