



Analysis of salt dynamics in 4D: structural, sedimentary and salt tectonic evolution of the East Frisia area and its implications for the North German basin

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The 4D analysis of salt dynamics include a detailed genetic 3D seismic interpretation, reconstruction modeling and 3D visualisation in order to investigate the spatial distribution of salt and sediment and to evaluate the effects of changing stress regimes through time.

A high-quality prestack depth-migrated 3D seismic cube (10 x 13 km) from the East Frisia area and stratigraphic correlation based on numerous exploration wells provide an excellent data set to unravel the complex geological history of this western part of the North German basin. Results from seismic interpretation, sedimentary thickness maps, 3D modeling, seismic variance analysis and structural backward modeling bear implications for regional salt tectonics, structural evolution and sedimentary style through time.

Our results suggest that initial salt movement in the study area was controlled by extension of a rifted sub-basin at the beginning of Triassic Middle Bunter times. Strong extension at the basin margin and structural decoupling from the underlying salt sequences caused gravity gliding and rafting of the Bunter layers. We propose a broader distribution of these mechanisms in other marginal positions of the North German basin, where the Lower and Middle Bunter sequences are also locally absent.

Incipient North Sea rifting in the Middle Keuper caused a change of the main structural direction and brought about major extension and faulting in the study area. Intensive

sub-salt faulting triggered extension in the overburden. Extension in the supra-salt was focussed on weakness zones like on top of a faulted salt pillow as in the case of the study area. The concept of diapirism being triggered by extension is proposed for the breakthrough of most Triassic North German salt diapirs as well as for Jurassic to Lower Cretaceous diapirs.

The initial diapiric rise was followed by sedimentary downbuilding with the continued passive growth of the diapir. We expect that most of the diapirs in the North German basin have a long-term downbuilding history, which resulted in a complex salt-sediment interface and diapir geometry. Typical features observed are sedimentary wedges with onlap-structures and angular unconformities close to the diapir as well as lateral salt extrusions.

We interpreted several salt extrusions during periods of diapir emergence, reduced sediment accumulation and rapid salt rise. Marine and continental salt glaciers are expected as a common feature of the German salt basin during times of strong salt tectonic activity mainly in the Late Triassic and the Upper Cretaceous. We identified a small influence of Upper Cretaceous to Paleogene compressional tectonics on salt movement in the study area. The salt diapir was shortened and uplifted while the overlying sediments were faulted and folded. Moderate thrusting, buckling and local transpression can be observed in the Rotliegend sub-salt basement. Our study demonstrates that an integrated approach of detailed 3D seismic analysis, sedimentary, structural and salt tectonics modeling is a key for the understanding of complex salt basin dynamics.