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Borehole prototype for seismic high-resolution exploration

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Target reservoirs for the exploitation of hydrocarbons or hot water for geothermal energy supply can comprise small layered structures, for instance thin layers or faults. The resolution of 2D and 3D surface seismic methods is often not sufficient to determine and locate these structures. Borehole seismic methods like vertical seismic profiling (VSP) and seismic while drilling (SWD) use either receivers or sources within the borehole. Thus, the distance to the target horizon is reduced and higher resolution images of the geological structures can be achieved. Even these methods are limited in their resolution capabilities with increasing target depth. To localize structures more accuracy methods with higher resolution in the range of meters are necessary.
The project SPWD – Seismic Prediction While Drilling aims at s the development of a borehole prototype which combines seismic sources and receivers in one device to improve the seismic resolution. Within SPWD such a prototype has been designed, manufactured and tested. The SPWD-wireline prototype is divided into three main parts. The upper section comprises the electronic unit. The middle section includes the upper receiver, the upper clamping unit as well as the source unit and the lower clamping unit. The lower section consists of the lower receiver unit and the hydraulic unit. The total length of the prototype is nearly seven meters and its weight is about 750 kg. For focusing the seismic waves in predefined directions of the borehole axis the method of phased array is used. The source unit is equipped with four magnetostrictive vibrators. Each can be controlled independently to get a common wave front in the desired direction of exploration. Source signal frequencies up to 5000 Hz are used, which allows resolutions up to one meter.
In May and September 2013 field tests with the SPWD-wireline prototype have been carried out at the KTB Deep Crustal Lab in Windischeschenbach (Bavaria). The aim was to proof the pressure-tightness and the functionality of the hydraulic system components of the borehole device. To monitor the prototype four cameras and several moisture sensors were installed along the source and receiver units close to the extendable coupling stamps where an infiltration of fluid is most probably. The tests lasted about 48 hours each. It was possible to extend and to retract the coupling stamps of the prototype up to a depth of 2100 m. No infiltration of borehole fluids in the SPWD-tool was observed. In preparation of the acoustic calibration measurements in the research and education mine of the TU Bergakademie Freiberg seismic sources and receivers as well as the recording electronic devices were installed in the SPWD-wireline prototype at the GFZ. Afterwards, the SPWD-borehole device was transported to the GFZ-Underground-Lab and preliminary test measurements to characterize the radiation pattern characteristics have been carried out in the newly drilled vertical borehole in December 2013. Previous measurements with a laboratory borehole prototype have demonstrated a dependency of the radiated seismic energy from the predefined amplification direction, the wave type and the signal frequencies.
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