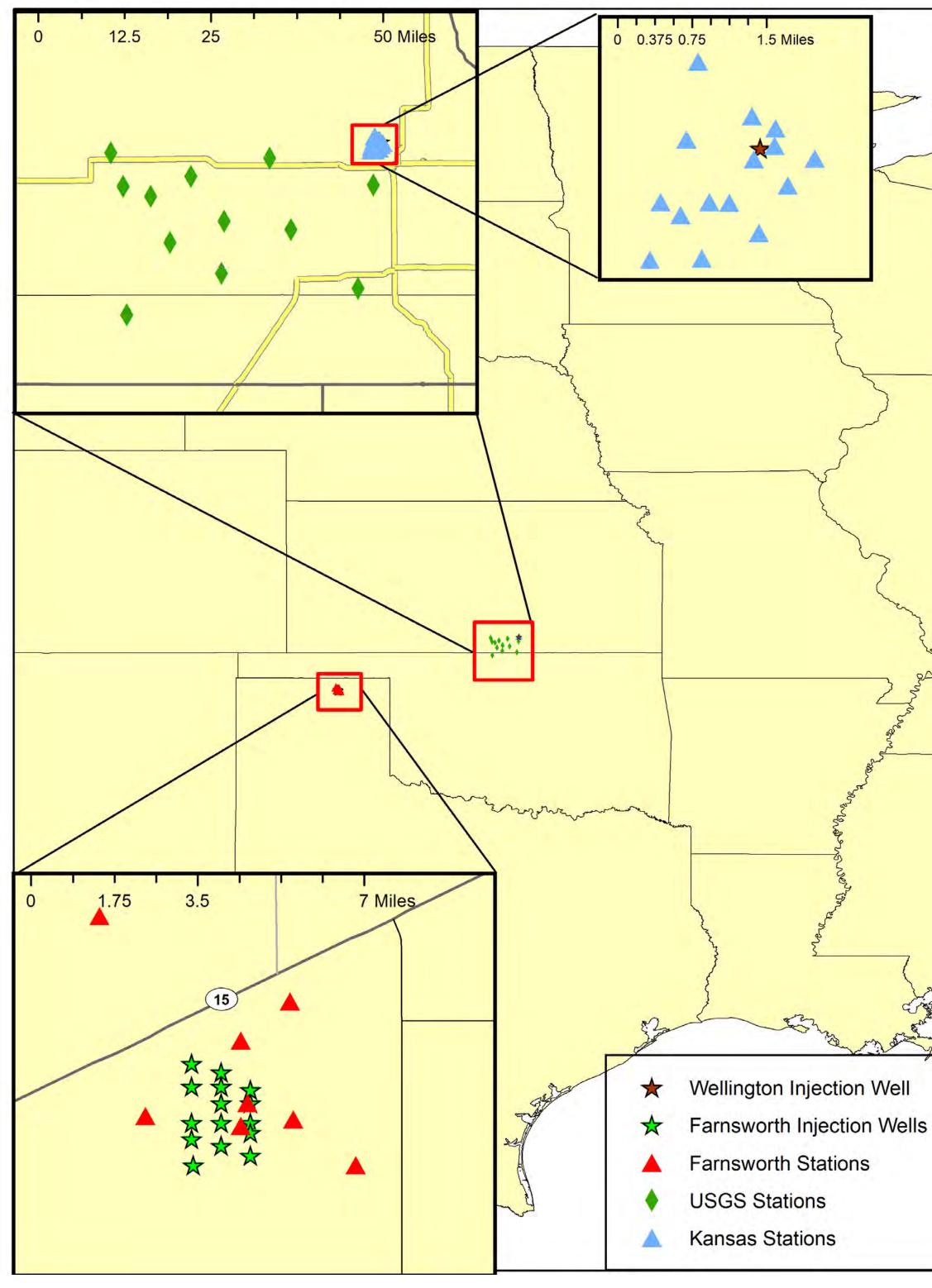
# The Observation of Long-Period, Long-Duration Seismic Waveforms at **CO<sub>2</sub> EOR Operations in Texas and Kansas** Abhash Kumar<sup>1,2</sup>, Alexander Bear<sup>1,3</sup>, Richard Hammack<sup>1</sup>

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# Introduction

- During Enhanced Oil Recovery (EOR), CO<sub>2</sub> 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<sub>2</sub> 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)
- event in Farnsworth (Fig. 4)

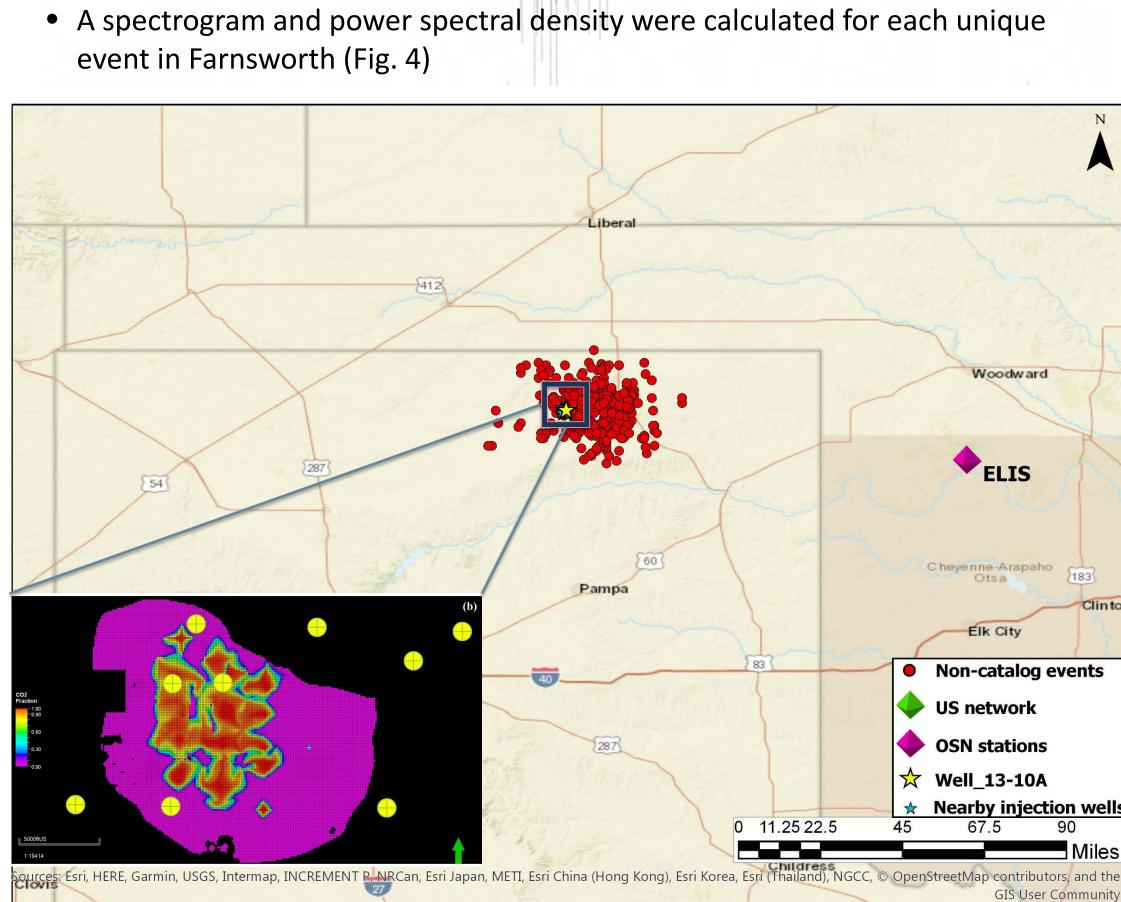
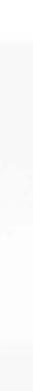
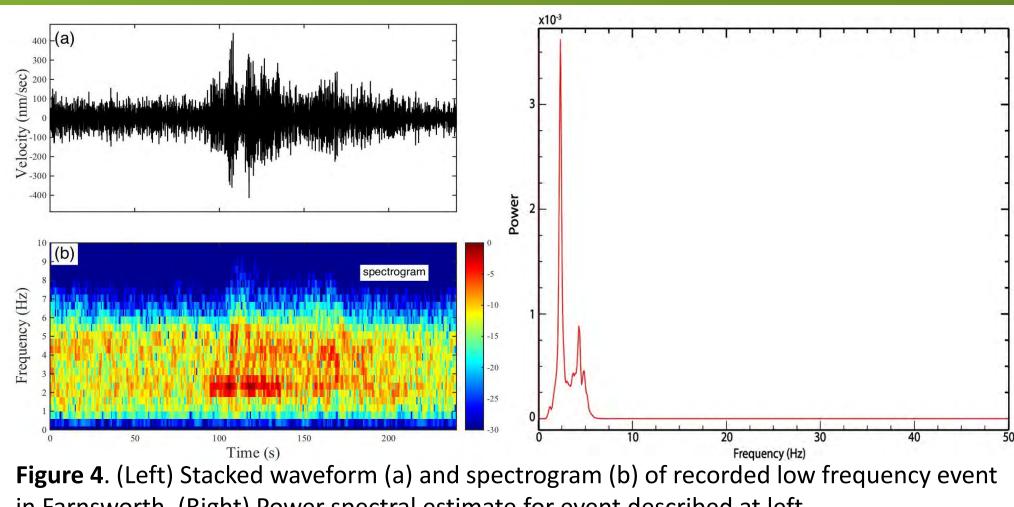


Figure 3. Map showing locations of LPLD events detected by NETL's Farnsworth seismometer network. Inset map shows locations of low-frequency events within CO<sub>2</sub> plume model (heat map) and pressure plume model (magenta) at Farnsworth EOR. Four LPLD events are within the modeled pressure plume; two events are within the  $CO_2$  plume area. Map of  $CO_2$  and pressure plume provided by New Mexico Tech.

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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<sub>2</sub> plume; 4
- LPLD events were located within the modeled pressure plume
- The number and spatial distribution of LPLDs within the CO<sub>2</sub> 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<sub>2</sub> injection

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

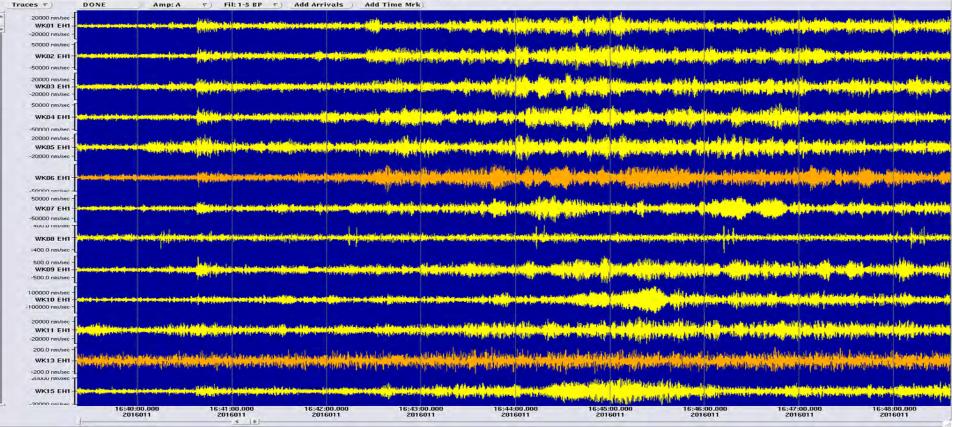


Figure 6. Distant earthquake recorded by Wellington seismometer network.

### 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<sub>2</sub> 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<sub>2</sub> injection

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