Effect of chemical composition to large scale CO_2 Injection in Morrow Sandstone, Farnsworth Hydrocarbon Field, Texas, USA

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Introduction

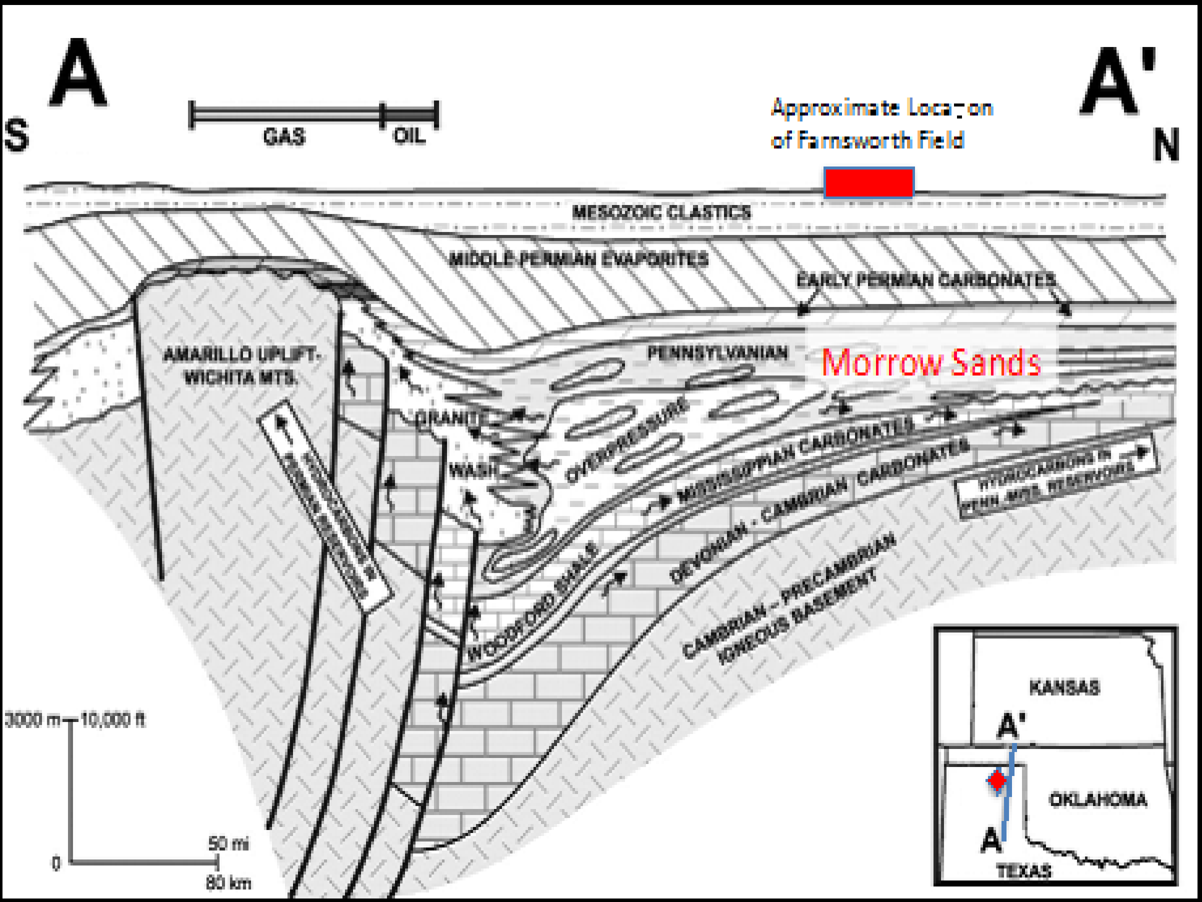
Location map: Farnsworth oil field, Amarillo, Texas, USA

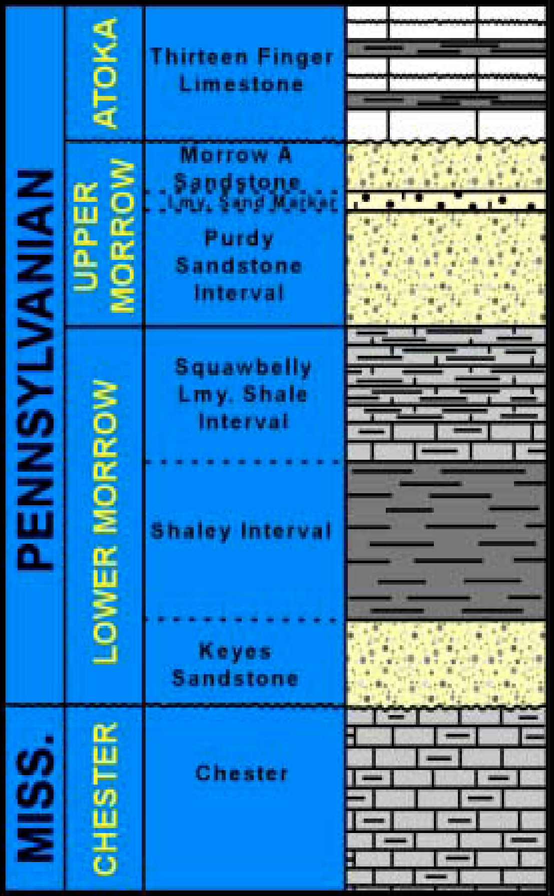
Injection well 1310A

Well AWT3

Introduction

Stratigraphy of Morrow





Generalized cross section of Anadarko basin near the Farnsworth unit (Modified after Sorenson, R.P; 2005)

(Zuahir, A and Puckett J Modified from Harrison, 1990, and Luchtel, 1999)

Research Questions

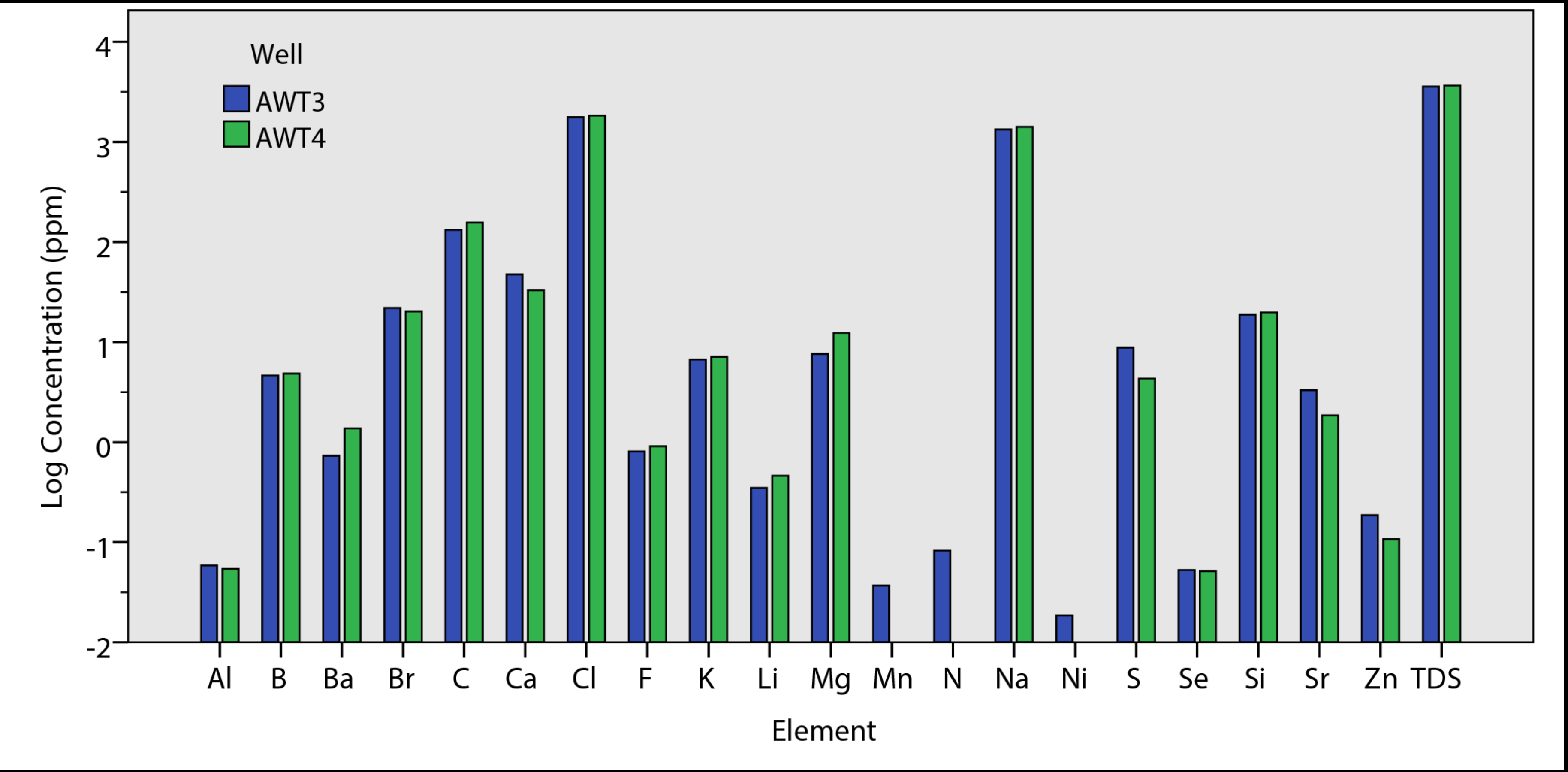
1. Nature of groundwater in the Morrow sandstone at Farnsworth Hydrocarbon Field.

2. How will the groundwater respond chemically to large scale injection of CO_2?

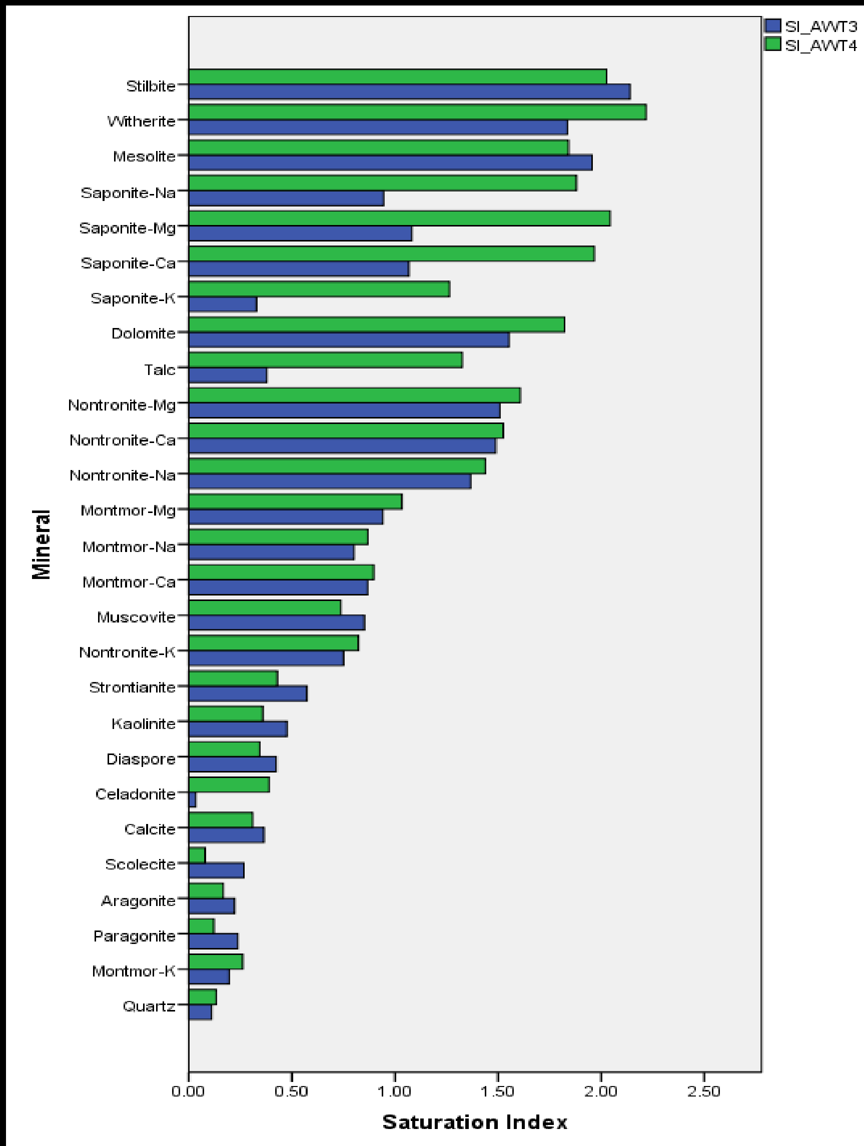
3. How will CO_2 rich groundwater react with the host rock?

Elemental composition of Morrow Sandstone groundwater

- from wells AWT3 and AWT4
- at depth of ~7800 ft
- on September 24, 2012; January 15, 2013; April 11, 2013



Results of chemical speciation modeling supersaturated minerals



Major minerals

Zeolite

Clay

Carbonate

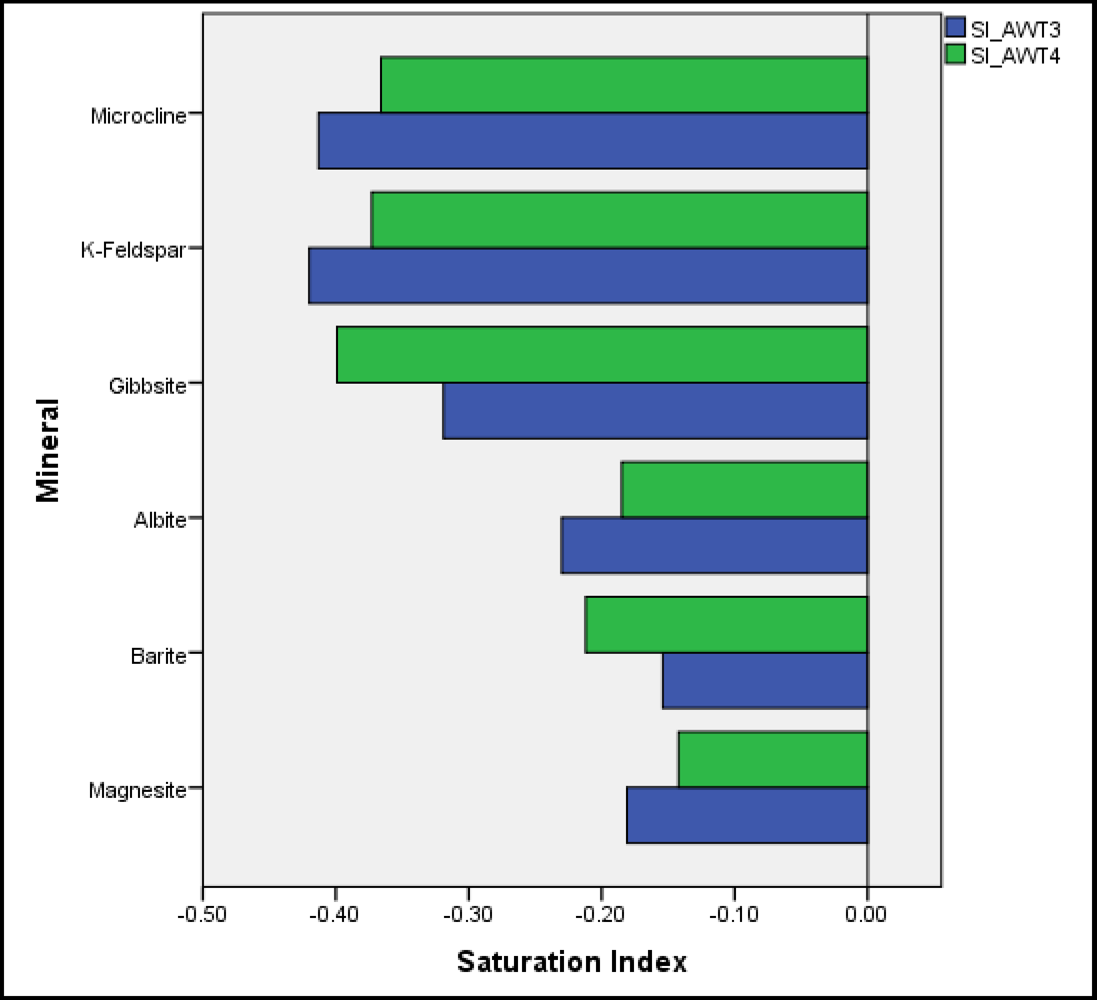
Quartz

Mg silicates

Micas

Al hydroxides

Results of speciation modeling
Under-saturated minerals

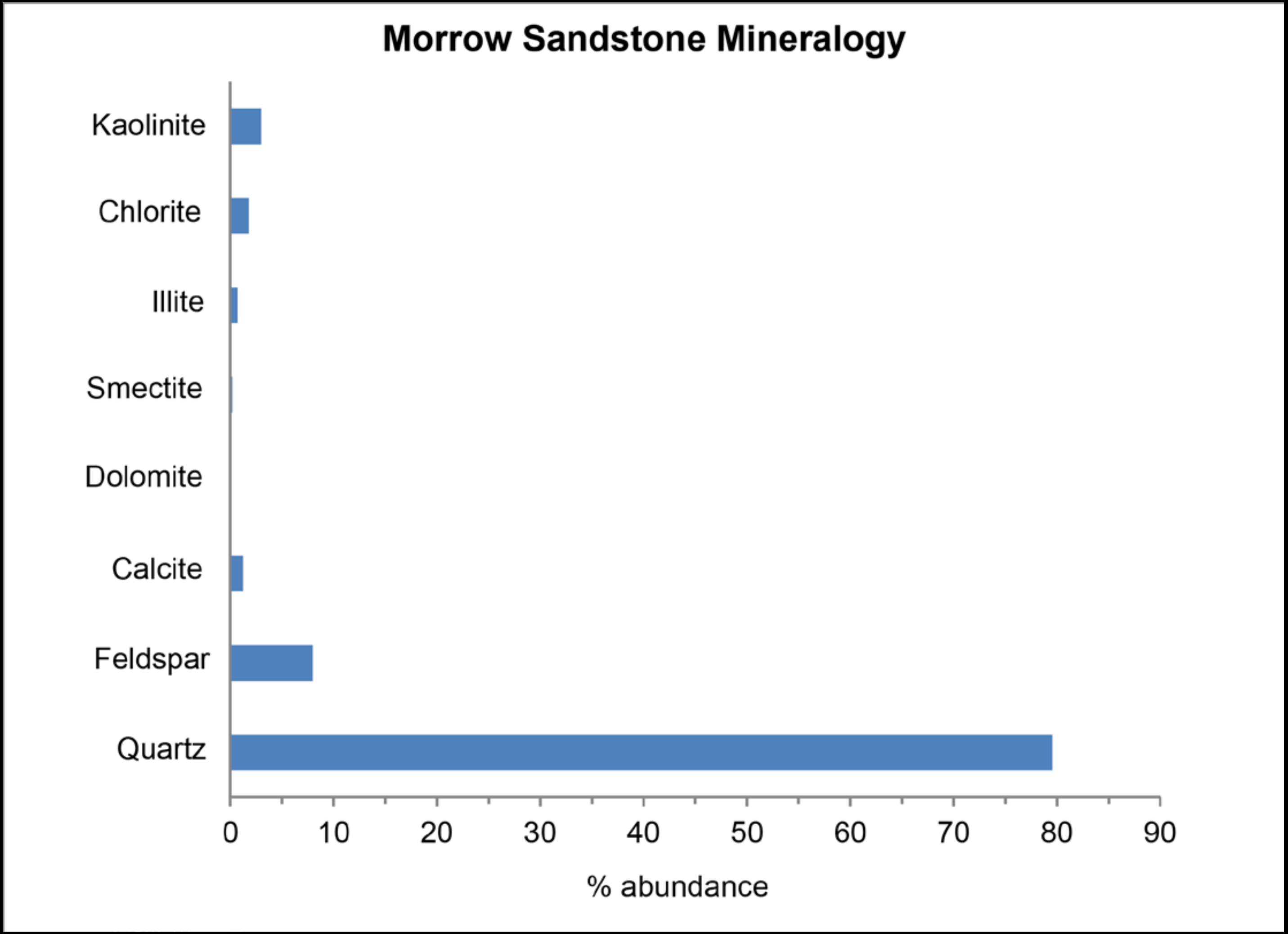


Major minerals

Feldspar

Carbonate

Mineralogy of the Morrow Sandstone



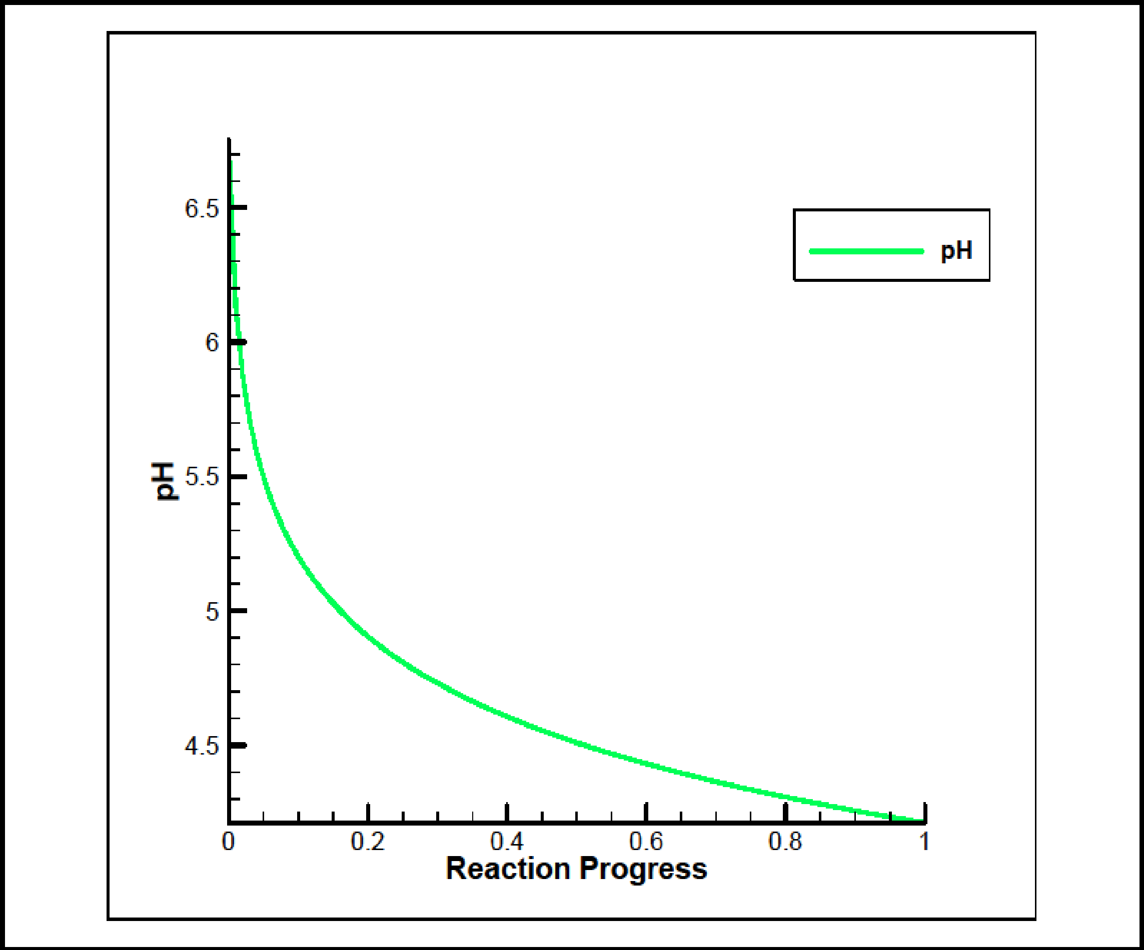
Munson (1989)

Reaction path modeling conceptual design

Stage 1: Reaction of AWT3 and AWT4 groundwater with CO_2 up to solubility of 46 g/kg fresh water at 75°C (Duan & Sun, 2003)

Stage 2: 1 kg of resultant CO_2-saturated fluid allowed to react with 560 g of Morrow Sandstone host rock (assuming 15% porosity)

Stage 1: pH versus reaction progress



Reaction between CO_2 and water

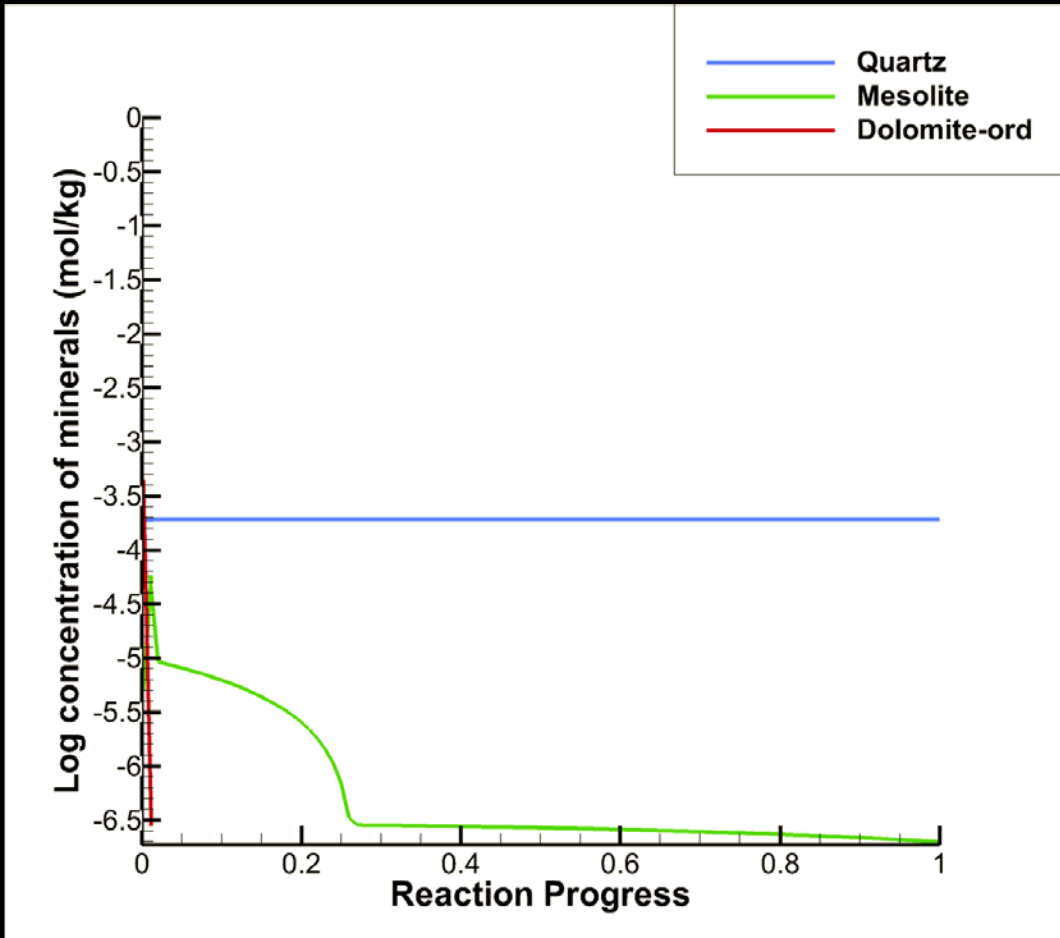
$H_2O + CO_2 = HCO_3^- + H^+$

$HCO_3^- + H_2O = CO_3^{2-} + H^+$

The increased amount of H^+ in solution is responsible for lowering down pH

Morrow groundwater pH is decreasing as CO_2 is being injected and dissolved

Stage 1 Results: Mineral precipitation and dissolution



Produced minerals after reaction between groundwater and CO_2

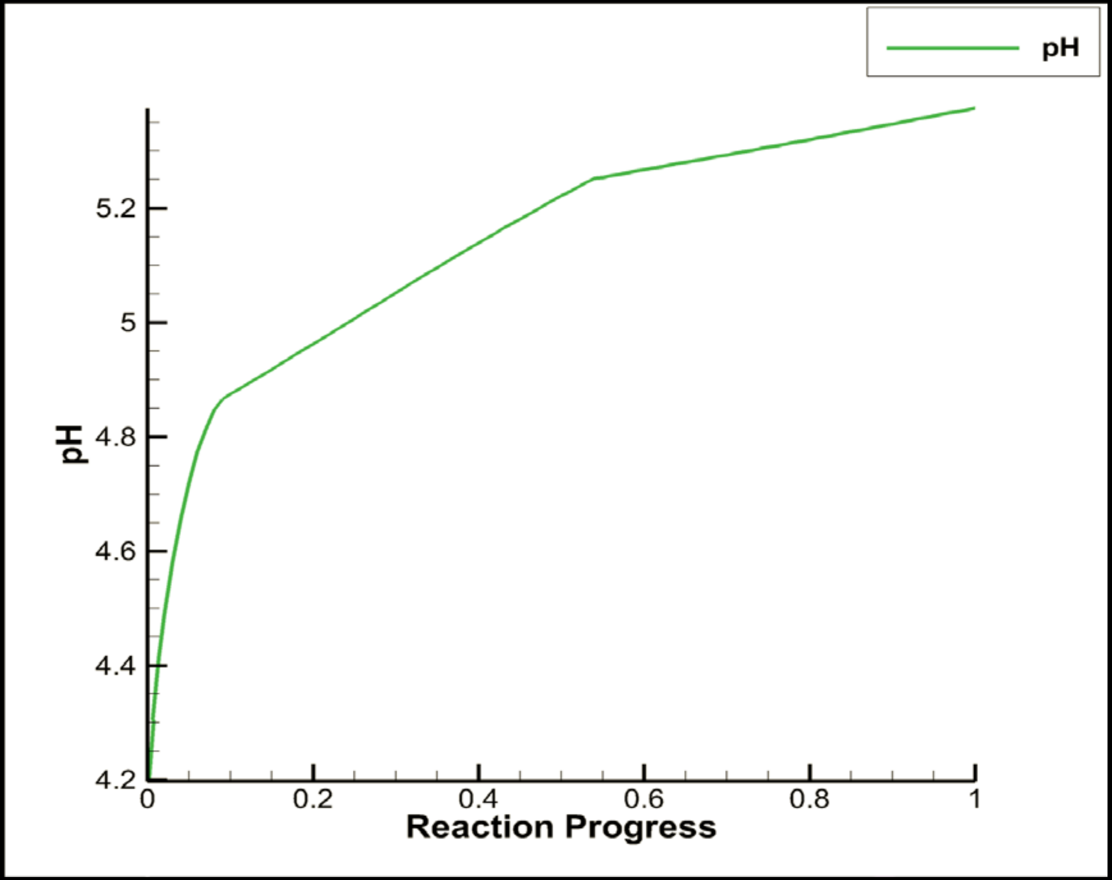
- Quartz solubility does not depend strongly on pH, so its abundance remained constant.

- At first mesolite formed
  - As pH decreased it dissolved away.

Stage 2 : Morrow mineralogy in model

Mineral before injection	Concentration in g/kg of water
Quartz	460
Chlorite	20
Illite	20
K-Feldspar	20
Kaolinite	20
Albite	20
Total	560

Stage 2: Change in pH



pH is increasing with reaction progress

Reactions of Morrow minerals with fluid

Albite + $4H^+ = Al^{+++} + Na^+ + 2H_2O + 3SiO_2(aq)$

K-feldspar + $4H^+ = Al^{+++} + K^+ + 2H_2O + 3SiO_2(aq)$

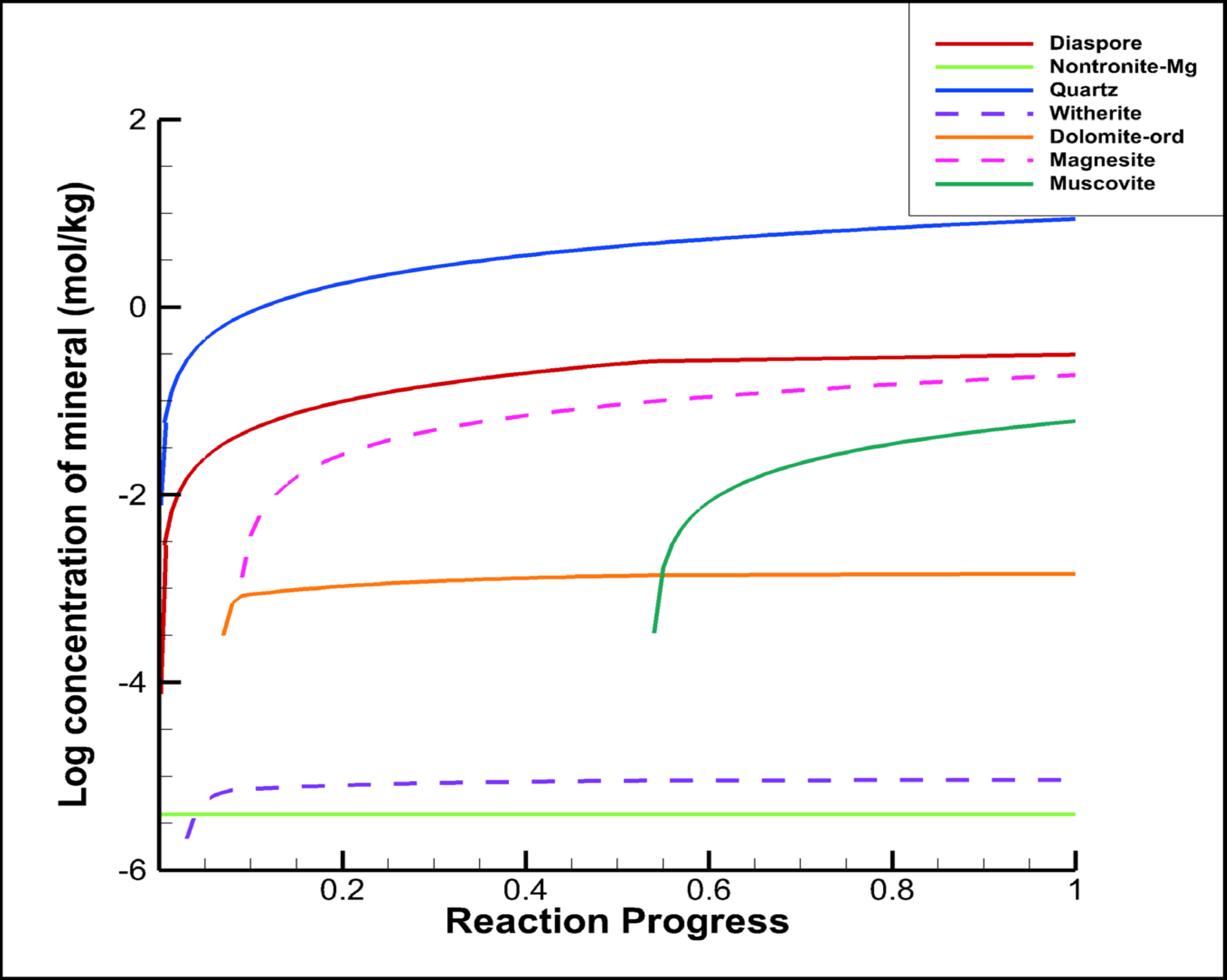
Kaolinite + $6H^+ = 2Al^{+++} + 5H_2O + 2SiO_2(aq)$

Illite + $16H^+ = 0.25\ Mg^{++} + 2.3Al^{+++} + 0.6K^+ + 5H_2O + 3.5SiO_2(aq)$

Clinochlore-7A + $16H^+ = = 2Al^{+++} + 5\ Mg^{++} + 12H_2O + 3SiO_2(aq)$

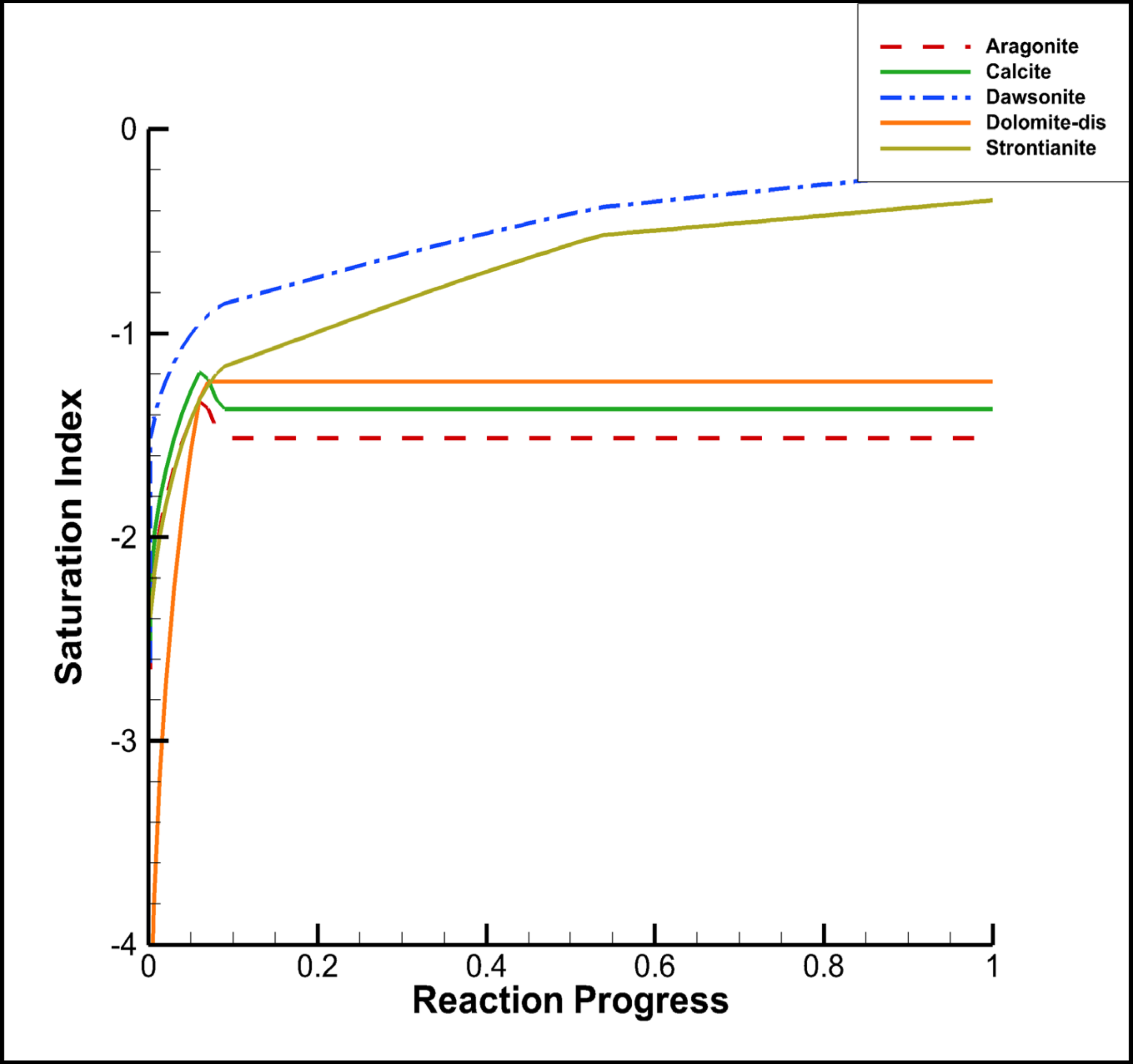
Each mineral is taking up some H^+ ion from fluid which is the main reason of rising up of pH

Stage 2 Results: Mineral precipitation



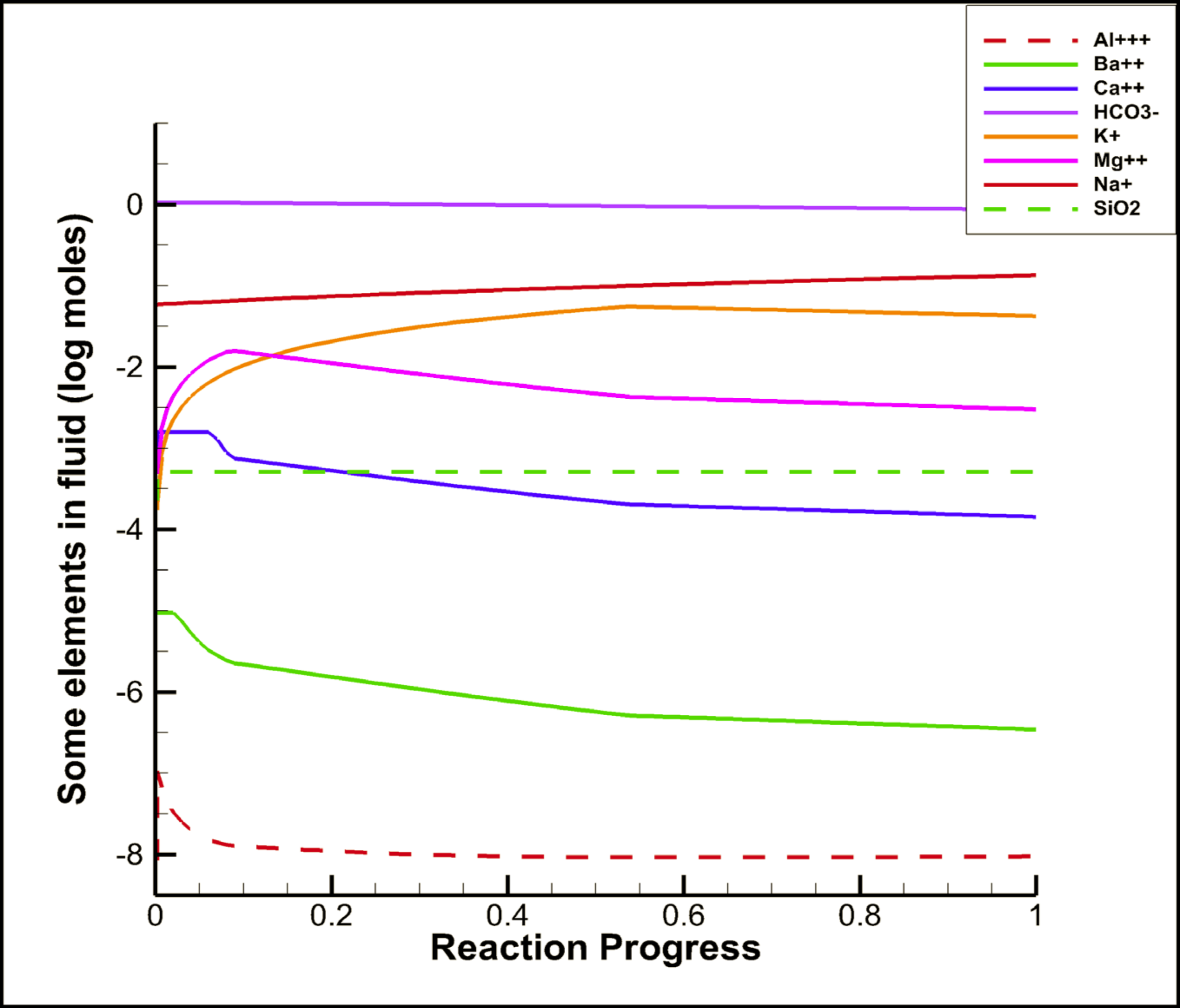
Stage 2 Results

- Change in carbonate mineral saturation



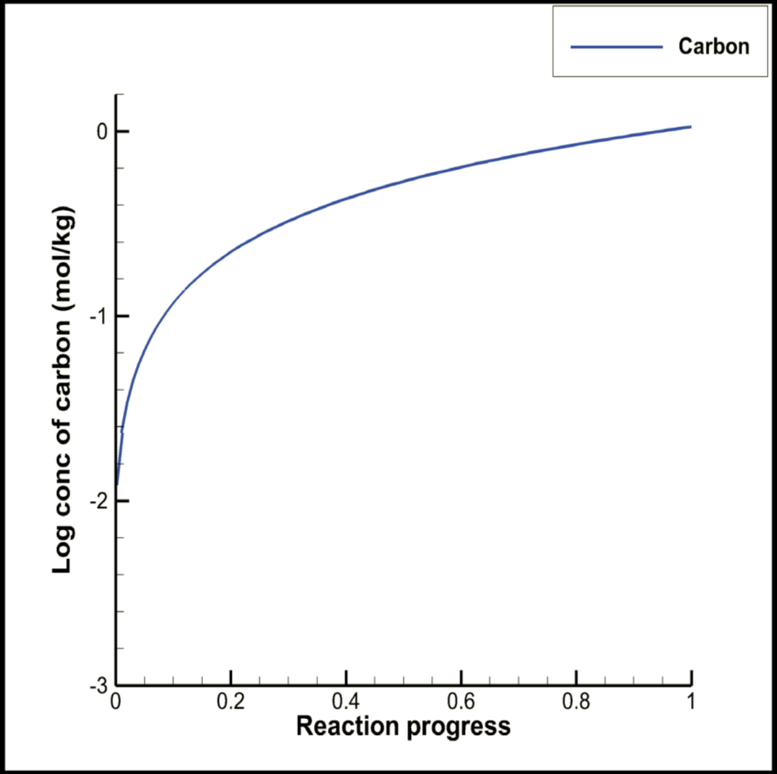
Most of the carbonate minerals remained under-saturated during reaction of CO_2-rich groundwater with Morrow host rock

Stage 2 Results: Major element concentrations in groundwater



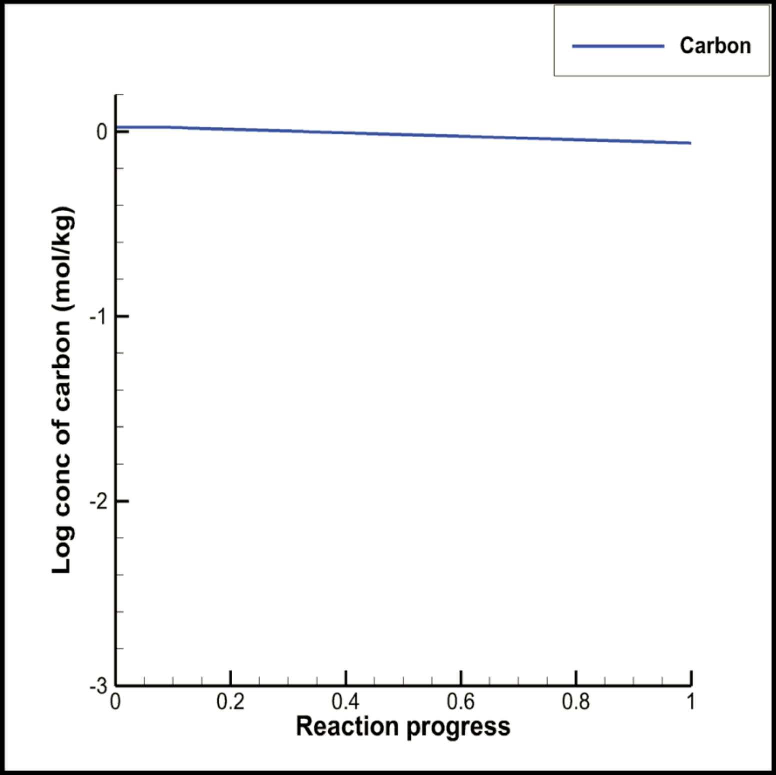
Changes in total carbon concentration

Stage 1: CO_2 injection



Carbon is increasing

Stage 2: Reaction of CO2-rich groundwater with host rock



Carbon is decreasing

Effects on porosity

Mineral before injection	Volume (cm^3)
Albite	7.646
Clinochlore-7A	7.611
Illite	7.148
K-Feldspar	7.823
Kaolinite	7.71
Quartz	181.2
Total	219.138

Mineral after injection	Volume (cm^3)
Diaspore	5.541
Dolomite-ord	0.09301
Magnesite	5.295
Muscovite	8.578
Nontronite-Mg	0.0005111
Quartz	197.4
Witherite	0.0004212
Total	216.9

Porosity increased up to 1.0212%

Effects on permeability

15% porosity	16% porosity
2.59×10^{-9}	3.22×10^{-9}

Change in permeability respect to permeability at 15% porosity up to 24%

Hydraulic properties do not undergo significant change

Conclusions

- Initial groundwater composition:
    - Fluid is fairly dilute given its depth
    - Major cations: Na^+, Ca^{++}, Mg^{++}, K^+
    - Major anions: Cl^-, bicarbonate, sulfate
    - Super-saturated with respect to carbonates, Mg silicates, clays, micas, zeolites, Al hydroxides
    - Quartz saturated
    - Feldspar minerals unstable

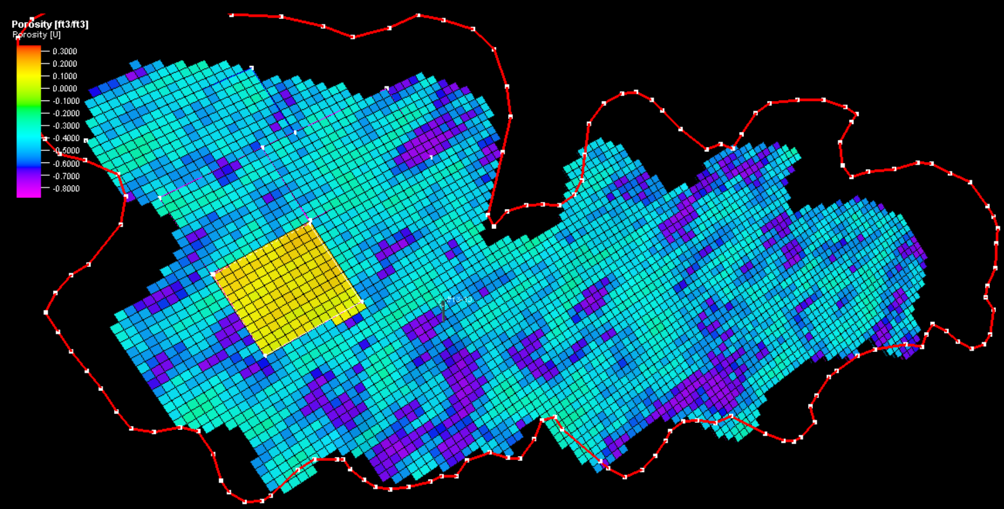
- CO_2 injection into Morrow groundwater to solubility limit:
    - Lowers pH to 4.2
    - Prevents carbonate mineral precipitation

- Reaction of CO_2-charged groundwater with Morrow host rock:
  - Consumes C through mineral sequestration
  - Neutralizes pH up to 5.3
  - Leads to precipitation of carbonate minerals
  - Leads to porosity increase up to 1.012%
  - Leads to permeability increase up to 24%

Therefore, hydrologic properties of the Morrow Sandstone will not undergo significant changes due to sequestration of CO_2

Future work

- Reactive transport modeling of CO_2 injection into the Morrow Sandstone



Porosity map of the Morrow Sandstone in the Farnsworth Unit

Acknowledgments

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