X-RAY IMAGING OF WEATHERING IN BUILDING STONES

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Summary: Laboratory-based, time-resolved X-ray imaging allows to study the dynamic processes related to stone weathering at the pore scale. The generated 3D data can act as valuable 3D input for pore network models and as an important validation for pore-scale modelling in order to obtain better insights in stone's weathering.

1. INTRODUCTION

Weathering of building stones and the complex interactions between a variety of physical, chemical and biological processes still contains some important open questions. Although these processes have a major effect on the macroscale, the main dynamic processes are occurring on the pore scale inside building stones.

The presence and transport of moisture, one of the most significant environmental factors contributing to stone decay, is influenced by the porous network of the stone. Since this moisture transport is strongly linked to the complex three dimensional pore network (morphology, open or closed porosity, size, connectivity, etc.) inside stones, a quantification of such networks is thus of crucial importance, not only to characterize the stone but also to assess and potentially predict its rate of deterioration.

Little data is available on the direct response of microstructural changes, such as pore structure modifications, on the moisture transport inside the pores. Due to recent developments in X-ray imaging technologies that greatly facilitate measurements of micro-structures in both space and time, it is currently possible to study the fluid flow and pore structure modifications at the pore scale in real time [1,2,3]. This offers the possibility to perform laboratory-based, time-resolved imaging in order to obtain new detailed insights in our understanding of stone weathering. Additionally, this technique can act as 3D input for pore network models and as a valuable validation for pore-scale modeling [4,5].

2. EXPERIMENTAL METHOD

The main examples were generated using the UGCT's environmental micro-CT scanner (EMCT), designed and built in-house [1,6]. This scanner is specially developed to image samples under controlled environmental conditions or during dynamic experiments. This setup has a rotating X-ray source and detector assembly on a gantry, while the sample and its controlling add-on modules remain static. This eliminates problems with flow instabilities and helps to avoid unwanted sample movement during acquisition. The system is equipped with a standard directional microfocus X-ray tube with integrated high-voltage power supply (maximum high voltage 130 kV, maximum power output 39 W, minimum spot size 5 μm). The detector is a CMOS flat-panel detector (1316 by 1312 pixels with a 100 μm pitch) with a thick, structured CsI scintillator. The scanner's source-detector combination, together with the applied smooth-scanning (rather than step-and-shoot) acquisition, allows for fast scanning (currently 12 s per 360° rotation).

3. RESULTS

First, we will shortly discuss the potential workflow for 3D multi-scale characterization of the pore structure [7,8] and how this can be used as input in multi-scale pore network models [5]. Then, some dynamic fluid flow experiments will be illustrated, such as the one in figure 1, with attention towards solute transport, salt crystallization [7], reactive transport and the potential effect of bacteria on transport inside building materials.

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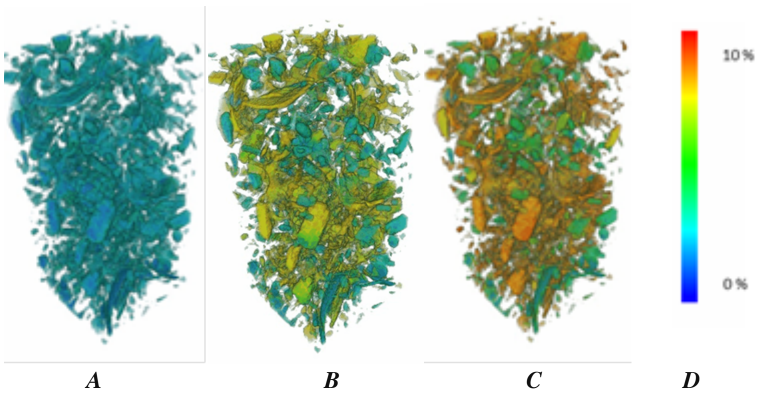

Figure 1: ***3D renderings of solute fluid flow experiment in Savonnières limestone, with condition A: fully water saturated pore network; Condition B: after 60 s of CsCl brine being pumped inside pores, and Condition C at 240 s. In D an indicative CsCl concentration by mass fraction is given (after [1]).***