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On NaCl efflorescence formation and growth at the surface of a porous medium

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Rocks or building materials are often altered by the presence of dissolved salts. Salt precipitation is one of the main processes damaging the porous matrix. In this context, our study focuses on salt crystallization which results from evaporation at the surface of porous media. These crystallized salt structures are called efflorescence. Efflorescence is an important issue for the conservation of old paintings and frescoes.

The challenge is to understand why these structures do not form everywhere at the porous medium surface but at some specific locations and why there exists an exclusion distance around an efflorescence structure where no new efflorescence forms. These behaviours are explained from a visualization experiment, pore-network simulations and a simple efflorescence growth model.

A wicking/evaporating experiment is conducted on packings of glass beads ($\sim$1mm diameter) contained in a hollow cylinder. The porous sample is open at the bottom where it is in contact with a brine solution. The upper surface is open to external dry air. In this configuration, the sample remains fully saturated and salt precipitation takes place at the sample surface. This setup is set in an enclosure where temperature is kept constant and dry air is maintained, which imposes a nearly uniform evaporation flux over the sample surface. After a few days of evaporation, efflorescence structures appear, grow and remain discrete, i.e. continue to form individual halite structures.

Simulations with a 3D pore network model enable us to show that discrete location of efflorescence results from small scale heterogeneities of the beads packing. Locally some menisci are connected to smaller pores which enhance salt transport by advection.

The second objective of the study is to understand the mechanism which makes the efflorescence to growth under the form of a set of individual structures. By studying numerically the growth of one efflorescence structure, we observe a global increase of the evaporation rate at the surface of the efflorescence structure as it grows. Moreover the evaporation flux distribution along the surface and in the neighborhood of the cristal also varies during its growth. Evaporation flux increases at the higher part of the efflorescence and decreases at its basis and close by.

As evaporation flux distribution is modified, salt transport inside the efflorescence and under the porous medium surface is also affected. Efflorescence has both a pumping effect, enhancing advection towards its higher part, and a screening effect on its neighborhood and its basis, limiting salt crystallization. These coupled effects can explain why the efflorescence remains discrete at the surface of porous medium.