



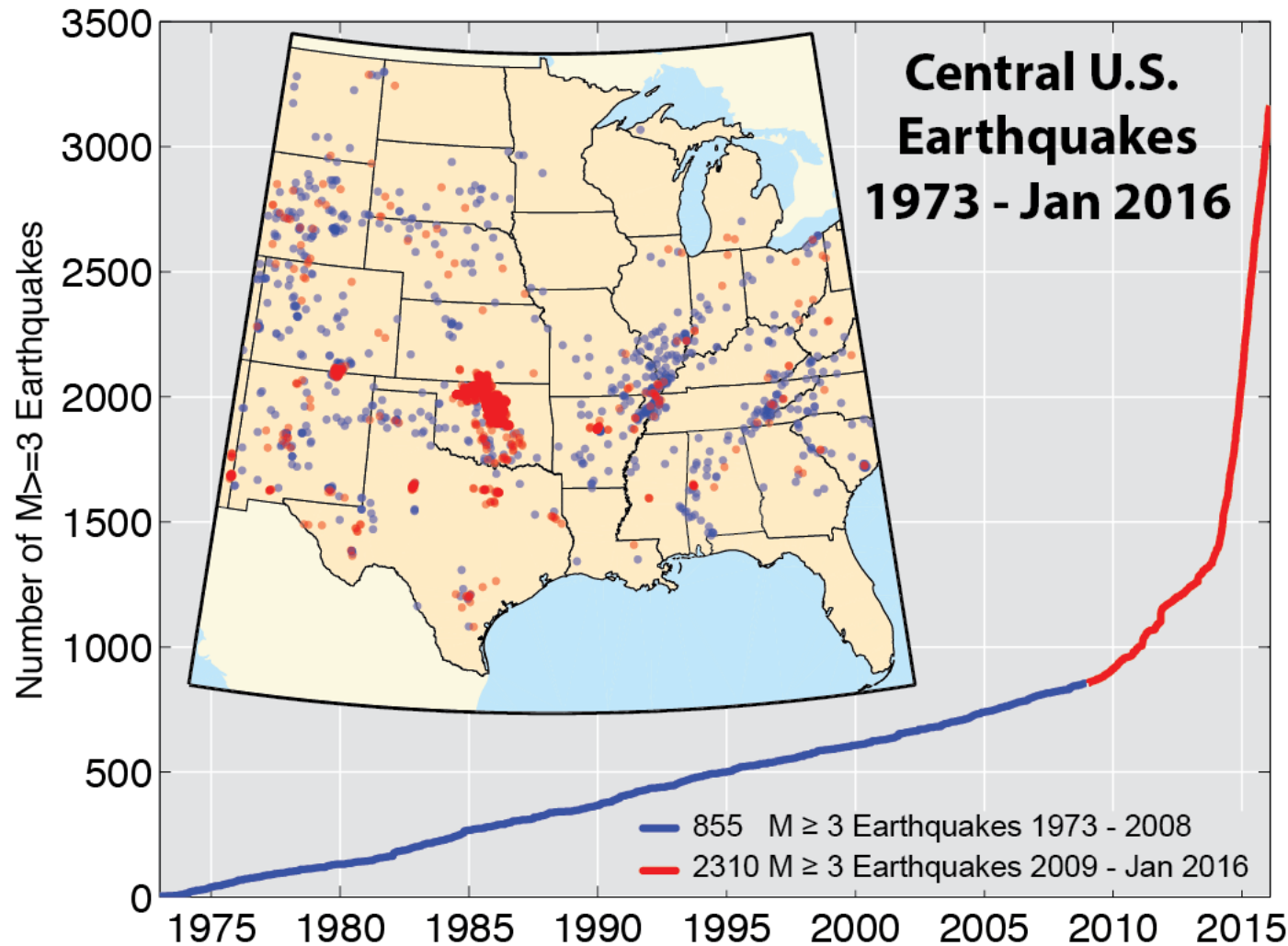
Texas Disposal Well Rules And Seismicity

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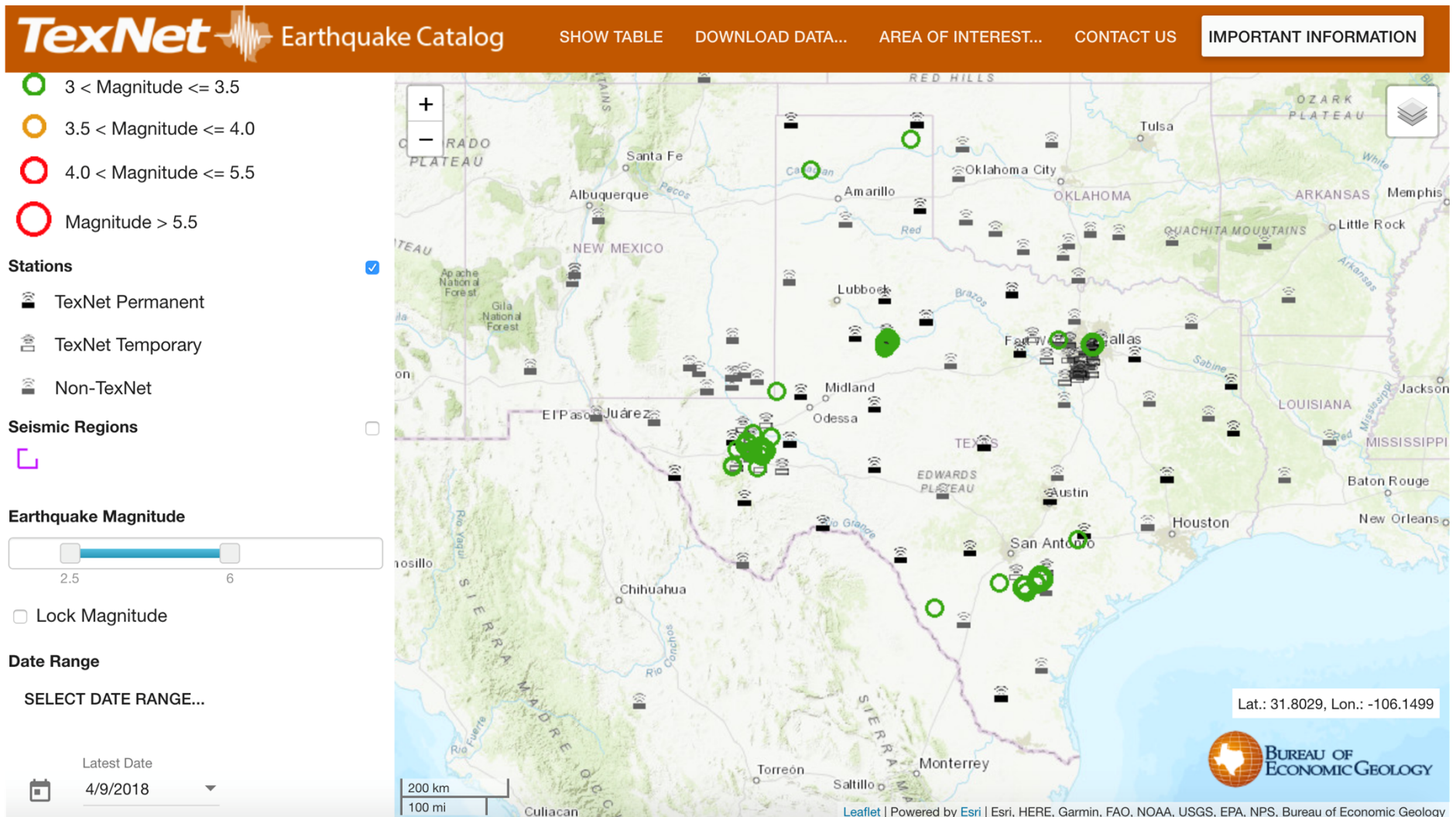
Seismic Activity in Central U.S.



Cumulative number of earthquakes with a magnitude of 3.0 or larger in the central and eastern United States, 1973–2016. The long-term rate of approximately 29 earthquakes /year increased sharply starting around 2009 (from USGS)

Seismic Activity in Texas

TexNet: Launched Oct. 2017 and has a complete catalog beginning Jan. 2017; significant accomplishment by the Bureau of Economic (BEG)



Texas Seismicity Overview



- Earthquakes recorded in Texas since 1882 (Spindletop discovered in 1901)
- Natural vs. induced?
- Correlation $\neq$ Causation
- Can be induced by fluid extraction
- Can be induced by fluid injection
 - Hydraulic fracturing
 - Enhanced recovery
 - Disposal

Oil & Gas Activity in Texas



- Production
 - Thousands of fields in Texas
 - 315,000+ active wells
 - Billions of barrels of oil & water produced
 - Billions of cubic feet of gas produced
- Injection
 - 110,000+ UIC wells permitted since 1930's
 - 26,000+ active enhanced recovery injection wells
 - 8,000+ active disposal wells

Underground Injection Control (UIC)



Permitting, monitoring & testing of wells
injection wells

- Class II
 - Enhanced recovery
 - Disposal of oil and gas wastes
- Class III – Brine mining
- Class V - Geothermal

Underground Injection Control (UIC)



Program Goals:

- Confine fluids to the permitted strata
- Protect groundwater (USDWs)
- Protect surface water
- Protect strata productive of hydrocarbons

Key Observations



- Majority of faults stable
- “Faults of Concern” characterized by
 - Optimal orientation for movement
 - At or near critical stress
 - Sufficient size and accumulated stress/strain, such that fault slip has potential to cause significant event
- Identifying “Faults of Concern” challenging – generally not effectively mapped in the US

Texas Seismicity Overview



- Hired seismologist April 2014
- Amended disposal well rules November 2014
 - Survey of historical seismic activity in proposed area
 - Additional information
 - More intense application review
 - Special permit conditions
 - Clarified authority to modify, suspend or cancel permit

Texas Disposal Well Rules



- Amended disposal well rules November 2014
 - Survey of historical seismic activity in area
 - Survey of a circular area of 100 square miles (circle with a radius of 9.08 km/5.6 miles) centered around the proposed disposal well location for seismic activity
 - If historic seismic activity in survey area or conditions that may increase the risk that fluids will not be confined to the injection interval, operator must provide additional information

Texas Disposal Well Rules



- Additional Geologic Data
 - Structure/isopach maps, geologic/seismic cross sections
 - Relevant geologic data for area/disposal zone
- Review additional information
 - Proposed maximum daily injection volume
 - Depth of injection interval to faulted basement rock
 - Mapped known faults in the area
 - Relevant articles, map or other research

Structure Map

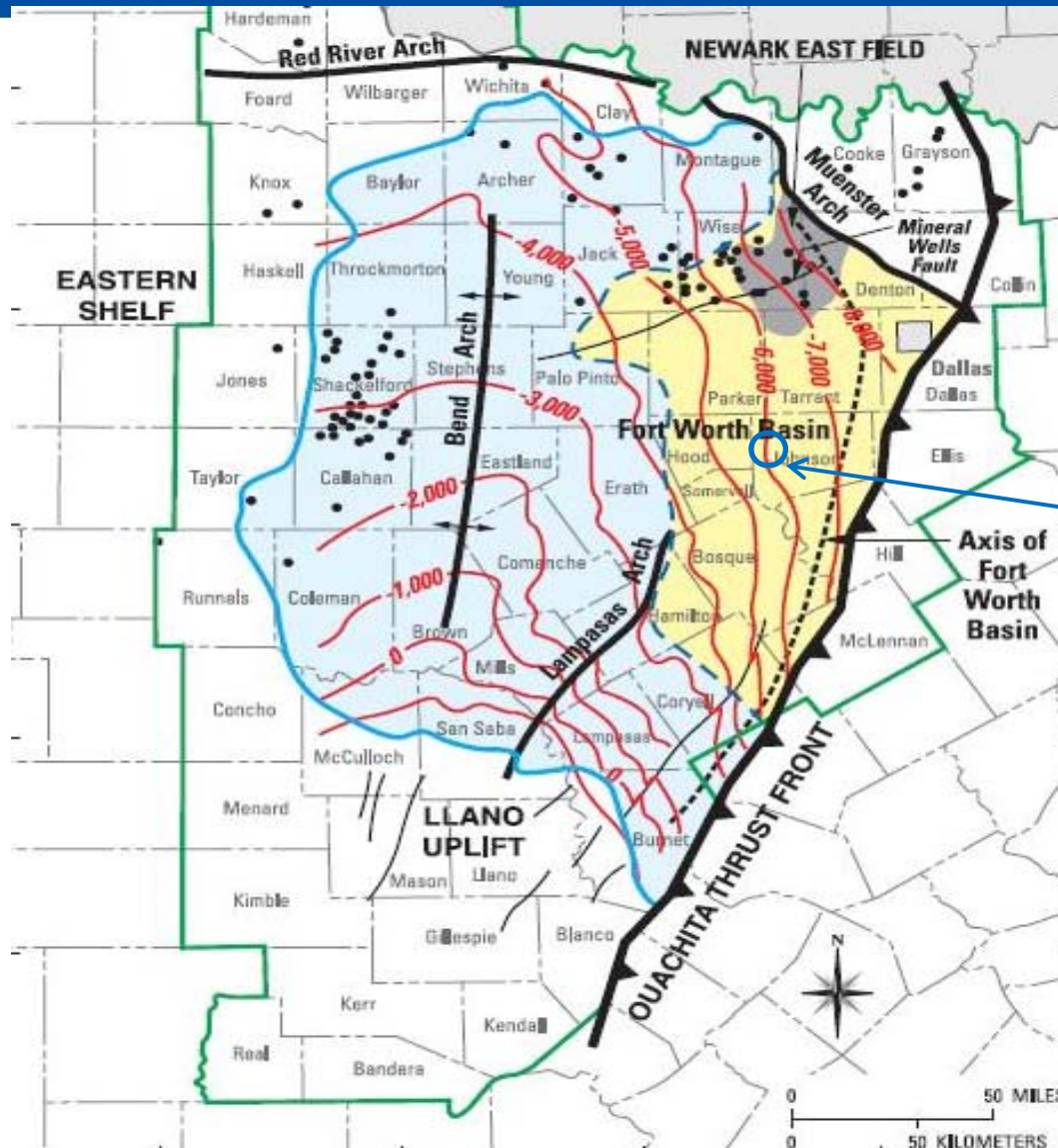
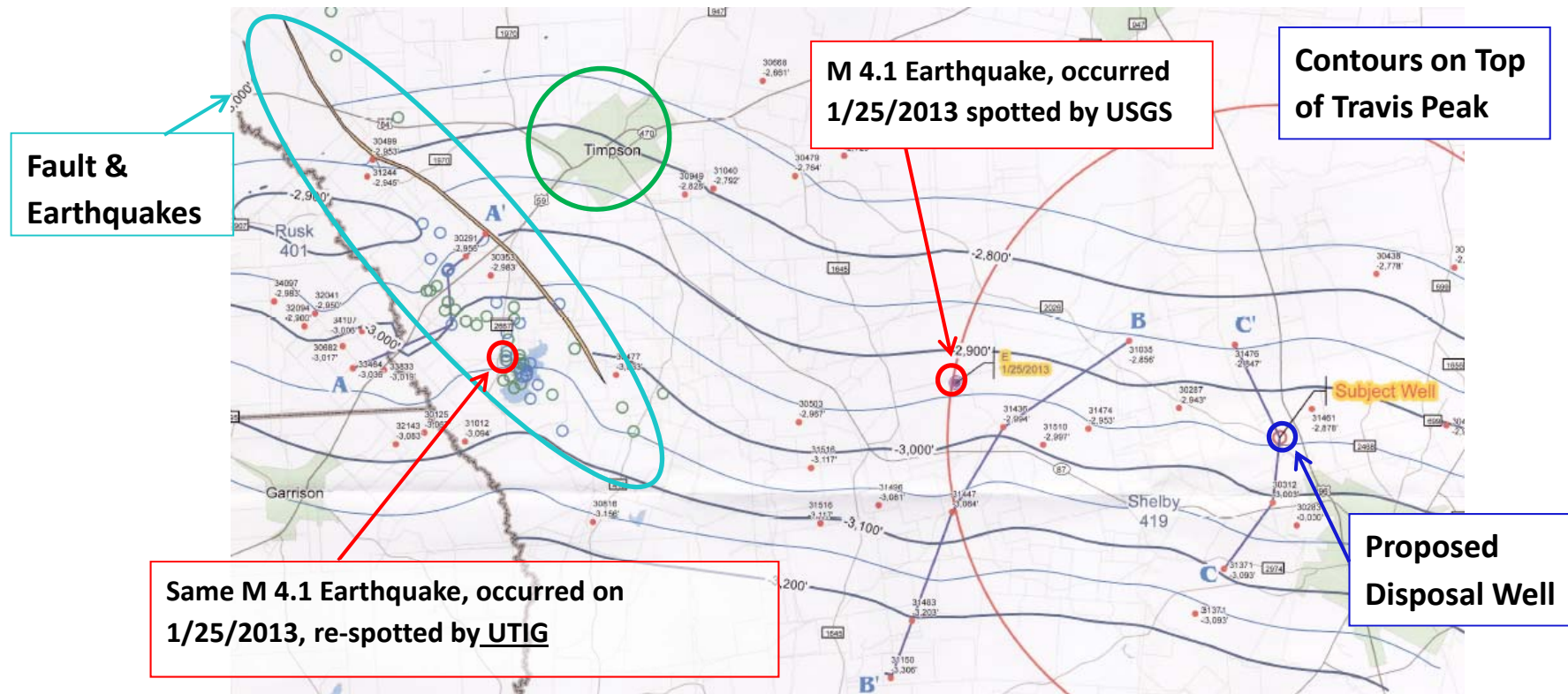
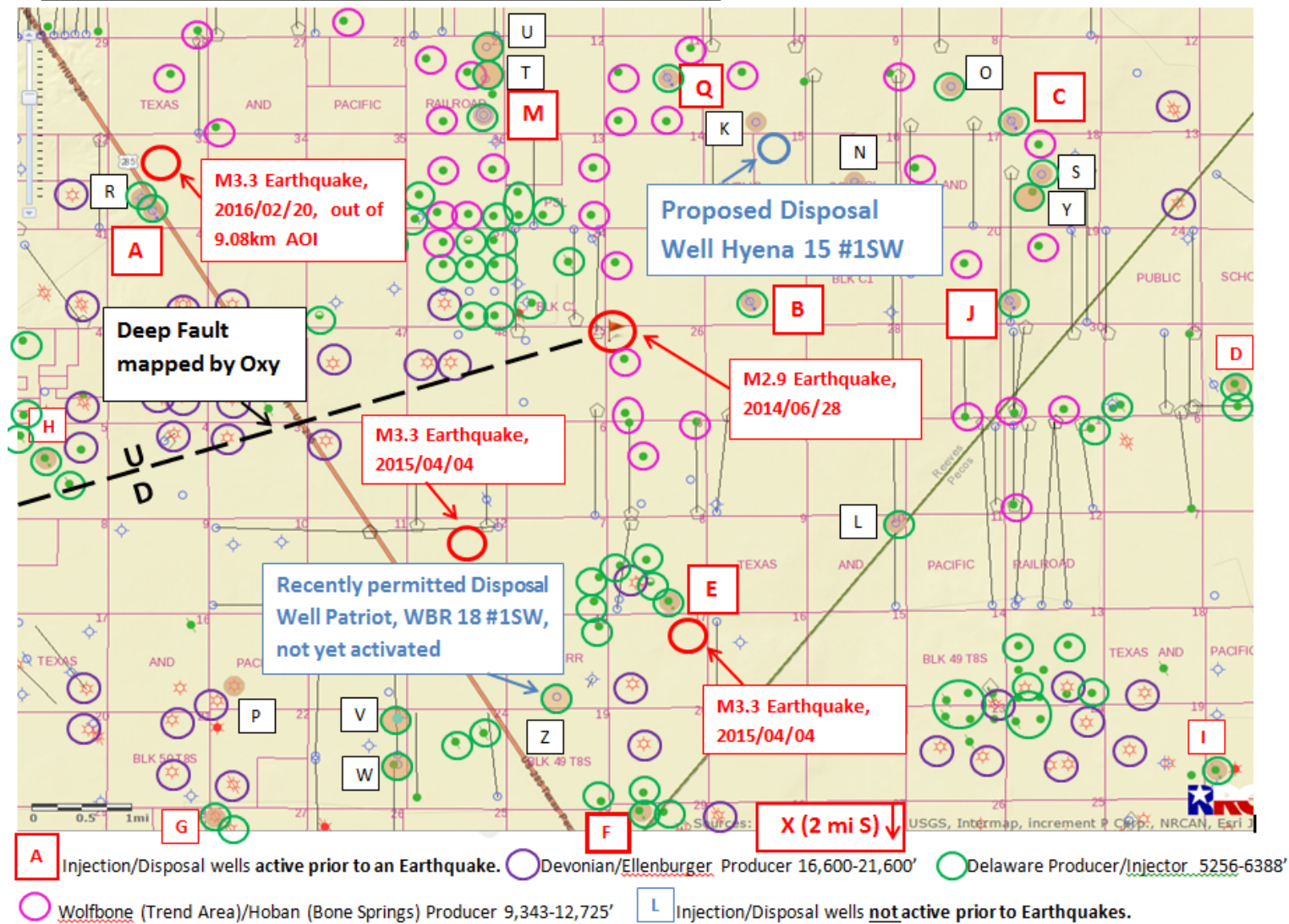


Fig 5. Sub-Sea Structure Map of Top of Ellenburger Formation
from: **“Geology of the Barnett and Marcellus Shales”** by Lauren Hudson

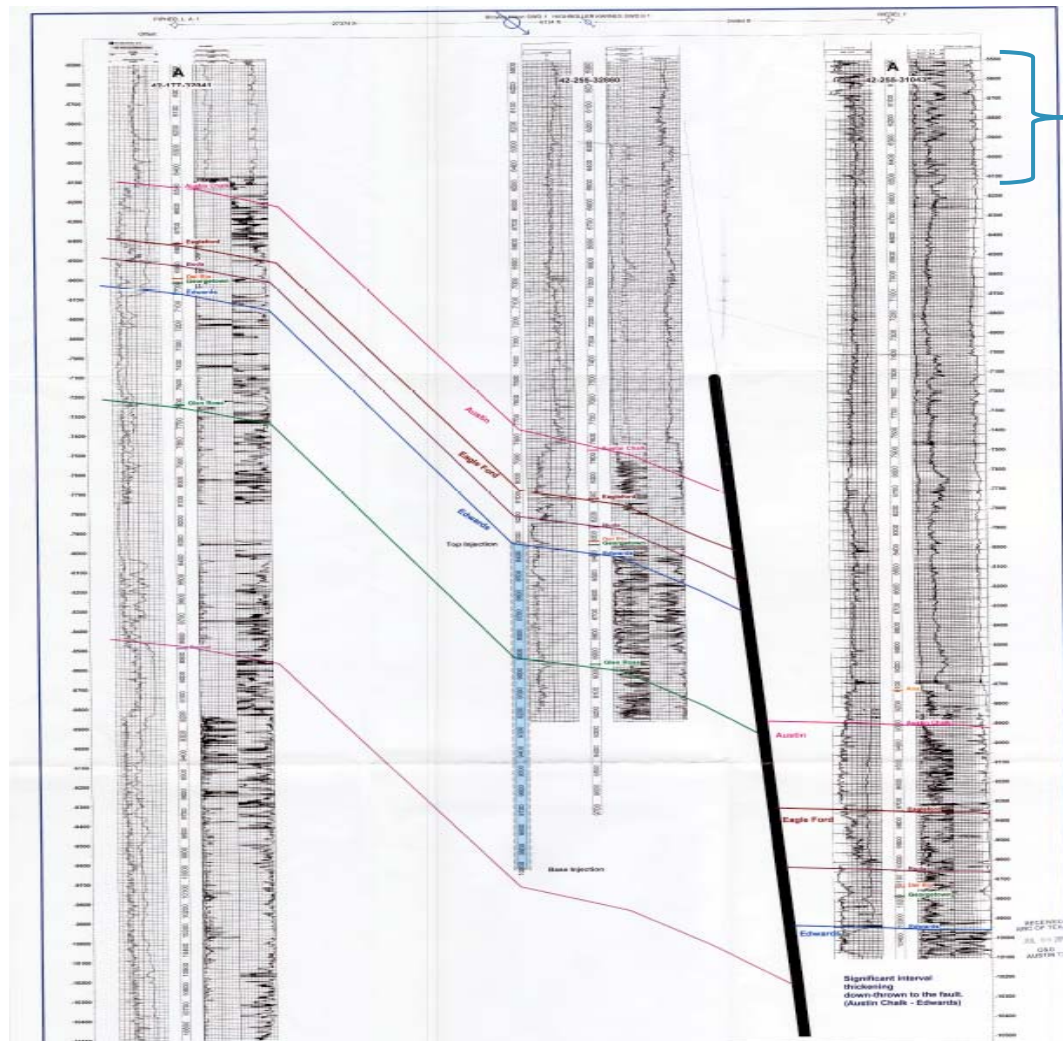
Proposed Disposal Well
est Top Ellenburger = -5775 +
975kb = 6750' sub kb

Structure Map with Epicenters





Geologic Cross Section



Disposal Interval

Unfaulted rock

faulted rock

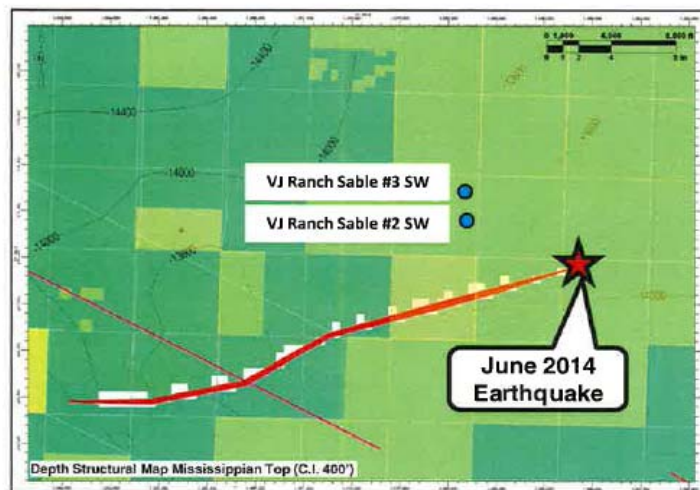
Seismic Cross Section



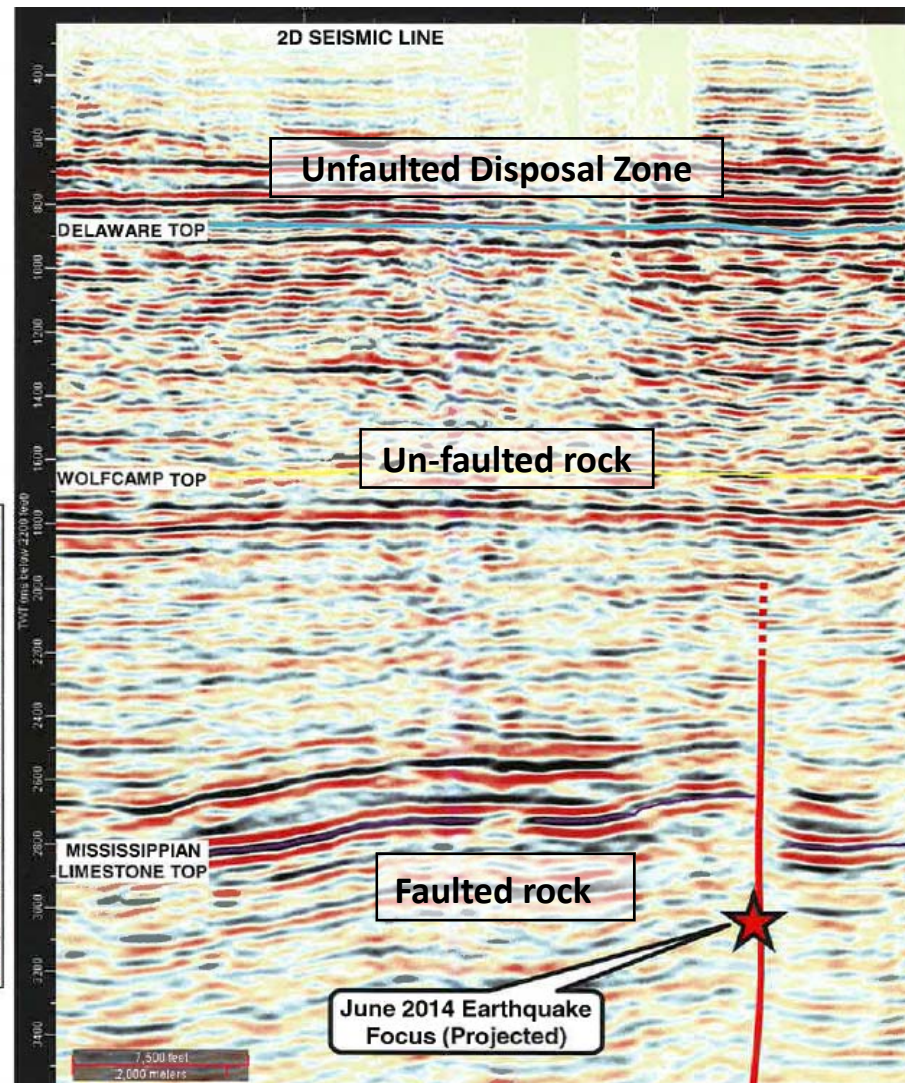
**Seismic Survey near NW Red Bull, with
proposed Delaware Mountain Group SWD
locations and focus of the 28 June 2014
Magnitude 2.9 Earthquake**

**To accompany Form H-1 for VJ Ranch Sable #2 SW
and VJ Ranch Sable #3 SW**

Balmorhea Ranch (Bell Canyon L Field)
Reeves County, Texas (District 008)



*Geophysical Interpretation by Maria Cristina Bernal,
Geophysical Advisor, Occidental Worldwide Exploration*



Texas Disposal Well Rules



- Mitigating hazard
 - Evaluate hazard and determine whether hazard can be mitigated
 - Discuss hazards with operator
 - Request additional information
 - Discuss modification of application or conditioning of permit to mitigate risk
 - Operator hazard management plan

Texas Disposal Well Rules



- Mitigating Hazard
 - Possible special permit conditions
 - More frequent monitoring & reporting of injection rate and pressure
 - Reduced volume and/or pressure
 - Plugback to increase distance from basement rock/faults
 - Seismic monitors
 - Permit expiration date
 - Deny application

Texas Disposal Well Rules



- Application Activity as of April 11, 2018
 - Received 189 disposal well applications or amendments in which survey included seismic event(s)
 - 92 Permitted with special conditions
 - 9 Permitted without special conditions
 - 36 Returned or withdrawn
 - 10 scheduled for hearing due to protests
 - 42 pending review

Texas Disposal Well Rules



- Clarified authority to modify, suspend, or cancel existing permit
 - If disposal well suspected of or shown to be causing seismic activity
 - Notice and opportunity for hearing



- House Bill 2, 84th Texas Legislature (2016–17), Section 16 provides funding for TexNet:

“...for the purchase and deployment of seismic equipment, maintenance of seismic networks, modeling of reservoir behavior for systems of wells in the vicinity of faults, ...”

Current Actions



- Working with the BEG on data/products that can be shared and used in our decisions
- Developing set of guidelines in Permian Basin for permitting based on current research
- Basic and applied research from BEG/TexNet and others and others will be the foundation of regulatory action.

TexNet Seismic Monitoring System



- Denser seismic monitoring array will result in:
 - Increase detection of smaller events
 - More accurate location of suitably oriented, critically stressed faults
 - More accurate location of epicenter/hypocenter
 - Better definition of suitably oriented, critically stressed faults

State Primer on Induced Seismicity



- Emphasis on potential induced seismicity associated with Class II disposal wells
- Solely informational - not intended to offer recommended rules or regulations
- <http://www.statesfirstinitiative.org>



Summary



- Induced seismicity
- Actions by RRC and the BEG
- Challenges to address
 - Current state of seismicity in Texas
 - Knowledge of faults in Texas
 - Understanding of induced earthquake mechanics
 - How do we manage permitting in the context of earthquakes
- Benefits, challenges, and opportunities with publically available research
- Continued research is critical