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# Facies evolution of the Southern Permian Basin depending on tectonics, eustatic sea-level fluctuations of the Proto-Atlantic and variability of climate (Upper Rotliegend, Northwest Europe)

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During the Permian two large depositional basins existed in Northwest Europe. The Northern Permian Basin extended from West Scotland to Northern Denmark, the Southern Permian Basin (SPB) from England, the Southern North Sea, the Netherlands, and Northern Germany to Poland. Both basins were separated from each other by the Ringkøbing-Fyn-High and the Mid-North-Sea-High. During Upper Rotliegend II-deposition, the SPB was filled with up to 2000 m of siliciclastics and evaporates. The depositional setting of these sediments was reconstructed and the controlling parameters of this deposition were analysed. The interfering factors of tectonics, climate and pre-Zechstein marine ingressions and their influence on sedimentary patterns and cyclicity should be discussed.

Eleven wells with about 2500 m of core material were documented, sampled carefully and interpreted in detail. Four different lithofacies associations were identified. They were formed at different distances from the base level (lake-level of the Rotliegend saline lake and groundwater table respectively). The lithofacies associations are characteristic of special time slices as well as for clearly defined positions within the basin. In the sphere of influence of the Rotliegend saline lake, lake-level fluctuations are clearly recognisable in the sedimentary record. Drying-upward cycles, which cover a complete member, are well pronounced. Only in the Niendorf and in the Munster Members of the Hannover Formation these cycles are not visible. Two to three indistinct cycles occur within each member instead.

Miscellaneous geochemical methods were tested to detect marine pre-Zechstein ingressions. The boron-content of claystones depend on water salinity. Low- and high-salinity deposits were easy to distinguish but marine ingressions were not identified. $\delta^{13}$C- and $\delta^{18}$O-values of calcareous claystones show a large area to depth ratio but a marine influence is not observable. In contrast to these, the S-isotopic values of anhydrite samples indicate marine ingressions during deposition of the middle Niendorf and middle Munster Members as well. The Niendorf-ingression has long been proven by marine fossils, but it is the first evidence of the Munster-ingression. Both marine ingressions correlate with a changing cyclicity of sedimentary patterns. All anhydrite samples have continental Sr-isotope ratios. High Sr-concentrations in lake water prevent marine signals.

A 1 Ma cyclicity was detected in Upper Rotliegend II deposits. They become obvious in remarkable events: the formation of the perennial Rotliegend saline lake at the base of the Sande Member, the marine Garlstorf-ingression, the P-highstand of the Schmarbeck Member, the Ameland-highstand at the base of the Ebstorf Member, the Bahnsen-lake expansion, the marine Niendorf-ingression and the Zechstein-transgression. These events can be correlated with sea-level highstands of the Proto-Atlantic. These highstands are visible in the depositional patterns of Permian sediments of East-Greenland. This results in the first correlation of Upper Rotliegend II-sediments of the SPB with the marine. Furthermore the evolution of the Proto-Atlantic was reconstructed.

Marine pre-Zechstein ingressions into the SPB were triggered by short term events. The base level of the basin (lake level of perennial saline lake respectively) was below sea level during the upper part of the Rotliegend. The Proto-Atlantic had have flooded the basin completely during a long-lasting connection. In contrast to this, only a limited amount of water flowed into the basin during pre-Zechstein marine ingressions. Wide-ranging salt precipitation was stopped and sediment-cyclicity was changed by the ingressions. The SPB was not connected to the Proto-Atlantic until the Zechstein-transgression flooded the basin.

Upper Rotliegend II-deposition in the SPB was controlled by the interference of tectonics, eustatic sea-level changes of the Proto-Atlantic and climatic variability. Tectonic activity, which occurred with a 2 Ma periodicity, is the least influencial parameter on deposition. Proto-Atlantic sea-level fluctuations with a periodicity of 1 Ma caused remarkable occurrences in depositional evolution. 400 ka lake-level fluctuations are caused by climatic variability. These fluctuations are only superposed by marine pre-Zechstein ingressions in the middle Niendorf and middle Munster Members.