Chapter II

MAIN SALT DEPOSITS WITHIN THE GLUECKSTADT GRABEN

2.1. Regional overview

The CEBS contains a thick sedimentary fill, which was deposited over a wide area within Central Europe and the North Sea. Since the Late Palaeozoic, this region evolved into a number of different tectonic settings. Initially, this basin system was part of Pangea in Paleozoic times and included the Southern and Northern Permian Basins. A system of more or less N-S oriented Mesozoic graben structures was superimposed on the CEBS in Mesozoic times, and finally it became partially inverted during Late Cretaceous-Cenozoic times. The resulting lithological column of Upper Palaeozoic and Mesozoic sediments contains salt deposits at different stratigraphic levels in different parts of the CEBS. Permian salt deposits were the main viscous decollements during post Permian evolution within the CEBS. The Lower Permian (Rotliegend) salt is the oldest salt with regional extent, and the Upper Permian (Zechstein) salt is the thickest and most wide-spread evaporitic unit within the region. The paleogeographical map of the Rotliegend deposits indicates that the Upper Rotliegend salt was deposited in a narrow (about 130 km wide) and elongated basin (almost 650 km long), extending from the Sole Pit Basin to the North German Basin (Ziegler, 1990b). The Rotliegend salt-rich strata overlie a sequence of shales which have been deposited in semi-desert areas or continental deserts (Ziegler, 1990b). The salt-rich Rotliegend represents sabkha and desert-lake evaporites (Plein, 1990; George and Berry, 1997; Evans et al., 2003). At the beginning of the Zechstein, a marine environment developed during the initial transgression of the Zechstein Sea (Ziegler, 1990b). Zechstein salt was deposited in two giant evaporite basins, the Northern and Southern Permian Basins. The Zechstein halite precipitation was separated by the Mid North Sea High and the Ringkoebing-Fyn High. During the Zechstein, carbonates and thick evaporite rocks accumulated under arid climatic conditions. The marine Zechstein evaporites are characterised by the presence of chloride–sulphate evaporites and potassium salt, reflecting full cycles of evaporite precipitation. A third salt sequence of the CEBS consists of Triassic salt beds.

The basin infill of the GG contains all three major salt sequences (salt-rich Rotliegend, Zechstein salt and Triassic salt beds), mentioned above. The Rotliegend and Zechstein

evaporites formed the majority of the huge salt structures within the GG (Fig. 1.3). A 3D view on the modelled top Permian salt surface (Fig. 2.1) demonstrates that the high amplitude salt walls are located mainly within the Central Triassic Graben and the

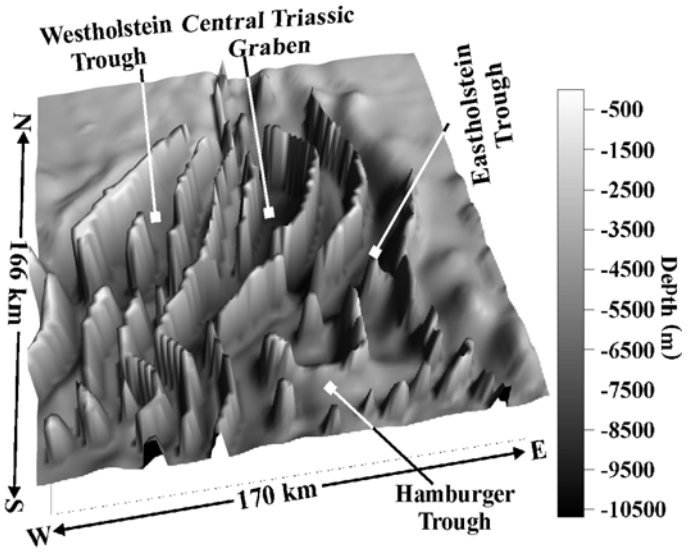

Figure 2.1. 3D view of the present-day top of the Permian salt in the Glueckstadt Graben and adjacent areas.

Westholstein Trough with decreasing amplitudes towards the marginal Eastholstein and Hamburger Troughs. Accordingly, the salt deformation is less intense at the north-western and south-eastern flanks of the basin (Fig. 2.1). The salt-rich Rotliegend mainly consists of an alternation of salt and shales which are concordantly overlain by the Zechstein evaporites. During the Late Triassic (Keuper) times, the thickest Triassic salt layers were deposited in the GG. Salt-rich Keuper is widespread within the GG and has a maximum thickness of up to 2000 m within the Central Triassic Graben. In terms of depositional environment, the Keuper is characterized by arid or semi-arid intracontinental conditions (Ziegler, 1990b).

2.2. Detailed lithology of the Rotliegend, Zechstein and Keuper salt-rich deposits within the GG

Rotliegend, Zechstein and Keuper salt successions have been distinguished because they played an important role during the evolution of the GG due to their great thicknesses and broad occurrence. In addition, solitary salt beds are present in the Bundsandstein and

Muschelkalk strata but they are rather thin (known thickness is up to 100 m) and they were not able to form significant salt structures during the post-depositional period. Several wells have been evaluated to characterize and correlate the different salt-rich intervals.

2.2.1. Rotliegend sequence

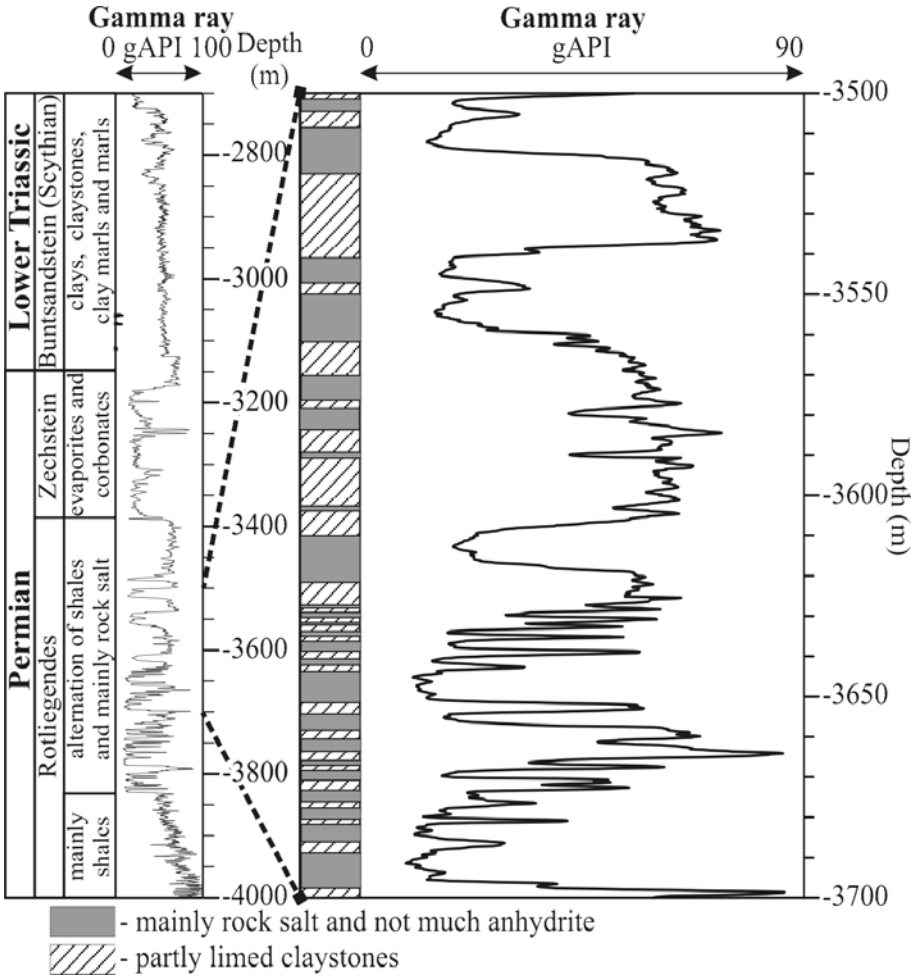

Figure 2.2. Detailed Rotliegend (Lower Permian) salt-rich section, gamma-ray log of Well 1.

The salt-rich Rotliegend is present in all boreholes of the GG, which penetrated the deposits of Lower Permian age. The typical sequence of the salt-rich Rotliegend is shown in Fig. 2.2, the interpreted gamma-ray log of Well 1 (for its location see Fig. 1.6.). The true composition of the Rotliegend is unknown within the deep part of the basin because these sediments have only been drilled in the crest of salt diapirs where they consist of displaced

carbonates, clastics and salt. The beginning of the salt-rich sequence is marked by a distinct fall in gamma-ray values (Fig. 2.2), lithologically corresponding to the presence of evaporites. The detailed structure of this argillaceous-evaporite sequence is shown in Fig. 2.2 by the enlarged interval of the gamma log. The rock salt is placed where the gamma log shows the lowest response. It is seen that the salt-rich succession consists of shales with some radioactivity (up to 88 g API) and intercalated salt layers as well as some anhydrite. The thickest salt beds reach up to 80-85 m thickness and, together with other salt layers, form more than fifty percentages of this argillaceous-evaporite sequence.

2.2.2. Zechstein sequence

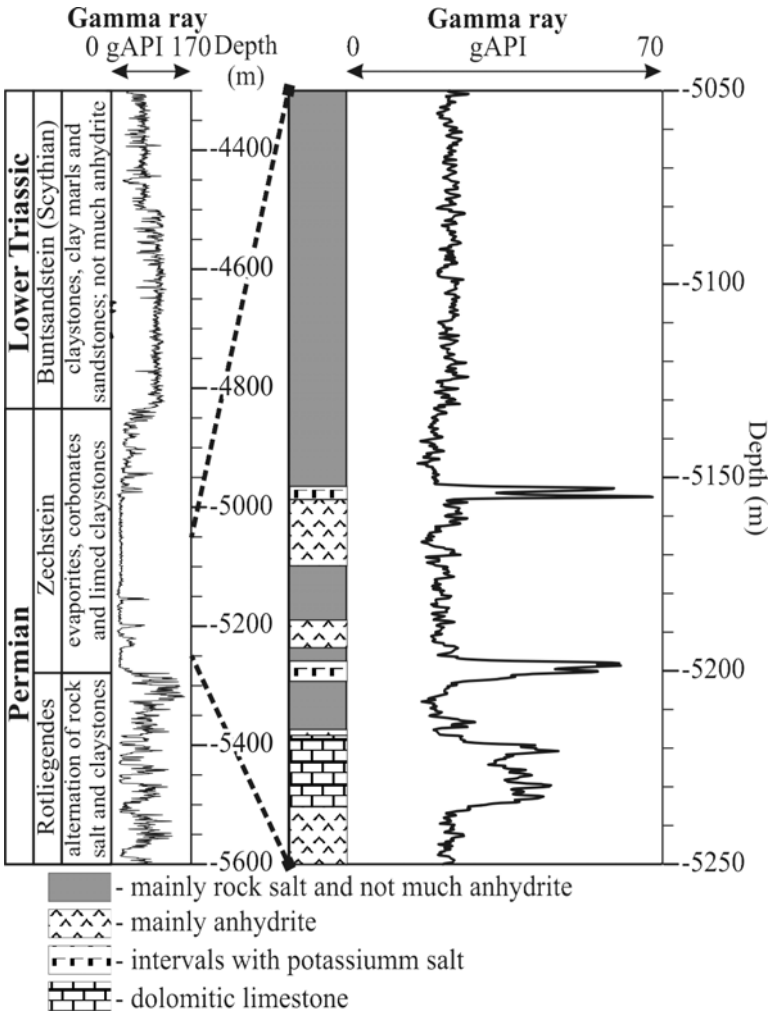

Figure 2.3. Detailed Zechstein (Upper Permian) salt section, gamma-ray log of Well 2.

The Zechstein sequence is shown by the example of the gamma log from Well 2 (Fig. 2.3; for location see Fig. 1.6). In the GG, the Zechstein is characterized by five cycles of evaporite deposition, reflecting increasing evaporation and salinity through time. One of these cycles is shown in Fig. 2.3 at the depth interval 5235 to 5198 m. It indicates the gradual precipitation from dolomitic limestone, anhydrite, halite to potassium salt. The enlarged interval of the data in Fig. 2.3 shows sharp spikes within the gamma-ray curve, related to the alternation of carbonates, anhydrites, halite and potassium. Radioactive potassium salt coincides with high gamma-ray peaks up to 68 gAPI. Carbonate beds are characterised by lower (up to 40 gAPI) gamma-ray values. The lowest gamma-ray values correspond to almost pure rock salt intervals. It is observable from the well-log data that rock salt predominates in the Zechstein section occupying more than seventy percent of it.

2.2.3. Keuper sequence

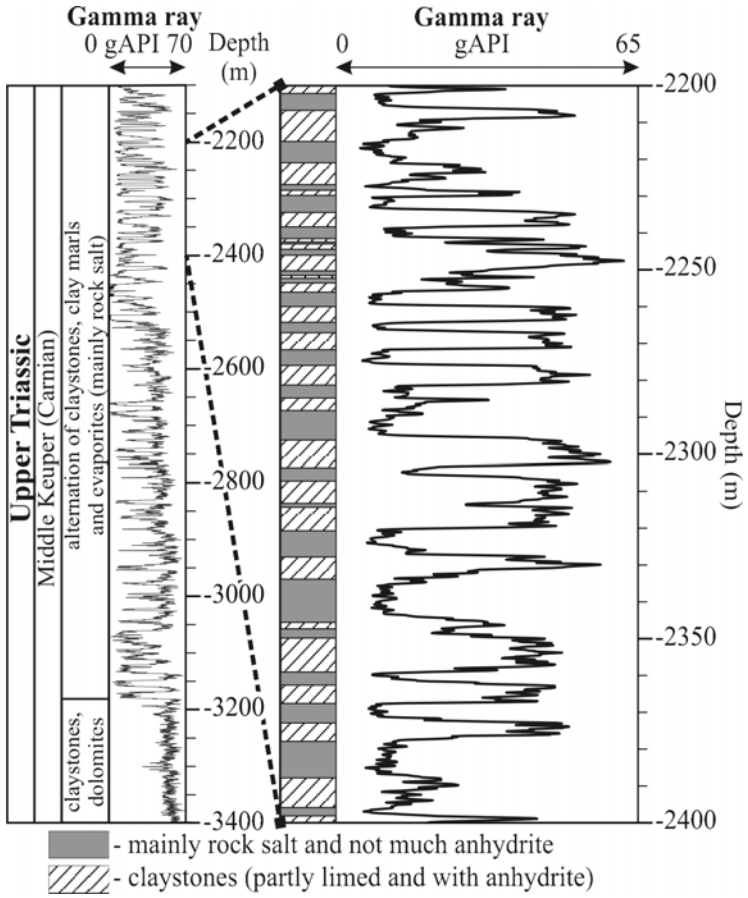

Figure 2.4. Detailed Keuper (Upper Triassic) salt-rich section, gamma-ray log of Well 3.

The Keuper succession consists of alternations of claystone, carbonate and evaporite series. The evaporite sequences are mainly represented by successions of interbedded halite, claystone, anhydrite and carbonates. The salt-rich Keuper is very thin within the flanks of the basin and is sometimes mainly represented by anhydrite or almost complete pinching-out of evaporite beds. It has been postulated that the Keuper was a syn-tectonic sediment deposited in SW-NE trending central trough of the GG (Brink et al., 1992; Baldschuhn et al., 1996; Baldschuhn et al., 2001; Kockel, 2002; Maystrenko et al., in press). It has also been suggested that a large proportion of the Keuper salt was reprecipitated from Permian salt that was dissolved from the many diapirs which were extruding on the paleosurface within the central part of the GG (Trusheim, 1960; Maystrenko et al., in press). The detailed section of the salt-rich Keuper is shown by the gamma-ray curve of Well 3 (Fig. 2.4). The well-log data highlighted in Fig. 2.4 illustrate that the gamma log has a serrate shape resulting from alternating beds of claystones and evaporites within the depth interval from 2400 to 2200 m. Higher gamma-ray values (up to 65 gAPI) are related to claystone layers, contrasting with the lower gamma-ray minima of salt seams. Salt beds are characterized by variable thickness within the limits of 5-18 meters and occupy about fifty percent of the salt-rich interval.

2.3. Summary

In summary, it can be stated that almost pure salt is prominent in the Zechstein and dominates in diapiric movements that have influenced the regional evolution of the GG. However, the presence of Rotliegend salt within the salt structures of the GG (Fig. 2.1) suggests that the initial thickness of Rotliegend salt was greater than is observed at the flanks of the basin today. The role of the Keuper salt is also important but mostly restricted to the area of the Central Triassic Graben where its thickness is significant.