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Influence of initial aperture field under varied in-situ stress conditions on incipient karst formation in carbonate rocks

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We use numerical simulations to investigate the role of initial aperture heterogeneity under varied in-situ stress loadings in the early-time karstification in an anisotropic natural fracture network. We found that the importance of the stress-dependent initial aperture effect on karstification depends on the relative relationship between the flow direction and structural hierarchy/anisotropy of the fracture network. When the flow occurs in the direction of the dominant fracture set with more through-going discontinuities, karst conduits only develop locally along a few large fractures with a preferential orientation for frictional sliding under the differential stress due to enhanced transmissivity caused by the important shear-induced dilation. In contrast, when flow is in the direction transverse to the dominant fracture set, the far-field stress loading has a negligible impact on the emergent dissolution pattern while only somewhat impact on the onset time of breakthrough. In this case, the developed conduits are much more tortuous with numerous branches. In both cases, the presence of initial aperture variability enhances the stress effects and significantly changes the dissolution pattern and delays the breakthrough time. Our results demonstrate that the flow heterogeneity induced by geometrical complexities and in-situ stress conditions seems to play an essential role in the karstification processes in fractured rocks.

The proposed reactive transport model based on realistic fracture networks may be used to investigate the spatial relationship between tectonic structures and karst cavities. Our results demonstrate that the heterogeneity induced by geometrical complexities and in-situ stress conditions may play a decisive role in the karstification processes in fractured rocks. Thus, they must be properly considered in reactive transport simulations to make reliable designs for practical engineering applications.

Keywords: discrete fracture network, karst, network topology, reactive flow, in-situ stress