Observation and prediction of the relation between salt creep and land subsidence in solution mining-The Barradeel case

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Abstract

Since 1995, solution mining off halite is carried out by Frisia Zout B.V. (formerly: Frima) from two caverns in the Barradeel concession in the Netherlands. Barradeel is situated near the west coast of the province of Friesland near the Wadden Sea.

An upper limit of 35 cm has been set to the subsidence in the centre of the bowl. This limit stems from the delicate water management in the area, mostly lying beneath sea level and protected from the sea by dikes and a system of pumped polders. The operational solution mining plan has to be devised accordingly.

Earlier studies on this case were aimed at predicting the land subsidence from the then limited set of production and monitoring data. Subsidence in the bowl centre was only a few centimetres. At this moment, after 8 years of production, subsidence at the bowl centre has increased to around 28 cm and is nearing the limit.

Studies are now ongoing in order to define the best way to abandon the caverns from the point of view of safety and commercial interest. The hardware safety considerations on this issue are beyond the scope of this paper. However, this paper does deal with the important question how subsidence will behave in the end of production, possible shut-in and final abandonment phases.

A strongly data-driven analytical model has been developed. Calibration of this model on field data indicates that apart from cavern convergence through power low dislocation creep another salt transport mechanism is active. This mechanism is interpreted in terms of pressure solution creep, having a wider spatial range and longer relaxation time than the power law creep.

The findings from the data analysis and analytical modelling have been further investigated using numerical Finite Element modelling. The numerical modelling confirms the existence of two distinct salt creep phenomena, that are attributed to dislocation creep and pressure solution creep. It is shown, that the deceleration in subsidence is to be regarded as caused by pressure solution, while cavern convergence is likely to be a combined effect of dislocation creep and pressure solution creep.

This observation is of interest from a technical/scientific point of view: as far as known to us, this is the first simultaneous observation of two very different types of in situ creep in rocksalt. The Barradeel solution mine indeed is the deepest in the world and mechanical processes are likely to be different from other halite solution mines at shallower depths.

From the point of view of safety and commercial interests, the following benefits have been found:

a) the net effect of the pressure solution creep is to slow down subsidence during the solution phase;
b) a significant rebound is predicted after cessation of the solution and squeeze phases; therefore, salt production may possibly be extended for a longer period of time than previously thought without exceeding the 35 cm limit.

Key words: The Netherlands, Cavern Development, Environmental Protection, Rocksalt Mechanics, Subsidence, Pressure solution creep