Fluid segregation and chemical compaction through efficient solute transport along wet grain boundaries

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Segregation of geological fluids such as supercritical aqueous fluids and silicate melts is an essential elementary process for volatile cycles in subduction zones. To explain the mechanism of fluid segregation, various processes have been examined including matrix deformation¹,², interfacial tension driven fluid redistribution³,⁴,⁵ and melt rock reaction⁶,⁷. A common feature in these processes is that fluid migrates through interconnected networks along the grain boundaries and channels. In this presentation, we will report a model of efficient fluid segregation which occurs without fluid interconnections.

The CHO fluid-bearing quartz aggregates were synthesized with nominal fluid fractions between 0 and 0.18 from powdered mixture of Arkansas quartz and amorphous silica prepared by sol-gel method. The mixture was hot-pressing in a piston–cylinder apparatus at 900°C and 1.0 GPa for 24–382 hours for $X_{\text{CO}_2} = 0–0.44$. The recovered run products were imaged with synchrotron X-ray microtomography and the porosity was measured. The quartzites with high initially added fluid fraction ($\phi_{\text{add}} > 0.056$) tend to consist of fluid rich section and fluid poor section, which irrelevently locate to top and bottom of the run products. The fluid poor sections retained very small fluid fractions (< 0.01) regardless of the high added fluid fraction. Partially deformed platinum sleeves and nickel capsules demonstrate that fluids were squeezed out from this region at the initial stage of the segregation. This deformation-assisted fluid segregation would continue until the fluid interconnection was pinched off. The pinch-off fluid fractions of our samples were 0.031–0.037 for $X_{\text{CO}_2} = 0$ and 0.044–0.048 for $X_{\text{CO}_2} = 0.28–0.44$, implying the occurrence of the second stage fluid segregation to form the very dense section of quartzite after the deformation. We calculated diffusive flux of the dissolved SiO₂ driven by the difference in the fluid pressure between the fluid rich section and the fluid poor section that lacks fluid interconnection considering the matrix viscosity. We found that the silica flux from the fluid poor to rich sections was $10^5$ times larger than that expected from the reported grain boundary diffusivity. Our results imply that efficiency of the fluid segregation through silica redistribution along the wet or transient grain boundaries is comparable to the fluid segregation along interconnected fluid networks driven by interfacial tension⁸ and deformation⁹ when the spatial scale is less than ~0.1 meter.

Reference:
experiments on partially molten mantle rocks. Geology, 43, 575–578.


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