Mineralogy and structure of the shallow mantle wedge: evidence from seismic anisotropy in the Ryukyu Arc and structural petrological studies

*Takayoshi Nagaya[1], Simon Richard Wallis[1], Andrew Walker[2], James Wookey[3], Kazuhiko Ishii[4], Michael Kendall[5]

1. Graduate School of Science, The University of Tokyo, 2. University of Leeds, 3. University of Bristol, 4. Osaka Prefecture University, 5. University of Oxford

The dynamics of hydrated mantle in subduction zones is a key part of understanding recycling of materials from the Earth’ s surface into the deep interior. Antigorite is the main hydrous phase in the forearc mantle and the amount, distribution and alignment of antigorite are essential to understanding anisotropy, strength and fluid transport in this region. Seismic velocities are commonly used to identify antigorite-rich domains. However, antigorite is highly-anisotropic and depending on the seismic ray path, its properties can be very difficult to distinguish from non-hydrated olivine-rich mantle. Here, we utilize this anisotropy and show how an analysis of seismic anisotropy that incorporates measured ray path geometries in the Ryukyu arc can constrain the distribution, orientation and amount of antigorite. The Ryukyu arc is associated with very large s-wave splitting of around 1 s for both local slab and teleseismic events. These observations show the main source of anisotropy is within the mantle wedge. The size of the mantle wedge is insufficient to account for the large delay times by olivine alone and several previous workers have suggested that presence of aligned antigorite is the main cause of the anisotropy. We show that to account for the large delay times requires the presence of foliated antigorite-rich domains with an alignment that changes from vertical to slab-parallel. This orientation change suggests the presence of convective flow in the hydrated forearc mantle, a new insight into this zone that is traditionally considered to rigid block. Our modelling also allows quantitative estimates of the amount and distribution of the antigorite in the forearc. These estimates incorporate various sources of uncertainty including: variations in strength of natural antigorite CPO patterns, the degree of anisotropy caused by the crust, differences due to the method used to estimate seismic anisotropy from rock texture, and the model used to estimate anisotropy from the recorded seismicity. We find more than 54 % of the wedge must consist of antigorite. In addition, shear wave splitting analysis in several other subduction zones indicates large-scale serpentinization and forearc mantle convection are likely to be more widespread than generally recognized.

Keywords: Anisotropy, Hydrous forearc mantle, Antigorite, Shear wave splitting, Ryukyu, Crystallographic preferred orientation

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