

Chapter 2

Geological Setting

2.1 Regional Geological Setting

The Middle European Permian/Dyas is subdivided by its facies into the mainly terrestrial Rotliegend (302–258 Ma = Million years) and the lagoonal sabkha deposits of the Zechstein (258–251 Ma). The Rotliegend Group/Lower Dyas (Germany), Rotliegend Group (United Kingdom) or Rotliegend Super Group (Netherlands) contains fine grained clastic sediments and evaporites deposited in an arid environment, with a succession of volcanics and evaporites at its base. The Rotliegend contains most of the gas fields of Europe (STD [1]).

In Germany, the Rotliegend is subdivided into: (1) the Lower Rotliegend (including the Altmark Subgroup), which is composed of max. 3,000 m of volcanics erupted from several volcanic complexes. (2) The Upper Rotliegend I (including the Müritz Subgroup), which is due to its only regional extent laterally not traceable. Its biostratigraphic layers match the Upper Rotliegend I in intramontane basins (southern Germany). The lithology is similar to the Upper Rotliegend I intramontane depressions and to the sedimentary layers of the Altmark Subgroup [2]. (3) The up to 2,000 m thick Upper Rotliegend II [3], which provides the framework of this study. It is characterized by continental siliciclastics and minor evaporites, which were deposited under arid to semi-arid climates [4, 5]. The Upper Rotliegend II consists of two subgroups: the Havel and the Elbe Subgroup. In northern central Germany and the German North Sea sector, the Altmark I–IV tectonic pulses, defined by Bachmann and Hoffmann [6], correlate to a series of stratigraphic units that divide the Upper Rotliegend II into four upward-fining successions (Figs. 2.1 and 2.2; [7–10]): the Parchim, Mirow, Dethlingen and Hannover Formations, of which only the upper Dethlingen and Hannover Formations form tight gas reservoir units. These formations have durations of approximately 2 Ma. According to the Stratigraphic Table of Germany (STD 2002) these formations correlate with the late Wordium (264 Ma) to the middle Wuchiapingium (258 Ma) in global stratigraphic context (Figs. 2.1 and 2.2).

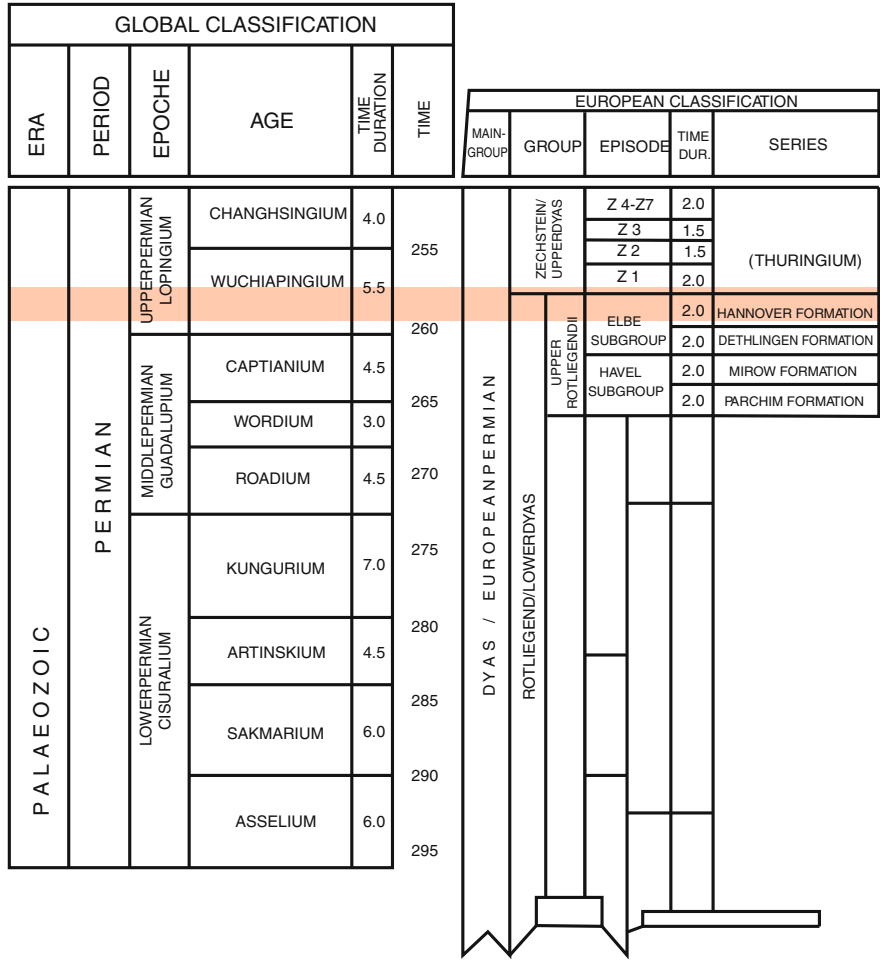


Fig. 2.1 Stratigraphic overview of the Permian; modified from STD (2002). The studied time interval is highlighted in light red

This thesis deals with the Hannover Formation, comprising the Ebstorf, Wustrow, Bahnsen, Dambeck, Niendorf, Munster and Heidberg Members, which were deposited between 260 and 258 Ma (Fig. 2.2).

The study area is located at the south-western margin of the Southern Permian Basin (SPB), which underwent a stepwise enlargement of its depositional area from the centre towards the west and the east [3]. During the Upper Rotliegend II, the SPB had a width (north–south) of 300–600 km and extended over ~1,700 km from the eastern UK to central Poland and the Czech Republic, covering an area of ~430,000 km² [11]. The basin was asymmetric and deepest in the north [12, 13]. Today, the basin configuration reflects the cumulative effects of changes of the regional stress regime that affected the re-organization of European crust during

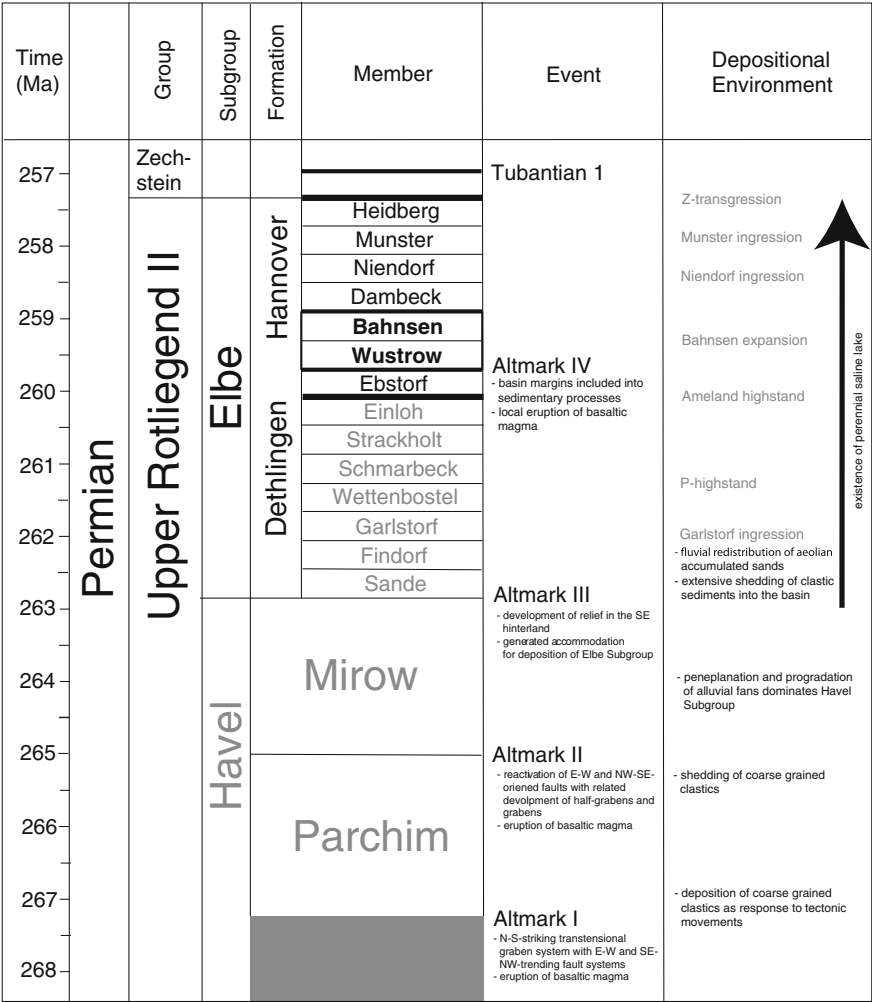


Fig. 2.2 Stratigraphic chart of the *upper* Rotliegend II in northern Germany [2] and contemporaneous tectonic events [28, 6, 14]. The timing of the Elbe Subgroup is based on Gast [7]. Table modified from Stollhofen et al. [3]. Weighted lines mark horizons, which border isopach map thickness (cf. Chap. 4)

decline and after the Variscan Orogeny. The basin comprises several NW–SE-trending pull-apart (en échelon) sub-basins, including the Silverpit/Dutch, North German and Polish Basins, which are separated by north–south and NNW–SSE-trending Variscan basement highs [14].

Since the deposition of the Dethlingen Formation (Figs. 2.1 and 2.2), a perennial saline lake occupied the central part of the SPB [15]. Short-term, but widespread marine transgressions and ingressions into the ephemeral shallow lake are represented by the Garlstorf and Schmarbeck Members of the Dethlingen

Formation and by the Niendorf and Munster Members of the Hannover Formation [16, 17]. These marine incursions required a basinward topographic gradient which resulted from subsidence of the basin floor below sea level, but have also been interpreted to have originated from sea level highstands [18, 19]. Apart from lacustrine and marine deposits, fluvio-aeolian deposits form an important part of the sedimentary record of the Dethlingen and Hannover Formations in the study area. Gast [20] and Rieke et al. [21] concluded that aeolian sediment was supplied by the prevailing easterly winds favouring the accumulation of aeolian dunes on a belt of saline mudflats and sandflats, which fringed the ephemeral shallow lake [22]. These fluvio-aeolian deposits form the major plays targeted by Rotliegend gas exploration [3]. The main source areas of fluvial sediment are located in the Variscan hinterland further south [13, 23].

2.2 Geology of the Study Area

The subsurface study area is located at the eastern boundary of the Ems Graben at the south-western margin of the SPB and is characterized by a mainly N–S-trending Zechstein salt wall situated above an asymmetric Upper Rotliegend II graben. The stratigraphic record of the study area covers the Ebstorf to Heidberg Members (Fig. 2.2). Sedimentary thicknesses range ~200–450 m. The Ems Graben in the central SPB underwent Upper Rotliegend II synsedimentary tectonics. Later subsequent phases of tectonic activity, e.g. rifting in the North Sea during earliest Triassic until late Jurassic to Early Cretaceous [24] overprinted the Rotliegend structural grain.

Source rocks for the gas fields of the Upper Rotliegend II of the study area are Westphalian coals. The top seal is provided by Zechstein evaporites [25]. The reservoir rocks are situated in the Wustrow and Bahnsen Members of the Hannover Formation (Fig. 2.2). The thickness of the sandstone-dominated Wustrow Member is possibly linked to tectonic activity (local basalt volcanism, Soltau high; [2]). Sandstones deposited in the coastal area around the salt lake are of high sedimentary maturity (high poro-perm values, high quartz content) and are therefore of great interest for the gas exploration in the Rotliegend. The Wustrow Member represents the best gas reservoir of the study area [2, 25]. During the Bahnsen Member the Bahnsen ingression took place [19]. The saline lake that occupied the central part of the SPB expanded and wide marginal areas of the basin were influenced by damp to wet synsedimentary conditions [2] resulting in higher clay contents and decreased sedimentary maturity. Until the Zechstein transgression, only minor regression phases with little sand accumulation in basin parallel beach belts occurred [2]. Core data analysis of the study area's Wustrow and Bahnsen Member sediments reveals that they are of fluvio-aeolian origin, including braided stream, aeolian dune and wet to dry interdune deposits. The majority of the aeolian sediment was supplied by prevailing eastern trade winds [20, 21]. In contrast, the source of major fluvial sediment input was located in the

Variscan hinterland towards the south [13, 23]. The preservation of aeolian dunes was governed by tectonic subsidence [26].

The Upper Rotliegend II sediments overlie patchy andesitic to basaltic volcanics (also preserved in the cores) and local Carboniferous highs. Both provided essential local sources for the aeolian sediment supply (e.g. [12, 27]).

The second study area in northern central Germany was investigated with the focus on the sediments overlying the main reservoir successions. It is situated in the southern part of the SPB. During the Dambeck Member of the Hannover Formation thin sandstones accumulated, but sabkha and lake sediments prevailed [2]. The area was influenced by short-term, widespread marine incursions (Niendorf and Munster Members of the Hannover Formation; [16, 17]) into the shallow lake that occupied the central SPB since the onset of the Dethlingen Formation.

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