Fluid segregation and cementation in undrained rocks invoked by poroelasticity

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Fluid segregation from rocks is a significant elementary process to enhance material transport and change the physical properties of rocks. Fluid flow driven by gravity is a dominant segregation mechanism, while chemical redistribution with solids via diffusion becomes prominent after the pore fluids practically lose the interconnection for advective flow. We simulated spontaneous fluid enrichment and pore cementation in undrained quartzite in a series of piston-cylinder experiments. The difference in poroelastic response between the initially fluid-rich and -poor domains was the driving force, which invoked the difference in pore-fluid pressure and thus silica solubility. This "poroelastic cementation" will be effective in fluid-bearing rocks where fluid fraction and lithology are heterogeneous. Although the length scale of diffusional transport is limited, the growing fluid fraction may form additional fluid segregation pathways and drive the pore fluids out of the rocks.
We fit the experimental results with a porosity evolution model under fluid pressure difference. The time-averaged flux between the fluid-rich (10%) and -poor (1%) domains was comparable to silica diffusivity in aqueous fluid with a fluid fraction of 0.1%. To investigate the effect of rheological properties of minerals on the efficiency of poroelastic cementation, we calculated the cementation rate and relaxation timescale for quartzite and garnetite in subduction zone settings. We found that the poroelastic cementation was effective in garnetite at lower temperature conditions despite the reduced diffusivity because of the extended relaxation. The poroelastic cementation may explain the formation of veins with <~cm width within ~1.0×10^4–1.0×10^7 years from layered rocks without differential stress. It may contribute to the final stage segregation of fluids retained in the pores of subducting rocks with initial elasticity heterogeneity with less than 30–40 cm.

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