Grain growth-induced fluid localization and permeability reduction

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Efficiency of segregation of geological fluids such as aqueous fluids and melts is an essential elementary process for volatile cycles in subduction zones. Permeability is an intrinsic rock property that controls flow rate of fluid. Various permeability models have been presented by numerical models of textually equilibrated rocks (e.g. 1, 2), laboratory measurements on synthetic rocks (e.g. 3) and estimation from cross-sectional area of synthetic rocks (4). However, there exist discrepancies among those models. Because permeability is very sensitive to microscopic geometry of pore fluid, those disagreements may arise from lack of understanding toward three-dimensional (3D) microstructure of fluid network.

Dihedral angle has been considered to be a critical parameter that controls fluid geometry and thus permeability. Beside, some previous studies shed light on the effect of grain growth on fluid distribution because it could induce pore fluid distortion and coalescence (5, 6). These studies suggest that in the actual systems where the microstructure of rocks evolve in dynamic processes, grain growth would be important along with the dihedral angle.

To investigate the effect of grain growth on the fluid distribution and permeability, we present 3D images of quartz–CHO fluid aggregates, containing nominal fluid fractions between 0.03 and 0.10. Samples were synthesized from a powdered mixture of Arkansus quartz and amorphous silica prepared by sol-gel method and hot-pressed in a piston–cylinder apparatus at 900°C and 1.0 GPa for 192h. The fluid fractions and the dihedral angles were controlled using brucite added in the capsule bottom and oxalic acid dihydrate mixed with SiO_2 powder. 3D images were obtained using synchrotron X-ray microtomography at BL20XU experimental hutch2 of SPring-8. Regardless of dihedral angles (CO_2 content in fluids), both cross-sectional area and 3D images of samples showed grain-scale fluid localization which would be formed by pore fluid coalescence induced by grain growth. Computed permeabilities using numerical model, LaMEM (7) were almost consistent with laboratory measurements by (3) but more than one order of magnitude lower than a numerical model by (2). This would indicate that localized fluids extensively reduce permeability by reducing the diameter of fluid tubes along grain edges, which would suggest transport of water into Earth’s deep interior by the subducting slab.

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