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Fault evolution in the Bavarian Molasse Basin: a case study of urban geothermal exploration around Munich, Germany

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Faults are favoured targets for geothermal exploration in the Bavarian Molasse Basin, because they could be potential fluid pathways with higher permeability. As a part of the research project GeoParaMoL* we focus on structural interpretation and fault history within the reservoir and overburden. The project explores the Malm carbonate reservoir, at a depth of 3 km, as a source of deep geothermal energy and the cover of Tertiary Molasse sediments.

On the basis of a 3-D seismic survey (170 km^2) in Munich, we analysed the fault evolution of a complex fault system consisting of synthetic and antithetic normal faults that strike parallel to the alpine front and also show strike-slip characteristics.

We built a 3-D geological model containing seven stratigraphic horizons, from Top Aquitanian down to Upper Jurassic, and 24 main faults, with offsets up to 350 m. We calculated thickness maps, attributes of the fault surfaces, and Allan (juxtaposition) diagrams to analyse the fault history and evolution.

Thickness maps show new information about the fault evolution during the Tertiary: changes in sediment thickness (up to 100 m thicker) over the fault, indicative of syn-sedimentary movement, are present from Oligocene to Lower Miocene on all faults.

The results of the fault surface attributes curvature and cylindricity visualise a prominent change in fault dip: most major faults dip between 60° and 70° towards S or SE in the weaker Molasse sediments and steeper (80°90°) in the deeper, competent Jurassic limestone. The change of the fault dip is reflected in structural features: the hanging-walls in the Molasse sediments change from roll-over to drag-folding over the fault bend, back to brittle roll-over within the carbonates. Allan map diagrams show that the maximum offset is between Upper Jurassic and Eocene strata and fault throw decreases both towards younger and older strata. The throw profiles of the Upper Jurassic (Top Malm) and Eocene (Top Lithothamnian limestone) strata are significantly different. Therefore, we surmise that the main activity was during Cretaceous. However, Cretaceous sediments pinch out within the study area, excluding the possibility to further investigate this aspect.

We postulate that all the major faults below Munich do not continue into the crystalline basement. This is an important information to understand the induced micro-seismicity.

* https://www.liag-hannover.de/en/fsp/ge/geoparamol.html