Geology and Seismicity

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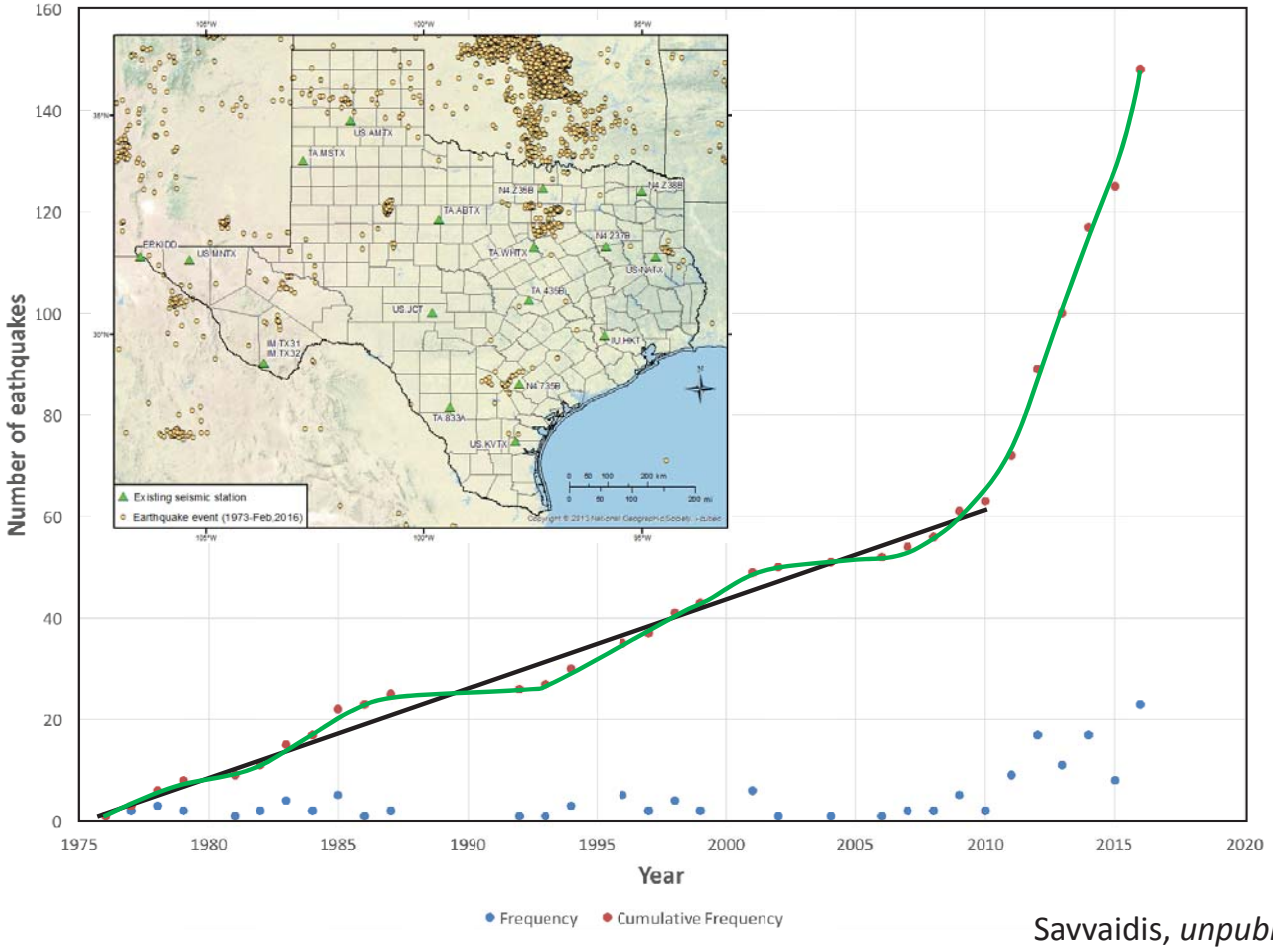
The University of Texas at Austin

Texas Seismicity – USGS/ANSS catalog M>=3.0



Savvaidis, *unpublished*

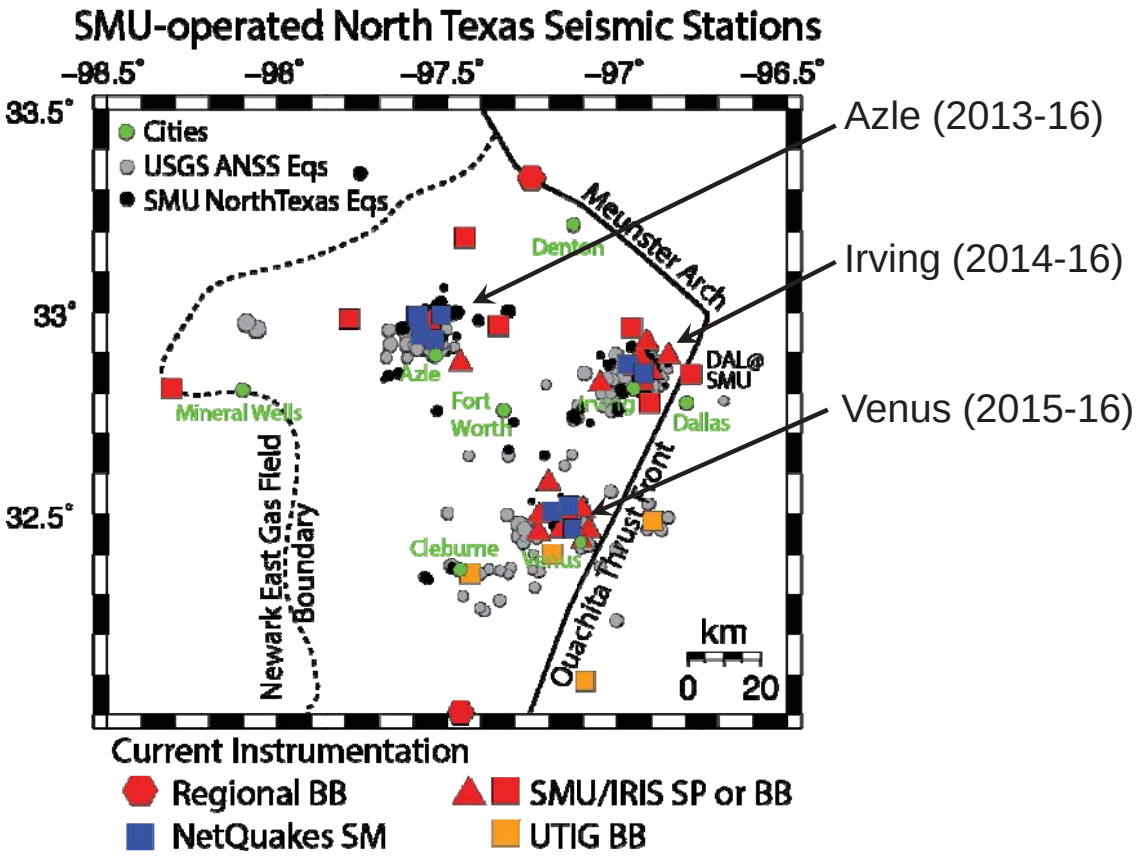
Fort Worth Basin Seismicity

Seismograph stations currently operating in the Fort Worth Basin.

USGS has reported 204 M1.8+ earthquakes in this region since 2008.

SMU has reported over 1500 small earthquakes ranging from M<0 to M4 since beginning network operations in late 2013.

Heather DeShon (SMU)



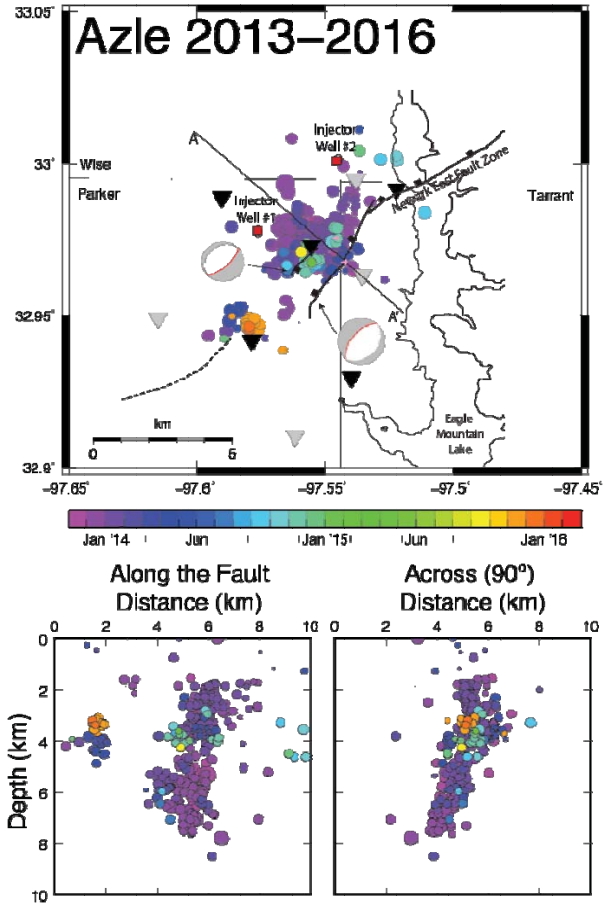
Azle (2013-16)

Irving (2014-16)

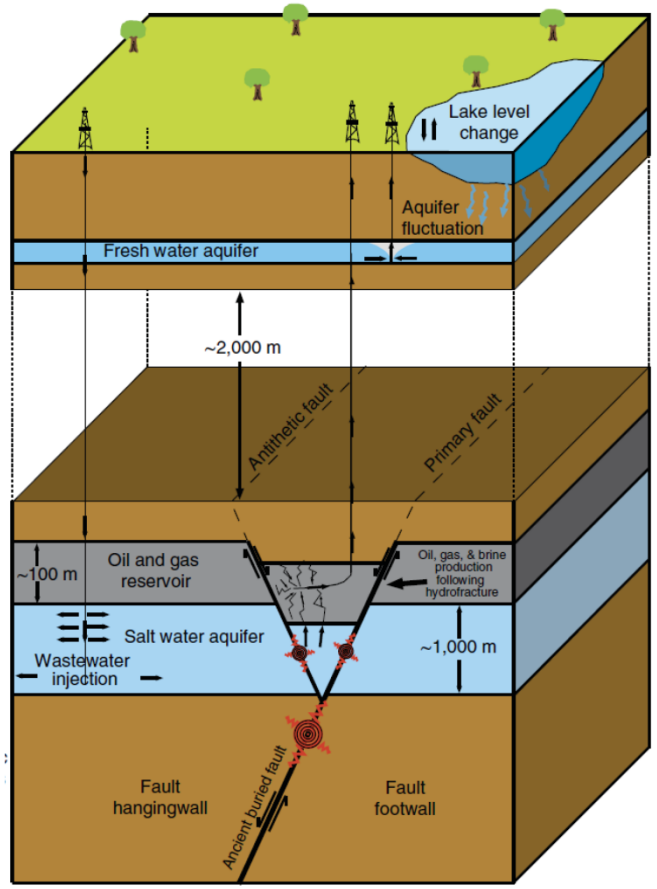
Venus (2015-16)

TexNet CISR

Fort Worth Basin Seismicity - Azle

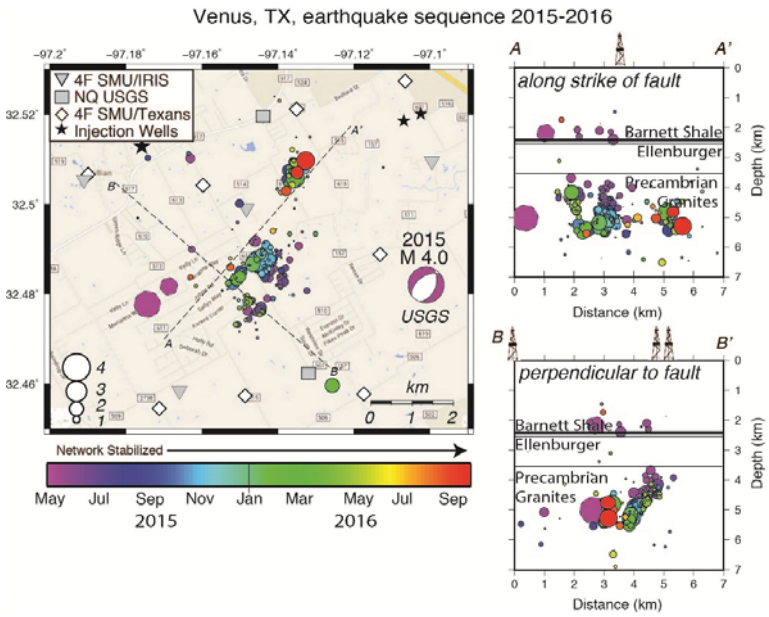


Azle earthquakes 2014-16, DeShon.

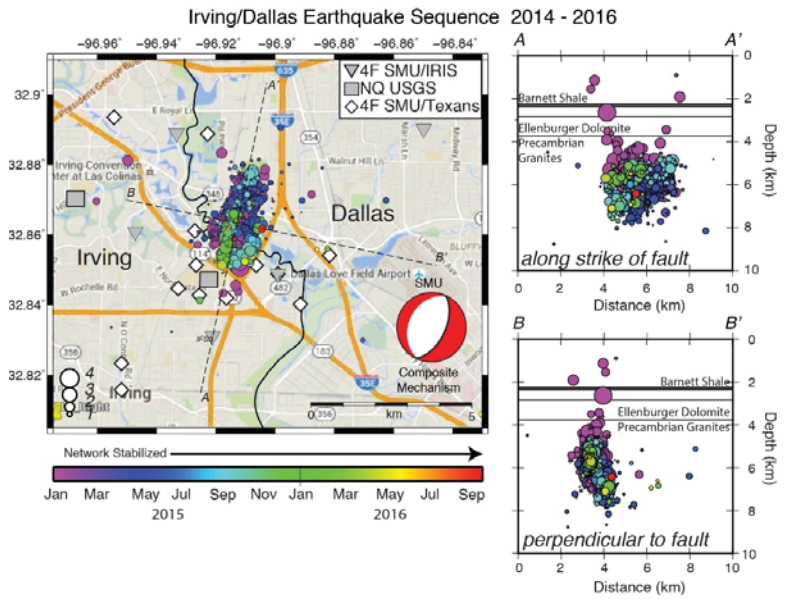


Azle conceptual model, Hornbach (2015)

Fort Worth Basin Seismicity – Venus and Irving

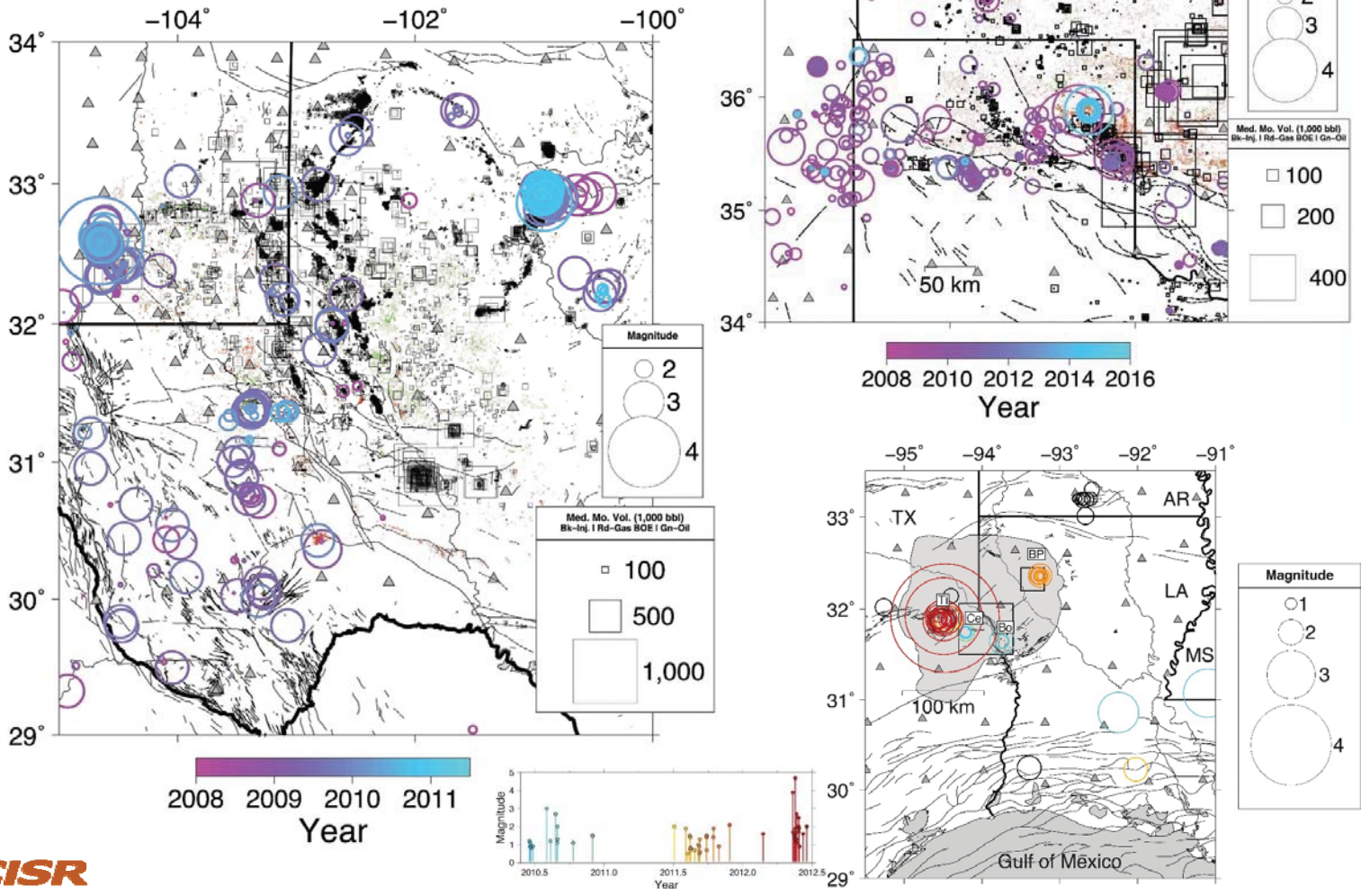


Venus earthquakes 2015-16, DeShon.



Irving earthquakes (2014-16), DeShon.

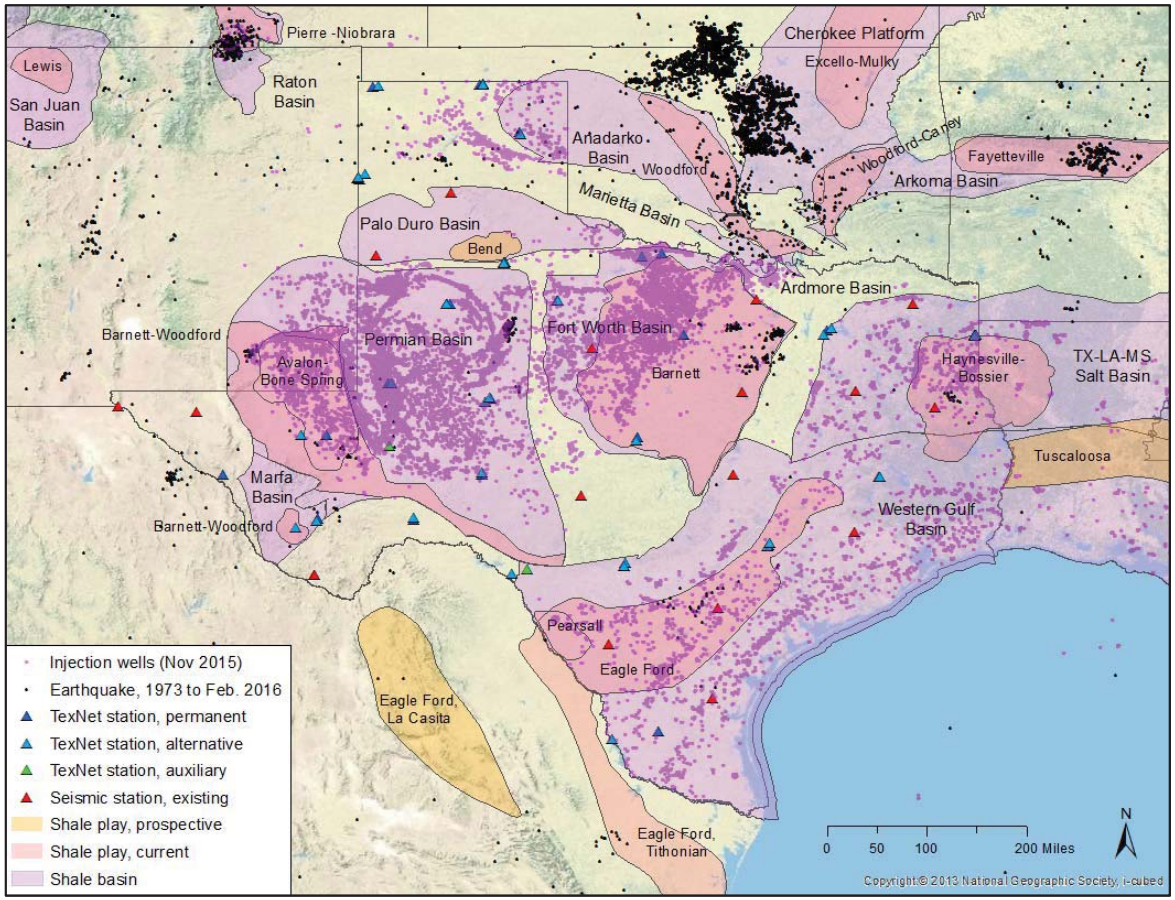
Texas Seismicity Walter et al., *in prep*



TexNet–CISR

Texas Shale Basins and Injection

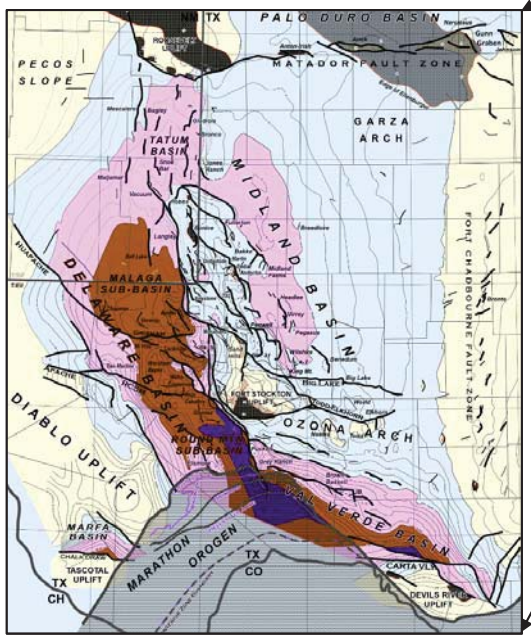
- ~50,000 injection wells permitted since 1930's
- ~34,000 active injection wells associated with enhanced oil production
- ~8,000 permitted disposal wells (UIC Class II)



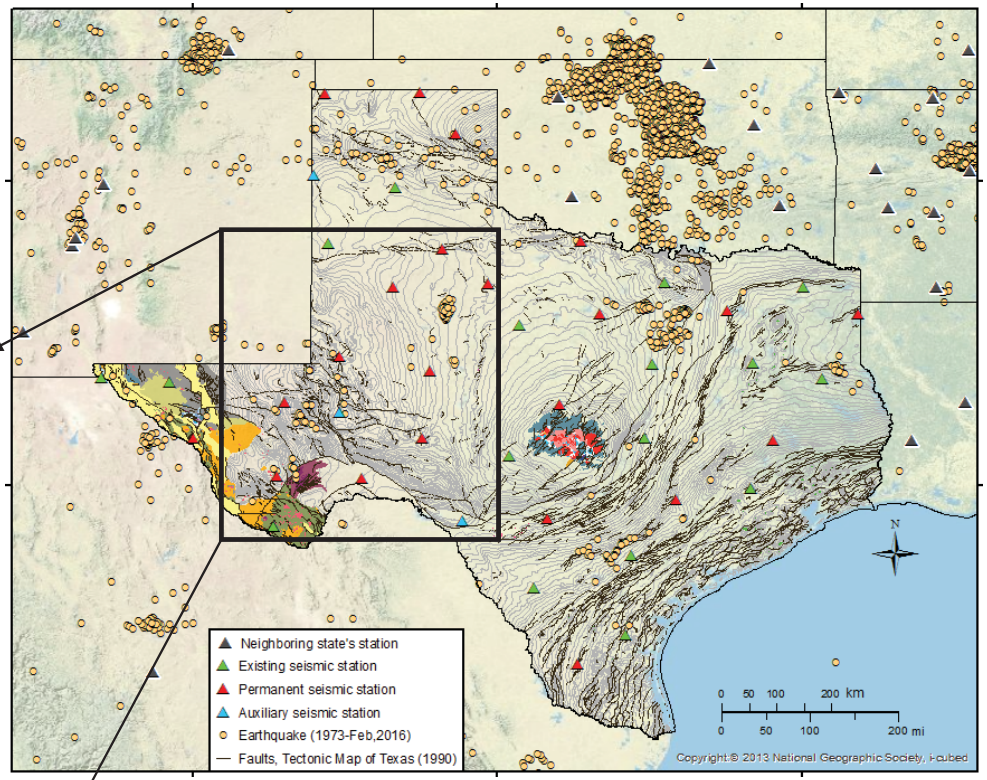
TexNet-CISR

Texas Geology

Many known subsurface fault systems that are poorly documented publically



Ewing, *in press*

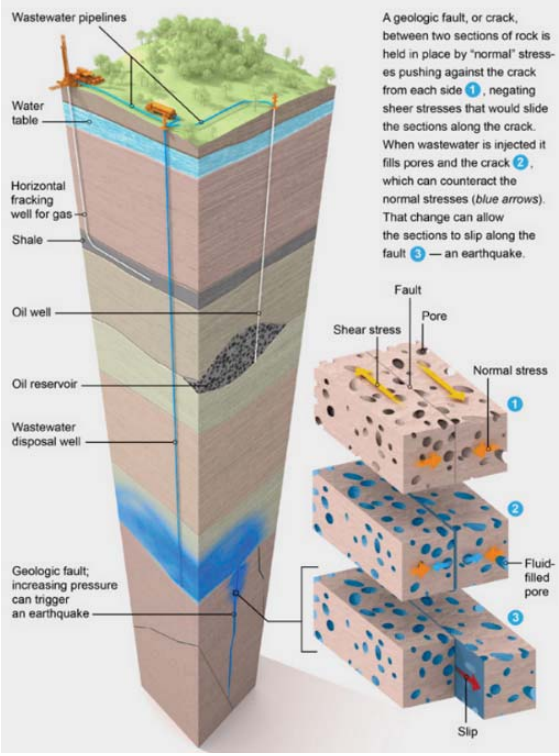


BEG after Ewing

12+ distinct tectonic areas

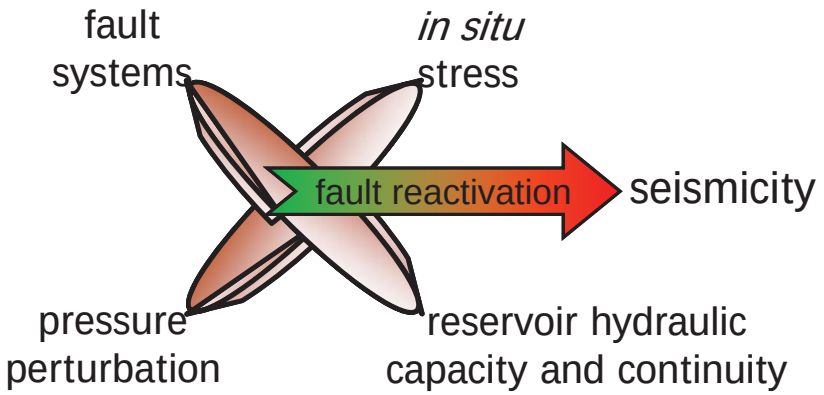
- Anadarko Basin
- Amarillo Uplift
- Palo Duro Arch
- Midland Basin
- Delaware Basin
- Trans-Pecos/Marathon
- Val Verde
- Gulf Coast
- Talco/Mexia/Balcones
- East Texas Basin
- Sabine Uplift
- Ft Worth Basin
- Llano/Bend Arch

Induced Seismicity Mechanisms



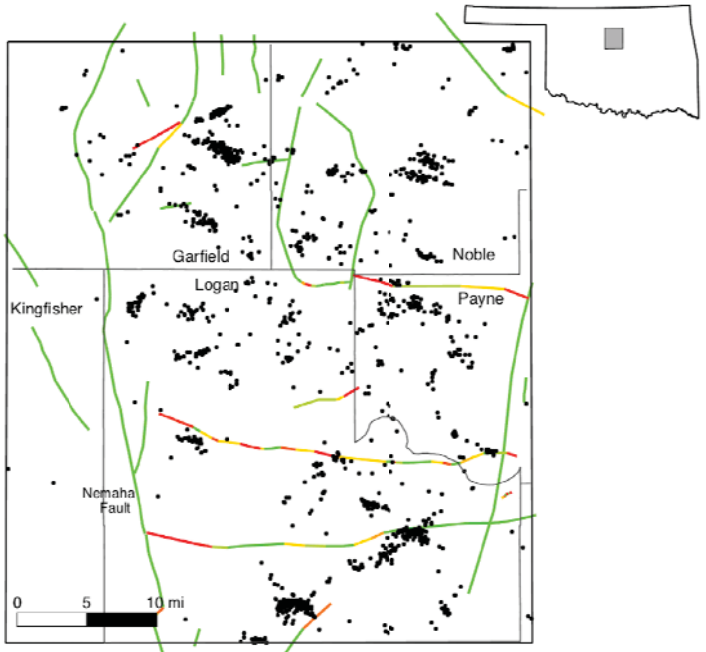
Scientific American, Anna Kuchment, 2016

KEY FACTORS:

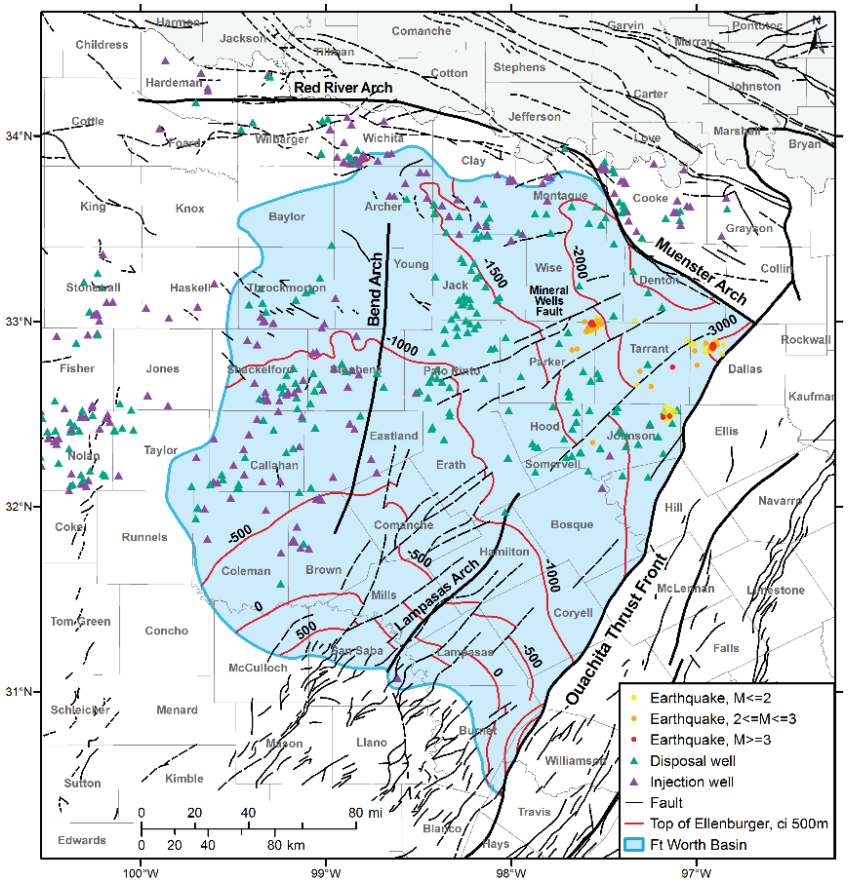


These factors are dynamically coupled...

Faults - most of the recent earthquakes are occurring along undocumented faults



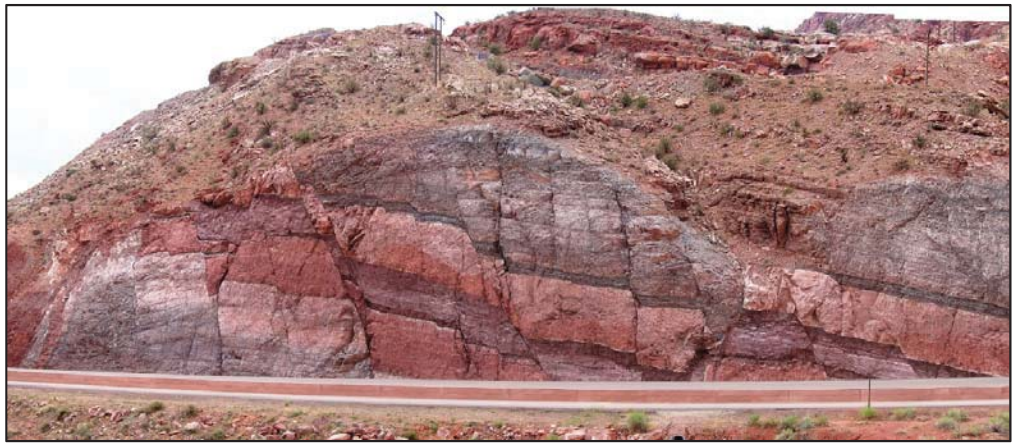
Walsh and Zoback, *in press*



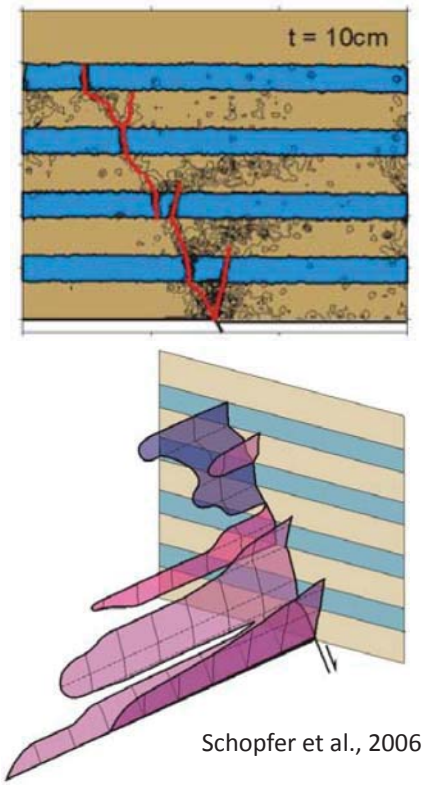
BEG, *unpublished*

TexNet-CISR

Faults – not simple planes

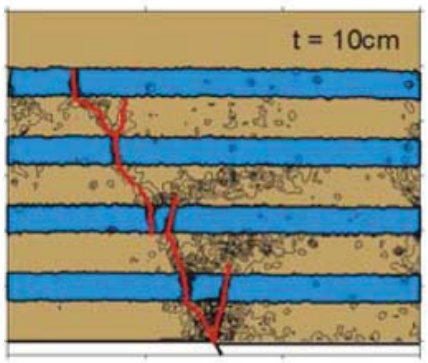


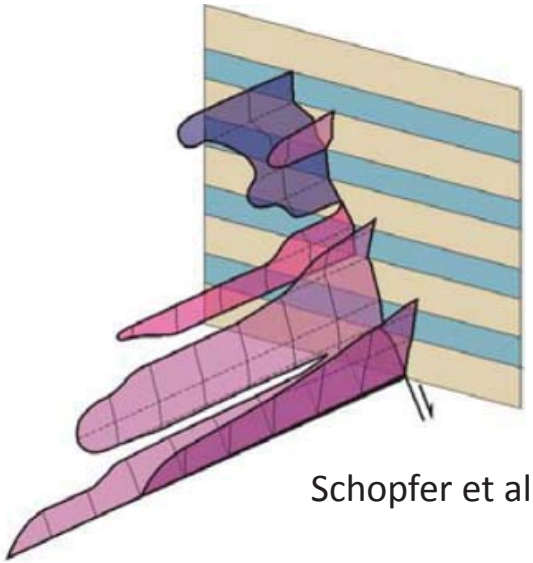
Moab Fault, Hennings



Schopfer et al., 2006

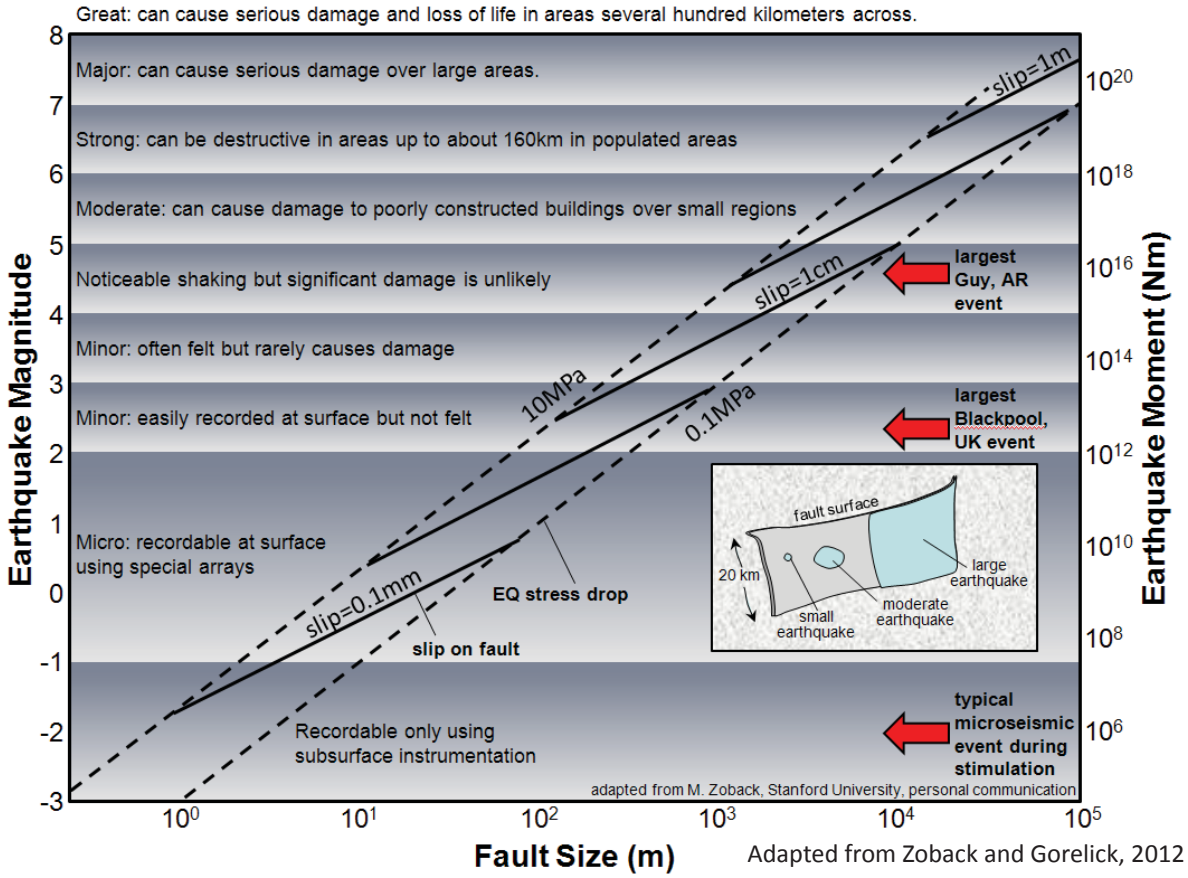
Faults – not simple planes





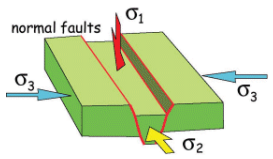
Schopfer et al. (2006)

Earthquake magnitude, fault size, rupture distance

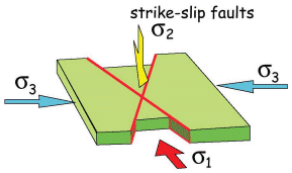


Adapted from Zoback and Gorelick, 2012

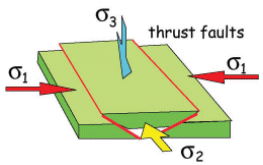
Required Basics - Stress



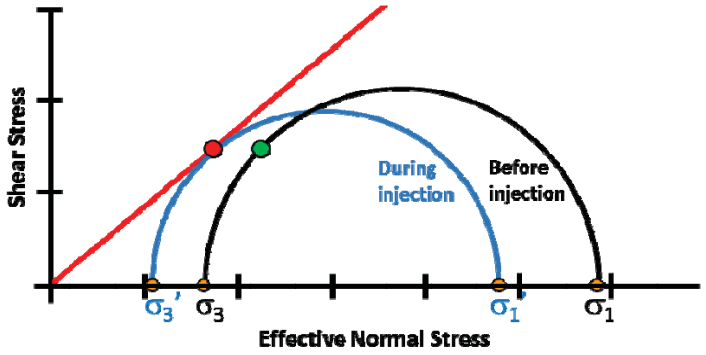
$S_v > S_{Hmax} > S_{hmin}$

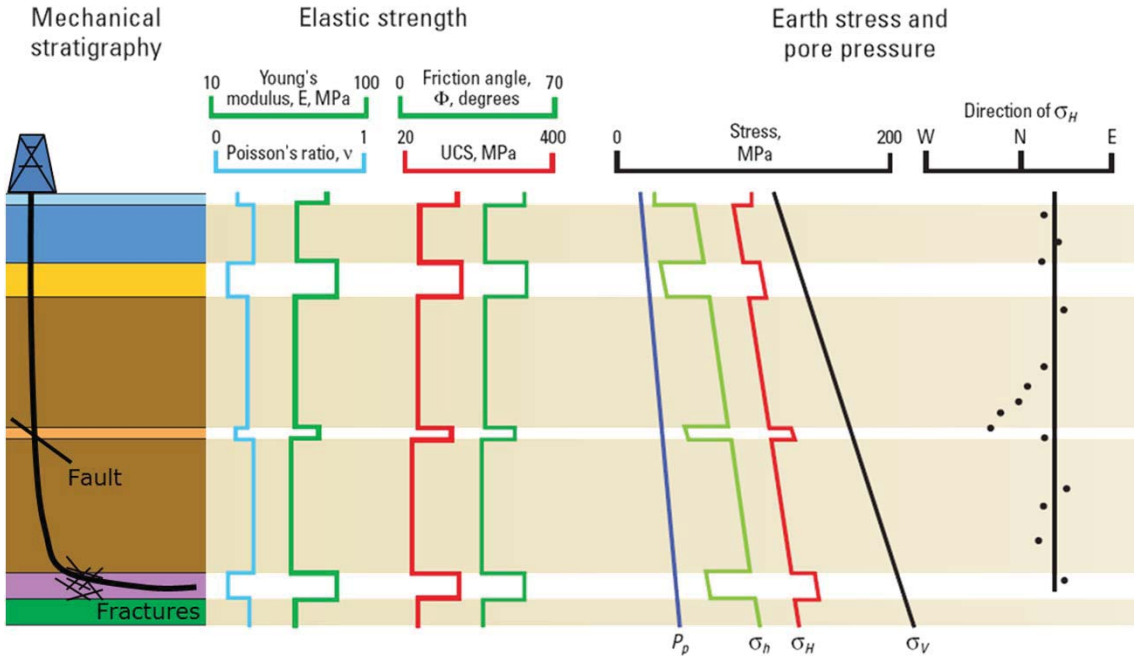


$S_{Hmax} > S_v > S_{hmin}$

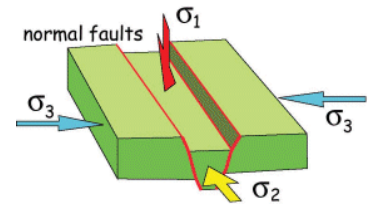


$S_{Hmax} > S_{hmin} > S_v$

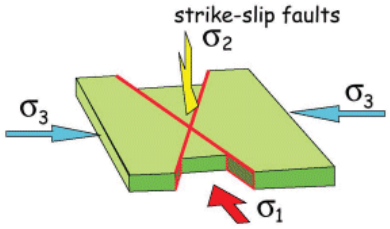




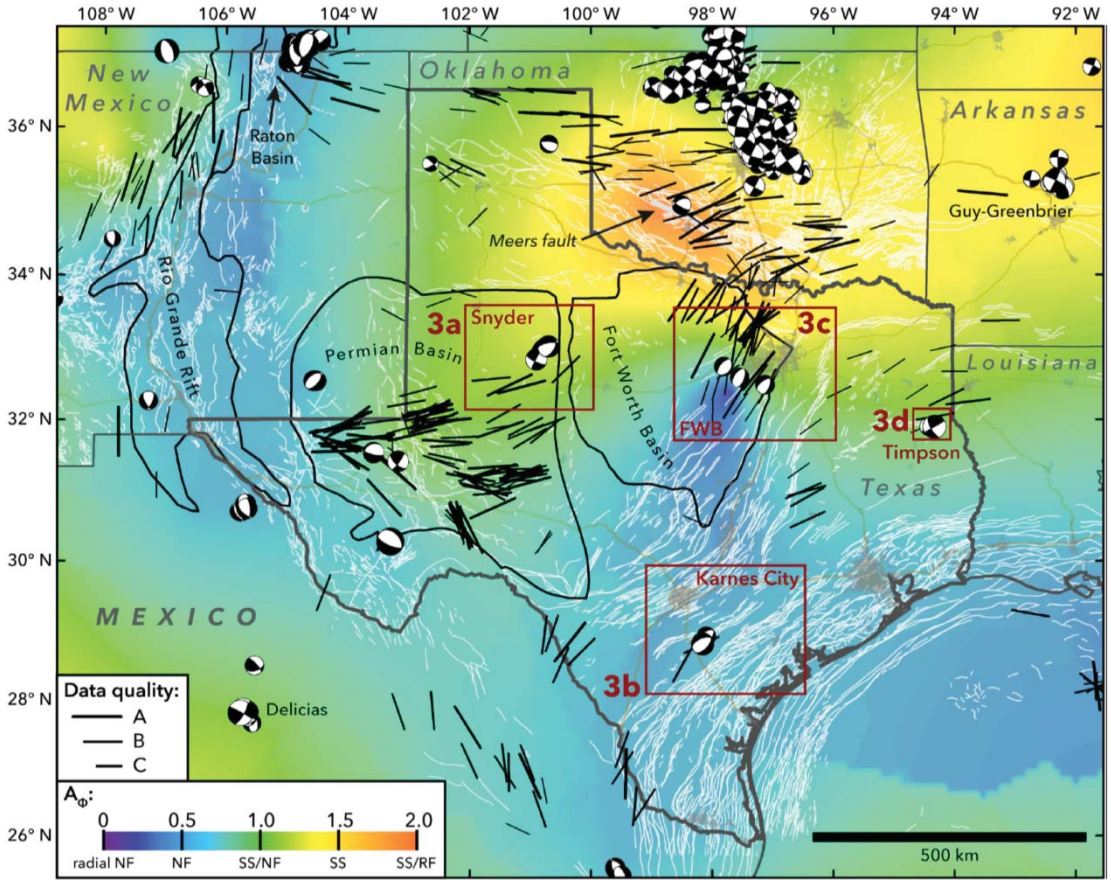
Texas Stress Map



$S_v > S_{Hmax} > S_{hmin}$



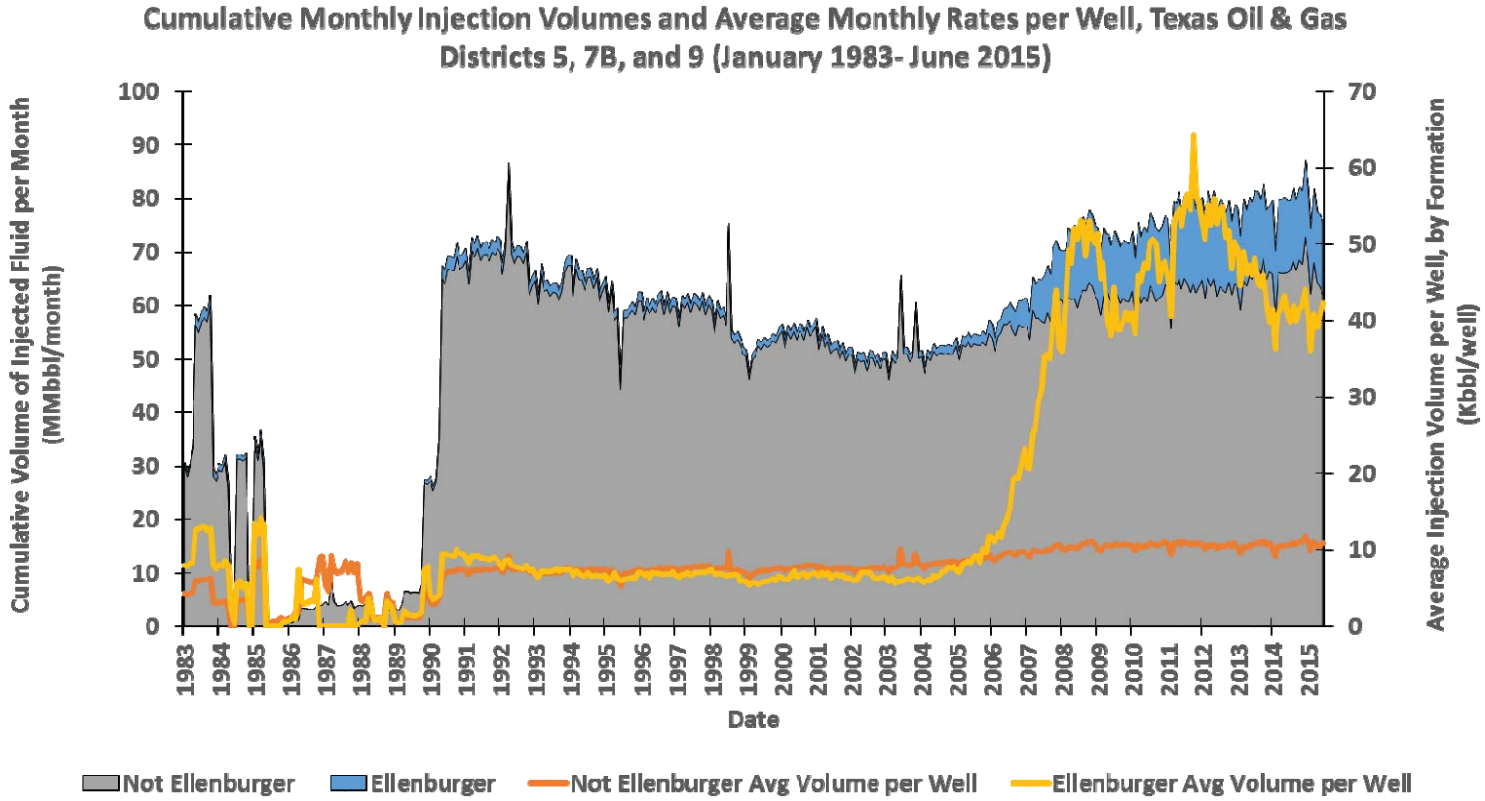
$S_{Hmax} > S_v > S_{hmin}$



Lund Snee and Zoback, *in review*

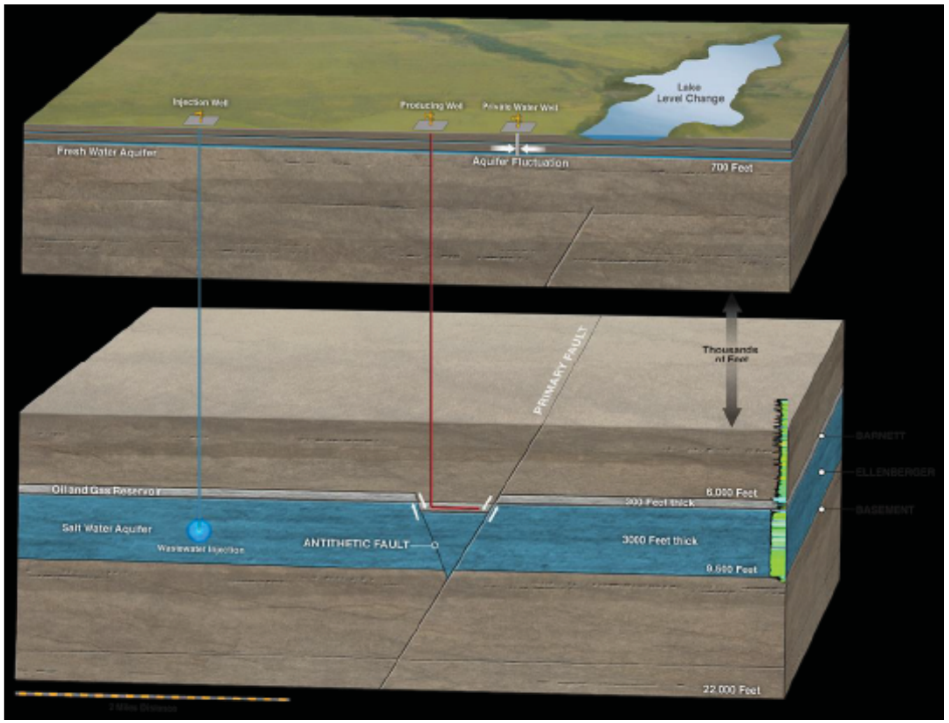
Injection and Pore Pressure

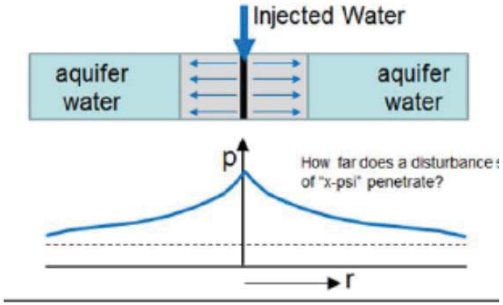
Fort Worth Basin area injection



Lemons and Hennings, *unpublished*

Injection and Pore Pressure





Wellbore pressure given by:

$$p_w = p_{init} + \frac{Q\mu}{4\pi kh}\left\{E_1\left(\frac{r_w^2}{4\eta t}\right) + 2S\right\}$$

Reservoir pressure given by:

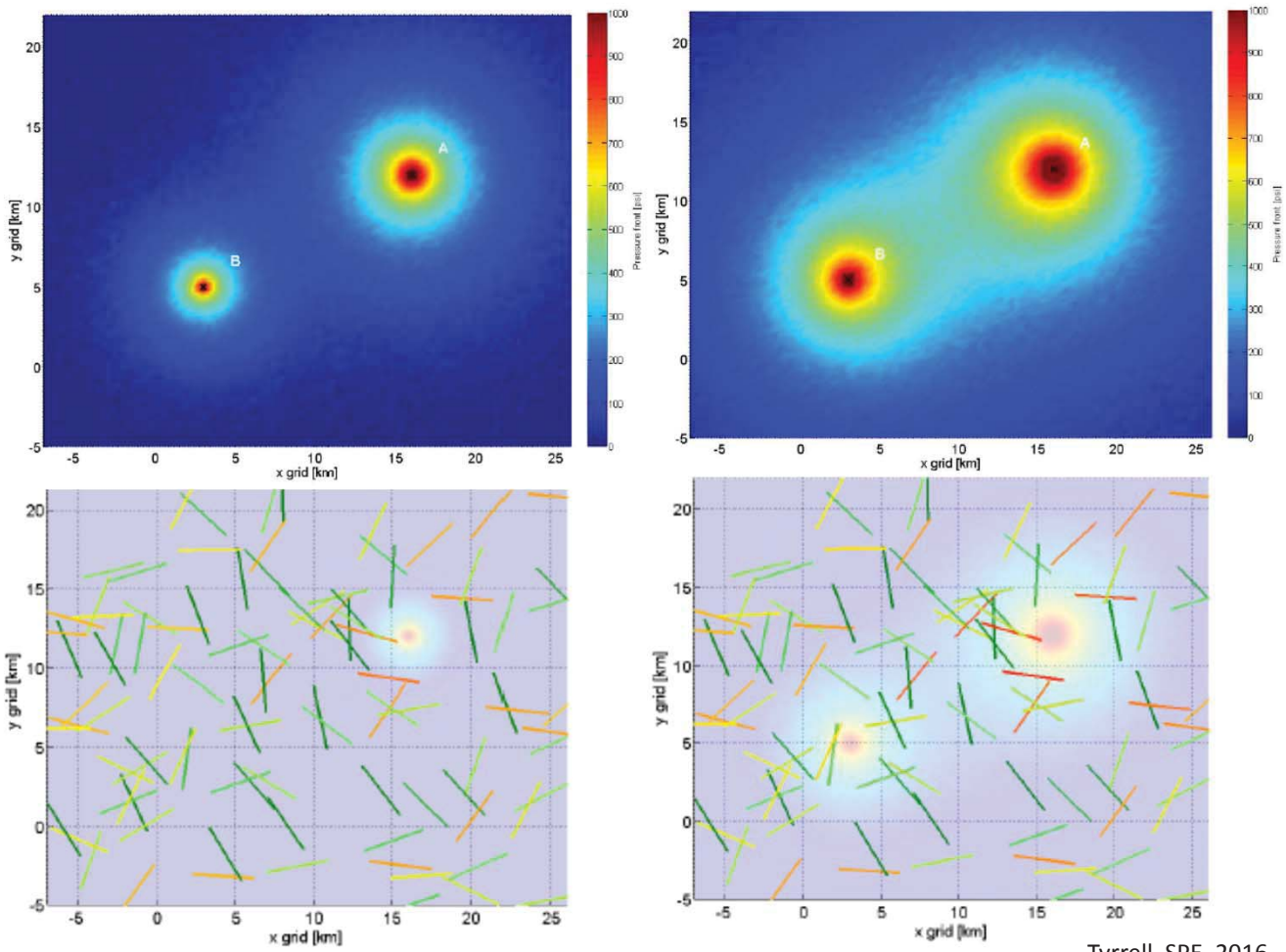
$$p_w = p_{init} + \frac{Q\mu}{4\pi kh}\left\{E_1\left(\frac{r^2}{4\eta t}\right)\right\}$$

Penetration of Δp-isobar given by:

$$r_{\Delta p} = \sqrt{\frac{4\,k\,t}{\phi\,C_T\mu}\,E_1^{-1}\left(\frac{\Delta p}{\left(\frac{Q\mu}{4\pi kh}\right)}\right)}$$

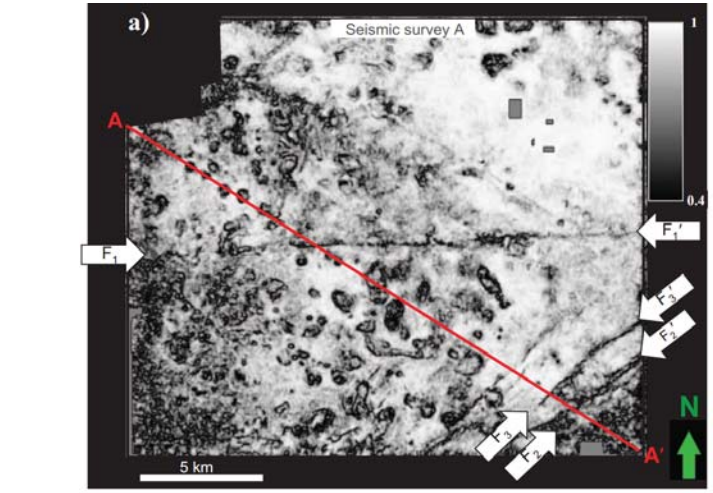
Tyrrell, SPE, 2016

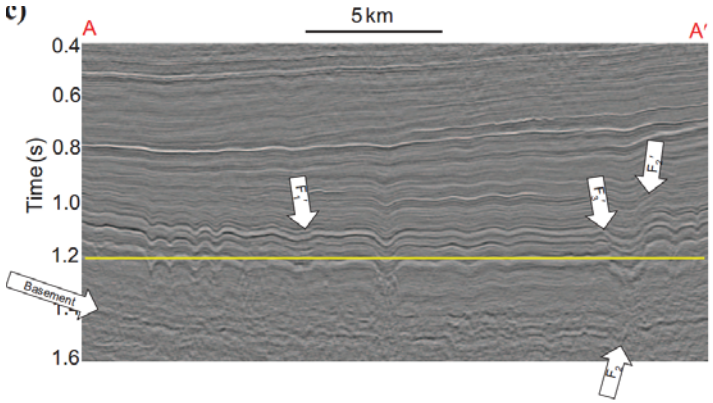
Injection and Pore Pressure



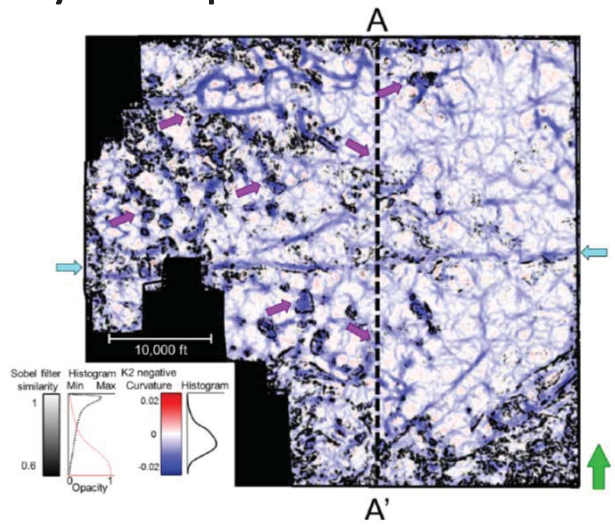
Tyrrell, SPE, 2016

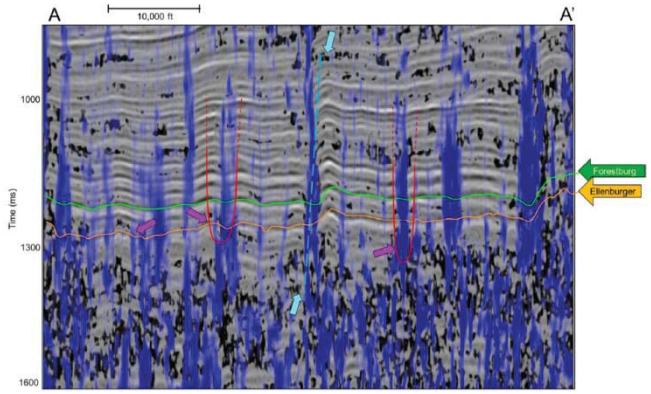
Injection Intervals are Hydrologically Complex





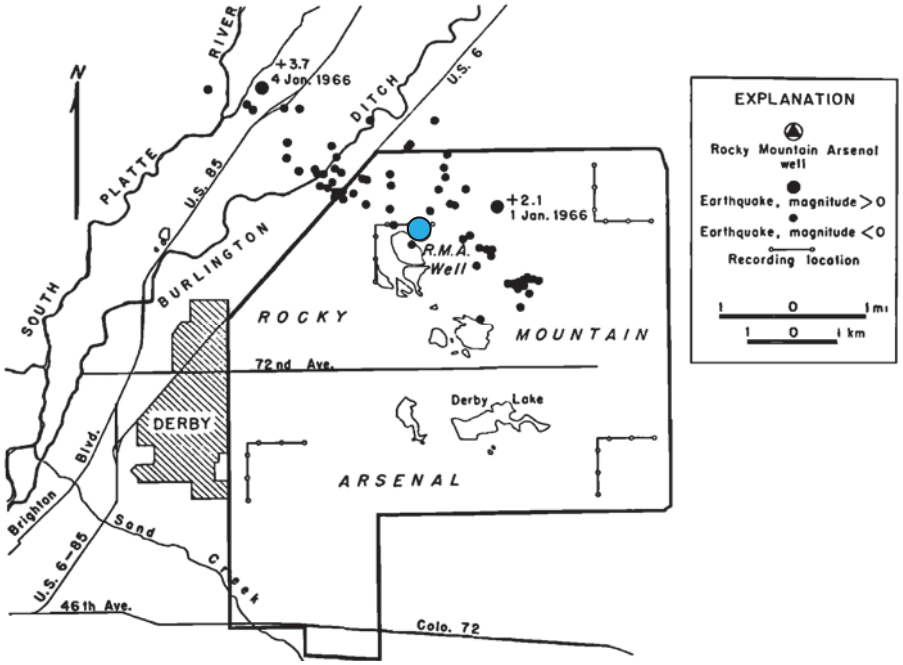
Elebiju et al., 2010



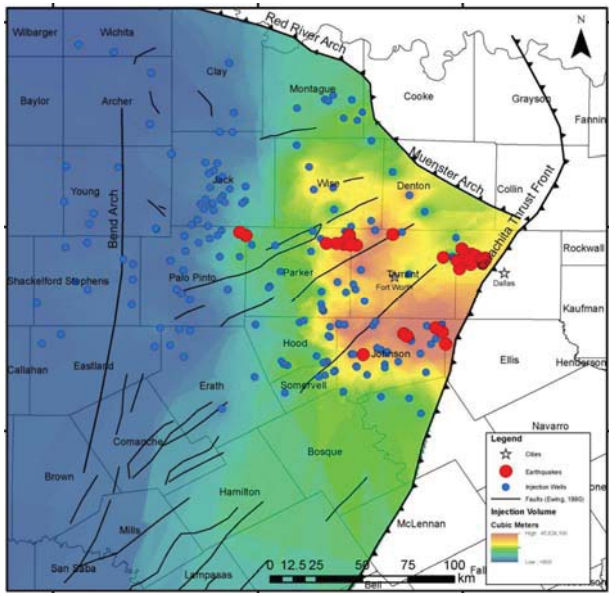


Abad, 2013

Pore Pressure Perturbations May Spread Far and Fast

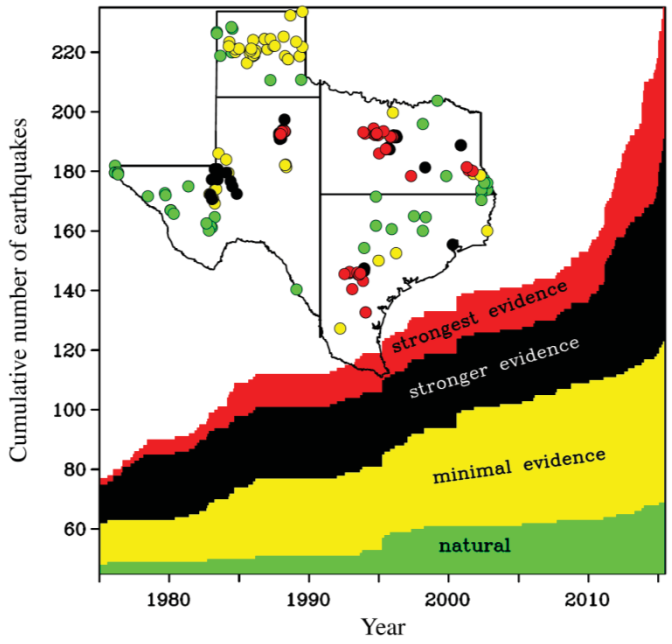


Hsieh and Bredehoeft (1981)

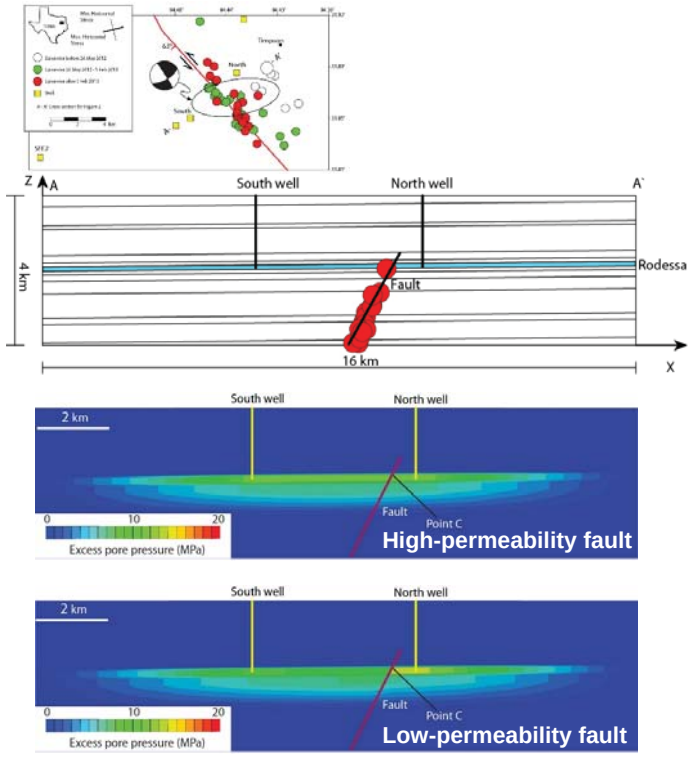


Hornbach et al. (2016)

Need to Move from Associative to Mechanistic Analyses



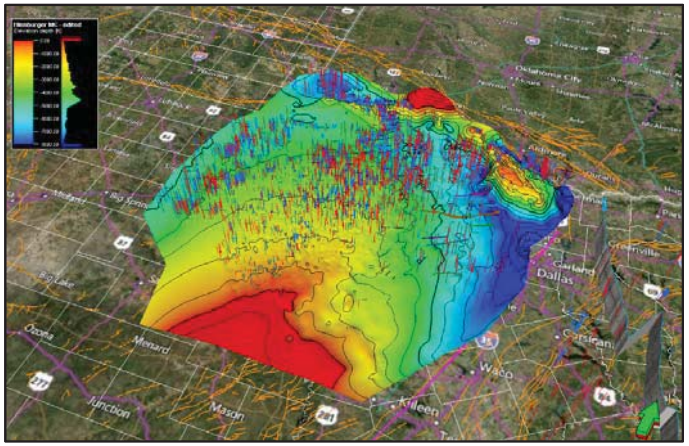
Frohlich et al. (2016)



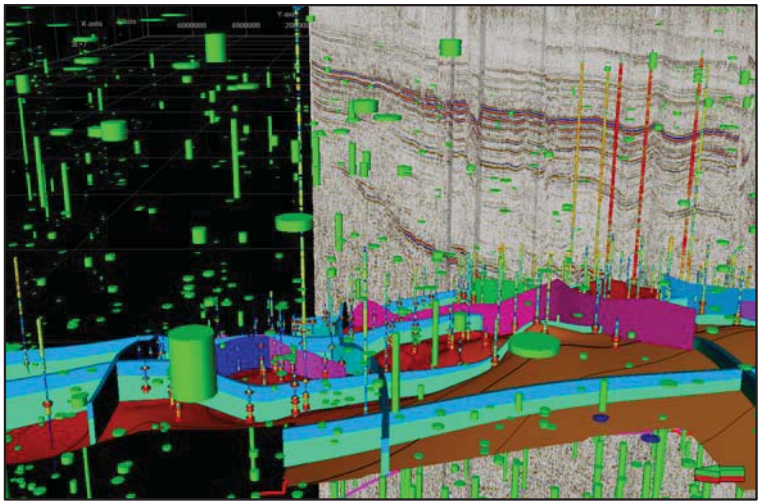
Fan et al. (2016)

Need to Include Comprehensive Geological Controls

Fort Worth Basin 3D model

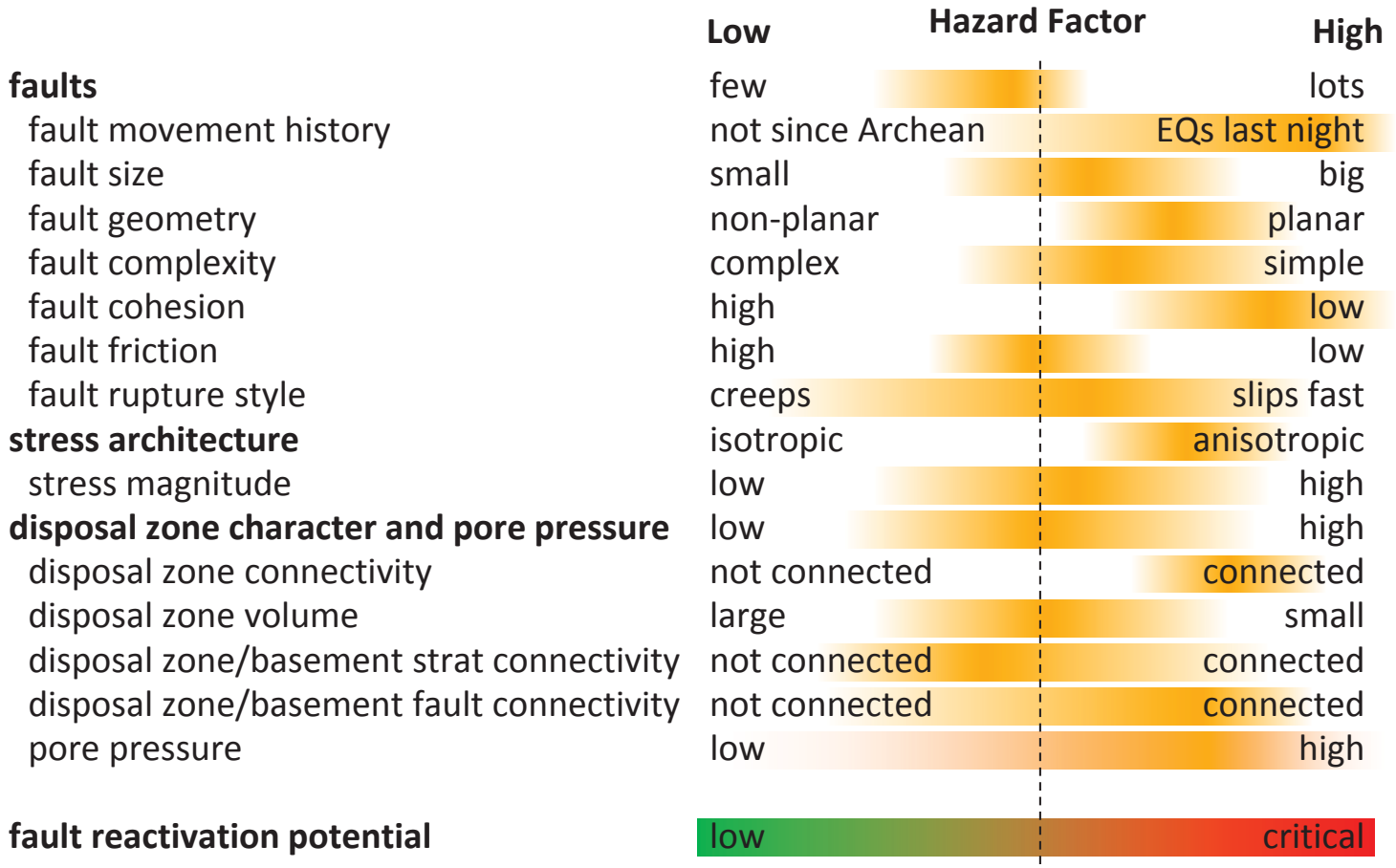


Top Ellenburger surface



Characterization of injection intervals

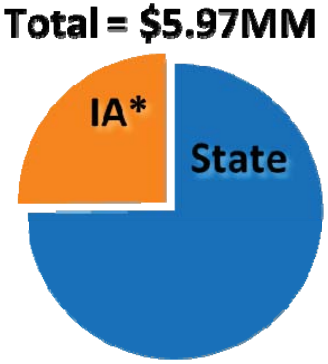
Synthesis of Key Factors (fictitious example)



TexNet Seismic Network and CISR Research

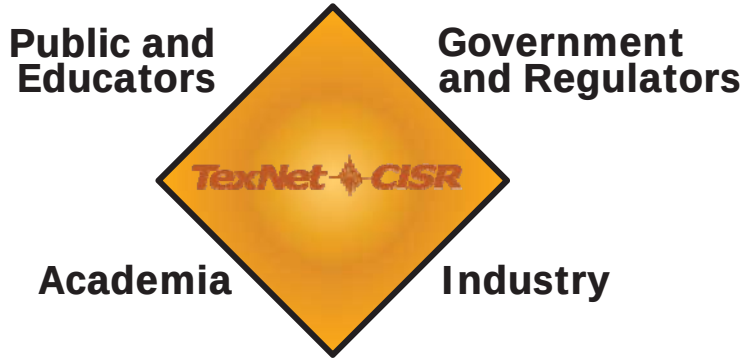
TexNet

Will monitor, locate, and catalog seismicity across Texas, capable of detecting and locating earthquakes with magnitudes ≥M2.0 using the new *backbone* network and improve investigations of ongoing sequences by deploying temporary seismic monitoring stations and conducting site-specific assessments.



Center for Integrated Seismicity Research

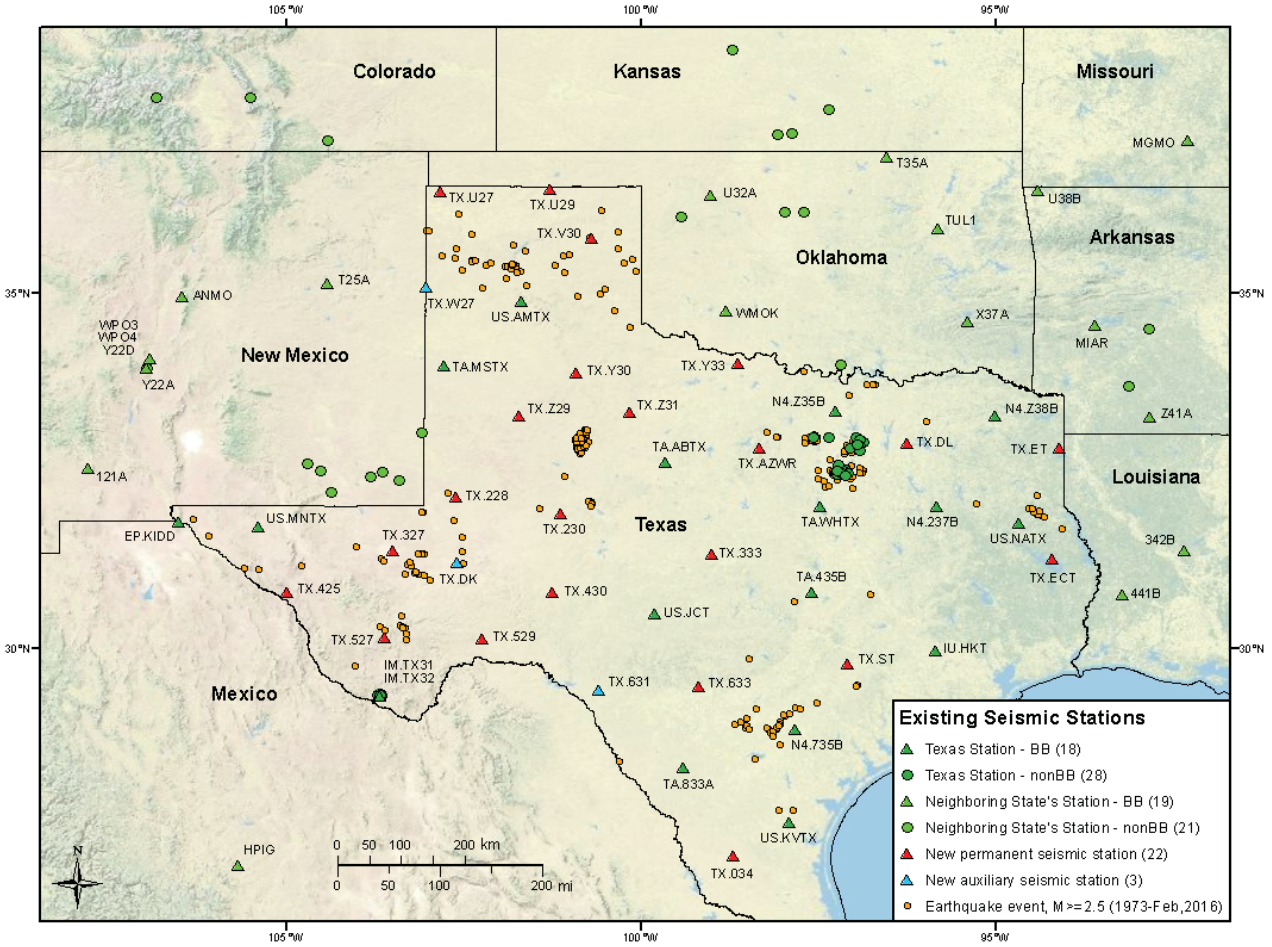
CISR will conduct fundamental and applied research to better understand naturally occurring and potentially induced seismicity and the associated risks, and to discern strategies for communicating with stakeholders and responding to public concerns regarding seismicity.



Anadarko Petroleum Corporation
bhpbilliton
OXY
Apache
eog resources
PIONEER NATURAL RESOURCES
Chevron
ConocoPhillips
ExxonMobil
UNIVERSITY LANDS

TexNet CISR

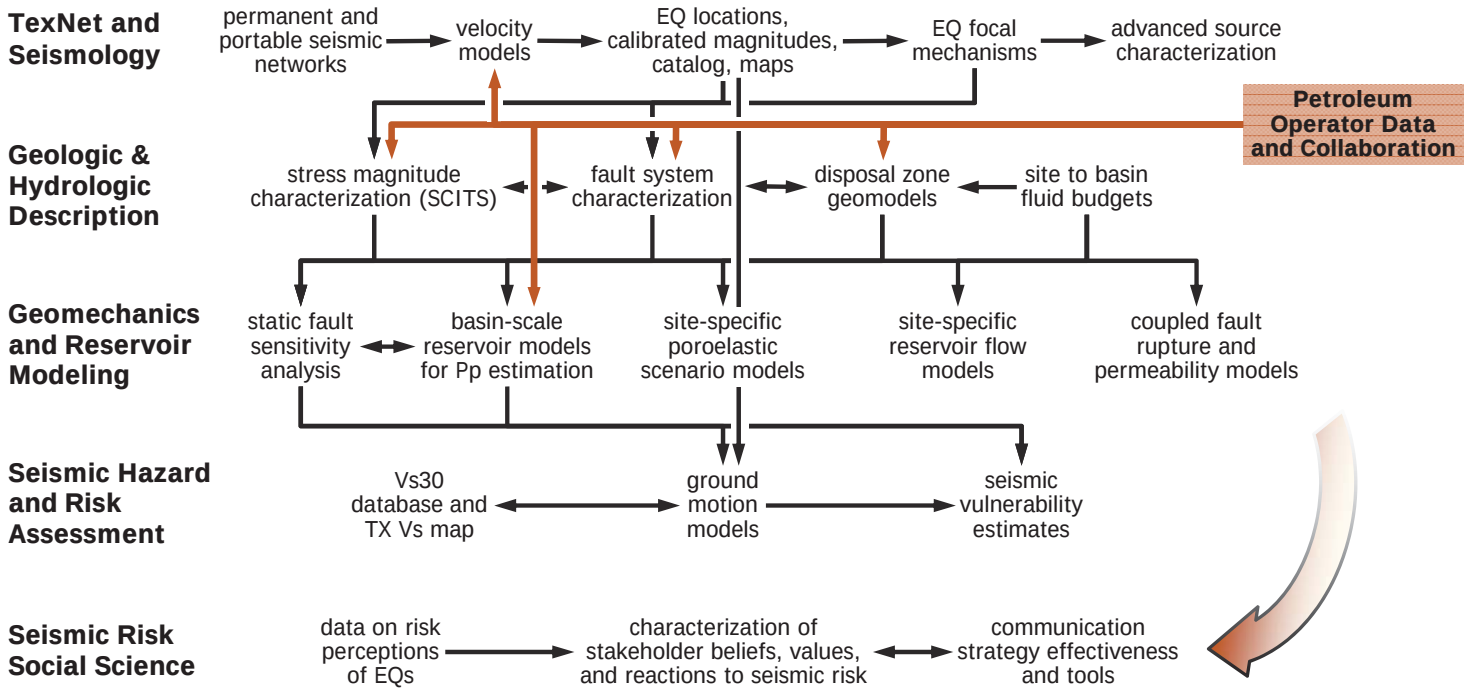
The TexNet Seismic Network



TexNet-CISR

TexNet and CISR Research (13+ active projects)

UT Bureau of Economic Geology	UT Moody College of Communications
UT Institute for Geophysics	UT Civil, Architectural, and Environmental Engineering
UT Petroleum and Geosystems Engineering	TAMU Petroleum Engineering
UT Psychology	SMU Geology and Geophysics



TexNet CISR

TexNet and CISR Research Timeline

State-Wide and General Topics
1. network procurement and installation
2. network management and data stream
3. R&D products to improve network performance
4. EQ compilations and characterizations
5. fault mapping and disposal zone characterizations
6. seismic risk communication and outreach

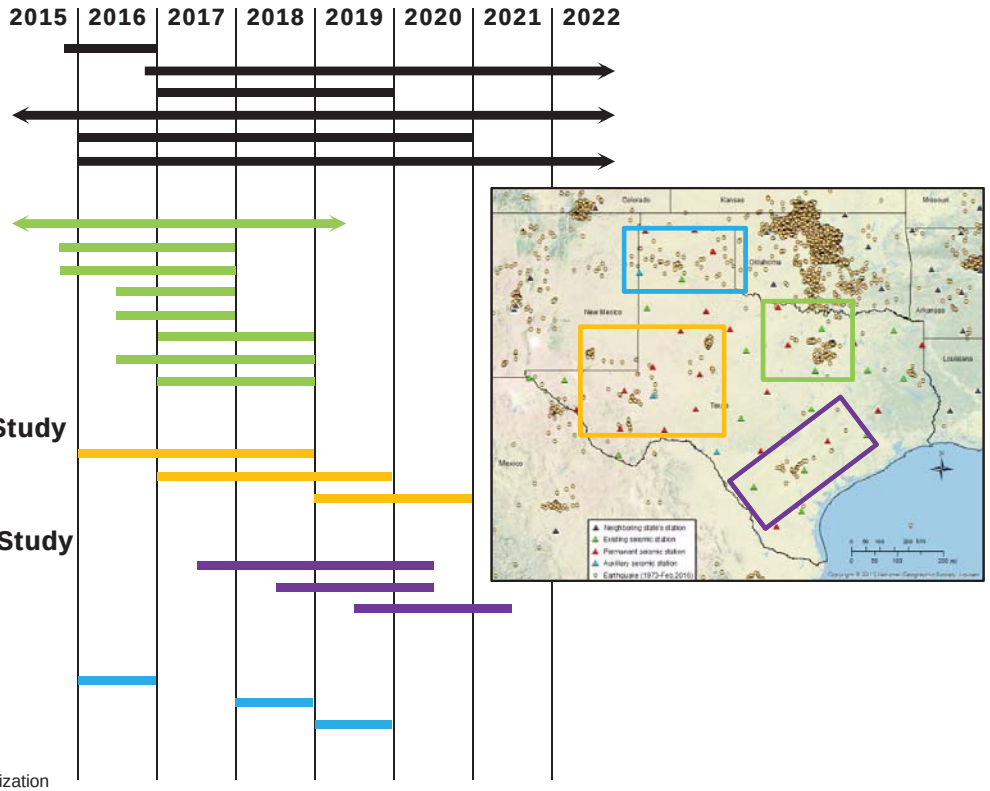
Ft Worth Basin Integrated Study
1. local seismic networks and EQ studies
2. basin-scale fluid budgets and pore pressure
3. stress characterization (Stanford)
4. fault characterization
5. 3D basin geo and hydrologic and modeling
6. fault reactivation analysis and mapping
7. reservoir modeling of seismicity mechanics
8. assessment of basin seismogenic potential

*

Greater West Texas Basin Integrated Study
1. local seismicity base-line studies and analyses
2. *integrated geological characterization
3. assessment of basin seismogenic potential

Eagle Ford Operating Area Integrated Study
1. local seismicity base-line studies and analyses
2. *integrated geological characterization
3. assessment of basin seismogenic potential

Panhandle Seismicity Study
1. seismicity analysis (existing and TA stations)
2. *integrated geological characterization
3. assessment of basin seismogenic potential



*integrated geological characterization

Closing Thoughts

a physical understanding of possible linkages between oil and gas operations and earthquakes is the first real step to mitigating these effects

Data Needs

- better earthquake data in areas of natural and induced activity
- better controls on fault presence and characteristics, can't rely only on EQ seismicity
- better controls on disposal zone pore pressure and pressure history from down-hole data

Collaboration Needs

- fluid flow simulations for pore pressure estimation need to be far more comprehensive and include realistic geological controls and boundary conditions
- subsurface integrated and mechanistic models that are shared and revisited by interdisciplinary groups
- models for fault-triggering mechanisms based on more complete physical descriptions
- development of resource assessments for disposal capacity of select Texas basins