January 7th, 2013
Washington, D.C.

U.S. EPA
STAR Grant R834503

Diagnostic Monitoring of Biogeochemical Interactions of a Shallow Aquifer in Response to a CO_2 Leak

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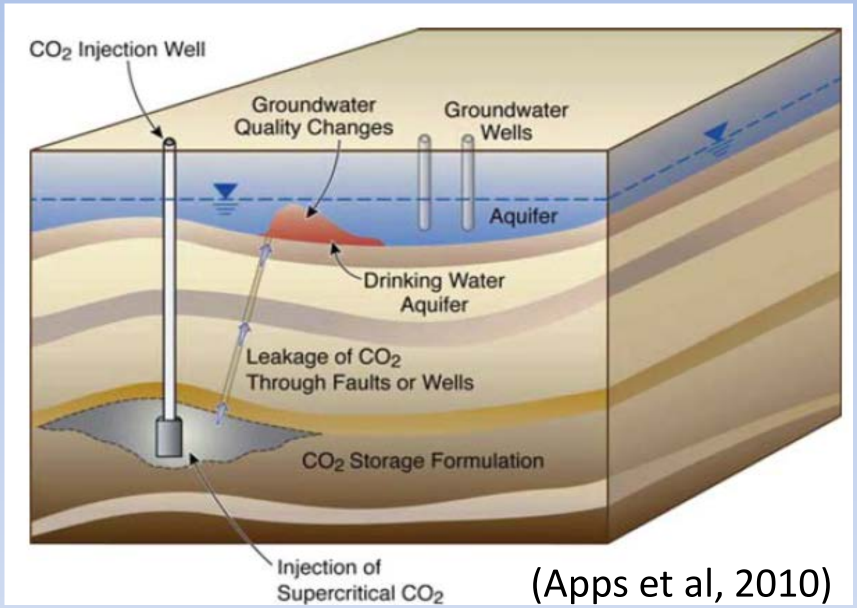
Columbia University | Earth Institute

Queens College

Barnard
The Liberal Arts College for Women in New York City

Project overview
– leaking scenario



(Apps et al, 2010)

(1) Estimate element release, microbial dynamics and their impacts in response to CO_2 leakage;

(2) Develop criteria for diagnostic monitoring and risk assessment of groundwater contamination.

Qiang Yang: geochemical perspective
Eli Dueker: microbiological perspective

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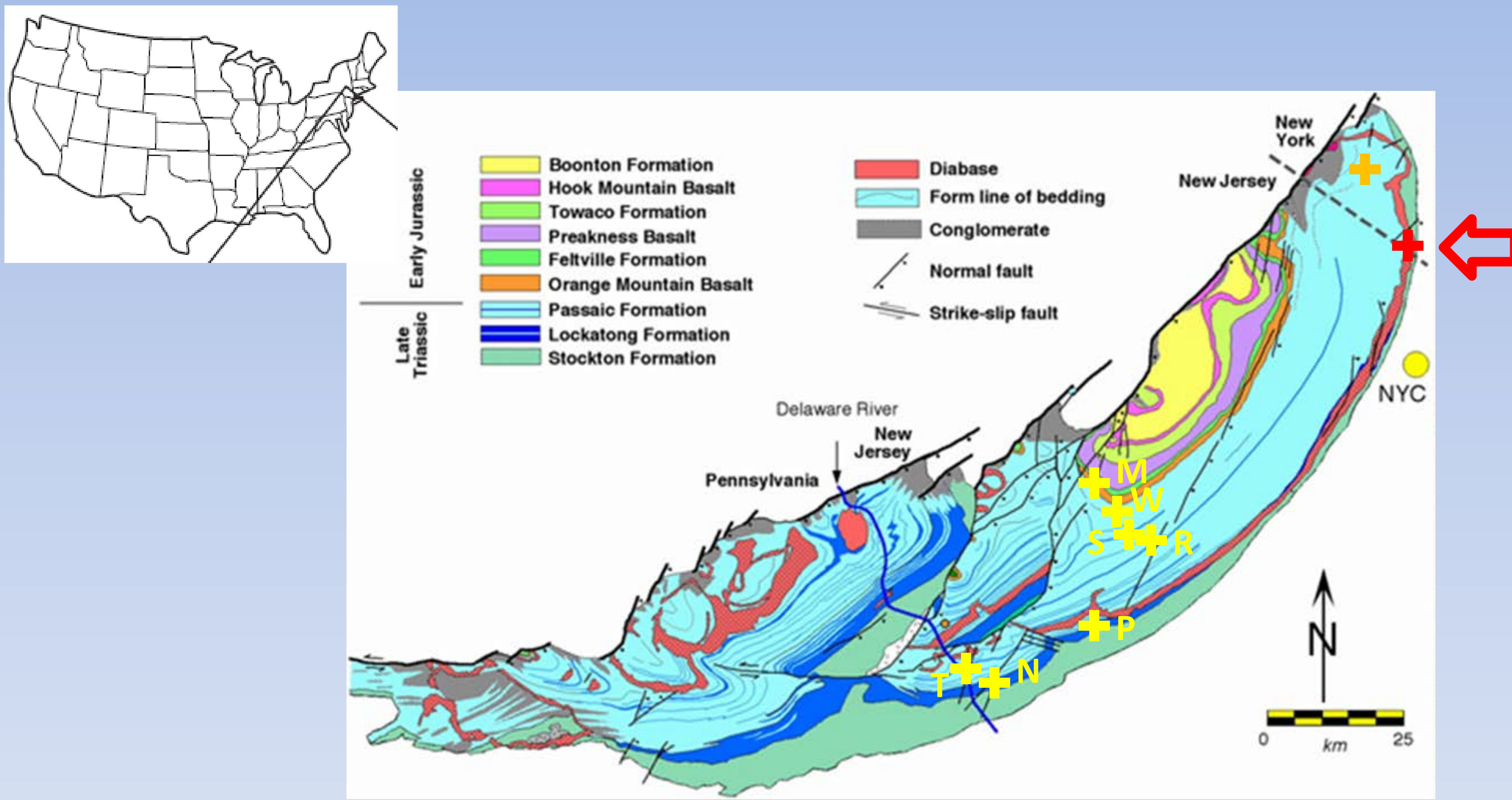
Groundwater geochemistry in field injection and lab incubation experiments simulating CO_2 leakage into shallow aquifers in Newark Basin

Qiang Yang

1) Introduction (study site, research question);
2) In-situ field injection of simulated CO_2 leakage;
3) Lab incubation experiments;
4) Implications for groundwater quality monitoring

Study Site – Newark Basin

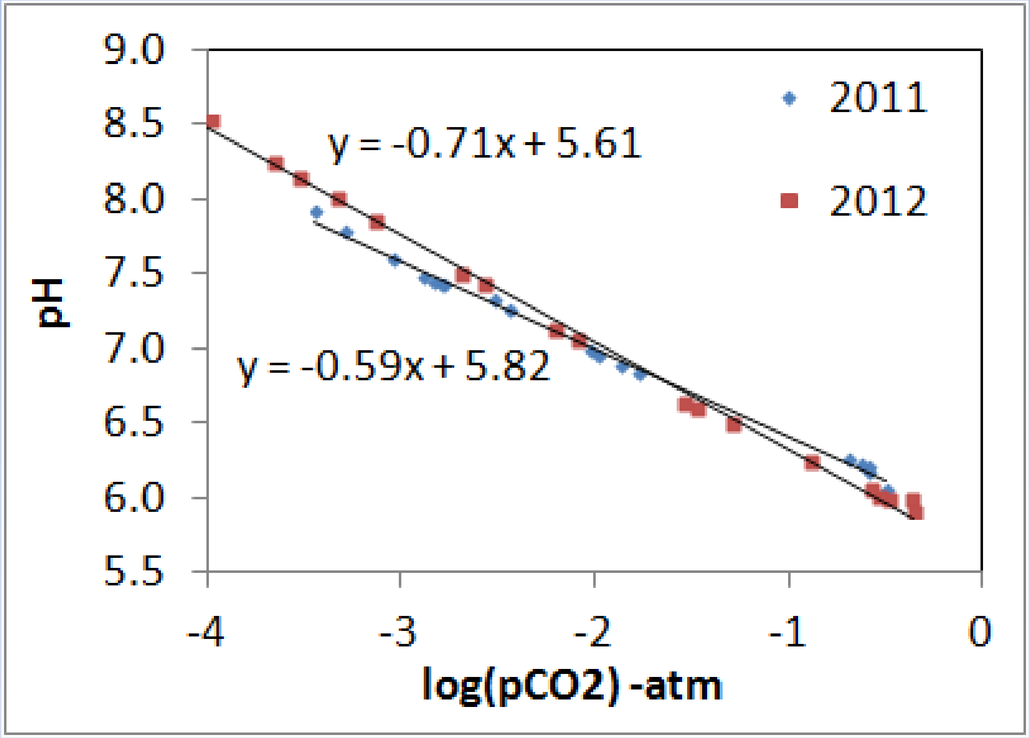


- Sediment-filled rift basin intruded by Palisades sill
- Fractured sedimentary bedrock aquifers

Introduction

Research Questions

(1) What is the dependence of major and trace element release on $p\mathrm{CO_2}$(pH) in response to CO_2 leakage?



Research Questions

(1) What is the dependence of major and trace element release on $p$$CO_2$(pH) in response to CO_2 leakage?

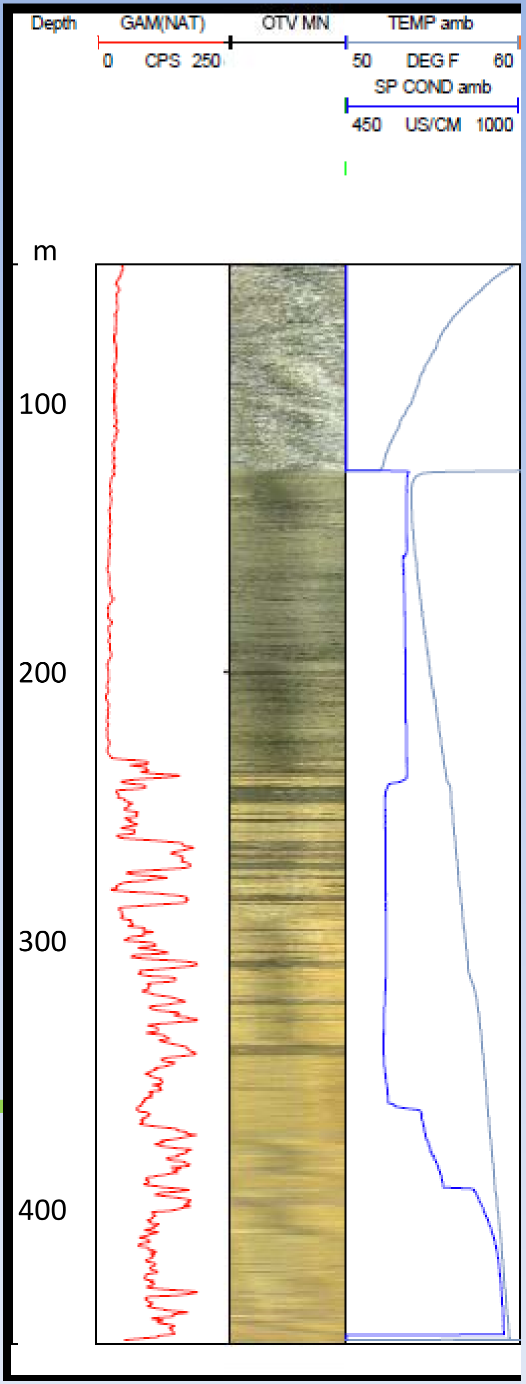
(2) What is the difference of groundwater response to CO_2 in aquifers with different rock types?

(3) What are the potential impacts on groundwater quality and monitoring?

In-situ injection tests
lab incubation experiments

Field injection

Test well TW-3



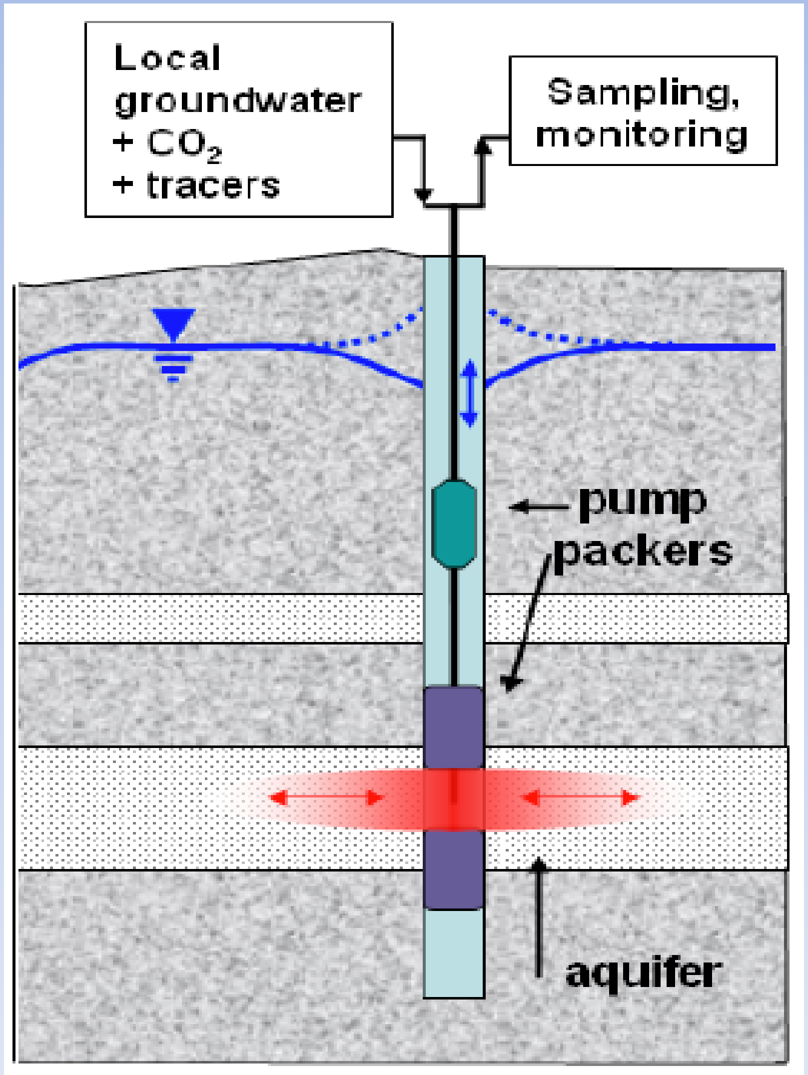
intruded Palisades sill

T=0.02 m^2/day

sand and clay sedimentary rock

Field injection

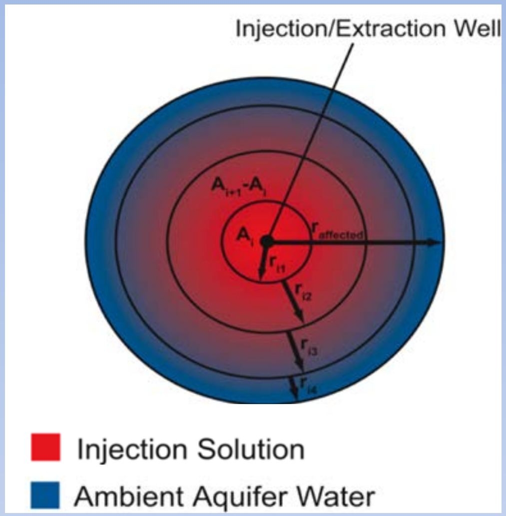
Single-well push-pull tests



- interval: 362-366 m
- volume: ~3 m^3 aquifer water with 1 bar of CO_2
- duration: 10 hours
- period: 3-6 weeks
- Tracer: KBr (50-100 mg/L of Br^-), SF_6 (~10 pmol/L)

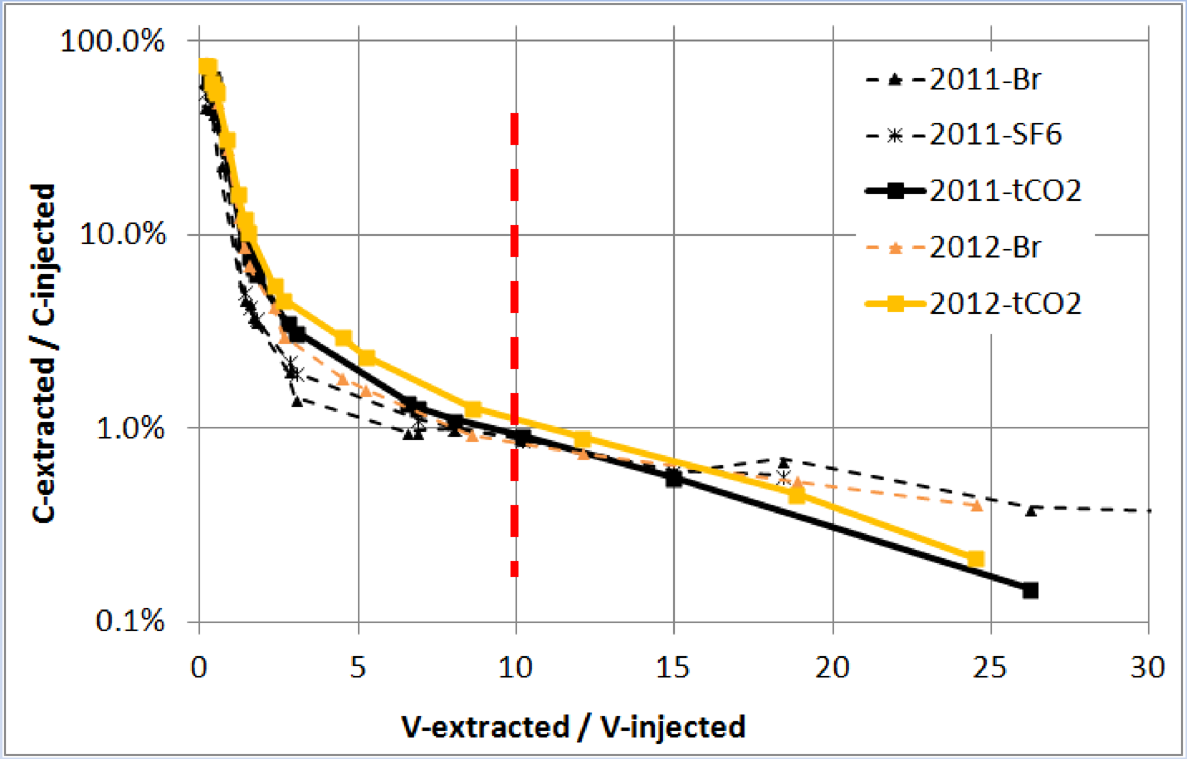
Field injection

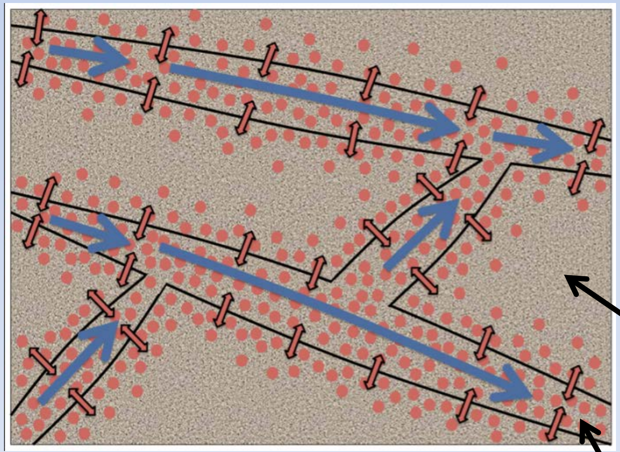
Single-well push-pull tests



(Matter et al, 2007)

tracers





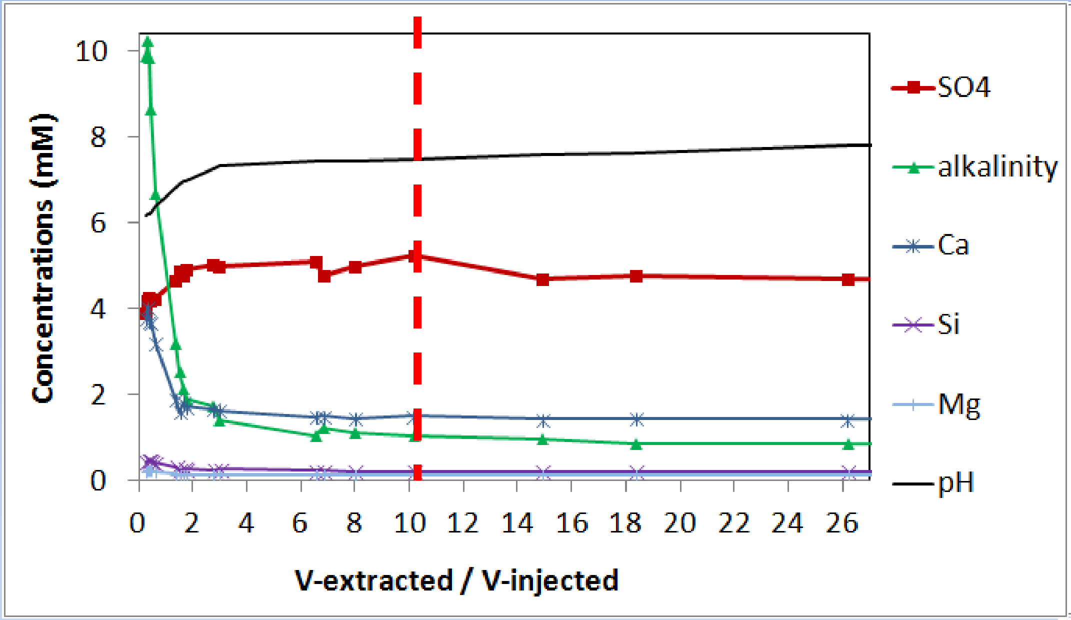
(Umemoto thesis, 2012)

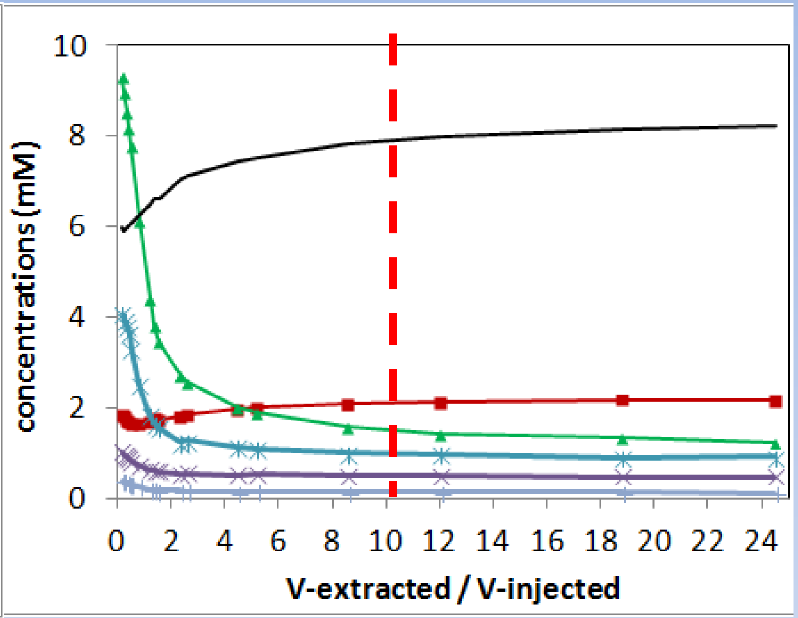
Field injection

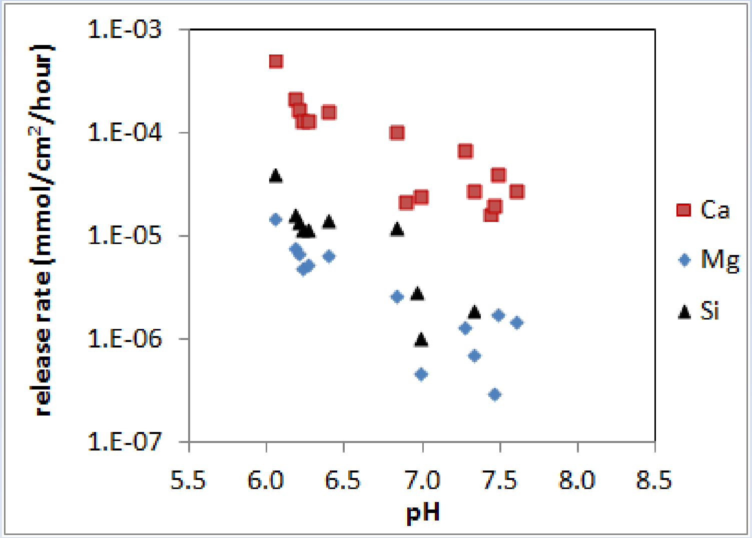
Element release - major ions

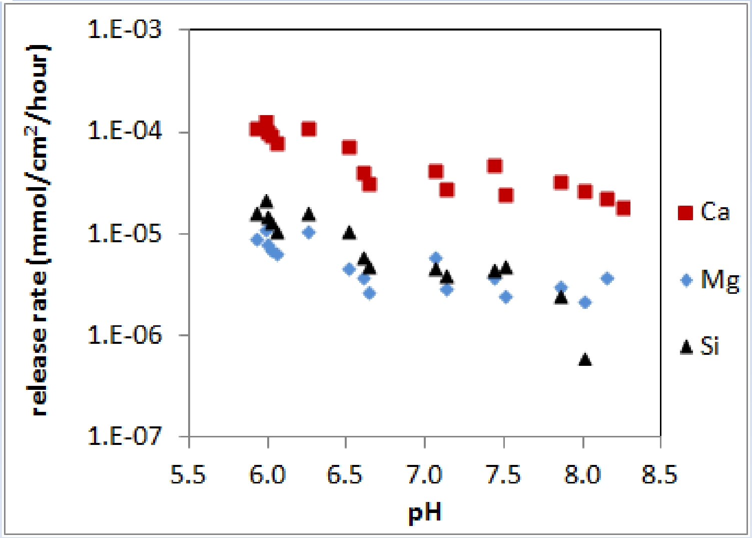
2011

2012



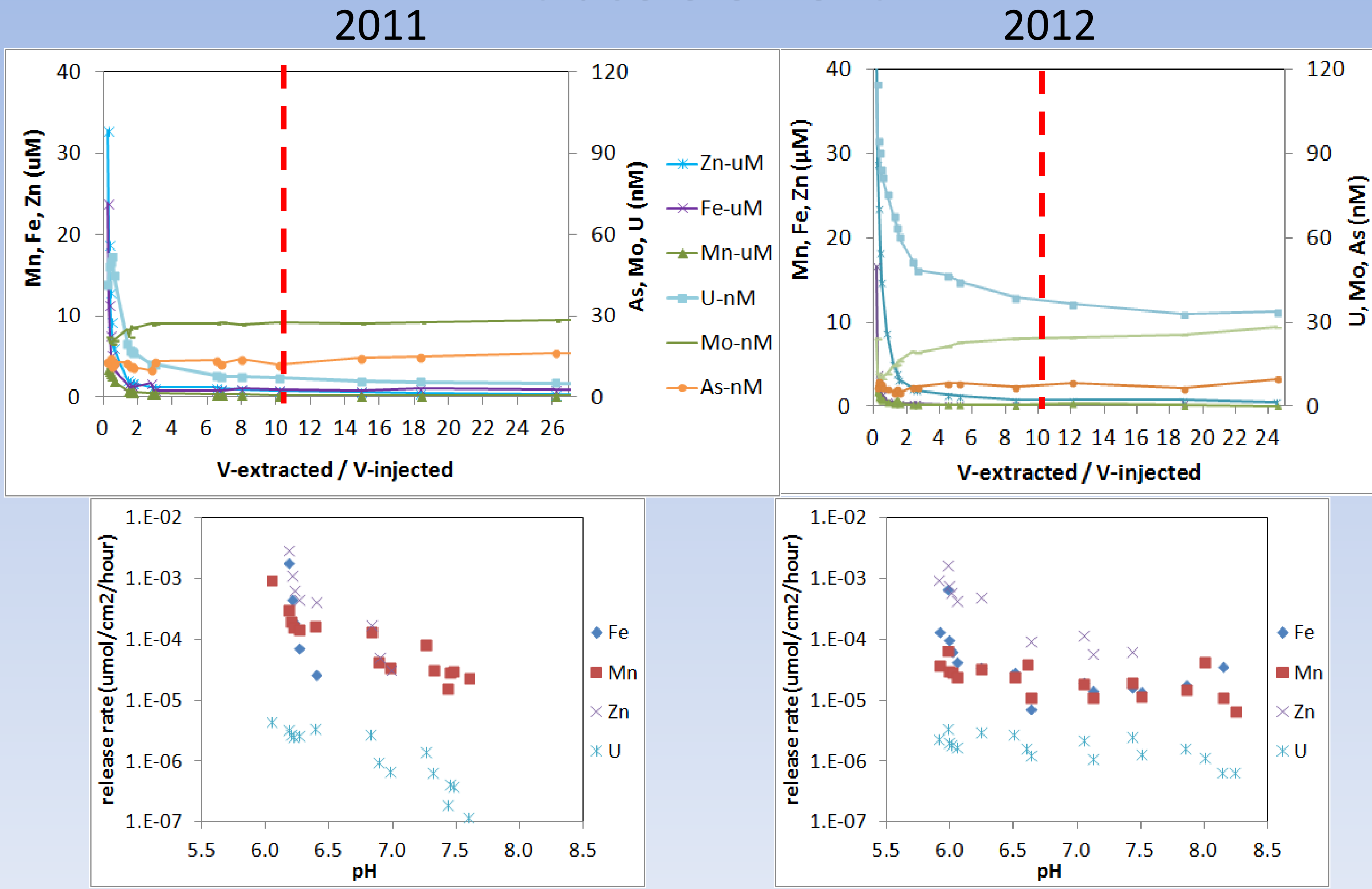






Field injection

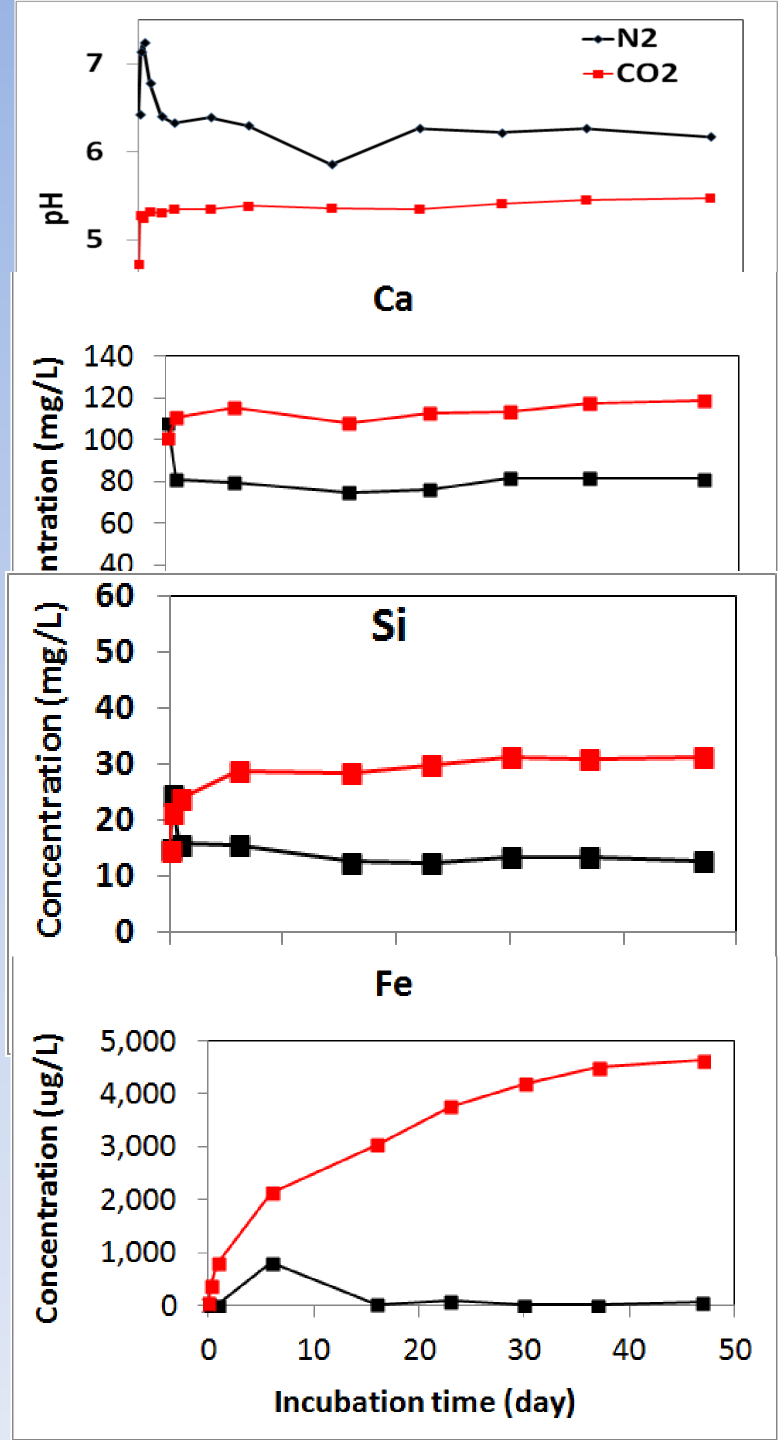
Element release
- trace element



Lab incubation

Element release

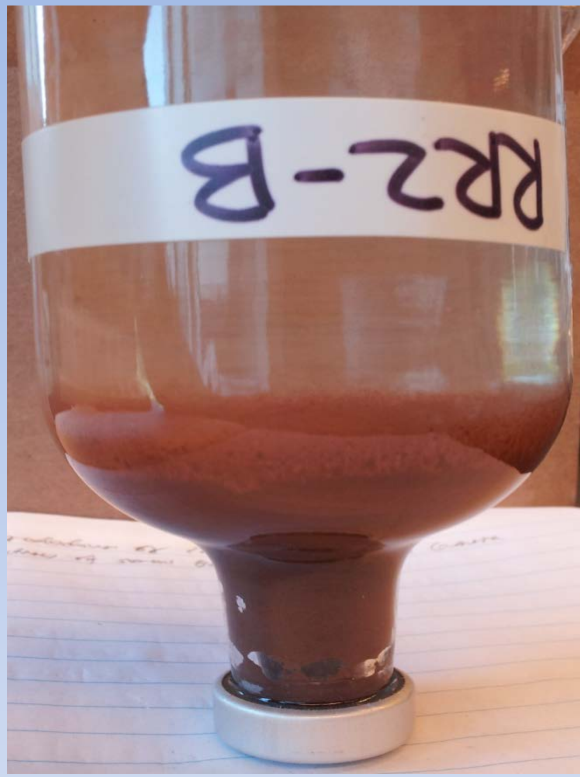
-TW3 sediment

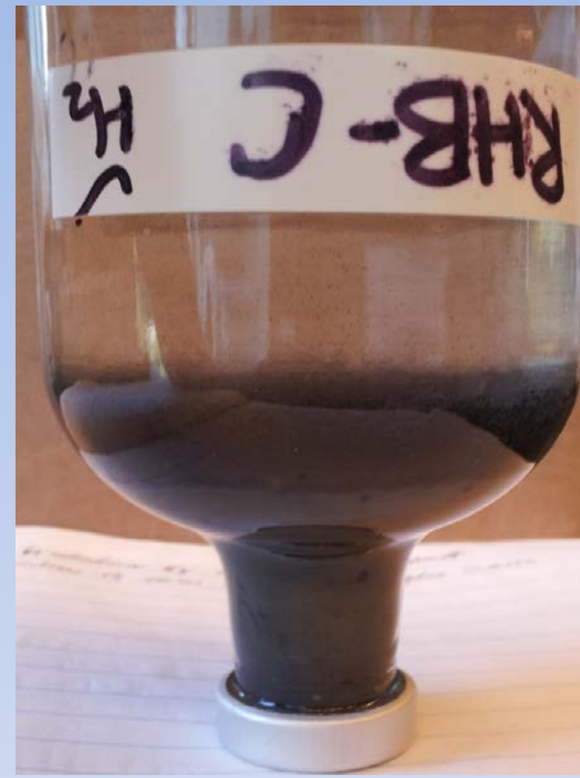


TW-3 sediment (coarse, medium, fine)

- DI or aquifer water
- continuous N_2 or CO_2 flow

Lab incubation



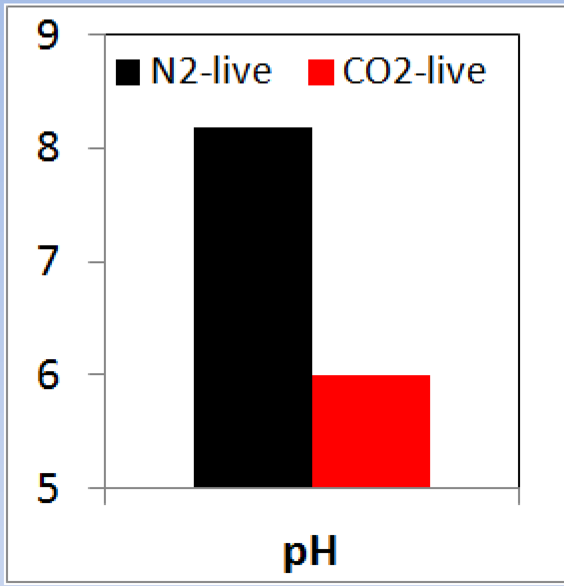


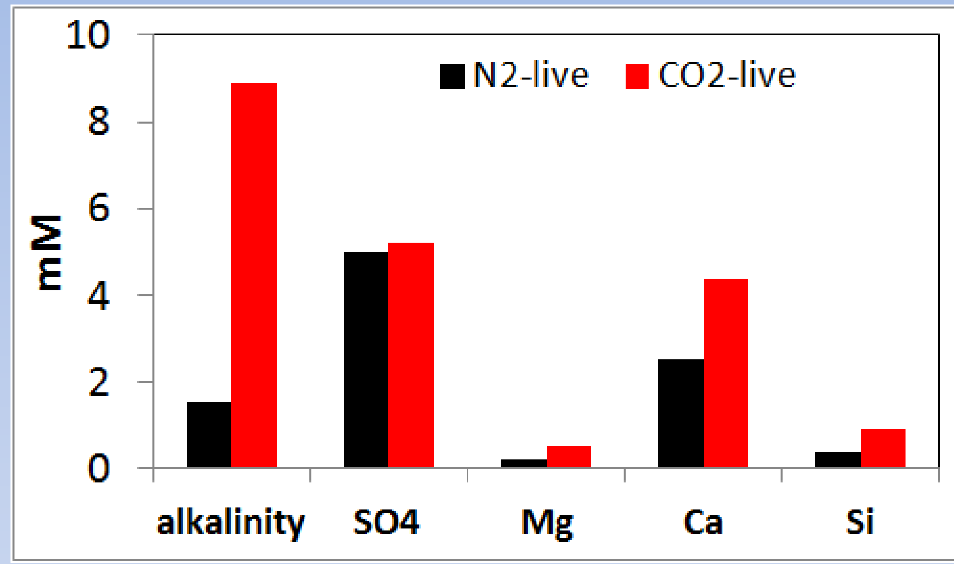
Newark Basin outcrops (n=6) and cores (n=25) (sandstone, mudstone, basalt), aquifer water

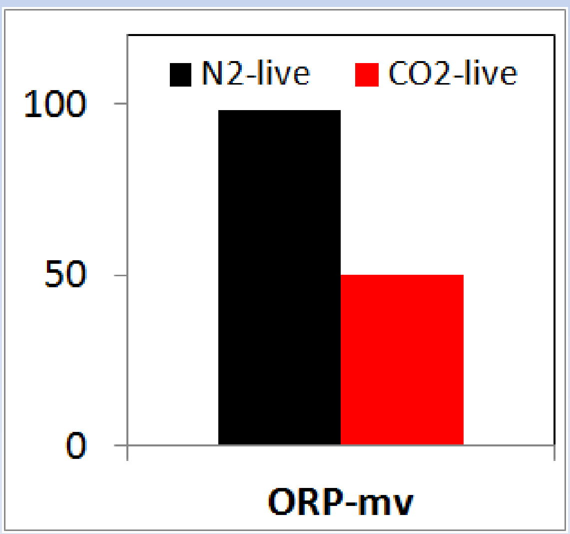
- N_2 or CO_2 saturated initially
- live, dead

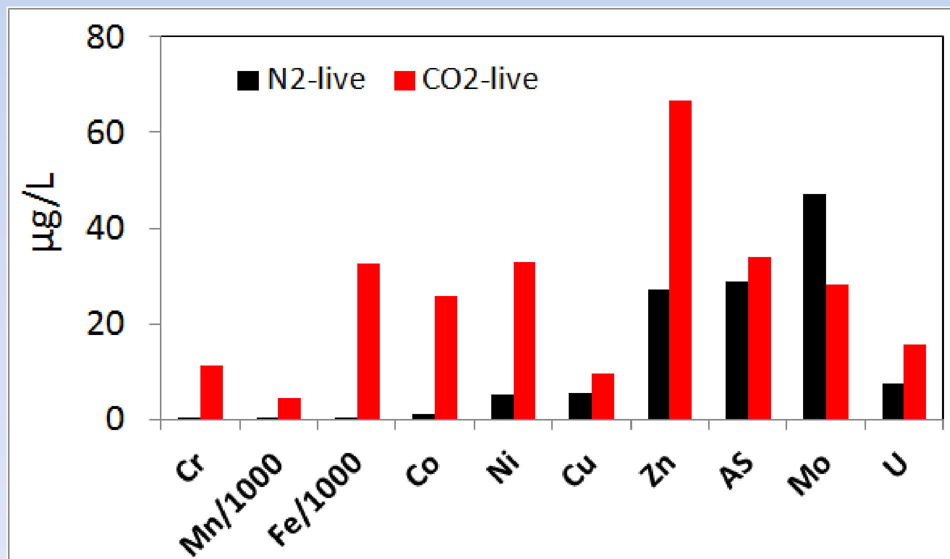
Lab incubation

Element release - N_2 vs. CO_2 experiments

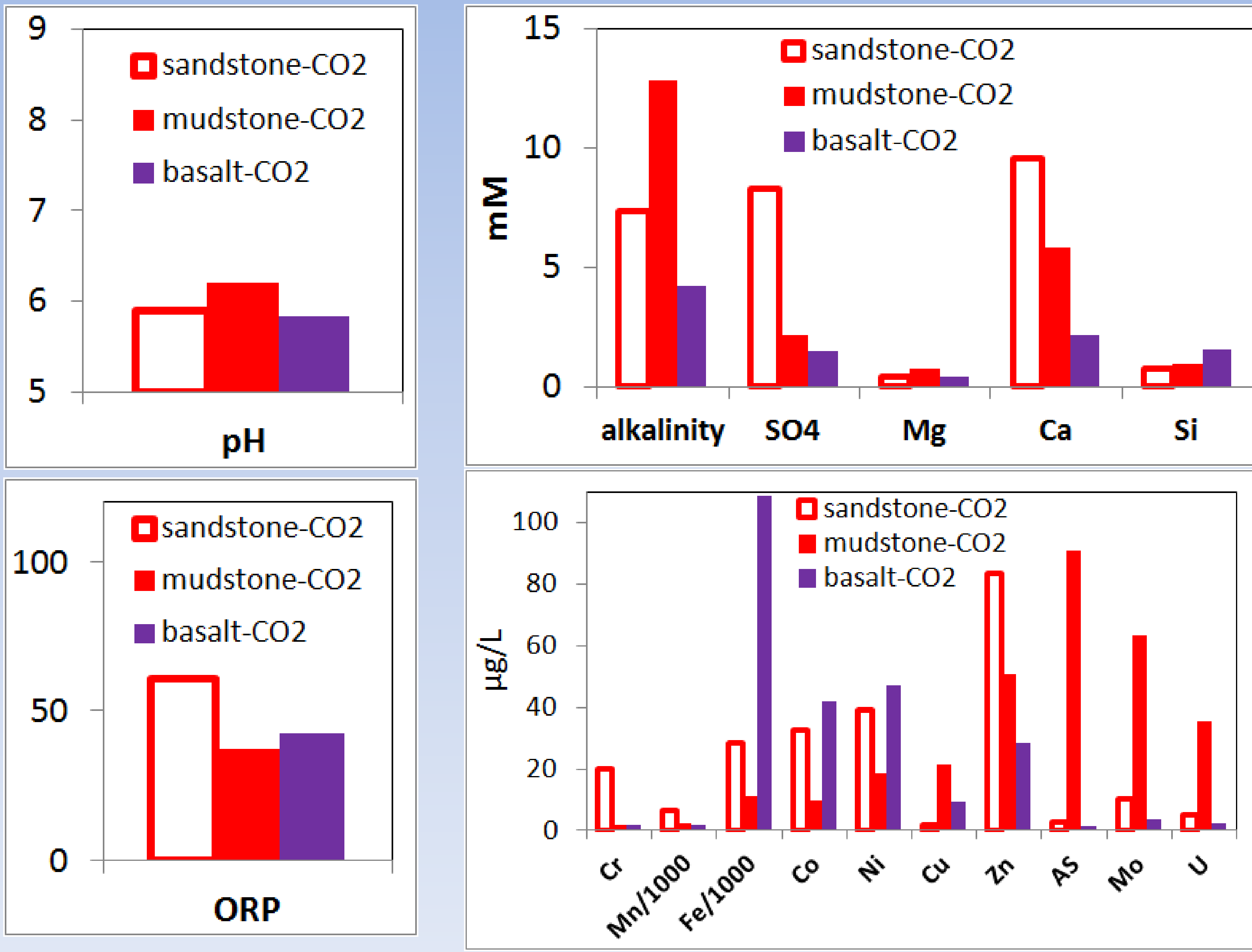








Rock type - CO_2 experiments only



Implications for drinking groundwater quality

Primary drinking water standards (MCLs)

- Inorganic chemicals (in mg/L)
  - **As** (0.01), Ba (2), Be (0.004), **Cd** (0.005), **Cr** (0.1), Cu (1.3), Pb (0.015), Sb (0.006), Se (0.05), Tl (0.002)
  - **F** (4), NO_3_N (10), NO_2_N (1)
- Radionuclides: **U** (30 μg/L)

Secondary drinking water regulations (in mg/L)

- **pH** (6.5-8.5);
- **Al** (0.2), Cu (1.0), **Fe** (0.3), **Mn** (0.05), **Zn** (5)
- F (2), Cl (250), **SO_4** (250)

Red: exceeding MCLs in field
Underscore: exceeding MCLs in lab

Implications for groundwater monitoring

- monitoring parameter:
  - -- pH (*p*CO_2), EC
  - -- alkalinity, Ca, Mg, Si
  - -- Mn, Fe, Cr, Co, Ni, Cu, Zn, Rb, Sr, Ba, U
- sensitive indicator:
  - -- pH, alkalinity, Ca, Mn, U (at 1% atm *p*CO_2)

Conclusions

(1) What is the dependence of major and trace element release on $p$$CO_2$(pH) in response to CO_2 leakage?

Under CO_2 leakage scenario, the release of elements is enhanced, and release rates are dependent on pH (pCO_2) caused by increased acidity, and/or redox condition in altered aquifer environment.

(2) What is the difference of groundwater response to CO_2 in aquifers with different rock types?

Sedimentary rocks tend to release more carbonate species, while basalts tend to release more silicates and metals such as Fe, Co, Ni. Elements such as Cu, As, Mo, U tend to bond with fine sediments and release to water under elevated CO_2 conditions.

(3) What are the potential impacts on groundwater quality and monitoring?

CO_2 leakage has negative impacts on shallow water quality, including increased acidity and inorganic chemicals such as Fe, Mn, Zn, Al, U, As, Cd, Cr.