Evidence for deep melting in the European upper mantle from seismology

JEANNOT TRAMPERT[1], LAURA COBDEN[1] & ANDREAS FICHTNER[2]

[1]Department of Earth Sciences, Utrecht university, The Netherlands. E-mail: j.a.trampert@uu.nl; l.j.cobden@uu.nl

[2]Department of Earth Sciences, ETH Swiss Federal Institute of Technology Zurich, Zurich, Switzerland. E-mail: andreas.fichtner@erdw.ethz.ch

The recent development of full waveform seismic tomography on continental scales has provided new insights into the seismic structure of the lithosphere and asthenosphere. In particular, we can map shorter wavelength, high-amplitude velocity anomalies which would traditionally be damped and spatially smeared using classical methods. Quantitative interpretation of these anomalies – expressed as absolute rather than relative velocities – may open up the possibility of identifying important dynamic processes such as melting, that would otherwise go undetected or unconstrained.

In this study we focus on the S-wave speed (Vs) structure beneath Europe, as obtained from full waveform inversion. The European upper mantle is characterised by seismic wave speeds that are slower than the global average. However, especially low velocities (< 4.0 km/s) are seen beneath Iceland and other parts of the mid-Atlantic ridge, as well as beneath Iberia, reaching a minimum between 120-130 km.

Using Vs alone, in the absence of any other observable (e.g. Vp, density), it is difficult to constrain the chemical composition beneath Europe. This is because chemistry (C) and temperature (T) have sensitivities to Vs which trade off with each other. However, even considering the full range of possible chemical compositions, taking into account mineral intrinsic anelasticity, and allowing for the presence of fluids, it is very difficult to create sufficiently low velocities to fit the slowest regions of the tomography model, using simple variations in T or C. Doing so requires either extremely high temperatures or unrealistically high attenuation. However, the slowest velocities can readily be modelled by including c. 1-2% melt. We discuss whether melt provides the most likely explanation for the slow regions, considering also the effect of more advanced anelasticity models such as "elastically accommodated grain boundary sliding", recently suggested by Karato et al. (2015).

The possibility of deep melting beneath Europe, and its quantitative identification via seismic tomography, offers exciting new constraints on geodynamic and geochemical processes.