Chapter VI

CONCLUSIONS

In the present work, the structure and evolution of the GG have been investigated in relation to salt tectonics. The main purpose was to examine the interplay between tectonic and salt induced processes. In order to resolve the role of salt tectonics during the evolution of the GG, one-dimensional analysis of the borehole data, two-dimensional interpretation of seismic lines and three-dimensional structural model and modelling were carried out.

The integrated study shows that the sedimentary cover of the GG contains several salt-rich sequences within the Permian and Triassic intervals. The most important are the salt-rich Rotliegend, the relatively pure Zechstein salt, and the salt-rich Keuper. It was revealed that the Zechstein salt is the main component involved in the diapiric movements that have influenced the regional evolution of the GG. Rotliegend salt is not significantly disturbed within the flanks of the basin where it is still characterized by flat-laying strata. However, the Rotliegend salt could have played an important role in the formation of salt structures in the central part of the GG, where it contributes in addition to the Zechstein salt to the total volume of some salt structures. Thus, the Rotliegend salt may have been much thicker within the central part than on the flanks of the basin. 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.

Three main phases of growth of the salt structures have been identified by the analysis of the seismic pattern. A major phase of growth occurred during the Keuper extension in response to normal faulting of the salt base. This activation of salt tectonics was followed by a Jurassic pulse of salt movements, which temporally correlate with an extensional event in the Pompeckj Block and the Lower Saxony Basin. The third, Paleogene-Neogene tectonic event caused significant growth and amplification of the salt structures mainly at the margins of the basin. This event is extensional with a possible horizontal component of the tectonic movements. These three phases of salt tectonics were separated by intervals associated with minor salt mobility, especially in the Late Cretaceous.

Triassic extensional faults have been identified on the salt base below salt walls and diapirs which formed in the same time interval. This fault activity most likely controlled the location and orientation of the NNE-SSW elongated salt walls. In this case, the formation of the salt walls and diapirs was triggered by salt movements above active extensional faults in the Keuper. During the Jurassic and the Cenozoic, the tectonic events played a minor role in the initiation of the formation of salt structures, but aided in their growth.

During the Late Jurassic to Early Cretaceous the area around the Glueckstadt Graben was affected by relative uplift with regional erosion of the elevated relief. This relative uplift coincides with contemporaneous rifting in adjacent areas, the Central Graben, Broad Fourteens basin, Central and Western Netherlands Basin, and the Lower Saxony Basin. Furthermore, the area of the Glueckstadt Graben remained a rather stable high and the Lower Cretaceous indicates minor subsidence within the Central Triassic Graben. The small amount of the eroded Keuper sediments, the presence of truncated toplaps in Jurassic strata and the absence of visible unconformities at the NW flank of the basin suggest that the present-day thinning of the Jurassic sequence could reflect the proximal depositional limit with little Late Jurassic-Early Cretaceous erosion near rising salt structures. Thus, the erosional features did not extensively modify the thickness distribution of the depositional sequences in the Jurassic. Furthermore, the present-day remains of thick Jurassic still represents the areas of intensive subsidence, which was strongly controlled by the withdrawal of the Permian salt from the source layer.

During the Late Cretaceous and Tertiary, the area of the CEBS was affected by inversion related to the Alpine Orogeny. However, there is no major effect observable within the Graben area in terms of seismic stratigraphy or significant variations of sedimentary patterns. Furthermore, the GG was not inverted during the Late Cretaceous and Tertiary, when up to 4.5 km of sediments were eroded in the Lower Saxony Basin (Petmecky et al, 1999) and along the southern margin of the NE German Basin (Scheck et al., 2002). In contrast to other parts of the CEBS, the rise of salt in almost N-S-striking salt walls indicates an E-W directed extension. This is consistent with the assumed regional stress field during Late Cretaceous-Early Tertiary inversion within other parts of the CEBS. For this period, the stress field is characterized by N-S compression and E-W extension that is generally derived from the regional structural analysis within Central Europe (Ziegler, 1990b). The Glueckstadt Graben was parallel to the principal strain direction and therefore was not prone to an inversion in the Late Cretaceous-Early Tertiary.

Initially Permian salt may have been up to 3000 m thick within the central part of the basin and about 1300-1900 m at the flanks. Possibly, the initial thickness distribution of the

Permian salt controlled the structural style of the basin regionally. Where salt was thick, salt diapirs and walls formed. Where salt was relatively thin, simple salt pillows and shallow anticlines developed.

According to results of the 3D structural modelling, the formation of the deep Central Triassic Graben and the subsequent Jurassic-Cenozoic marginal troughs was strongly controlled by salt structures and their development through time. In summary, it can be stated that the centre of sedimentation was moving away from the central part of the of the initial Graben structure towards its margins due to gradual withdrawal of Permian salt. In this sense, the Glueckstadt Graben was formed at least partially as a "basin-scale rim syncline" during post-Permian times. Therefore, the results show that salt withdrawal may have played an important role during the Meso-Cenozoic evolution and that the effects of the salt-driven subsidence during the Meso-Cenozoic may be considered a main reason for formation of the deep Central Triassic Graben and the subsequent Jurassic-Cenozoic marginal troughs.

This study shows that more or less east-west directed stresses caused the formation of the Triassic graben structures between the Tornquist Zone and the Elbe Fault System within the CEBS (Figs. 1.1 and 1.2). In addition, the available data indicate that the originally thick Permian salt deposits provide another important mechanism of subsidence, which has its own dynamics, once initialized, and which reacts very sensibly as far as it is affected in some way by the general stress field. However, the questions concerning the potential localization of strain in the sedimentary cover above the salt layer is still unsolved, although, some evidence for stress and strain partitioning was provided by Marotta et al. (1999). However, it can be stated that salt dynamics certainly involves its own mechanisms with regard to a changing external stress fields and may cause essential interpretation problems in many regions. Open questions are still remained concerning the structure of the deep crust and the depth position of the Moho within the area under consideration due to an absence of the regular coverage by deep seismic lines.