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chemo-mechanical coupling in water unsaturated domains: capillary tension and crystallization pressure

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Unsaturated zones are widely present in natural systems, such as soils, deep aquifers and building stones under wetting-drying cycles. Such porous media contains the three phases liquid, gas and solid and present specific physico-chemical processes or properties - as soluble salts precipitation or capillary water properties rise - have important impact on environmental issues since they are coupled with mechanical effects. The driving force of both phase transitions and capillarization is the decreasing relative humidity below the saturated value in the atmospheric air contacting the unsaturated materials.
- Decreasing relative humidity leads to evaporation, creating local supersaturation and then driving crystallization. According to the usual theory of crystallization pressure, a confined growing crystal can exert a constraint against the pore wall, leading to its rupture if it exceeds the tensile strength of the pore material. This coupled chemo-mechanical process requires a nano-scale film of solution to hold between the crystal and the pore, which allows the solutes to diffuse and the solution not to precipitate despite increasing supersaturation. The repulsive effect between growing and host solids, ultimately increases the local pressure and may induce the host rupture
- Capillarity has a large occurrence in unsaturated porous media and depends on pore radius and relative humidity of air. The capillary state makes the internal pressure of capillary water can drop down to negative values, meaning it is under tensile state and potentially exert traction on pore wall.

These effects of chemo-mechanical coupling are observed using an experimental approach on three simplified natural analogues: porous membrane, borosilicate microcapillaries, and synthetic fluid inclusions. In the two former samples, sodium sulfates precipitates are induced through wetting-drying cycles and the role of both the capillarity and the crystallization pressure are observed. In the latter samples, a direct measurement of the traction effect of capillary liquid on the host solid has been devised and performed. These experiments make to expect that fatigue processes, well-known in metallurgy, could significantly act in water-bearing minerals.

These experimental results confirm that chemical processes can induce mechanical traction and pressure. There is some evidence that capillary water or a superheated solution, both under negative pressure – so under tensile state - are able to exert traction on substrate.