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Intense fracturation induced by mineral growth in porous rocks

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When minerals precipitate in the pores of a rock, they may exert a force that depends on the supersaturation of the fluid; this is the so-called force of crystallization. This process happens in a wide range of geological systems, e.g. vein formation in deep crust, frost heave in soils, and salt damage in cultural heritage monuments. Sometimes, the force of crystallization is so large that it leads to a permanent damage and fracturation of the porous medium. Here, we have studied this process experimentally and imaged in 3D how an intense fracture pattern may emerge from purely chemical processes.

Core samples of limestone (22% porosity) and sandstones (19% porosity) were left for one month in contact with an aqueous solution saturated with sodium chloride in an autoclave, at 40°C, under a normal stress in the range 0.2-0.3 MPa. The fluid was allowed to rise in the core samples by capillary forces, up to a height where evaporation occurred. The samples were left in a rubber jacket with the same height as the capillary fringe, allowing therefore an accurate control of the region of water evaporation and salt precipitation. The uniaxial deformation of the samples was measured using high resolution displacement sensors. After the experiments we have imaged the samples in three dimensions, using laboratory computed X-ray tomography, allowing therefore imaging the intensity and localization of the damage, as well as the regions of salt precipitation.

During the initial fluid capillary rise, the deformation measurements indicate a small shortening of the samples ($\tilde{5}$ micrometers), and then an increase of the samples' height (50-100 micrometers) during salt precipitation. Two kinds of damage could be observed in tomography. Firstly, small rock fragments were pealed from the sample surface. Secondly, and more interestingly, a radial fracture network developed, by nucleation of microcracks at the interface where evaporation occurred, and propagation to the free surface. Two families of fractures could be identified: a first set of fracture parallel to the free surfaces explain the inflation of the samples through time, and a second perpendicular network accommodates the first set of fractures. An analytical model where fluid flow is coupled to evaporation and mineral nucleation localization explains the shape of this fracture network.