Passive seismic monitoring of an active CO_2-EOR operation in Farnsworth, Texas

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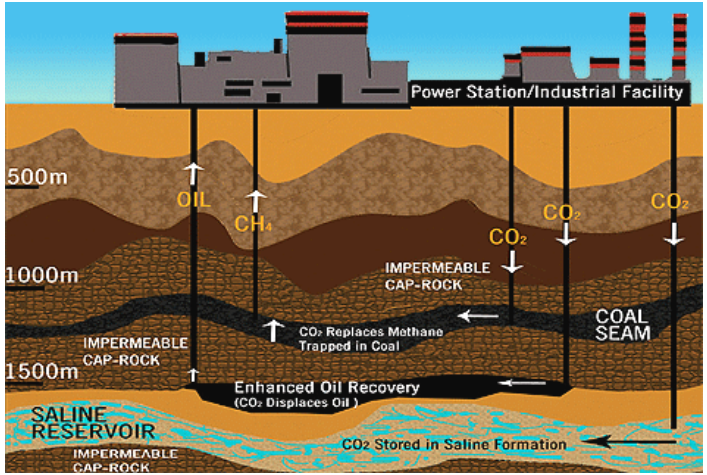
Background

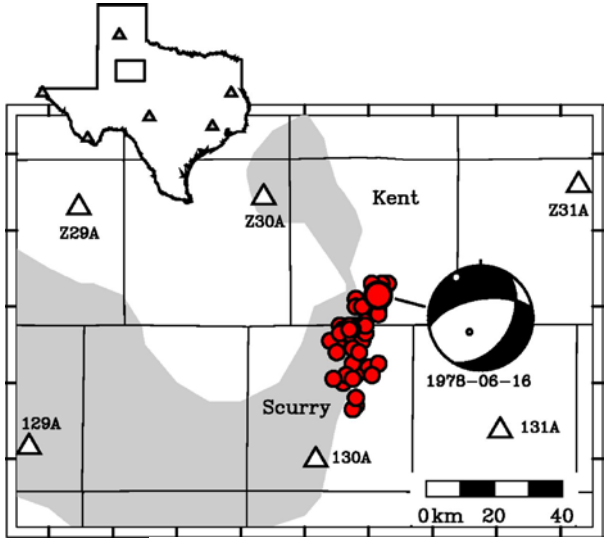
Benefits

- Long term CO_2 storage
- Enhanced oil recovery (EOR)
- Enhanced Coalbed Methane (ECBM)



Concern

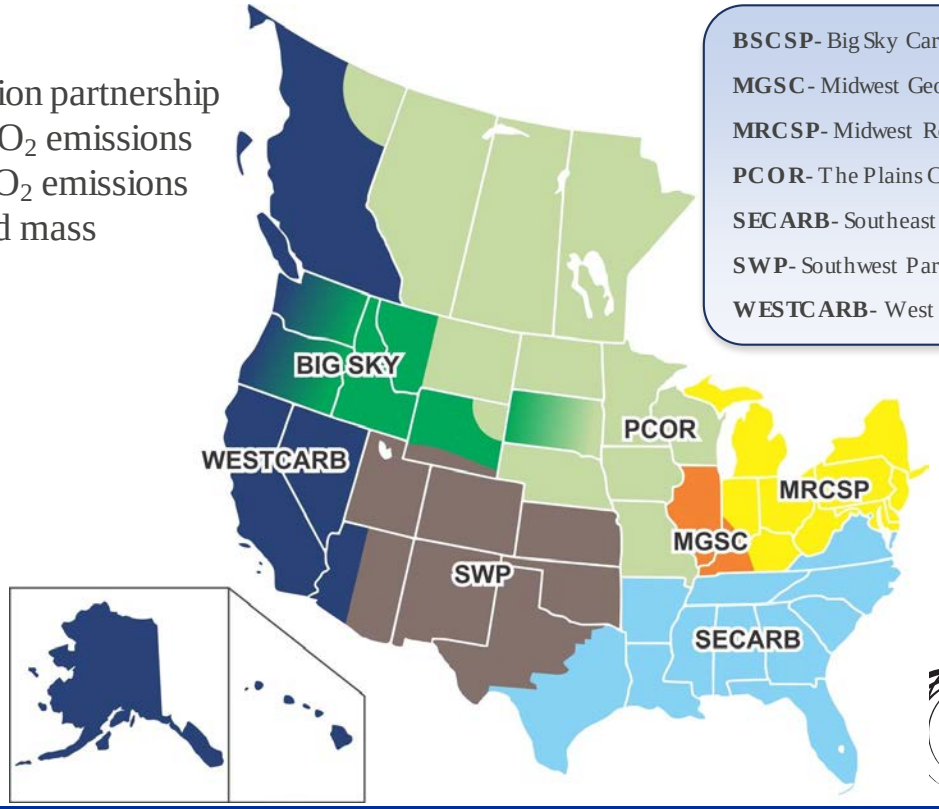
- Induced earthquakes
- Potential caprock deformation
- Risk of CO_2 leakage



Wei Gan, and Cliff Frohlich PNAS 2013

Regional Carbon Sequestration Partnership

- Seven regional sequestration partnership
- 97 percent of coal-fired CO_2 emissions
- 97 percent of industrial CO_2 emissions
- 96 percent of the total land mass



BSCSP- Big Sky Carbon Sequestration Partnership

MGSC- Midwest Geological Sequestration Consortium

MRCSP- Midwest Regional Carbon Sequestration Partnership

PCOR- The Plains CO_2 Reduction Partnership

SECARB- Southeast Regional Carbon Sequestration Partnership

SWP- Southwest Partnership on Carbon Sequestration

WESTCARB- West Coast Regional Carbon Sequestration Partnership

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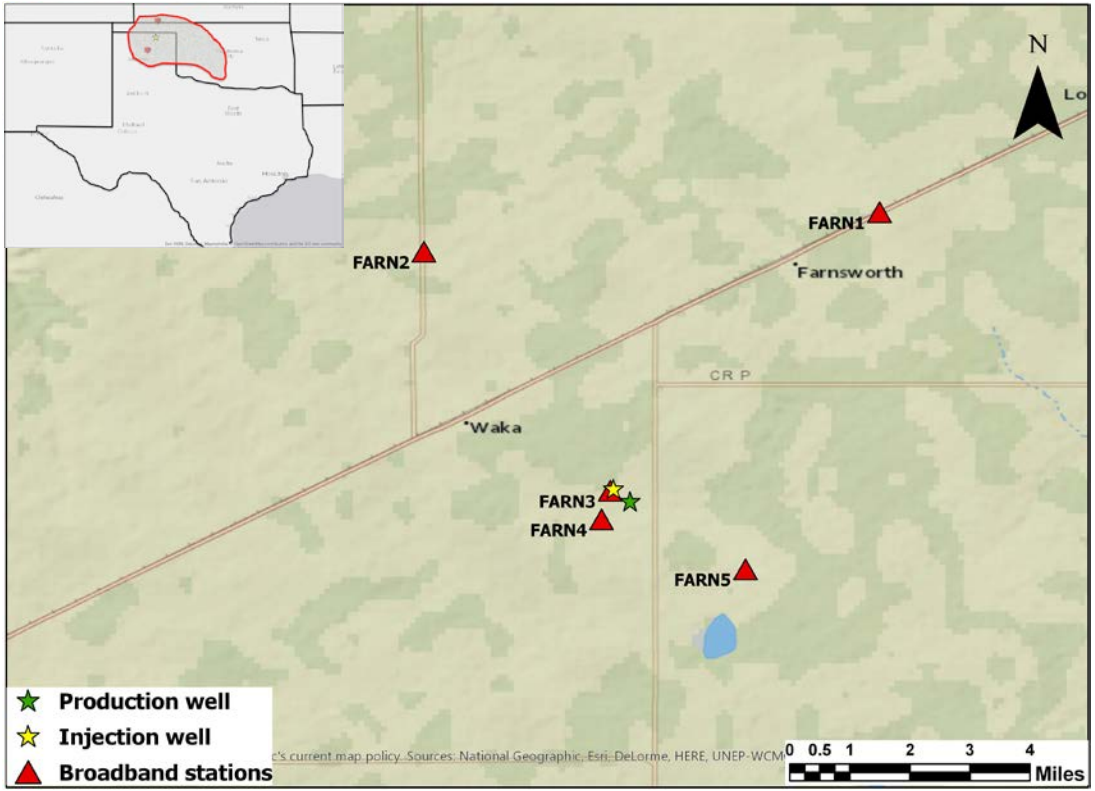
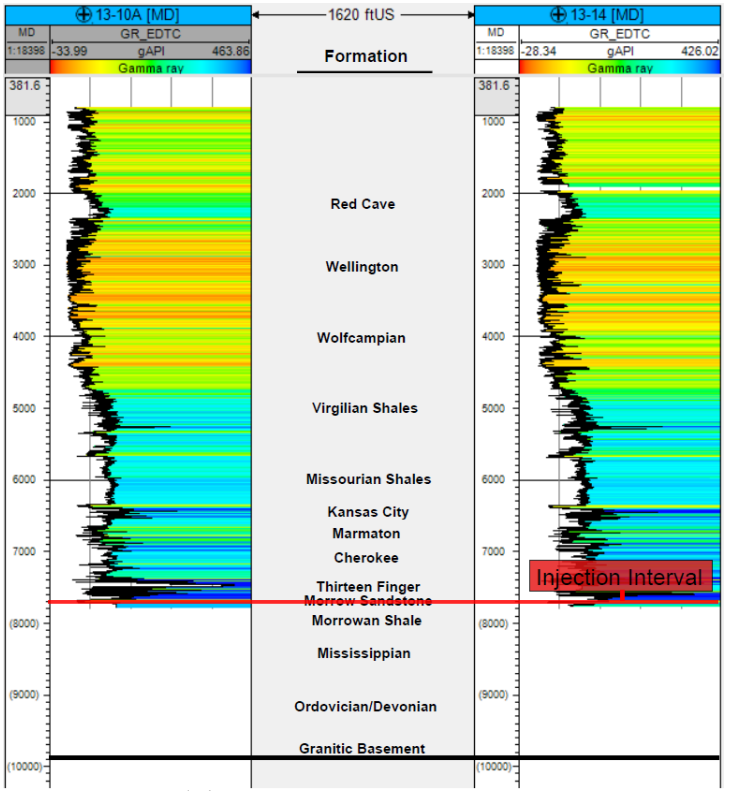
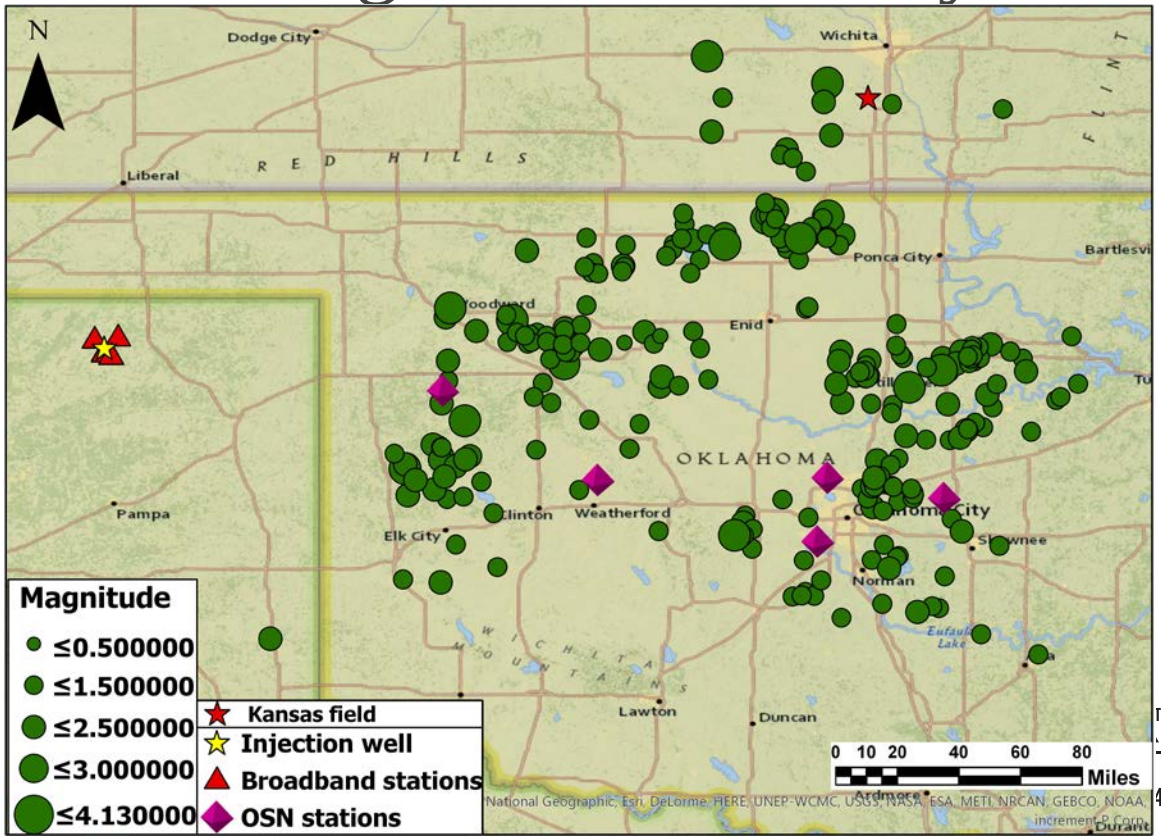
Site details: Farnsworth, Texas





Background seismicity



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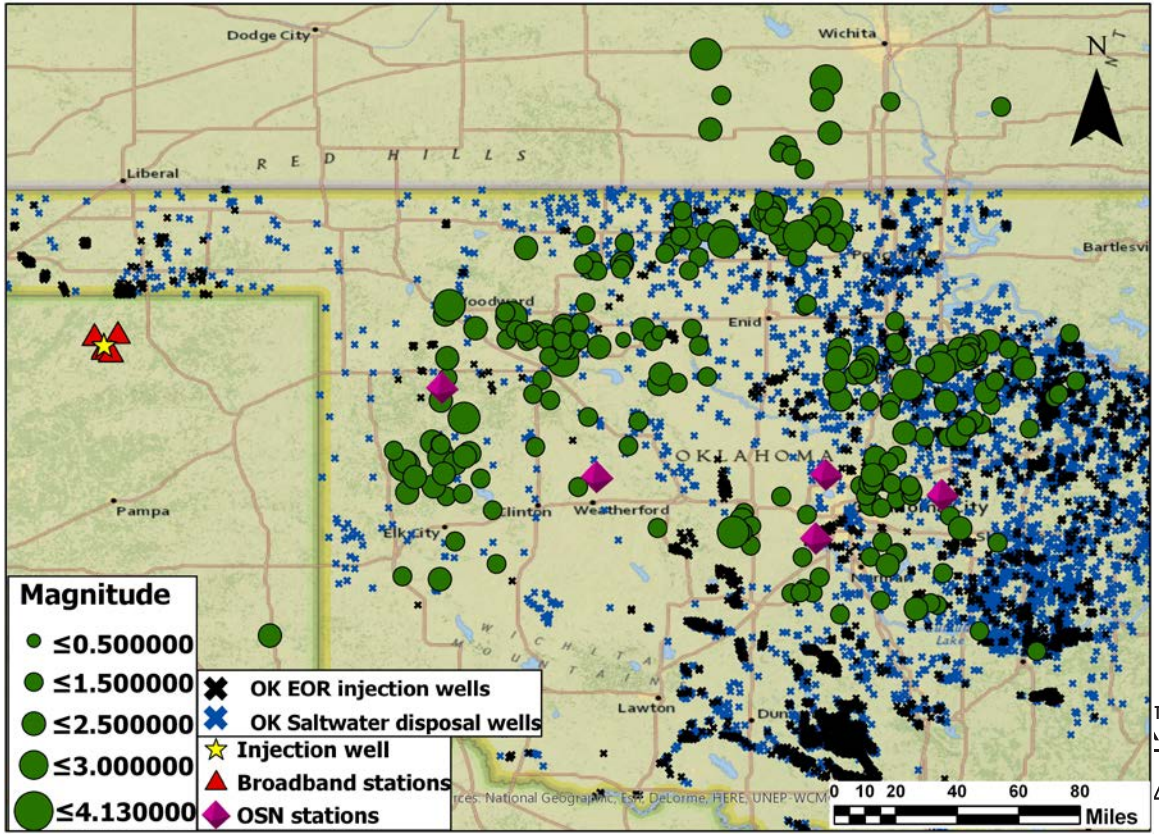

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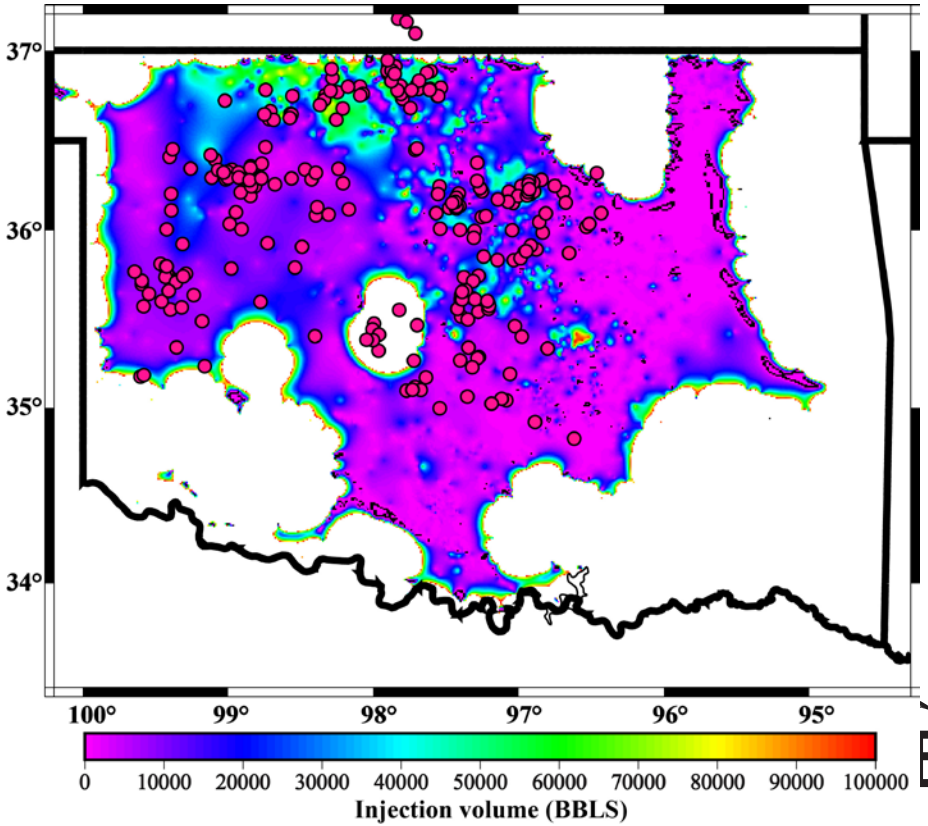
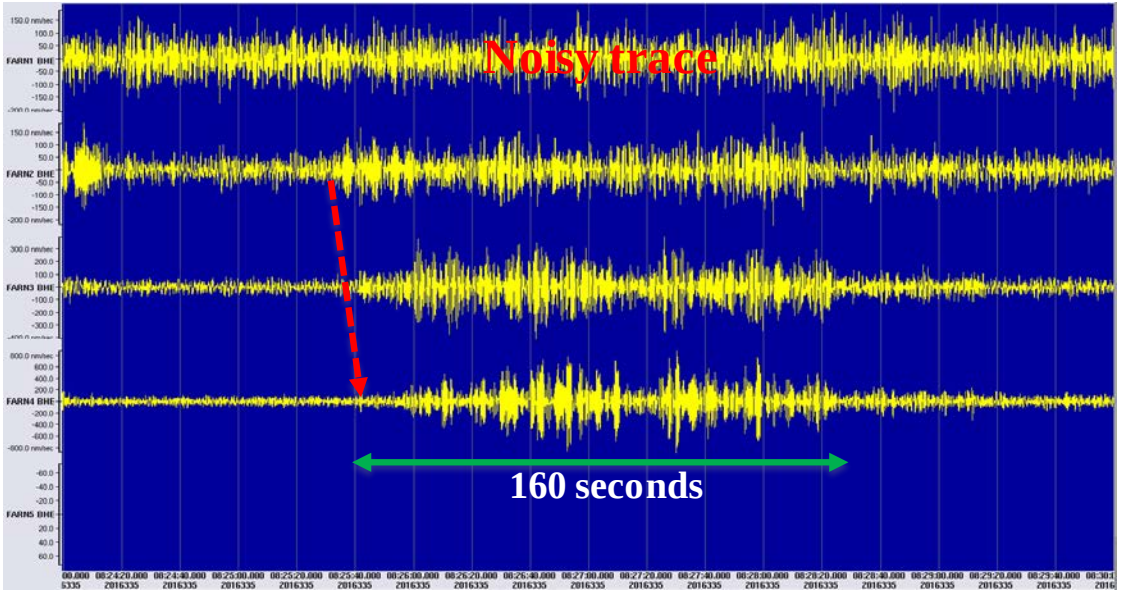
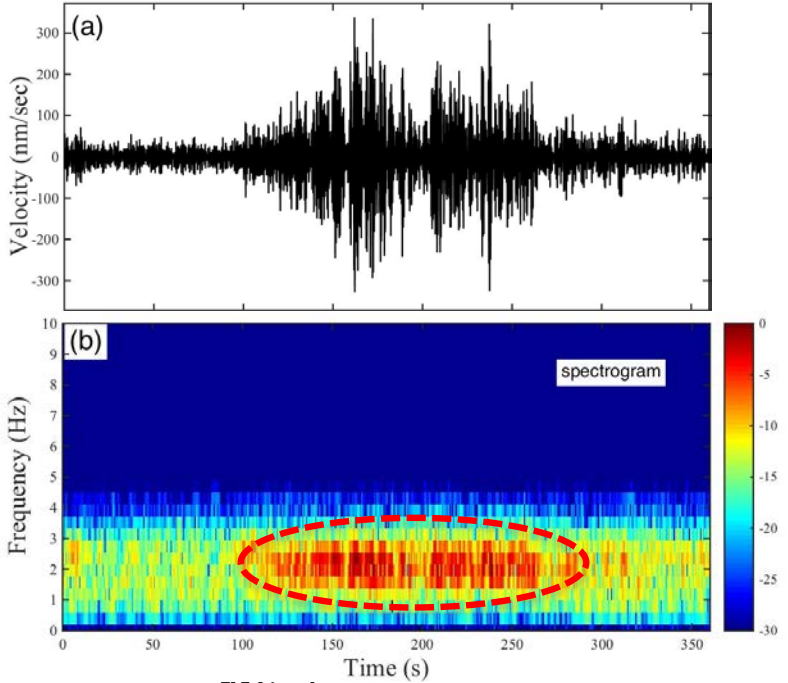


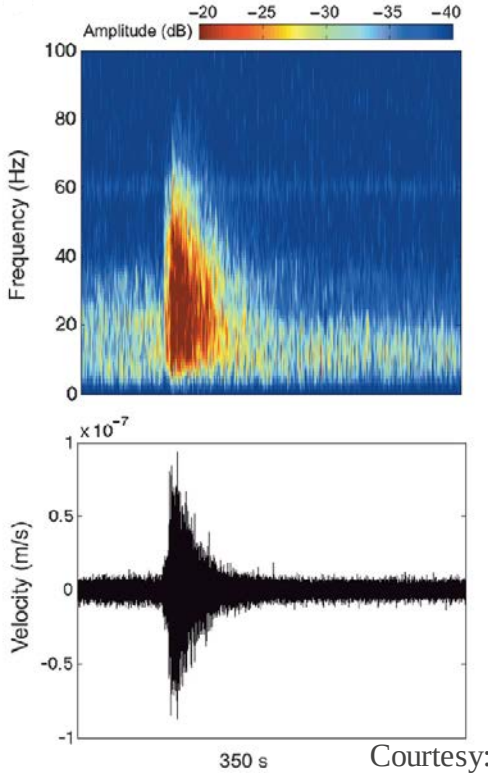
Long period events





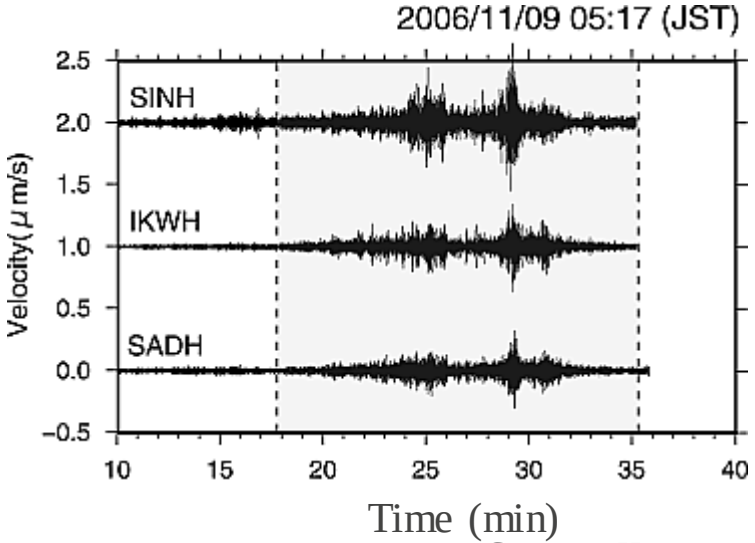
Previous observations

LPLD at a hydraulic fracturing site in Texas



Courtesy: Das and Zoback (2013)

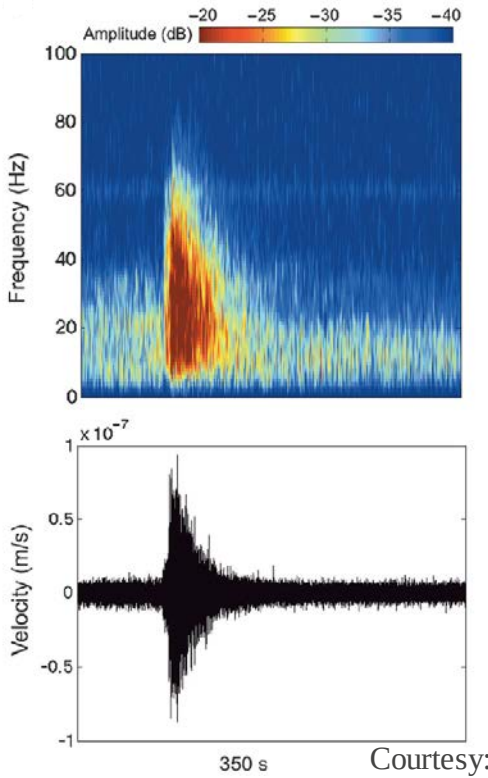
Low frequency tremor in Shikoku, Japan



Courtesy: Hirose et al. (2010)

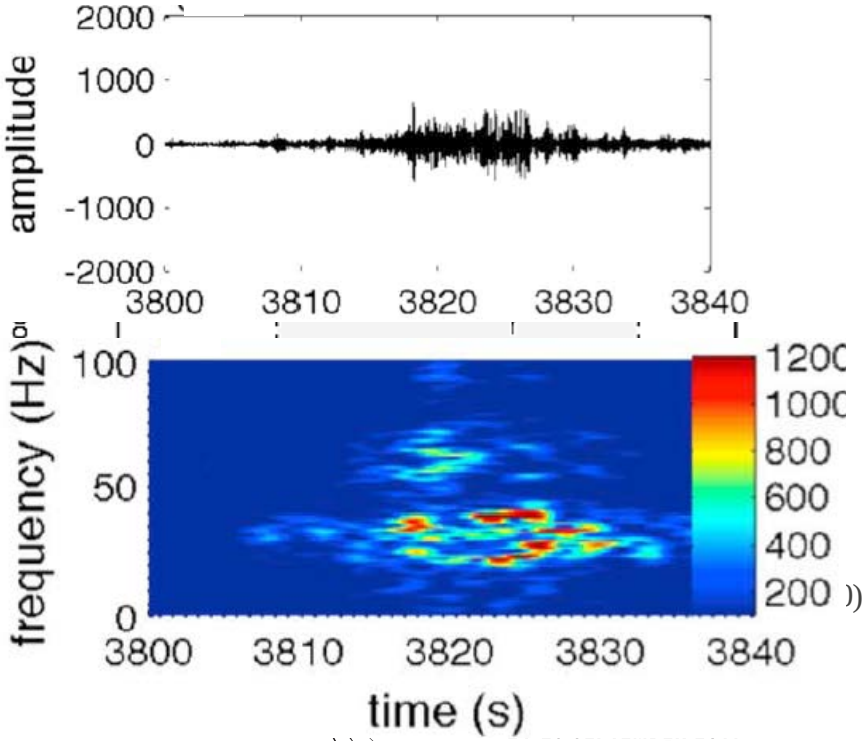
Previous observations

LPLD at a hydraulic fracturing site in Texas



Courtesy: Das and Zoback (2013)

LPLD at a hydraulic fracturing site in Mexico

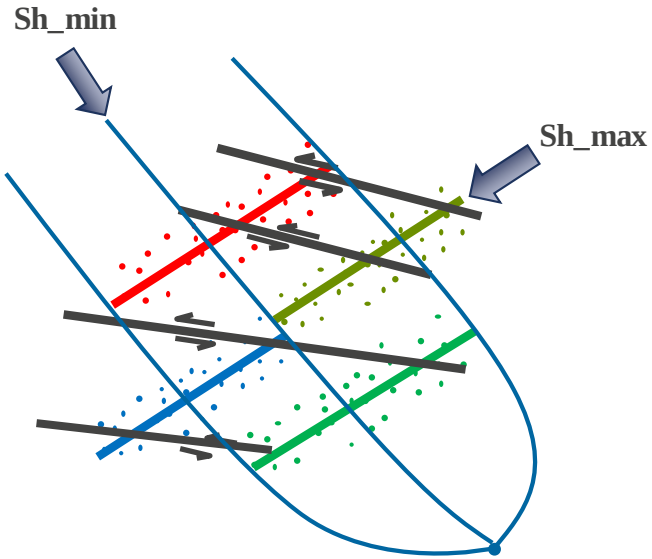


Courtesy: Hu et al. (2017)

Deformation mechanism

Shear slip (Das and Zoback, 2011)

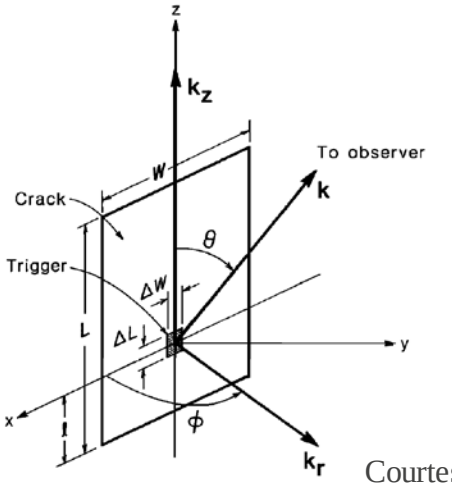
- Stimulation of sub-optimal faults
- High clay content



Adapted from Zoback et al. 2012

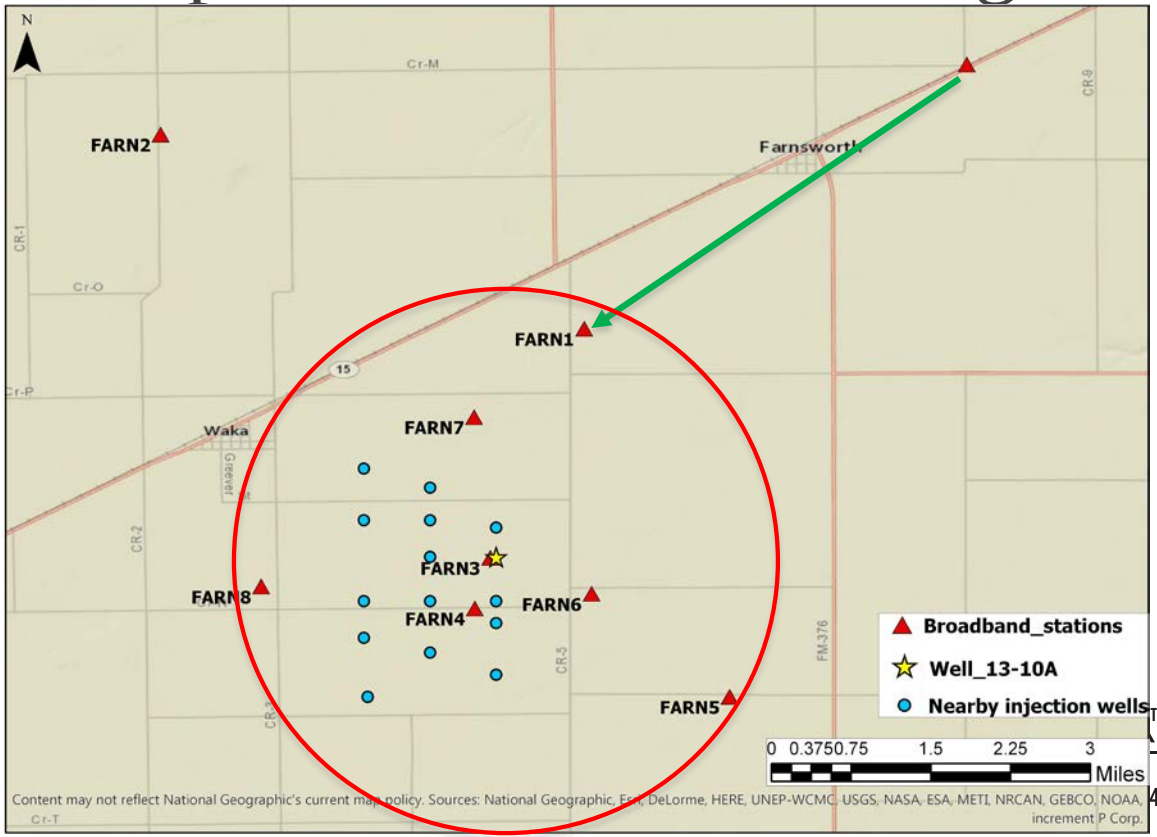
Tensile opening (Hu et al. 2017)

- Jerky opening
- Resonance of fluid filled cracks

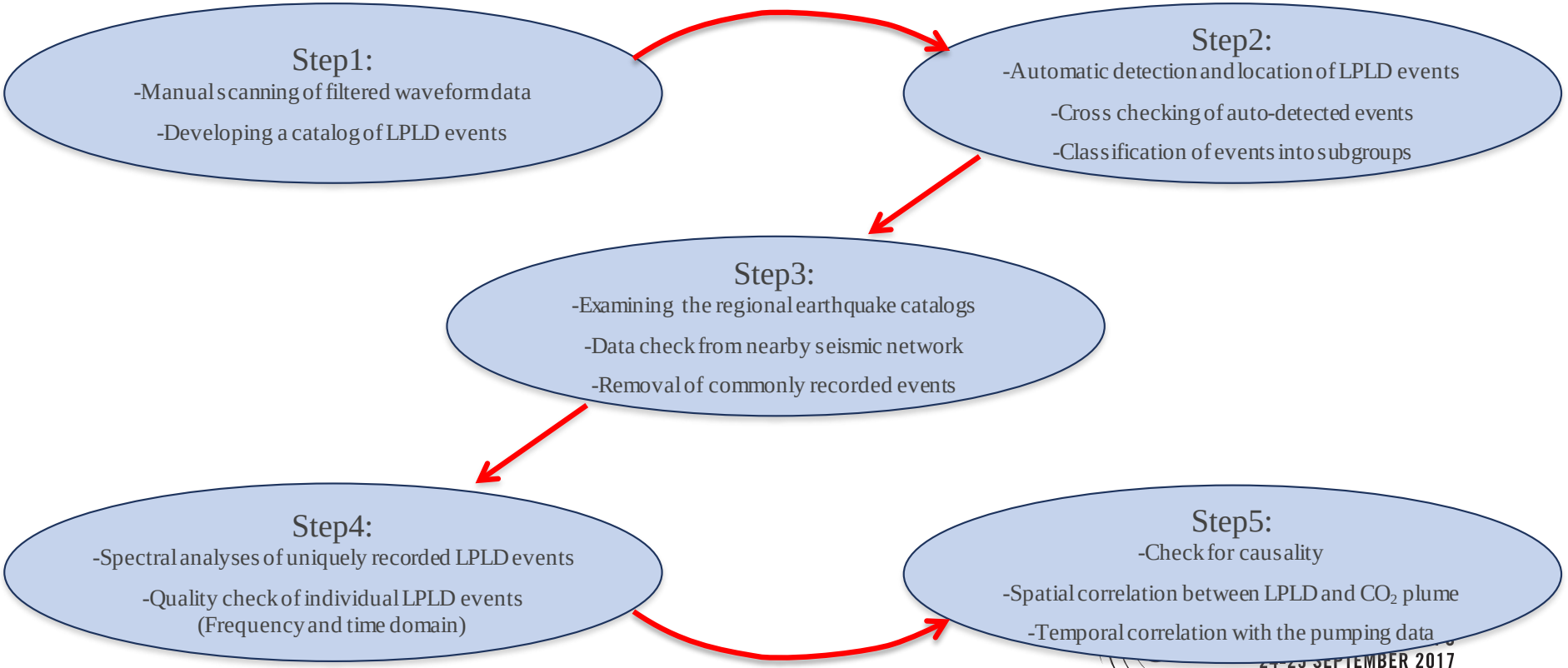


Courtesy: Chouet 1988

Improved seismic coverage

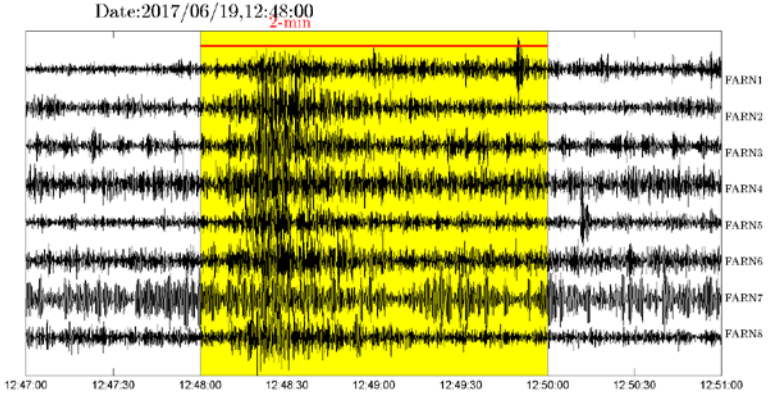


Workflow

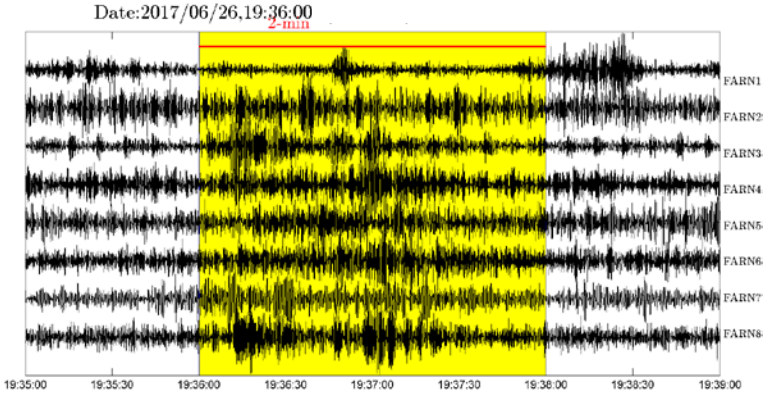

Step1:
-Manual scanning of filtered waveform data
-Developing a catalog of LPLD events
Step2:
-Automatic detection and location of LPLD events
-Cross checking of auto-detected events
-Classification of events into subgroups
Step3:
-Examining the regional earthquake catalogs
-Data check from nearby seismic network
-Removal of commonly recorded events
Step4:
-Spectral analyses of uniquely recorded LPLD events
-Quality check of individual LPLD events
(Frequency and time domain)
Step5:
-Check for causality
-Spatial correlation between LPLD and CO_2 plume
-Temporal correlation with the pumping data

Events classification

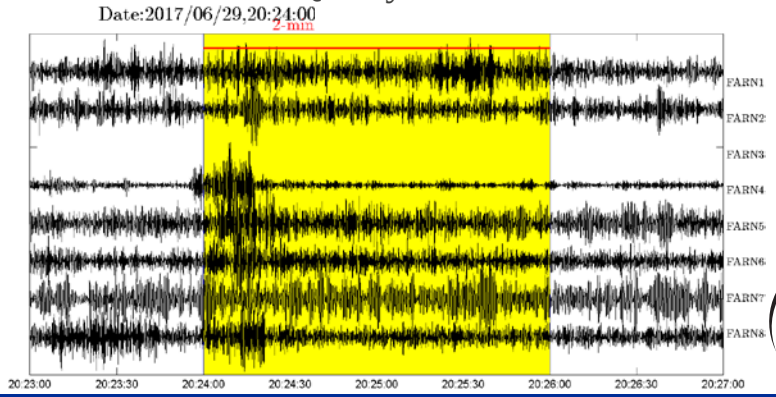
Quality 1



Quality 2



Quality 3



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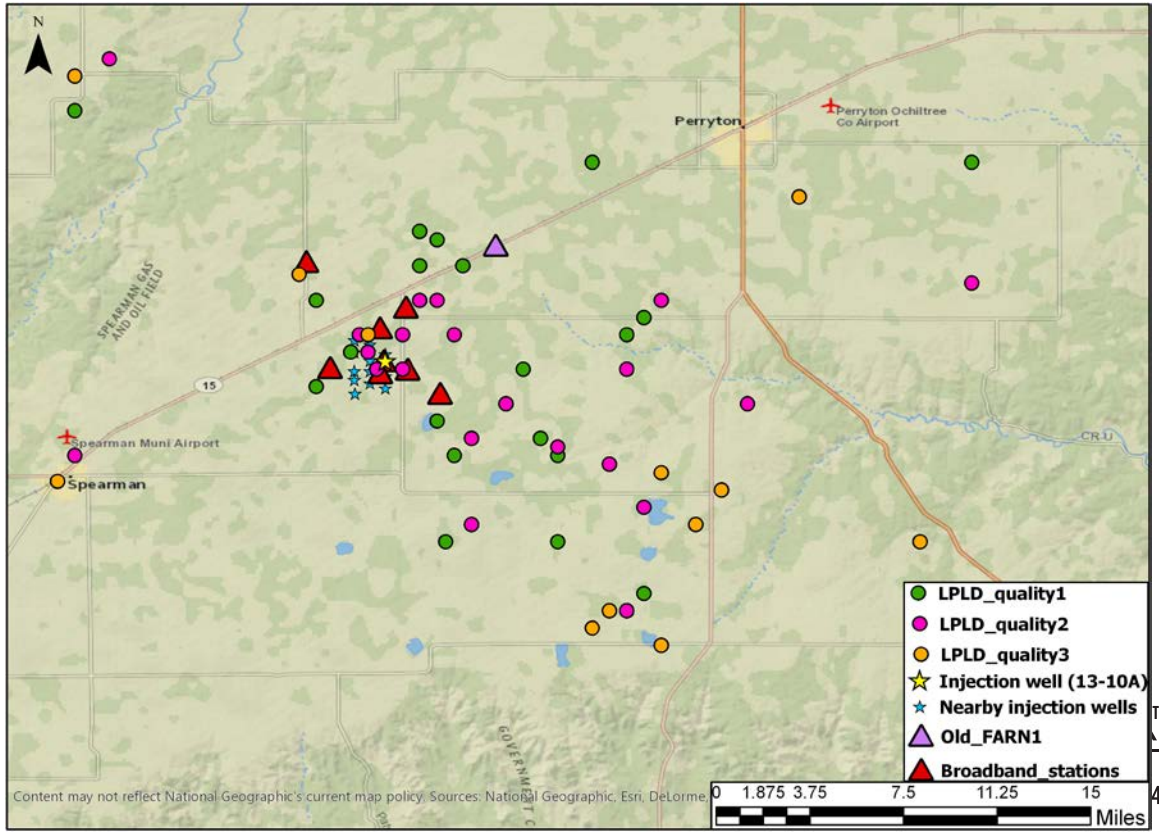
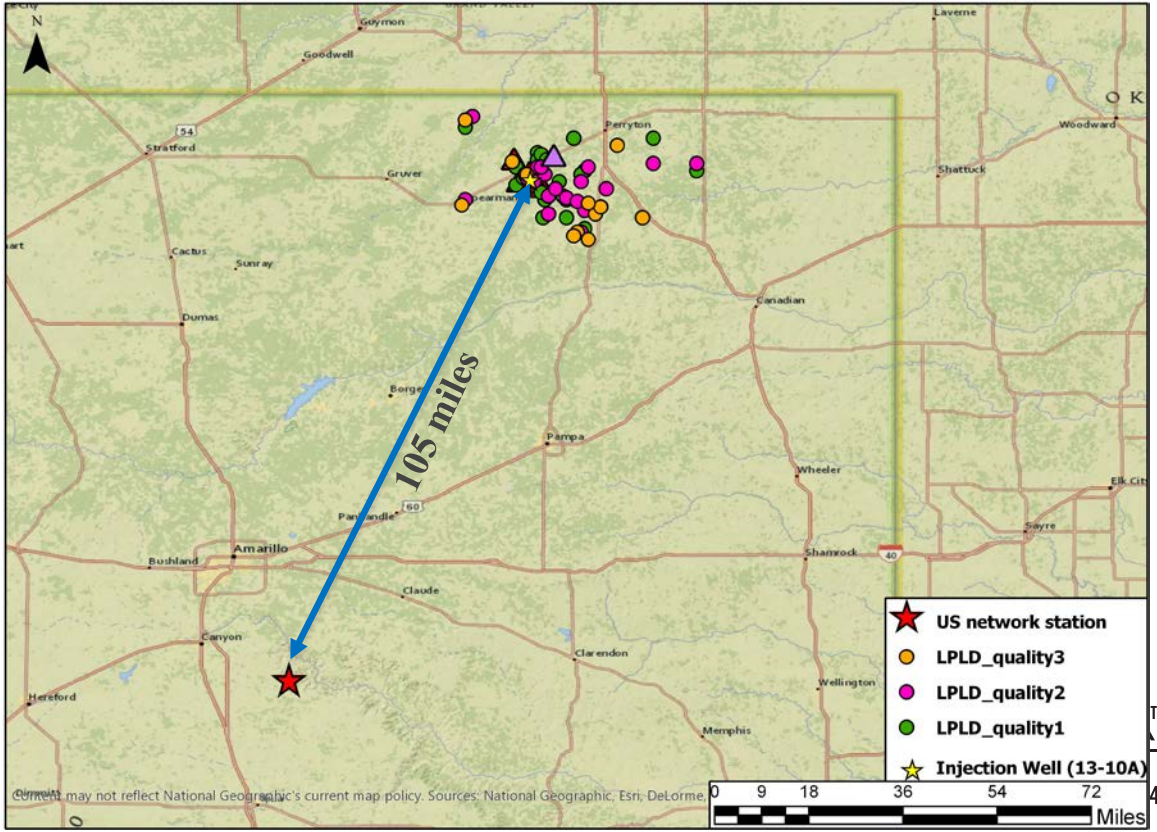
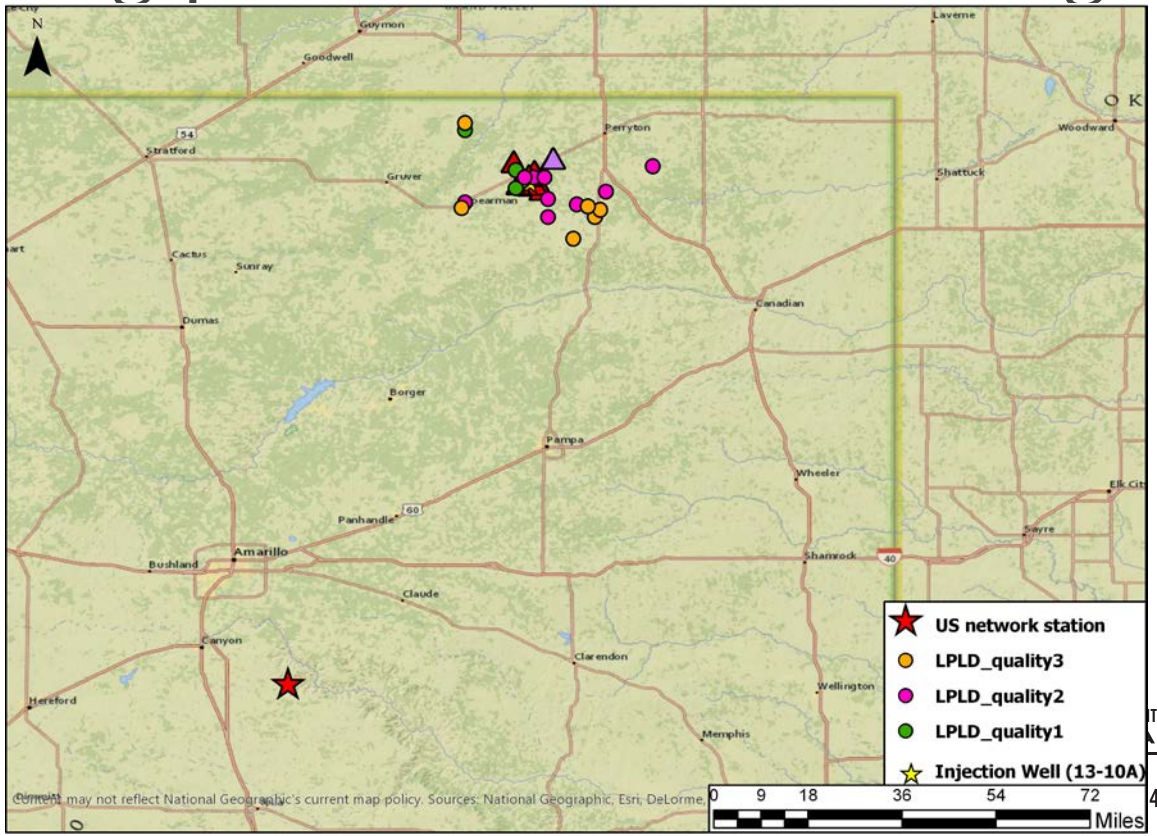
Event distribution



Cross check with nearby seismic station



Long period events of local origin



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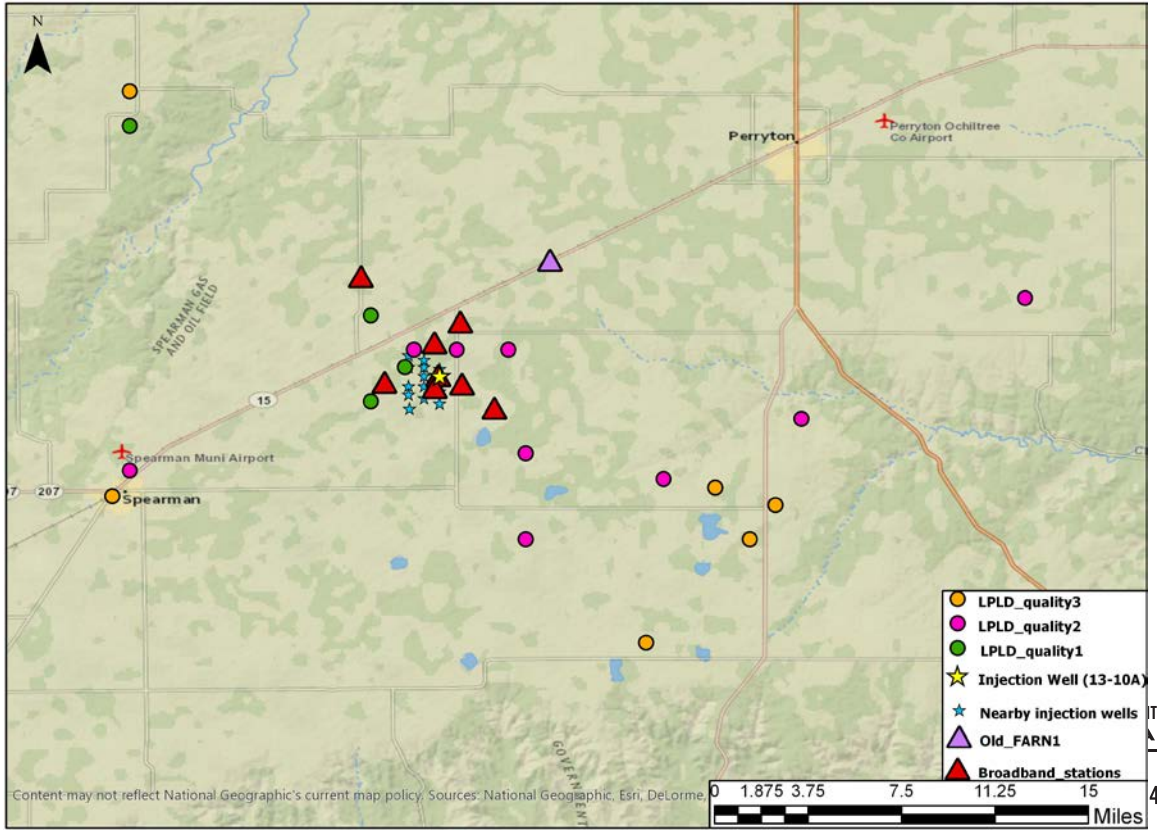
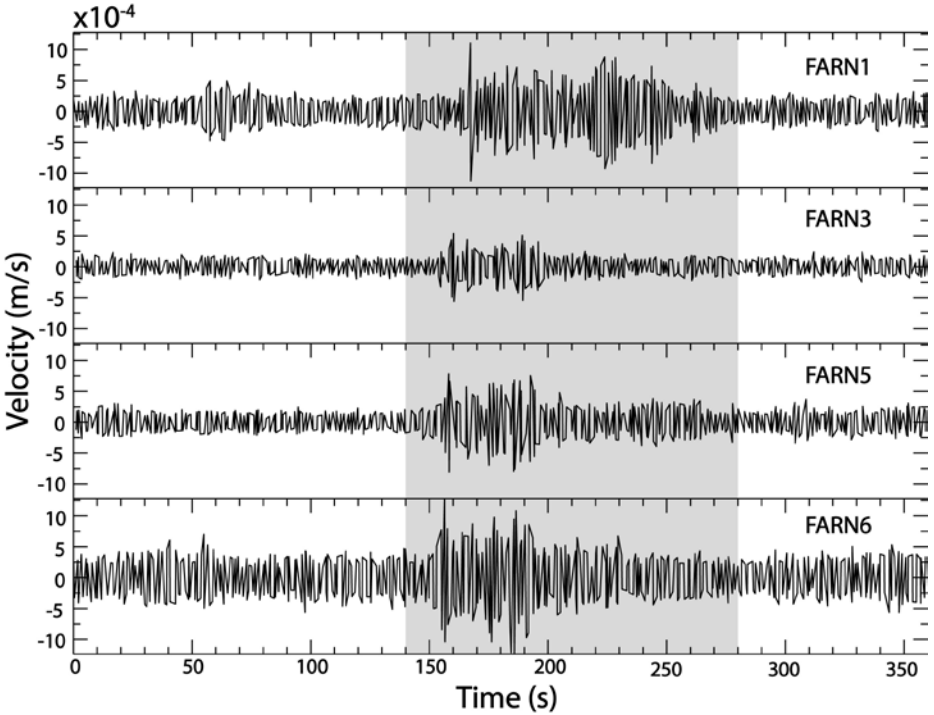
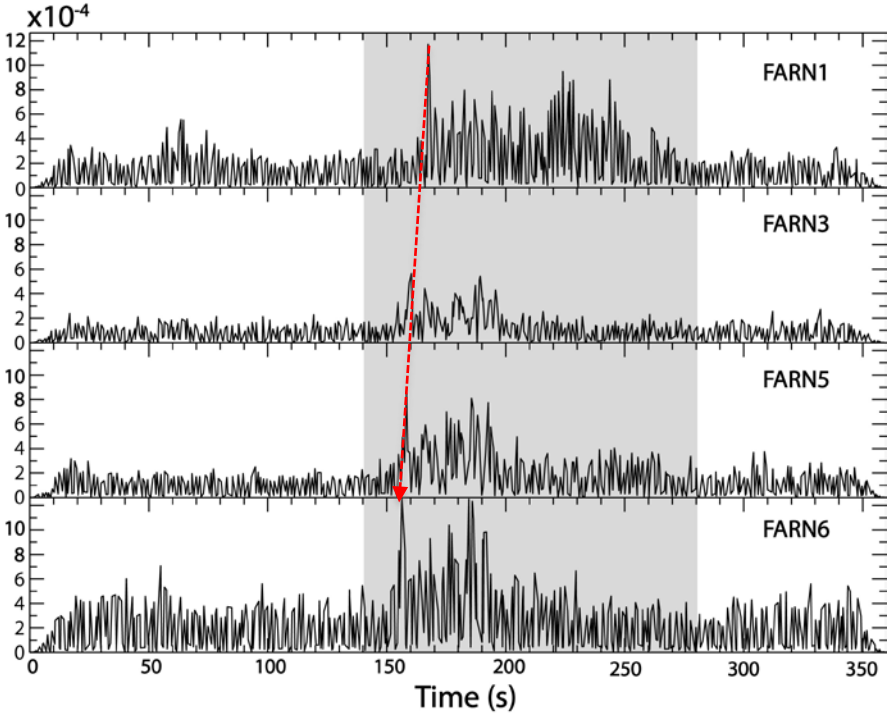


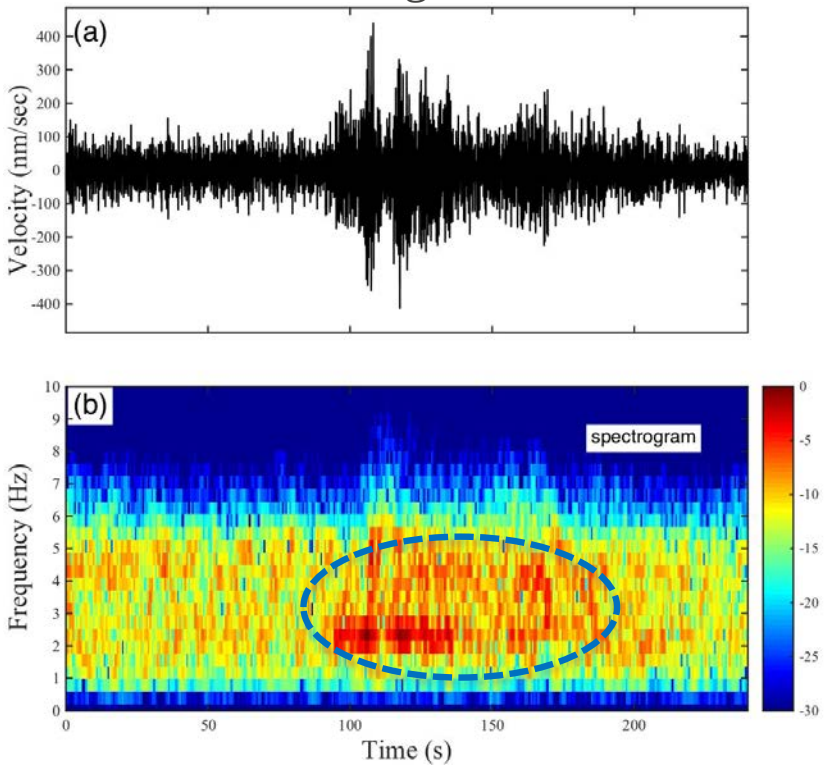
Waveform characteristics



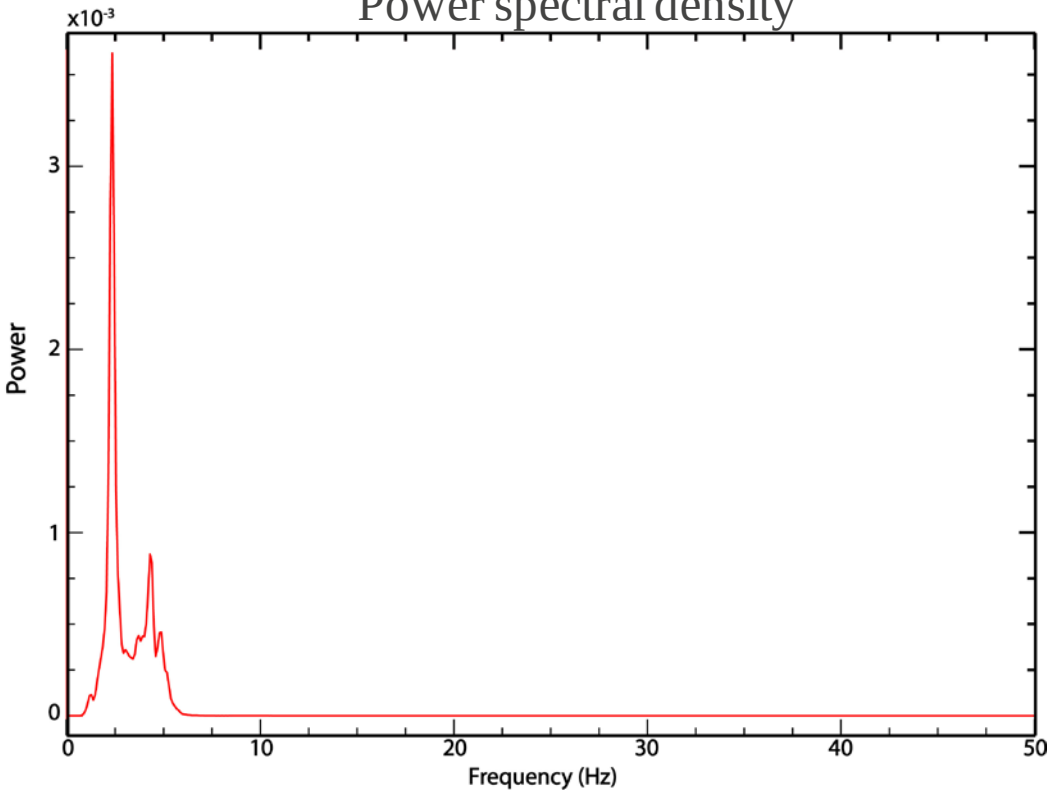


Spectral analyses

Seismogram

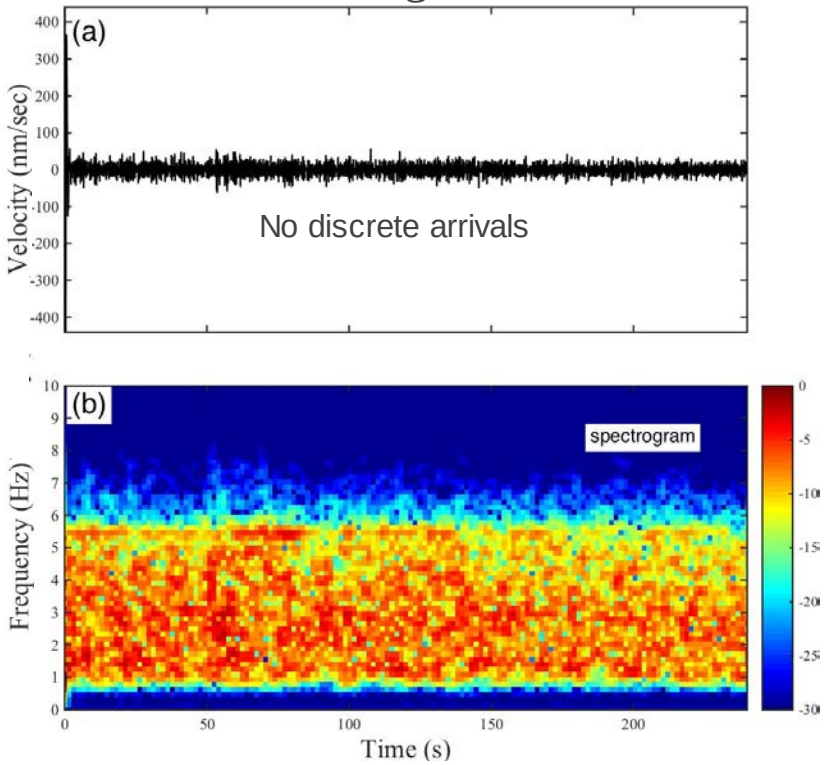


Power spectral density

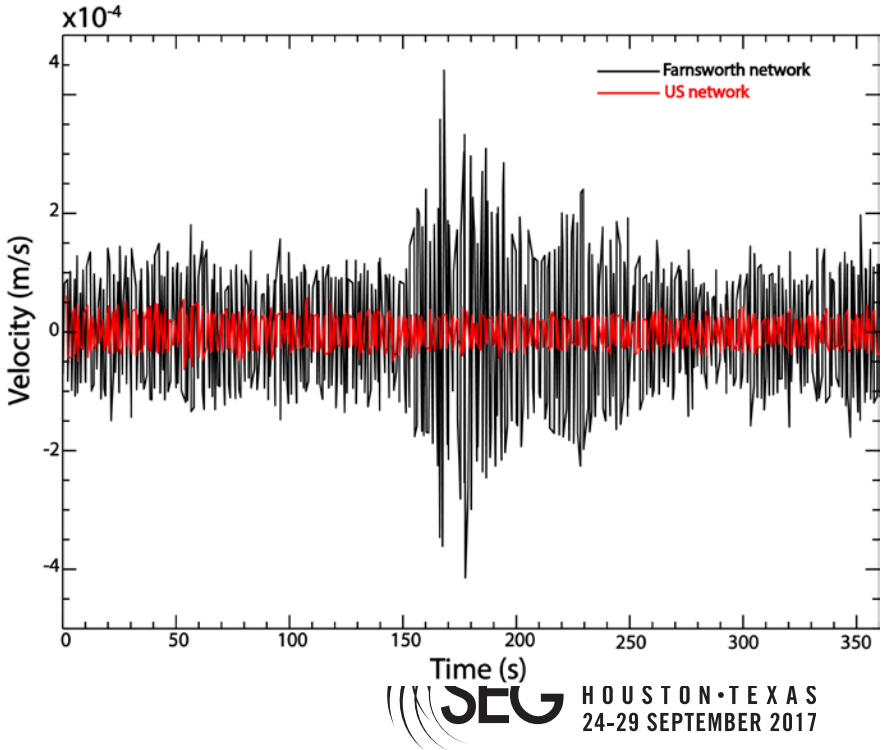


Quality check

Seismogram



Waveform comparison



Key Points

- Distant seismic events (> 90 miles) from Oklahoma are dominantly recorded as normal (short period) earthquakes
- LPLD events observed in this study have highly emergent phase arrivals that persist for 30-70 seconds
- Spectral characteristics of the low frequency events are partly similar to LPLD events observed in Barnett Shale in Texas and in Eagle Ford Shale in NE Mexico
- Local source of deformations (some combination of slow shear slip and resonance of fluid filled cracks) are perhaps responsible for the generation of long period events observed in this study
- Further examinations (temporal and spatial) of the pumping data and reservoir models (pore pressure and the extent of CO_2 plume migration) would be important to understand the more definite cause of LPLD events

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Thank You!

Questions?

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