Injection, Pressure, and Seismicity: From Data to Decision-Making

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Center for Injection and Seismicity Research | Bureau of Economic Geology, UT Austin

April 8, 2026 | 3:00 PM | Injection, Pressure and Seismicity Session

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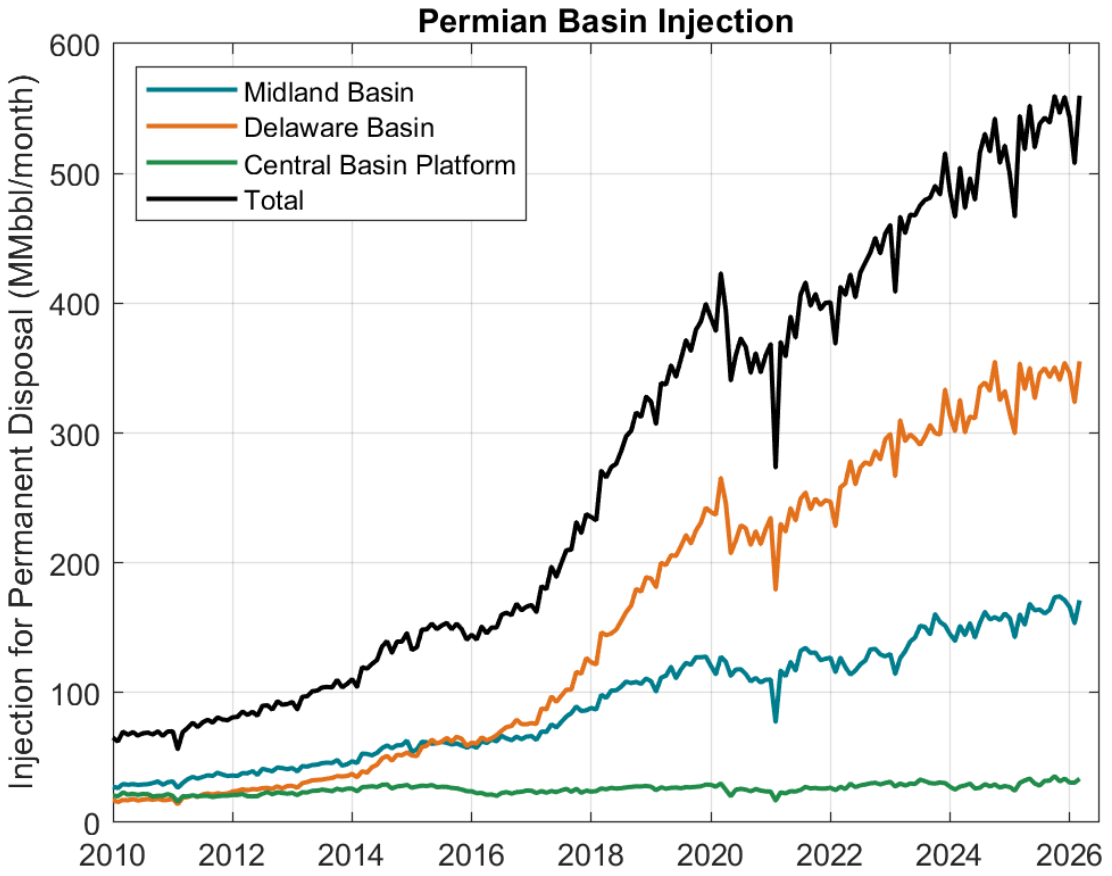
The Scale of the Challenge: Managing the Permian Water Cycle

- Permian Basin produces >20 million barrels of water per day alongside oil — nearly all requires permanent disposal
- Recycling for hydraulic fracturing is growing (~70%) but PW eventually has to be managed
- **Total disposal: ~18+ MMbbl/day — one of the largest subsurface injection programs on earth**
  - ~2/3 of injected volumes in Delaware Basin
  - Across the Permian, ~75% injected into shallow reservoirs; ~25% into deep reservoirs
- **Injection demand is not temporary: hundreds of billions of barrels of future disposal needs projected for the Permian Basin region**



Smye et al. 2024, AAPG Bulletin;
Hennings & Smye 2024, AAPG Bulletin;
Injection data: B3 Insight

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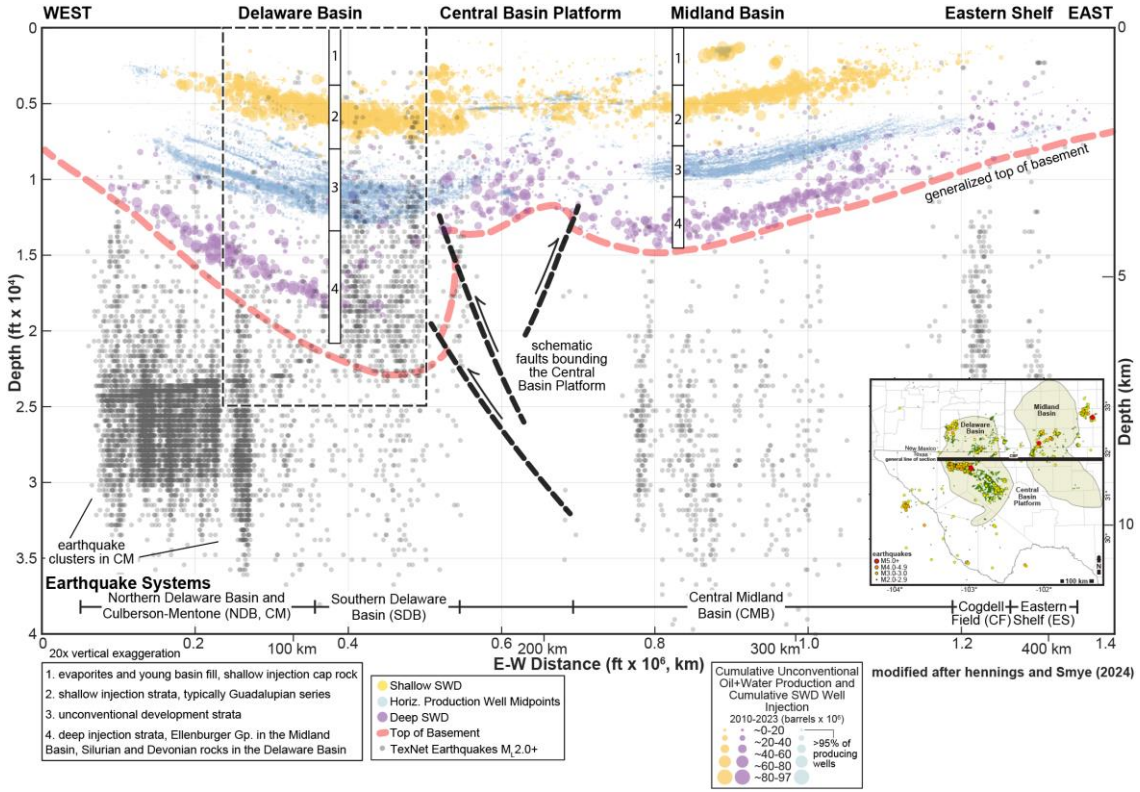

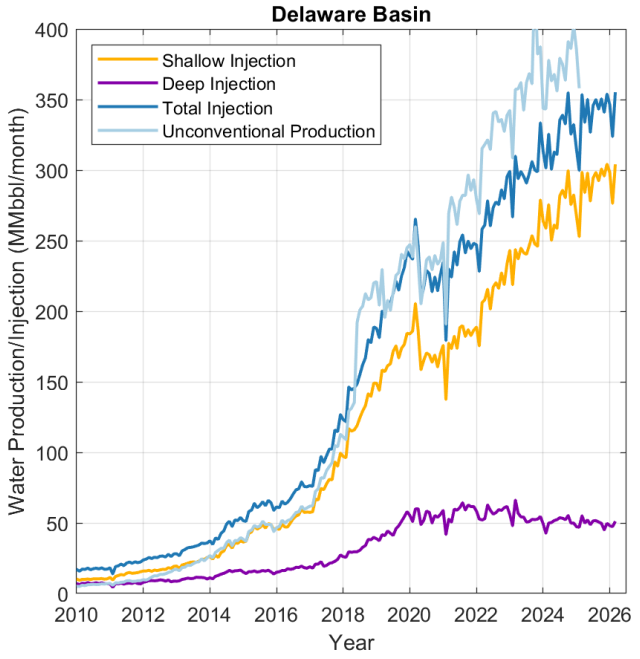

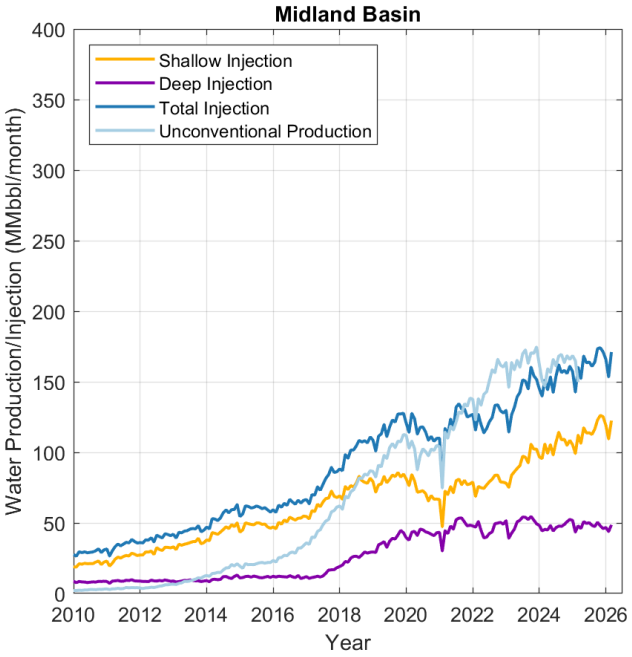

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The Data Ecosystem: Connecting Geology and Operations

Injection & operational data	Subsurface geology	Pressure & stress evolution	Injection impacts
Injection rates & volumes (regulatory)	**2D / 3D seismic reflection data**	**Downhole pressure gauges (BHP / BHT)**	**Earthquake catalogs (TexNet, NMT, HQ)**
Wellhead pressure records (operator)	**Well logs & formation tops**	Stress orientation (breakouts, FMI logs)	**Surface flows & well blowout incidents**
Produced fluid volumes (estimated)	**Core samples & petrophysical analysis**	Regional pore pressure simulation models	**InSAR surface deformation**
Well completion & perforation intervals	Outcrop analogs & stratigraphic correlation	Geomechanical stress models	Focal mechanisms & fault plane solutions
Water balance & disposal projections	Mapped faults & slip sensitivity	Injection capacity & fracture gradient scenarios	Spatiotemporal injection-EQ correlation
	Injection reservoir geocellular models		Causal mechanisms & induced seismicity models

Confidence level:

Direct measurement | Compiled / estimated | Interpreted | Modeled / synthesized

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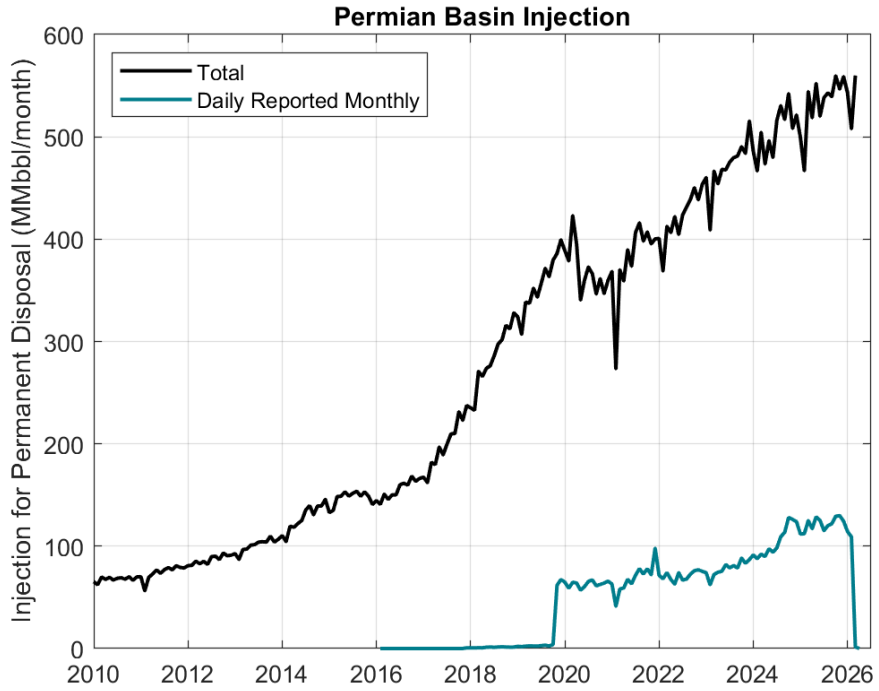
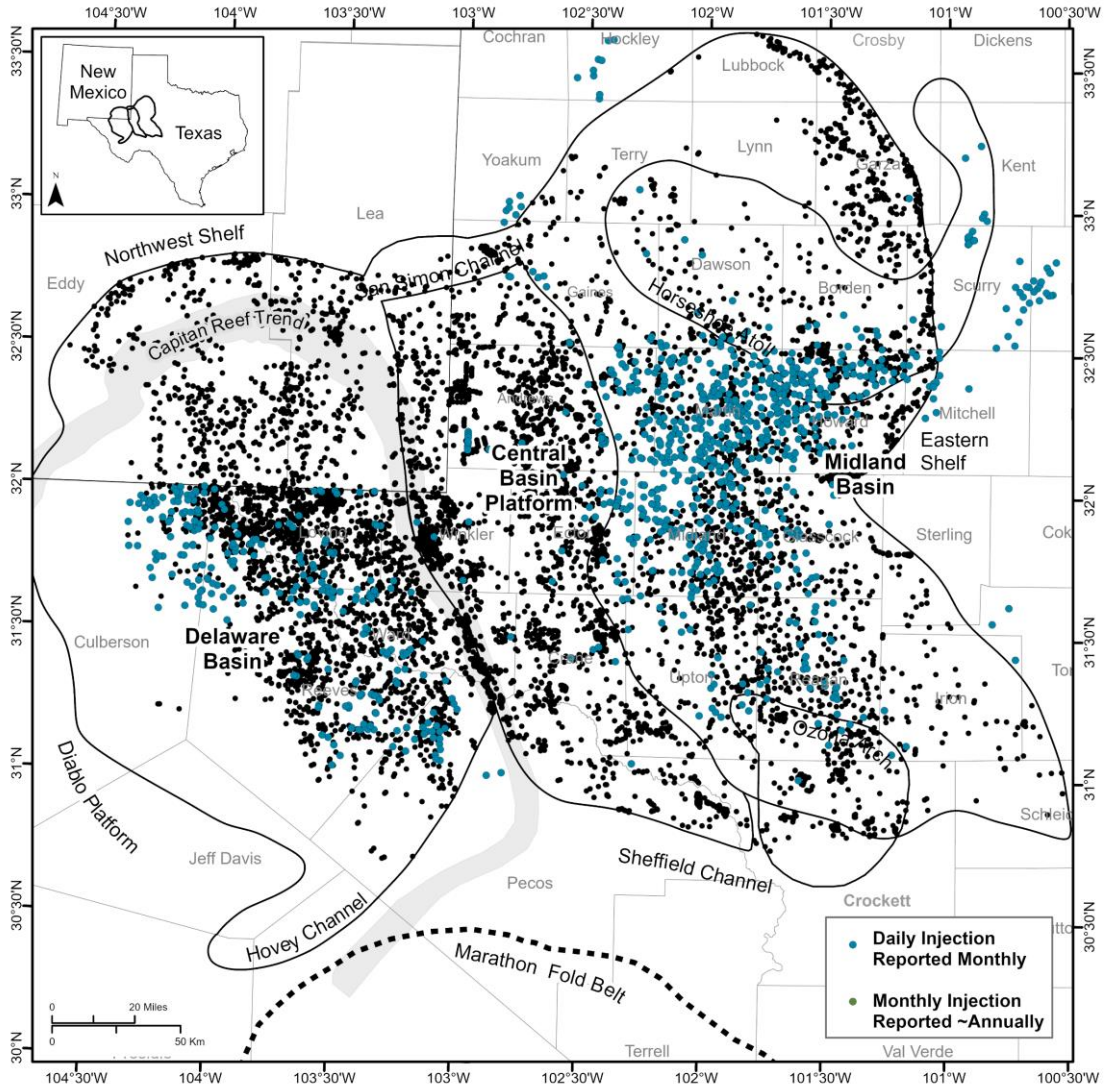
Injection & Operational Data

- ~1,000 Permian Basin SWDs reporting daily volumes on a monthly basis rather than monthly volumes on an annual basis
- Data frequency impacts models of pressure buildup, creation of hydraulic fractures with injection, association to EQs, understanding of injectivity, and many more

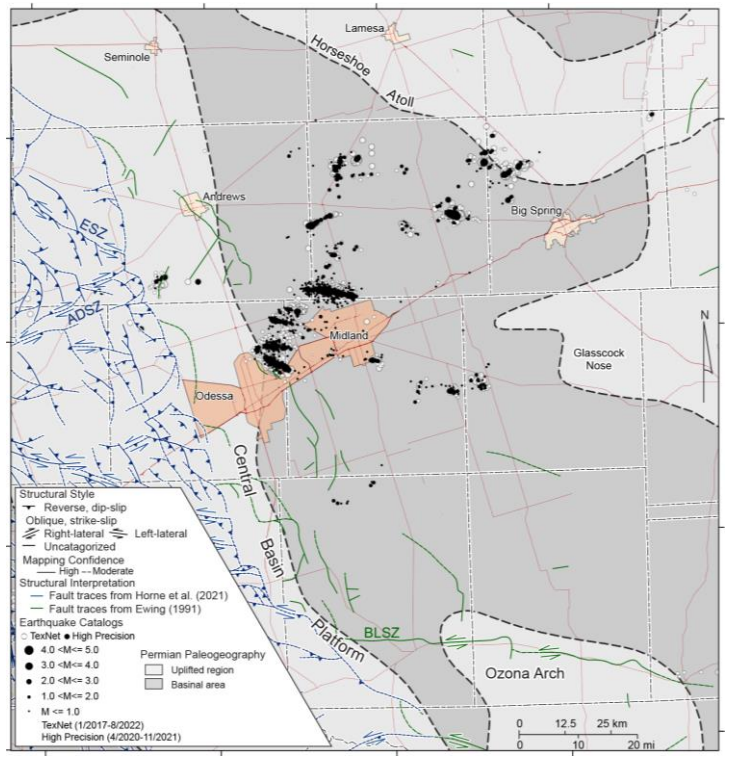




Data Integration for Fault Interpretation

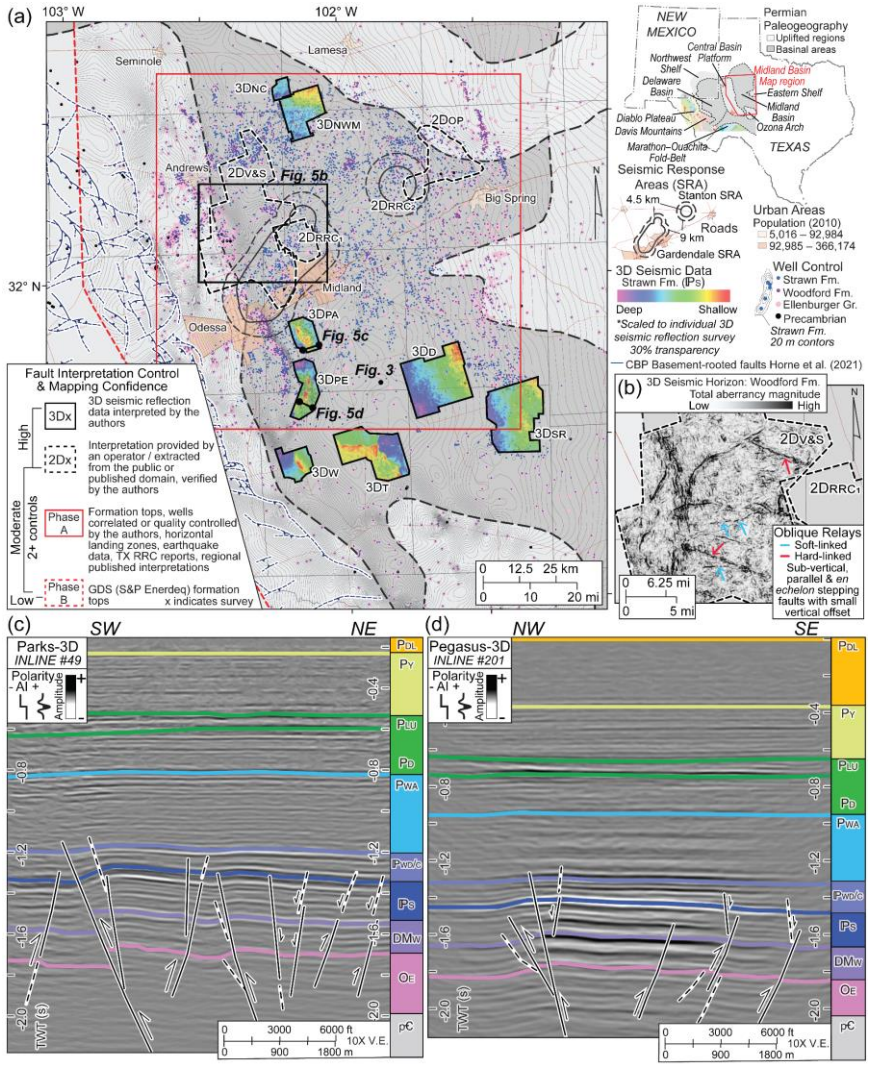
Publicly-available Midland Basin fault interpretation pre-SWD

Basement-Rooted Faults
Ewing (1991)



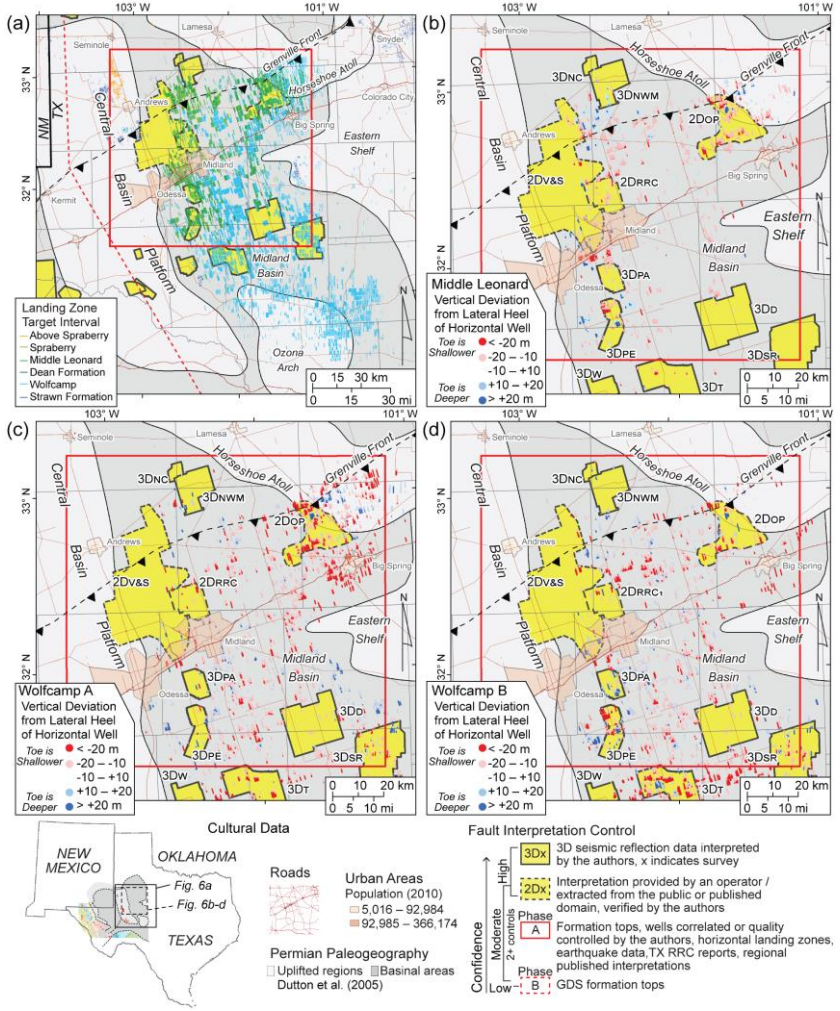
Deep well penetrations, 3D seismic, structural contours

Compiled in Horne et al.



Vertical deviation in horizontal wells (subtle structures)

Compiled by Smye et al.



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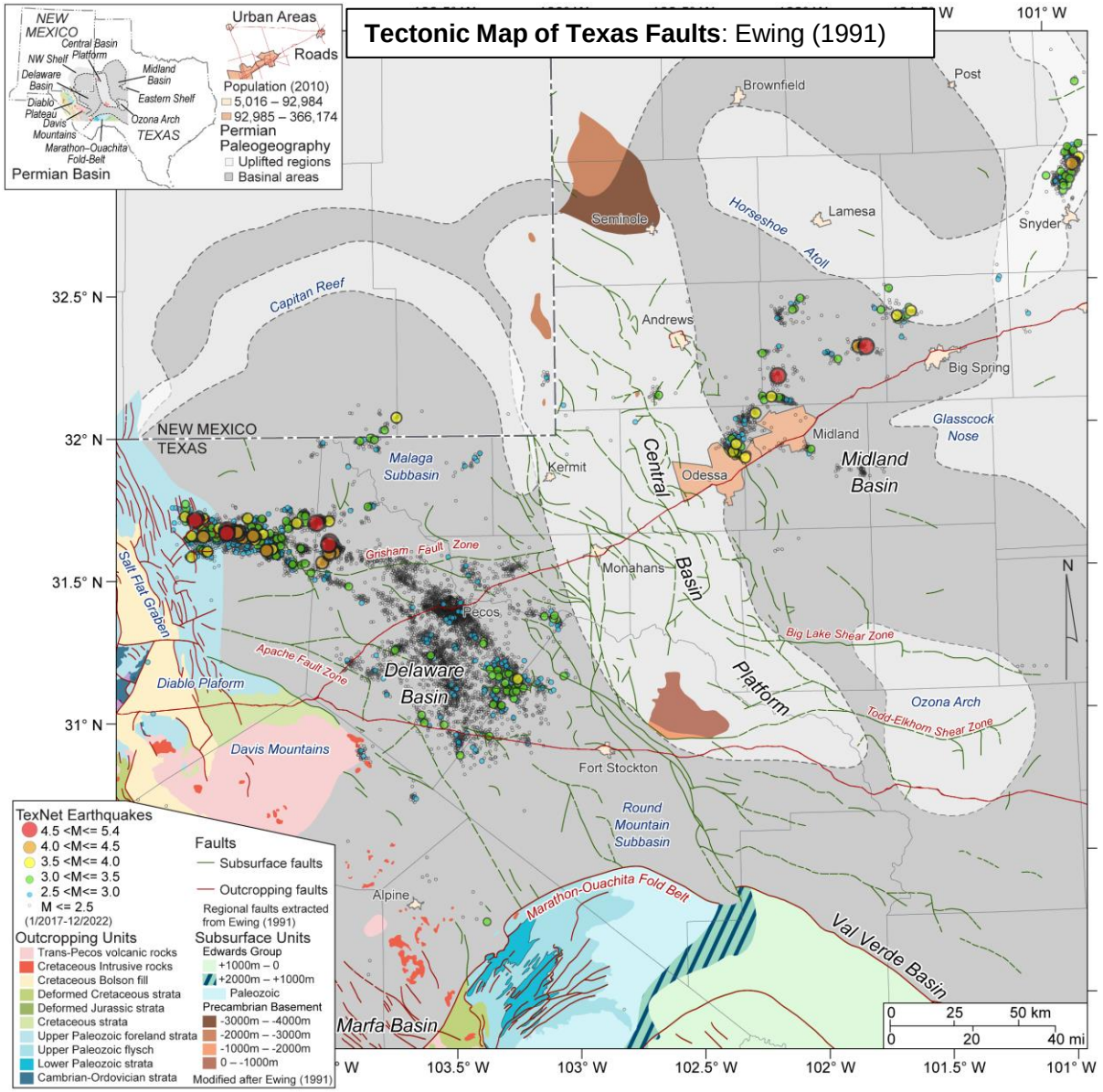
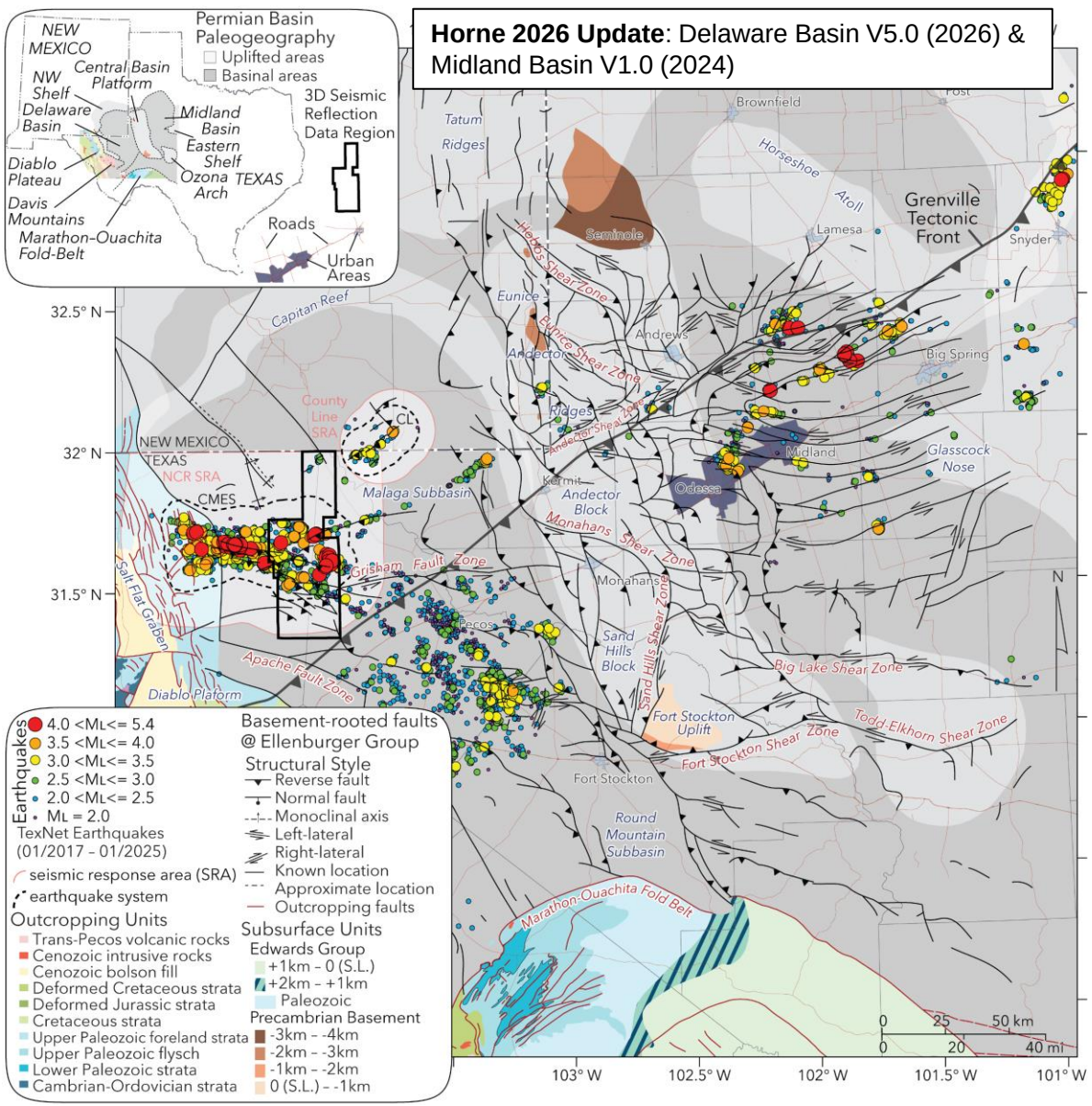
Data Integration for Fault Interpretation – 1991 vs 2026





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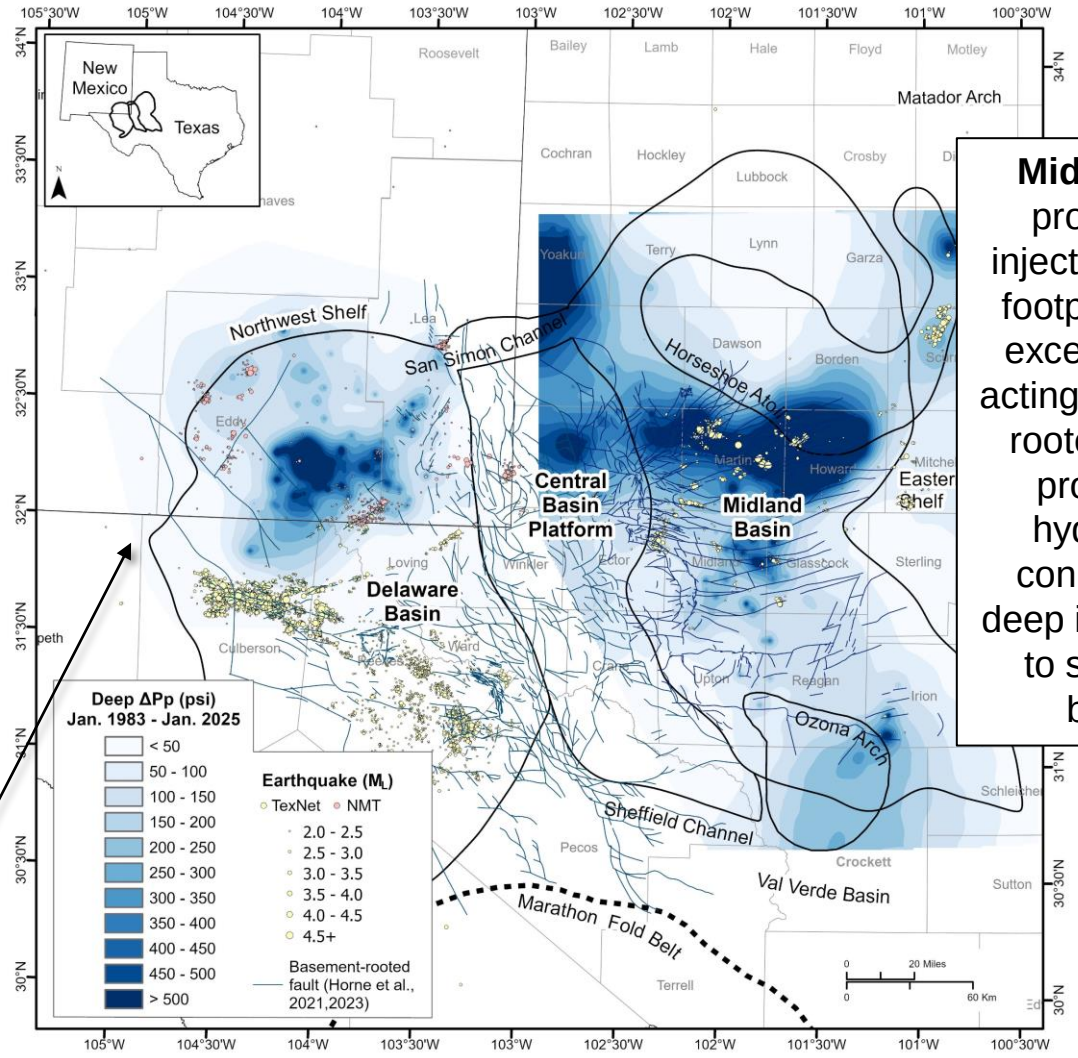
Injection Reservoir Pressurization (Models)

- Dynamic reservoir simulation models constructed using upscaled geocellular models developed with core, log, and seismic data
- Calibrated using BHPs estimated from SIPs and rare downhole pressure gauge data and BHP measurements
- Both shallow and deep injection systems show significant pore pressure (ΔPp) increase across the Permian Basin
- Pressure is not uniform — lateral diffusivity, fault connectivity, and stratigraphy control spatial patterns

northern Delaware Basin:
ΔPp plume from regional and distal deep injection intersects basement-rooted fault system that is highly sensitive as related to basement heterogeneity and connects to deep injection strata; *consideration of anisotropy and increased diffusivity needed*



Midland Basin: proximal deep injection and broad footprint of ΔPp in excess of 500 psi acting on basement-rooted faults that provide direct hydrogeologic connection from deep injection strata to seismogenic basement

CISR dynamic pressure models (Ge, Nicot, Leng); updated from Ge et al. (2022), Smye et al. (2024), Smye, Ge et al. (in prep), Leng et al. (in prep)

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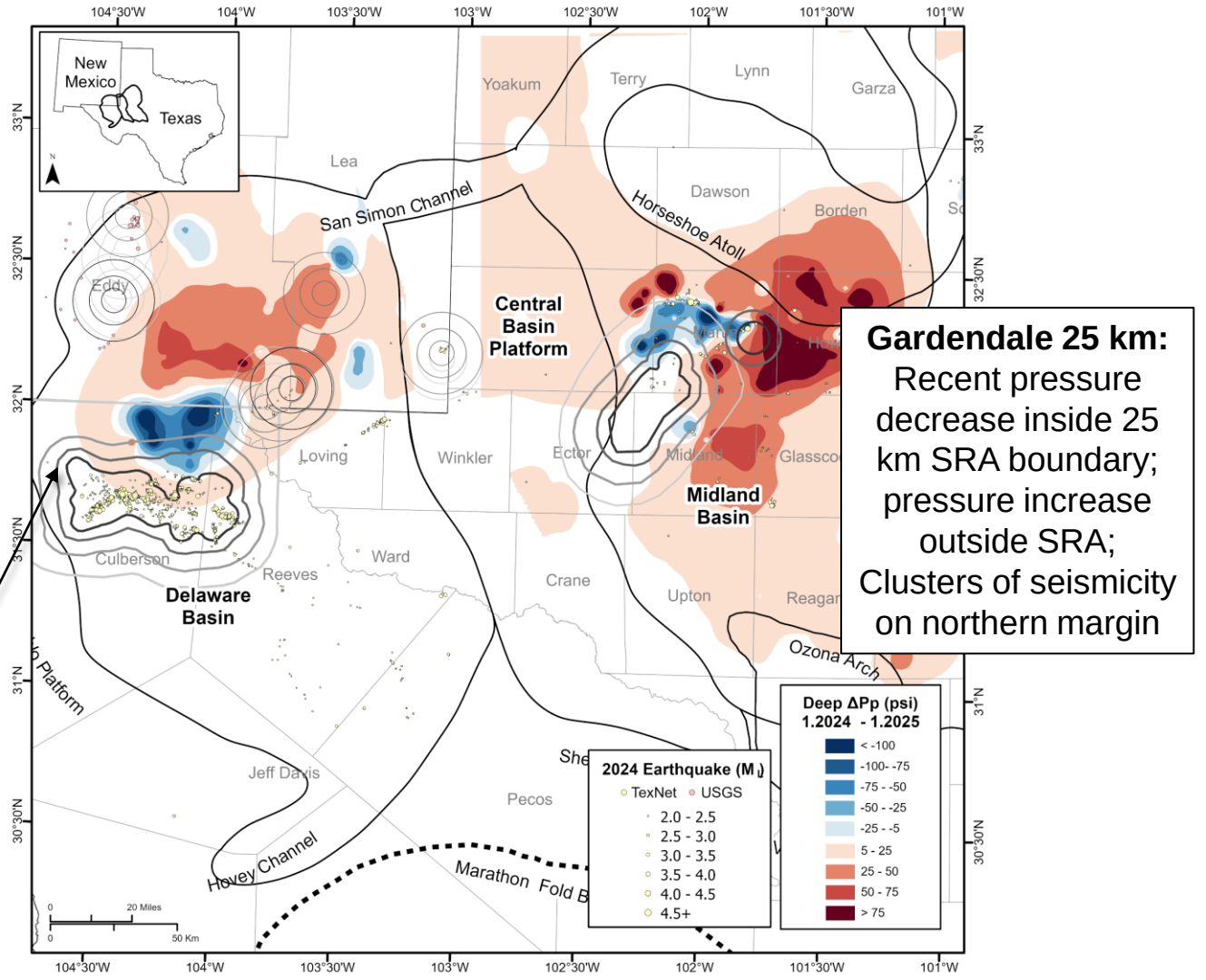
North Culberson-Reeves:
Recent pressure decrease due to shut-in of TX DB deep injection wells
Seismicity rate decrease



Gardendale 25 km:
Recent pressure decrease inside 25 km SRA boundary; pressure increase outside SRA;
Clusters of seismicity on northern margin

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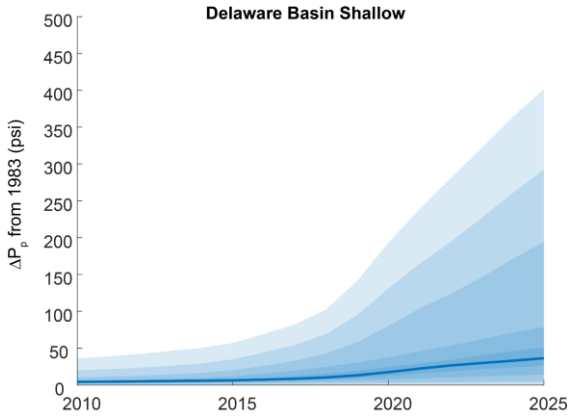

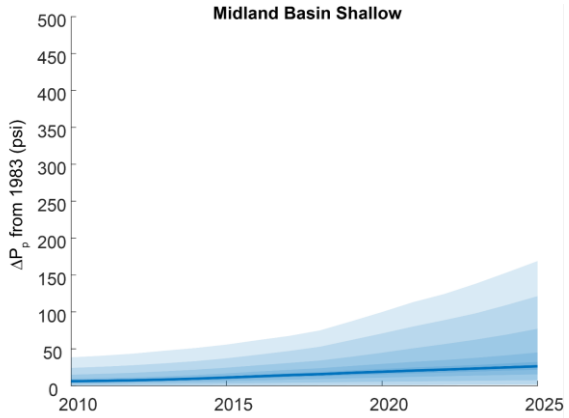

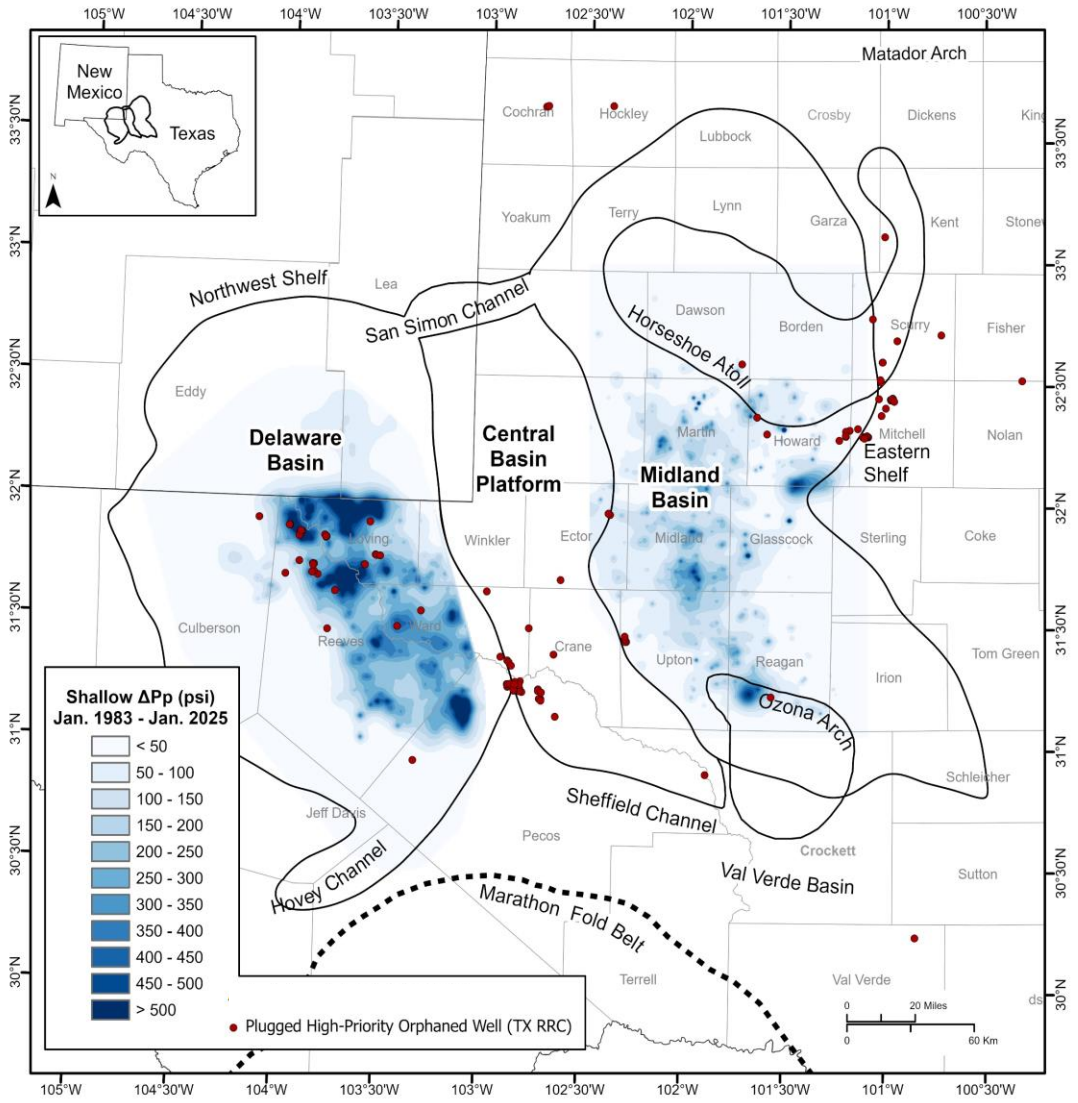

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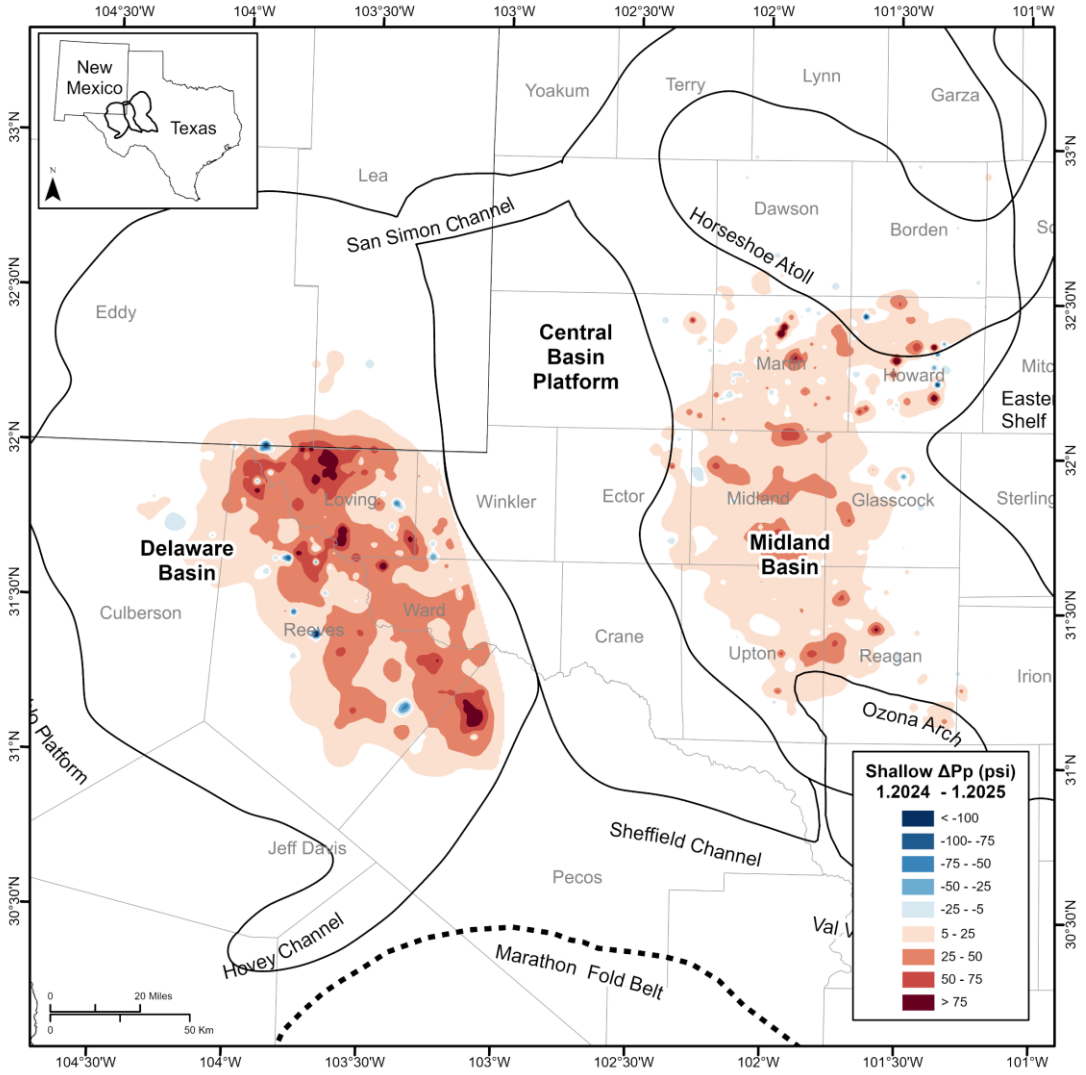

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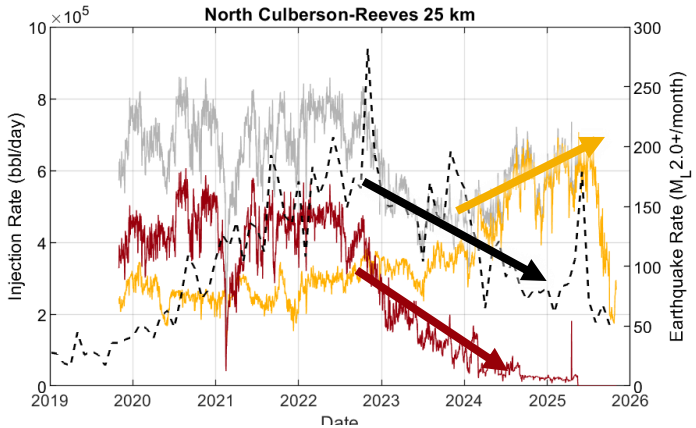
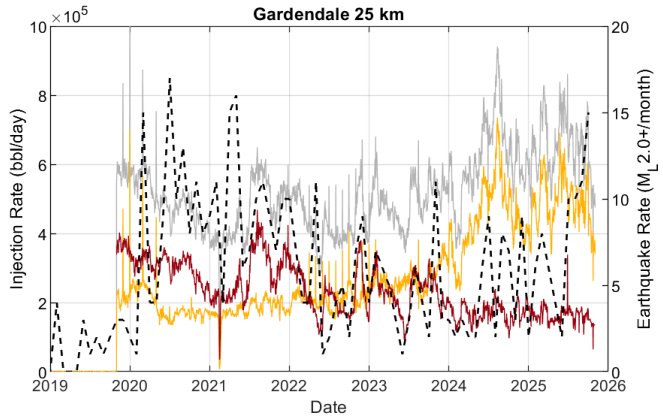
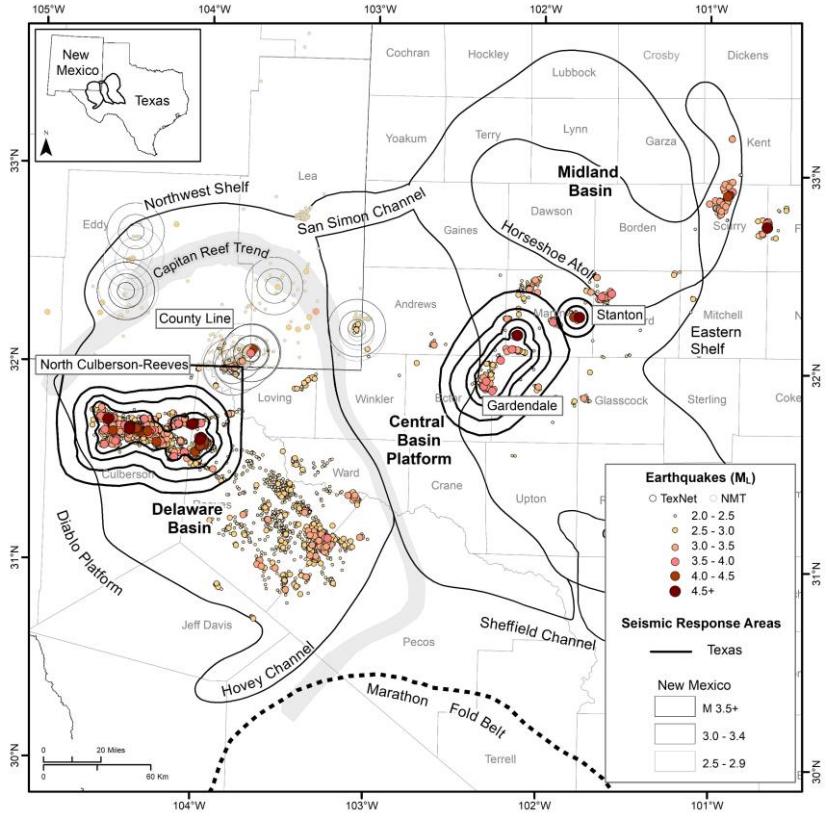
Injection Impacts: What the Data Are Telling Us

- >1,000 M_L3.0+ earthquakes in the Permian Basin through 2025; >20 M_L4.5+ (updates to Hennings & Smye 2024)
- **Seven distinct induced seismicity systems identified — each with unique geology, injection context, and management needs**
- Dominant mechanism: deep injection pressurizes basement-rooted faults that directly connect injection strata to seismogenic basement
- Shallow injection driving seismicity in some areas via strata-bound faults — different mechanism, different risk profile
- HF likely contributing to seismicity in some areas, in concert with both shallow and deep injection







Hennings & Smye 2024, AAPG Bulletin;
TexNet Earthquake Catalog; NMT catalog

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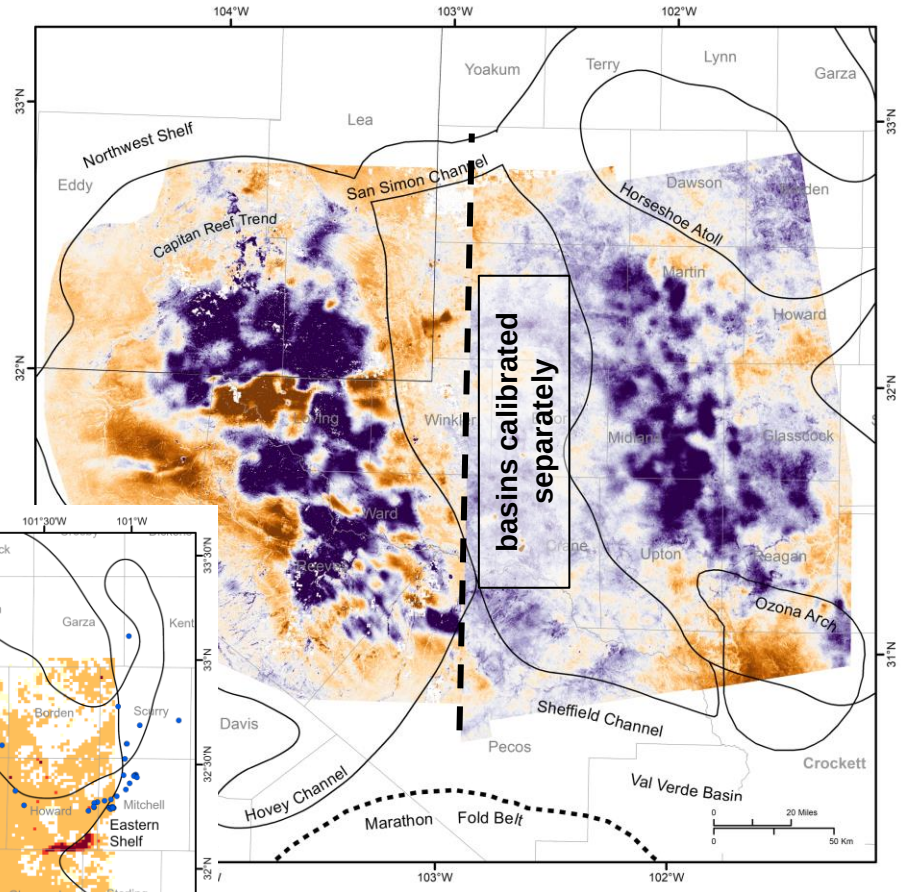
Injection Impacts: What the Data Are Telling Us

- Change in elevation of the ground surface is an indicator of shallow pressurization in the subsurface
- Near-surface containment losses including surface release of fluids can often be linked to uplift of the ground surface
- Areas at greater risk for near-surface challenges have surface uplift, legacy wellbores, and shallow injection reservoir pressurization



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From Data to Decision-Making

- **What we know:**
  - 18+ MMbbl/day injected; reservoir pressure building basinwide in shallow and locally in deep systems
  - Deep injection drives seismicity via basement-rooted fault connectivity to seismogenic basement
  - Shallow injection creating surface uplift, legacy well hazards, and strata-bound seismicity
  - Injection capacity is finite and must be managed proactively
- The decision-making chain **data collection → model integration → actionable thresholds → operational response → monitoring feedback** relies on collaboration between industry, academia, regulators, and commercial data providers
- **Key opportunities: shorten lag time between data releases and model updates, and between research and operational decisions — closing this requires near-real-time data sharing, evergreen models, and the ability to disseminate information more quickly than peer-review publication**