

Southwest Regional Partnership on Carbon Sequestration

Permian Basin, Texas Project Overview

October 3, 2006

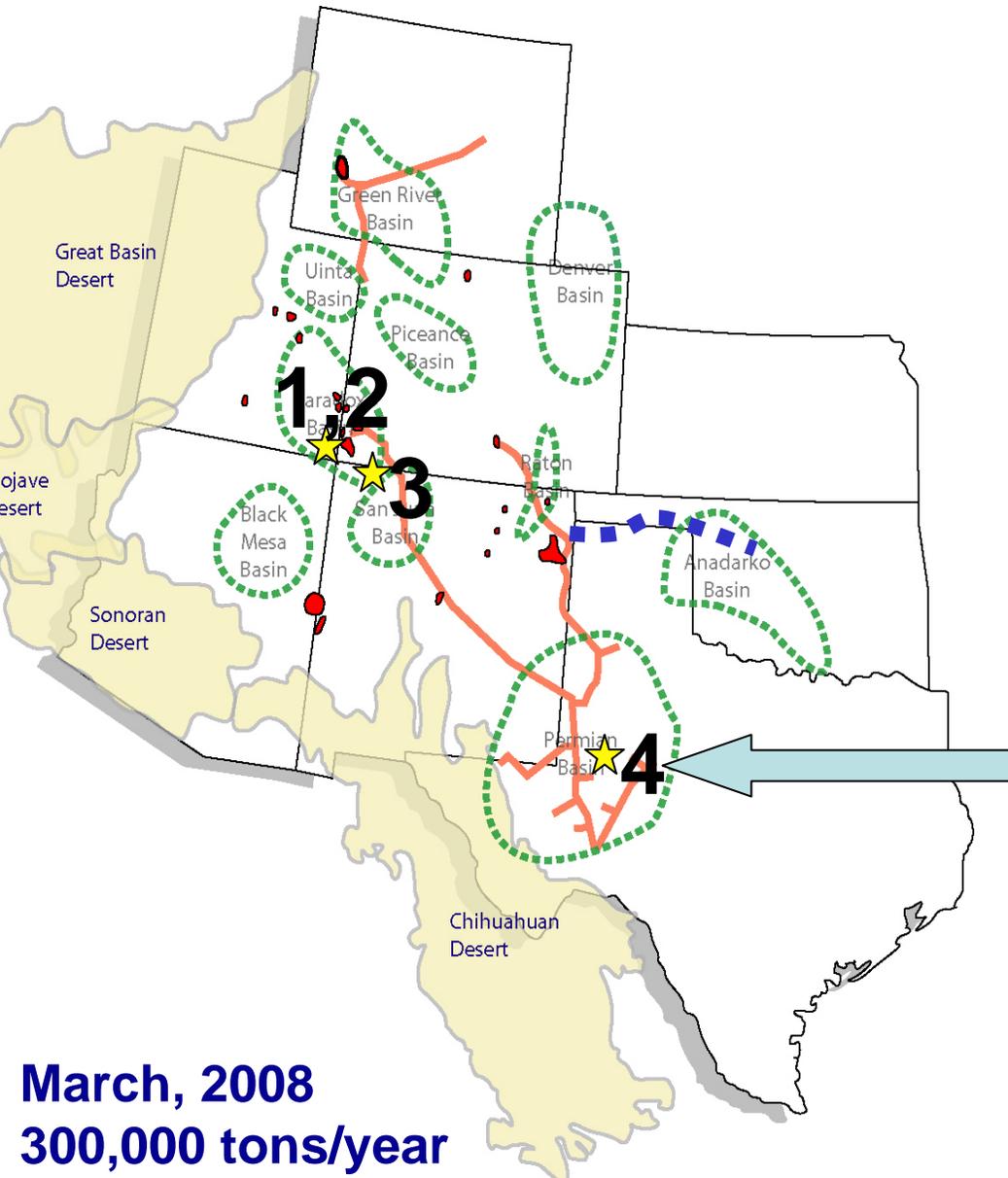
Pittsburgh, Pennsylvania



Presented by Dick Benson
Applied Sciences Laboratory



Project Portfolio



Four of over 100 geologic options were selected as the most promising opportunities for evaluation:

Combined enhanced oil recovery and sequestration testing, Permian Basin, TX

March, 2008
300,000 tons/year

Permian Basin, TX

Two-Tiered Project:

(1) Detailed Analysis of SACROC field, site of 30 yrs of CO₂ injection for EOR: what happened to CO₂ at SACROC?

- Current operations inject ~13.5 Mt CO₂/yr and withdraw and reuse ~7 Mt CO₂/yr = net storage of ~6.5 Mt CO₂/yr
- the site has accumulated ~ 55 Mt CO₂
- in comparison, Sleipner injects ~1 MtCO₂/yr since 1996
- history-matching analysis valuable for future EOR-sequestration

Permian Basin, TX

Two-Tiered Project:

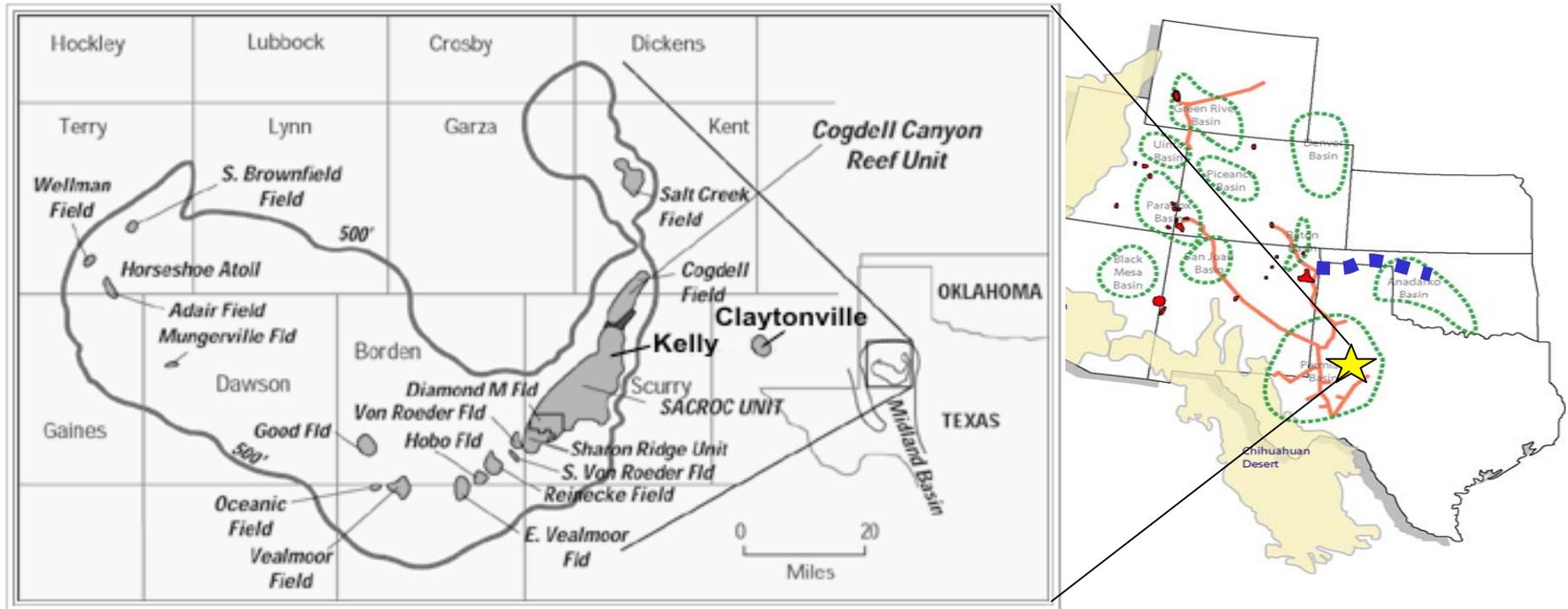
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(2) New CO₂ injection for EOR and sequestration analysis at the nearby Claytonville field, never subjected to CO₂ injection

- geology very similar to that of SACROC
- planned injection of ~300,000 tons per year for life of project`

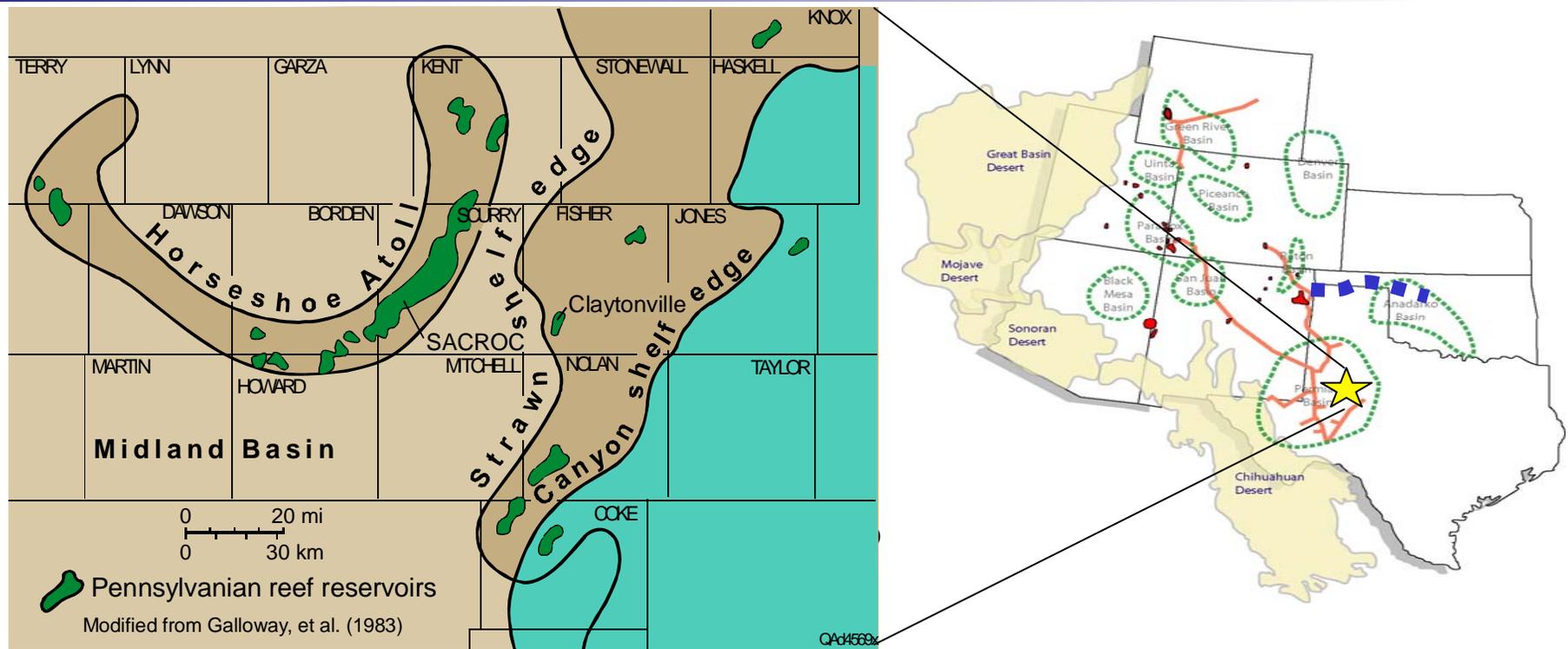
Claytonville, TX: EOR and Sequestration Demo



Broader implication: regional geology “Horseshoe Atoll”

- most of western half of atoll reservoirs are below oil-water contact
- represents a potentially huge CO₂ storage site

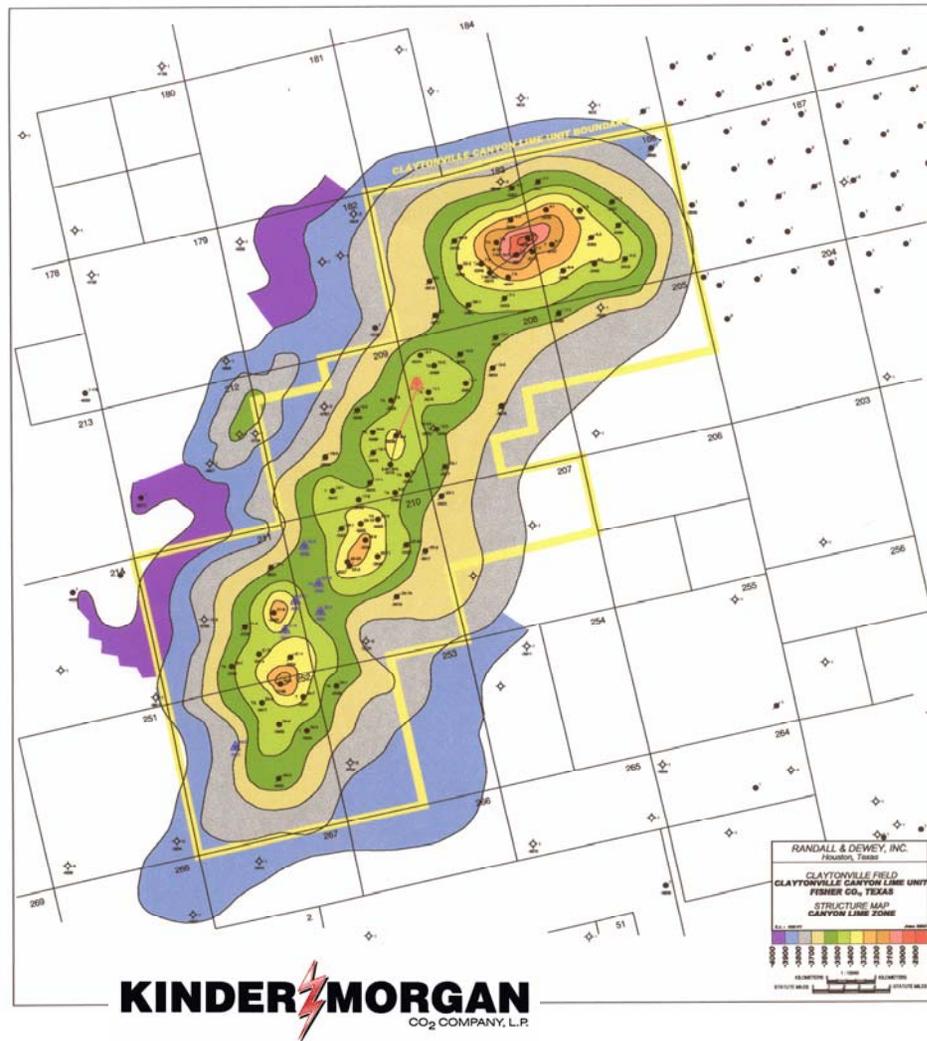
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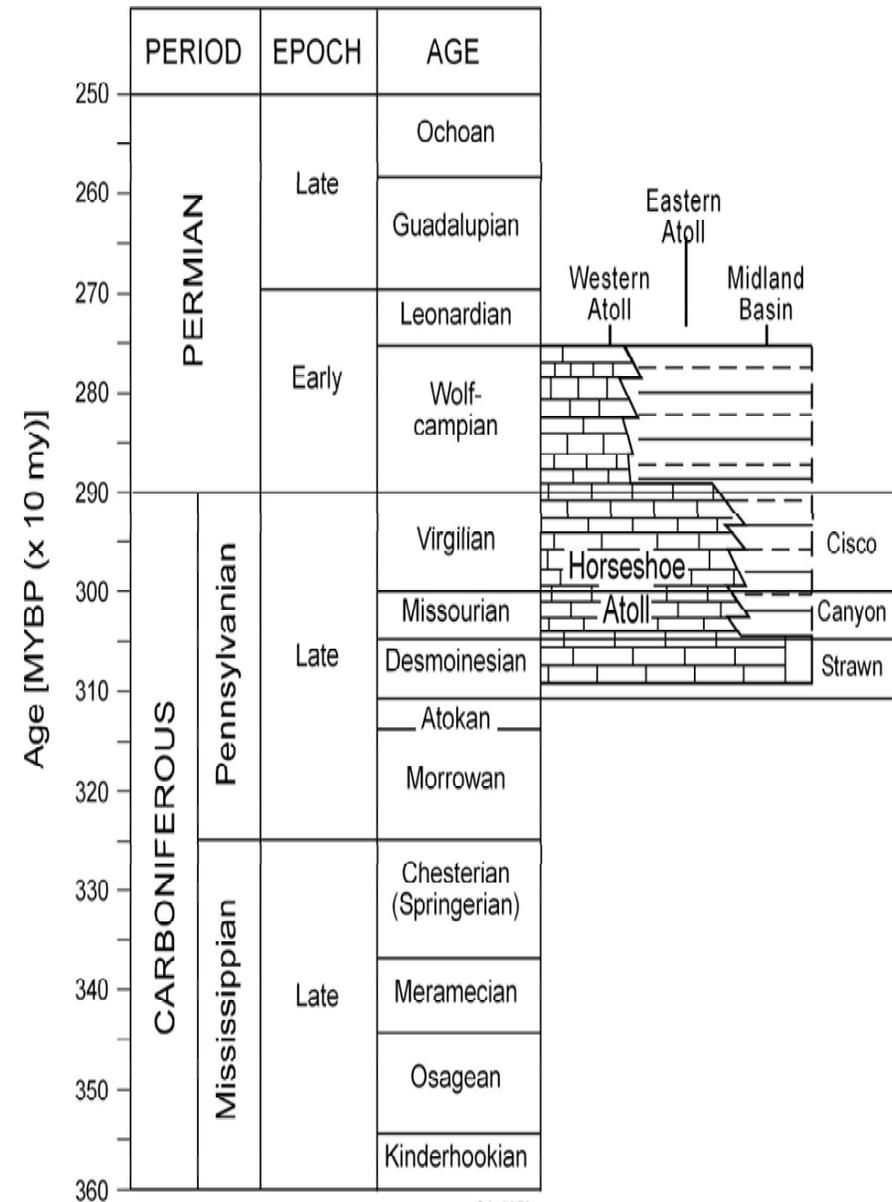


**Target Reservoir:
Pennsylvanian Aged
Canyon Reef Fm - 5700' depth**

**CLOSEST CO₂ Analogue:
SACROC**

**3-D seismic and advanced
reservoir characterization is
being used for engineering
and MMV planning**

Claytonville, TX: EOR and Sequestration Demo



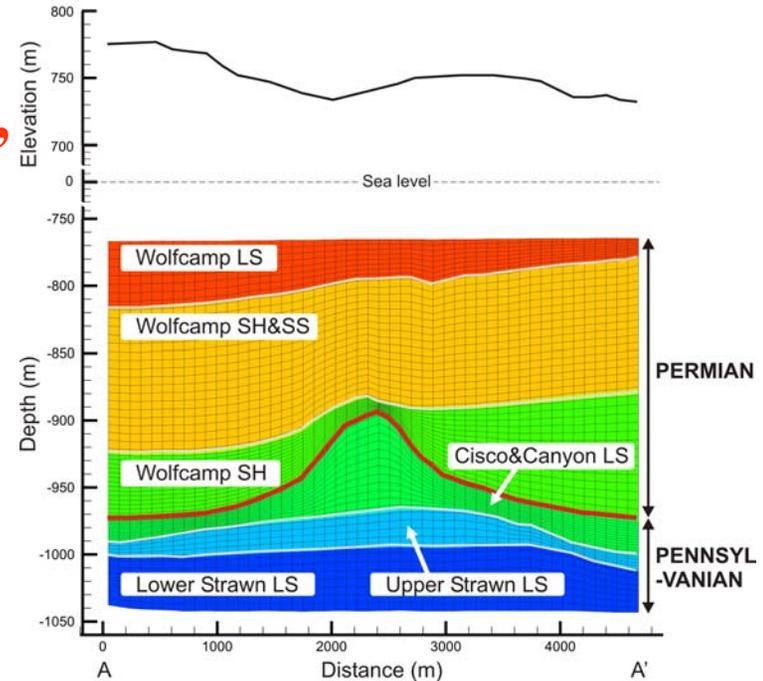
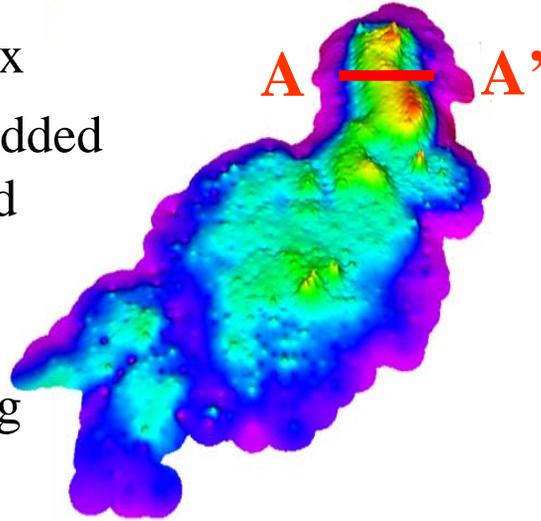
Target Reservoir:
Pennsylvanian Aged
Canyon Reef Fm - 5700' depth

Intended Seal:
Permian Aged Wolfcamp Fm,
consisting of marine shales.

Site Characterization (Geology & Reservoir)

Top of the Cisco formation

- Limestone reef complex
- Massive amounts of bedded bioclastic limestone and thin intercalated shale beds
- Most of oil is producing from Cisco&Canyon



• Rock properties

Avg. porosity: 7.11%
Avg. perm.: 3.06E-14 (m²)

• Fluid properties

Gravity: 42°API(=0.861)
Water salinity : 1.5 mg/L
Water saturation : 28.2%
Formation volume factor (bbl/bbl@SP): 1.5

• Pressure

Ini. Reservoir pressure: 21.53 MPa@-1310.64 m
Bubble point pressure: 12.45 MPa

• Pay section

Avg. pay thickness: 69.80 m
OOIP: 2.73 billion bbl
Estimated total oil recovery: 51.7%

Texas Demonstration Summary

Location	Type of Test	Test Details	Capacity & Value Added Benefits
SACROC-Claytonville Fields, Permian basin, TX	Combined EOR with Sequestration	Over 150,000 (?) tons per year for 2 years	<ul style="list-style-type: none"> - An estimate of minimum capacity of test unit: 100,000,000 tons
			<ul style="list-style-type: none"> - Value added Benefit: enhanced oil recovery -- Estimated additional oil recovery: unknown (reservoir modeling underway)

 Pennsylvanian reef reservoirs
 Modified from Galloway, et al. (1983)

Measurement, Mitigation and Verification (MMV)

(1) General Types:

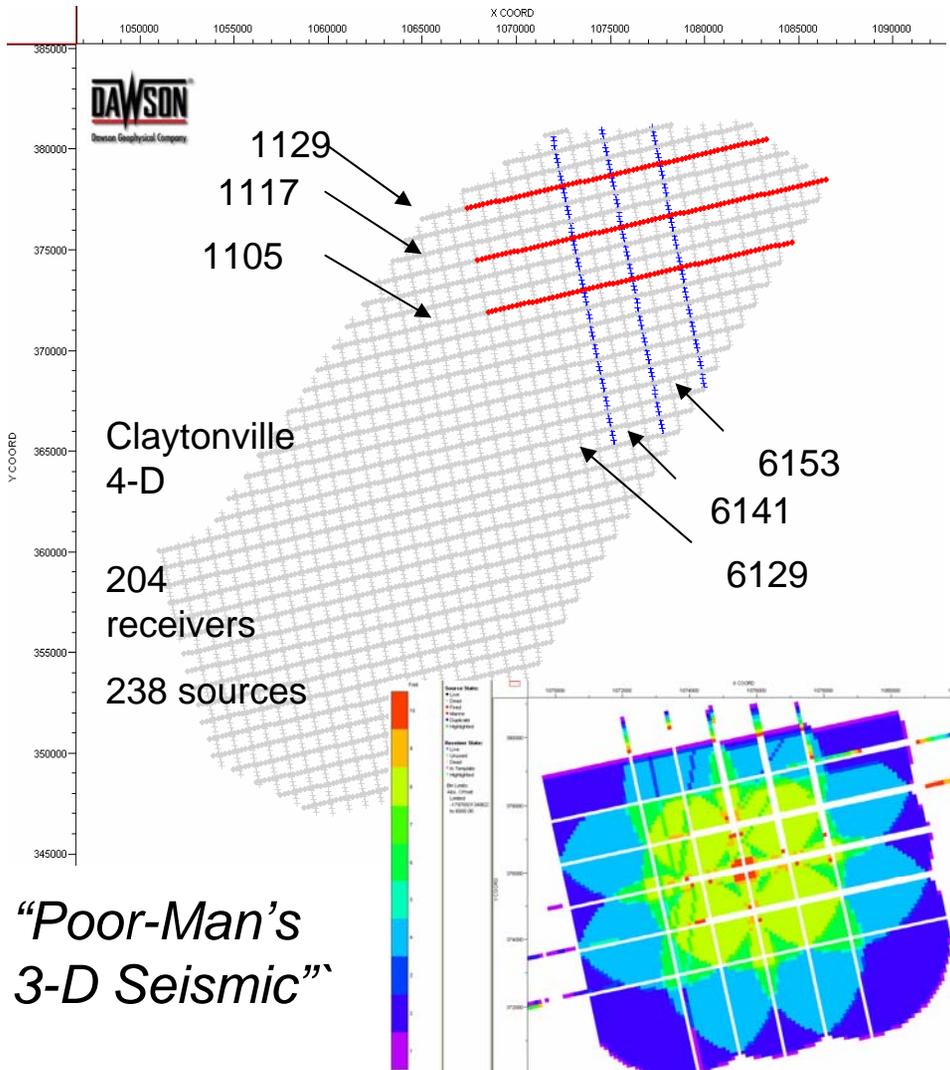
- Direct methods (e.g., flux surveys, etc.)
- Indirect methods (e.g., seismic, geo-electric, etc.)

(2) Most general purposes:

- Detect if CO₂ leaves intended reservoir
- Track CO₂ fate and facilitate estimates of capacity/storage

Goal: Maximize Efficacy of Monitoring and MMV Plans

Tentative Components of Texas MMV Plan



*“Poor-Man’s
3-D Seismic”*

Claytonville, Tx: 2006 to 2009

Baseline/Background:

- Jan 06: 3D seismic, Passive Seismic, Crosswell, VSP, Active Doublet
- Mar 06: Water Chem, Gas Fluxes, Constant P-T-bicarb
- Monthly water chemistry, Fluxes, remote sensing
- Constant passive seismic

During Injection (Starts Mar 08):

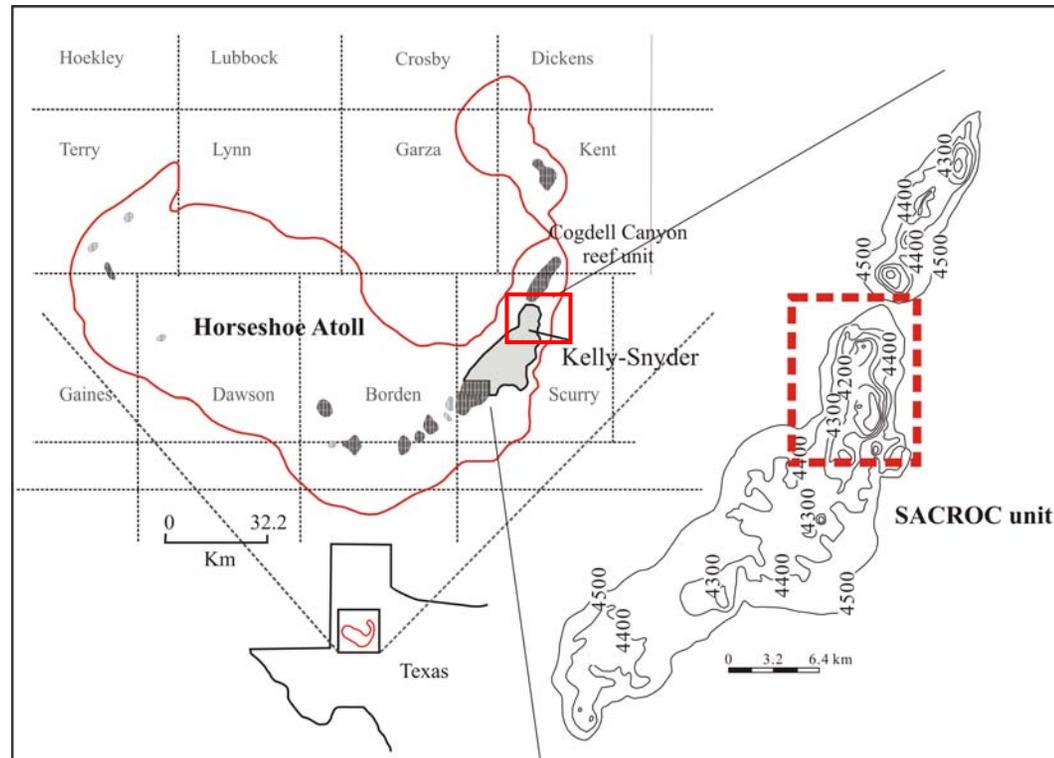
- Bi-monthly: Water chem, gas fluxes, remote sensing, passive seismic
- Every 4-6 months: other seismic, including “Poor-Man’s 3-D” surveys
- Constant P-T-bicarb

Ongoing Site Characterization (SACROC)

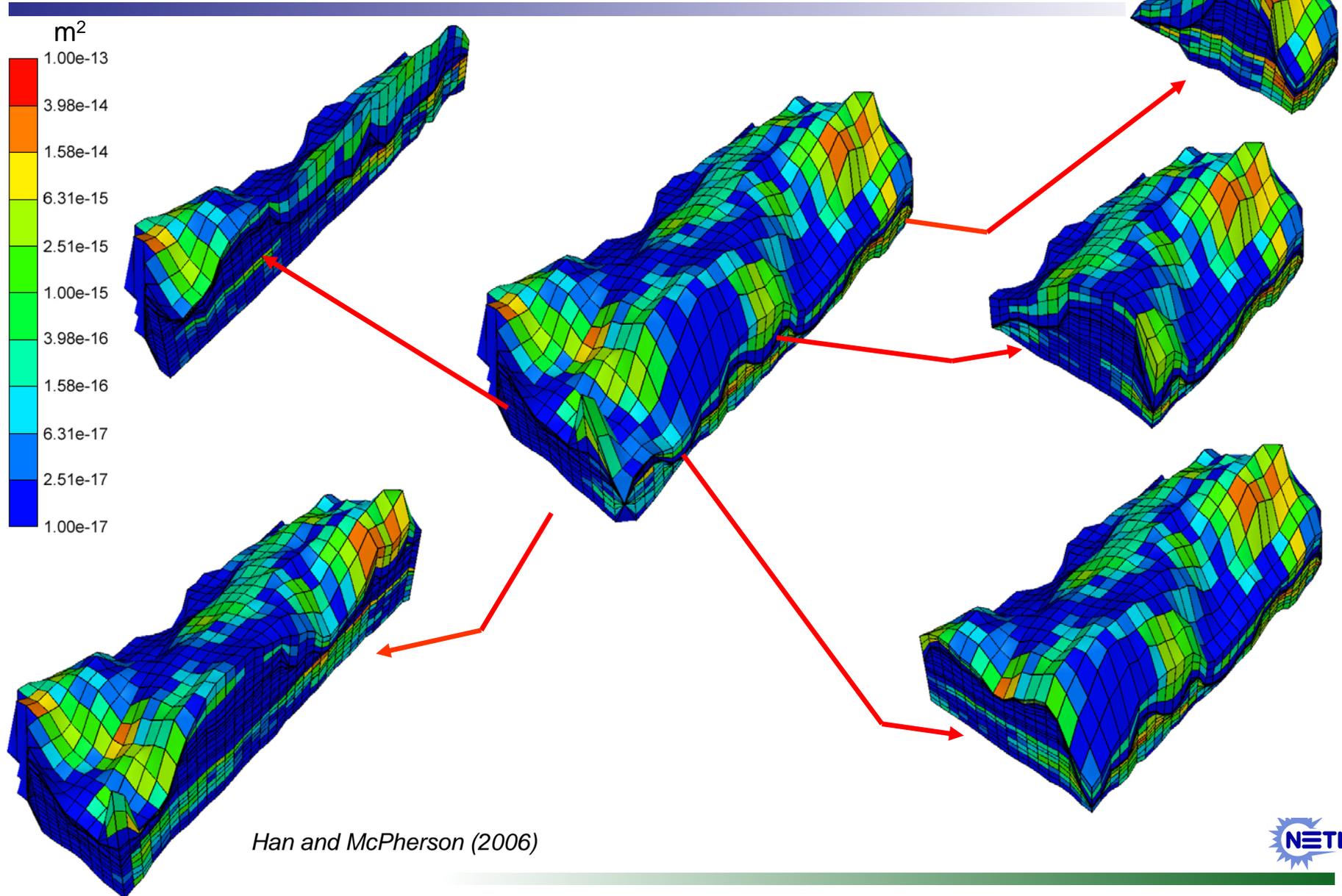
SACROC Unit: the oldest CO₂ Enhanced Oil Recovery (EOR) operation in the United States since 1972 years

Current operations inject about **13 million tons** CO₂ and recycle about **6 million tons** CO₂, for a net storage of about **7 million tons** CO₂

Natural heterogeneity has been identified with **seismic surveys** conditioned using 400 wells logs



Natural heterogeneity (Permeability) at SACROC



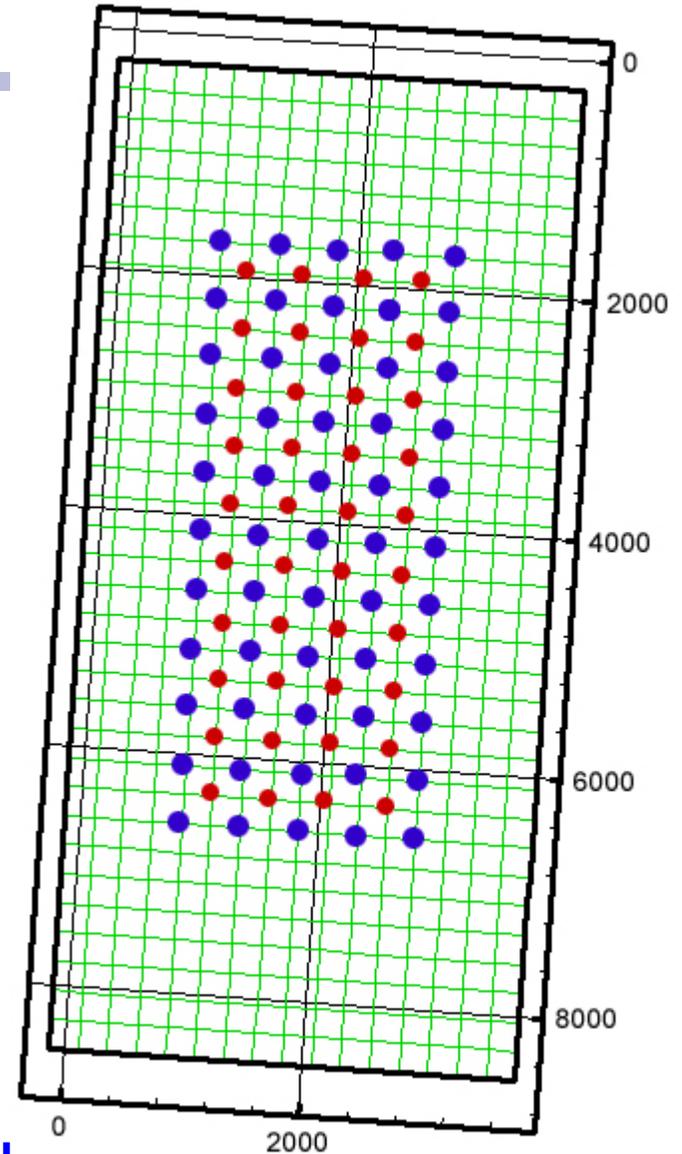
Han and McPherson (2006)

Analysis of CO₂ Injection at SACROC

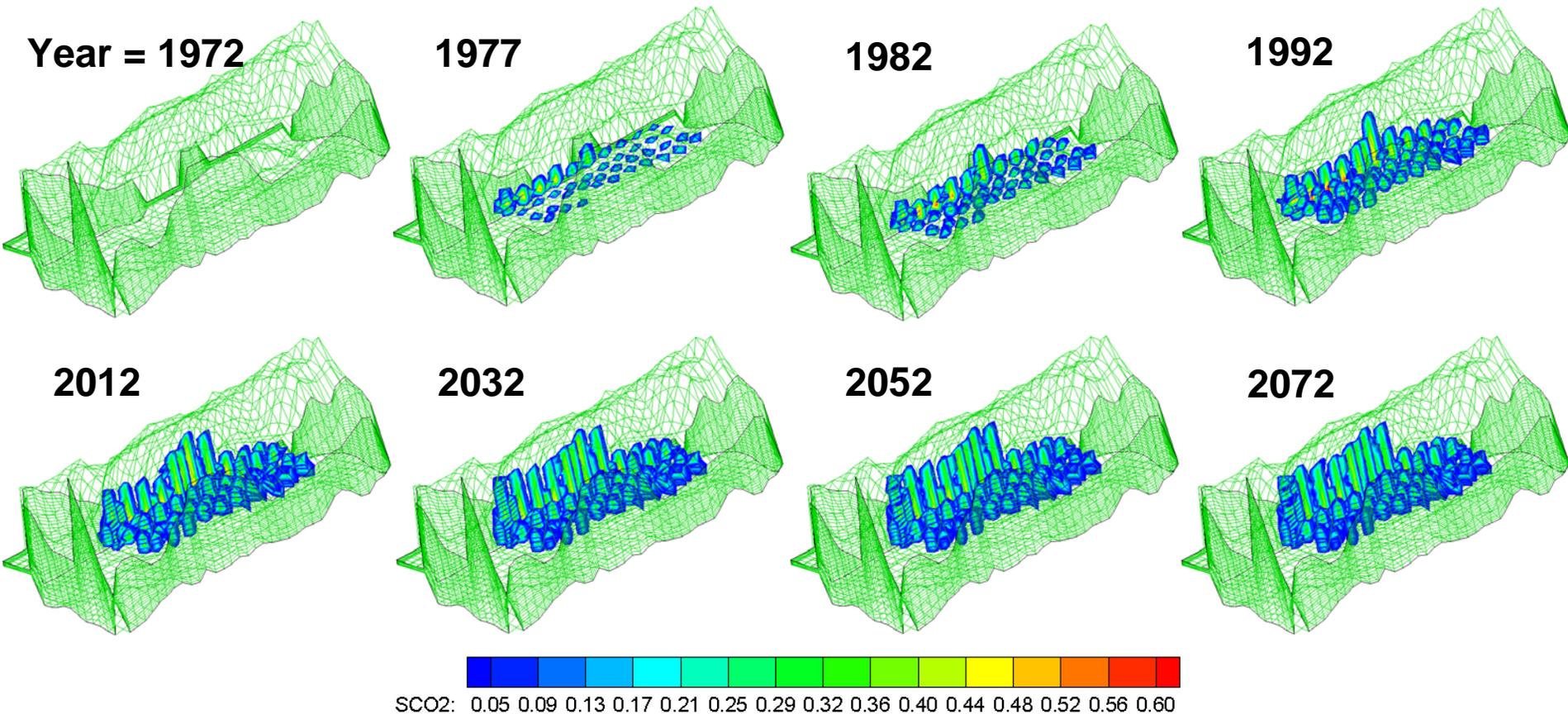
- Total number of CO₂ injection well: 40
Total injected CO₂ mass: 1.3 million tons from 1972 to 2002
- Total number of CO₂ pumping well: 135
Total produced mass: 1.18 million tons from 1972 to 2002
- Total simulation time is 100 years, from 1972 to 2072

Han and McPherson (2006)

- CO₂ injection well
- CO₂ production well



Reservoir History Modeling of SACROC: Separate CO₂ distribution

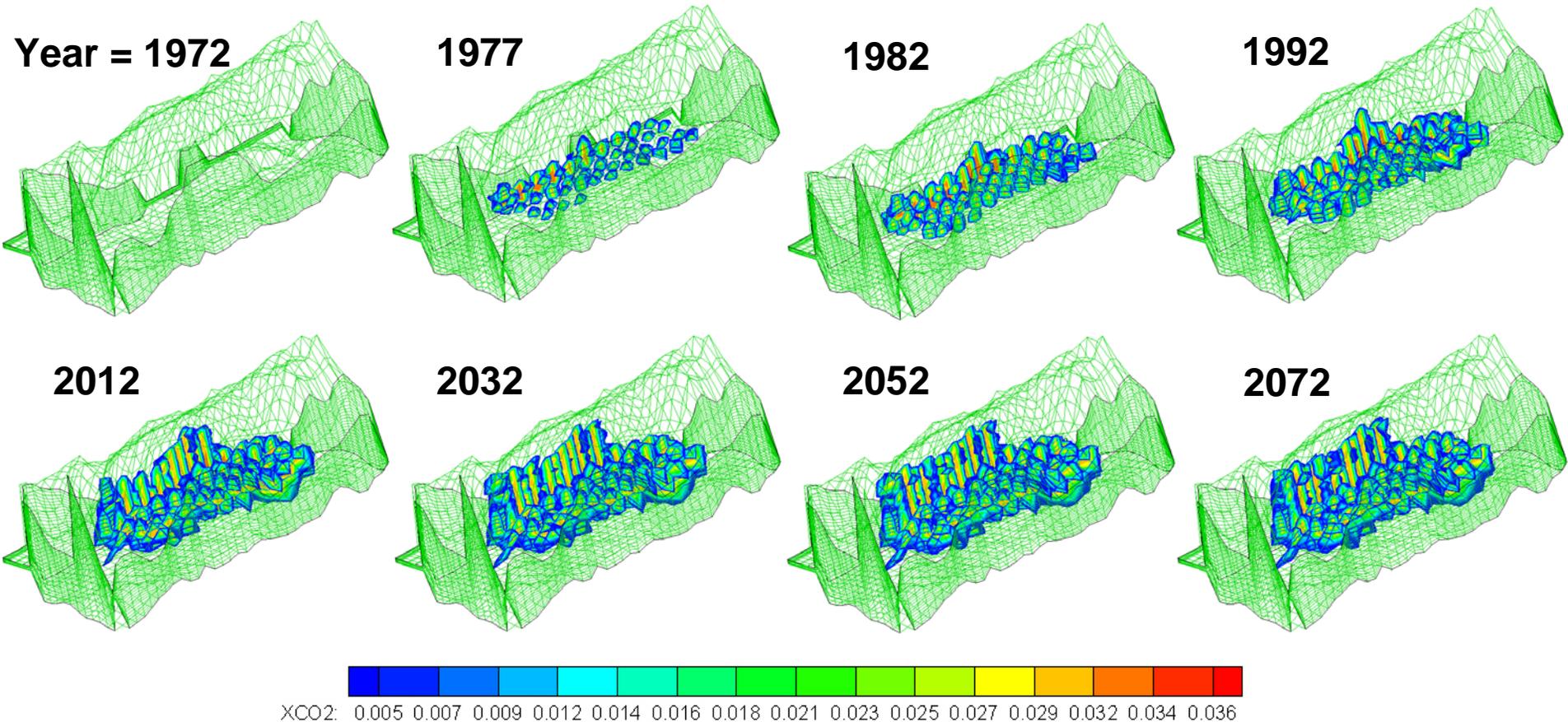


Han and McPherson (2006)

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Reservoir History Modeling of SACROC: Dissolved CO₂ distribution



Han and McPherson (2006)

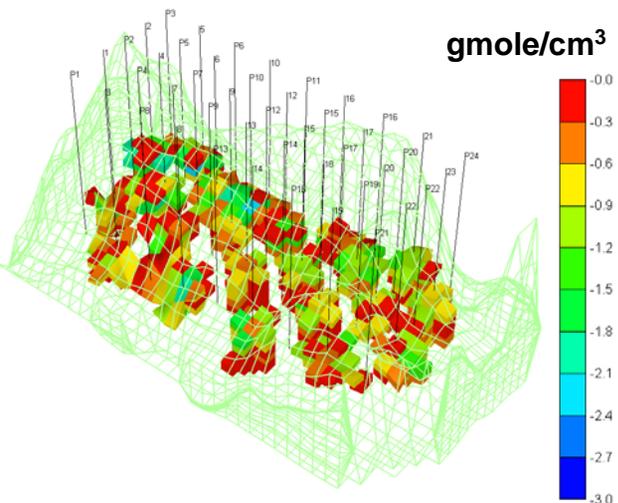
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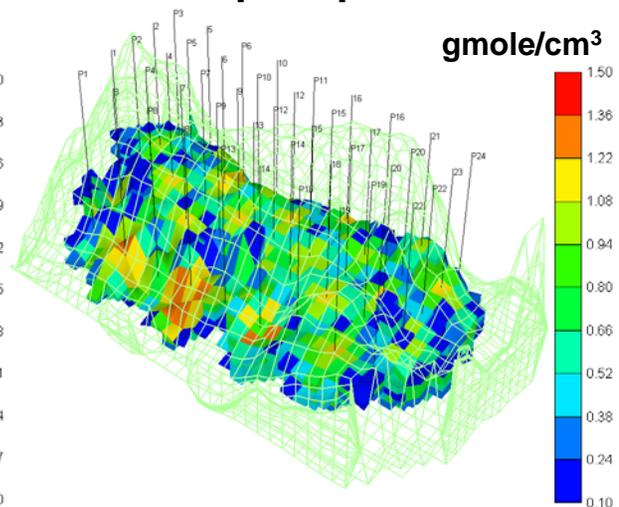
Reservoir History Modeling of SACROC: Multiphase and Multispecies Reactive Transport Modeling

Mineral precipitation/dissolution at end of injection period:

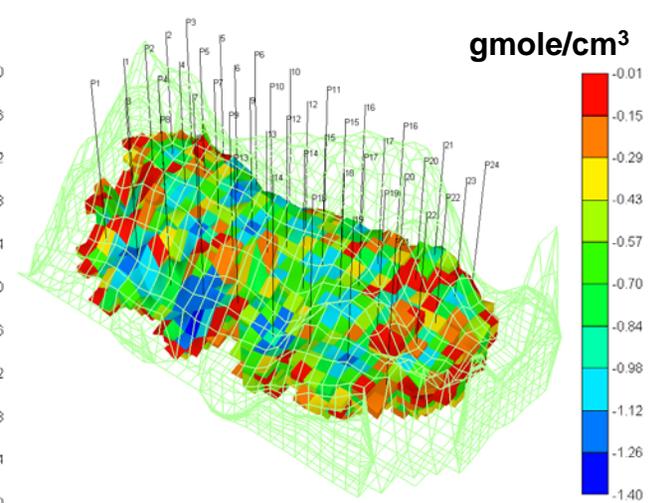
Calcite dissolution



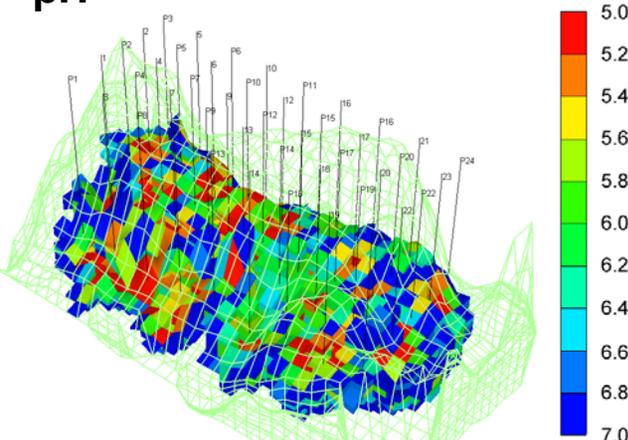
Kaolinite precipitation



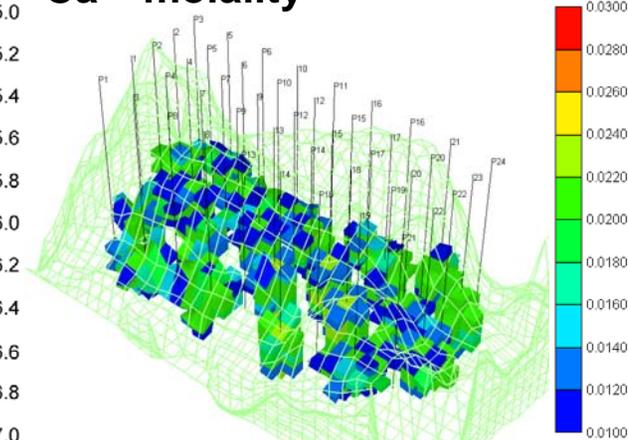
Anorthite dissolution



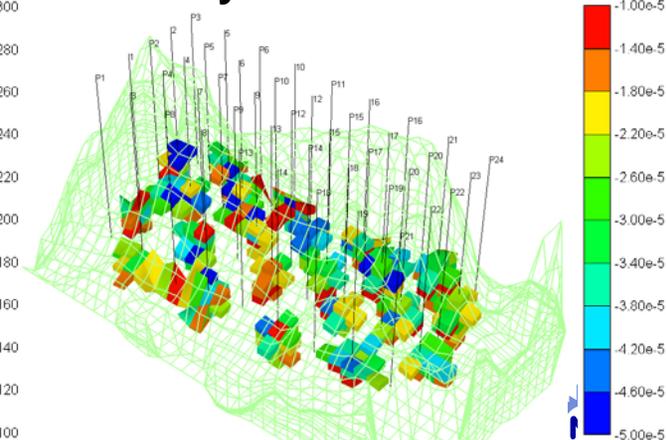
pH



Ca²⁺ molality

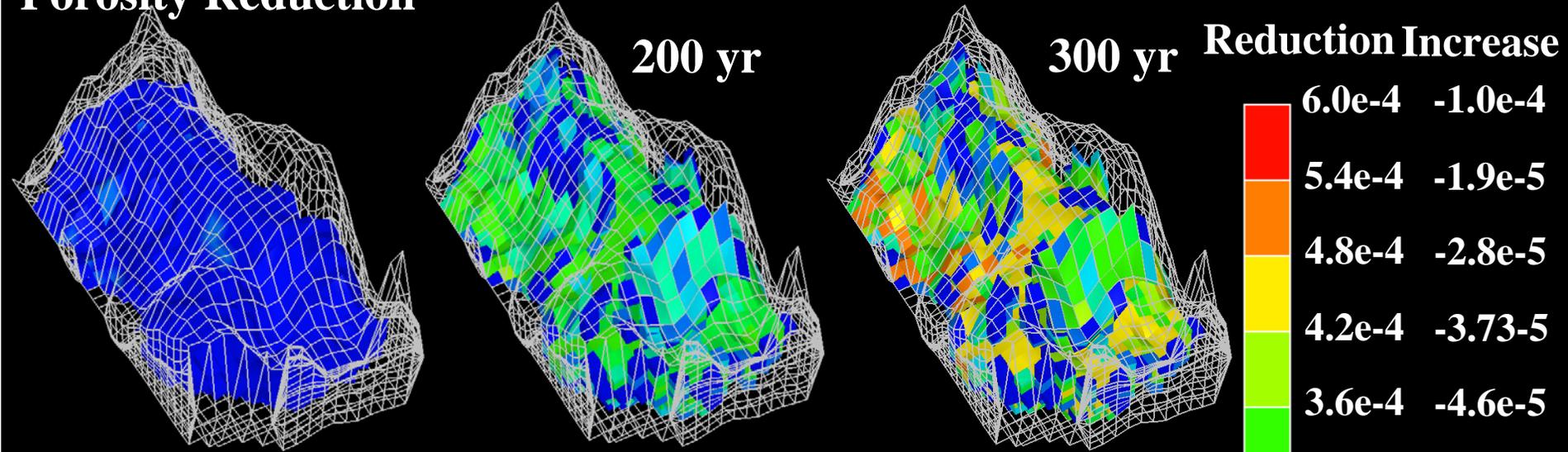


Porosity increase

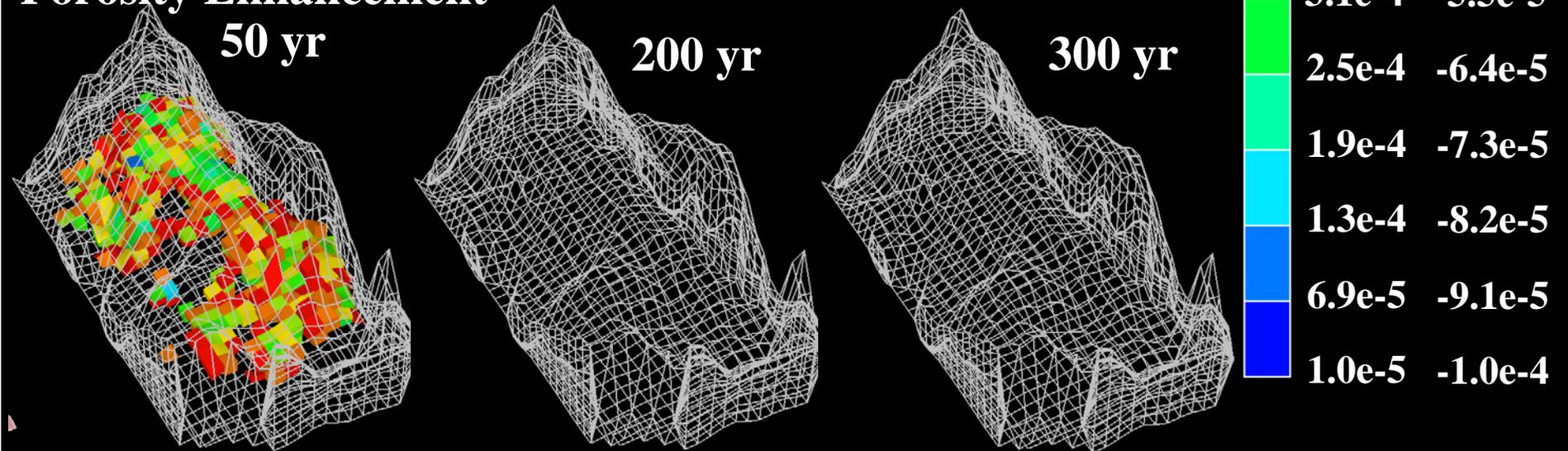


Reservoir History Modeling of SACROC: Porosity changes and implications for injectivity

Porosity Reduction



Porosity Enhancement



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by the Southwest Regional Partnership**

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