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Self-similar evolution of stress distributions in a porous limestone under dissolution

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The heterogeneous spatial distribution of pore space within a porous rock leads to a strong heterogeneity in fluid flow rates and in the stress distribution in the rock mass. In this work, we consider a limestone sample that has undergone several steps of dissolution, which at each step has been scanned by 3D X-ray tomography. We calculate numerically at each step the coupled system of steady-state fluid flow in the pore space and elasticity in the solid. We quantify by using probability density functions (PDFs) the effect of the fluid flow field upon the stress distribution both at the pore wall surface and in the solid rock matrix. We find that, during dissolution, the distributions of stress evolve in a self-similar manner as the porosity is increased. Moreover, the PDFs display heavy tails towards large stresses. The common master curves offer a unified description of the stress for a rock with evolving microstructure, and if the results can be generalized to other porous media, they may provide an additional explanation of the sensitivity to failure of porous rocks under small changes of stress.