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Development of a seismic borehole sonde for high resolution geophysical exploration ahead and around the drill bit

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The importance of exploration with high resolution increases more and more because reservoirs especially in geothermal fields are characterized of small-scale geological structures. Today, surface seismic surveys were often combined with borehole seismic measurements like VSP or SWD to improve the velocity model and to image the structures with higher resolution. The accuracy of structure localization depends strongly on the surveying depth. There is the need for resolution of such small-scale structures in the range of meters to explore deeper structures with a high resolution. In the project "Seismic Prediction While Drilling" (SPWD) a new approach for a seismic exploration method in boreholes will be examined. SPWD comprises the seismic sources and receivers in one device. This allows an exploration with a resolution independent from depth and a system development for an exploration ahead and around the drill bit.

At first a prototype of a borehole device for dry horizontal boreholes in a mine was developed and tested. The source device consists of four magnetostrictive vibrators emitting sweep signals from 500 Hz to 5000 Hz. To achieve a radiation pattern for focusing the seismic wave energy in predefined directions the signals of each vibrator must be independently controlled in amplitude and phase. The adjustment of amplitudes and phases of each sweep signal resulting in constructive interference with a predefined direction. A control of the emitted signals is retained by 30 three-component receivers mounted along the surrounding galleries in distances of up to 50 m. In measurements several parameters were examined to control the radiation pattern. The enhancement and diminishment of the wave amplitudes in the predefined directions of the radiation pattern is clearly exhibited also a dependency of the frequency. Using a three–component Fresnel-Volume-Migration to image the reflected wave field the results show clearly the effect of the radiation pattern on 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 complex borehole source. Also, structures passing through the borehole can be detected with an additional characterization by different radiation patterns. Further improvements were realized in focusing the seismic energy with advances in technical devices and also in the control of the vibrators.

As a next step a wireline prototype for borehole measurements was designed and constructed. Currently the manufacturing is in progress. This prototype will be used in vertical boreholes up to 2000 m 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. Also the mine was expanded with a 70 m vertical borehole for further research aspects. This project is funded by the German Federal Environment Ministry.