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Permeability despite extensive carbon mineralization: field and experimental insights on reactive porosity renewal in listvenites

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Strategies of underground carbon mineralization by CO_2 injection into ultramafic rocks face a major conundrum beyond kinetic challenges: carbonation of Mg-silicates in most cases is volume-increasing. Thus, the desired outcome –carbonate precipitation– can clog fluid flow pathways and strongly self-limit the carbonation efficiency. Natural decameter-scale carbonation reaction fronts pose a similar question: the reaction products need to remain permeable despite precipitation and volume expansion. Here we present field and experimental insights on the renewal of porosity in listvenites. Listvenites are ultramafic rocks fully transformed into carbonate–quartz, involving a 20 – 60 % volume increase relative to serpentinite and peridotite, respectively.

Listvenites from the Baie Verte ophiolite, Newfoundland [1], show pervasive and localized processes of porosity renewal. Pervasive pressure solution is evident in ~10 m wide domains consisting of nearly pure magnesite with abundant stylolite seams enriched in insoluble Cr-rich mica. These rocks formed by preferential quartz dissolution, consistent with thermodynamic models of continuous CO_2-bearing fluid flow at high temperature (~300°C) and orders of magnitude higher cumulative fluid-rock ratios (*f/r*) than the required minimum for listvenite formation. Furthermore, H_2O-dominated fluids locally infiltrated some listvenite zones, indicated by decarbonation of quartz–magnesite to talc along micro-scale shear planes.

We observe a similar process in deformation experiments performed on listvenite gouges at 300°C, 250 MPa normal stress and 100 MPa pore pressure [2]. Along closely spaced *P*-shears, quartz–magnesite back-reacted to talc + CO_2 due to disequilibrium with the H_2O-rich pore fluid, requiring a local *f/r* >13. Notably, this causes characteristic fluctuations in friction coefficients that are likely due to nm-scale back-slip events during local CO_2 release, volume decrease and replenishment of H_2O pore fluid.

Thus, permeability in listvenite can be renewed particularly along deformation zones that act as fluid pumps. However, seismic risks make induced carbon mineralization in active fault zones challenging. Decarbonation triggered by H_2O-rich fluid, as observed here, may be applicable to temporarily re-open flow paths, increasing the efficiency of water-alternating-gas cycling strategies for CO_2-injection.

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References

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