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Spontaneous channel formation in dissolving rock fractures and its effect on early development of karst conduits

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A dissolution front in a single rock fracture may become unstable to small variations in local permeability, leading to spontaneous formation of wormhole-like channels. These channels have a very high flow rate and can carry an under-saturated solution deep into the fracture, thus dramatically increasing the conduit growth rate. Numerical simulations are used to study conditions under which wormholes form in various fracture geometries. The effects of flow rate and mineral dissolution rate are investigated numerically and optimal conditions for channel formation determined. The timescales for solutional widening of initially narrow fissures are compared with those obtained with a simple one-dimensional model of fracture dissolution. One-dimensional models, in which the fracture aperture is assumed to depend only on the distance from the inlet, are frequently used in quantitative assessments of conduit growth. Although analytically tractable, such models cannot account for wormhole formation and thus their results need to be critically reassessed. Wormholing, if present, leads to a dramatic decrease of fissure widening times, since the flow becomes focused in highly permeable channels, which transport the reactants and products very efficiently. These effects should be taken into account not only in the estimation of karstification times but also in the assessement of ground subsidence, dam collapse or toxic seepage risks.