

Geochemical investigation of shallow groundwater over SACROC oilfield

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Geochemical Investigation of Shallow Groundwater Over SACROC Oilfield

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Significance of Study Area

CO₂

~150 MMt CO₂
injected ~75 MMt CO₂
recovered

Trapped in
injection zone?

Mobilized outside
of injection zone?

Time

Natural Analogues

Geologic time span

Naturally over-
pressured reservoir

Engineered Injection

Short time span

Artificially over-
pressured reservoirs

Research Questions

1. Has CO₂ from 36 years of EOR at SACROC entered the Dockum aquifer?
2. What parameters can be used to detect injected CO₂ in shallow aquifers, especially at low concentrations?
3. Has CO₂ affected ground water quality above SACROC?

Broad Implications

Performance

- Can we distinguish leakage through geologic seals from leakage through wells?
- Impact from CO₂-charged brine movement due to increased pressure?
- What factors affect the success of EOR as a method of sequestration?

Monitoring

- What geochemical parameters will detect CO₂ in complex systems?
- What are the lowest concentrations of injected CO₂ that can be detected in complex systems?

Approach

Conventional

Characterize background conditions before injection

Compare background with geochemical changes during and after injection

Examples:
deep storage formation- Frio
shallow groundwater - ZERT

SACROC Study

No opportunity for pre-injection sampling

Temporal

Limited TWDB data pre-CO₂ injection
Long-term samples outside SACROC.
Minimal geochemical parameters.

Spatial

Inside vs. outside SACROC.
Limited capability for spatial background comparison. Due to abundant regional oilfield activity +/- CO₂ injection.

Approach

Work in Progress:

Compare geochemistry inside versus outside SACROC.

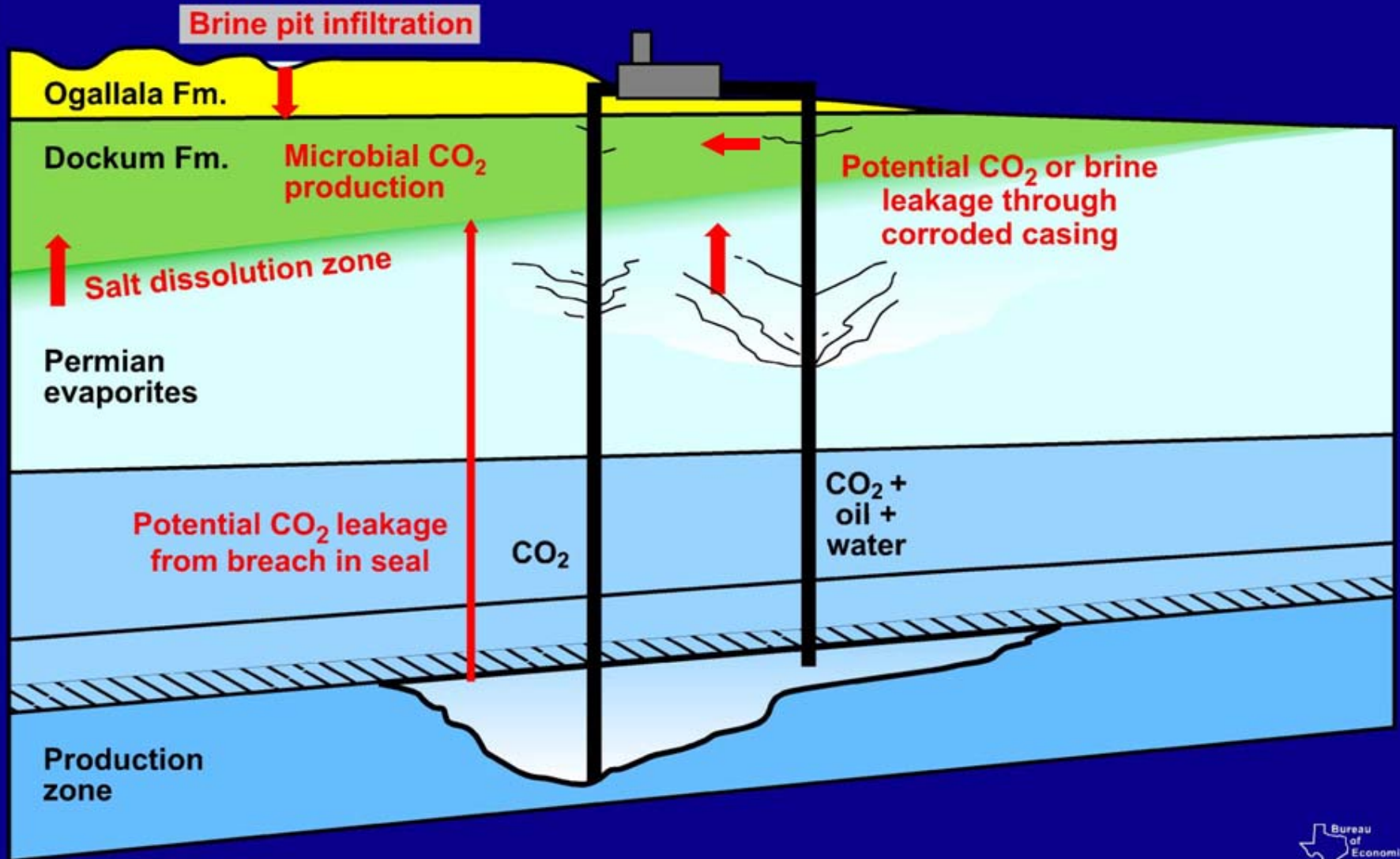
Examine temporal trends that link pre and post injection.

Compare geochemistry to EPA drinking water standards.

Preliminary Results:

- **No definitive evidence of injectate CO₂ in Dockum aquifer.**
- **No definitive evidence of degradation of ground water quality due to CO₂.**

Potential Influences



Specific Parameters of Interest

- Injectate and/or microbial CO_2 : PCO_2 , DIC, HCO_3^- , carbon isotopes, pH

Dissolved inorganic carbon (DIC) = C_t or total inorganic carbon

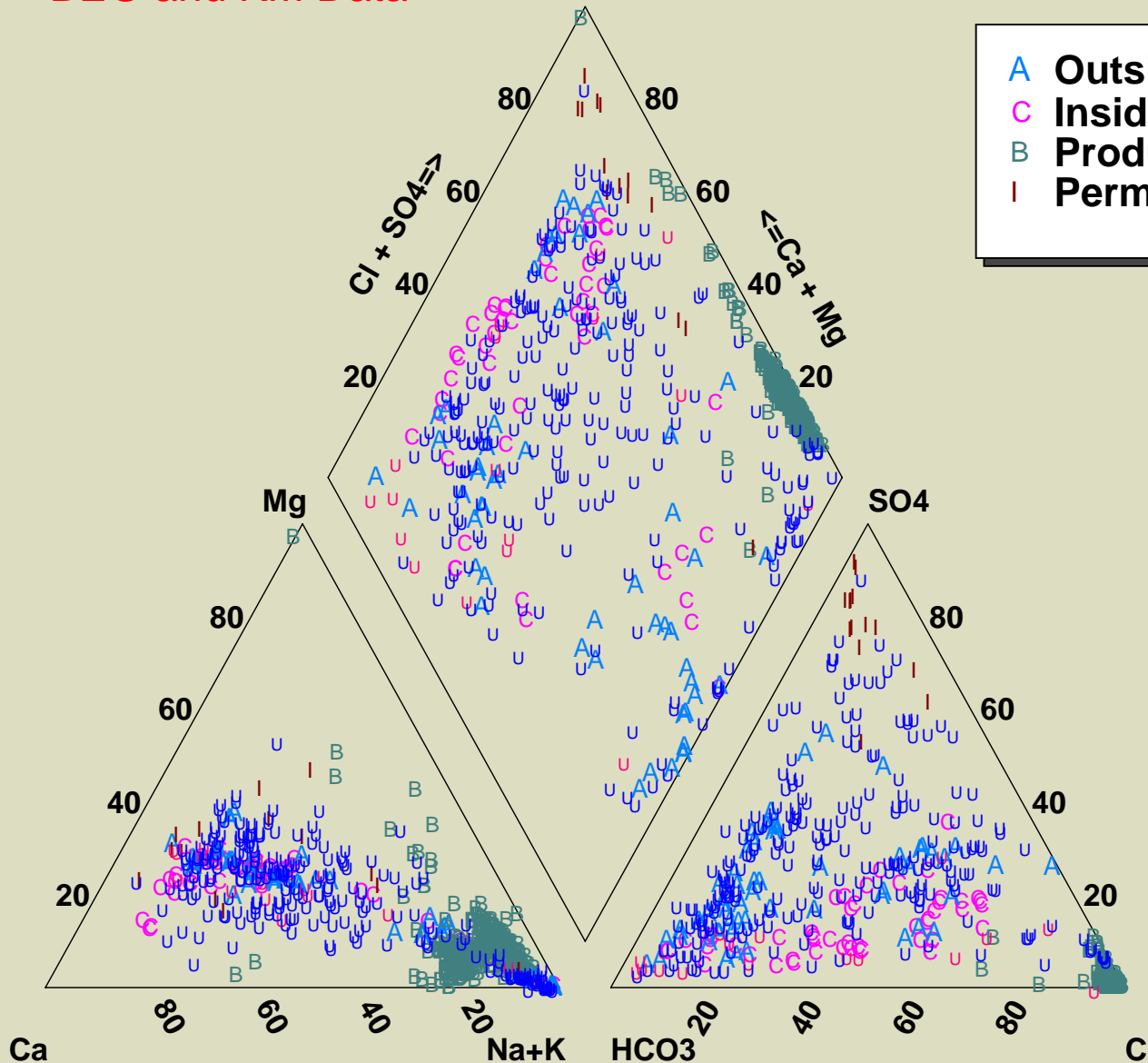
Alkalinity = concentration of titratable bases

HCO_3^- = one of 3 carbonate species that make up DIC

- Mineral dissolution: Ca^{2+} , Mg^{2+} , Si, HCO_3^- , mineral saturation indices, pH
- CO_2 mobilization of metals: Pb^{2+} , As, Ba^{2+} , Cd, Hg^{2+} , Sb, Se, U and Zn^{2+}
- Oilfield brine: Na^+ , Cl^- , Br^-
- Underlying Permian evaporites: Ca^{2+} , SO_4^{2-}

Geochemical Relationships

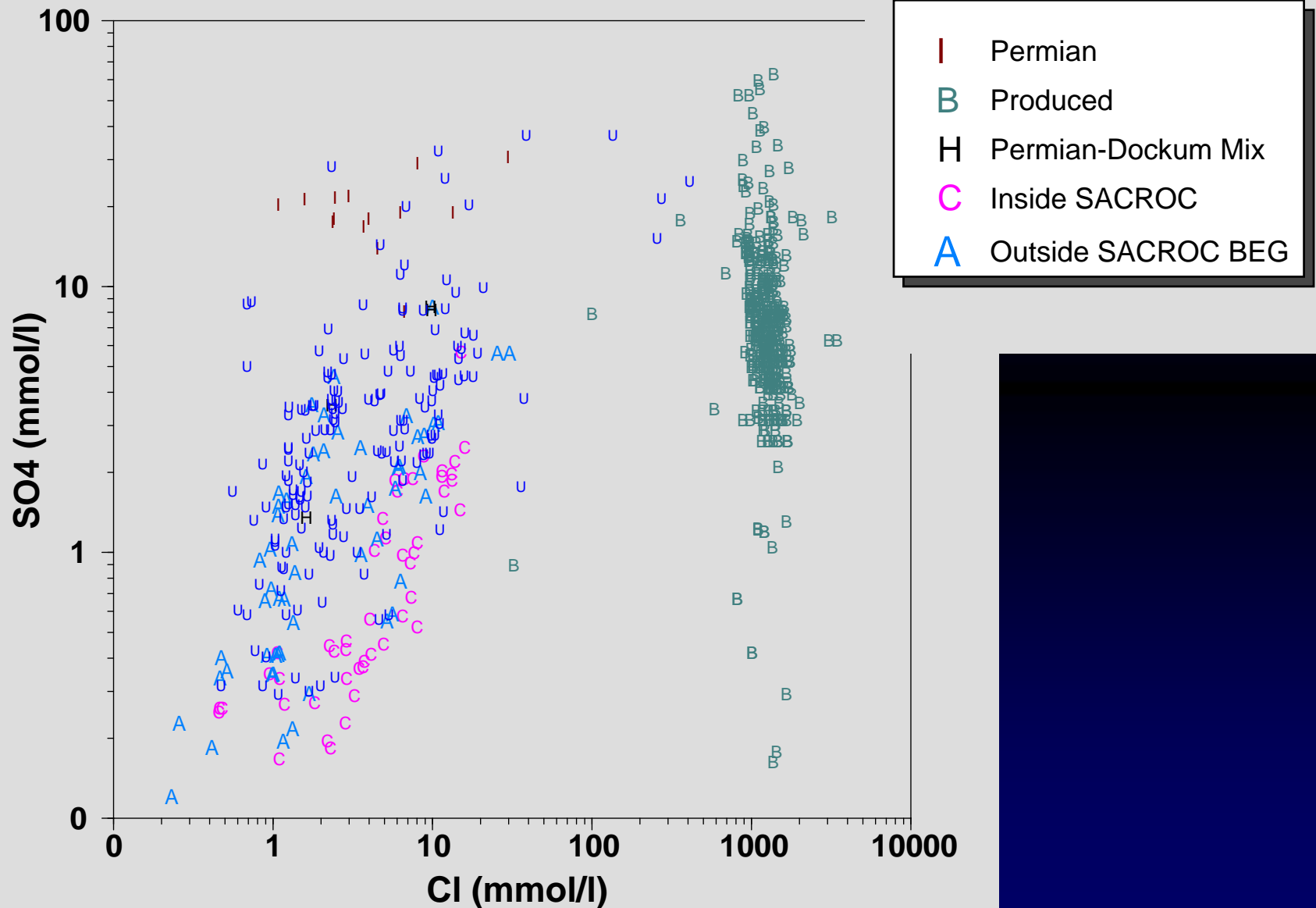
BEG and KM Data



- A Outside SACROC BEG
- C Inside SACROC
- B Produced
- I Permian

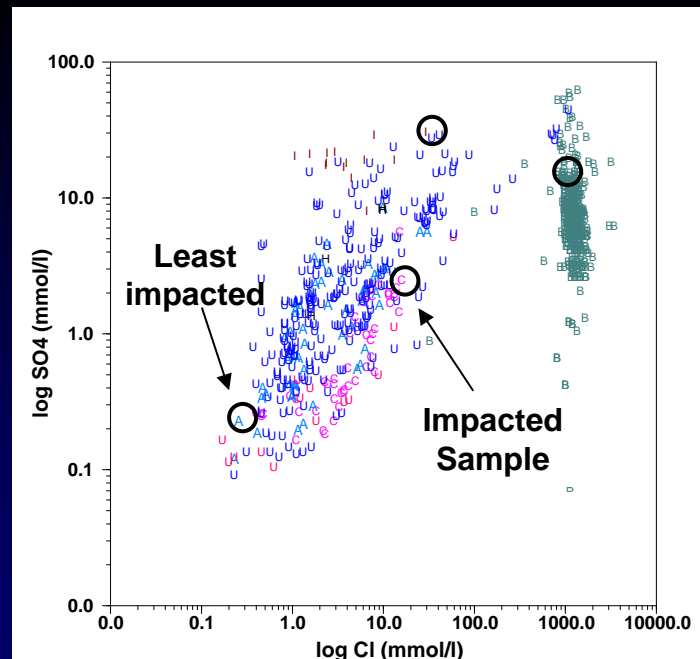
No distinction
between samples
collected inside
SACROC and
regional Dockum
trends.

Components of Dockum Water



Mixing Model

	Non-impacted		Production	Calculated	Impacted
	Dockum	Permian	(77-9p)	Mixture	Sample
	(Hint-Herm)				(House)
SO4	21.8	1332	750.6	187	188
Cl	9.41	172	50532	433	471
Br	0.05	1.25	276	2.4	2.2
mixing fraction	87.00%	12.20%	0.80%		



Modeling assistance
from Changbing Yang

Effects of Mixing on Carbonate Geochemistry

Brine infiltration into carbonate aquifer initiates cation exchange.

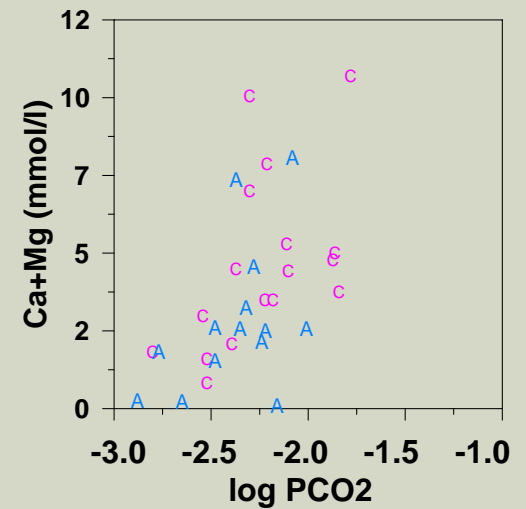
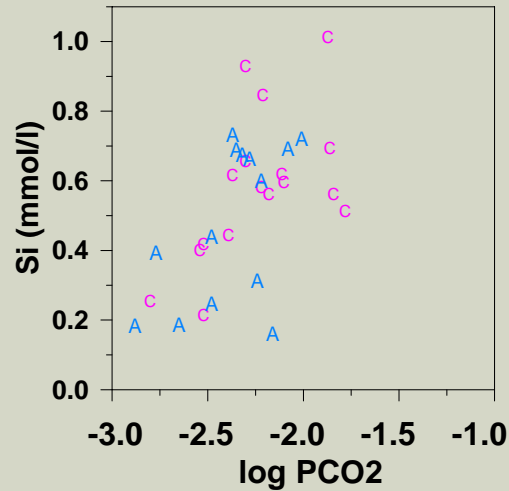
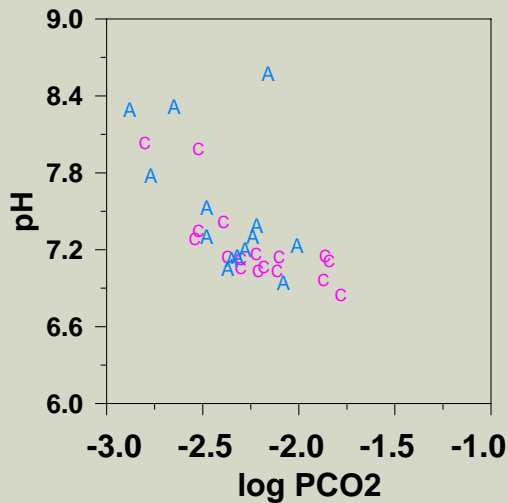


Addition of calcium ions
drives calcite precipitation



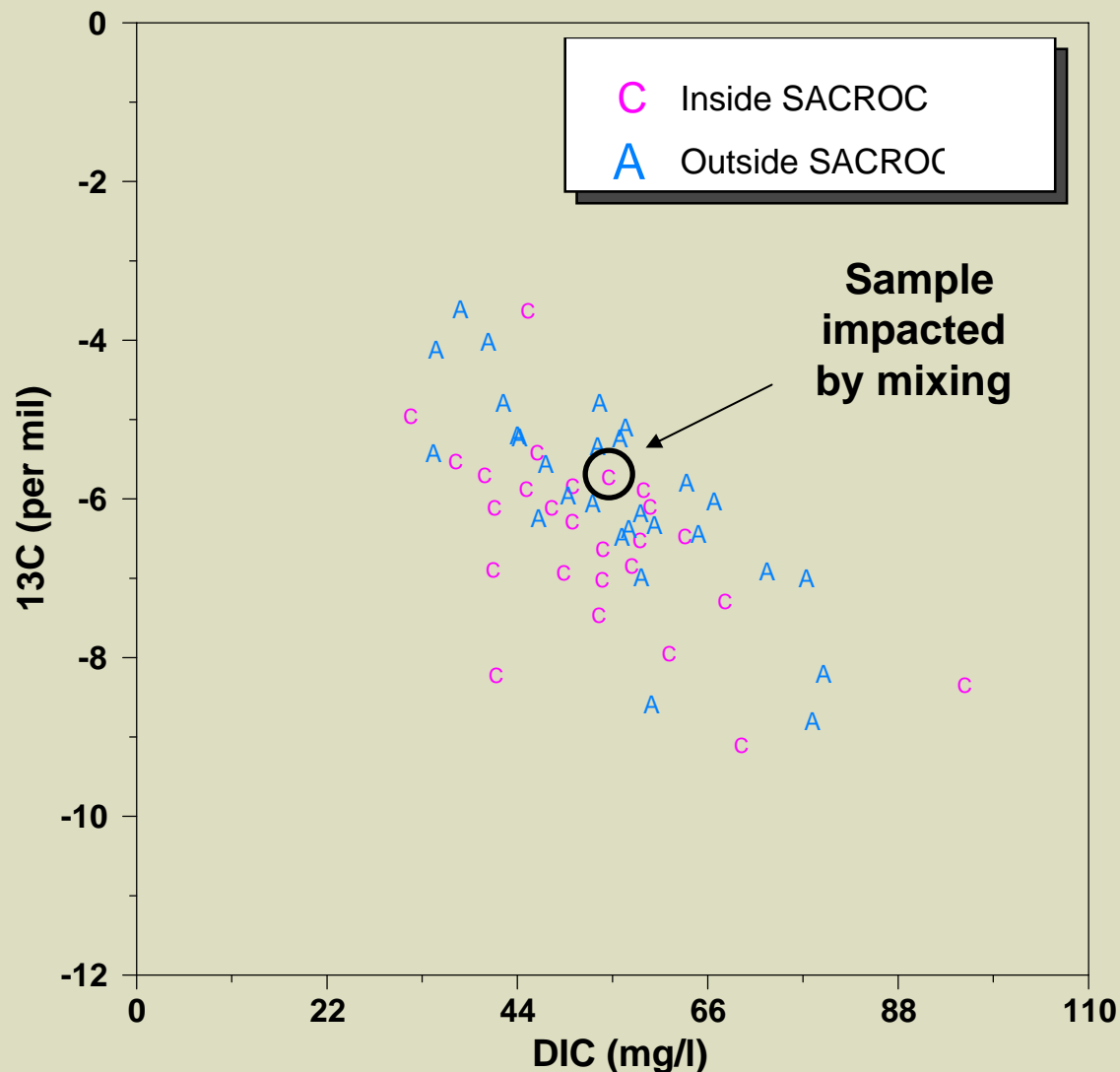
CO₂ Controls on Carbonate & Silicate Geochemistry

C Inside SACROC
A Outside SACROC BEG



Increasing CO₂ →

Carbon Isotopes



Collected to date:

Injectate CO_2
(-6.1 to - 0.5 per mil)

Dockum ground water
(-13.2 to -3.6 per mil)

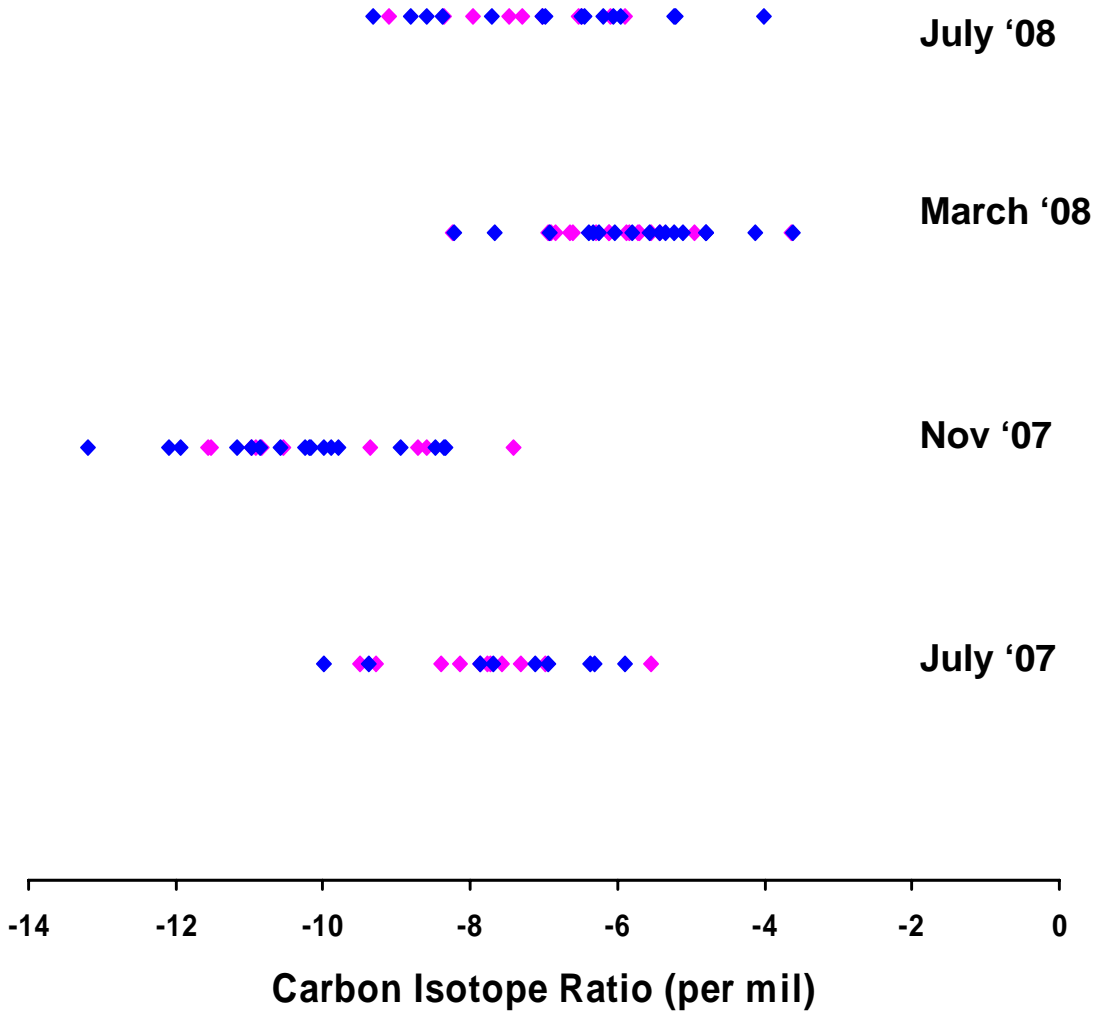
Produced water
(1.3 to 9.0 per mil)

Plant material
(-23.5 to -28.8 per mil)

Still needed:

Solid phase carbonate

Isotope Variations



Water Quality

114 samples, 61 wells,
Water is filtered

Analyte	EPA/TCEQ Drinking Water Standard (mg/L)	BEG Samples Exceeding EPA Standards	BEG Samples Exceeding EPA Standards - Inside SACROC	BEG Samples Exceeding EPA Standards - Outside SACROC
<u>Primary Maximum Contaminant Level (MCL)</u>				
Arsenic (As)	0.01	5.3 %	0.9 %	4.4 %
Cadmium (Cd)	0.005	0.9 %	0	0.9 %
Fluoride (F ⁻)	0.4	2.6 %	0.9 %	1.8 %
Nitrate (NO ₃ -N)	10	7.0 %	2.6 %	4.4 %
Selenium (Se)	0.05	2.6 %	0.9 %	1.7 %
<u>Secondary Drinking Water Standard</u>				
Aluminium (Al)	0.05	18.4 %	7.0 %	11.4 %
Chloride (Cl ⁻)	250	17.5 %	7.9 %	9.6 %
Fluoride (F ⁻)	0.2	20.2 %	7.9 %	12.3 %
Manganese (Mn)	0.05	7.9 %	2.6 %	5.3 %
Sulfate (SO ₄ ²⁻)	250	14 %	0.9 %	13.1 %
Total Dissolved Solids (TDS)	1000	27.2 %	9.7 %	17.5 %

Conclusions

**Has CO₂ from 36 years of
EOR at SACROC entered the
Dockum aquifer?**

Evidence of minimal CO₂ impacts.

Currently no source identification.

Must understand isotope systematics

Conclusions

How can we detect injected CO₂ in the Dockum, especially at low concentrations?

CO₂ indicators (headspace gas, HCO₃, field Alkalinity, DIC, pH)	Major Elements	Carbon isotopes	Trace metals
Direct/Indirect measurement of inorganic carbon	Give the geochemical big picture	Distinguish CO₂ source	Indicate mobilization predicted by experiments and define water quality
Not yet but holds promise	Yes to a degree - supports dissolution relationships & indicates mixing	Not yet- Need more data Sort out variations	Yes, very helpful to understanding metal mobilization as a function of CO₂

Conclusions

Has CO₂ affected ground water quality above SACROC?

Samples inside SACROC are not geochemically distinct from samples outside SACROC except for TDS and Cl concentrations.

TDS impact in SACROC is volumetrically small and very common in oilfields.

Minimal degradation of water quality with respect to EPA standards exists inside SACROC and is comparable to degradation observed outside SACROC.

Future Work

- **Model carbon isotopes to determine the source of CO₂.**
- **Perform a sensitivity analysis to determine the amount of CO₂ that could be detected in this geochemically complex system.**
- **Investigate the source of temporal variation observed in BEG carbon isotope data.**
- **Relate temporal geochemical trends (TWDB data) to historical CO₂ injection.**