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Creep strain heterogeneity in Green River shale using synchrotron X-ray microtomography

Cecilia S. N. Cheung, Hiroki Sone, Mark L. Rivers, Yabin Wang, Tony Yu

Accurate knowledge about the time-dependent constitutive behavior of geological materials is essential when forecasting the production potential of shale reservoirs or evaluating the long-term seal integrity of a subsurface waste repository. To this end, it is not only important to measure the bulk time-dependent behavior of the rock, but also important to understand the microscale mechanism responsible for the bulk behavior in order to predict the long-term behavior from limited information about the rock. We conducted creep experiments using Green River shale samples while obtaining synchrotron X-ray tomographic images (GSECARS 13BM-D) in order to capture the microscale strain-partitioning that occurs within the sample. Cylindrical shale samples of 2-3 millimeter diameter and height were stressed up to 45 MPa by small deformational apparatus with an X-ray transparent load frame, after which the load was held constant to allow creep deformation for up to 4 months. Tomographic images of about 2-micron resolution were reconstructed from images collected at different timings of the experiment, which allowed us to analyze where the rock is deforming with the aid of volumetric image registration. Displacement fields and strain fields recovered from the analysis showed that both elastic and creep strain was larger at organic rich portions. Elastic constants calculated from the stress and strain magnitudes agree with measurements with larger samples by conventional methods. The creep compliance estimated from the results is also in general agreement with values measured from larger samples. Our results also confirm the model of composite layers is a good prediction for isostress and isostrain conditions in vertical and horizontal bedding samples, respectively.