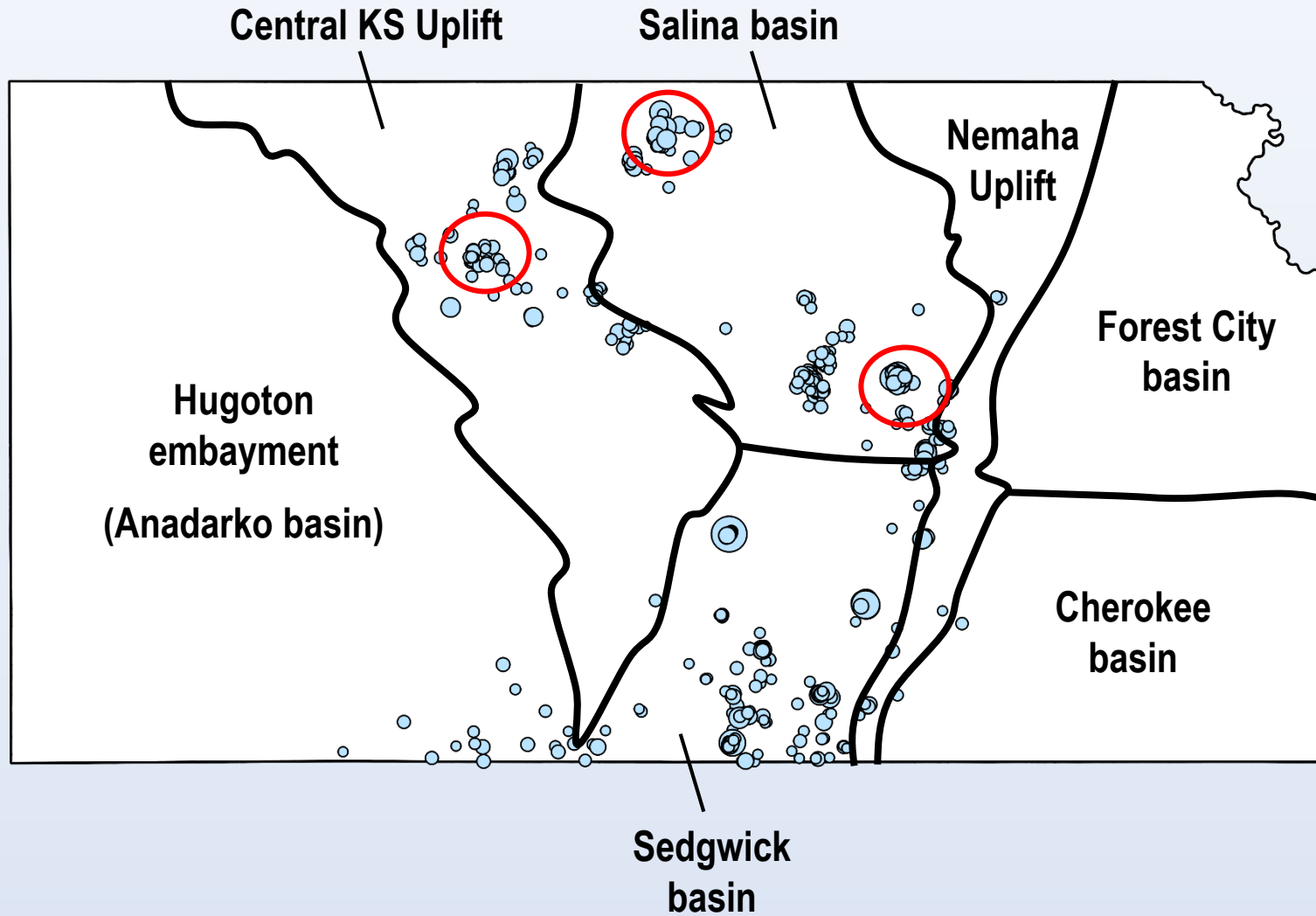


Statewide Seismicity Highlights and Earthquakes along the Wichita Trend 11/26/20 to 03/15/21

Kansas Geological Survey

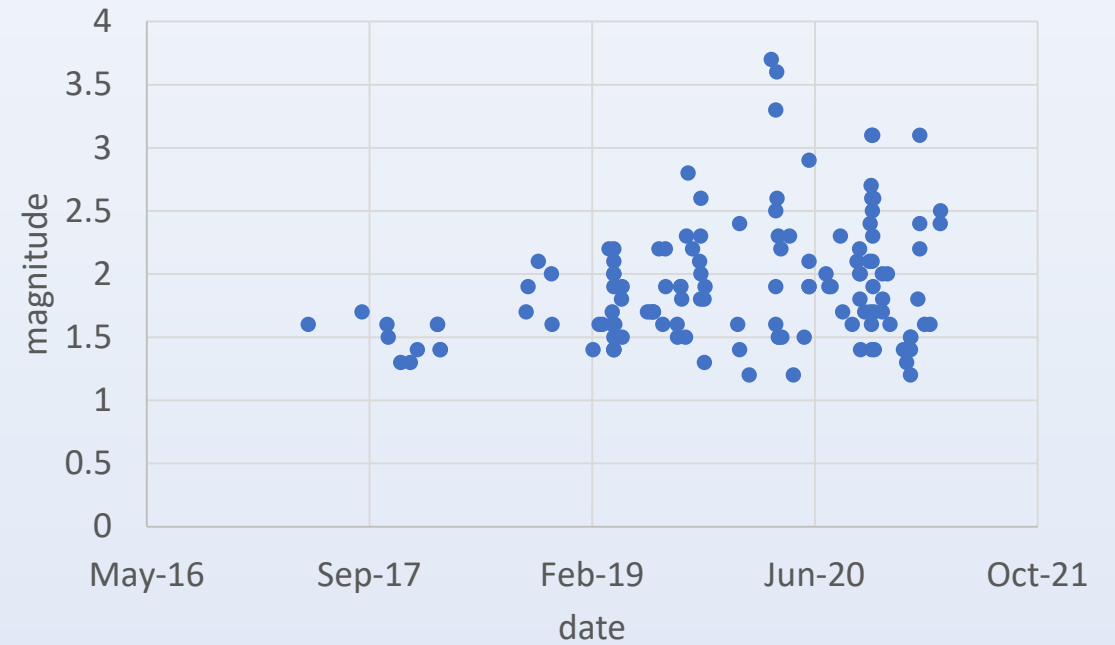
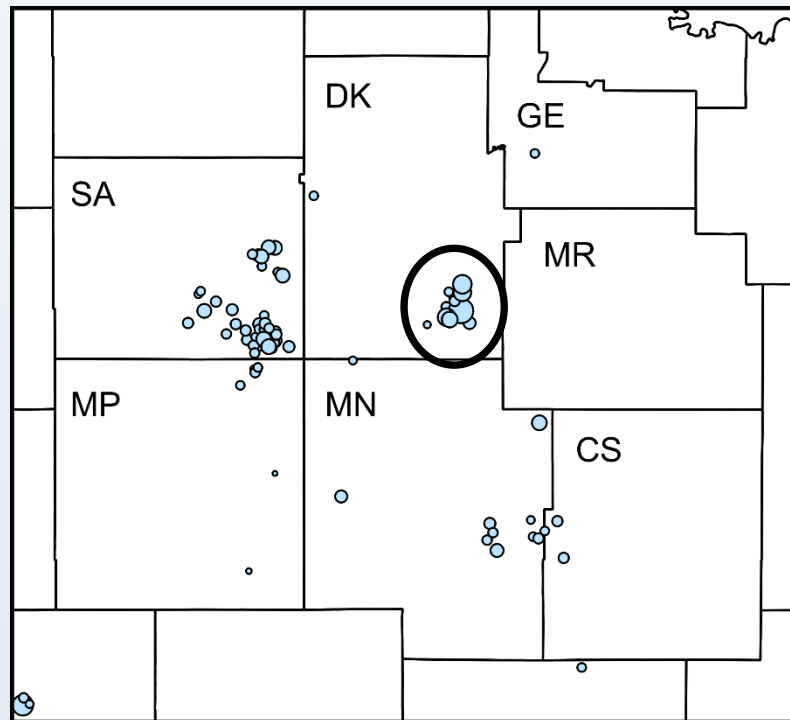
Miller, Peterie, Gonzales, Buchanan

2020 & 2021 Earthquakes with consistent hotspots relative to Geologic Provinces



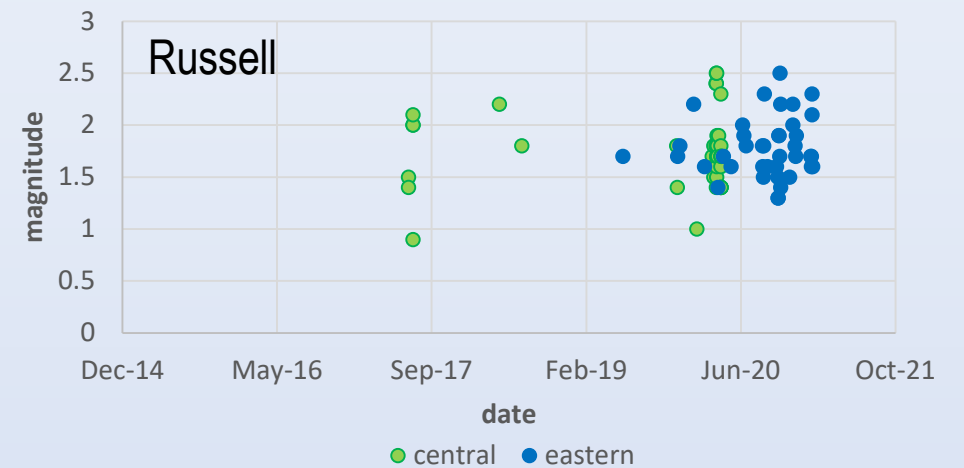
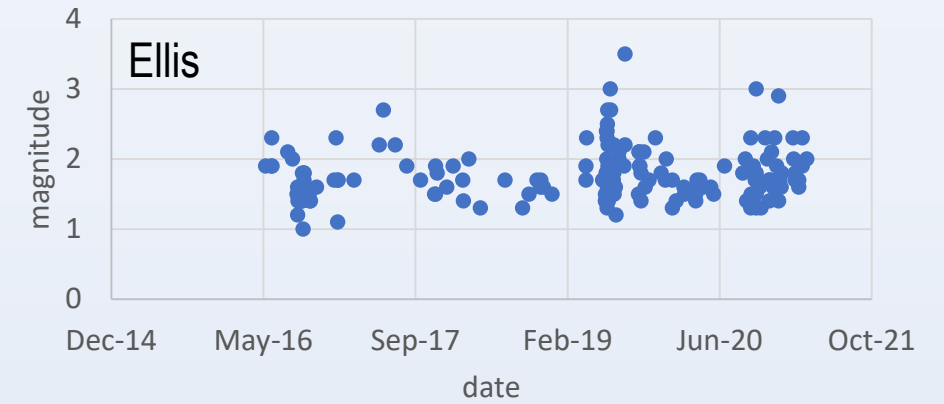
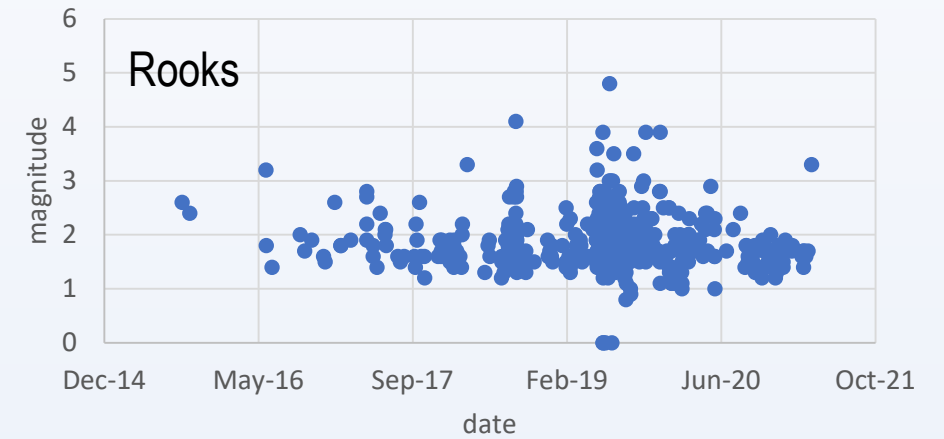
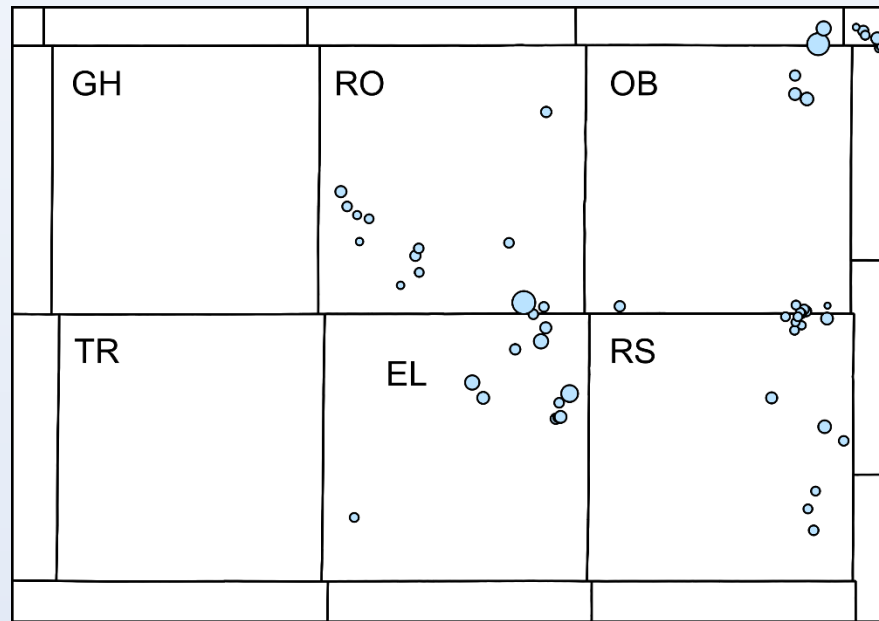
MGA/Nemaha Ridge

January to present



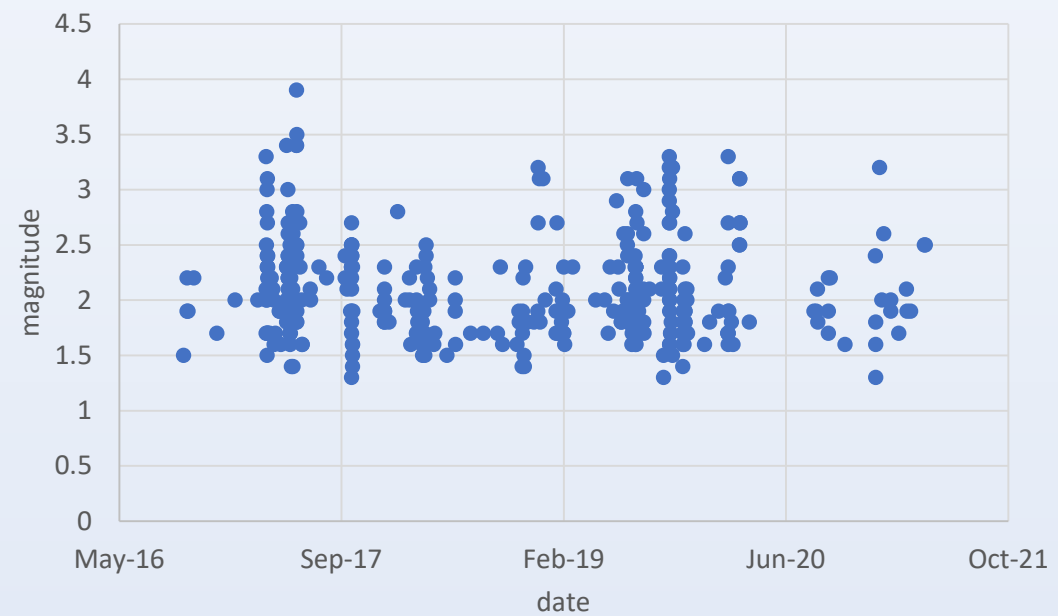
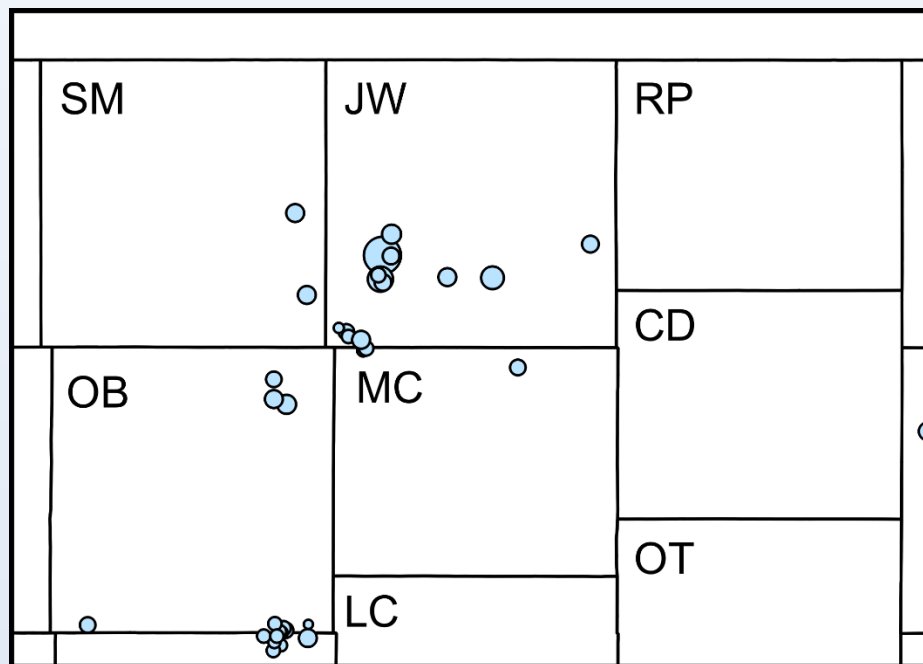
Rooks, Ellis, Russell

January to present



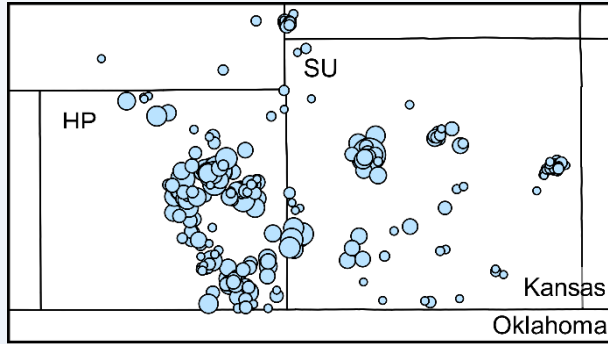
Jewell

January to present

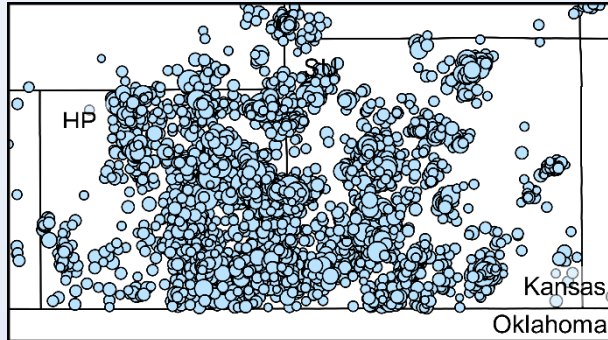


Harper and Sumner Counties

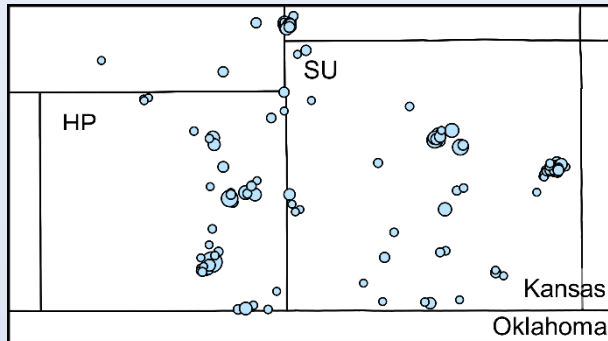
2013 – 2014
USGS



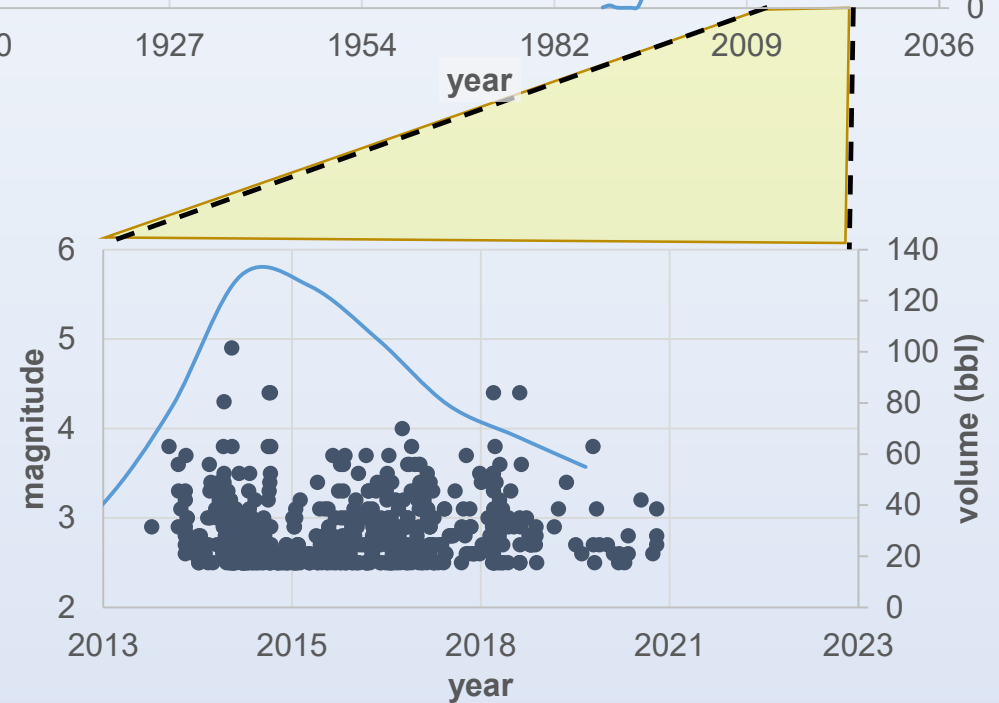
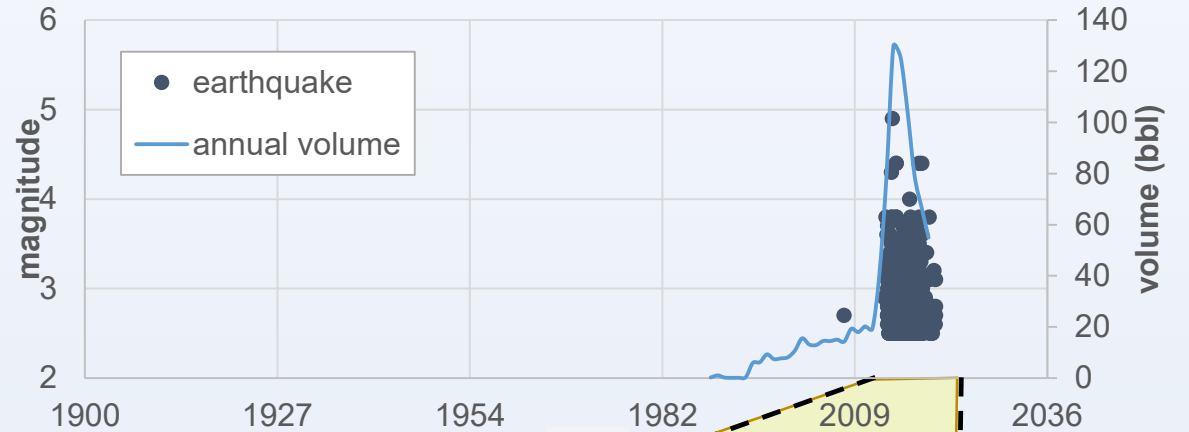
2015 – 2019
KGS



2020 – 2021
KGS

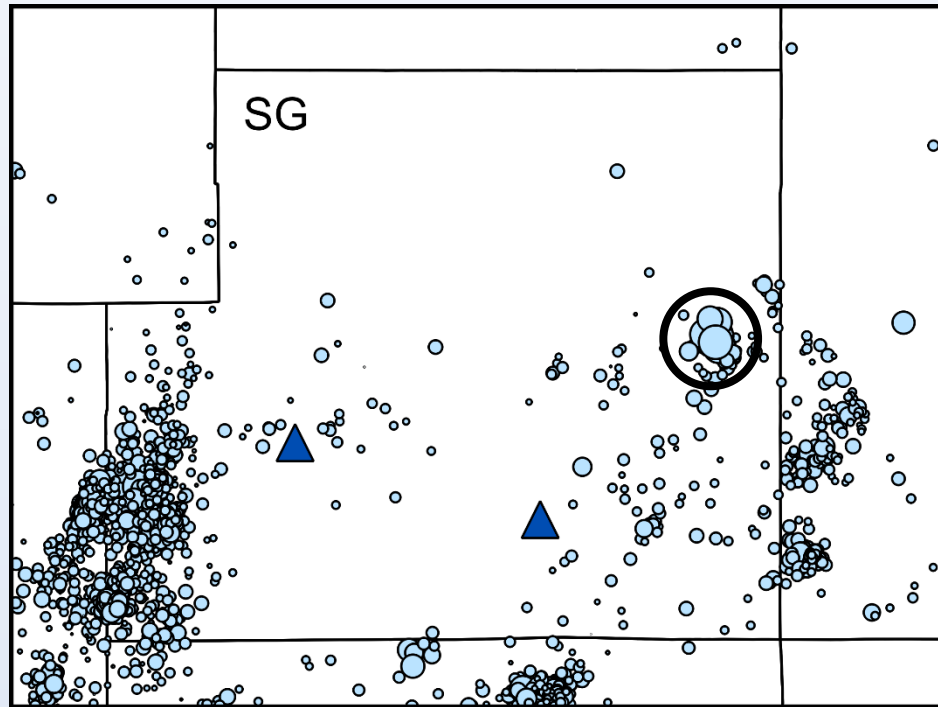


560 Felt Earthquakes & Annual Injection Volume

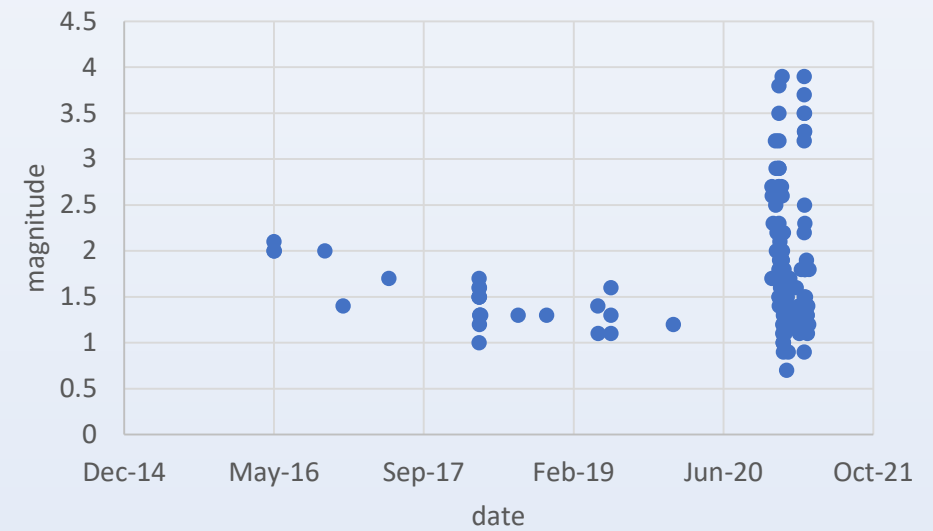


Wichita Earthquakes and Local Stations

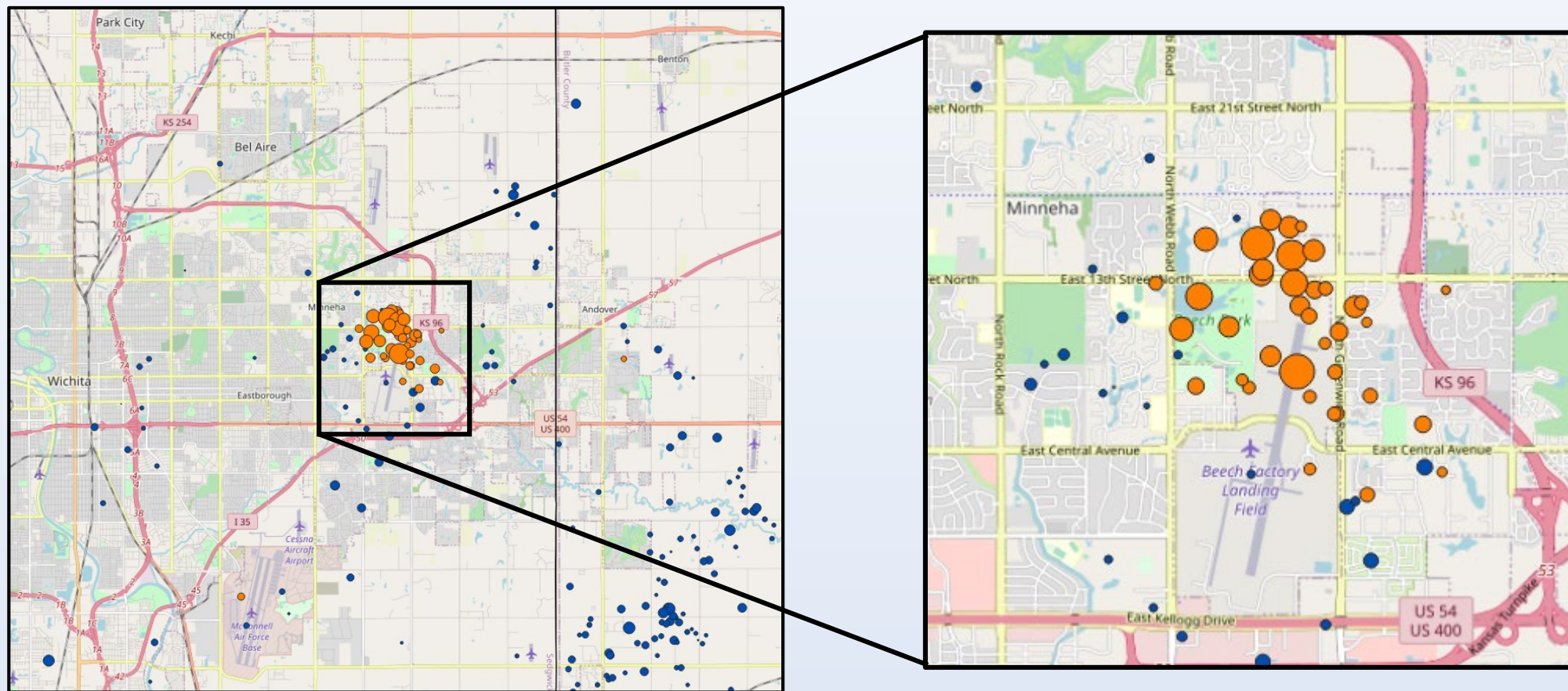
128 Wichita earthquakes (2 mi radius)



KGS catalog earthquakes 2015-present



Close-up of Wichita Earthquakes

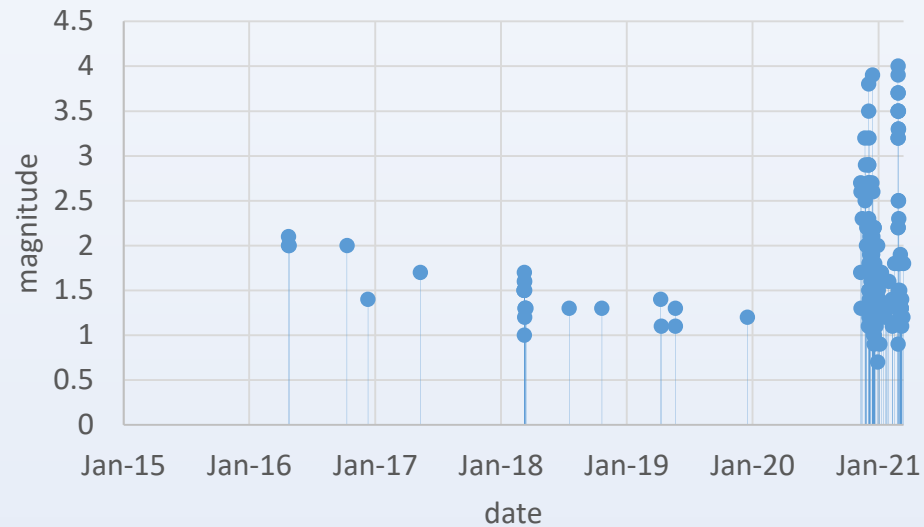


● 2015 to October 2020

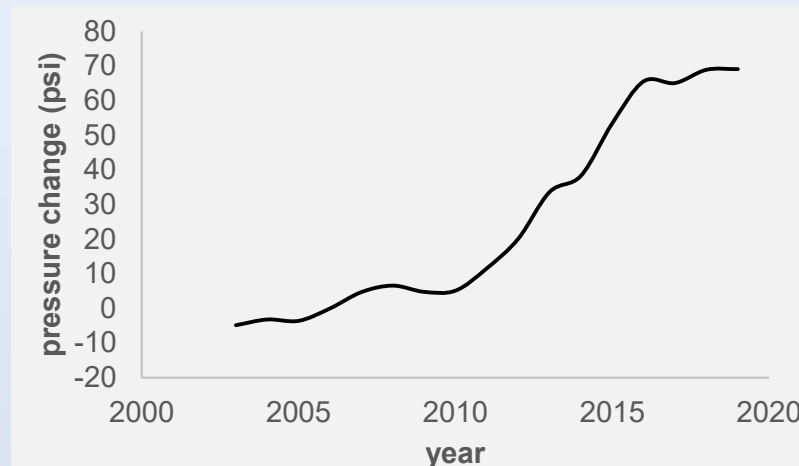
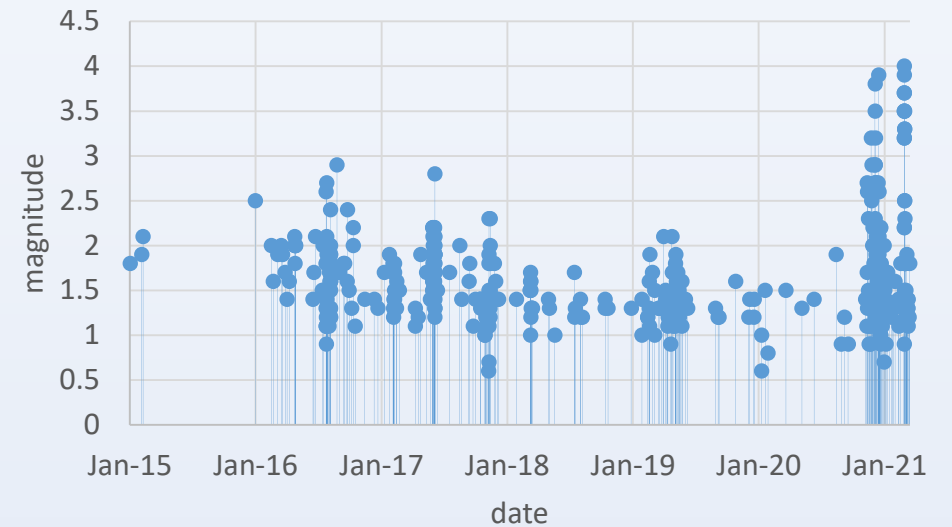
● November 2020 to January 2021

Sequence of Wichita Area Earthquakes

2 mi radius

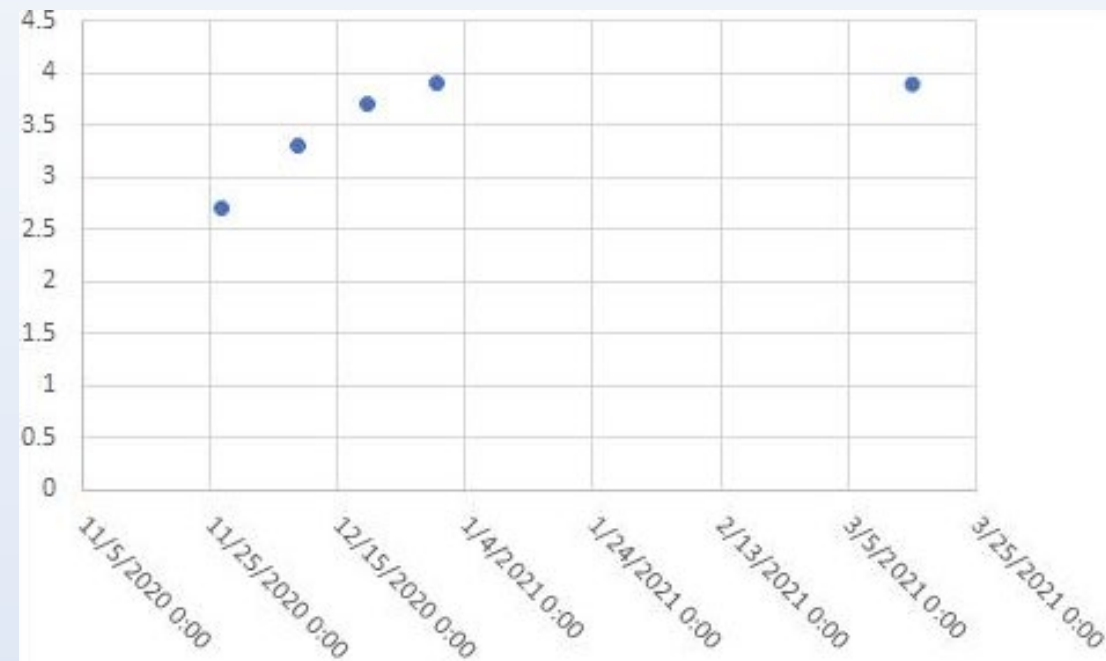
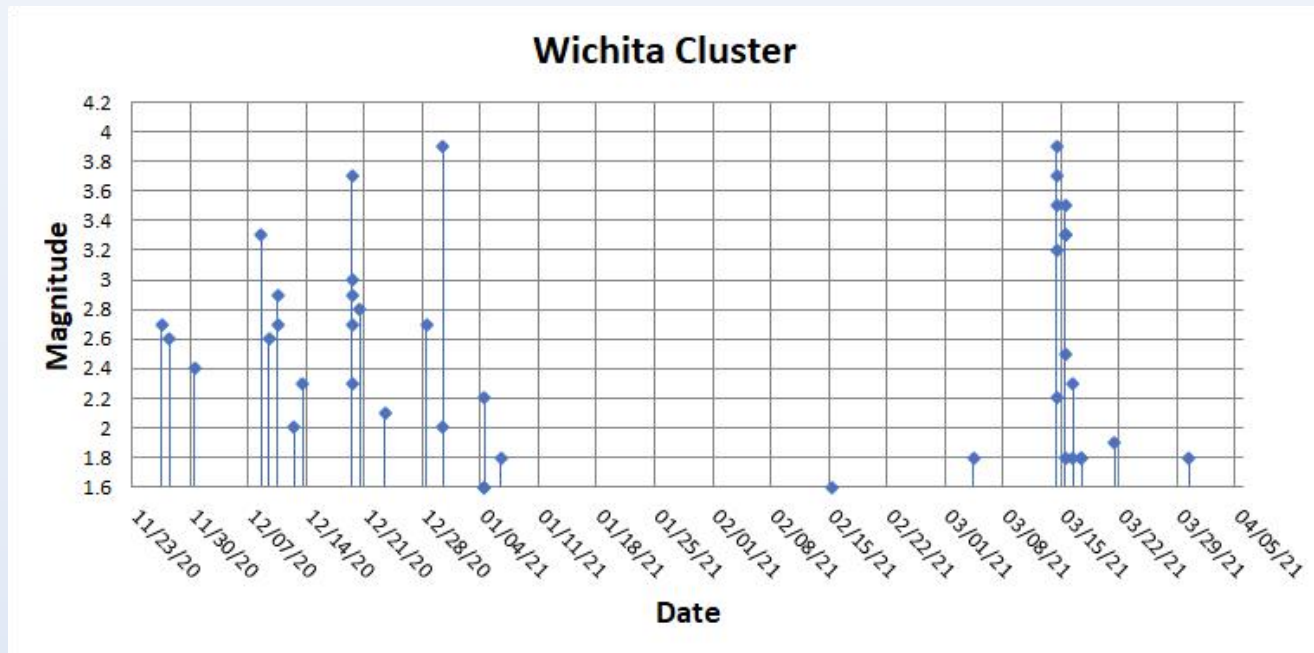


15 mi radius



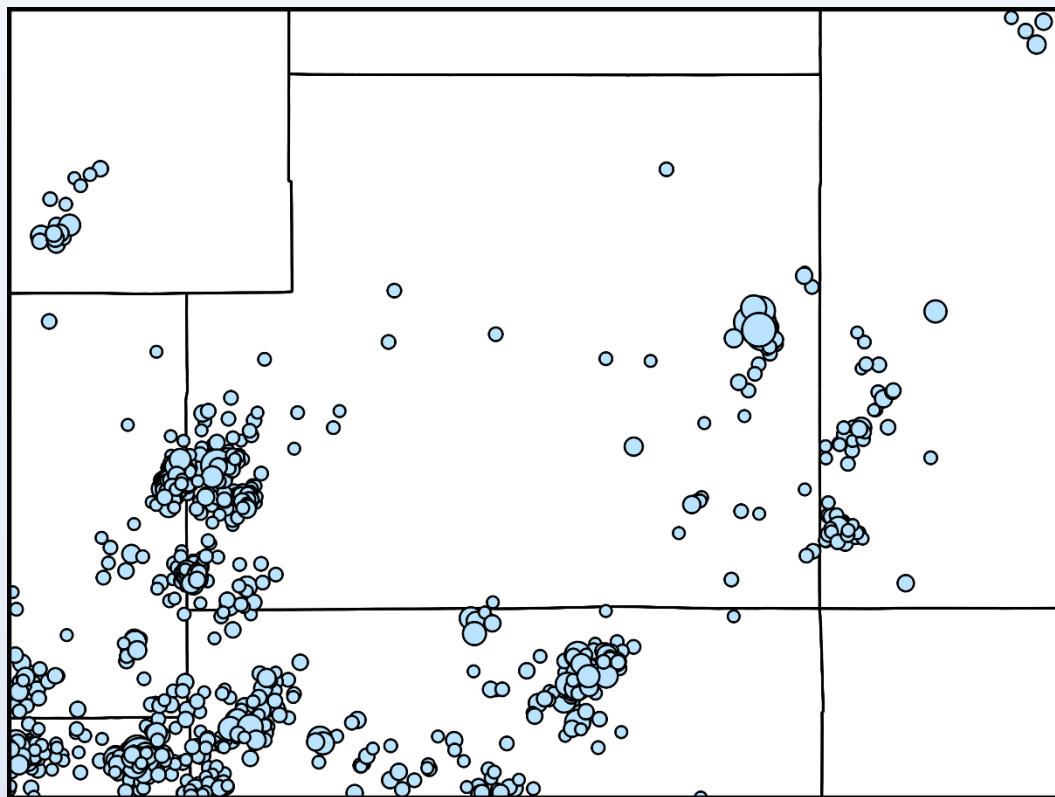
Arbuckle pressure has been steadily increasing since around 2003 with a marked change in slope around 2011

Sequence of Earthquakes > M2 Wichita Cluster Between Thanksgiving and March 15, 2021

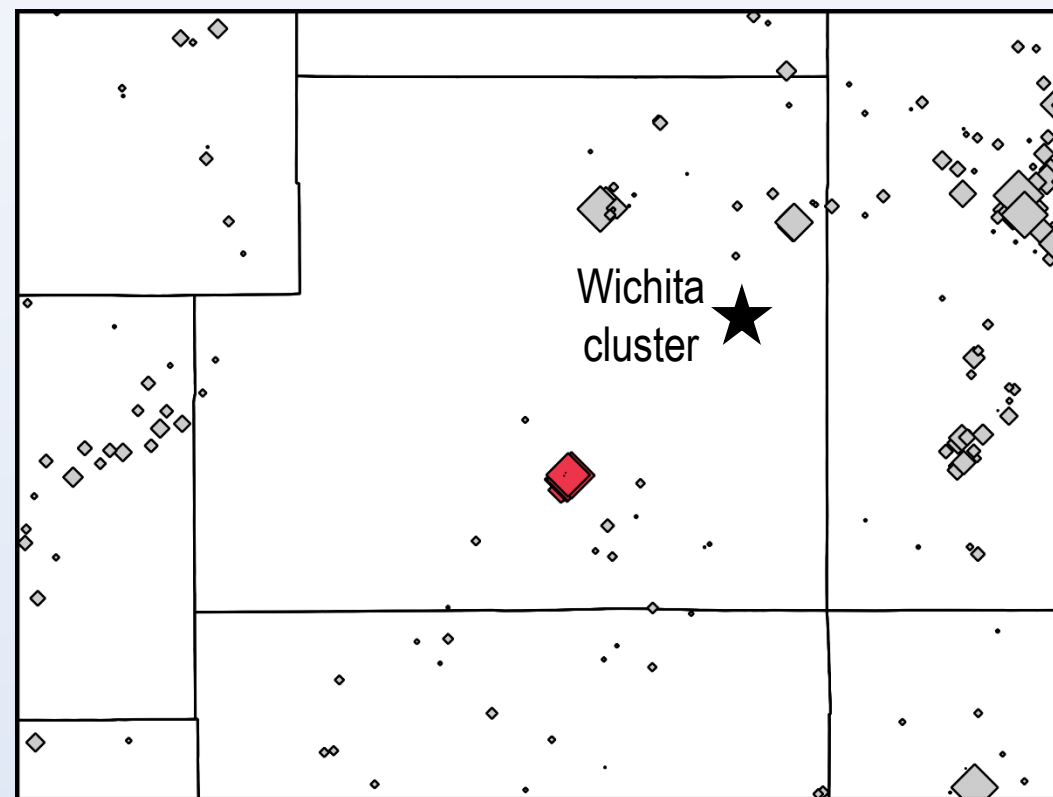


Sedgwick County Area Disposal Wells Relative to Earthquakes

earthquakes 2015-2021 ($M \geq 1.8$)



disposal wells (2019)



Class I

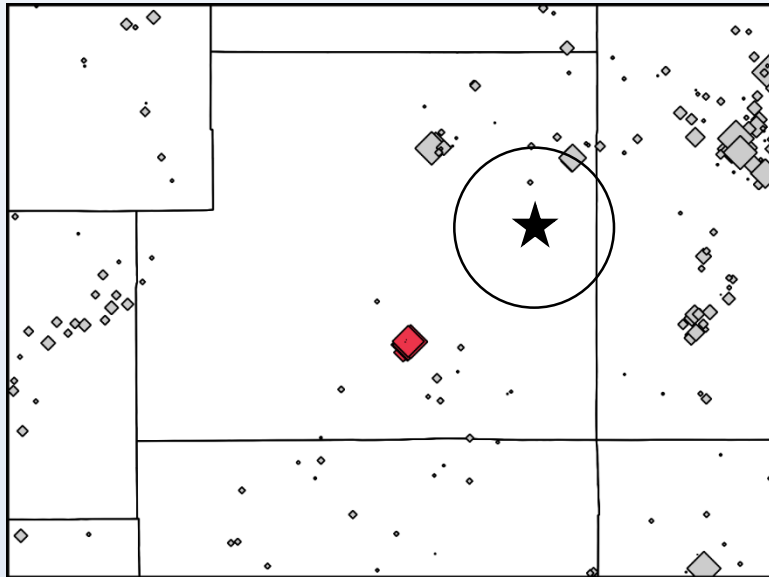
Class II

10 mi

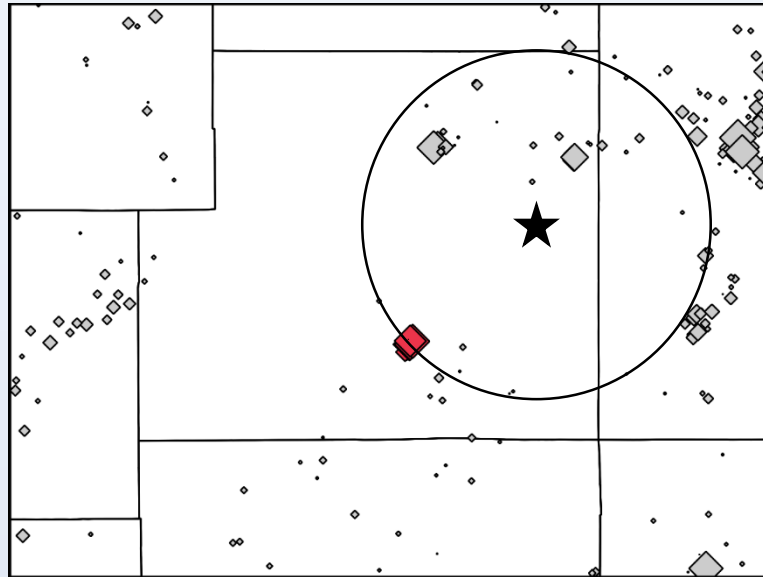
Hydraulic Diffusivity

Now that statistically there is very likely an anthropogenic influence an in-depth investigation has begun
search radius at various lag times for reasonable diffusivity ($3 \text{ m}^2/\text{s}$), will be used to guide and inform our investigation

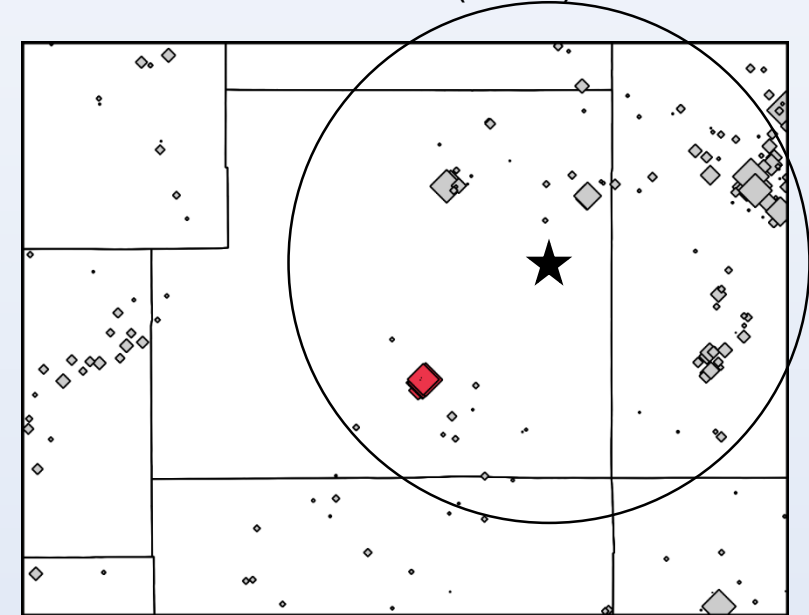
one month (6 mi)



6 months (14 mi)



12 months (21 mi)



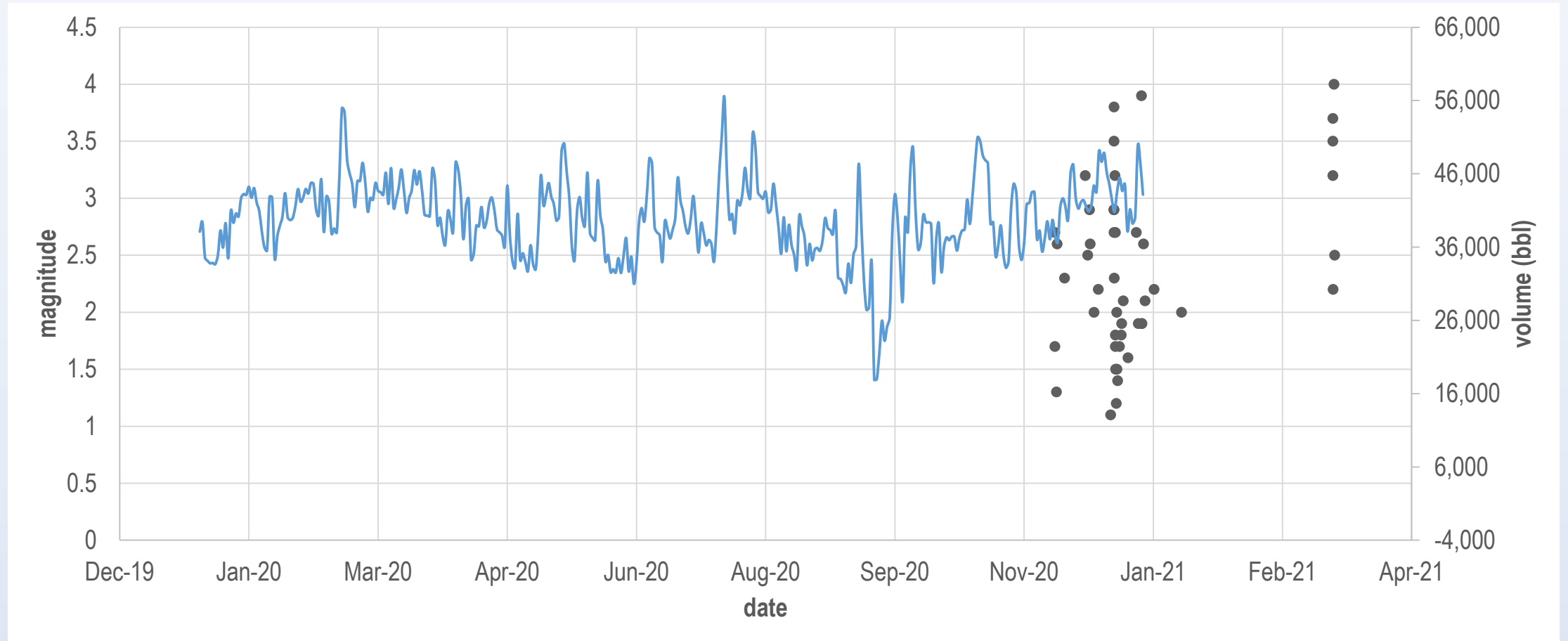
◆ Class I

◇ Class II

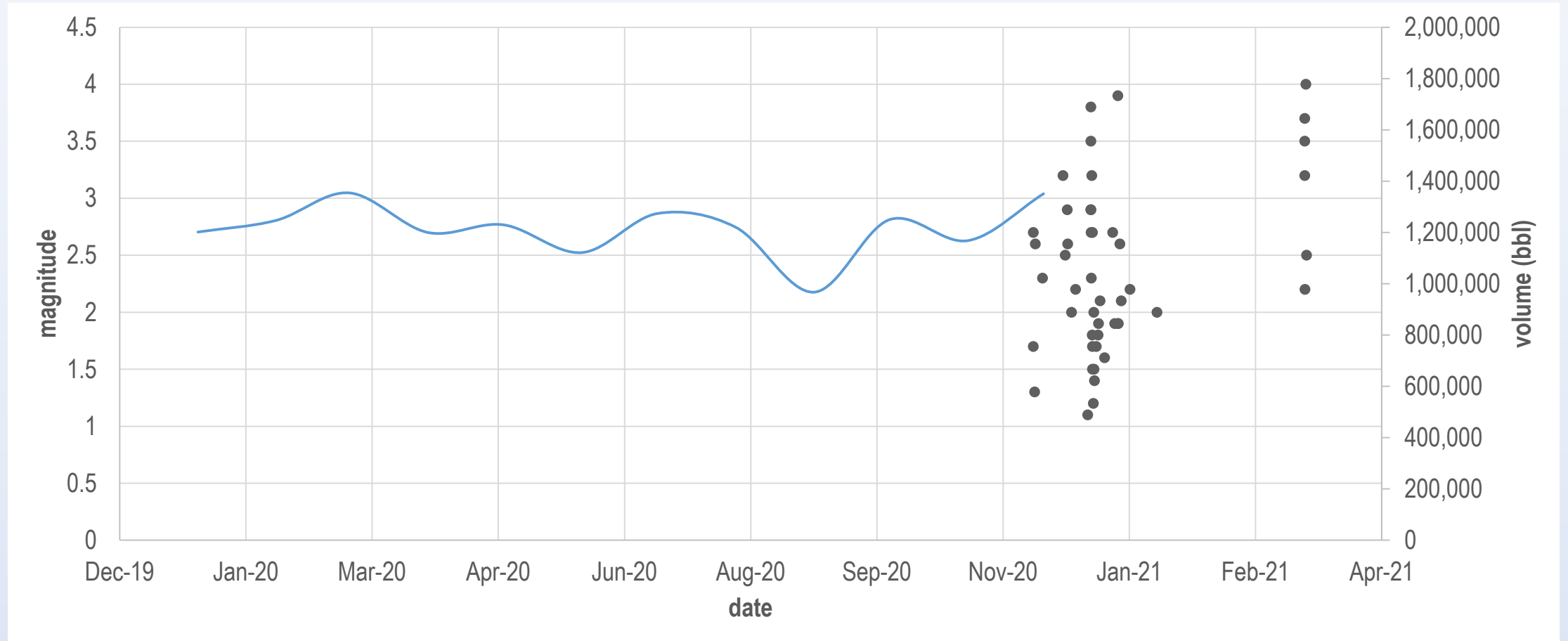
10 mi

★ Wichita cluster

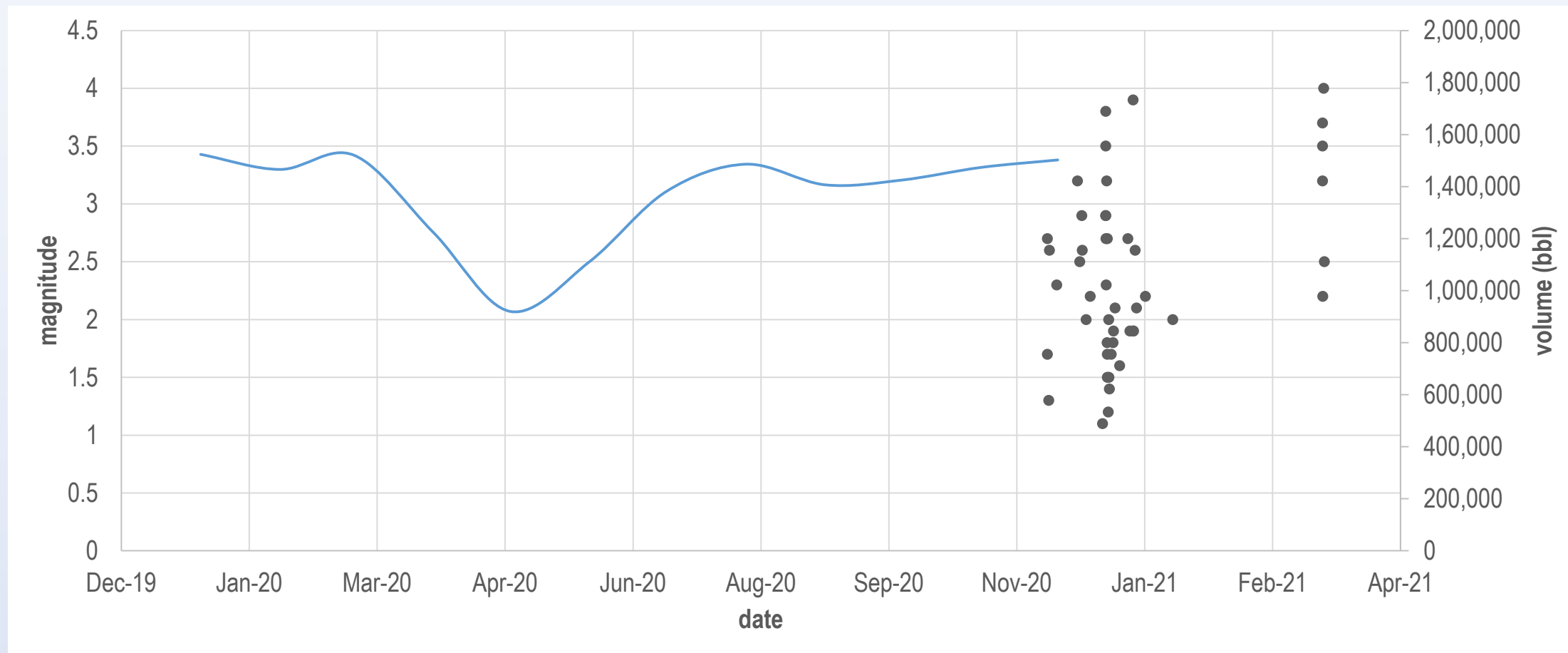
2020 Class I Disposal Volumes (daily within 15 mi)



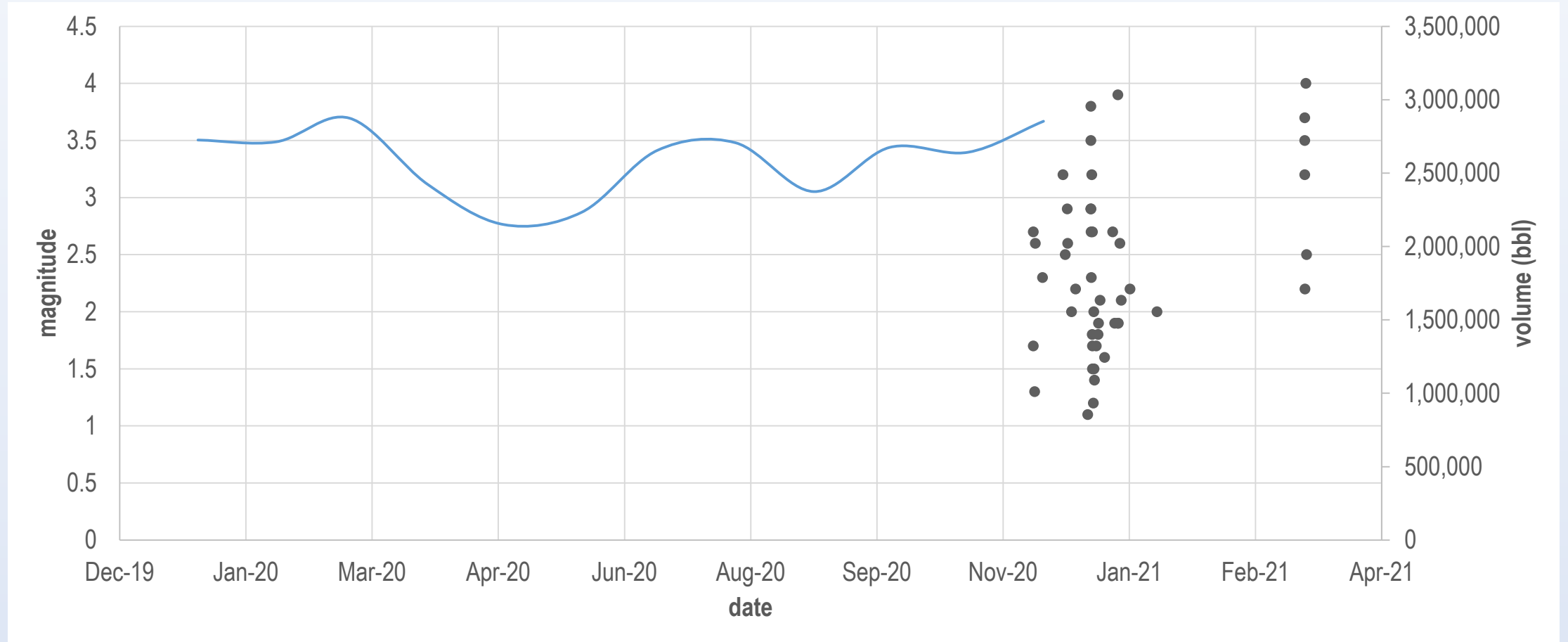
2020 Class I Disposal Volumes (monthly within 15 mi)



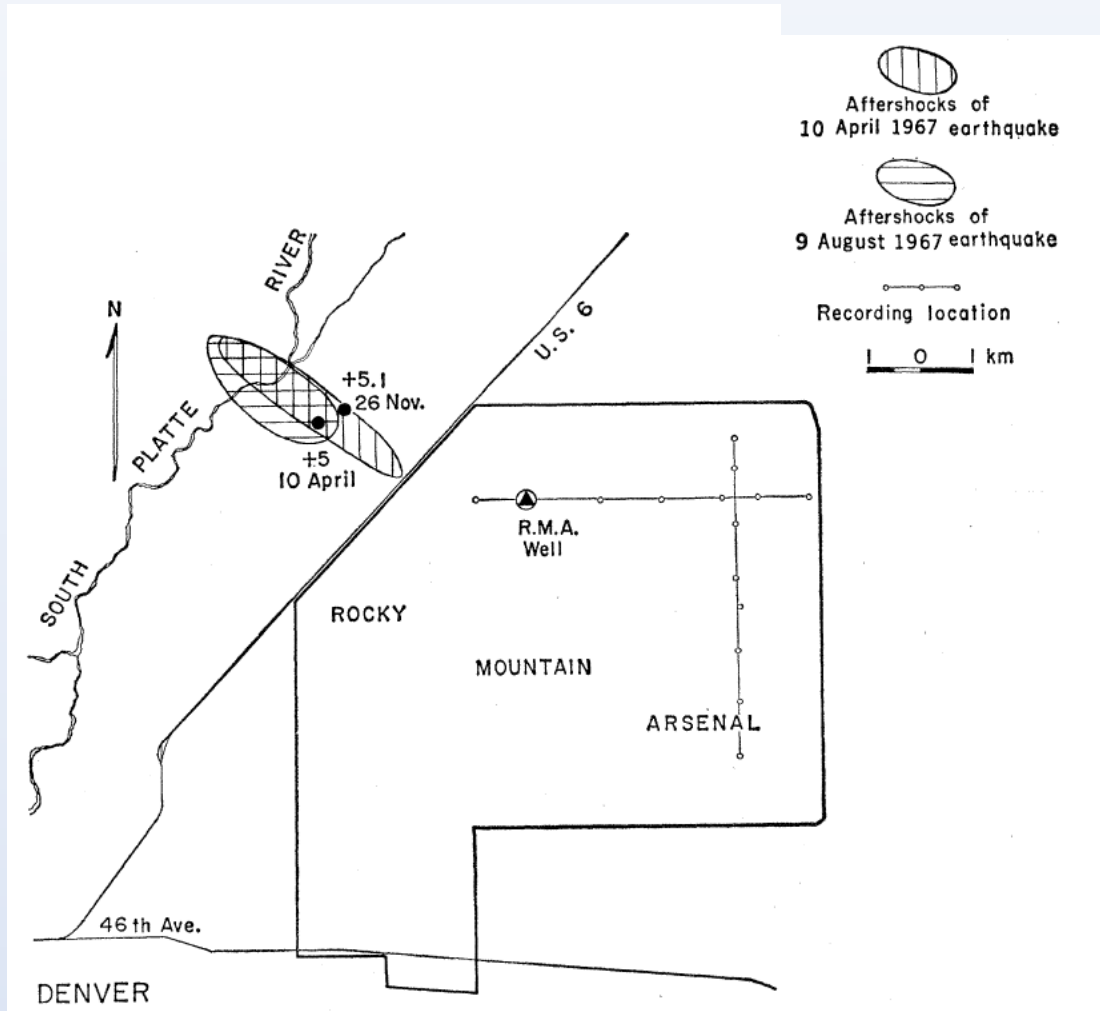
2020 Class II Disposal Volumes (monthly within 15 mi)



2020 Class I & II Disposal Volumes (monthly within 15 mi)

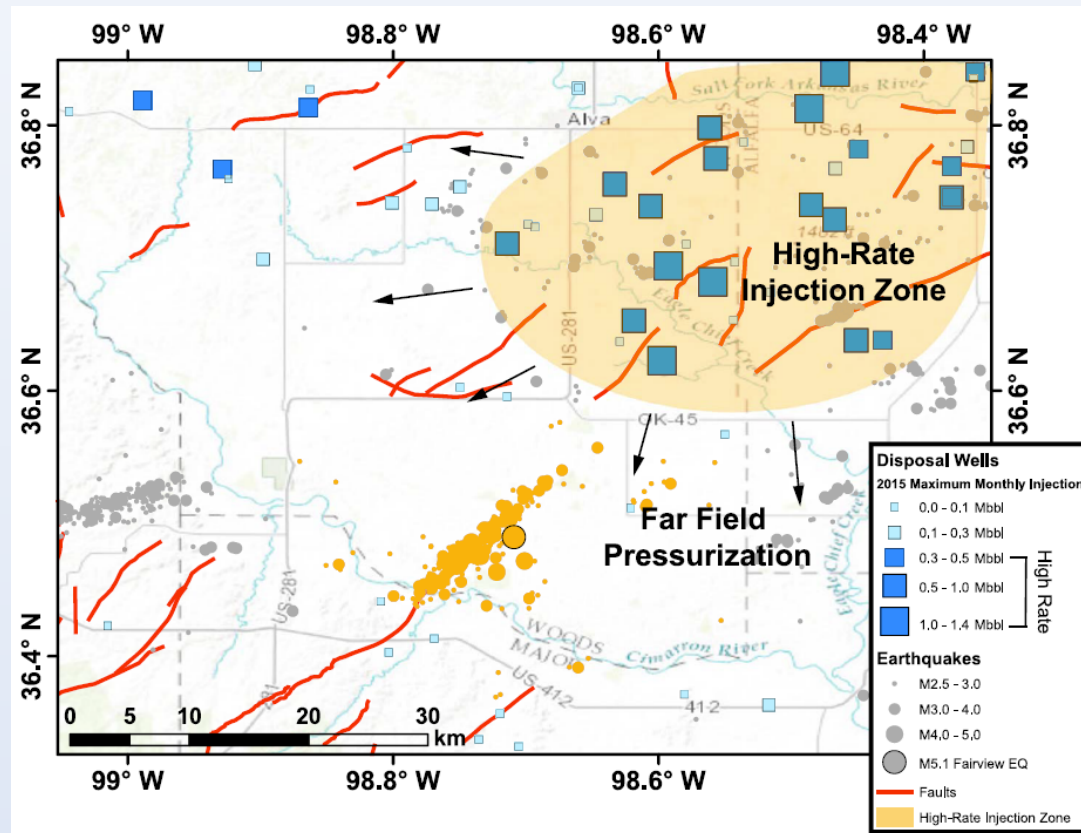


Rocky Mountain Arsenal



- Shut-in February 1966
- M 5.0 in April 1967 4-5 km away

January 2016 Oklahoma Power Outage

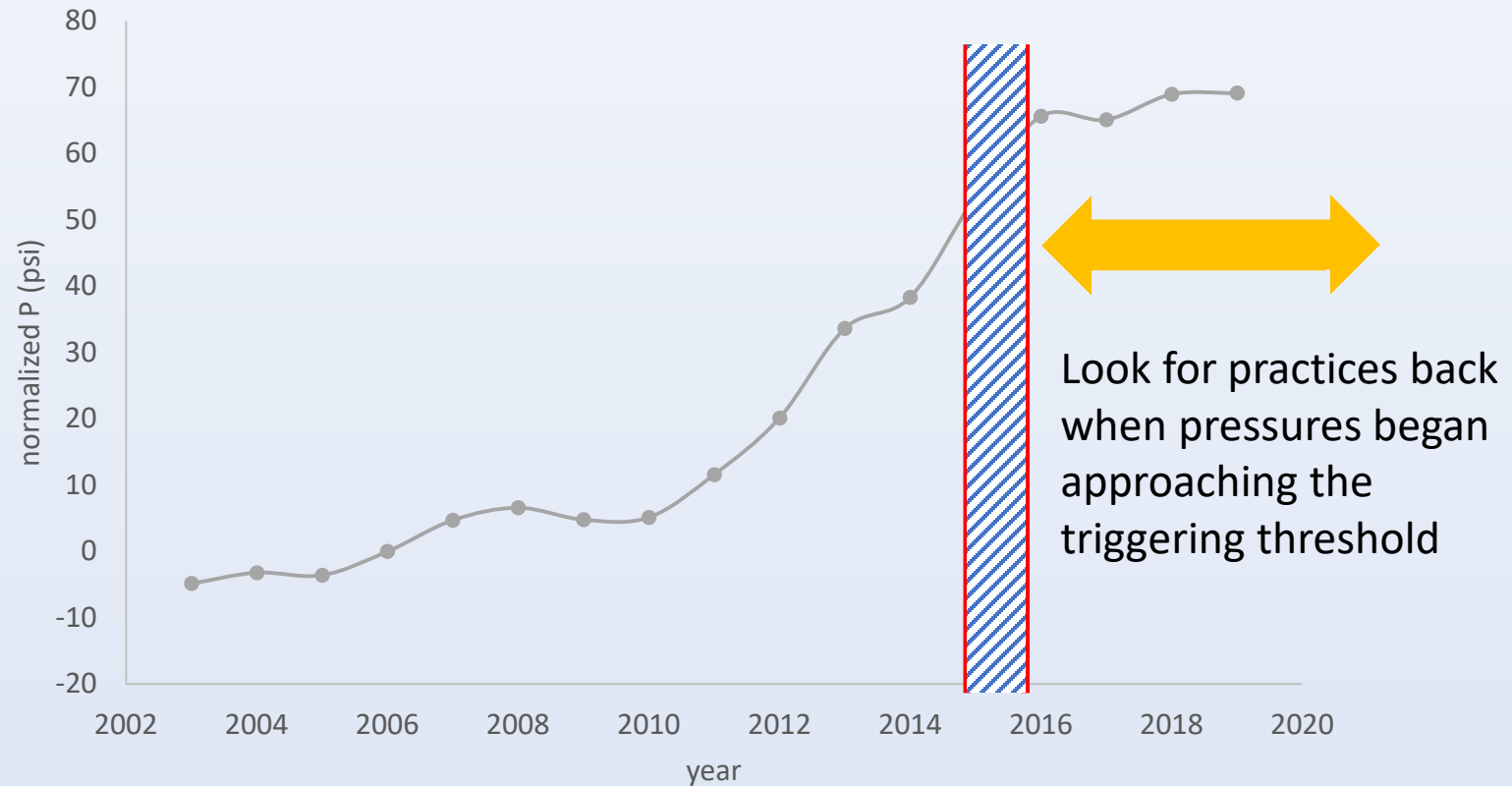


Far-field pressurization likely caused one of the largest injection induced earthquakes by reactivating a large preexisting basement fault structure

W. L. Yeck¹, M. Weingarten², H. M. Benz¹, D. E. McNamara¹, E. A. Bergman³, R. B. Herrmann⁴, J. L. Rubinstein⁵, and P. S. Earle¹

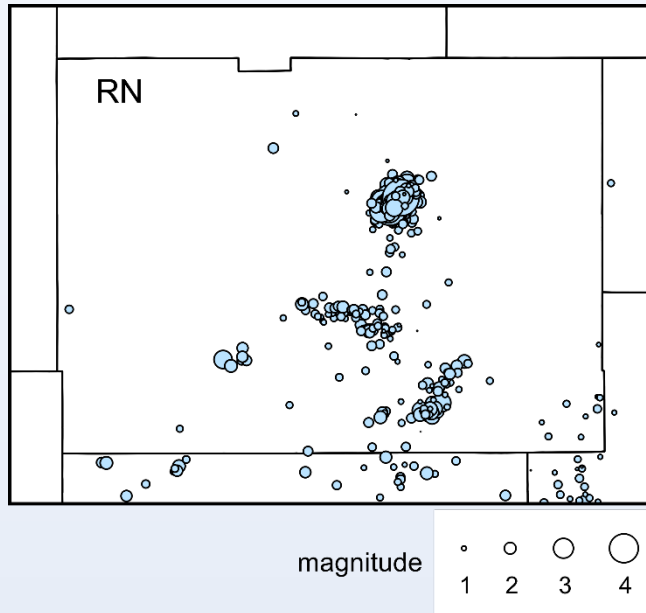
- Researchers concluded physically unrealistic hydraulic diffusivity (250-3500 m²/s vs expected 1 m²/s) would have been required for power outage 15+ km away 3 days before to cause the earthquakes

Sedgwick County Arbuckle Pressure

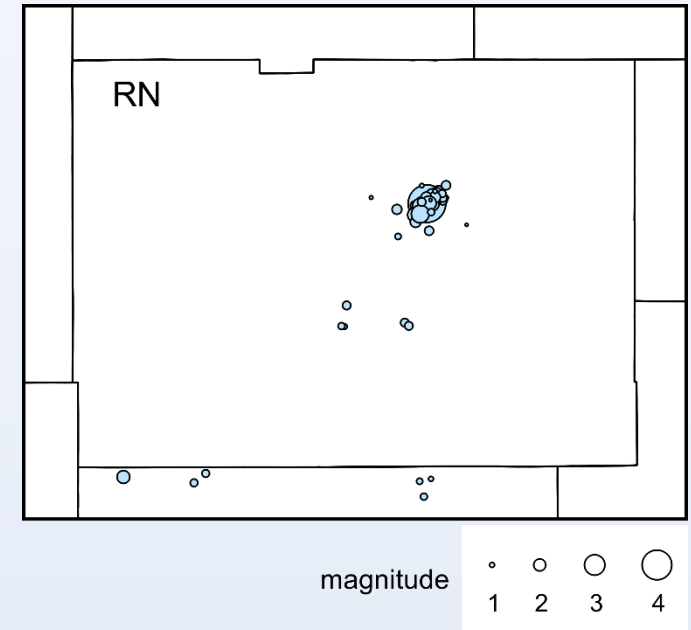


Reno County

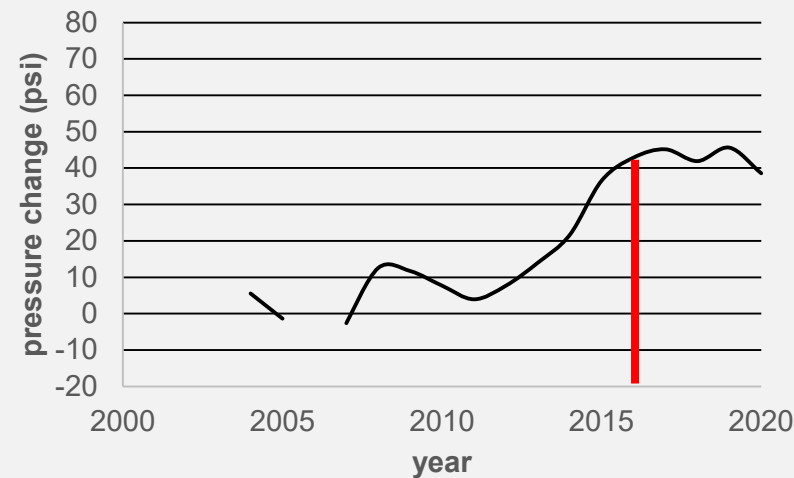
678 earthquakes 2015 to 2021



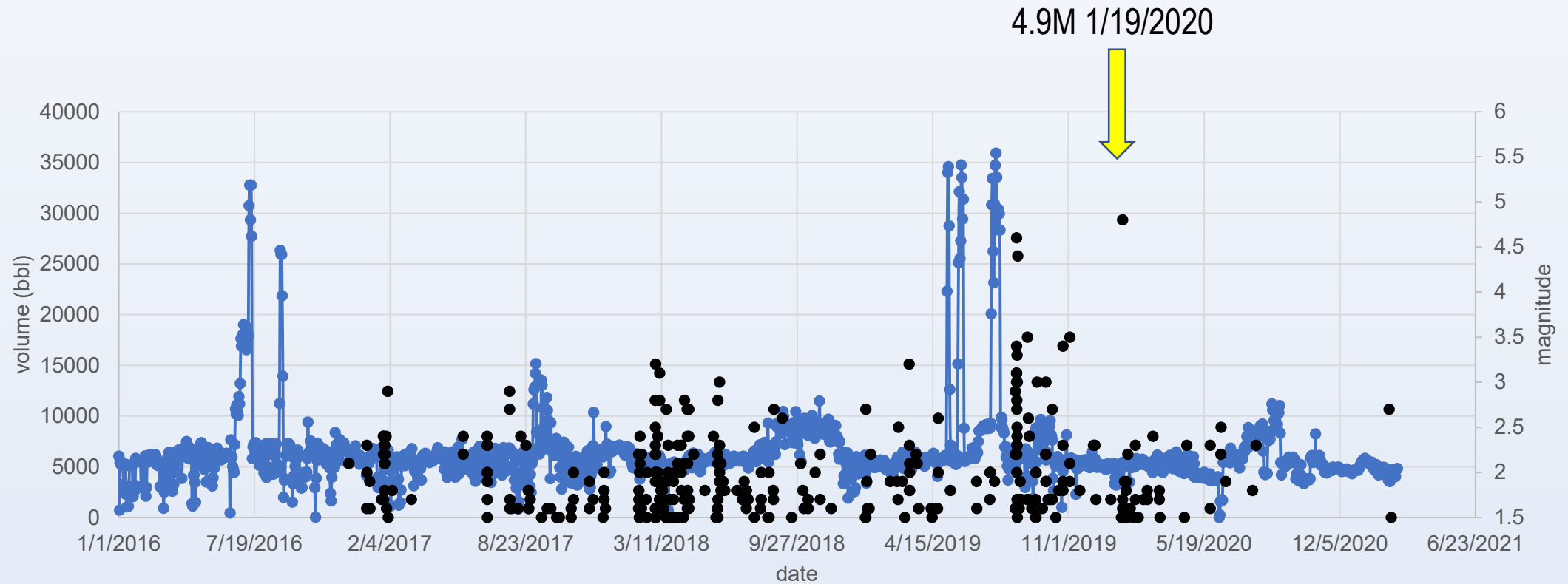
61 earthquakes 2020 to 2021



Arbuckle pressures have been steadily increasing since around 2012 with a marked leveling off around 2016



490 Earthquakes and Injection History: Hutchinson (2 mi radius)



Any Conclusions for Current Analysis?

- Wichita Cluster
 - No smoking gun.
 - Very early in process. We only recently received the first requested injection numbers.
 - We are trying to integrate all the data we have.
 - Spatially, temporally, and statistically under sampled problem.
- Hutchinson cluster has responded how we suggested it would last year.
- Seismicity in Harper/Sumner Co is responding consistent with total injected volumes.
- Over the last 10 years pressures in much of the Sedgwick basin have likely exceeded the triggering threshold.
- Cumulative injection pushed the region above the triggering threshold and now activities that historically have not triggered earthquakes, might now.