A Brief Update of Projects and Results from SMU's Geothermal Lab this year

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Southern Methodist University

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Benefiting the community by promoting and supporting interdisciplinary research at the interface of people, Earth, and the environment.

Anadarko

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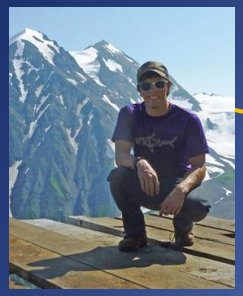
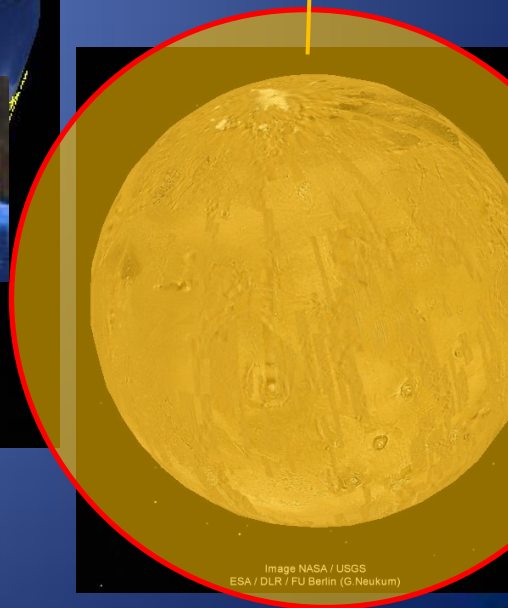
Lab Projects 2015-2016





Project Focus:

Basin HF Analysis (5)

Oil and Gas Exploration (3)

Climate Change (2)

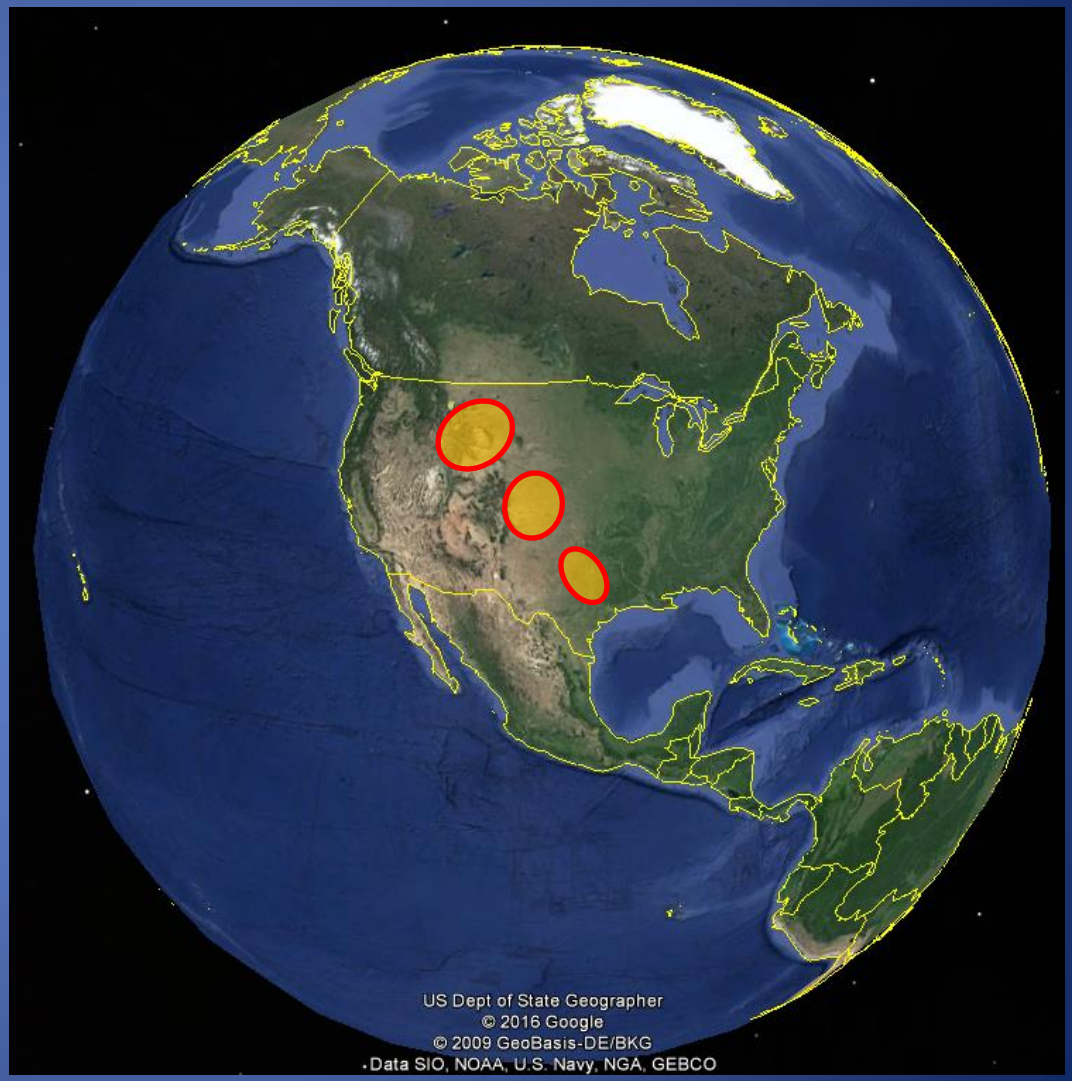
Induced Seismicity (1)

Initial Results from Three Projects

(1) **Heat Flow Measurements and Modeling in the Denver Basin**

(2) **Surface Warming in the N. Rockies**

(3) **Quantifying/Mitigating Induced Seismicity in Texas**

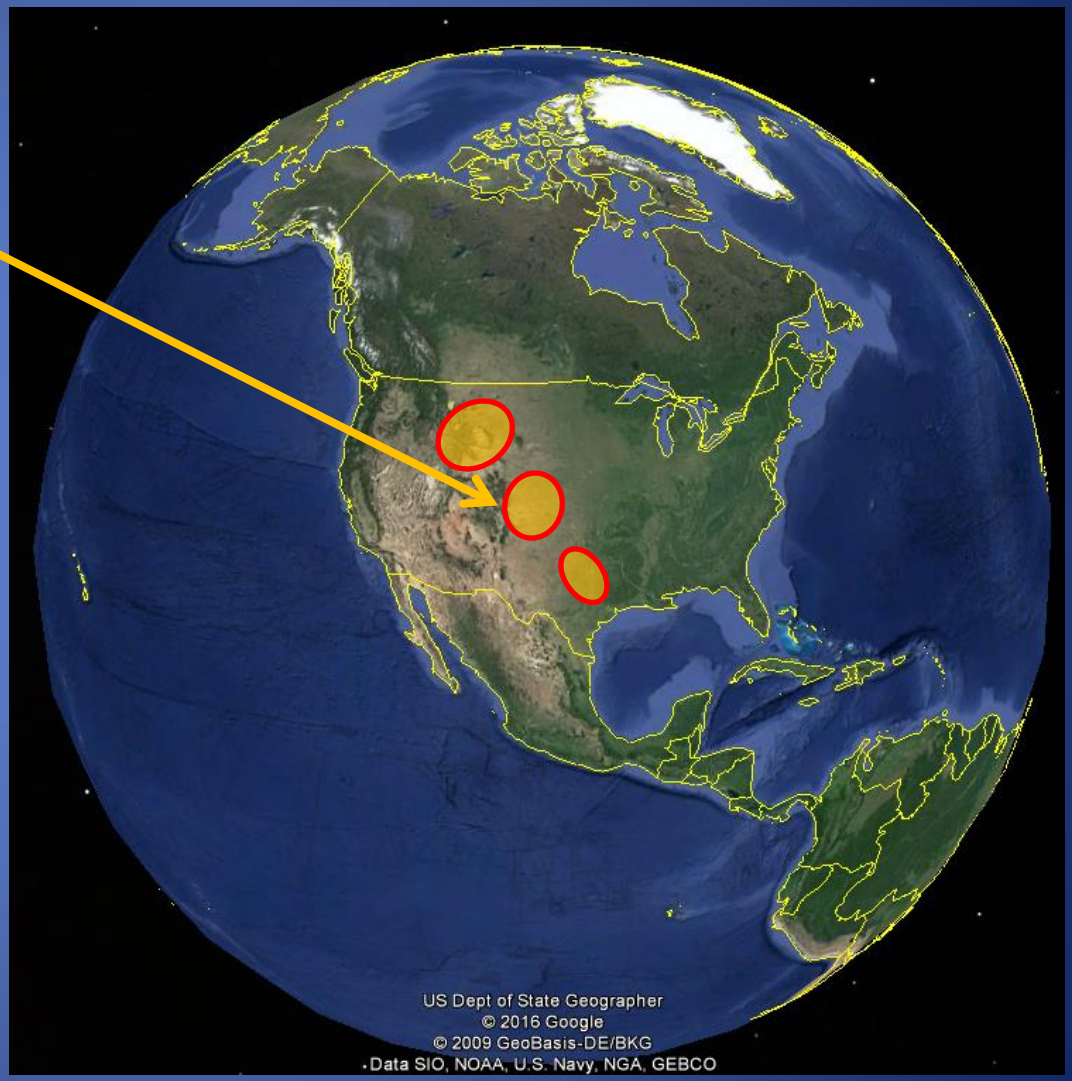


Focusing Today on Three Projects

(1) **Heat-Flow/K Measurements and Modeling in the Denver Basin**

(2) **Surface Warming in the N. Rockies**

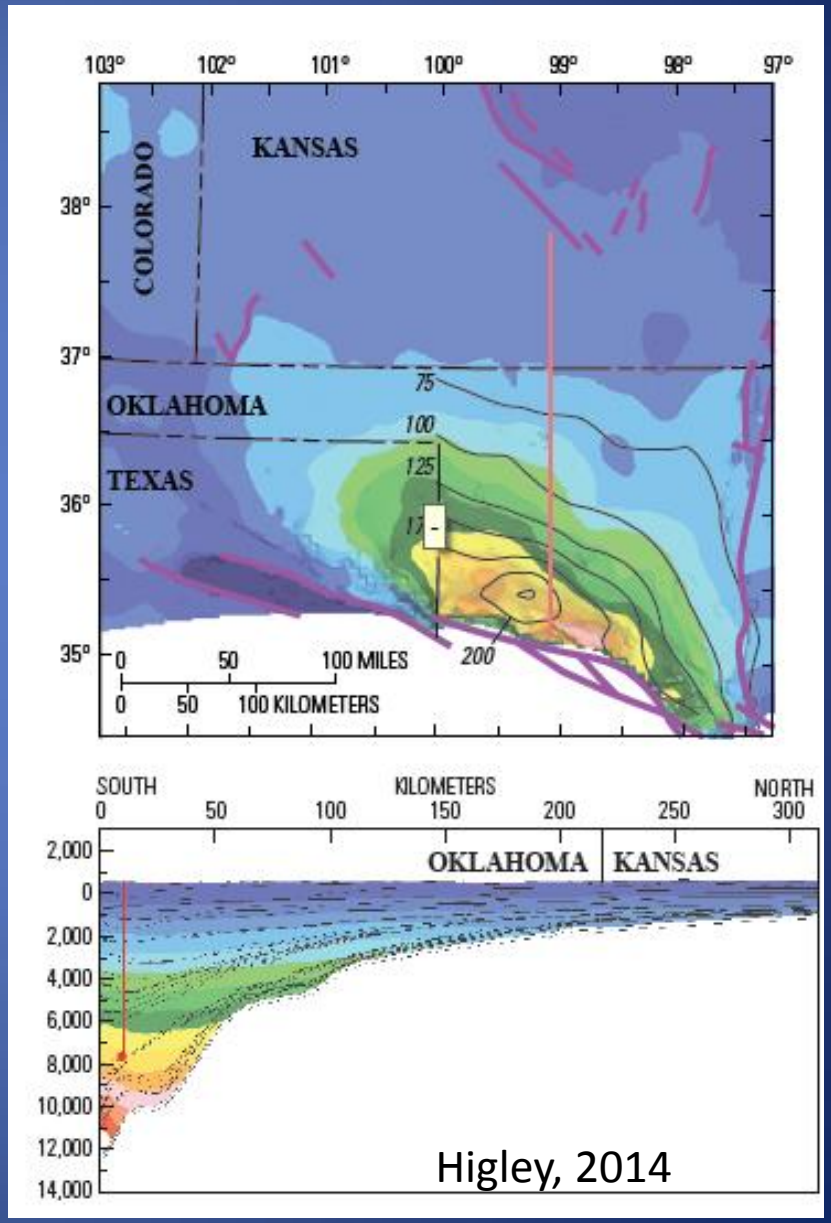
(3) **Quantifying/Mitigating Induced Seismicity in Texas**



The Basin-Scale HF Problem: Under-sampling →Spatial Aliasing

$$q = k\nabla T = k\left(\frac{dT}{dx} + \frac{dT}{dy} + \frac{dT}{dz}\right)$$ *(Fourier's Law)*

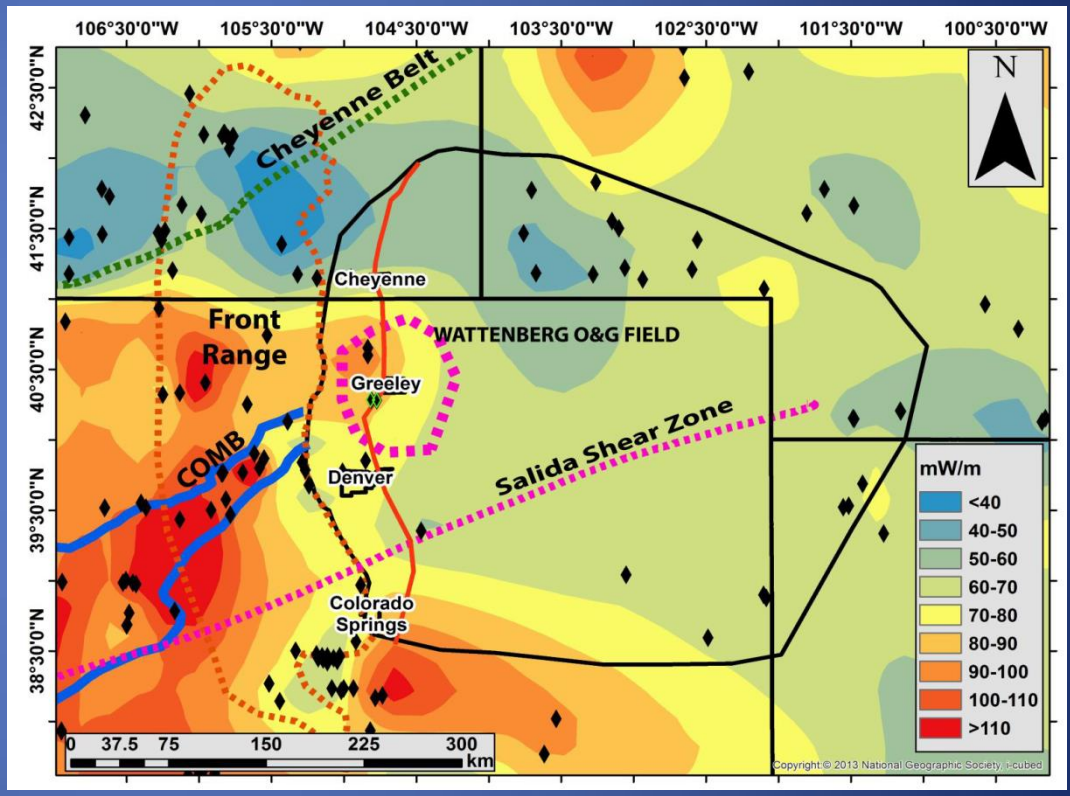
- Although thermal basin models report meter-scale resolution, most models use only a few thermal parameters interpolated across 100-1000 kms.
- Some (such as VR) are empirical and observer dependent, resulting in widespread systemic error.
- Severe spatial aliasing is a limiting factor often both overlooked and misunderstood when interpreting thermal maturation models.



Constraining Denver Basin Heat Flow (Casey Brokaw)

Why the Denver Basin?

1. High Temps: but poorly constrained.
2. Infrast./Market: Front Range home to >5 mil.
3. O&G Industry interest/Support.



The problem: most 3D basin models are severely spatially aliased in K and Q. This results in sometimes 25% error subsurface temperature estimates. Optimizing both geothermal energy potential as well as hydrocarbon maturation requires high-quality 3D constraints on HF and K.

One Solution: Use both publically and privately available Core/drilling and HF data to more tightly constrain K and Q.

---Then, Field Test results with new Q measurements, to determine improvements.

Constraining Denver Basin Heat Flow (Casey Brokaw)

Approach:

(1) Measure K in samples obtained from the USGS and Anadarko.

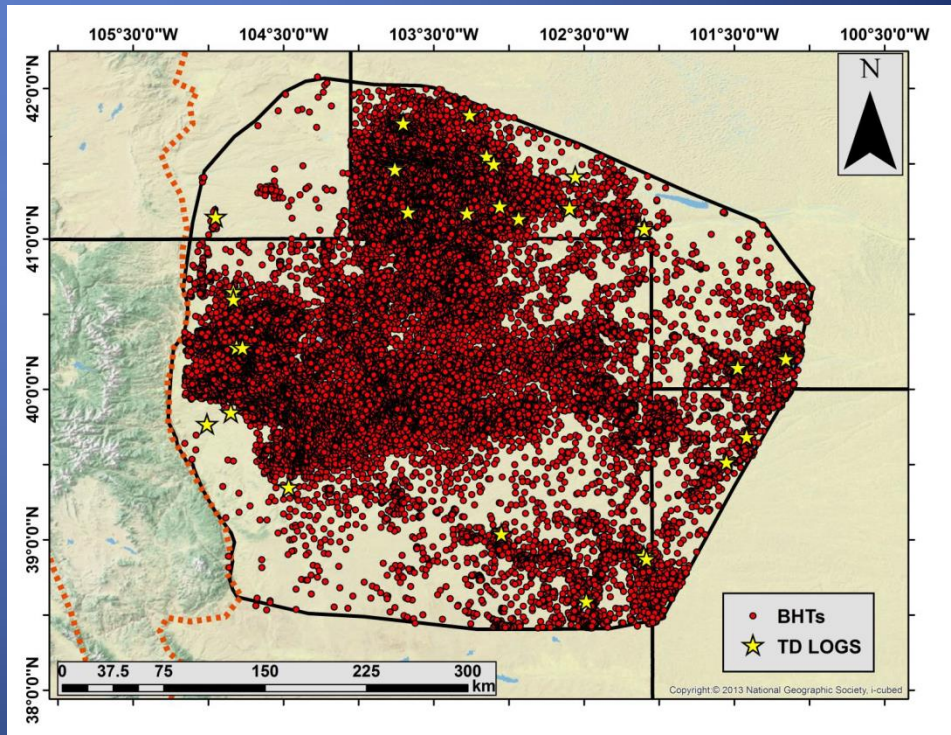
(2) Collect, Analyze , Calibrate, and Compare BHT-corrected T-D values with equilibrium logs for 60,000 wells.

(3) From this,

--refine the T-D regime in 3D in the Basin using new data.

--predict T-D in key areas of interest.

--compare measured values with our predictions *(this summer)*



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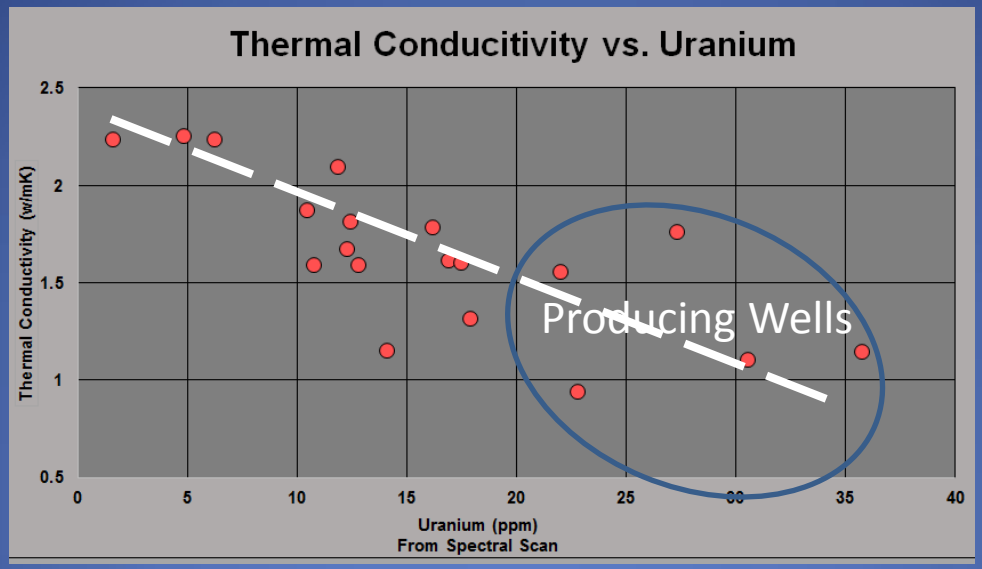


RESULT #1: K values correlate with TOC and Maturity

Greater TOC → lower K Greater Graphite → Higher K

Why?

--Thermal conductivity of organic carbon, oil, and gas is 1-2 orders of magnitude *lower* than typical minerals found in sedimentary basins. Graphite K is 1-2 orders of magnitude *higher* than typical minerals.

--A 2% change in gas/oil/TOC concentration results in a 12% change in conductivity for Quartz-rich sediment.

Our partners can use this result to estimate missed O&G targets and for determining mature/over-mature zones.

Constraining Denver Basin Heat Flow (Casey Brokaw)

Result #2: New, More Precise HF and K Maps Suggest focused High Temperature Zones

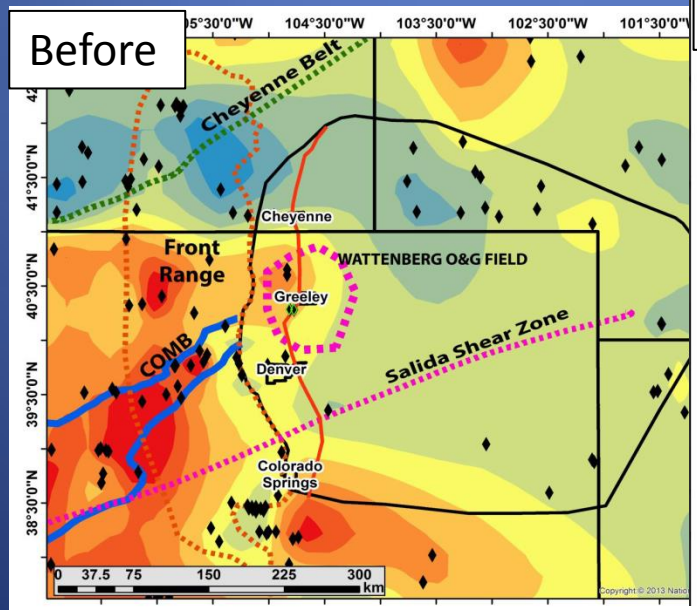
Lith. thermal K (W/m.K)	Formation
1.1 - 1.3	Pierre Shale
1.6	Smoky Hill (Niobrara)
2.2	Fort Hays LS (Niobrara)
2.3	Codell SS (Benton Frm)
	Carlile Shale / Greenhorn LS (Benton Frm)
1.3	Benton Frm Shale (Benton Frm)
2.9	Muddy/Dakota SS

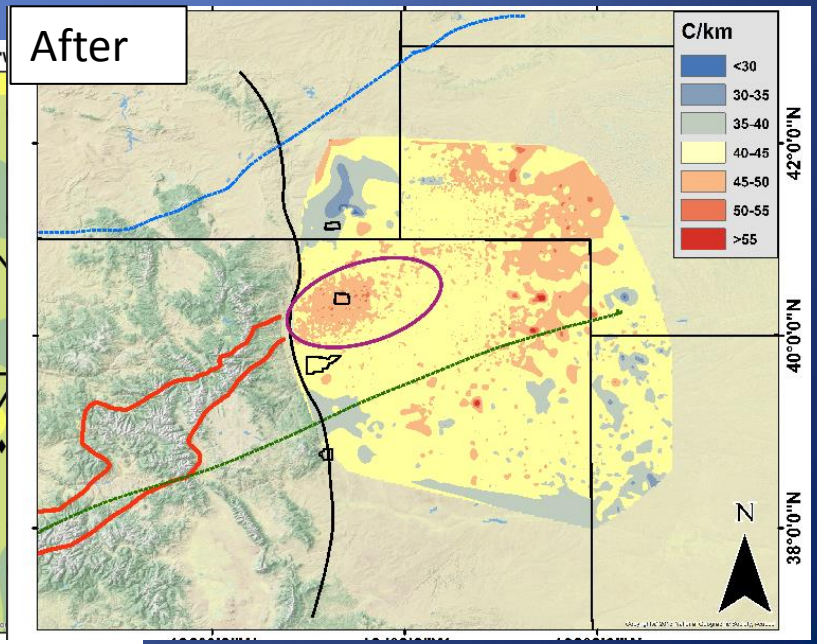
--Results indicate >100 deg. C Temps in the NW. Corner of the Basin.

--High HF appears associated with the Colorado Mineral Belt and Salida Shear Zone.

--Model ground-truthing will occur this summer.

--For More Results, See Casey's Poster.





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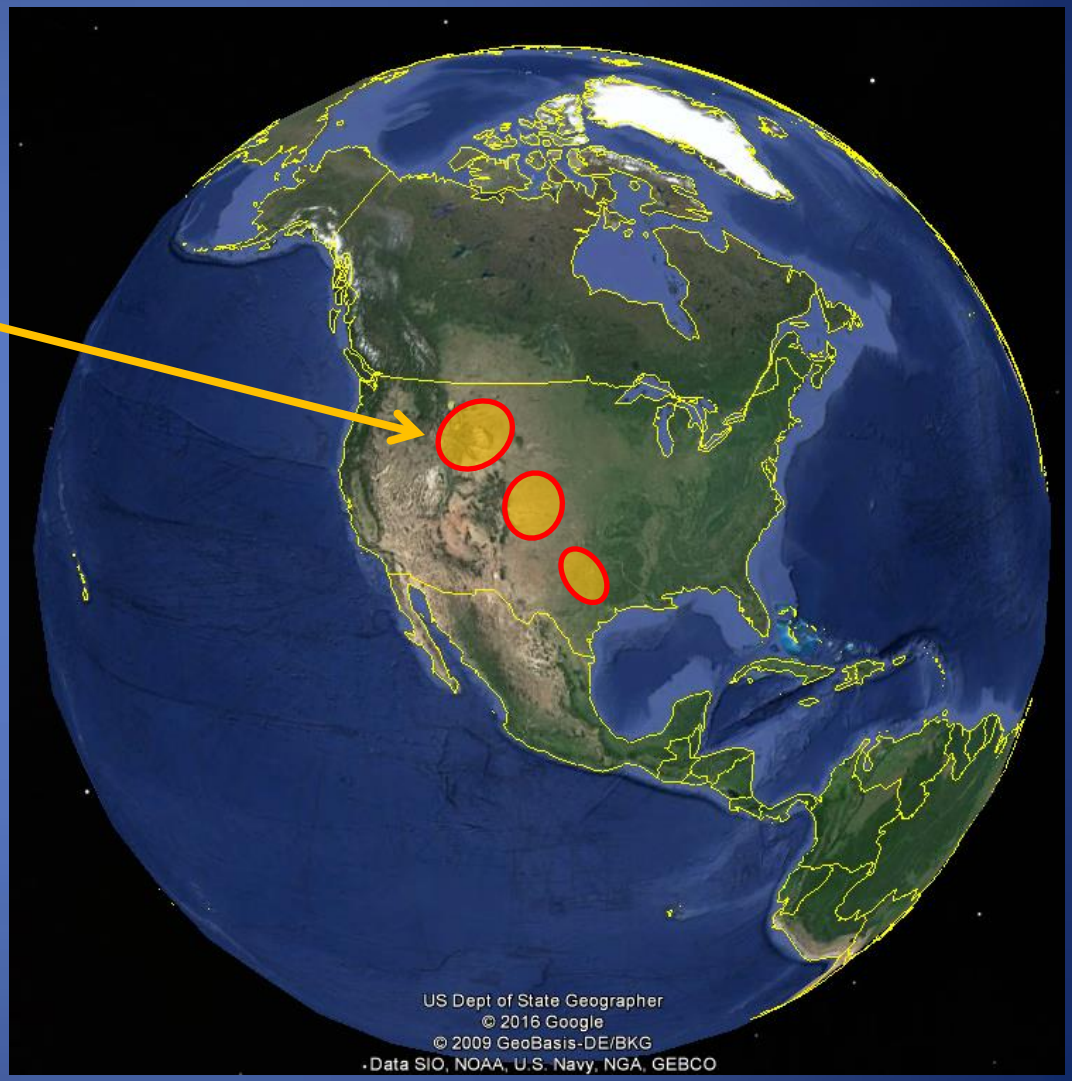
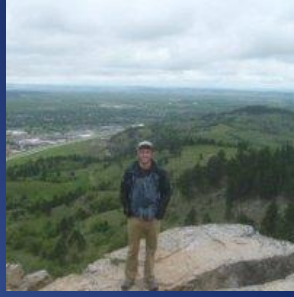
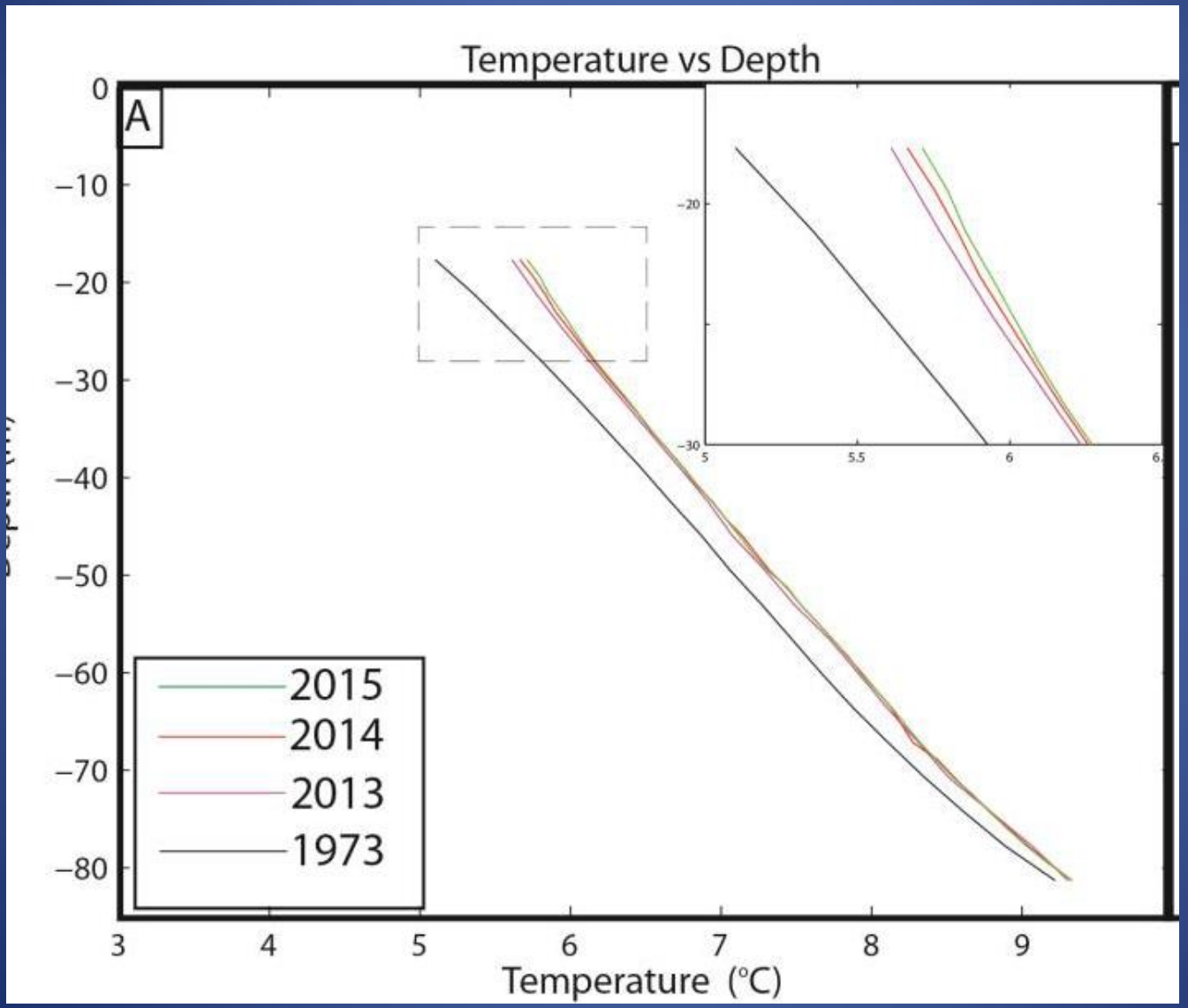


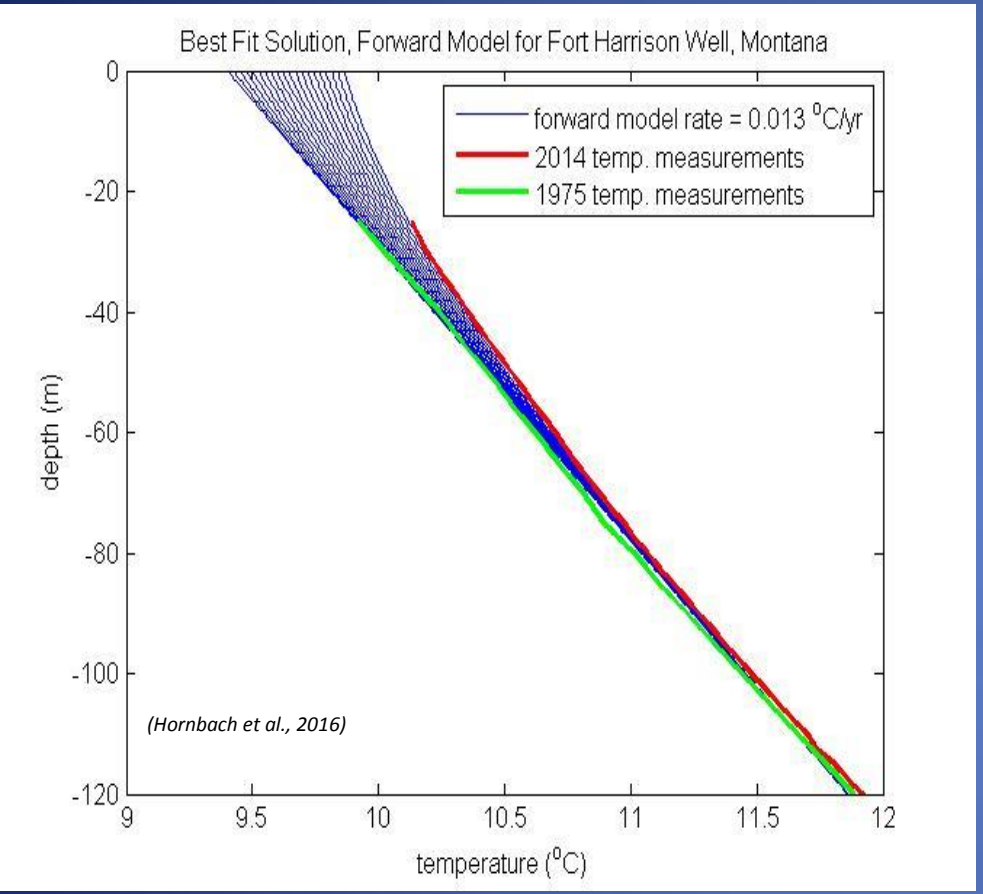
Northern US Rocky Mountain Winter Freeze-Line Retreat (Cliff Mauroner)





Northern US Rocky Mountain Winter Freeze-Line Retreat

(Both Measured and Projected by SMU Geothermal Lab)



Key Findings from SMU borehole climate study:

-- The N. US Rockies have warmed at ~0.4 deg. F per decade , or 1.5 deg. F since 1974.

--the rate of warming has accelerated (we get a best model fit if we increase warming rate with time).

--The warming rate appears higher at higher elevations.

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Northern US Rocky Mountain Winter Freeze-Line Retreat

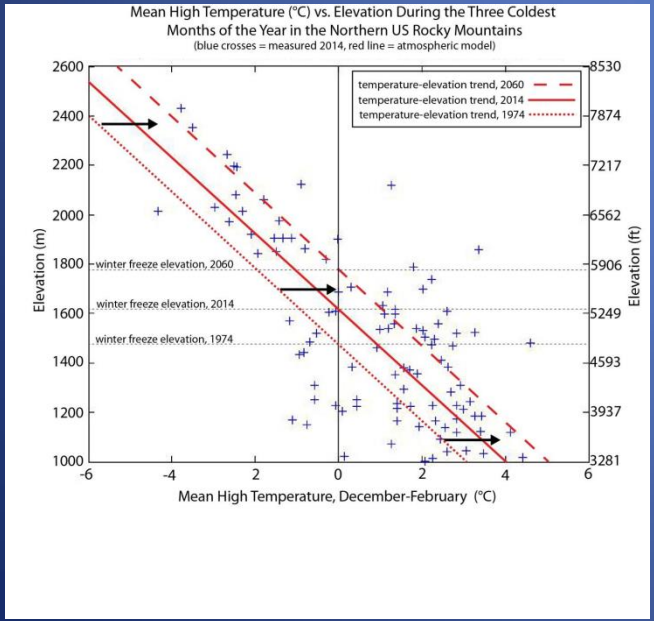
(Both Measured and Projected by SMU Geothermal Lab)

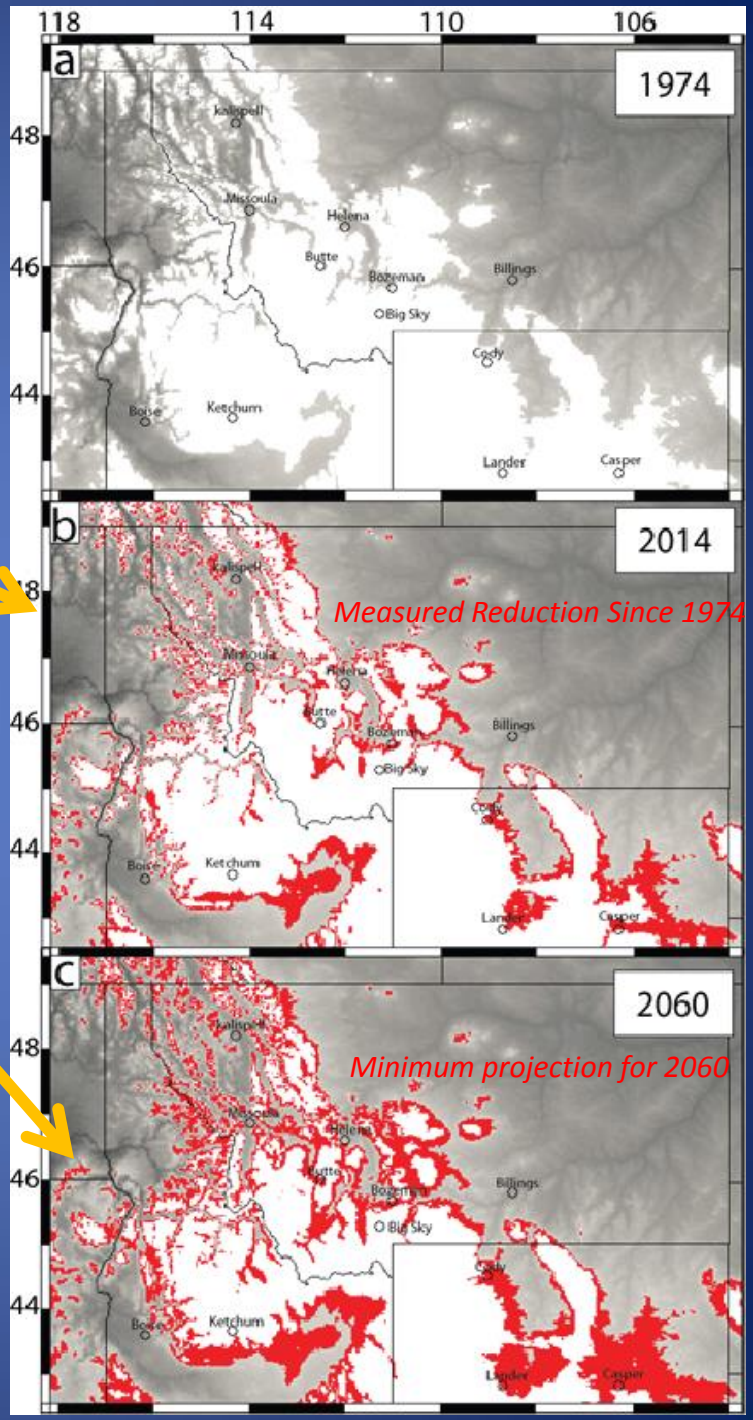
Implications

--Elevation of the winter freeze-line has migrated vertically >10 ft/year for the last 40 years.

--This implies an ~20% reduction in the average winter Freeze-Line Area since 1974.

--If rates stay constant (no acceleration) we expect a 40% reduction by 2060.





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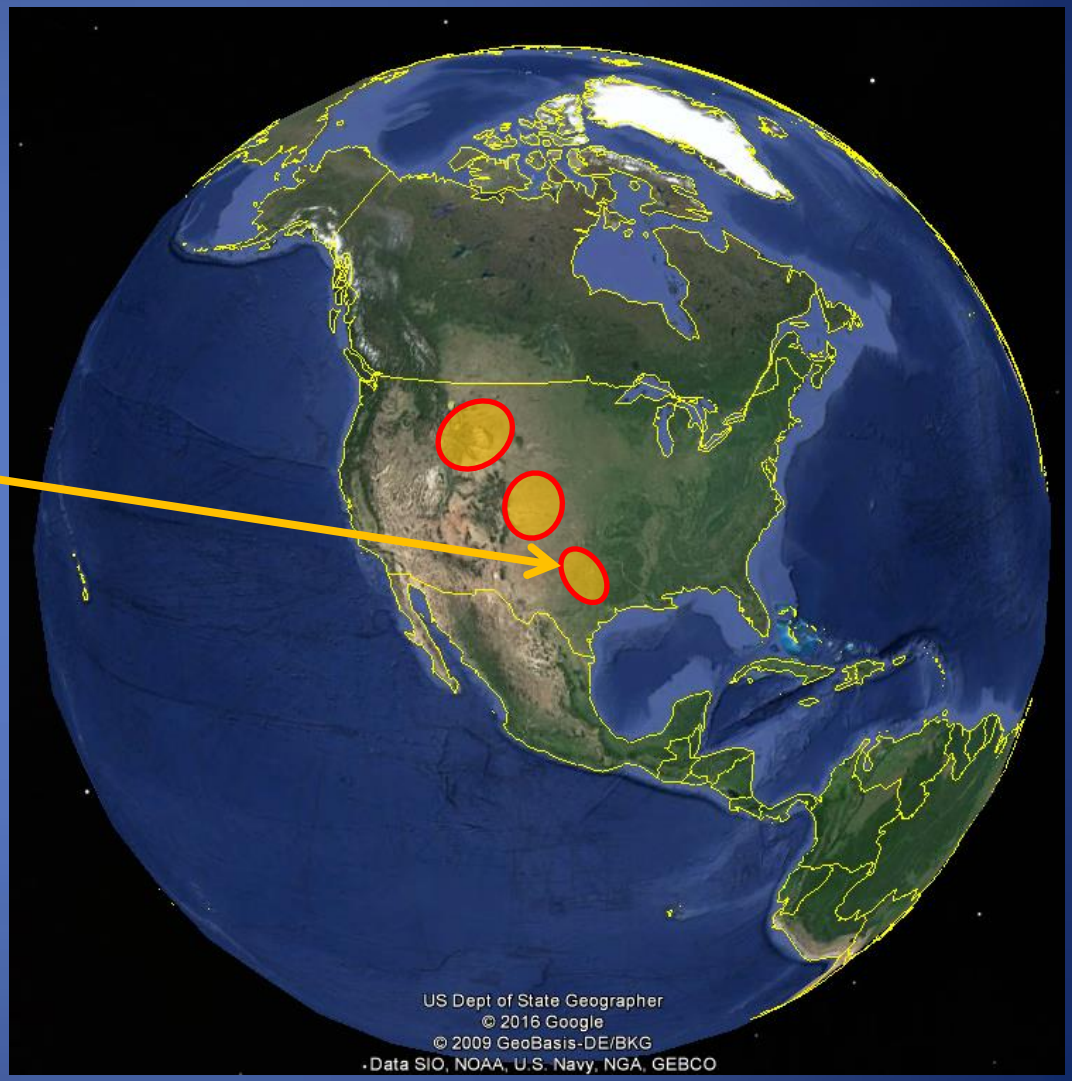


North Texas: An Ideal Testing Ground for Understanding/Mitigating Induced Seismicity associated with Geothermal systems

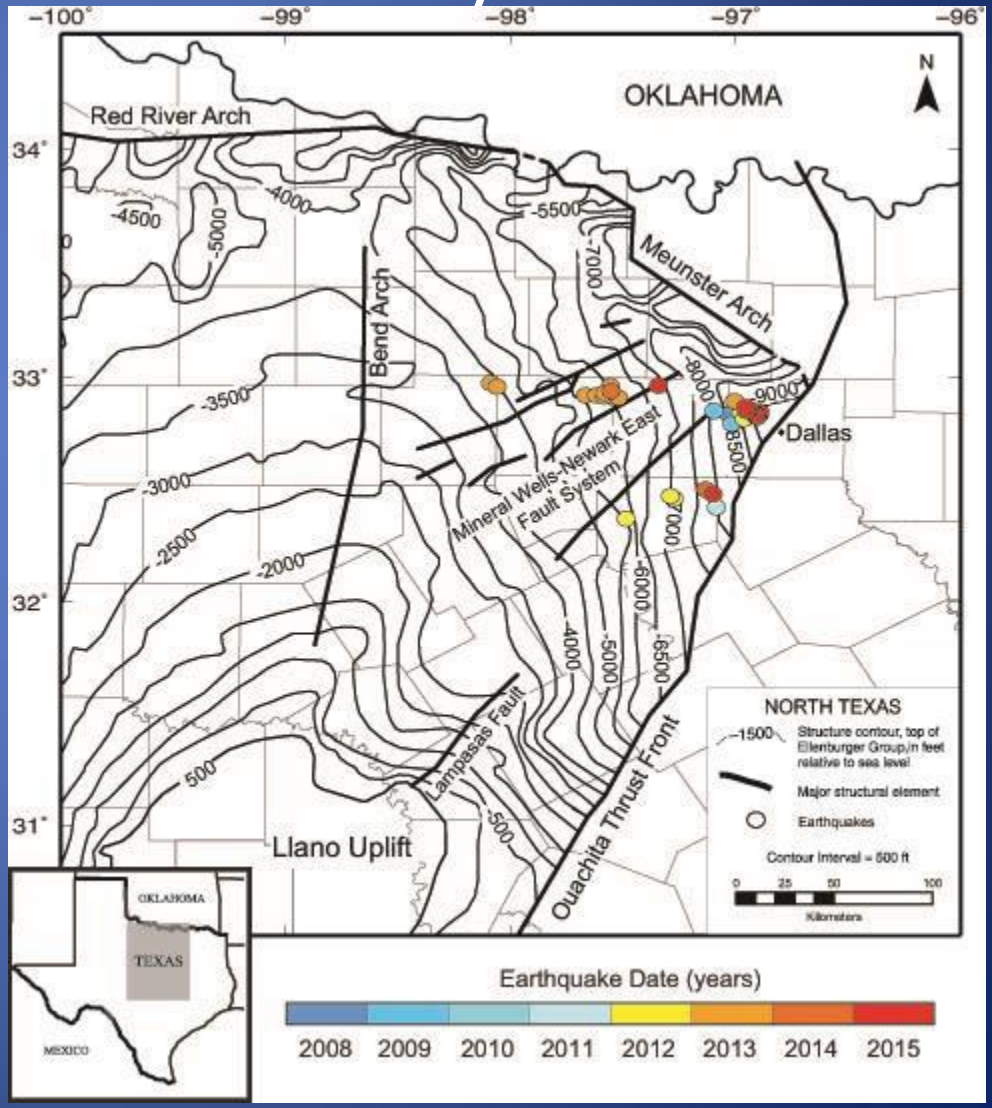
Why?

--Several large (>100,000 bbls/month) Wastewater injector sites exist

--Multiple Geological Geophysical datasets exist to constrain study.

--Plenty of induced seismicity

--SMU operates the only high-resolution seismic networks in the area and maintains an extensive geothermal dataset in the region.



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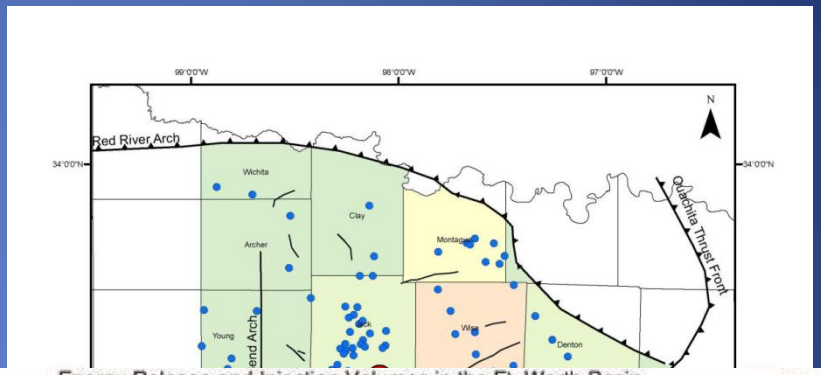
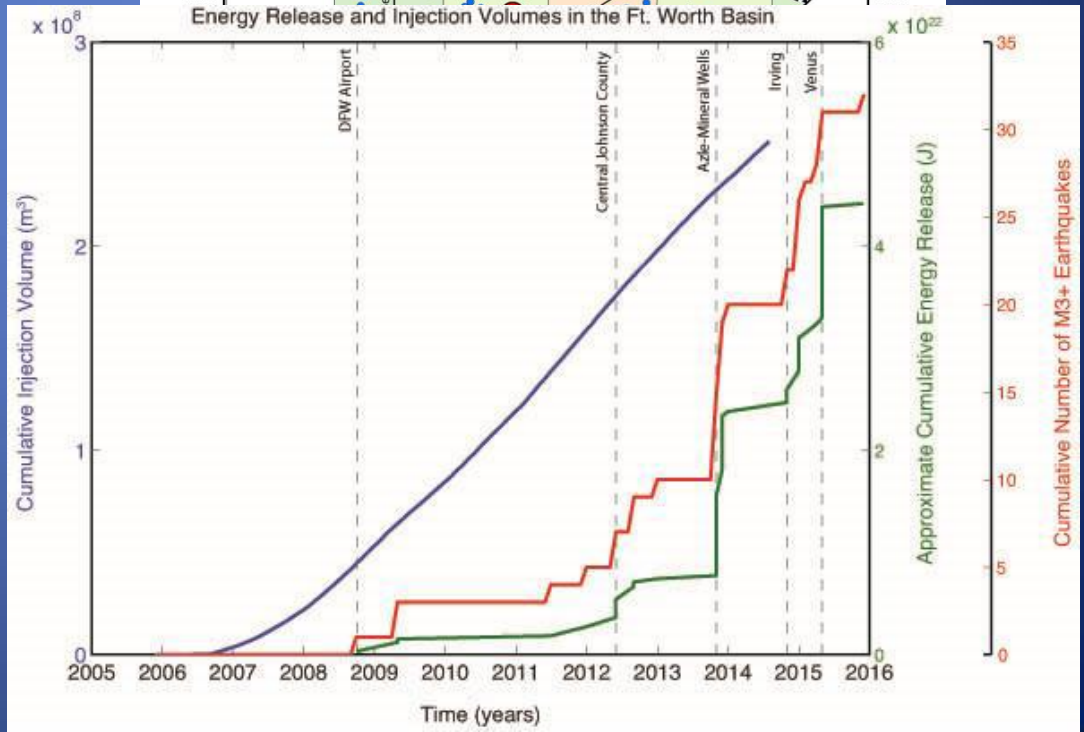




North Texas: An Ideal Testing Ground for Understanding/Mitigating Induced Seismicity associated with Geothermal systems

<u>Key Preliminary Conclusions</u>

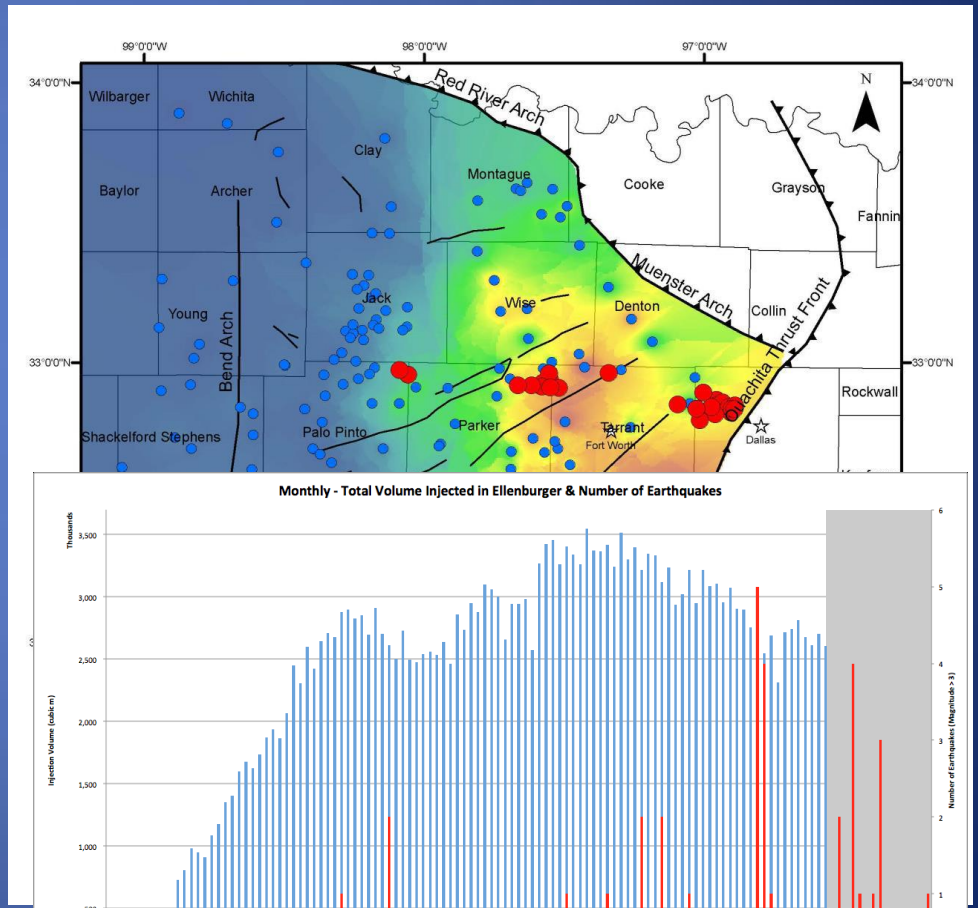
--Areas of Highest Seismicity correlate to areas of highest injection volume.

--Basin-wide pressures have likely elevated by ~13 psi, but areas of induced seismicity show pressure increases of 50-600 psi.

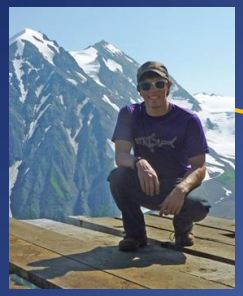
--Faults that active have similar orientations.

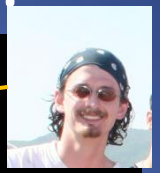
--Pressure and fault info can be used to mitigate seismicity risk.

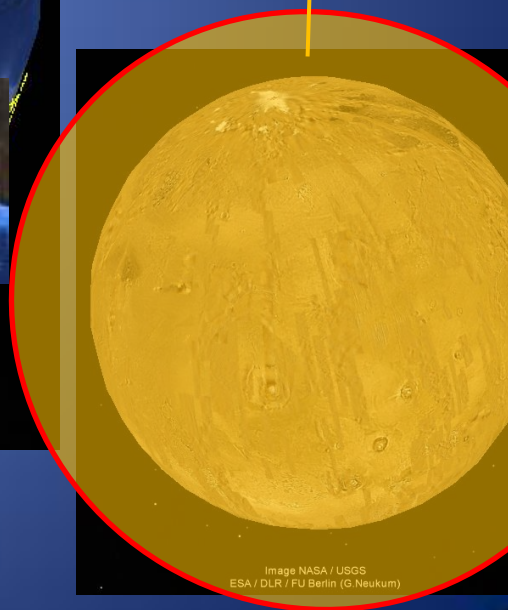
--Appears to be, on average, a 1-2 year delay between injection and seismicity to get the best correlation—one might speculatively predict less seismicity in the coming years due to reduced injection rates and lower production in the Ft. Worth Basin since ~2014.



We are always looking for new, exciting projects to support new students!







Special Thanks to