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The influence of reaction conditions on the generation and evolution of mineral porosity during dissolution-precipitation mineral replacement reactions

FANG XIA[1], MUHAMMET KARTAL[2] AND ANDREW PUTNIS[2,3,4]

[1]Murdoch University
[2]Harry Butler Institute, Murdoch University
[3]The Institute for Geoscience Research, Curtin University
[4]Institut für Mineralogie, University of Münster

Presenting Author: f.xia@murdoch.edu.au

The permeability of many rocks is very low but can increase dramatically due to the formation of connected porosity during coupled dissolution-precipitation mineral replacement reactions. Such reaction-induced porosity can evolve with time in a rather complicated way, and a full understanding of the phenomenon requires quantitative analyses of porosity and microstructure as a function of reaction time and condition. In this experimental study, we use quantitative electron microscopy and nano- and micro-tomography to show strong dependence of the behaviour of porosity generation and evolution on mineral system and reaction conditions. In the replacement of pentlandite by violarite, permeable nanopores were formed at 125 °C and pH 4, leading to complete replacement of pentlandite; these nanopores coarsened slowly during the 17 months of experiment and occurred preferentially near the grain surface. In experiments conducted at 125 °C and pH 5, however, violarite became impermeable in partially replaced grains due to hematite precipitation in the pore space. In the replacement of calcite by calcium sulphates, the experiments at 25-60 °C produced intragranular nanopores in gypsum replacing calcite and intergranular micropores due to gypsum overgrowth on the grain surface. Porosity coarsening occurred in a few weeks, leading to the formation of micro-voids in the core of gypsum grains. The experiments at 220 °C produced anhydrite with different porosity evolution behaviour compared to gypsum at lower temperatures. Fundamentally, these complex porosity evolution phenomena are controlled by the interplay between dissolution, precipitation, epitaxial nucleation, Ostwald ripening processes which are all sensitive to reaction conditions and mineral system.