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Monitoring nano-scale fluid films in porous rock with AFM

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During fluid displacement in porous rock or soils, as they occur in aquifers or other fluid reservoirs such as CO2 or H2 storage sites or hydrocarbon reservoirs, water films form along the internal pore surface of porous rocks due to its wetting properties and capillarity. Near connate water saturation, these water films dominate the macroscopic flow behaviour as observed e.g. in relative permeability experiments.

We use Atomic Force Microscopy (AFM) to study the sub-pore scale configuration of microscale water films on the rough pore surface of Ketton and Estaillades rocks to illustrate the potential of AFM to qualitatively assess the nature of such fluid films at different static and dynamic conditions. Experiments were performed on model systems to test the methodology of AFM fluid film measurements [1]. The static conditions include measurements after drainage, alteration of the surface with crude oil and water flooding. The dynamic conditions include spontaneous imbibition and drying cycles [2]. The experiments were compared to various computational models and macroscopic responses monitored with micro-computed tomography data [2,3].

The results show that the nano-scale water films forming along the internal surface of porous rocks, facilitate corner flow as described by [4] rather than a thin continuous layer of water along the surface frequently assumed [5]. We notice that the water coverage along the pore walls surface shows a variation in continuity and depth depending on the preconditioning of the sample. The results showed that water films can prevail the wetting alteration process. However, only one out of three crudes provided evidence for such water films. The measurements after the water flood further revealed water entrapped by an oil layer as well as regions of different adhesion following a pattern similar to the water distribution observed prior to the wetting alteration. The dynamic scans indicate swelling and shrinkage, which may relate to larger sale pore-scale displacement events in other regions.

The combination of different experimental studies illustrates the capacity of AFM to inform us about the behaviour of nano-scale fluid films during multiphase flow in porous media. Whereas quantitative estimates remain difficult due to the small scanning area, this methodology can provide insights into the mechanisms of fluid film formation, swelling and shrinkage during multiphase flow in porous rock.

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References

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