

Regional Trends and Local Seismicity Near CSTS Member Wells



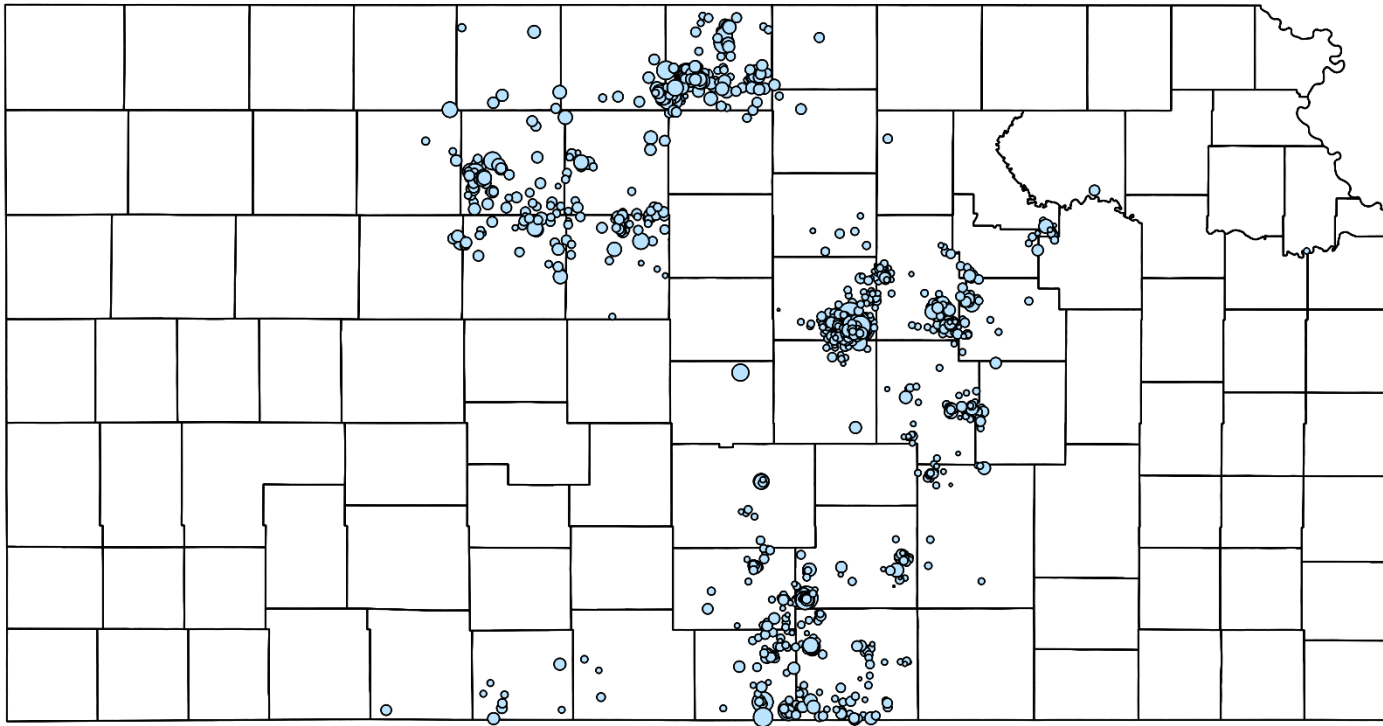
Shelby Peterie, Rick Miller, Carl Gonzales, Erik Knippel, Marcus Tamburro
Kansas Geological Survey

Fifth Annual CSTS Meeting
August 3, 2022
McPherson, KS

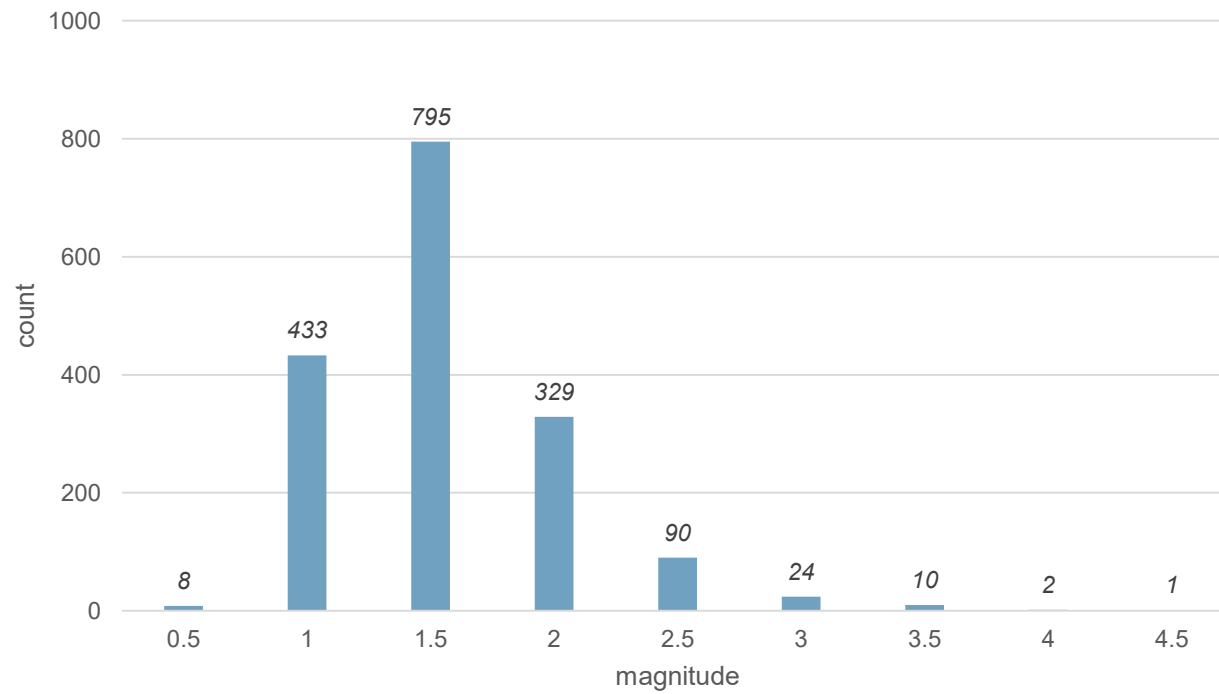


Statewide Overview: 2021-2022

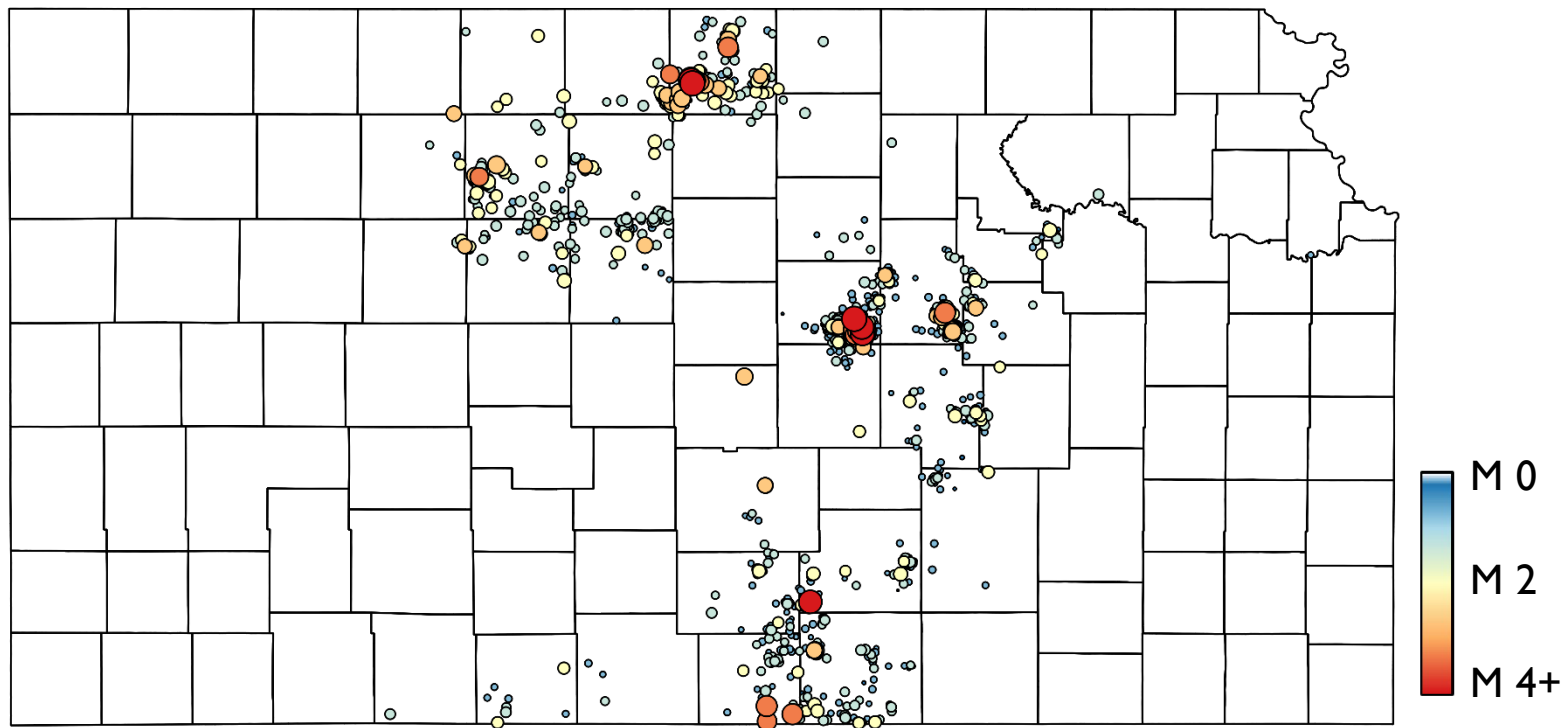
*total earthquakes = 1692
(2020-2021 = 1180)*



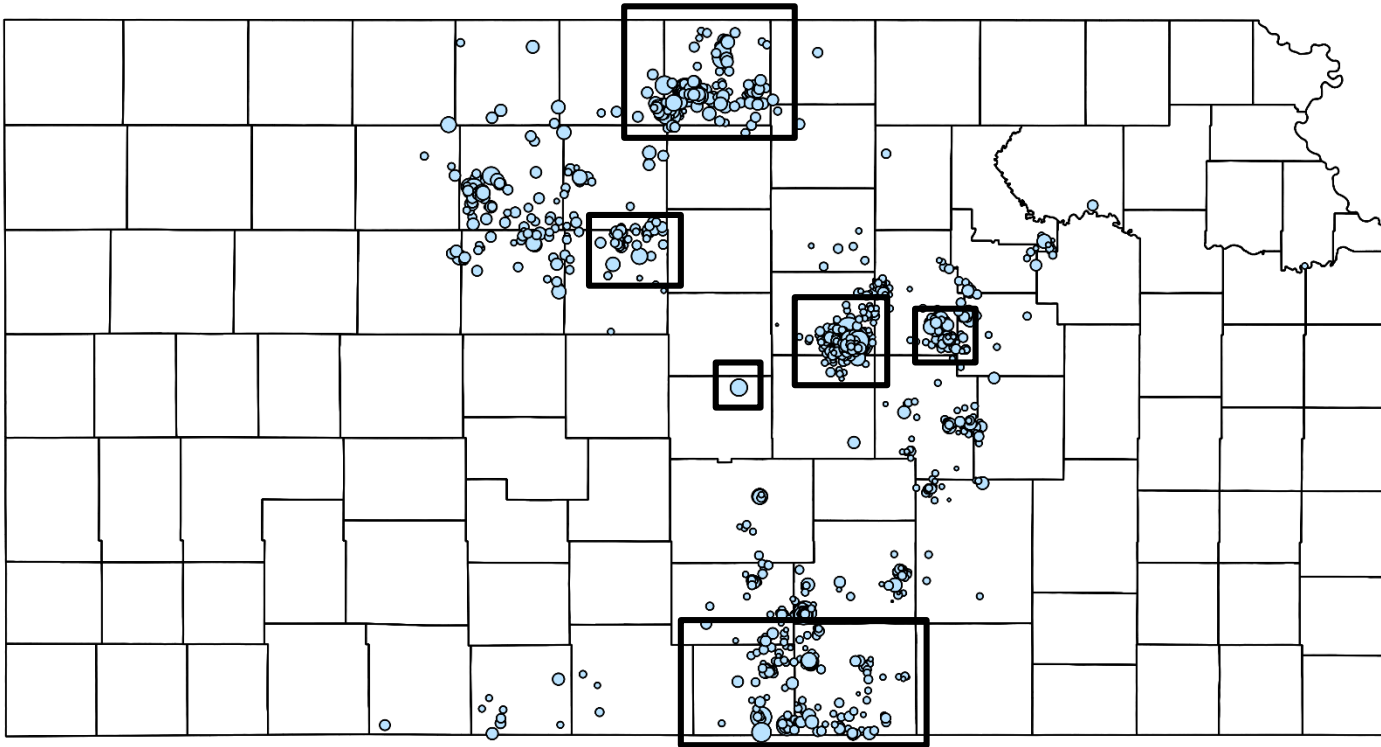
Magnitude Distribution



Earthquake Magnitudes

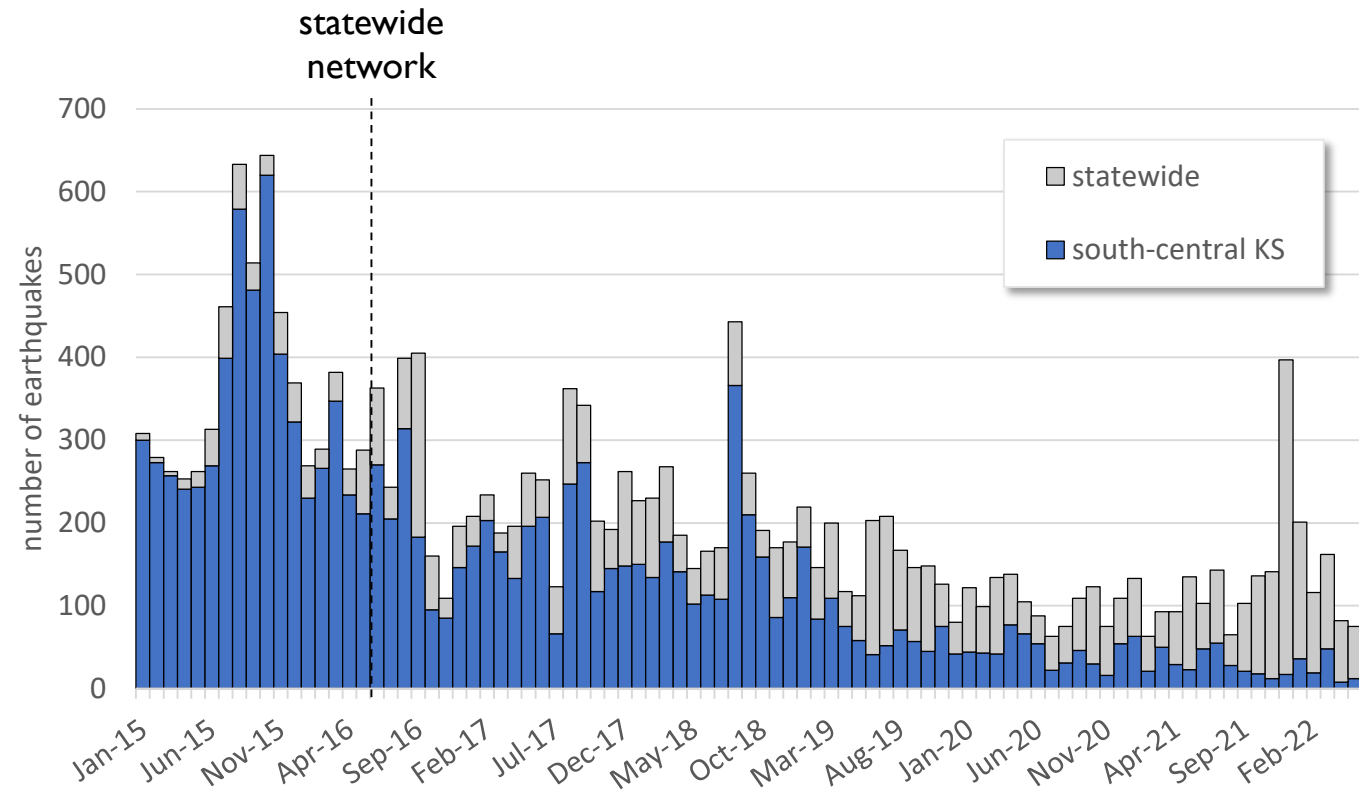


Notable Observations



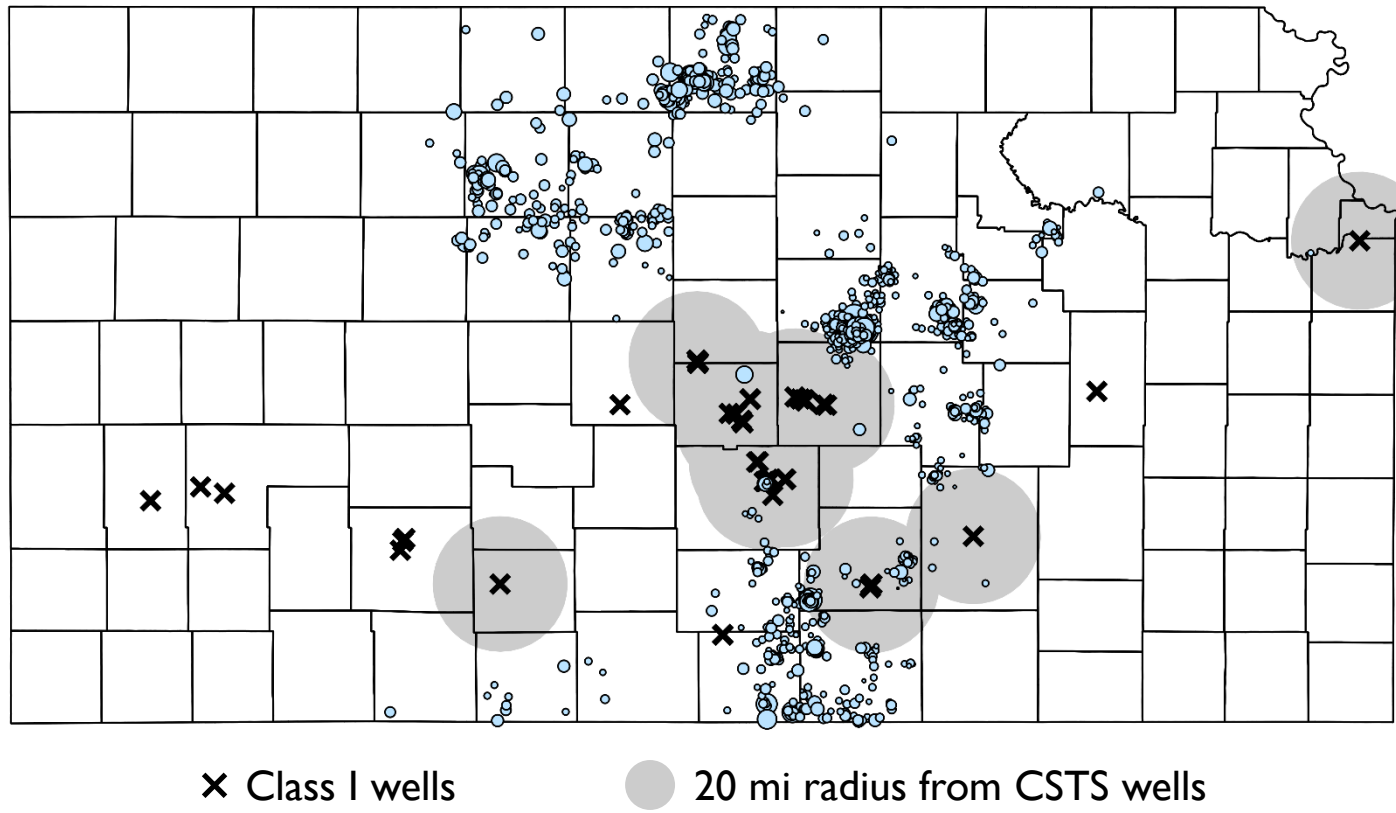
- Saline County
 - three M 4+
- Rice County
 - M 2.9 in June 2022
- Russell County
 - M 2.8 in December 2021
 - tie for largest
- JW, DK: most events in 1 yr
- Harper, Sumner: no M 3+ earthquakes in 6 mo

Monthly Earthquakes

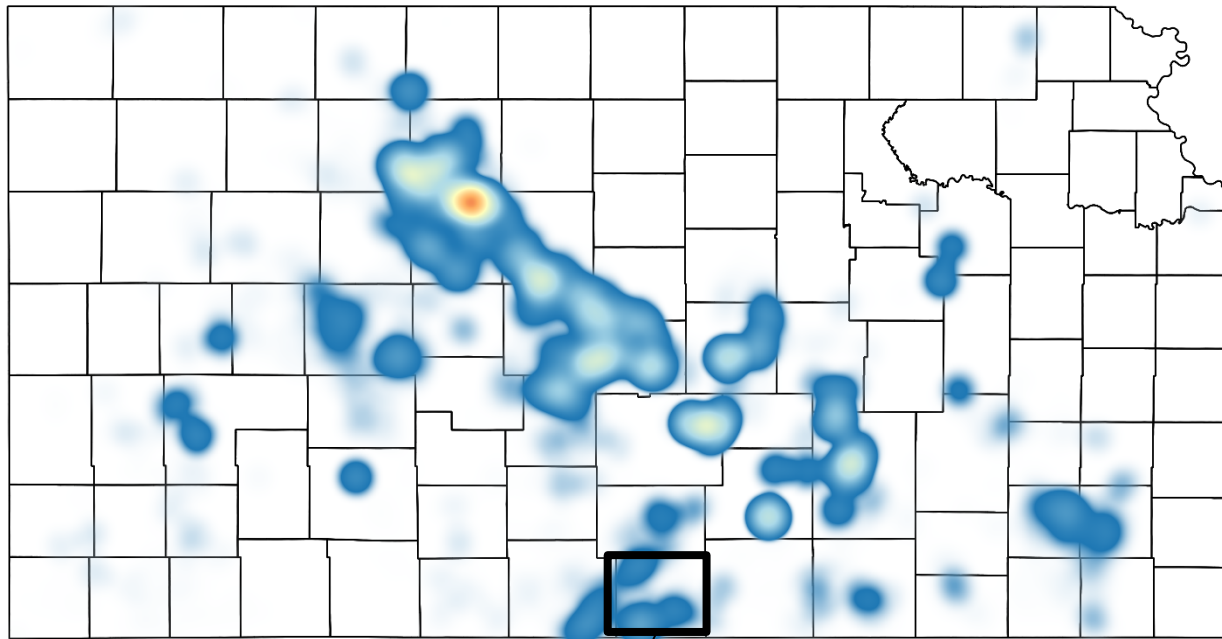


Relation to CSTS Member Facilities

2021-2022 = 157 within 20 mi (283 last year)

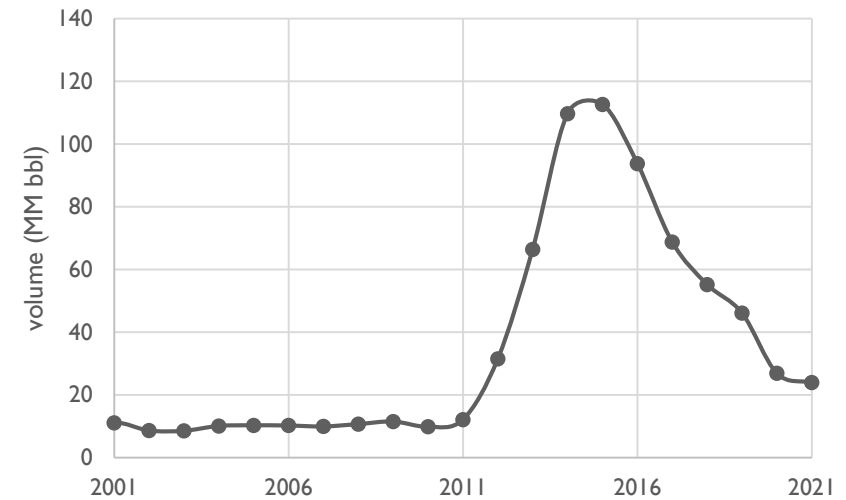


2021 Disposal Volumes

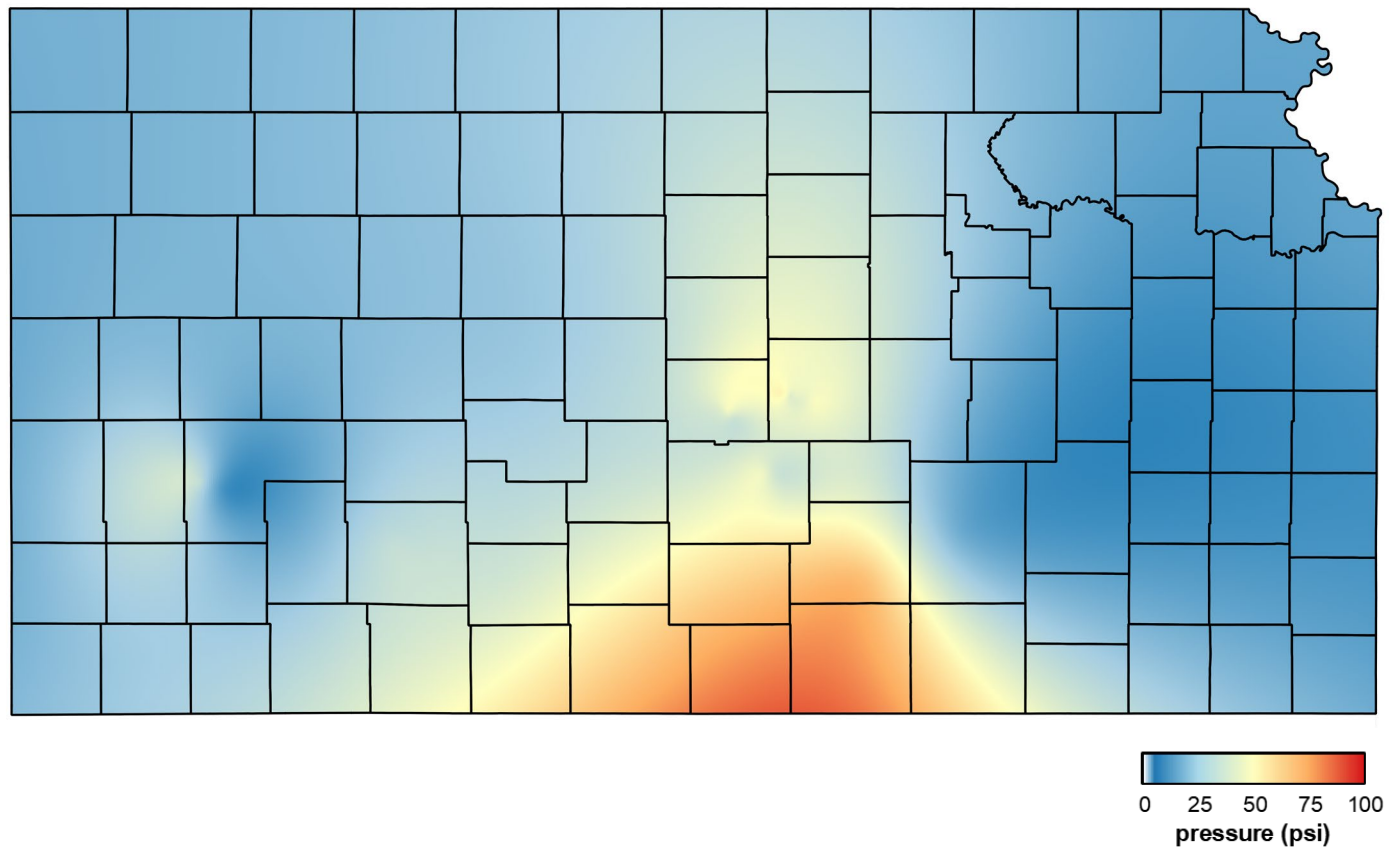


Harper Co.

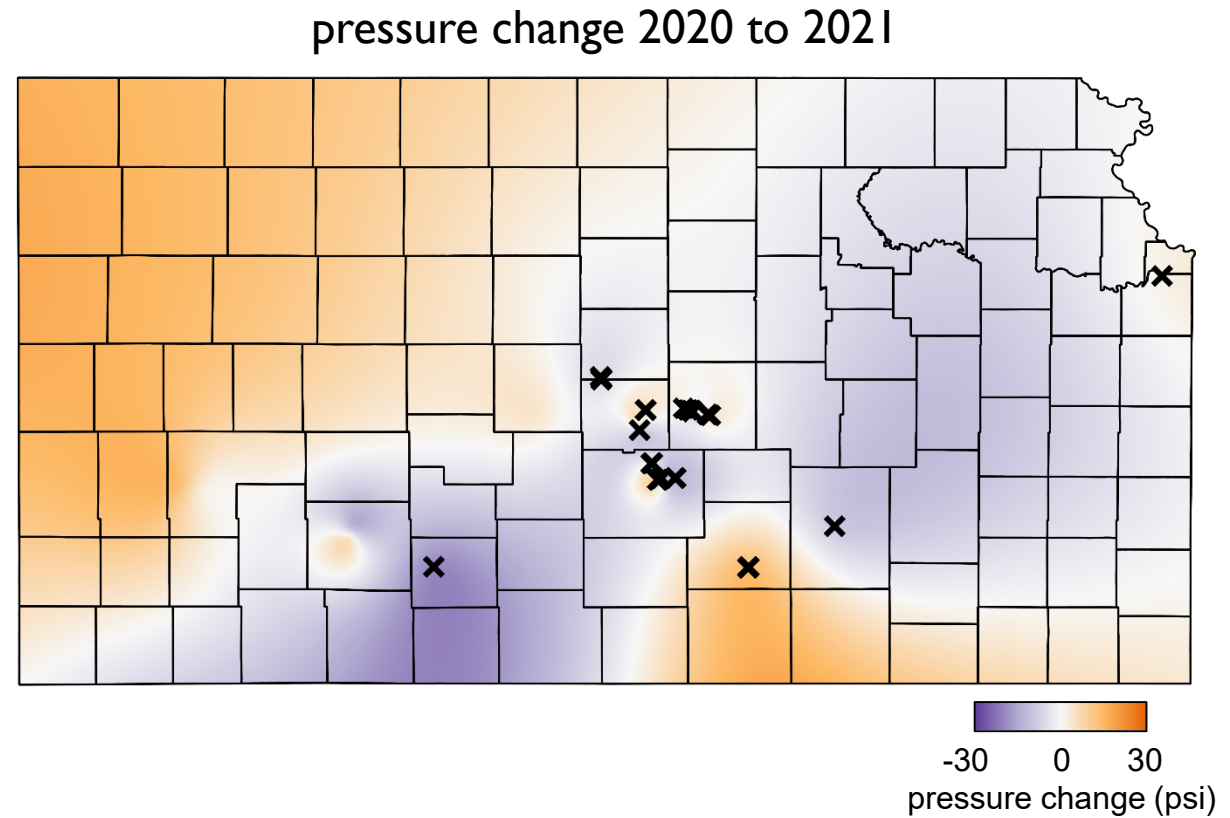
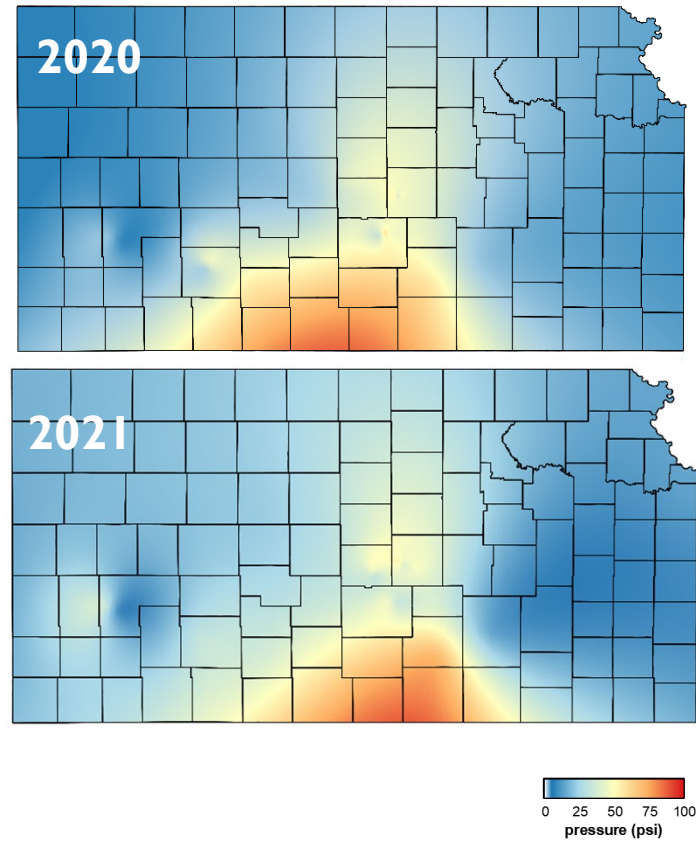
HP Annual Disposal



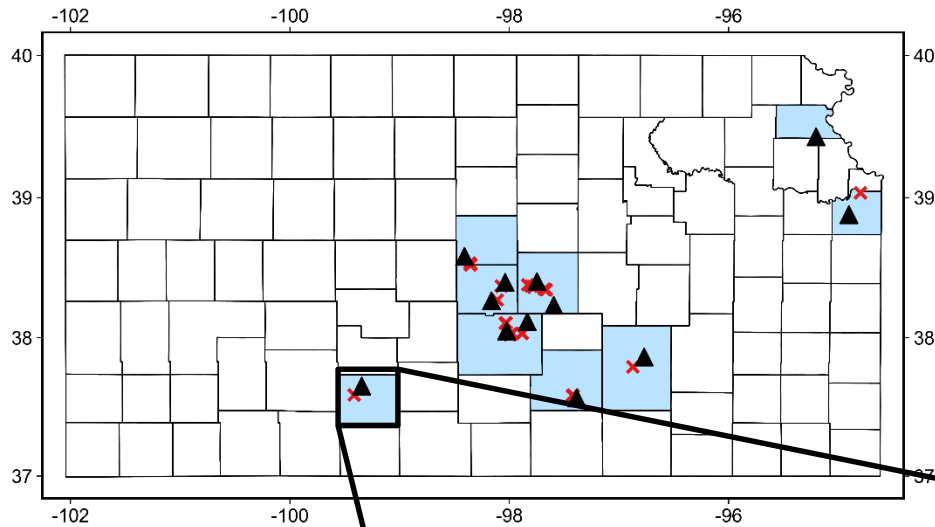
2021 Formation Pressure



Formation Pressure Change



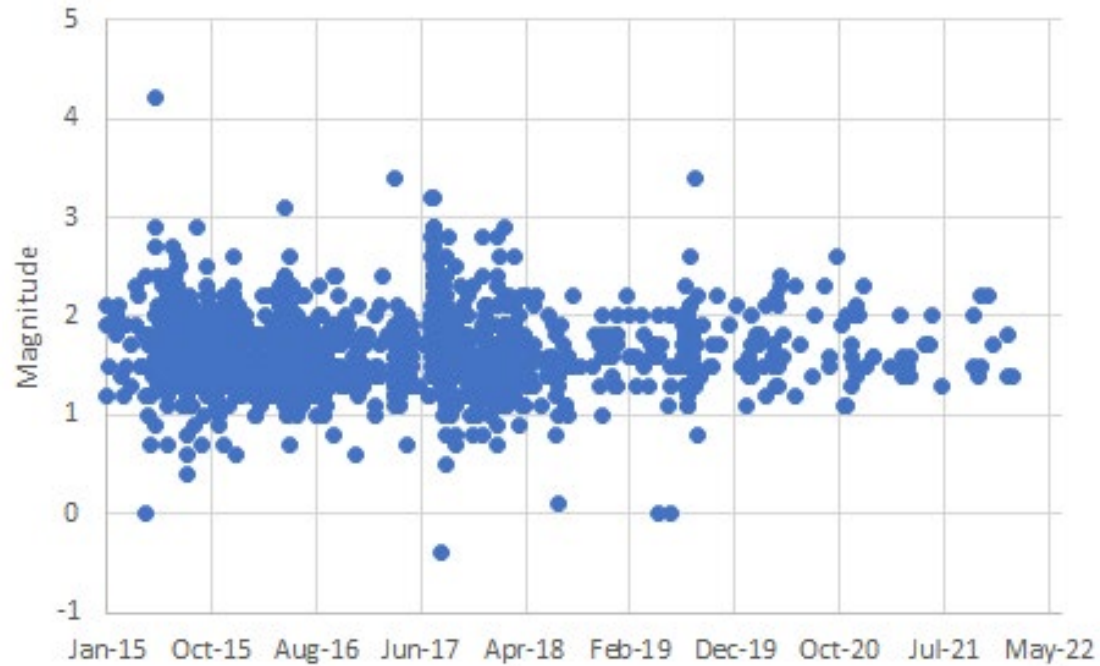
Kiowa County



- KW02
 - north central KW
 - pasture
 - Greensburg

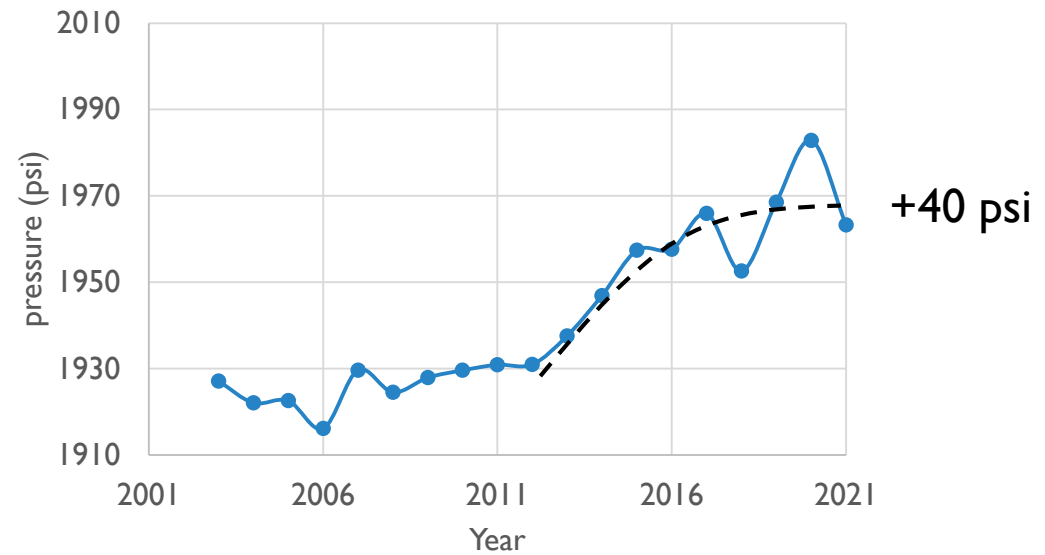
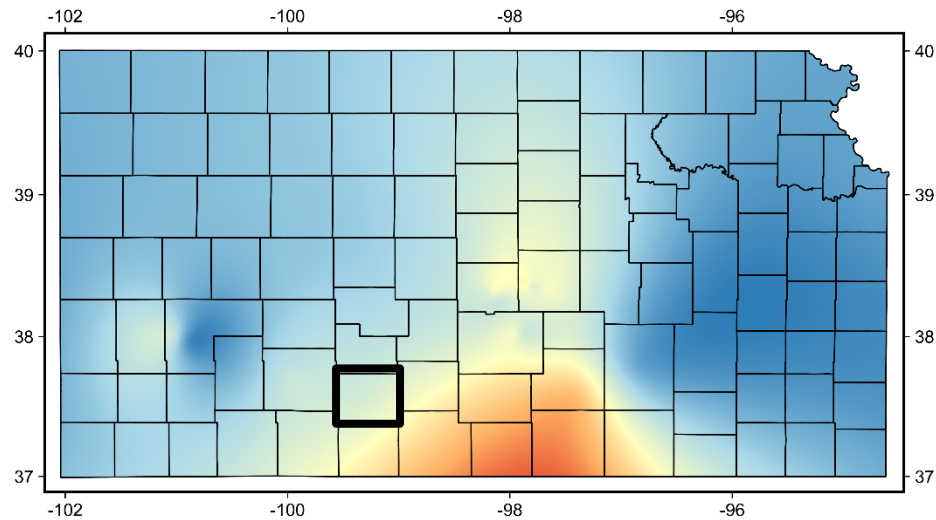


Kiowa County

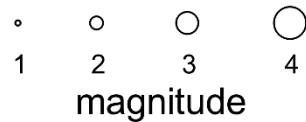
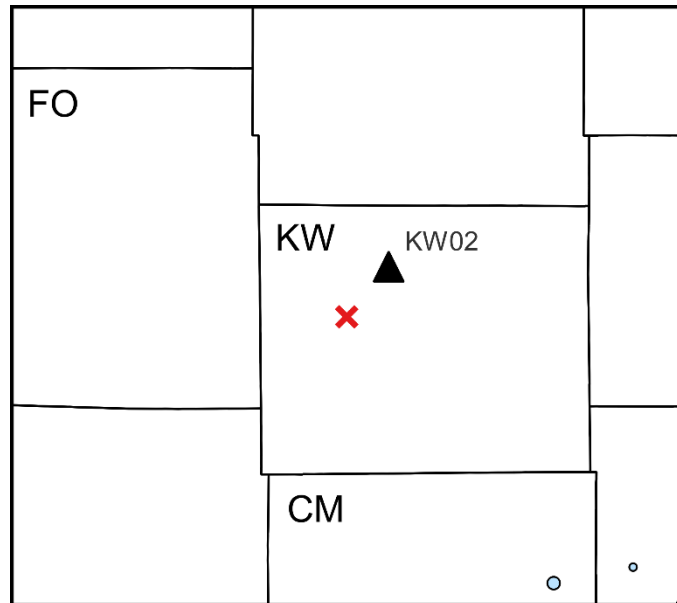


- Central Kansas Uplift
 - southwest margin
 - west of Pratt Anticline
- Mapped faults
 - None
- Historic earthquakes
 - None
 - Influenced by pore pressure
 - Sparse recent seismicity

Kiowa County



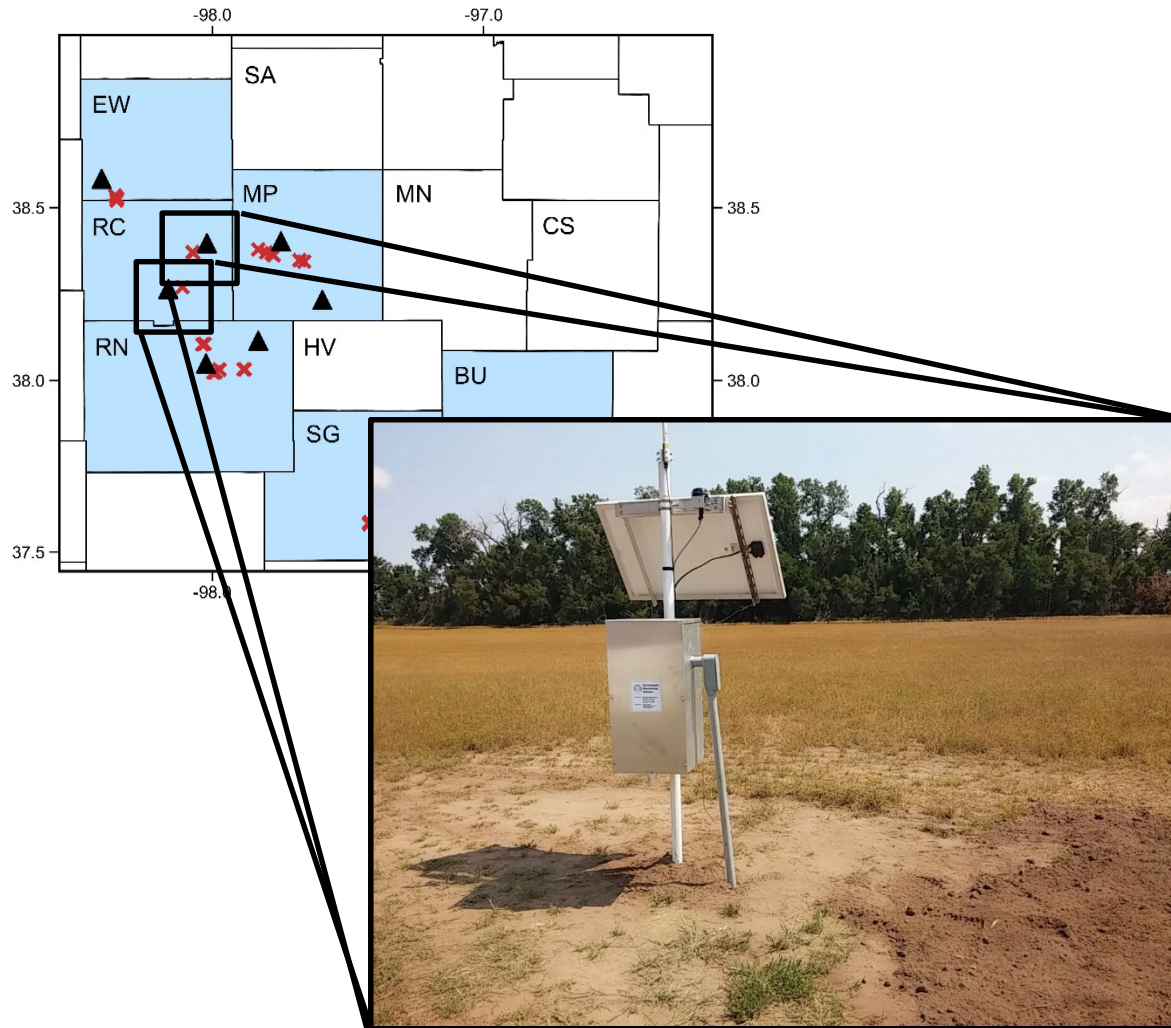
Kiowa County



● KGS/CSTS network (2021-2022)

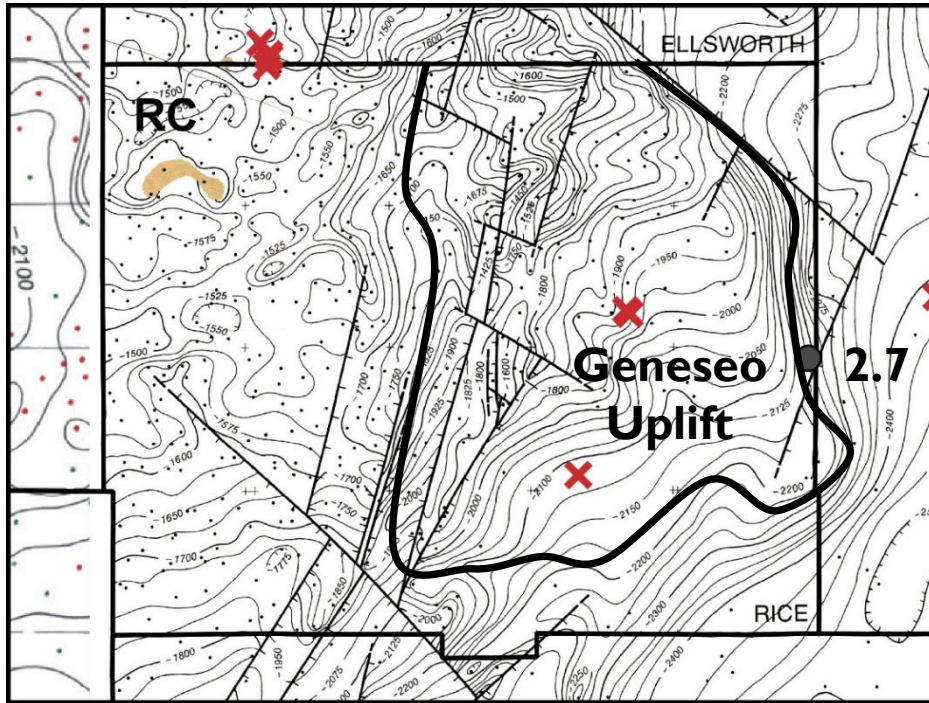
- Local Earthquakes (<20 mi)
 - None
 - ~30 miles away in Comanche and Barber
- Subnetwork events
 - 17 events (8/yr average)
 - M -1.5 to 0.1
 - < 5 mi from KW02
- More subnetwork events, sparse

Rice County



- RC02
 - northeast RC
 - pasture
 - Little River
- RC03
 - between Lyons and Sterling
 - pasture

Rice County

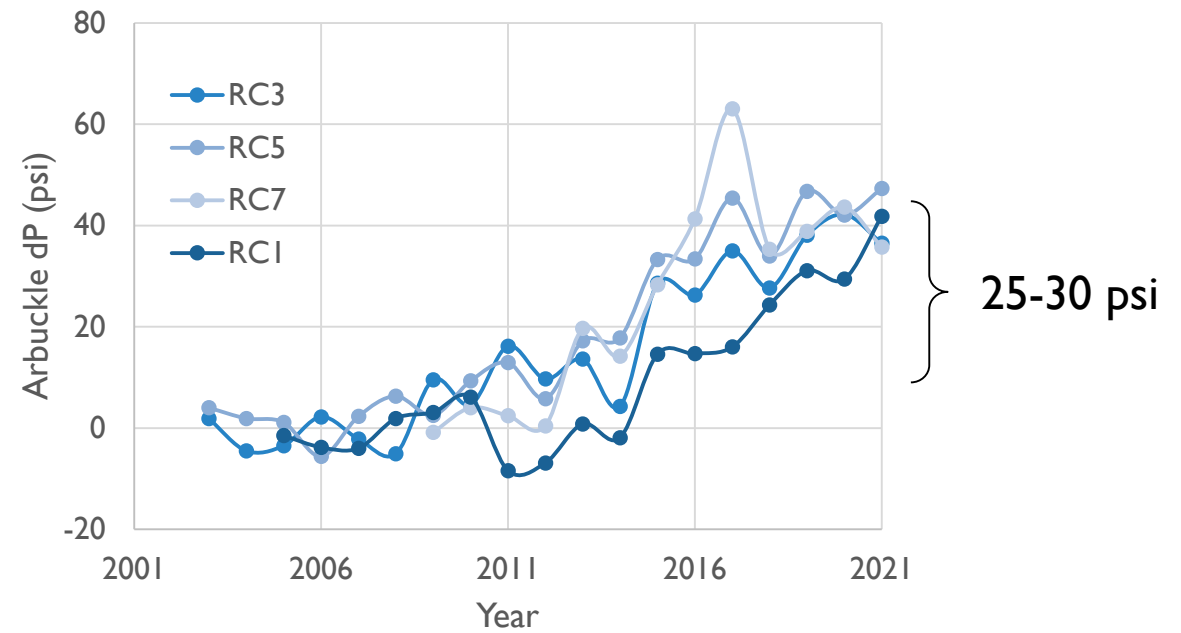
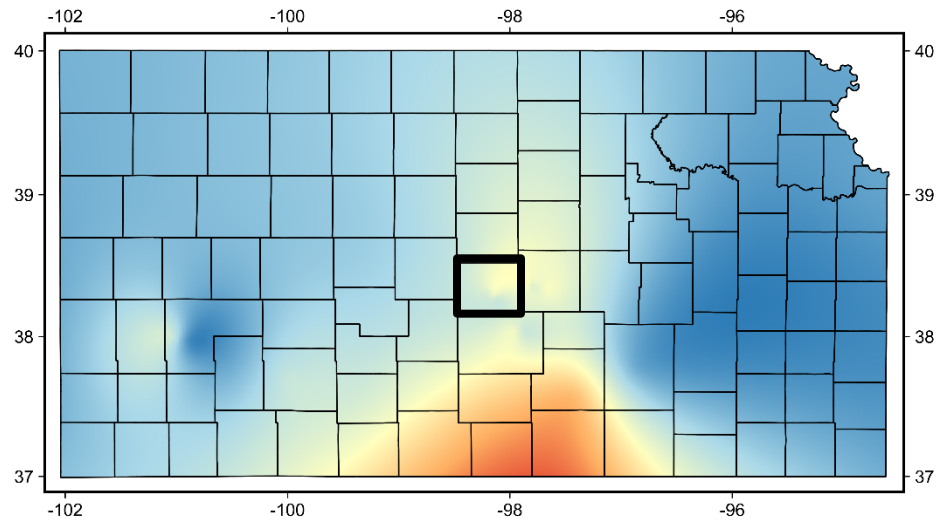


magnitude ○ ○ ○ ○
 1 2 3 4

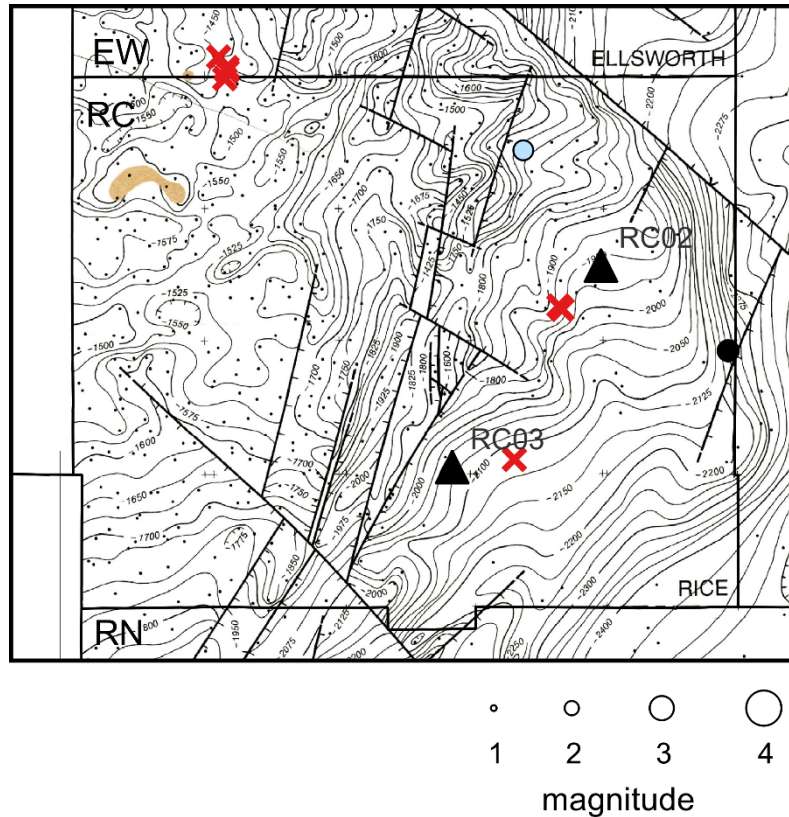
● Historic (1977-2014)

- Eastern margin of the CKU
- Mapped structures
 - Geneseo Uplift
 - bounded by faults
- Historic earthquakes
 - M 2.7 in 1981

Rice County



Rice County

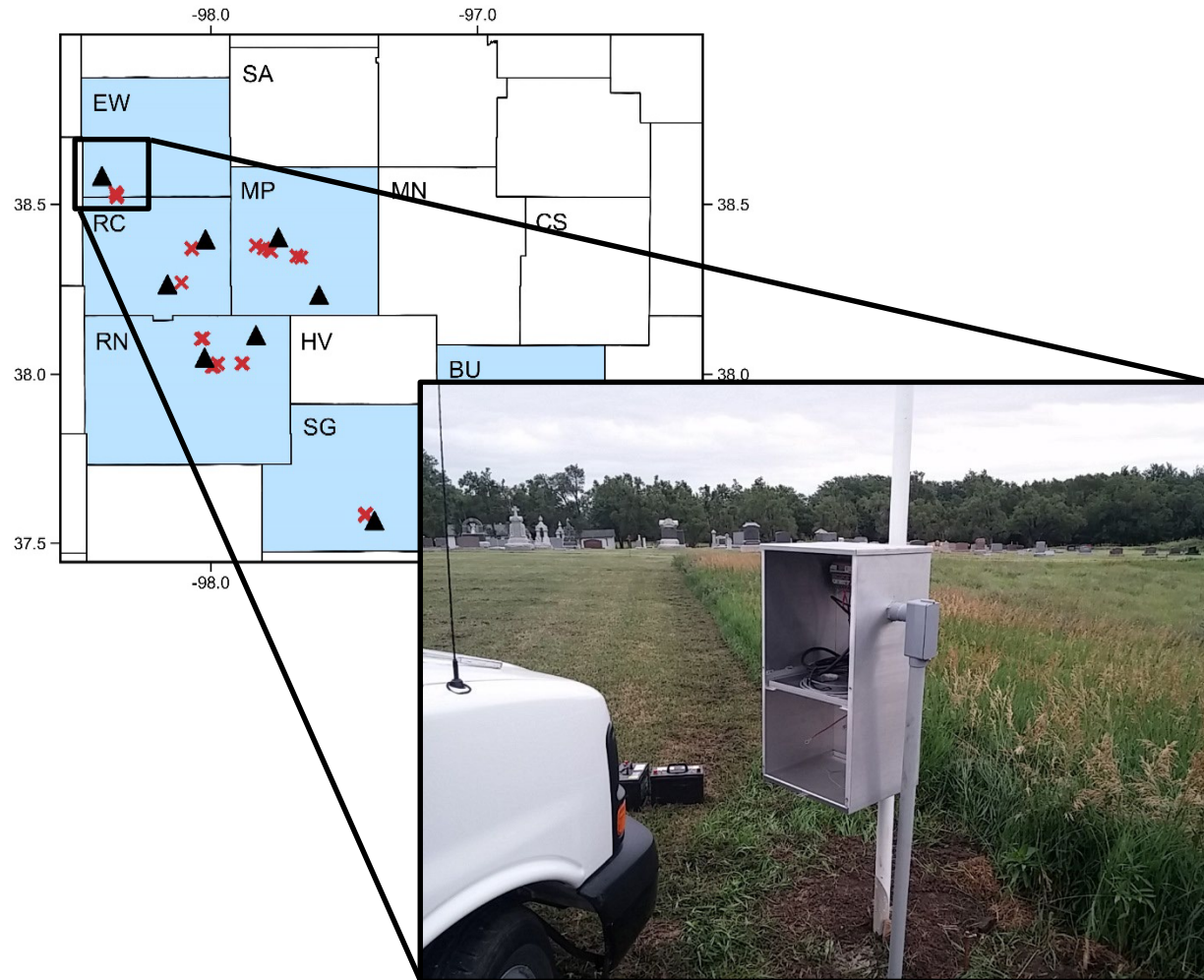


● KGS/CSTS network (2021-2022)

● Historic (1977-2014)

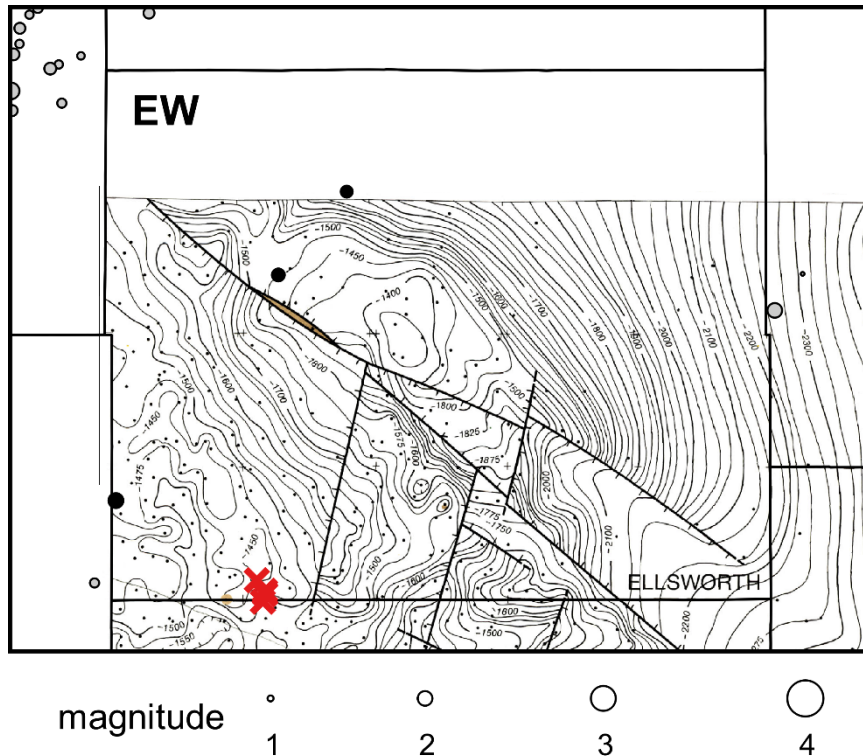
- Local earthquakes (< 20mi)
 - M 2.9 on June 28, 2022
 - only detected by KGS/CSTS
 - first since 1981
- Subnetwork events
 - RC02: 26 (22/yr avg.)
 - M -1.5 to 1.1
 - distance: 1-11 mi
 - Geneseo Uplift
 - RC03: 15 (19/yr avg.)
 - M -1.5 to 0.6
 - distance: 5 mi

Ellsworth County



- EW01
 - southwest EW
 - Holyrood
 - pasture, cemetery

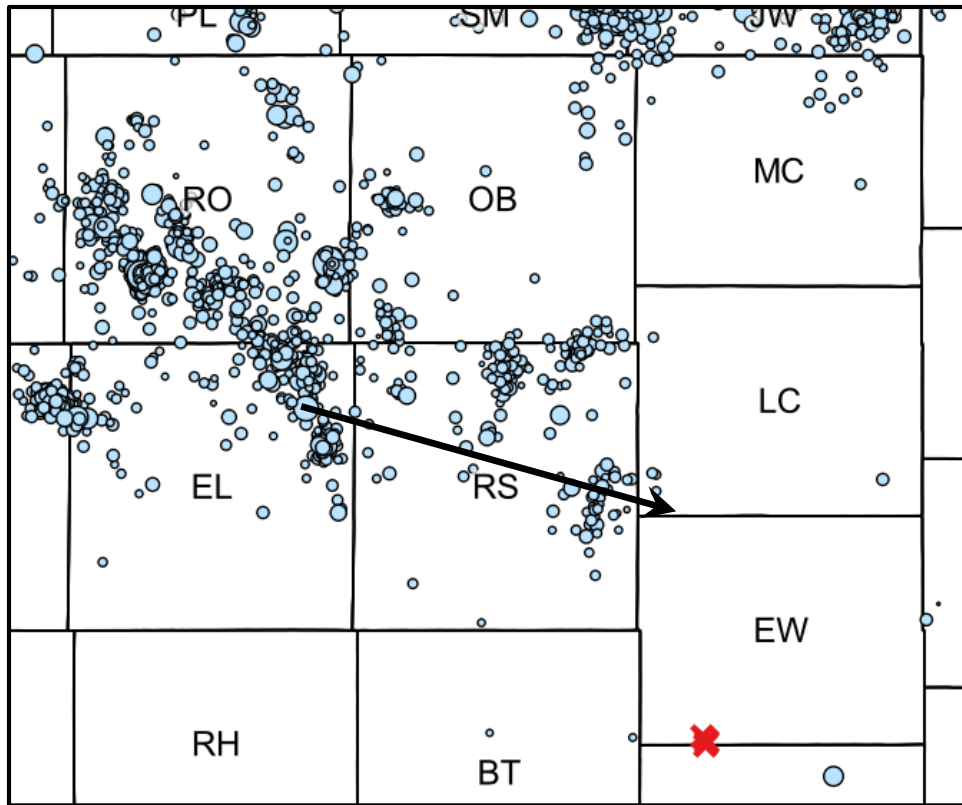
Ellsworth County



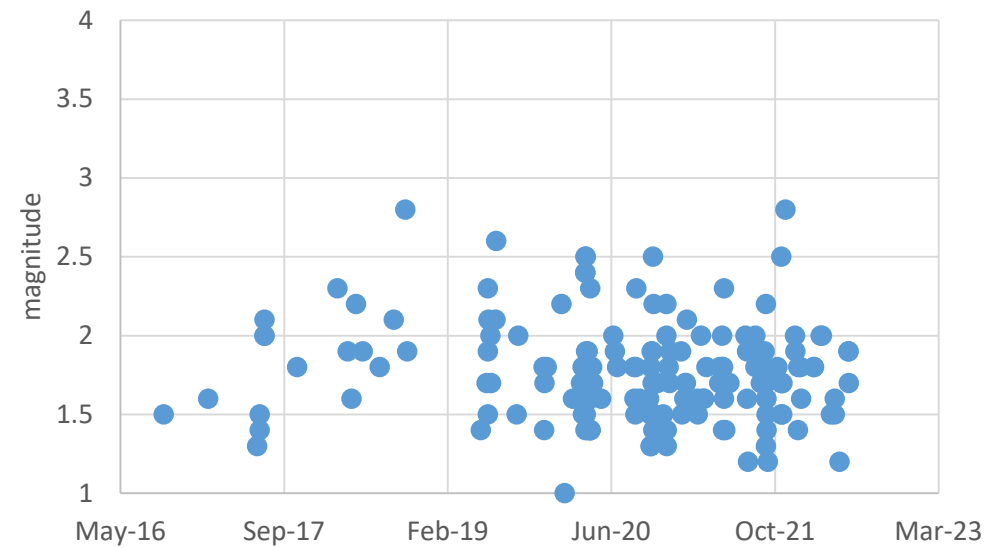
- Historic (1977-2014)
- KGS network (2015-2021)

- Eastern margin of the CKU
- Mapped structures
 - faults
- Historic earthquakes
 - M 1.7 to 2.0 in 1980s
 - M 1.4 in 2018 (Barton)

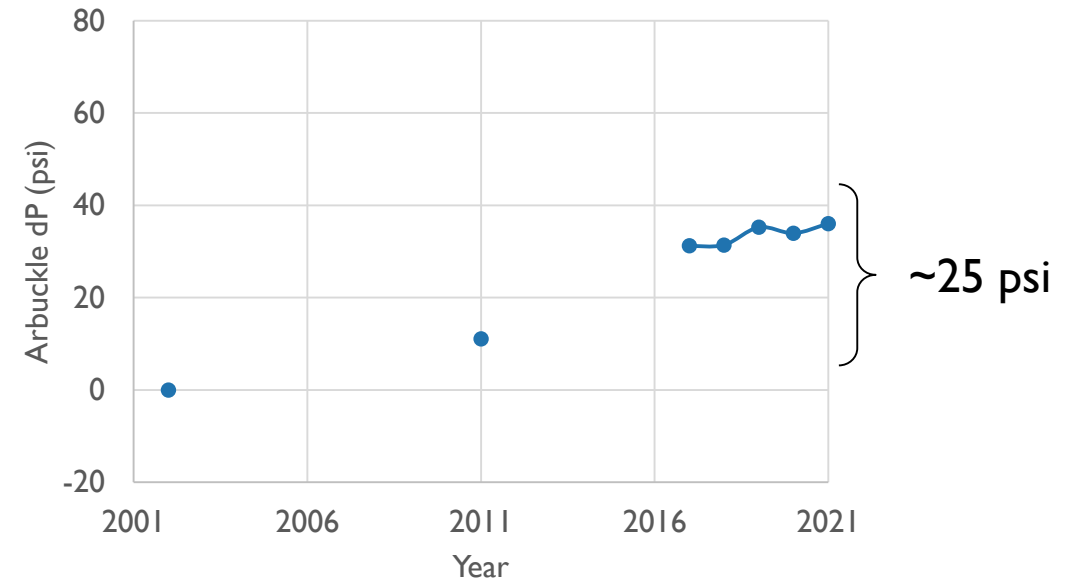
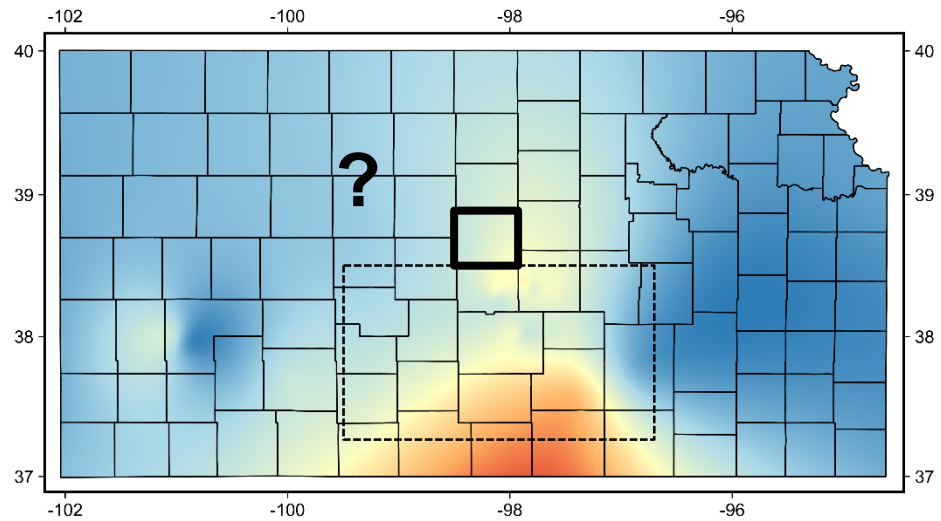
Earthquake Migration



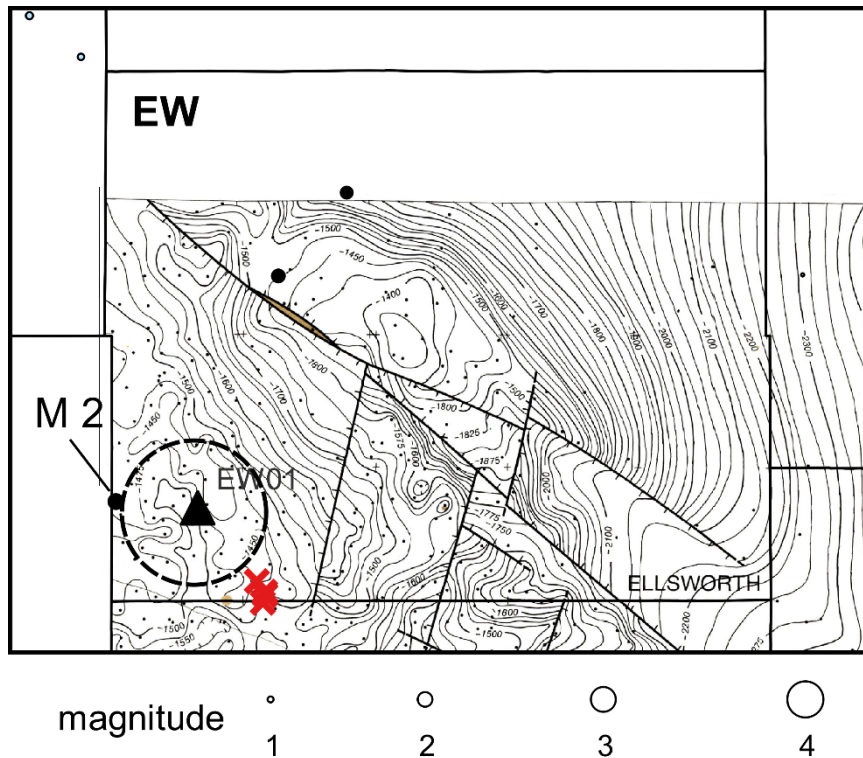
Russell County Earthquakes



Ellsworth County



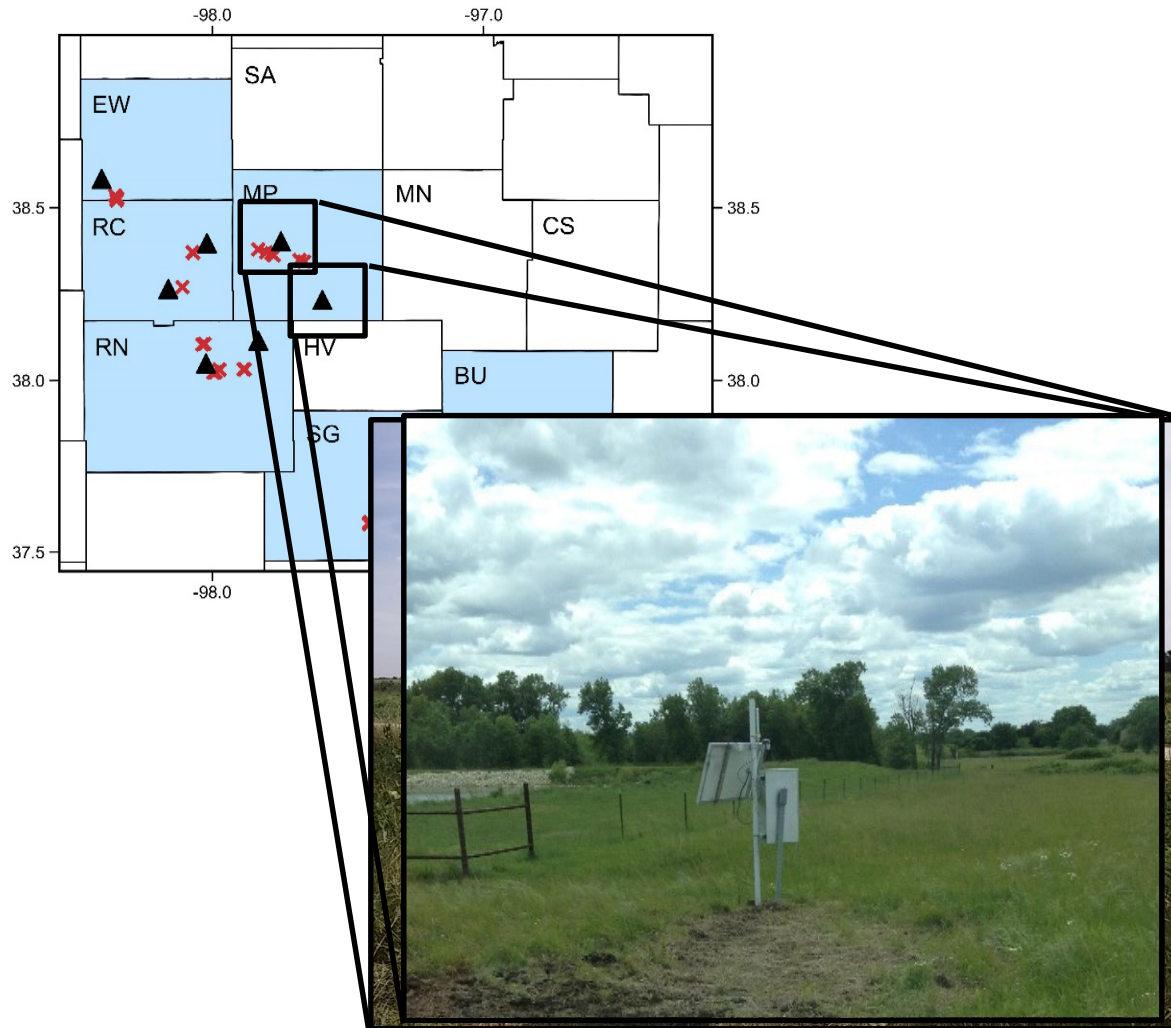
Ellsworth County



- Historic (1977-2014)
- KGS/CSTS network (2020-2021)

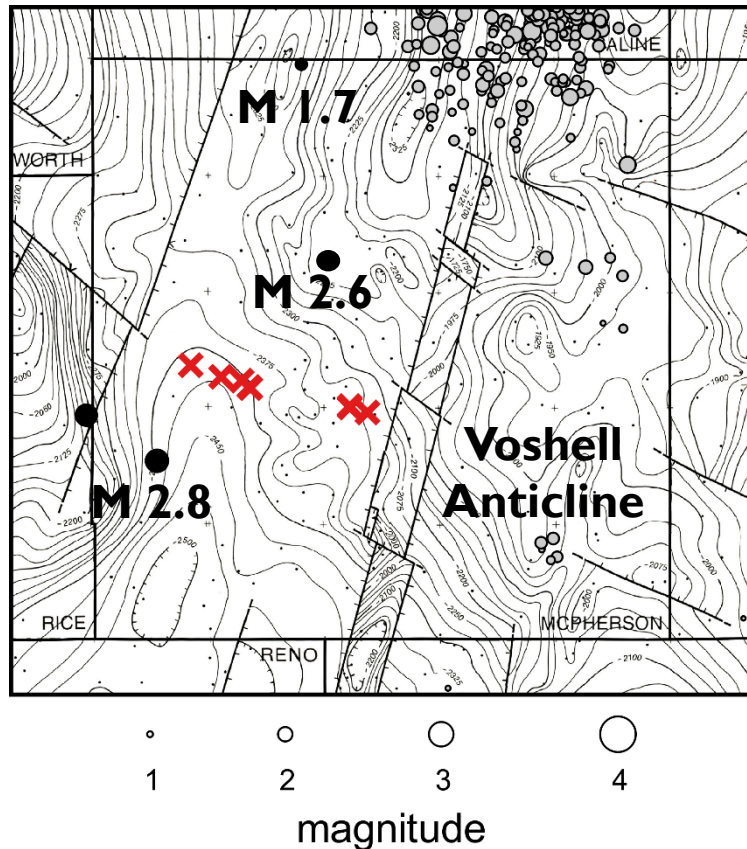
- Local earthquakes (< 20 mi)
 - M 2.9 in Rice Co
 - events in Russell Co > 20 mi
- Subnetwork events
 - 13 events (9/yr avg.)
 - M -0.9 to 1.5
 - 2-12 mi from station
- Consistent with past years

McPherson County



- MP01
 - northeast of Conway
 - pasture
 - McPherson Valley Wetlands
- MP02
 - south of McPherson
 - pasture
 - local church

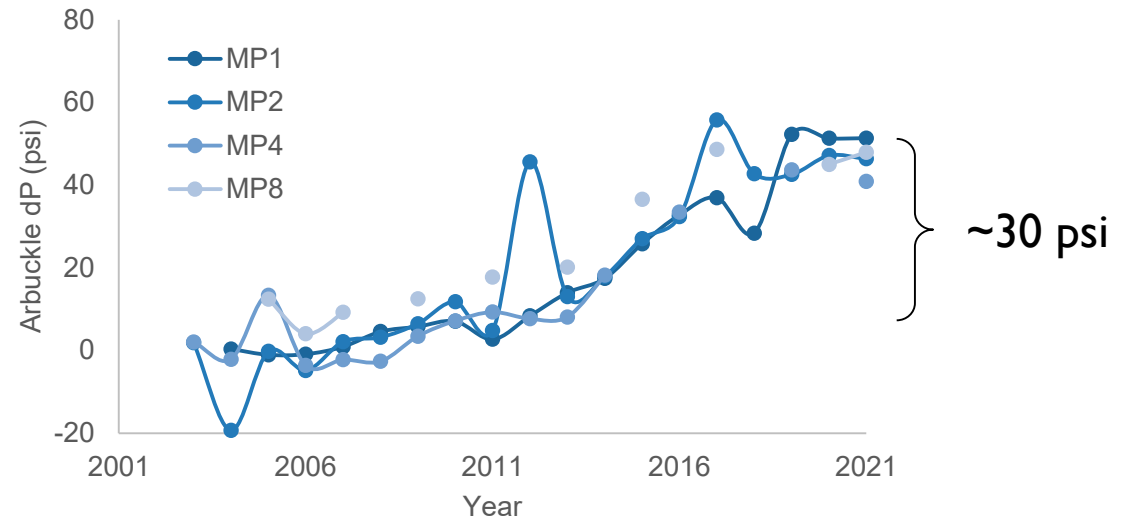
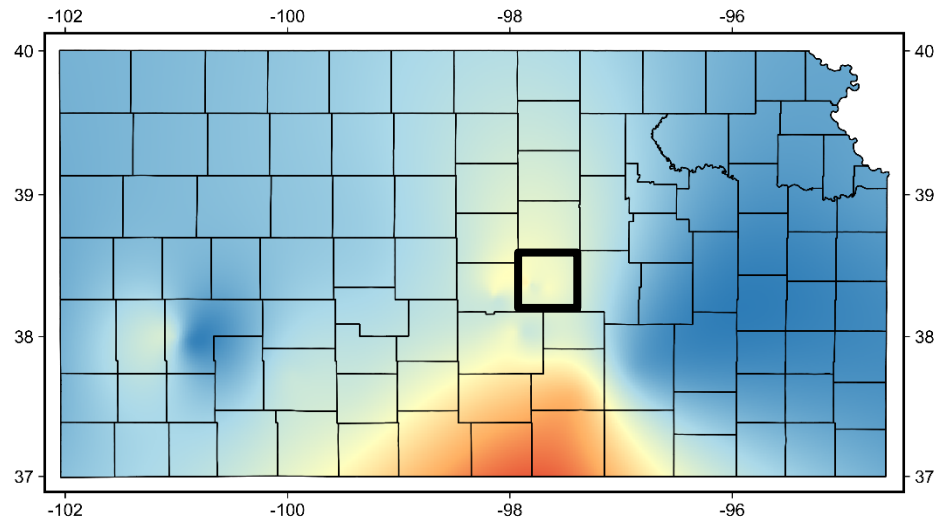
McPherson County



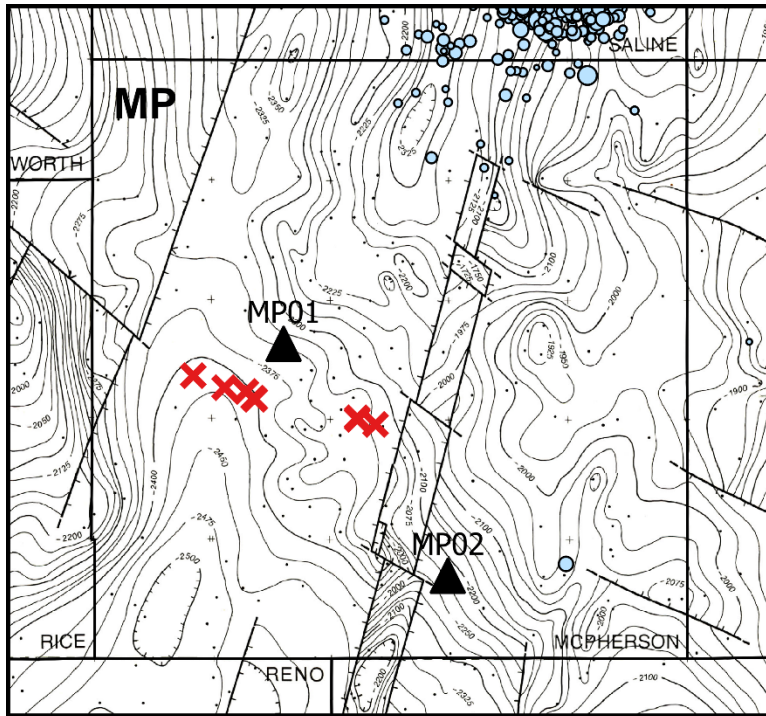
- Midcontinent Rift System
- Mapped structures
 - Voshell Anticline
 - bounded by faults
- Previous earthquakes
 - M 2.8 in 1981
 - M 1.7 in 1983
 - M 2.6 in 2014
 - Recent seismicity near MP–SA county line
 - Cluster in southeast corner

- Historic (1977-2014)
- KGS network (2015-2021)

McPherson County



McPherson County

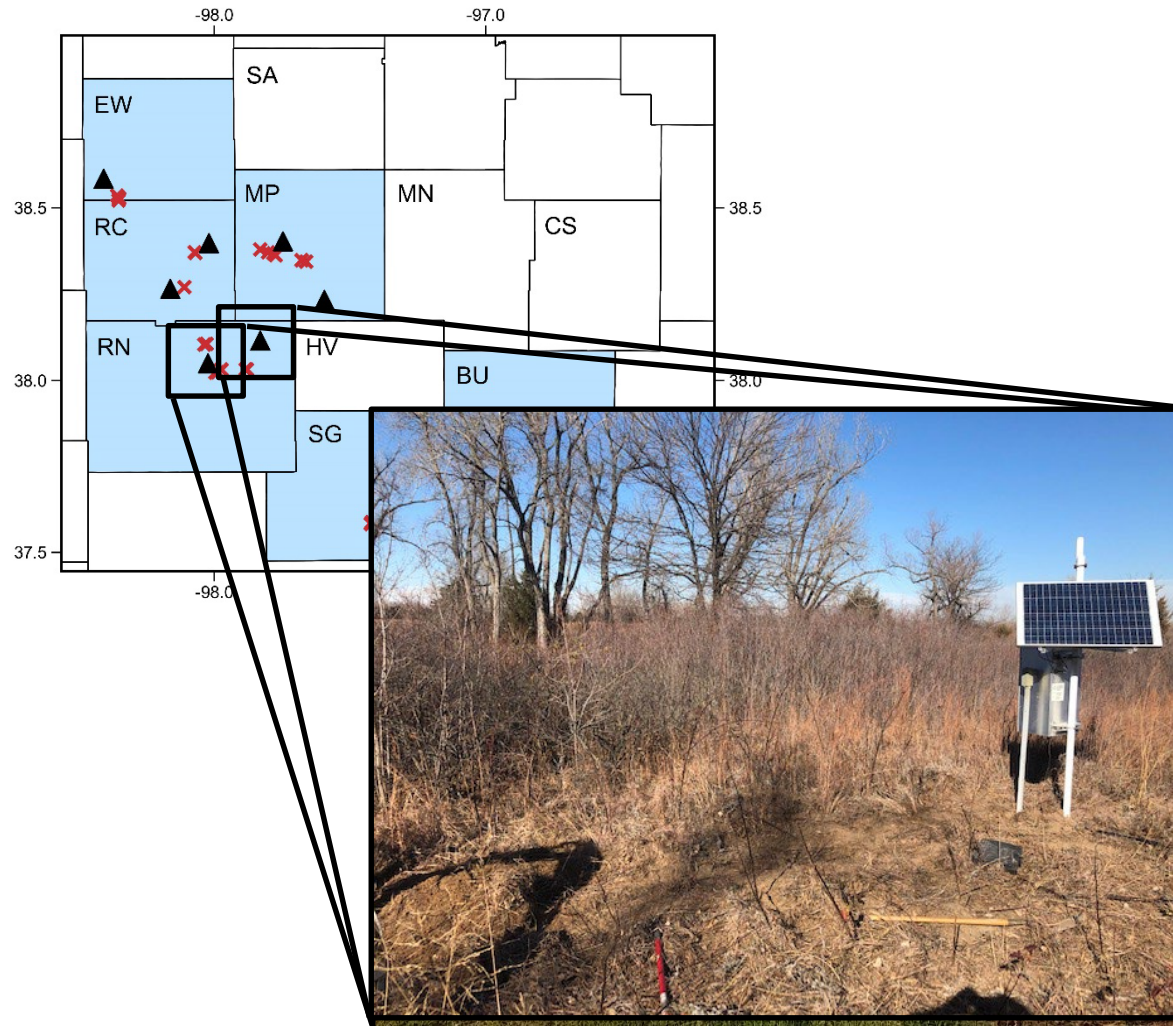


● Historic (1977-2014)

● KGS/CSTS network (2021-2022)

- Local earthquakes
 - 22 earthquakes, M 1.1 to M 2.2
 - mostly near Saline cluster
 - largest in SE corner near previous cluster
- Subnetwork events
 - MP01: 42 events (12/yr avg.)
 - M -1.5 to 0.4
 - avg. 4 mi away, corresponds to historic earthquakes
 - MP02: 37 events (24/yr avg.)
 - M -1.5 to 0.4
 - 0.5-7 mi away
 - corresponds to anticline, SE cluster

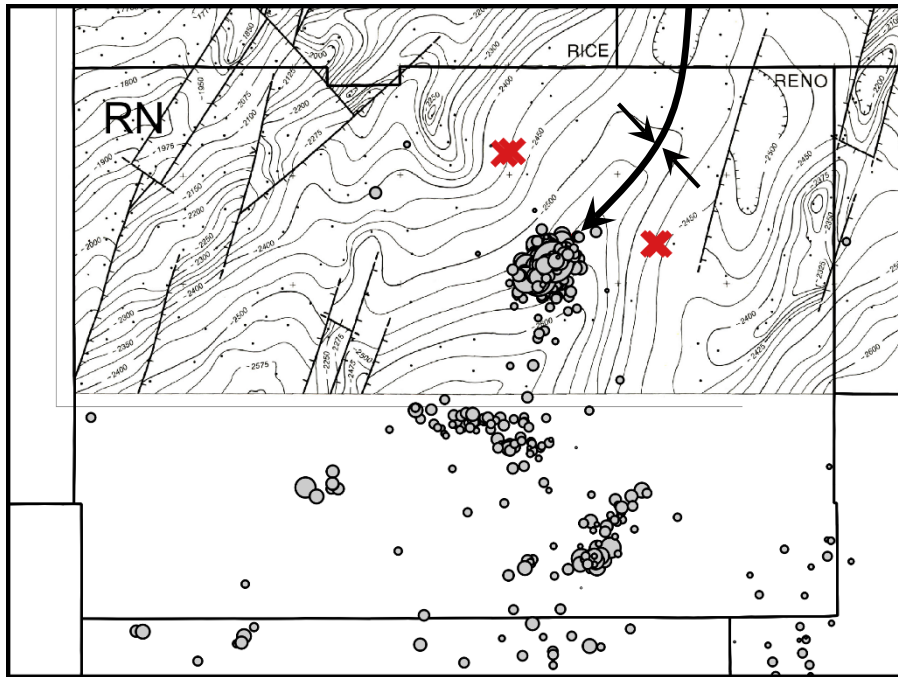
Reno County



- RN01
 - west of Hutchinson
 - cemetery
- RN03
 - pasture
 - Sand Hills State Park

Reno County

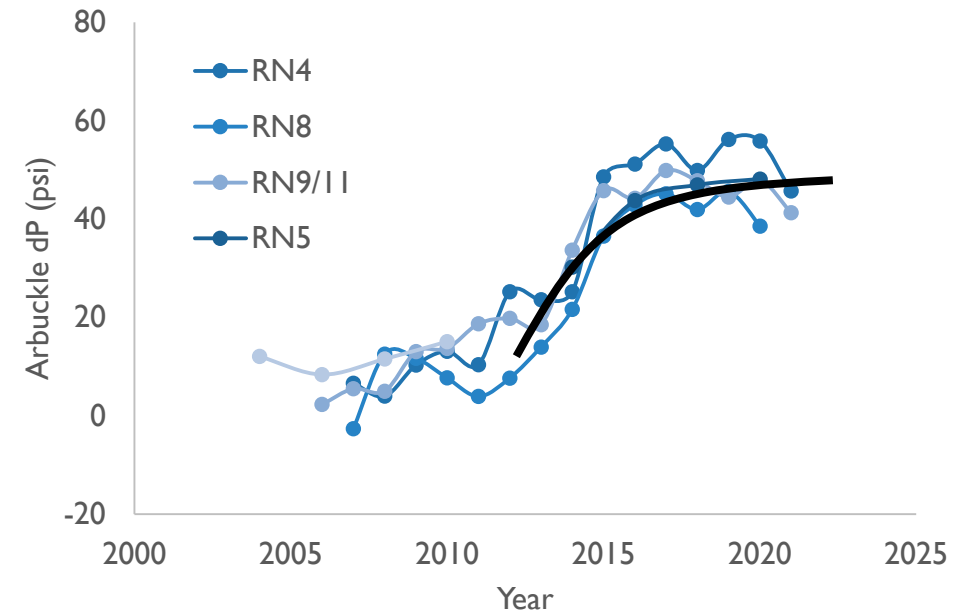
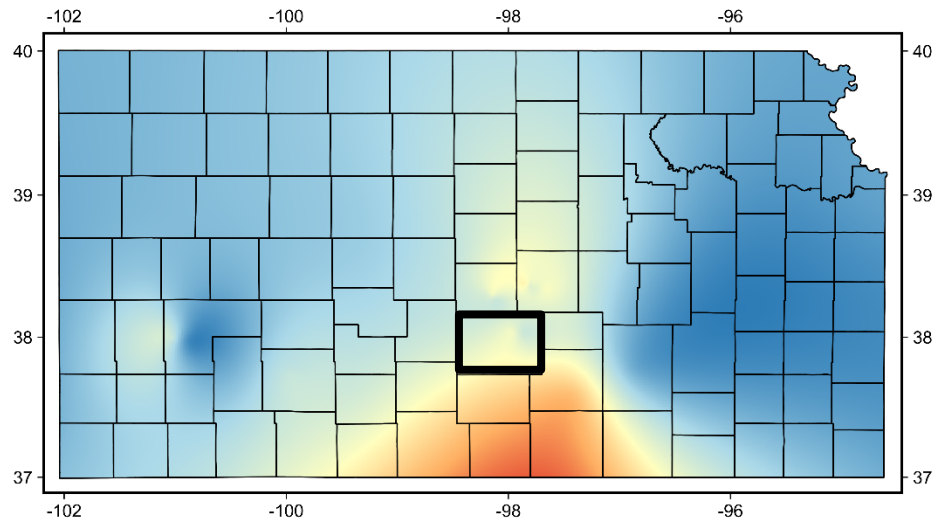
Conway Syncline



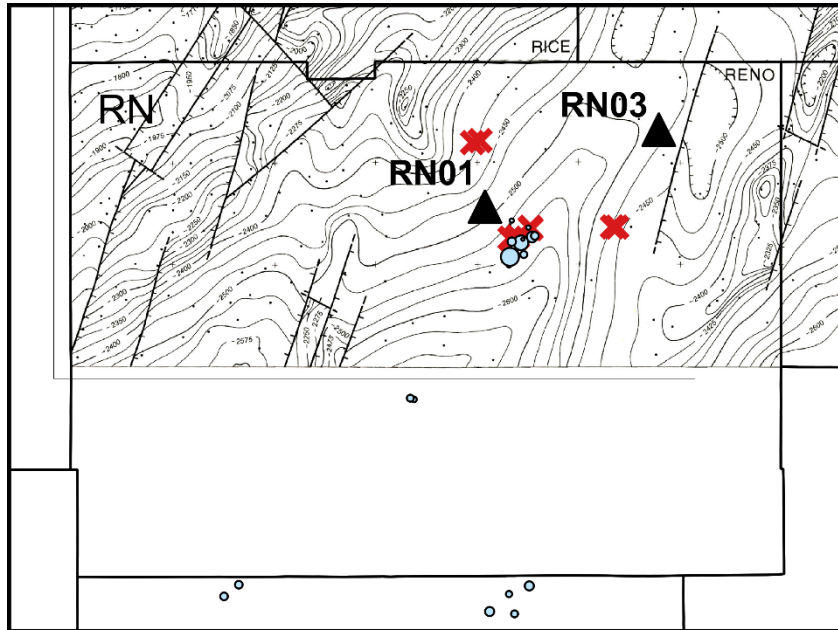
○ KGS network (2015-2021)

- Geologic Setting
 - CKU and MRS
 - structural low
 - Conway Syncline
 - faults bounding uplifted areas
- Historic earthquakes
 - None (M 3+)
 - Recent seismicity (2015-present)
 - progressed north
 - structural low
 - three M 4+ in 2019-2020

Reno County



Reno County



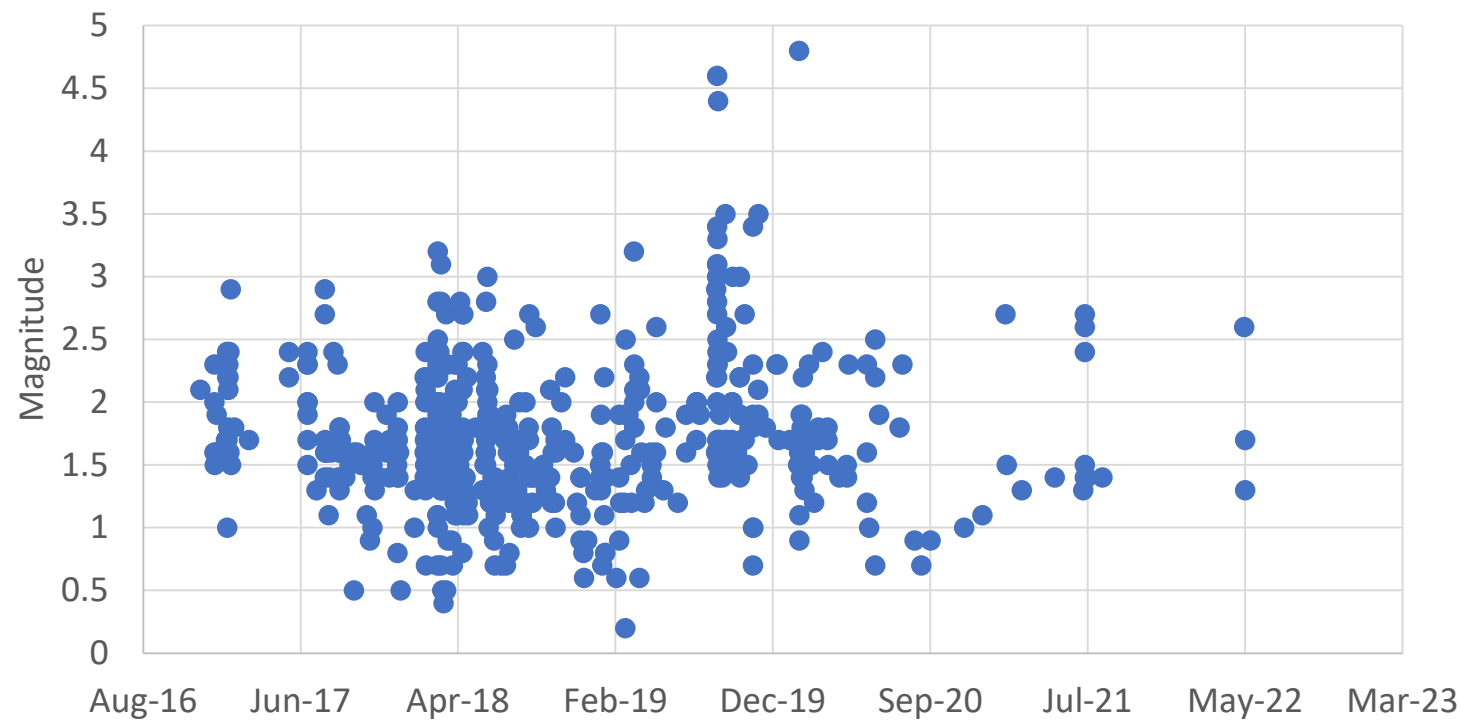
magnitude ◦ ◯ ○ ○

1 2 3 4

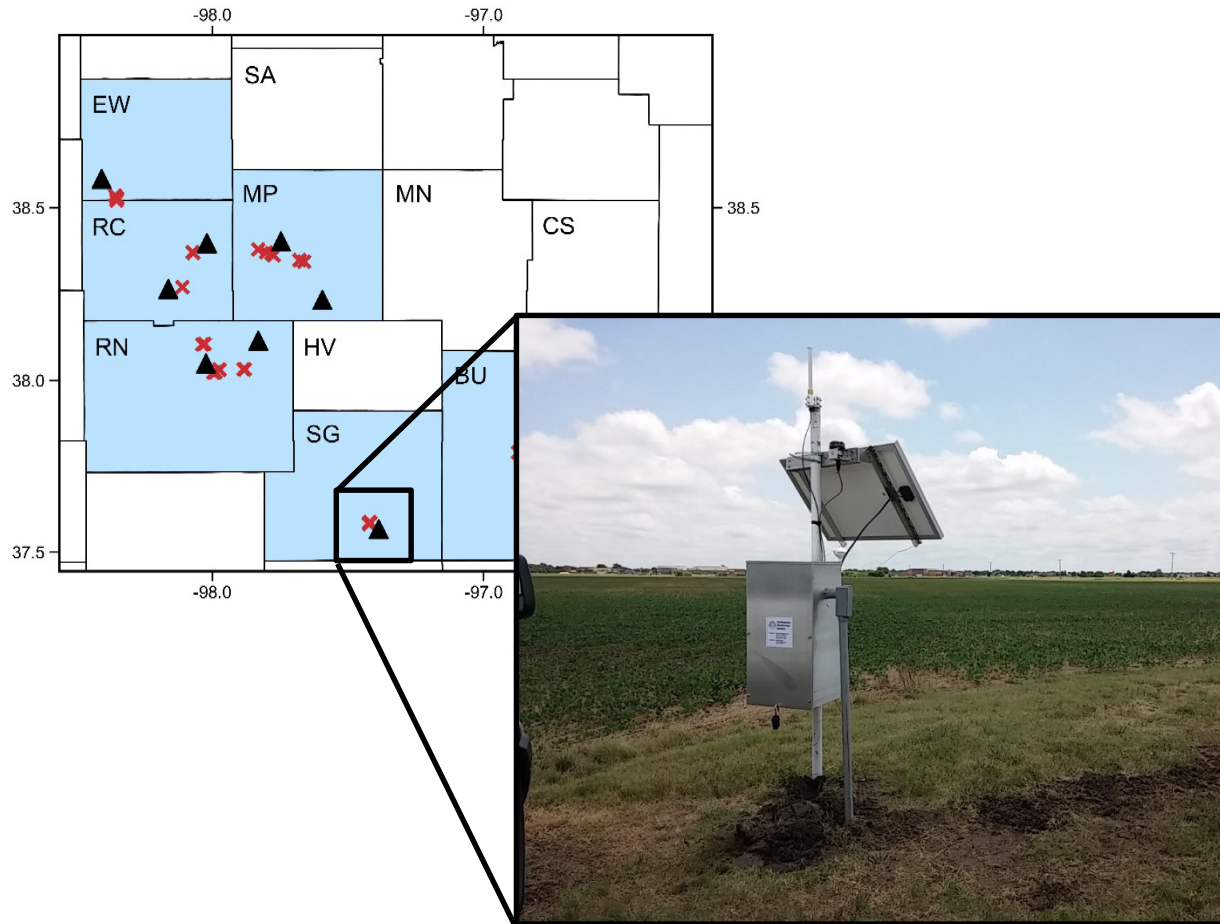
● KGS/CSTS network (2020-2021)

- Local earthquakes (w/in 20 mi)
 - 16 events
 - M 2.7 on July 17, 2021
 - M 2.6 on May 17, 2022
 - fore/aftershocks
- Subnetwork events
 - RN01
 - 42 (400/yr avg.)
 - M -1.5 to 0.6
 - corresponds to Hutchinson cluster
 - RN03
 - 22 (19/yr avg)
 - M -1.5 to 0.7
 - 1-9 mi
 - Hutchinson fault

Hutchinson Cluster



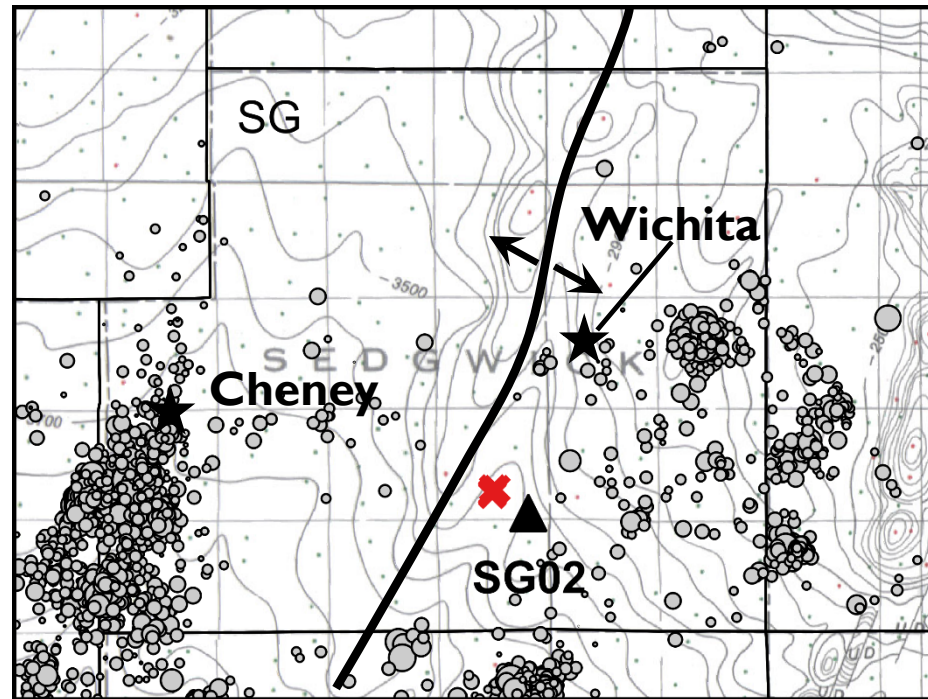
Sedgwick County



- SG02
 - south of Wichita
 - pasture
 - local church

Sedgwick County

Valley Center Anticline



magnitude

1

2

3

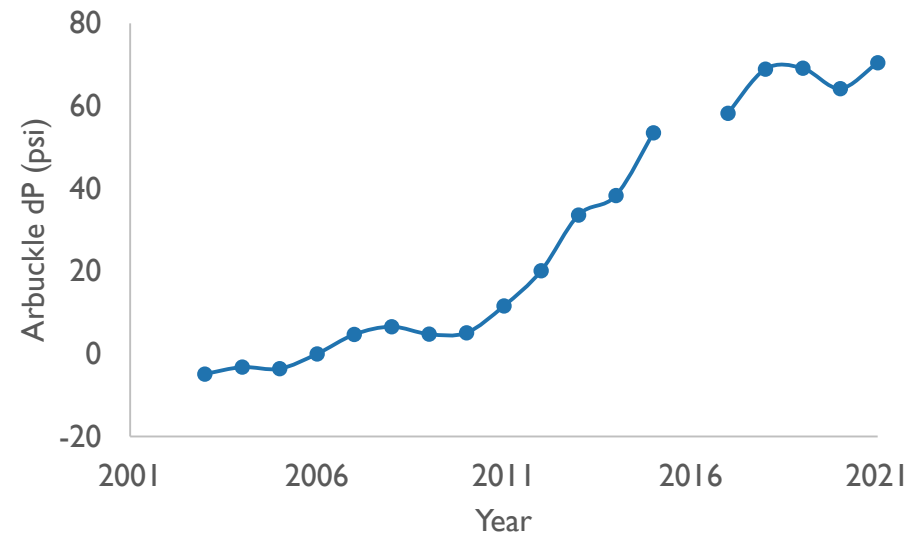
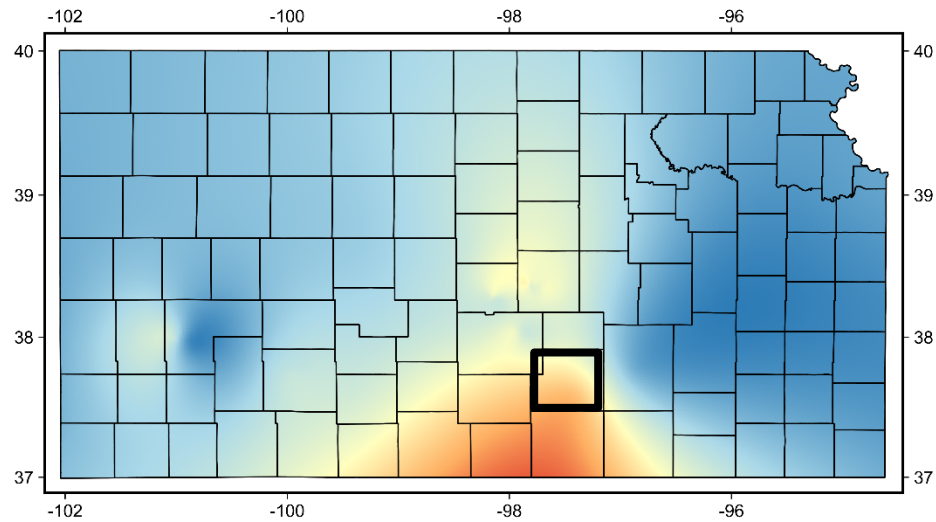
4

● Historic (1977-2014)

○ KGS network (2015-2021)

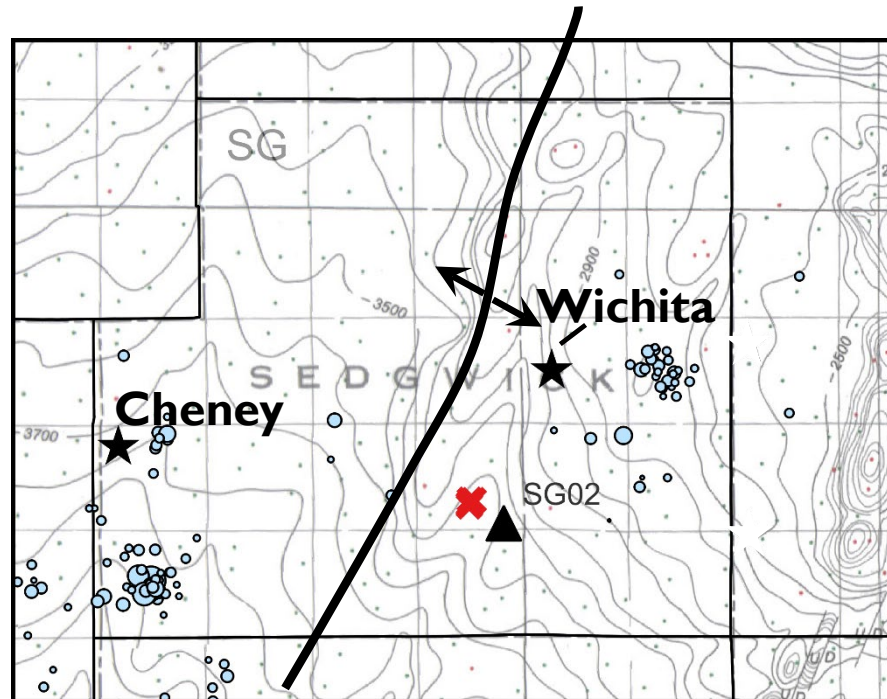
- Nemaha Ridge
- Mapped structures
 - Valley Center Anticline
 - likely associated faults
- Previous earthquakes
 - Historic
 - none recorded
 - felt events in early 1900s
 - Recent seismicity recorded by KGS network
 - predominantly NE trends
 - migrated from KS-OK
 - likely induced
 - dozen M 3 2021-2021

Sedgwick County



Sedgwick County

Valley Center Anticline



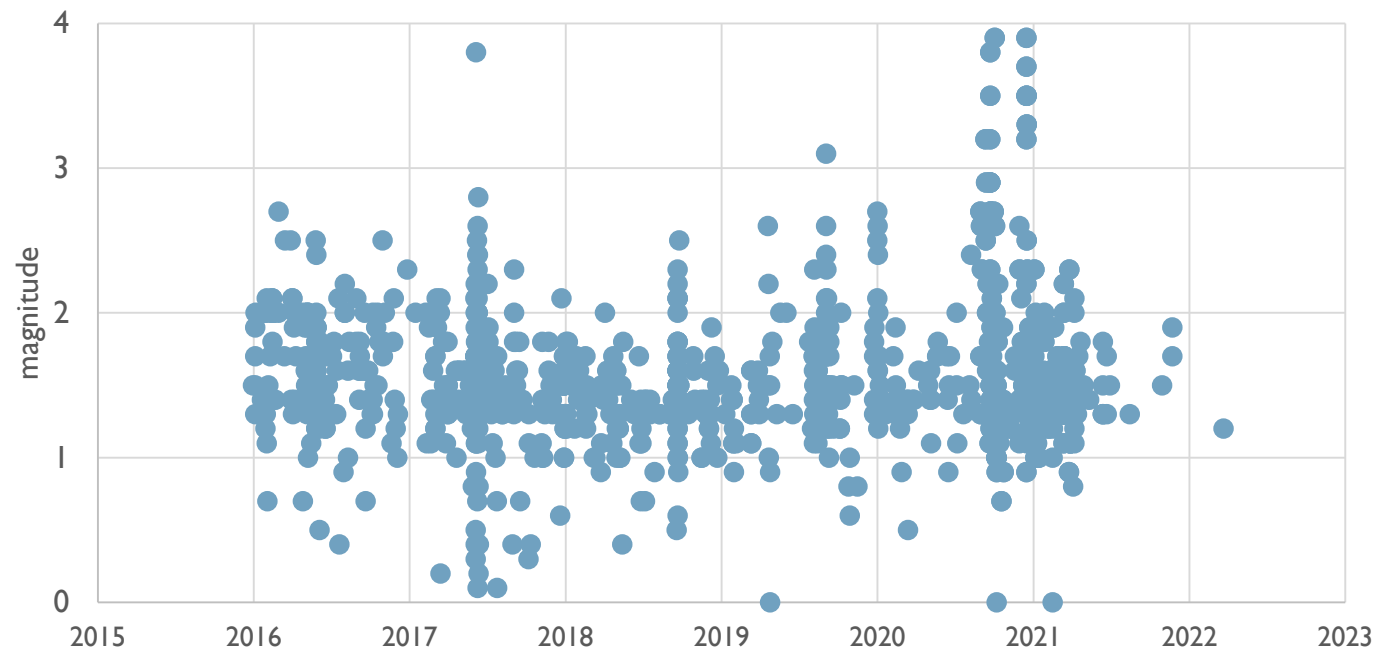
magnitude

•	○	○	○
1	2	3	4

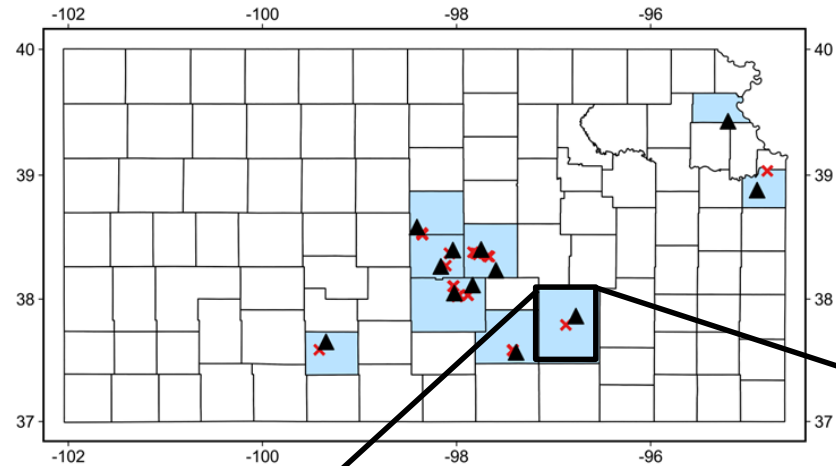
● KGS/CSTS network (2021-2022)

- Local earthquakes
 - 102
 - M 0.7 to 3.7
 - clusters identified previously
- Cheney
 - ~40, largest was M 3.7
- Wichita
 - 34, largest M 2.5
- Subnetwork Events
 - 29 events (27/yr avg.)
 - M -1.5 to 0.4
 - 0.5-11 miles

Wichita

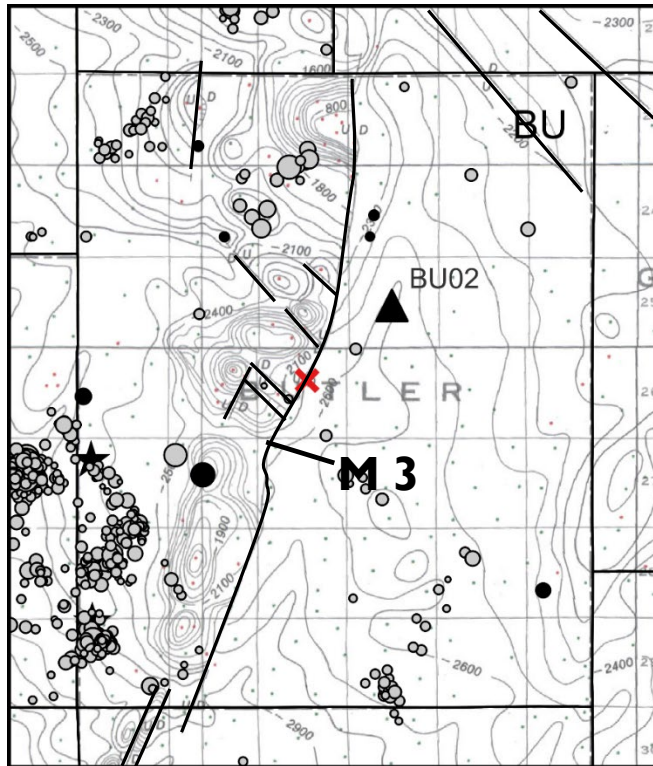


Butler County



- BU02
 - northeast of El Dorado
 - pasture
 - El Dorado State Park

Butler County



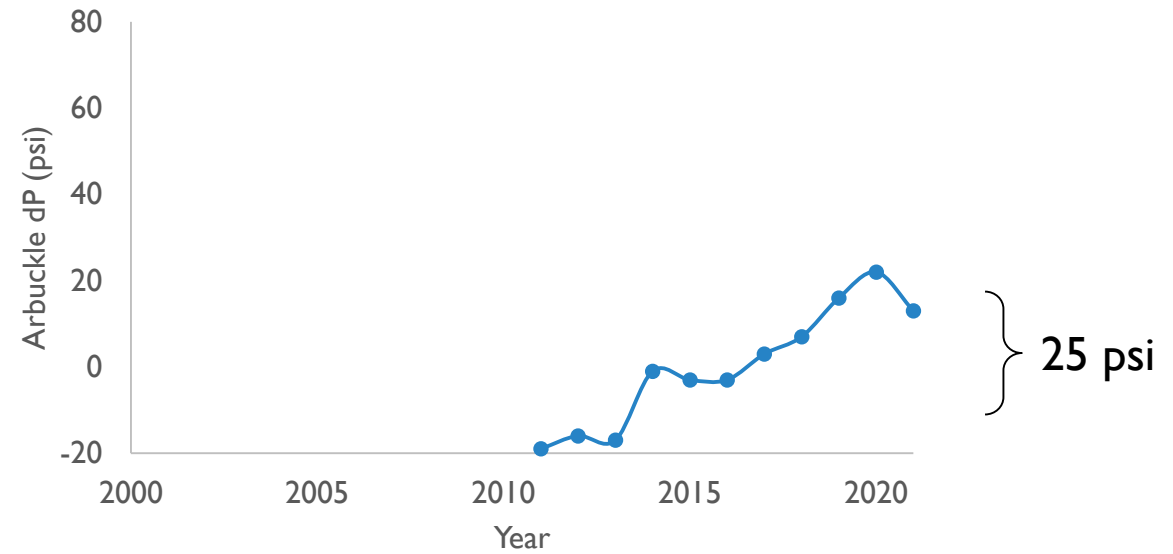
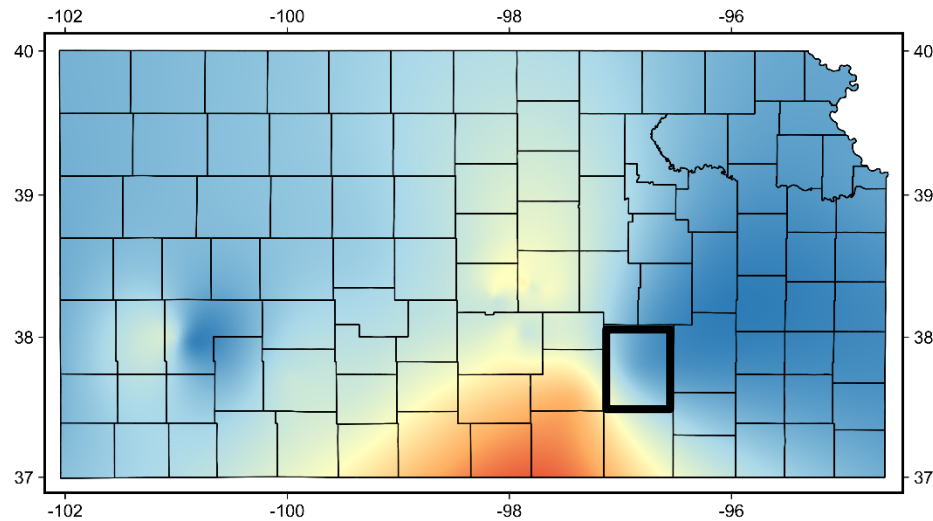
magnitude

- 1
- 2
- 3
- 4

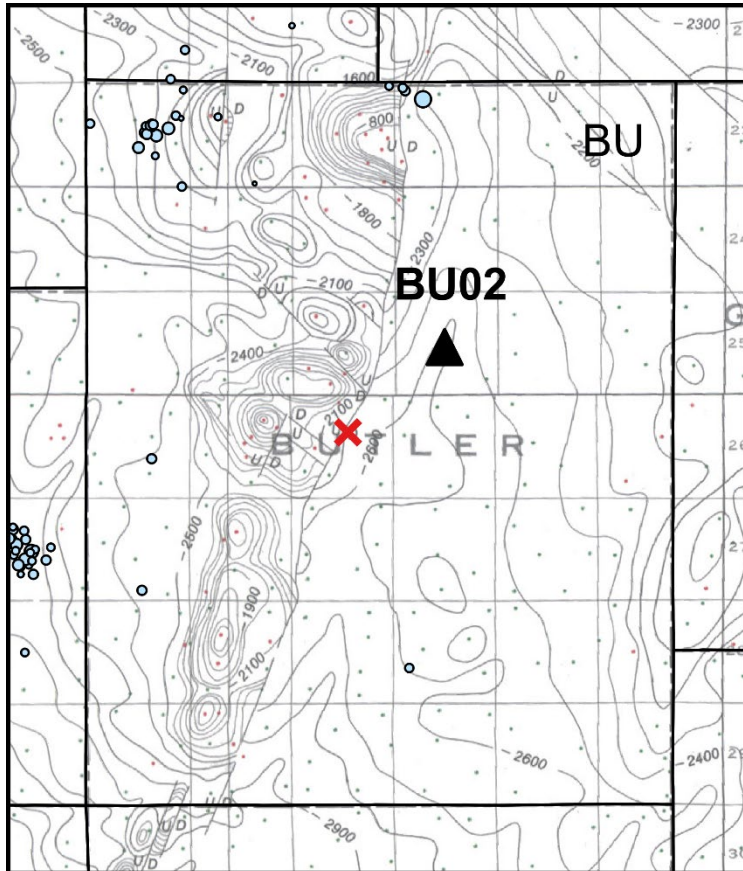
- Historic (1977-2014)
- KGS network (2015-2021)

- Nemaha Ridge
- Mapped structures
 - Nemaha Ridge/Humboldt FZ
 - anticlines/synclines
 - mapped faults
- Previous earthquakes
 - 7 historic events (M 3 in 2001)
 - Recent seismicity recorded by KGS network
 - clusters in northern and southern BU

Butler County



Butler County



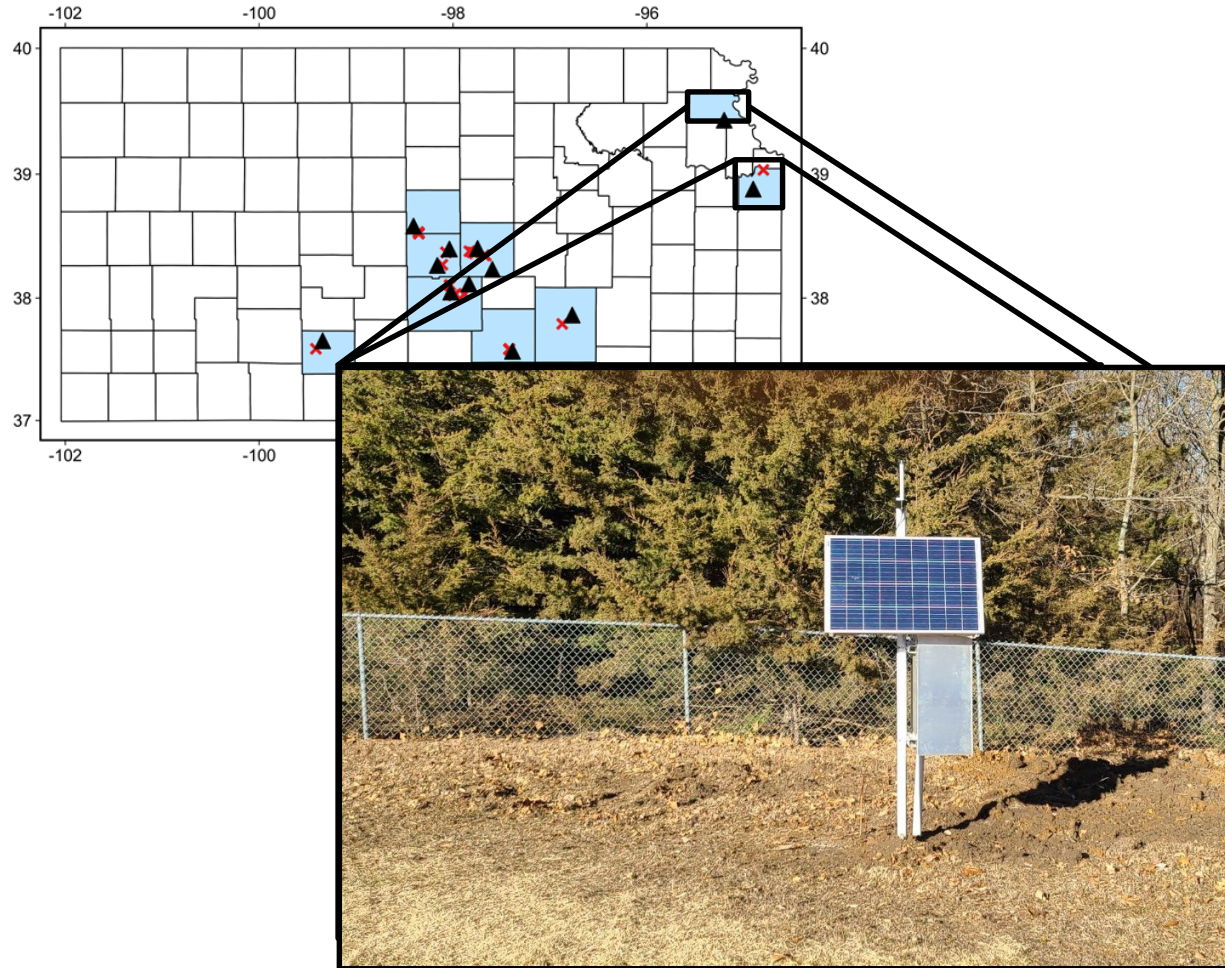
magnitude

- 1
- 2
- 3
- 4

- Local earthquakes
 - 11 earthquakes
 - M 0.8 to 2.3
 - previously identified clusters
- Subnetwork events
 - 11 (8/yr avg.)
 - M -1.5 to 0.7
 - 0.5-11 mi
 - Consistent with mapped faults
 - likely natural
- Overall reduced earthquake magnitudes and rate

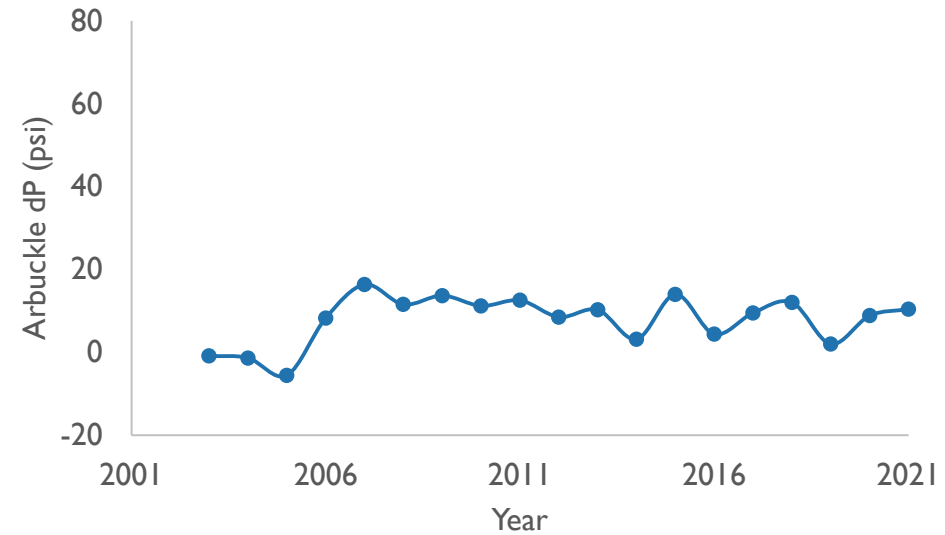
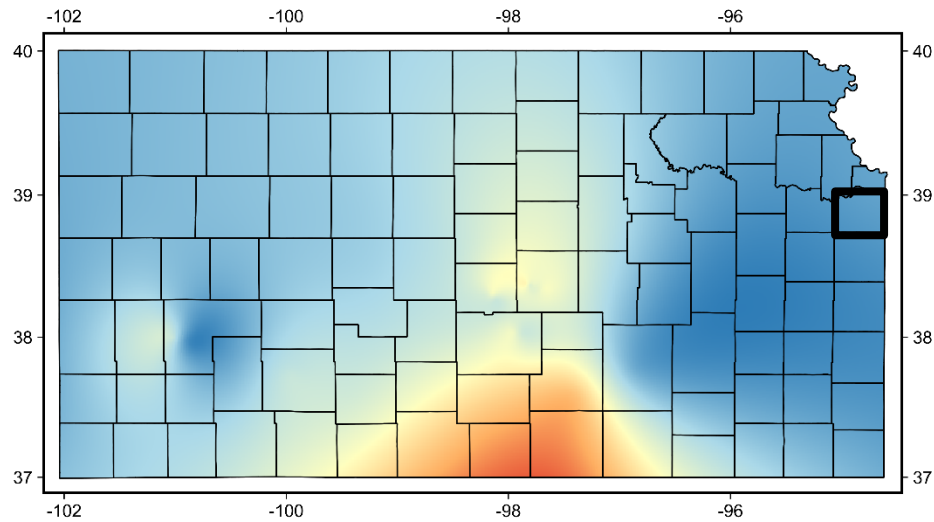
○ KGS/CSTS network (2021-2022)

Johnson and Atchison Counties

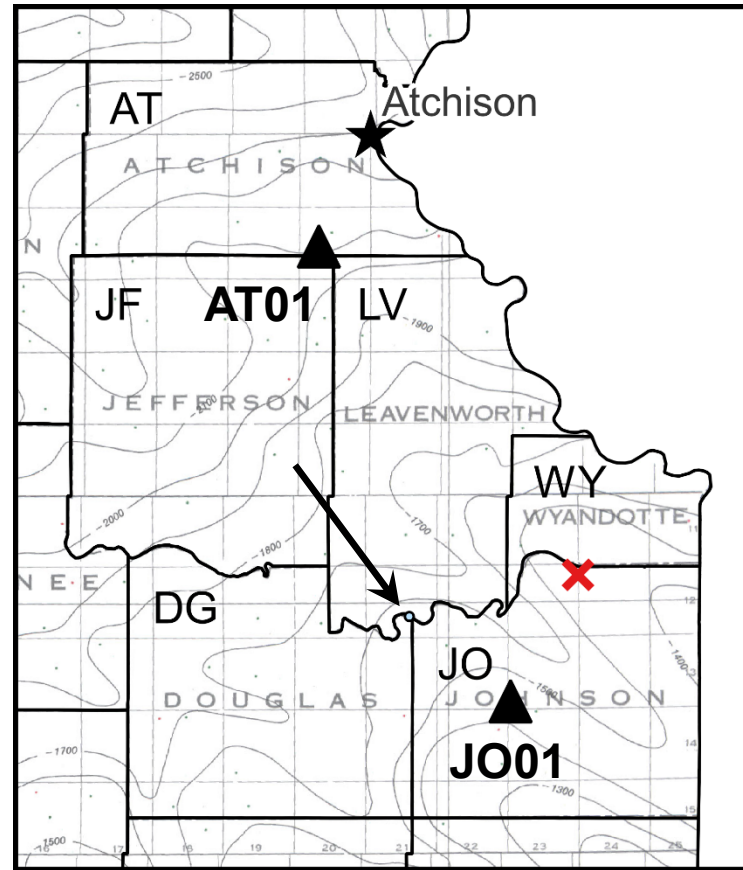


- JO01
 - western JO
 - pasture
 - Olathe Prairie Center
- 2 Quarries within 5 mi
 - characteristic waveforms
 - confidently identified
 - not cataloged
- AT01
 - cemetery

Johnson County



Johnson and Atchison Counties



magnitude

1

2

3

4

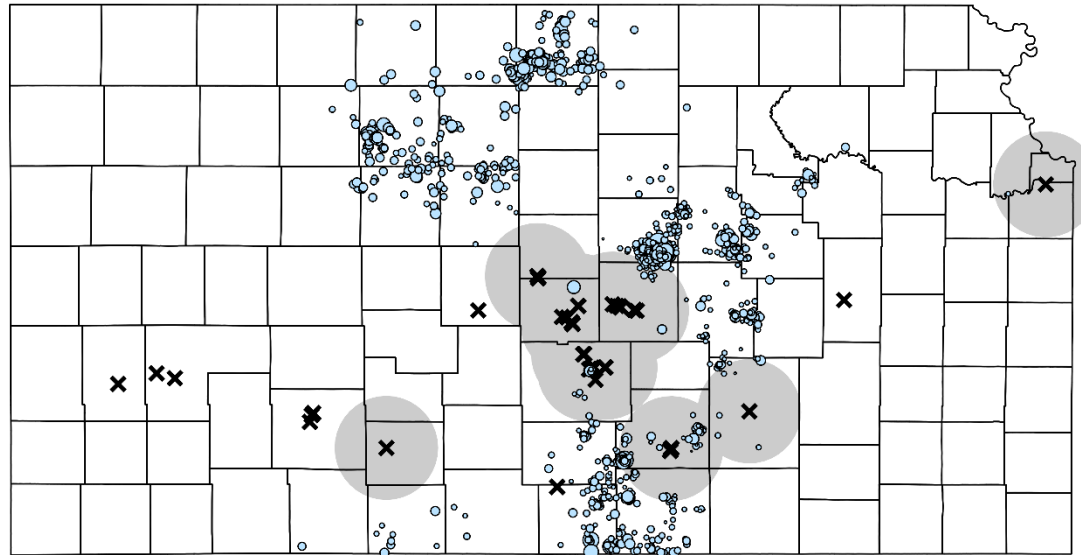
- Forest City Basin
 - Nemaha Ridge
 - Bourbon Arch
 - no mapped faults, NW structural trends
- Historic seismicity
 - WY: M 3.0 in 1999
 - AT: M 3.1 in 2007
- Mapped earthquakes
 - M 1.3 in Douglas Co
- Subnetwork events
 - JO01: 7 ($M \leq 0.4$)
 - AT01: 3 ($M < 0$)

● historic (1977-2014)

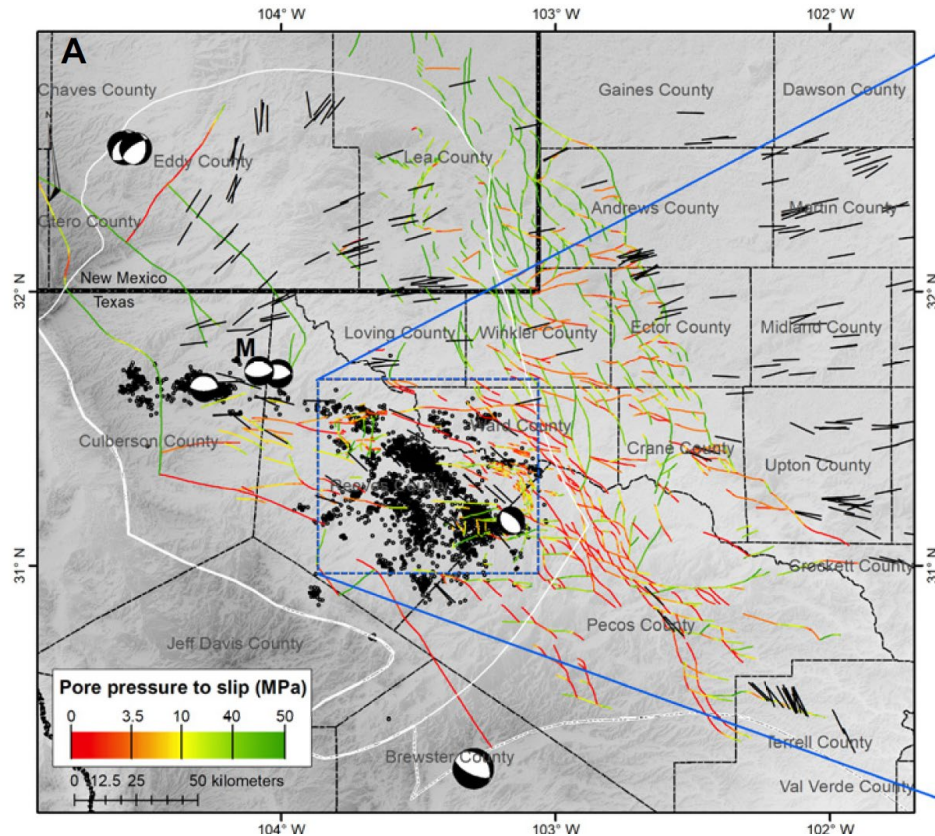
● KGS/CSTS network (2021-2022)

Summary

- Uptick of Earthquakes in some areas
 - Saline County
 - Jewell, Dickinson
- Formation pressure stable
- CSTS network seismicity
 - Earthquake rates continuing to drop
 - Notable events
 - Rice County M 2.9
 - McPherson County M 2.2

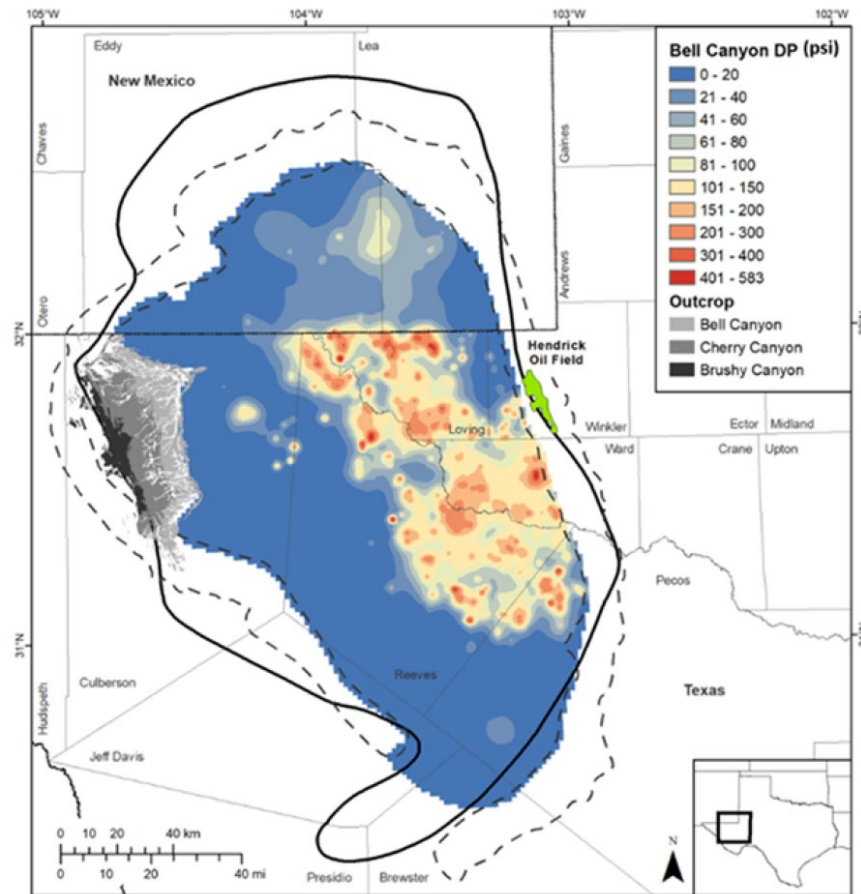


Recent Publications



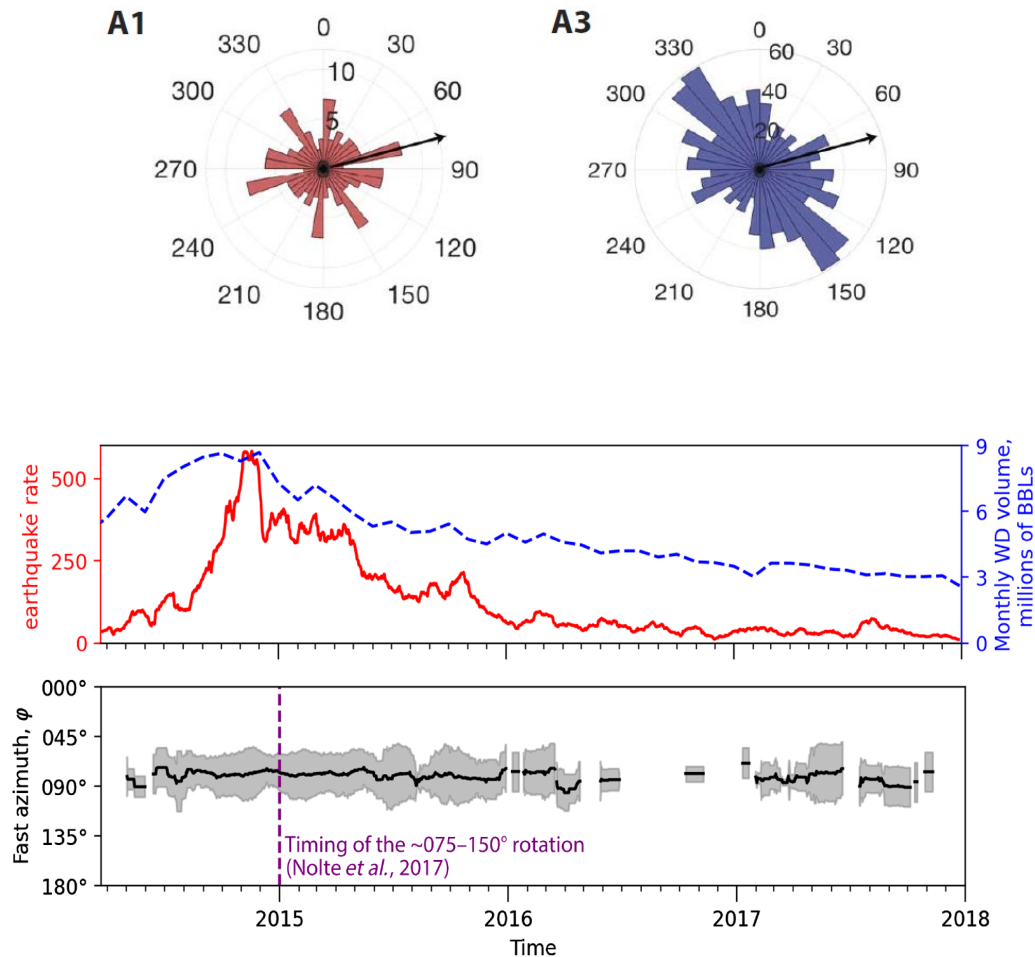
- **Dvory and Zoback (2021)**
- *Prior oil and gas production can limit the occurrence of injection-induced seismicity: A case study in the Delaware Basin of western Texas and southeastern New Mexico, USA*

Recent Publications



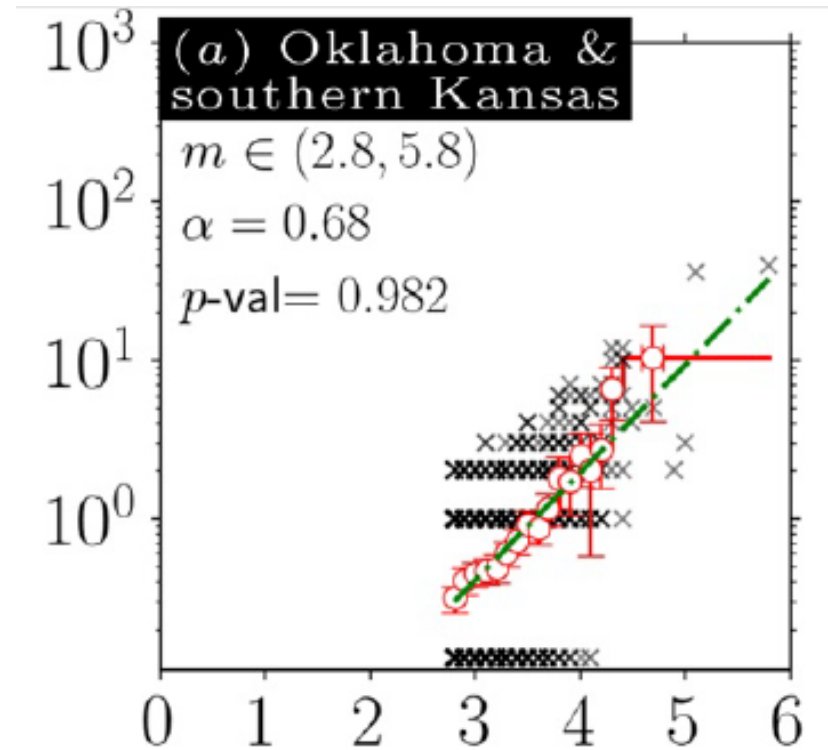
- **Ge et al. (2022):** *Recent water disposal and pore pressure evolution in the Delaware Mountain Group, Delaware Basin, Southeast New Mexico and West Texas, USA*
- Pressure change limited near produced areas
- Potentiometric surface above land surface

Recent Publications



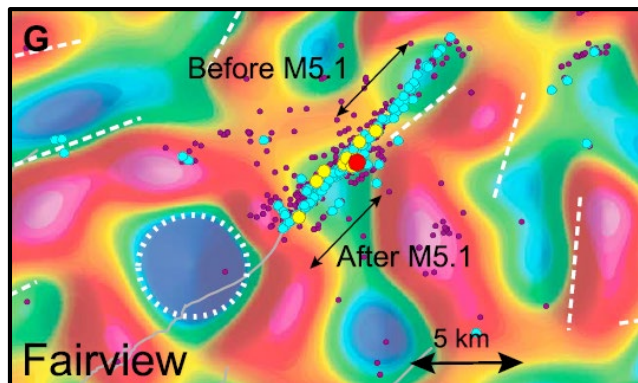
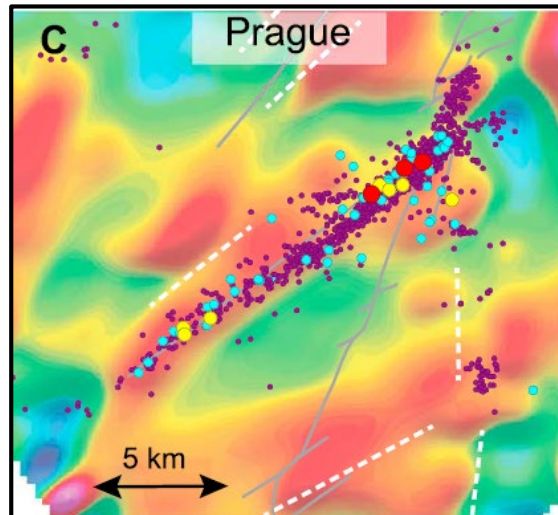
- **Skoumal and Cochran (2021):**
Wastewater Disposal Has Not Significantly Altered the Regional Stress State in Southern Kansas
- Response to Nolte et al. (2017)
 - shear wave anisotropy
 - interpreted rotation in fast polarization direction
 - aligned with minimum horizontal stress
- Polarization direction is constant, in-line with SH_{\max}
- Apparent flip caused by inconsistent source-receiver paths

Recent Publications



- **Karimi and Davidsen (2020):** *Aftershock Triggering and Spatial Aftershock Zones in Fluid-Driven Settings: Discriminating Induced Seismicity From Natural Swarms*
- Inter-event triggering (aftershocks)
- Natural earthquakes
 - a few large triggers (main shock)
 - fewer aftershocks
- Induced earthquakes
 - many small triggers
 - more aftershocks

Recent Publications



- **Shah and Crain (2018):** *Aeromagnetic Data Reveal Potential Seismogenic Basement Faults in the Induced Seismicity Setting of Oklahoma*
- OK earthquake sequences aligned with aeromagnetic lineaments
- Intrusions locally inhibit induced seismicity due to fault termination or changes in permeability

Regional Trends and Local Seismicity Near CSTS Member Wells



Shelby Peterie, Rick Miller, Carl Gonzales, Erik Knippel, Marcus Tamburro
Kansas Geological Survey

Fifth Annual CSTS Meeting
August 3, 2022
McPherson, KS

