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Technical Conference Paper

1965 – 2025

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SMRI Spring 2025 Technical Conference
27-29 April 2025
Wilhelmshaven, Germany

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Abstract

Understanding the mechanical behaviour of heterogeneous rock salt is critical for ensuring the stability of mining operations, including cavern abandonment and the post-abandonment phase. While high-stress experiments emphasize dislocation creep, low-stress creep tests reveal unexpectedly high strain rates, highlighting the role of pressure solution creep. However, such tests require months to years to reach steady-state conditions or rely on extrapolations from high-temperature experiments and are limited by the size constraints of representative natural samples. To address these challenges, we present a two-stage 3D Digital Twin approach. High-resolution CT imaging and machine learning were used to generate digital microstructure models (Schmatz et al., same submission), which were subjected to advanced thermal-hydromechanical simulations replicating low-stress uniaxial creep tests (Bérest et al., 2019). Validation against physical experiments showed strong agreement at σ_d = 3 MPa (435.1 PSI), with Bayesian-derived creep rate estimates. Simulations at σ_d = 0.6 MPa (87.0 PSI) fell within uncertainty limits, underscoring the complexity of modelling deformation at very low stresses. Microstructural heterogeneities, such as grain size variations and impurities, significantly influenced strain localization, which remains obscured in physical tests. This study demonstrates the feasibility of the digital twin approach for accelerating low-stress creep rate determination. By supplementing physical experiments with high-resolution numerical simulations, this approach provides enhanced data density for developing site-specific creep laws and improving long-term stability predictions for salt mining operations.

Key words: 3D numerical models, digital twins, creep experiments, pressure solution creep