AQUIFER STUDIES RELATED TO GEOLOGIC STORAGE OF CO_2

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100 Years of Scientific Impact

1909-2009

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CCS FACTS

- Carbon capture and storage (CCS) is a process that will be used to reduce atmospheric emissions from coal-fired power plants across the globe
- Geologic sequestration (GS) is a method of isolating CO_2 in the deep subsurface via injection of compressed fluid and subsequent trapping
- A properly selected GS site should not impact underground sources of drinking water (USDWs), <10,000 mg/L TDS
- Monitoring is necessary!

CONSIDERATIONS

- **Types of monitoring – Really want to look for early warnings!**
  - **Deep subsurface – look for pressure changes just above low permeability seal overlying injection zone**
  - **Intermediate depth subsurface – base of USDWs and below**
  - **Shallow subsurface – saturated and unsaturated zones**
  - **Surface/Atmospheric – a way to confirm sequestration credits**
- **Displacement/migration of high salinity fluids (brine) with dissolved CO_2 by conduit flow along high permeability pathways:**
  - **insufficiently plugged well bores**
  - **transmissive faults**
  - **upward along gently dipping, regional water-bearing strata (i.e. Carrizo-Wilcox aquifer)**
- **Different aquifers contain different matrix minerals that will react with CO_2 at different rates - dissolution and precipitation**
- **Shallow groundwater contains natural sources of CO_2 – NOT A HAZARDOUS WASTE!**

WATER QUALITY ISSUES

CO_2 injected into a water-bearing formation (freshwater or brine) will partially dissolve and:

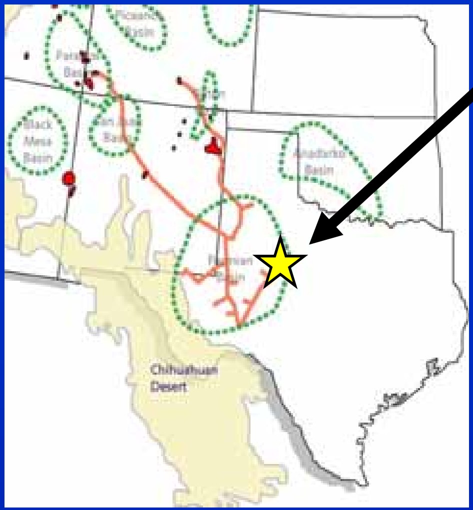
– Reduce pH of solution

$$CO_{2(g)} + H_2O \leftrightarrow H_2CO_{3(aq)}$$
$$H_2CO_{3(aq)} \leftrightarrow HCO_{3(aq)}^{-} + H^{+}$$
$$HCO_{3(aq)}^{-} \leftrightarrow CO_{3(aq)}^{2-} + H^{+}_{(aq)}$$

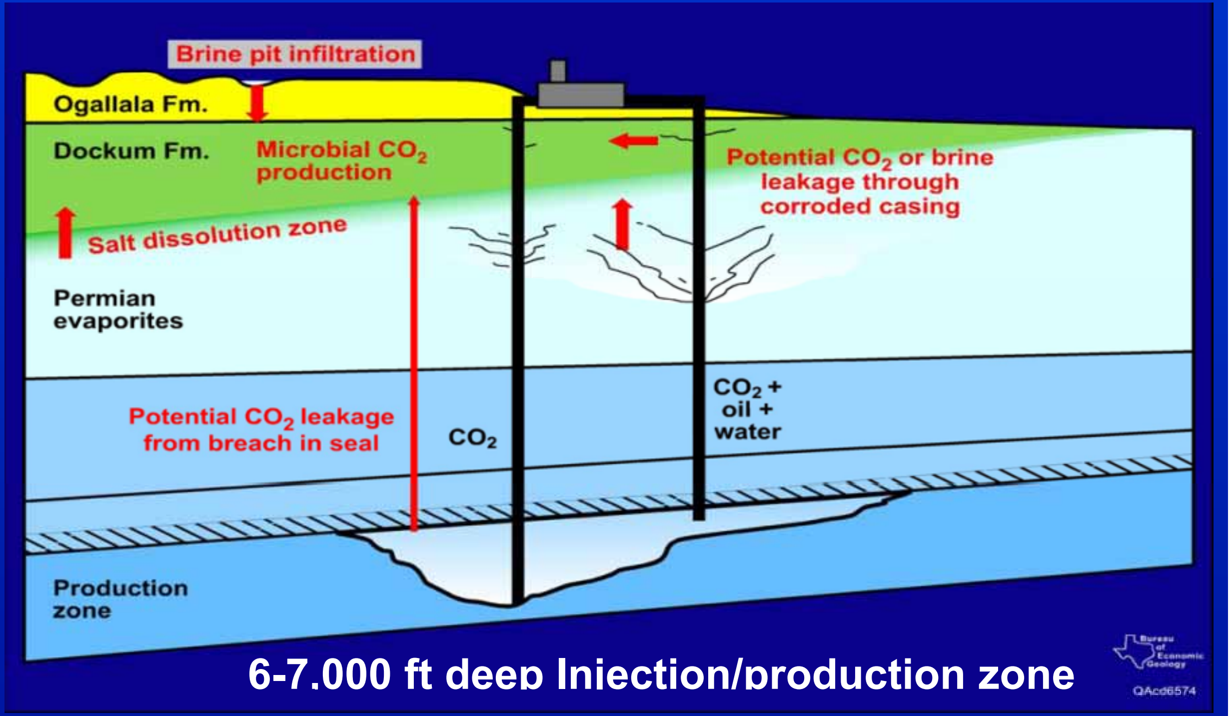
– Chemically interact with formation matrix to:

- increase dissolved cation concentrations (Group 1 - B, Ba, Ca, Co, K, Mg, Mn, Sr, and Zn)
- increase dissolved cations followed by concentration decline (Group 2 – Al, As, Cs, Cu, Fe, Mo, Ni, Rb, U, and V).

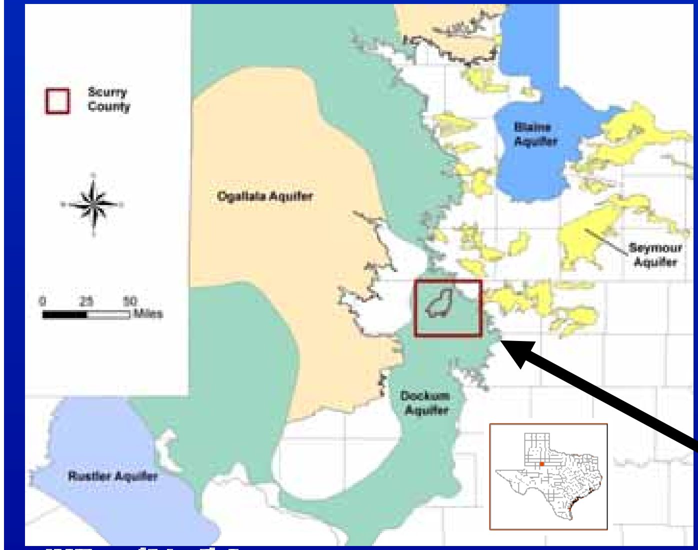
CASE STUDY – SACROC Oilfield



Scurry Area Canyon Reef Operators Committee (SACROC) – enhanced oil recovery using CO2 since 1972

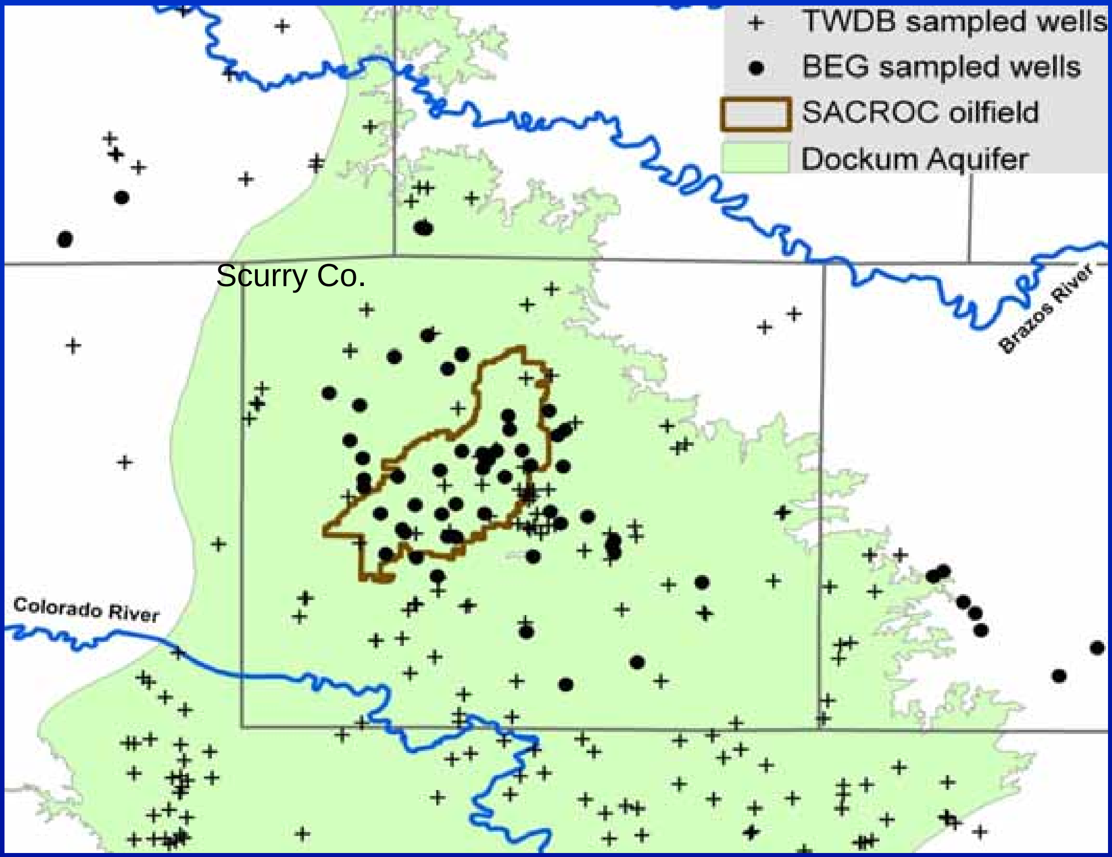


6-7,000 ft deep Injection/production zone



Scurry County – Texas Water Development Board (TWDB) minor aquifer – Dockum aquifer base at ~ 500 ft

CASE STUDY – Dockum Aquifer



Not all of these wells are completed in the Dockum aquifer!

Six groundwater monitoring trips – June 2006, July 2007, November 2007, March 2008, July 2008, November 2008, and hopefully July 2009

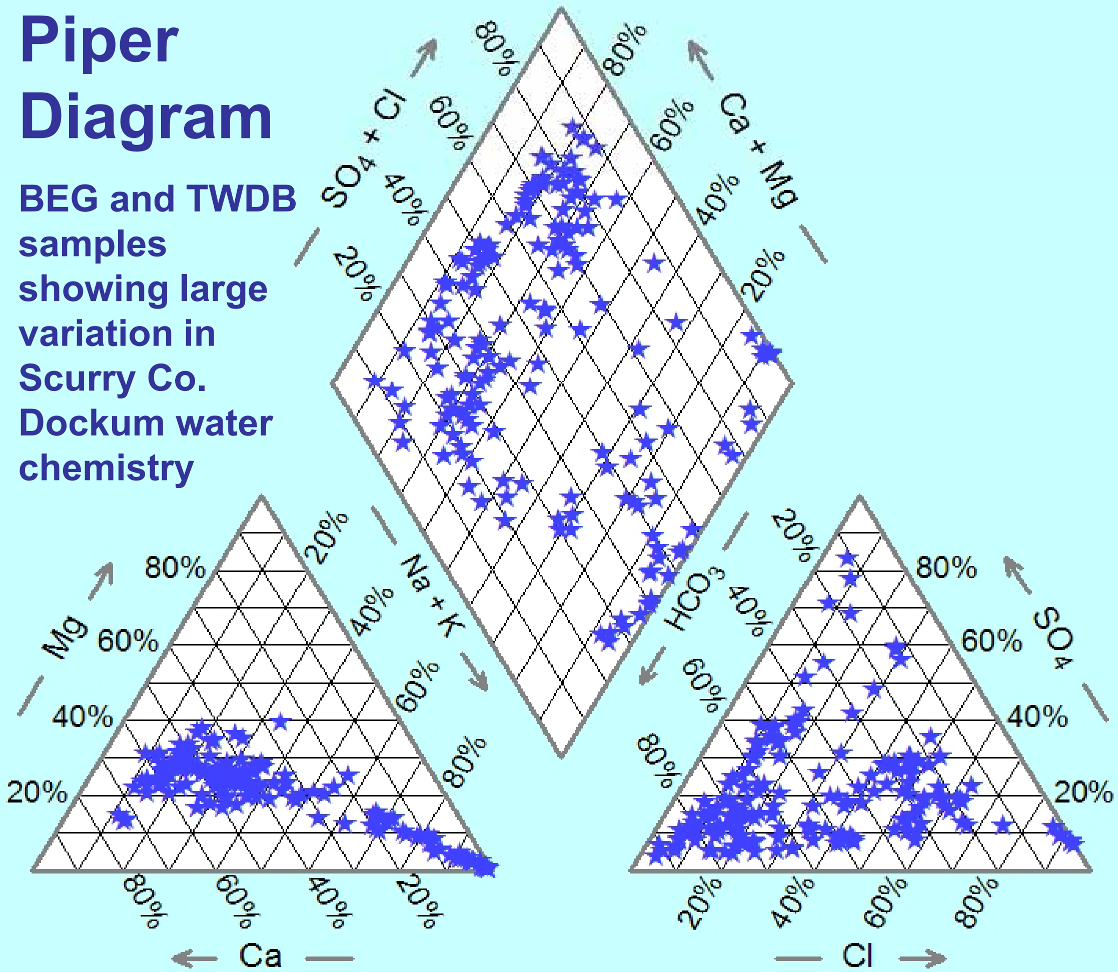
BEG sampled 60 private water wells, 1 freshwater spring, and brine from 8 CO_2 injection zone wells – total 123 samples

TWDB database water quality data for analyses with charge balance error <10%, potassium analysis, and good reliability code

CASE STUDY - Challenges

Piper Diagram

BEG and TWDB samples showing large variation in Scurry Co. Dockum water chemistry



Need indirect measurement of CO_2 in groundwater

↑ CO_2 = ↓ pH,
↑ Alkalinity,
↑ dissolved metals

Need Landowner Permission for Access to Private Water Wells

BEG and TWDB Water Well Data

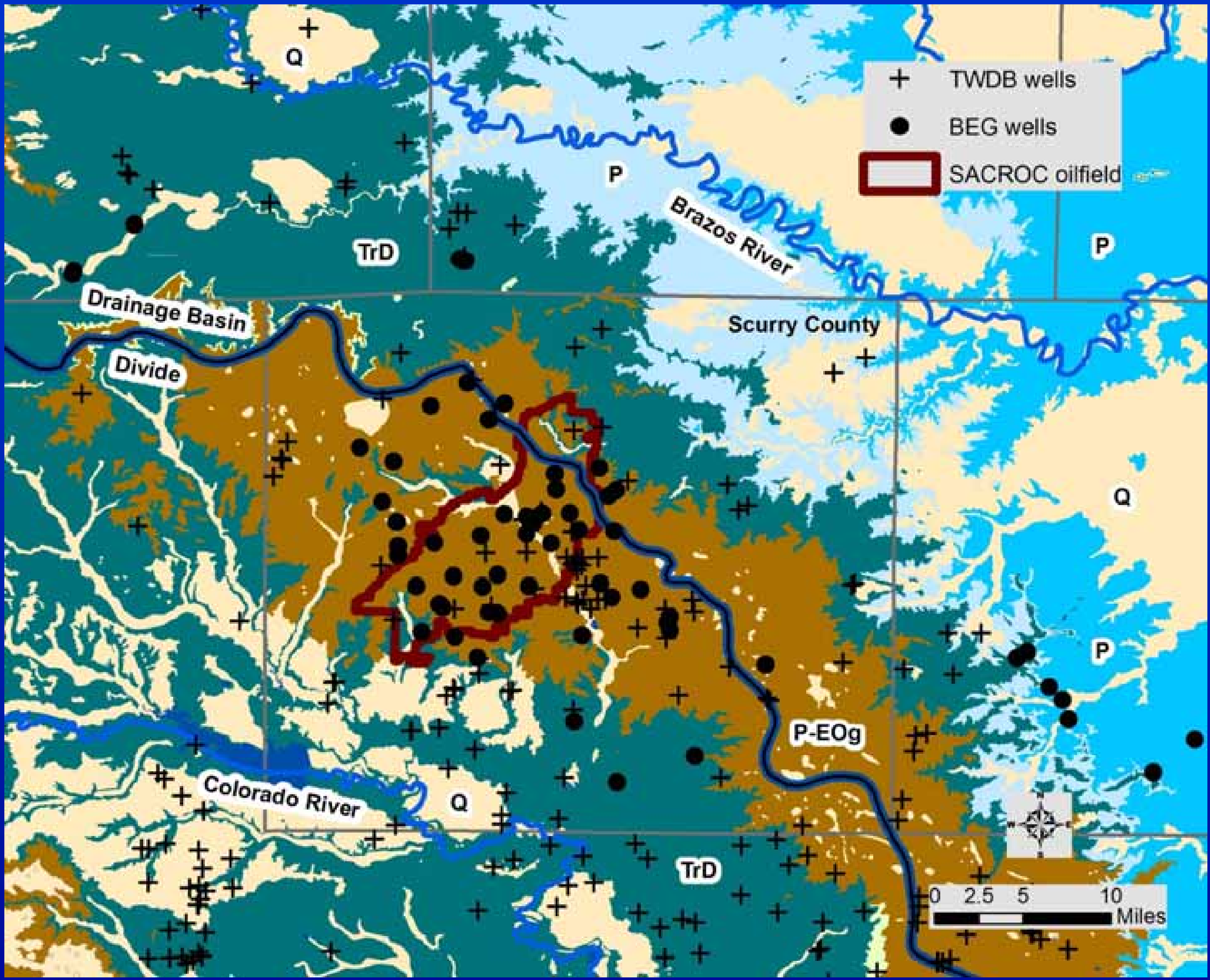
Geologic units

Q – Quaternary undifferentiated

P-Eog – Paleocene-Eocene Ogallala

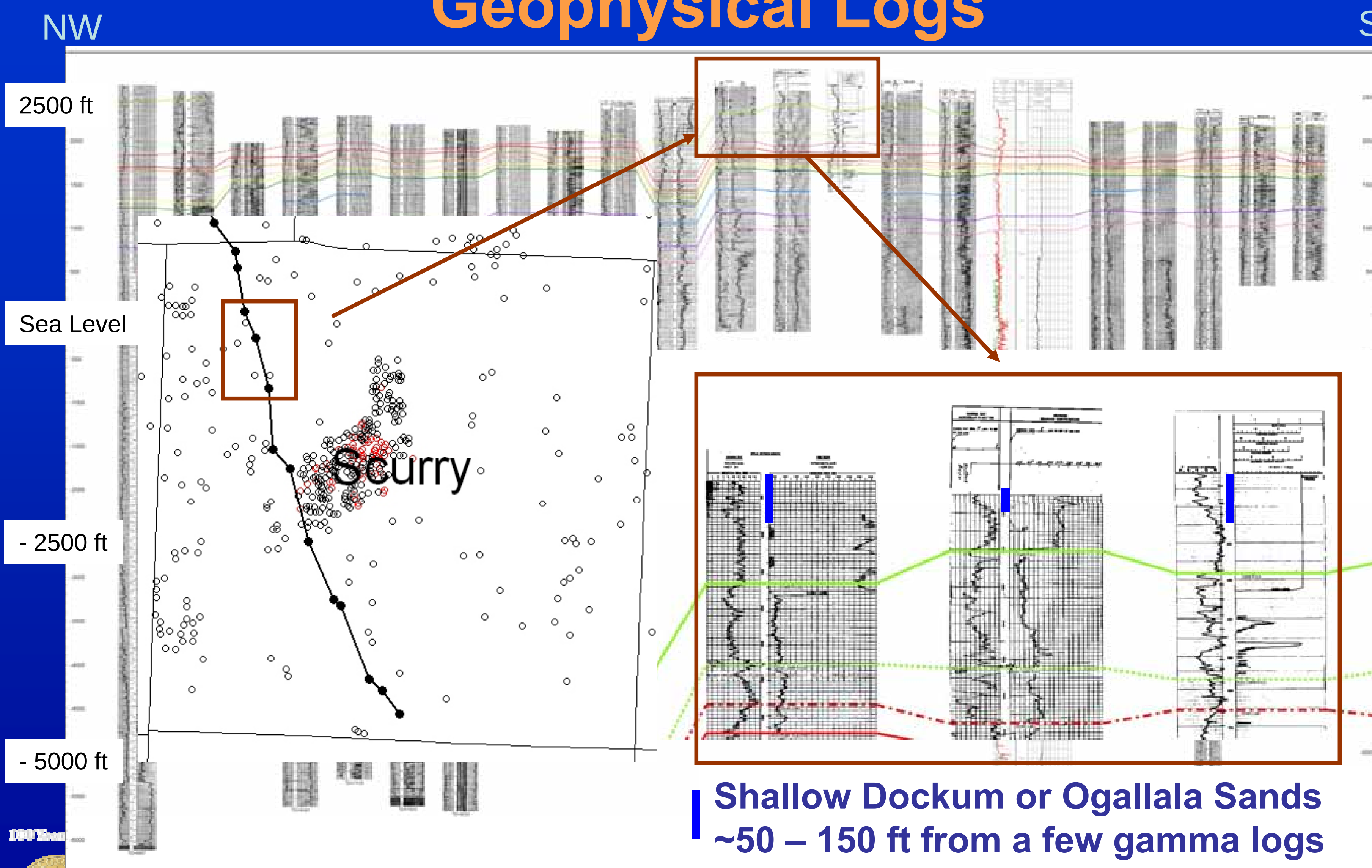
TrD – Triassic Dockum

P – Permian undifferentiated



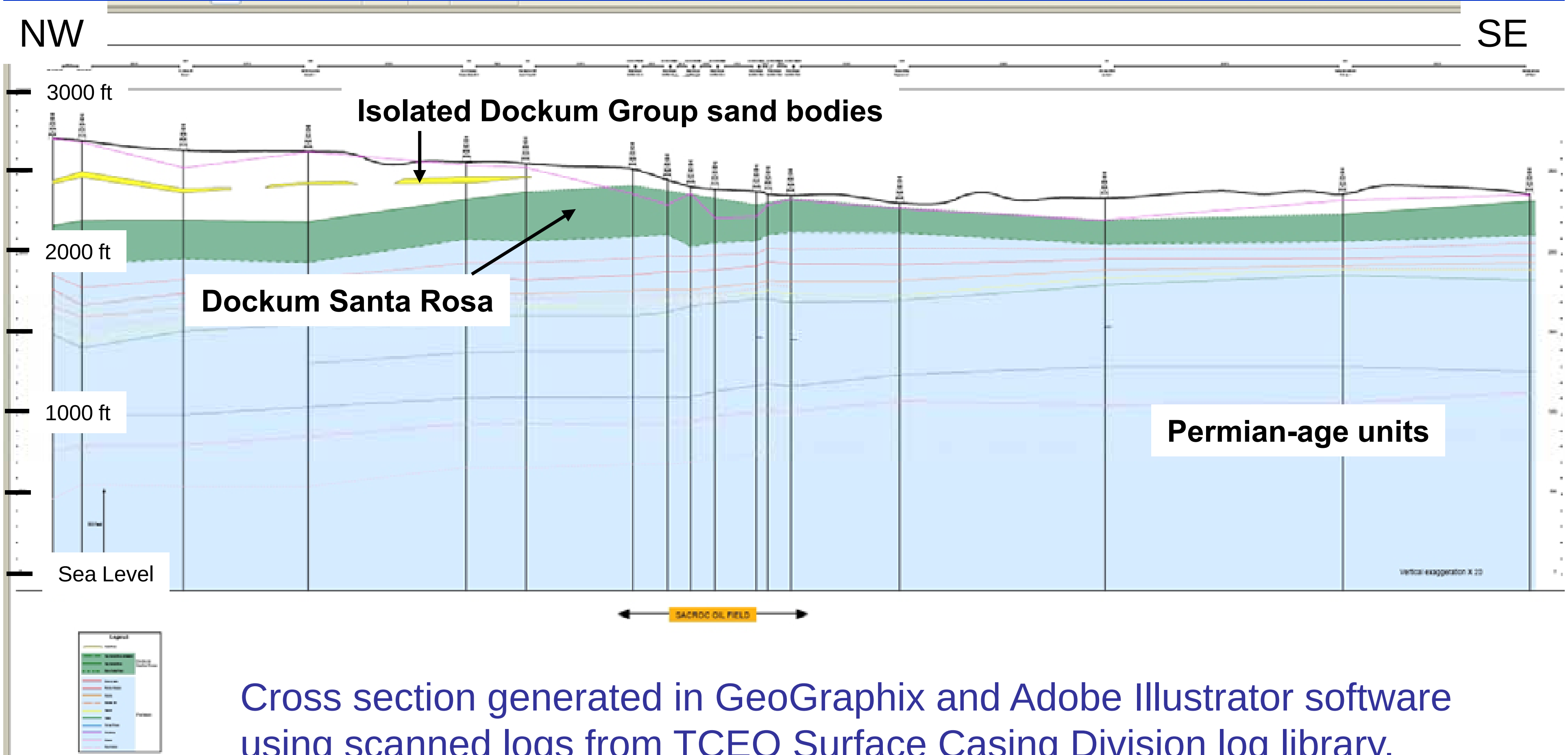
Surface geology from BEG Big Spring and Lubbock GAT sheets

Stratigraphic Cross-sections from Shallow Geophysical Logs



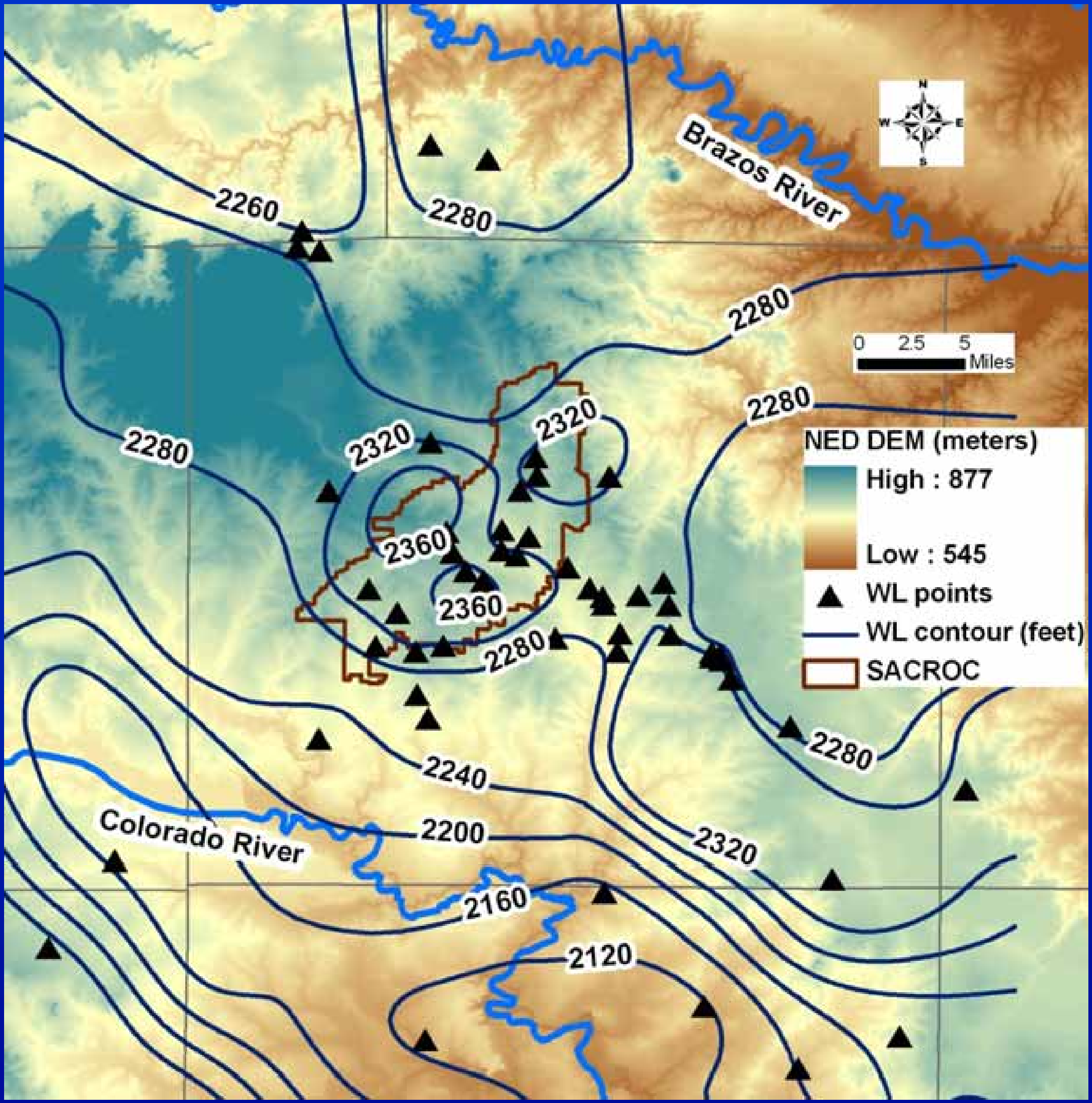
Shallow Dockum or Ogallala Sands
~50 – 150 ft from a few gamma logs

NW-SE Cross Section Based on TCEQ Surface Casing Geophysical Logs



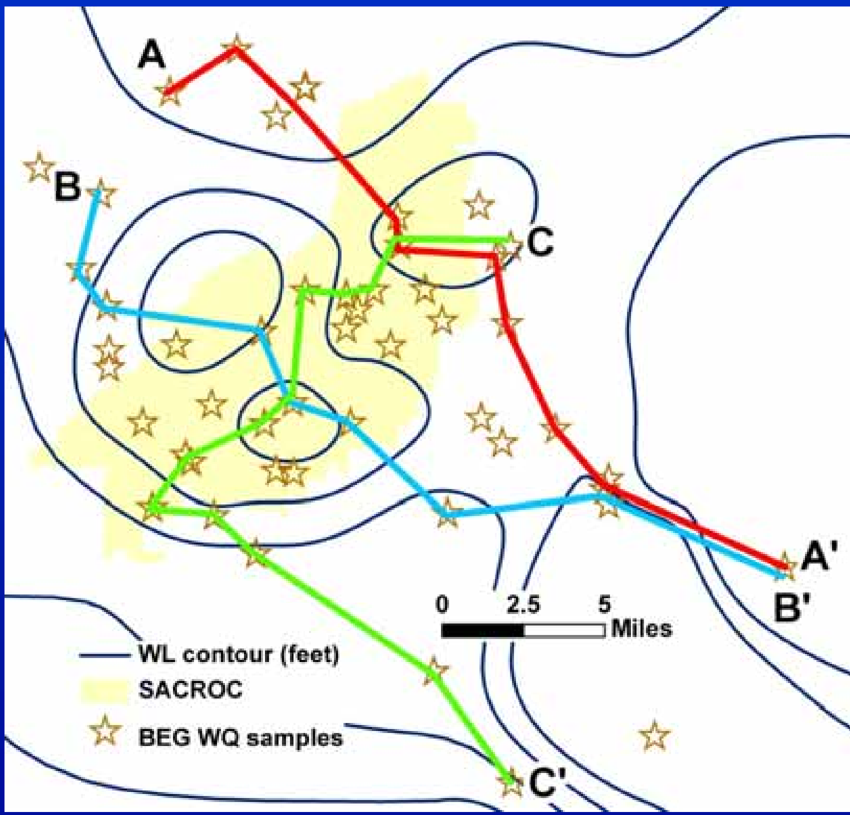
Cross section generated in GeoGraphix and Adobe Illustrator software using scanned logs from TCEQ Surface Casing Division log library.

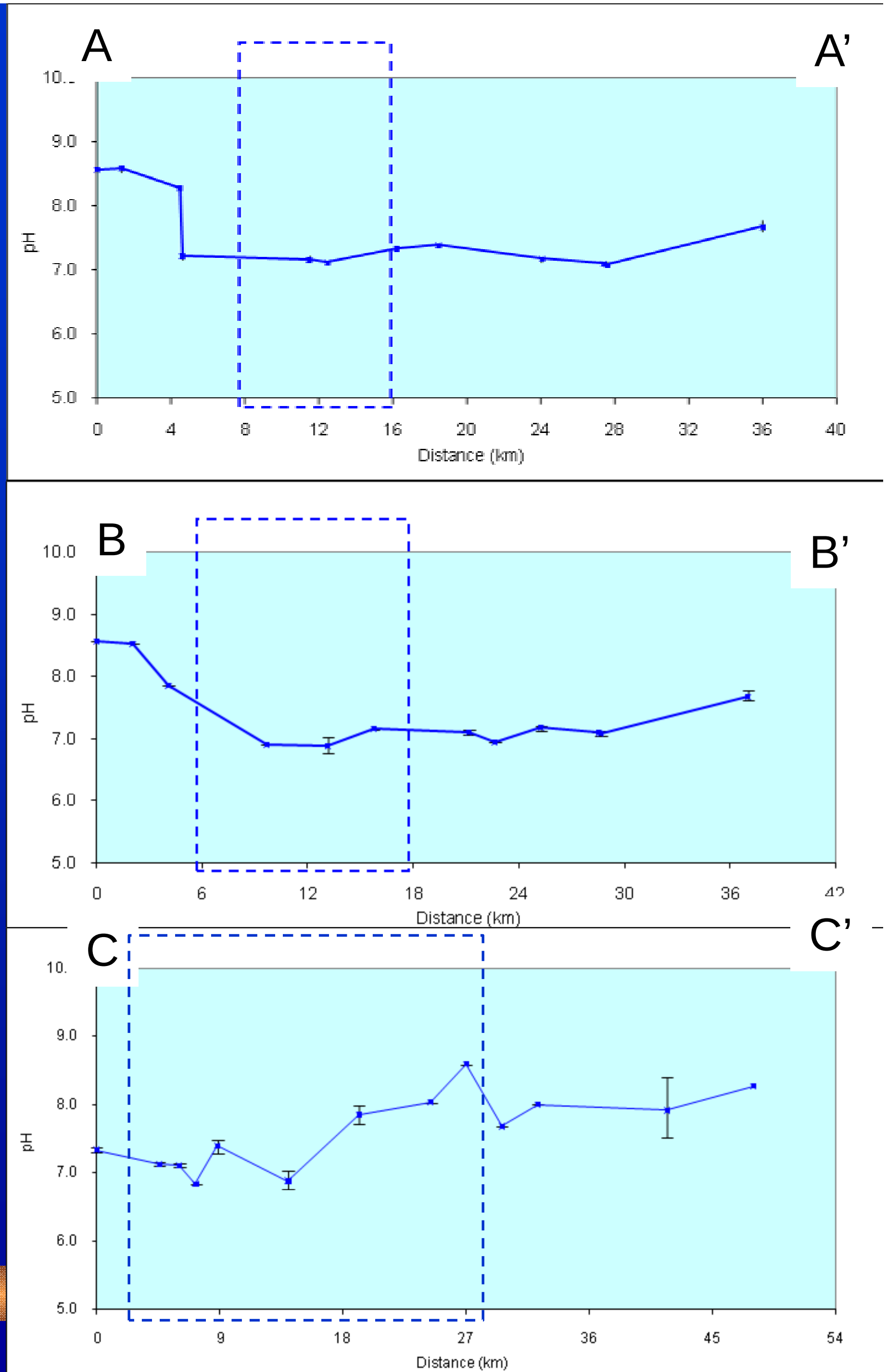
Potentiometric Surface Map for Scurry and nearby counties – only wells with total depth (TD) in Dockum Santa Rosa



pH Along Gradient-parallel Transects

All BEG-sampled wells completed through Ogallala with TD in Dockum Santa Rosa





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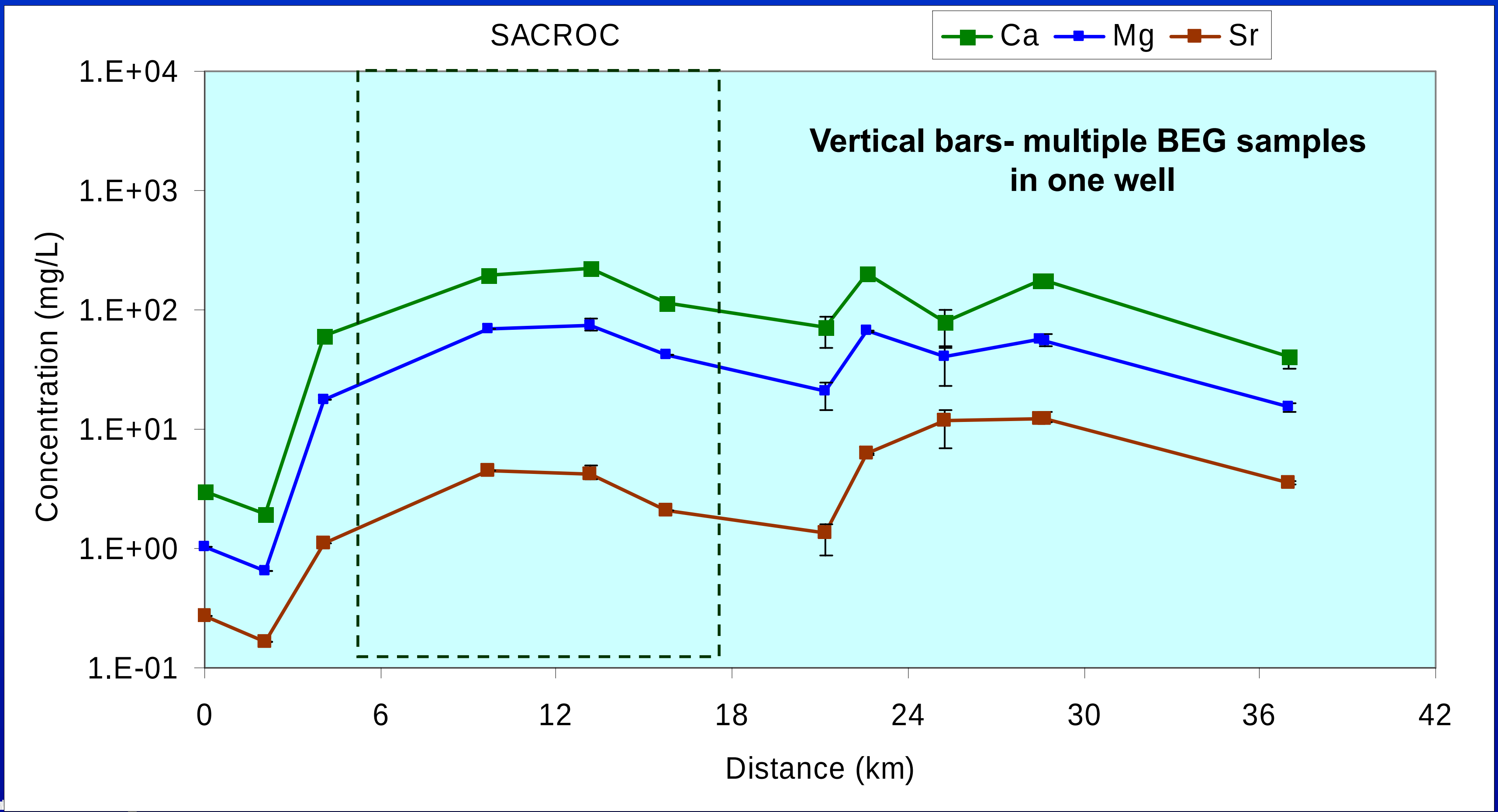
Line A-A' – Example Well Transect for Reactive Flow Path Modeling



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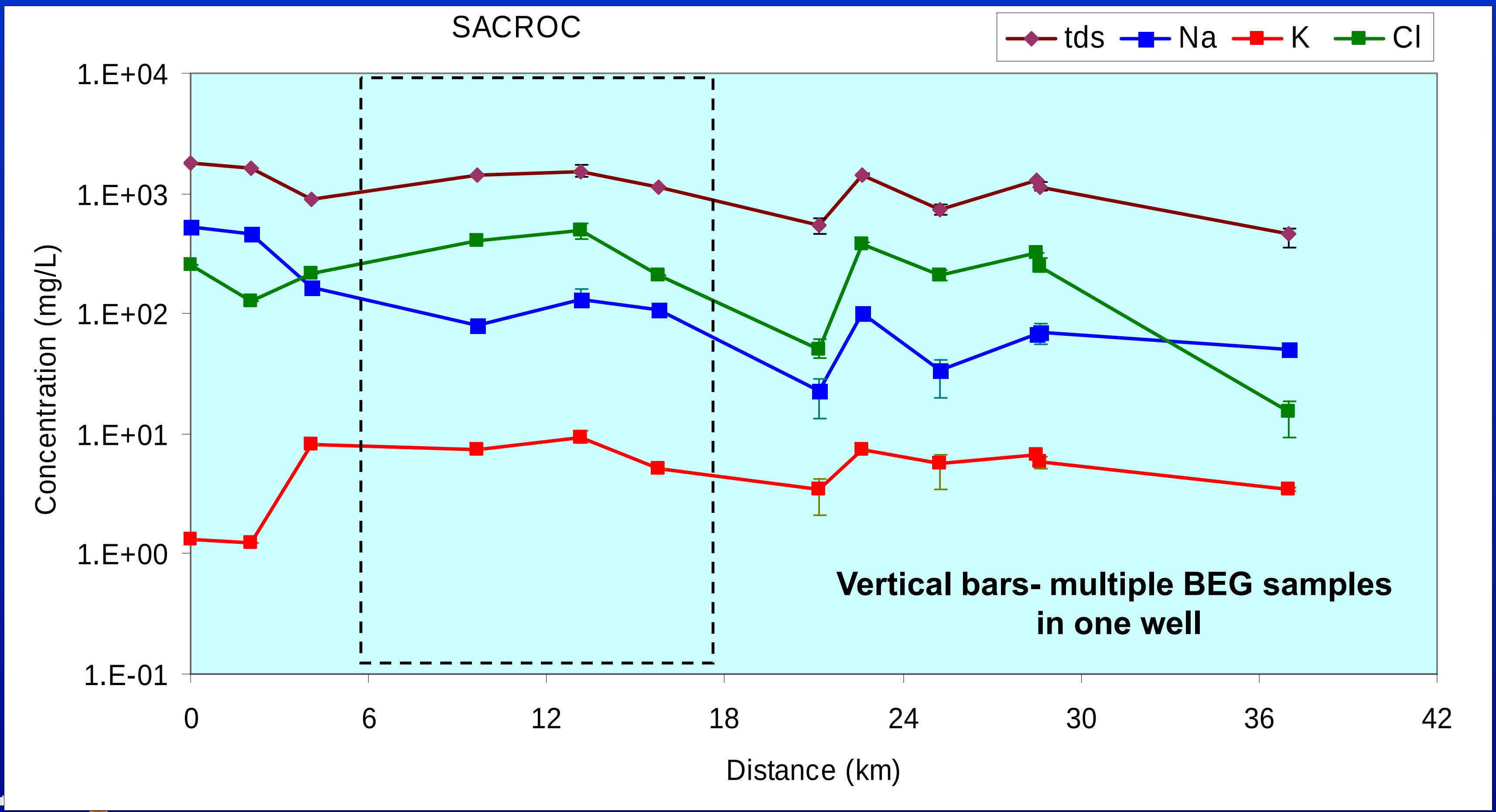
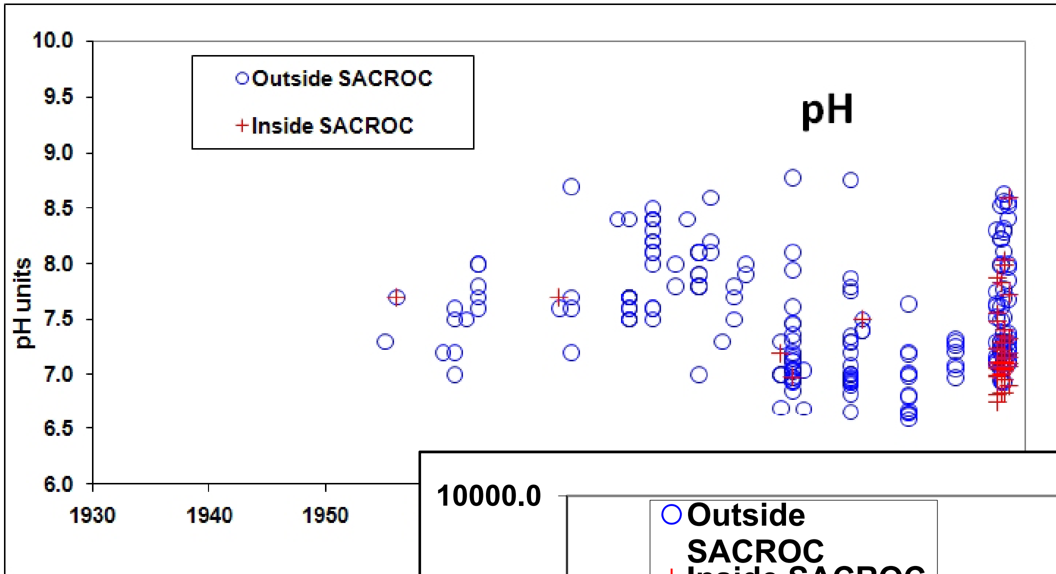
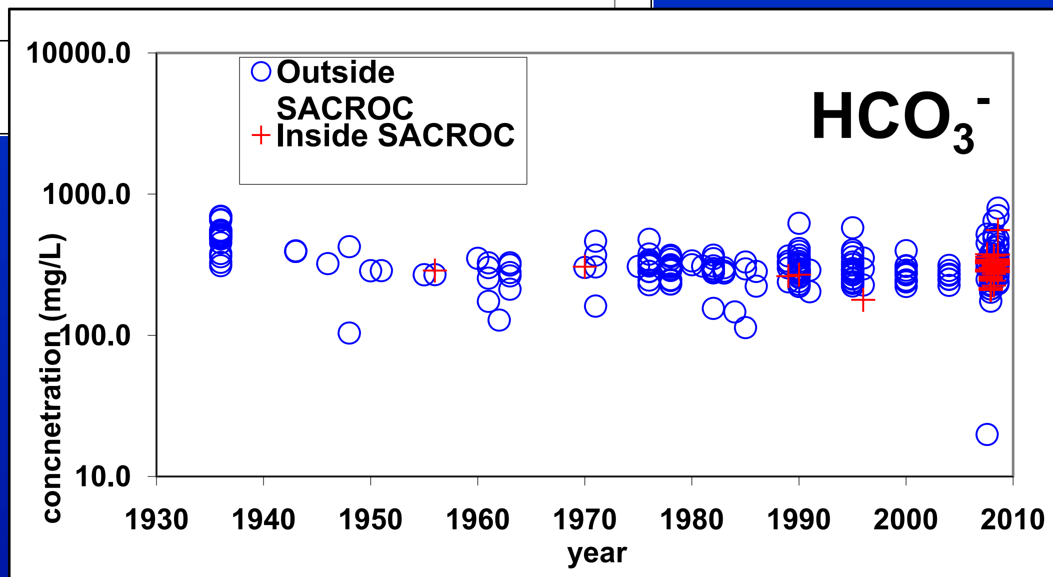
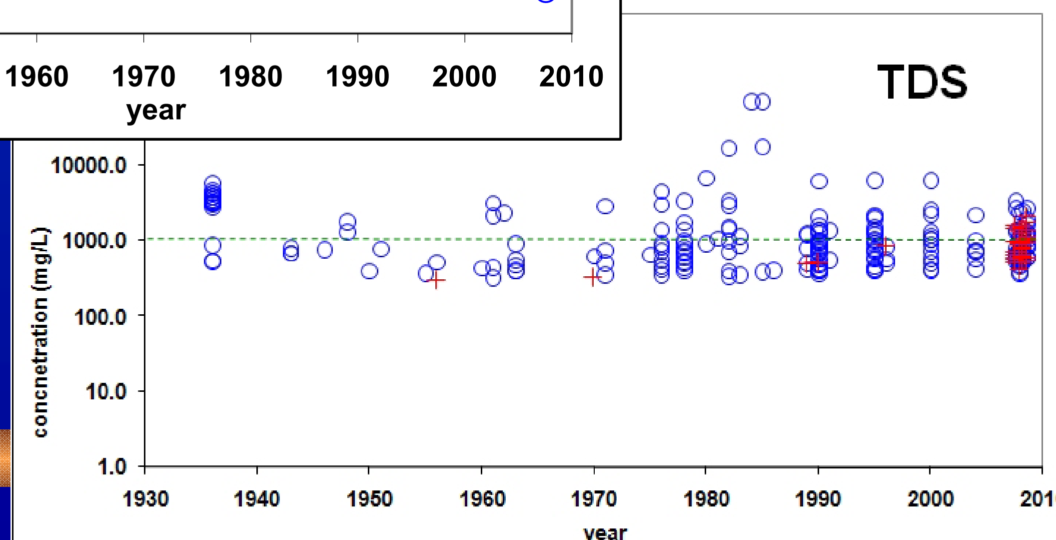


Temporal Trends of all TWDB & BEG Data







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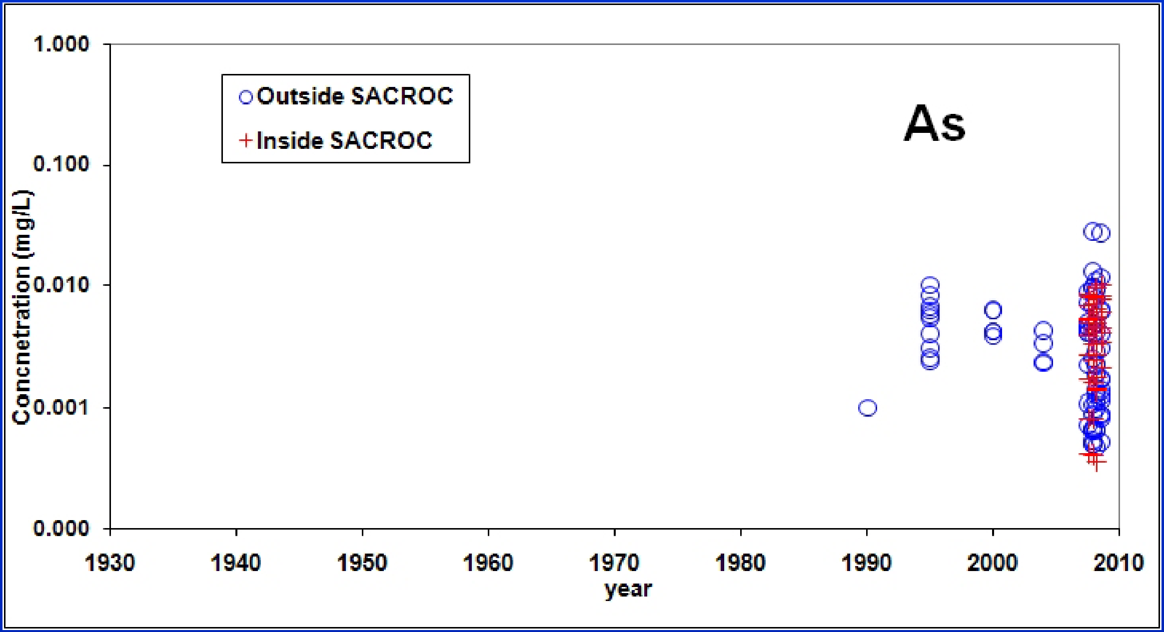
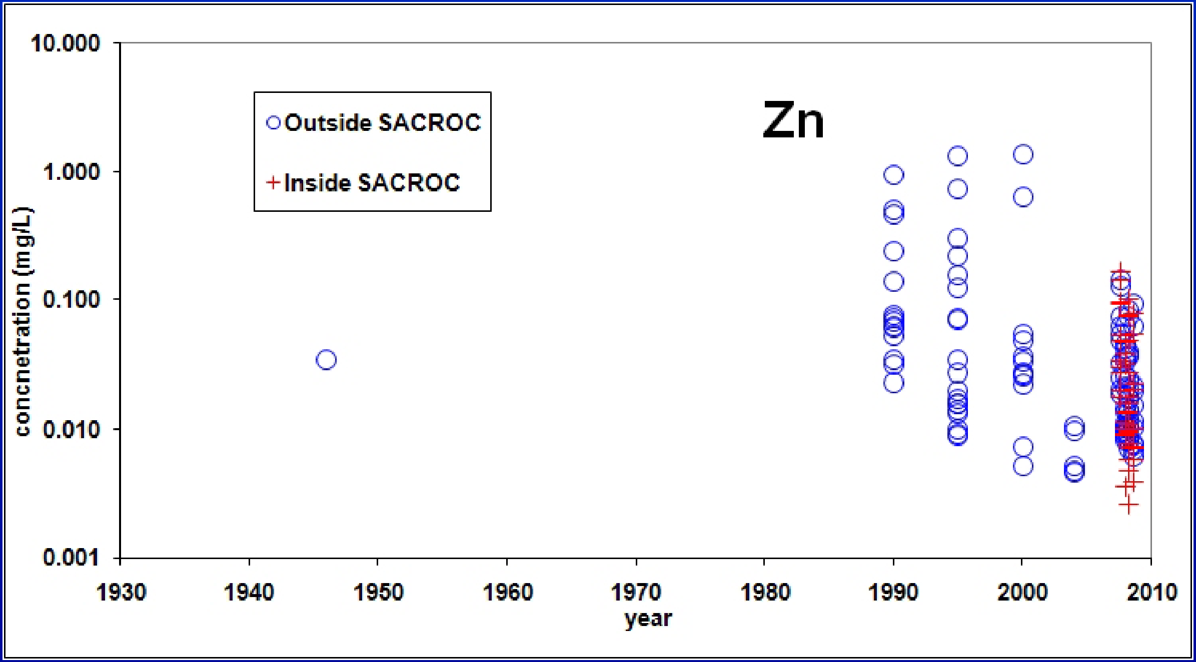


Temporal Trends of all TWDB & BEG Data

Gulf Coast Carbon Center



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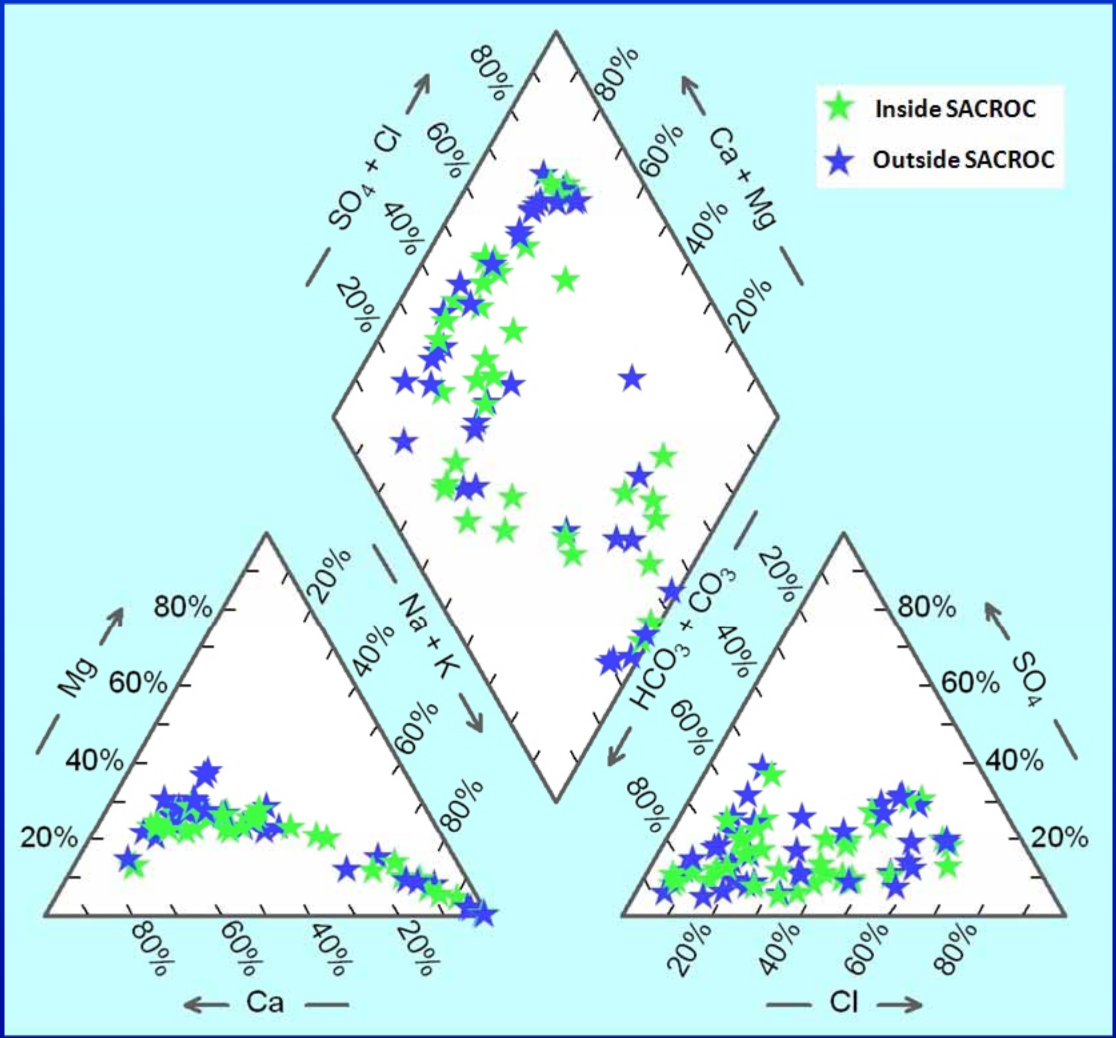
SACROC AREA WATER QUALITY

60 wells and 1 spring; filtered cations; unfiltered anions; highest concentration measured in each well

Analyte	EPA/TCEQ Primary Drinking Water MCL (mg/L)	BEG Wells Exceeding EPA Standards	BEG Wells Exceeding EPA Standards - Inside SACROC	BEG Wells Exceeding EPA Standards - Outside SACROC
Primary Maximum Contaminant Level (MCL)				
Arsenic (As)	0.01	9.8 %	1.6 %	8.2 %
Cadmium (Cd)	0.005	1.6 %	0.0 %	1.6 %
Fluoride (F^-)	0.4	4.9 %	1.6 %	3.3 %
Nitrate (NO_3-N)	10	13.1 %	4.9 %	8.2 %
Selenium (Se)	0.05	4.9 %	1.6 %	3.3 %
Secondary Drinking Water Standard				
Alumnium (Al)	0.05	34.4 %	13.1 %	21.3 %
Chloride (Cl^-)	250	32.8 %	14.8 %	18.0 %
Fluoride (F^-)	0.2	37.7 %	14.7 %	23.0 %
Manganese (Mn)	0.05	14.7 %	4.9 %	9.8 %
Sulfate (SO_4^{2-})	250	26.2 %	1.6 %	24.6 %
Total Dissolved Solids (TDS)	1000	50.8 %	18.0 %	32.8 %

CONCLUSIONS



- No distinction between Dockum water quality inside and outside of SACROC
- Dockum is a heterogeneous groundwater system
- Not clear if we can – or will be able to - see evidence of injectate CO_2 in Dockum groundwater
- Good news for GS of CO_2 at least at SACROC
- Good job Kinder Morgan!

QUESTIONS?

TCEQ Environmental Trade Fair and Conference
Austin, TX - May 12, 2009

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BEG Water Well Monitoring

- Six sampling trips – Fisher Co. in June 2006; Scurry, Garza, and Kent counties in July 2007, November 2007, March 2008, July 2008, and November 2008
- Total wells – 60 wells and 1 spring (+8 SACROC production and brine injection wells)
- Total samples sets collected – 123
- Laboratory analytes (LANL): Al, Ag, As, B, Ba, Be, Br, Ca, Cd, Cl, Co, CO_3, Cr, Cs, Cu, $d^{13}C$, dD, $d^{18}O$, F, Fe, HCO_3, Hg, K, Li, Mg, Mn, Mo, Na, Ni, NO_3, Pb, PO_4, Rb, Sb, Se, Si, Sn, SO_4, Sr, TDS, Th, Ti, Tl, U, V, and Zn
- Laboratory analytes (UT DGS - Romanak): DIC, DOC, headspace gases (CO_2, CH_4)
- Field parameters: dissolved oxygen, pH, specific conductivity, and temperature; alkalinity titrations
- Well information: total depth, water level (where possible), x and y coordinates from GPS, elevation (z) from digital elevation model, stratigraphic unit from BEG-constructed structure contour maps (based on shallow geophysical logs)