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Experimental study of visco-elasto-plastic deformation of sedimentary rocks

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It is known that understanding of long-term hydrocarbon recovery or CO₂ storage problems depend on proper addressing the physical coupling between the fluid flow and mechanical deformation. The success of geo-energy applications such as hydraulic fracturing, wellbore stability, and geological storage of CO₂ is directly connected to the comprehensive formulation of appropriate rock rheology. Effective viscosity is an important parameter that allows to couple fluid flow and deformation processes occurring in the Earth. However, this parameter is rarely measured in the laboratories as it is a challenging task. Moreover, few existing measurements were made in the compaction regime and make no reckoning of decompaction. However, decompaction may affect fluid flow distribution in a porous medium and create highly porous channels such as chimneys observed in the subsea reservoirs and caprocks. In this study, we present results of multistage laboratory creep and relaxation experiments that were conducted on different materials including artificial specimens, limestones, heterogeneous shales with sandstone inclusions, and pure sandstones and shales. Both compaction and (de)compaction regimes were considered. We studied the influence of historical changes in the thermal regime during the glaciation and deglaciation cycles, water saturation, preliminary damage of the samples on their viscous behavior. The first stage of the experiment is the initial fast loading to dilation point, where the transition from compaction to dilatancy occurs. The second stage is a purely viscous creep. The third stage is the stress relaxation phase. During the fourth stage, repeated cycles of fast visco-elasto-plastic loading/ unloading were conducted. Effective viscosity was calculated for all samples. Experimental curves are explained using the theoretical model for visco-elasto-plastic (de)compaction of porous rocks.