The Observation of Long-Period, Long-Duration Seismic Waveforms at $C0_2$ EOR Operations in Texas and Kansas

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Introduction

- During Enhanced Oil Recovery (EOR), CO_2 is injected into oil-bearing formations to increase production from depleted wells
- Long-Period, Long-Duration (LPLD) events are seismic events of low frequency (0.8-10 Hz), that can have a duration from tens of seconds to a few minutes
- Seismic waveforms recorded by broadband seismometers during CO_2 injection operations in Farnsworth, Texas and Wellington, Kansas were screened for the presence of LPLD events (Fig. 1)

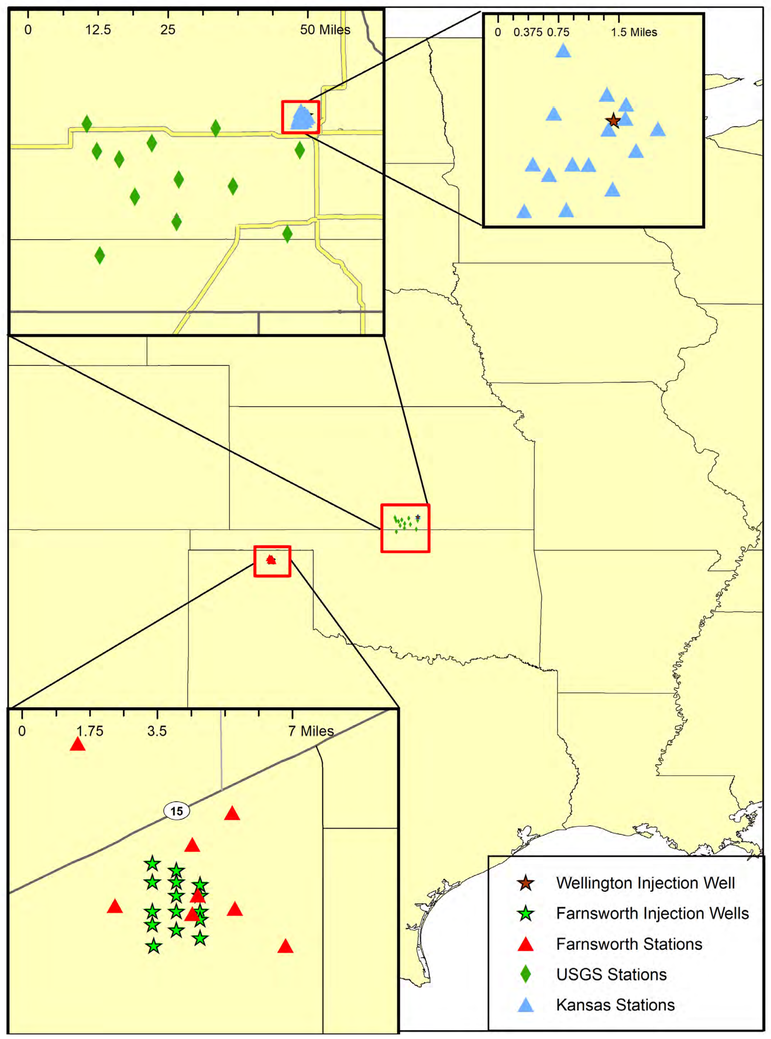

Figure 1. Seismic networks and injection wells for the Farnsworth site (Bottom), and Wellington site (Top)

Data

- Seismic data for the Farnsworth site was obtained from a broadband seismometer network operated by the United States Department of Energy-National Energy Technology Laboratory (USDOE-NETL)
- Seismic data for the Wellington Site was provided by the Kansas Geological Survey (KGS) and the U.S. Geological Survey (USGS)

- NETL and USGS used an array of Nanometrics-Trillium Compact 120 Posthole broadband seismometers to record seismic data (Fig. 2)
- KGS used an array of Mark Products L22 broadband seismometer/Reftek 130 Data Logger to record seismic data

Figure 2. Example of a posthole seismometer station at the Farnsworth Site. Broadband seismometer sensor (right) is buried at about 1-m depth.

Methods

- Seismic data were manually scanned in the frequency ranges of 0.8-3Hz, 1-5Hz, and 1-13Hz
- Low frequency events were detected and located using cross correlation techniques for the Farnsworth site.
- Regional earthquakes were removed by comparing the record with the Advanced National Seismic System Catalogue (ANSS) and the United States National Seismic Network (USNSN)
- A spectrogram and power spectral density were calculated for each unique event in Farnsworth (Fig. 4)

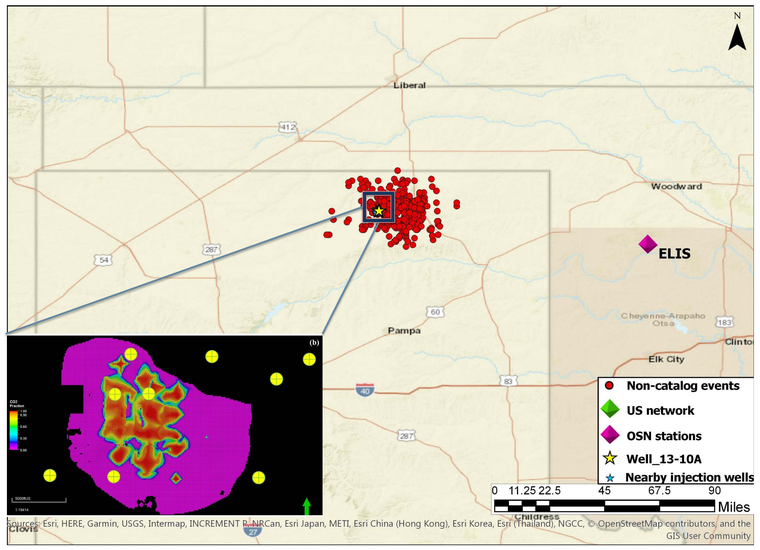

Figure 3. Map showing locations of LPLD events detected by NETL's Farnsworth seismometer network. Inset map shows locations of low-frequency events within CO_2 plume model (heat map) and pressure plume model (magenta) at Farnsworth EOR. Four LPLD events are within the modeled pressure plume; two events are within the CO_2 plume area. Map of CO_2 and pressure plume provided by New Mexico Tech.

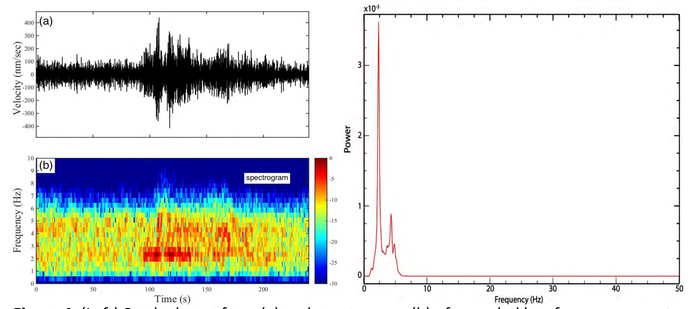

Figure 4. (Left) Stacked waveform (a) and spectrogram (b) of recorded low frequency event in Farnsworth. (Right) Power spectral estimate for event described at left.

Results and Discussion

- LPLD events were found at both the Farnsworth and Wellington EOR sites
- At Farnsworth, 466 low-frequency events were detected; of these, 155 events were determined to be LPLD events of local origin (within 40 km).
- At Wellington, 433 low-frequency events were detected; of these, 112 events were determined to be LPLD events of local origin
- At Farnsworth, two LPLD events were located within the CO_2 plume; 4 LPLD events were located within the modeled pressure plume
- The number and spatial distribution of LPLDs within the CO_2 and pressure plume is similar to the regional occurrence and distribution of LPLD events, suggesting that LPLD events may not be directly related to the CO_2 injection

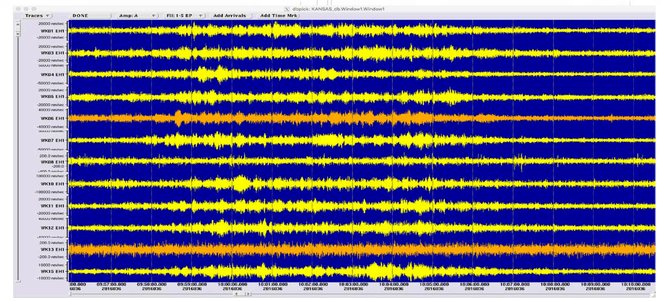

Figure 5. Low frequency event recorded by Wellington seismometer network with absence of clear arrivals.

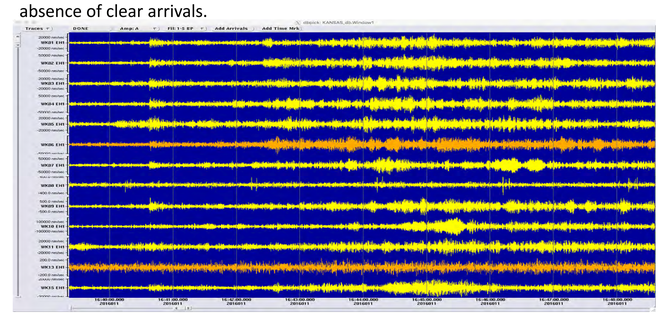

Figure 6. Distant earthquake recorded by Wellington seismometer network.

Conclusion

- LPLD events were identified in Wellington, Kansas and Farnsworth, Texas during EOR operations by manually scanning seismic data in the low-frequency range of 0.8-10Hz
- Of 466 detected events at Farnsworth, only 2 were found to be within the CO_2 plume; 4 events were found to be within the modeled pressure plume
- Spatial distribution of LPLD events at Farnsworth suggests that LPLD events may not be directly related to CO_2 injection