The effect of anisotropic viscosity in the asthenosphere, for different geodynamic scenarios. The white to black arrow shows the mantle weakening path. The evolution of plate velocity and several texture parameters as a function of accumulated strain (top panel) with pole figures (below) showing the orientation density of olivine aggregates for different total strains. The shear direction (marked by red arrows) is towards the right and the shear plane is the same as the figure’s plane.

Figure 1: Relation between anisotropic viscosity and olivine texture formation. a): A force (F1) applied to an initially isotropic asthenosphere (random texture) yields a moderate plate speed. b): The same force applied parallel to the a-axis of a well-developed texture drives a much larger plate speed. c): Applying this force across the weak one (b) in two ways: either the force can be rotated relative to the fabric (as for many geodynamic scenarios) or the "mantle" can be rotated respect to the fabric's plane. The evolution of plate velocity and several texture parameters as a function of accumulated strain (top panel) with pole figures (below) showing the orientation density of olivine aggregates for different total strains. The shear direction (marked by red arrows) is towards the right and the shear plane is the same as the figure’s plane.

Figure 2: Evolution of plate velocity and several texture parameters as a function of accumulated strain (top panel) with pole figures (below) showing the orientation density of olivine aggregates for different total strains. The shear direction (marked by red arrows) is towards the right and the shear plane is the same as the figure’s plane.

Figure 3: Possible ways to change the shear orientation away from F1. F2 represents a change in the direction of the plate driving force, F3 and F5 a represent a force that creates shear-deformation along a transitional shear zone, F4 and F6 impose subduction initiation or a dripping instability. All forces have the same magnitude as F1.

Figure 4: Strain rate vs accumulated strain for the five different changes to the imposed shear force (Fig. 3). On the left side, an initially isotropic aggregate is deformed with shear strain ε = 1 and a strain rate of 1. At a strain of 1, the direction of the shear force is instantaneously changed onto the direction F3 (Fig. 3). On the right side, pole figures show the texture for several moments denoted by arrows in the left diagrams. Note that all of the texture orientations are shown relative to the initial normal to c-axis. The two shear axes on the right are normal to a-axis and parallel to b-axis. (Panel A) shows the flow behavior computed related to the actual shear stress for the case of a change in the direction of the plate driving force, F2 to F1.

Figure 5: The relationship between the asthenosphere’s effective viscosity and the plate motion. Isotropic mantle is shown with black arrow, while a white to black arrow marks a strain of 1 (based on results shown in Fig. 4). Geodynamic processes for which the effective viscosity elevates (F1, plate motion) and transforms fault will be initially impacted by anisotropic viscosity, while those for which the effective viscosity decreases (F2, subduction and dripping, and F3, transform fault) will be initially protected. Subsequent changes to the effective viscosity along each path indicate how continued texture development should either speed up or slow down each process as it develops.

Figure 6: Strain rate vs accumulated strain for the five different changes to the imposed shear force (Fig. 3). On the left side, an initially isotropic aggregate is deformed with shear strain ε = 1 and a strain rate of 1. At a strain of 1, the direction of the shear force is instantaneously changed onto the direction F3 (Fig. 3). On the right side, pole figures show the texture for several moments denoted by arrows in the left diagrams. Note that all of the texture orientations are shown relative to the initial normal to c-axis.