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Seismic Prediction While Drilling (SPWD): Seismic exploration ahead of the drill bit using phased array sources

Katrin Jaksch, Rüdiger Giese, and Matthias Kopf
Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, Germany (kawi@gfz-potsdam.de)

In the case of drilling for deep reservoirs previous exploration is indispensable. In recent years the focus shifted more on geological structures like small layers or hydrothermal fault systems. Beside 2D- or 3D-seismics from the surface and seismic measurements like Vertical Seismic Profile (VSP) or Seismic While Drilling (SWD) within a borehole these methods cannot always resolute this structures. The resolution is worsen the deeper and smaller the sought-after structures are. So, potential horizons like small layers in oil exploration or fault zones usable for geothermal energy production could be failed or not identified while drilling. The application of a device to explore the geology with a high resolution ahead of the drill bit in direction of drilling would be of high importance. Such a device would allow adjusting the drilling path according to the real geology and would minimize the risk of discovery and hence the costs for drilling.

Within the project SPWD a device for seismic exploration ahead of the drill bit will be developed. This device should allow the seismic exploration to predict areas about 50 to 100 meters ahead of the drill bit with a resolution of one meter. At the GFZ a first prototype consisting of different units for seismic sources, receivers and data loggers has been designed and manufactured. As seismic sources four standard magnetostrictive actuators and as receivers four 3-component-geophones are used. Every unit, actuator or geophone, can be rotated in steps of 15° around the longitudinal axis of the prototype to test different measurement configurations. The SPWD prototype emits signal frequencies of about 500 up to 5000 Hz which are significant higher than in VSP and SWD. An increased radiation of seismic wave energy in the direction of the borehole axis allows the view in areas to be drilled. Therefore, every actuator must be controlled independently of each other regarding to amplitude and phase of the source signal to maximize the energy of the seismic source in order to reach a sufficient exploration range. The next step for focusing is to use the method of phased array. Dependent of the seismic wave velocities of the surrounding rock, the distance of the actuators to each other and the used frequencies the signal phases for each actuator can be determined.

Since one year several measurements with the prototype have been realized under defined conditions at a test site in a mine. The test site consists of a rock block surrounded from three galleries with a dimension of about 100 by 200 meters. For testing the prototype two horizontal boreholes were drilled. They are directed to one of the gallery to get a strong reflector. The quality of the data of the borehole seismics in amplitude and frequency spectra show overall a good signal-to-noise ratio and correlate strongly with the fracture density along the borehole and are associated with a lower signal-to-noise ratio. Additionally, the geophones of the prototype show reflections from ahead and rearward in the seismic data. In particular, the reflections from the gallery ahead are used for the calibration of focusing. The direct seismic wave field indicates distinct compression and shear waves. The analysis of several seismic measurements with a focus on the direct seismic waves shows that the phased array technology explicit can influence the directional characteristics of the radiated seimic waves. The amplitudes of the seismic waves can be enhanced up to three times more in the desired direction and simultaneously be attenuated in the reverse direction.

A major step for the directional investigation in boreholes has accomplished. But the focusing of the seismic waves has to be improved to maximize the energy in the desired direction in more measurements by calibrating the initiating seismic signals of the sources. A next step this year is the development of a wireline prototype for application in vertical boreholes with depths not more than 2000 meters are planned. The prototype must be modified and adapted to the conditions in deep boreholes with respect to pressure and temperature. This project is funded by the German Federal Environment Ministry.