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Geodynamic modeling of the age-depth dependence of radial anisotropy beneath the oceans

Elodie Kendall (1), Manuele Faccenda (2), and Ana Ferreira (1)

(1) Earth Sciences, University College London, United Kingdom (elodie.kendall.14@ucl.ac.uk, a.ferreira@ucl.ac.uk), (2) Dipartimento di Geoscienze, Università di Padova, Italy (manuele.faccenda@gmail.com)

The geometry and strength of the radially anisotropic structure of the lithosphere-asthenosphere boundary (LAB) in recent 3D models is currently debated because it tends to show a flat pattern as the age of the oceanic lithosphere increases (Burgos et al., 2014, Beghein et al., 2014, Auer et al., 2015, Hedjazian et al., 2017). Several mechanisms have been proposed for this flat signature, such lattice preferred orientation (LPO) from lithosphere-plume interactions (Auer et al., 2015). This study examines the mechanisms of deformation-induced radial anisotropy beneath oceanic lithosphere from ridge to subduction with and without a Hawaiian like plume. It is critical to understand the mechanisms of radial anisotropy causing this flat possible “thermo-mechanical” boundary in order to understand the relationship between deep mantle convection and its surface expressions.

We present various large 2D ridge flow models built with I2VIS (Gerya and Yuen, 2003) using a numerical domain of 12750km by 700km (x-y), with a resolution of 2-4km, corresponding to $\sim$170Ma for a convergence rate of 7.5cm/yr. The thermal structure of the oceanic plate is defined according to the half-space cooling model, below which a constant thermal gradient of 0.5K/km is imposed in a mixed Newtonian - non-Newtonian rheology (Karato and Wu, 1993).

We determine the magnitude and depth of the anisotropic LAB from the ridge to subduction by predicting the LPO in non steady-state (Faccenda and Capitanio, 2013) from the kinematic model D-Rex (Kaminski et al., 2004) with a olivine -enstatite crystal aggregate assemblage. We then compare the computed radial anisotropy with observations from the global 3D radially anisotropic tomography models S362WMANI (Ekström and Dziewoński, 2008), SAVANI (Auer et al., 2014) and SGLOBE-rani (Chang et al., 2015). We find a depth-age dependent anisotropic signature of A-type olivine with strong $\xi \sim 1.15$ down to 100km at the ridge, with ξ deepening with age and reaching a maximum at 150km. The correlation with surface wave tomography improves again with E-type olivine in the asthenosphere, reducing ξ beneath the lithosphere to a lower value of 1.1.

Furthermore, we build a 2D model with the addition of a plume of radius 100km, ΔT =200K and hydrated with 1000ppm of water to analyse possible perturbations of the anisotropic LAB from the Hawaiian plume. In addition, we examine the effect of the dimensionless grain boundary mobility, M* parameter (Kaminski et al., 2004) on the models and we compute anisotropy from various olivine fabrics, notably A-type in the lithosphere, E-type in the asthenosphere and C-type in the plume, where water content and temperatures are higher but there are low stresses (Karato et al., 2008).