CO_2 Batch Experiments and Regional Spring Sampling

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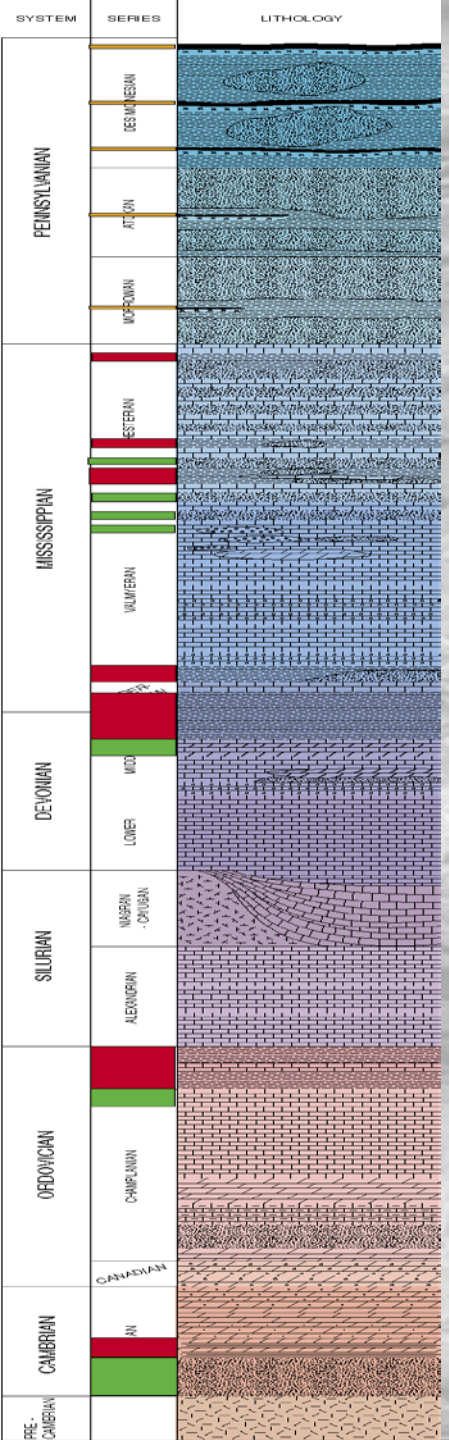
Mt. Simon and Seals



- Mt. Simon Sandstone is the primary injection target
- Eau Claire Shale is the primary seal
- Maquoketa and New Albany Shales are secondary seals
- Knox formation and St. Peter are potential reservoirs

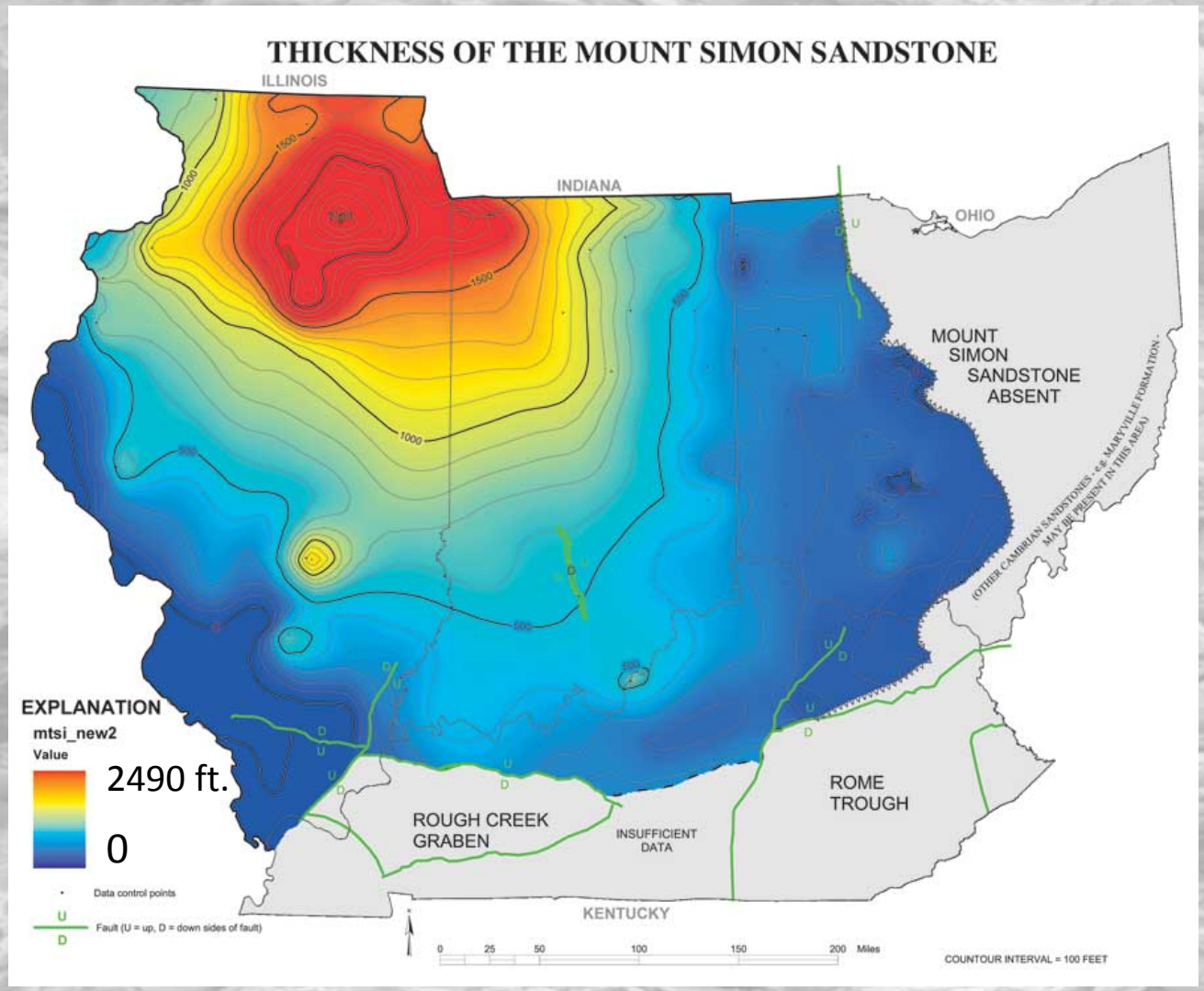
New Albany (Seal)

Maquoketa (Seal)

Eau Claire (Seal)

Mt. Simon (Sink)

Regional Extent



Hickman, et al., 2003

Illinois Basin - Decatur Project (IBDP)

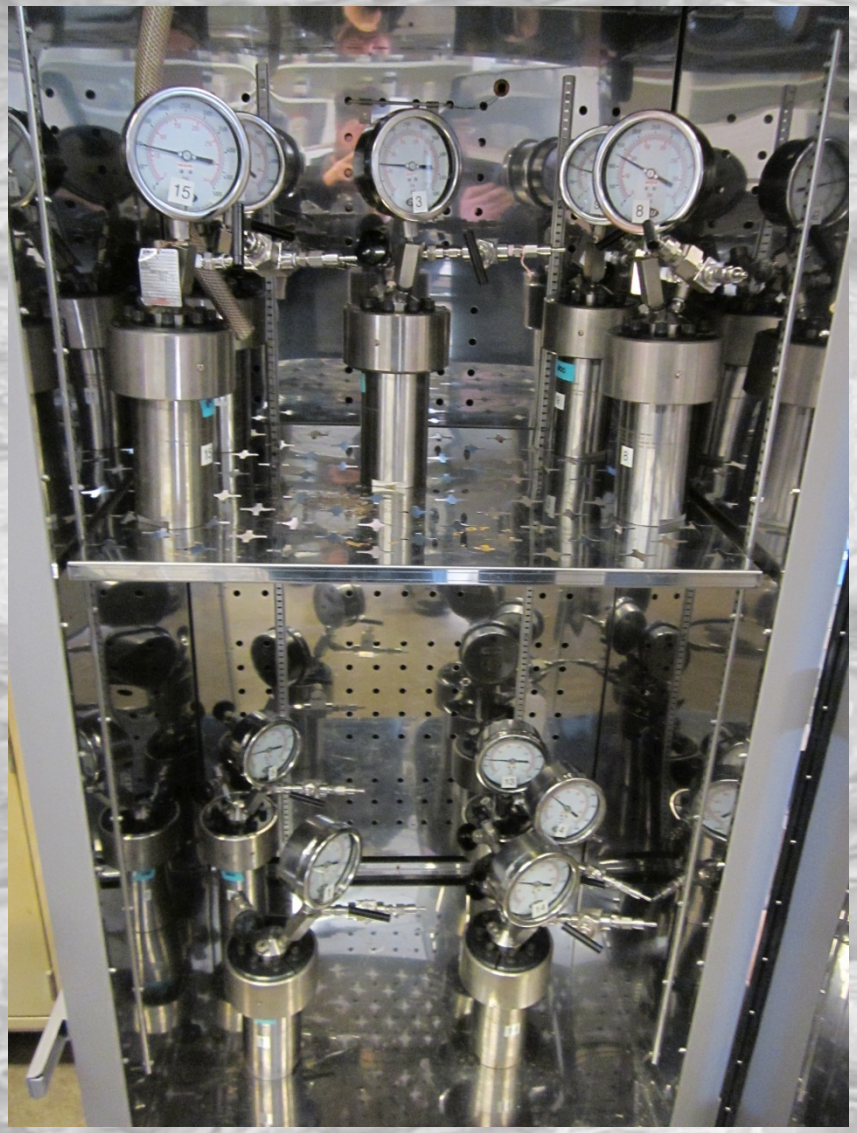
- Located at an ADM ethanol plant in Decatur, Illinois
- More than 333,000 tonnes injected so far into the Mt. Simon Sandstone
- Injection at a depth of 7,000 ft (2,135 m)

Source: sequestration.org

Core and Brine Sampling

- Currently have core from 2 wells at IBDP injection site
- Brine samples from 9 zones in the Mt. Simon and 2 zones above the Eau Claire
- Collected more core samples from other, older core in the ISGS core storage facility (cores from gas storage fields, hazardous waste injection)

Reaction Vessels



- 20 Parr reaction vessels
  - Teflon liners
  - Unstirred
  - Pressure ranges of 5000 and 2000 psi
- Air baths to maintain reservoir temperatures

Experimental Conditions

	Temp (°C)	TDS (mg/L)	Pressure (psi)
New Albany	25	95,700	830
Maquoketa	30	64,000	1,130
Eau Claire	43	119,900	2,430
Mt. Simon	50	168,900	3,000

- Conditions based on well logs, chemical analysis, and historic data
- Most experiments performed with lab mixed brines
- Some Mt. Simon experiments done with collected brines
- Experiments run for up to 9 months

Sample Processing

- Petrography
  - Plane light, Point counts, Phase analysis
  - Mineral composition/Space relations
- XRD
  - Mineral composition
- XRF
  - Elemental composition
- SEM/EDX
  - Space relations/Point composition
- QEMSCAN on select samples
  - Mineral composition/Space relations
- Brine analysis with blanks

Kinetic Modeling

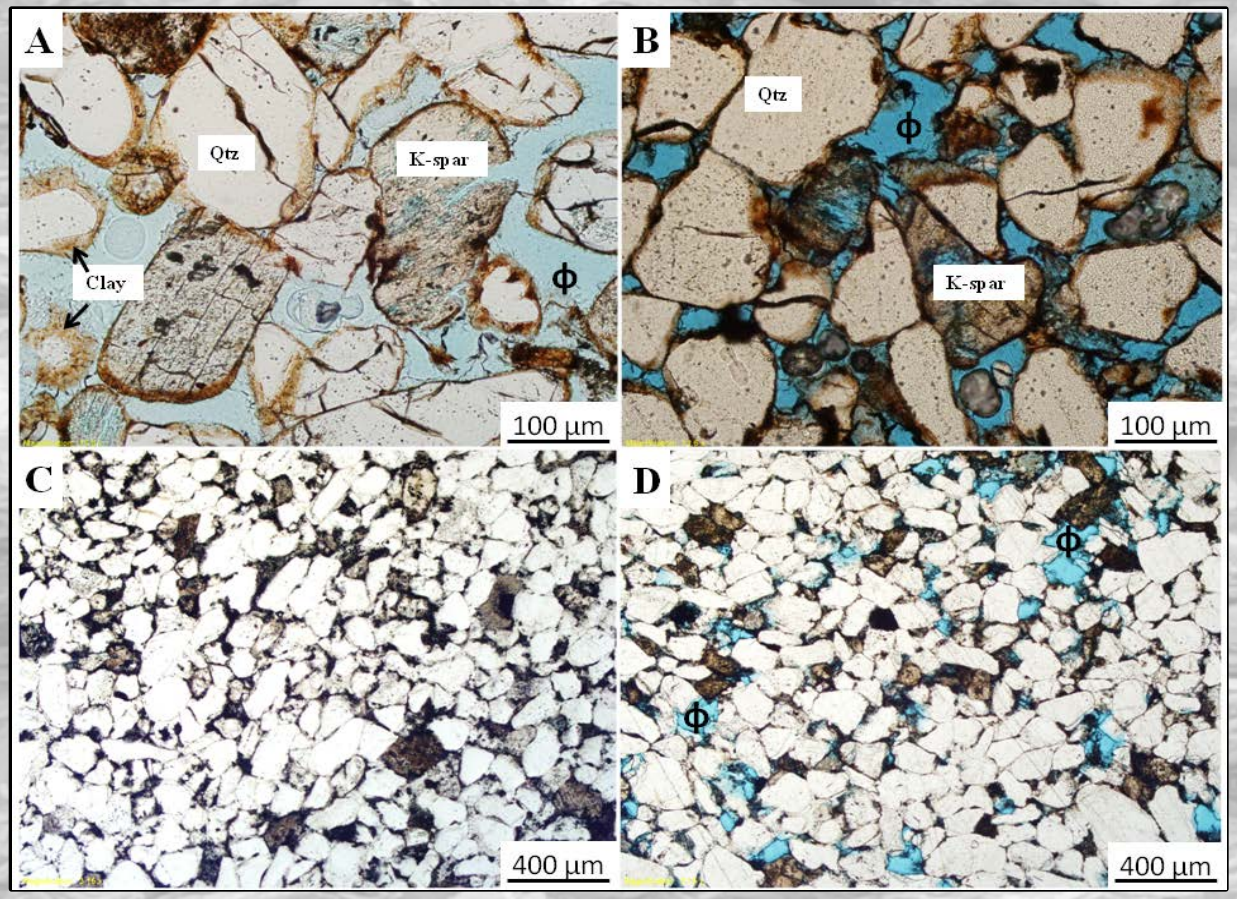
- Use the initial brine and mineralogic composition to create a geochemical model in React
- Use Differential Evolution software* to optimize kinetic rates
  - Creates a population of solutions and evolves improved ones
  - Goal is to match final solution chemistry and mineralogy

* http://www1.icsi.berkeley.edu/~storn/code.html

Mt. Simon Sandstone

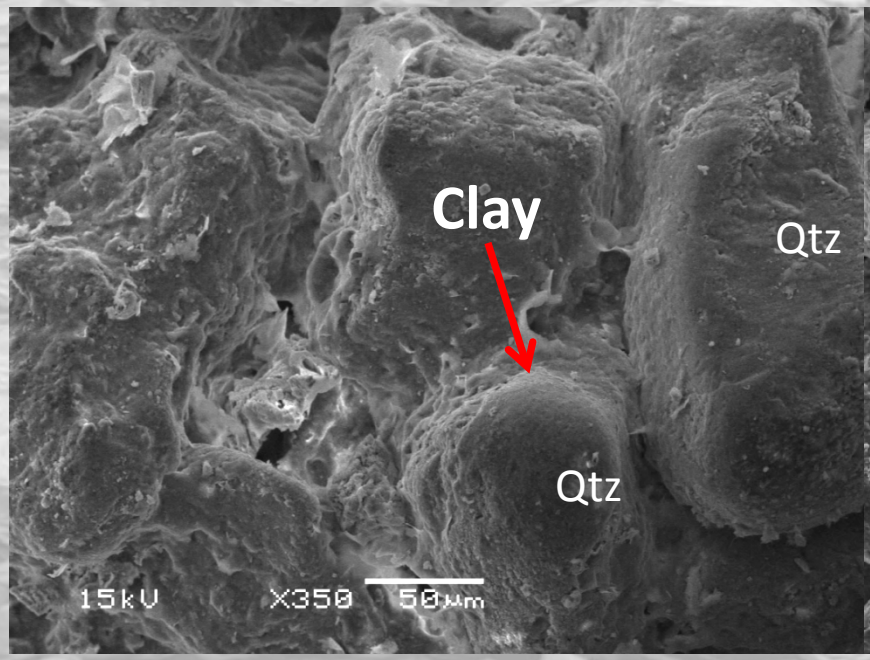
Before

After 6 months

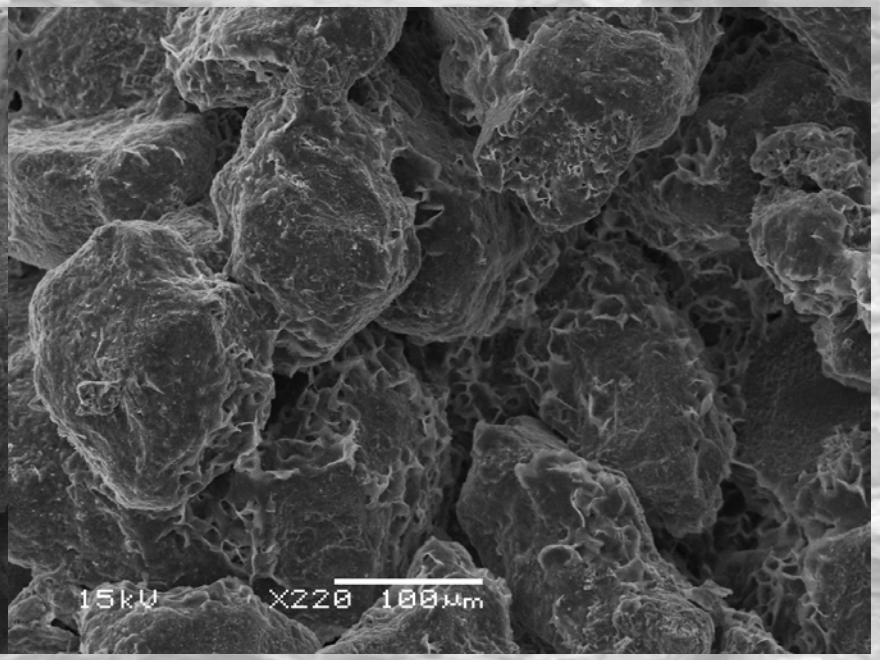


Mt. Simon Sandstone

Before



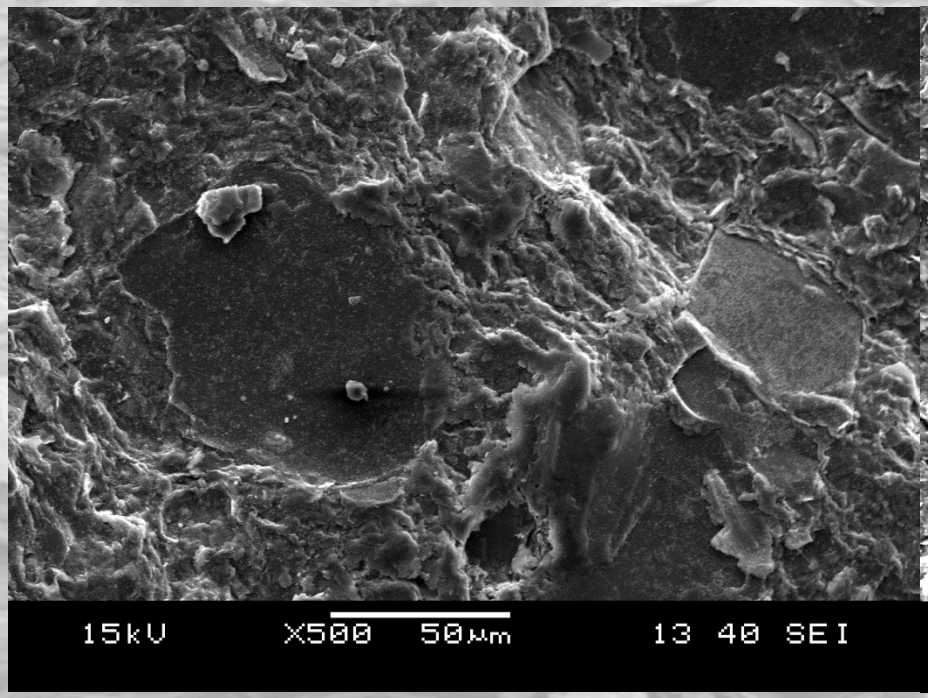
After 6 months



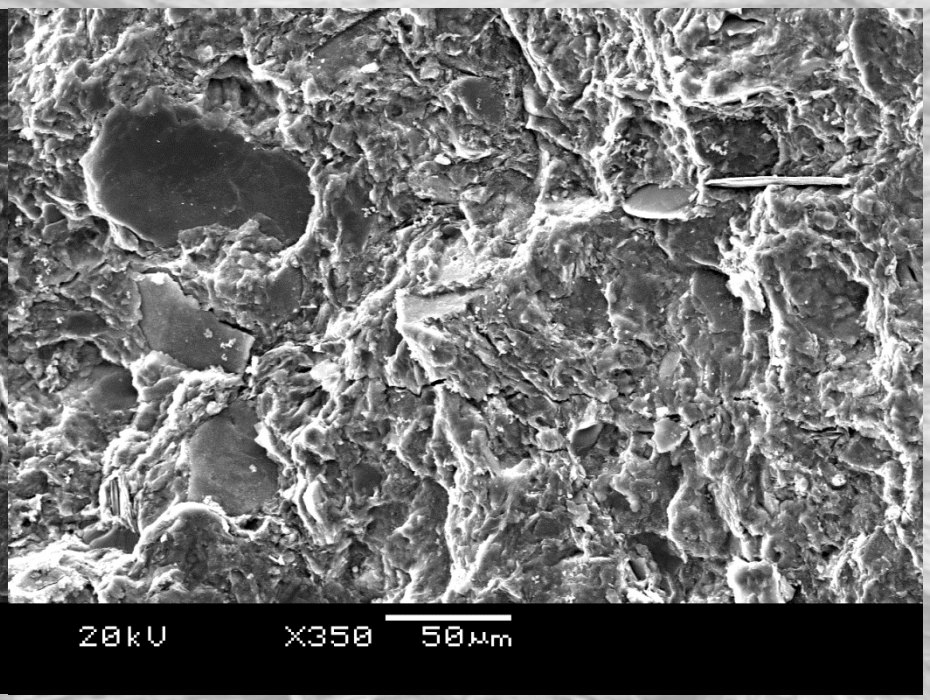
- Dissolution of clay mineral coatings
- Possible Illitization of clays
- Quartz stays inert

Eau Claire Shale

After 3 months



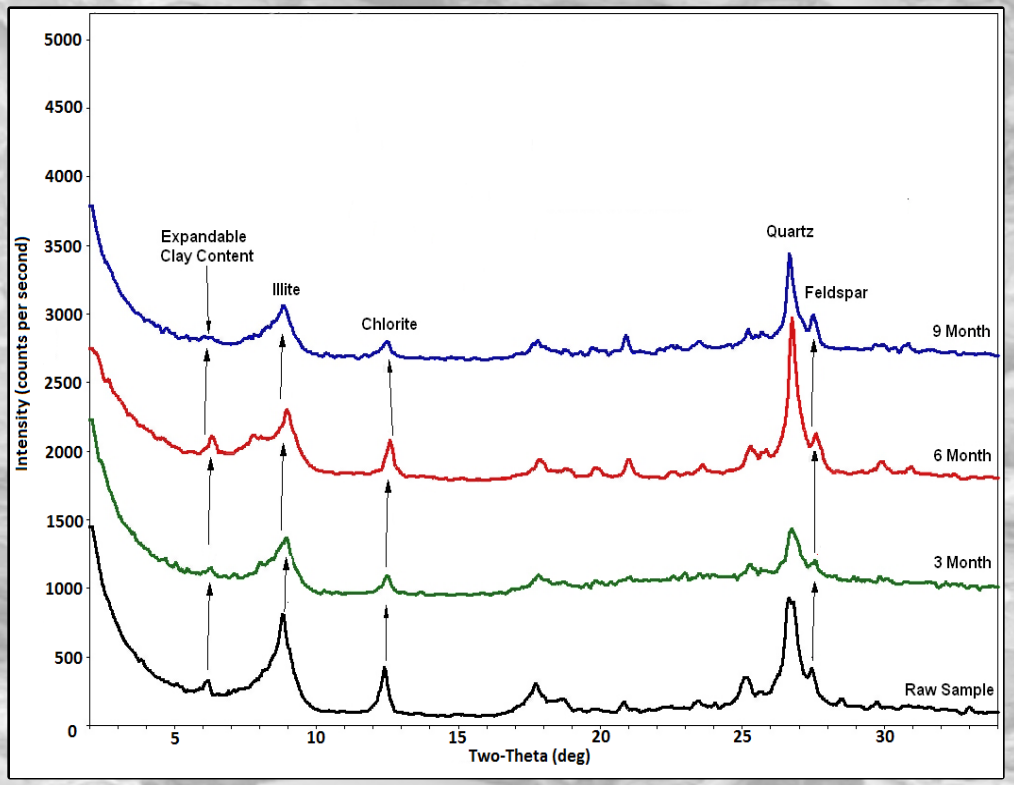
After 6 months



- Samples visibly altered
- Pervasive etching of clay minerals
- Preferential dissolution of pyrite and biotite

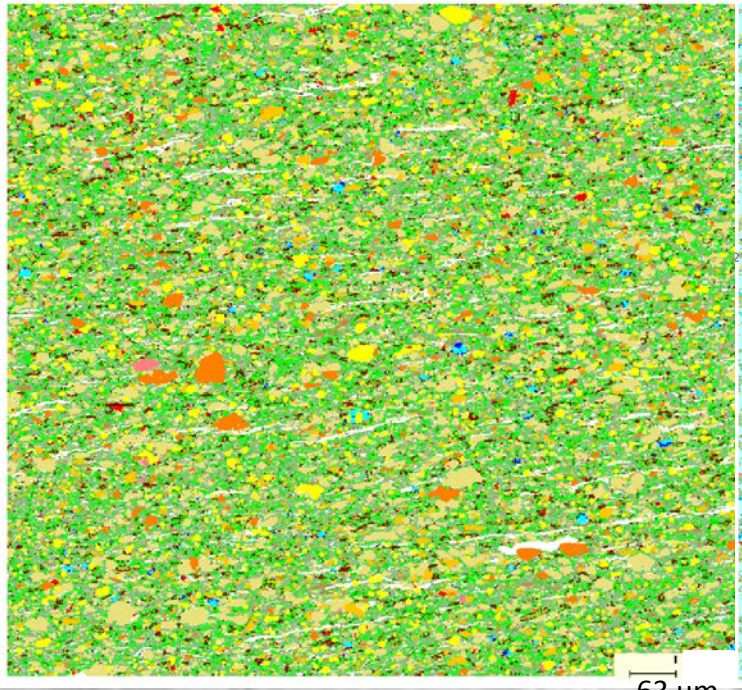
Eau Claire Shale

- Broadening of peaks denoting the etching of crystal faces
- Ratios remain constant
- Increase in Si, K, Ca, and Mg in solution

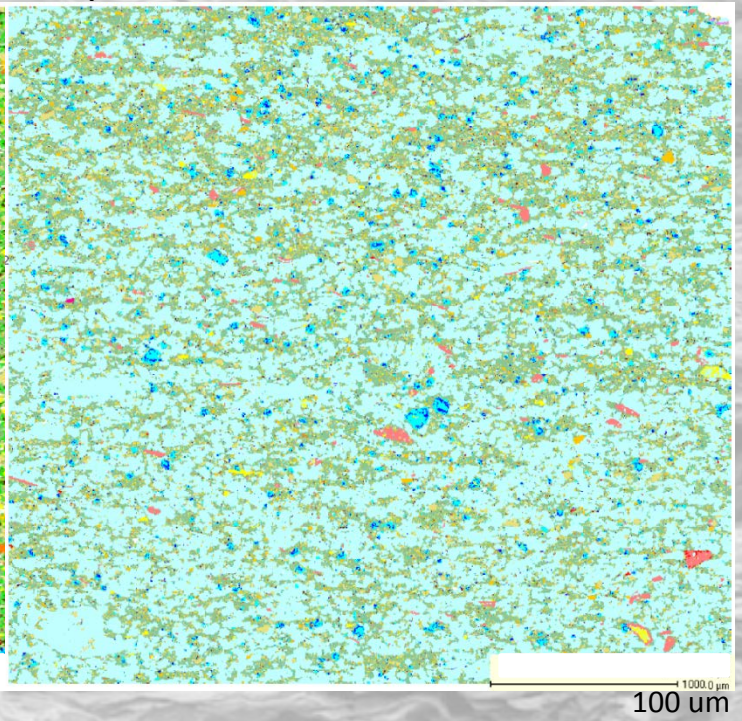


New Albany and Maquoketa Shales

New Albany



Maquoketa



- Maquoketa experiments are ongoing
- New Albany experiments began in November

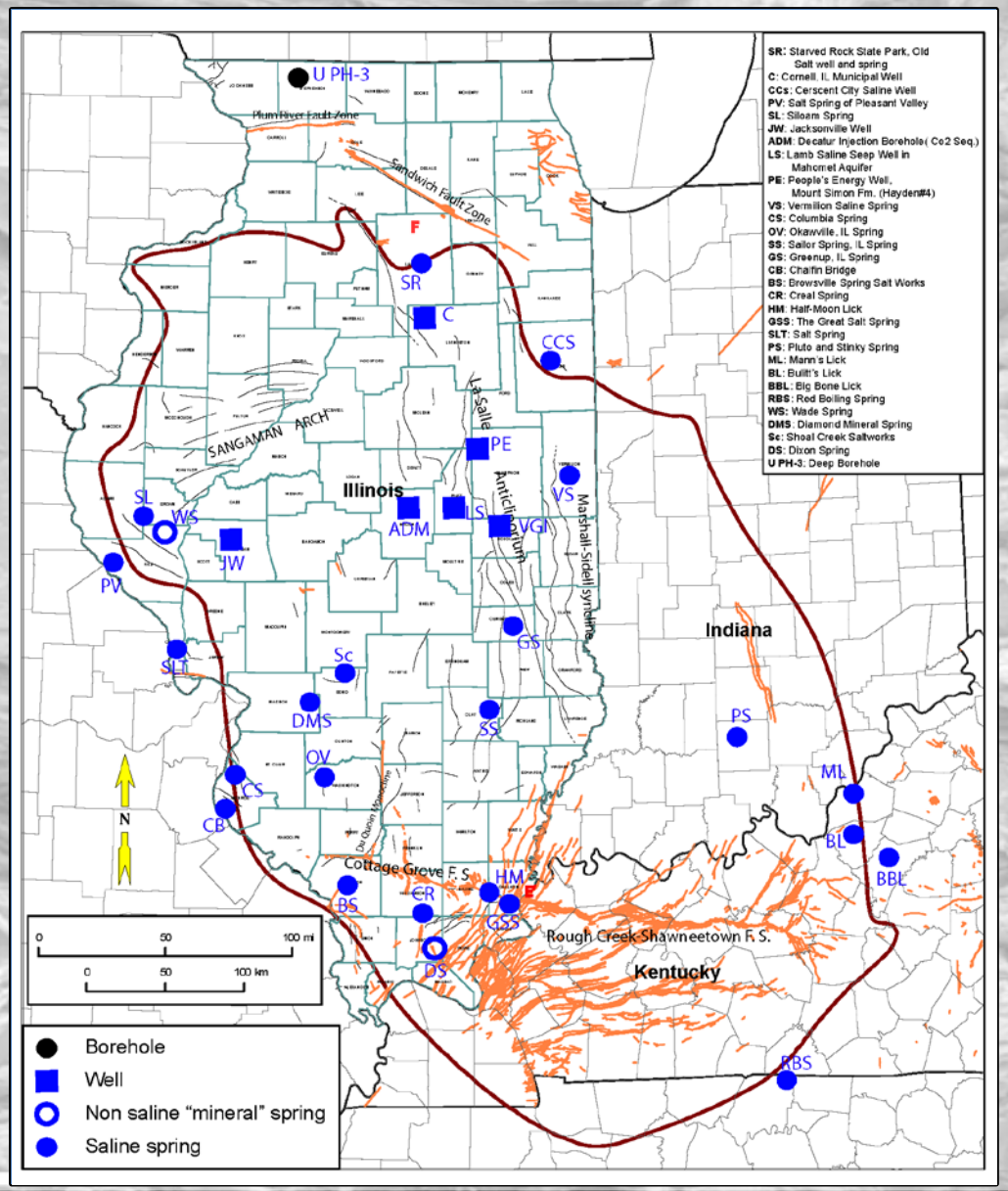
Batch Reactor Kinetic Rates

Derived with Differential Evolution software running React

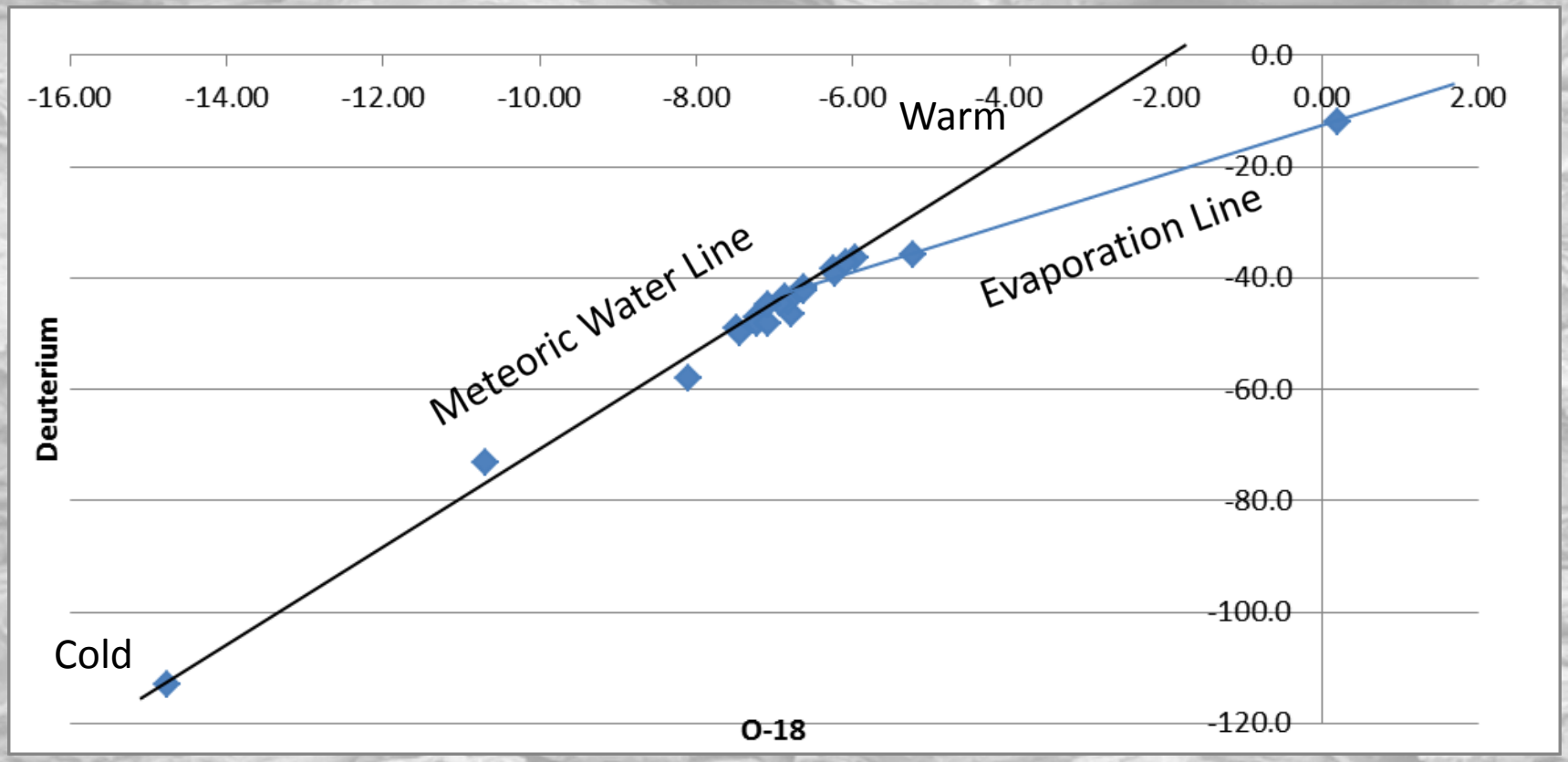
	Eau Claire Shale (43°C) mole/m^2/s	Mt. Simon Sandstone (50°C) mole/m^2/s
Smectite	9.76E-07	9.55E-07
Illite	1.28E-08	9.31E-07
Kaolinite	1.56E-07	8.03E-07
Chlorite	7.51E-07	5.81E-07
Quartz	3.31E-14	3.80E-12
K-feldspar	8.31E-07	8.04E-08

Spring and Well Sampling

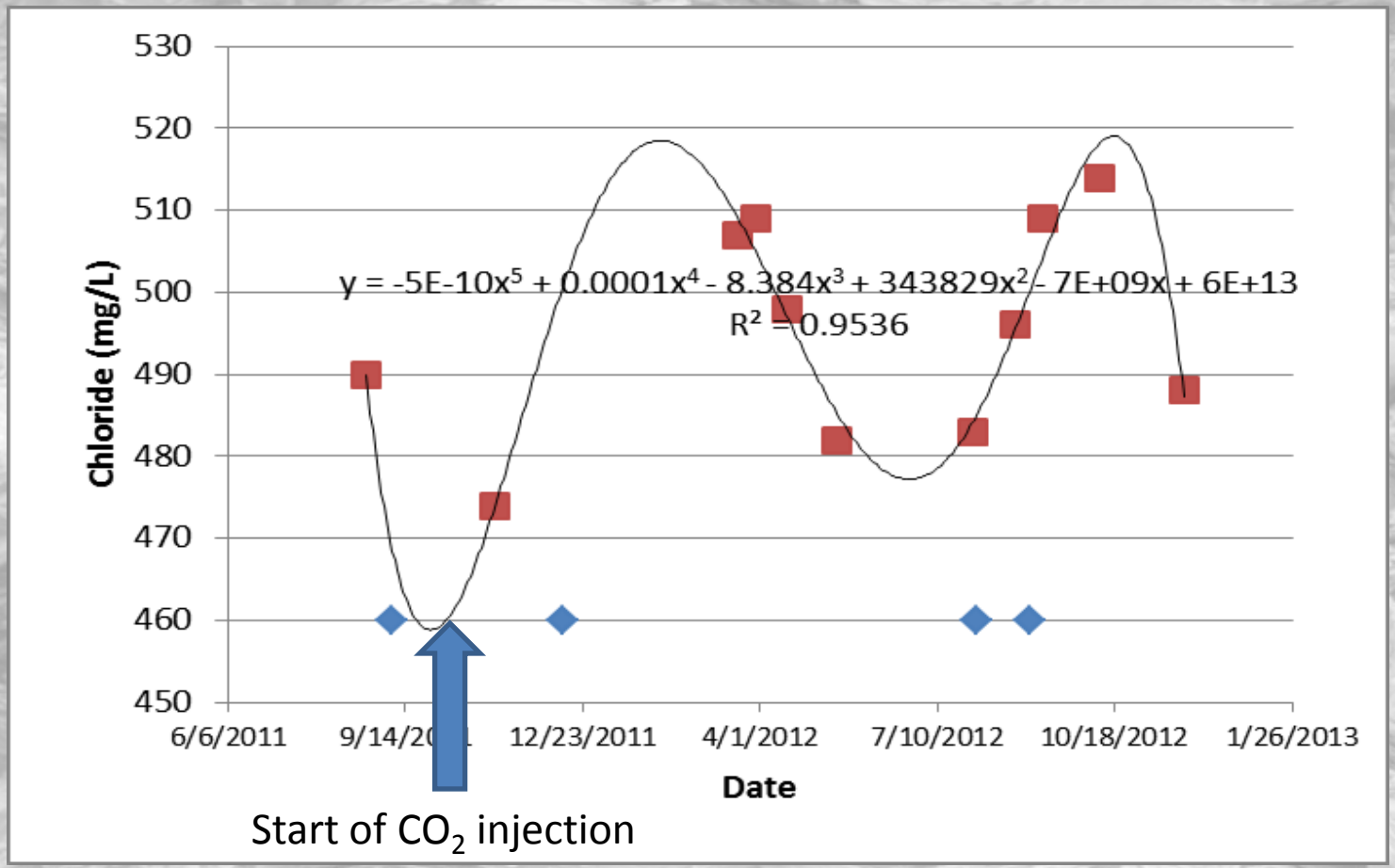
- First spring inventory of Illinois
- Gather baseline data on spring locations and water composition
- Trace the origin of brines
- Most springs fall along structural features



Stable isotope distribution for saline spring samples showing evidence of Pleistocene-age recharge and evap. for some springs



Polynomial fit to Cl data, well located 15 miles from CO_2 inj. well and natural variation.



Saline spring has Penn. formation brine mixed with Pleistocene-age water
3,800 mg/L Cl, H_2S, white filamentous, sulfide-oxidizing bacteria

Big Bone Lick, northern Kentucky
Cl = 4350 mg/L, Cambrian formation waters

Summary and Conclusions

- Mt. Simon sandstone is largely inert due to the high amount of quartz
- Eau Claire shale shows higher reactivity with clay minerals
- New Albany and Maquoketa experiments ongoing
- Performed 1st spring inventory of the Illinois Basin
- Springs fell along structural features
- Cambrian formation water in springs around the basin margin

Potential Future Work

- Petrographic and geochemical investigation of the effect of carbon sequestration activity on the organic content of the New Albany and Maquoketa seal rocks
- Continued studies of the Mt. Simon Sandstone and Eau Claire Shale using increased temperature and/or pressure to simulate longer experimental reaction intervals
- Mixed gas (CO_2 and O_2) experiments to more closely represent the composition of the IBDP injection gas
- Flow-through experiments with CO_2/brine mixtures