Modeling fluid migration in deep crust with modeled permeability based on wettability and energy consideration

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Under the high-temperature and high-pressure system in deep crustal setting, it is considered that fluid flows through deformative polycrystalline solid [1]. Here, the solid–liquid dihedral angle which express the wettability of the system is considered to be an important factor in determining internal pore structure, and hence, permeability [2, 3]. The pore structure is formed so as to satisfy texturally and energetically stable conditions under certain dihedral angle and fluid fraction [2, 3].

We constructed a permeability model to formulate a relationship among dihedral angle, permeability and fluid fraction by taking into consideration the textural and energetic conditions. The model is based on the assumption that there exists a fluid fraction to minimize grain boundary interfacial energy under certain dihedral angle [3]. We calculated the fluid fraction and the permeability under the "minimum" interfacial energy condition as a function of dihedral angle. The generalized permeability was described as functions of the permeability and the fluid fraction under the "minimum" interfacial energy condition.

We numerically calculated fluid migration processes by applying the modeled permeability to the governing equations formulating both solid deformation and fluid flow through polycrystalline solid. We found that fluid fraction increased with decreasing permeability in the case that the change of dihedral angle was inversely proportional to depth. By setting the solid bulk/shear viscosity to be 10^{20} Pa•s, fluid fraction showed repeated fluctuation. Consequently, intervals with relatively high fluid fraction were formed. Moreover, flow regime drastically changed depending on the solid bulk/shear viscosity. Our result emphasizes the importance of wettability and spatial heterogeneity of deep crust on the fluid flow processes.

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A new mechanism for transport of water into CMB

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Water circulation in global Earth is one of the most important issues in geodynamics, because water can affect the physical properties including rheological property of the Earth's materials [1]. Several hydrous minerals in subducting slabs work as water carriers or reservoirs under the conditions of the upper mantle and transition zone [2]. However, it has been debated whether water can be transported into the lower mantle and core [2]. Dehydrated water in subducting oceanic crusts by decomposition of lawsonite may be trapped as a pore fluid because of a high wetting angle between garnet and water, thus resulting in coexistence of water and aluminous $MgSiO_3$ perovskite, which is the major mineral in the subducting oceanic crust [3]. Here we report a new mechanism for water transport into the lower mantle and core, i.e., a reaction between aluminous perovskite and water to form alumina-depleted perovskite and δ-AlOOH [4] along the slab and mantle geotherms under the lower mantle conditions. δ-AlOOH coexists with the aluminous $MgSiO_3$ perovskite and post-perovskite phases in the $MgSiO_3$–Al_2O_3–H_2O system along the slab and mantle geotherms in the lower mantle. Chemical analysis of these phases revealed that the perovskite and post-perovskite phases were depleted in Al_2O_3. Our results demonstrate the coexistence of alumina-depleted $MgSiO_3$ perovskite or post-perovskite phase and Mg, Si-bearing δ-AlOOH phase in wet slabs subducting in the lower mantle. Thus, Mg, Si-bearing δ-AlOOH phase thus formed transports hydrogen into the core-mantle boundary (CMB) region.

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