Transforming an abandoned well into a permanent downhole receiver array: Harvey-3 case study

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SUMMARY

Fibre optic sensing is an emerging technology enabling reliable long term monitoring and surveillance of the subsurface. In this contribution, we detail the first Australian installation of a fibre optic sensing system as part of a stratigraphic well decommissioning or plug and abandon (PandA) process including preliminary results of the cementing operations. Additionally, we propose options for long term enduring research at the resulting facility.

Key words: fibre optic sensing, decommissioning, well plug and abandonment, seismic monitoring, temperature, cementing

INTRODUCTION

Distributed fibre optic sensing can be used to monitor changes in strain, temperature and some other physical properties at high sampling rates both spatially and temporally. Measuring dynamic strain referred to as distributed acoustic sensing (DAS) allows to convert single optical fibre into an array of optical acoustic or seismic sensors with very small receiver interval (could be as small as 0.25 cm), broad frequency range (from practically static strain to hundreds of hertz) and high enough sensitivity. Such receiver arrays can be used to monitor local and regional seismicity as well as detect distant seismic events. Deployment of the seismic receiver array along deep vertical wells allows to have seismic sensors in a quiet environment with no surface wave contamination. Sensing temperature along the fibre optic cable, that often referred to as distributed temperature sensing (DTS), can be performed to infer the physical properties of the subsurface. Temperature monitoring helps with the wellbore and reservoir characterization. From passive monitoring, it is possible to add complementary information to wireline logs but also characterize downhole flow operations. Another application of DTS is the monitoring of the cement curing process which allows to provide near-real time information about the cement injection process and verify the quality of the cement job a posteriori. When combined with active heating of the cable, DTS can inform about the near-wellbore characteristics for the well, completion and the reservoir.

Fibre optic cables for downhole monitoring (both active and passive) were successfully trialled in Australia on several sites, including the National Geosequestration Laboratory (NGL) 900 m well drilled at the Curtin University campus (Pevzner et al., 2018a, Pevzner et al., 2018b), the CSIRO In-Situ Lab Harvey-2 site (Michael et al., 2019) and the CO2CRC Otway site (Correa et al., 2018; Ricard and Pevzner 2018). Different type of installation and cables have been tested: PE coated cables where inert downhole conditions are expected and stainless steel coating where harsh conditions such as high CO_2 concentration are forecast. Additionally, different types of deployment were tested: casing conveyed and tubing conveyed cables. These installations are associated with research projects of 'live' monitoring wells'. To date, fibre optic sensing was not used to monitor a PandA process in Australia. Using fibre optic cables for downhole instruments has the critical advantage over other types of downhole instrumentation because the most sensitive equipment (interrogator) is located and connected (upon request) at the surface and therefore can be maintained, upgraded and changed without accessing downhole. The fibre optic cable itself is the more robust and inert (no electronics and no moving parts) section of the distributed fibre optic sensing system, making it a perfect instrumentation for a plug and abandonment (PandA) process and an enduring research facility.

The South West Hub is one of the projects under the Commonwealth of Australia Carbon Capture and Storage Flagship initiative. As part of an extensive program of geological characterisation and uncertainty reduction, several wells were drilled (Harvey-1, -2, -3 and -4). Harvey-1 was plugged and abandoned (PandA) in 2011. Harvey-2 is now the part of the long term enduring CSIRO In-Situ Laboratory research facility (Michael et al., 2019). Harvey-3 and Harvey-4 were plugged and abandoned in January 2019. The PandA operation at Harvey-3 presented an opportunity to deploy permanently a fibre optic cable and install it in place. The objective of such an operation was to monitor the PandA process while transforming the Harvey-3 well into a permanently instrumented well equipped for fibre optic sensing such as DAS and DTS. The cable acts as a receiver array providing measurements coming from thousands of points in the subsurface.

In this presentation we discuss installation of the fibre optic cable, and monitoring of the cementing operations using a combination of DAS and DTS. We then propose opportunities for long term research applications of such a facility.

DEPLOYMENT OF FIBRE OPTIC CABLE IN HARVEY-3 WELL

Well Description

The Harvey-3 well was drilled between December 2014 and June 2015 as a part of the South West Hub project (Stelfox et al., 2018). The well is located in the Southern Perth Basin, 120 kilometres from Perth. During the drilling stage the well reached the top of the Wonnerup Member that was the target horizon. The well is completed with 3 stages of casing (Figure 1) including a 4.5" production casing to a total depth of 1,550 m below ground level. The well was left suspended shortly after drilling with van Ruth plugs at the bottom.

Fibre Optic Cable Installation

The fibre optic installation occurred as part of the PandA operations on 22nd and 23rd January 2019. A stainless steel coated fibre optic cable with two single mode, two multi-mode cores and two 18 AWG electrical conductors was selected for this experiment. The fibre optic cable was terminated with a double ended configuration for the multi-mode cores and with attenuators for the single mode cores while the electrical conductors were connected together to enable heating of the cable. The downhole terminations were inserted inside a 6 m long weight for protection and to ease the cable deployment. A sacrificial 2-3/8" tubing was first installed to enable the fibre optic (FO) cable deployment to TD and well cementation in line with the decommissioning requirements. Once the tubing was installed and fluid swapped, the fibre optic cable was lowered down inside the tubing (Figure 1). A custom designed tee connection at the wellhead enabled the simultaneous FO monitoring and cementing process.

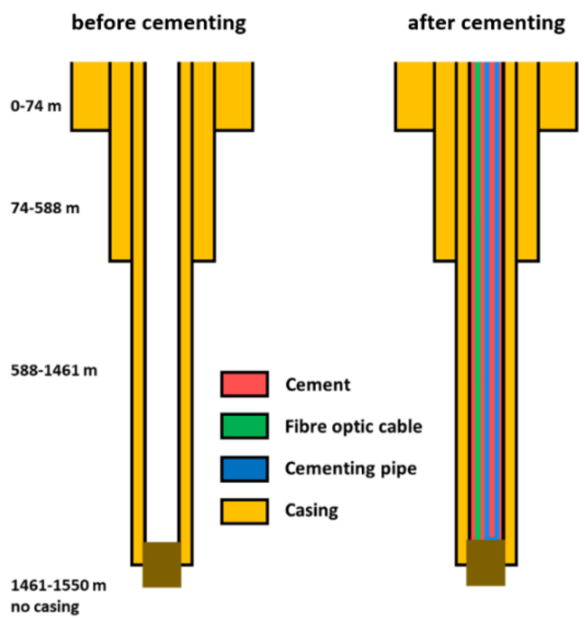

Figure 1. Harvey-3 well scheme. Before and after cementing.

MONITORING OF CEMENTING PROCESS USING DAS AND DTS

The first operation using the fibre optic sensor in the well was the monitoring of the cementing operations associated with the PandA process. Monitoring operations covered baseline, cementing injection and post-injection with both DAS and DTS.

Distributed Acoustic Sensing

For DAS monitoring of the cementing process we used single mode fibres and two different interogators: Fotech Helios Theta and Silixa iDAS. Monitoring acquisition started at 10 am of 23rd of January and had been finished by 5 pm of the same day.

Time-lapse response of one of the interrogators over three hours time interval is shown in Figure 2. Colour indicates the intensity of the fibre disturbance. The vertical axis represents the length or depth along the cable. Thus, the zero metre mark indicates the land surface. The horizontal axis is the time axis. Any horizontal line on the diagram shows the response of a single point in the well over the time.

Injection of slurry cement lasted for 30 minutes from 1:05 pm till 1:35 pm. During the cementing process we observed a response at different parts of the well. While the analysis of all the observed events is underway, some could be clearly tied to cementation. The active injection process can be easily observed on the DAS data middle plot (Figure 2) as an intensive red area. Surface activity near the wellhead is indicated by short red bursts at the low depth interval of 0-200 m.

Distributed Temperature Sensing

Temperature was monitored for two days covering baseline (after cable installation and prior to cement injection), cement injection and then post-injection (cement curing). The unit used was a Sensornet Oryx with a spatial resolution of 1m and a temporal sampling of 1 minute. Figure 3 shows the temperature evolution over the PandA experiment in Harvey-3 well. Four different stages can be observed in the dataset: baseline, cement injection, cement equilibration and cement curing. The cement was injected at constant temperature before it reached formation temperature. Cement curing only started 18 h after injection.

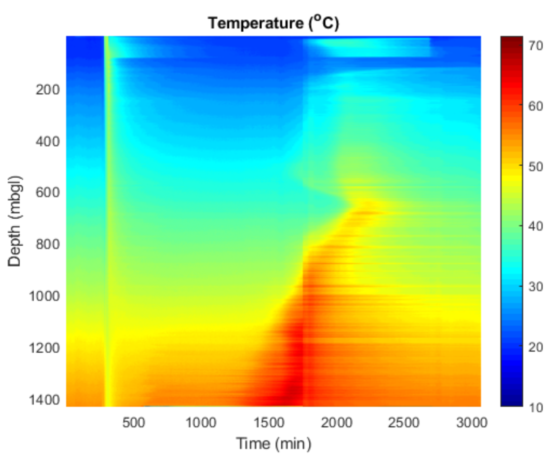

Figure 3. Temperature evolution over time and depth during cementing operations.

DISCUSSION AND CONCLUSIONS

The PandA process is often seen as the end of the well as no more information could be gathered from the reservoir the well penetrated. It is a process which by definition restricts access to the well for future use. With the growing activity on decommissioning, there is a need to improve our knowledge of such activities. Complementary to other PandA assessment techniques which focuses on surface and shallow monitoring, fibre optic sensing can measure from surface to TD with high spatial sampling resolution and at high temporal frequencies over a very long time (FO installation can last 10+ years before degradation). Hence, fibre optic sensing by the nature of the sensing equipment is perfectly fitted to contribute to monitor this process down to the reservoir level.

Additionally, building a long term enduring research facility is often a costly exercise as it requires drilling a well, instrumenting and maintaining it. Here, by been opportunistic, one can combine the inevitable PandA process with the development of an enduring research facility at low cost (compared to the drilling and maintenance of a well for this sole purpose). Such a facility could be used in the future for DAS and DTS monitoring. More specifically, the well with the cable can be used for the following research activities:

- Monitoring of the PandA process (cement) from temperature measurements using passive and active measurements;
- Long term monitoring of the subsurface (identification of groundwater flow changes, reservoir characterization and surveillance) from temperature measurements using passive and active measurements;
- Global and regional seismology studies, the well can be used in conjunction with other instrumented wells;
- Development of passive seismic monitoring approaches using the ambient noise;
- Long-term strain monitoring which could be used in geomechanical studies.

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REFERENCES

Correa, J., Pevzner, R., Popik, S., Tertyshnikov, K., Bona, A. and Freifeld, B. 2018. Application of 3D VSP acquired with DAS and 3C geophones for site characterization and monitoring program design: preliminary results from Stage 3 of the CO2CRC Otway project. In: SEG Technical Program Expanded Abstracts 2018, pp. 4933-4937.

Michael, K., Avijegon, A., Ricard, L., Myers, M., Tertyshnikov, K., Pevzner, R., Strand, J., Freifeld, B., Woitt, M., Peruvkkina, M., Feitz, A., Pejcic, B., Stalker, L., Harris, B., Myers, J., Larcher, A., Rachakonda, P., Langhi, L., Dance, T., Hortle, A., Roberts, J., Woltering, M., White, C. 2019. In-Situ Laboratory for CO2 Controlled-Release Experiments and Monitoring in a Fault Zone in Western Australia. AEGC 2019, Perth, Western Australia.

Pevzner, R., Bona, A., Correa, J., Tertyshnikov, K., Palmer, G. and Valishin, O.2018a. Optimising DAS VSP data acquisition parameters: theory and experiments at Curtin training well facility. 80th EAGE Conference and Exhibition 2018 Copenhagen, Denmark, Extended Abstracts, WS08, 10.3997/2214-4609.201801923.

Pevzner, R., Tertyshnikov, K. and Bona, A.2018b. Feasibility of Passive Vertical Seismic Profiling Using Distributed Acoustic Sensing for Monitoring Applications. 80th EAGE Conference and Exhibition 2018 Copenhagen, Denmark, Extanded Abstracts, Th F16, 10.3997/2214-4609.201801473.

Ricard, L.P., Pevzner, R. 2018. Evaluation of Sensitivity of Downhole Temperature Estimates from Distributed Temperature Sensing Measurement. Energy Procedia, 154, pp 106-111, 10.1016/j.egypro.2018.11.018.

Stelfox, L., Western Australia. Department of Mines, Industry Regulation and Safety, 2018. DMP Harvey 2, 3 and 4 well completion and preliminary observation report: South Perth Basin. Department of Mines, Industry Regulation and Safety, East Perth, Western Australia

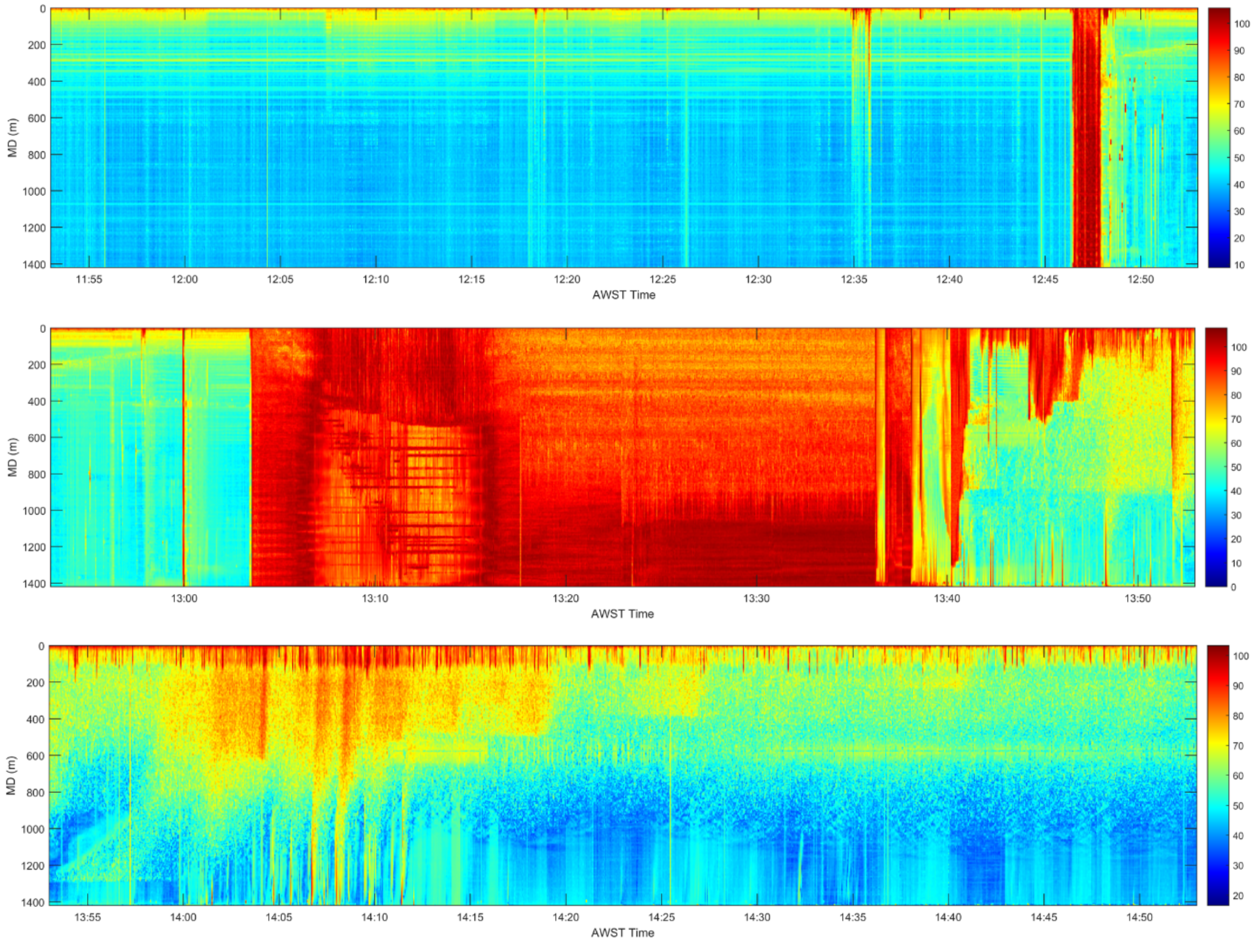

Figure 2. Fragment of DAS data recorded in Harvey-3 well during cementing operations.