Evolution of rheologically heterogeneous salt structures: 
a case study from the NE Netherlands

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Abstract. The growth of salt structures is controlled by the low flow strength of evaporites and by the tectonic boundary conditions. The potassium-magnesium salts (K-Mg salts) carnallite and bischofite are prime examples of layers with much lower effective viscosity than halite: their low viscosity presents serious drilling hazards but also allows squeeze solution mining. In contrast, intrasalt anhydrite and carbonate layers (stringers) are much stronger than halite. These rheological contrasts within an evaporite body have an important control on the evolution of the internal structure of salt, but how this mechanical layering affects salt deformation at different scales is not well known. In this study, we use high-resolution 3-D seismic and well data to study the evolution of the Veendam and Slochteren salt pillows at the southern boundary of the Groningen High, northern Netherlands. Here the rock salt layers contain both the mechanically stronger Zechstein III Anhydrite-Carbonate stringer and the weaker K-Mg salts, thus we are able to assess the role of extreme rheological heterogeneities on salt structure growth. The internal structure of the two salt pillows shows areas in which the K-Mg salt-rich ZIII 1b layer is much thicker than elsewhere, in combination with a complexly ruptured and folded ZIII Anhydrite-Carbonate stringer. Thickness maps of supra-salt sediments and well data are used to infer the initial depositional architecture of the K-Mg salts and their deformation history. Results suggest that faulting and the generation of depressions on the top Zechstein surface above a Rotliegend graben caused the local accumulation of bittern brines and precipitation of thick K-Mg salts. During the first phase of salt flow and withdrawal from the Veendam area, under the influence of differential loading by Buntsandstein sediments, the ZIII stringer was boudinaged while the lens of Mg salts remained relatively undeformed. This was followed by a convergence stage, when the K-Mg salt-rich layers were deformed within the inflating salt pillows. This deformation was strongly disharmonic and strongly influenced by folding of the underlying, ruptured ZIII stringer, leading to thickening and internal deformation of the K-Mg salt layers.

1 Introduction

Salt bodies are often depicted as a homogeneous mass of mechanically weak rock salt with deformation driven by buoyancy, differential loading, or gravity gliding (Jackson and Talbot, 1986; Hudec and Jackson, 2007). Our understanding of large-scale salt tectonics has grown tremendously over the last century (e.g. Jackson et al., 1996; Warren, 2006), but the internal deformation of evaporites, as can be observed in outcrops, mines and surface exposures (Jackson et al., 1990), is less well known. Our knowledge of this domain is making some progress, because the internal layering of salt bodies can now be studied at high resolution using modern industrial 3-D seismic reflection data (Van Gent et al., 2011; Cartwright et al., 2012; Fiduk and Rowan, 2012; Strozyk et al., 2012, 2014; Jackson et al., 2014, 2015). In addition, improvements in geomechanical modeling techniques has allowed major advances to be made (Chemia et al., 2008; Albertz et al., 2010; Albertz and Ings, 2012; Goteti et al., 2012; Li et al., 2012a, b).