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Interpretation of seismic reflection vintage lines from the Variscan Fold and Thrust Belt in the Aachen region, Germany: Implications for geothermal exploration

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Vintage seismic lines from the area of the city of Aachen from the early 1980s were reprocessed and interpreted in order to characterize the deeper subsurface for its geothermal energy potential. In focus are Lower Carboniferous and Middle to Upper Devonian carbonates as possible karstification is assumed due to the occurrence of thermal springs in the region. Further, extensional NW-SE striking faults of the Tertiary Lower Rhine Graben Rift may provide opportunities for geothermal field development.

The Paleozoic units northwest of the Variscan Rhenish Massif range from Lower Devonian to Upper Carboniferous. Upper Devonian to Upper Carboniferous strata was thrusted onto folded Upper Carboniferous rocks of the foreland molasse basin (e.g. Wurm Syncline) during the Variscan orogeny. As a result, a complex tectonized belt with (at least) three major NE-SW striking thrusts developed, which are cropping out in the region of the city of Aachen. Later, during Upper Cretaceous and Cenozoic times, the region experienced SW-directed rifting and block faulting orthogonal to the Variscan strike as well as inversion movements. Along two of these Paleozoic thrusts, the Aachen Thermal Springs are arising from the subsurface with a temperature of up to 72°C assuming pathways for thermal water from karstified rocks in the deeper subsurface of the Inde Synclinorium. In addition, the strata is exposed along the margins of the Inde Synclinorium or was encountered in wells such as the RWTH-1 well located in the Wurm Syncline or Frenzer Staffel 1 in the Inde Syncline. While the stratigraphy of the geological units is well known from outcrops, their facies distribution and related lithology in the subsurface and within the different fault blocks of the thrust system remains fairly unknown. This was shown from the drilling of the well RWTH-1 in 2004 where the Kohlenkalk (platform carbonates) and the Massenkalk (reef carbonates) were expected but not encountered despite cropping out 10 kilometers to the southwest.

For this investigation, two roughly NW-SE trending seismic lines (~70 km long) were interpreted. The lines were acquired perpendicular to the strike of the Variscan structural elements. The seismic data imaging is challenging due to highly consolidated rocks and very high impedances, partly steep inclination of bedding planes due to thrusting and back-thrusting, low angle faulting (thrust planes), and possible 3D effects where migration is difficult. However, based on the new processing, surface geology correlation, integration of well data, and back-stripping check-ups, we were able to map the key thrust outlines at depths and lithology targets based on their characteristic reflectivity pattern. The most prominent feature on the seismic data is a sharp reflection, which dips approx. south from a very shallow level (~1.000 m) below 6.000 m. The feature was also evident on vintage DEKORP-data and is interpreted as the seismic expression of the Aachen Thrust. Current models can thus be validated or adapted based on our sweet spot maps including the deeper tectonic fabric of the region and regional distribution of carbonate sequences with possible insights on karstification to de-risk future geothermal developments in the area.