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Permeability anisotropy of serpentinite and fluid migration in subduction zones

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Subduction zones are the place where water is transported into the Earth's interior and causes arc volcanism and seismic activities. Subducting slabs release most of the water to the mantle wedge by the dehydration reactions, and the expelled water reacts with mantle rocks, forming serpentinite at the plate interface. The existence of hydrous layer has been detected by low-velocity anomaly and high-Poison's ratio in several subduction zones (Kamiya and Kobayashi 2000 ; Brocher et al. 2003). The migration of water is generally considered to move upward by buoyancy in the mantle. However, if the hydrous layer is extensively deformed, the migration of water can be controlled by the deformation plane within such layer. In order to test this hypothesis, we analyzed the permeability anisotropy of serpentinite with a strongly-developed schistosity and discuss fluid migration in the subduction systems.

Serpentinite samples were collected from Nishisonogi metamorphic terrane in Nagasaki, which schistosity is well-defined developed. Two types of experimental samples were prepared: one is parallel to schistosity and the other is perpendicular. We used intra-vessel deformation and fluid-flow apparatus (IVA) in Hiroshima University to measure the permeability. In this study, we measured gas permeability using nitrogen gas and water permeability under isotropic pressure. Gas permeability was measured using the constant flow method, and water permeability was similar to gas and the transient pulse method was also used. The experiments were conducted at confining pressures up to 50 MPa, pore pressures up to 8 MPa at room temperature. We converted gas permeability to intrinsic permeability with Klinkenberg effect.

The permeability decreased with increasing confining pressure, and intrinsic permeability of samples parallel to schistosity were about $10^{-20}m^2$at confining pressure of 50 MPa. We observed two types of pressure effect: one is significant decline due to crack filling at low-pressure and the other is a gradual decline due to crystal grain boundary consolidation at high-pressure. Intrinsic permeability for sample perpendicular to schistosity was about 100 times lower than that parallel to schistosity. Experimental data shows that fluid migration was influenced by not only water buoyancy but also by the schistosity of the rock (deformation geometry). In that case, released water from subducting oceanic slab can be migrated along plate interfaces and result extensive hydration.

Keywords: serpentinite, permeability, subduction zone, fluid migration