Understanding the Relationship Between Fluid Injection and Seismicity in New Mexico

RISC Webinar

June 18, 2019

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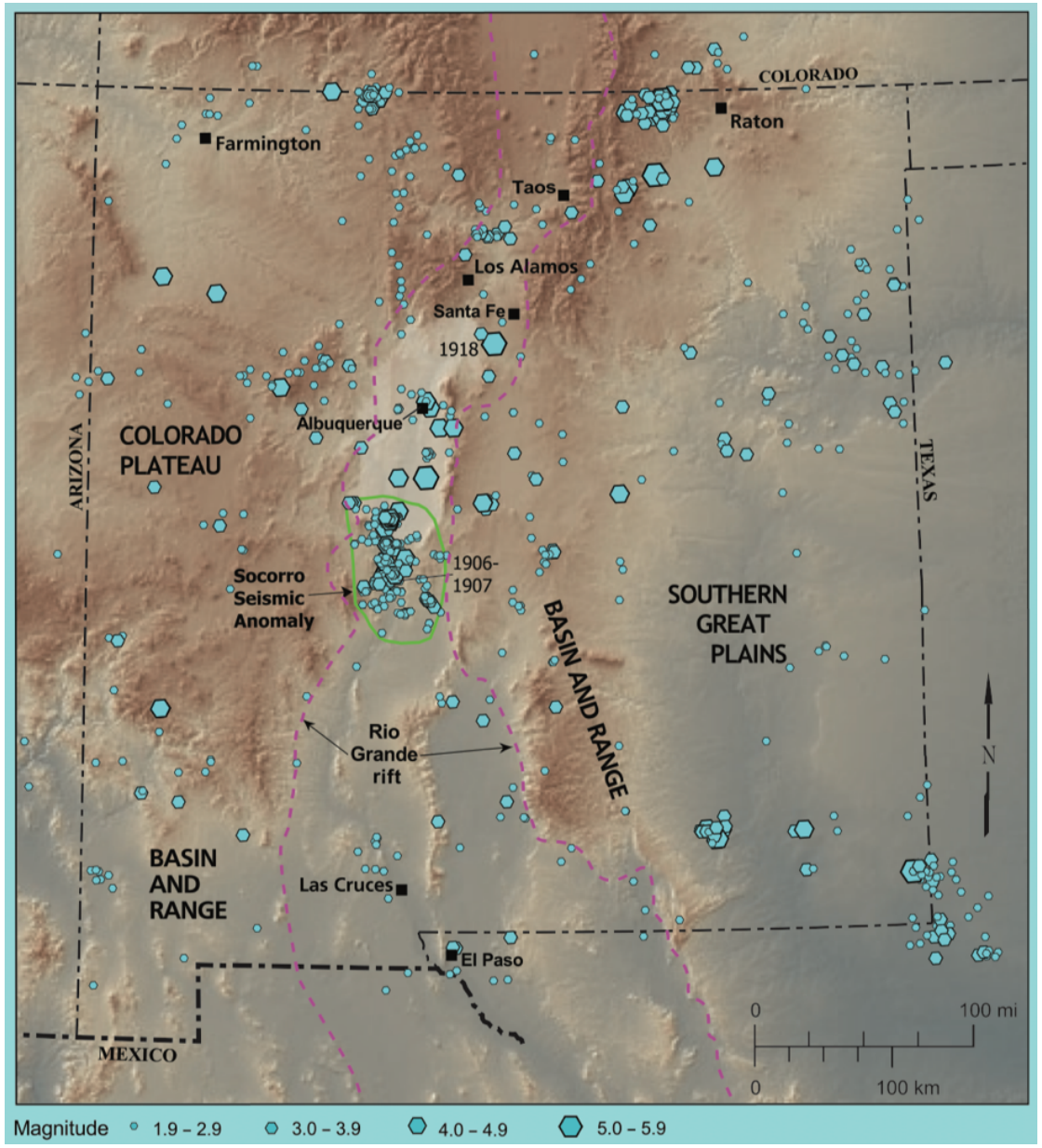
Margaret Glasgow *University of New Mexico*

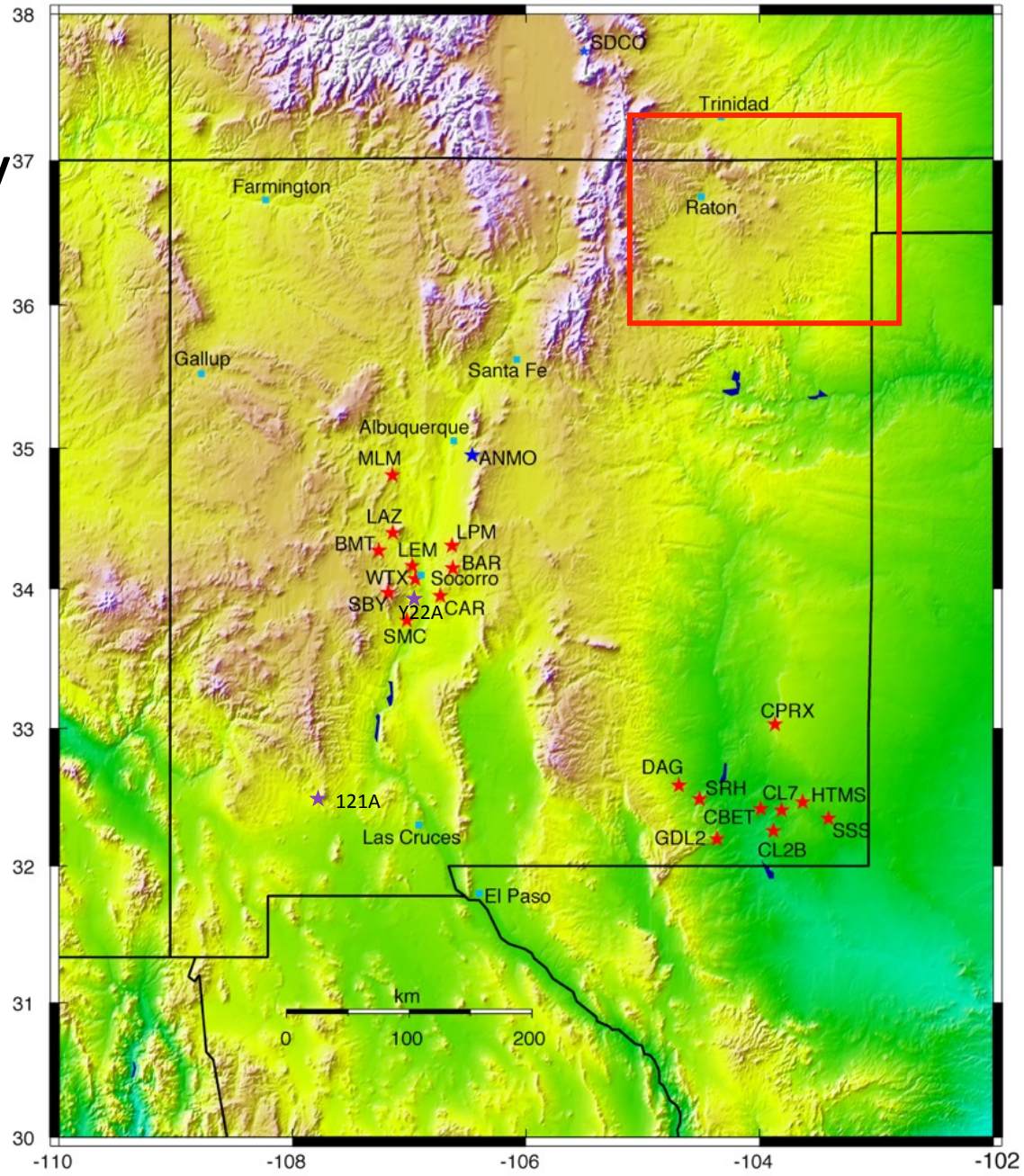
Earthquakes in NM

- Tectonic activity from Rio Grande Rift, E-W extending rift that extends from Colorado to northern Mexico
- Recent activity from induced seismicity in Delaware and Raton Basins



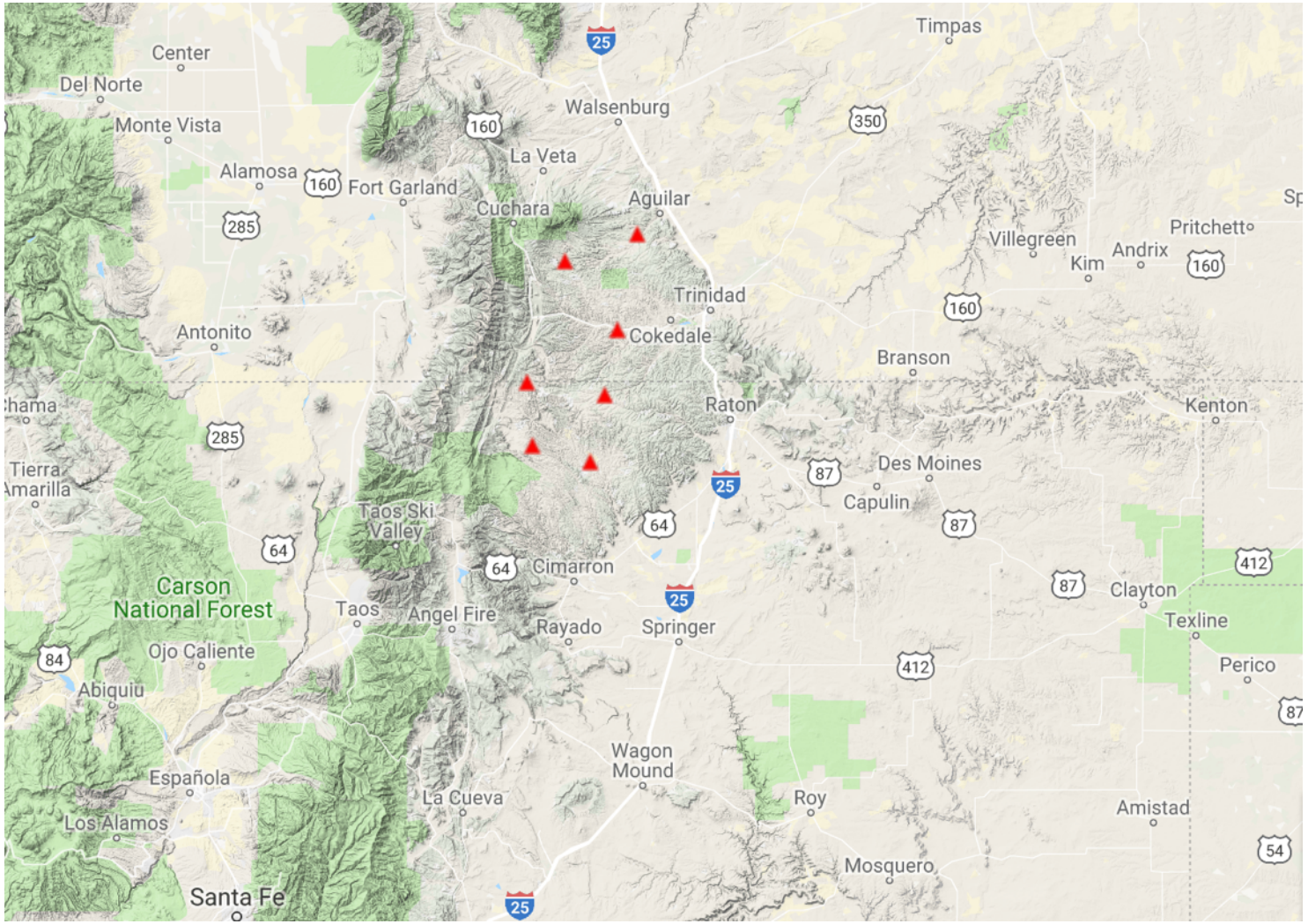
New Mexico Tech Seismological Observatory

- Socorro Seismic Anomaly
  - Region with ~50% of state's tectonic seismic activity
- SE New Mexico
  - Monitoring of seismicity near the Waste Isolation Pilot Plant (WIPP)
  - Also records potential induced activity in Delaware Basin



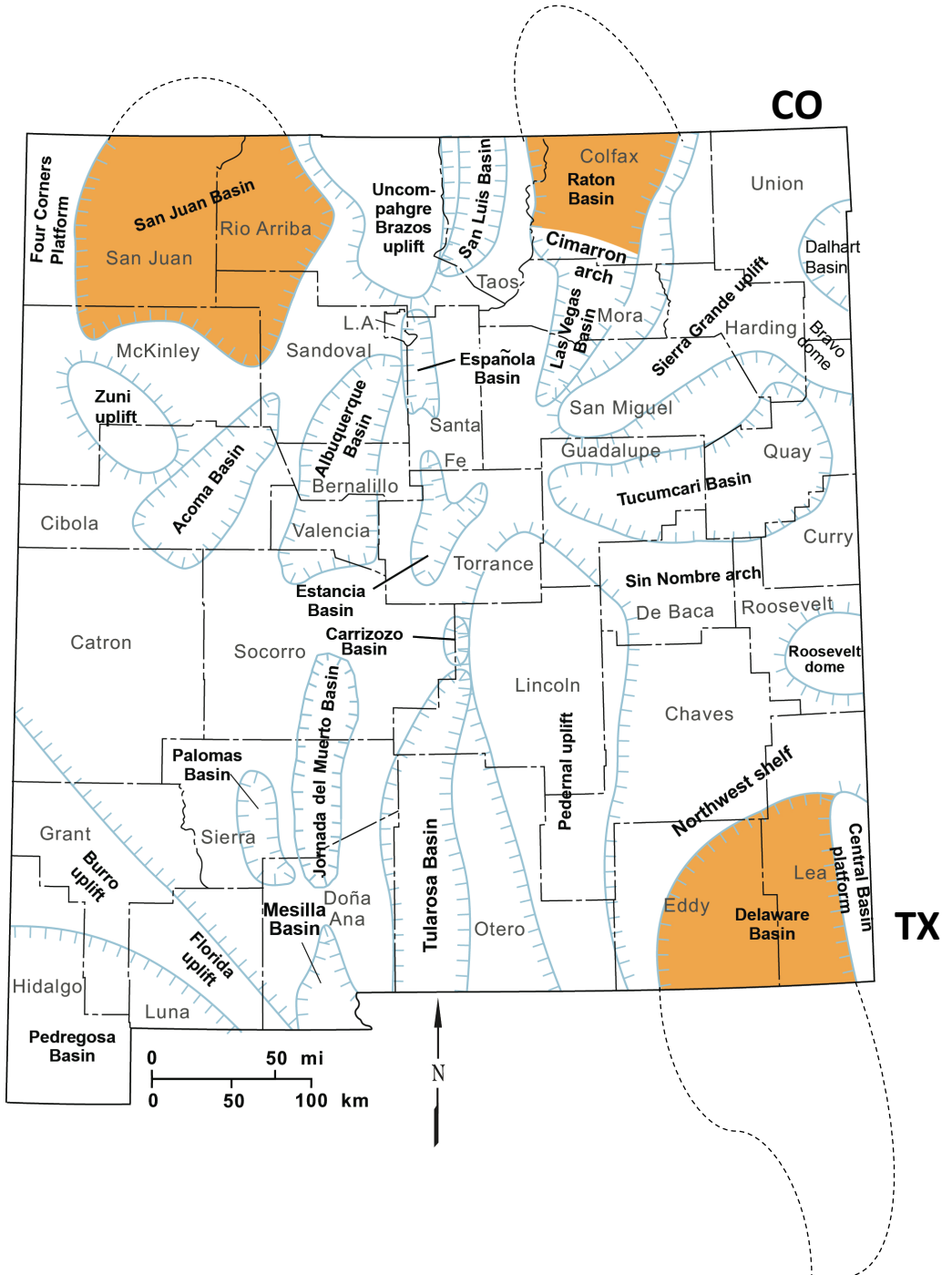
UNM network (Raton Basin)

- 7 station broadband network operated by UNM
- Installed in 2016
- Monitors increased local seismicity potentially related to fluid injection from coal-bed methane production

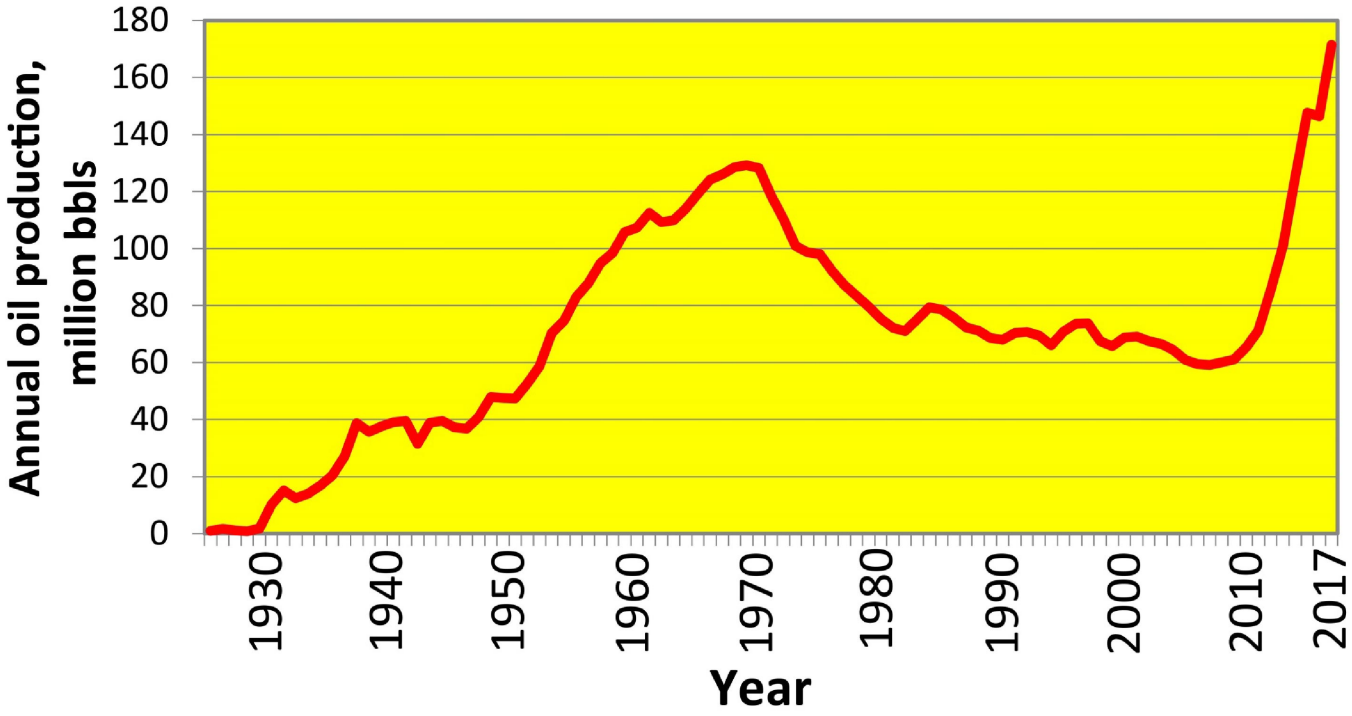


New Mexico basins

- Oil and gas production in NM has increased significantly in past few years thanks to enhanced recovery techniques
- Majority occurring in Delaware Basin in SE NM
- Raton basin has extraction from coal-bed methane deposits
- Least activity in San Juan Basin



New Mexico oil and gas production



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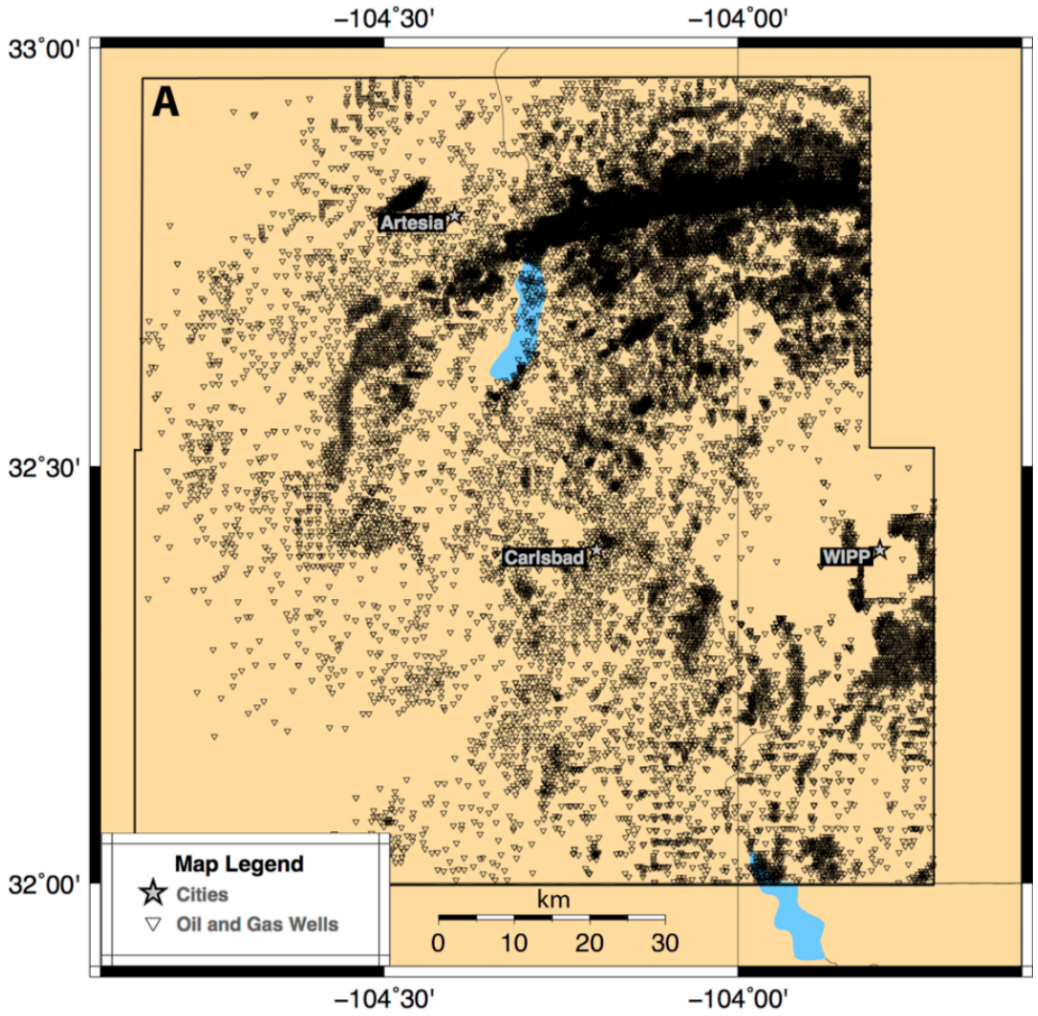
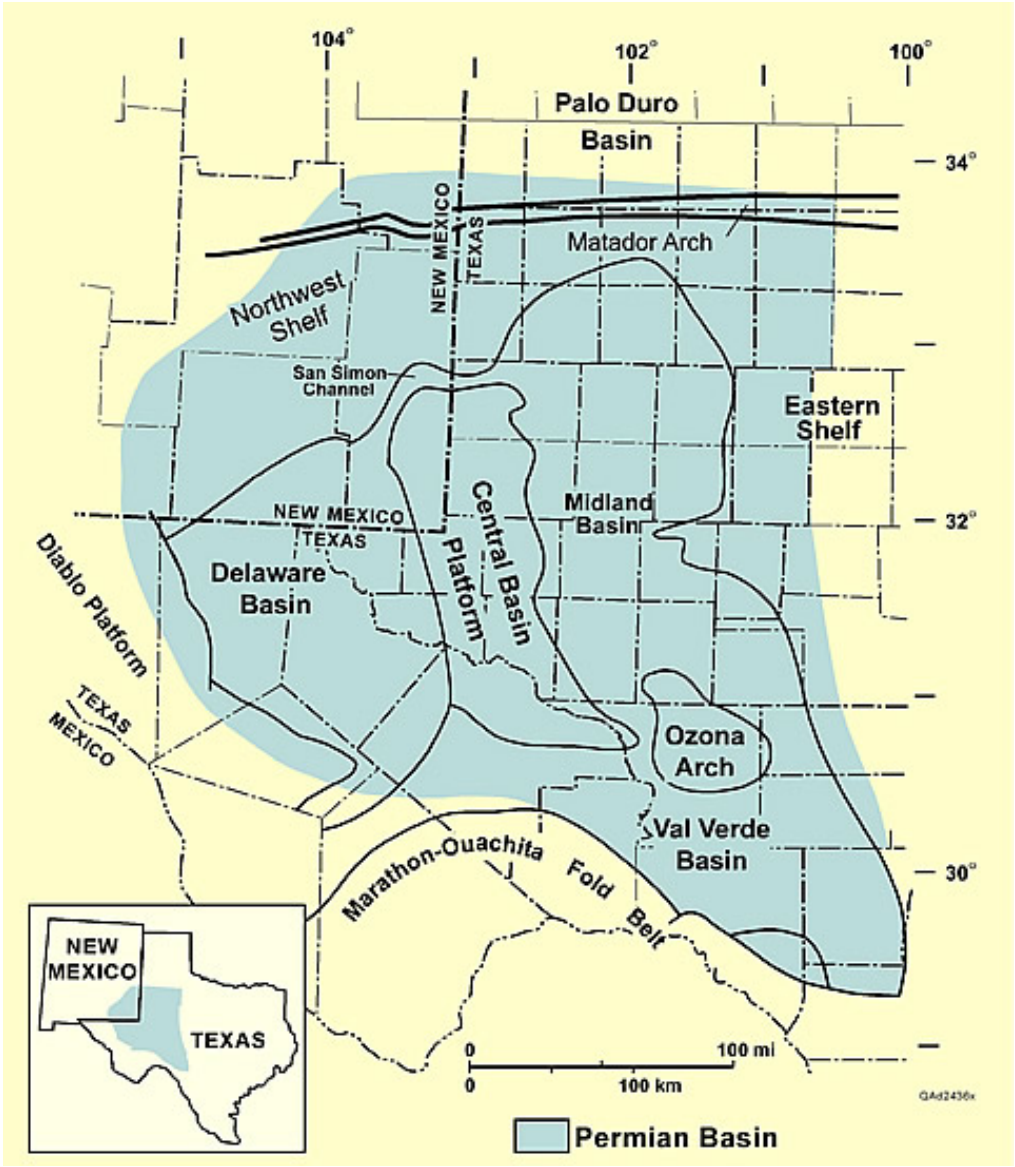
Delaware Basin





Early seismic observations

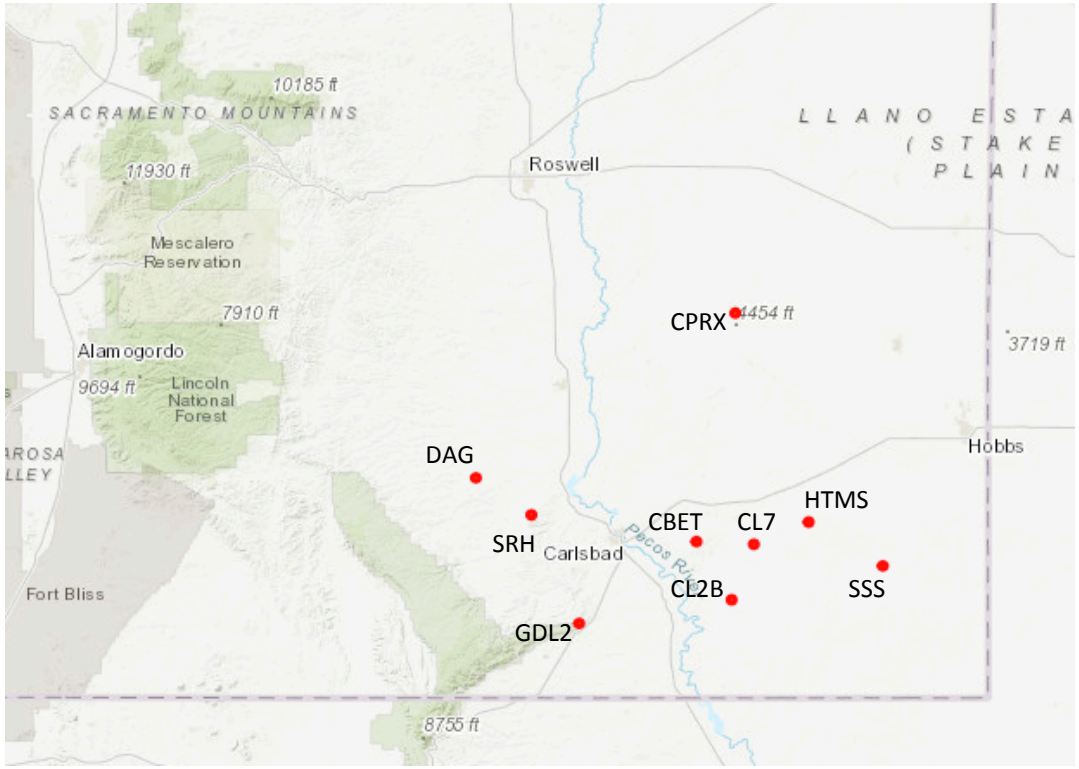
- Squares represent felt earthquakes prior to 1961, circles recorded earthquakes from 1961-1972
- Felt events biased by population density
- Events recorded in the Central Basin Platform beginning in 1964 when nearby seismic stations began operation

Sanford and Toppozada, 1974

Station	Nearest Population Center	Location Lat°N Long°W	Elevation Meters	Period of Operation
ALQ	Albuquerque, N.M.	34.94 106.46	1853	Oct. 1961 to Present
EPT	El Paso, Tex.	31.77 106.51	1186	1963 to Present
FOTX	Ft. Stockton, Tex.	30.90 102.70	880	June 21, 1964 to April 12, 1965
JCT	Junction, Tex.	30.48 99.80	591	March 1965 to Present
LC	Las Cruces, N.M.	32.40 106.60	1590	Jan. 1962 to Nov. 1965 Aug. 1967 to Dec. 1967
LUB	Lubbock, Tex.	33.58 101.87	979	Dec. 1961 to Present
SNM	Socorro, N.M.	34.07 106.94	1511	July 1961 to Present
TFO	Payson, Ariz.	34.27 111.27	1402	1963 to Present
TJC	Trinidad, Colo.	37.22 104.69	2103	1966 to Present
TUC	Tucson, Ariz.	32.31 110.78	985	Pre-1961 to Present
WMO	Ft. Sill, Okla.	34.72 98.59	505	1962 to 1969

Sanford and Toppozada, 1974

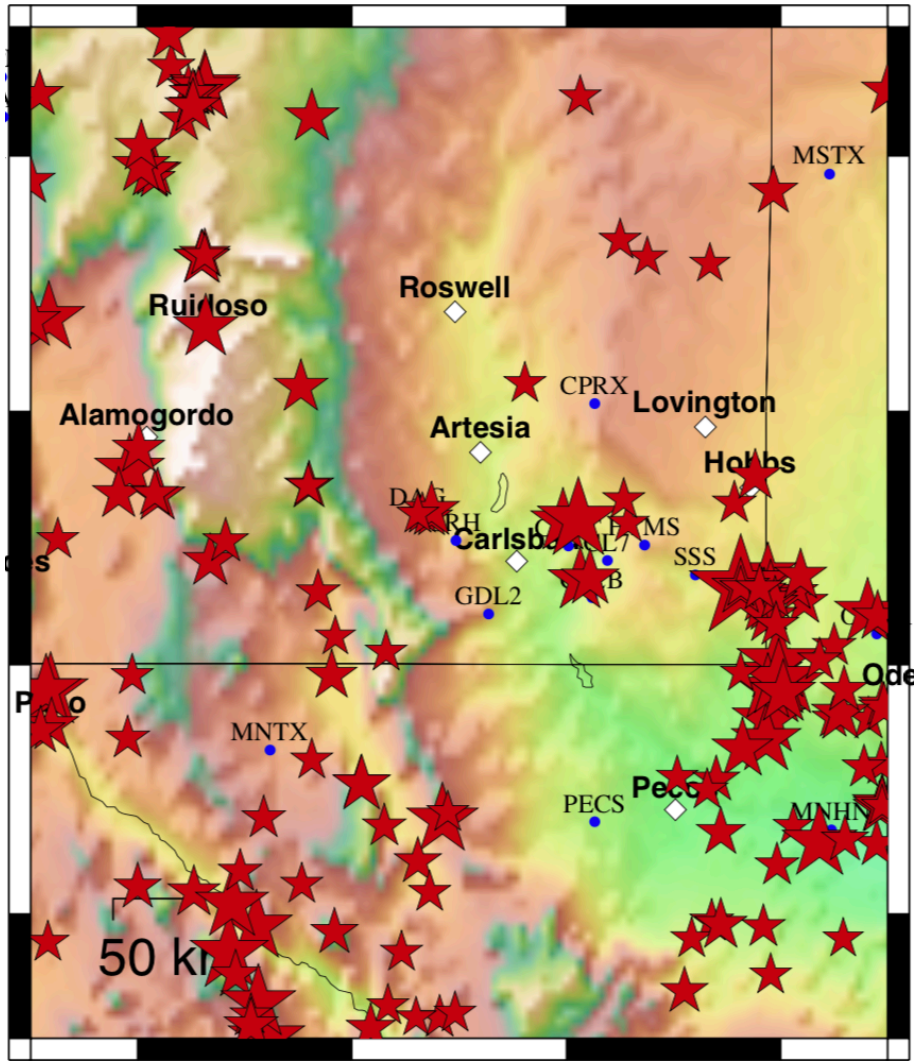
WIPP Network



- 1974: first continuously recording station near WIPP
- 1979: WIPP site authorized by Congress
- 1998: current permanent network installed
- 1999: first shipment received at site

Mag 2+ earthquakes in SE NM

1962-1998

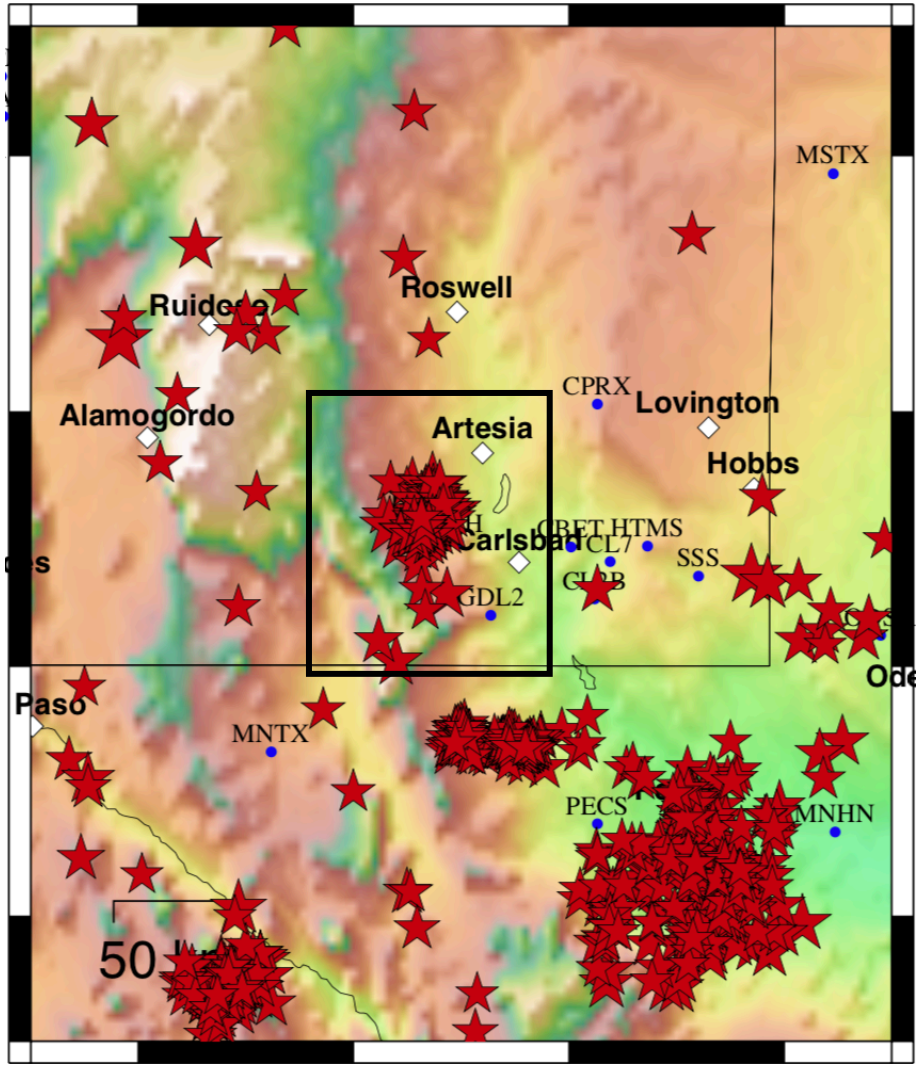


M2

M3

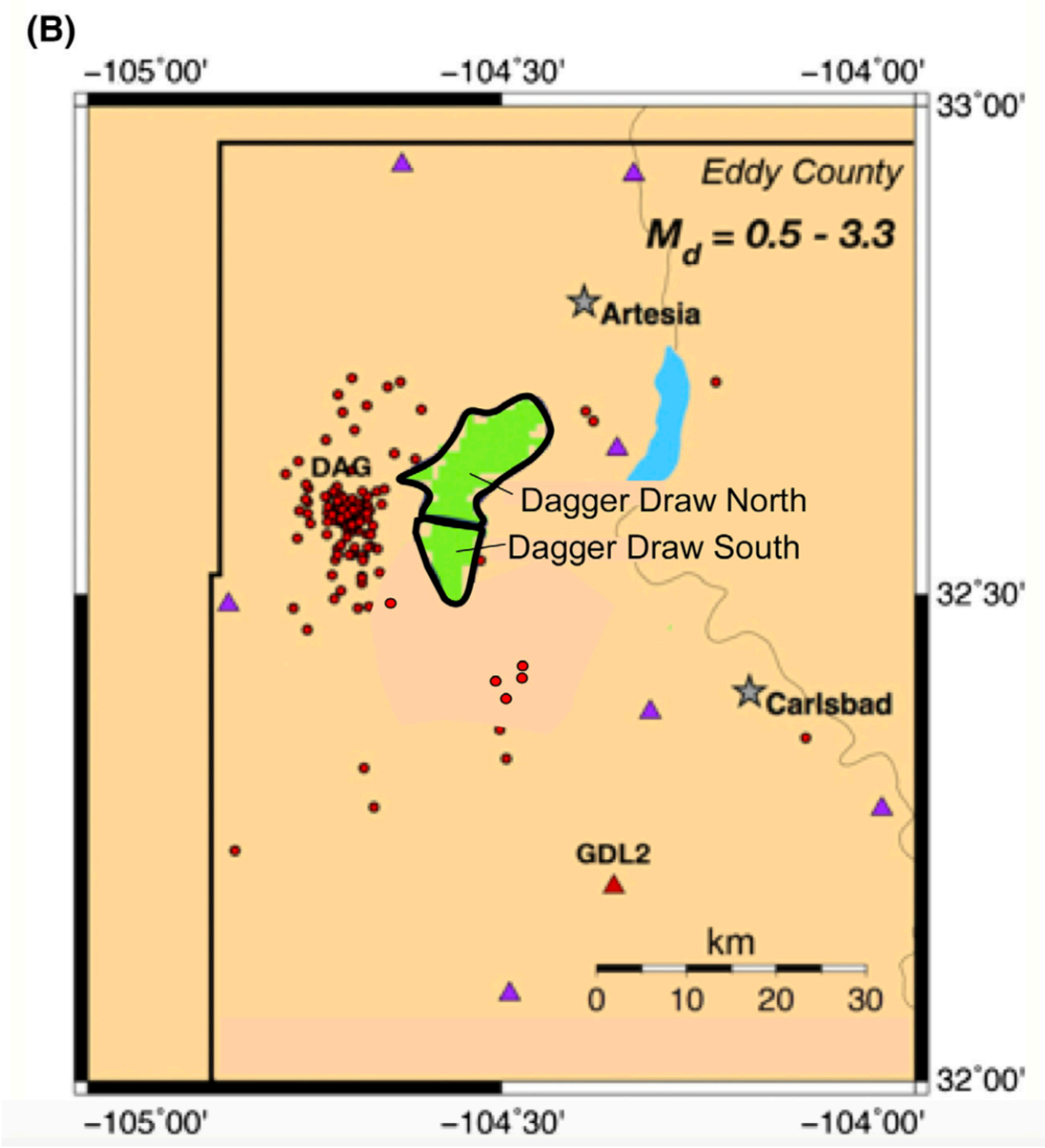
M4

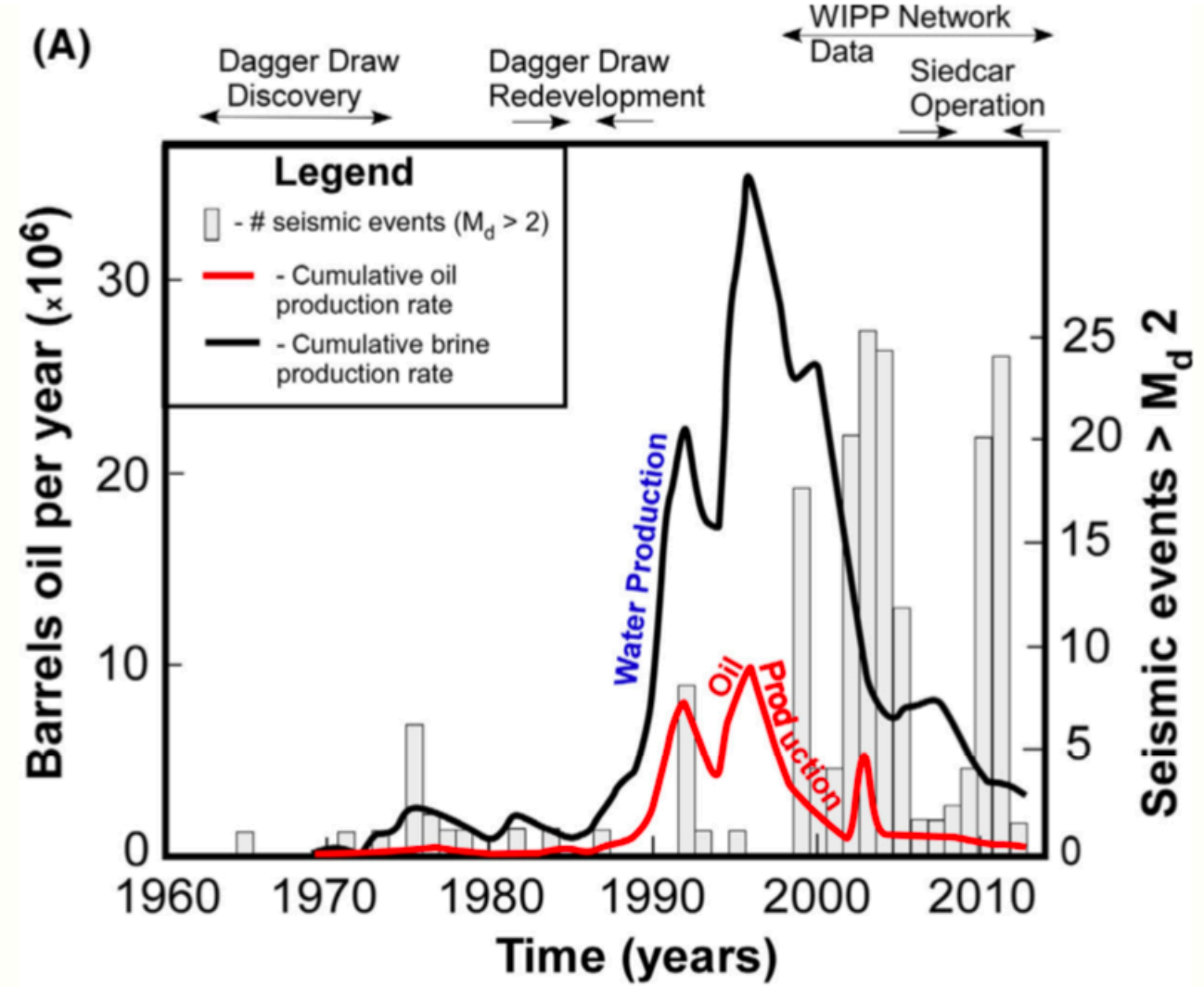
1999-2018

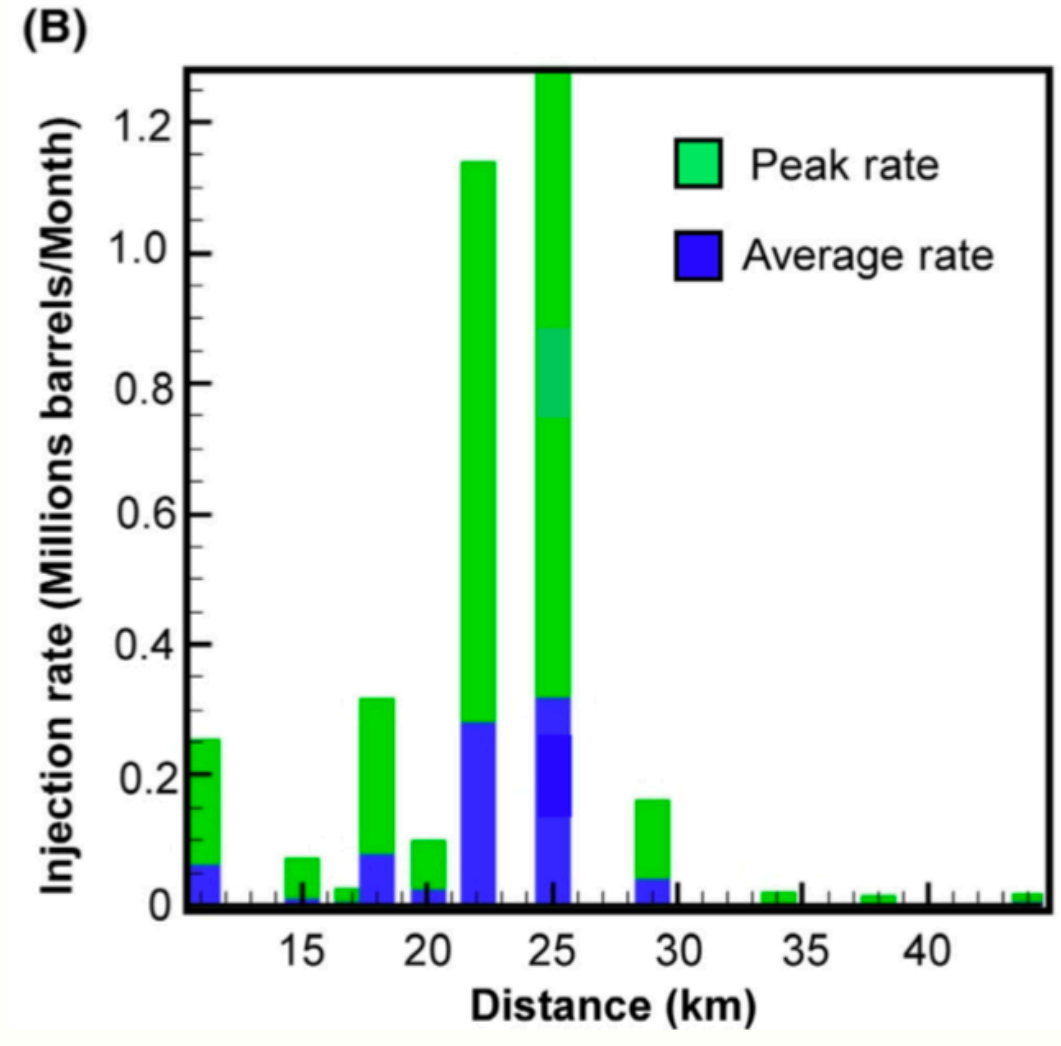


Dagger Draw

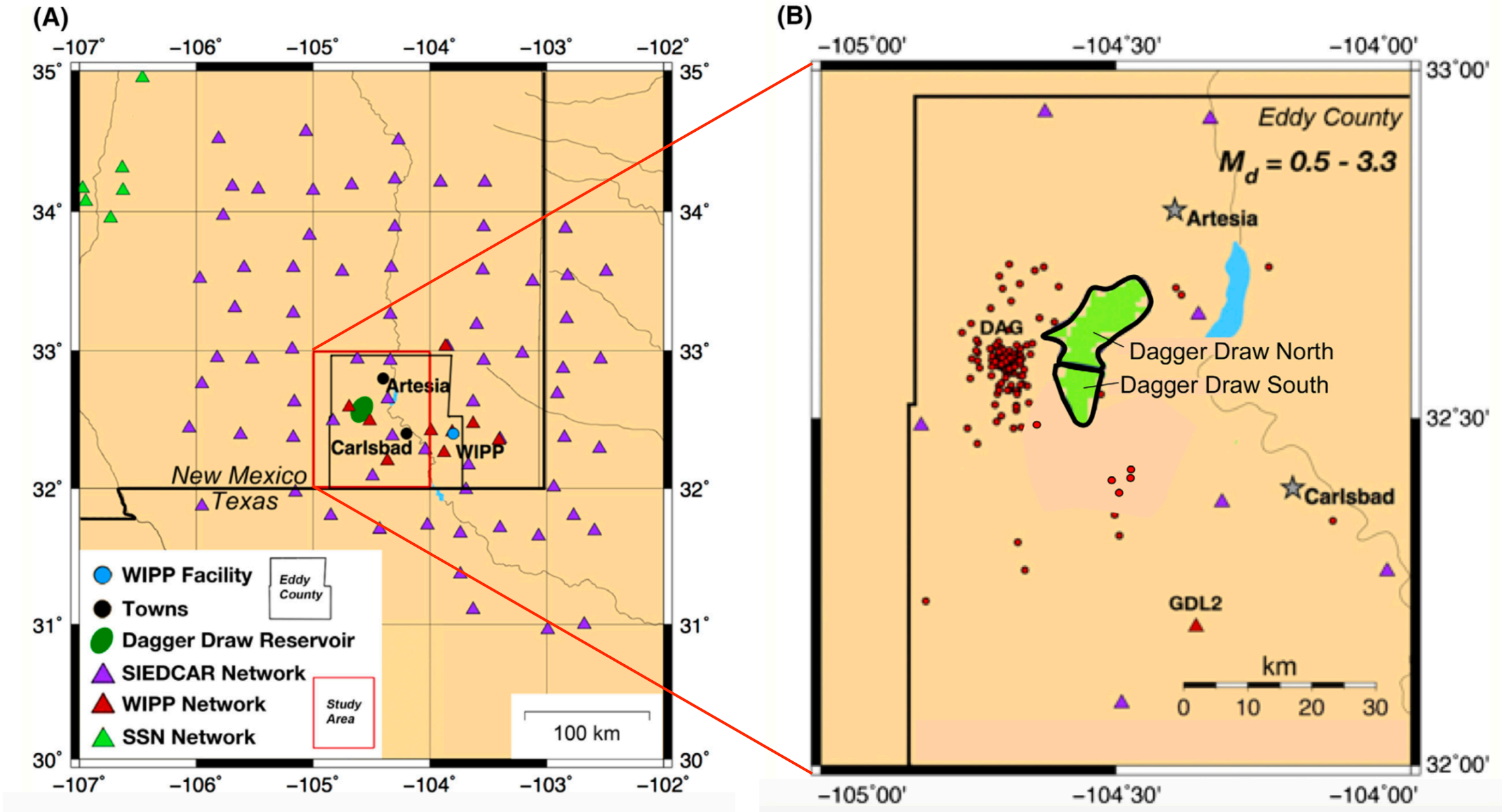
- Production began in 1969
- Originally considered two separate fields
- Production low until redevelopment in 1990's
- Seismicity occurred ~5 years after peak fluid injection and ~15 km west of field







Zhang et al., 2016



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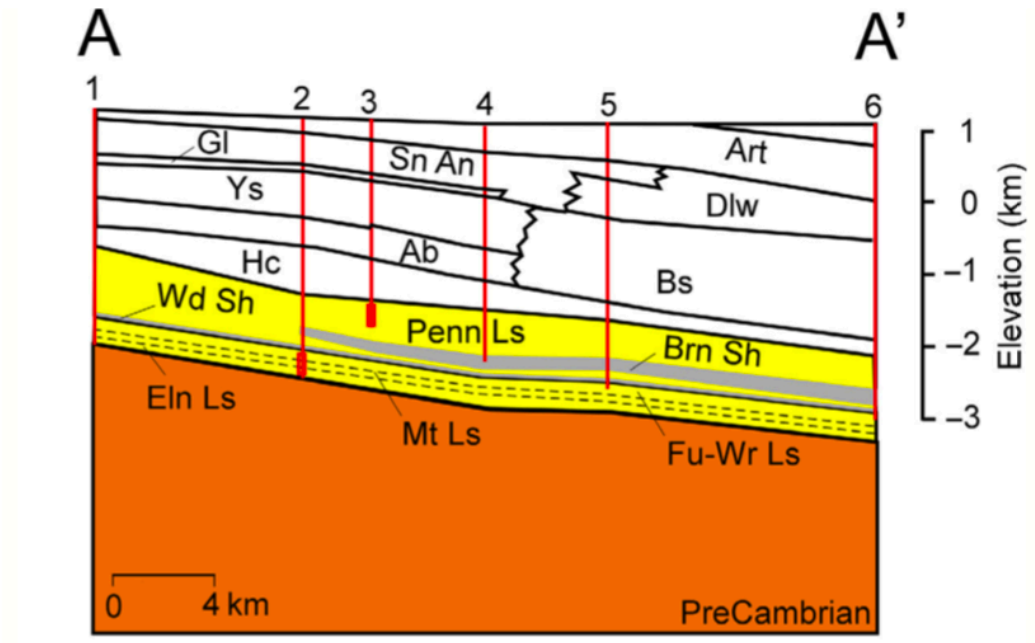

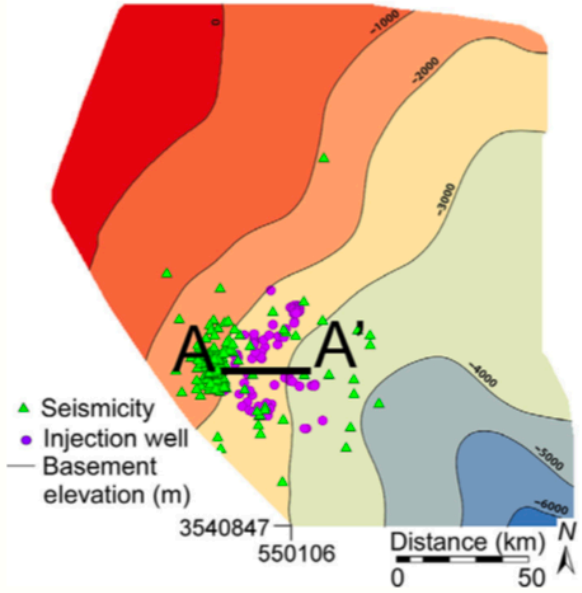

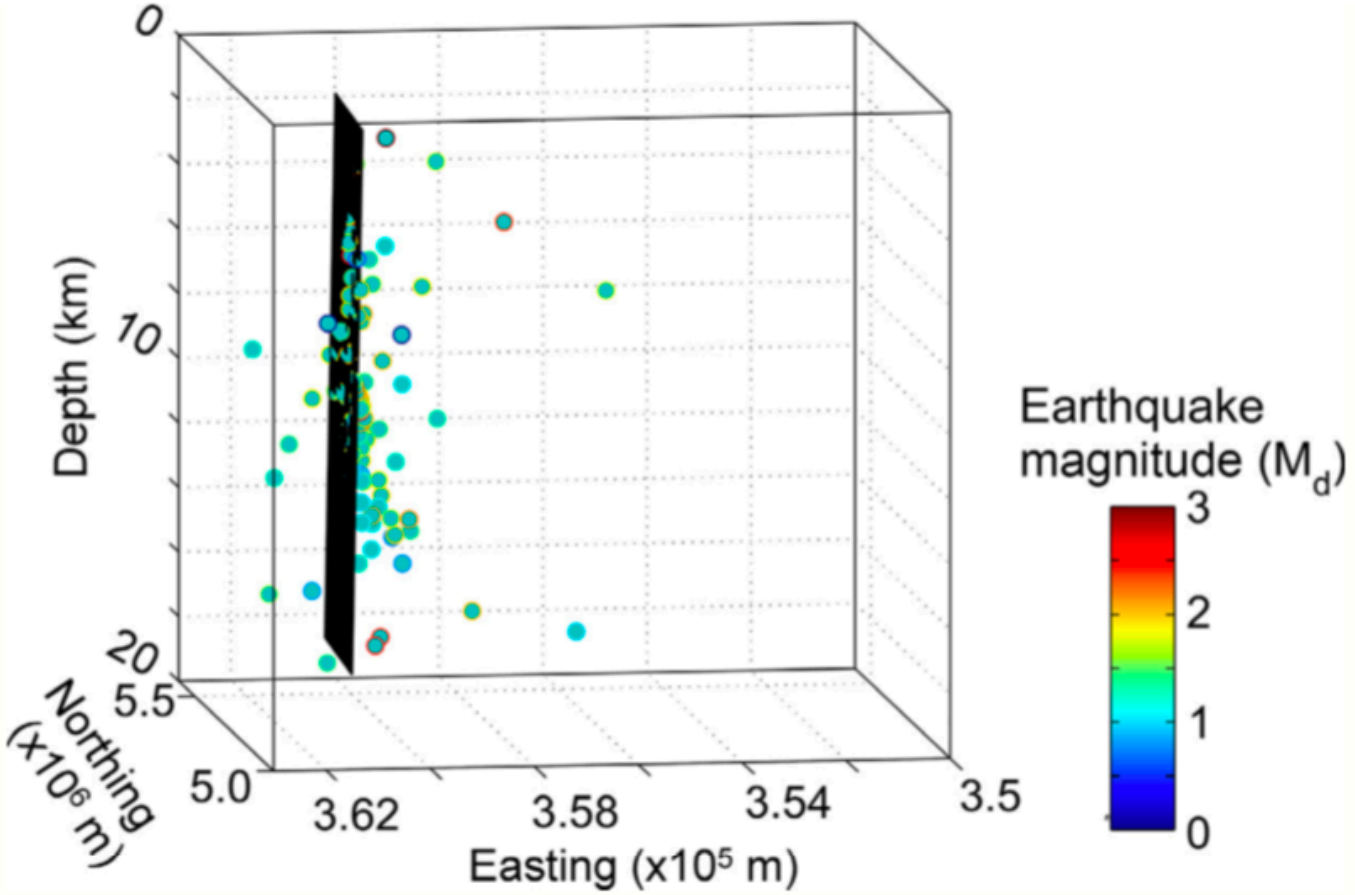

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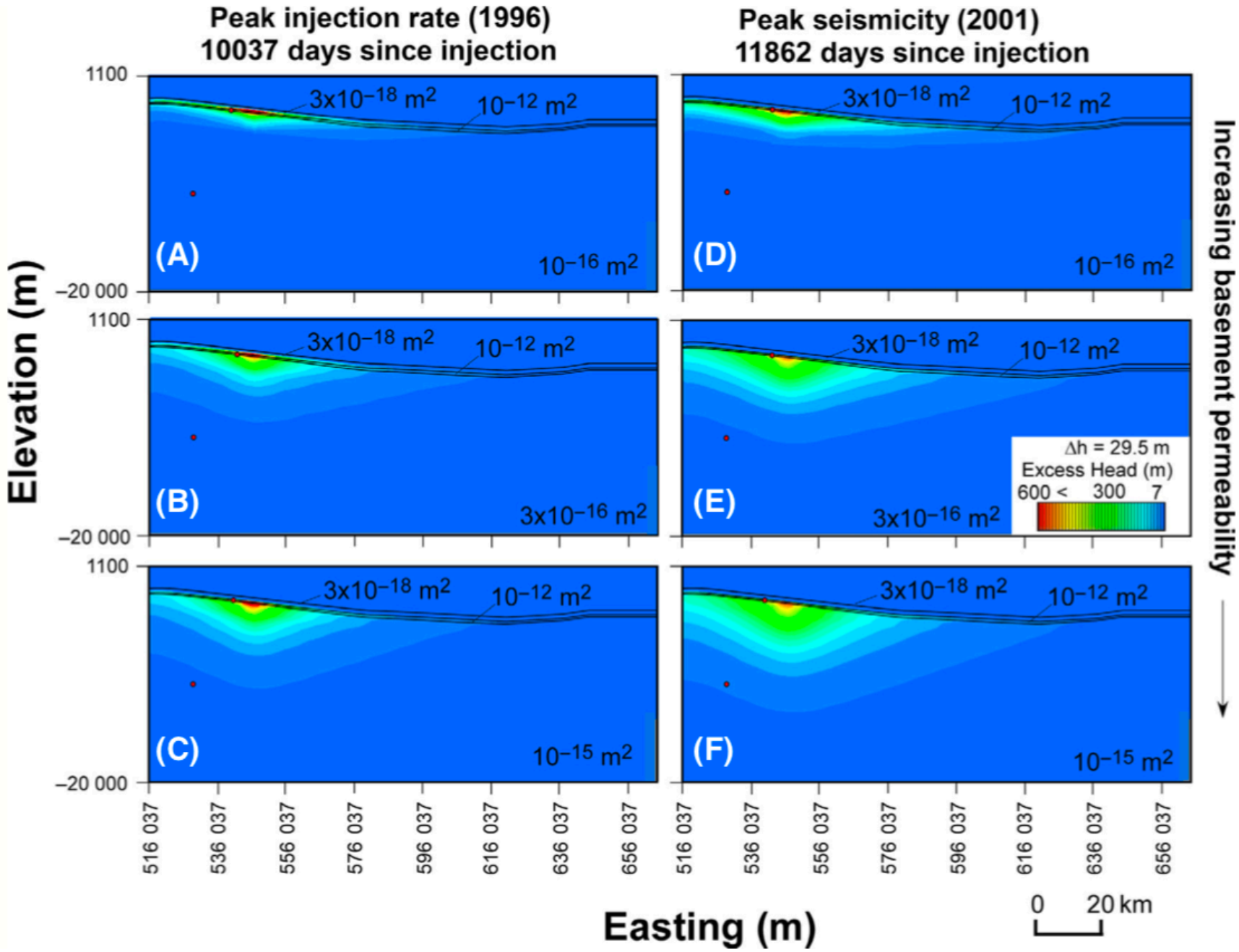

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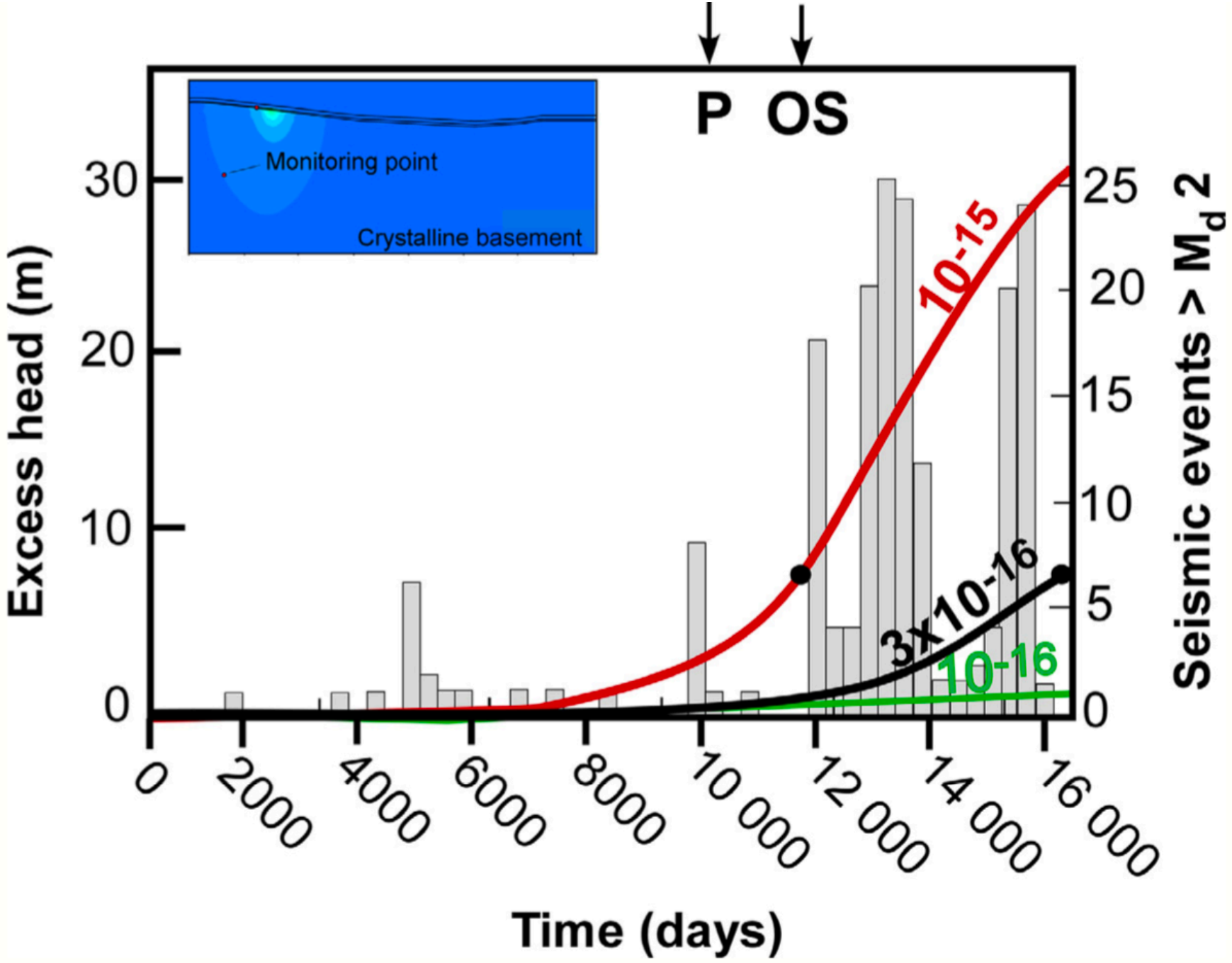

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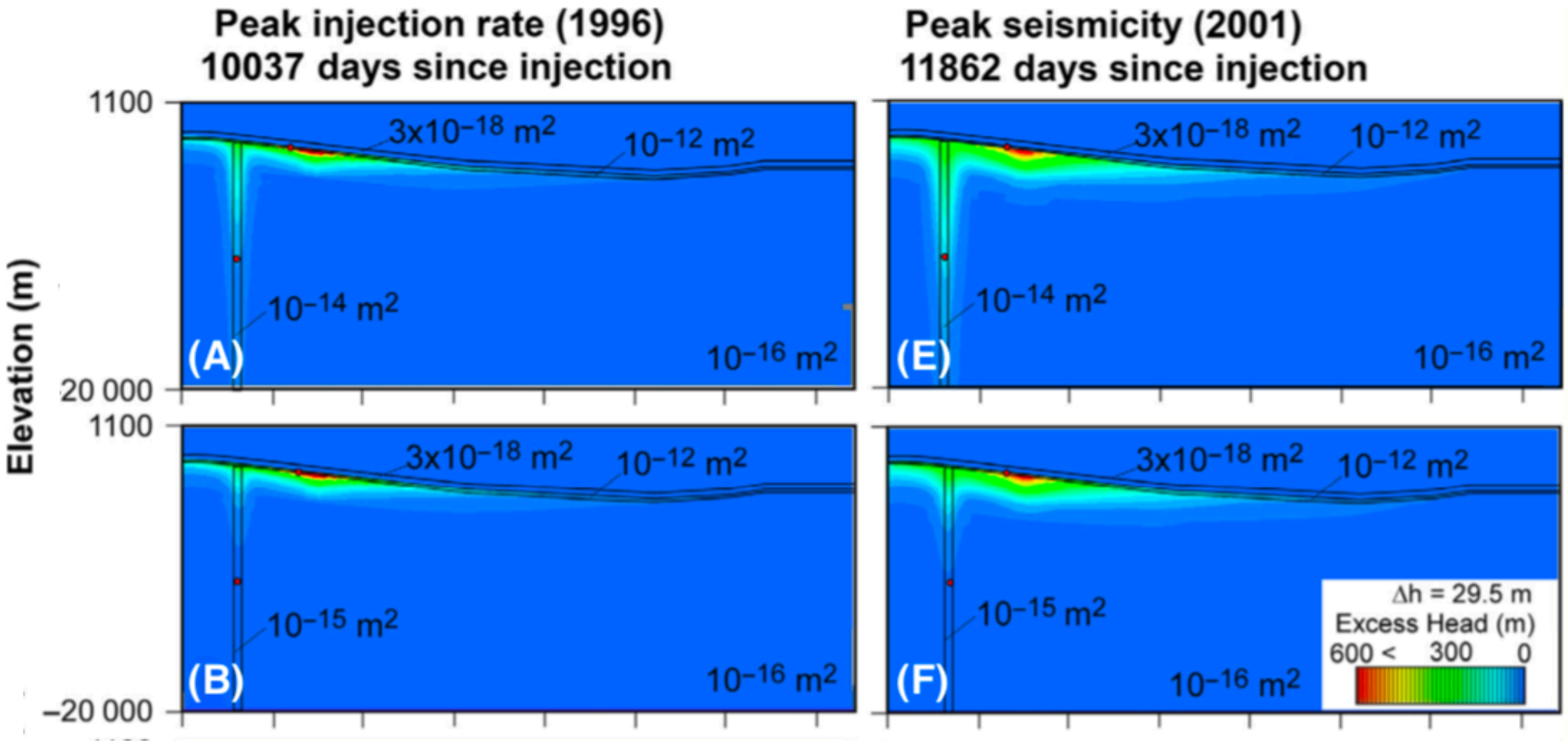


Zhang et al., 2016

Conclusions

- Hydrological modeling suggests permeability of crystalline basement between 10^{-15} and 10^{-16} would explain 5 year delay between injection and onset of seismic activity
- Dense seismic network allowed relocation of earthquakes onto fault plane where most activity occurred
- Production in Dagger Draw field declined in 2005 and seismic activity dropped after 2012

Investigating induced seismicity in the Raton Basin 2016-2019

Margaret Glasgow, Brandon Schmandt, Sarah Rysanek, Ryan Stairs

University of New Mexico

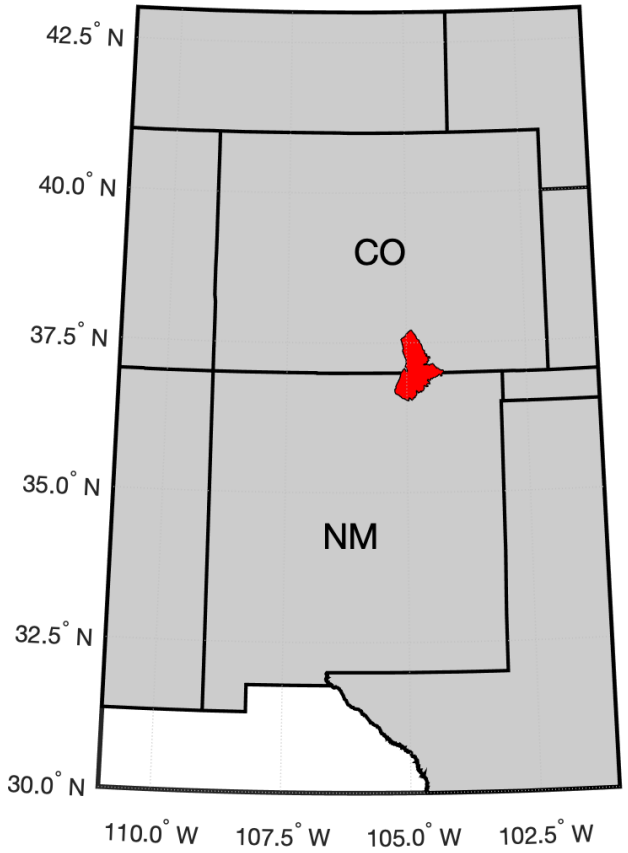
June 18th, 2019

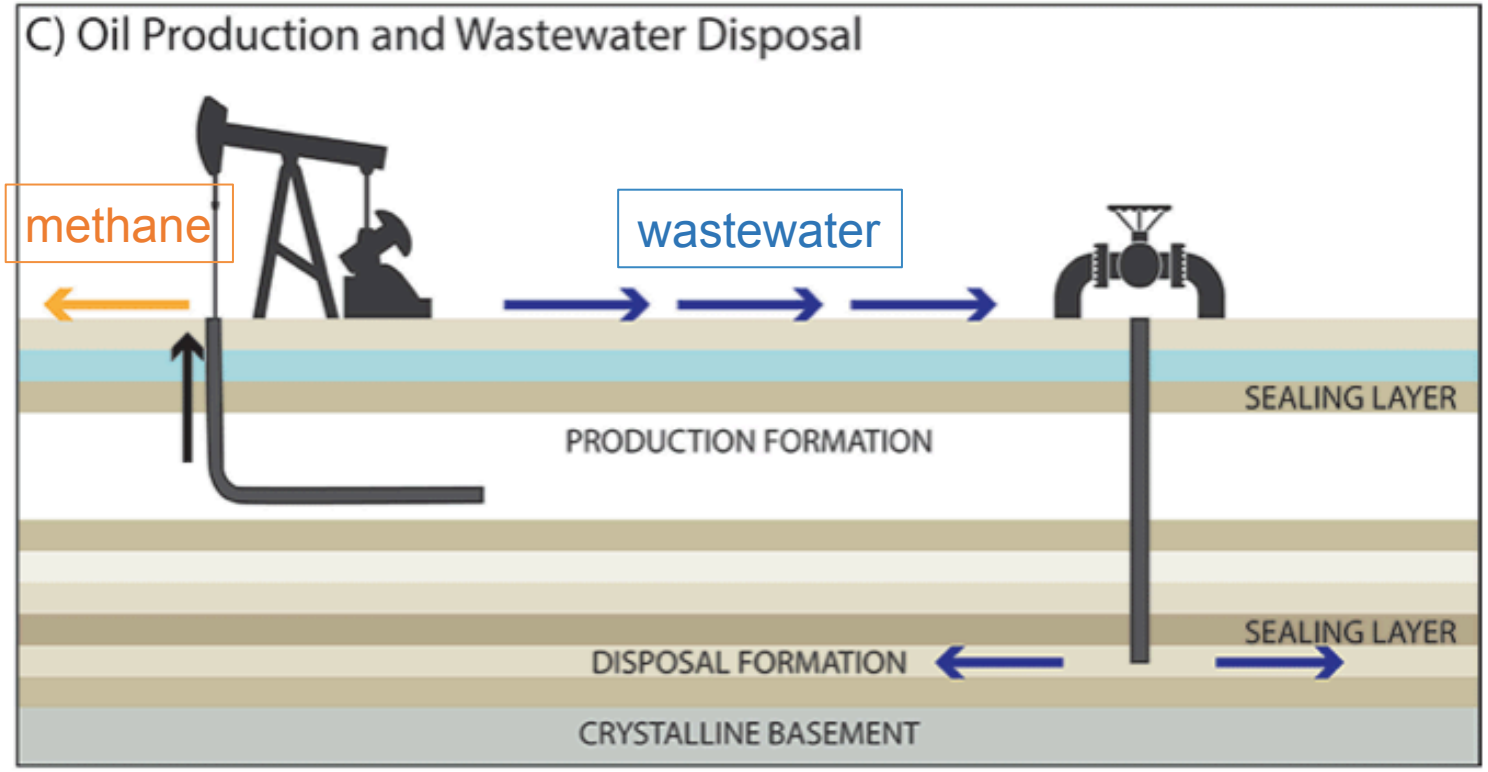
Contact: mglasgow@unm.edu

Introduction to production, injection, and seismicity

RATON BASIN: Production and injection

- Methane extracted from shallow formations
- Wastewater disposal ~2 km deeper than production





(USGS, 2018)

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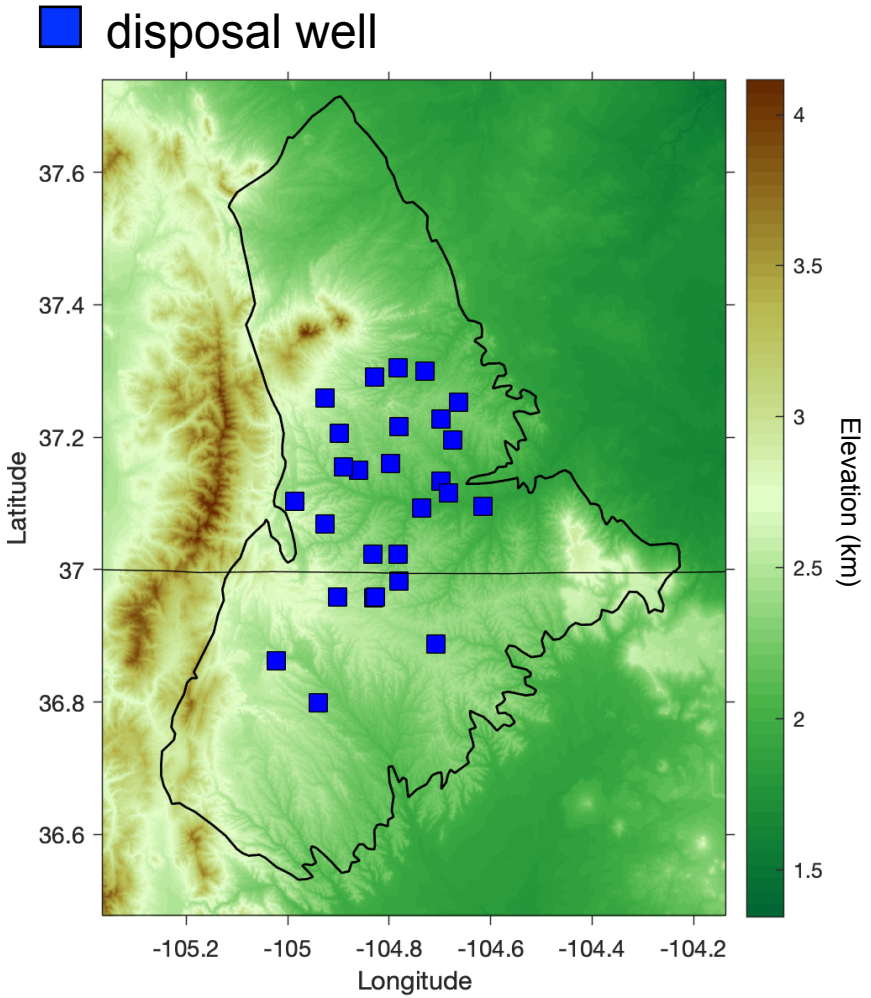
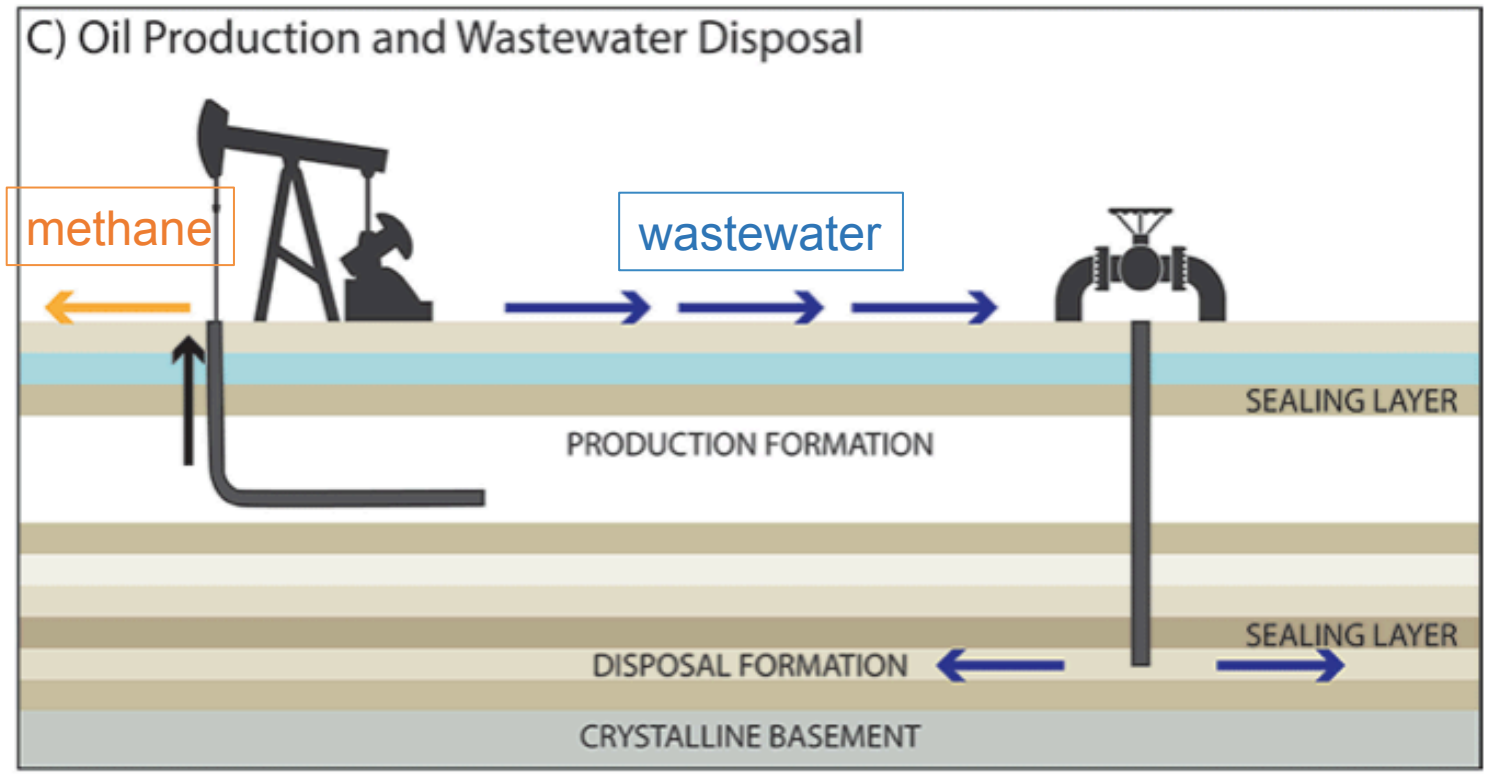
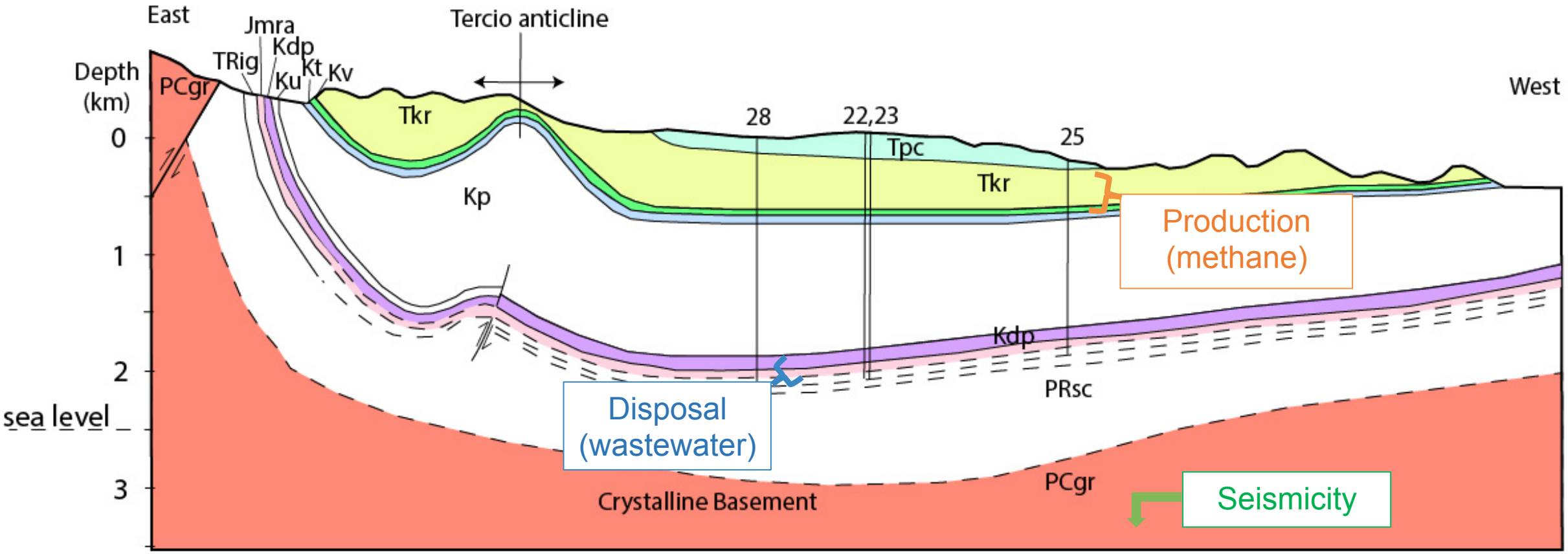




(USGS, 2018)

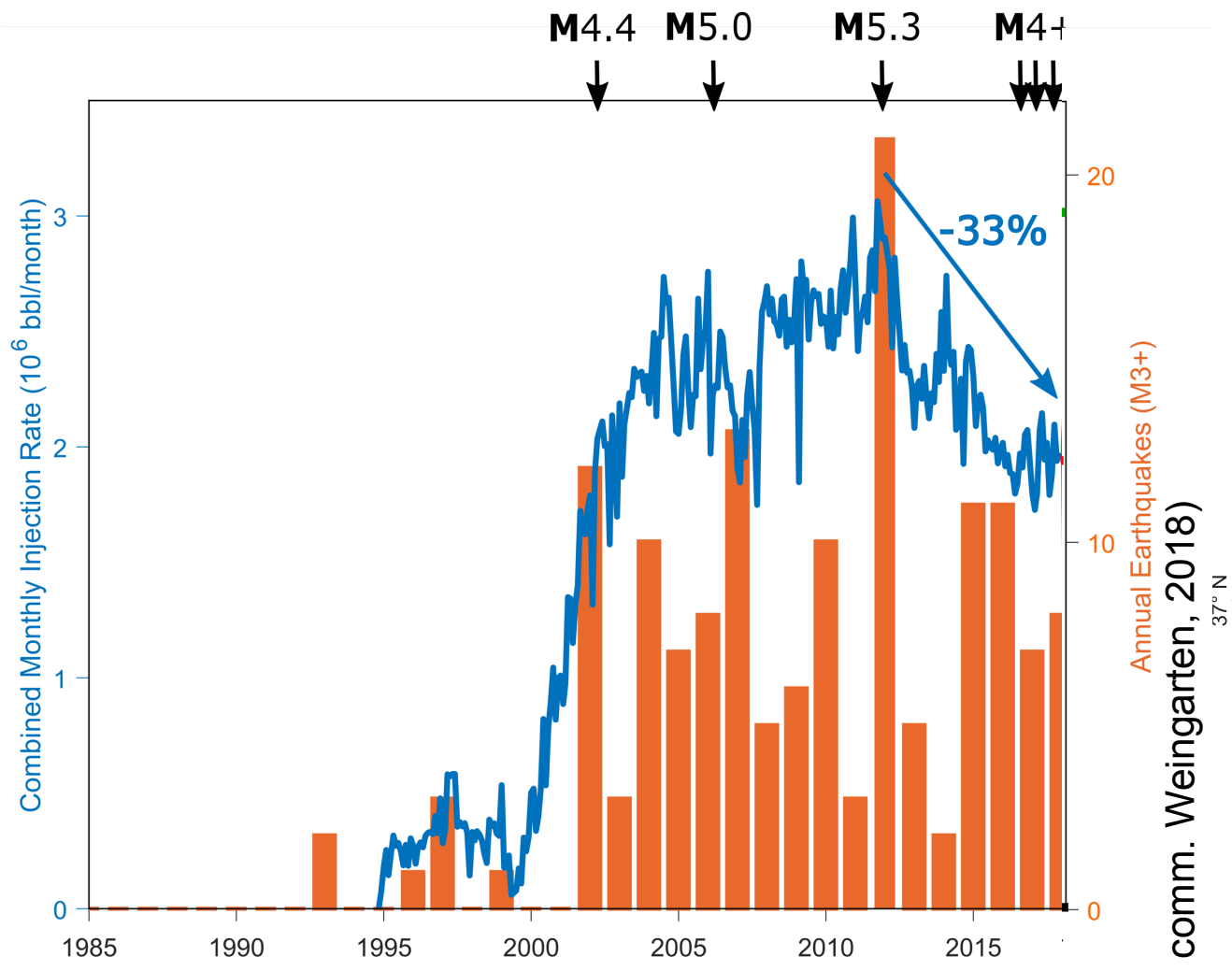
RATON BASIN: Production, injection, and seismicity

- Methane extracted from shallow formations
- Wastewater disposal ~2 km deeper than production
- Seismicity is >1 km deeper than disposal

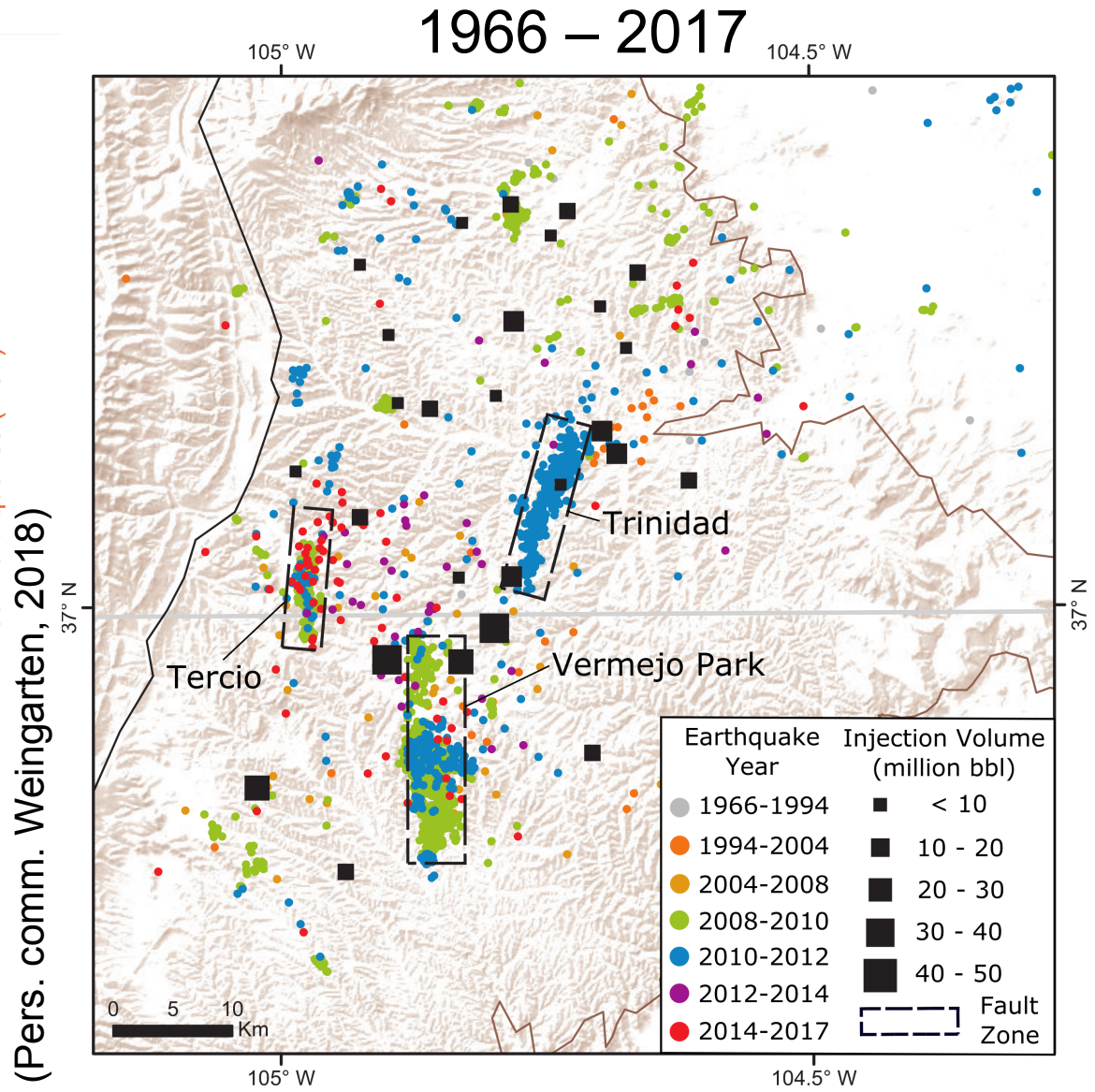


Updated from Nakai et al., 2017

RATON BASIN: Injection and seismicity



- Most recently production is decreasing

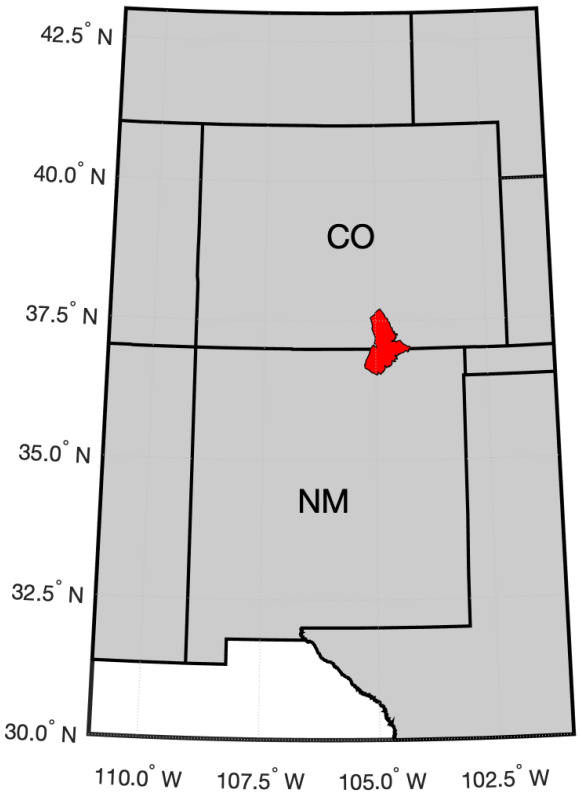


(Pers. comm. Weingarten, 2018)

Data: Seismic and industry

RATON BASIN : Seismic Array

https://doi.org/10.7914/SN/YX_2016



FDSN International Federation of Digital Seismograph Networks

Home / Networks / YX (2016-2021): Raton Basin UNM Broadband Network Sign in

YX (2016-2021): Raton Basin UNM Broadband Network

FDSN Network Information

Are you the operator of this network? Update this information.

FDSN code	YX (2016-2021)	**Operated by**	University of New Mexico (UNM)
Network name	Raton Basin UNM Broadband Network	**Deployment region**	United States of America
Start date	2016-07-01	**End date**	2021-10-28

Raton Basin Seismic Array:

- Publicly available
- Start Date: 2016
- Actively recording until 2021+

Contact: mglasgow@unm.edu

RATON BASIN : Seismic Array

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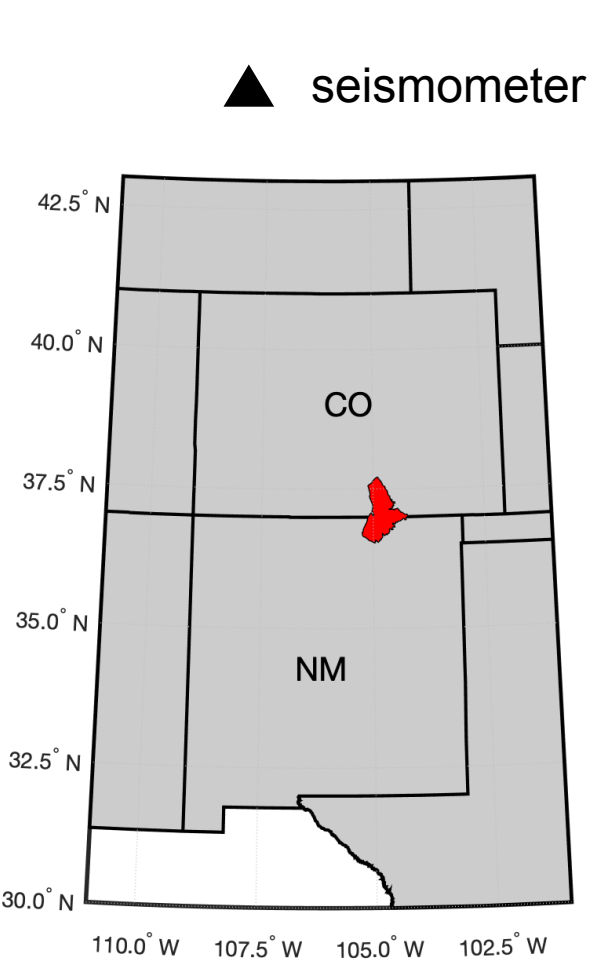

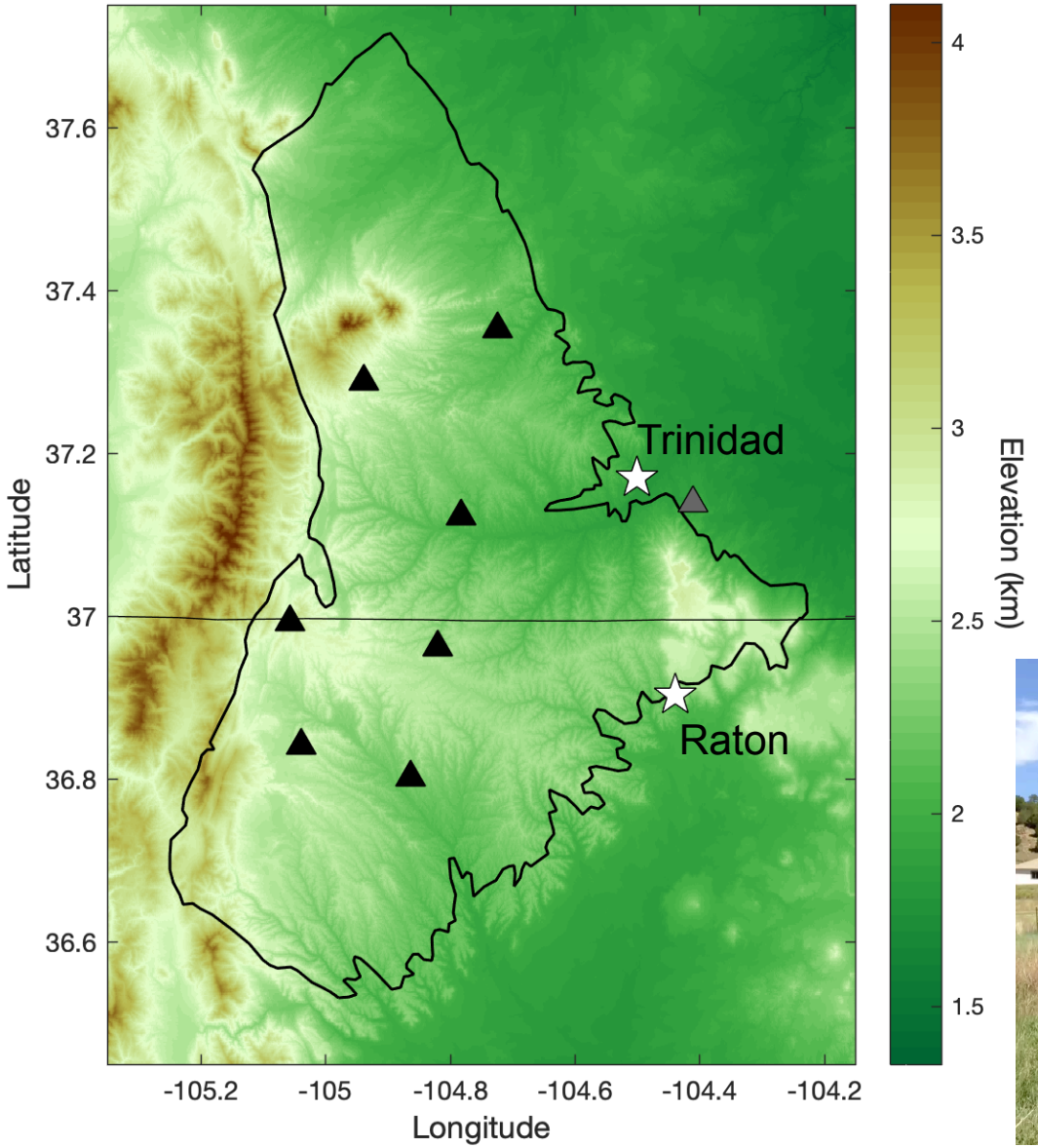

Seismic Array:

- Publicly available
- 8 broadband stations
- 7 deployed in 2016 by University of NM

RATON BASIN : Seismic Array

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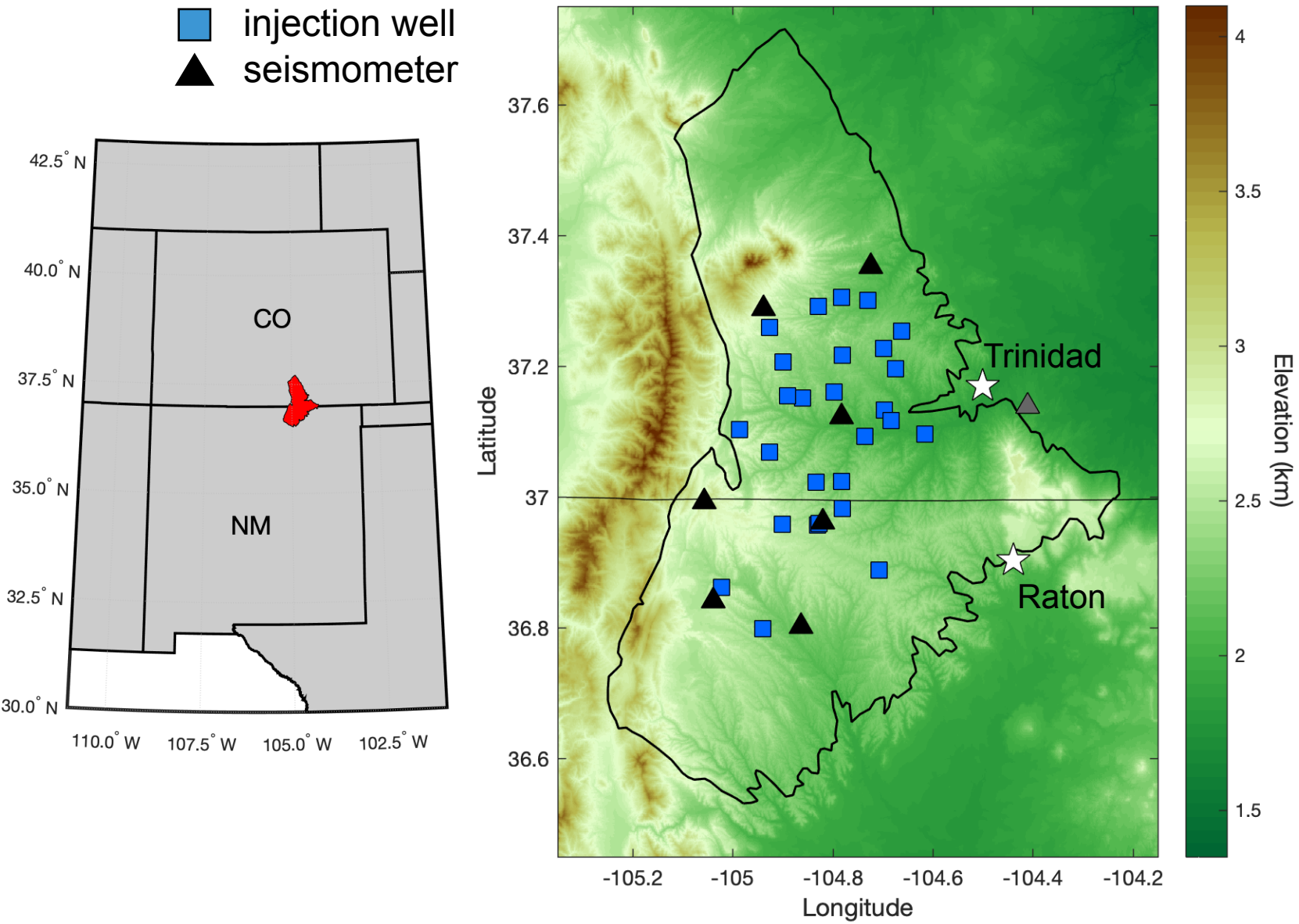


Seismic Array:

- Publicly available
- 8 broadband stations
- 7 deployed in 2016 by University of NM

Industry Data:

- Publicly available
- 27 injection wells
- 1 sample per month at injection wells

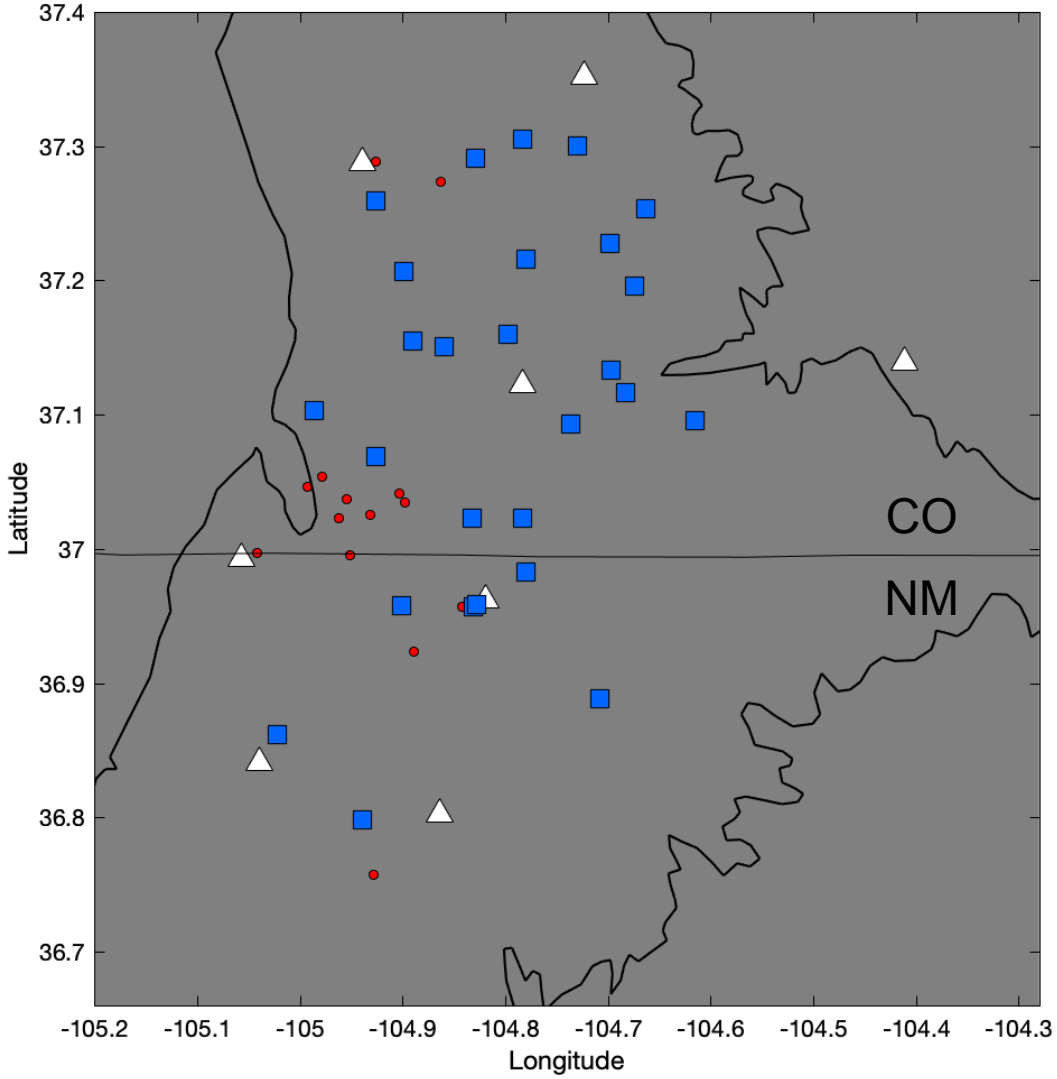
Results: Earthquake locations and magnitudes

RATON BASIN : Comparison of catalogs

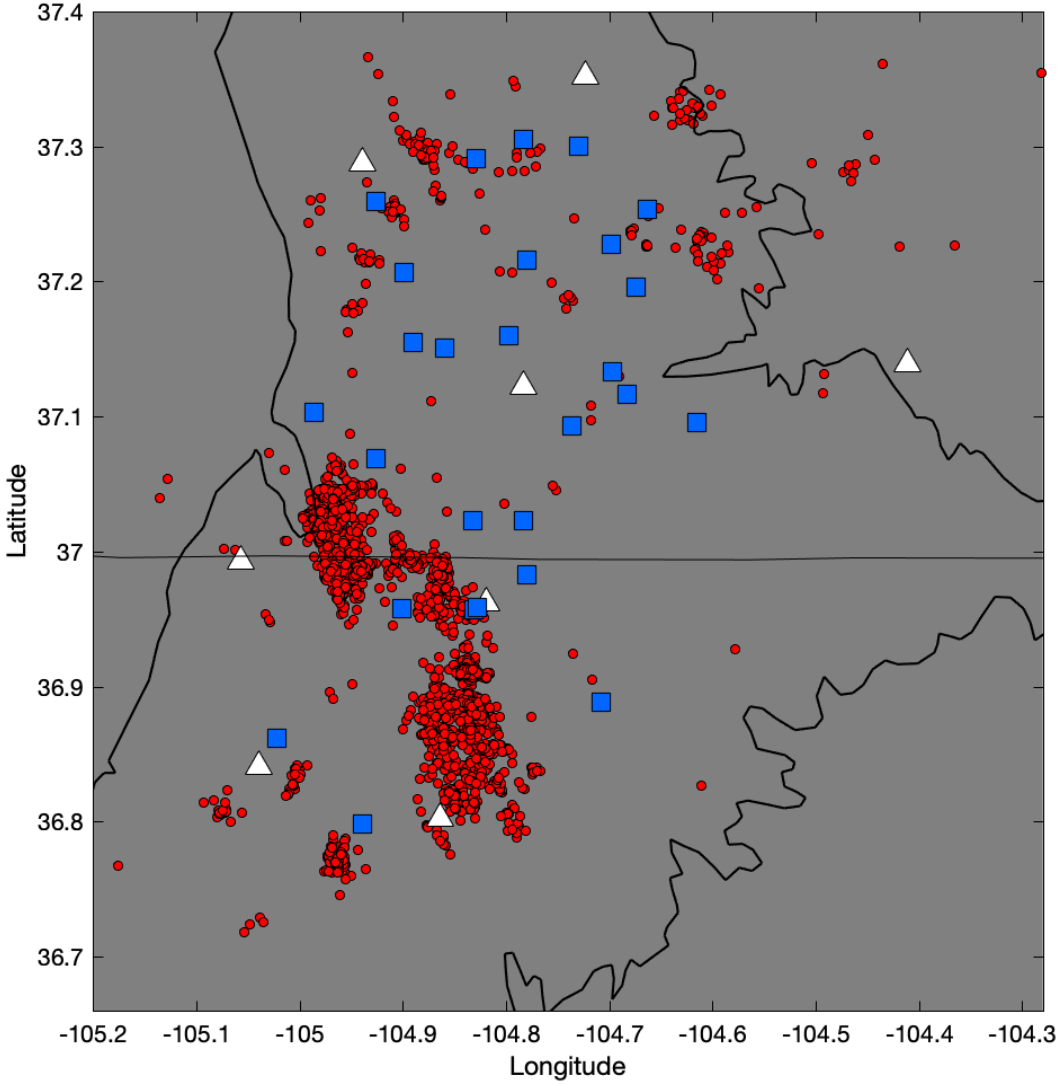
injection well
seismometer

Time period: 10/16 – 1/18

USGS catalog



Our catalog



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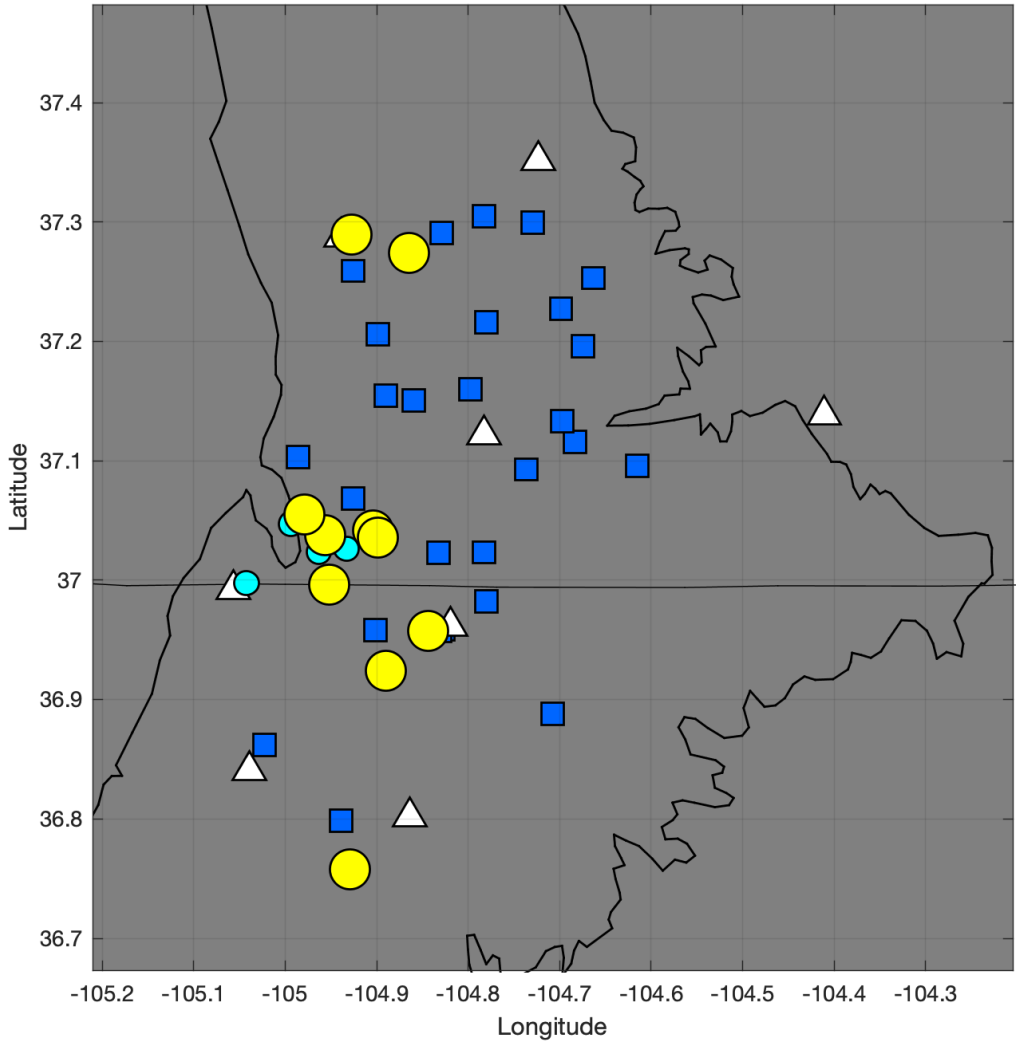

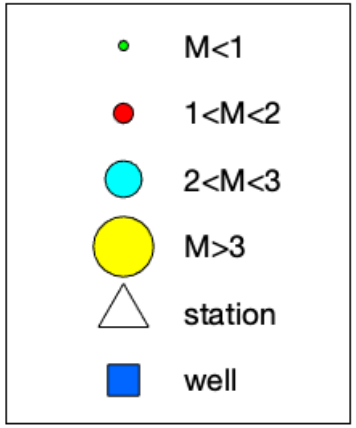

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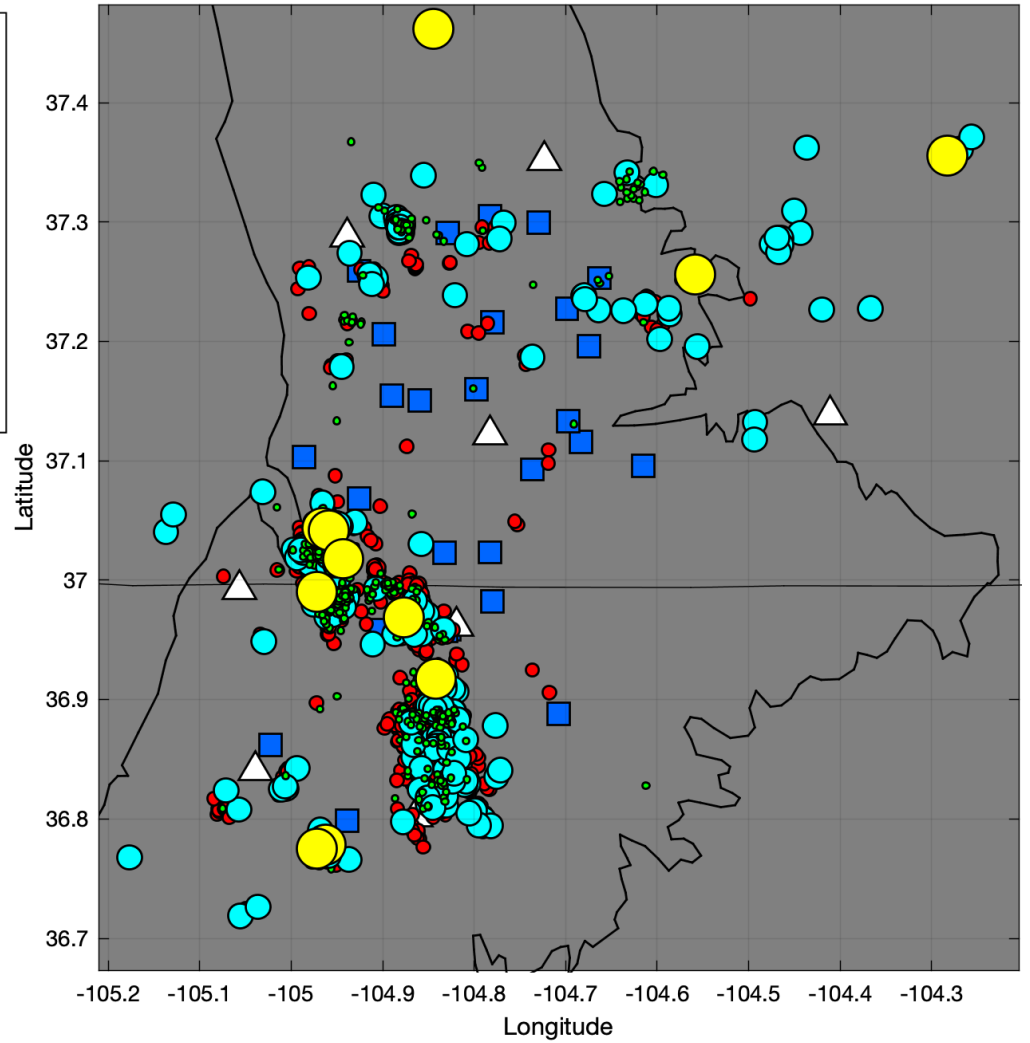
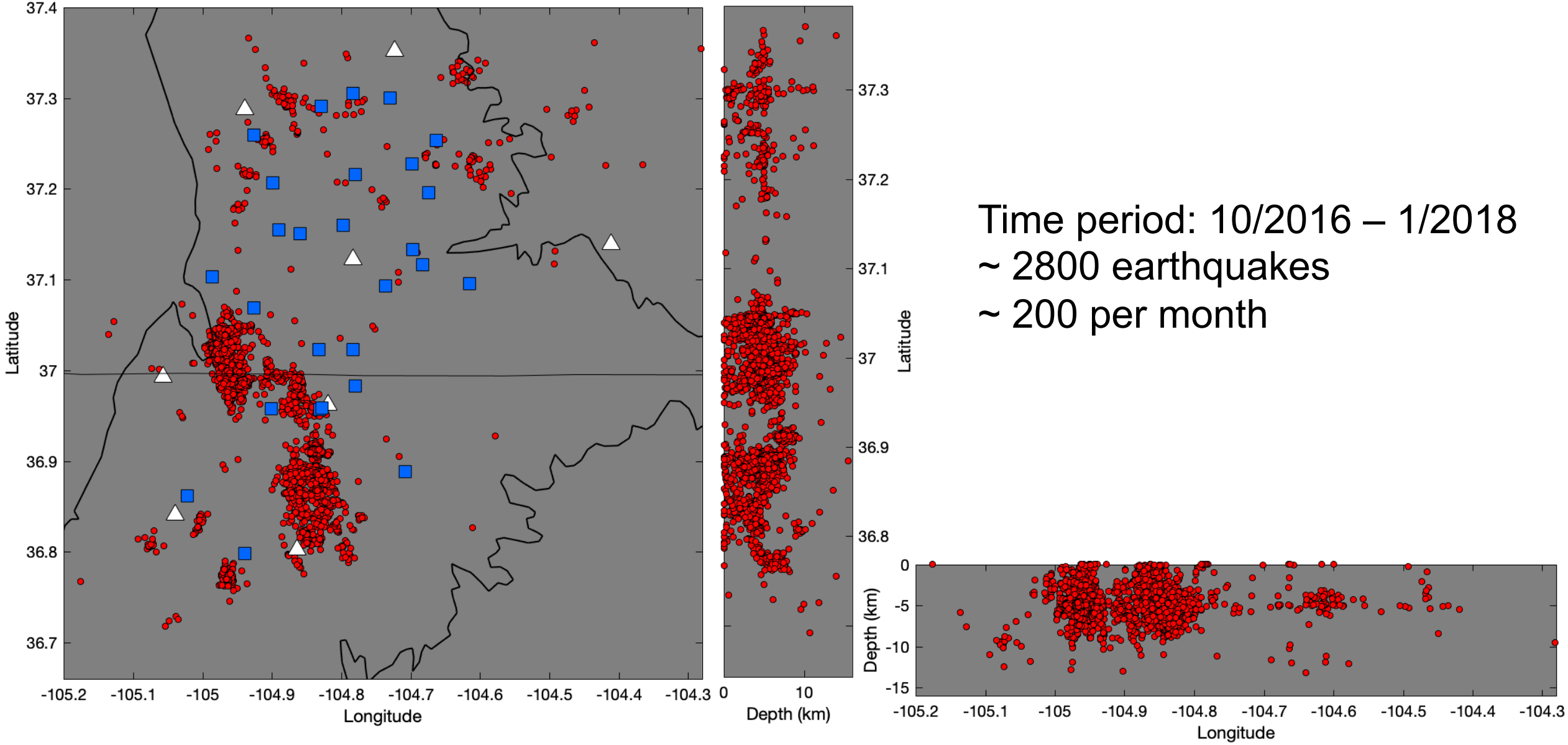


RESULTS: Location

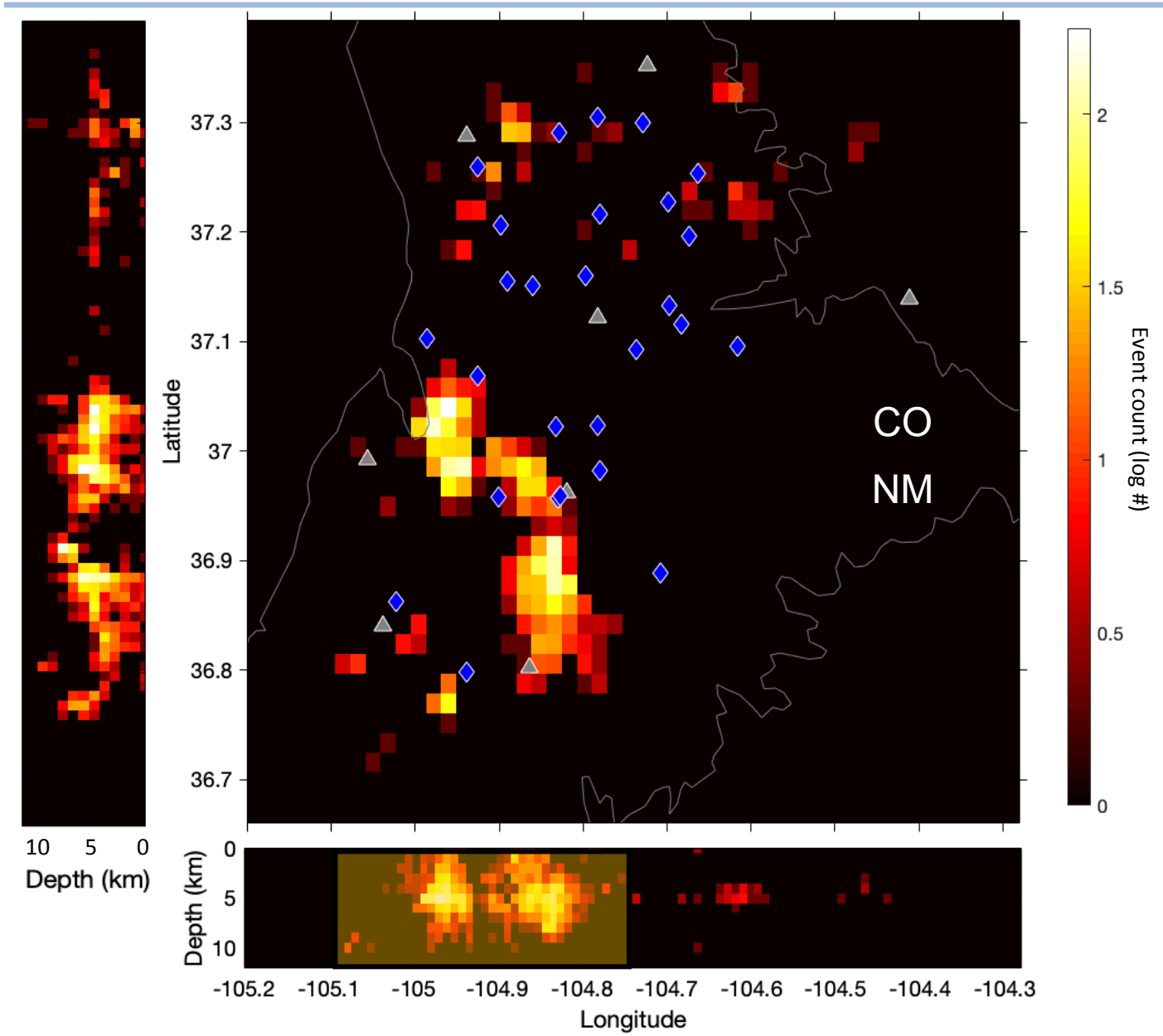
injection well
seismometer



Time period: 10/2016 – 1/2018
~ 2800 earthquakes
~ 200 per month

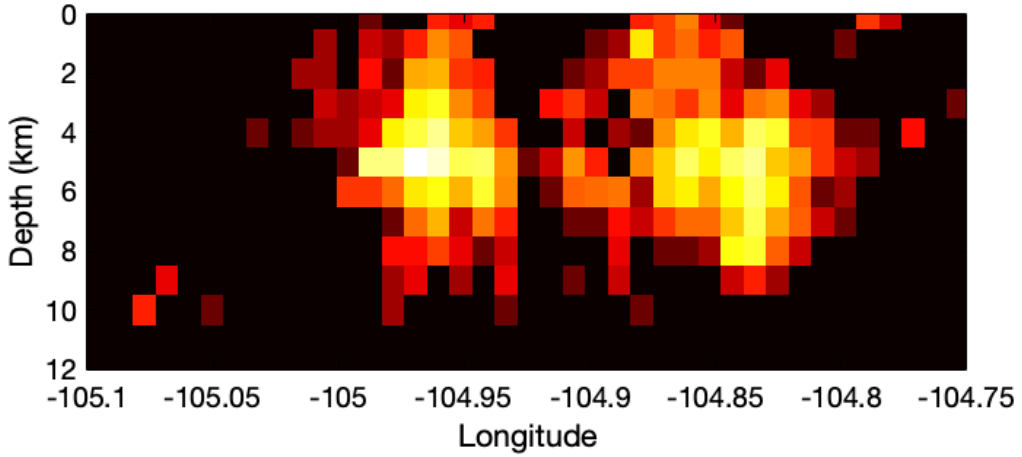
RESULTS: Location

injection well
seismometer



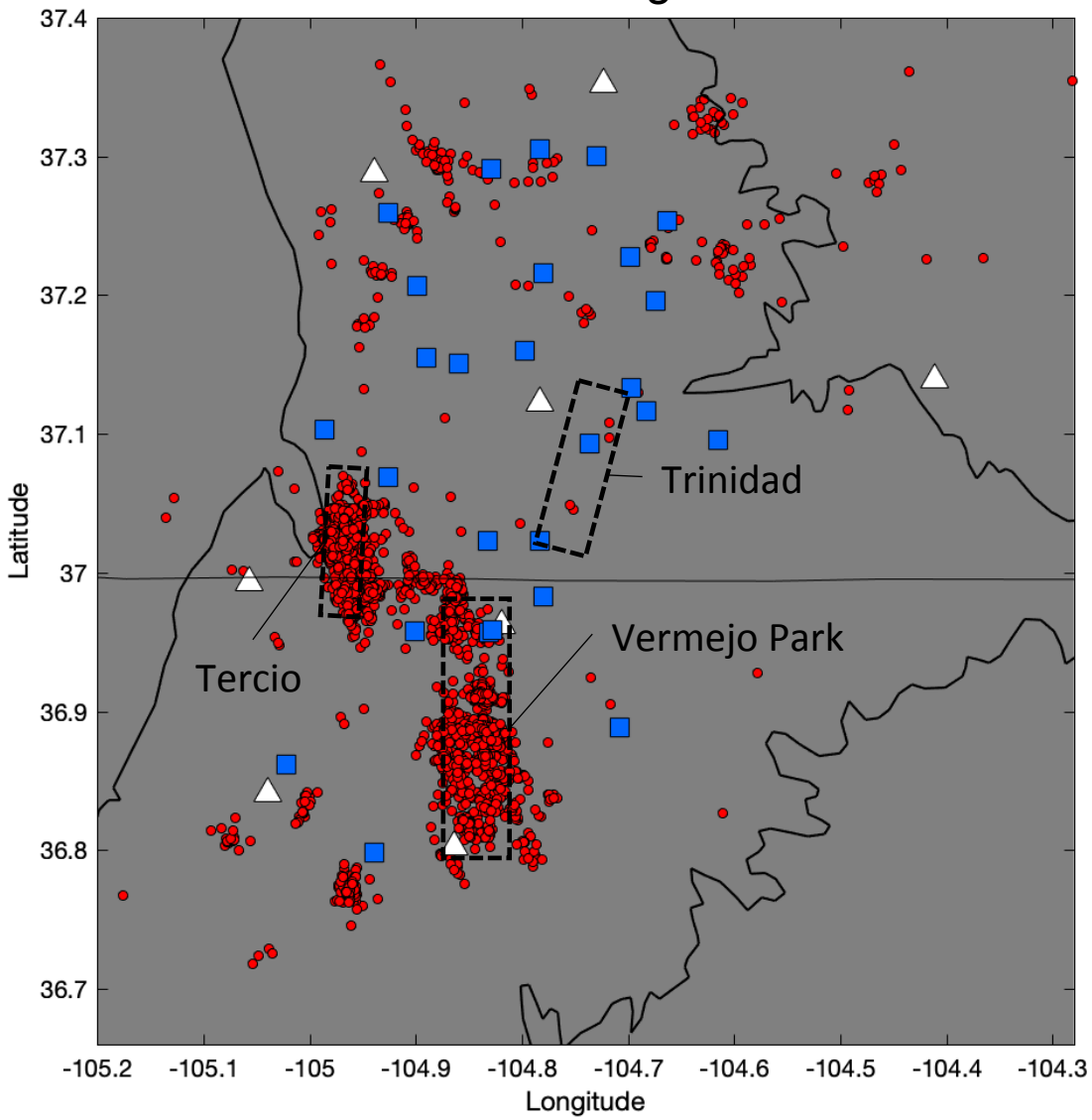
Majority of seismicity:

- In west-central basin at basement depths
- From 3–6 km depth

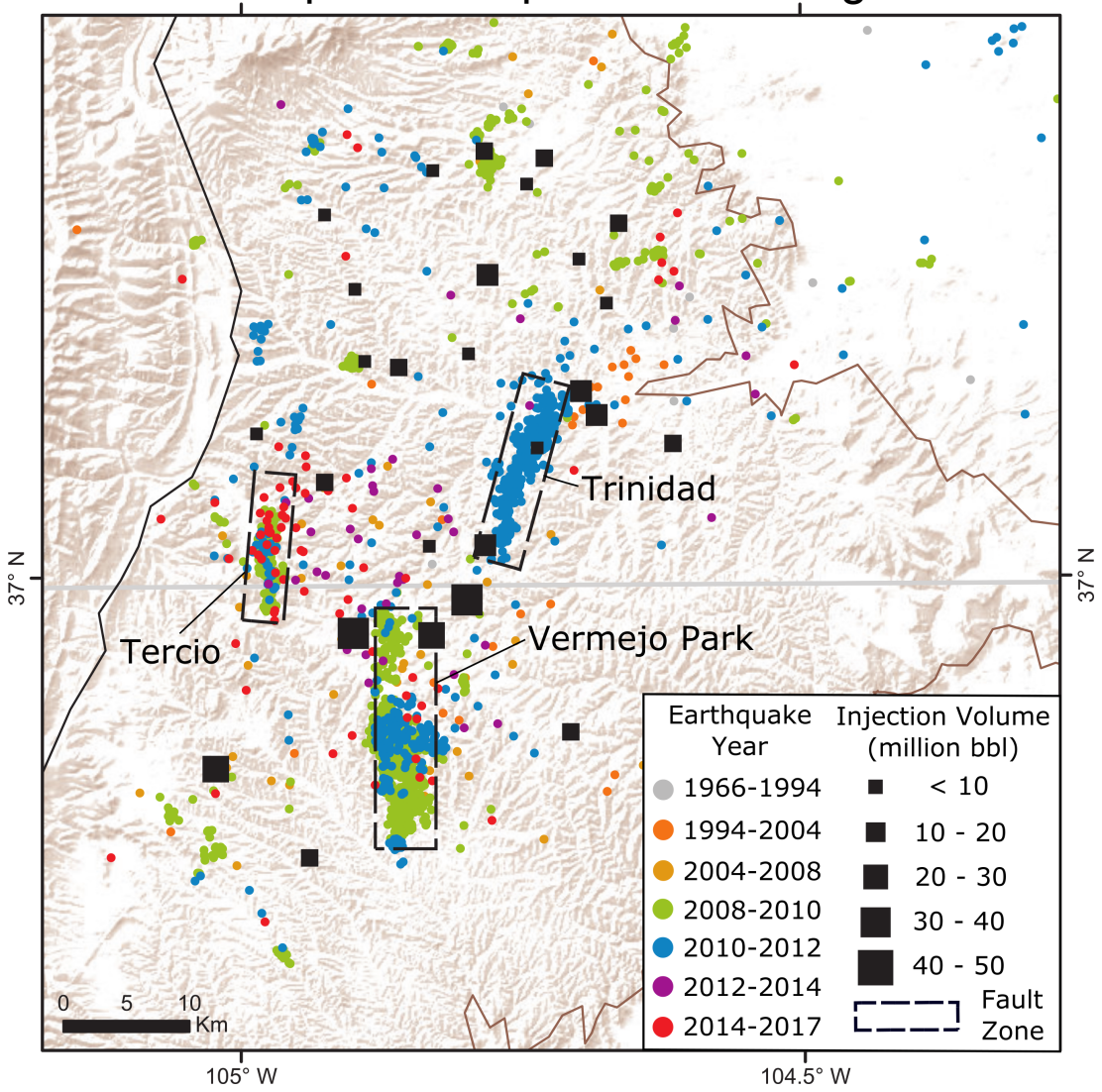


RESULTS: Comparison of location studies

Our catalog



Compilation of previous catalogs

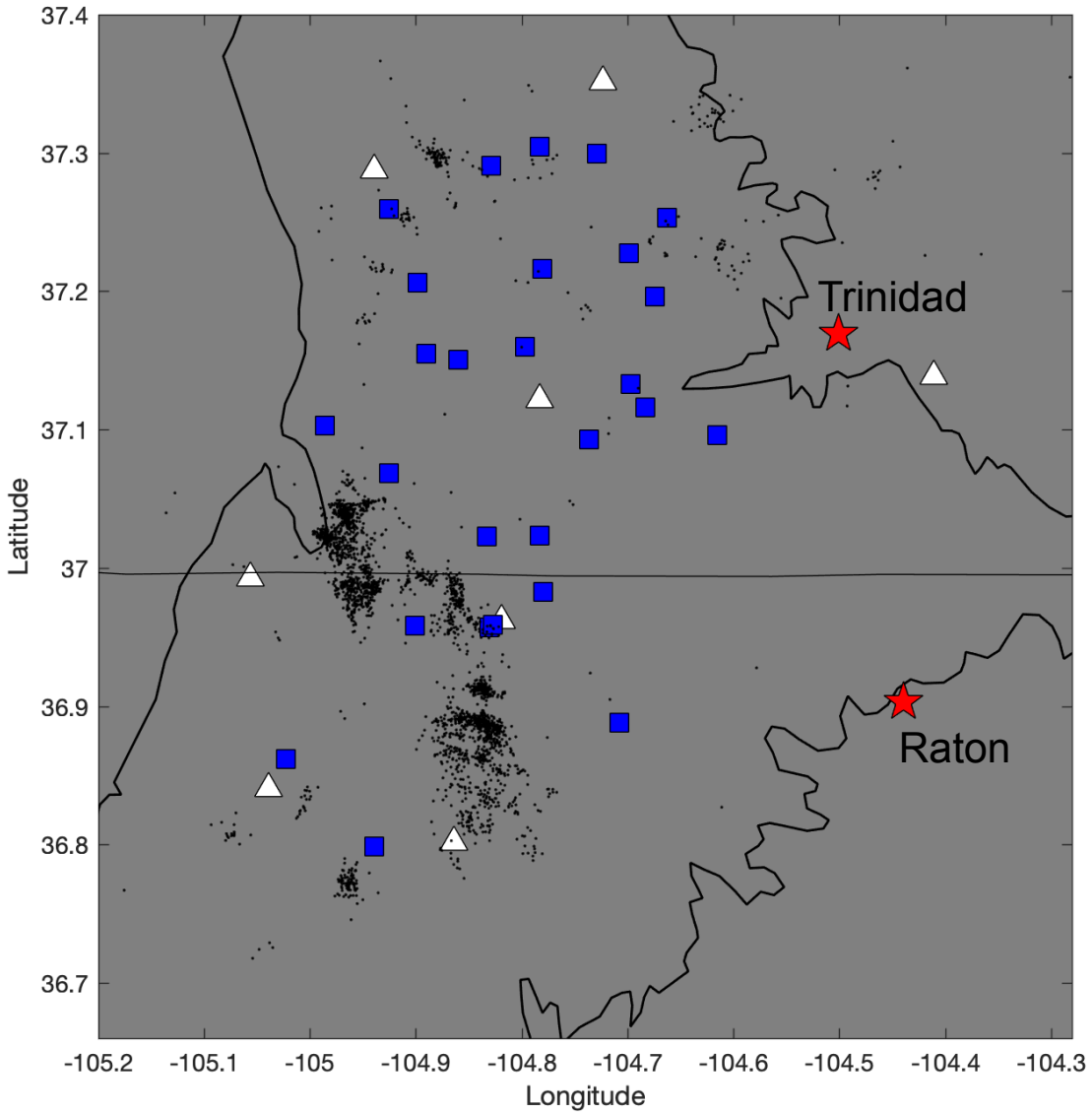


(Pers. comm. Weingarten, 2018)

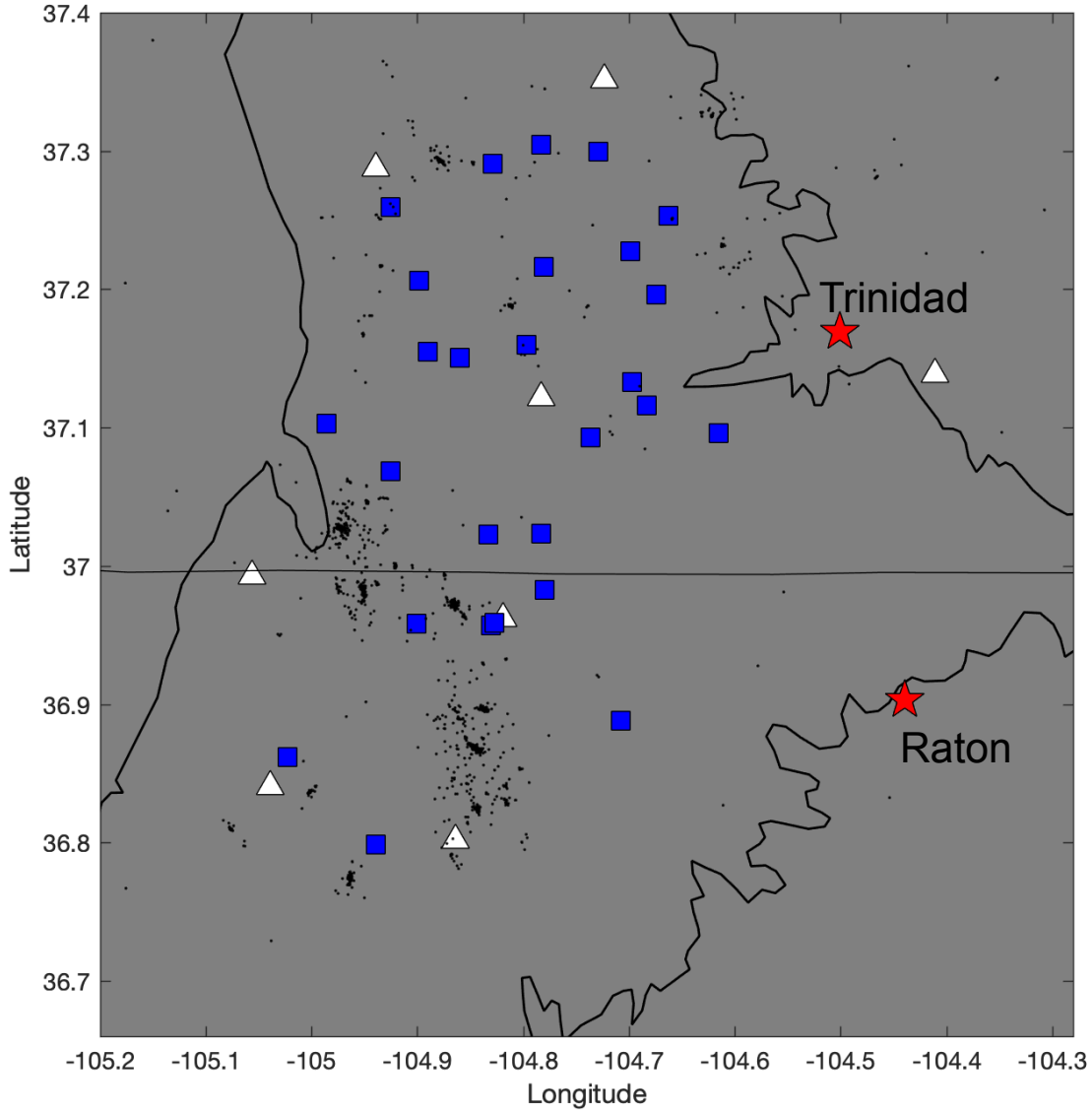
Preliminary results: Earthquake relocation

Prelim RESULTS: Relocating earthquakes

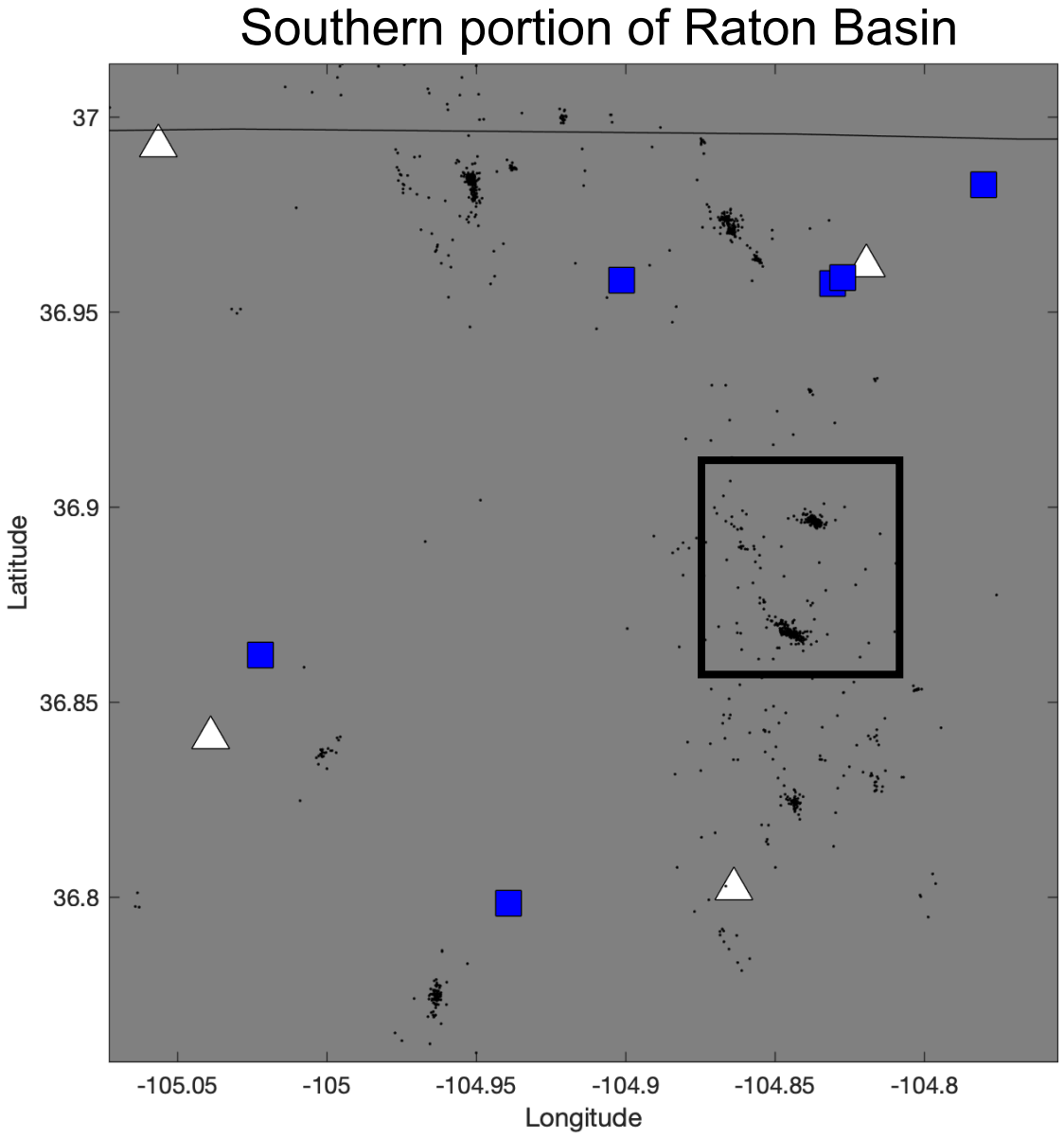
Before relocation

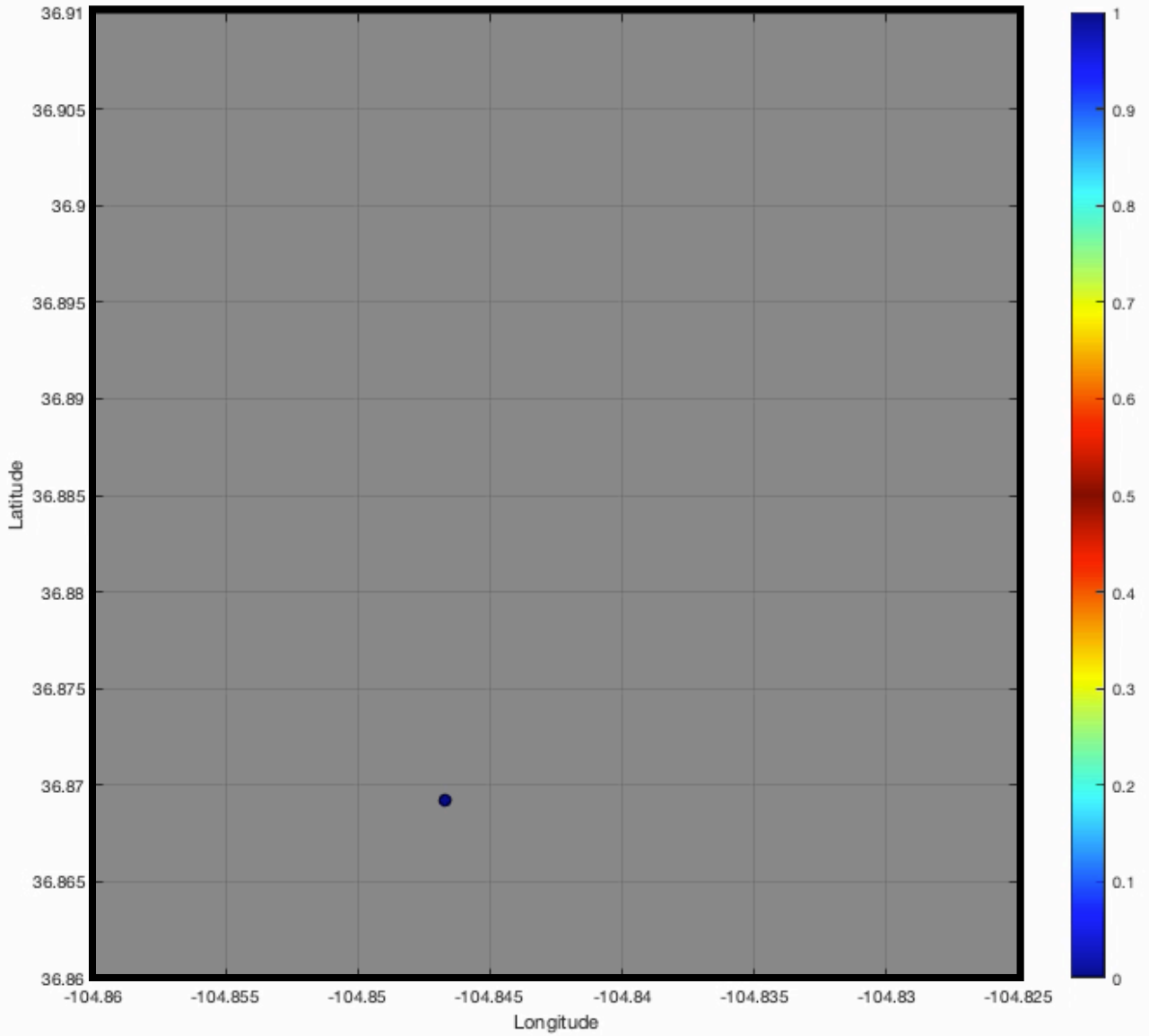


After relocation

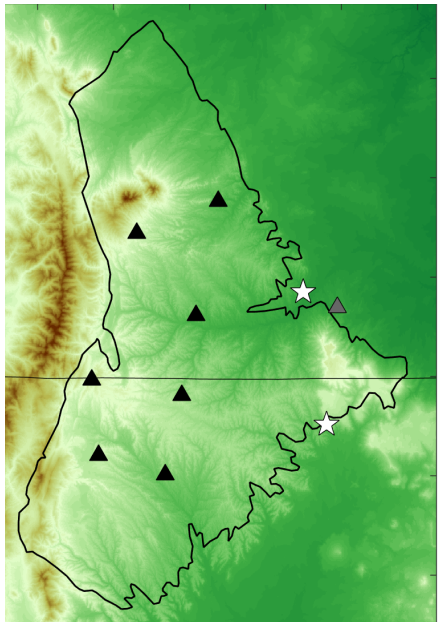


Prelim RESULTS: Relocating earthquakes

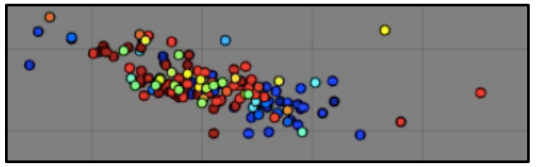




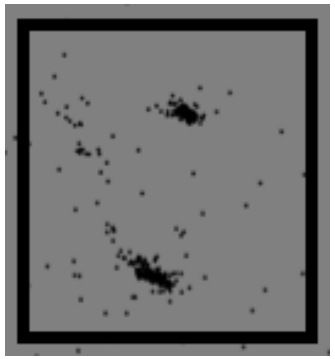
Conclusion



1) Raton Basin seismic data is open source



2) University of NM has an ongoing project to build an earthquake catalog for the Raton Basin



3) Continued investigation active faults in the region and how they could be linked to wastewater injection

Contact: mglasgow@unm.edu

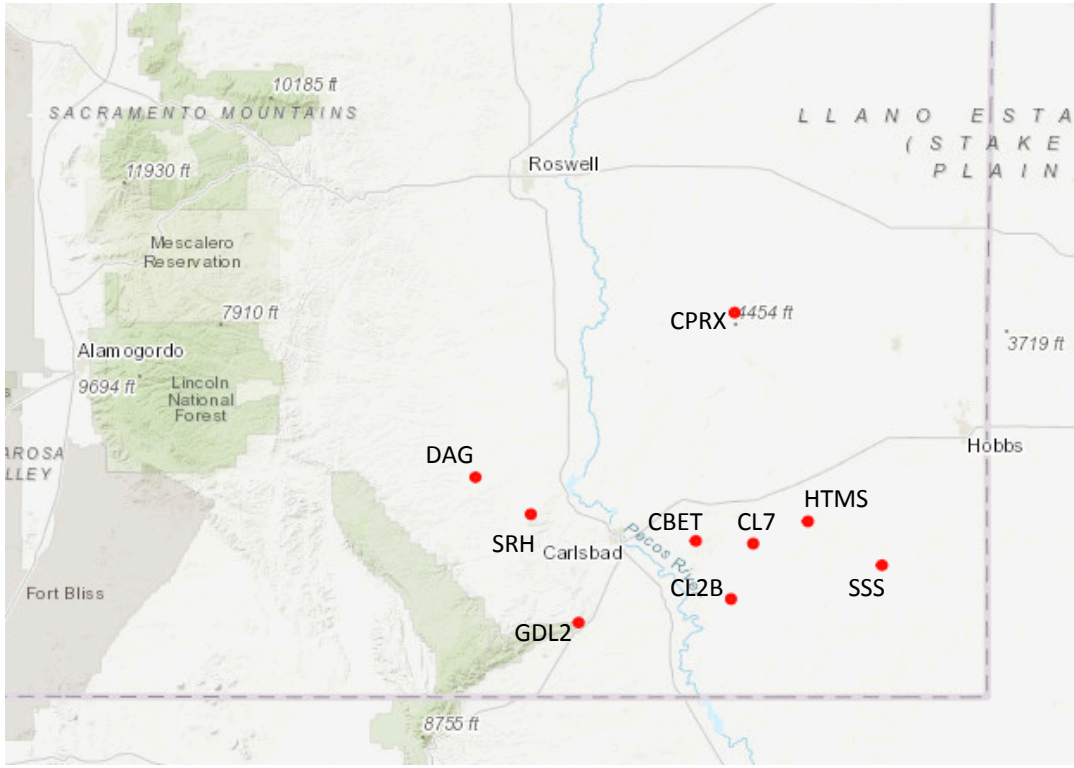
https://doi.org/10.7914/SN/YX_2016

Summary

- Seismic activity linked to fluid injection has occurred in the last 20 years in New Mexico in the Delaware Basin in SE NM and the Raton Basin in NE NM
- Dense seismic networks allow us to locate earthquakes more precisely, which is necessary for understanding the link between injection and seismicity
- We hope to continue improving our monitoring capabilities across New Mexico

Future Plans for Network

- Increased activity in the Permian Basin has caused increasing noise for seismometers
  - Improve existing stations: broadband seismometers, bury sensors more deeply
  - Add new stations
- Collaborations with other states and government agencies, as well as industry
- Make earthquake locations available in near-real time online



https://geoinfo.nmt.edu/nmtso

Thanks!