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Influence of stress on incipient karst generation in natural fracture networks

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We develop a new numerical model that couples hydraulic, mechanical and chemical processes to investigate the dynamic influence of stress on incipient karst formation in natural fracture networks. Our geological models are constructed based on realistic fracture patterns mapped from outcrops, which capture a wide range of spatial distribution and organization of carbonate fracture networks. We simulate the dissolutional growth of karst conduits in the fractured formation under varied initial aperture distribution and in-situ stress loading. We found that the impact of the stress effect on karstification depends on the relative relationship between the flow direction and the structural anisotropy of the fracture network. When the flow occurs in the direction corresponding to the most continuous fracture network structures, karst conduits only develop locally along a few long fractures with an orientation favorable to frictional sliding under the differential stress. Indeed, the important shear-induced dilation of these fractures generates a higher aperture and thus hydraulic conductivity. In contrast, when flow is in the direction transverse to the most continuous fractures, the far-field stress loading has a negligible impact on the emergent dissolution pattern but a perceptible impact on the onset time of breakthrough. In this later case, the developed conduits are much more tortuous with many branches. In both cases, the presence of initial aperture variability facilitates the development of a uniform dissolution front and therefore delays breakthrough. Our results demonstrate that the heterogeneity induced by geometrical complexities, enhanced by in-situ stress conditions, may play a decisive role on the karstification processes in fractured rocks. The results from this research provide important insights into the spatial relationship between tectonic structures, geomechanical constraints and karstogenesis.