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Time-dependent deformation of gas shales – role of rock framework versus reservoir fluids

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Hydraulic fracturing operations are generally performed to achieve a fast, drastic increase of permeability and production rates. Although modeling of the underlying short-term mechanical response has proven successful via conventional geomechanical approaches, predicting long-term behavior is still challenging as the formation interacts physically and chemically with the fluids present in-situ. Recent experimental work has shown that shale samples subjected to a change in effective stress deform in a time-dependent manner (“creep”). Although the magnitude and nature of this behavior is strongly related to the composition and texture of the sample, also the choice of fluid used in the experiments affects the total strain response - strongly adsorbing fluids result in more, recoverable creep. The processes underlying time-dependent deformation of shales under in-situ stresses, and the long-term impact on reservoir performance, are at present poorly understood.

In this contribution, we report triaxial mechanical tests, and theoretical/thermodynamic modeling work with the aim to identify and describe the main mechanisms that control time-dependent deformation of gas shales. In particular, we focus on the role of the shale solid framework versus the type and pressure of the present pore fluid. Our experiments were mainly performed on Eagle Ford Shale samples. The samples were subjected to cycles of loading and unloading, first in the dry state, and then again after equilibrating them with (adsorbing) CO_2 and (non-adsorbing) He at fluid pressures of 4 MPa. Stresses were chosen close to those persisting under in-situ conditions.

The results of our tests demonstrate that likely two main types of deformation mechanisms operate that relate to a) the presence of microfractures as a dominating feature in the solid framework of the shale, and b) the adsorbing potential of fluids present in the nanoscale voids of the shale. To explain the role of adsorption in the observed compaction creep, we postulate a serial coupling between 1) stress-driven desorption of the fluid species, 2) diffusion of the desorbed species out of the solid, and 3) consequent shrinkage. We propose a model in which the total shrinkage of the solid (Step 3) that is measured as bulk compaction, is driven by a change in stress state (Step 1), and evolves in time controlled by the diffusion characteristics of the system (Step 2). Our experimental and modeling study shows that both the nature of the solid framework of the shale, as well as the type and pressure of pore fluids affect the long-term in-situ mechanical behavior of gas shale reservoirs.