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Effect of stress on grain boundary wetting and subsequent evolution of rocks

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Grain boundary wetting (GBW) is one of predominant mechanisms of fluid transport through non-porous polycrystalline rocks. Kinetics and topology of GBW are highly sensitive to the stress state at grain boundaries. While compressive stresses normal to a boundary plane may inhibit or even stop its invasion by a wetting liquid, shear and especially tensile stresses enhance it strikingly. In the latter case, GBW often leads to a dramatic weakening of the rock which becomes subject to intergranular pressure solution and/or to fluid-induced failure.

In this contribution, the authors will report experimental and numerical results referring to the intergranular intrusion of fluids into stressed rocks (mainly rock salt and the core from the Kola Superdeep borehole) and model materials, as well as their further evolution under a constant load.

Studying typical orientation patterns of wetted grain boundaries with respect to applied or residual stresses in a number of loading modes allows describing the GBW process on the basis of combined interfacial and mechanical energy considerations. Orientation dependence of GB wettability in a non-hydrostatically stressed polycrystal leads to anisotropy of the structure and properties of resulting medium. The degree of interconnectivity of the network formed by wetted GB's also becomes anisotropic, and under certain conditions a quasi-2D liquid path appears in one direction while it is absent in another. A modification of the percolation theory (oriented percolation) has been used to formulate conditions determining continuous or discontinuous character of internal liquid network. At a greater amount of wetted GB's, a next percolation transition can occur: the continuous solid framework disappears, which usually implies a sharp (often by several orders of magnitude) increase in deformability. Pressure solution becomes the preferential deformation mechanism, involving dissolution at stressed sites, diffusion to stress-free parts and precipitation. Analyzing rheological characteristics of internally wetted rocks requires taking into account increase of available mass transport paths with increasing stress. Adding adsorbing species to the intergranular liquid has been shown to decrease significantly the strain rate, which can be used as a method for controlling liquid-enhanced creep rate in long term nuclear waste repositories.