Key Advances in CCS Storage and Implications for Project Deployment

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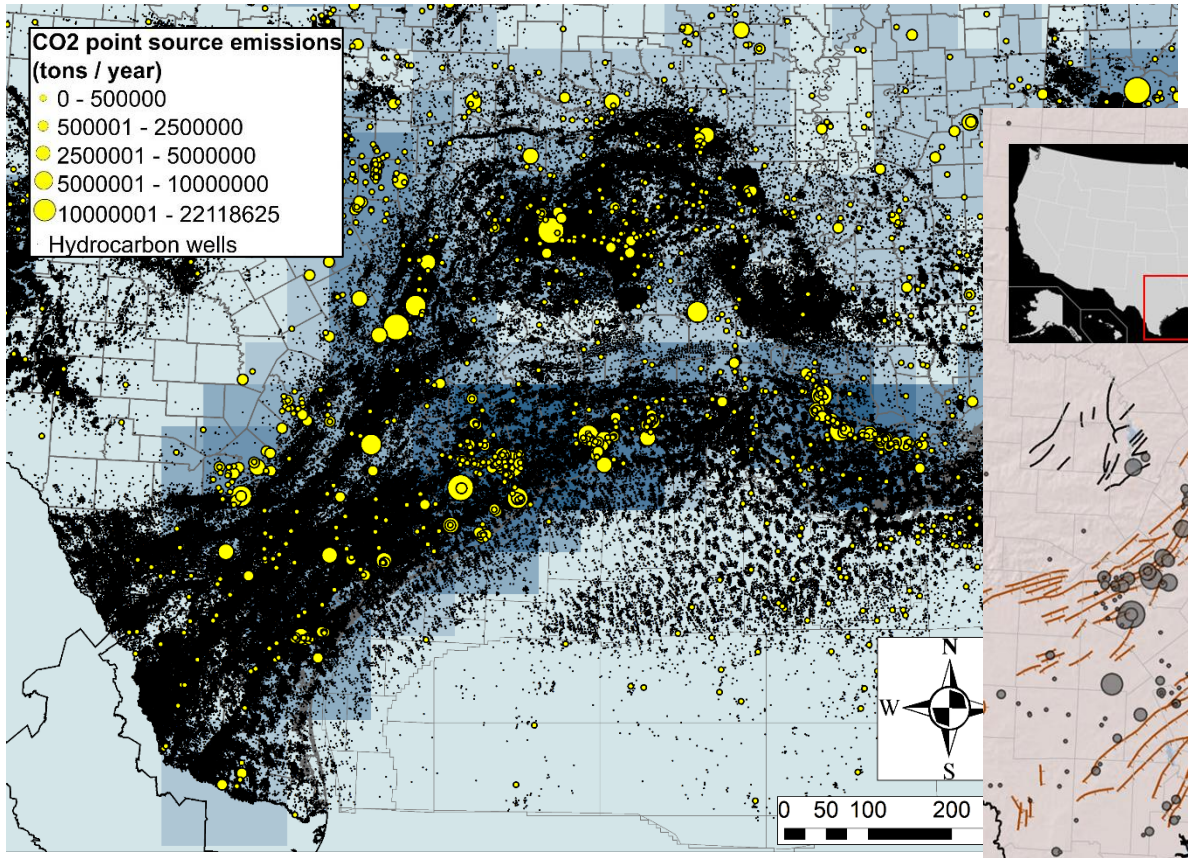
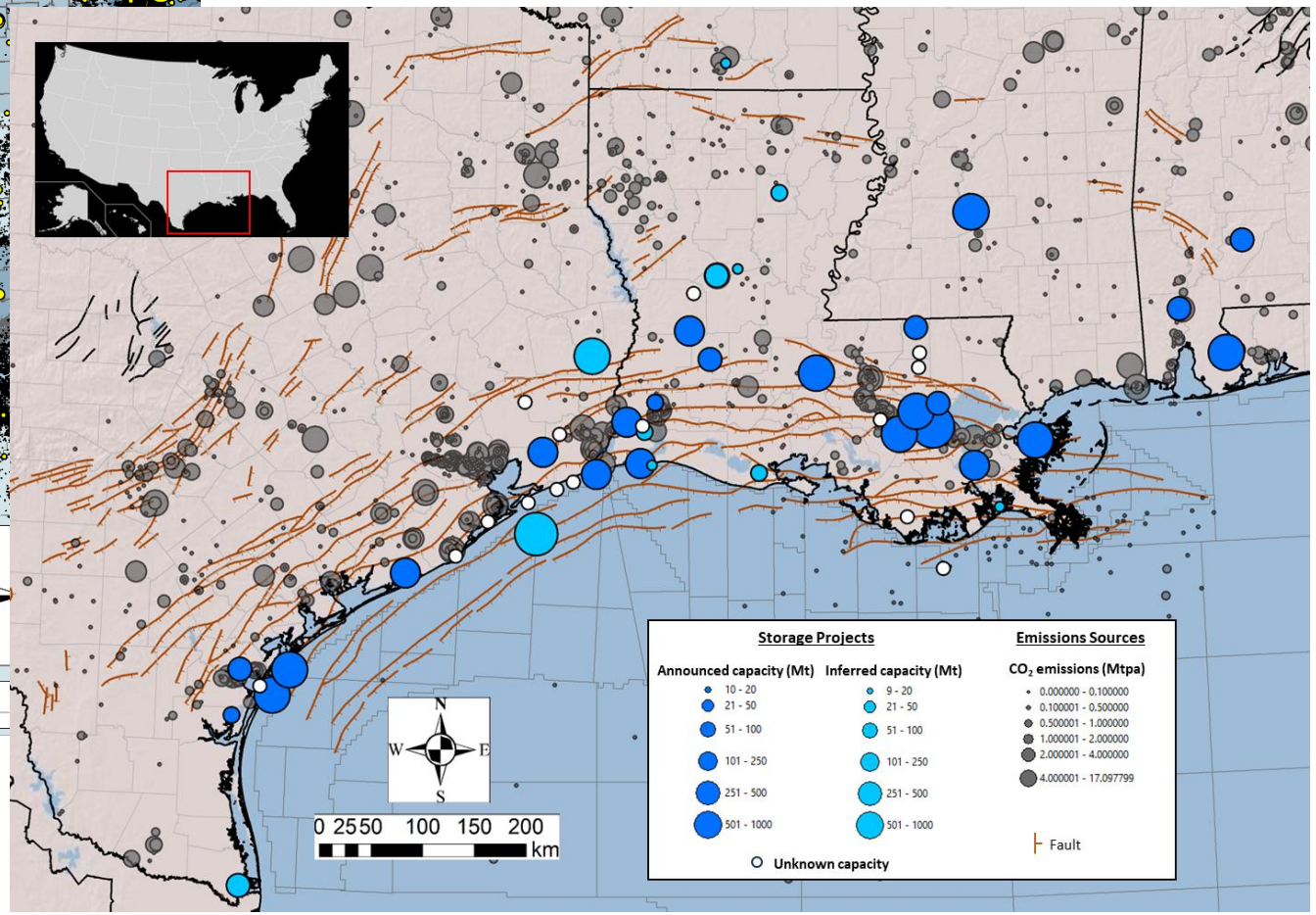
Funding: GoMCarb, SECARB, GCCC Industrial Sponsors

A Chance To Look Over the Horizon



Wells and emissions (Bump and Hovorka, 2023)

Publicly Announced Storage Projects



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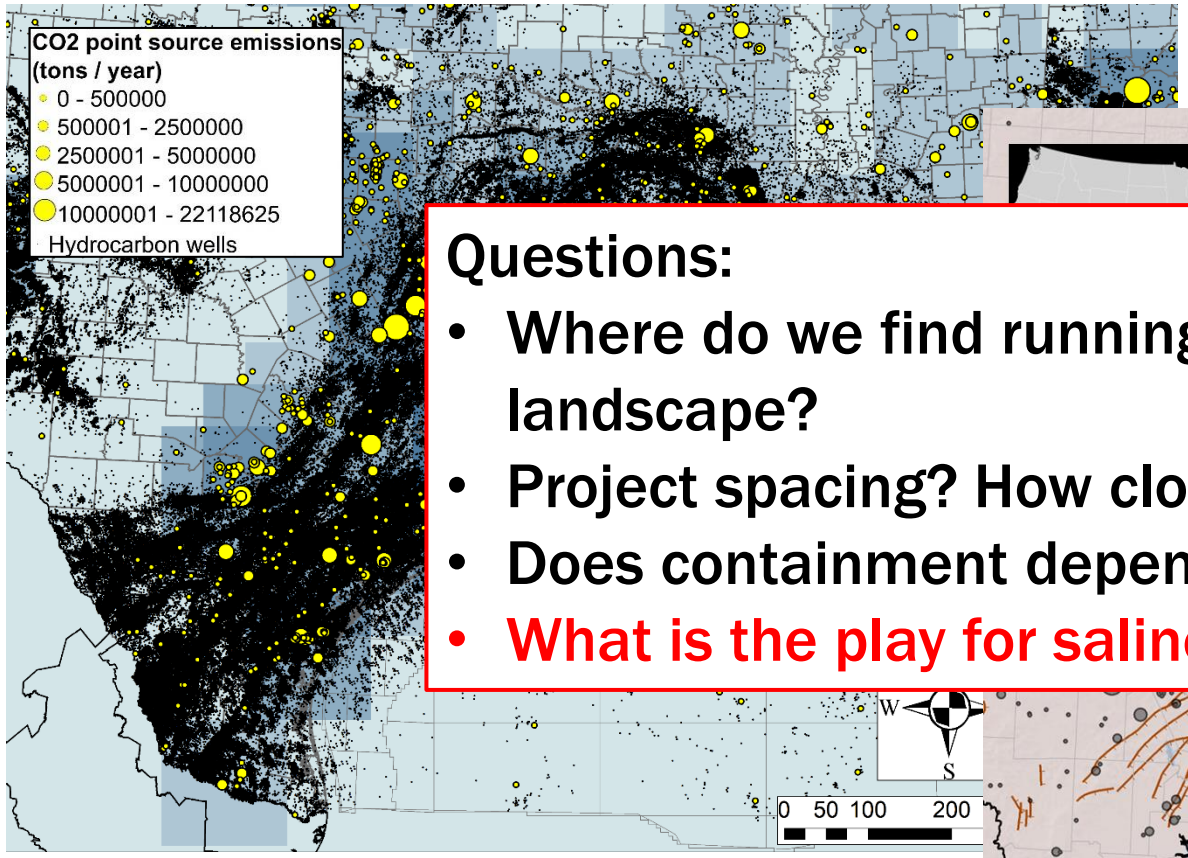
A Chance To Look Over the Horizon



Wells and emissions (Bump and Hovorka, 2023)

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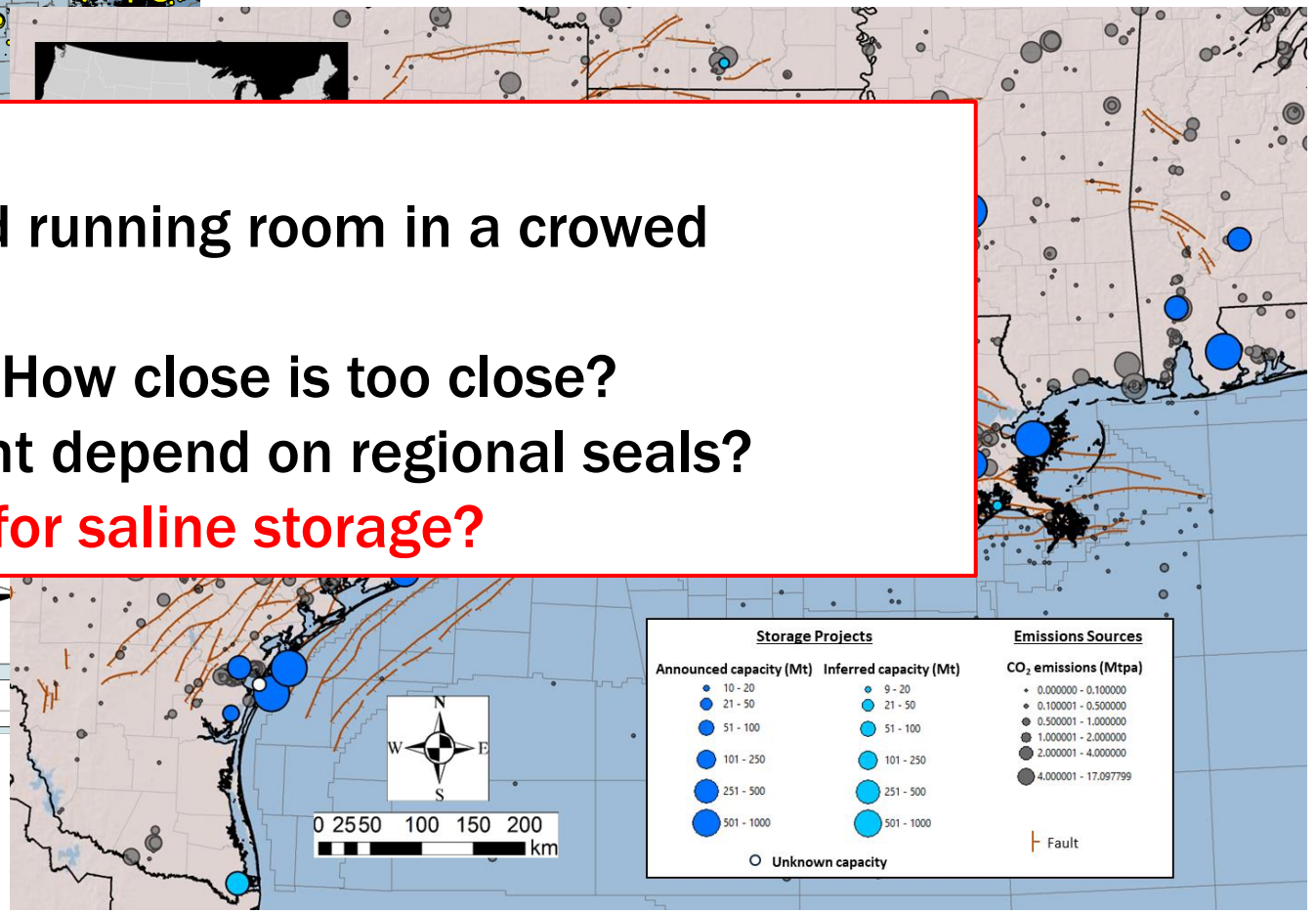

Questions:

- Where do we find running room in a crowed landscape?
- Project spacing? How close is too close?
- Does containment depend on regional seals?
- What is the play for saline storage?

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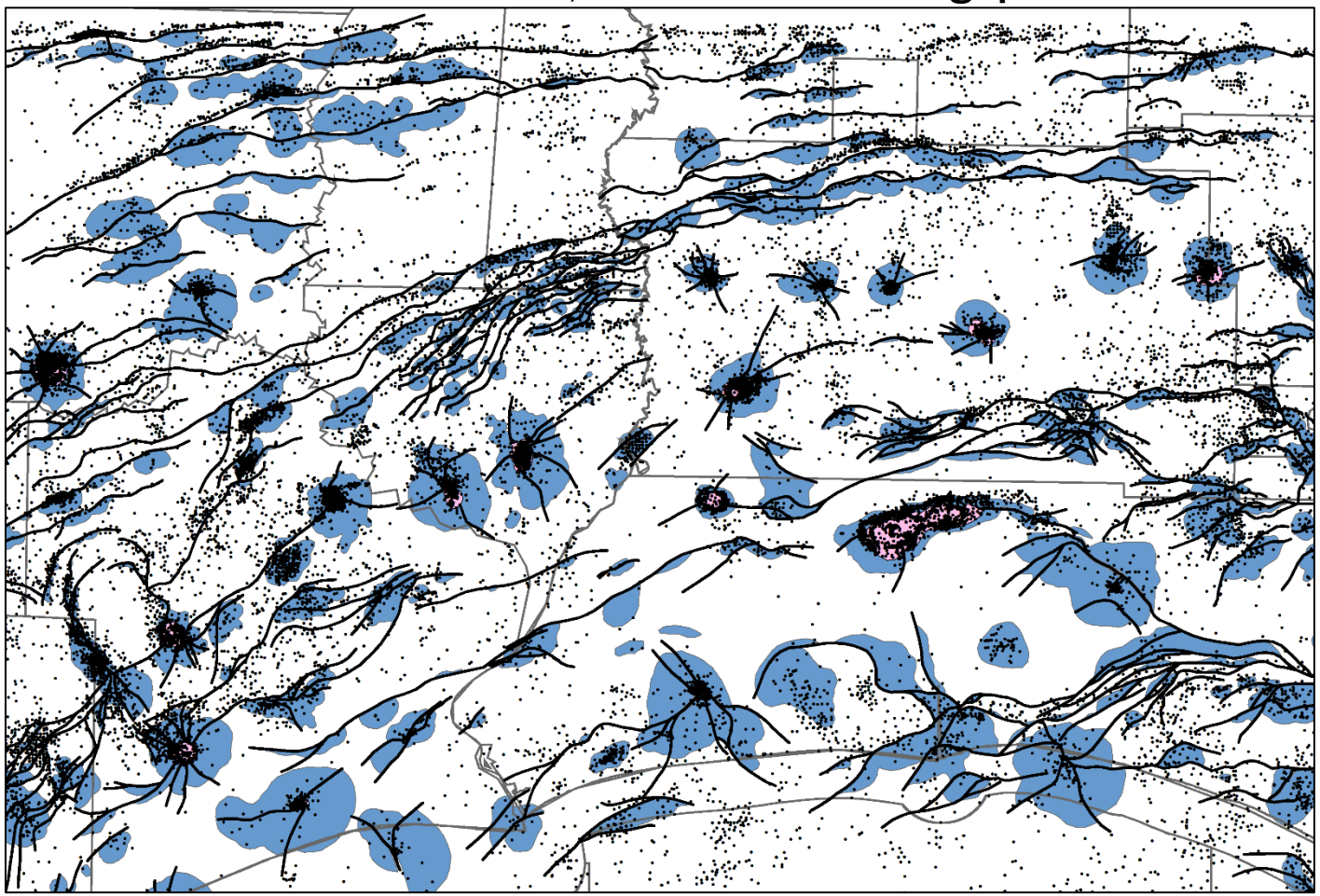
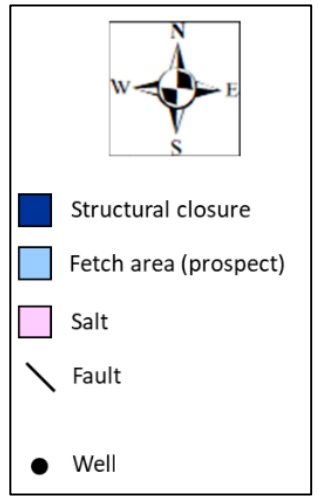
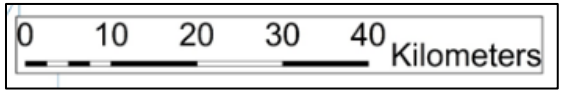
Finding Running Room

Wells are not evenly distributed

~14000 wells, but also ~100km^2 gaps!







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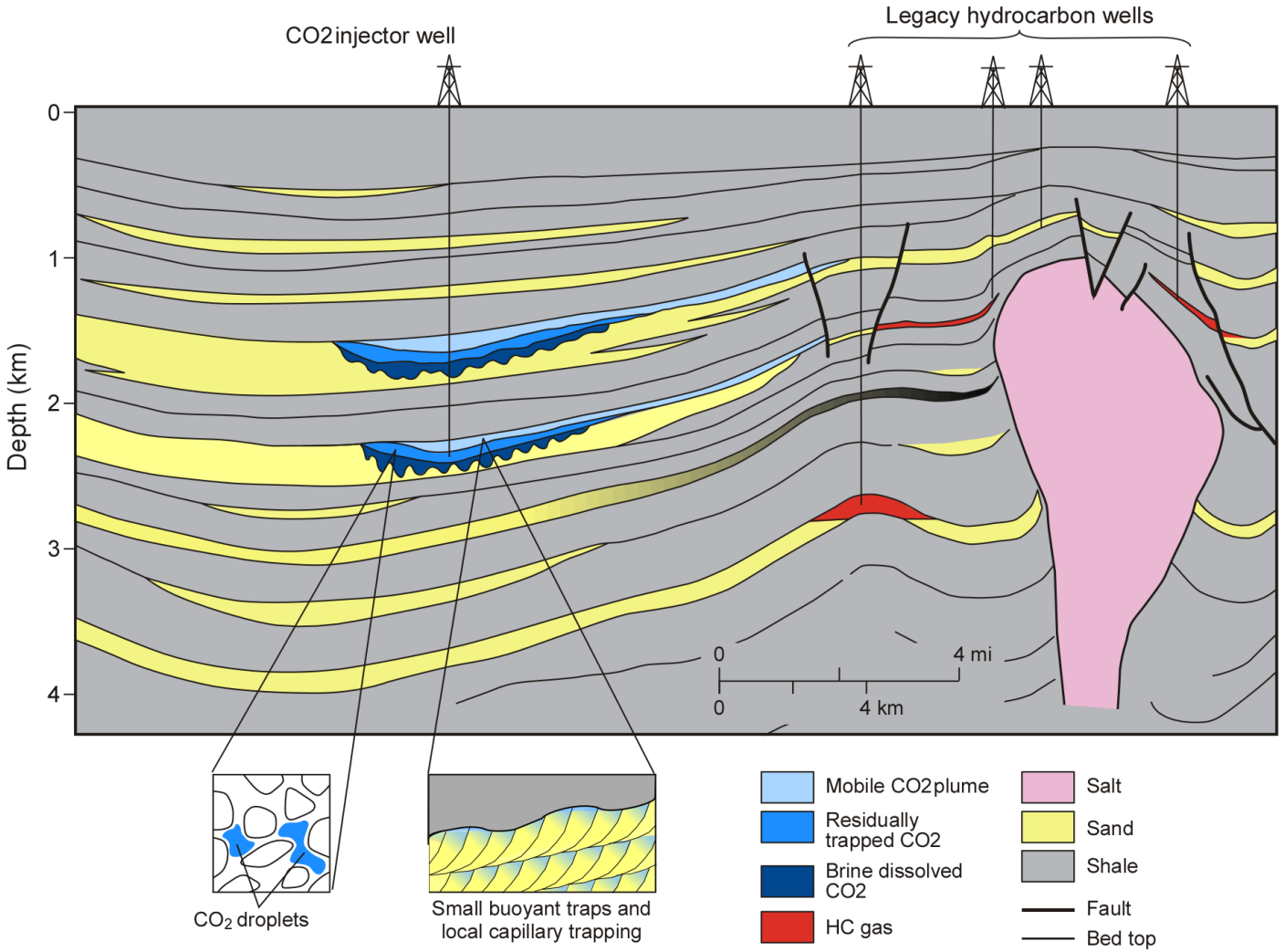
After Bump and Hovorka, 2023

A Play for Migration Loss



Bump and Hovorka, 2023

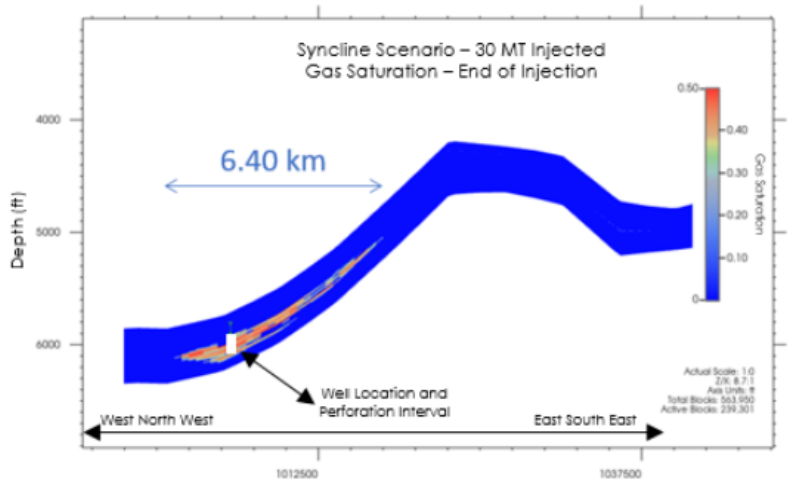
Modelled Plume Stabilization

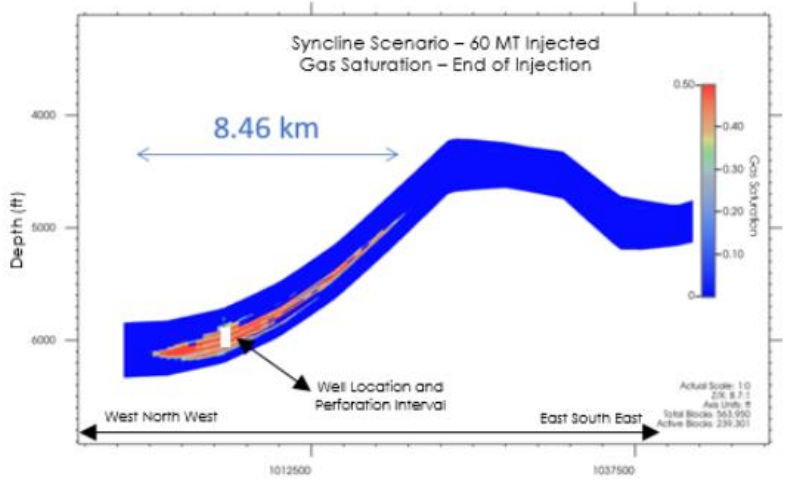
30Mt

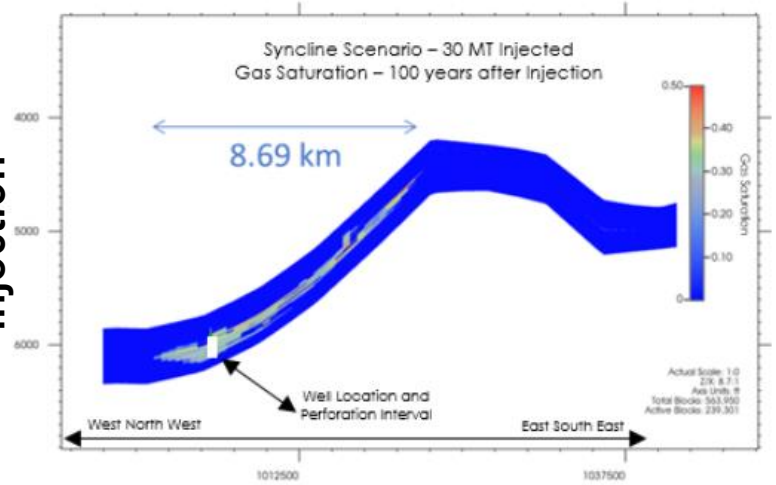
60Mt

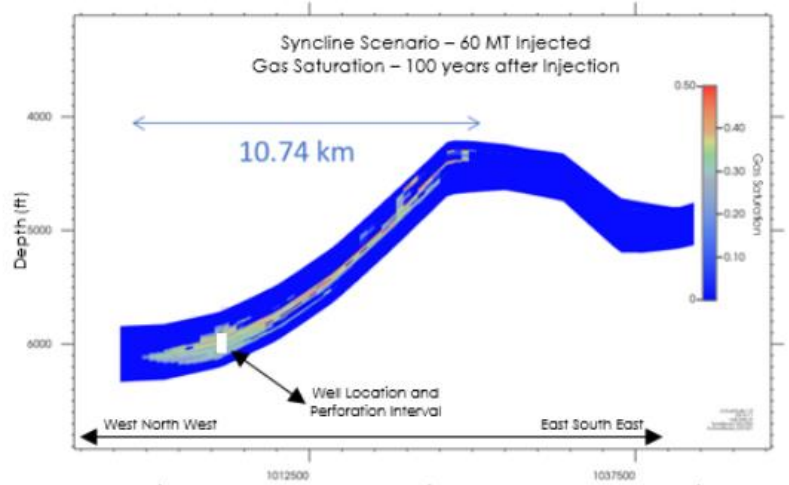
End of injection

100 years post-injection









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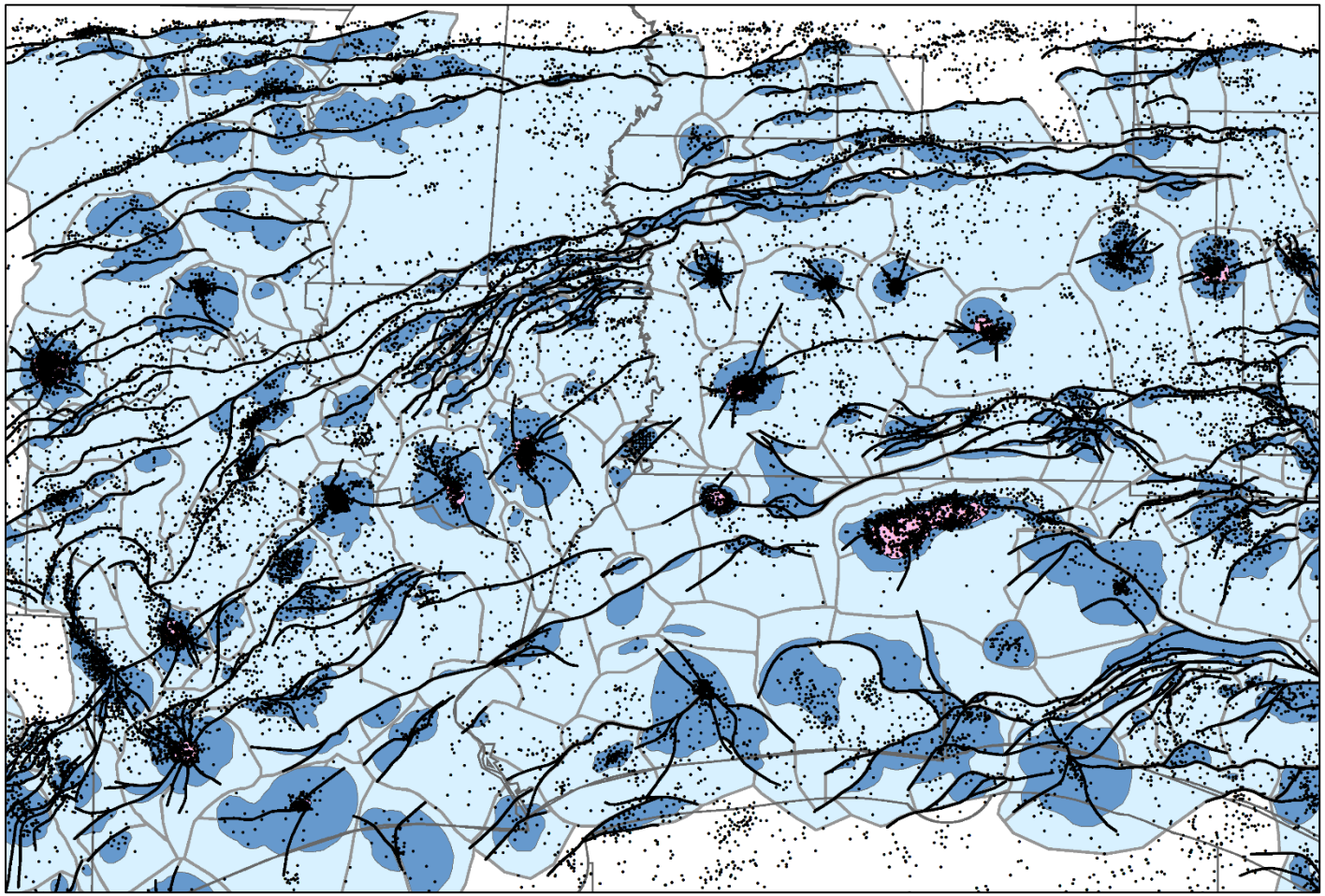
Ulfah et al, 2022

Focus on the Fetch

Regions of coherent buoyant flow



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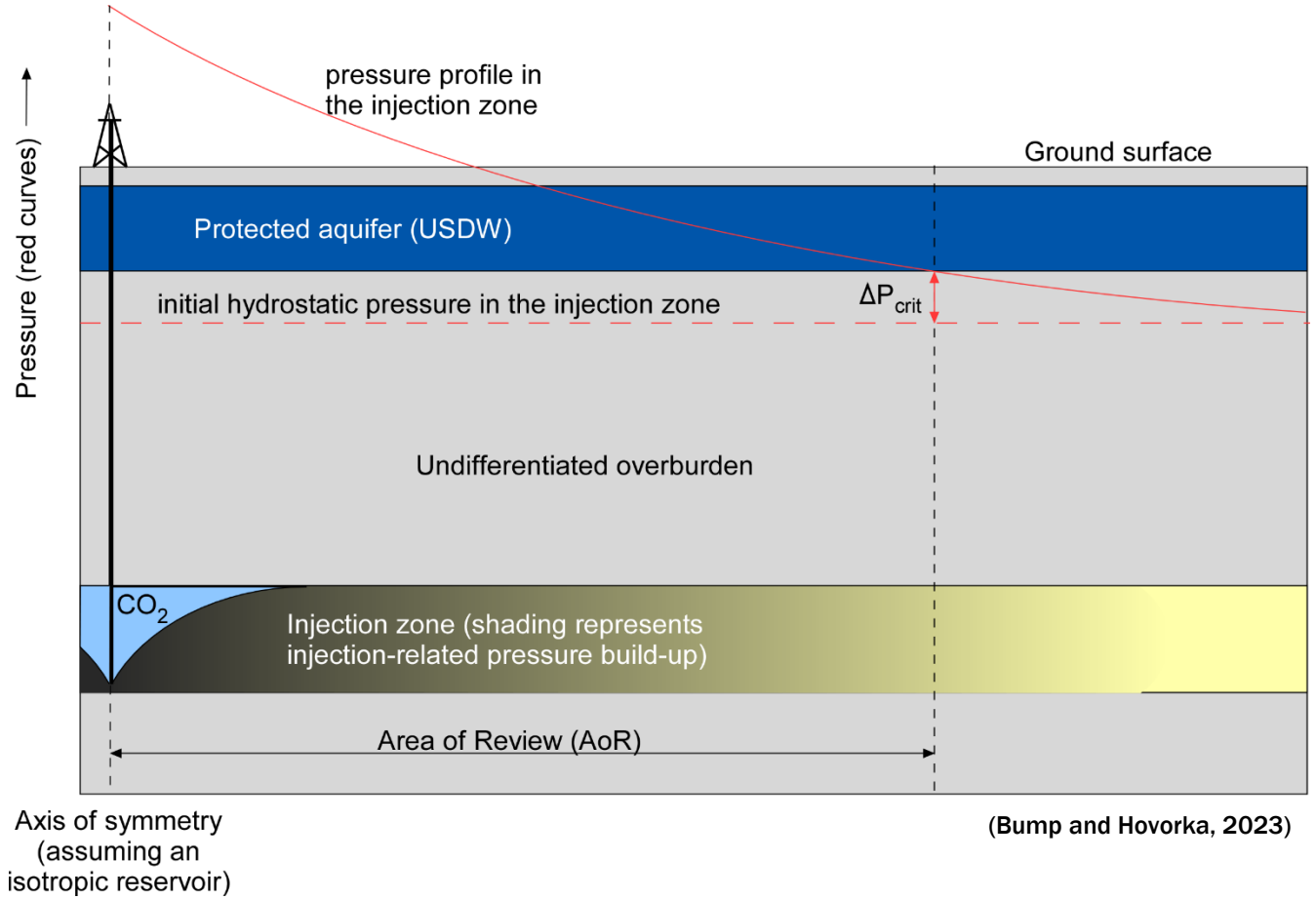
After Bump and Hovorka, 2023

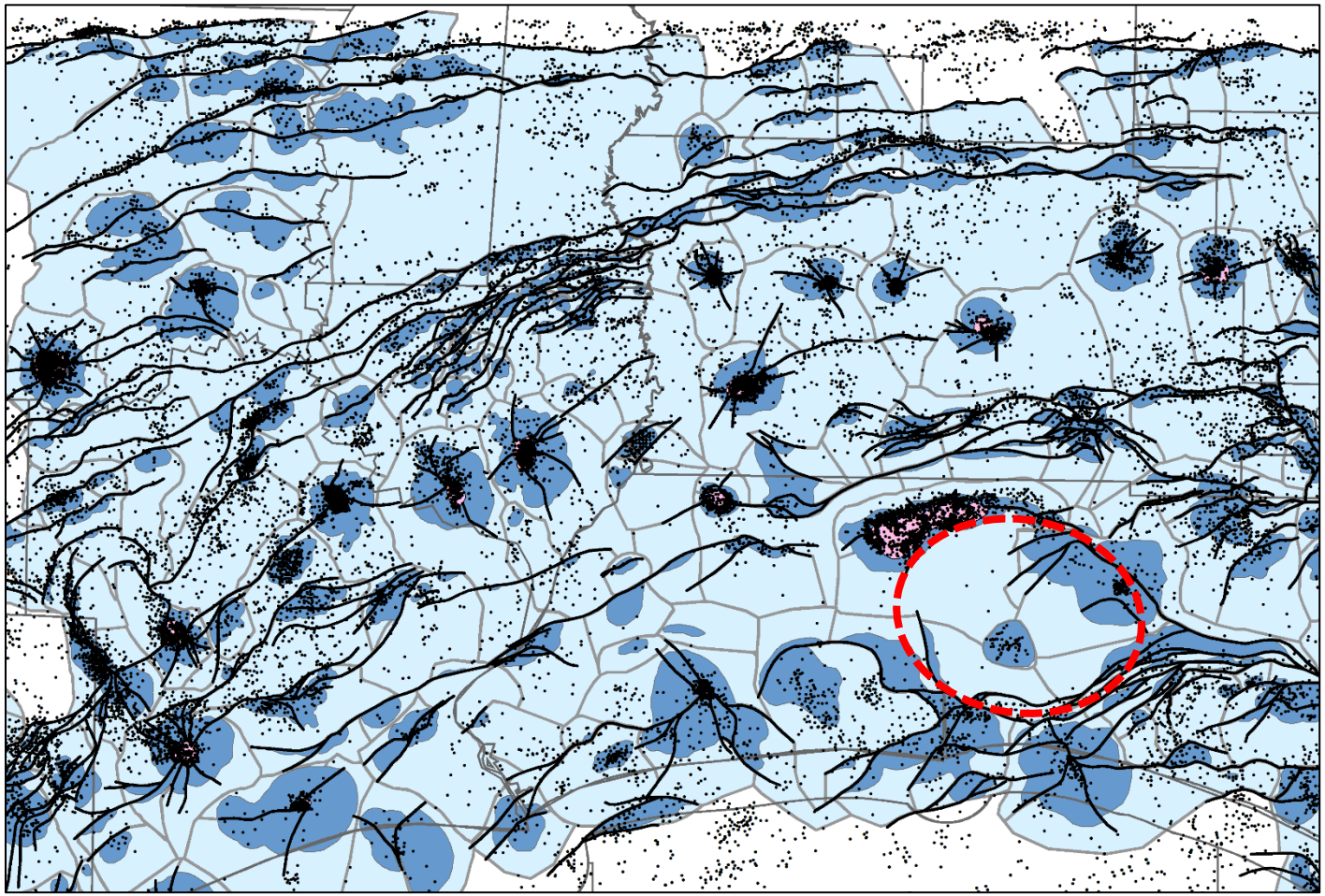
Project Spacing: How Close is Too Close?

Area of Review: A Project's Pressure Footprint



(Bump and Hovorka, 2023)

Storage Prospect Example



After Bump and Hovorka, 2023

Area of Review (EASiTool)

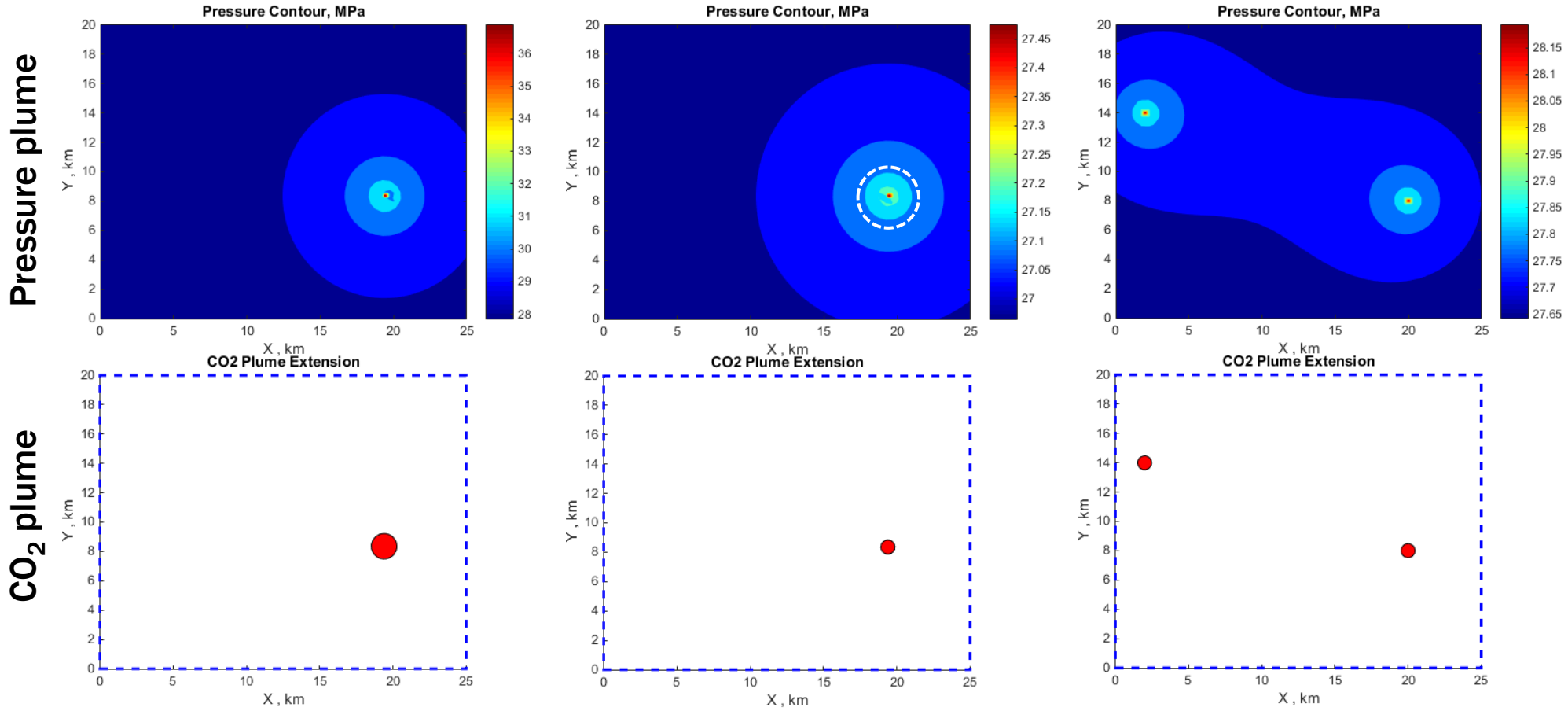
A. 100m net reservoir

B. 400m net reservoir

C. 400m net reservoir, 2 wells

Pressure plume

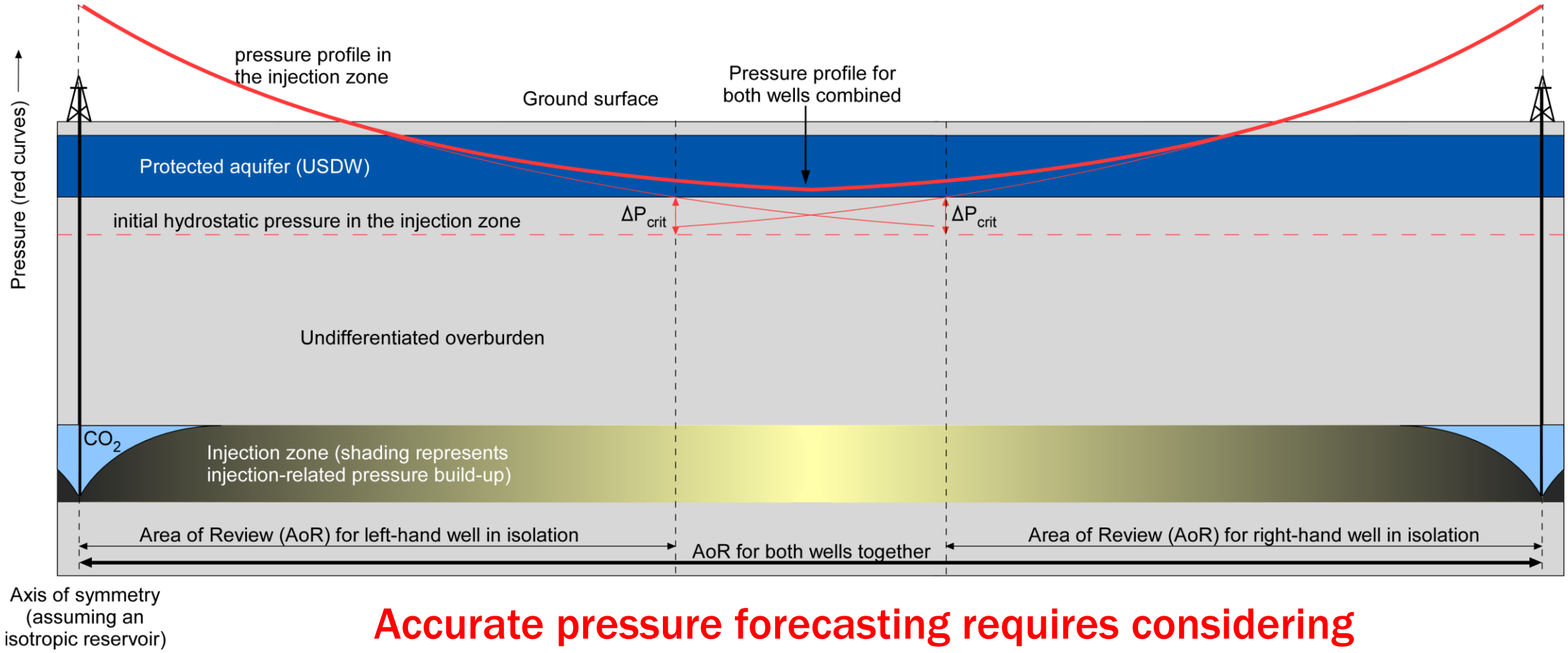
CO_2 plume



All models: 400km^2, closed boundaries, 25% porosity, 100mD, injecting 1Mtpa for 20 years at 2.5km depth

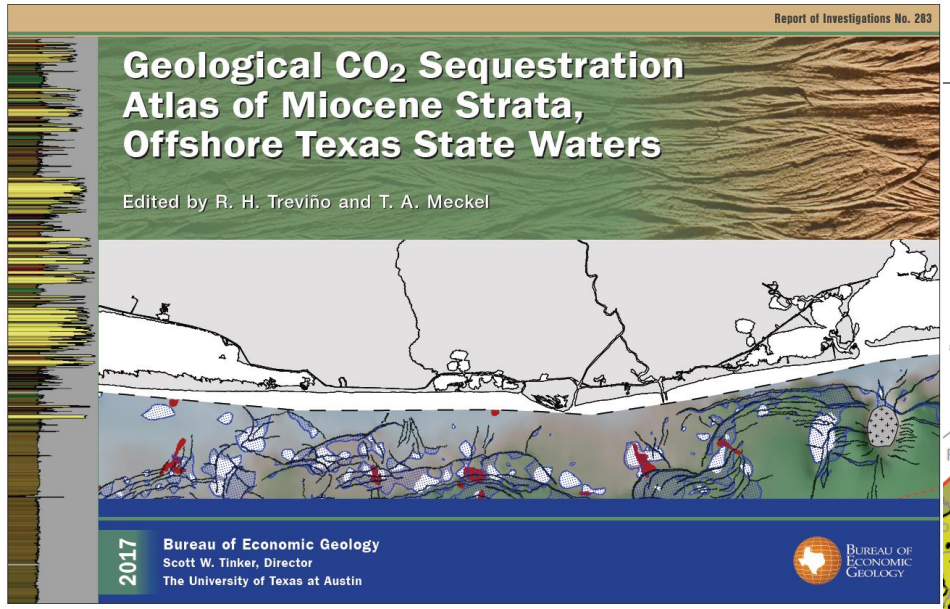
Bump and Hovorka, 2023

Pressure Interference



Accurate pressure forecasting requires considering ALL projects that might be in communication

Demonstrated Large Storage Capacity



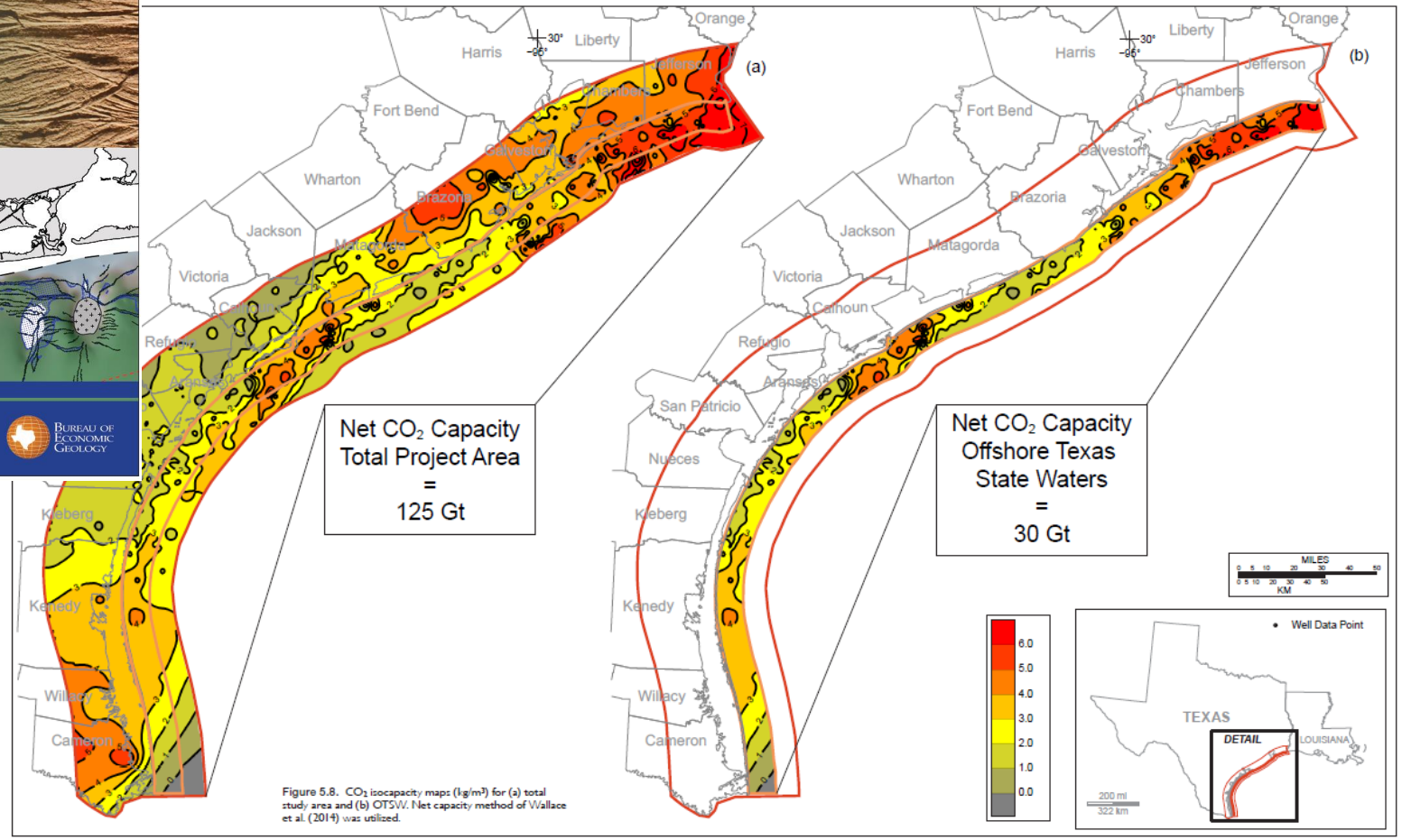


Figure 5.8. CO_2 isocapacity maps (kg/m³) for (a) total study area and (b) OTSW. Net capacity method of Wallace et al. (2014) was utilized.

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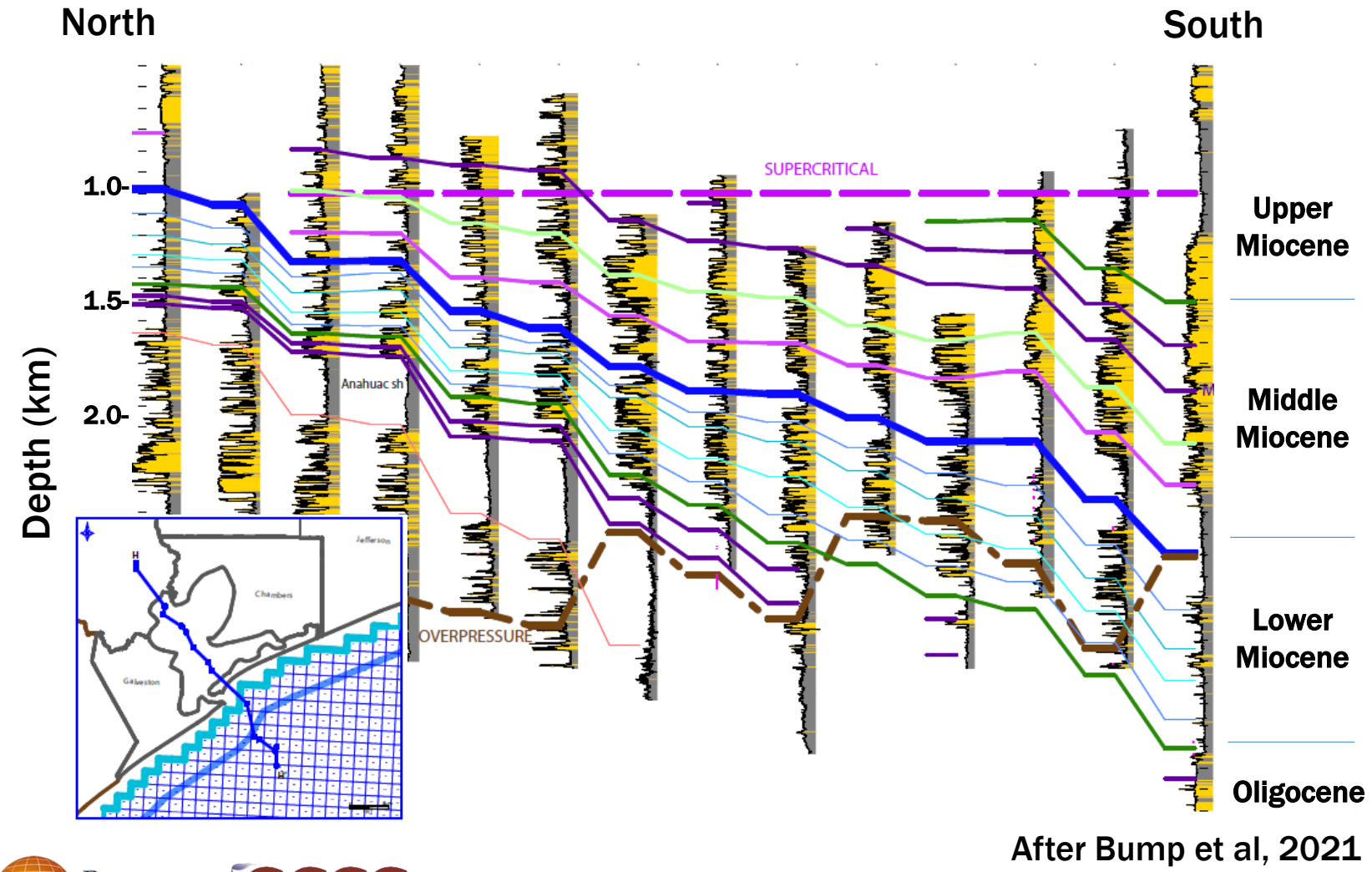
But static capacity numbers depend on open boundaries....

Trevino and Meckel, 2017

Boundaries NOT open at Regional Scale



After Bump et al, 2021

Injection zone boundaries

- Up-dip: Freshwater
- Down-dip: Overpressure
- Above and below: seals
- Along strike: basin edges

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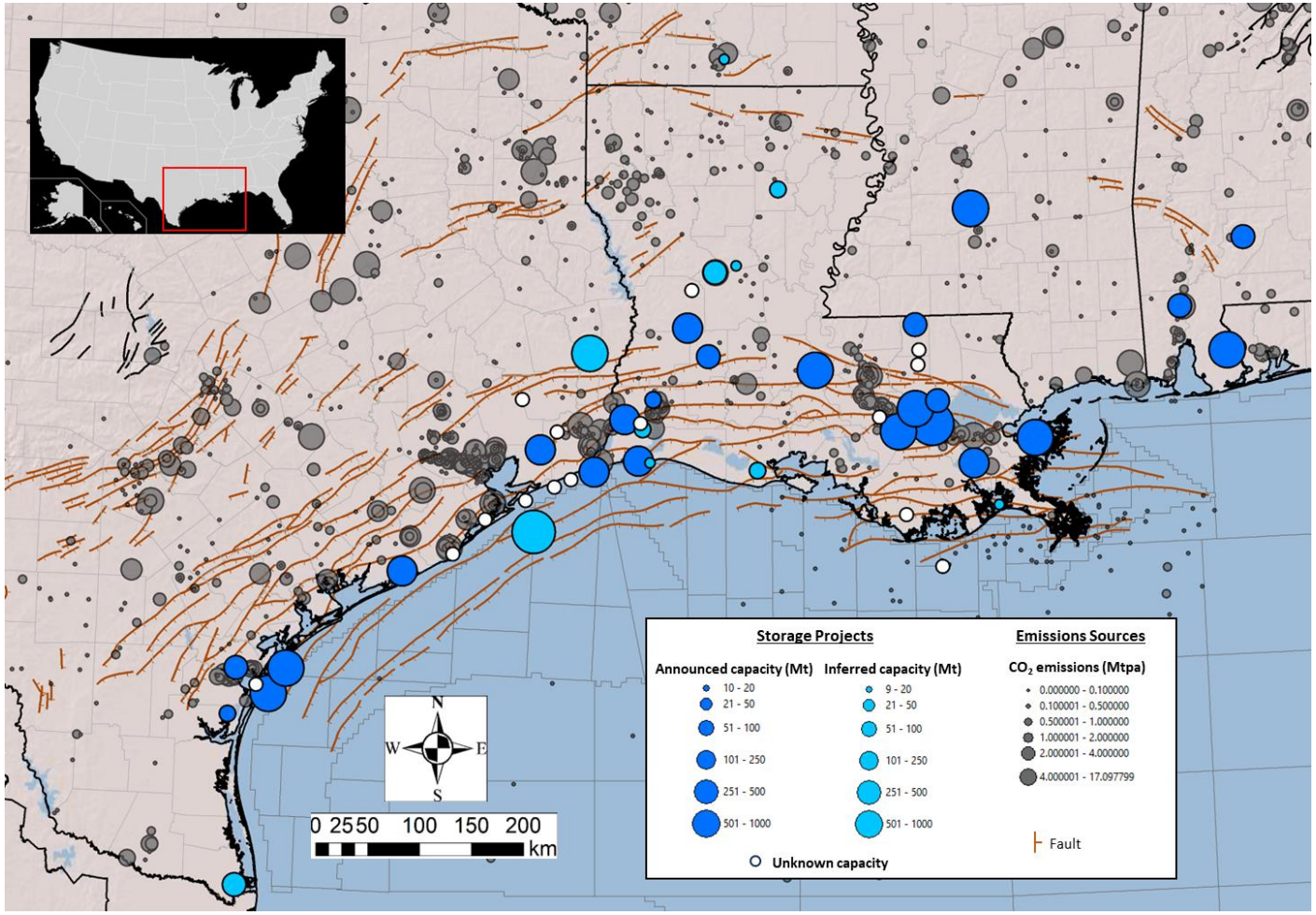
Pressure Interference = Local Boundaries



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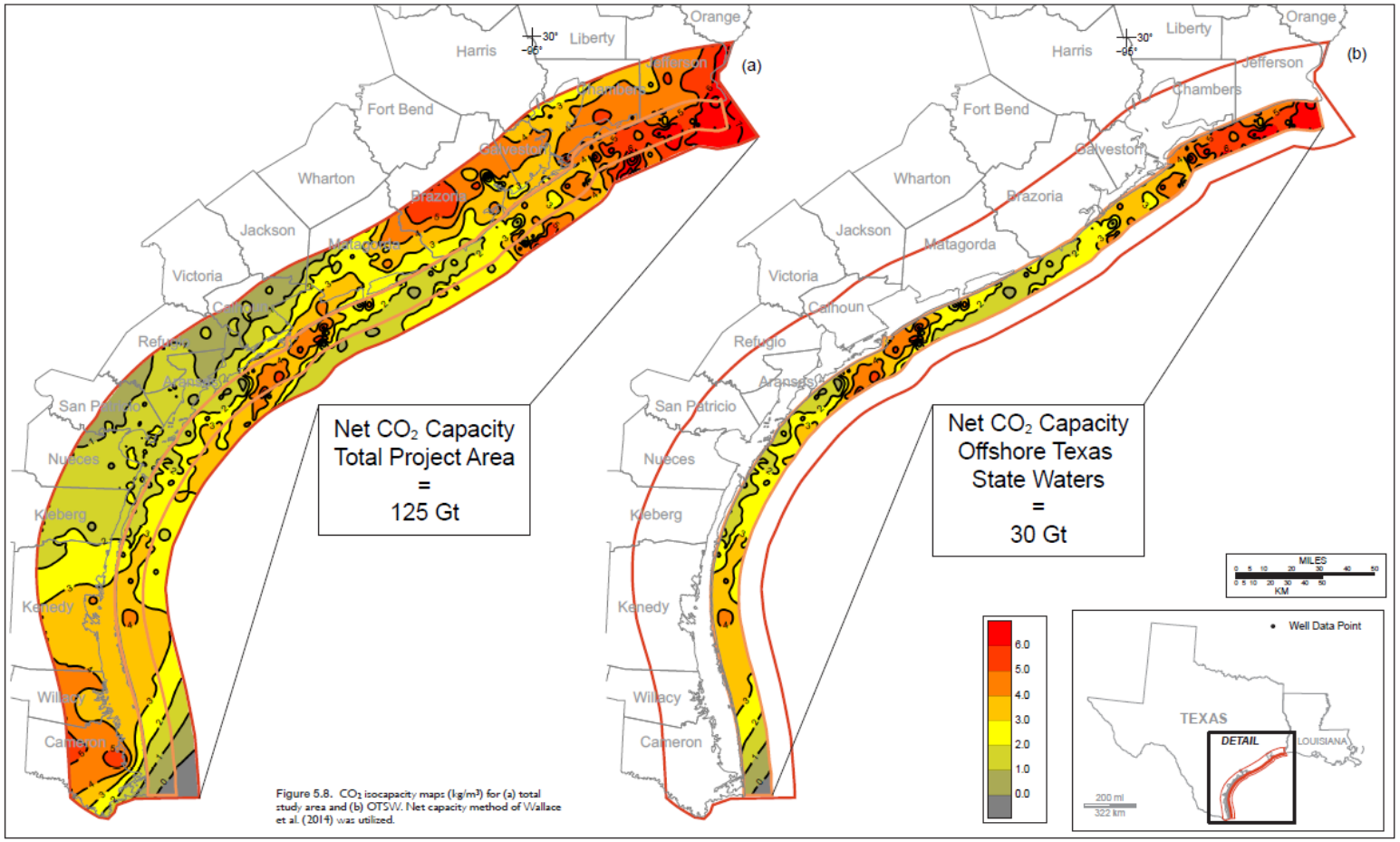
What if we pressured it all up?



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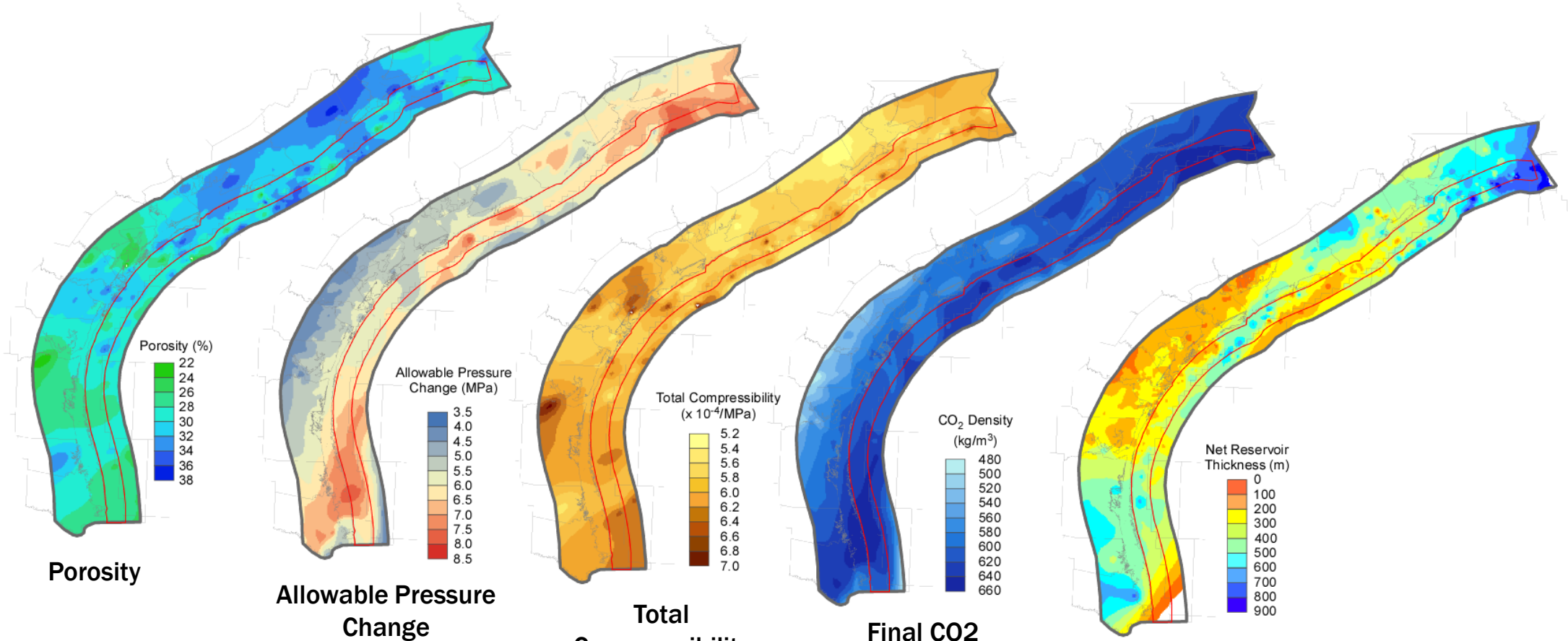
Trevino and Meckel, 2017

Calculating Pressure-based Storage Capacity



Porosity

Allowable Pressure Change

Total Compressibility

Final CO2 Density

Net Reservoir Thickness

Original data courtesy of Dave Carr

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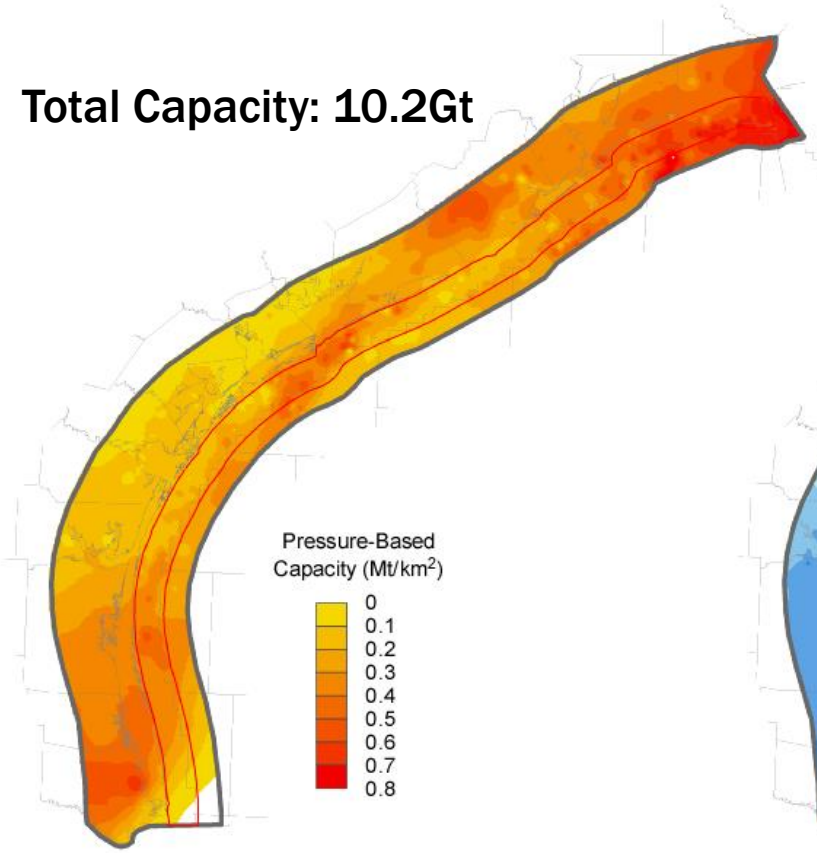
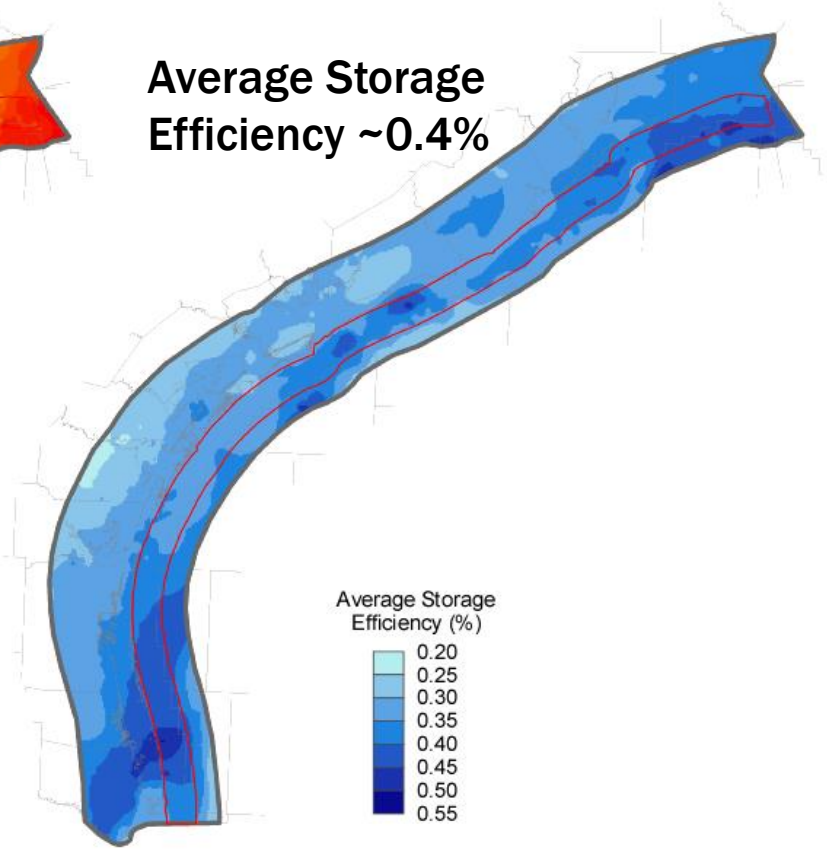
Pressure-Based Capacity

Total Capacity: 10.2Gt



Storage Capacity (Mt/km²)

Average Storage Efficiency ~0.4%



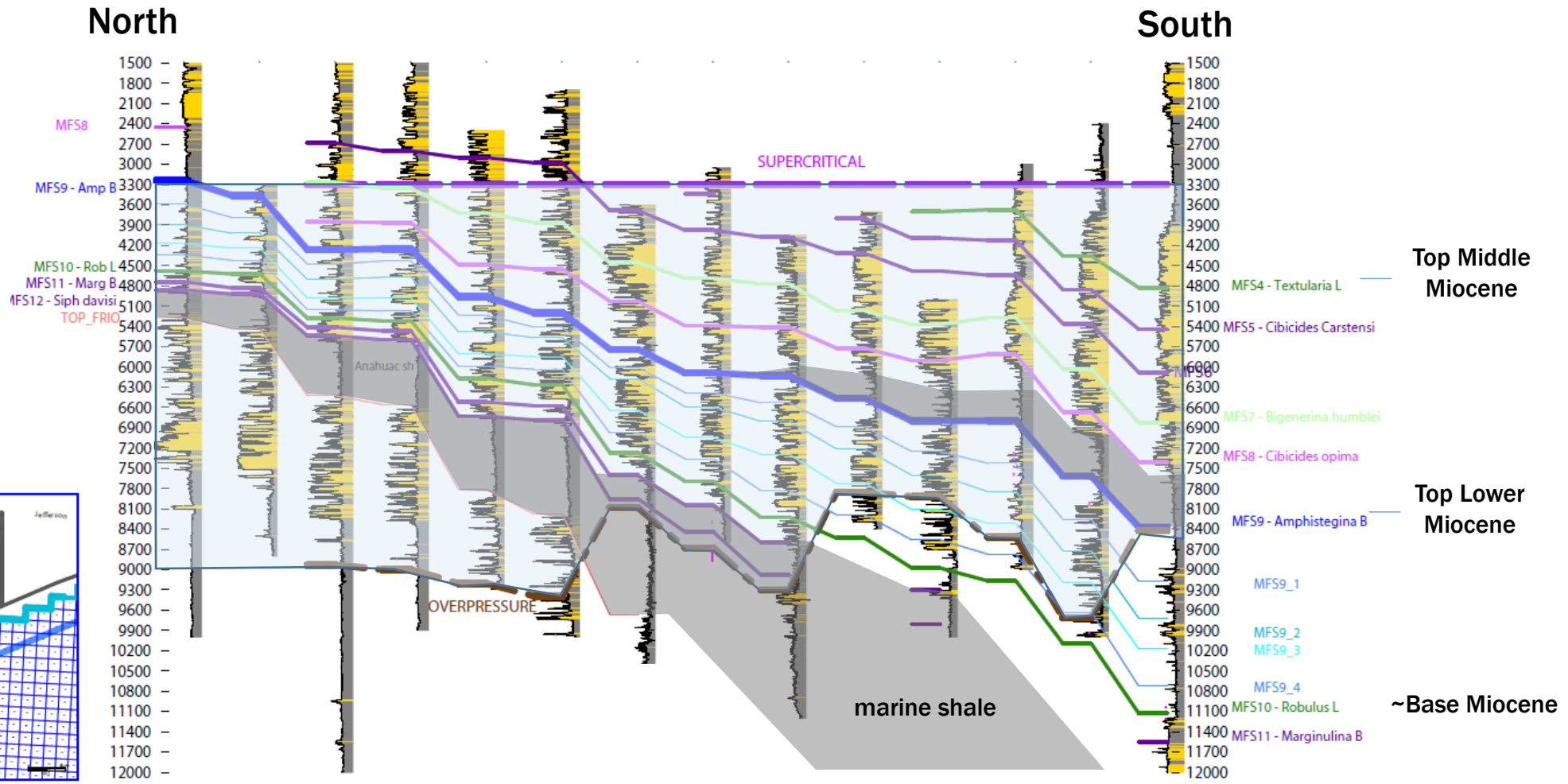
Average Storage Efficiency (%)

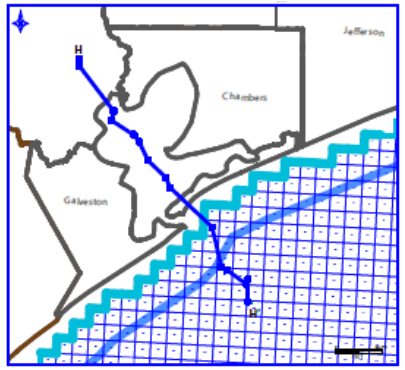
Broader Implications

- Pressure space is critical
- Uncertainty in the details—cuts both ways
- Big variable is water production
- Without water production, upper limit is an <u>average</u> ~1Mt/km^2
  - More commonly ~0.5Mt/km^2
  - Considering the area of entire pressure plume
- Pressure build-up limits injectivity, increases AoR
  - Requires consideration of all projects in hydraulic communication
- First mover advantage
- Considerations for land value, project leasing, regulatory spacing

Regional Seals and Composite Confinement

Gulf Coast Stratigraphy





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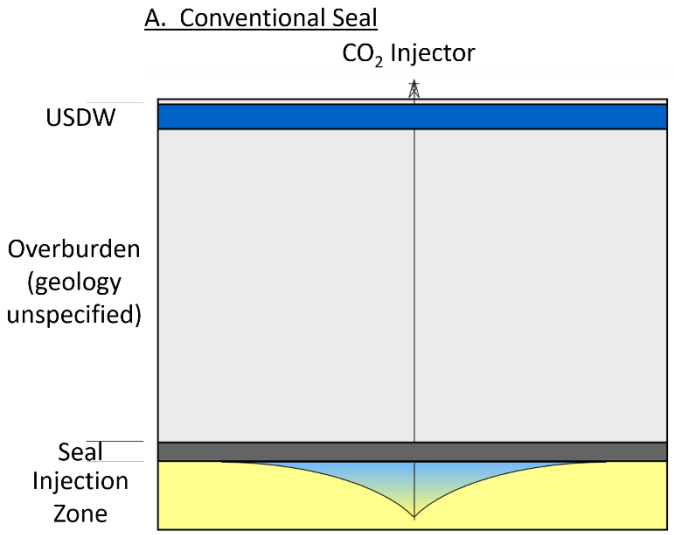
Bump et al, 2023

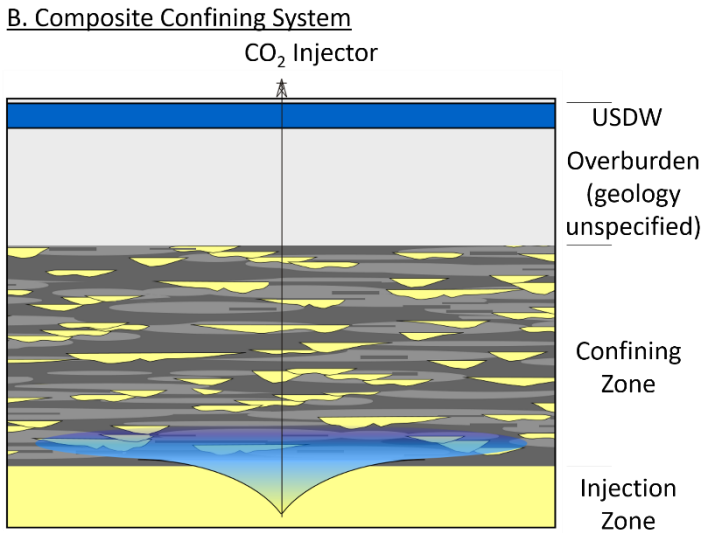
We Know Petroleum Seals Work for CO_2...



- But CCS is not petroleum
  - Inject on industrial quantities not geologic volumes
  - Goal is sequestration, not production
    - Injected CO2 does not need to remain recoverable, concentrated or mobile
    - More secure if it's none of those!
- What do we actually need for confinement? Is there a better way?
  - Regulations are not prescriptive
  - Proving other systems would unlock new acreage
  - Might offer greater security for permanent sequestration

Bump et al, 2023

New Concept: Composite Confining Systems



- A multi-layered system of discontinuous barriers
- No a priori requirements for continuity or capillary entry pressure
- In aggregate, the system creates a long, tortuous path for vertical flow that spreads migrating CO2 horizontally, reduces the driving force (column height) and attenuates the mobile fraction
- Questions
  - What constitutes a barrier?
  - What are real barrier geometries? Frequencies?
  - How much CO_2 could they contain?
  - How to de-risk performance?

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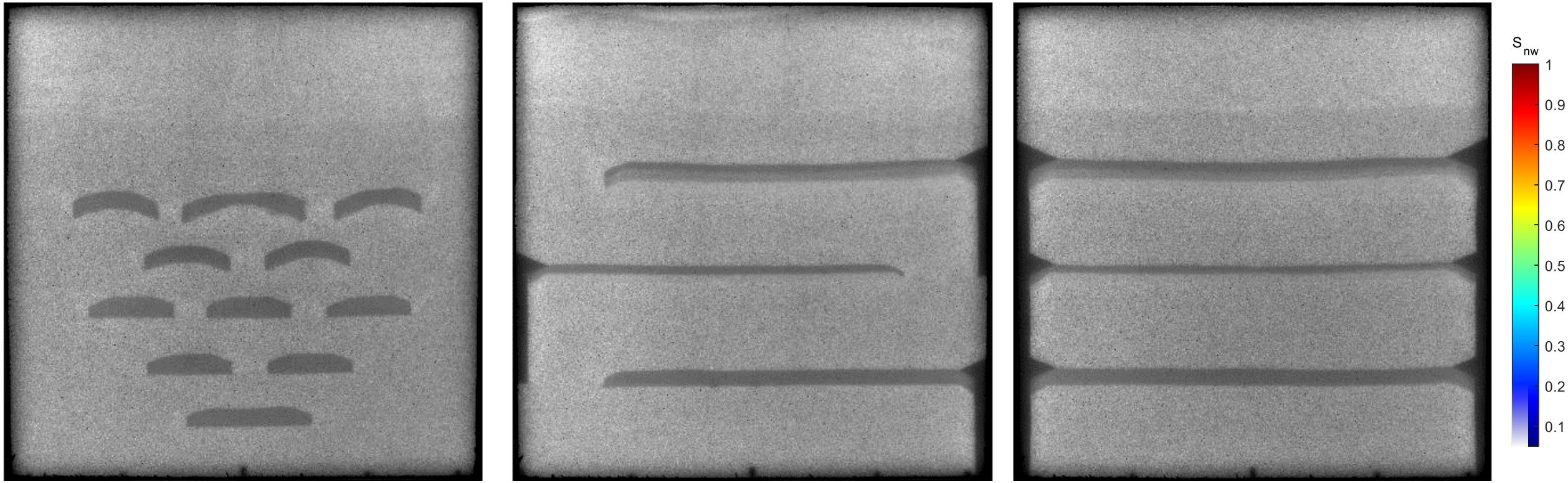
What makes a barrier? What matters?



Bump et al, 2023

Key Insights

- Discontinuous barriers each trap some CO_2
- The longer and more numerous the barriers, the more CO_2 we can trap
- Capillary entry pressure contrasts need only be enough to divert flow

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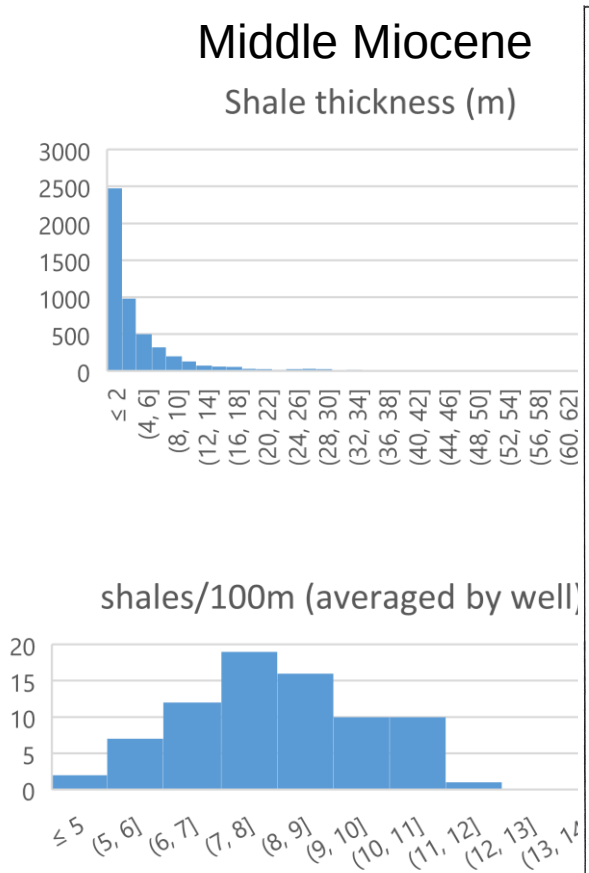
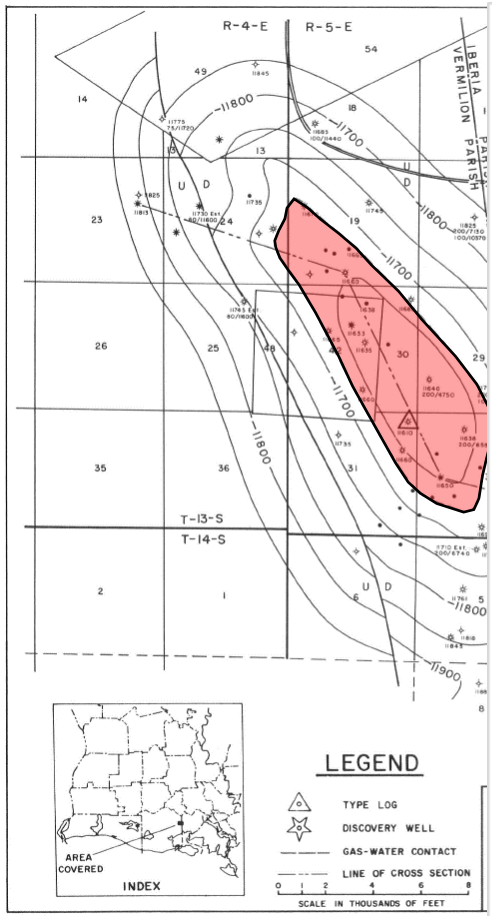
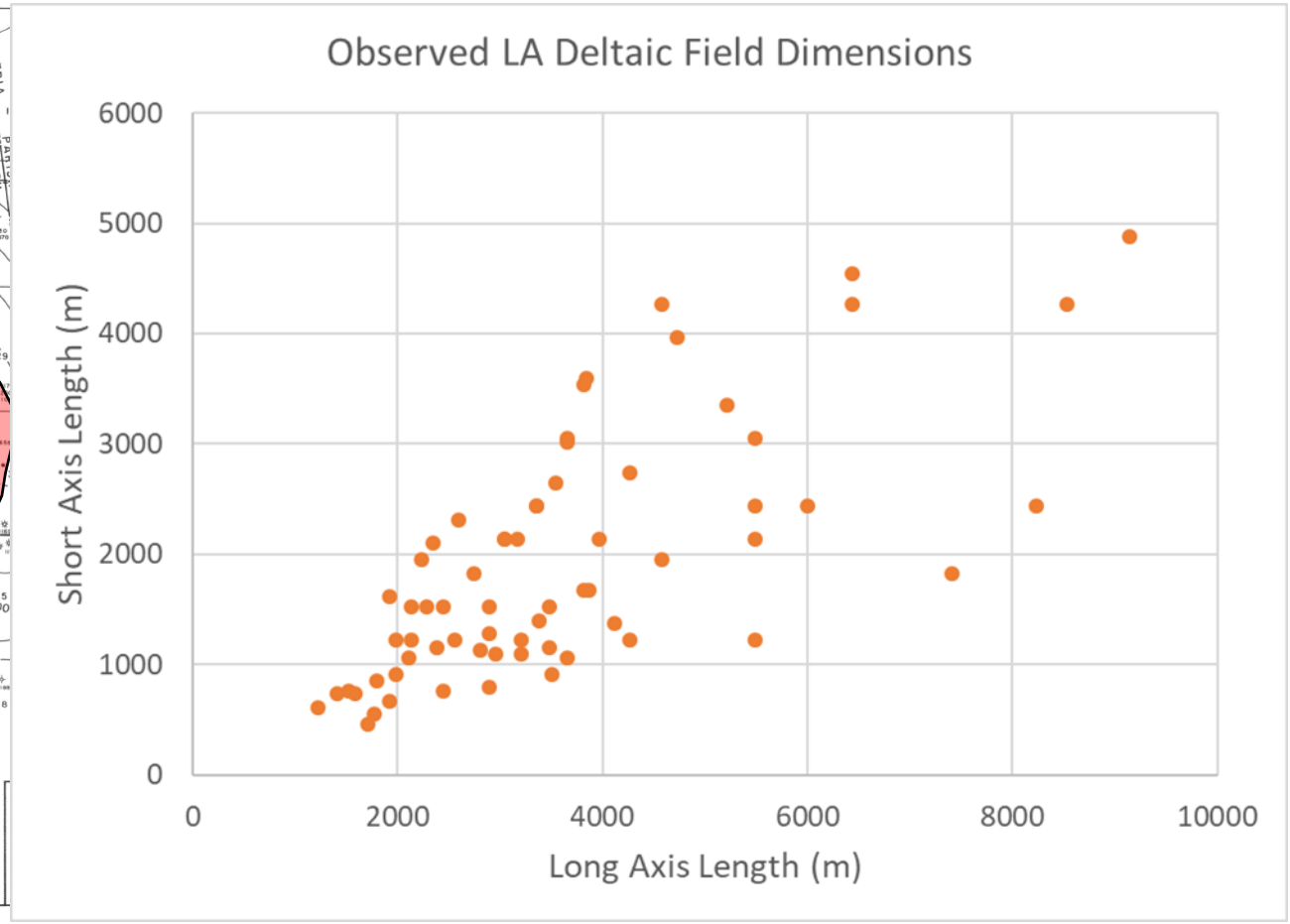
Deltaic Systems: Observed Barrier Statistics







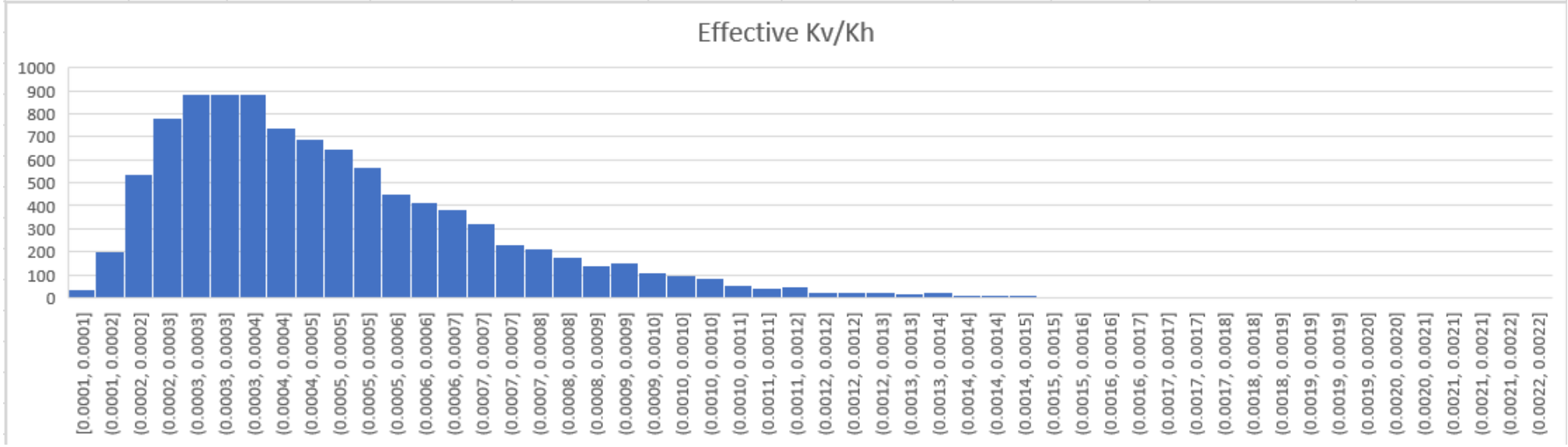
Bump et al, 2023

Monte Carlo Analysis: Effective Kv/Kh

Input the numbers in the yellow boxes						
	N:G (fraction)	avg. shale length (m)	number of shales/100m	sand perm (mD)	sand kv/kh	avg. shale aspect ratio (W:L)
Min	0.7	1000	6	499	0.1	0.5
Most Likely	0.8	1500	10	500	0.3	0.7
Max	0.9	2000	16	501	0.6	0.9

Based on equations of Begg et al, 1985: SPE 14271

Effective vertical perm (mD)	Kv/Kh
p10	0.1141	0.0002281
P50	0.2116	0.0004234
P90	0.4081	0.0008173
Mean	0.2416	0.0004831



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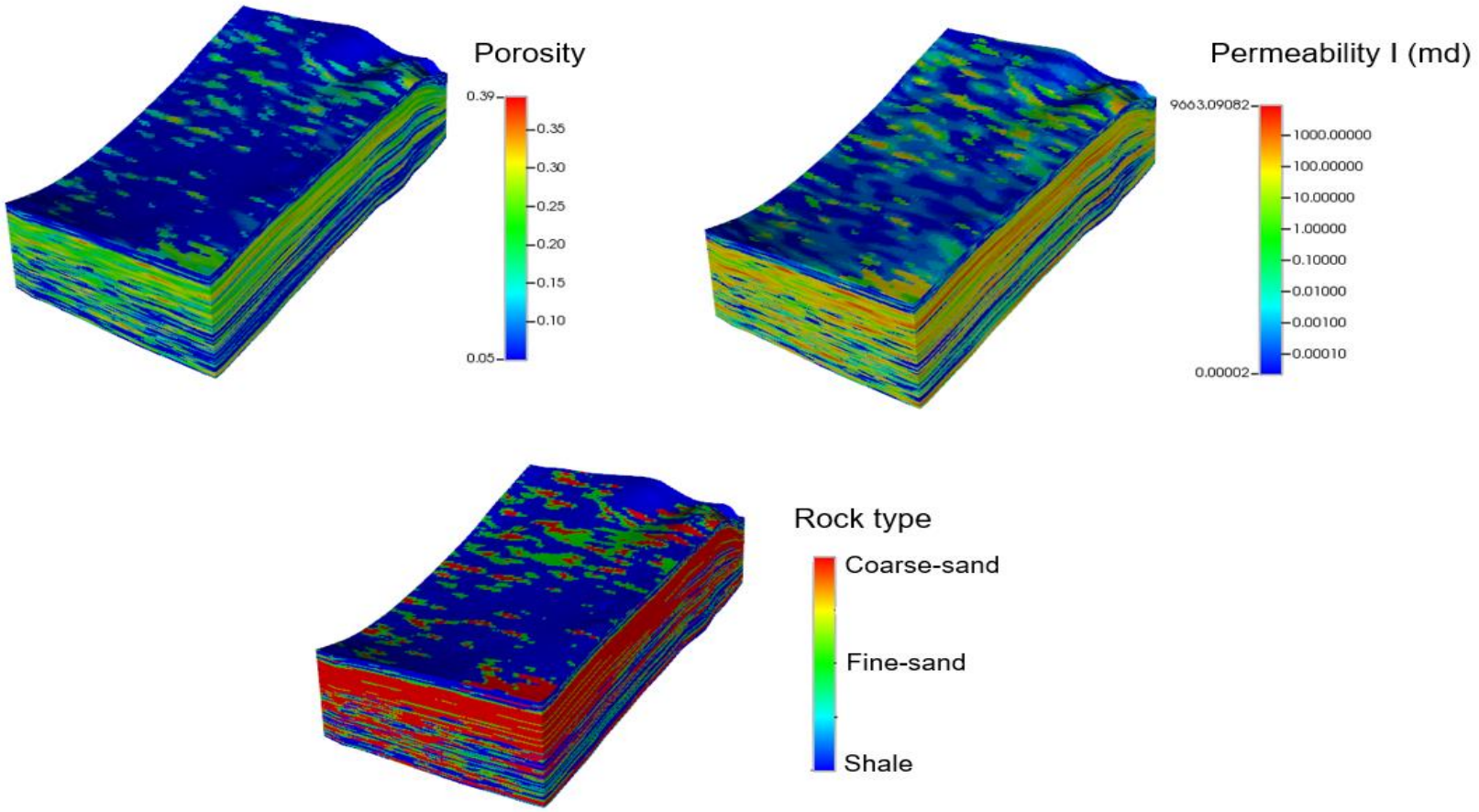
3D Reservoir Modelling

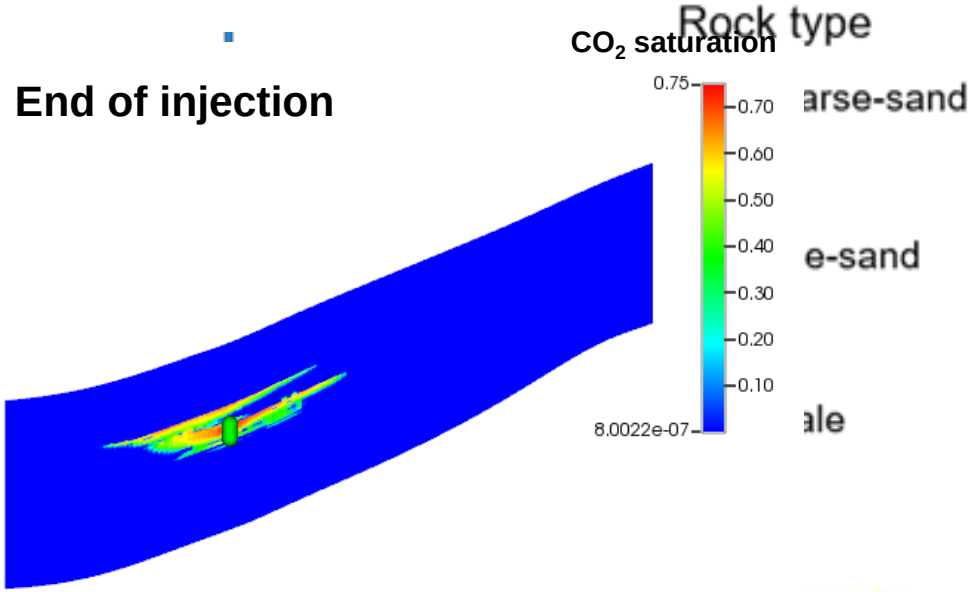


- 3D geologic model: 1,8884,610 grid blocks (upscaled version)
- Based on Southern LA Miocene
- CO_2 injection: 12 years, total injected CO_2~ 12 Mt, 100 years post-injection

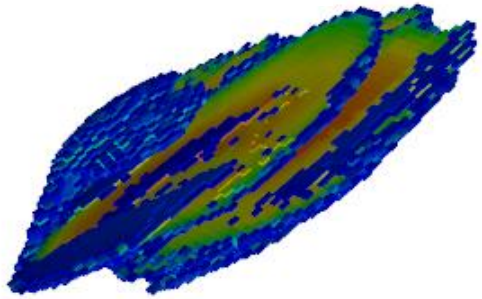
Bump et al, 2023

Modelled CO_2 Saturation

End of injection

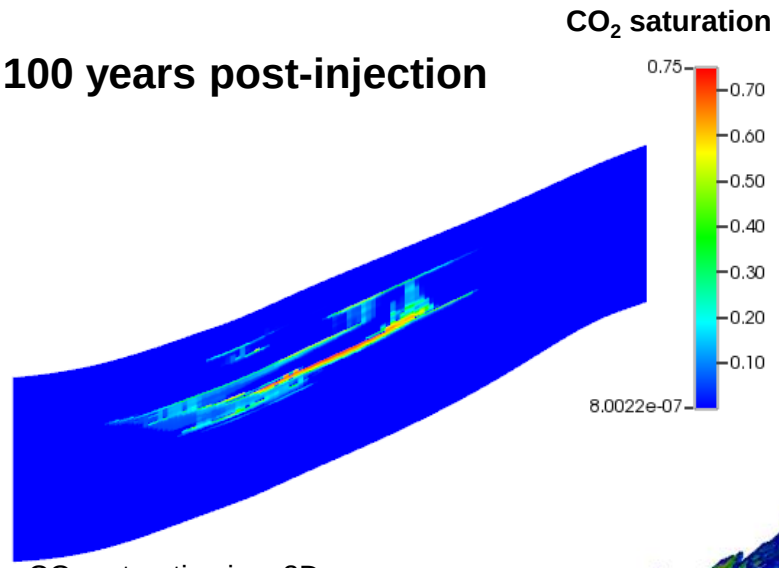


CO_2 saturation in a 2D section

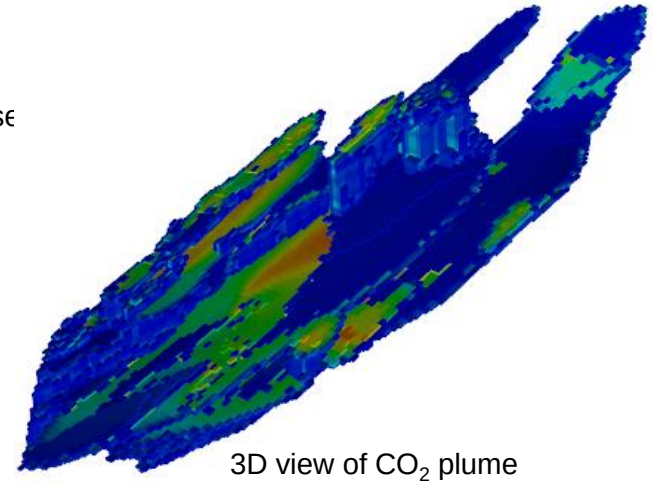


3D view of CO_2 plume

100 years post-injection



CO_2 saturation in a 2D se



3D view of CO_2 plume

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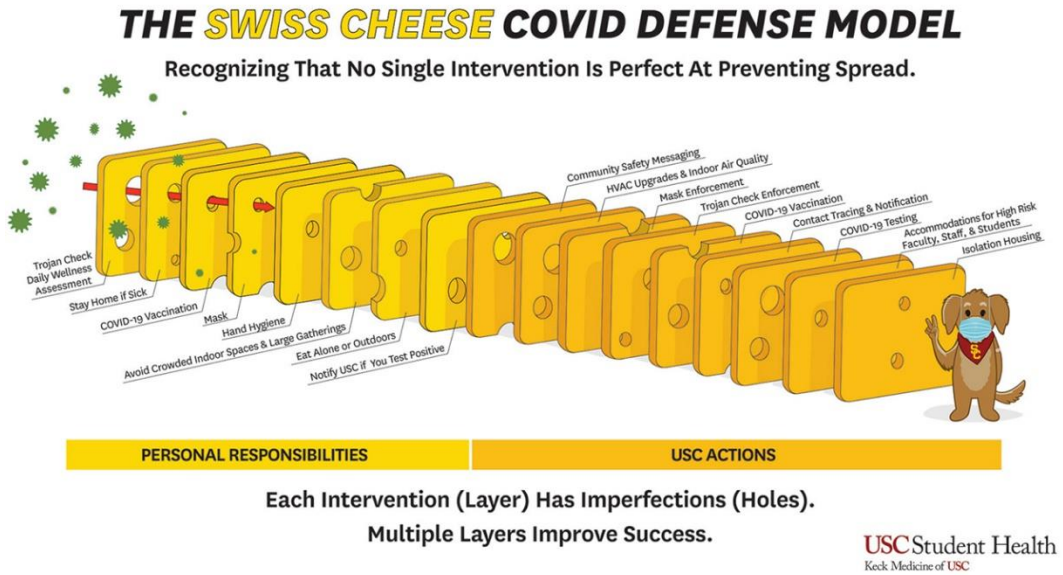
Composite Confinement in Practice

- Familiar concept: aquitards, migration loss
- Analogous to Reason's Swiss Cheese Model
- What's new?
  - 10s of barriers over 100s of meters of section
  - Average barriers may be km-scale
- Robust under a wide variety of scenarios
- Ultra-secure storage—mobile fraction is small and dispersed and column heights are low
- Fundamentally different from regional seals
  - Expect fluids to invade them
  - Care less about details of individual barriers than aggregate performance of the system
- De-risking:
  - Describe the geology and the uncdertainty
  - Push the models to failure—find the weak points
  - Dial back injection and monitor the weak points



https://hscnews.usc.edu/usc-tests-nearly-27000-students-for-covid-yielding-surprisingly-low-positivity-rates

Summary

Lessons Learned

- **Petroleum is a valuable analog, but CO_2 storage is not petroleum production**
- Goal of sequestration opens more trapping mechanisms
- Fetch areas offer large running room with few competing uses
- The rules require pore space, but the business requires pressure space
  - Projects need room and/or hydrologic bounds to avoid interference
  - Capacity and AoR assessment needs to include all projects in hydraulic communication
  - Potential impacts to land value, regulation and project development
- Composite confinement is incredibly effective
  - Requires new ways of assurance but offers increased security and new storage targets
  - Legacy wells are still the key risk

Thank you

Feel free to contact Alex Bump
(alex.bump@beg.utexas.edu) for more information

Read More

- Bump, Alexander P., and Susan D. Hovorka. “Minimizing exposure to legacy wells and avoiding conflict between storage projects: Exploring Area of Review as a screening tool.” *International Journal of Greenhouse Gas Control, in press.*
- Bump, Alexander P., Sahar Bakhshian, Hailun Ni, Susan D. Hovorka, Marianna I. Olariu, Dallas Dunlap, Seyyed A. Hosseini, and Timothy A. Meckel. “Composite Confining Systems: Rethinking Geologic Seals for Permanent CO2 Sequestration.” *International Journal of Greenhouse Gas Control* 126 (June 2023): 103908. https://doi.org/10.1016/j.ijggc.2023.103908.
- Bump, Alexander P., and Susan D. Hovorka. “Fetch-Trap Pairs: Exploring Definition of Carbon Storage Prospects to Increase Capacity and Flexibility in Areas with Competing Uses.” *International Journal of Greenhouse Gas Control* 122 (January 2023): 103817. https://doi.org/10.1016/j.ijggc.2022.103817.
- Meckel, T.A., A.P. Bump, S.D. Hovorka, and R.H. Trevino. “Carbon Capture, Utilization, and Storage Hub Development on the Gulf Coast.” *Greenhouse Gases: Science and Technology*, May 19, 2021, ghg.2082. https://doi.org/10.1002/ghg.2082.
- Meckel, T.A., R.H. Treviño, S.D. Hovorka, and A.P. Bump. “Mapping Existing Wellbore Locations to Compare Technical Risks between Onshore and Offshore CCS Activities in Texas.” *Greenhouse Gases: Science and Technology*, April 30, 2023, ghg.2220. https://doi.org/10.1002/ghg.2220.
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