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Distinguishing thermal vs compositional signatures in the lithospheric mantle from seismic studies: not a simple task

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Seismic tomography studies and measurements of the Vp/Vs ratio are the most commonly used methods to estimate compositional variations in the upper mantle. In these studies, seismologically derived Vp/Vs ratios are directly compared with estimations of seismic velocities in ideal aggregates using laboratory data in either single crystal or monomineralic samples; attenuation being often ignored in the estimation of the aggregate's seismic velocities. However, unless an appropriate model of attenuation is considered in each particular case, the interpretation of Vp/Vs variations as a measure of compositional variability is no longer valid due to the different response of Vs and Vp to anelastic attenuation.

In this paper 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. Synthetic model samples (i.e. theoretical rock compositions) representative of both oceanic and continental lithosphere, as well as real subcontinental mantle xenoliths, are used to assess parameter correlations, composition-modifying processes, and potential indicators of chemical and thermal heterogeneities. We also present realistic 2D and 3D thermal-compositional lithospheric models to evaluate the applicability and reliability of these indicators for conditions pertaining to the lithospheric and sub-

lithospheric upper mantle.

Our results show that 1) the behaviour of compositional indicators such as the Vp/Vs and Poisson's ratios changes dramatically depending on which Al-rich phase is stable (i.e. Pl-Sp-Gt), 2) anelastic attenuation effects (and associated uncertainties) preclude a robust interpretation of compositional vs thermal signatures in seismic studies, 3) uncertainties in seismologically derived quality factors Q are typically of the same order as variations in Q produced by compositional changes within the lithosphere. All these factors make it unfeasible to identify compositional variations in the middle-lower lithospheric mantle from seismic studies only. We also show that previous contradictions on the magnitude and meaning of some correlations (e.g. ∂lnVp/∂Mg#, ∂Vs/∂F) proposed by different authors as indicators of chemical anomalies can be reconciled in light of our results.