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Freeze-thaw fracturing in porous limestone

Tim De Kock (1), Maxim Deprez (1), Geert De Schutter (2), and Veerle Cnudde (1)

(1) Ghent University, Geology, Ghent, Belgium (tim.dekock@ugent.be), (2) Ghent University, Magnel Laboratory for Concrete Research, Ghent, Belgium

The pore-scale mechanisms of freeze-thaw weathering are investigated on porous limestone with different moisture content subjected to freeze-thaw cycles by means of temperature logging, dilatation measurements and continuous X-ray radiography and tomography. The results show that dilatation due to fracturing occurs at higher moisture contents at the end of a temperature exotherm, which is taken as a proxy for ice crystallization. 2D radiography reveals the movement of water near the fracture in the minutes during which ice is crystallizing and the fracture is supposed to wedge. Dynamic computed microtomography allows for 3D rendering of the fracture at the time step just before and just after the temperature exotherm. It confirms the development of a fracture along flaws (microfossils in this case) within the rock. These flaws are formed by the alignment of larger (tens of microns) pores surrounded by submicron pores. Moreover the fracture closes during subsequent thawing. These observations suggest that the underpinning mechanism as what is to be expected from most recent theoretical and experimental observations; namely that the (i) ice crystallization pressure is responsible for stress development since the fracture only relaxes after thawing; (ii) ice crystals are formed preferentially in the larger pores where larger ice crystals are thermodynamically more stable and which in this case provide a flaw due to their alignment, (iii) high pressures are built up when ice is forced to grow into smaller surrounding pores (and adopting an according curvature) at higher degrees of undercooling.