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Permeability anisotropy of serpentinite and fluid pathway in subduction zone

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Subduction zones are the only sites where water is transported into the Earth's deep interior. Water that is transported into the mantle affects the physical properties of mantle rocks, including their melting temperature and mechanical strength; consequently, the presence of water is believed to influence arc volcanism and seismicity. Permeability is a key parameter in controlling fluid flow in a mantle wedge. Although the fluid released into the wedge is generally believed to ascend under buoyancy, it is possible that fluid movement is influenced by anisotropic permeability in localized shear zones. The mantle rocks at the plate interface of a subducting slab are subjected to non-coaxial stress and commonly develop a strong foliation. Indeed, the existence of foliated serpentinite is indicated by strong seismic anisotropy in the forearc mantle wedge (e.g., Katayama et al. 2009). Therefore, fluid pathways in the mantle wedge may be controlled by the preferred orientation of highly anisotropic minerals. In this symposium, we present results of permeability experiments of highly foliated serpentinites (Kawano et al. 2011).

We used an intra-vessel deformation and fluid flow apparatus housed at Hiroshima University. Permeability measurements were performed using a steady-state flow, which consists of generating a known pore-pressure gradient across the specimen and measuring the flow rate. Under low confining pressure, all the experiments show similar permeability, in the order of 10-19 m2. However, permeability anisotropy appears under high confining pressures, with the specimens oriented parallel to the foliation having higher permeability than those oriented normal to the foliation. At a confining pressure of 50 MPa, the difference in permeability between the samples with contrasting orientations reaches several orders of magnitude, possibly reflecting the pore tortuosity of the highly sheared serpentinite.

The present experimental data show that the highly foliated serpentinites have a marked permeability anisotropy: consequently, fluid migration is strongly influenced by the orientation of the foliation in the mantle wedge. Serpentine forms in the mantle wedge because of the infiltration of water expelled from the subducting plate, above which deformation is concentrated in a relatively thin layer (e.g., Hilairet and Reynard 2009). In such a case, the water released from the subducting plate migrates along the plate interface. The total flux of fluid expelled from the subducting plate would be expected to result in a thick layer of serpentinized mantle, if the water migrates vertically in the mantle wedge. However, geophysical observations, including seismic tomography and reflection data, have shown that the serpentinized layer is limited to a narrow zone above the subducting plate. These data are consistent with our hypothesis that fluid tends to migrate within the highly sheared serpentinite layer, along the plate interface, rather than vertically upward. The migrating water along the subducting plate boundary may accumulate at the corner of the wedge, which might trigger low-frequency earthquakes due to a pore pressure build-up at the boundary.

Keywords: permeability, serpentinite, fluid migration, subduction zone