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Dynamics of water films during wetting and drying cycles in porous media

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Wetting and drying cycles in porous media are encountered in many natural systems, as well as engineered systems. Soils are exposed to these cycles many times, as water infiltrates during rain and dries out afterwards. These cycles are also important in cyclic usage of underground reservoirs, for example for storage of natural gas or hydrogen [1]. Important during gas storage is to retain a high injection or extraction potential from the reservoir. This depends largely on the relative permeability of the liquid and gas phase.

While water largely fills the pores at high saturation, it mostly forms water films on the pore surface of water-wet rocks at lower saturations. These water films swell ahead of the main displacement front during imbibition, and can snap off to cause trapping of gas phase clusters in the pore space [2]. The films can also evaporate into dry gas and precipitate minerals that exceed the saturation limit onto the pore surface [3]. This can eventually lead to blocking of pore connections and decrease well injectivity [4]. In porous soils containing clays, wetting and drying cycles can lead to expansion or shrinkage of the medium itself, leading to a change in mechanical behavior of the soil [5].

In order to understand the likelihood of events such as snap-off or mineral precipitation in porous media, it is crucial to know how the water films are distributed on the rock surface during displacement processes. Since these water films can have a thickness of a few microns or less, many imaging techniques, such as micro-computed tomography or optical microscopy are able to capture those, but are limited in quantifying them. Atomic force microscopy (AFM) is able to detect fluid films on nanometer scale [6], and with this technique, we can track their configuration on the rough features of the internal pore surface.

We use AFM to investigate the dynamic behavior of water films in porous rocks during wetting and drying cycles. Using force measurements, we track the thickness of the fluid film on the surface over time and characterize the swelling or shrinkage rate at different locations. We relate the observed dynamics to sub-pore scale events such as triple phase contact point jumps and pore-scale displacement events, which are imaged by dynamic micro-CT (EMCT at Ghent university [7] through the EXCITE network*). This study will give fundamental insights into the role of water films on multiphase displacement processes at different length scales, and can be used for construction of more accurate and physics-based predictive models for multiphase flow in porous media.

Participation

In-Person

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