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CO_2 reservoir monitoring with a permanent seismic source (ACROSS) and DAS at the Aquistore CCS site

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Summary

We focus on the high accuracy permanent reservoir monitoring system for combined use of ACROSS and DAS. Monitoring survey data was acquired at the Aquistore CCS site in Dec. 2016, Mar. 2018 and Apr. 2019. We applied data processing including ACROSS signal processing, data matching, VSP data processing and 4D noise suppression with calculating repeatability index for evaluating 4D responses. Data acquisition and processing was successful, resulting in repeatable VSP-CDP sections. Though the data processing method for combining use of ACROSS and DAS data was established, we will improve the data processing and continue the data acquisition to detect 4D responses in this area.

Introduction

We are now working on developing a permanent reservoir monitoring (PRM) system for oil/gas reservoirs using the permanent seismic source ACROSS (Accurately Controlled Routinely Operated Signal Source) since 2012 (e.g. Nakatsukasa et al., 2018). In particular, we consider that combined use of ACROSS and DAS (Distributed Acoustic Sensing) can acquire high accuracy monitoring data because the source and receivers are installed permanently. As part of the demonstration experiments, monitoring survey data using ACROSS and DAS was acquired at the Aquistore CCS site (e.g. White et al., 2019) in Estevan, Saskatchewan, Canada three times. Data processing for offset VSP data was applied and images of the CO_2 reservoir were obtained including repeatability index of both reservoir and upper layer. Through these studies, we organize the characteristics and issues of this PRM system.

Data acquisition and processing overview

The target area is the Aquistore CCS site. CO2 injection started in 2015 and total injection volume reached ~200 kilotonnes by Mar. 2019 with sustained injection rates of 400-600 tonnes/day (White et al., 2019). Fig. 1 shows the location of the observation well, the injection well and ACROSS with CDP line. Fiber optic cable was permanently installed behind casing of the observation well. The distance between the injection well and the observation well is about 100 m. Although ACROSS was initially operated near the observation well, it was subsequently moved to about 750m from the observation well in 2016. After that, we acquired ACROSS and DAS data in Dec. 2016 (baseline; 104 kilotonnes CO2 injected), Mar. 2018 (1st repeat; 141 kilotonnes CO2 injected) and Apr. 2019(2nd repeat; 200 kilotonnes CO2 injected).

The data processing can be divided into 4 sections. The first is ACROSS signal processing. S/N separation, vertical stacking and deconvolution using ACROSS signal spectrum were applied in the frequency domain. The result of these processes is an ACROSS shot gather. The second is data matching. To correct the amplitude level and global phase, the global matching filter was designed near the first break time, and applied only to the whole repeat data. The third is VSP data processing. Standard offset VSP processing including median filter, F-K filter, VSP-CDP mapping and post stack time migration was applied to the matched ACROSS shot gather. The last step is the 4D noise suppression. To eliminate the differences of the reflection wave observed over the CO2 injection layer, 4D amplitude regularization and residual static correction was applied only to the repeat data. After applying these processes, the repeatability index (Kragh et al., 2002) was calculated for both reservoir gate and upper gate to evaluate the 4D responses of baseline and repeat data.

Results and conclusions

Fig.2 is the results of the ACROSS-DAS data acquisition and processing. Fig. 2(a) is the ACROSS shot gather after applying global matching filter to the 1st and 2nd repeat data. Although there are some quality differences due to the acquisition parameter changes (Ichikawa et al., 2019), direct wave and some later phases were similar with each other. This means that the data acquisition using ACROSS and DAS was successful and data matching was good for these data. Fig. 2(b) is the final VSP-CDP sections after the 4D noise suppression. 4D noise was eliminated adequately and the repeatability index of the upper injection layer gate was higher (NRMS<15% and PRED>95%). It suggests that the data processing for combining use of ACROSS and DAS was established and the method of evaluating 4D responses became applicable. However, the repeatability index near the reservoir reflector was unstable and could not detect the 4D responses in the injection layer. Applying some noise reduction processes and increasing the number of stacking may improve the repeatability. In addition, according to another monitoring results (Harris et al., 2017), there is a possibility that our imaging area is slightly out of the CO_2 plume. We will continue the data acquisition so that we will be able to detect 4D responses in our imaging area as the CO2 plume size will increase enough.

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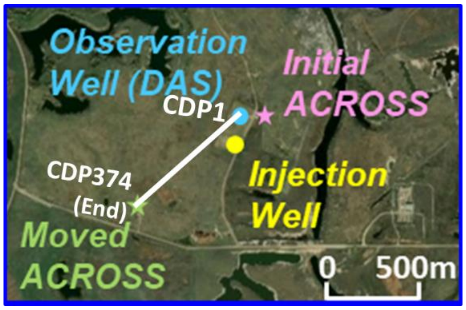

Fig. 1 Observation well, injection well and ACROSS location map in the Aquistore CCS site

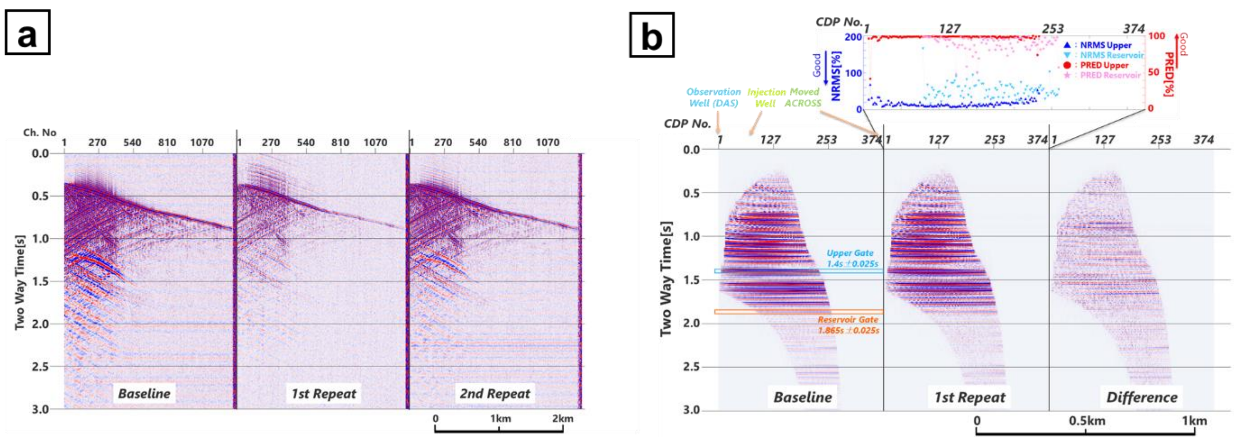

Fig. 2 ACROSS-DAS data acquisition and data processing results (a) ACROSS shot gather after data matching (b) VSP-CDP section of baseline and 1st repeat data after the 4D noise suppression with difference section and repeatability index