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Seismic investigations for high resolution exploration ahead and around boreholes

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Deep reservoirs usually will be explored with a surface seismic survey often in combination with borehole seismic measurements like VSP or SWD which can improve the velocity model of the underground. Reservoirs especially in geothermal fields are often characterized by small-scale structures. Additionally, with depth the need for exploration methods with a high resolution increases because standard methods like borehole seismic measurements cannot improve their resolution with depth. To localize structures with more accuracy methods with higher resolution in the range of meters are necessary.
Within the project SPWD - Seismic Prediction While Drilling a new exploration method will be developed. With an implementation of seismic sources and receivers in one device an exploration method ahead and around the borehole will be enabled. Also, a high resolution independent from the depth will be achieved. Therefore active and powerful seismic sources are necessary to reach an acceptable penetration depth.
Step by step seismic borehole devices were developed, which can be used under different conditions. Every borehole device contains four seismic sources and several three-component geophones. A small distance between actuators and geophones allows detecting also the high frequency content of the wave field reflected at geological structures. Also, exploration with a high resolution is possible. A first borehole device was developed for basic conditions in horizontal boreholes without special terms to temperature or pressure. In a mine first methodical measurements for the initiated wave field were performed. Therefor an existing seismic test area at the research and education mine of the TU Bergakademie Freiberg was extended with boreholes. In the seismic test area, consisting of a dense geophone array with three-component geophone anchors, two horizontal and one vertical borehole was drilled.
To achieve a radiation pattern in predefined directions by constructive interference the signals of each vibrator must be independently controlled in amplitude and phase. This allows a systematic exploration of areas around the borehole and also in direction ahead of the borehole. Measurements of the developed borehole devices with this seismic method show that structures like nearby galleries of the mine or zones of cracks can be explored depending on the issued direction. Imaging with a three–component Fresnel-Volume-Migration shows clearly the effect of the radiation pattern to the distribution of the seismic wave energy. The migration of the reflected wave field reveals an amplification of the reflected amplitudes at the galleries corresponding to the radiation pattern of the seismic borehole sources.
A second borehole device was developed for usage in boreholes up to 2 km depth. After completion first measurements are planned to verify the exploration method for a directional investigation in boreholes. The measurements will take place in different geologies of hard and soft rocks and also depths.
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