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Temporal evolution of faults in the southern Bavarian Molasse Basin: a case study of Wolfratshausen, Germany

Vladimir Shipilin (1,2), David Colin Tanner (1), Inga Moeck (1,2), and Hartwig von Hartmann (1)

(1) Leibniz Institute for Applied Geophysics, Hannover, Germany (vladimir.shipilin@leibniz-liag.de), (2) Georg-August-Universität Göttingen, Germany

In the last decade, there has been an increasing interest in foreland basins to host geothermal resources because of the existence of deep aquifers. Understanding of tectonic evolution and fault kinematics is crucial to evaluate potential geothermal reservoirs, which at great depth are primarily controlled by fault and fracture density. The focus of this work is an in-depth analysis of deformation structures within the geothermal prospect of Wolfratshausen in the southern Bavarian Molasse Basin.

Based on a 3D seismic survey, acquired 30 km south of Munich, we analysed fault patterns within the Upper Jurassic carbonate reservoir and its Molasse overburden. To determine the temporal activity of the interpreted faults, we built a 3D geological model of the Wolfratshausen prospect. From this we calculated juxtaposition diagrams of the faulted strata and thickness maps of seismic horizons.

The seismic interpretation reveals three groups of faults; (1) normal faults in the Mesozoic and the earliest Molasse sediments, (2) normal faults in the Tertiary Molasse, and (3) reverse and thrust faults that overprint the earlier Tertiary normal faults. All the faults are longitudinal with respect to the Alpine deformation front. The Tertiary faults are detached from the faults in the carbonate platform by the Rupelian marls.

According to the results of the kinematic analysis, the interpreted faults reflect three distinct phases of tectonic evolution in the southernmost area of the Molasse Basin. From juxtaposition maps of the pre-Alpine faults, we observe that the maximum offset is between the Upper Jurassic and Priabonian strata, indicating that the main activity on the faults occurred during the Cretaceous. The reactivation of the pre-Alpine faults and formation of new normal faults within the Chattian Baustein beds is attributed to a later phase of active continent collision, and subsequent flexure of the European lithosphere. As evidenced by syn-sedimentary structures, and observed in isochore maps, this phase reached its peak in the study area during the Late Oligocene. As the Alpine thrusts propagated north, the extensional deformation in Wolfrathausen was succeeded by contraction in the Middle Miocene, which resulted in thrusting and reactivation of the normal faults as reverse faults. The thrusting activity was contemporaneous with activity along the main thrust of the Folded Molasse Basin.

We attribute the decoupling between the reactivated pre-Alpine faults and the faults in the Baustein beds to the intermediate 600 to 900 m thick, mechanically incompetent Rupelian marls. The soft marls most probably impeded the up-dip propagation of the faults, instead accommodating the displacement by ductile deformation.

The present study shows that the various strata at Wolfratshausen have undergone different deformation phases; extension in the pre- and early-orogenic stages of basin formation and contraction in the Miocene times. The Upper Jurassic carbonate reservoir of the Wolfratshausen prospect is controlled by isolated longitudinal normal faults that have not been active since the Late Oligocene. The identified structures, their temporal activity, and deformation style indicate active stress regime in the study area and thus provide an insight into the hydraulic transmissivity of the fault zones.