Geophysical Research Abstracts
Vol. 17, EGU2015-12812, 2015
EGU General Assembly 2015

Fault zone exploration in a geothermal context using P- and S-wave measurements

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In the framework of the collaborative research programme gebo ('Geothermal Energy and High Performance Drilling') we applied seismic P- and S-wave measurements to analyse and characterise fault zones. Fault zones have a high potential for geothermal energy extraction, but their usability depends on complex factors (structure, lithology, tectonics), underlining the need for detailed fault zone exploration and the deeper understanding of the factors' interplay.

In this study, we carried out both P- and S-wave reflection seismic surveys parallel and perpendicular to the eastern border of the Leinetal Graben, Lower Saxony, to explore the fault system. The seismic data reveal a high-resolution image of the complex graben structure which comprises both steeply-dipping normal faults and shallowly west-dipping normal faults, which cause a roll-over structure. In addition halokinesis is observed. The structural image of the graben structure indicates independent tectonic development of the uppermost (<500 m) and deeper (>500 m) depth levels.

One of the shallowly west-dipping normal faults is traceable from the surface down to 500 m depth. To further investigate this fault zone which shows different reflection characteristics of P- and S-waves, a petrophysical analysis was conducted, including elastic parameter derivation and seismic modelling. Elastic parameters change strongly in the near-surface area, e.g., vs increases from 300 m/s at the surface to 900 m/s at 100 m depth, leading to a decrease in vp/vs from 6 to approx. 2.5. Changes in elastic parameters correlate with the geological interpretation and are in correspondence to literature values for the given lithologies. However, the fault zone itself shows no significant changes in elastic parameters due to the low resolution of the derived seismic velocities. Seismic modelling is a helpful tool to check elastic parameters which are assigned to the fault zone in the model. A comparison between synthetic and field data shows that the field data are better reproduced if the fault zone is modelled as an extended layer instead of an interface.