Geophysical Research Abstracts, Vol. 7, 00152, 2005
SRef-ID: 1607-7962/gra/EGU05-A-00152

Structural Architecture and Deformation Styles in the North German Basin – First Results from seismic and tectonic Interpretation of a 3-D Reflection Seismic Data Set

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One of the general questions that drive basin research is the transfer of stress and its accumulation. Thus, amongst others, basin evolution depends on the magnitude of deformation, the strain accumulation in space and time, and the processes controlling both factors under varying kinematic constraints.

We study seismic and sub-seismic deformation in the North German Basin in an area east of Bremen (north Germany), at the northernmost margin of the Lower Saxony Basin at the transition to the Pompeckj Block. Here, deformation throughout transtensional and transpressional stress regimes, thermal subsidence and inversion affected the Mesozoic basin infill. A prestack depth-migrated 3-D reflection seismic volume from oil industry (RWE-DEA; 17.5 x 22.5 km x 7 km depth) is calibrated with 13 wells, containing information about lithology, petrophysical data, core sections, log curves, or FMI/FMS data.

The whole working area is disturbed by a large-scale NW-SE striking strike-slip system, influencing Carboniferous to Cretaceous rocks, but also in parts Tertiary rocks. Steep dip-slip normal and thrust faults, as well as positive and negative flower structures indicate inversion tectonics during multistage-deformation, causing this fault system to operate in transtensional and transpressional modes. The complex kinematics along this strike-slip zone involves rocks at least down to the Carboniferous, and is, therefore, a dominant and important structural feature in the area.

To improve the identification of subtle lineaments and small-scale structures an ensemble of workflows was developed for a better coherency processing based of the 3-D seismic data set. The new algorithms "Structural Entropy" (measure of local discontinuity on a scale from zero to one) and "Shaded Relief" (consideration of different intensities of reflected light with color) allow better identification of small-scale lineaments, which are barely visible on the conventional seismic amplitude display. With the help of these methods we have recognized persistent lineaments of N- to NNE-orientation, as well as lineaments of NW-orientation, which in part parallel the large-scale structures.

Four Zechstein salt diapirs, rooted above the Rotliegend at depths between 4.5-4.8 km, are located in the area. The cover rocks on top of the salt generally show a pervasive deformation of predominately normal faulting, but at a much smaller scale than the basement rocks. Listric normal faults developed within Mesozoic layers of more competent rocks and detach horizontally along bedding. Salt uplift causes normal faults on top of the diapirs. The basement underneath the salt is disturbed by large N-S to NW-SE striking graben systems, which were active in the upper Permian. The steep normal faults at the flanks of the grabens show the largest offset with 300 m at the Top A2 horizon (Zechstein). These faults can be traced down to about 7 km depth into the Carboniferous. However, also younger sediments of Triassic age were affected by deformation along these faults, indicated by down-drag of these layers. This indicates that post-Zechstein deformation was not uncoupled by the Zechstein salt.