New Developments: Solved and Unsolved Questions Regarding Geologic Sequestration of CO_2 as a Greenhouse Gas Reduction Method

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New Developments – Solved and Unsolved Questions Regarding Geologic Sequestration of CO_2 as a Greenhouse Gas Reduction Method

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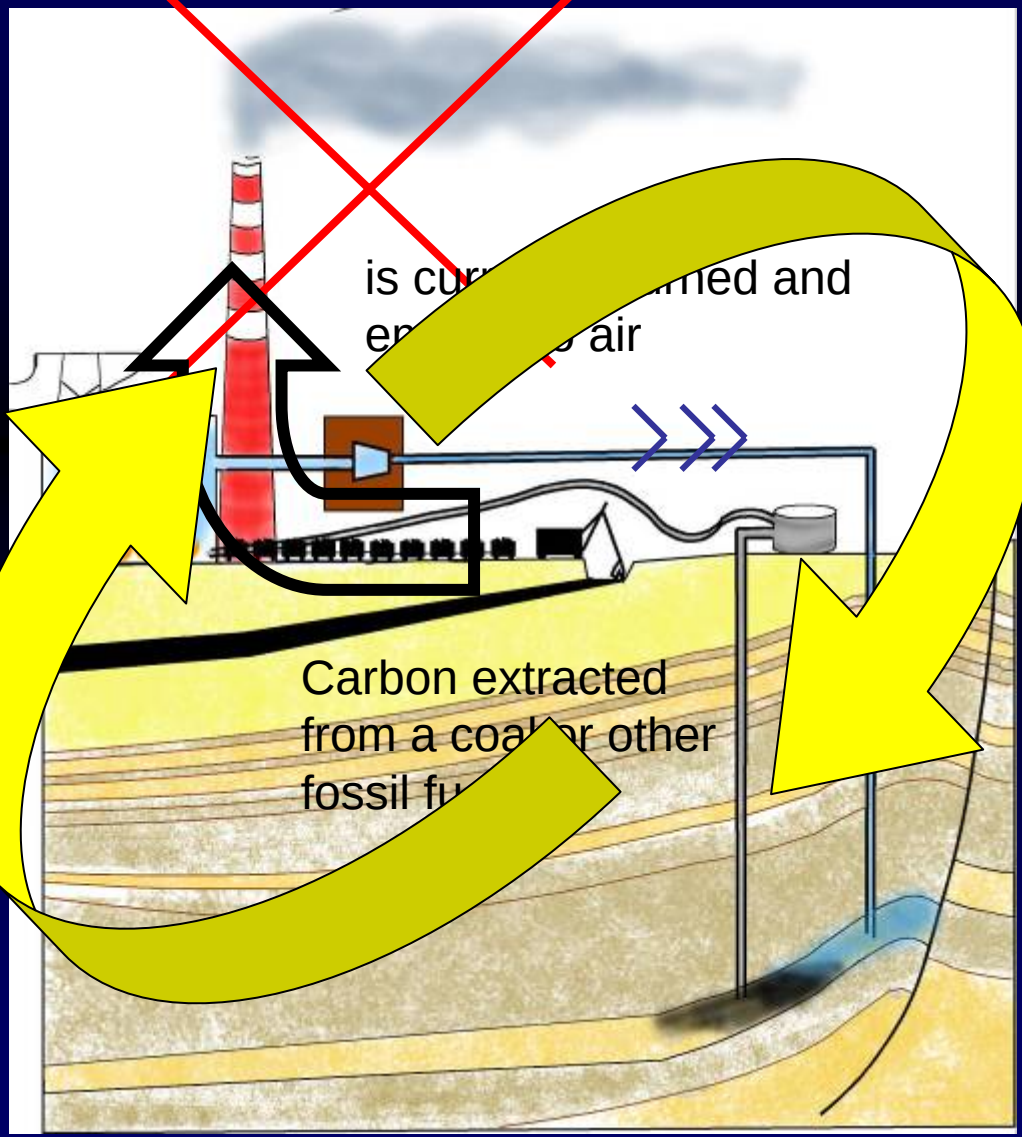
Gulf Coast Carbon Center

Presented at TCEQ Trade Show, April 30, 2008 Austin, TX

Geologic Sequestration of Carbon – Put it back



To reduce CO_2 emissions to air from point sources..

Return it to the Earth where it came from

Gulf Coast Carbon Center (GCCC)

Gulf Coast Carbon Center

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Entergy
THE POWER OF PEOPLE

PRAXAIR

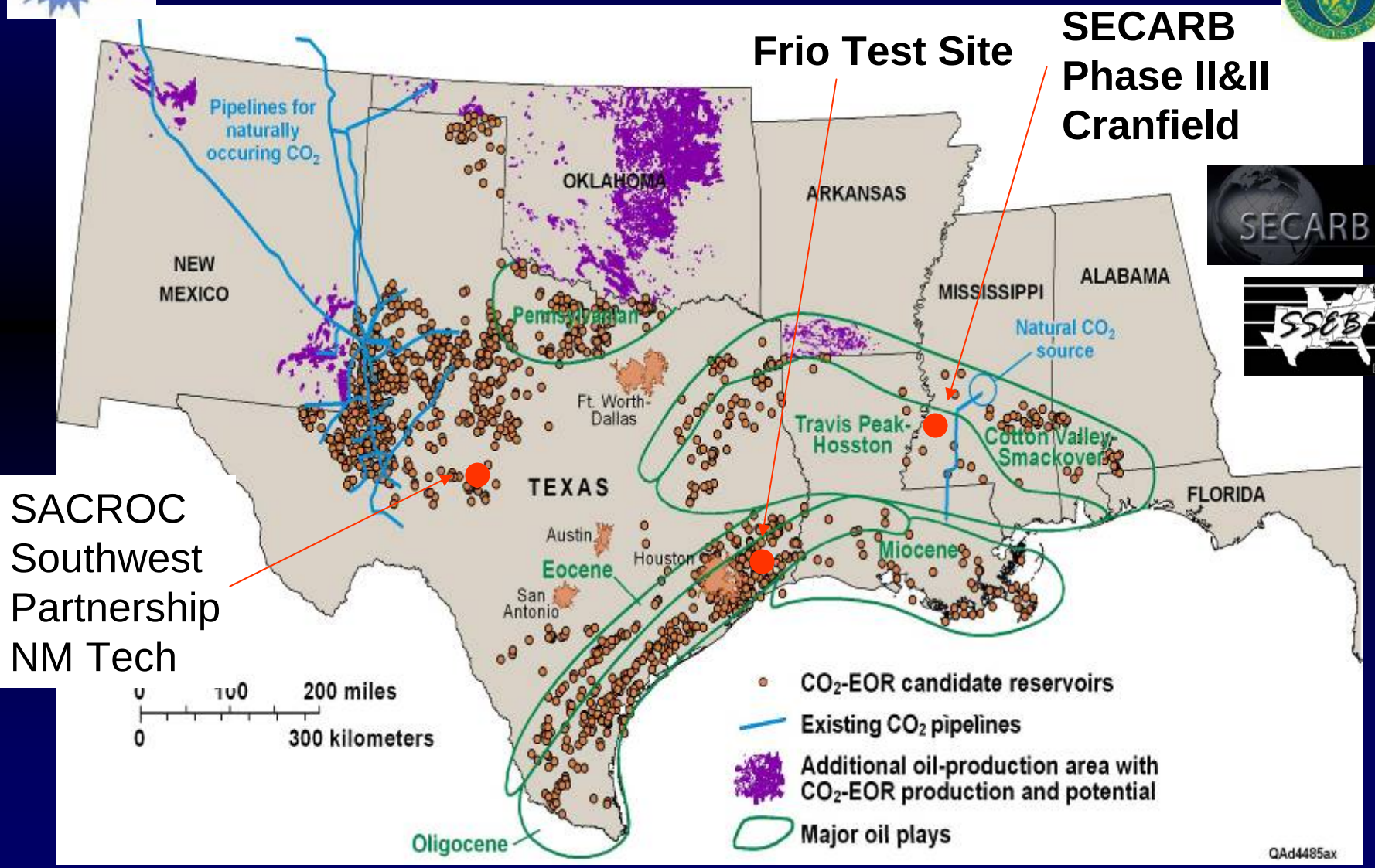
MARATHON

NRG

e
ENVIRONMENTAL DEFENSE
finding the ways that work

Schlumberger

GCCC Field Tests for Monitoring and Verification Technologies DOE NETL support



Geotechnical Progress - Permanence

- Field documentation of immiscible non-wetting phase residual saturation (Phase trapping). Increased confidence in long term trapping [Frio pilot]
- Continued uncertainty about the significance of dissolution of CO_2 into brine – volumetrics of dissolution trapping
- Reduced expectation for mineral trapping in average sedimentary rocks

Geotechnical Progress- Risk

- Risks of brine displacement resulting from large scale CO_2 injection recognized (Area of Review –AOR issue) [Nicot/Hovorka model results]
- Concerns about old well and long term well performance have not been resolved (Celia Princeton, LANL, CCP II)
- Risks to fresh water as a result of leakage of CO_2 – role of reactive grain coats rather than bulk mineralogy identified (BEG/Kharaka USGS)

Geotechnical Progress - Monitoring

- Increasing documentation of poor performance of soil gas methods for leakage monitoring (Weyburn, Otway, natural analogs; ZERT).
- Increasing interest in feasibility of groundwater monitoring for leakage (SACROC, Canfield) no results yet
- Realistic (reduced) expectations for seismic monitoring
- New method– deep above-zone monitoring – Favorable initial result (Frio), larger-scale testing planned (Cranfield).

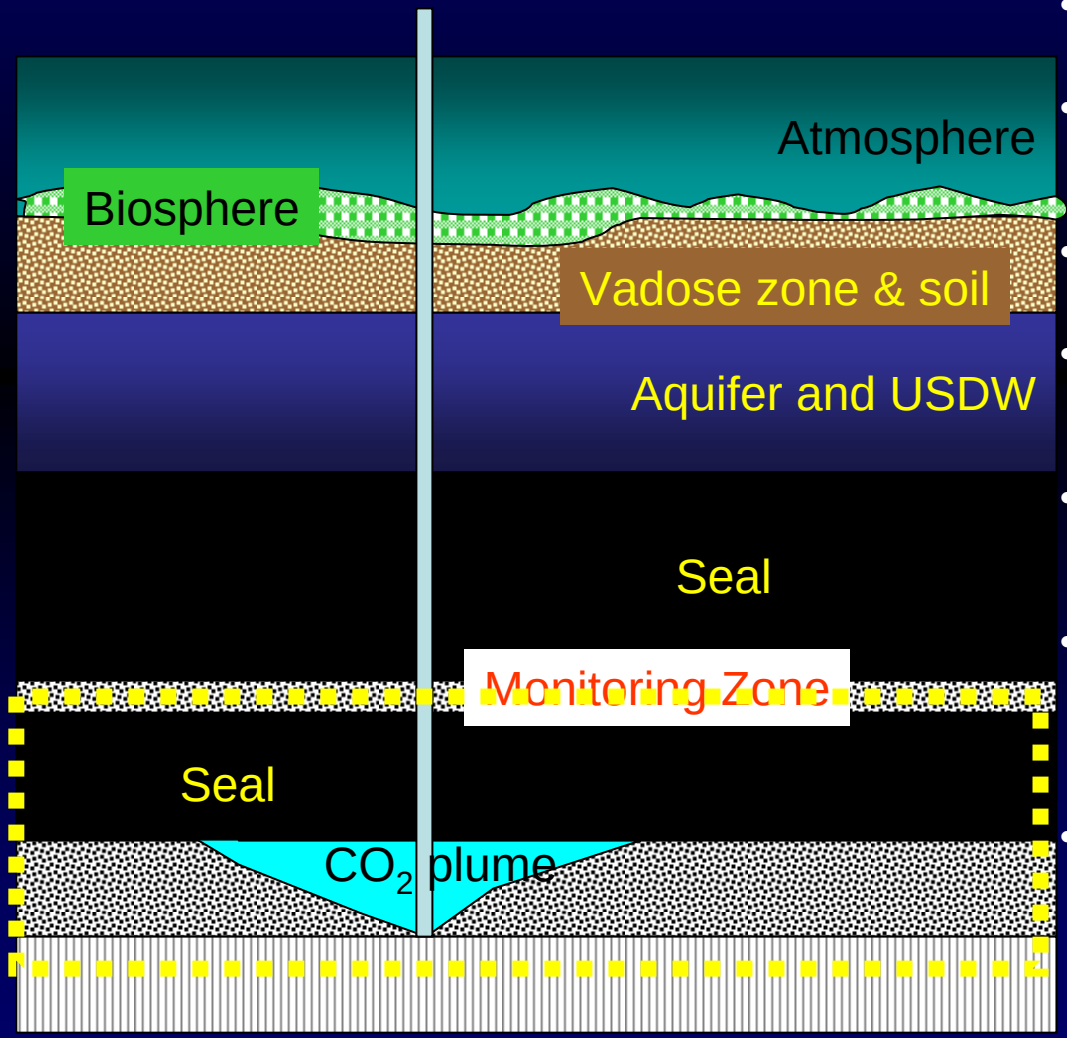
Monitoring Schemes: Monitoring in Mature Commercial Context

- Benson study showing that cost of a monitoring scheme, basic or enhanced, is a small fraction of the cost of the whole project.
- Should a large injection then have a large monitoring program?

Current Monitoring Selection is Not Mature

		White papers	Sliepner	Weyburn	West Pearl -Queen	Frio	InSalah	Otway	Cranfield	SACROC	Class I	Class II
Engineered Systems	MIT, positive annular pressure	x	?	?	?	x	?	?	no	no	x	x
Characterization	3-D seismic	x	x	x		no	x	x	x	x	no	no
	Wireline logs	x	no	x	x	x	?	x	x	x	x	x
	Fluid and rock chemistry	x	no	x	?	x	x	x	x	x	x	x
	Hydrology/production history	x	no	x	x	x	?	x	x	x	x	x
	other	x						x				
	Stress conditions	x						x			x	x
Plume Monitoring	4-D seismic	x	x	x	x	no	x	x	x	x	no	no
	borehole geophysics	x	no	no	no	x	no	x	x	no	no	no
	wireline logs	x	no	no	no	x	no	x	x	x	no	no
	Fluid chemistry	x	no	x	?	x	?	x	no	no	no	no
	in-zone pressure	x	no	no	no	x	no		x	?	no	no
	above zone pressure	x						no	x		no	no
	Stress conditions	x						?	x	no	no	no
	Surface - air, soil, water	x	no	x	x	x	x	x	x	x	no	no

Parsimonious Monitoring Hypothesis: the Box



- Atmosphere
  - Ultimate receptor but dynamic
- Biosphere
  - Assurance of no damage but dynamic
- Soil and Vadose Zone
  - Integrator but dynamic
- Aquifer and USDW
  - Integrator, slightly isolated from ecological effects

Complex!

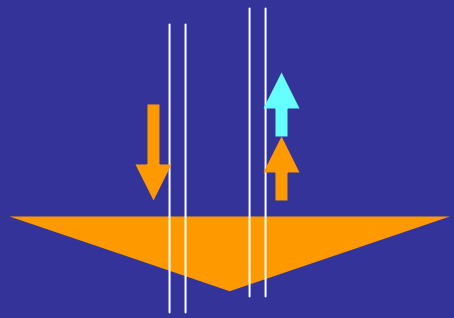
- Above injection monitoring zone
  - First indicator, monitor small signals, stable.
- In injection zone - plume
  - Oil-field type technologies. Will not identify small leaks **Complex!**
- In injection zone - outside plume
  - Assure lateral migration of CO_2 and brine is acceptable

New proposal - monitoring box

Two areas need monitoring:

buoyant CO_2 and elevated pressure in brine

In EOR CO_2 injection is approximately balanced by oil, CO_2, and brine production no pressure plume beyond the CO_2 injection area

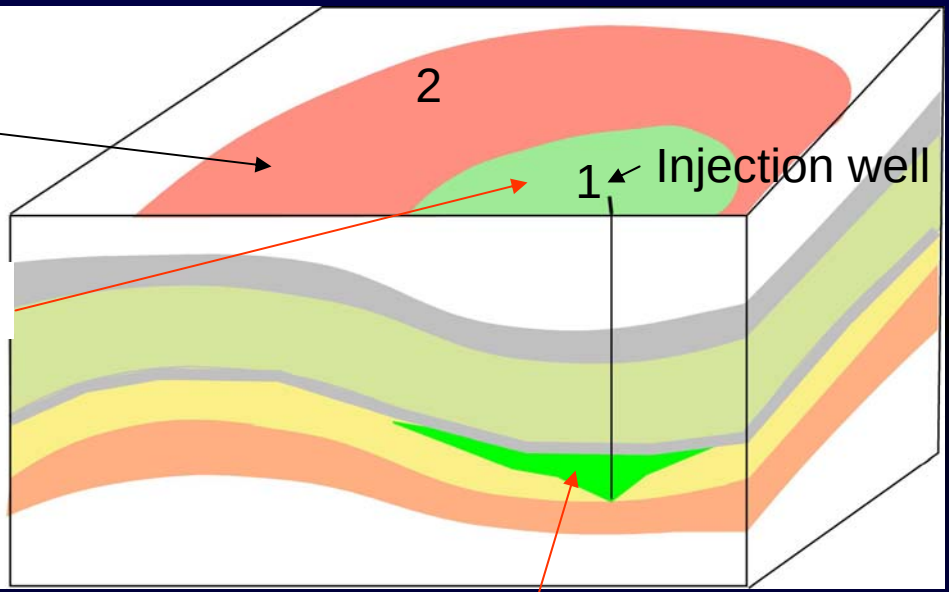


CO_2 injection (no production) pressure plume extends beyond the CO_2 injection area

Two Areas of Concern in Area of Review

Footprint of area of elevated pressure

Footprint of area over CO2



Plume of injected CO2

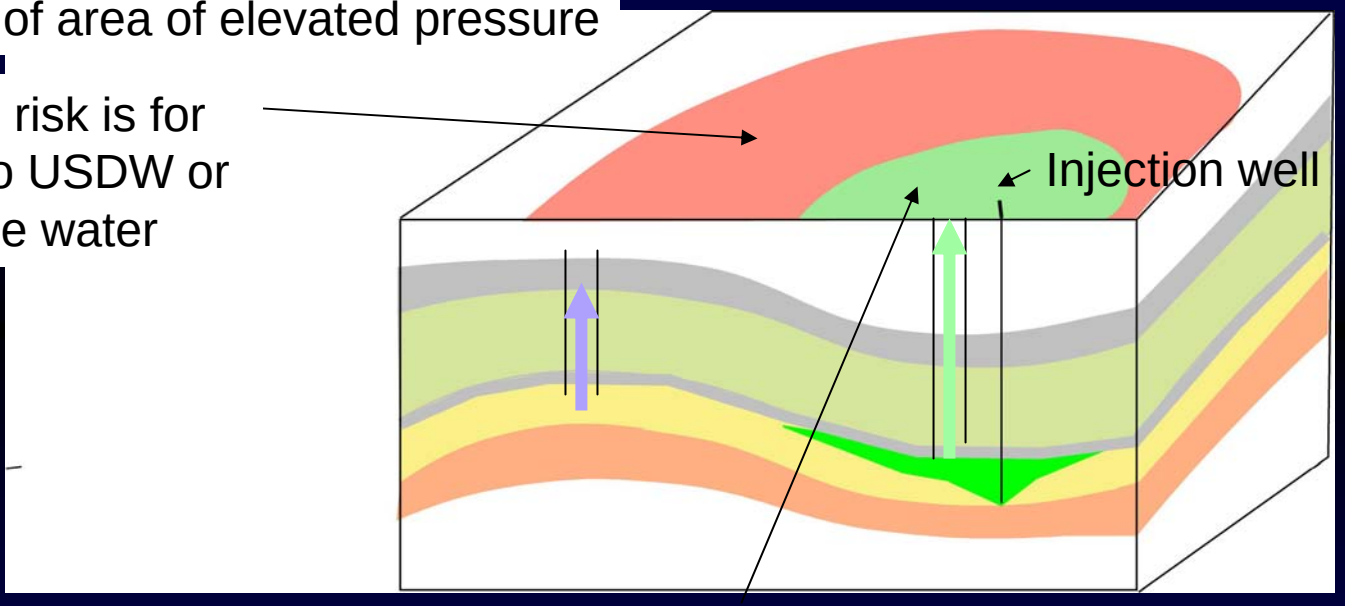
Most workers in CCS are most concerned about area (1).

Most UIC is concerned about area 1 +2

Risk is different in different parts of the AOR, and changes with time

Footprint of area of elevated pressure

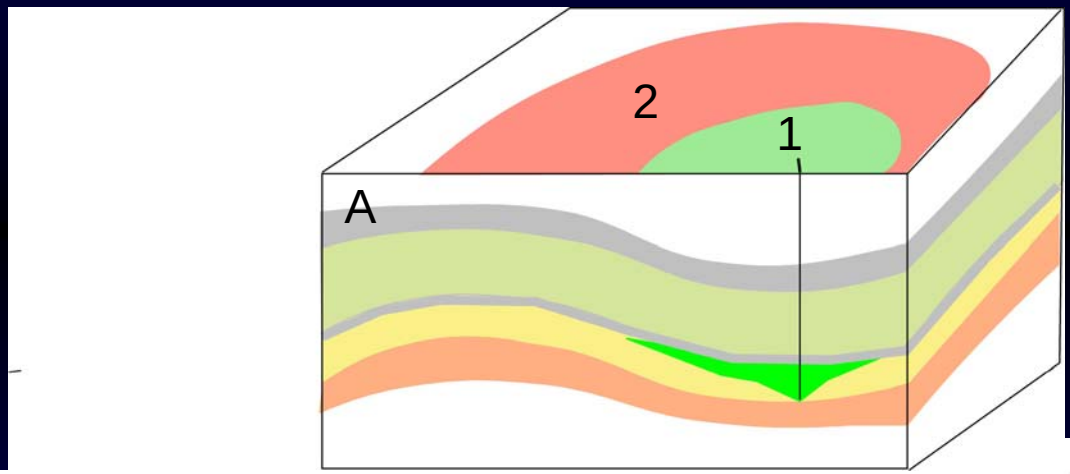
Leakage risk is for brine into USDW or to surface water



Footprint of area over CO_2

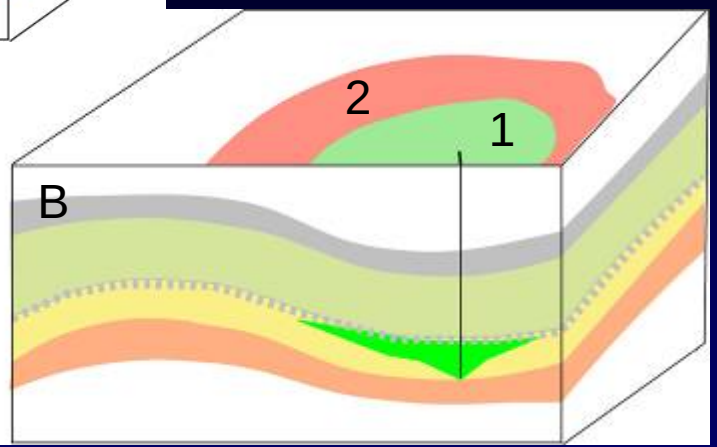
Leakage risk is for
CO_2 into the atmosphere,
also possibility for damage to biosphere,
to USDW or surface water

The relative size of both parts of the area of review is sensitive to geologic characterization

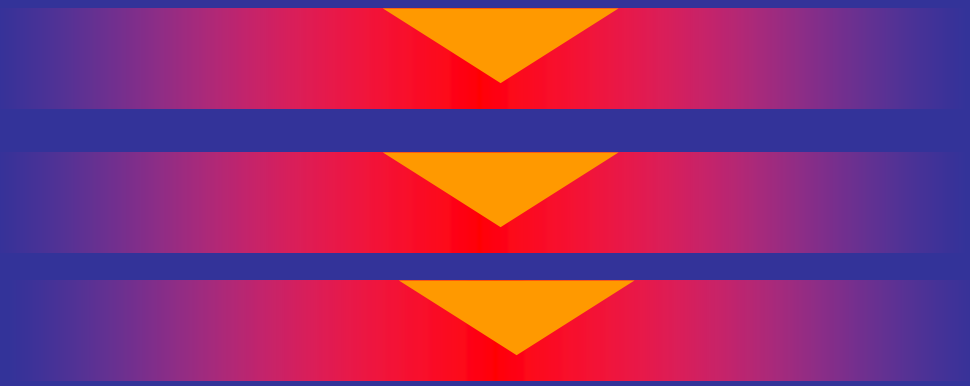


Case A has a pressure seal essentially no fluid flow under possible pressure contrasts.
The area of pressure elevation is large relative to area of CO_2 foot print

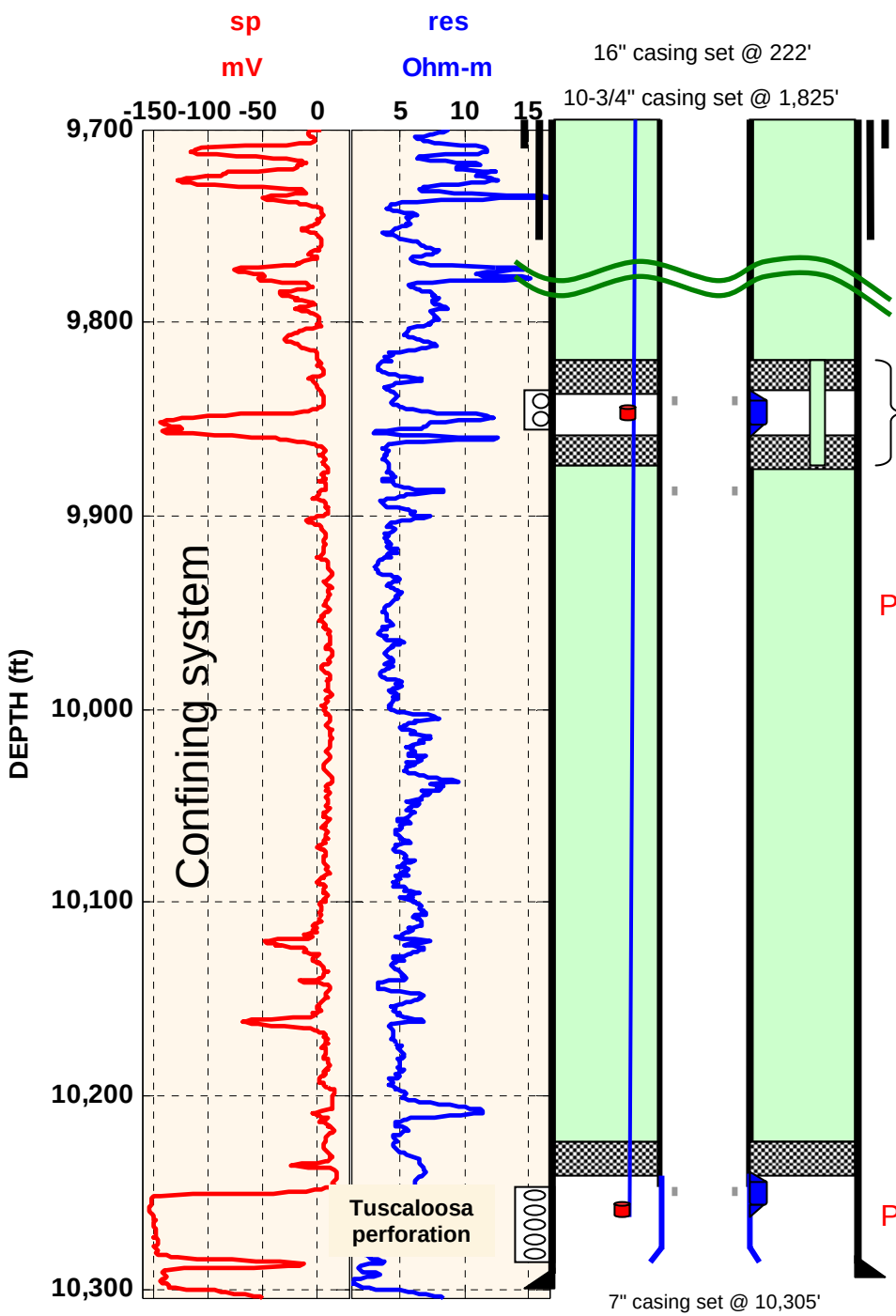
Case B has a capillary entry seal vertical hydraulic conductivity contrast allows brine movement however CO_2 cannot cross the seal.
The area of pressure elevation is smaller relative to area of CO_2 foot print.



Stacked Storage



- By Developing multiple injection zones footprint of the CO_2 and pressure plume can be minimized



Test adequacy of Mississippi well completions for CO_2 sequestration

Monitoring Zone

13-Chrome Isolation packer w/ feed through

13-Chrome Selective seat nipple

Pressure transducer Side Pocket Mandrel w/dummy gas valve

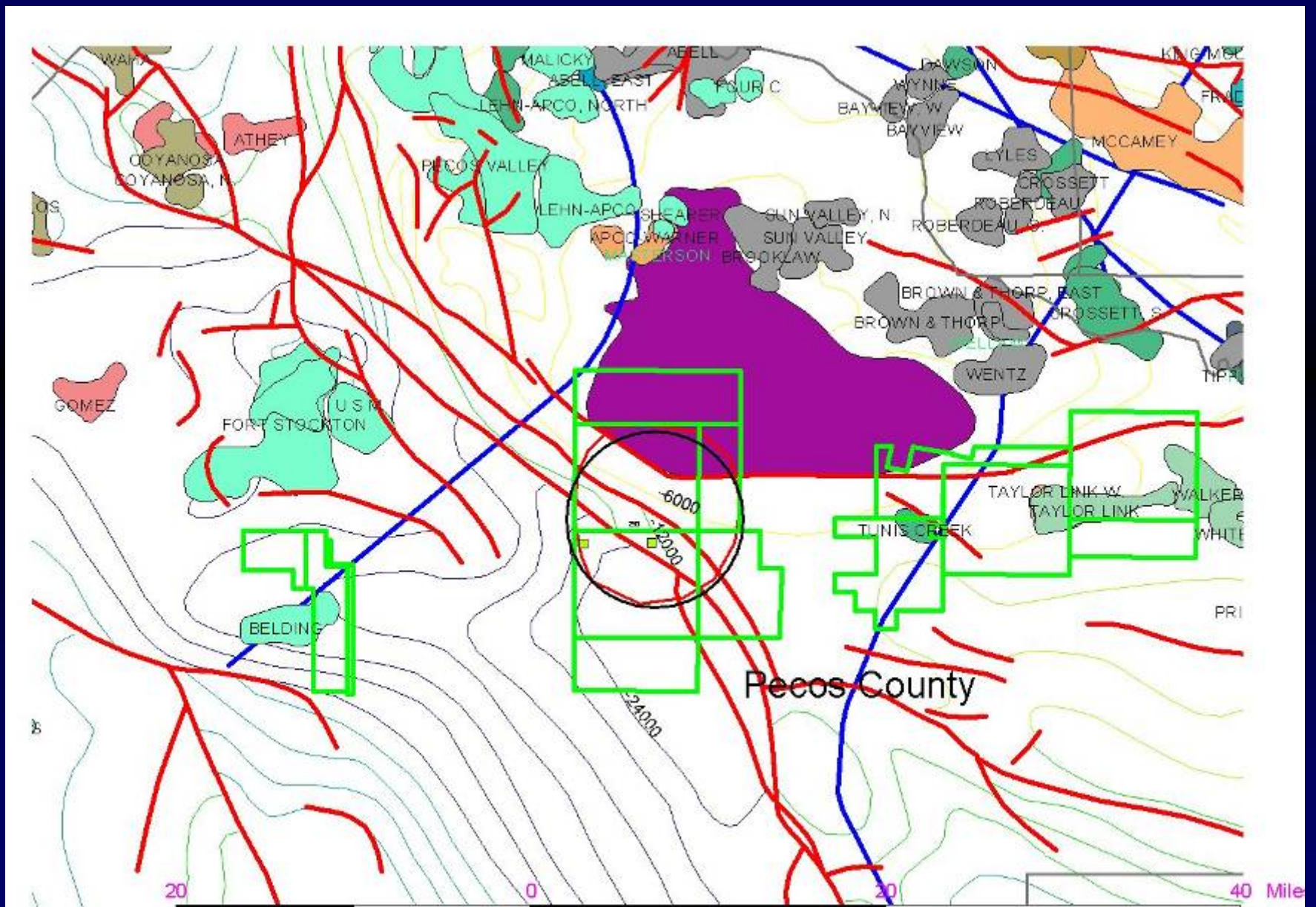
1/4" tubing installed between packers to Provide a conduit between isolation packers

CO_2 Injection Zone

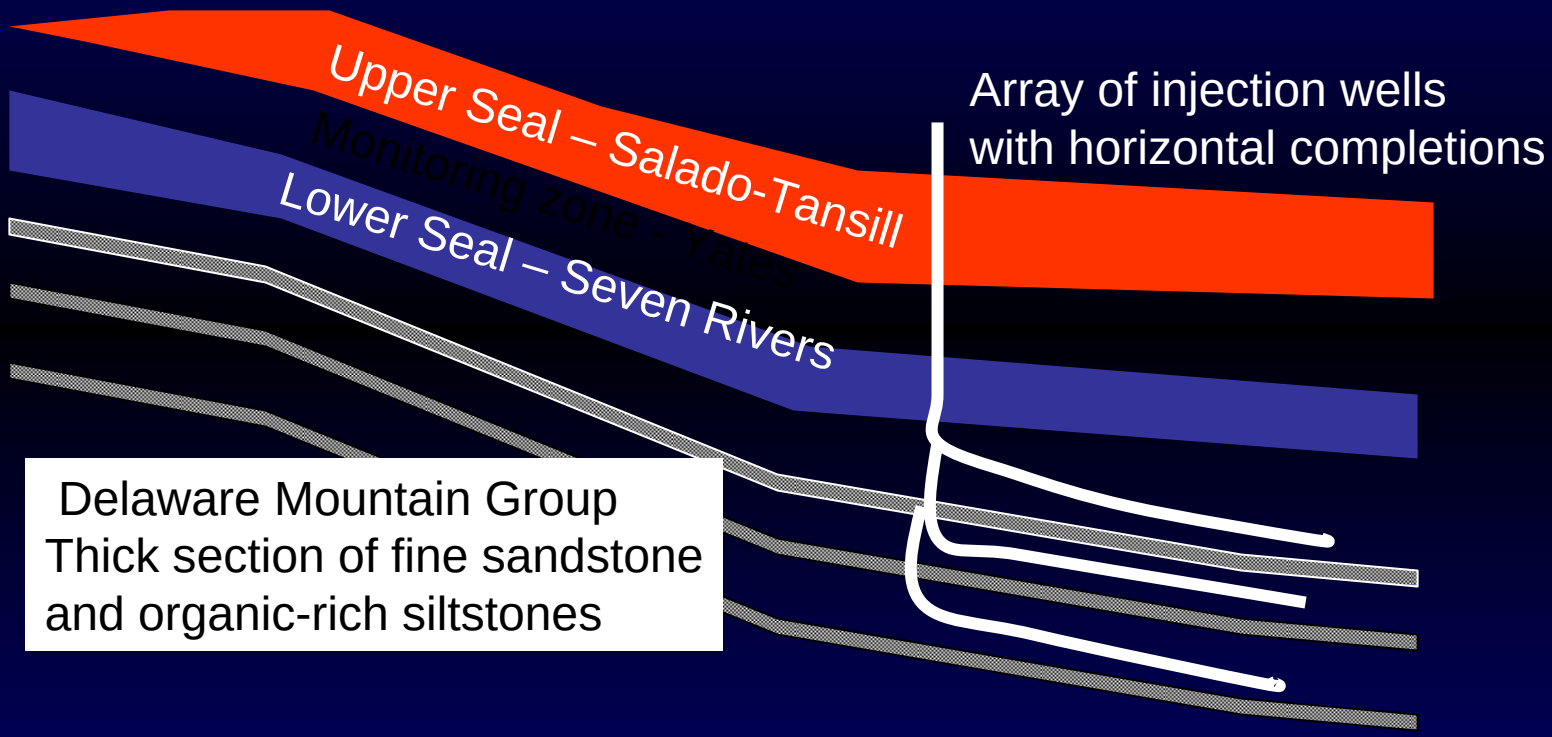
13-Chrome Production packer w/ feed thrus

Pressure transducer Side Pocket Mandrel w/dummy gas valve

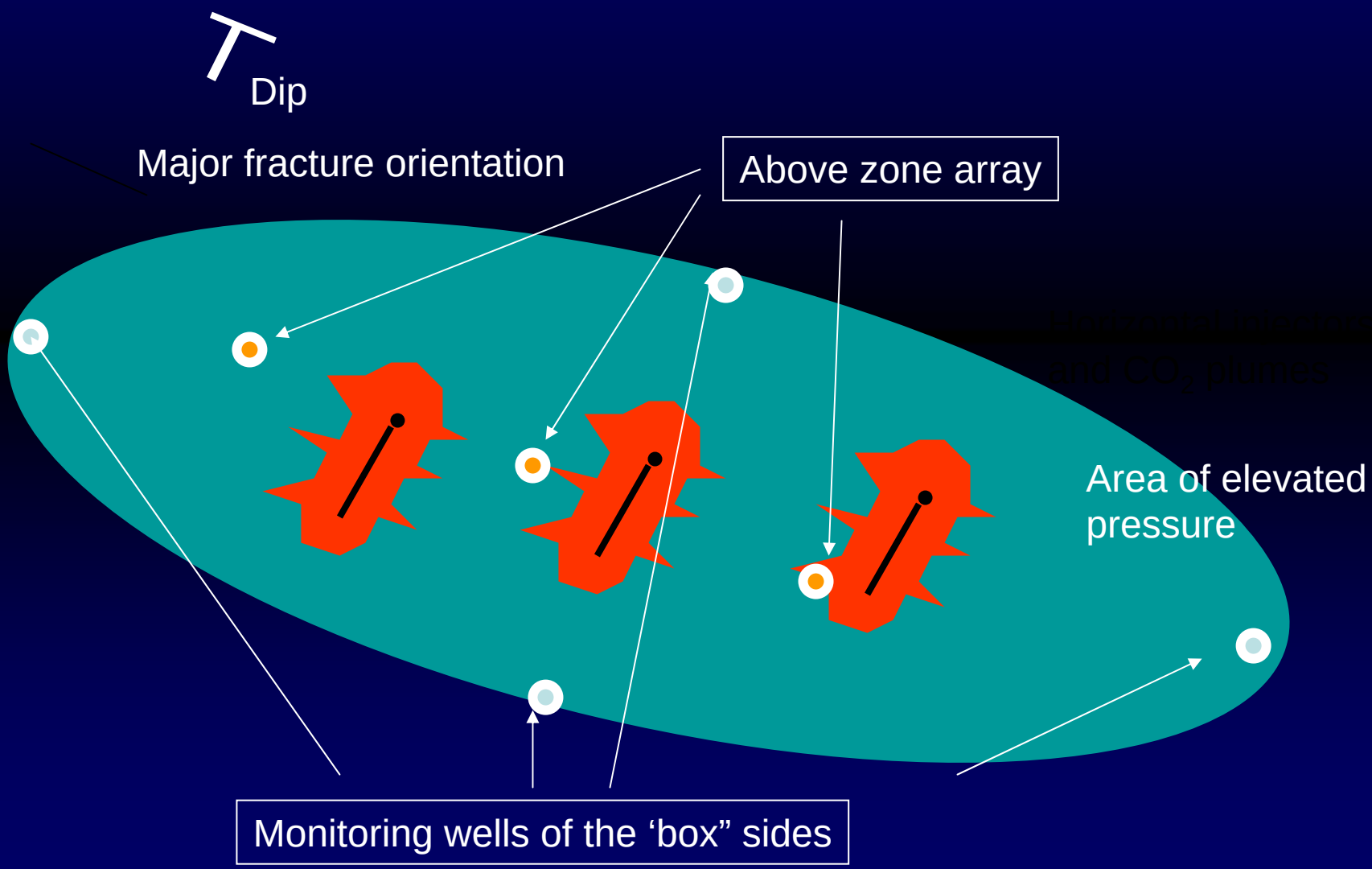
Box Case example 1 - Dipping saline formation



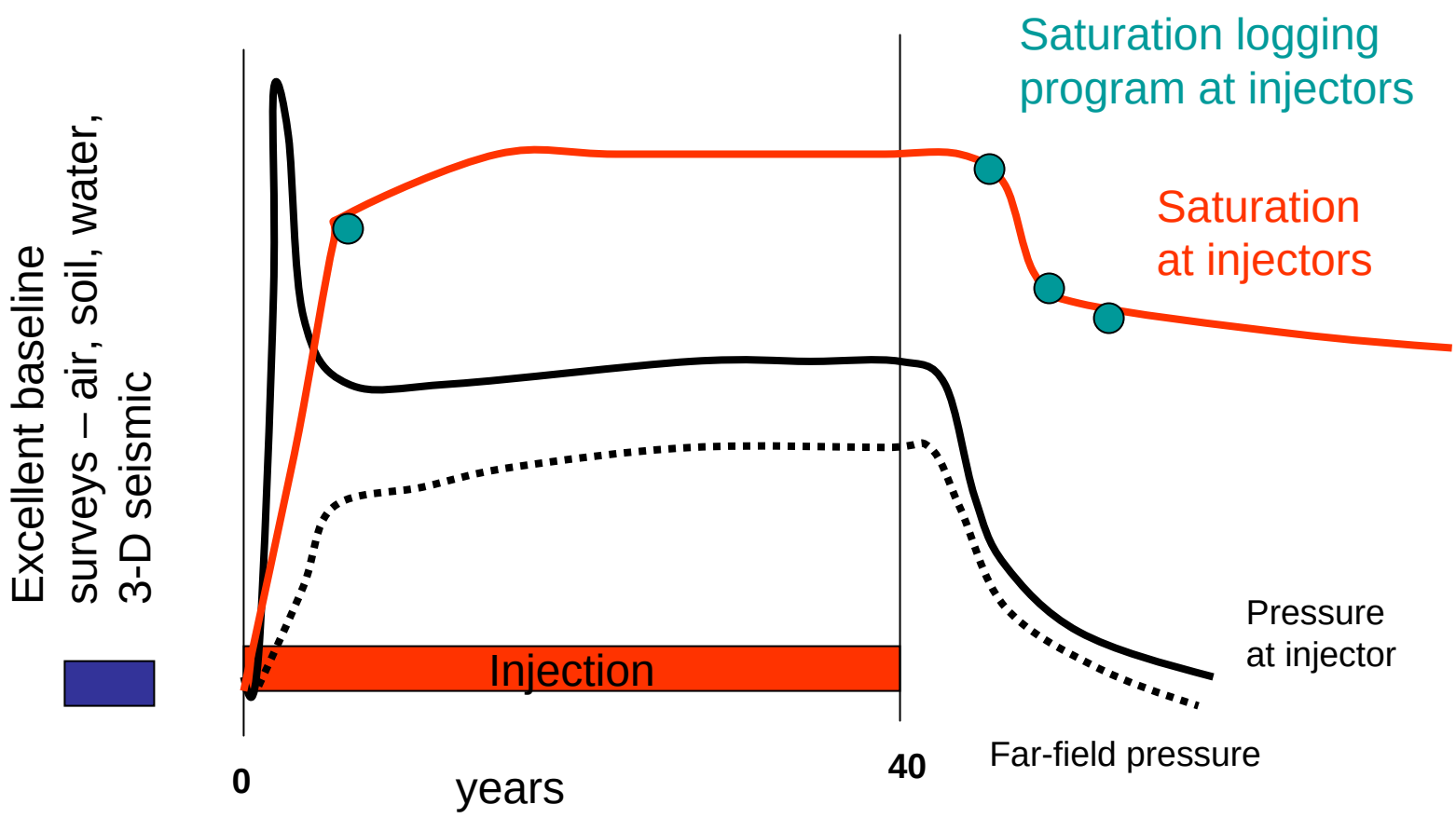
Large volume injection plan



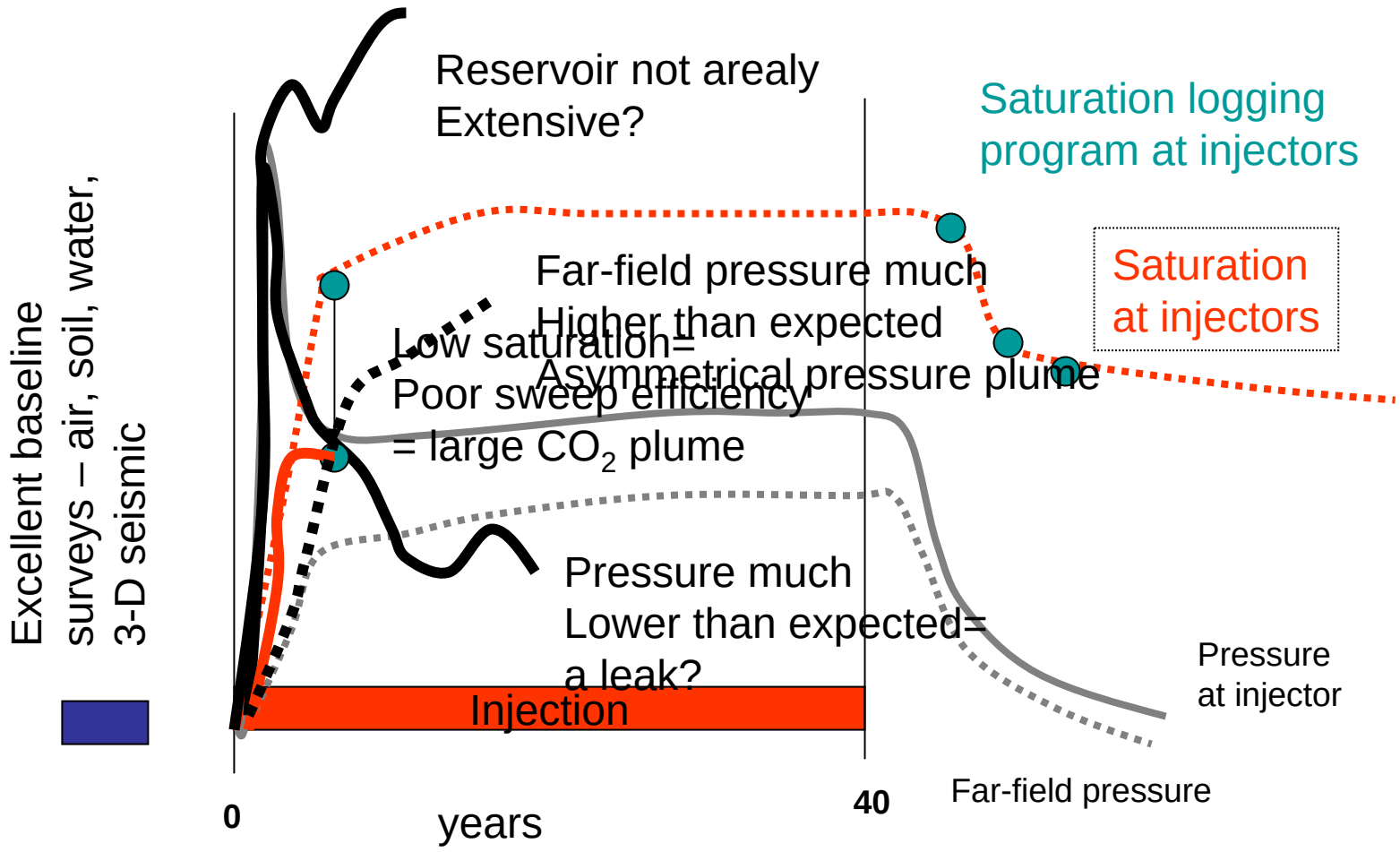
Large volume monitoring plan – the box



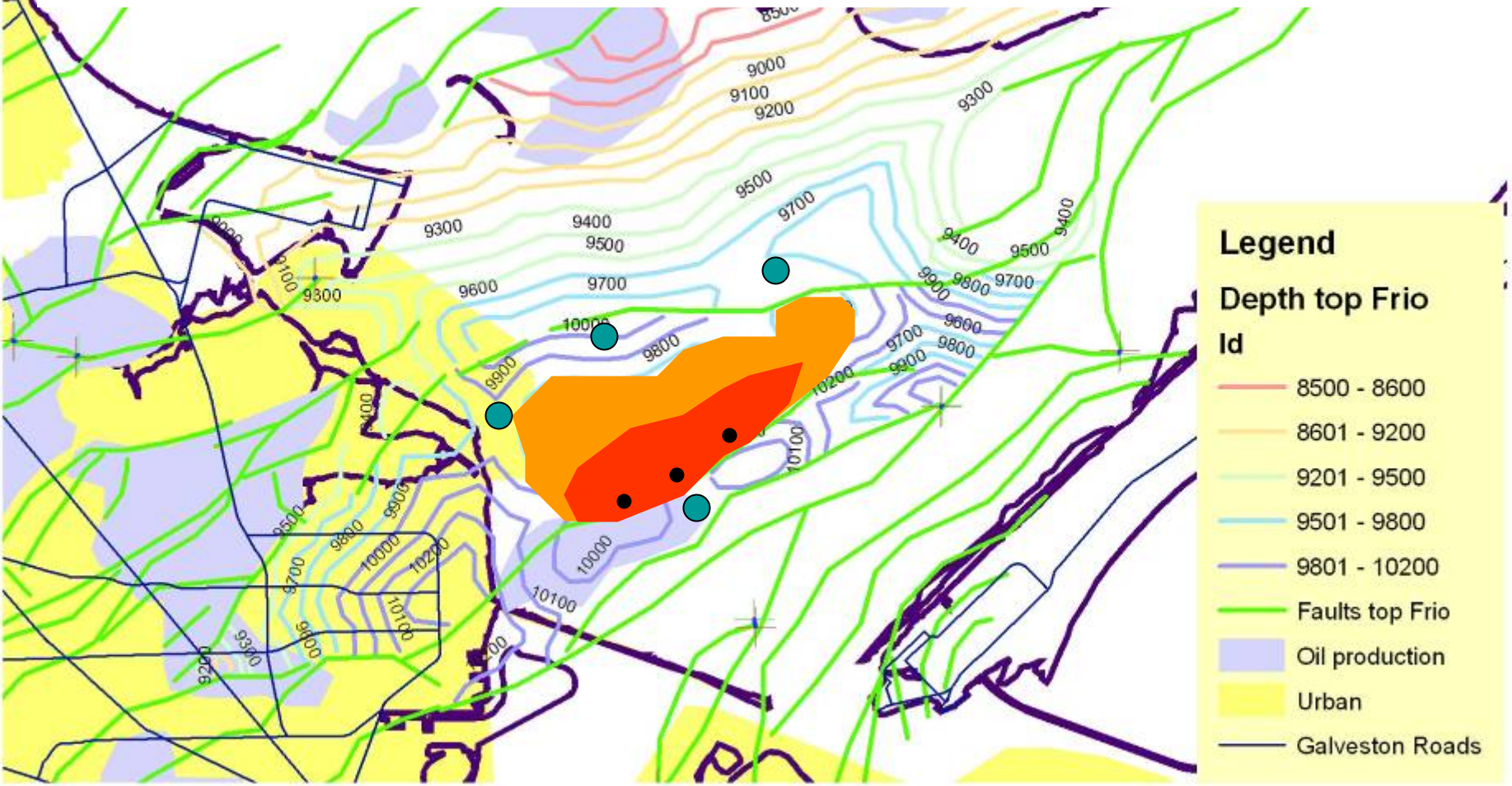
Monitoring Plan



Monitoring Plan – finds unacceptable response

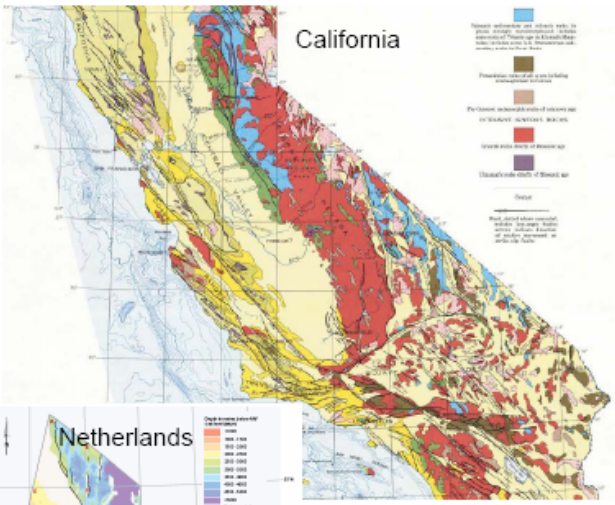


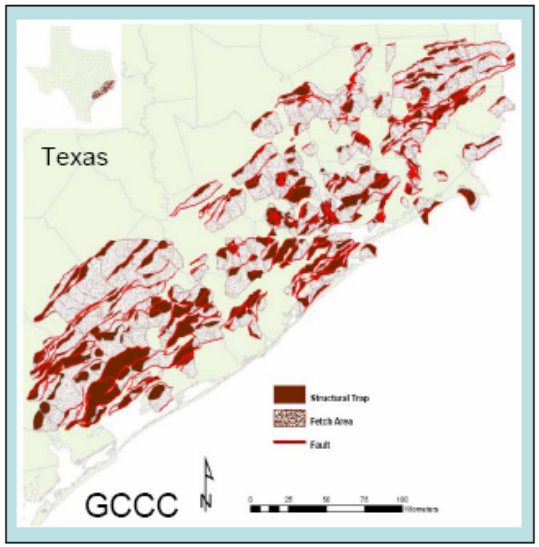
Injection into a structure

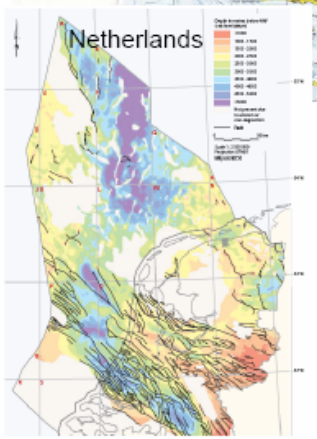


Faults as seals and as conduits

Faulted environments fairly common in prospective CCS areas







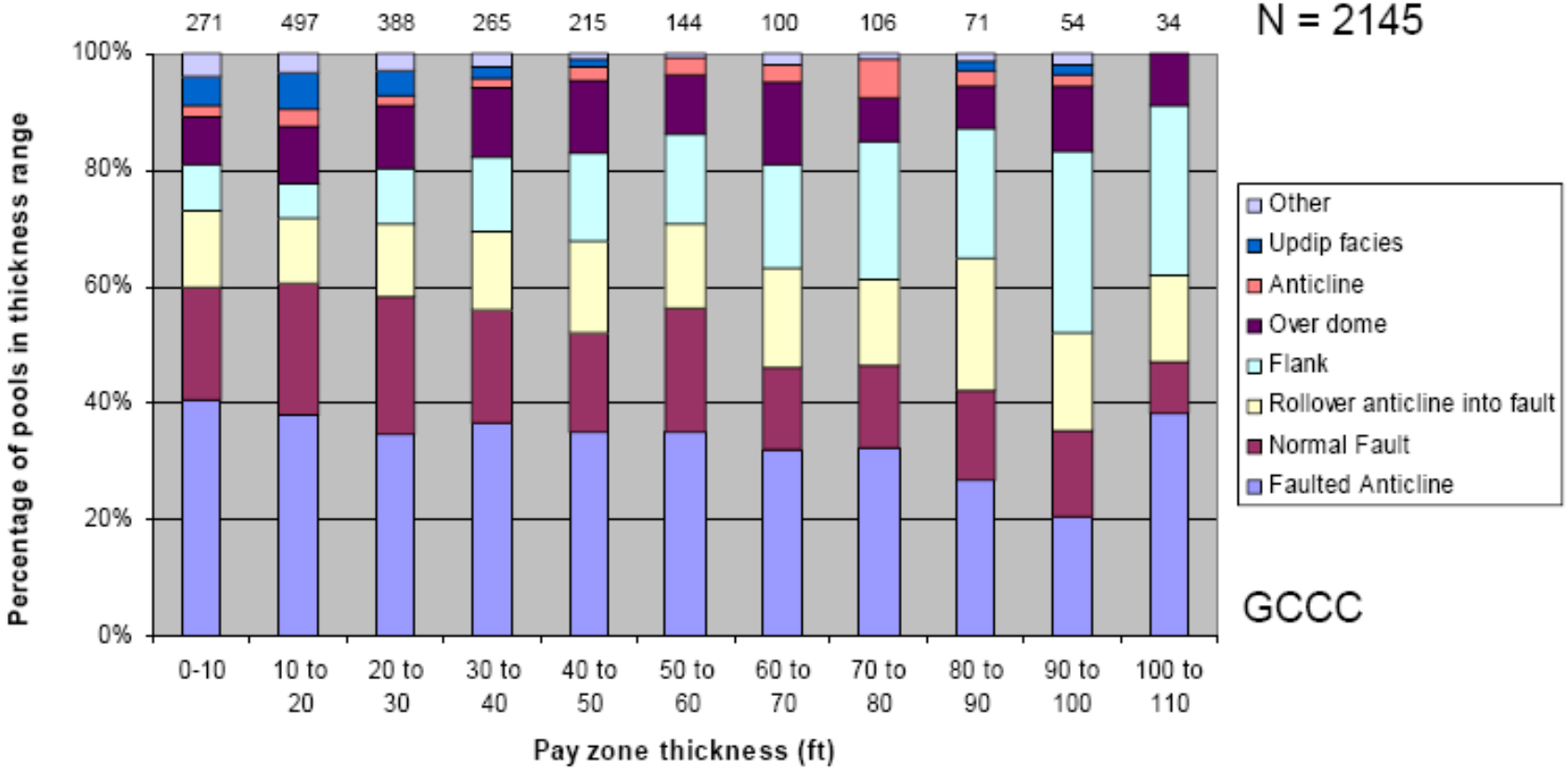
Duin et al., 2006

Limited lateral and vertical distribution.

You don't have to work in faulted areas, but other considerations may make those areas attractive.

Meckel, 2007

Common environments for economic hydrocarbon accumulations
Example: Offshore Gulf of Mexico



- Majority of HC environments involve faults: provide structure
- Faults demonstrably sealing with respect to hydrocarbons

Meckel, 2007

Prediction – Integrate knowledge

- Future performance knowable

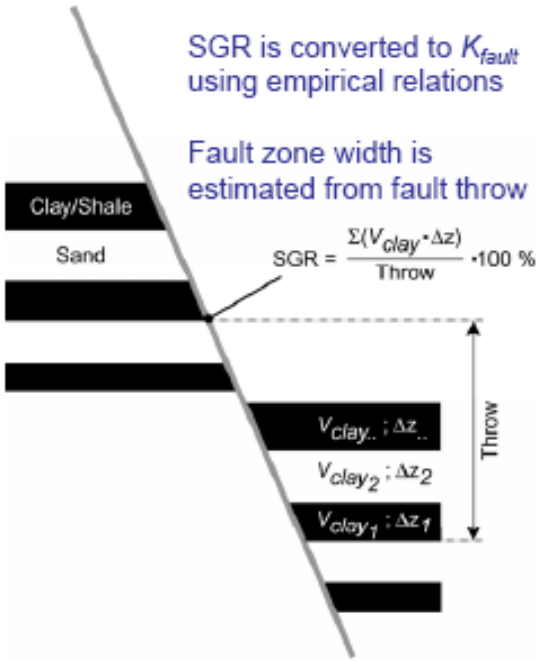
TRANSMISSIVE PROPERTIES:
Predicting fluid flow

Shale Gouge Ratio *(e.g. Yielding et al, 1997; AAPG Bull.)*

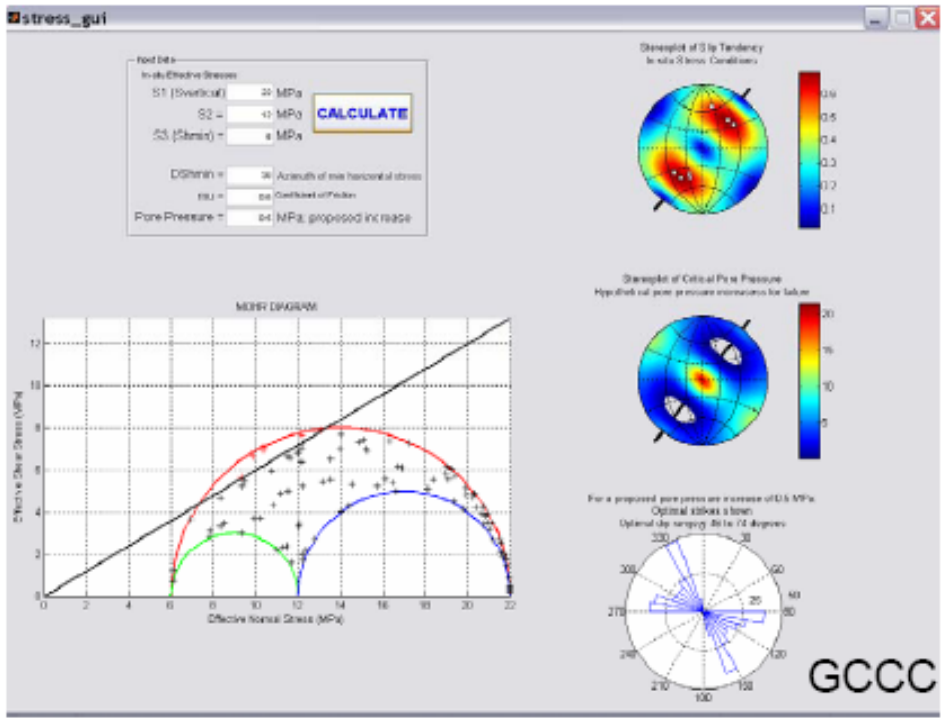
The Shale Gouge Ratio is used to estimate the amount of clay in the fault zone

SGR is converted to K_{fault} using empirical relations

Fault zone width is estimated from fault throw



DYNAMICS:
Predicting slip tendency with increases in fluid pressure

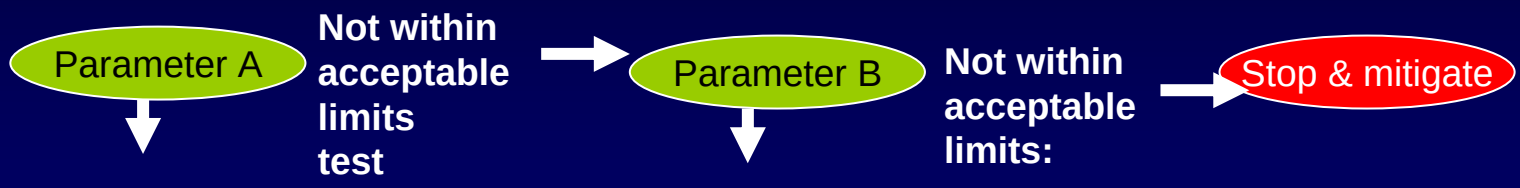


After Streit and Hillis, 2004: Energy 29:1445-1456.

Meckel, 2007

Hypothesis: Parsimonious Monitoring Program in a Mature Industry

- Standardized, dependable, durable instrumentation, reportable measurements
- Frequent pressure measurements above-zone and in-zone – documents conformance
- Episodic saturation logging (at injectors?) syn- and post-injection documents sweep.
- Trigger points:
  - an unexpected measurement initiates a pre-planned research type monitoring program to assess origin of response.



Technical input to policy issues

- Well leakage concern- needs resolution with respect to GHG reduction role for EOR - several tests are underway
- Area of Review – large footprint of high pressure area in brine around a large volume plume. Not applicable to EOR context.
- Mature monitoring plan is needed - hierarchical with trigger points.

Technical input to policy

- Recent policy concerned with feasibility of large scale (M tone/year), long term injection is not technically justified. Methods for increasing injectivity in low permeability rocks (long horizontals) are mature and have been deployed for CCS (Weyburn, In Salah).
- Focus should be shifted to documentation of (1) proof of adequacy of characterization (lateral connectivity of reservoir, quality of seal, sealing faults) and (2) correct prediction of maximum pressure and maximum plume extent.