Large Volume CO_2 Injection at Cranfield, Early Field Test of the SECARB Phase III: Near-Surface Monitoring

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Acknowledgements

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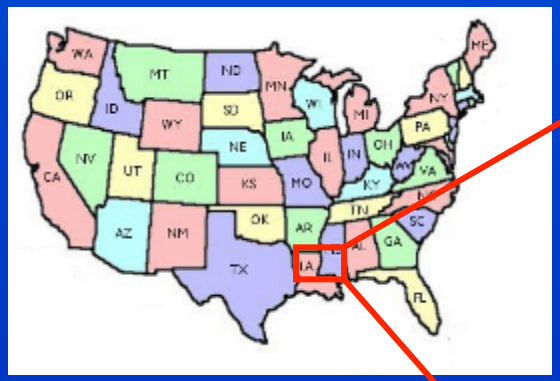
Cranfield, Mississippi



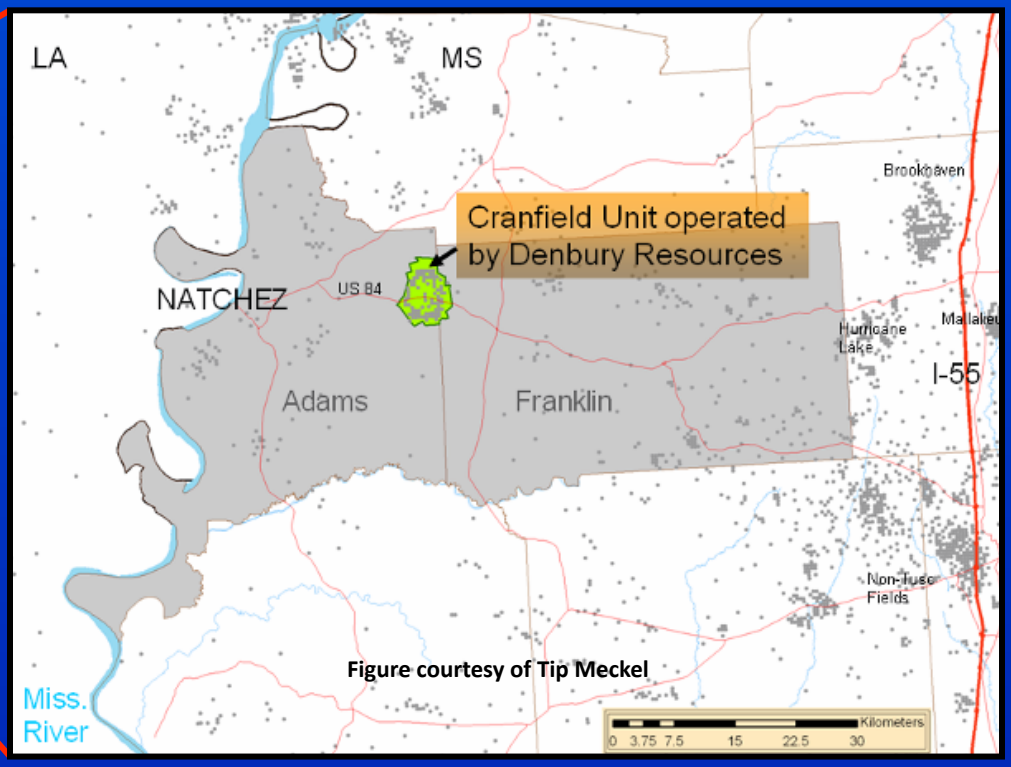
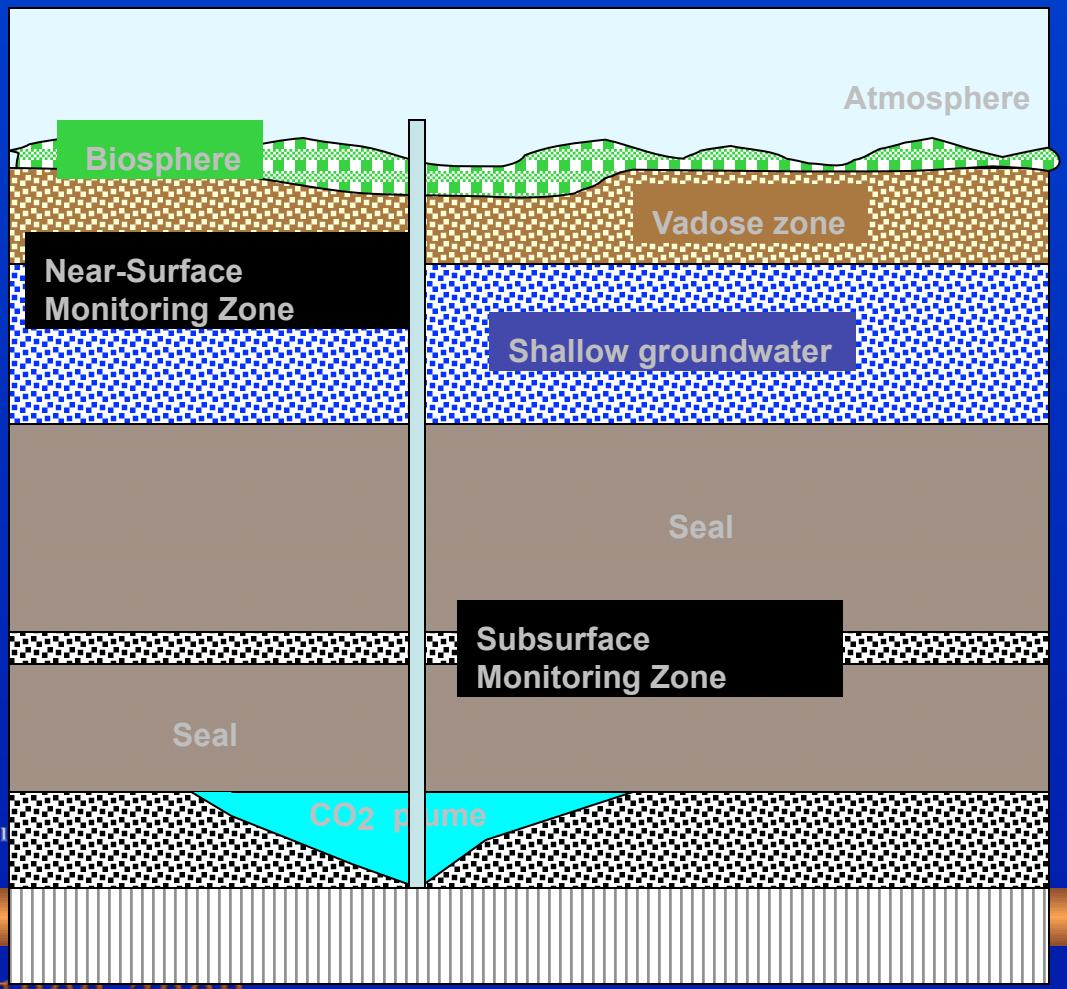


Figure courtesy of Tip Meckel

- Located 15 miles east of Natchez, MS
- Owned and operated by Denbury Resources
- Injection of CO_2 for EOR since 2008

Near-surface Monitoring

- Shallow groundwater monitoring
- Soil gas monitoring (P-site)



Objective

Assess near-surface monitoring technologies for leakage detection at a CO_2 sequestration site

Address environmental variability in the near-surface

Potential Geochemical Outcomes in a Shallow Aquifer

- CO_2 dissolution into groundwater
  - Possible mineral dissolution

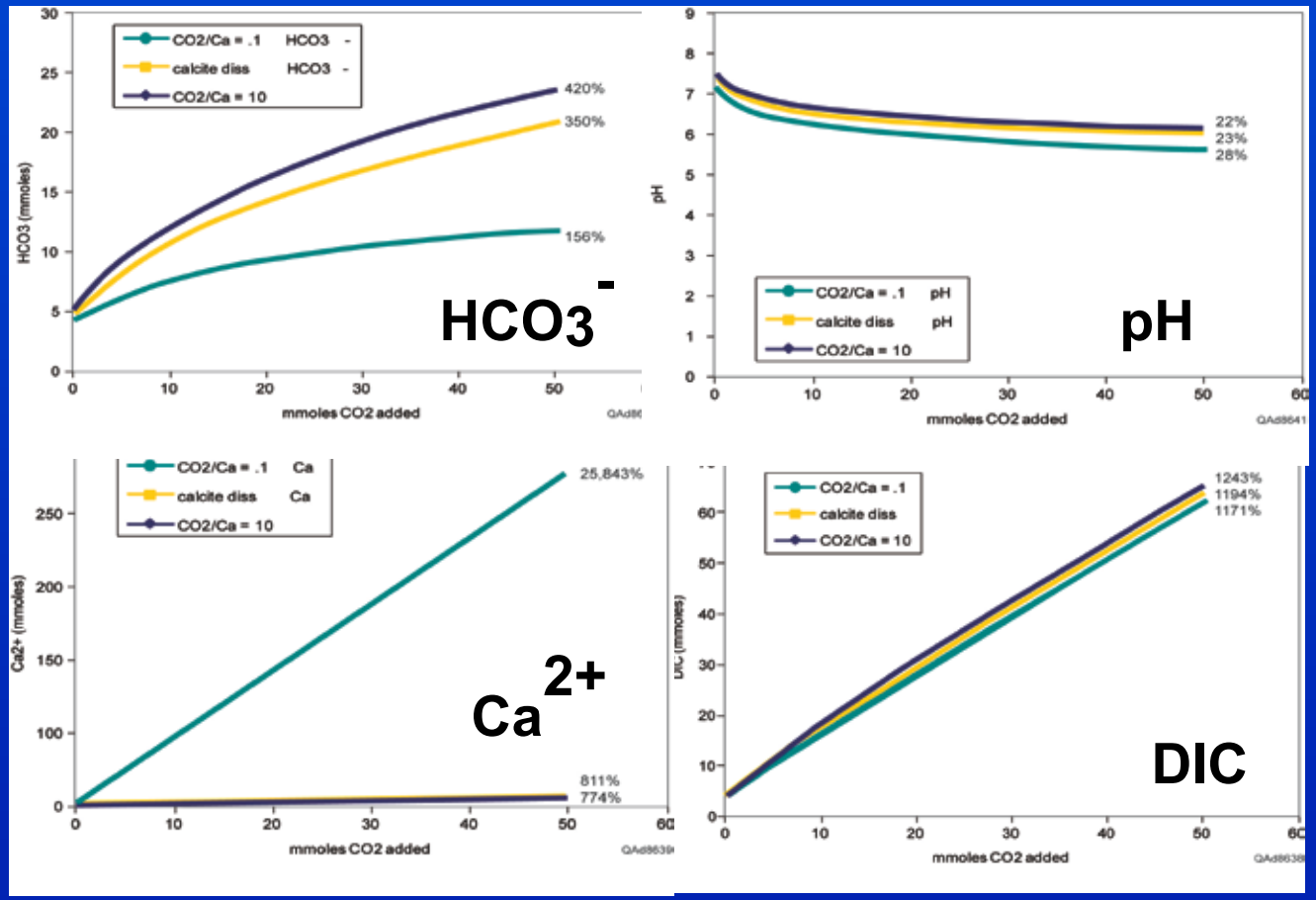
$$H_2O + CaCO_3 + CO_2 \rightarrow 2HCO_3^- + Ca^{2+}$$

- Potential effects on mobilization of trace metals (Fe, Pb, As…)

Geochemical parameters for detecting CO_2 leakage

pH, HCO_3-, Ca^{2+}, DIC, $\delta^{13}C$, trace metals

Global Monitoring Parameters



Romanak et. al., International Journal of Greenhouse Gas Control, Jan 2012

Groundwater Monitoring Strategy

Characterize shallow groundwater geochemistry

Identify a set of geochemical parameters for detecting CO_2 leakage

Test and validation

- Numerical modeling
- Lab experiments
- Field experiments (Push-pull tests)

Application

Groundwater chemistry monitoring for detecting CO_2 leakage

Groundwater Geochemistry

Nine field trips for groundwater sampling since August, 2008

Measured pH, temperature, alkalinity, water level

Cations:

Ag, Al, As, Ba, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Pb, Se, Zn

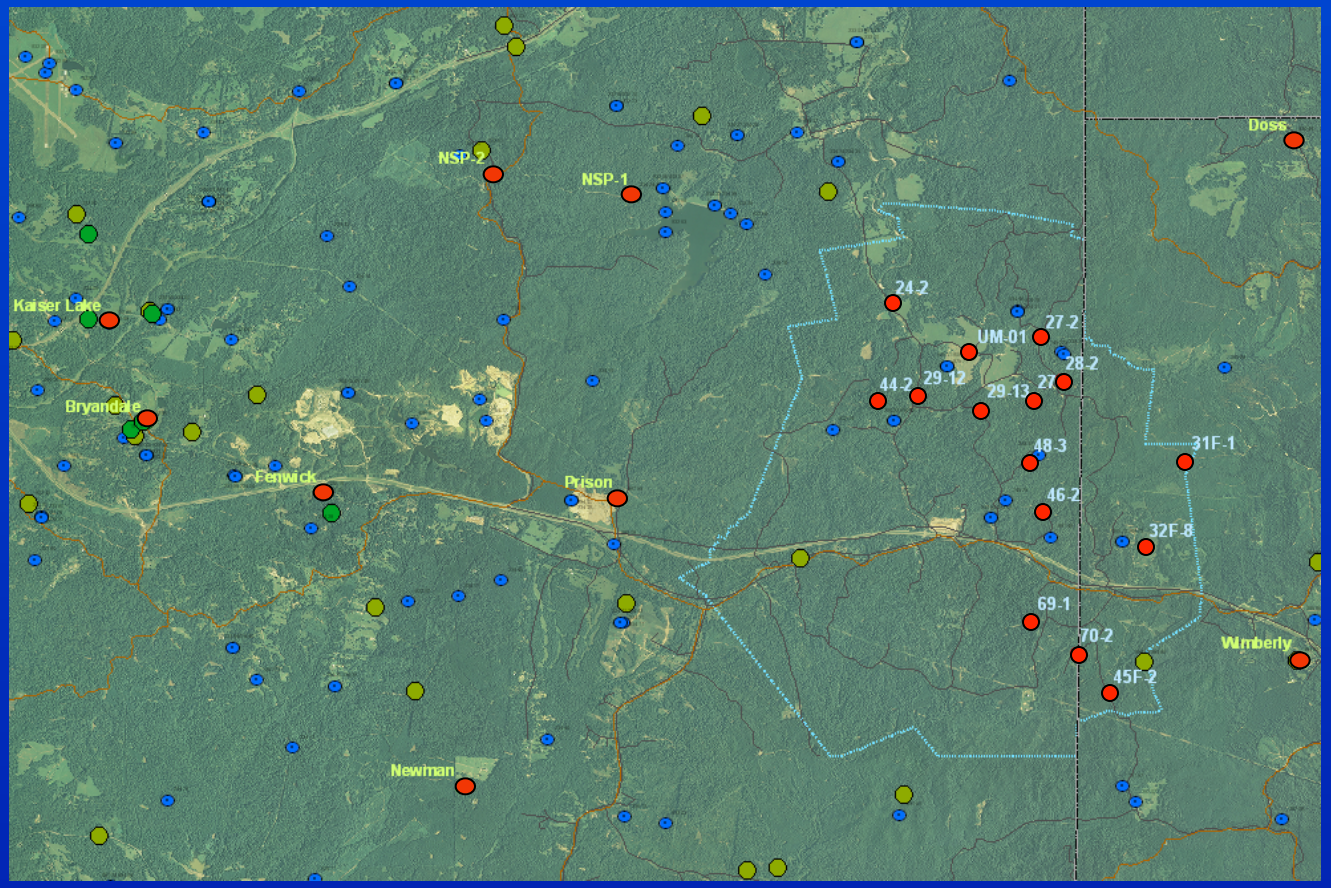
Anions:

F-, Cl-, SO42-, Br-, NO3-, PO43-

TOC, TIC

VOC

δC13



"makeup" wells

Private wells

Wells surveyed by USGS

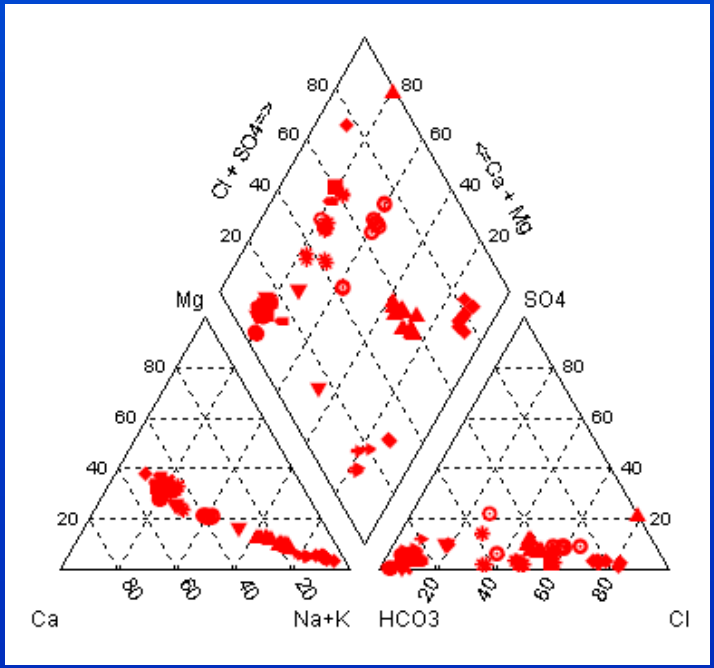
Public wells

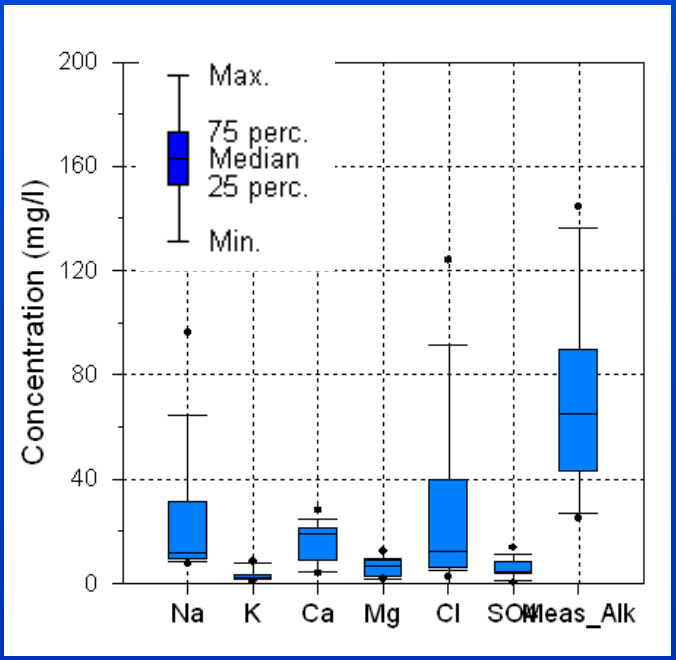
100 Years of Scientific Impact

1909-2009

Bureau of Economic Geology

Groundwater Geochemistry





Groundwater types mainly are Na-Cl, Ca-Na-HCO3, and Ca-Na-HCO3-Cl

Na and Cl concentrations show variations

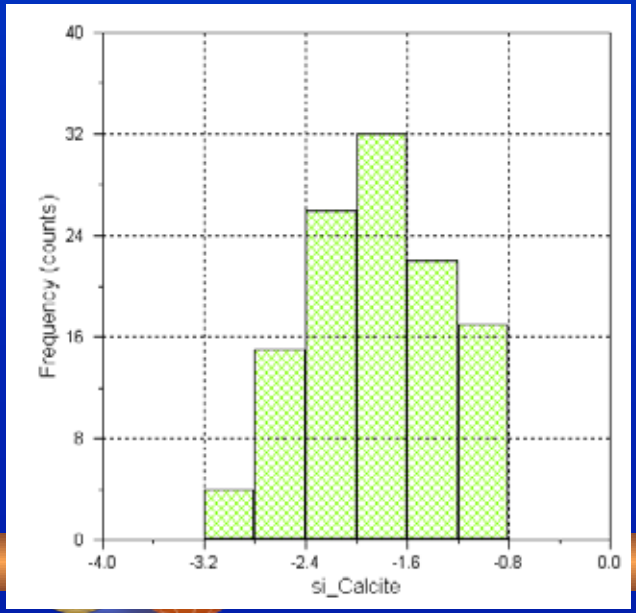
Metals	Fe (mg/L)	Ba (mg/L)	Pb (ug/L)	Zn (mg/L)	Mn (mg/L)	Cd (ug/L)	Cu (ug/L)
Maximum	17.04	0.237	65	2.625	0.71	6	6

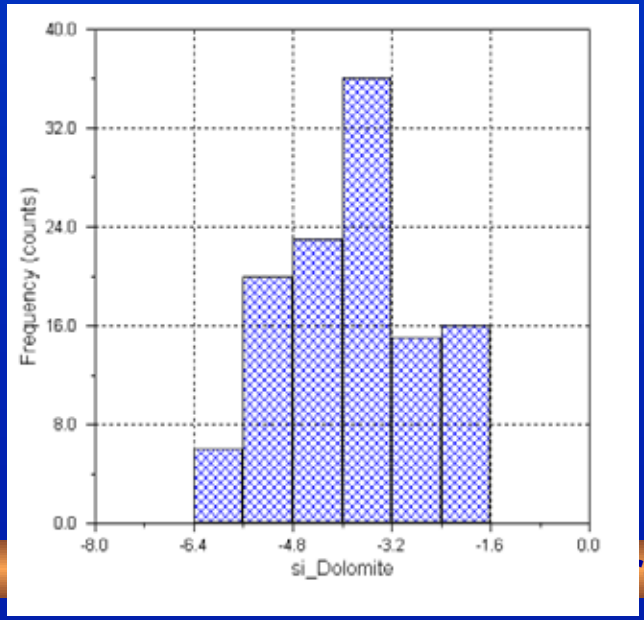
- **Other metals are non-detectable, such as As**

Groundwater Geochemistry

Mineralogy of the sediments

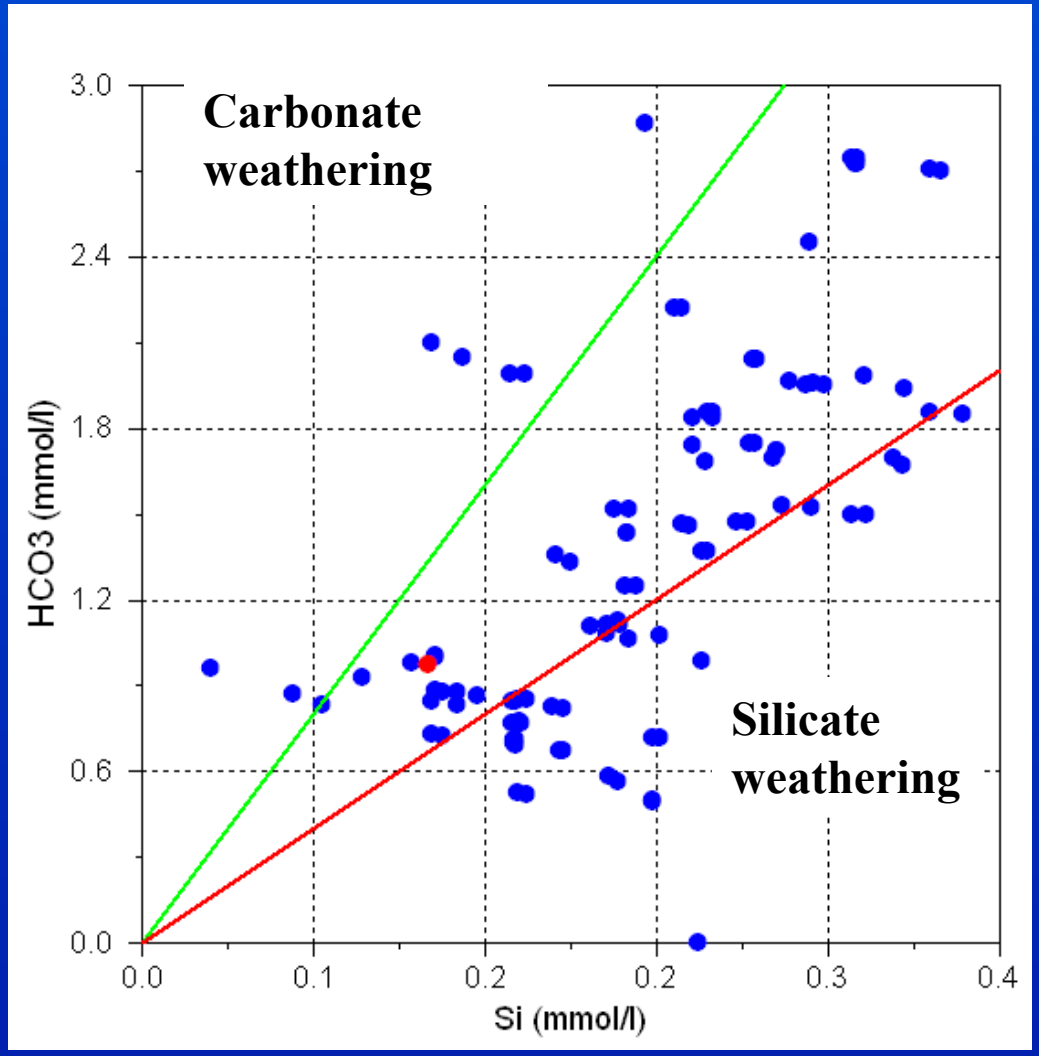
- **Preliminary XRD and SEM analyses indicate the shallow aquifer sediments are mainly silicate minerals**



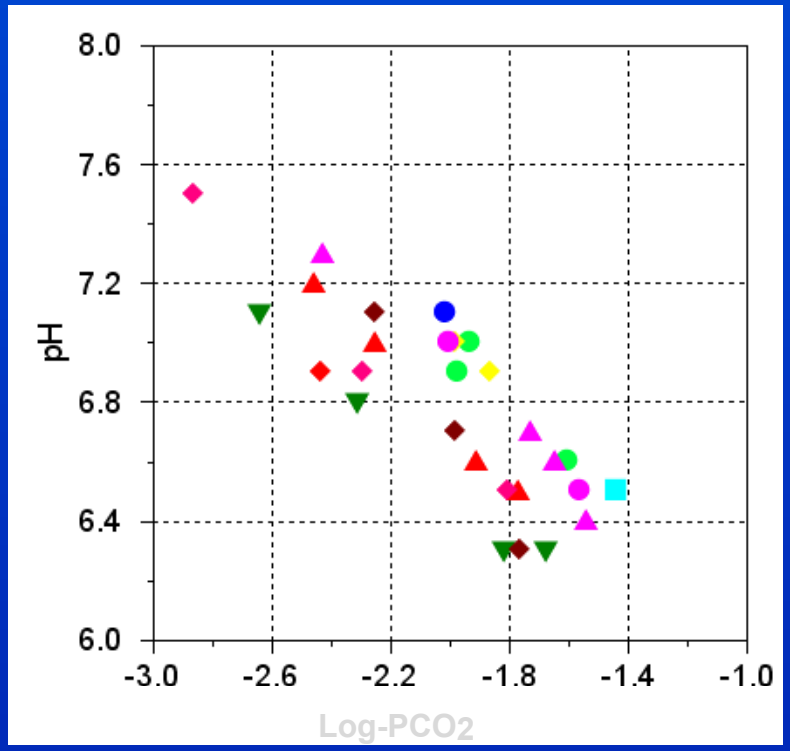


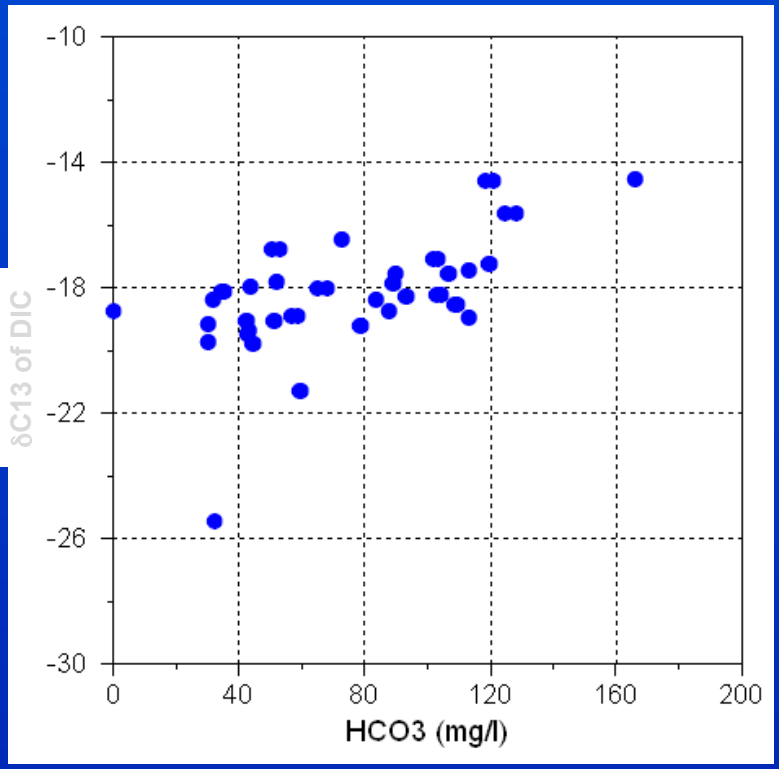
- **Groundwater is undersaturated with respect to carbonate minerals (calcite and dolomite**

Groundwater Geochemistry



Groundwater geochemistry

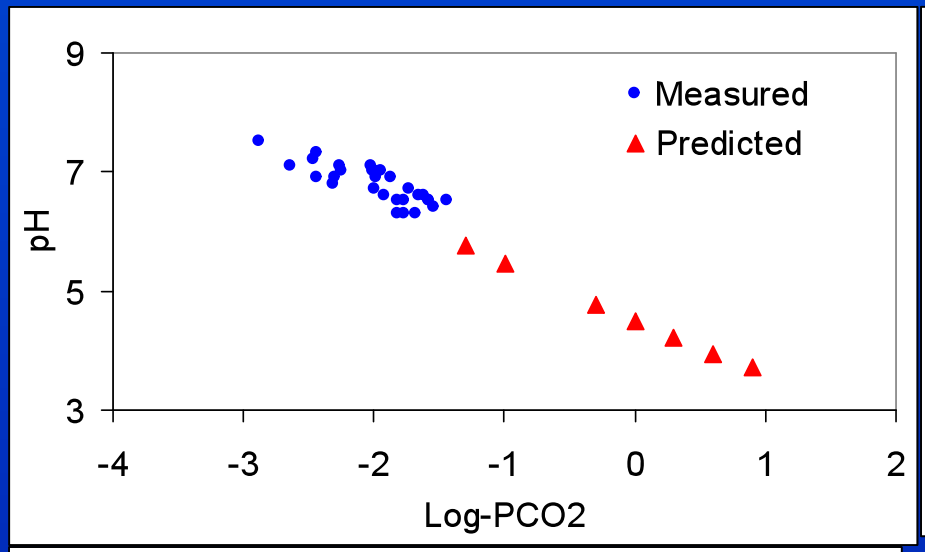


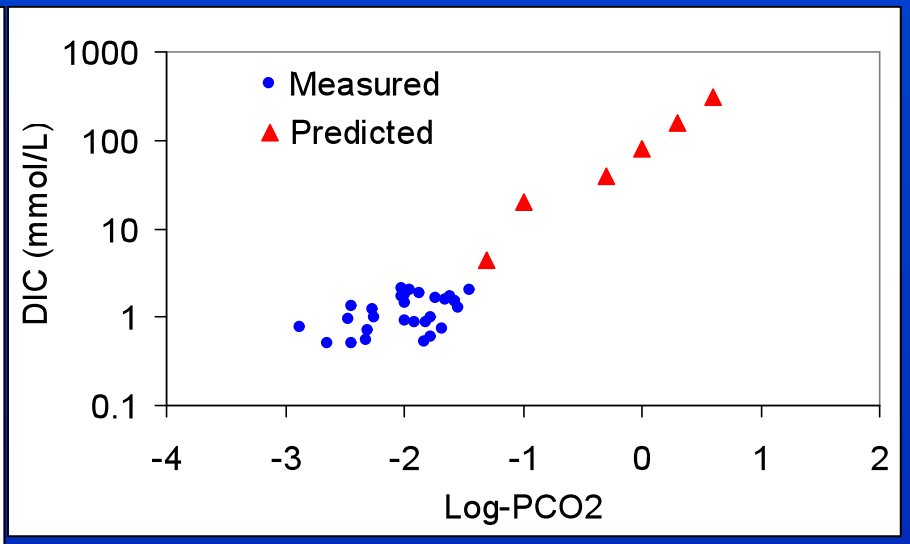


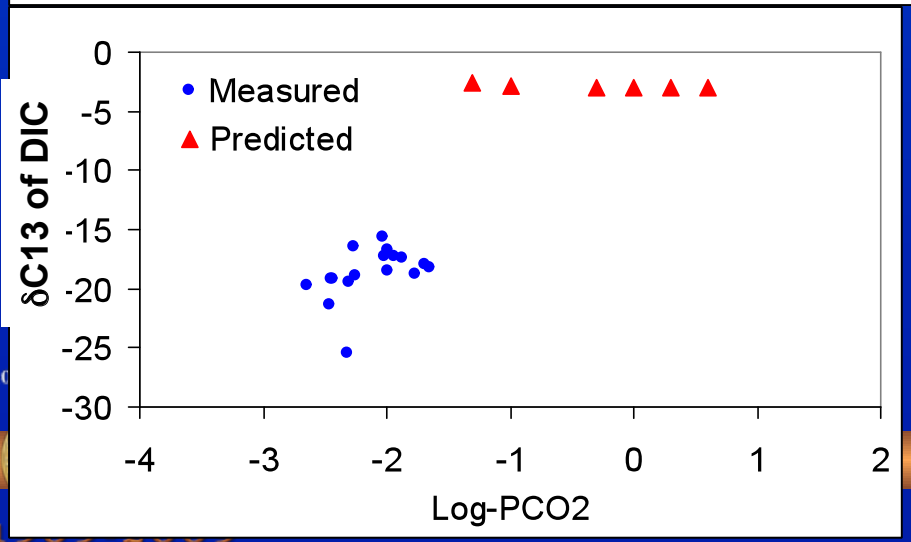
- pH shows good linear relationship with log-PCO_2
- δC13 of dissolved inorganic carbon (DIC) ranges from -14‰ to -26 ‰

Test and validation

Geochemical modeling







Simulating CO_2 leakage into the Cranfield-type shallow aquifers as CO_2 pressure builds up:

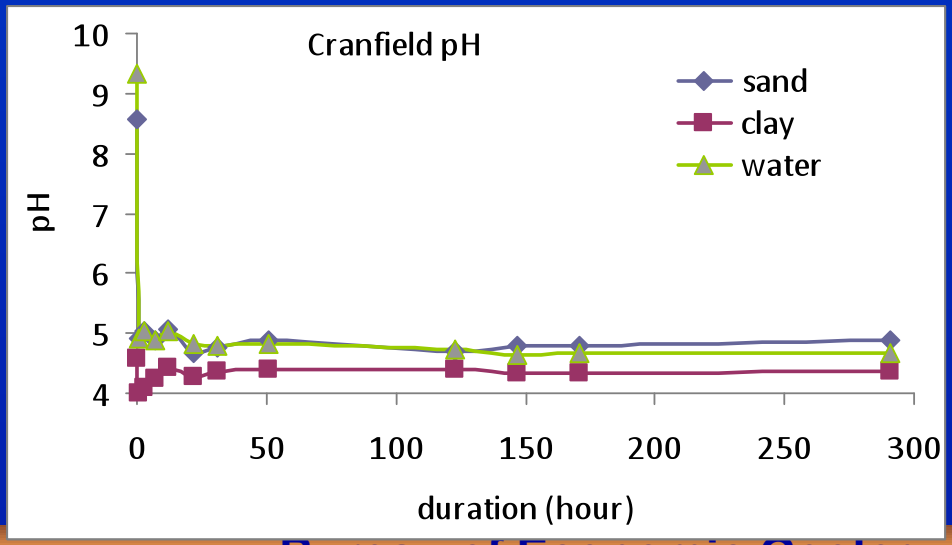
- **pH will be lowered**
- **DIC will increase**
- **δC13 of DIC will approach -3‰, the value of δC13 of CO_2 injected**

Test and validation

Water-Rock-CO2 interaction lab experiments

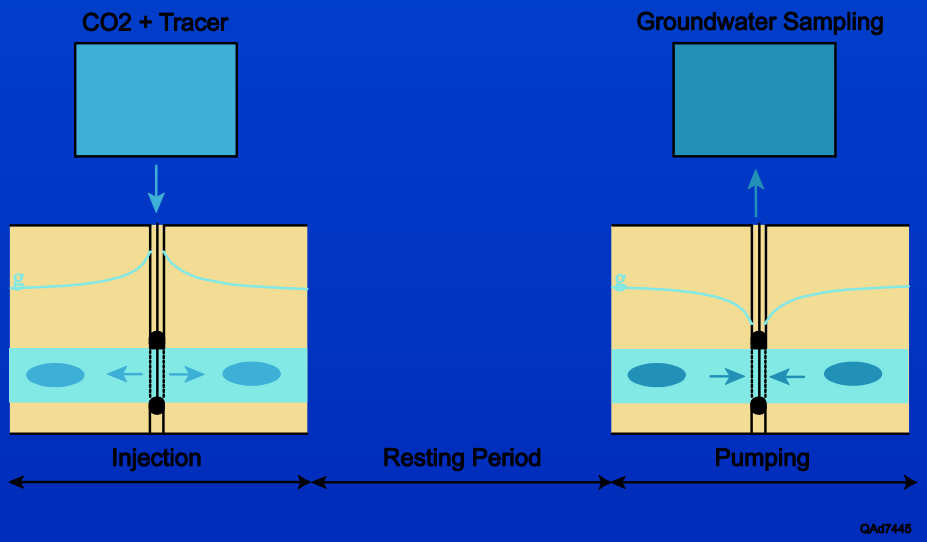
Three batches:
Rock samples from

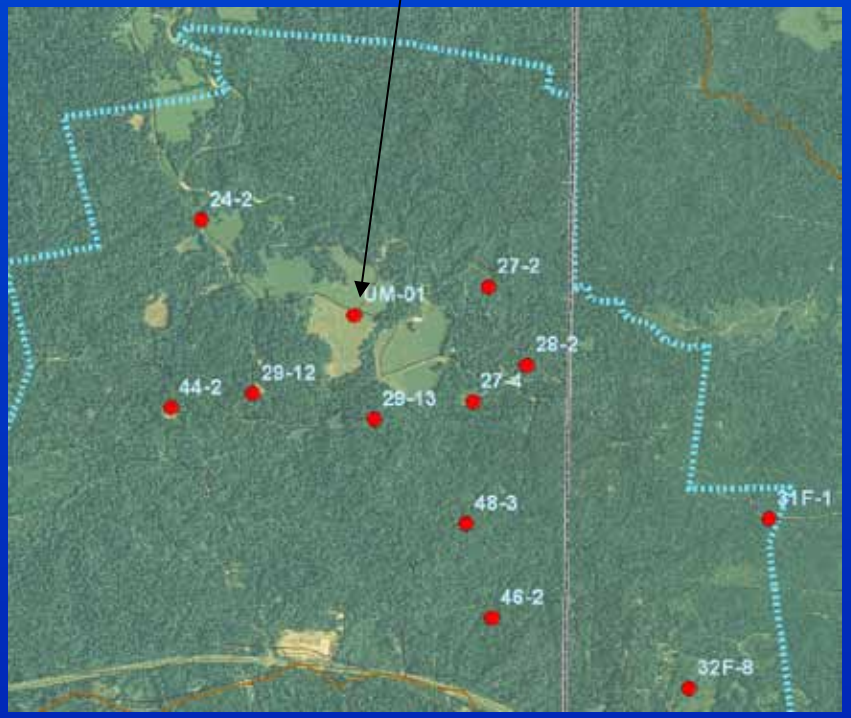
- aquitard
- aquifer
- control with no rock



Test and Validation

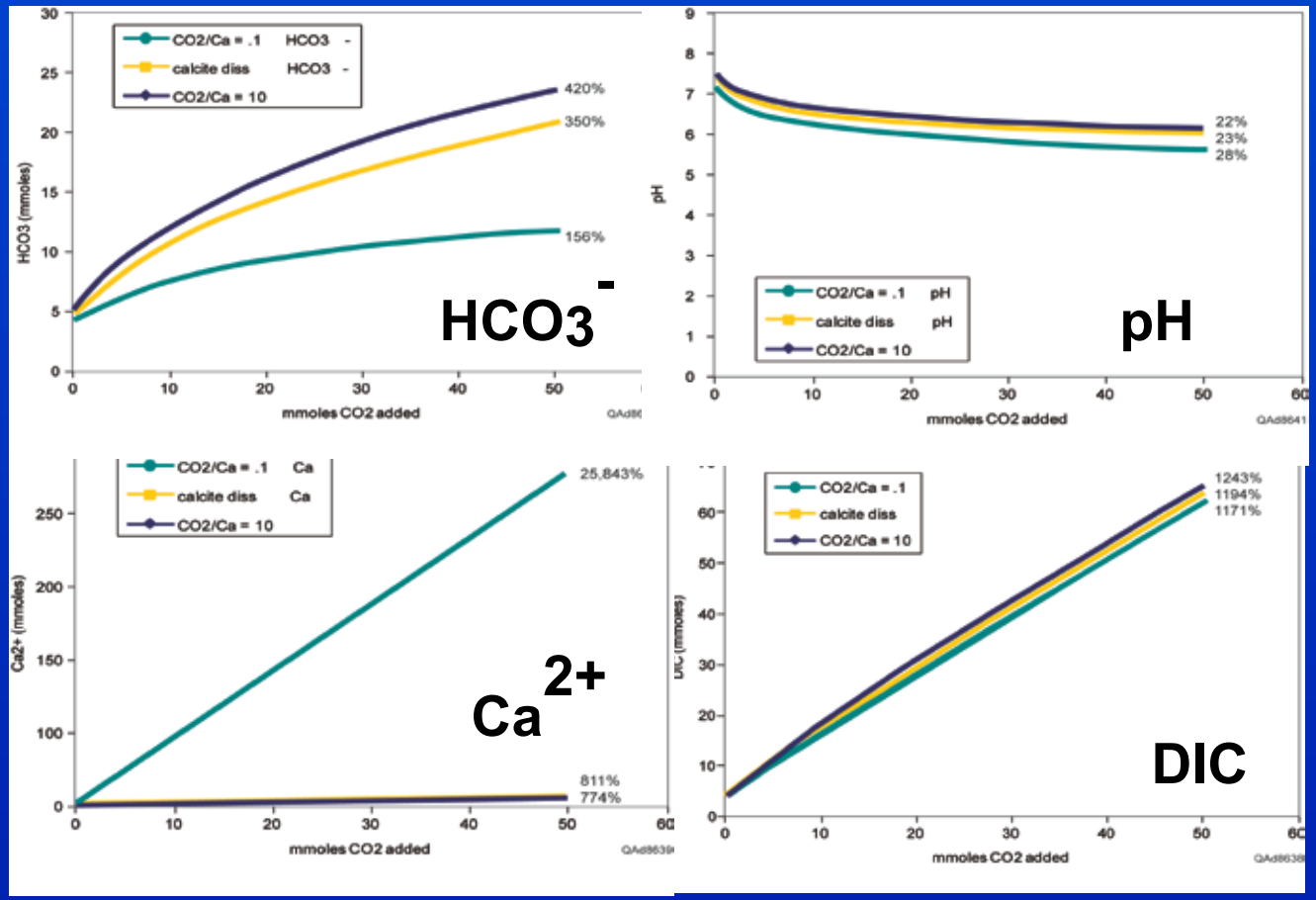
Push Pull Tests





- **Depth of the well: 240 ft to surface**
- **Depth of water: 90 ft to surface**
- **The well is screened at the 180 to 240 ft**

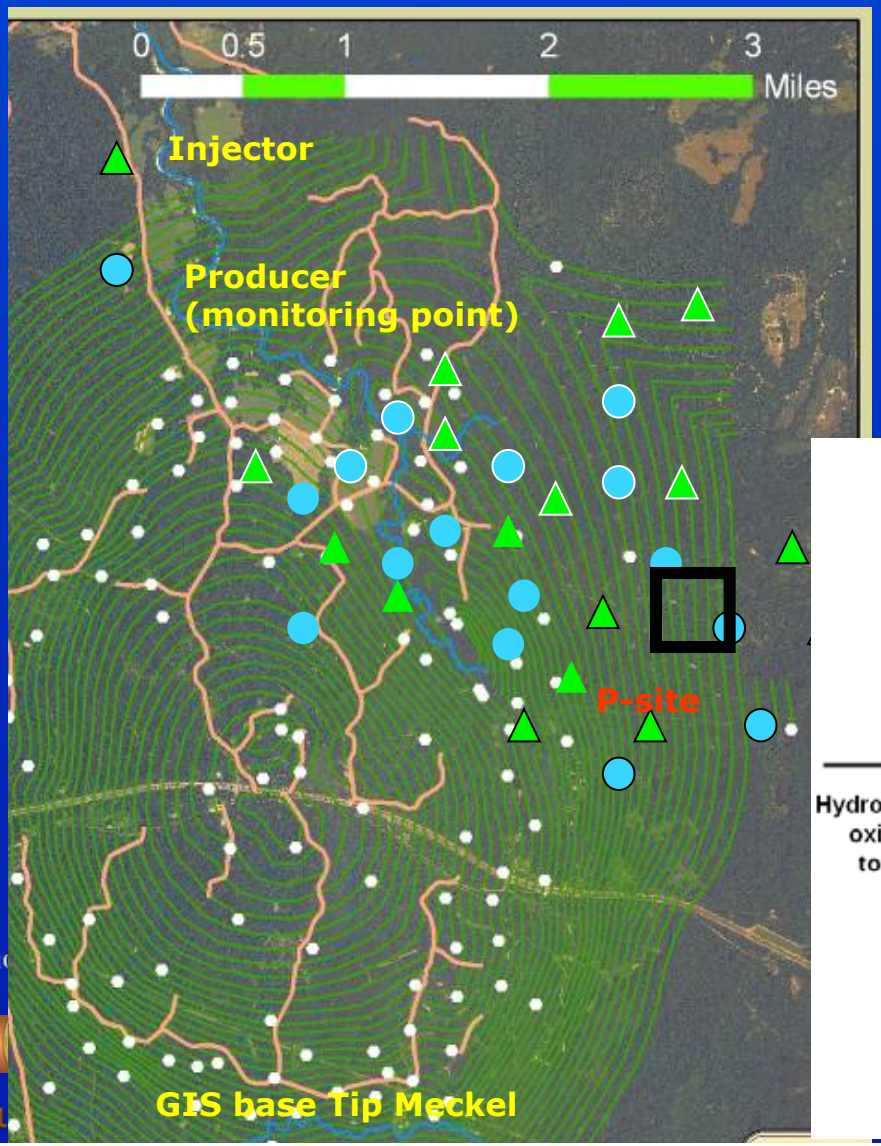
Global Monitoring Parameters



Romanak et. al., International Journal of Greenhouse Gas Control, Jan 2012

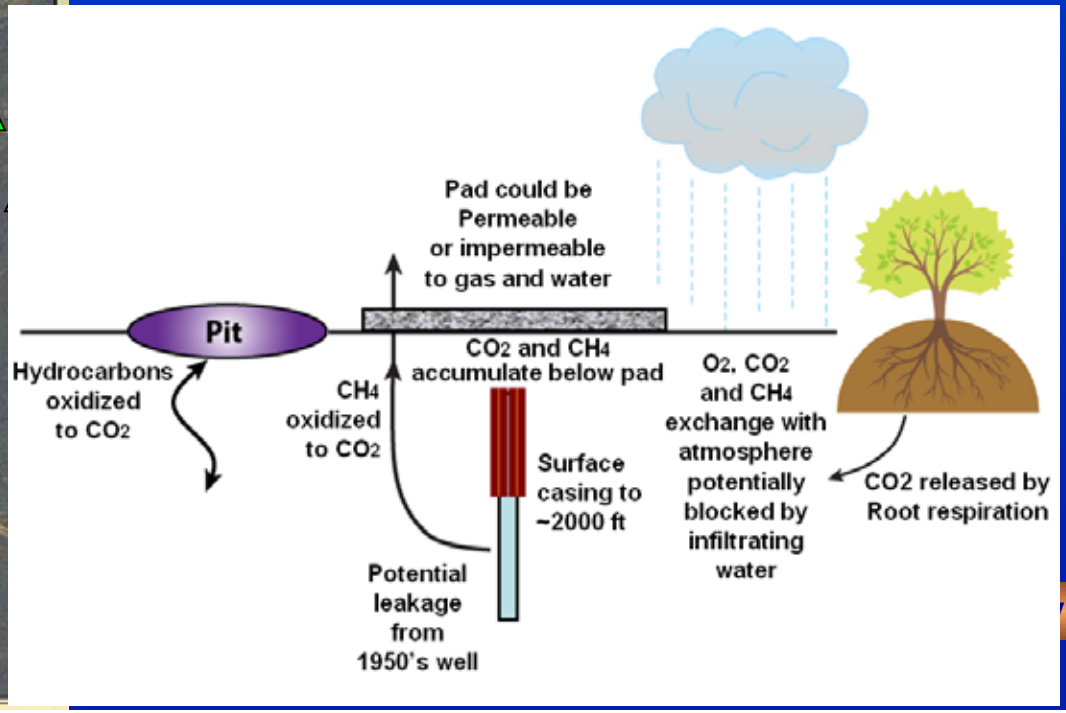
P-site Soil Gas

- Potential leakage pathway: Abandoned wells



P-site

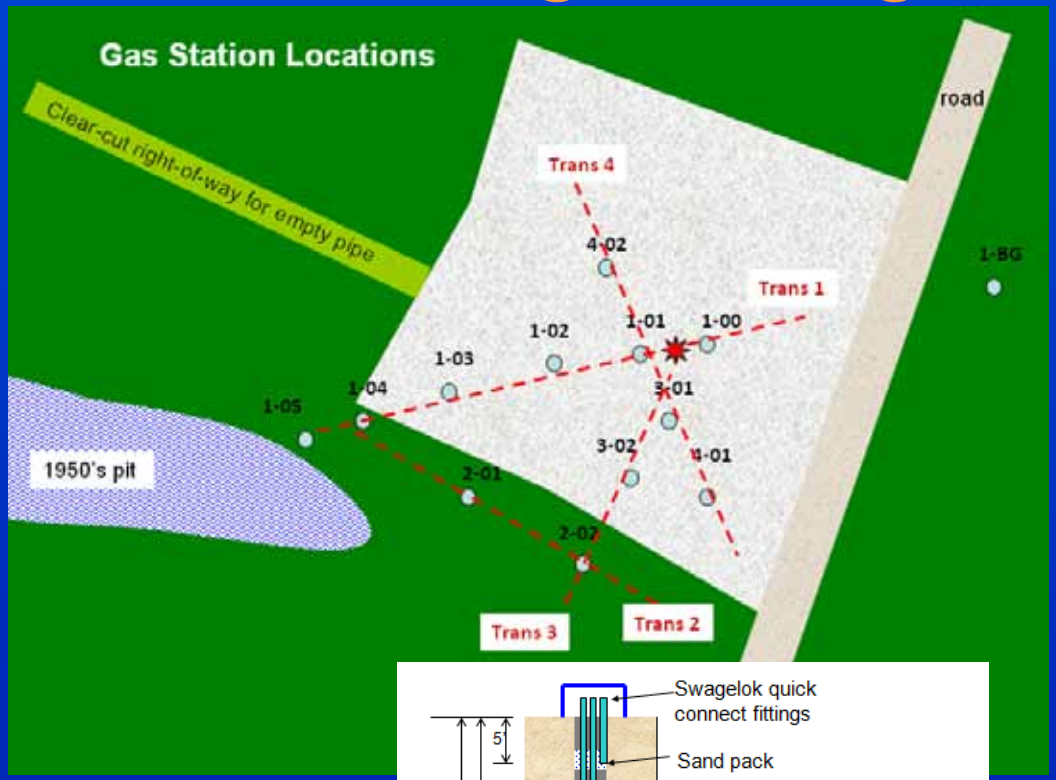
- **Pit**
- **Pad**
- **Plants**
- **Plugged & abandoned well**



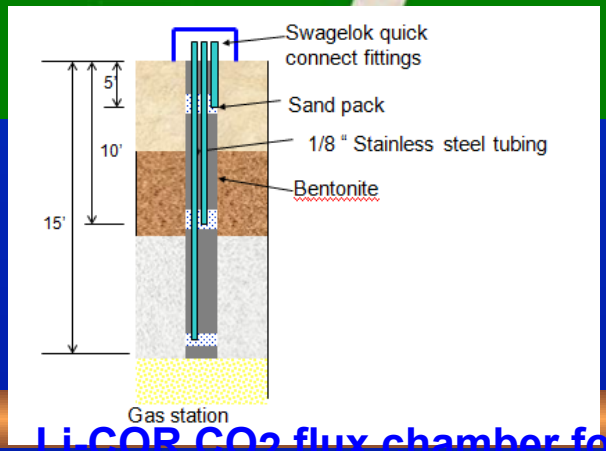
Near-surface Observatory

- Weather station
- Underground sensors for measuring soil temperature, matric potential, water content, CO_2 concentrations, etc

Soil gas composition measured through soil gas stations



- 4 transects
- 12 stations
- 36 wells
- Measure soil gas compositions (N2, CH4, O2, CO2) using GC

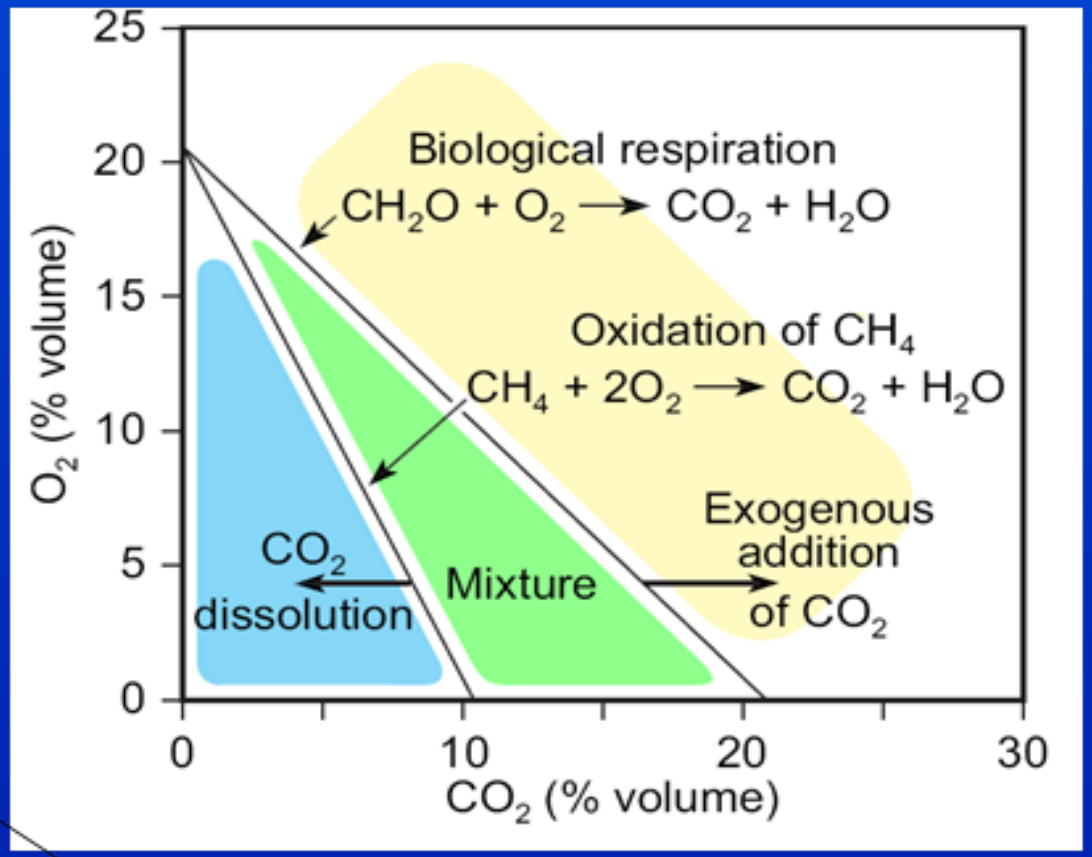


- Li-COR CO_2 flux chamber for CO_2 flux measurements

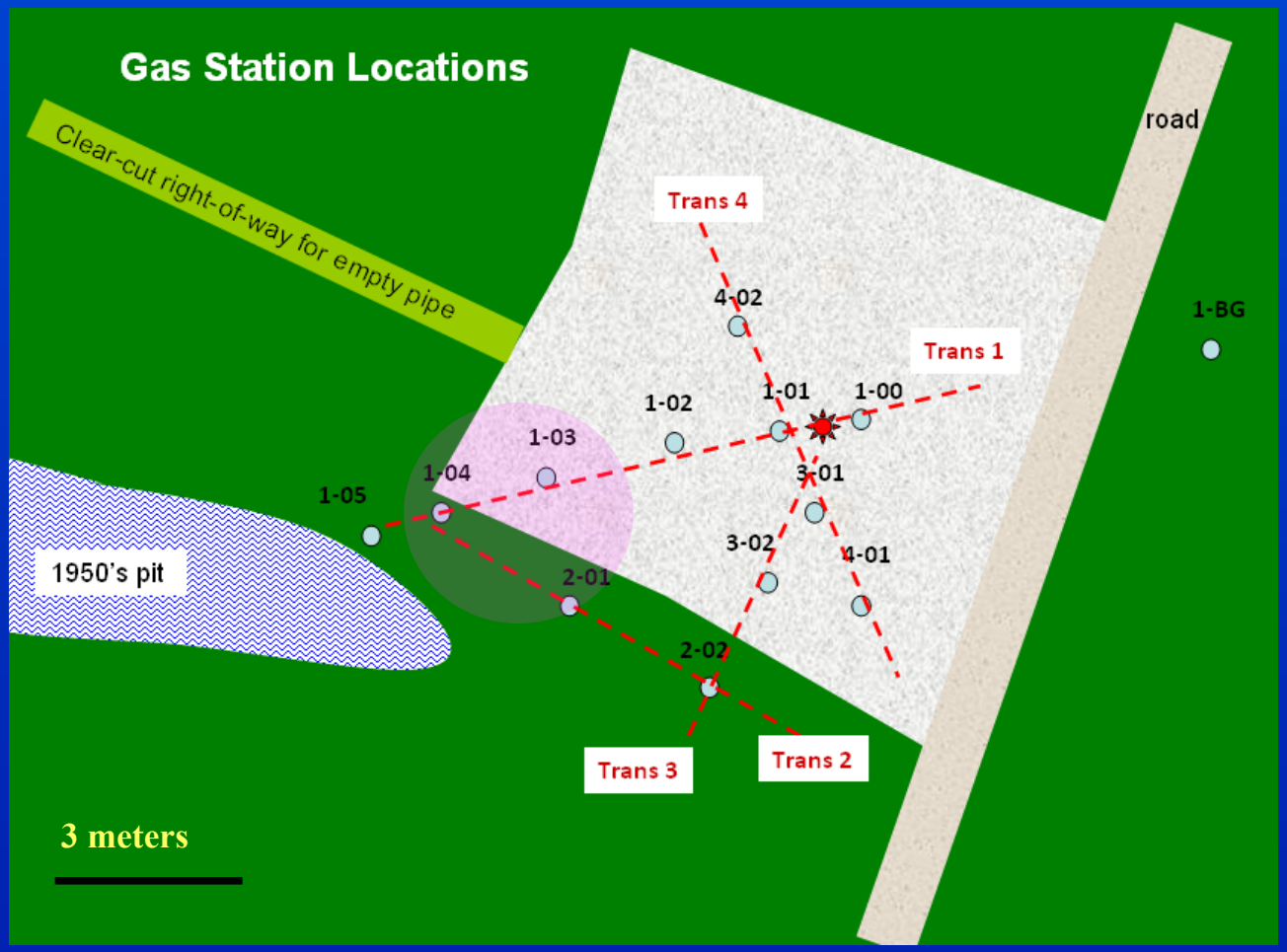
Process Based Method for Near Surface Leakage Detection

Uses gas concentration relationships to understand process.

Requires no background measurements



Fixed Soil-Gas Monitoring



4 transects
12 stations
36 wells

7 sampling trips
Sept, 2009 –
Feb, 2011

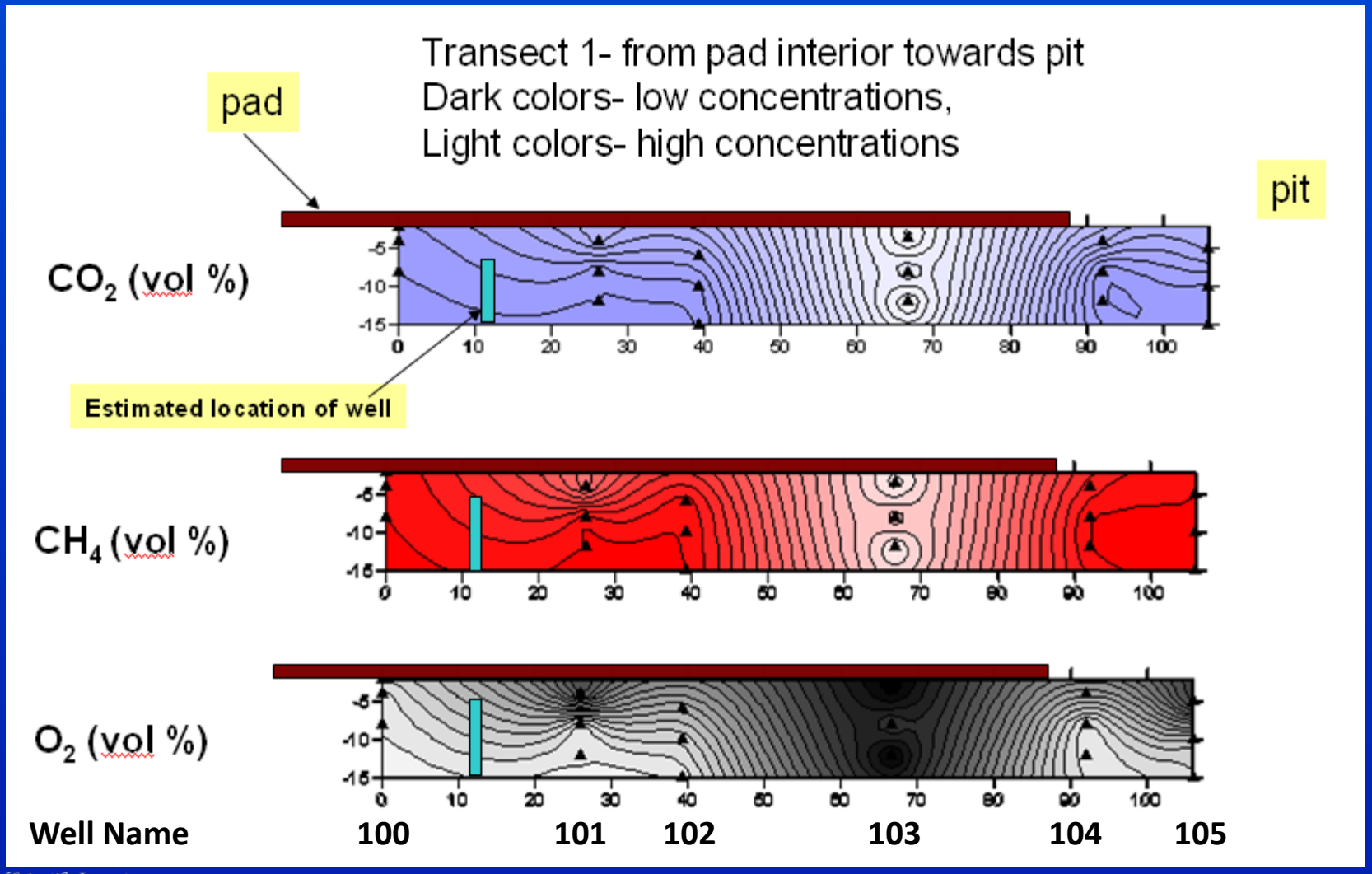
$CH_4 \leq 34$ vol. %

$CO_2 \leq 45$ vol. %

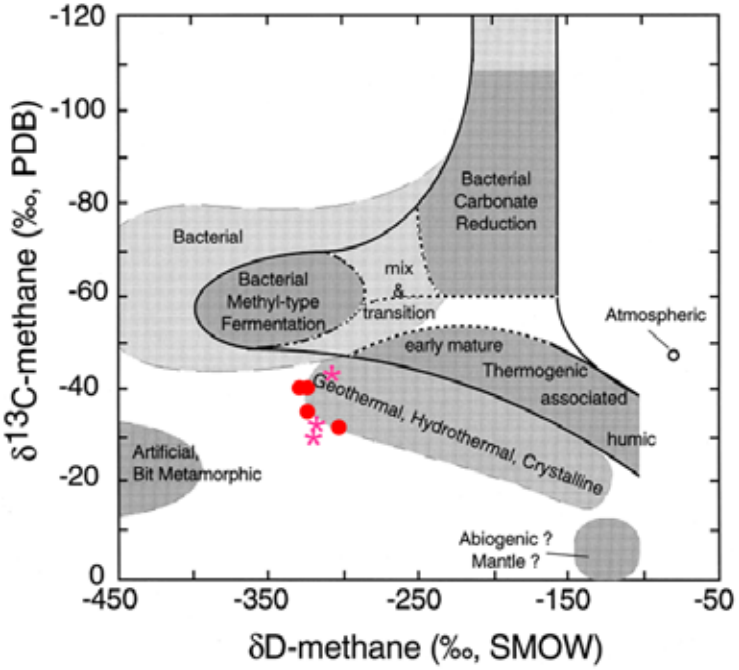
N_2 42-85%

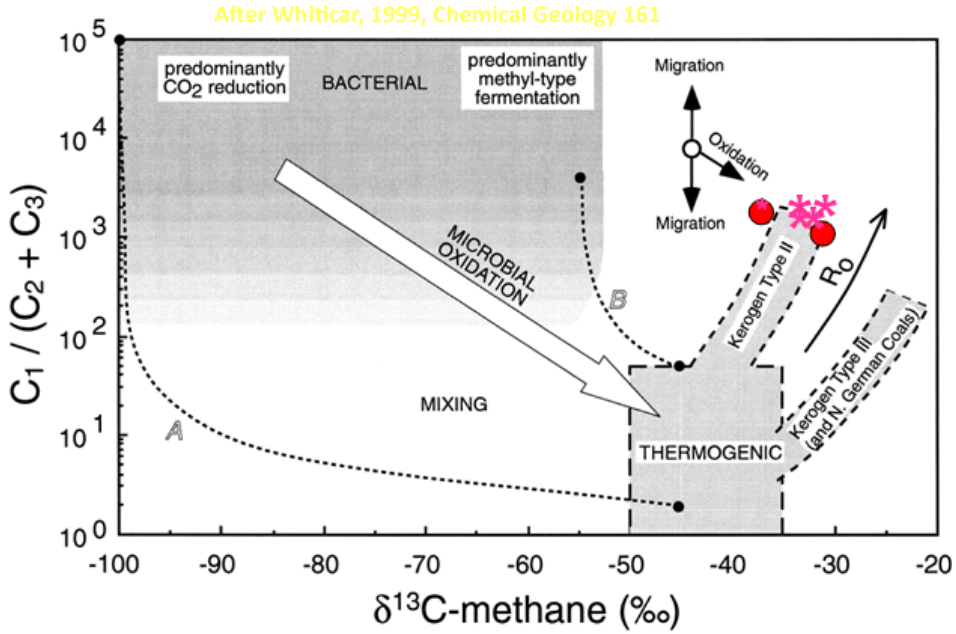
O_2 2- 21%

Gas Concentration Gradients



Methane Source Identification





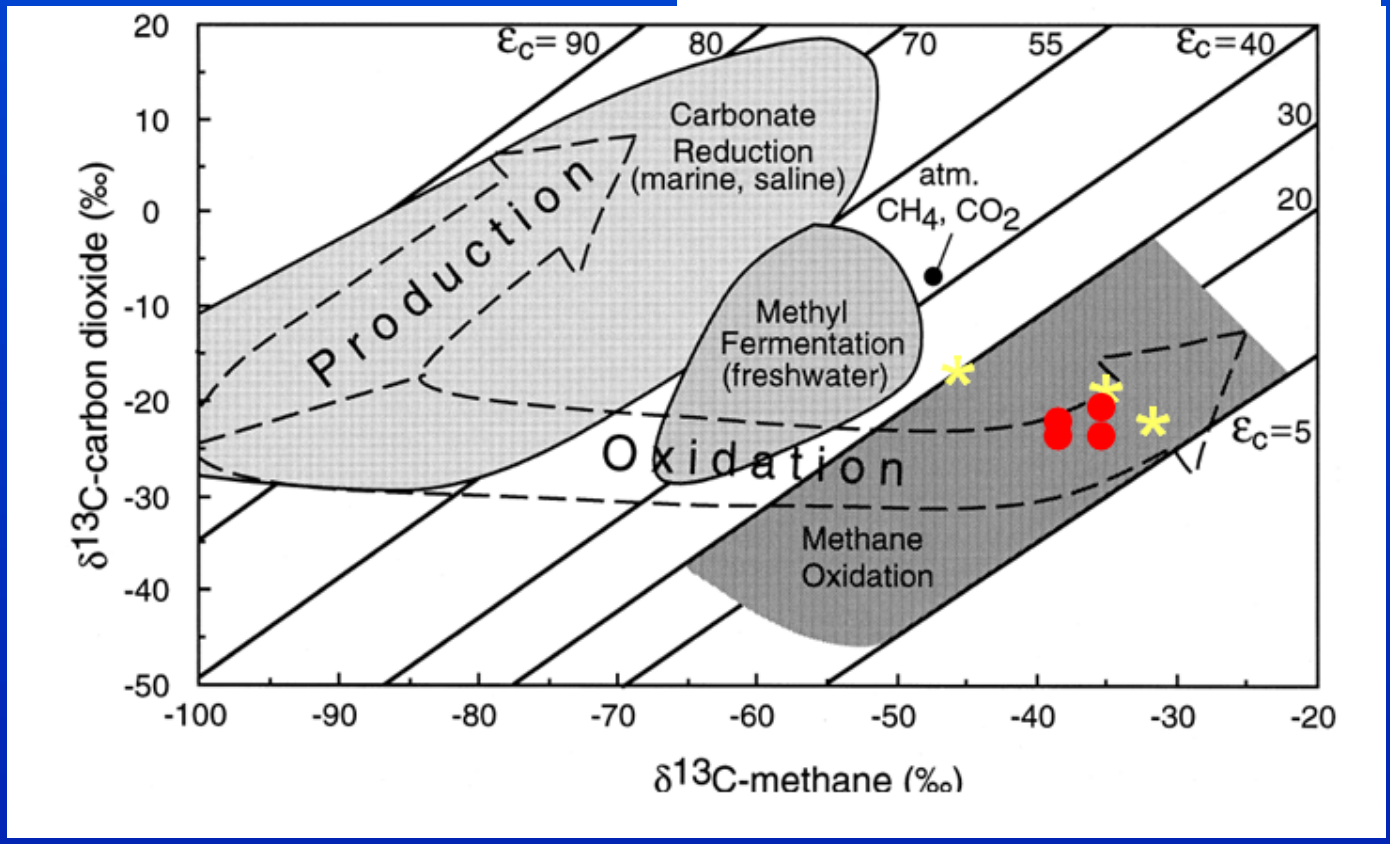
- Thermogenic
- Kerogen Type II
- Signifies oil and gas reservoir

QUESTION:
Field-wide seepage or leakage from well?

*

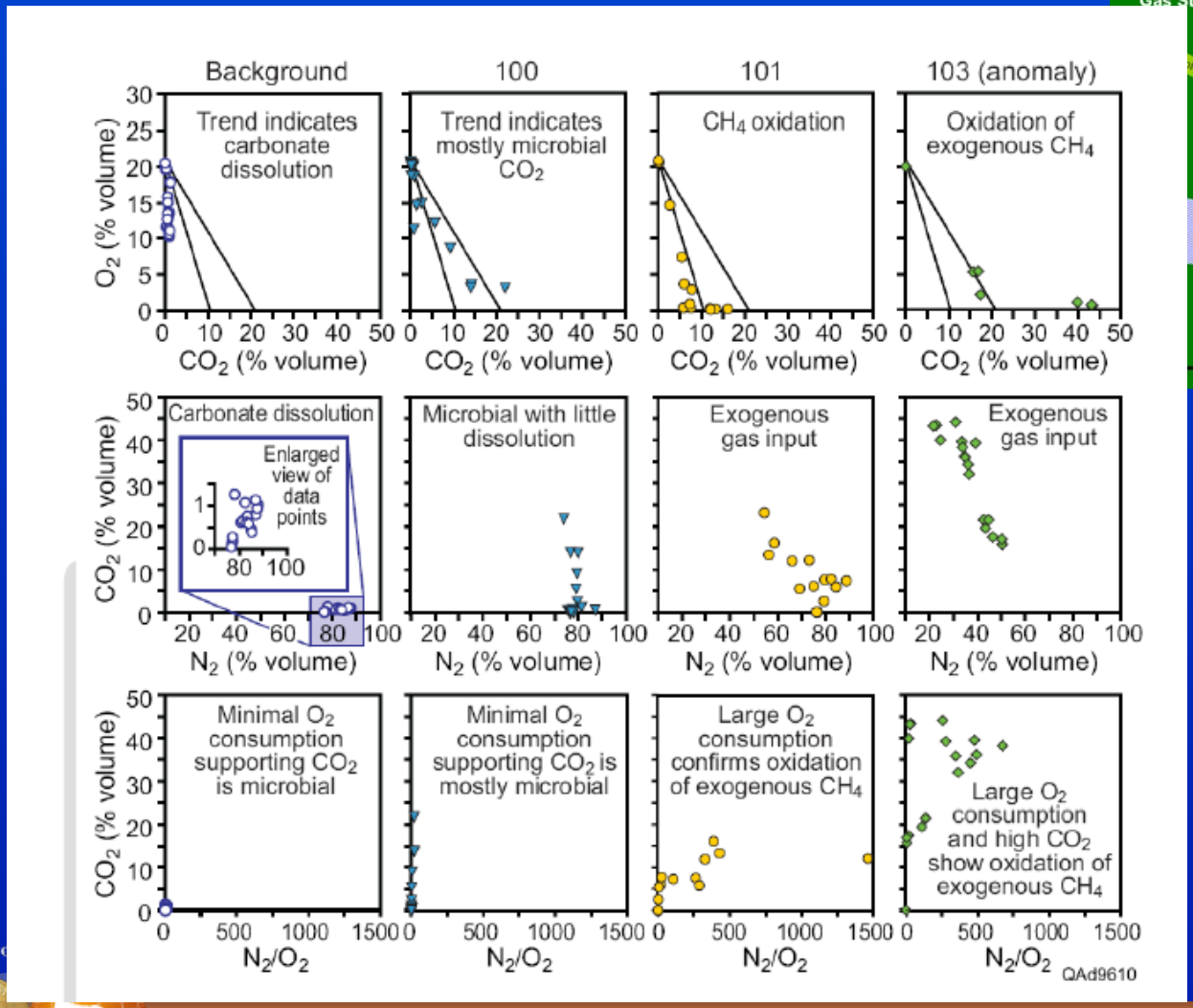
CO_2 Source Identification

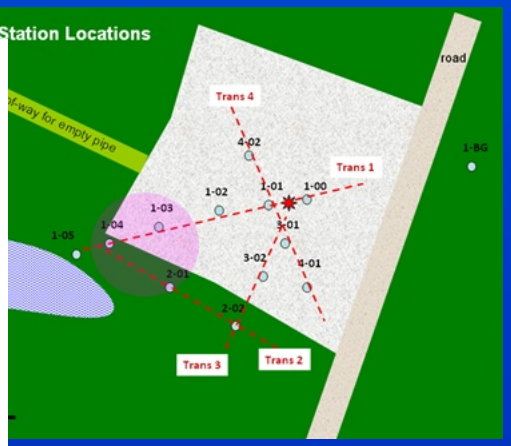
After Whiticar, 1999, Chemical Geology 161



- **Methane oxidation**

Validation of Process Based Method: CCUS Setting





Summary

- A four-step working procedure (characterization, selection, verification and application) is used for conducting shallow groundwater monitoring at the Cranfield site
- Characterization of shallow groundwater indicates mostly silicate minerals control shallow aquifer geochemistry with little influence from carbonate minerals.
- .The utility of various geochemical monitoring parameters is being tested and validated in many environments through hydrologic characterization, lab experiments, geochemical modeling, and field experiments
- Dissolved inorganic carbon (DIC) is proposed as a global monitoring parameter

Summary

- Soil-gas monitoring was conducted at the P-site by measuring soil CO_2 concentrations, flux and soil-gas compositions.
  - CO_2 and CH_4 at the site are “anomalously” high.
  - The source of CH_4 appears to be thermogenic, kerogen type II which is indicative of an oil & gas reservoir.
  - The source of CO_2 from oxidation of CH_4.
  - Currently not proven if the CH_4 is from the well or general seepage from the reservoir

Summary

- Soil CO_2 concentration measurements may be insufficient for CO_2 leakage detection.
- Soil gas composition measurements may be more reliable than CO_2 concentration measurements alone.
- A new *Process-Based* approach to near surface leakage detection is proposed and was successfully tested at Cranfield.

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