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Estimating Rheological Parameters of Anhydrite from Folded Evaporite sequences: Implications for Internal Dynamics of Salt Structure

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Salt structures have been identified as a potential target for hydrocarbon, CO_2, or radioactive waste storage. The most suitable locations for magazines are considered in the thick and relatively homogeneous rock salt layers. However, salt structures often consist of the evaporite sequence including rock salt intercalated with other rock types e.g.: anhydrite, gypsum, potassium and magnesium salt, calcite, dolomite, or shale. The presence of such heterogeneities causes a serious disturbance in the structure management. Detailed analysis of the internal architecture and internal dynamics of the salt structure are crucial for evaluating them as suitable repositories and also their long-term stability.

The goal of this study is to analyse the influence of the presence of anhydrite layers on the internal dynamics of salt structures. Anhydrite is a common rock in evaporite sequences. Its physical and mechanical properties strongly differ from the properties of rock salt. The density of anhydrite is much higher than the density of salt, thus anhydrite is likely to sink in salt causing the disturbance of the surrounding structures. This suggestion was the starting point to the discussion about the long-term stability of the magazines in salt structures [1]. However, the other important parameter that has to be taken into account is the viscosity of anhydrite. The high viscosity ratio between salt and anhydrite can restrain the layer from sinking.

The rheological behaviour of anhydrite has been studied in laboratory experiments [2], but the results only provide information about the short-term behaviour. The long-term behaviour can be best predicted using indirect methods e.g. based on the analysis of natural structures that developed over geological time scale. One of the most promising are fold structures, the shape of which is very sensitive to the rheological parameters of the deforming materials. Folds can develop in mechanically stratified materials during layer parallel shortening. Mechanical model have been developed to rigorously correlate rheological properties of rock to the fold shape. A quantitative fold shape analysis combined with the folding theory allows deciphering the rock rheology.

In this study, we analyse anhydrite layers embedded in the rock salt from the Upper Permian Zechstein salt formation from Dutch offshore. The anhydrite layers are common intercalation in the sequence. Their thickness varies between few millimetres up to hundred meters. The layers are strongly deformed often forming fold structures, which can be observed on a wide range of scales: in core samples, mine galleries, and also in the seismic sections. For our analysis, we select single layer fold trains. Quantitative fold shape analysis is carried out using Fold Geometry Toolbox [3], which allows deciphering the viscosity ratio between anhydrite and salt. The results indicate that anhydrite layer is ca. 10 to 30 times more viscous than the embedding salt.

Further, we use the estimated rheological parameters of anhydrite in the numerical analysis of the internal salt dynamics. We solve an incompressible Stokes equation in the presence of the gravity using the finite element method solver MILAMIN [4]. We show that the presence of denser and more viscous anhydrite layers in the tectonically stable regime is insignificant for the internal stability of the salt structures.

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