

Role of geochemical monitoring in geologic sequestration

GCCC Digital Publication Series #10-08

Jean-Philippe Nicot
Katherine D. Romanak
Changbing Yang
Rebecca Smyth
Susan Hovorka



Keywords:

Monitoring, Overview

Cited as:

Nicot, J.-P., Romanak, K.D., Yang, C., Smyth, R.C., and Hovorka, S., Role of geochemical monitoring in geologic sequestration: presented at the Geologic Carbon Sequestration Site Integrity Workshop – Characterization and Monitoring Science and Technology, Ohio State University, Columbus, OH, June 7-8, 2010. GCCC Digital Publication Series #10-08.



Role of Geochemical Monitoring in Geologic Sequestration

Jean-Philippe (JP) Nicot

Katherine Romanak, Changbing Yang

Rebecca Smyth, Susan Hovorka

Gulf Coast Carbon Center

Bureau of Economic Geology

Jackson School of Geosciences

The University of Texas at Austin

Geologic Carbon Sequestration Workshop

OSU - Columbus, OH

June 7, 2010



Purposes of Monitoring (*General*)

Bureau of Economic Geology

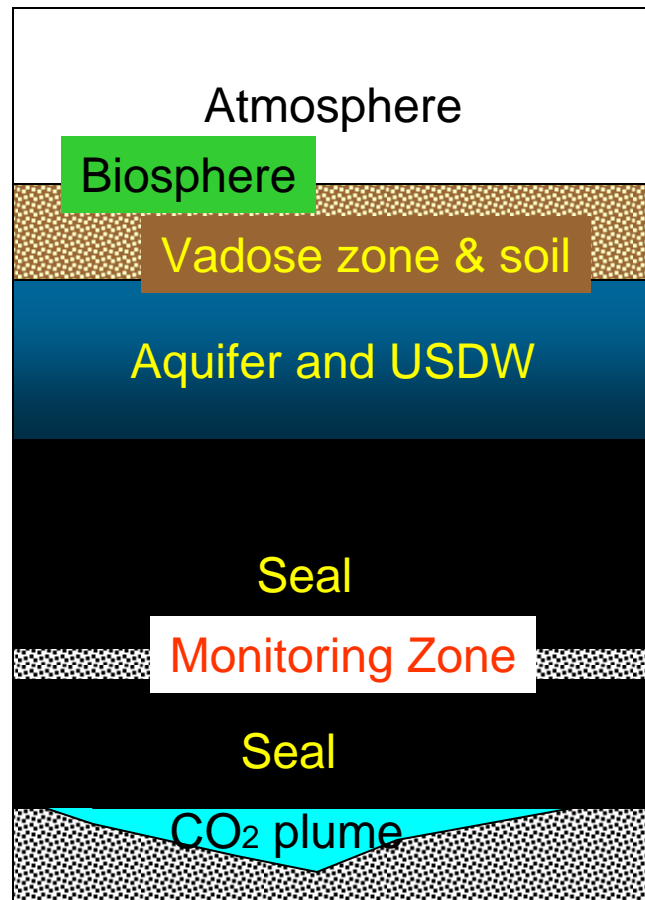
- Ensure HSE of public and workers
 - injection wells, pipeline – operational phase
 - seismicity, environment, ground water quality
- Verify CO₂ storage (mass balance)
- Confirm predictions of CO₂ migration (plume movement, migration rates, but also pressure distribution)
- Early warnings of storage failure

From IPCC, 2005



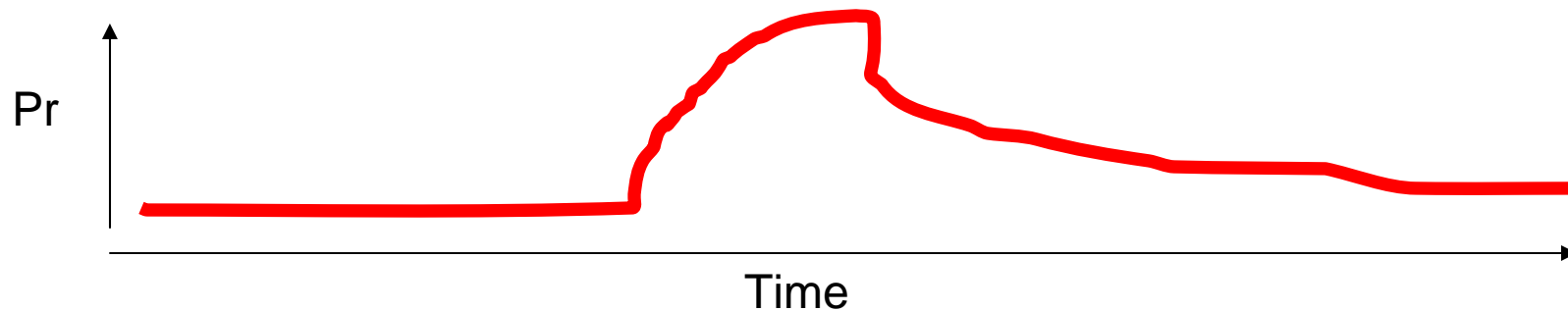
Where: Location of Geochemical Sampling

Bureau of Economic Geology



- **Low pressure, lower cost**
 - Atmosphere (dynamic)
 - Soil gas (dynamic – cumul.)
 - Aquifer (cumul.)
- **Downhole / wellhead – high pressure, higher cost**
 - Above zone (first indicator)
 - Seal
 - In plume
 - Outside plume

From Sue Hovorka



- When: Establish **baseline** (reservoir and injection fluids, aquifer composition, soil gas composition, rock mineralogy, etc.) – **characterization vs. monitoring** – how much, how long before injection? Monitoring occurs during and post-injection
- Mode: **research** vs. commercial:
 - Learn about subsurface processes
 - Provide data for model calibration
 - Compare monitoring methods

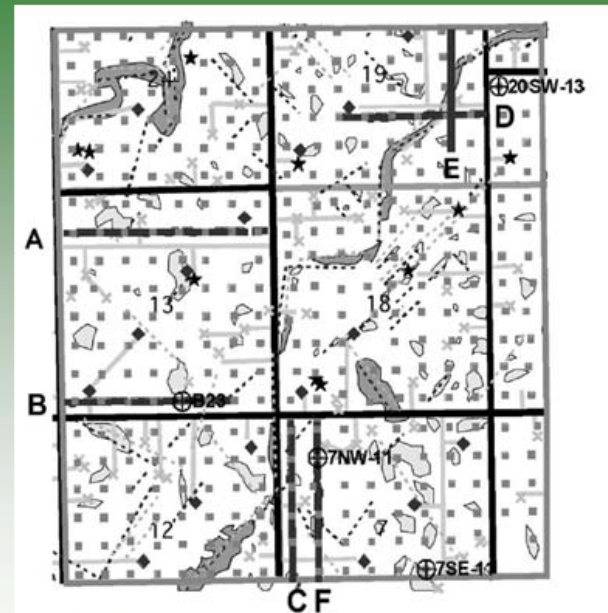
Research vs. commercial

Bureau of Economic Geology

- Weyburn dense grid – not realistic in commercial mode – what is the real value?

Soil-Gas Approach

- Full-field characterization- large spatial area with dense grids.
- Targeted - small spatial area focused on process.



Weyburn soil-gas grid. (Riding and Rochelle, 2009). 14 km², 200 m spacing

What to measure:

Bureau of Economic Geology

- Direct vs. indirect and intrusive vs. non-intrusive, geochemical measurements are necessarily intrusive (bar atmospheric) and mostly indirect
- TDS (EC), major, minor, and trace element concentrations
- pH, alkalinity
- Natural tracers (C, O, H isotopes, noble gases)
- Introduced tracers (SF_6 , PFC, noble gas)

Proposed regulations

Bureau of Economic Geology

- Class VI:
 - Monitoring plan must be submitted with application
 - geochemical characterization of rock and water of injection strata, confining zones, above-zone strata, and USDWs §146.82(g)
 - GW monitoring required §146.82(d)
 - Soil gas and atmospheric not required §146.82(h)
 - “monitoring geochemical changes in the subsurface” in preamble – would require monitoring wells in injection Fm.
 - Use of (introduced) tracers not required

Is geochemical monitoring useful?

Bureau of Economic Geology

- It is required by proposed regulations but is it useful?
- Workflow: characterization, modeling, risk assessment, monitoring plan
- Permits dispensed by regulators, they will need standards to assess applications
- Let's monitor pH, alkalinity, and trace elements. Is it this simple?

Ideal (necessary?) attributes of geochemical monitoring

Bureau of Economic Geology

- In addition to efficient (no false >0 <0 at cost), monitoring needs to be:
 - 1) parsimonious (no redundant techniques) – not sustainable to have many heavily instrumented sites – what is the minimum set of techniques needed
 - 2) hierarchical (escalate monitoring as indicators go red) – not practical to monitor many parameters all the time – who is going to interpret the data?
 - 3) simple (no expert guidance needed) – monitoring of numerous sites cannot be done by experts only; clear standards on sampling and interpretation
- Primary, core, basic vs. secondary, additional, enhanced

Shallow aquifer monitoring

Bureau of Economic Geology

- Need to find a parameter sensitive enough
- Increase in DIC and trace metals, decrease in pH?
- Water-rock interactions must be part of the water chemistry interpretation (e.g., Yang, BEG)
- CO₂ concentrations vary spatially and temporally: seasons, land-use changes (change in recharge – Scanlon, BEG) = false positives
- Calcite rock/cement buffers pH but complications with incongruent dissolution of dolomite and gypsum dissolution (Romanak, BEG) = false negatives

Shallow aquifer monitoring

Bureau of Economic Geology

- Need to find a parameter sensitive enough
- Increase in DIC and trace metals, decrease in pH?
- Water-rock interactions must be part of the water chemistry interpretation (e.g., Yang, BEG)
- CO₂ concentrations vary spatially and temporally: seasons, land-use changes (change in recharge – Scanlon, BEG) = false positives
- Calcite rock/cement buffers pH but complications with incongruent dissolution of dolomite and gypsum dissolution (Romanak, BEG) = false negatives

Shallow aquifer monitoring

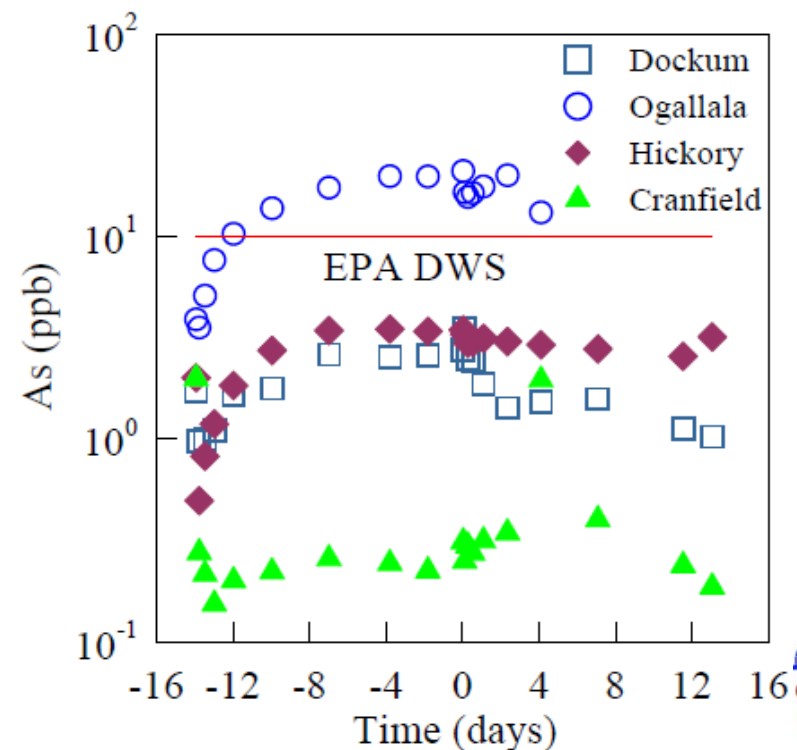
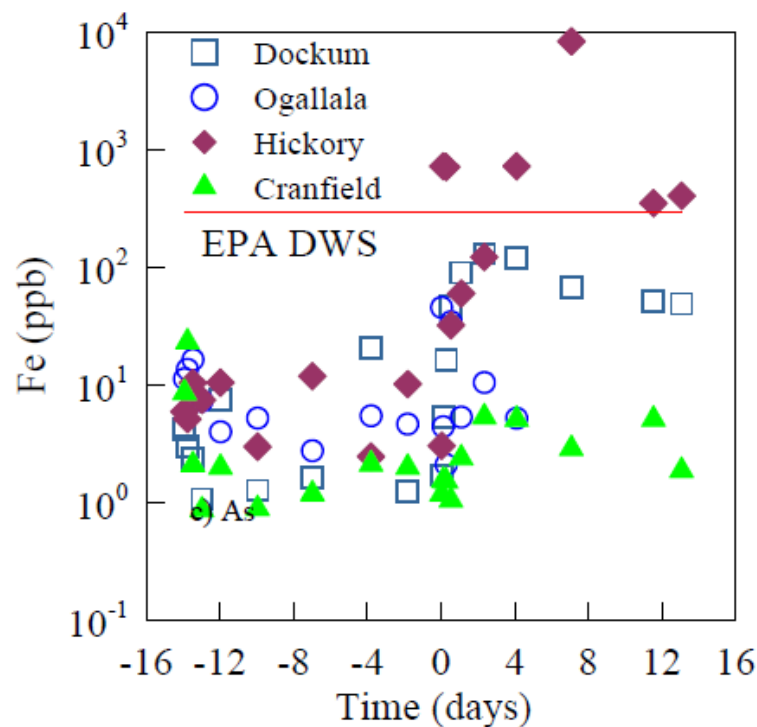
Bureau of Economic Geology

- Need to find a parameter sensitive enough
- Increase in TDS and possible heavy metal increase if brine leakage pH?
- Water-rock interactions must be part of the water chemistry interpretation (e.g., Yang, BEG)
- CO₂ concentrations vary spatially and temporally: seasons, land-use changes (change in recharge – Scanlon, BEG) = false positives
- Calcite rock/cement buffers pH but complications with incongruent dissolution of dolomite and gypsum dissolution (Romanak, BEG) = false negatives

Laboratory batch experiments

Bureau of Economic Geology

- Ar then CO₂ bubbling (1 atm) in water-rock systems
- Siliciclastic aquifers w/ carb. (Dck, Og) and w/o (Hck. loess)

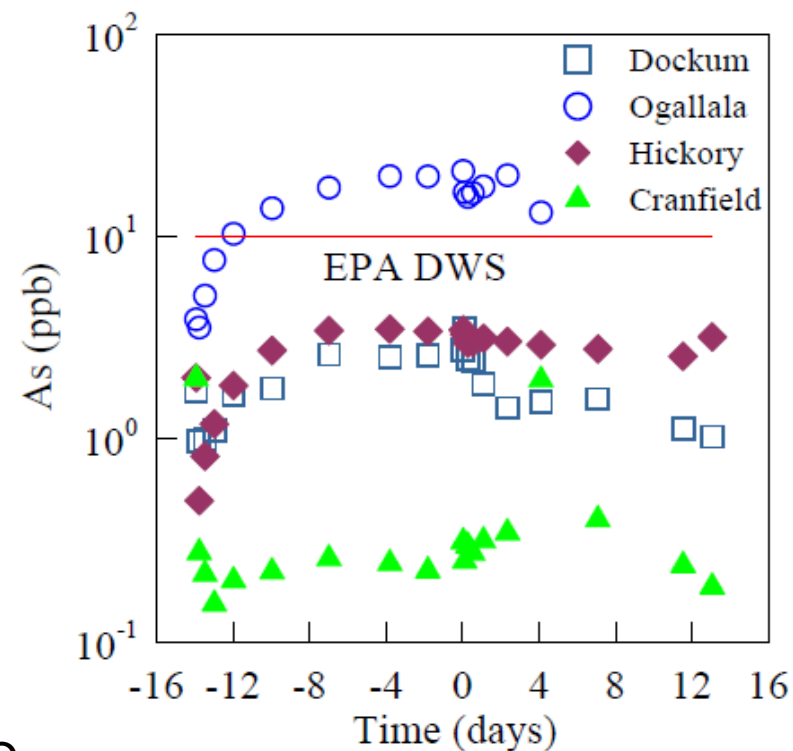
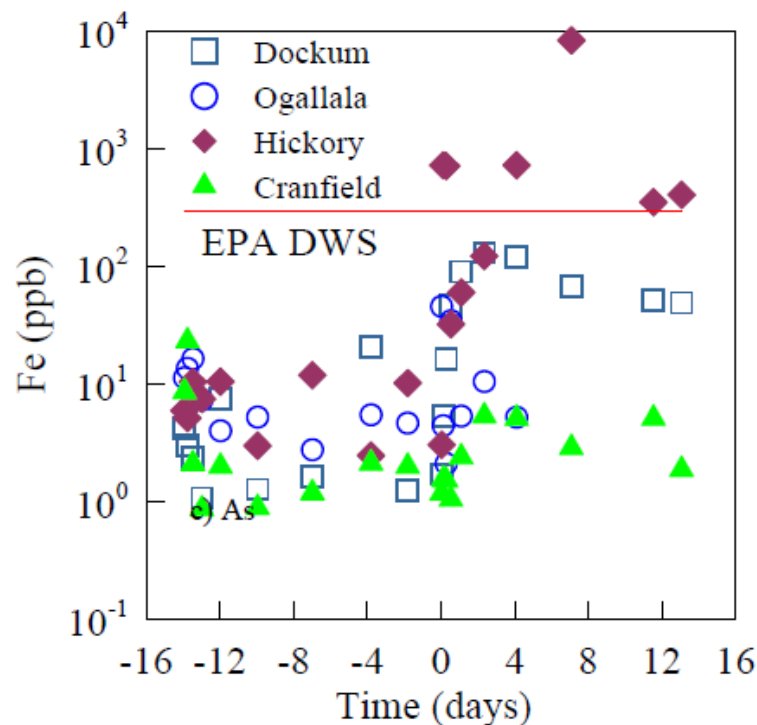


Lu et al., 2009, EEG; Yang et al., 2010, IJGGC

Laboratory batch experiments

Bureau of Economic Geology

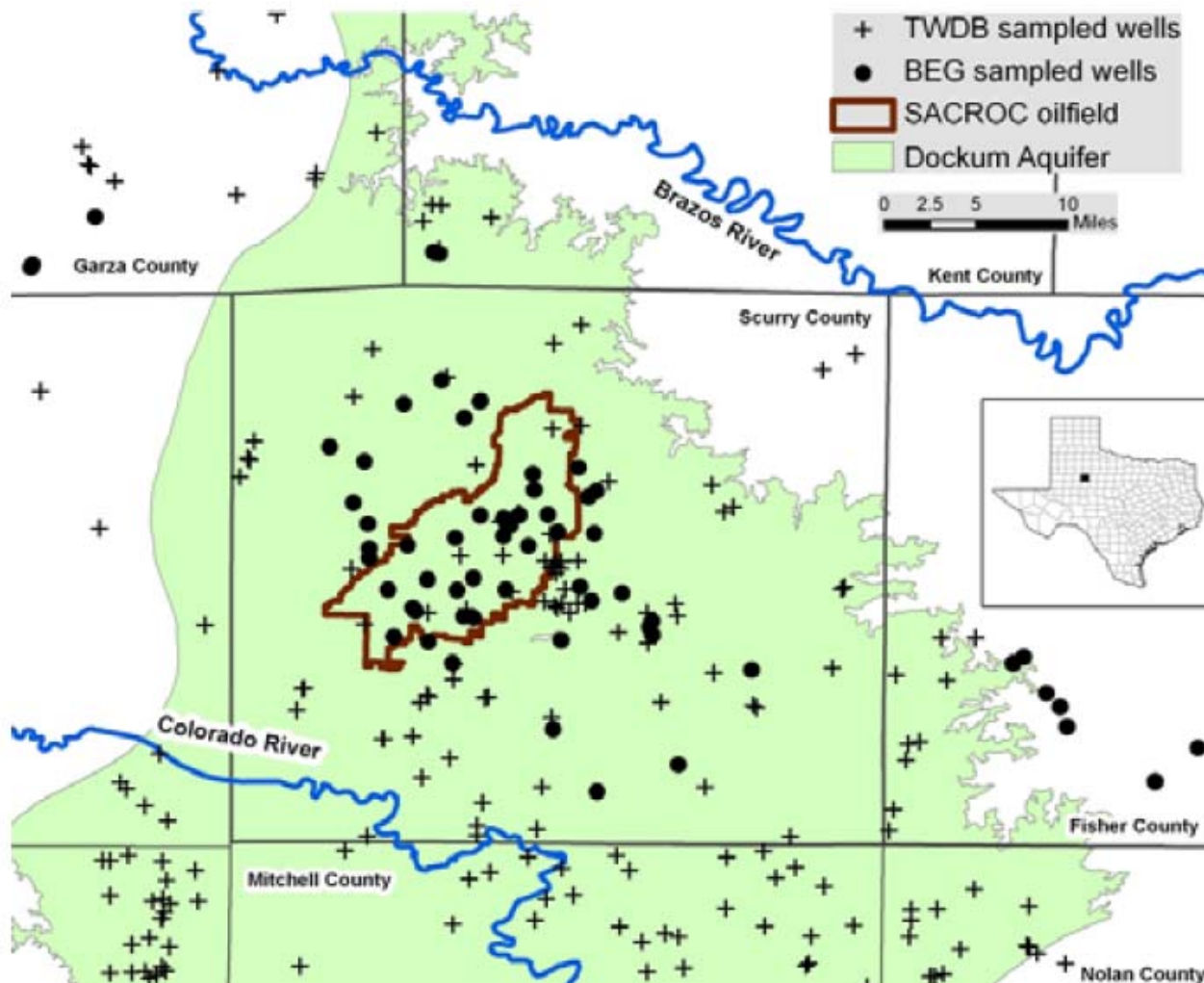
- Some decrease in concentration after a few days even as injection continues (are trace metals a good indicator?)
- Increase in As (cation group 2) before injection of CO₂ (is increase necessarily due to CO₂ leakage?)



Lu et al., 2009, EEG; Yang et al., 2010, IJGGC

The SACROC case

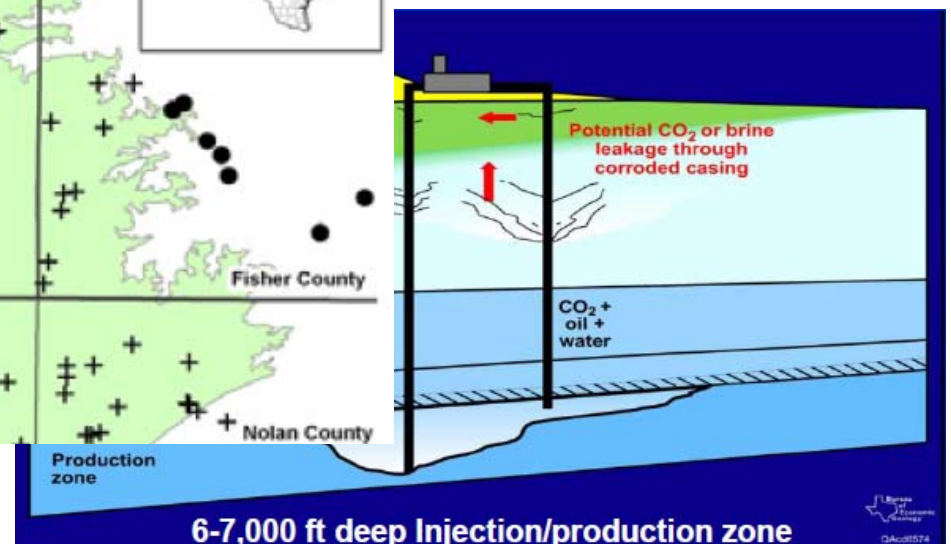
Bureau of Economic Geology



Sampling points

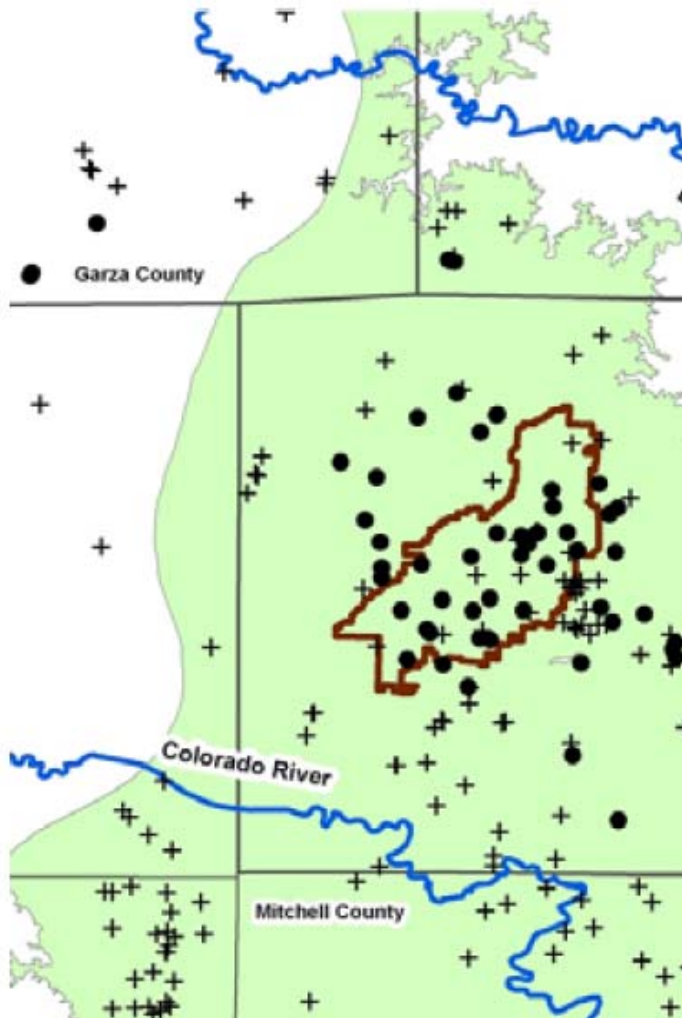
Smyth et al., 2008

15

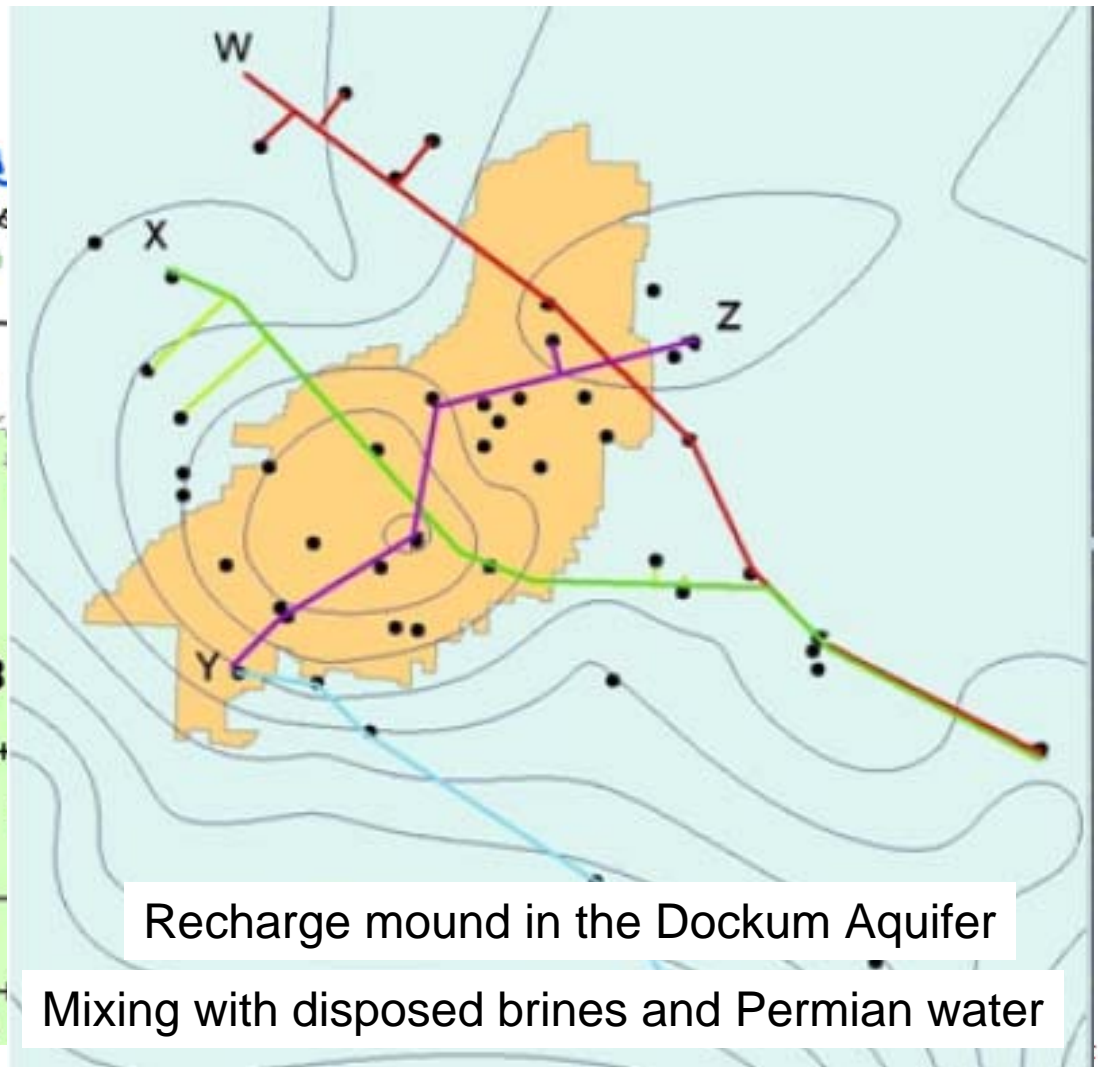


The SACROC case

Bureau of Economic Geology



Smyth et al., 2008



Recharge mound in the Dockum Aquifer
Mixing with disposed brines and Permian water

The SACROC case

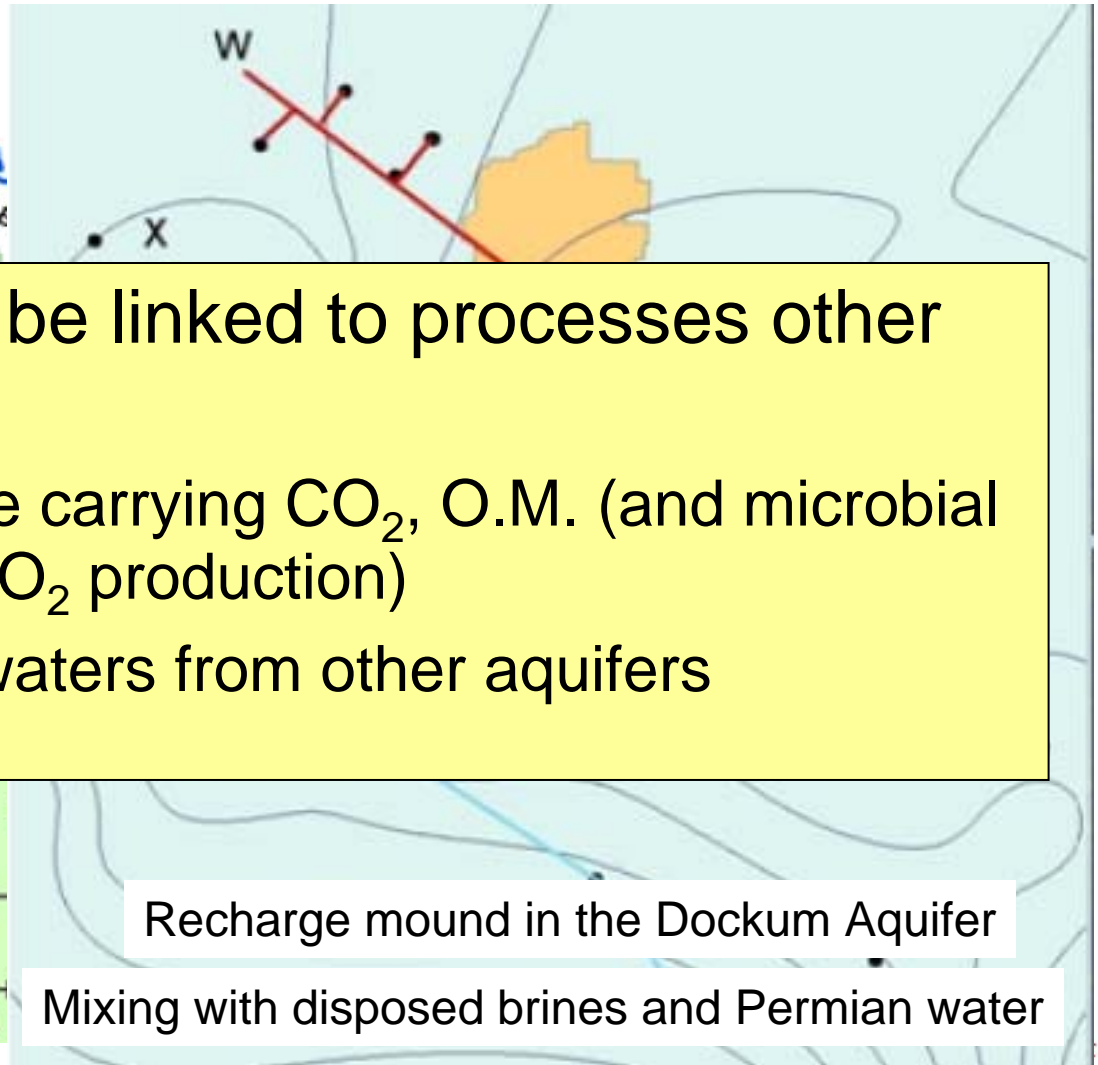
Bureau of Economic Geology

CO₂ increase may be linked to processes other than leakage:

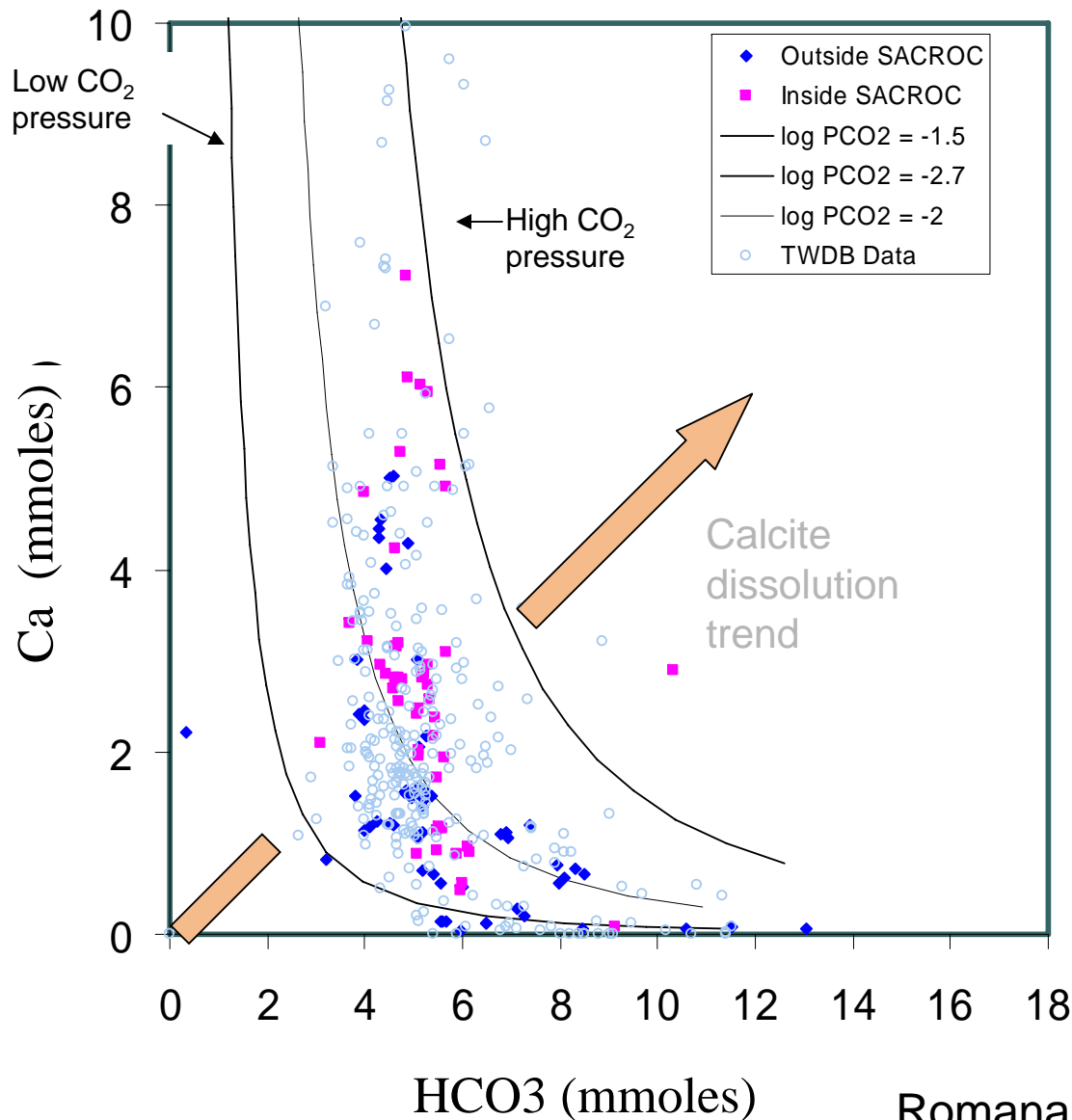
- Enhanced recharge carrying CO₂, O.M. (and microbial degradation with CO₂ production)
- Local mixing with waters from other aquifers



Smyth et al., 2008



Mixing creates a complex carbonate system



Bureau of Economic Geology

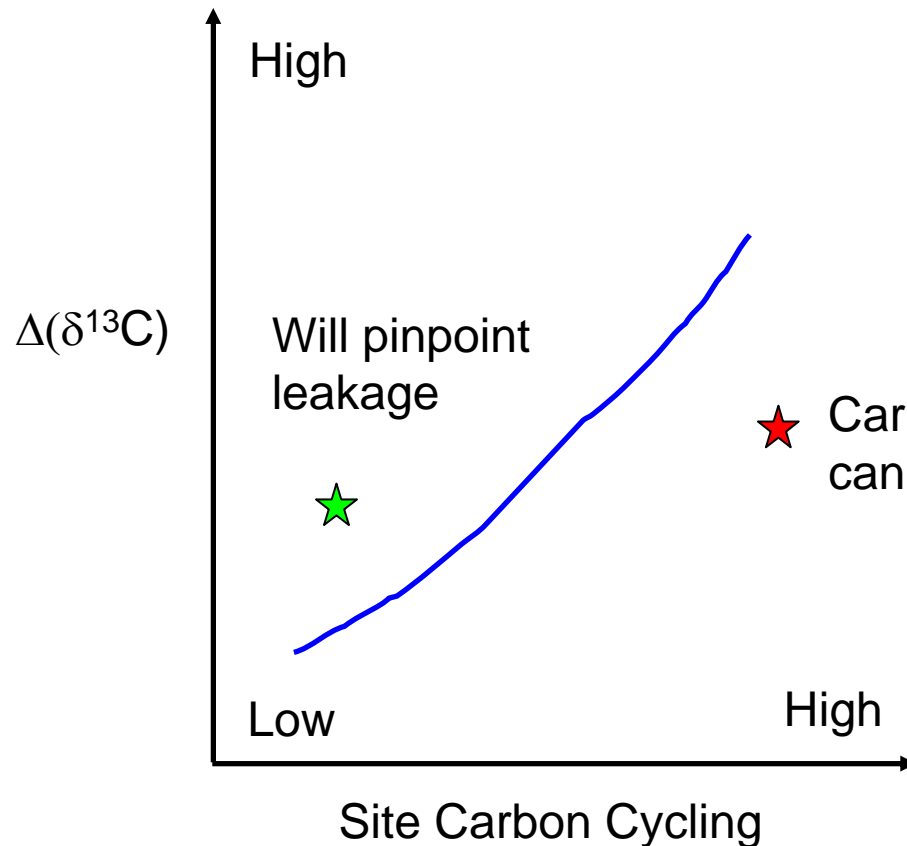
- Look for evidence of CO₂ leakage: do we have calcite dissolution?
- Trends follow dedolomitization rather than calcite dissolution as hypothesized.

Romanak, NETL meeting, 2010

CO₂ Source Identification

Bureau of Economic Geology

| End member | $\delta^{13}\text{C}$ Range |
|-------------------------------|-----------------------------|
| Injectate CO ₂ gas | 0 to -6 |
| Natural CO ₂ gas | -23 to -29 |
| Carbonate | -2 to -8 |
| Dockum Water | -4 to -13 |
| Permian water | -8 to -10 |
| Produced water | +1 to +9 |



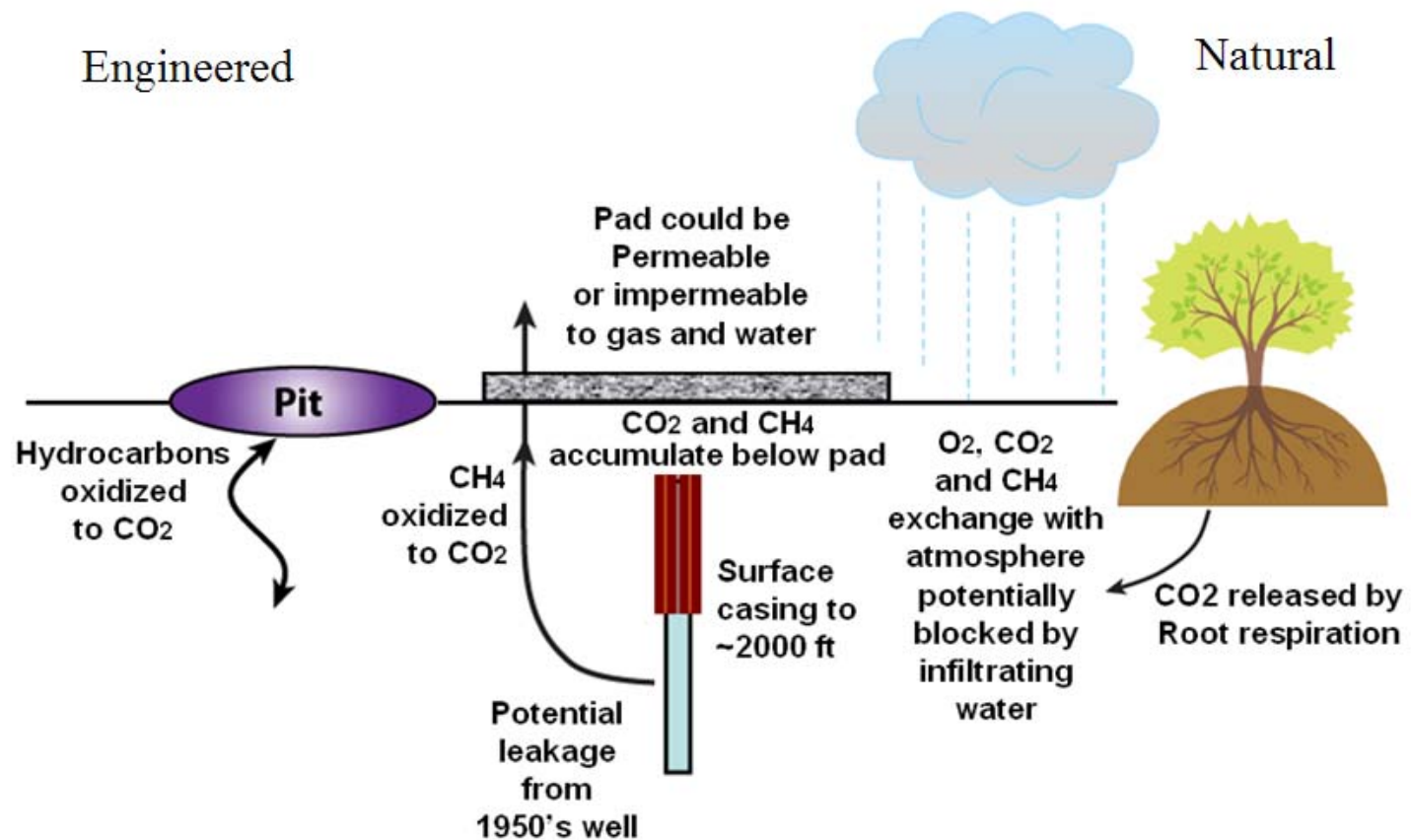
STAR EPA project
in progress at BEG



Soil gas monitoring

Bureau of Economic Geology

Conceptual Model of an Engineered Site



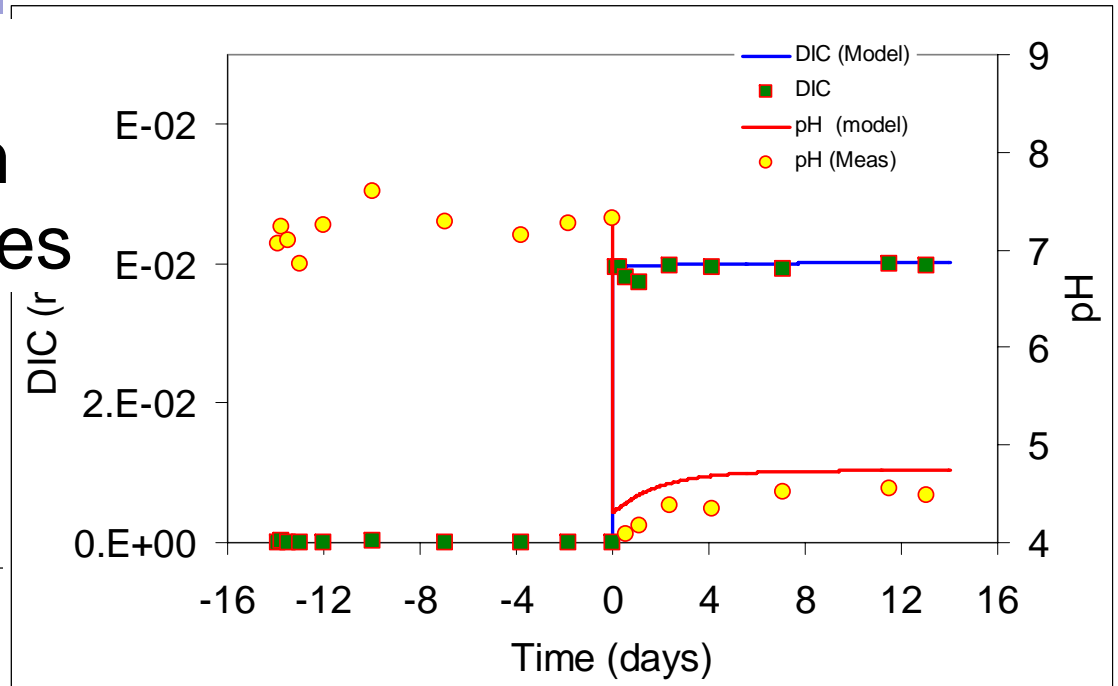
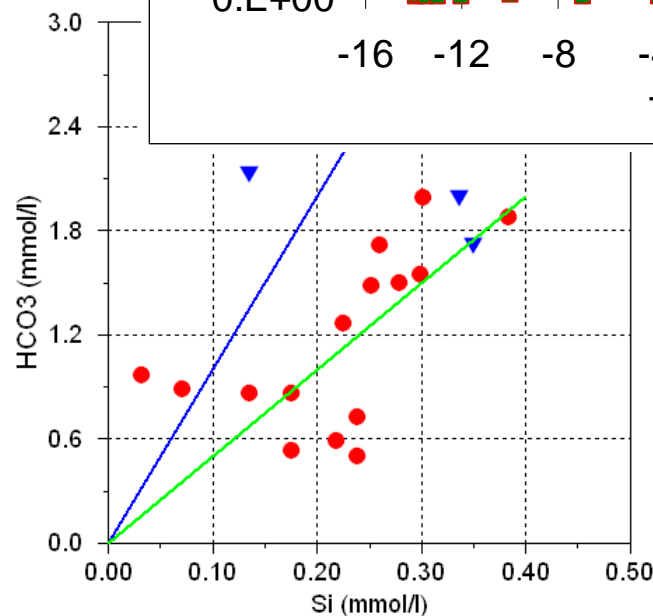
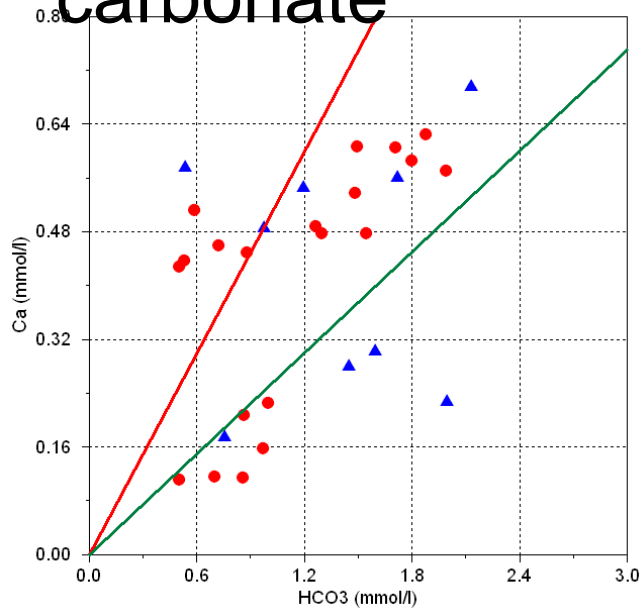
SACROC take-away points

Bureau of Economic Geology

- No evidence for injectate CO₂ in the Dockum aquifer.
- Simple carbonate systems cannot be assumed and carbonate parameters may be unreliable indicators. A complex system may not yield an unequivocal response
- Monitoring of natural parameters (pH, alkalinity, etc.) in shallow aquifers may be impractical and/or ineffective for evaluation of CO₂ storage permanence
- Carbon isotopes may have limited use for identifying CO₂ sources in shallow groundwater.
- Site-specific context is critical.
- How much leakage do we need to catch a leak? How many sampling points?

Cranfield, MS

- Very shallow aquifer:
a less complex system
pH drops, DIC increases
- Silicate weathering
dominant, very little
carbonate



Yang, 2010
NETL Meeting

Tentative standard program for geochemical monitoring

Bureau of Economic Geology

- Characterization:
Sampling of formations during well construction/well testing, use of tracers
- First line = Core = Basic = Primary
Mandatory sampling of USDWs (quarterly, continuous)
Occasional, non-systematic, opportunistic sampling of injection and above-zone formations
No introduced tracers
- If Primary parameter (geochem. or not) over agreed-upon limit
Systematic sampling of all wells
Soil gas sampling

Conclusions – Food for thought – 1/2

Bureau of Economic Geology

- It comes down to a cost/benefit analysis in terms of funding and manpower
- The challenge: how little cost-effective (geochemical) monitoring can we afford? Do we need redundant techniques?
- Geochemical monitoring could be useful at some sites but the interpretation may be too complex at others – it may simply inform other techniques

Conclusions – Food for thought – 2/2

Bureau of Economic Geology

- It is more important to know how much CO₂/brine leaves the “box” than the details of processes within the “box”
- How much of the geochemical monitoring done at research sites is needed for commercial sites?
- Is there a role for geochemical modeling (prediction then observation – batch, RTM) for commercial sites?
- Because focus is on USWDs in onshore settings, geochemical monitoring not as important for offshore sites

What is needed?

Bureau of Economic Geology

- Need more field (push-pull) tests in various settings in research mode to increase confidence for commercial sites
- Develop standards / streamlined flow-charts for regulators and non-experts
- Explore emerging issues:
 - Impact of impurities (pH)
 - Investigation of redox changes (impurities, microbes)
 - ?