

Assessing Impacts to Groundwater from CO₂-Flooding of SACROC and Claytonville Oil Fields in West Texas

GCCC Digital Publication Series #06-04

**Rebecca C. Smyth
Mark H. Holtz
Stephen N. Guillot**



Keywords:

CO₂ Flooding, Pre-Injection Hydrogeology, SACROC, Claytonville, Groundwater Hydrochemistry

Cited as:

Smyth, R. C., Holtz, M. H., and Guillot, S. N., 2006, Assessing impacts to groundwater from CO₂-flooding of SACROC and Claytonville oil fields in West Texas, *in* Proceedings of the 2006 UIC Conference of the Groundwater Protection Council, Abstract 15. GCCC Digital Publication Series #06-04.

Assessing Impacts to Groundwater from CO₂-flooding of SACROC and Claytonville Oil Fields in West Texas

Rebecca C. Smyth¹, Mark H. Holtz¹, and Stephen N. Guillot², ¹Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin, Austin, Texas, ²Kinder Morgan CO₂ Company L.P., Houston, Texas; e-mail contact: rebecca.smyth@beg.utexas.edu.

Abstract

Comparison of groundwater above two Permian Basin oil fields (SACROC Unit and Claytonville Field) near Snyder, Texas should allow us to assess potential impacts of 30 years of CO₂-injection. CO₂-flooding for enhanced oil recovery (EOR) has been active at SACROC in Scurry County since 1972. Approximately 13.5 million tons per year (MtCO₂/yr) are injected with withdrawal/recycling amounting to ~7MtCO₂/yr. It is estimated that the site has accumulated more than 55MtCO₂; however, no rigorous investigation of overlying groundwater has demonstrated that CO₂ is trapped in the subsurface. Mineralogy of reservoir rocks at the Claytonville field in southwestern Fisher County is similar to SACROC. CO₂-EOR is scheduled to begin at Claytonville Field in Fisher County in early 2007. Here we have the opportunity to characterize groundwater prior to CO₂-injection and establish baseline conditions at Claytonville.

Methods of this study will include: (1) examination of existing analyses of saline to fresh water samples collected within an eight-county area encompassing SACROC and Claytonville, (2) additional groundwater sampling for analysis of general chemistry plus field-measured pH, alkalinity, and temperature, stable isotopic ratios of hydrogen (D/H), oxygen (¹⁸O/¹⁶O), and carbon (¹³C/¹²C), and (3) geochemical equilibrium and flowpath modeling. Existing groundwater data are available from previous BEG studies, Texas Water Development Board, Kinder Morgan CO₂ Company, and the U. S. Geological Survey. By examining these data we will identify regional groundwater variability and focus additional sampling efforts. The objective of this study is to look for potential impacts to shallow groundwater from deep CO₂-injection. In the absence of conduit flow from depth, we don't expect to see impacts to shallow groundwater, but methodology to demonstrate this to regulators needs to be established.

This work is a subset of the Southwest Regional Partnership on Carbon Sequestration Phase 2 studies funded by the Department of Energy (DOE) in cooperation with industry and government partners.

Biographical Sketches

Rebecca C. Smyth holds an M. A. in geology (specialty in hydrogeology) from University of Texas at Austin and is a registered professional geologist in the State of Texas. Over the past 10 years at BEG her work has included groundwater impact studies related to oil and gas exploration and production throughout Texas and elevated levels of arsenic in south Texas.

Mark H. Holtz has more than 20 years of reservoir characterization experience at the BEG. He has focused on integration of geology and engineering in both carbonate and siliciclastic oil and gas reservoirs throughout the *U.S. Gulf Coast, the Australian Cooper and Eromanga Basins, the Vienna Basin, Venezuela, Argentina, and Mexico.*

Stephen N. Guillot is Senior Reservoir Engineer for Kinder Morgan CO₂ Co. LP. He is managing Kinder Morgan's industry support of Southwest Regional Partnership for Carbon Sequestration research studies at the SACROC Unit and Claytonville Field east of Snyder, Texas.

Assessing Impacts to Groundwater from CO₂-flooding of SACROC and Claytonville Oil Fields in West Texas

BEG SWCARB Project

**Rebecca C. Smyth, Mark H. Holtz,
and Stephen N. Guillot**

**with acknowledgments to:
Jean-Philippe Nicot, Susan D. Hovorka, and others**

**Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin
and Kinder Morgan CO₂ Company L.P.,
Houston, Texas**

Overview of Hydrogeologic Study

BEG SWCARB Project

- Eight county study area encompasses SACROC (Scurry Area Canyon Reef Operations Committee) Unit and Claytonville fields in west Texas,
- Physical and chemical data sources on groundwater (fresh to saline) include: previous BEG studies, Texas Water Development Board (TWDB), Kinder Morgan CO₂, and U. S. Geological Survey,
- Identify regional variability in physical and hydrogeochemical properties of groundwater from existing analyses,
- Conduct additional sampling for major ion, total organic carbon, stable isotopes of hydrogen (D/H), oxygen (¹⁸O/¹⁶O), and carbon (¹³C/¹²C); pH, temperature, and alkalinity field measurements, might install two new water wells in Claytonville,
- Look for geochemical evidence of mixing starting with simple approach: decreased pH, decreased temperature, ion plots,
- Geochemical equilibrium and flowpath modeling to identify groundwater mixing. Models being considered include: PHREEQC, SOLMNEQ.88, EQ3/EQ6, Geochemist's Workbench.

Background

BEG SWCARB Project

- **SMALL subset** of Southwest Regional Partnership on Carbon Sequestration Phase 2 studies funded by Department of Energy (DOE) in cooperation with industry (Kinder Morgan CO₂) and government (New Mexico Tech, and LANL) partners. BEG water portion is a four-year project (50% time years 1&2, 25% time years 3&4).
- Since 1972, ~13.5 million tons per year (MtCO₂/yr) injected at SACROC with withdrawal and recycling amounting to ~7MtCO₂/yr. Estimated that site has accumulated more than 55MtCO₂.
- CO₂ sources in southwestern Colorado and northern New Mexico for which there are stable isotopic data available in literature.

Regional Geologic Setting

BEG SWCARB Project

SACROC Unit

- ~55 million tons CO₂ trapped in subsurface since injection began in 1972
- Reservoir horizon = 6,700 ft bgl

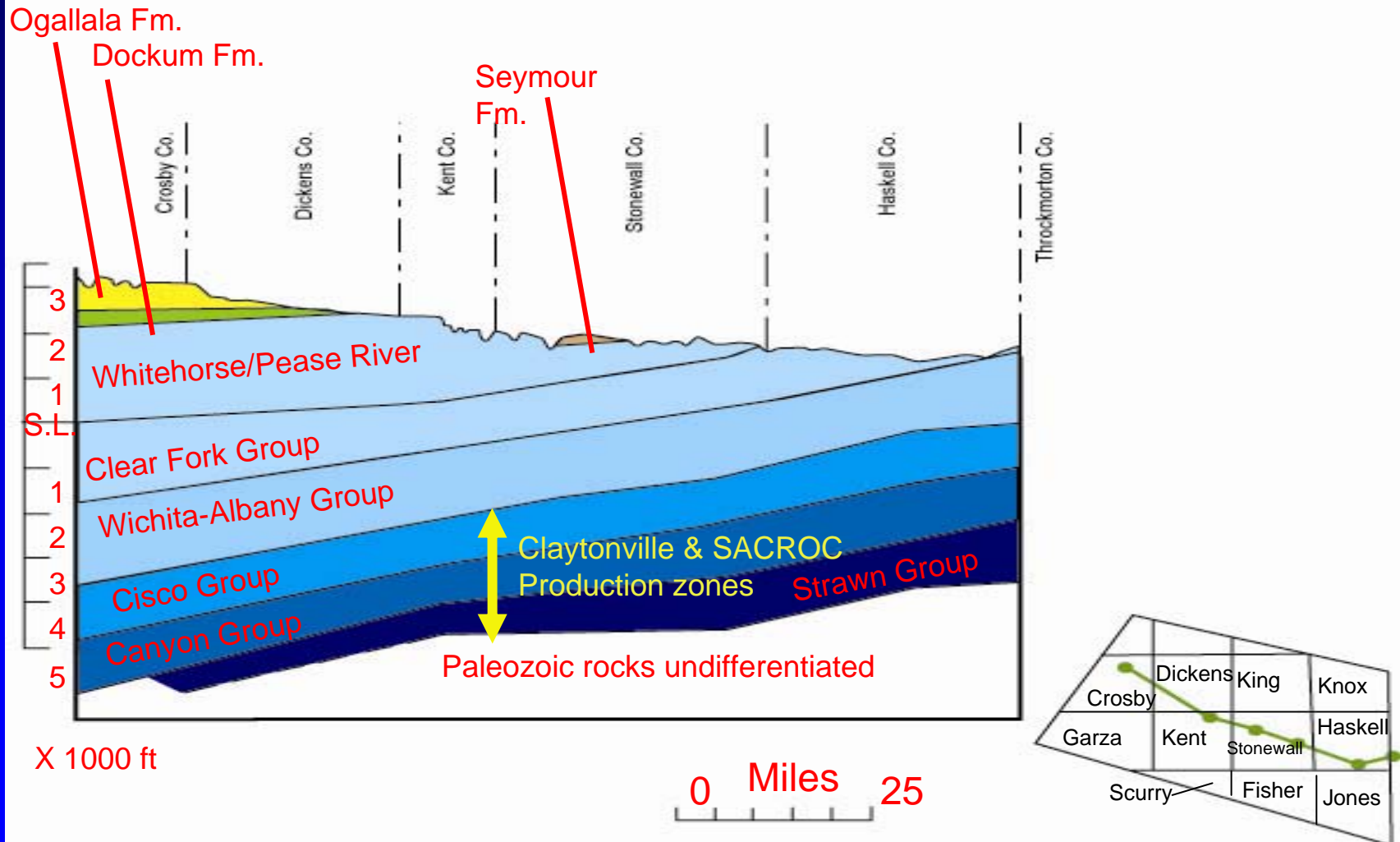
Claytonville Field

- CO₂ injection scheduled for early 2007
- Reservoir horizon = 5,700 ft bgl



Eastern Shelf Stratigraphy

BEG SWCARB Project



modified from Duffin and Benyon, 1992, TWDB Report No. 337

Overview of Hydrogeologic Study

BEG SWCARB Project

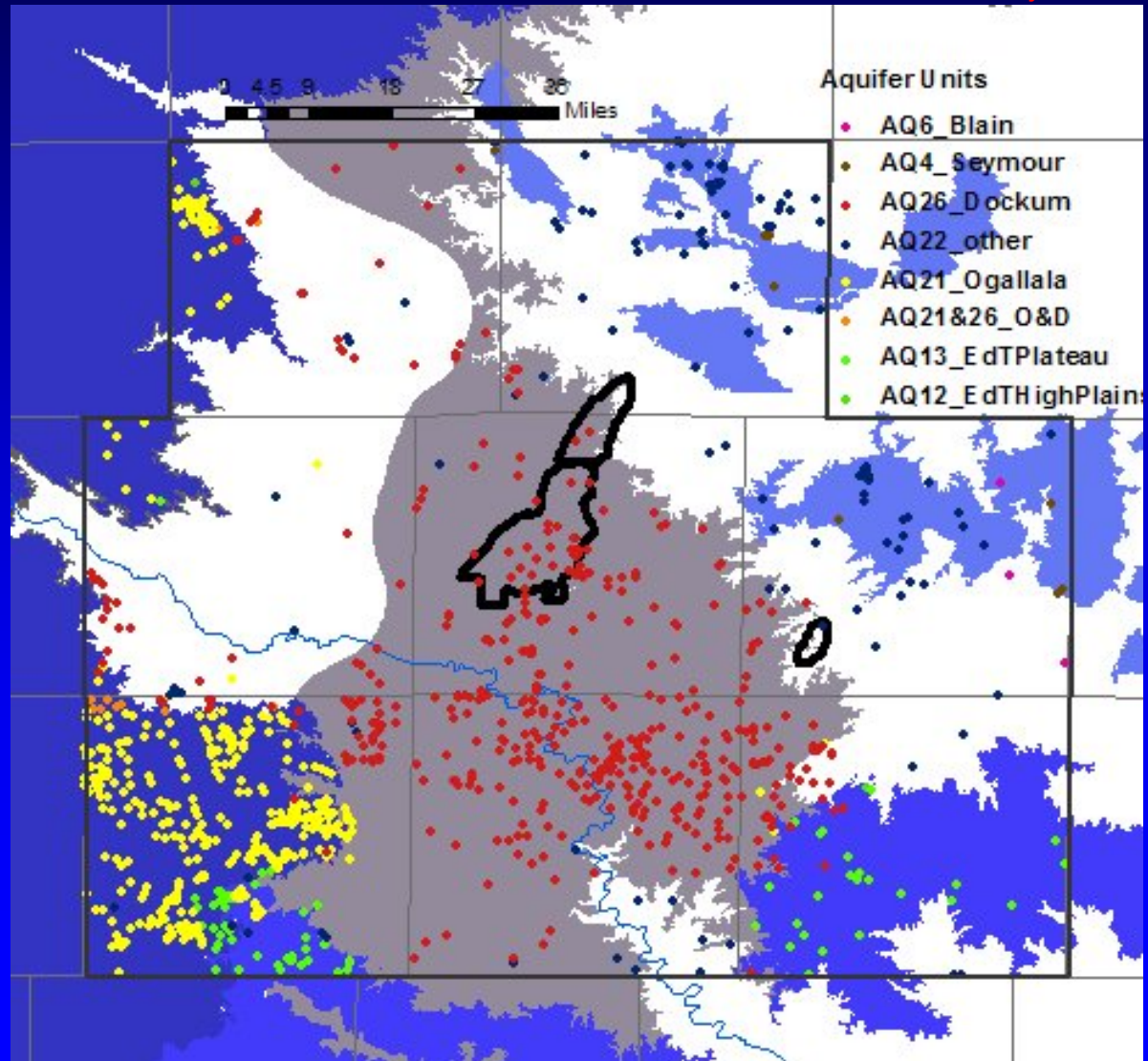
- Eight county study area encompasses SACROC (Scurry Area Canyon Reef Operations Committee) Unit and Claytonville fields in west Texas,
- Physical and chemical data sources on groundwater (fresh to saline) include: previous BEG studies, Texas Water Development Board (TWDB), Kinder Morgan CO₂, and U. S. Geological Survey,
- Identify regional variability in physical and hydrogeochemical properties of groundwater from existing analyses,
- Conduct additional sampling for major ion, total organic carbon, stable isotopes of hydrogen (D/H), oxygen (¹⁸O/¹⁶O), and carbon (¹³C/¹²C); pH, temperature, and alkalinity field measurements. Might install two new water wells in Claytonville,
- Look for geochemical evidence of mixing starting with simple approach: decreased pH, decreased temperature, ion plots,
- Geochemical equilibrium and flowpath modeling to identify groundwater mixing. Models being considered include: PHREEQC, SOLMNEQ.88, EQ3/EQ6, Geochemist's Workbench.

Study Area, TWDB Major and Minor Aquifers, TWDB Wells, and Oil Fields

BEG SWCARB Project

Eight County
Study Area
(upper left to
lower right)

Garza
Kent
Borden
Scurry
Fisher
Howard
Mitchell
Nolan



TWDB Aquifer Data in Eight County Area

BEG SWCARB Project

Aquifer	# wells	min t.d. (ft bgl)	max t.d. (ft bgl)	# old wq
Seymour	29	34	120	16
Ogallala	541	8	316	435
Cretaceous undiff.	248	20	665	90
Ogallala & Dockum	25	47	750	10
Dockum	1354	4	1510 (4807)	468
Permian	7	30	90	3
Other (P & K)	275	10	275	121
Not Applicable	213	990	8501	2

Overview of Hydrogeologic Study

BEG SWCARB Project

- Eight county study area encompasses SACROC (Scurry Area Canyon Reef Operations Committee) Unit and Claytonville fields in west Texas,
- Physical and chemical data sources on groundwater (fresh to saline) include: previous BEG studies, Texas Water Development Board (TWDB), Kinder Morgan CO₂, and U. S. Geological Survey,
- Identify regional variability in physical and hydrogeochemical properties of groundwater from existing analyses,
- Conduct additional sampling for major ion, total organic carbon, stable isotopes of hydrogen (D/H), oxygen (¹⁸O/¹⁶O), and carbon (¹³C/¹²C); pH, temperature, and alkalinity field measurements. Might install two new water wells in Claytonville,
- Look for geochemical evidence of mixing starting with simple approach: decreased pH, decreased temperature, ion plots,
- Geochemical equilibrium and flowpath modeling to identify groundwater mixing. Models being considered include: PHREEQC, SOLMNEQ.88, EQ3/EQ6, Geochemist's Workbench.

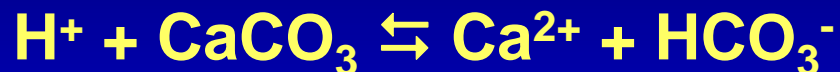
Hydrogeologic Units

AGE	GEOLOGIC UNIT	THICKNESS (FT)	ROCK TYPE
Quaternary	Alluvium	60	Coarse-grained clastic
	Seymour Fm.	125	Coarse-grained clastic
Tertiary	Ogallala Fm.	?	Medium grained clastic
Cretaceous	Fredericksburg/		Fossiliferous carbonate,
	Washita Groups	?	Carbonate mud
	Trinity Group	?	Cs. Gr. clastic, evaporites
Triassic	Dockum Fm.	400	Fn.-med. gr. clastic, evaporites
Permian	Whitehorse/Pease		Fn.-med. Clastic,
	River Groups	1,900	Carbonate, evaporite
	Clear Fork Group	1,800	Fn. Clastic, evaporite
	Wichita-Albany Gp.	1,400	Carbonate mud
Pennsylvanian	Cisco Group	1,200	Fn.-Cs. Clastic, coal,
	Canyon Group	1,600	Carbonate
	Strawn Group	2,500	Fn.-Cs. Clastic, minor carbonate

Potential Fluid-Rock Interactions in Production Zone

BEG SWCARB Project

Representative Reactions



Dissolution of calcite may buffer changes to pH and cause an increase in bicarbonate (HCO_3^-)

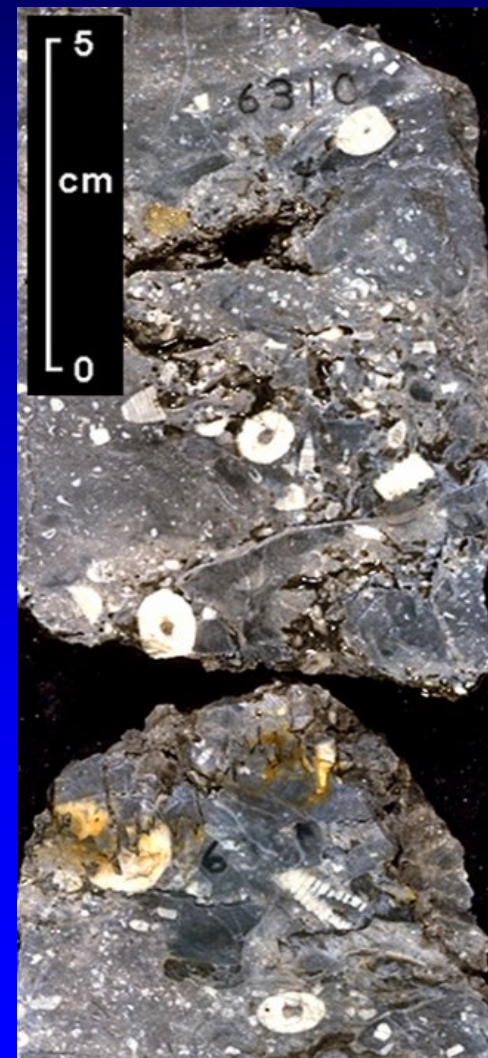


Oxidation of organic acids contributes to alkalinity.

Cannot assume all alkalinity is from carbonate species, especially in production zone.

Willey and Kharaka (1975), Kharaka et al. (2005), and Hovorka et al. (in press), Gunter et al. (2000)

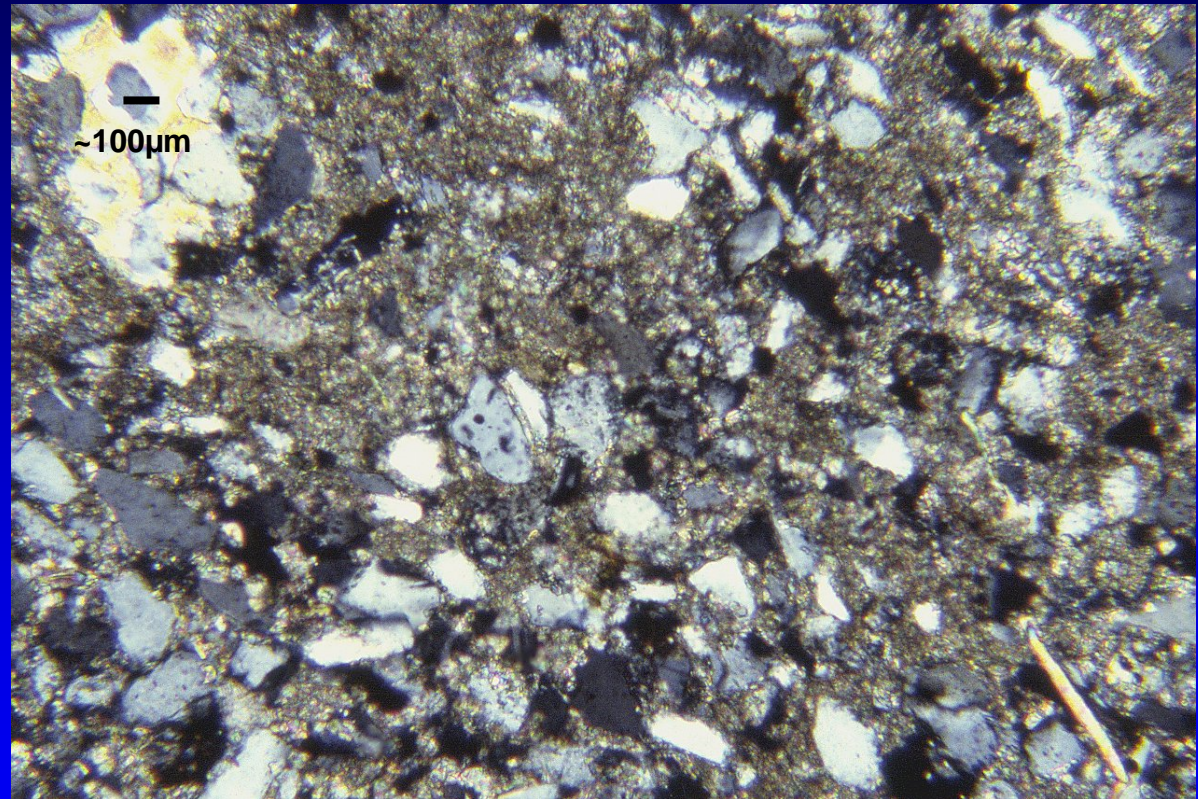
Right: production zone, fossil-rich carbonate core.



Potential Rock-Water Interactions in Units Overlying Production Zone

BEG SWCARB Project

right: thin section photomicrograph (cross-polarized light) of Upper Guadalupian (Permian) carbonate cemented sandstone



Representative Reactions

$\text{CaAl}_2\text{Si}_2\text{O}_8 + \text{CO}_2 + 2\text{H}_2\text{O} \rightleftharpoons \text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4 + \text{CaCO}_3$ = Dissolution of anorthite (Calcic plagioclase) to kaolinite (clay) and calcite.

$2\text{H}^+ + \text{CaMg}(\text{CO}_3)_2 \rightleftharpoons \text{Ca}^{2+} + \text{Mg}^{2+} + 2\text{HCO}_3^-$ = Dissolution of dolomite cement

Land and MacPherson (1992), Kharaka et al. (2005), and Hovorka et al. (in press)

Summary

BEG SWCARB Project

Hypothesis: CO₂ will be consumed/neutralized through hydrodynamic, capillary, solubility or mineral trapping at or near reservoir horizons.

This hypothesis assumes depths >800 m (supercritical CO₂) and very slow groundwater flow rates (Bachu et al., 1994), BUT what if corroded casing or compromised wellbore integrity result in cross-formational conduit flow upward to drinking water zone?

Also, this argument is stronger for clastic aquifers than it is for carbonate aquifers because carbonate minerals dissolve and re-precipitate faster than silicate minerals (Gunter et al., 2000) so we need to test samples from wells completed in single aquifers, not from wells completed across both carbonate and clastic aquifers.

UT SW CARB Water Group Objective: Groundwater study looking for impacts from deep CO₂-injection and potential risks to drinking water. In the absence of conduit flow, which will likely be in isolated areas, we don't expect to be able to detect impacts to shallow groundwater, but methodology to demonstrate this to regulators needs to be established.

Summary

BEG SWCARB Project

- Looking for evidence of mixing of deeper and shallow groundwater by either diffusion or conduit flow. At SACROC we have some chance of seeing mixing. At Claytonville we will be establishing background water quality.
- First must characterize regional variability of intermediate to shallow groundwater chemistry vertically and horizontally.
- Collect new groundwater samples quarterly for approximately three years to establish seasonal variation,
- Simple (comparison of ion concentration ratios to more complex analyses (geochemical modeling),
- I'm looking forward to applying accepted methodologies in groundwater study to the new application of CO₂ sequestration.
- Please provide comments or suggestions.