Gorleben Salt Dome (Germany)

Description: Gorleben is located in Northern Germany. This study is focussed on processes which are connected to the development of the salt dome at Gorleben site. It is a so-called self analogue, since the Gorleben salt dome has been foreseen as one potential site for disposal of radioactive waste in Germany.

Main topics of the study are detailed analyses of the diapirism and the formation of the cap rock. From these investigations quantitative information about halogenetic and subrosion processes have been derived. The development of the salt dome at Gorleben from the Zechstein period until today is schematically shown in Figure 1.

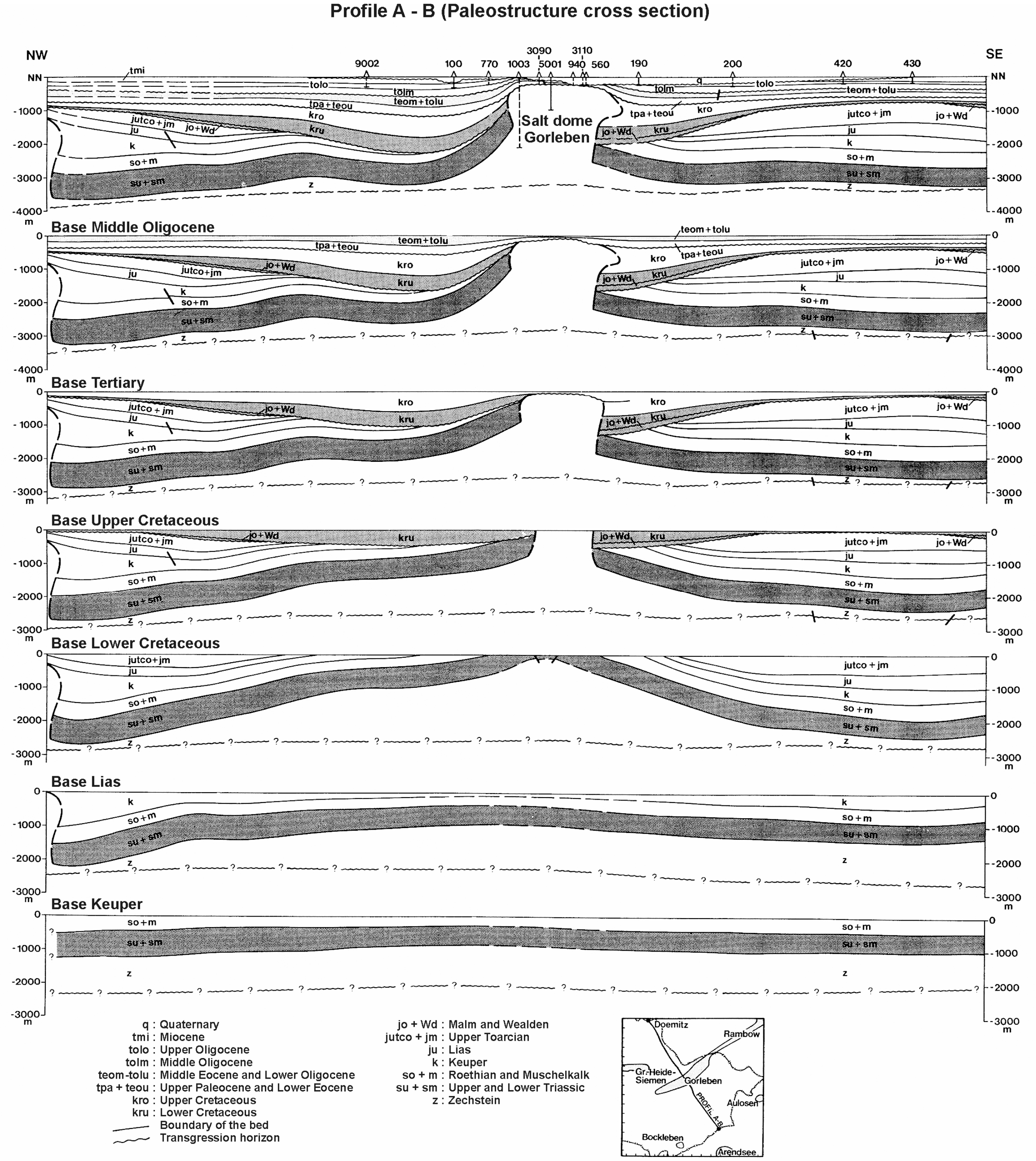

Figure 1. Diagenesis of the salt dome at Gorleben

Diapirism
Masses of salt move into upper levels of the crust due to its visco-plastic properties and differences in the density between salt and overlying rocks. This upward movement of salt is called diapirism. It could crucially affect the barrier properties of the entire repository system, since the repository could be elevated by this process and the barrier comprising the overburden could be reduced in thickness.

A quantitative analysis of the development of the salt dome in different geological eras was performed. Epeirogenic, tectonic and halogenetic movements have been reconstructed on the basis of structure contour maps, isopach maps and paleostructure-contour maps. Since the volume of the secondary rim syncline depends on the epeirogenic subsidence and the underground salt flow, it was possible to quantify salt movement by carrying out a detailed analysis of the rim syncline.

The results can be summarized as follows. In the geological time frame Malm – Lower Cretaceous the phase of diapirism started. The total amount of salt transported into the salt dome since then is about 280 km^3, i.e. 53 % of the originally 1400 m thick Zechstein salt moved upwards into the Gorleben salt dome. As shown in Figure 2 the rate of elevation of the salt dome varied from 0.08 mm/a to about 0.02 mm/a in the Miocene – Quaternary. The main uncertainty is due to the inaccuracy of the time frame of the geological periods. This is demonstrated in Figure 2 which shows the uplift rates based on the two different geological tables from Harland and Odin. It is in particular true for very short geological periods as the upper Oligocene, where due to the different time spans assumed for this period the difference in uprise rates from both time scales is about a factor of 2.

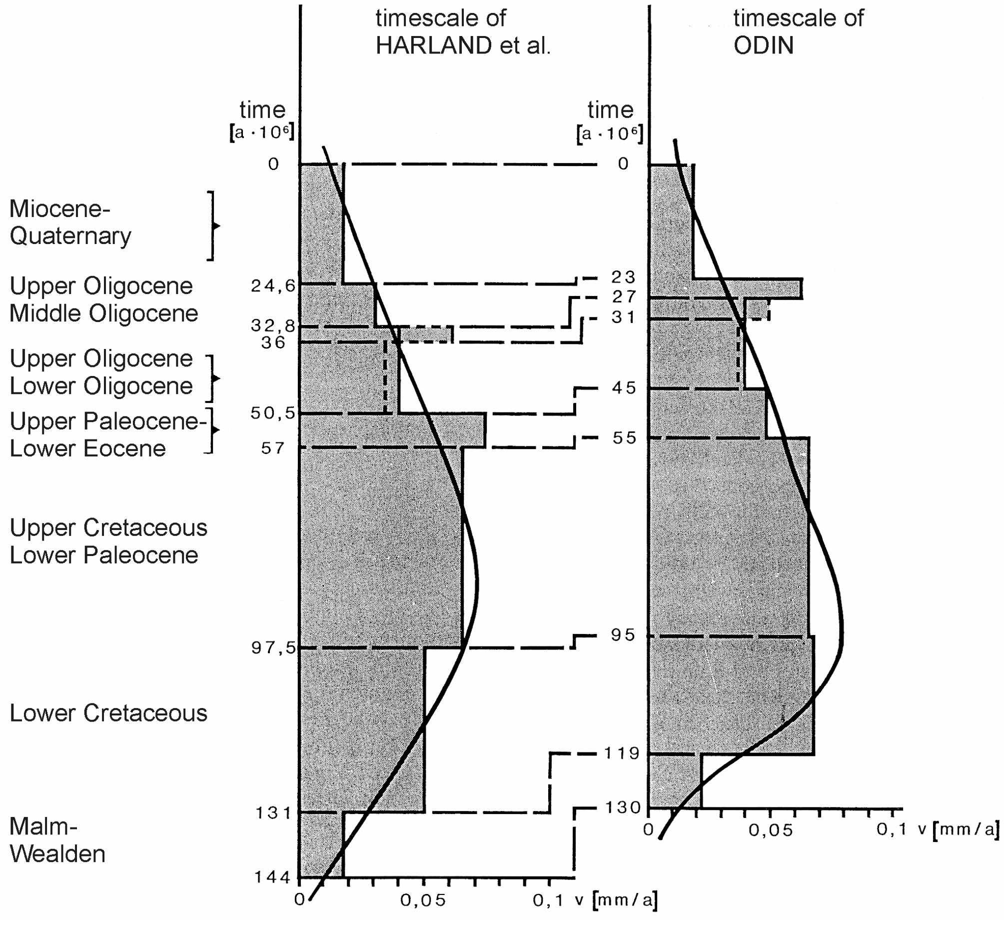

Figure 2. Mean rate of salt dome uprise at the top of the salt dome in different geological periods.

Because of the relatively constant dynamic conditions at the salt dome today it is expected that the elevation rate of the salt dome will not change within the next million years. Taking into account an elevation rate of 0.01 to 0.02 mm/a the uplift of the salt dome in the next million years will be 10 to 20 m, which will not affect the barrier function of the host rock.

Subrosion

An important scenario for the long-term behaviour of a repository in rock salt is the subrosion scenario. By subrosion salt becomes dissolved from top of the salt dome. During this process low solubility minerals such as anhydride or clayey material are enriched. This material builds the cap rock of the salt dome.

From a detailed investigation of the cap-rock material by analysis of cores from 49 boreholes subrosion rates have been derived. In Figure 3 the typical stratigraphy of the cap rock on top of the Gorleben salt dome is shown. It is important to note that in the quantification of subrosion rates, dating of the cap rock material is possible. This is not the case for a large number of other salt domes.

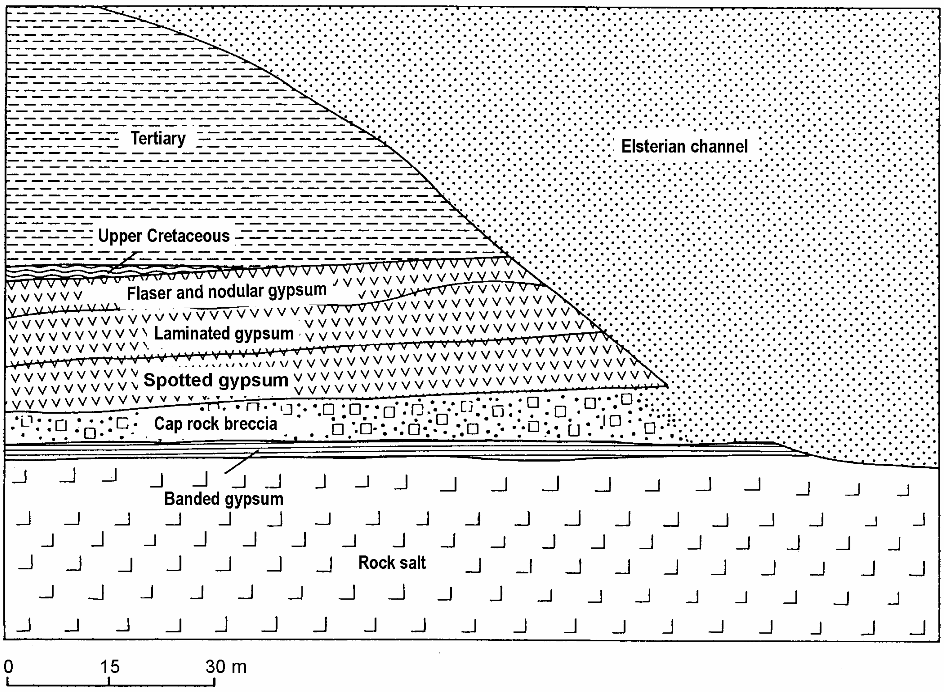

Figure 3 Diagram of the different layers on top of the Gorleben salt dome, the Elsterian channel, the rupture that was initiated from it and the resulting cap rock breccia

As shown in Figure 3 the cap rock consists of five different layers. The dissolution of salt occurs from top of the salt dome. The highly soluble salt is transported away and low soluble gypsum layers remain. Therefore, the age of these layers decreases with depth, i.e. the oldest cap rock layer is the flaser and nodular gypsum. The so-called cap rock breccia is exceptional; it was not formed by the subrosion process. The distribution of the cap rock breccia and its composition are clear evidence that they were formed in the period of Elsterian glaciation 500,000 to 300,000 years ago. It was formed simultaneously to the so-called Gorleben Trough due to the great load of the ice masses along the trough by pressing material not originating from the upper Permian into the trough.

Due to this fact it is clear, that the layers above the cap rock breccia are pre-Elsterian, whereas the banded gypsum below the cap rock breccia was formed by post-Elsterian metamorphoses of the salt. Therefore the thickness of the banded gypsum could be used as a measure for the subrosion process within the last 300,000 years.

In 16 drillings no post-Elsterian banded gypsum was detected, i.e. no subrosion took place in these areas. The highest thickness of the banded gypsum layer was found to be 40 m. From the measurement taken from 49 boreholes subrosion rates have been derived taking into account the different content of low soluble material in the salt in each borehole core. An averaged subrosion rate of 0.04 mm/a has been estimated.

Relevance: Diapirism could lead to the uplift of a salt dome and thereby a potential repository. This elevation process can lead to a significant decrease of the overburden of the salt dome, which represents an important barrier for radionuclides. Furthermore, uprise of the salt dome can facilitate the subrosion process.

One important process for the normal evolution scenario of a repository in rock salt is the subrosion of the salt dome. By subrosion the salt dome is eroded from the present salt-top down to repository depth. After contact of waste with water radionuclides will become dissolved and transported through the overburden into the biosphere. The time span until the salt barrier is totally dissolved is crucial, because a large amount of radionuclides in the waste decay during this period. This time span is determined by the subrosion rate.

Position(s) in the matrix tables: The study illustrates the process diapirism for salt in the far-field matrix table.

Limitations: The study is limited to a repository in salt rock. Effects of future climate changes i.e. glaciations on the subrosion have not been considered.

Quantitative information: The elevation of the salt dome within the next million years is estimated to be not more than 20 m. An averaged subrosion rate of 0.04 m/a has been determined.

Uncertainties: Concerning the diapirism, uncertainties stem from the determination of the normal thickness of the layers, the syncline volumes and the inaccuracies of the absolute duration of the geological periods. The error due to determination of layer thickness and syncline volume is estimated to -10 % to 20 %. The error from inaccuracy of the time scale is largest for relatively short geological periods as the upper Oligocene. In this case it is about 100 %. It is much lower for the Quarternary.

For the subrosion rates the largest uncertainty is due to the high spatial variation of the subrosion. Due to variation in thickness of the banded gypsum from 0 m to 40 m and considering differences in content of low soluble minerals in the salt a variation in subrosion rate from 0 m/a to about 0.15 m/a is derived.

Time-scale: The time-scale addressed by the study is geological.

PA/safety case applications: The elevation of the salt dome estimated in this study is not more than 20m in one million years. It is used as an argument in the safety case, that the barrier function of the salt dome will not be affected by diapirism for a time scale of 1 million years.

Best estimate value for subrosion rates have been used for the subrosion scenario in the PA study PAGIS. The upper value for the subrosion rate used in probabilistic calculations within the PAGIS study has been taken from highest subrosion rates observed at other salt domes in Northern Germany. These rates are much higher than the upper value observed post Elsterian at Gorleben site. This is an argument for a conservative approach.

Communication applications: None known.

References:

Jaritz W. 1994. Die Entwicklungsgeschichte des Standortes Gorleben als natürliches Langzeitverhalten eines Barrierensystems. Z. dt. Geol. Ges. 145, 192-206.

Zirngast M. 1991. Die Entwicklungsgeschichte des Salzstocks Gorleben – Ergebnis einer strukturgeologischen Bearbeitung. Geol. Jb. A132, 3-13.

Ehrlich D, Röthemeyer H and Stier-Friedland TB. 1986. Langzeitsicherheit von Endlagern. Zeitrahmen für Sicherheitsbetrachtungen – Bewertung der Subrosion des Salzstocks Gorleben. Atomwirtschaft Mai 1986, 231-236.

Bornemann O and Fischbeck R. 1986. Ablaugung und Hutgesteinsbildung am Salzstock Gorleben. Z. dt. geol. Ges. 137, 71-83.

Storck R, Aschenbach J, Hirsekorn R-P, Nies A and Stelte N. 1988. Performance Assessment of Geological Isolation Systems for Radioactive Waste (PAGIS): Disposal in Salt Formations. EUR 11 778 EN, GSF-Bericht 23/88. Commission of the European Communities, Gesellschaft für Strahlen- und Umweltforschung mbH München, Brussels-Luxembourg.

Added value comments: None identified.

Potential follow-up work: None identified.

Keywords: salt dome, cap rock, halogenesis, diapirism, subrosion

Reviewers and dates: Ulrich Noseck, GRS (January, 2004)