Development of a permanent reservoir monitoring system for continuous seismic monitoring during hydraulic fracturing: a case study at the Austin Chalk-Eagle Ford Field Laboratory

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ABSTRACT

A permanent seismic monitoring system, consisting of fixed location surface orbital vibrators (SOVs) and distributed acoustic sensing (DAS) cables, were deployed at the Austin Chalk/Eagle Ford Shale Laboratory to continuously monitor the hydraulic fracturing process (Hill et al., 2020). The SOV/DAS system is a novel method to acquire vertical seismic profiling (VSP) data using commercially available eccentric weight vibrators as swept seismic sources. SOV/DAS provides an unobtrusive methodology that can be operated autonomously and on demand before, during, and after stimulation to acquire high spatiotemporal resolution data. Our main objective was to acquire VSP data for fracture monitoring to detect scattering reflections from newly formed fractures due to treatment.

In this installation, five SOV pads were constructed along a transect above and in the same orientation as a cluster of three wells. Each SOV pad consisted of two 10 Ton-force and 15 ton-force vibration motors, which had maximum frequencies of 80 Hz and 55 Hz respectively. Unlike in a conventional vibroseis acquisition, which uses a phase-controlled source, the SOV is not phase-stabilized, relying on a 3-component geophone buried beneath the SOV pad to acquire the source signature for source-receiver deconvolution. Depending on the location of the fracturing stages a subset of two of the SOV pads were operated for half-hour time periods, permitting a sequence of SOV sweeps to be stacked to improve the signal-to-noise.

We acquired VSP data using DAS every hour, continuously, for nine days. Quantitative analysis of the VSP data shows good repeatability of normal-root-mean-square (NRMS) values of <40 % in-between stages, which indicates good quality of the seismic data. Time-lapse analysis of the VSP data acquired every hour revealed a series of scattered reflections from newly formed fractures after stimulation (Figure 1). Scattering anomalies on the shot gathers match well with frac-hits interpreted from the low-frequency DAS data (Zhu et al., 2023). Analysis of reflectivity of the scattered reflections reveal possible hydraulic connectivity with previously existing fractures.

The SOV/DAS technology for continuous and autonomous VSP data acquisition is an exciting opportunity to better understand fracture geometry, connectivity and compliance. The SOV/DAS system demonstrated that it has the repeatability and sensitivity to acquire highly repeatable time-lapse VSP data. More importantly, the time-lapse seismograms showed clear scattered reflections that could be attributed to individual fracturing stages and clusters. This data is highly complementary with other datasets, such as low frequency DAS and microseismic monitoring. The SOV/DAS methodology is applicable not only to unconventional oil and gas reservoirs, but can also be used for monitoring Engineered Geothermal Systems, and other dynamic subsurface processes, such as tertiary recovery operations.

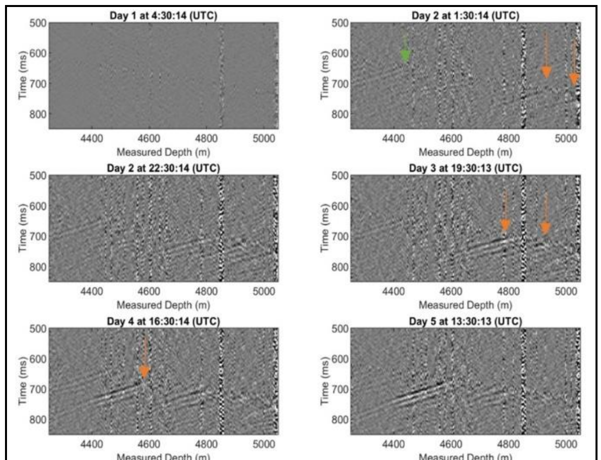

Figure 1: Timelapse difference seismogram examples for SOV3 of continuous operation as acquired in the monitor well. Day one is before treatment and the seismogram shows residual noise. A series of scattering events appear from the direct P as treatment commences in the injection well (Correa et al., 2024).

ACKNOWLEDGEMENTS

Funding to LBNL is provided from U.S. DOE, Assistant Secretary for Fossil Energy and Carbon Management, Office of Fossil Energy and Carbon Management, Resource Sustainability Program through NETL, under contract No. DE-AC02-05CH11231. The authors thanks Dr. Dan Hill and Dr. Ding Zhu, and collaborators from SM Energy and Silixa.