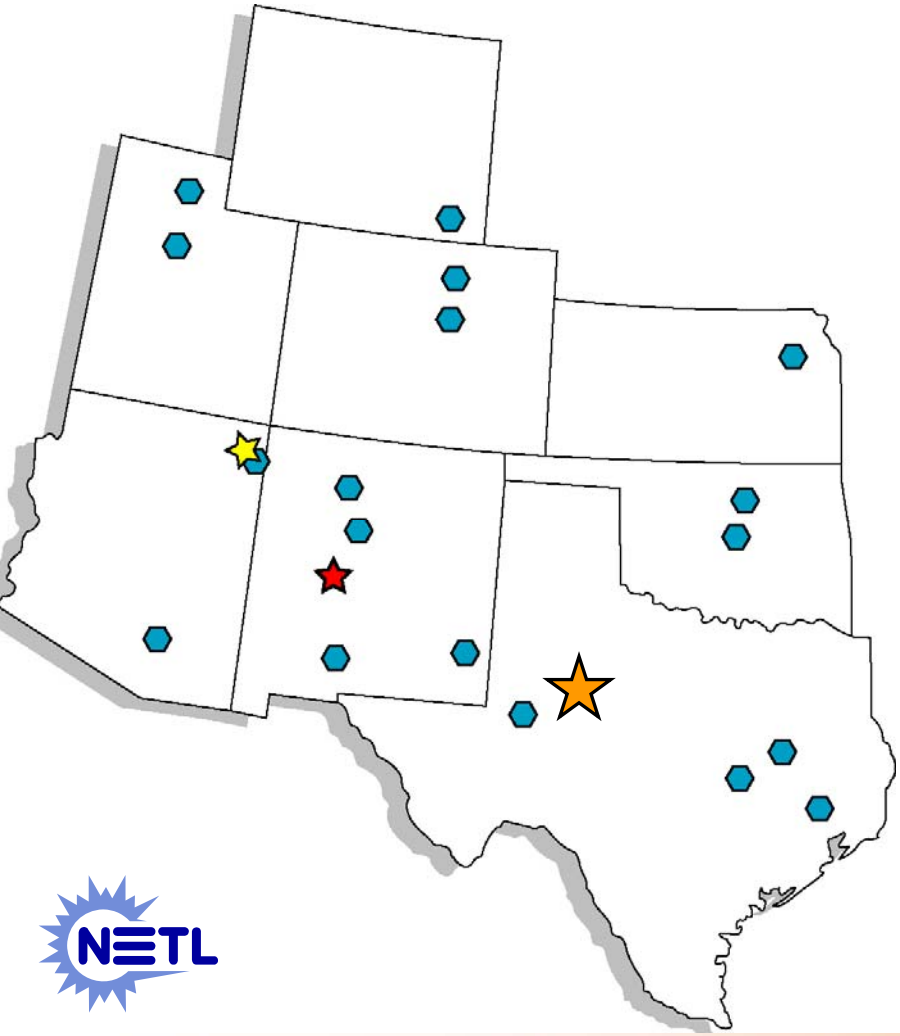
Southwest Regional Partnership on Carbon Sequestration



Permian Basin Project Overview

DE- FC26-05NT42591

December 12, 2007

Pittsburgh, Pennsylvania

Rebecca C. Smyth, Bureau of Economic Geology, Gulf Coast Carbon Center,
Jackson School of Geosciences, The University of Texas at Austin
and
Brian McPherson, New Mexico Tech and University of Utah

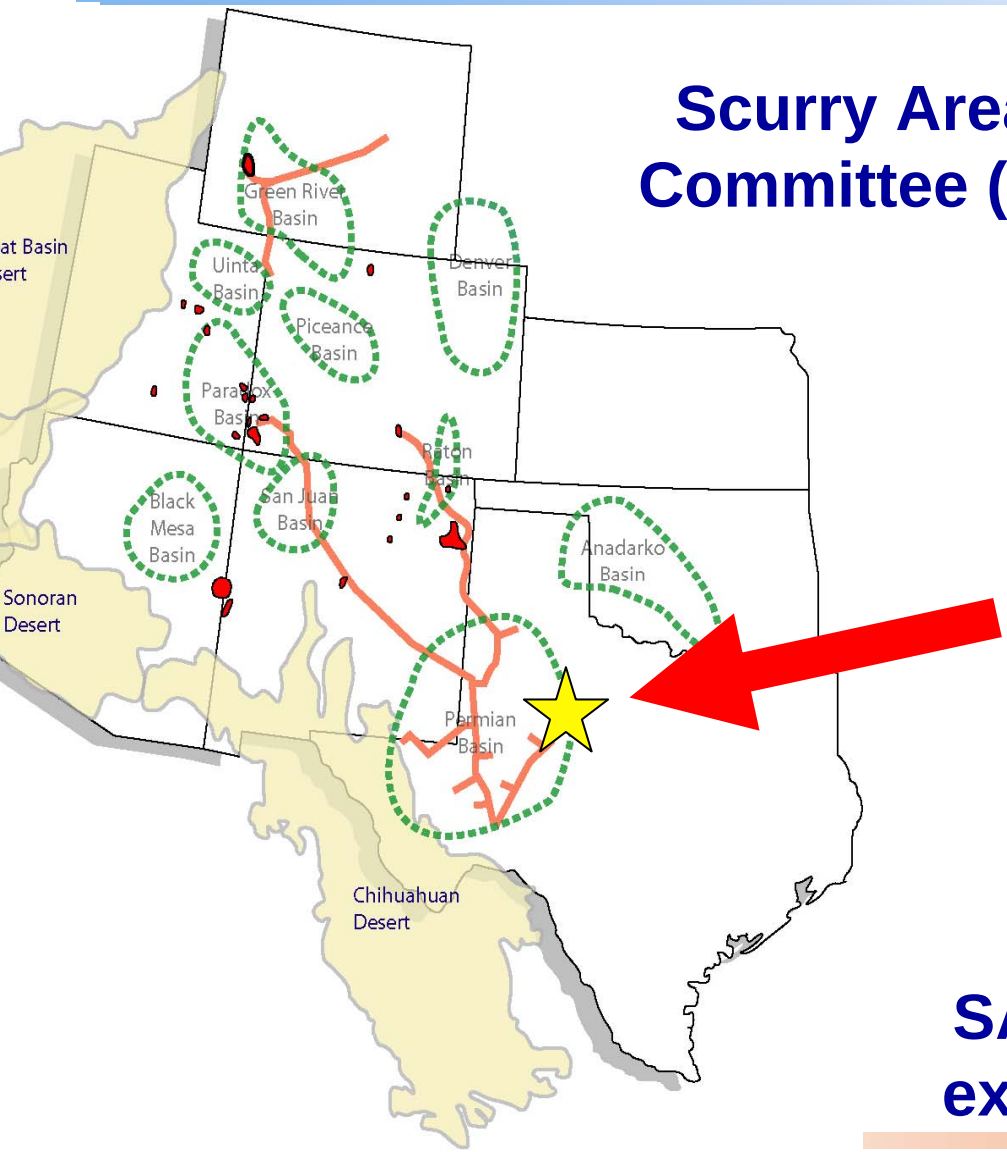
Acknowledgements

- Many thanks to the U.S. Department of Energy and NETL for supporting this project

- We also express gratitude to our many industry partners, who have committed a great deal of time, funding, and other general support for these projects

- The work presented today is co-authored by all partners in the Southwest Partnership (SWP)

SACROC – eastern edge Permian Basin

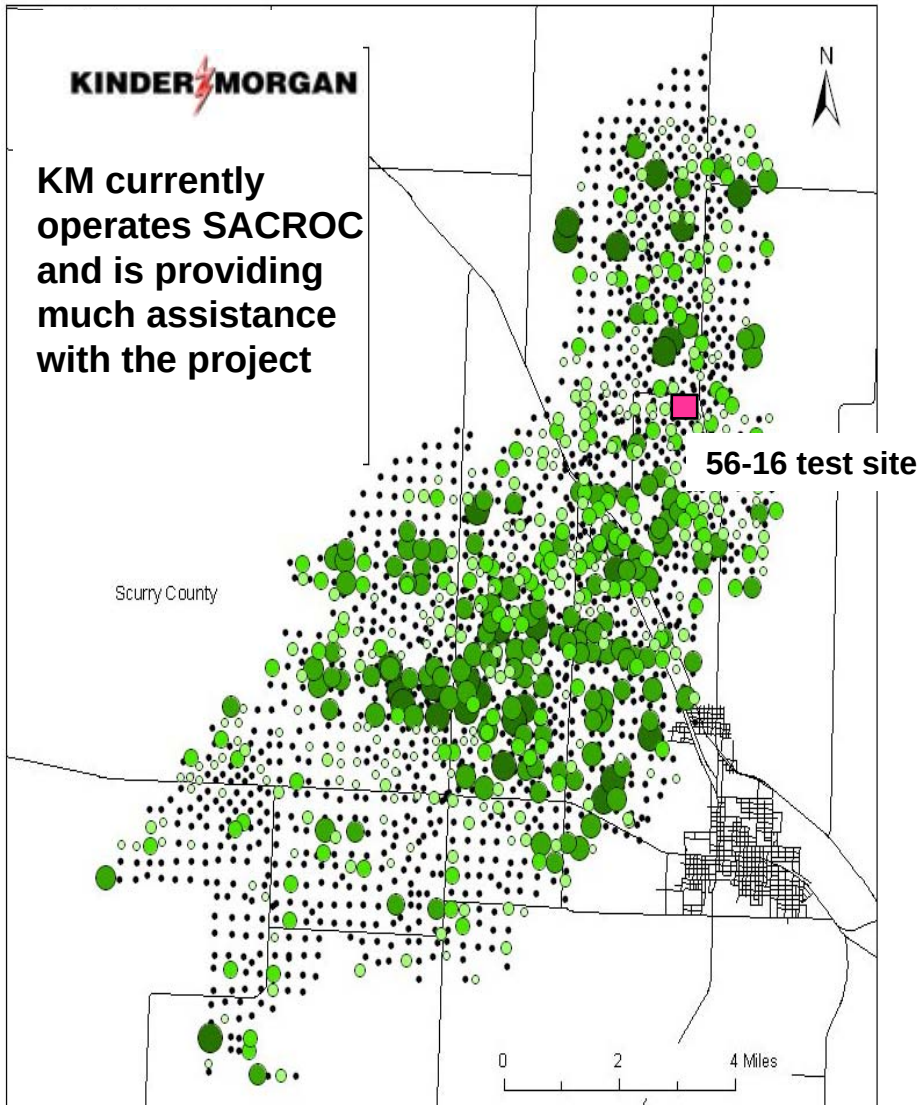


Scurry Area Canyon Reef Operators Committee (SACROC) unitized oil field

- **Ongoing CO2-injection since 1972**
- **Combined enhanced oil recovery (EOR) with CO_2 sequestration**
- **Depth to Pennsylvanian- Permian reservoir ~6,500 ft**

SACROC site 56-16 injection experiment: May - June, 2008

SACROC Previous CO_2 Injection



- ~140 million metric tons CO_2 injected for EOR since 1972 by various oil companies
- ~60 million metric tons CO_2 recovered
- SWP researchers are among first to test if this CO_2 is trapped in reservoir zones or if it has leaked into overlying strata
- Previous CO_2 injection history provides opportunity for (1) larger scale, inside vs. outside SACROC, and (2) longer time frame soil and groundwater monitoring

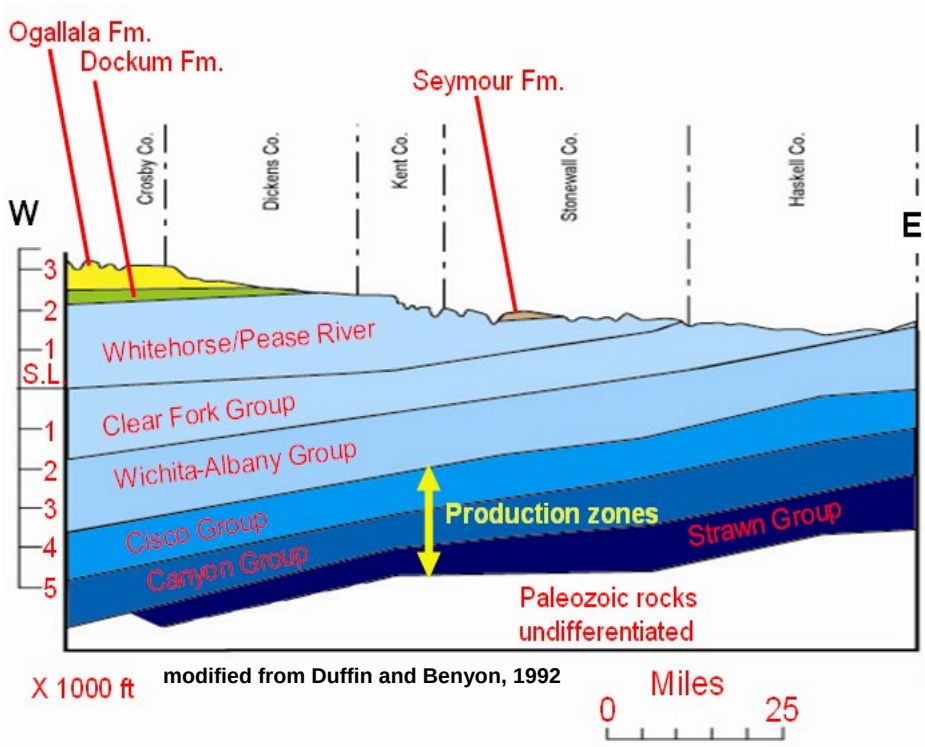
SACROC Study Components

Regional

- **Reservoir characterization utilized existing 3-D seismic data, core data, and geophysical log data; these data were used by BEG to assemble a 9-million node reservoir model**
- **Geologic cross sections in preparation (surface through reservoir zone)**
- **Initial soil flux survey inside SACROC conducted; more coming soon**
- **Groundwater sampling**
  - **July 07 and Nov 07 completed**
  - **March 08, July 08, November 08, and March 09 planned**

Injection Experiment Site 56-16

- **Pre- (April-May 08) and post-injection 3-D seismic**
- **Pre- (April-May 08) and post-injection 56-16 vertical seismic profiling (VSP)**
- **Pre- and post-injection geophysical logging**
- **Injection tracer experiment**



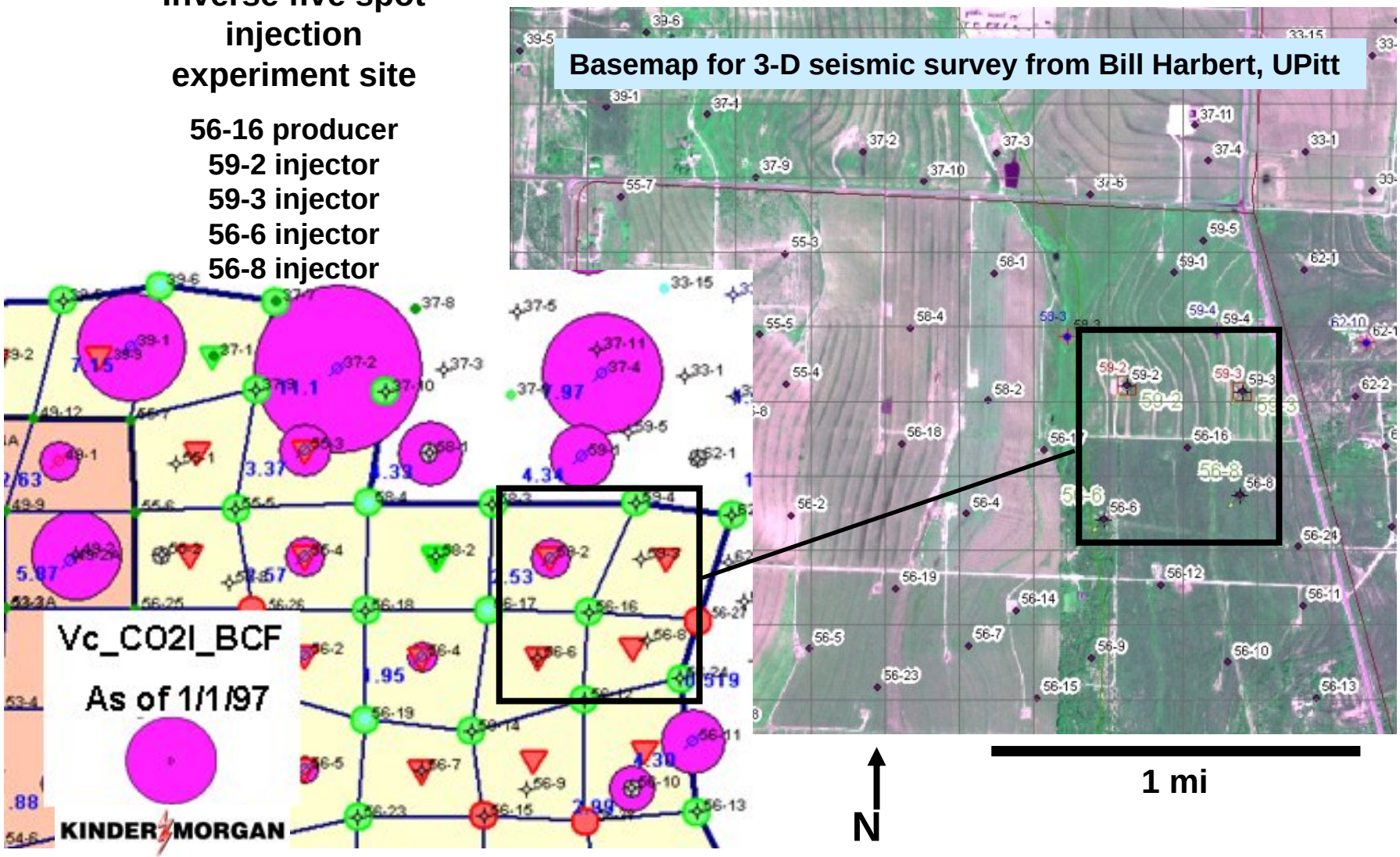
modified from Duffin and Benyon, 1992

Seismic Surveys at 56-16 Site

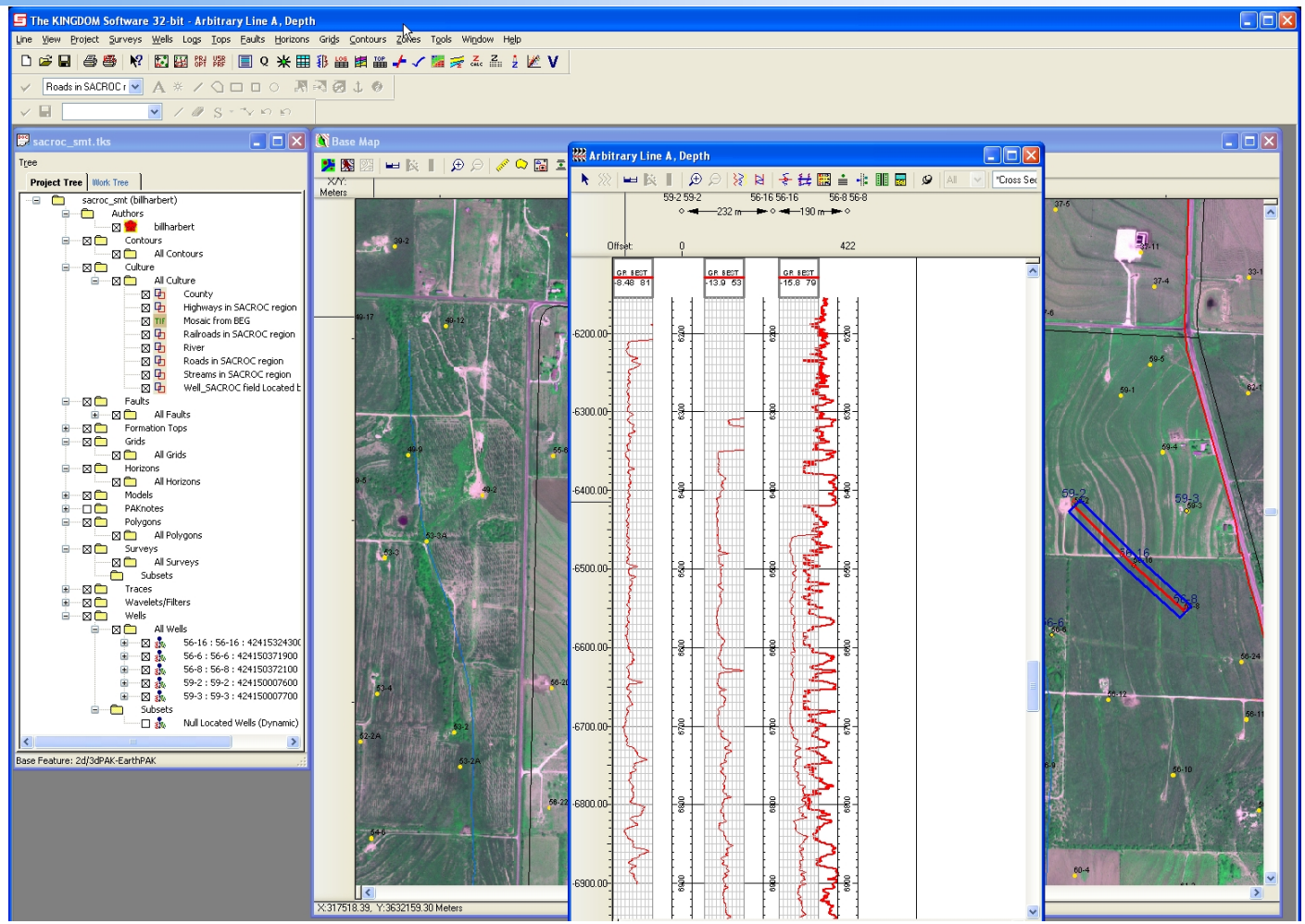
Site-specific validation of previous reservoir model

Inverse five spot injection experiment site

56-16 producer
59-2 injector
59-3 injector
56-6 injector
56-8 injector



Seismic Surveys at 56-16 Site



- **Geophysical logs are being used to model the expected seismic response**
- **KM has also provided detailed well completion information for the 56-16 site**

Surface Flux Monitoring

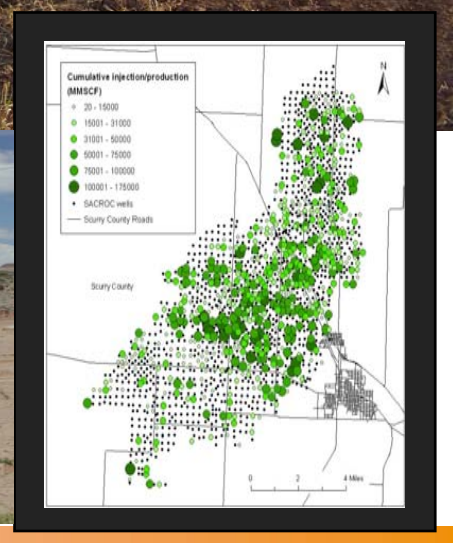
Orthogonal measurement patterns aligned along wells in hay fields underlain by Ogallala sediments

<u>Inside SACROC</u>

- shut-in wells where CO_2 EOR was active in the past (Bob Head and Jerry House properties)
- active injection and production (Tim Huddleston property)

<u>Outside SACROC</u>

- currently producing without EOR (Jack Martin property)
- plugged and abandoned dry holes (Billy Ray Browning property)



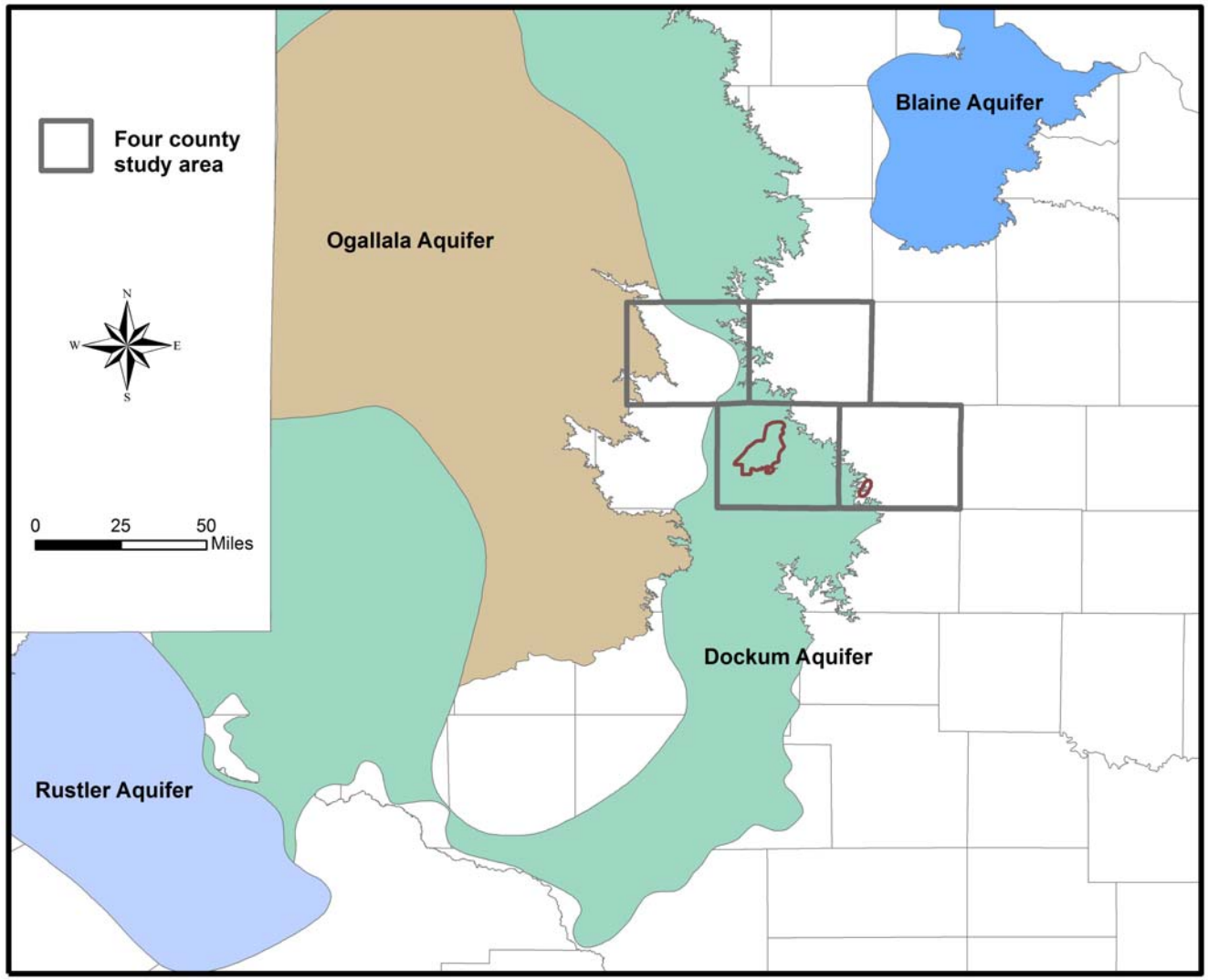
Objective of Groundwater Study

Determine if groundwater over SACROC has been impacted by 35 years of CO_2 injection.

Approach/Challenges

- **Determine regional variability in groundwater**
  - **existing geochemical data**
  - **cross sections of entire stratigraphic interval**
- **Interpret historical water level data to determine flowpaths**
- **Consider water well location with respect to production and injection (CO_2, water-flood, and co-produced brine) wells**
- **Obtain permission to sample water wells from local landowners**
- **Consider regional geologic setting and location of 56-16 test site**
- **Sample water wells**
  - **General chemistry, major ions, and trace constituents**
  - **Stable isotopes: hydrogen, oxygen, and carbon**
  - **Strontium isotopes (reservoir brines and shallow groundwater)**
  - **Field measurements of pH, temperature, specific conductivity, dissolved oxygen, and alkalinity**
- **Geochemical equilibrium and flowpath modeling**

Texas Water Development Board (TWDB) Regional Aquifers



Surface Geology and Groundwater Sampling near SACROC

Geologic Units

Qs = Quaternary windblown sand

Qu = Quaternary undifferentiated

Eo = Eocene Ogallala

TRd = Triassic Dockum

PERMIAN

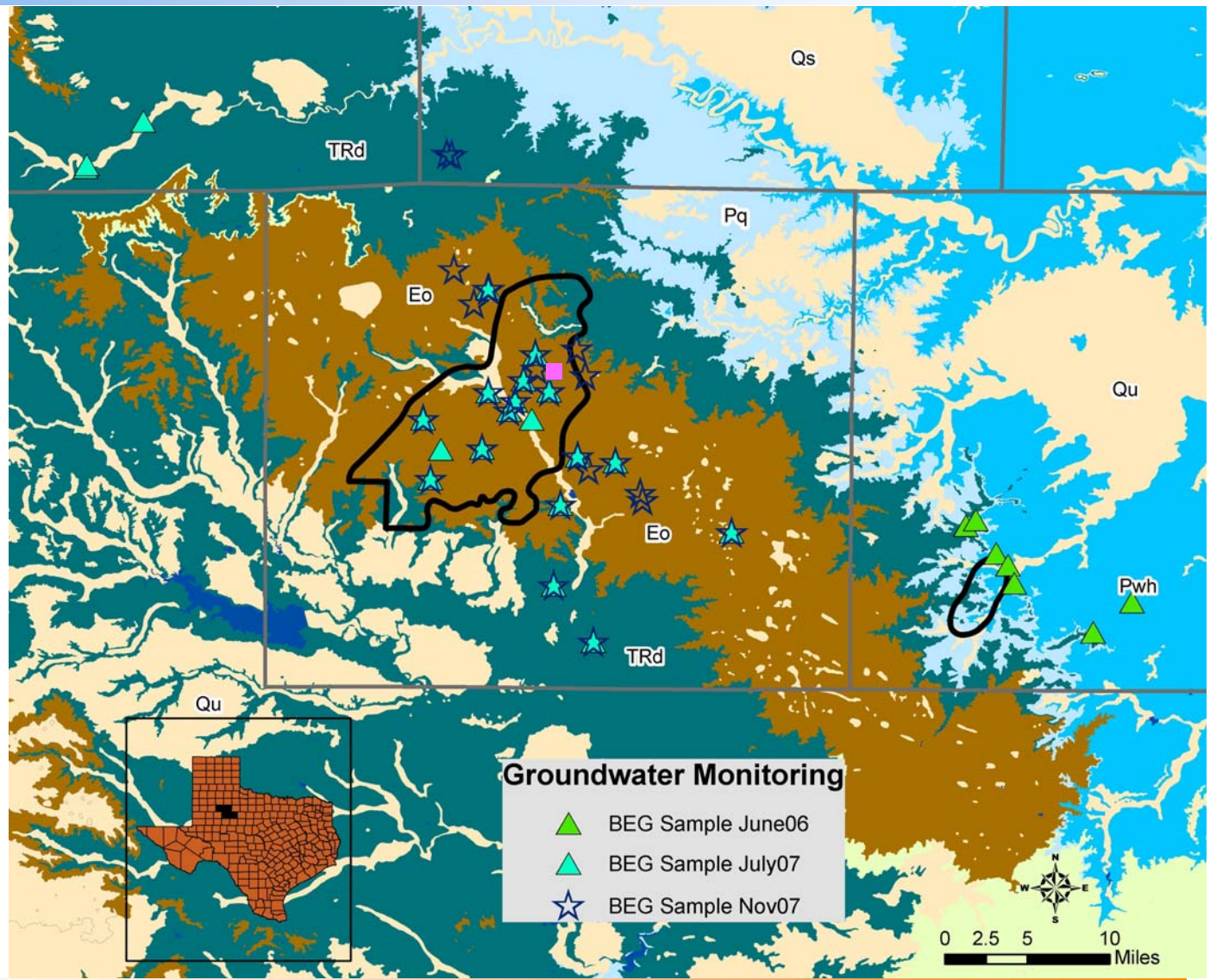
Pq = Quartermaster

Pwh = Whitehorse

Pb = Blaine

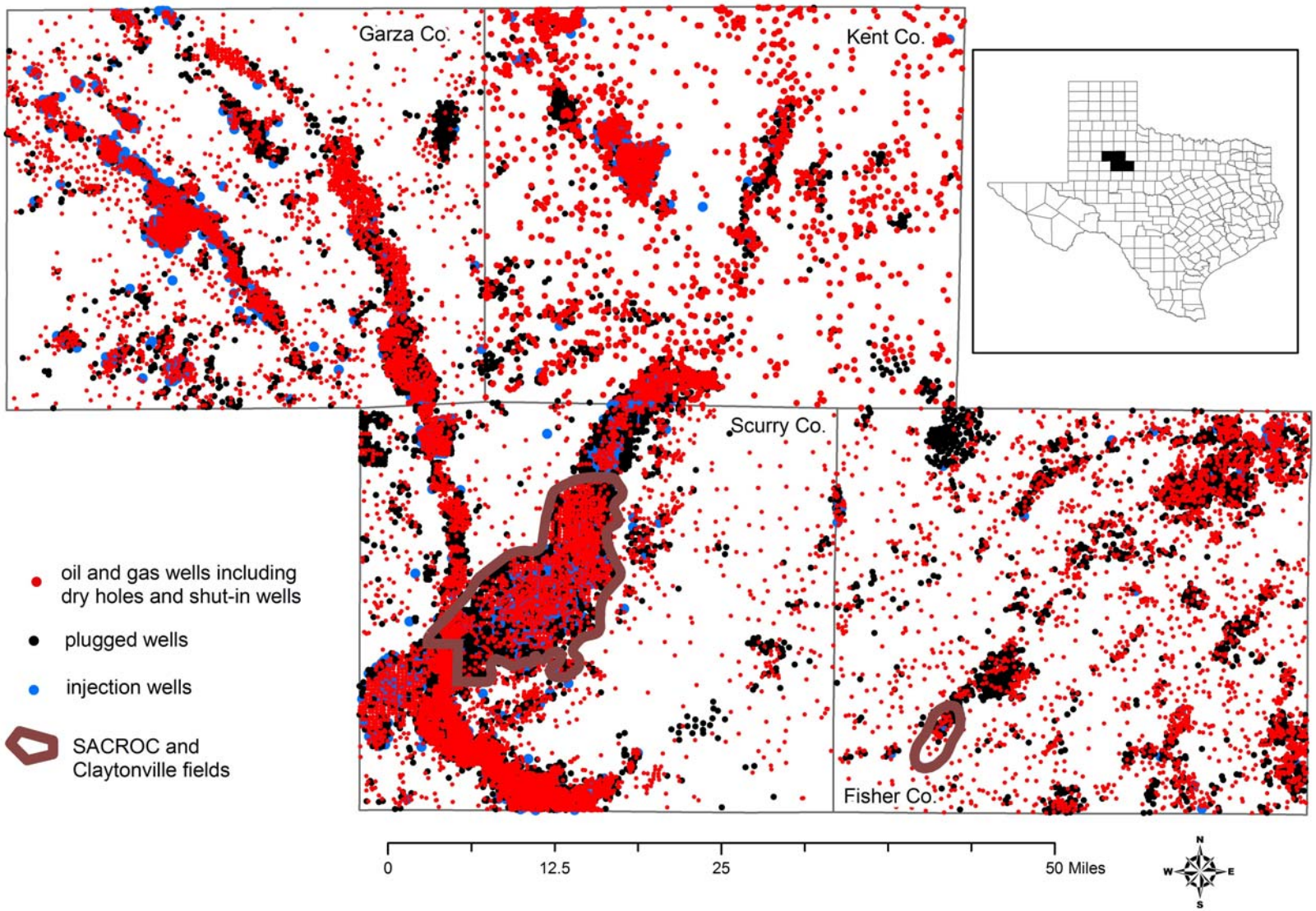
Ps = San Angelo

Pc = Clearfork

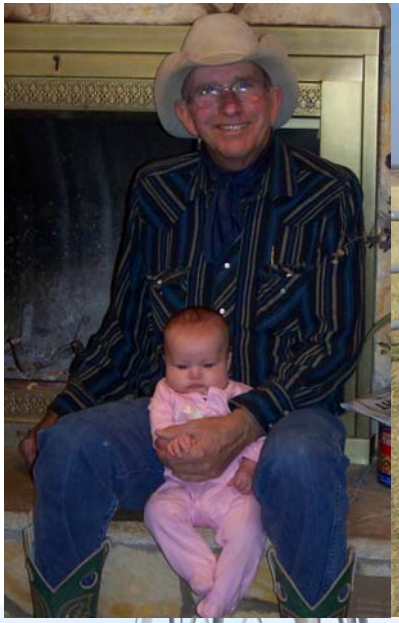


Geologic units from Lubbock and Big Spring Beg Geologic Atlas of Texas sheets

Previous O&G Well Drilling



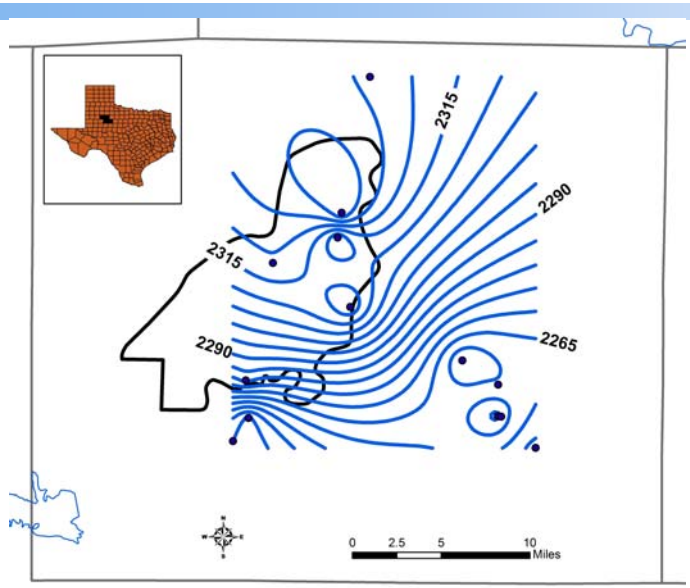
Obtain Access to Private Water Wells



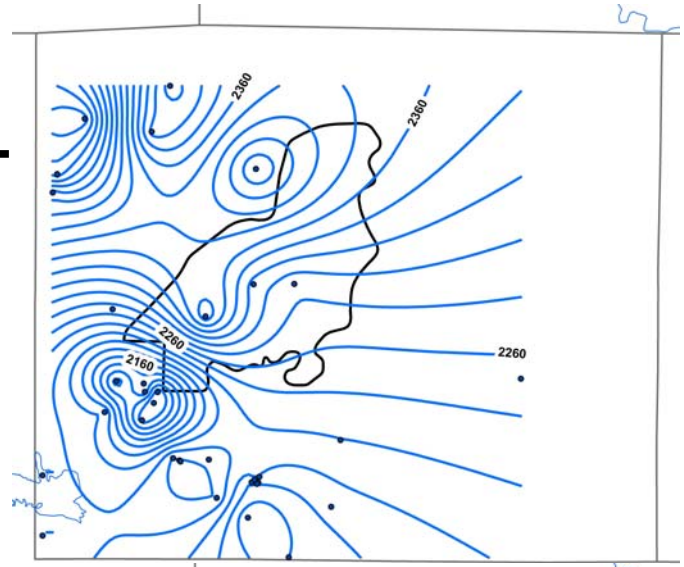
Scurry County Water Levels

Texas Water Development Board (TWDB) data

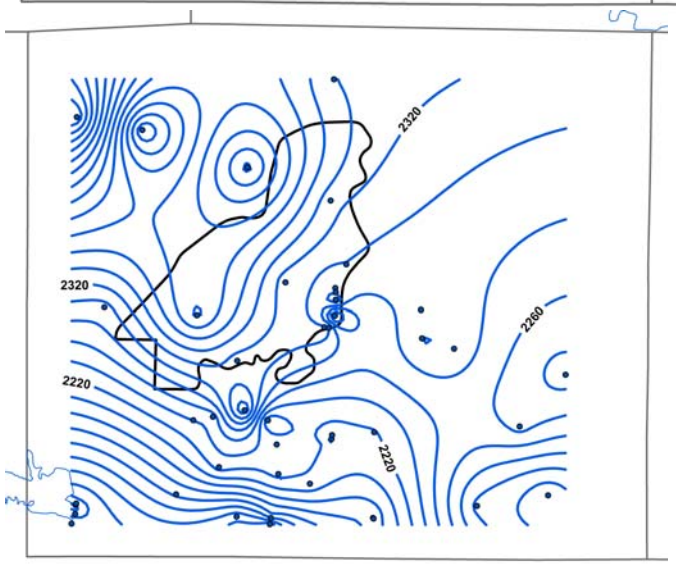
1957



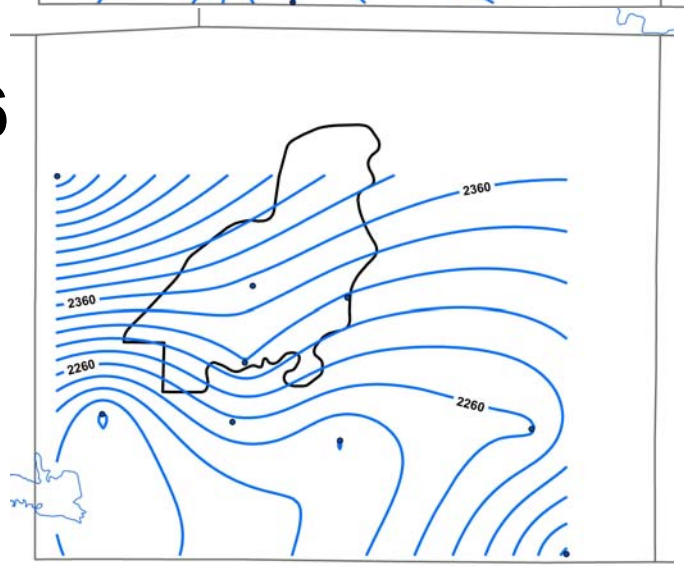
1971



1983



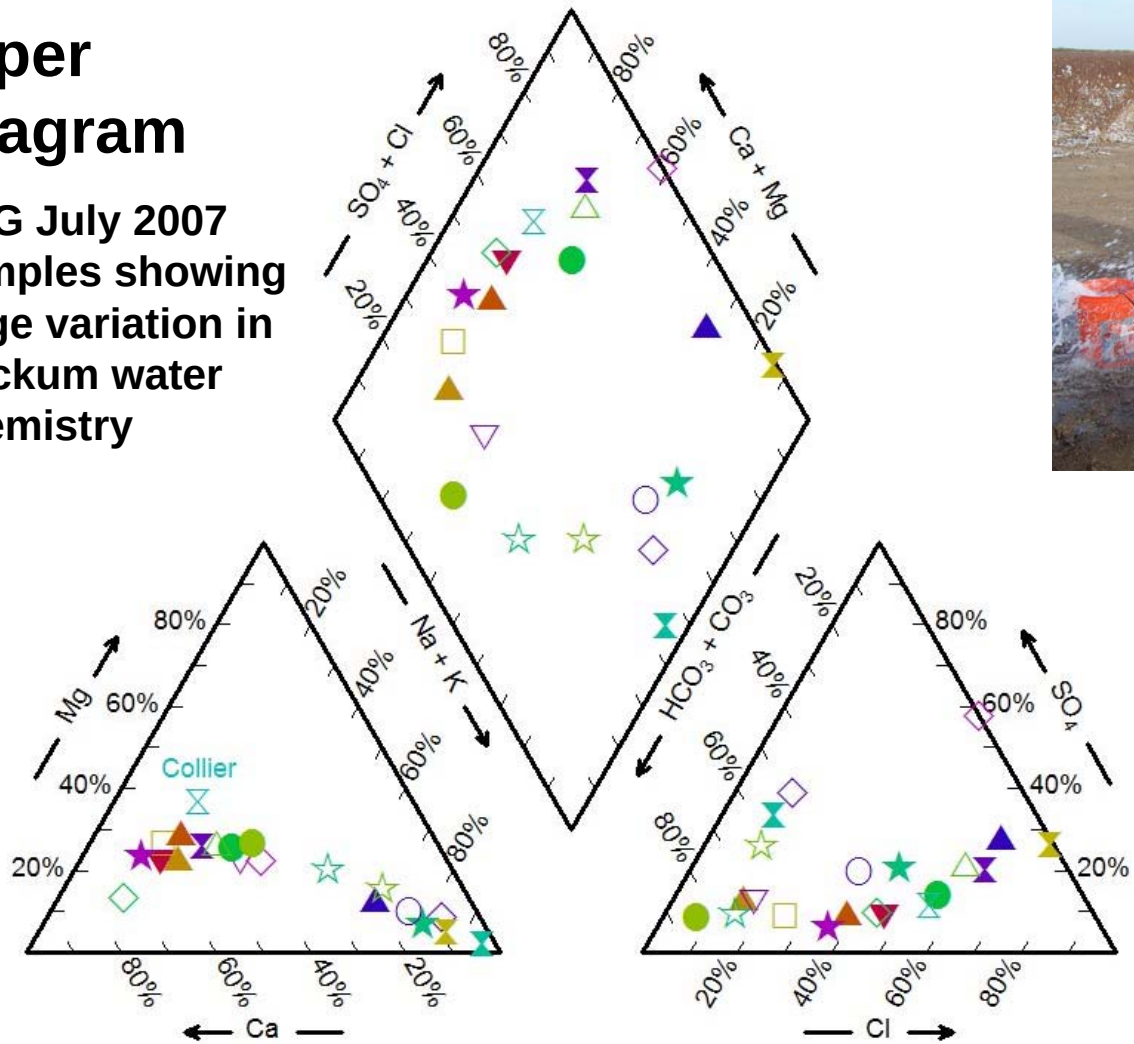
2006



Challenges to Detecting Increased CO_2 in Groundwater

Piper Diagram

BEG July 2007 samples showing large variation in Dockum water chemistry



Need indirect measurement of CO_2 in groundwater

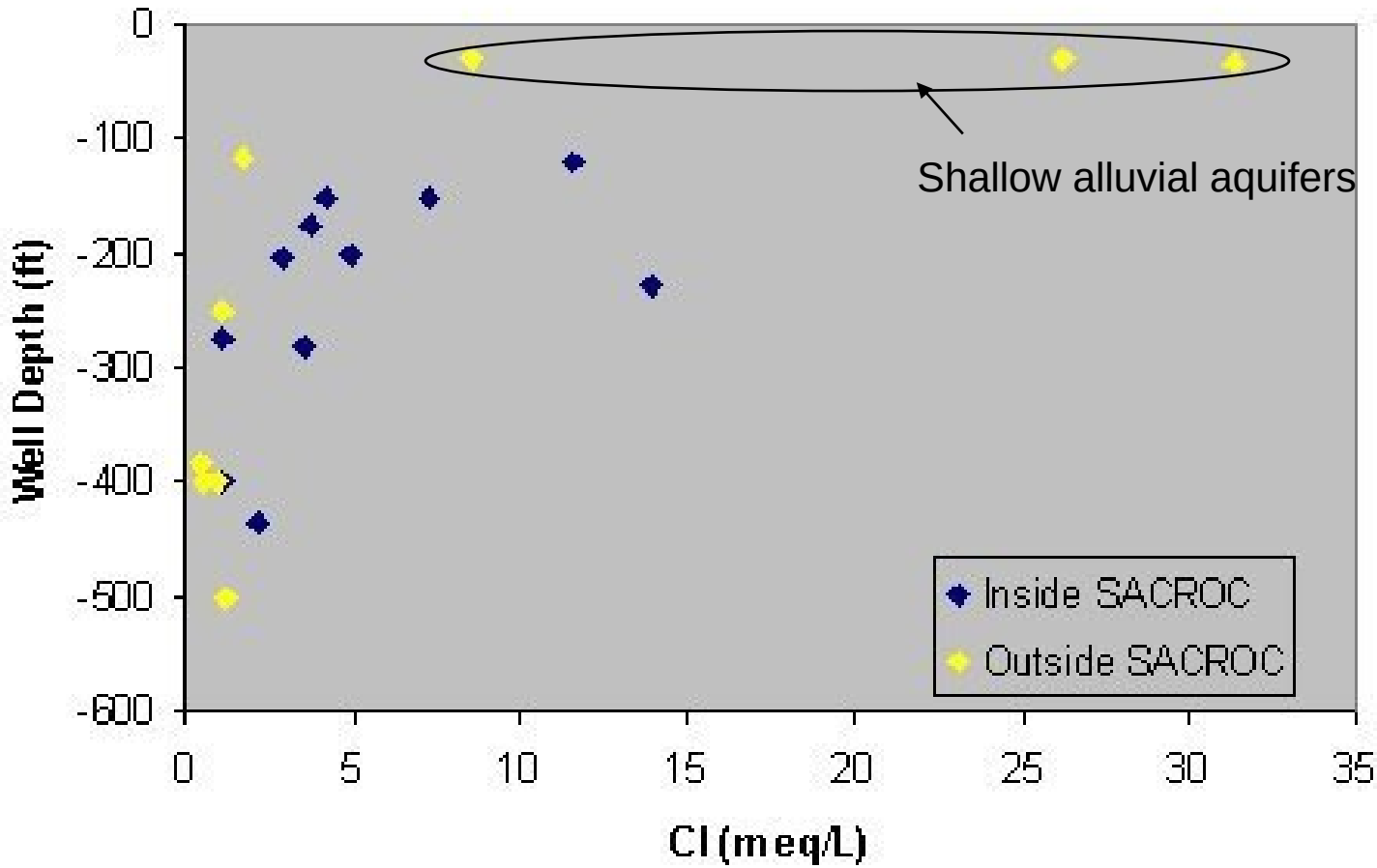
↑ **CO_2 = ↓ pH,**

↑ **Alkalinity,**

↑ **dissolved metals**

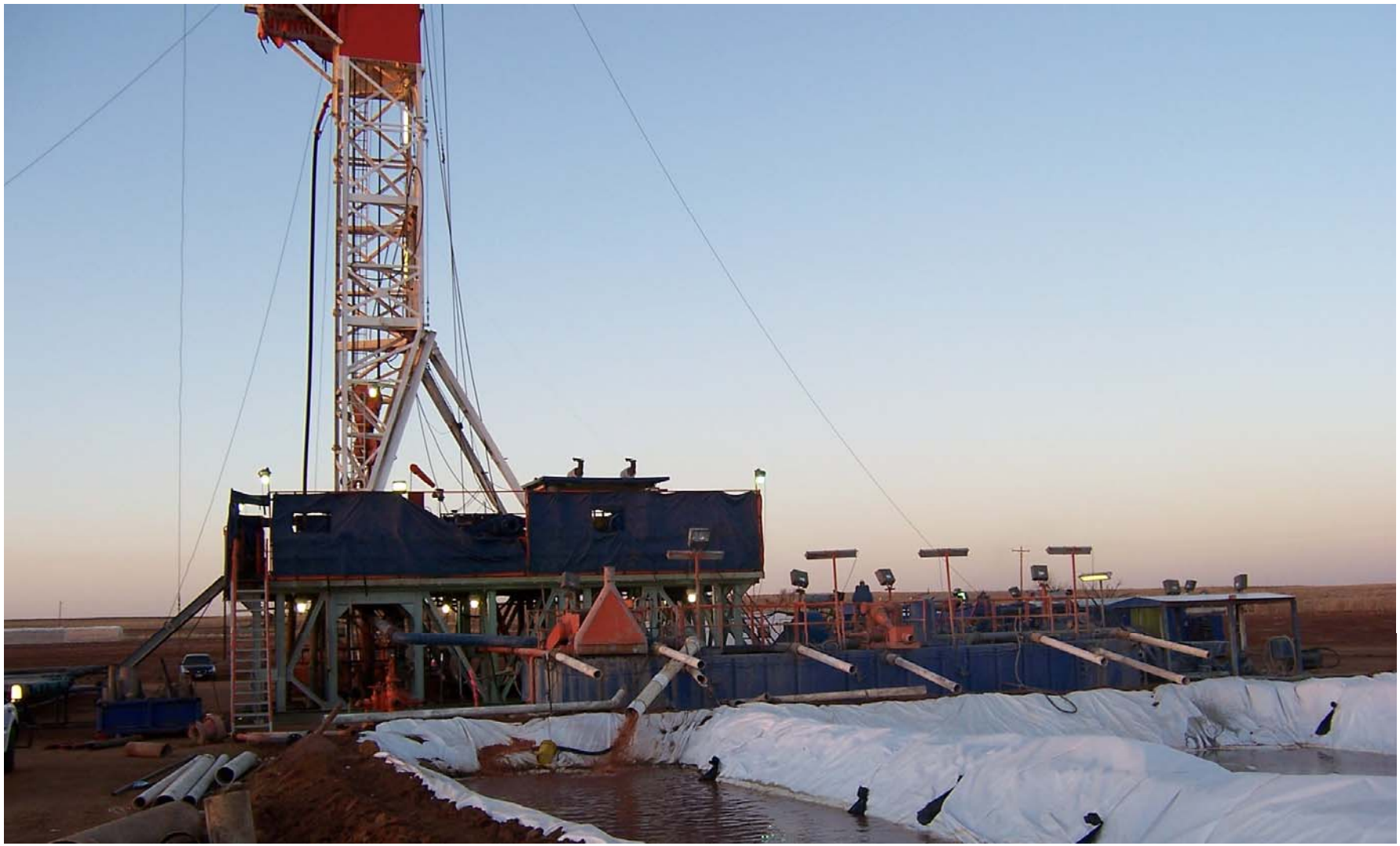
Chloride Variation with Well Depth

BEG July 2007 Groundwater Samples



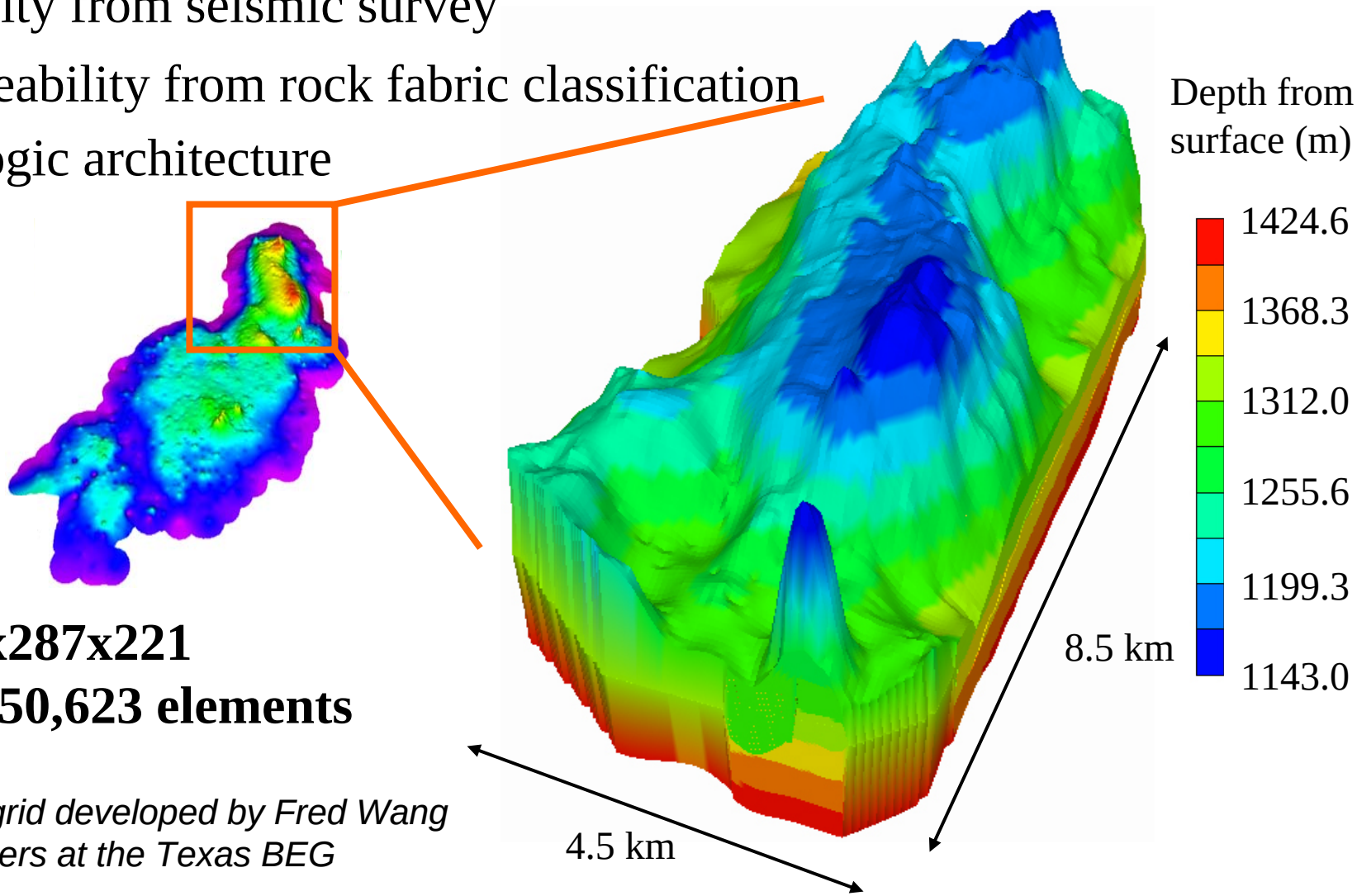
- **Trend of lower salinity with deeper well depth in Dockum aquifer**
- **Higher chloride content in wells inside SACROC versus outside SACROC**

Work in Progress



Quantification of Natural Heterogeneity (Architecture)

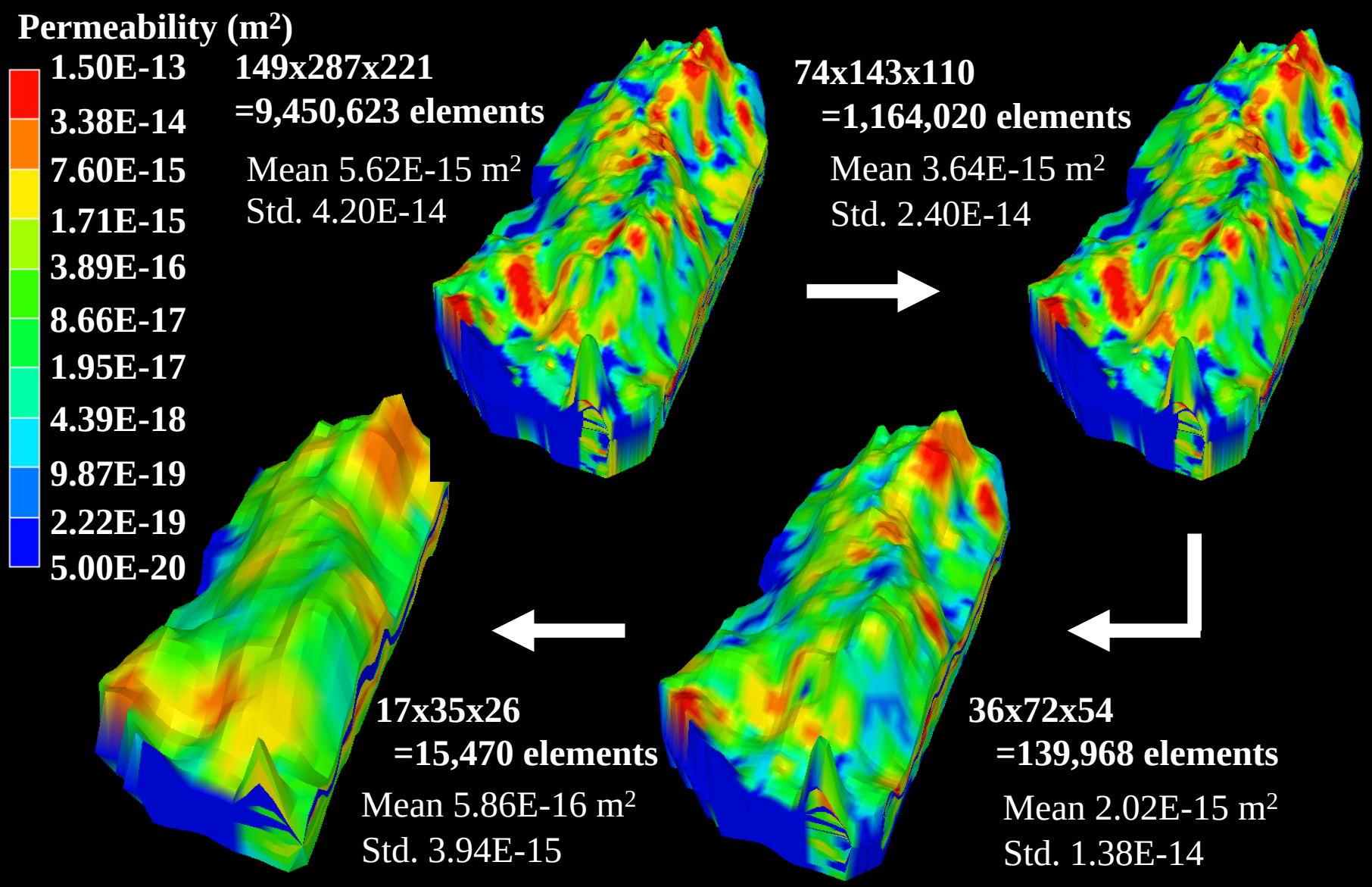
- Porosity from seismic survey
- Permeability from rock fabric classification
- Geologic architecture



149x287x221
=9,450,623 elements

Model grid developed by Fred Wang and others at the Texas BEG

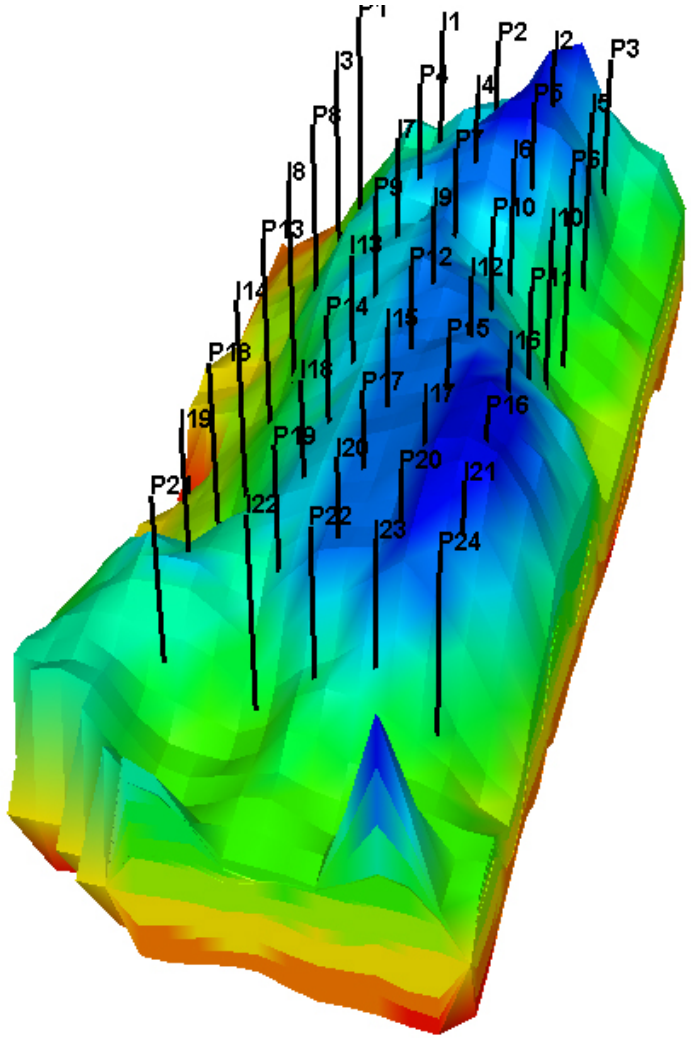
Upscaling (Renormalization): Register Network Model (King, 1989)



Integrated Modeling and Monitoring Results

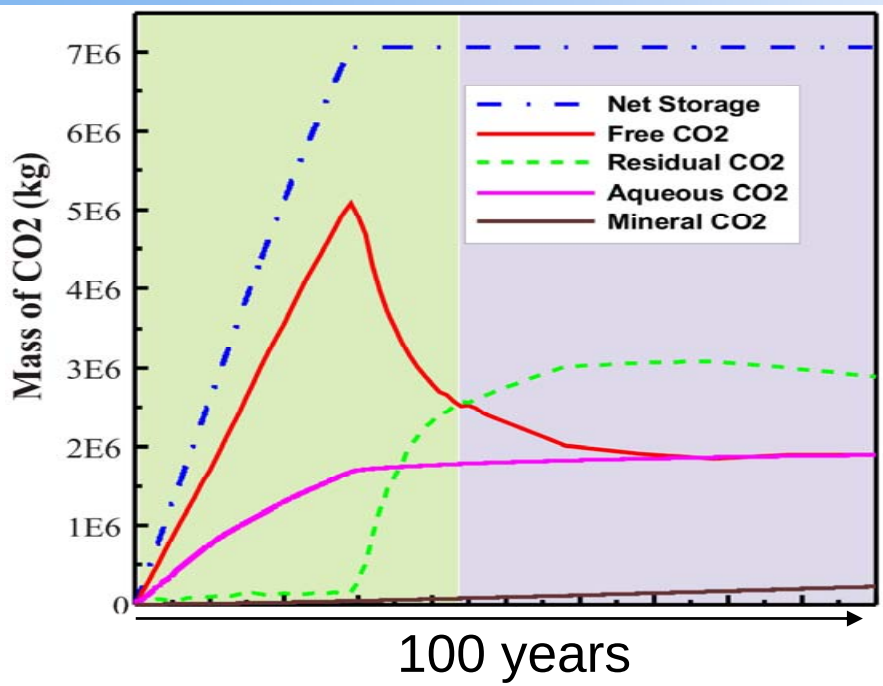
- *Baseline MMV completed, including*
  - ✓ *3-D seismic survey*
  - ✓ *3-D "poor-man's" seismic survey completed*
  - ✓ *baseline fluxes*
  - ✓ *water chemistry and isotopes*
- *High resolution reservoir models completed for capacity, injectivity, and long-term monitoring design*
- *MMV ongoing*
- *New injection at SACROC will begin in late spring*

SACROC (north platform)

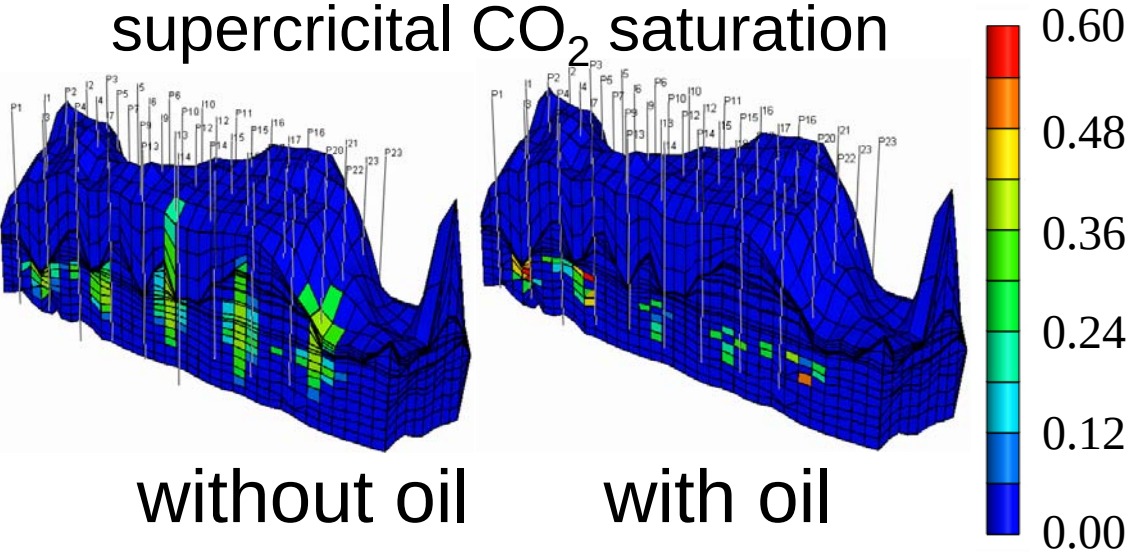


15,470 elements

Integrated Modeling and Monitoring Results



supercricital CO_2 saturation



without oil with oil

Summary results:

(1) Most CO_2 stored trapped by capillarity ("residual gas trapping")

(2) Injecting in deep saline reservoirs below oil/gas fields is preferred, for many reasons!

THE END

EXTRA PHOTOS

Water Well Sampling Assistance

Low or High Flow Rates from Irrigation Wells

Left: Low discharge rate - less aeration of water hence more accurate *insitu groundwater parameters.*

Right: High discharge rate - more aeration of water hence less accurate *insitu groundwater parameters.*

Types of power for pumping: solar to portable generator

Monitoring pH, T, SC, and DO during pumping prior to sampling