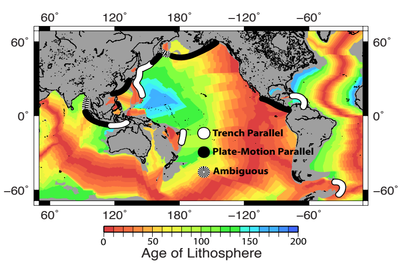
Probing sub-slab anisotropy beneath Central America and Tonga from geodynamic models

Colton Lynner and Maureen D. Long
Yale University

Abstract

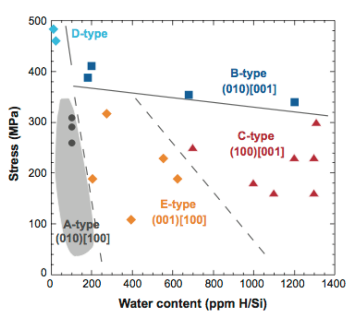
A number of conceptual models have been proposed to explain trench parallel shear wave splitting observations beneath subducting slabs. Recently, Lynner and Long (2014) tested several of these conceptual models against a quasi-global source-side shear wave splitting dataset and found that a model in which sub-slab dynamics varies with the age of the down-going plate best matches the observations. A major limitation of that study, however, was the employment of very simplified geodynamics; especially in cases that invoke 3-dimensional return flow, where highly complex flow patterns are expected near and around slab edges. Here, we examine sub-slab shear wave splitting patterns from geodynamic models aimed at mimicking real world subduction beneath Central American and Tonga; which exhibit entrained and 3D return flow patterns, respectively. Using a variety of olivine LPO and other anisotropic fabrics, we compare shear wave splitting from these models against actual source-side measurements in order to better understand sub-slab deformation.

Global Source-Side Patterns



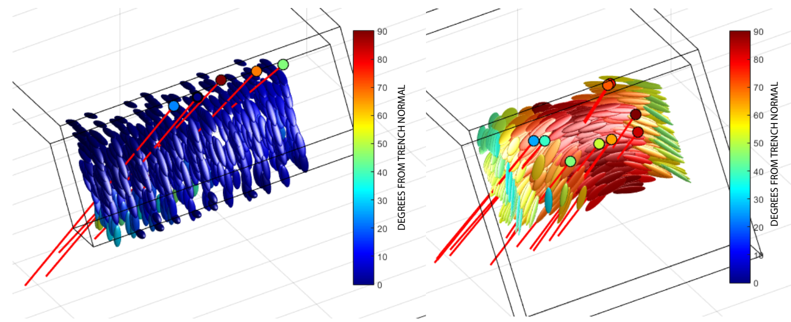
Schematic view of the fast directions of source-side shear wave splitting for all of the regions used in Lynner and Long (2014). The highlighted color represents the most commonly observed fast directions. The background is color coded to the age of the oceanic lithosphere from *Müller et al.* [2008b]. A general correlation is apparent between trench parallel fast directions and older subducting lithosphere, while plate motion parallel fast directions correlate with younger plate ages.

Olivine LPO Fabrics



Olivine LPO fabric development as a function of water content and Stress. From Karato et al., 2008

Mapping Anisotropic Fabrics onto Finite Strain Ellipses



FSEs from the Paczkowski et al. [2014b] models for Central America (left) and Tonga (right). The color and orientation of each FSE denotes the orientation of the maximum strain direction from a trench normal direction. Rays (red lines) are plotted from their source (circles) to the bottom of the model upper mantle. Circle colors correspond to specific rays.

Paczkowski et al. Models

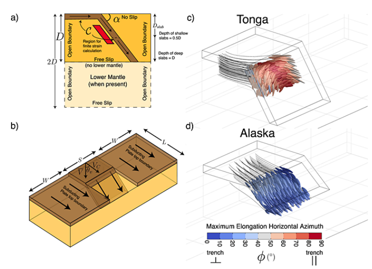
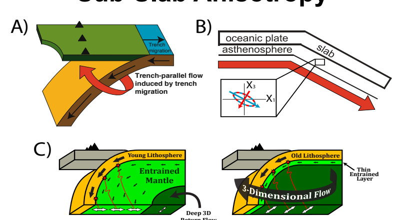


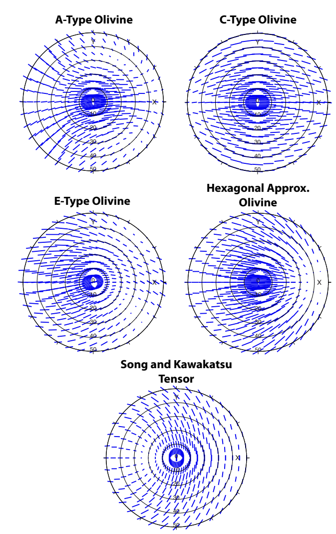
Figure from Paczkowski et al. [2014b]. (a) Side-view schematic diagram of the basic model setup. (b) Perspective view of the model geometry. (c) Finite strain ellipsoids and streamlines (black lines) for a fully decoupled model representing the Tonga subduction zone. (d) Same as (c) but for the Alaska subduction zone.

Sub-Slab Anisotropy



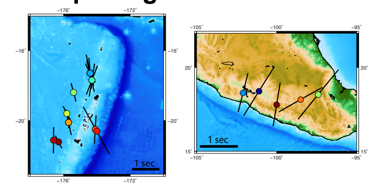
Conceptual diagrams of the A) 3D-return flow model of Long and Silver (2008), B) the strong radial anisotropy model of Song and Kawakatsu (2012), and C) the age-dependent model of Lynner and Long (2014).

Splitting from Different Anisotropic Fabrics



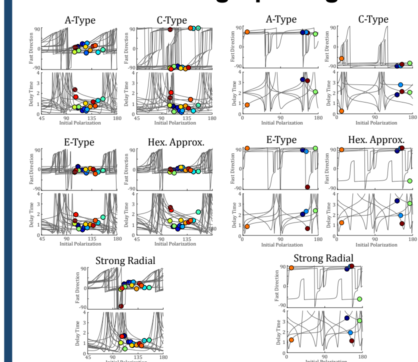
Splitting predictions as a function of takeoff angle and azimuth for 5 different anisotropic fabrics. The orientation and length of the bars correspond to fast direction and delay time. The distance from the center of the plot corresponds to the takeoff angle of the ray, while azimuth corresponds to event-to-station azimuth. All 5 are oriented such that the direction of deformation is in the X-direction with a dip of 45°. We will test all 5 fabrics when examining sub-slab anisotropy as each gives different splitting results for the same ray.

Splitting Observations



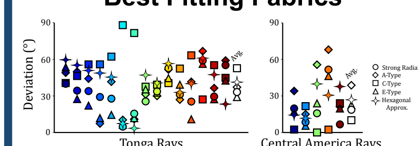
Source-side splitting measurements from Tonga (left) and Central America (right). The orientation and length of the bars correspond to fast direction and delay time, respectively. Circles are plotted at event location, and circle color denotes each individual ray.

Predicting Splitting



Splitting results from all 5 anisotropic fabrics for the Tonga (left) and Central American (right) models plotted as a function of initial polarization. Colored circles denote predicted splitting at the observed initial polarization of each ray. The color of each circle corresponds to the colors in previous figures. Gray lines show predicted splitting of each ray across all initial polarizations. A fast splitting direction of 0° is a perfectly trench parallel orientation.

Best Fitting Fabrics



Deviations between predicted fast splitting direction of all 5 fabric types and the observed source-side splitting color-coded by ray, for Tonga (right) and Central America (left). Open symbols denote the average regional deviation associated with each fabric type.

Long, M.D., and P.G. Silver (2008), The subduction zone flow field from seismic anisotropy: A global view. Science 319, 315–318.
Lynner, C., Long, M. D., (2013). Sub-slab seismic anisotropy and mantle flow beneath the Caribbean and Scotia subduction zones: Effects of slab morphology and kinematics. *Earth and Planetary Science Letters*, 361,367-378.
Lynner, C., and M.D. Long (2014), Sub-slab anisotropy beneath the Sumatra and circum-Pacific subduction zones from source-side shear wave splitting observations. Geochem. Geophys. Geosyst., 15, doi: 10.1002/2014GC005239.
Lynner, C., Long, M.D., (2014). Testing models of sub-slab anisotropy using a global compilation of source-side shear wave splitting data. *Journal of Geophysical Research*, 119, 7226–7244, doi:10.1002/2014JB010983.
Song, T-R. A., and H. Kawakatsu (2012), Subduction of oceanic asthenosphere: Evidence from sub-slab seismic anisotropy. Geophys. Res. Lett. 39, L17301, doi: 10.1029/ 2012GL052639.
Paczkowski, K., Montesi, L. G. J., Long, M. D., Thissen, C. J., 2014. Three-dimensional flow in the sub-slab mantle. Geochemistry, Geophysics, Geosystems, 15, 3989-4008, doi:10.1002/2014GC005441.