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Role of impurities within the salt layers on the long-term rheological variations within the evaporite sequence. A case study from the Ocnele Mari salt mine, Romania

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To predict long-term evolution of underground storage caverns and nuclear waste repositories, information about the mechanical behaviour of halite-dominated evaporites at time scales far longer than possible in the laboratory is critical for safe design and operation. In this project, we aim to interpret the long-term properties of rock salt based on the analysis of natural tectonic structures such as folds that developed over geological time scale. Fold geometry is a sensitive parameter to the rheological properties of the layers and thus it is valuable in the process of deciphering their mechanical behaviour.

We analyse the excellent exposures of layered, folded rock salt in Ocnele Mari salt mine in the Southern Carpathians of Romania. The formation is composed of over 90% of halite, where distinct layering demonstrates variation in the amount of impurities. The layers are millimetres to metres thick and show fold shapes on various scales forming spectacular multiwavelength structures. Our detailed analysis of these structures included field measurements, microanalysis, and 3D model reconstruction models using photogrammetry techniques. Our data clearly indicate that the sequence must be mechanically stratified.

In selected pillars, we digitized folded packages and estimated the relative layer thicknesses based on the assumption of plane strain deformation and no-volume change in the deformed rock mass. The layer thicknesses are then employed to constrain initial geometries for the numerical analysis. With an assumption of the constant fold arclength, we estimate the minimum amount of bulk shortening to be ca. 70-80%. Using FOLDER [1], a numerical tool for analysing the deformation in layered rock, we used different rheological properties of the layers to model the evolving the fold structures after 80% of shortening. For a range of values of viscosity ratio (Newtonian and Power-law) between the layers, our results are very similar to the fold shape pattern observed in the field. Systematic analysis of various models allowed us to constrain the mechanical properties of the formation.

The field observation and numerical data clearly show that the evaporite sequence within the Ocnele Mari salt is mechanically heterogeneous and anisotropic. The long-term viscosity ratio of

the layers depends on the amount of impurities and their type. Even a small amount of impurities within the layer can significantly change the viscosity of rock salt. We estimated that viscosity ratio between the selected layers can reach up to 20-30. This points to a significant mechanical anisotropy, even in relatively pure halite deposits. The presence of layers of anhydrite, clay, K-Mg salts etc. will further increase this anisotropy.

[1] Adamuszek, M., Dabrowski, M., Schmid, D.W., 2016. Folder: a numerical tool to simulate the development of structures in layered media. J. Struct. Geol. 84, 85–101.