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Is the strong seismic anisotropy at subduction zones caused by serpentine?

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Seismic anisotropy in the upper mantle is primarily due to the deformation-induced crystal-preferred orientation, and the relation between deformation and crystal-preferred orientation provides a direct constraint on flow geometry in the upper mantle. Trench-parallel anisotropy that show the fast shear-wave propagation direction subparallel to trench has been reported in several subduction zones, however delay time is markedly different in each system, for example, dt ~0.1-0.2 s in northeast Japan (Nakajima and Hasegawa, 2004) but dt ~1-2 s in Ryukyu arc (Long and van der Hilst 2006). The delay time depends on the thickness of anisotropy as well as the strength of the anisotropic media. If the anisotropy is caused by crystal-preferred orientation of olivine, the short delay time found in northeast Japan can is consistent with a relatively thin anisotropy layer (10-20 km thick). In contrast, the larger delay time found in the Ryukyu arc cannot be explained by olivine anisotropy even if the whole mantle wedge are anisotropic. Serpentine has much larger crystal anisotropy (AVs ~30%; Kern et al. 1997; Watanabe et al. 2007), which is approximately one order of magnitude stronger than olivine, and therefore the strong anisotropy in the Ryukyu arc can be caused by crystal-preferred orientation of serpentine. In order to test this hypothesis, we performed deformation experiments of serpentine using solid-medium deformation apparatus. Experiments are carried out at P=1GPa, T=400-500oC at constant strain-rates ranging 1.3x10-4 to 2.1x10-4 s-1. Starting materials are sandwiched by alumina pistons that cut at 45o from the maximum compression direction. We measured crystal orientation of the deformed serpentines using EBSD, that shows the [100] maximum subparallel to the long-axis of strain ellipsoid and the [001] pole normal to the plane of strain ellipsoid. Since the [001] axis has the slowest seismic velocity, the direction of [001] axis is a key for seismic anisotropy in serpentinites. In the Ryukyu arc, the Philippine Sea plate is subducting beneath the Eurasia plate with ~45o dipping angle, and serpentinization may occur in the forearc mantle due to dehydration in the subducting crustal materials. In such region, deformation is induced by the subducting slab with a dextral sense of shear, and consequently the slowest [001] axis tends to align normal to the plate interface or slightly tilt to continent-ward (depending on finite strain). This results the fast propagate direction normal to the subduction direction, which agrees with the strong trench-parallel anisotropy observed in the Ryukyu arc.