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Distributed Acoustic Sensing Technology in Magmatic Geothermal Areas – First Results from a Survey in Iceland

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ABSTRACT

Within this study, data from a fibre optic distributed acoustic sensing (DAS) survey in a magmatic geothermal environment is presented. Therefore, a 180 m long fibre optic cable was installed behind the anchor casing of a conventional geothermal well. In addition, data was acquired along a 15.3 km long cable deployed at the surface. DAS data was acquired continuously for 9 days. During the recording period both, signals from on- and offshore explosive sources as well as natural seismic events could be recorded. First results will be presented.

1. INTRODUCTION

Seismic methods are particularly suited for investigating Earth subsurface. Compared to measurements from the surface, wellbore measurements can be used to acquire more detailed information about rock properties and possible fluid pathways within a geothermal reservoir. For high temperature geothermal wells, however, ambient temperatures are often far above the operating temperature range of conventional geophones. One way to overcome this limitation is the application of fibre optic sensor systems, where only the passive optical fibre is subjected to downhole conditions (Reinsch et al. 2015). Their applicability is thus determined by the operating temperature range of the optical fibre. Choosing appropriate fibres, such sensor systems can be operated at temperatures far above 200°C (Reinsch and Henninges 2010, Reinsch et al. 2013). Along an optical fibre, the distributed acoustic sensing technology (DAS) can be used to acquire acoustic signals with a high spatial and temporal resolution. Previous experiments have shown that the DAS technology is well suited for active seismic measurements (e.g. Daley et al. 2013).

Within the framework of the EC funded project IMAGE, a fibre optic cable was set up within a newly drilled geothermal well (RN-34) within the Reykjanes geothermal field, Iceland. Additionally, a 15.3 km fibre optic cable already available at the surface was connected to a DAS read-out unit (Figure 1). Acoustic data was acquired continuously for 9 days with an iDAS unit from Silixa Ltd.. Hammer shots were performed at the wellhead as well as along the surface cable in order to locate individual acoustic traces and calibrate the spatial distribution of the acoustic information. During the monitoring period both signals from on- and offshore explosive sources and natural seismic events could be recorded. First results will be presented.

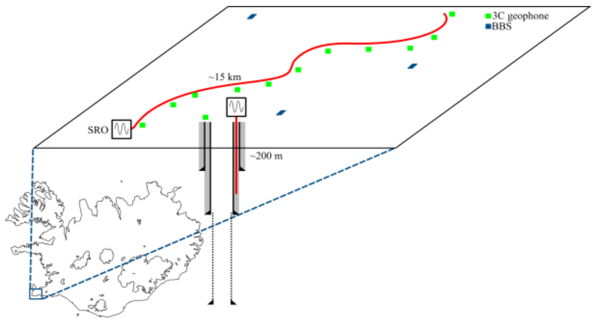

Figure 1: Concept for installation of fibre optic sensor cables and geophones at Reykjanes.

2. DISTRIBUTED ACOUSTIC SENSING

The fibre optic DAS technology is based on the optical time domain reflectometry (OTDR) measurement principle for elastically scattered photons (Rayleigh scattering). Here a light pulse is coupled into an optical fibre and a small portion of the light is scattered at randomly distributed defaults along the fibre, partly propagating backwards. In order to determine strain changes along the optical fibre, caused by seismic waves, the phase of the backscattered light from a coherent laser pulse can be analysed (Φ-OTDR, e.g. Masoudi et al. 2013). Stretching the fibre changes the distance to individual scattering points. Hence, the phase of the light arriving at the read-out unit changes as well. Phase differences between successive light pulses are analysed and a strain-rate is calculated for each pulse. The strain-rate can be converted to local strain by temporal integration.

3. EXPERIMENTAL SET-UP

Within this study a fibre optic cable was permanently installed behind the anchor casing of a conventional geothermal well in the Reykjanes geothermal field in February 2015 (Figure 2). The cable was strapped to the anchor casing using metal ties. Afterwards, it was cemented to the formation. Data could be acquired down to a depth of about 180 m.

Figure 2: Permanent installation of fibre optic sensor cable behind the anchor casing of well RN-34. Left: during installation, right: cable fully cemented after cementation.

3. RESULTS

3.1 Active seismic recording

Along the surface cable, seismic hammer shot recordings were performed every 250-500 m in order to locate the position of individual seismic traces. Figure 4 shows the local strain for 36 traces. With increasing distance from the shot point, attenuation increases. However, the signal is still visible in about 300 m distance for individual shot points.

3.2 Passive seismic recording

During the time of recording, several earthquakes occurred and passive seismic data could be acquired along the surface cable. Figure 5 shows the strain-rate response of an individual trace for an earthquake that has been localized beneath the surface cable. The p- and s-wave arrivals can be clearly separated.

3.3 Passive seismic recording at wellbore cable

Seismic data have been acquired along the wellbore cable as well. During the time of recording, there were periods of active drilling as well as fluid circulation. Figure 3 shows strain-rate data recorded for a magnitude 2.05 earthquake for the surface cable as well as for a single trace recorded downhole in a depth of about 65 m below surface. Due to the high noise caused by the low frequency fluid circulation within the well, wellbore data was high-pass filtered with a cut-off frequency of 1Hz. The arrival of the seismic wave can be clearly observed for both, the surface as well as the wellbore cable.

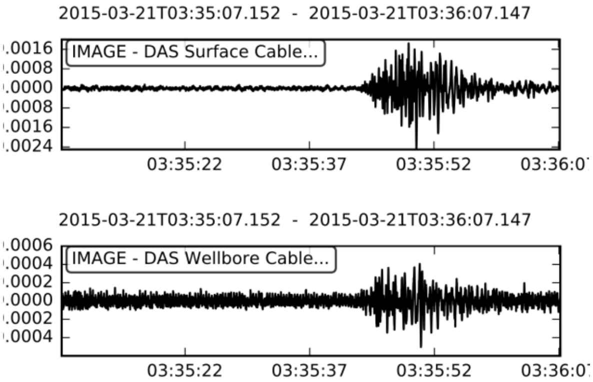

Figure 3: Strain data (high pass filter: 1 Hz) for an earthquake observed on the surface cable at about 1840 m from the beginning of the cable as well as the wellbore cable at 65 m below surface. Fluid was injected into the well during this measurement. Event was localised approx. 22 km to the SW of the tip of the cable by the Icelandic Meteorological Office: Depth 7.8 km, Local Magnitude 2.05.

4. CONCLUSIONS

A fibre optic cable was installed behind the anchor casing of a geothermal well. Seismic data was acquired for a period of 9 days along the wellbore as well as a 15.3 km surface cable. During this time, active and passive seismic signals could be recorded along the fibre optic cable. It has been shown, that the DAS technology is well suited to monitor seismic signals in a magmatic environment. Data is currently being processed to generate an image of the subsurface.

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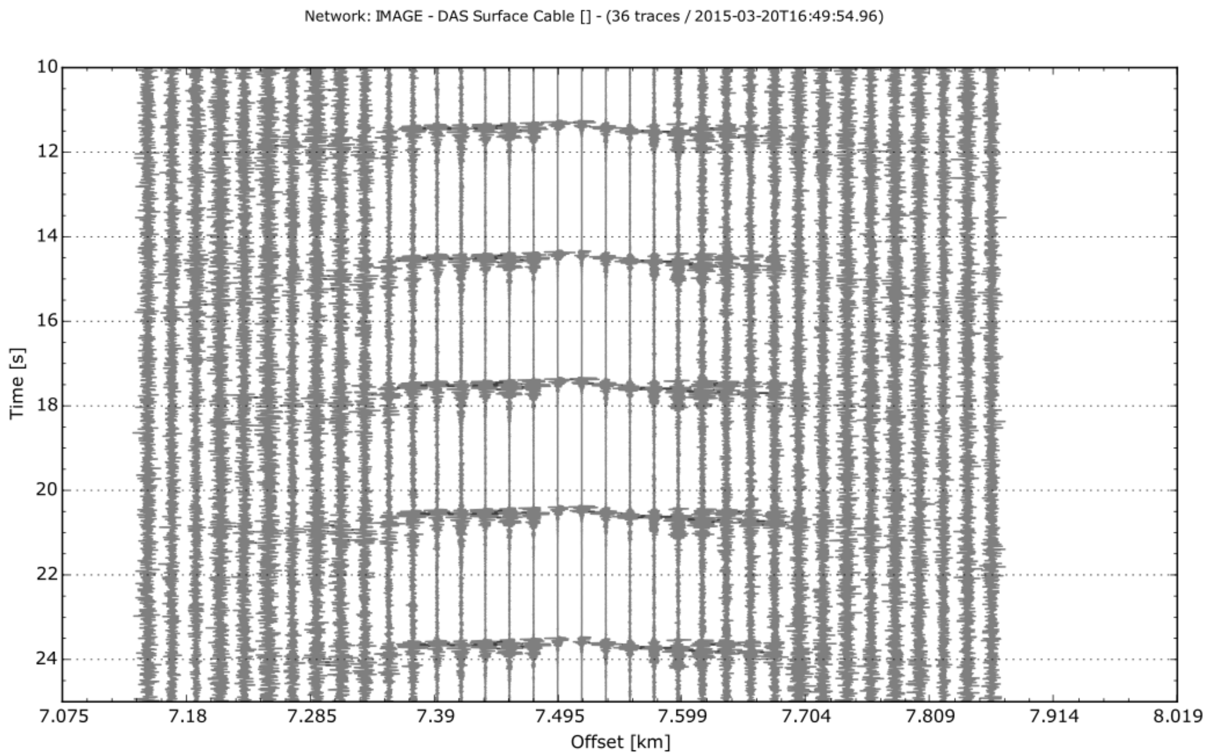

Figure 4: Strain-rate data of every 5th trace for individual hammer shots along a 1000 m section of the cable. Amplitude is normalized for each trace.

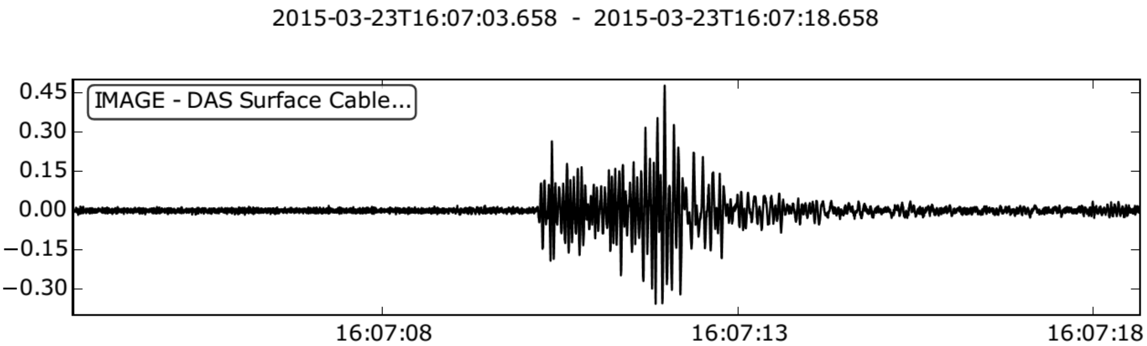

Figure 5: Strain-rate data for an earthquake observed on the surface cable. The event was localized beneath the cable by the Icelandic Meteorological Office: Depth 3.5km, Local Magnitude 1.02.