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Competition of wormholes during the evolution of cave passages

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Reactive fronts in two-dimensional plane parallel fractures, with constant head difference between input and output and with diffusion controlled first order reaction rates $R = k_{eff} \cdot (C_{eq} - C)$, where $k_{eff} = k \cdot (1 + ka/6D)^{-1}$, are instable to infinitesimal perturbations in fracture aperture width (1), causing spontaneous fingering of the reactive front resulting in the formation of wormholes. C is the actual concentration and C_{eq} the equilibrium concentration, a, is the actual aperture width of the fracture , and D the constant of molecular diffusion. Fingering happens also in plane-parallel rough fractures where it is triggered by the existence of statistically more favorable pathways. The same behavior is observed in rectangular two-dimensional networks of "one-dimensional" smooth fractures used in modeling the evolution of caves in soluble rock (2). Here the formation of caves can be regarded as the evolution of wormholes along the two-dimensional network.

Once fingering has been triggered, either by instability or by roughness, many small fingers compete with each other and only a few survive. Here we investigate the competition between two seeded fingers in initially homogeneous fracture networks with identical aperture width of all fractures and also in inhomogeneous ones where the aperture widths are distributed log normally. In both cases our modeling reveals the rules of competition: By instability one of the fingers grows faster than its competitor therefore penetrating somewhat deeper. As a consequence the hydraulic head at its tip is higher than that close to the tip of the shorter finger. Therefore the fractures connecting the tip regions of both fingers carry flow from the deep finger to the tip region of its competitor. This cross-flow is replaced by increasing inflow of aggressive solution into the input of the winner, enhancing further dissolution and growth. On the other hand the cross-flow increases the head at the tip of the losing finger, and consequently decreases inflow of aggressive solution into it, thus inhibiting its further evolution. This mechanism supports further growth of the winner (wormhole) and stops the growth of its competitor. Similar competition happens in the case of several fingers competing. In any case we observe flow from the winning fingers to the loosing ones. The communication between the competitors is always established by cross flow between its tip regions.

We will present various scenarios of wormhole formation, which demonstrate details of the competition of fingers arising from either the reactive instability or from the statistical distribution of fracture aperture widths.

In conclusion we find that the initiation of wormholes results either from instability or from the statistical distribution of favorable pathways. Once growth of fingers has been initiated the evolution of the wormhole patterns becomes deterministic.

(1) Szymczak, P., and A.J.C. Ladd (2011), The initial stages of cave formation: Beyond the one-dimensional paradigm, Earth Planet. Sci. Lett. 301, 424-432

(2) Dreybrodt, W., Gabrovšek, F., Romanov, D.(2005) Processes of Speleogenesis: A Modeling Approach. ZRC Publishing, Karst Research Institute at ZRC SAZU, Ljubljana