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X-ray microtomography imaging of abiotic carbonate precipitation in sands and its effect on permeability of sands

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Calcium carbonate (CaCO3) precipitation is a frequently-occurring natural subsurface process, in which supersaturated CaCO3 in brine can precipitate in subsurface environments. This phenomenon can naturally occur as part of diagenesis of rocks and can also be utilized for soil improvement. This study explored abiotic carbonate precipitation in coarse sands using X-ray microtomography (X-ray μCT) and examined its effect on permeability. CaCO3 was abiotically precipitated in a sand column, where brine supersaturated with CaCO3 was flowed into the column while controlling pH. During precipitation, the variations in porosity and pore saturation of precipitated carbonate were monitored by measuring the bulk mass of the test column. At the same time, the variation in permeability of the sand column was also measured using the falling-head permeability test. The pore-scale morphological pattern of carbonate precipitation was also examined by using X-ray μCT, imaging the interior structure of the cemented sand. Reductions in porosity and permeability and an increase in CaCO3 saturation were confirmed from the bulk mass measurement. The acquired X-ray images also showed that the precipitated CaCO3 usually coated sand grains. The porosity and CaCO3 saturation values were computed from the obtained X-ray images, and these values were validated against the bulk mass measurement. Further, the measured permeability was compared with the predicted values by Kozeny-Carman model and Kozeny-grain coating model. It indicated that the local porosity reduction, internal porosity within carbonate minerals, and the specific surface area had pronounced effects on the permeability reduction. Meanwhile, existence of of sub-voxel size carbonate crystals is found to act as limitation in the voxel-scale flow simulation.

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