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Tracking rock dissolution with synchrotron-based high-speed, high-resolution 4D X-ray tomography

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During the flow of a matrix-dissolving fluid through porous media, positive feedback between flow and reaction generates diverse, evolving structures [1]. These range from intricate, cave-like wormholes to simple surface dissolution patterns. The dynamics of this hydrochemical instability depend on both flow rate and the geometric properties of the pore space. While the effects of flow and reaction rates on wormhole formation are well established [2], the mechanisms governing their propagation dynamics remain poorly understood.

This study investigates the fast-progressing dominant wormhole regime, which has applications in various industrial and natural contexts, including carbon capture and storage. Understanding the dynamics of fluid interaction with the porous matrix requires high-resolution temporal and spatial data. We have recently conducted in-situ X-ray micro-CT imaging of developing wormholes in dissolving limestone cores flooded with hydrochloric acid, achieving high temporal frequencies (50–100 frames per experiment) [3]. To further improve temporal and spatial resolution, we utilized the ID-19 beamline at the European Synchrotron Radiation Facility. A limestone core was confined in a Hassler cell and flooded with hydrochloric acid, while high-frequency 4D tomographic data tracked the evolving 3D shape of the growing wormhole. The time evolution of the wormhole profile has been compared with an analytical model of the growth of the tube-like dissolution structure [4]. As we show, such data, when properly interpreted, allow for a measurement of the mineral dissolution rate constant and the assessment of the impact of diffusive transport on the dissolution process.

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Primary authors: Dr DZIKOWSKI, Michał (Faculty of Physics, University of Warsaw); Prof. SZYMCZAK, Piotr (Faculty of Physics, University of Warsaw)

Co-authors: Dr MAJKUT, Marta (European Synchrotron Radiation Facility); Dr KOSIŃSKI, Tymoteusz (Department of Nuclear Techniques and Equipment, National Centre for Nuclear Research); Mr WOŚ, Dawid (Faculty of Physics, University of Warsaw)

Presenter: Dr DZIKOWSKI, Michał (Faculty of Physics, University of Warsaw)

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