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Core-scale description of the growth of wormholing zone in dissolving fractures and porous media

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At sufficiently high flow rates, the dissolution front in fractured and porous rocks becomes unstable, with formation of localized flow paths called wormholes [1]. The dynamics of wormhole growth is highly complex, with incessant merging, fading, shielding, and tip splitting of individual wormholes. No detailed quantitative characterization of this nonlinear dynamics has been provided yet.

In this communication, we study the growth of the wormholing zone by a combination of experimental and theoretical methods. The experimental work is performed using a simple microfluidic setup, with a gypsum block inserted in between two polycarbonate plates, dissolved by inflowing water [2]. Despite the overall chaotic character of wormhole growth, we find a number of remarkable regularities in their dynamics. First, the tip of the longest wormhole (leading edge) is advancing with a constant velocity, U. Second, the trailing sections of the interface also move with a constant velocity, V, with V<U. At the same time, the width of the wormholes increases as a square root of time. These features are reminiscent of the growth of the mixing zone in miscible displacement of a more viscous fluid by a less viscous one [3]. Inspired by these similarities, we have formulated a two-fluid model of the evolution of the wormholing zone, where the dissolved phase is treated as the invading fluid and undissolved phase - as the displaced fluid. The model predicts the profiles of the mean porosity (averaged along the direction transverse to the flow) which agree well with the experimental ones. These results lay the groundwork for prediction of the growth velocity of the wormholes across a variety of different system, allowing for the effective estimation of the breakthrough time, i. e. the time at which the dissolution reaches the outlet of the system. This is important for a number of engineering applications, such as dam stability assessment, leakage of sequestered CO_2, and stimulation of petroleum reservoirs.

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