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Strain localization in plate tectonics: the role of olivine crystal preferred orientations in the upper mantle

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Plastic deformation in the upper mantle produces crystallographic preferred orientation (CPO) of olivine, which result in coherent seismic anisotropy patterns at the scale of hundreds of km. These coherent olivine CPO result in anisotropic mechanical behaviour in the upper mantle for subsequent deformation events; the resulting deformation depends on the olivine CPO intensity, symmetry, and on the orientation of the stresses relative to the pre-existing mantle fabric. Lateral variations in the olivine CPO in the lithospheric mantle may therefore lead to strain localization and structural memory in plate tectonics. We test this hypothesis by implementing an anisotropic viscosity, which was parameterized using the aggregate (rock)-scale viscoplastic self-consistent model, in the finite element code ADELI and running models, in which a plate composed by different tectonic domains, each characterized by a different pre-existing olivine CPO and, hence, by a different viscoplastic anisotropy, is deformed in compression or extension. These models show that lateral variations in the olivine CPO in the lithospheric mantle do result in a heterogeneous plate deformation, with preferential reactivation of domains in which the pre-existing mantle fabric is oblique to the imposed stresses. This olivine-controlled strain localization may influence the formation of new plate boundaries and explain localized seismicity in intraplate domains.