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Diagnostic Monitoring of Biogeochemical Interactions of a Shallow Aquifer in Response to a CO₂ Leak

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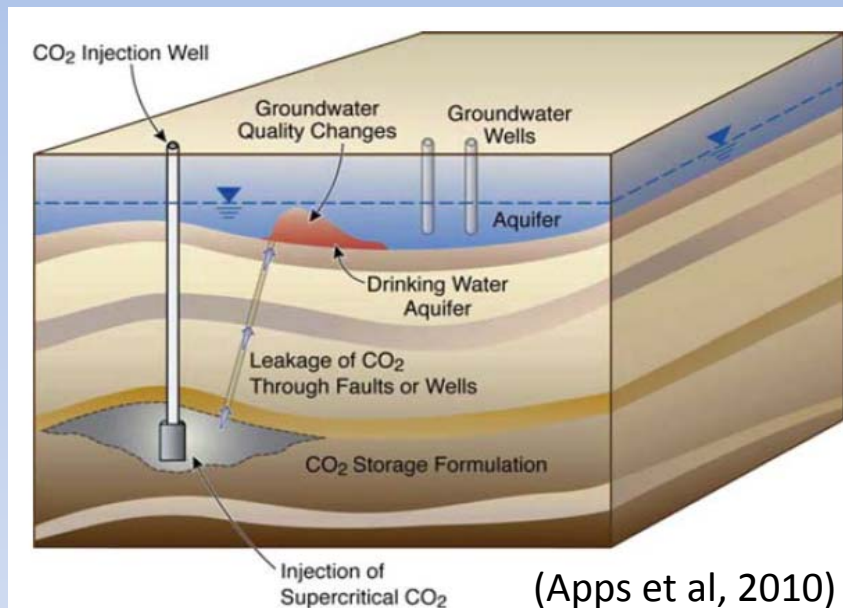
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Project overview

– leaking scenario



- (1) Estimate element release, microbial dynamics and their impacts in response to CO₂ 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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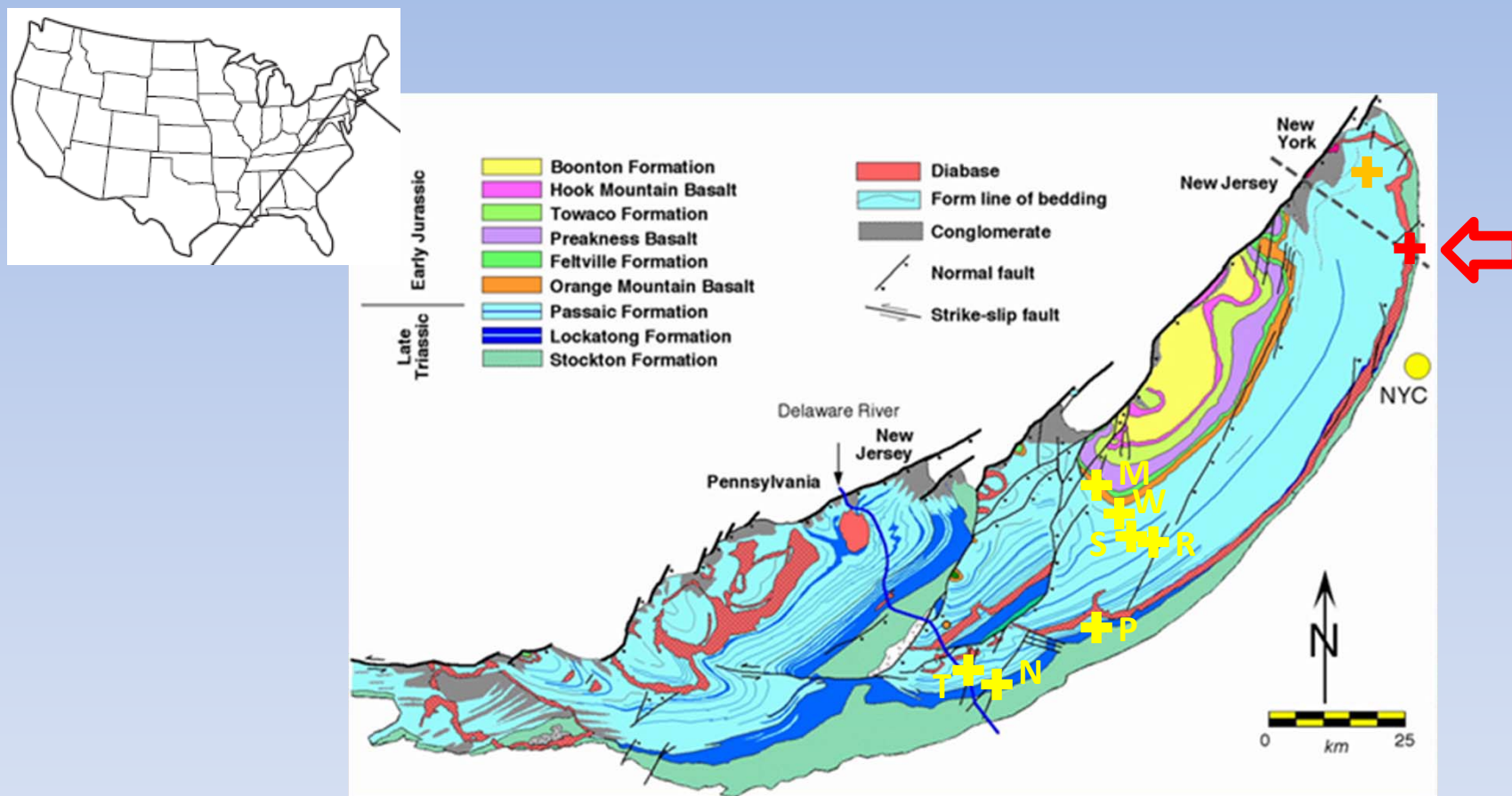
Groundwater geochemistry in field injection and lab incubation experiments simulating CO₂ leakage into shallow aquifers in Newark Basin

Qiang Yang

- 1) Introduction (study site, research question);
- 2) In-situ field injection of simulated CO₂ leakage;
- 3) Lab incubation experiments;
- 4) Implications for groundwater quality monitoring

Introduction

Study Site – Newark Basin

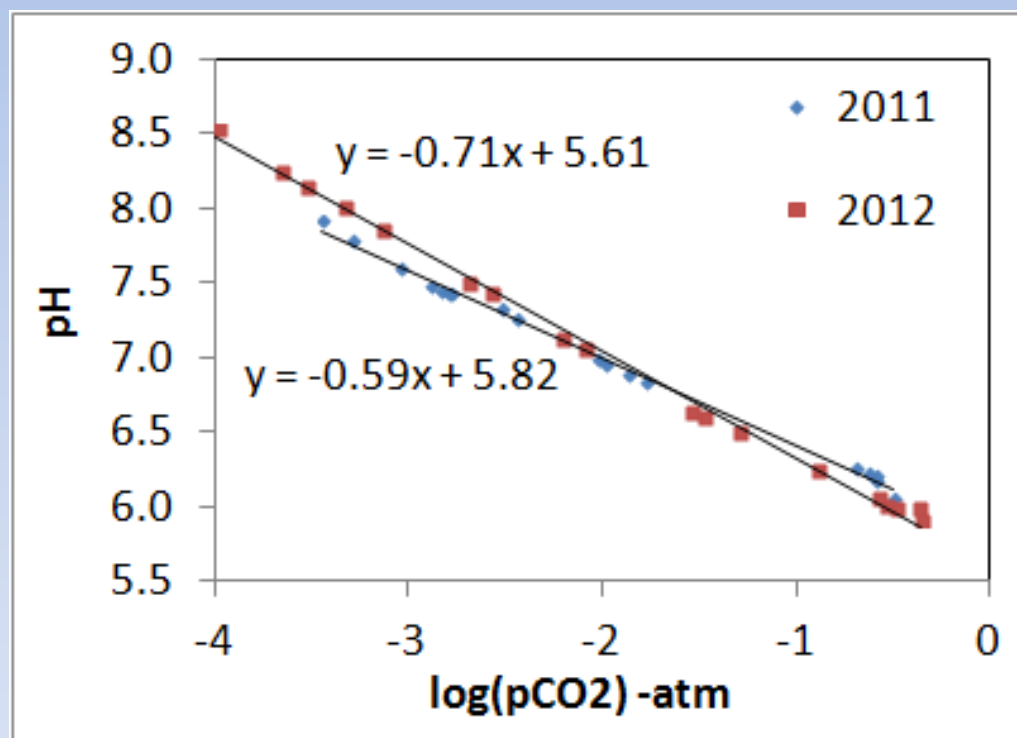


- Sediment-filled rift basin intruded by Palisades sill
- Fractured sedimentary bedrock aquifers

Introduction

Research Questions

- (1) What is the dependence of major and trace element release on $p\text{CO}_2(\text{pH})$ in response to CO_2 leakage?



Introduction

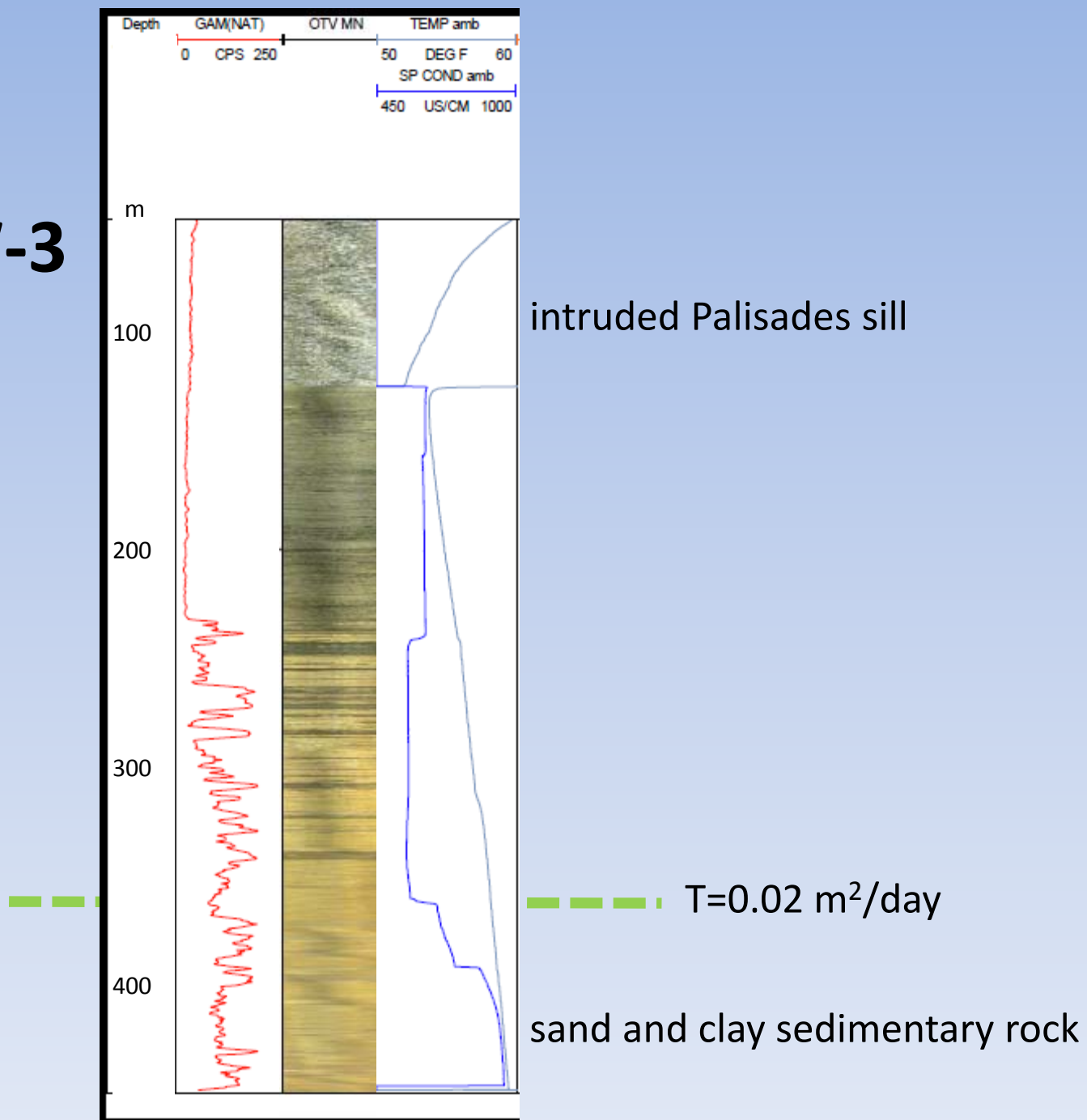
Research Questions

- (1) What is the dependence of major and trace element release on $p\text{CO}_2$ (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

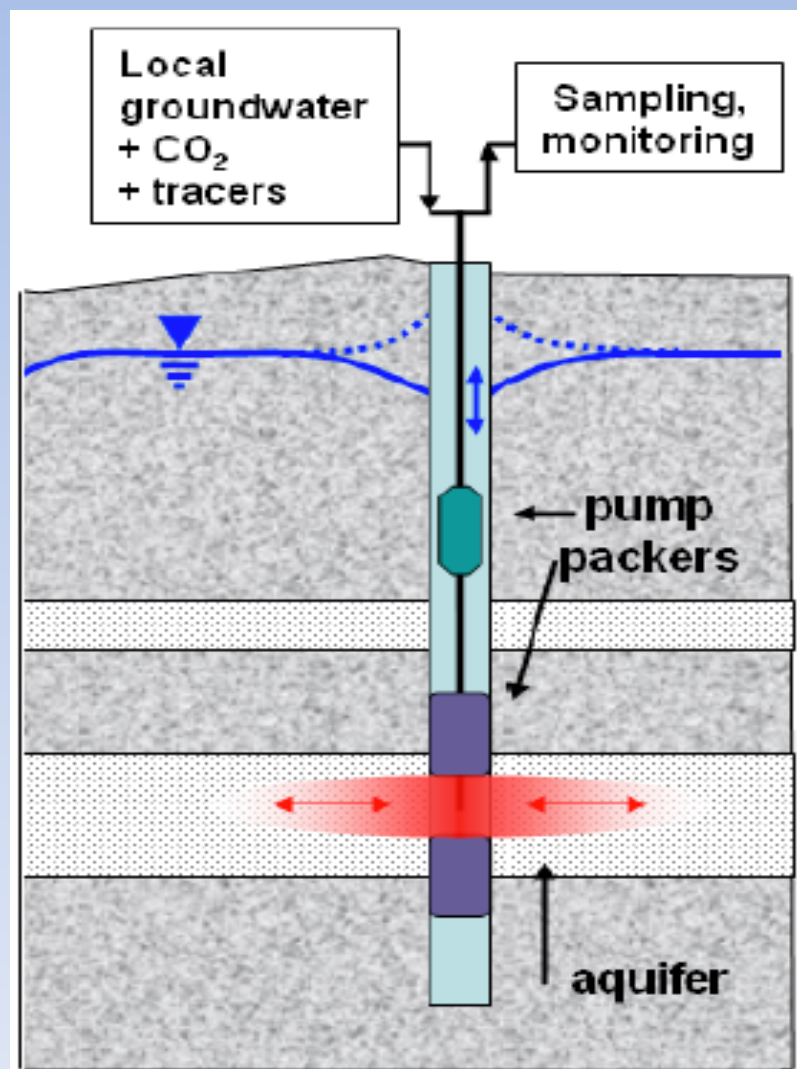
Field injection

Test well TW-3



Field injection

Single-well push-pull tests

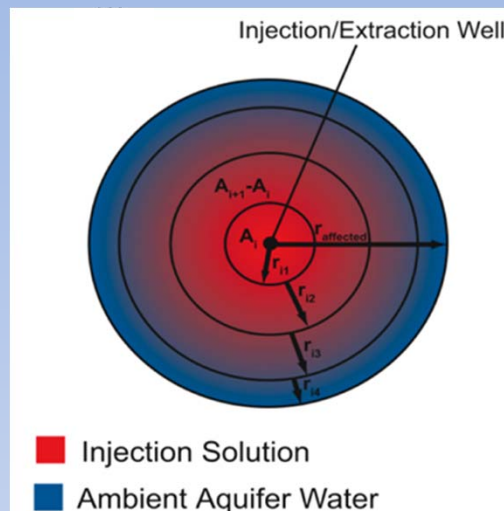


- interval: 362-366 m
- volume: $\sim 3 \text{ m}^3$ aquifer water with 1 bar of CO₂
- duration: 10 hours
- period: 3-6 weeks
- Tracer: KBr (50-100 mg/L of Br⁻), SF₆ ($\sim 10 \text{ pmol/L}$)

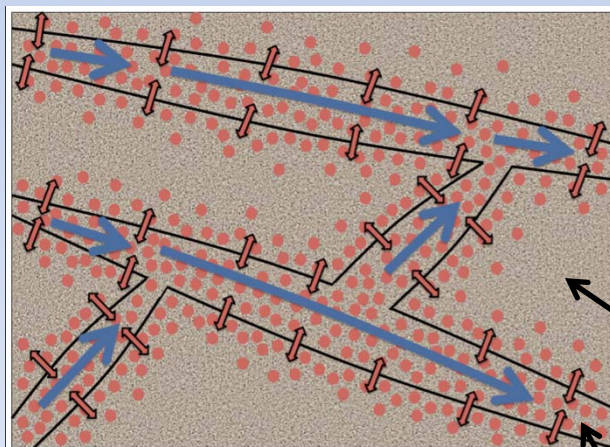
Field injection

Single-well push-pull tests

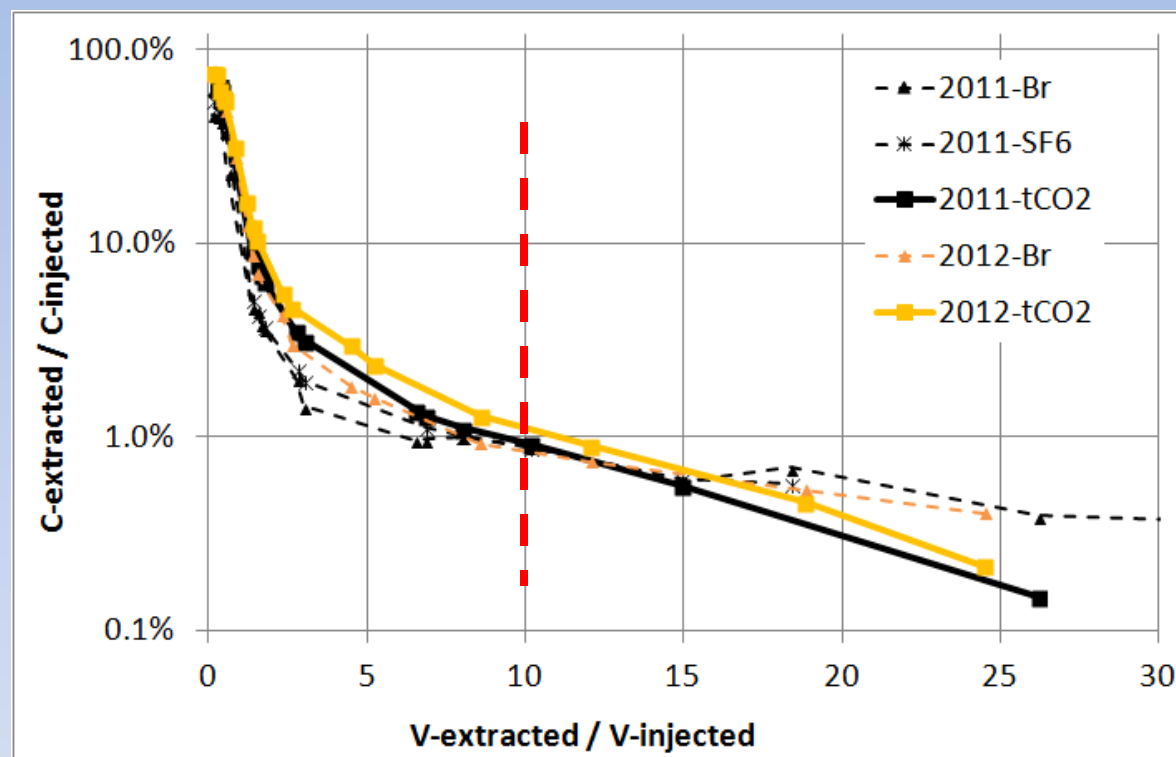
tracers



(Matter et al, 2007)



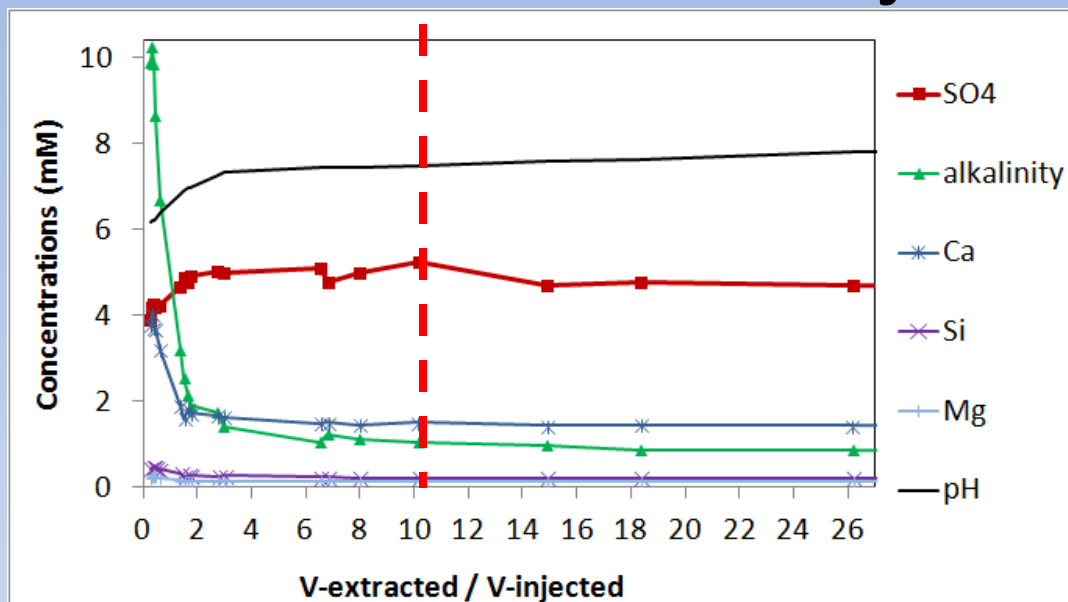
(Umemoto thesis, 2012)



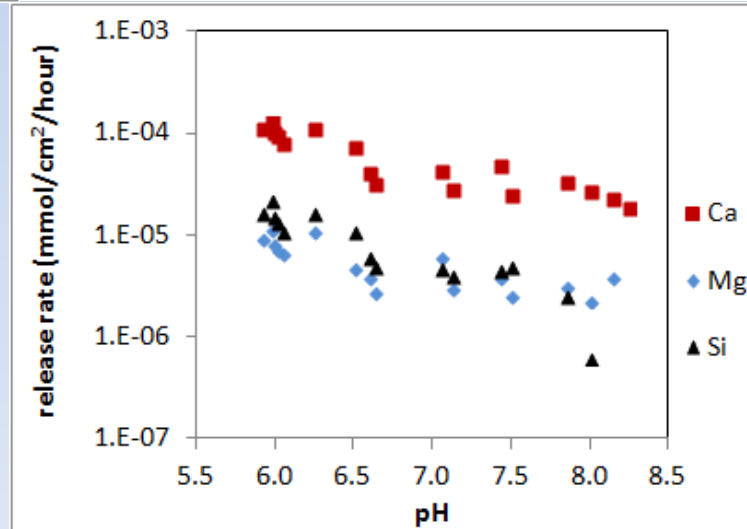
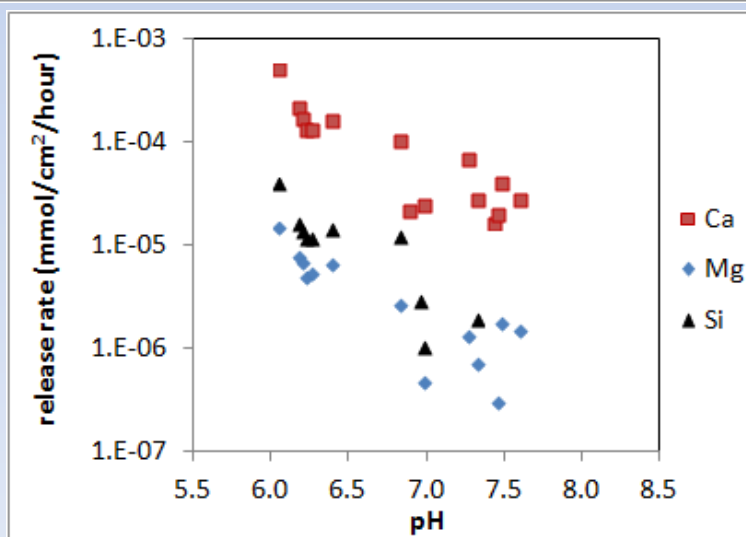
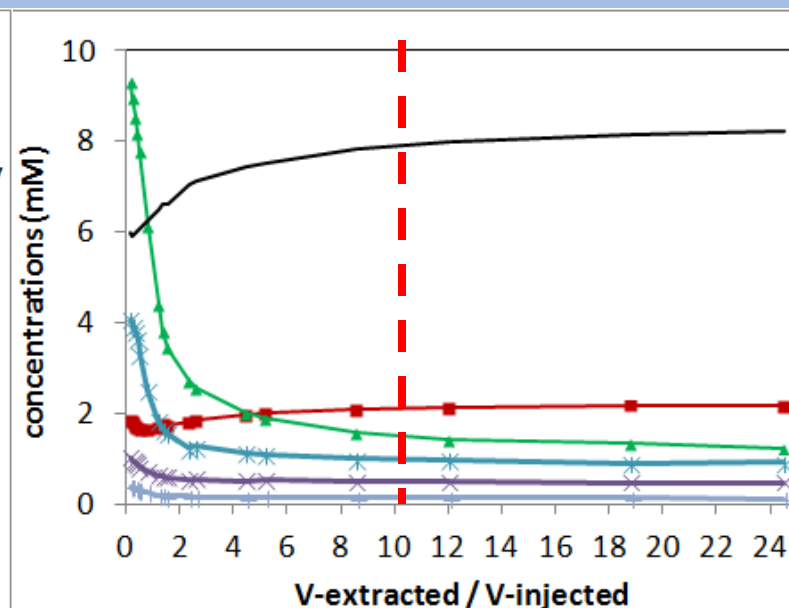
Field injection

Element release
- major ions

2011



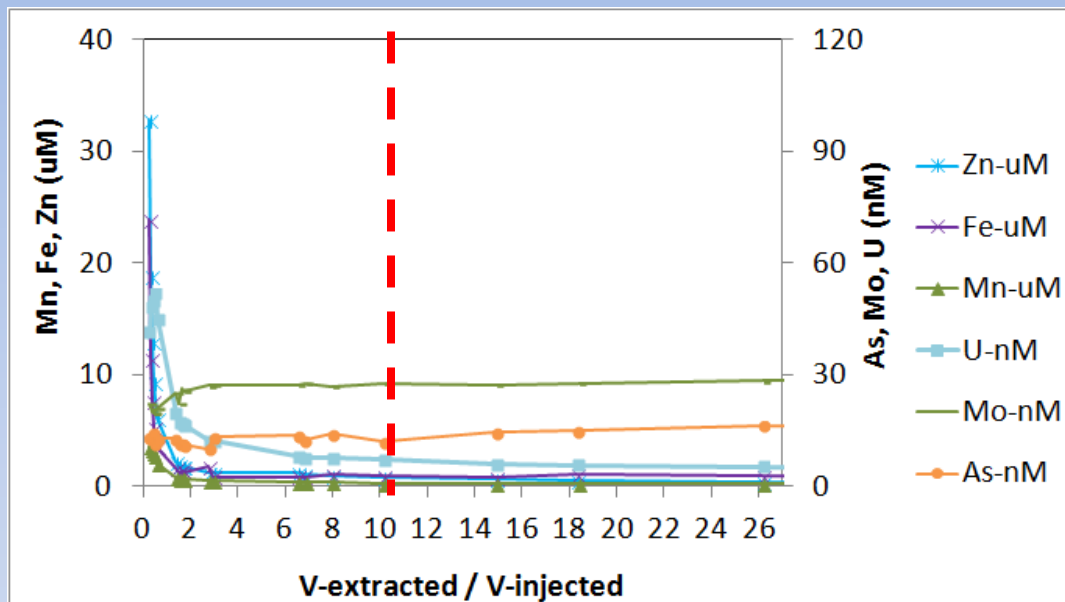
2012



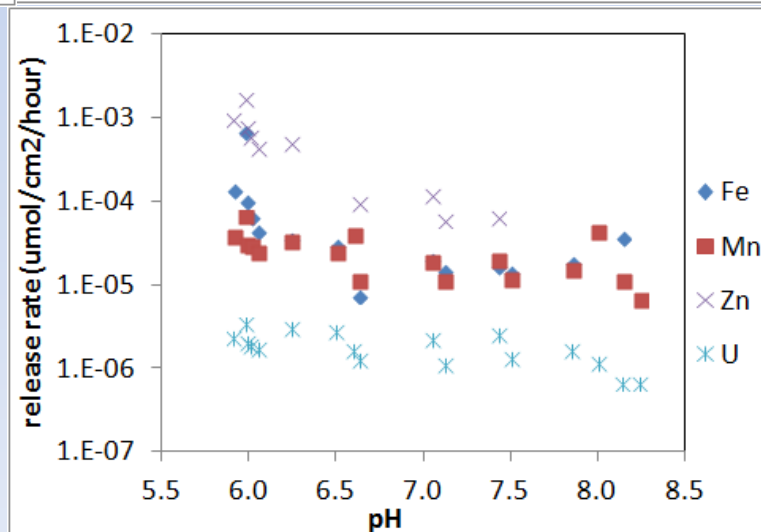
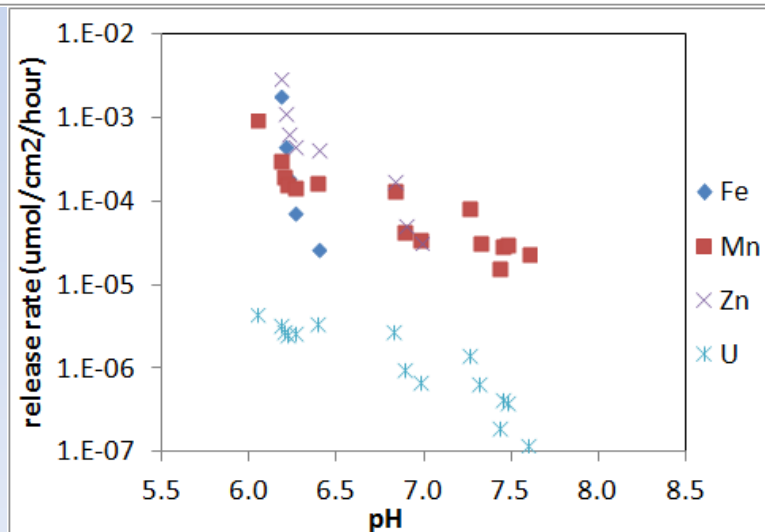
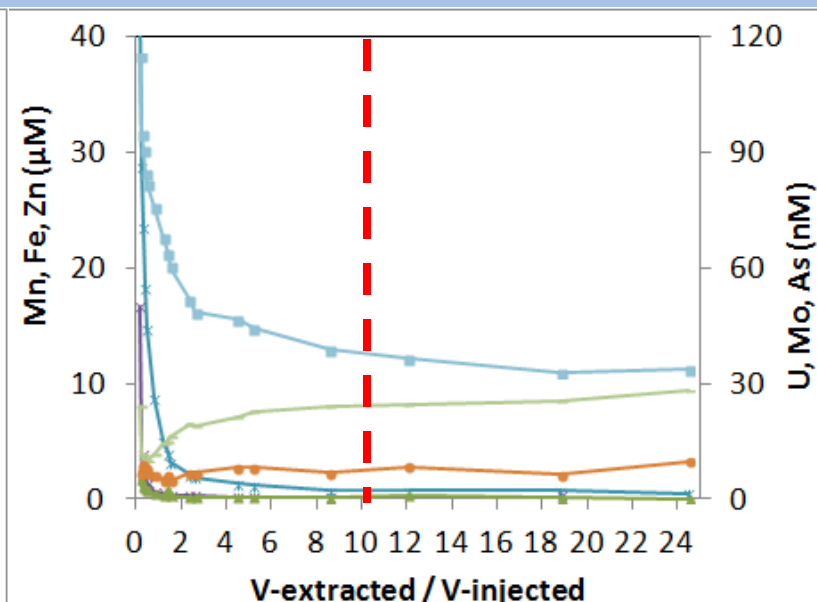
Field injection

Element release
- trace element

2011



2012



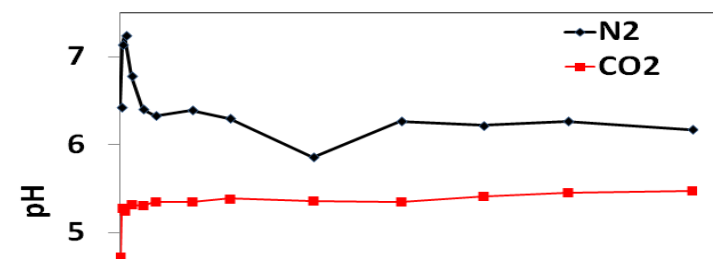
Lab incubation

Element release -TW3 sediment

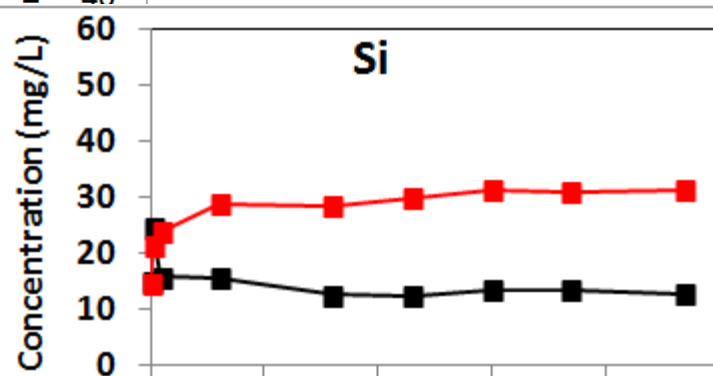
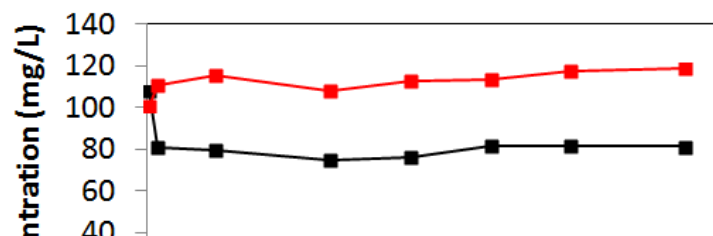


TW-3 sediment (coarse, medium, fine)

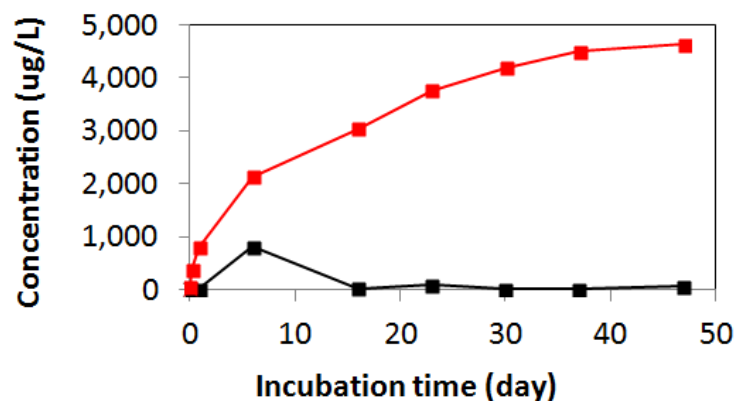
- DI or aquifer water
- continuous N₂ or CO₂ flow



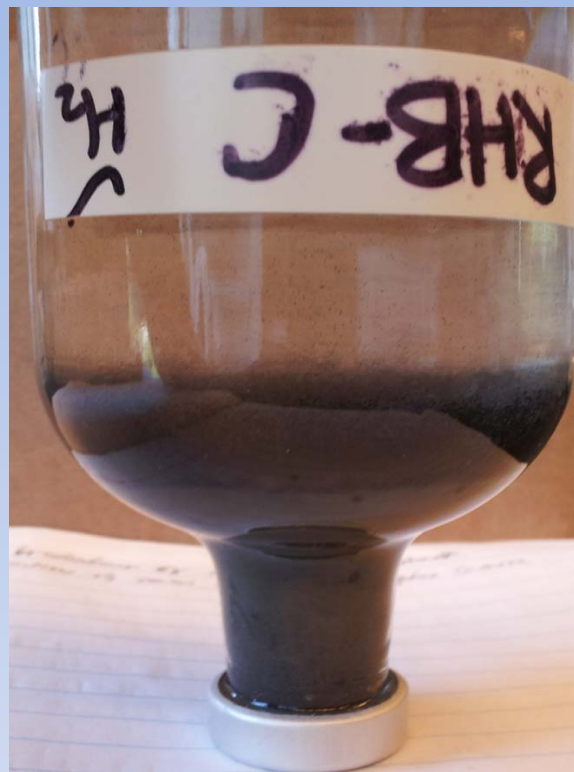
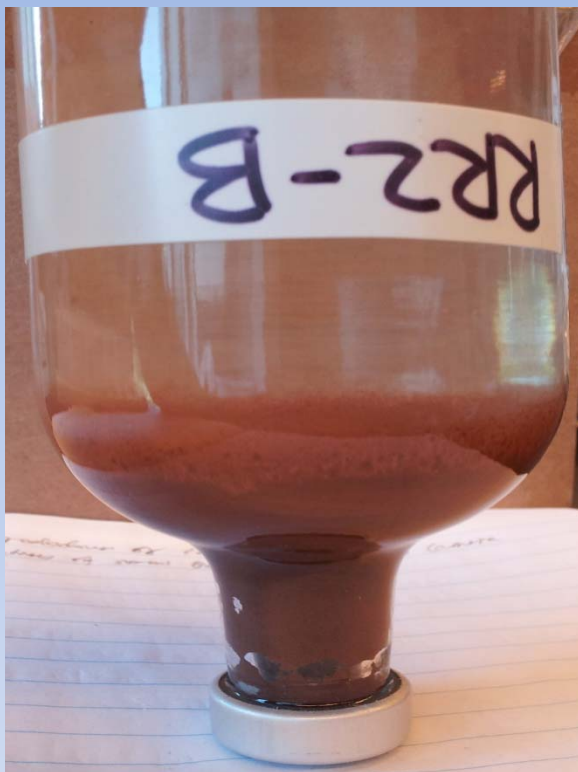
Ca



Fe



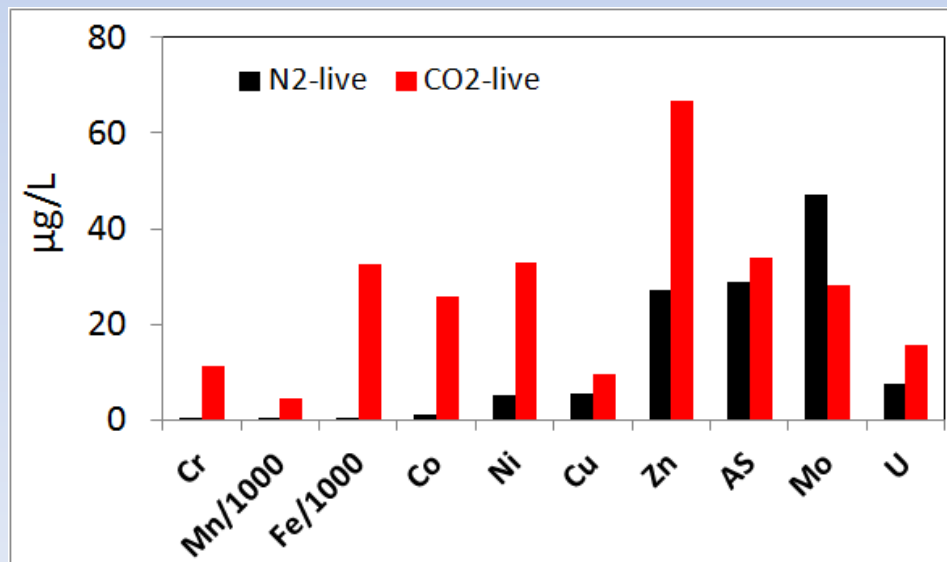
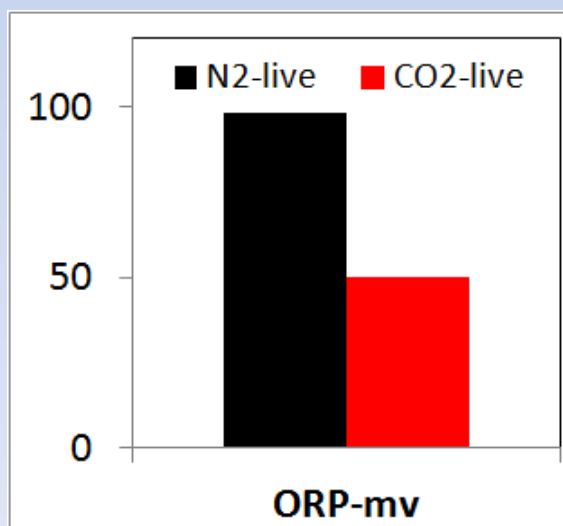
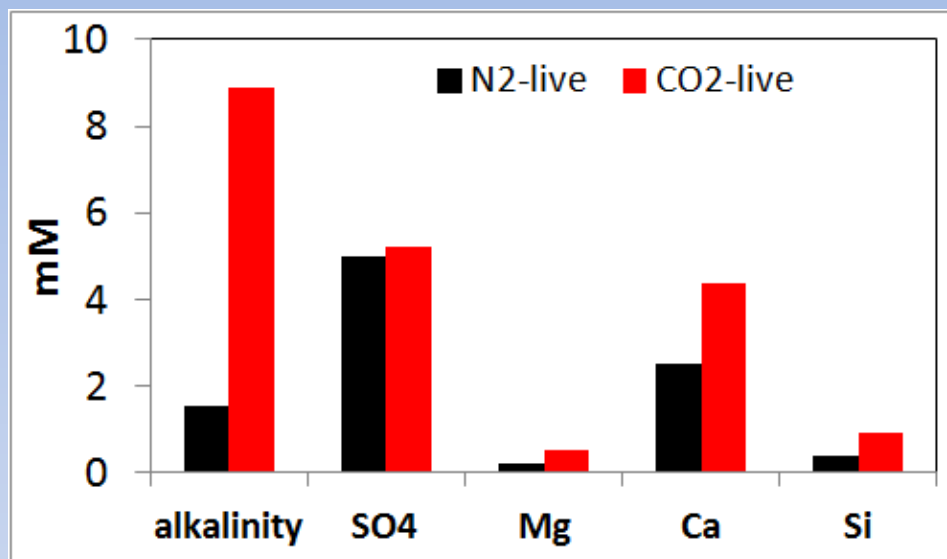
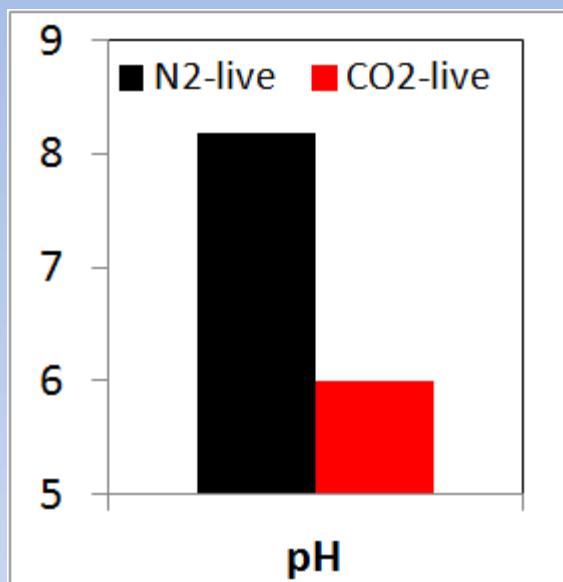
Lab incubation



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

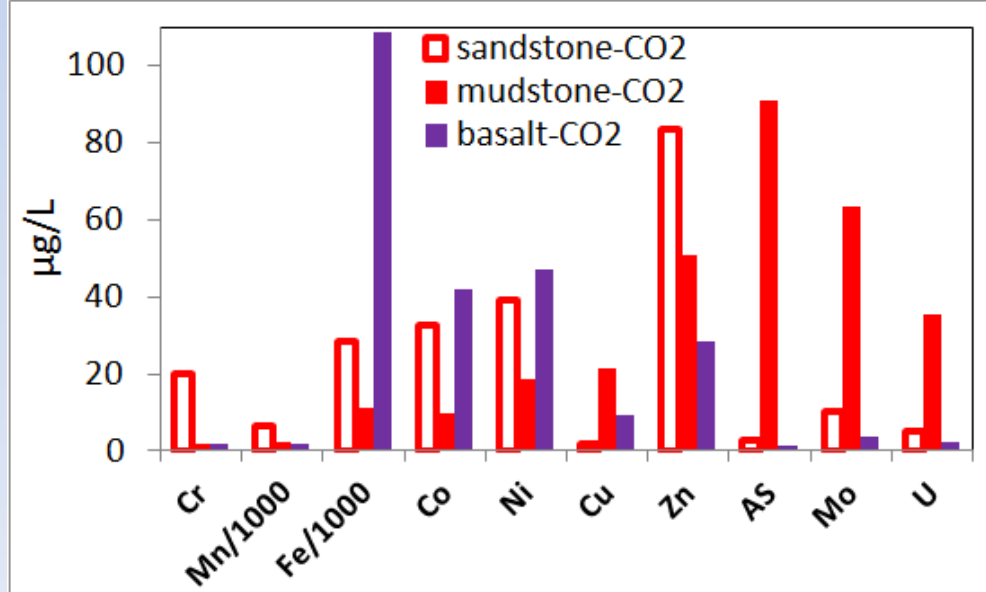
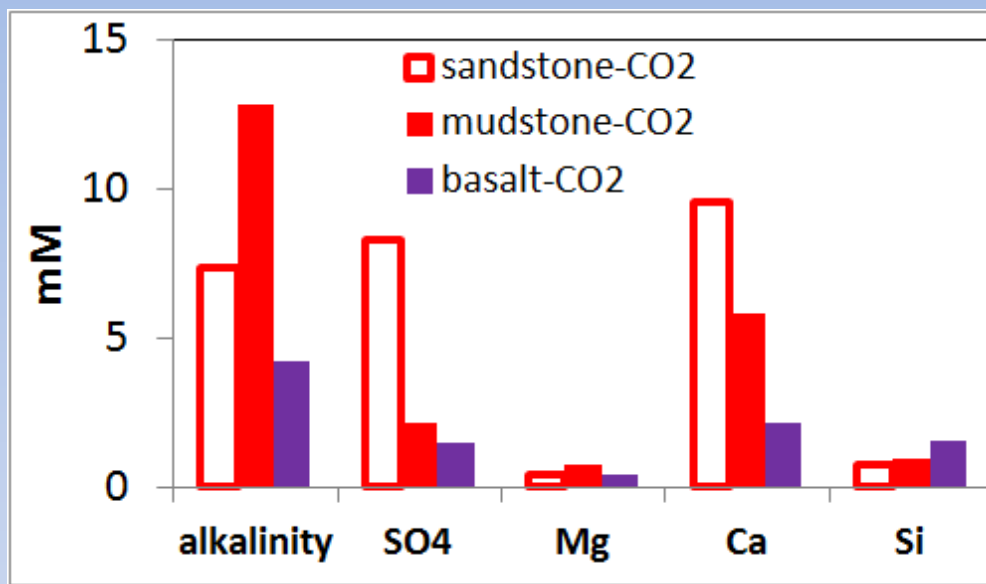
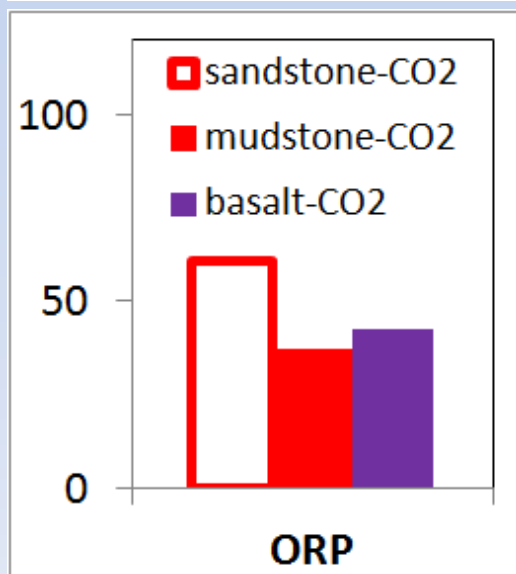
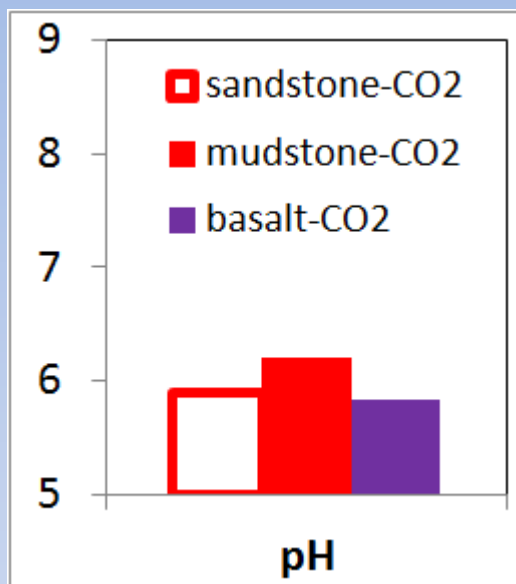
- N_2 or CO_2 saturated initially
- live, dead

Lab incubation

Element release - N₂ vs. CO₂ experiments

Lab incubation

Rock type

- CO₂ experiments only

Implication

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), NO₃_N (10), NO₂_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), SO₄ (250)

Red: exceeding MCLs in field

Underscore: exceeding MCLs in lab

Implication

Implications for groundwater monitoring

- ❖ monitoring parameter:
 - pH ($p\text{CO}_2$), 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 $p\text{CO}_2$)

Conclusions

- (1) What is the dependence of major and trace element release on $p\text{CO}_2$ (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 ($p\text{CO}_2$) 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.