Analysis of evaporation in a hydrophobic micro-model

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Résumé

1 Introduction
Numerous engineering and environmental applications involve evaporation from a porous medium. In the present work, evaporation is studied in a quasi-two-dimensional micro-model composed of spherical hydrophobic beads of 1 mm in diameter sandwiched between two hydrophobic glass plates with the lower plate coated by a polymeric film (RTV). The study is based on two visualization experiments. In the first experiment, the micro-model is held horizontally and filled with a NaCL aqueous solution at 5% in NaCl mass fraction. In the second experiment, the micromodel is vertical and filled with a solution at 25 % . The consideration of a saline solution is motivated by the study of salt crystallization induced by the evaporation process. However, the focus here is on the drying pattern prior to the occurrence of crystallization.

2. Results

As illustrated in Fig.1, the micromodel orientation, i.e. vertical or horizontal, leads to two markedly different drying patterns. In the horizontal case, invasion by the air as the result of evaporation occurs preferentially in the central region of the micromodel with a well-defined boundary between the gaseous region and the liquid region. In the vertical case, the pattern is characterized by an almost flat travelling front separating the gas region (on top) from the liquid region.

Figure 1: Drying pattern: on the left: horizontal micro-model (gas region in light grey, liquid region in dark grey, the red line corresponds to the boundary between both regions), on the right: vertical micro-model (the blue line corresponds to the boundary between the gas region (lighter grey) and the liquid region (darker grey)).

2 Analysis

The almost flat front in the vertical case is consistent with the expected combined effects of capillarity and gravity in a hydrophobic system. The puzzling pattern is the one observed in the horizontal case. From previous works on drying in hydrophobic systems (1, 2), it is indeed expected that an almost flat travelling front also forms in the horizontal case. In order to explain the observed unexpected pattern, the micromodel is partitioned in eight regions of interest. The porosity, pore body distribution (PSD) and pore throat distribution

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(TSD) are determined in each region of interest thanks to image processing techniques based on the identification of the Delaunay and Voronoi diagram from the centres of the beads in the micro-model (Fig.2).

Figure 2: (a) Zoom of Voronoi tessellation (in blue) and Delaunay triangulation (in red) from beads centres in the micromodel. (b) PSD in the eight regions of interest in the micro-model.

3 Conclusion

This investigation leads to the conclusion that the preferential invasion seen in the experiment is due to a different arrangement of the beads in the region preferentially invaded leading to different pore body and throat size distribution compared to the adjacent regions. In other words, a heterogeneity at larger scale than the bead scale disorder is responsible for the observed pattern in the horizontal case. Thus, the present investigation sheds light on the combined effects of hydrophobicity, gravity, capillarity and large scale disorder on evaporation in porous media. This situation is currently further investigated from pore network simulations on a two-dimensional network.

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References

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