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Geochemical investigation of shallow groundwater over SACROC oilfield

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Geochemical Investigation of Shallow Groundwater Over SACROC Oilfield

Prepared by: Gulf Coast Carbon Center at the Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin

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Significance of Study Area

CO_2

~150 MMt CO_2 injected ~75 MMt CO_2 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 CO_2 from 36 years of EOR at SACROC entered the Dockum aquifer?

2. What parameters can be used to detect injected CO_2 in shallow aquifers, especially at low concentrations?

3. Has CO_2 affected ground water quality above SACROC?

Broad Implications

Performance

- Can we distinguish leakage through geologic seals from leakage through wells?
-Impact from CO_2-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 CO_2 in complex systems?
- What are the lowest concentrations of injected CO_2 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-CO_2 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 +/- CO_2 injection.

Approach

Work in Progress:

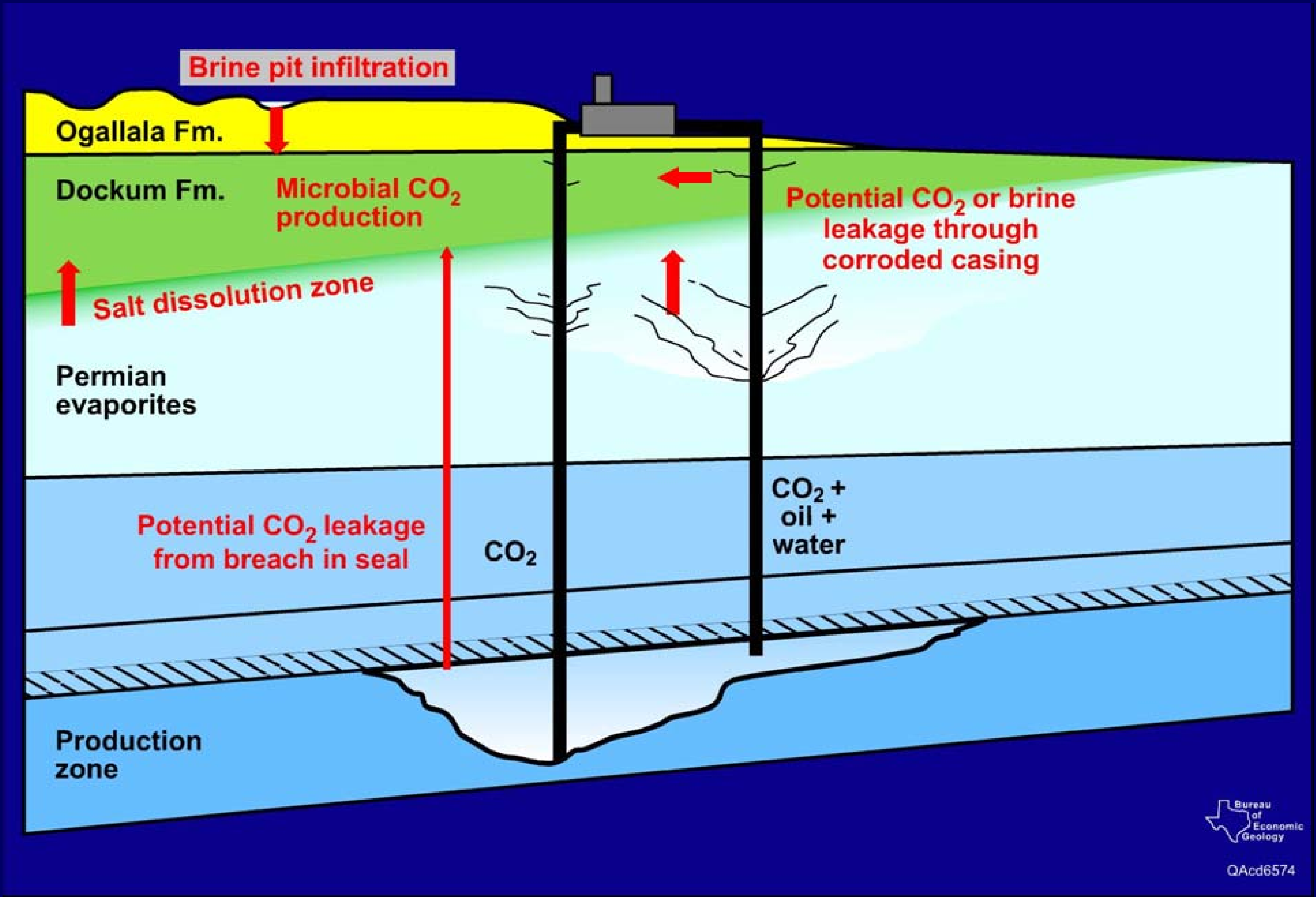
Compare geochemistry inside versus outside SACROC.
Examine temporal trends that link pre and post injection.
Compare geochemistry to EPA drinking water standards.

Preliminary Results:

- No definitive evidence of injectate CO_2 in Dockum aquifer.

- No definitive evidence of degradation of ground water quality due to CO_2.

Potential Influences



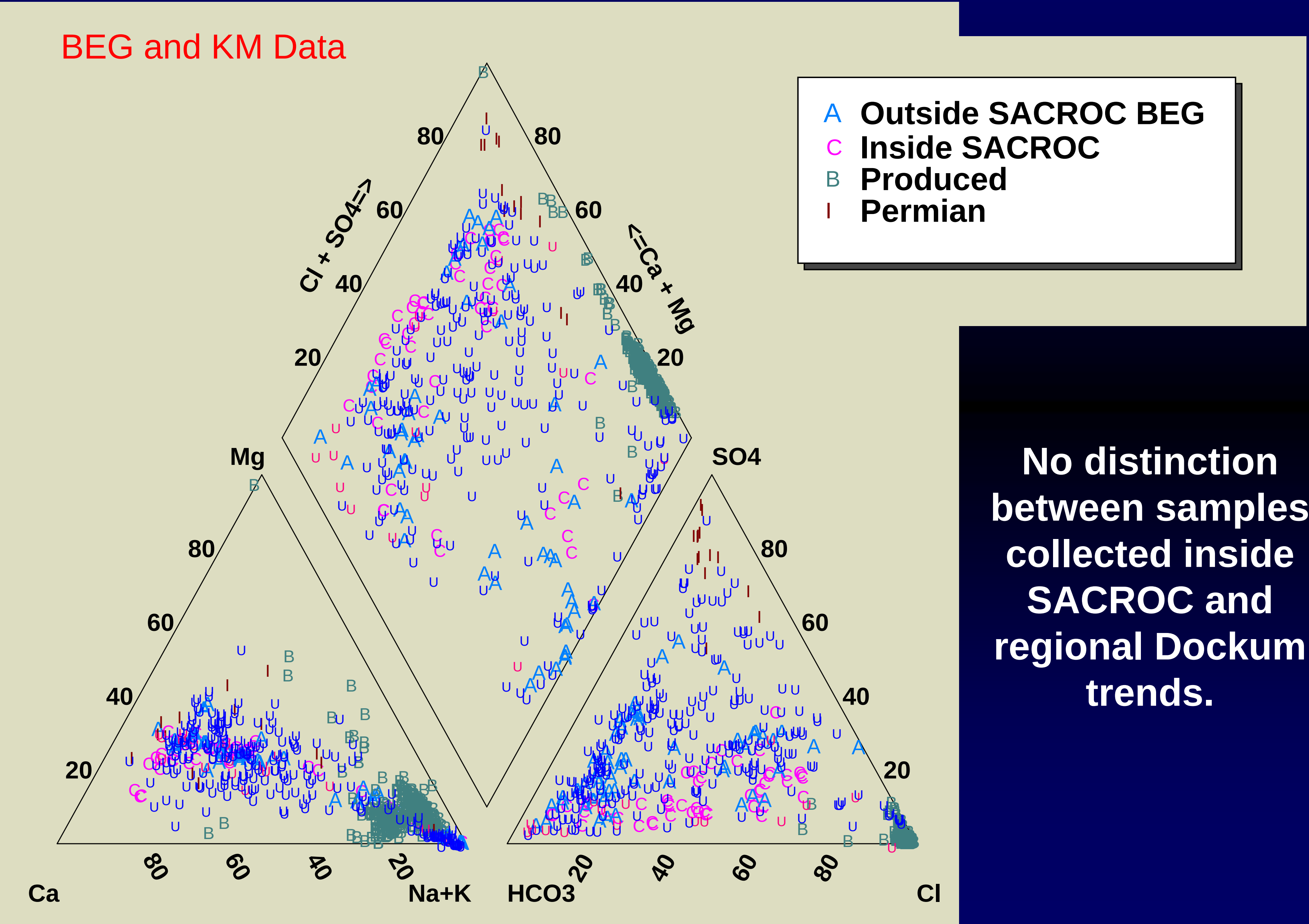
Specific Parameters of Interest

- 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

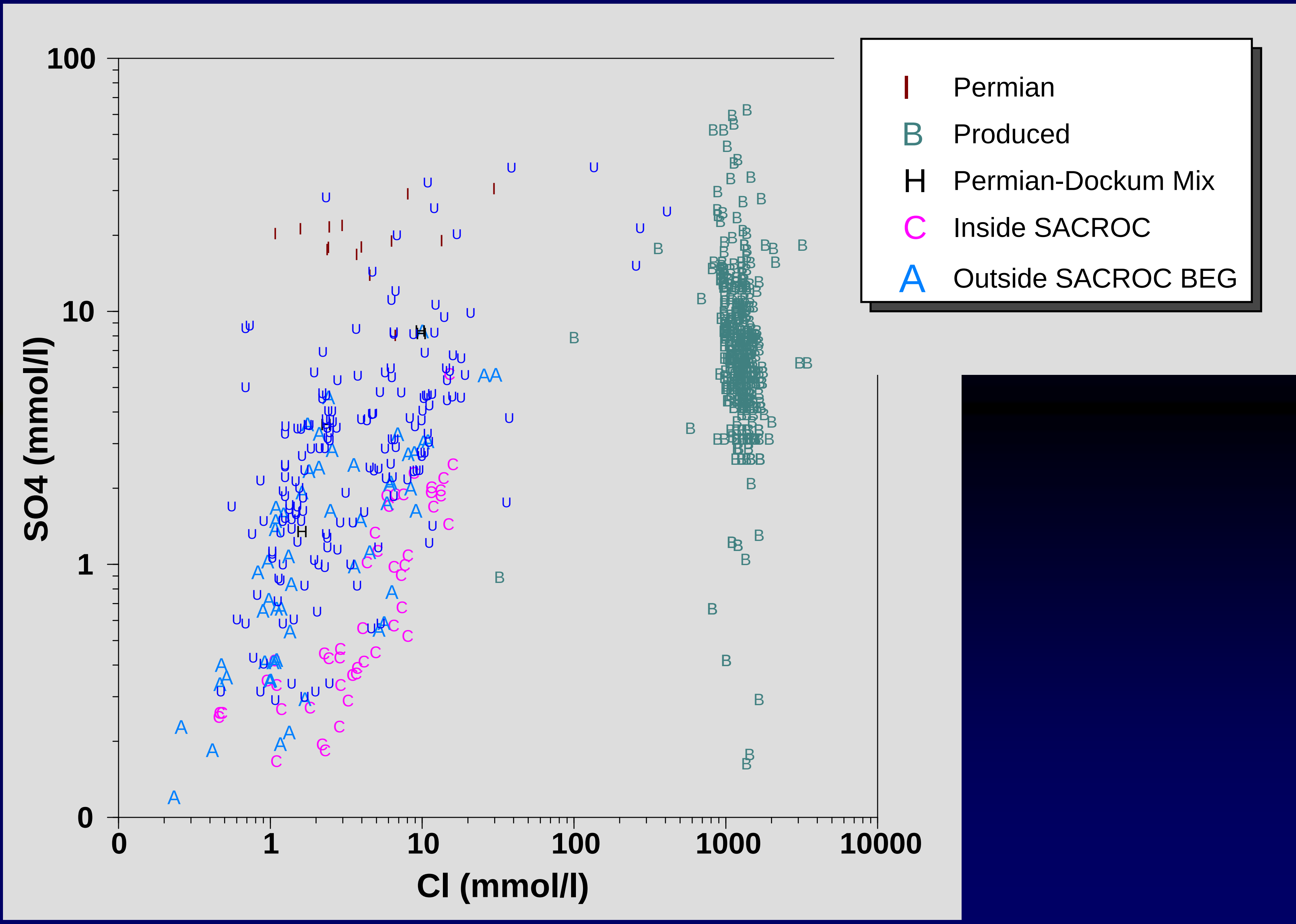
- Mineral dissolution: Ca^{2+}, Mg^{2+}, Si, HCO_3^-, mineral saturation indices, pH
- CO_2 mobilization of metals: Pb^{2+}, As, Ba^{2+}, Cd, Hg^{2+}, Sb, Se, U and Zn^{2+}
- Oilfield brine: Na^+, Cl^-, Br^-
- Underlying Permian evaporites: Ca^{2+}, SO_4^{2-}

Geochemical Relationships



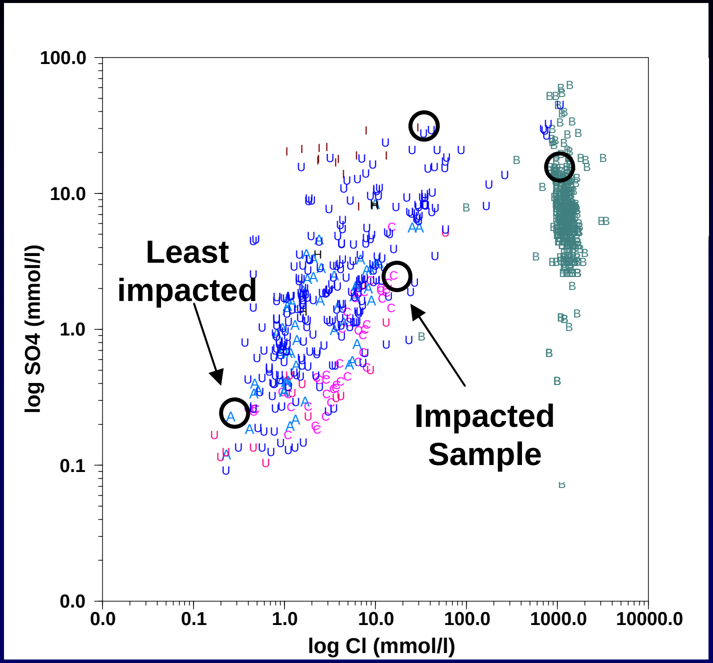
No distinction between samples collected inside SACROC and regional Dockum trends.

Components of Dockum Water



Mixing Model

	Non-impacted Dockum (Hint-Herm)	Permian	Production (77-9p)	Calculated Mixture	Impacted Sample (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

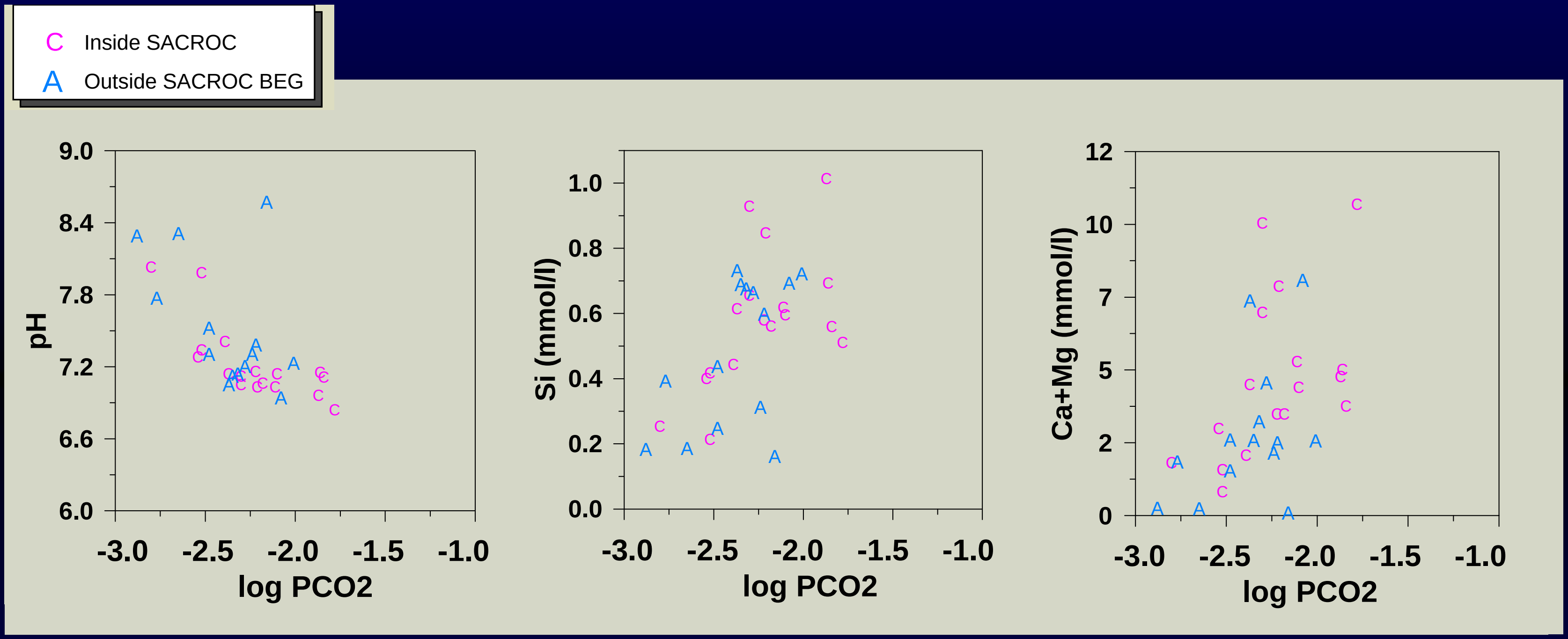
Brine infiltration into carbonate aquifer initiates cation exchange.

$$Ca\text{-}X_2 + 2Na^+ \Leftrightarrow Ca^{2+} + 2Na\text{-}X$$

Addition of calcium ions drives calcite precipitation

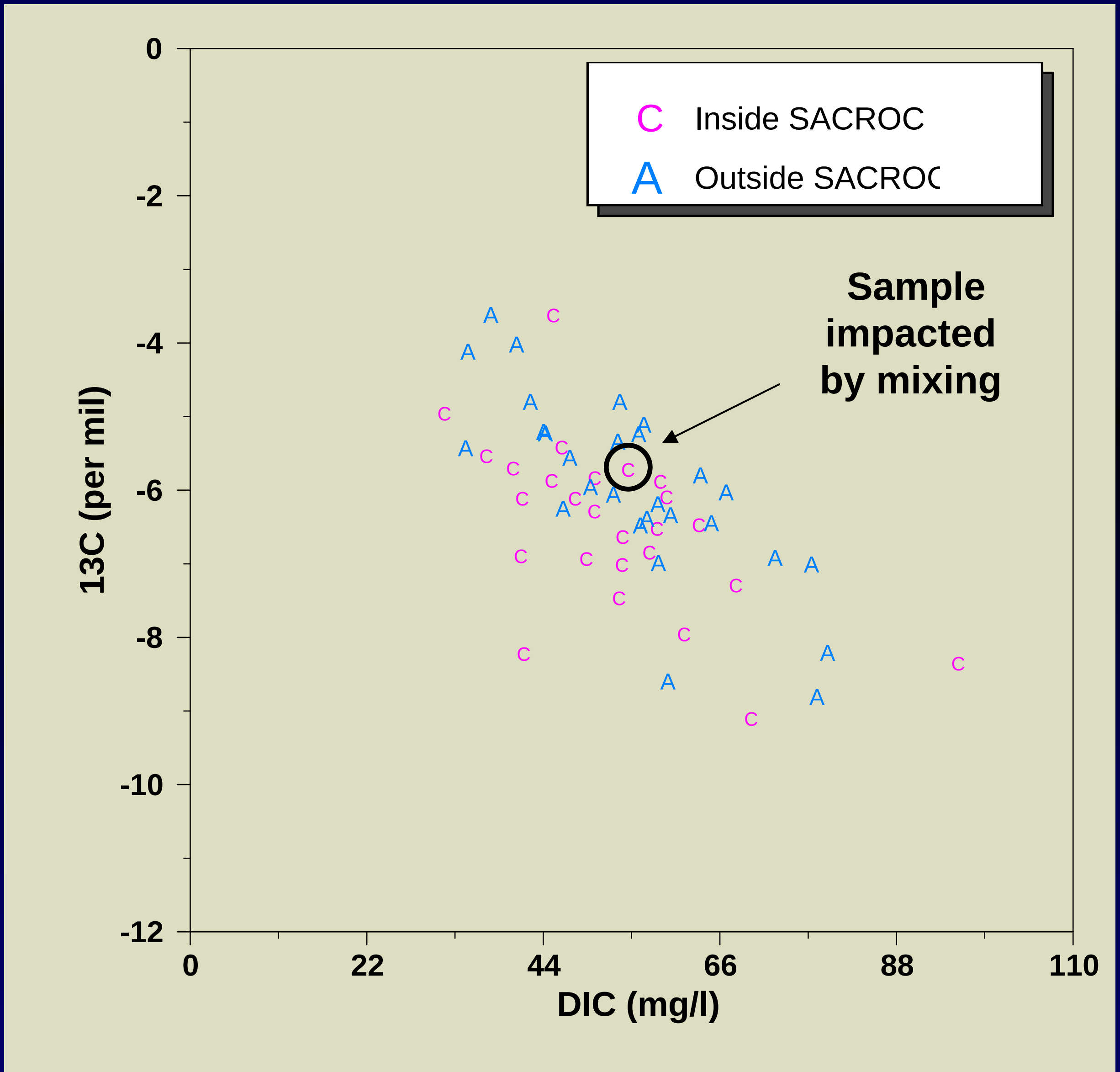
$$CaCO_3 \Leftrightarrow Ca^{2+} + CO_3^{2-}$$

CO2 Controls on Carbonate & Silicate Geochemistry



Increasing CO_2 →

Carbon Isotopes



Collected to date:

Injectate CO_2
(-6.1 to - 0.5 per mil)

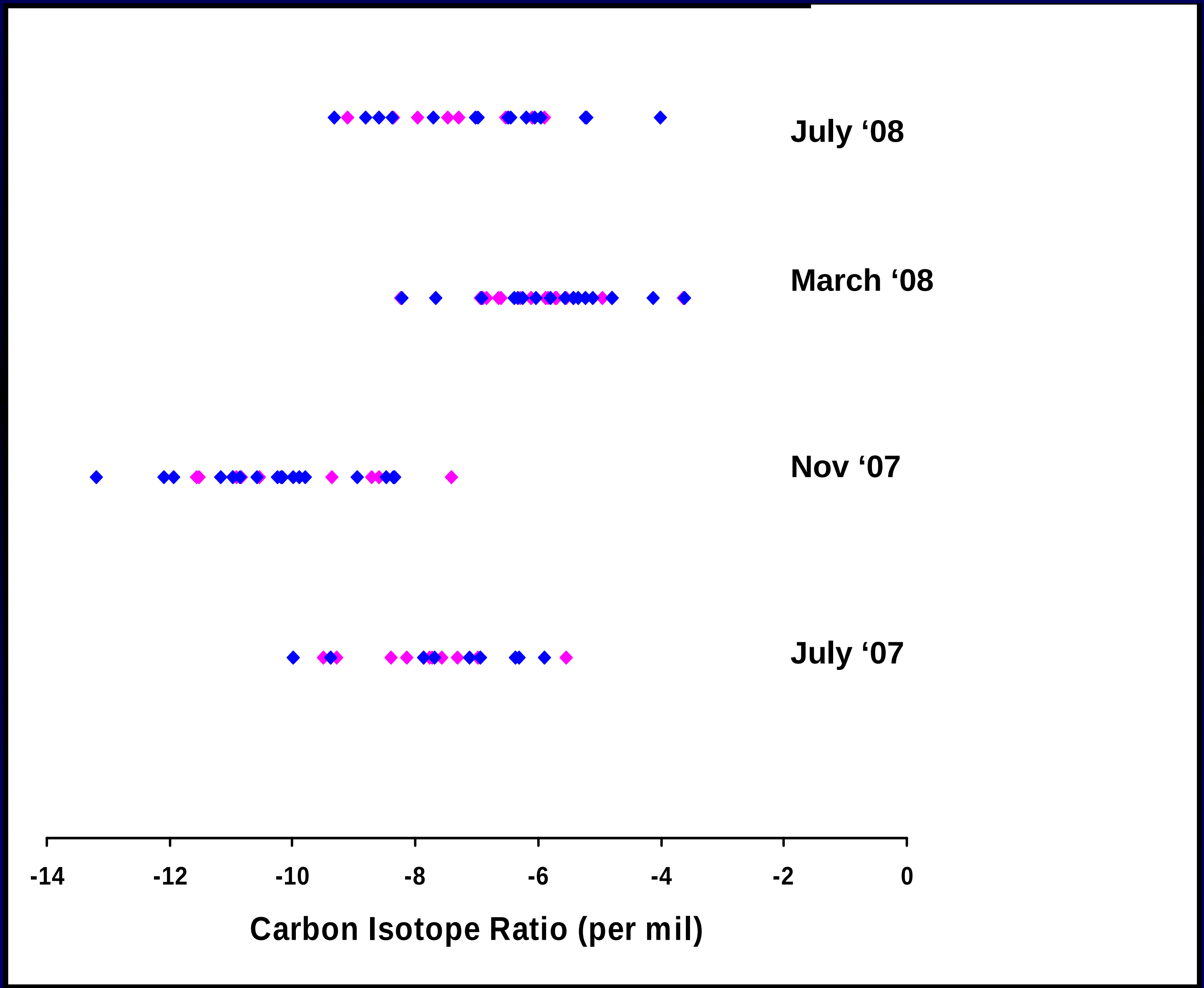
Dockum ground water
(-13.2 to -3.6 per mil)

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
Primary Maximum Contaminant Level (MCL)				
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 %
Secondary Drinking Water Standard				
Alumnium (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 CO_2 from 36 years of EOR at SACROC entered the Dockum aquifer?

Evidence of minimal CO_2 impacts.

Currently no source identification.

Must understand isotope systematics

Conclusions

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

CO_2 indicators (headspace gas, HCO_3, field Alkalinity, DIC, pH)	**Major Elements**	**Carbon isotopes**	**Trace metals**
Direct/Indirect measurement of inorganic carbon	**Give the geochemical big picture**	**Distinguish CO_2 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 CO_2**

Conclusions

Has CO_2 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 CO_2.
- Perform a sensitivity analysis to determine the amount of CO_2 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 CO_2 injection.