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Using a fibre-optic cable as Distributed Acoustic Sensor for Vertical Seismic Profiling – Overview of various field tests

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Fibre-optic Distributed Acoustic Sensing (DAS) or Distributed Vibration Sensing (DVS) is a technology, where an optical fibre cable is used as a sensor for acoustic signals. An ambient seismic wavefield, which is coupled by friction or pressure to the optical fibre, induces dynamic strain changes along the cable. The DAS/DVS technology offers the possibility to record an optoelectronic signal which is linearly related to the time dependent local strain. The DAS/DVS technology is based on the established technique of phase-sensitive optical time-domain reflectometry (phi-OTDR). Coherent laser pulses are launched into the fibre to monitor changes in the resulting elastic Rayleigh backscatter with time. Dynamic strain changes lead to small displacements of the scattering elements (non-uniformities within the glass structure of the optical fibre), and therefore to variations of the relative phases of the backscattered photons. The fibre behaves as a series of interferometers whose output is sensitive to small changes of the strain at any point along its length. To record the ground motion not only in space but also in time, snapshots of the wavefield are created by repeatedly firing laser pulses into the fibre at sampling frequencies much higher than seismic frequencies.
DAS/DVS is used e.g. for continuous monitoring of pipelines, roads or borders and for production monitoring from within the wellbore. Within the last years, the DAS/DVS technology was further developed to record seismic data. We focus on the recording of Vertical Seismic Profiling (VSP) data with DAS/DVS and present an overview of various field tests published between 2011 and 2014. Here, especially CO_2 storage pilot sites provided the opportunity to test this new technology for geophysical reservoir monitoring. DAS/DVS-VSP time-lapse measurements have been published for the Quest CO_2 storage site in Canada. The DAS/DVS technology was also tested at the CO_2 storage sites in Rousse (France), Citronelle (USA), Otway (Australia) and Ketzin (Germany). At Ketzin it was possible to record a multi-offset VSP simultaneously within four wells, allowing a high-resolution imaging of the reservoir. These publications represent a wide range of different source types, source-receiver geometries and cable deployments (on tubing, behind casing).
In conclusion, the DAS/DVS is a promising technology for VSP acquisition; the publications showed that it is possible to use DAS/DVS-VSP data for the calculation of velocity profiles, for well-ties and for seismic imaging. Some points have to be taken into account when recording DAS/DVS-VSP data. With an optical fibre, only a single value reflecting the strain between two points within the fibre is measured. The sensitivity of the fibre-optic cable is generally lower than that of a geophone with current readout units. If a fibre-optic cable has already been installed in a well, no well intervention is needed to acquire a VSP on demand, e.g. for time-lapse measurements. Several wells can be interrogated at the same time with full vertical coverage.