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# Structural Styles and Geothermal Exploration Results from 2D- and 3D-Seismic Surveys in a Continental Rift System

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The Upper Rhine Graben - southwestern Germany - is the central part of the European Cenozoic Rift system (figure 1) and was subjected to variable stress conditions. Recent stress condition arouse from alpine drift to the Northwest and forms complex structural styles.

Modern seismic measurements supply large data sets about the internal structure and sedimentary fill of one of the most important geothermal provinces in Central Europe. These data has been recorded for the single purpose to explore the the structural setting and geothermal reservoirs below the Tertiary filling of the Upper Rhine Graben which shows considerably higher geothermal gradient than observed in the surrounding areas. In this poster three different structural styles within the Upper Rhine Graben are presented:

- **Pull apart structures and accommodation zones between terminations of major fault zones with related rapid vertical movements,**
- **Basement involved fault tectonics with bloc faulting**

and

- **Divergent wrench faulting bound to deep seated fault systems in the basement as response to stress field causing horizontal movements.**

As a result of the available high quality of seismic information it is possible to identify the character of the faults as growth faulting and recent vertical movements up to the surface. Active fault systems intersect older inactive ones and confirm the structural pattern. In some cases the direct detection of zones percolated by hot fluids may be possible.

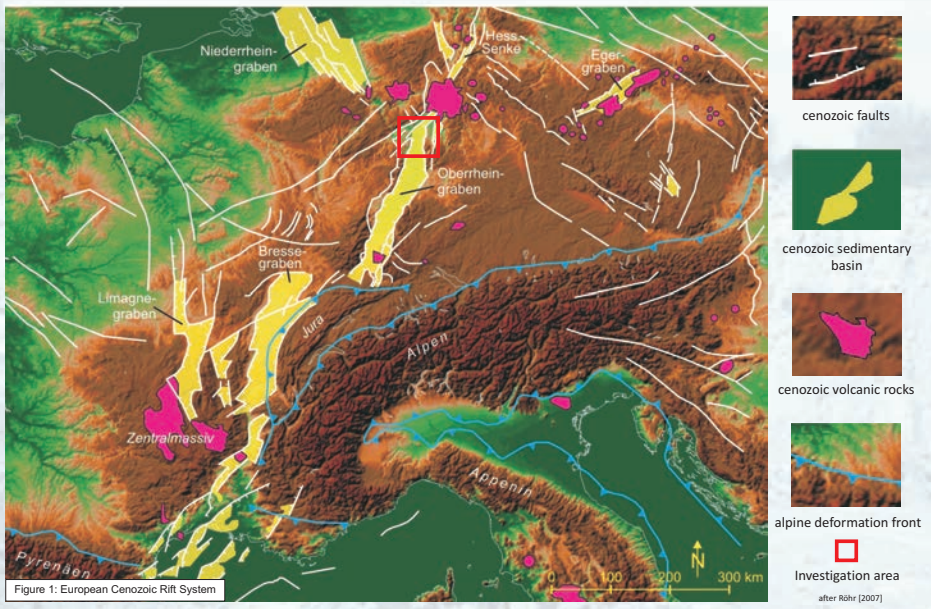

Figure 1: European Cenozoic Rift System

## Pull apart structures and accommodation zone

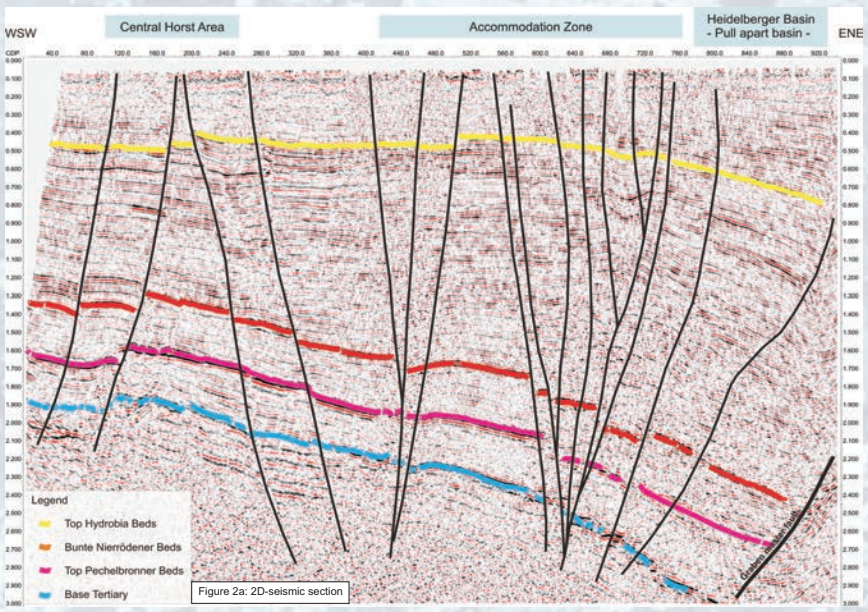

Figure 2a: 2D-seismic section

The 2D-seismic section seen in figure 2a shows various types of y-grabens between the Central Horst and the Eastern Master fault of the Rhine Graben that are typical for accommodation zones .

Accommodation zones are associated by rapid vertical movement towards a basin. In the given example it is the Heidelberg basin that is formed as a pull apart basin.

Notice open fractures reach the surface and document recent tectonic activity.

3D-seismic measurements over that region identified a north-north-west striking accommodation zone as seen in figure 2b.

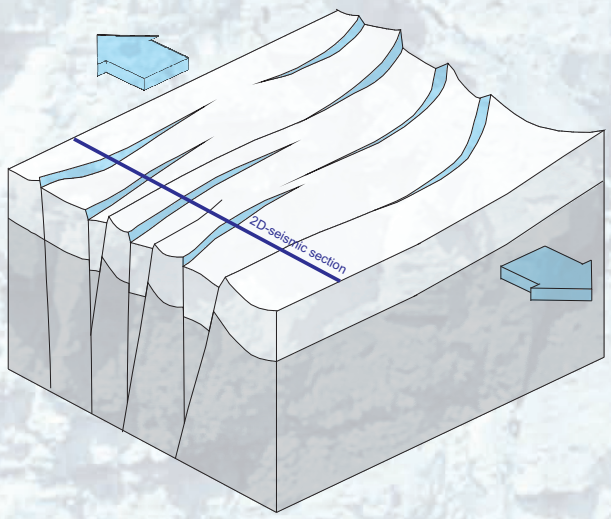

Figure 2b: Scheme of an accommodation zone

## Basement involved fault tectonics

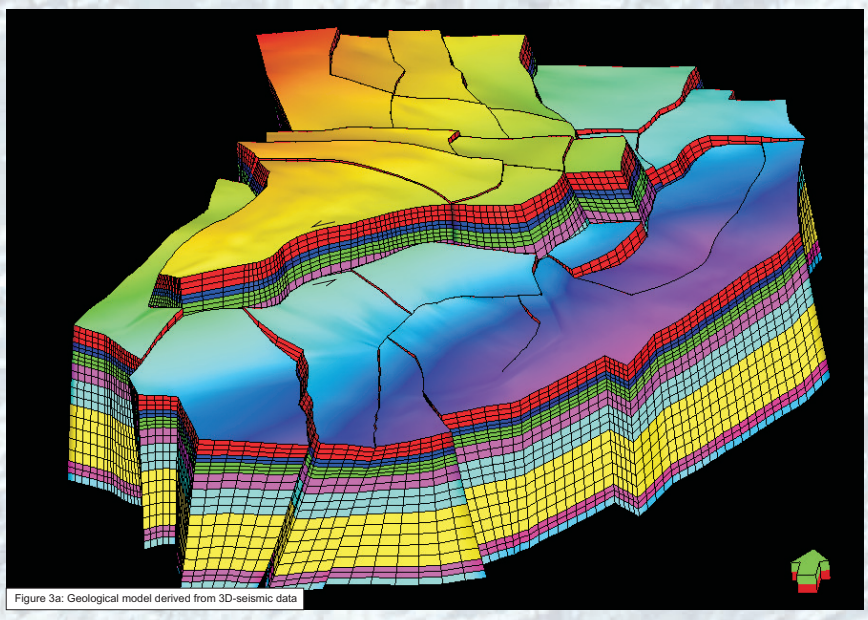
Figure 3a: Geological model derived from 3D-seismic data

A basement-high was clearly identified within the 2D-seismic section by slightly north-north-west respectively north-north-east striking major faults that are describable with the structure shown in figure 3b.The 3D-seismic data demonstrate a more complex structure (figure 3a). Deep seated fractures reaching the surface reveal as wide crushed fault zones. Furthermore the significant basement-high shows recent tectonical activity.

Under existing stress conditions a basement uplift combined with horizontal displacement documented by contemporaneous normal faulting and Riedel Shear mechanism is given.

Based on 3D-seismic data a reservoir model that ranges from Top Muschelkalk down to the volcanic basement was deduced.

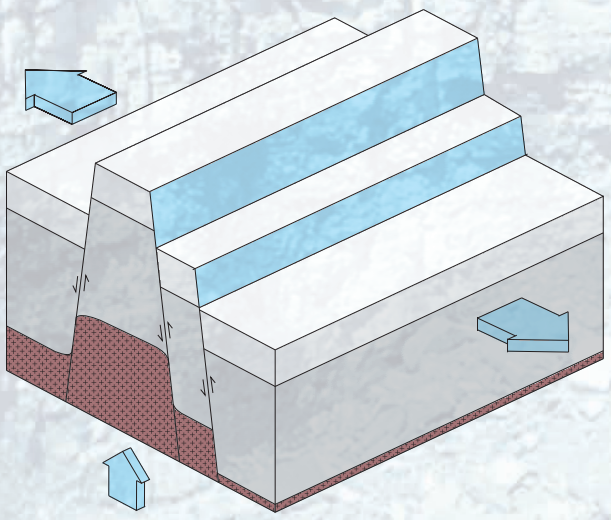
Figure 3b: Scheme of basement involved tectonics

## Divergent wrench faulting

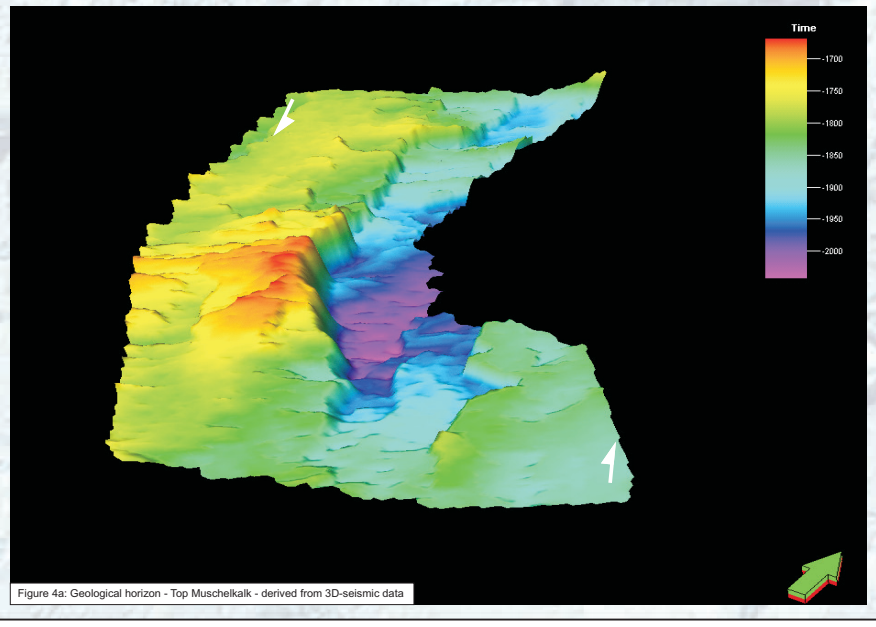

Figure 4a: Geological horizon - Top Muschelkalk - derived from 3D-seismic data

Divergent wrench faulting is a special deformation process in some parts of the Upper Rhine Graben region. Figure 4a shows the top of Bunter sandstone as a horizon within a special graben. This graben system is framed by step faults at the eastern side which are created by mainly divergent horizontal movements. They form a negative flower structure (figure 4b).

The fault lines are less structured as seen above (figure 3a) as they are not controlled by the basement grain.

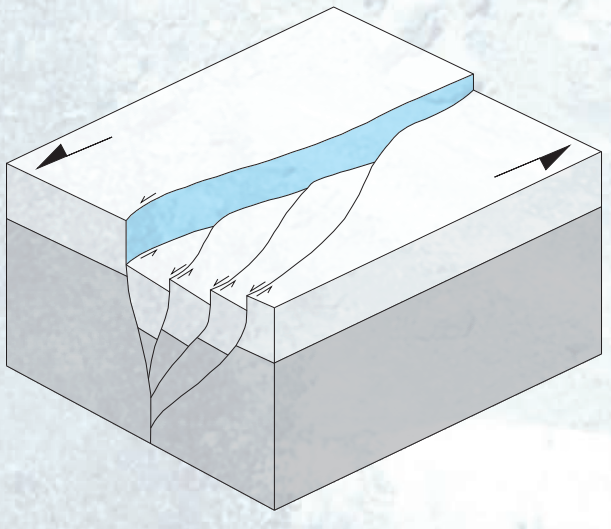
Figure 4b: Scheme of divergent wrench faulting