

Geochemical Reactions

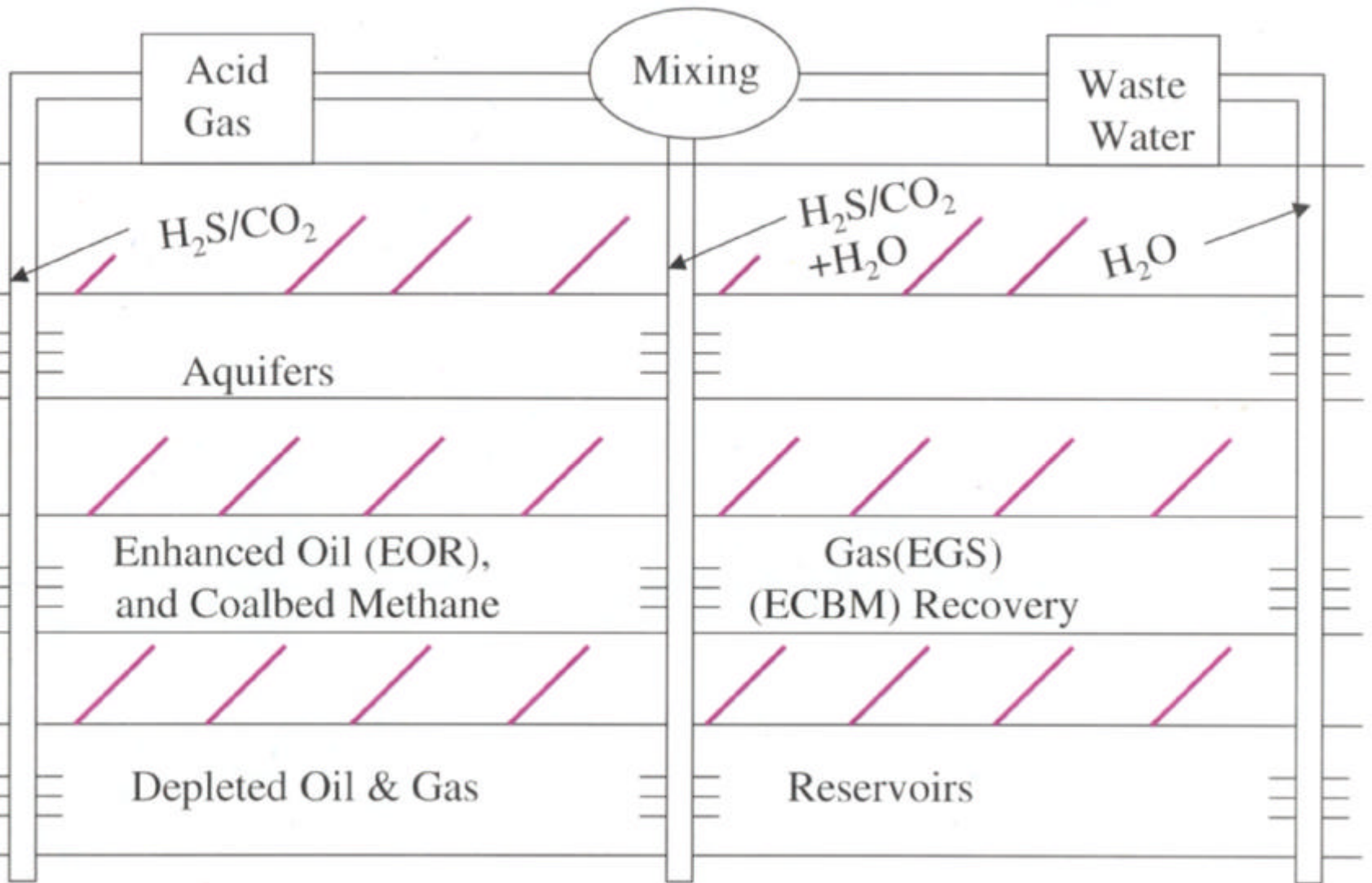
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Types of CO₂ Traps

- Hydrostratigraphic Traps
 - Closed Stratigraphic/Structural
 - Open Structures
- Geochemical Traps
 - Solubility
 - Ionic
 - Mineral

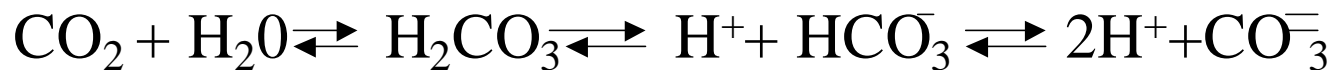
Acid Gas Disposal Targets



Geochemistry of CO₂ Storage

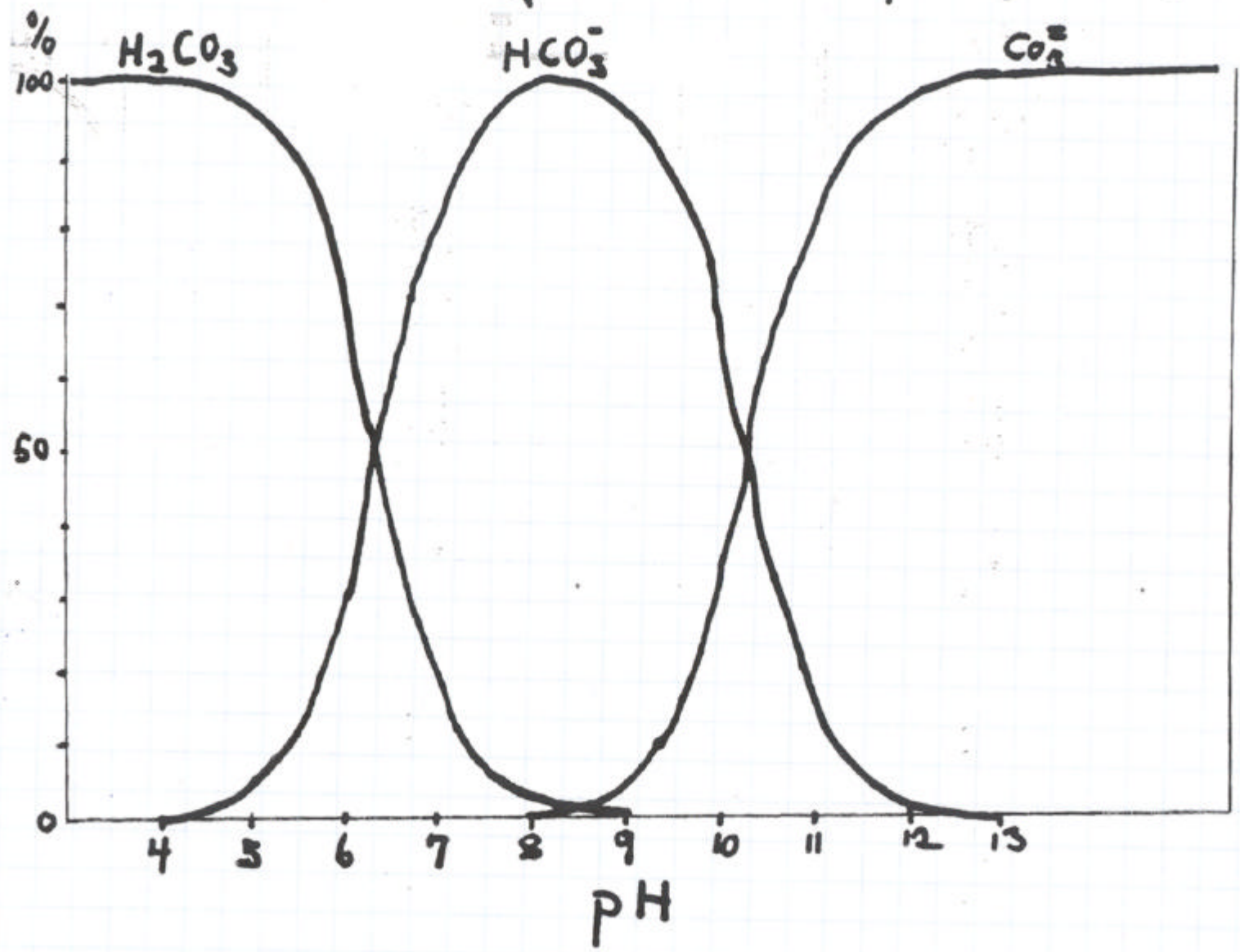
- Solubility Trapping
CO₂ (gaseous) + H₂O → H₂CO₃ (aqueous)
- Ionic Trapping
H₂CO₃ (aqueous) + OH⁻ → HCO₃⁻ (aqueous)
HCO₃⁻ (aqueous) + OH⁻ → CO₃⁼ (aqueous)
- Mineral Trapping
CO₃⁼ (aqueous) + Ca⁺⁺ → CaCO₃ (solid)

Aqueous Reactions

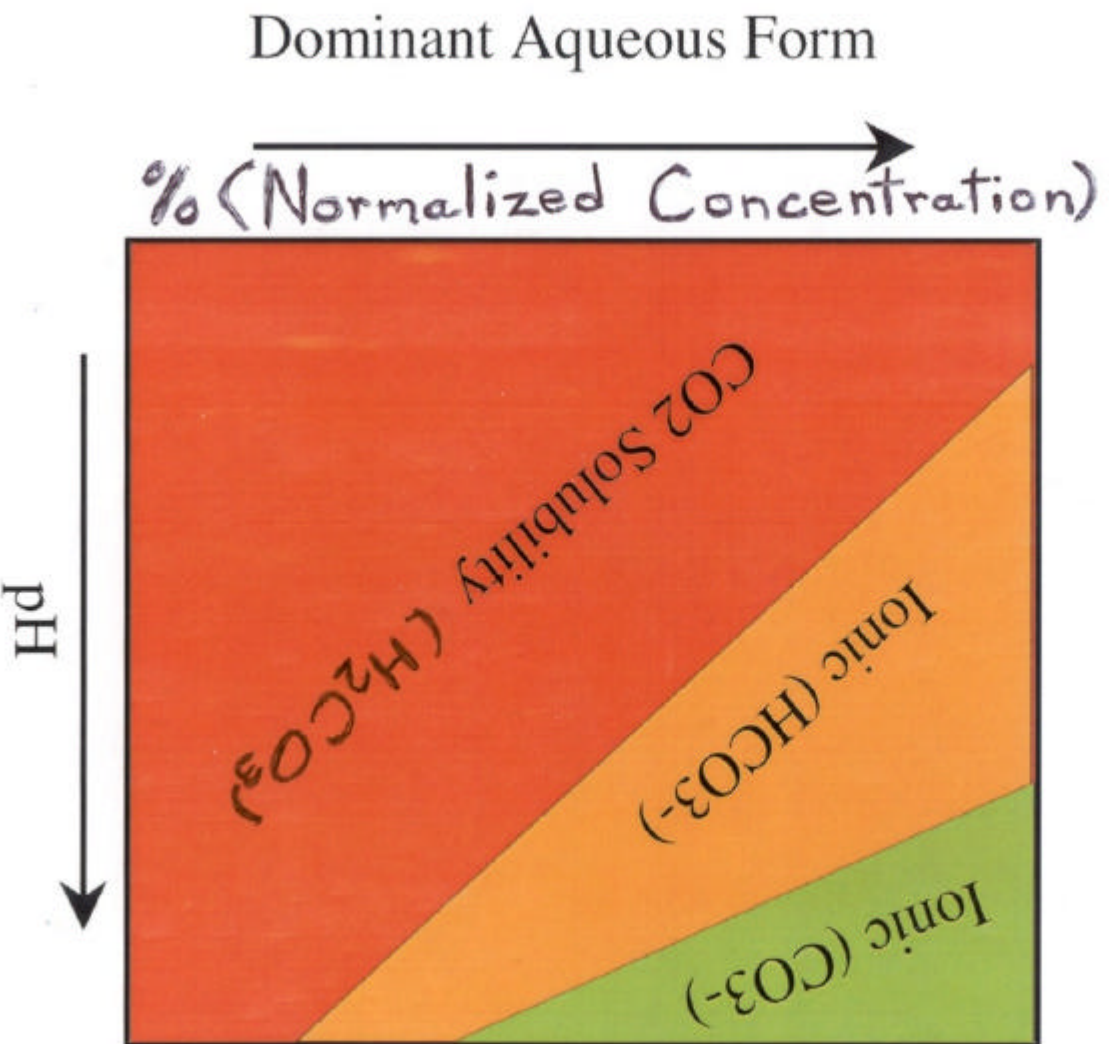


Highest solubility at basic pHs

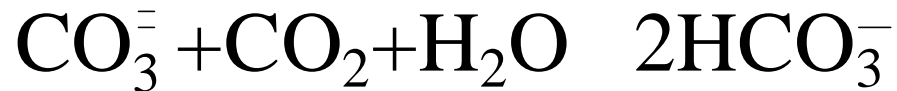
Concentration of Carbonate (Aqueous) vs. pH



Log Aqueous Dominance Diagram



Maximizing Trapping of CO₂ in Water



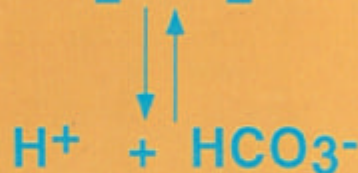
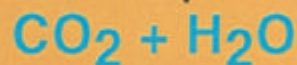
- Process ends when you reach saturation with calcite

Adding CO₂ to Dolomite



No
pH Buffer

Added CO₂



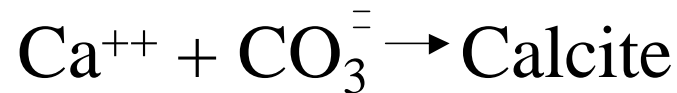
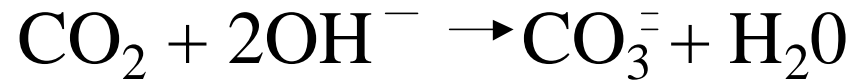
Decrease
pH

Dolomite
Dissolution

And MORE CO₂



Precipitation of Solids



- Need source of base

PRODUCTION OF BASE

- Aluminosilicate Reaction Series in acidic environment:

Na/K – Reaction Series

Analcmite or K-feldspar → Illite → Smectite → Kaolinite

Ca-Reaction Series

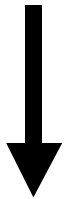
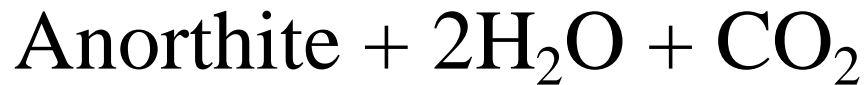
Laumontite or Anorthite → Smectite → Kaolinite

Mg-Reaction Series

Chlorite → Smectite → Kaolinite

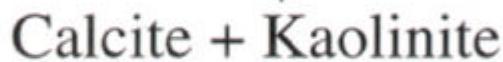
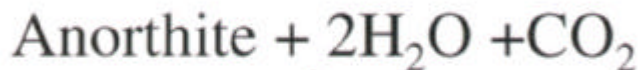
CO₂ Water-Rock Trapping Reactions

- CO₂– Trapping Reaction



Acid Gas Water-Rock Reactions

- CO₂ – Trapping Reaction



- H₂S – Trapping Reaction



Glaucconitic Sandstone Aquifer

Depth: 1480 meters

Temperature: 54⁰C

Pore Pressure: 13 MPa

Fracture Pressure: 33 MPa

Glauconitic Sandstone Aquifer

Mineralogy

wt%

Quartz

87

K-Feldspar

2

Plagioclase

1

Kaolinite

2

Calcite

1

Dolomite

1

Siderite

1

Glauconite

5

Framework

Grains Size

Diameters =

0.125 to 0.5mm

Matrix

Grains

Average Diameter =

0.008mm

Porosity

12%

Glauconitic Sandstone Aquifer

Formation Water Chemistry

| | |
|----------------------------------|-------------------------|
| Na | 28,000 |
| K | 690 |
| Ca | 2,970 |
| Mg | 578 |
| Cl | 51,600 |
| SO ₄ | 366 |
| T. Alkalinity(HCO ₃) | 198 |
| pH | 7.2 @ 25 ⁰ C |
| Units | mg/L |

Nisku Carbonate Aquifer

| | wt.% | FeO% |
|----------------|-------------|-------------|
| Dolomite | 91 | 1.15 |
| Calcite | 7 | 0.15 |
| Accessories | <1 | |
| Siderite (ss)* | 2 | |

*ss = solid solution in dolomite and calcite

Modelling Conditions

- Assume average reactive grain diameter of 0.1 mm
- Assume 1 molal solution of gas (unbuffered)
- Corresponds to reservoir conditions after injection has ceased

Reaction Kinetics

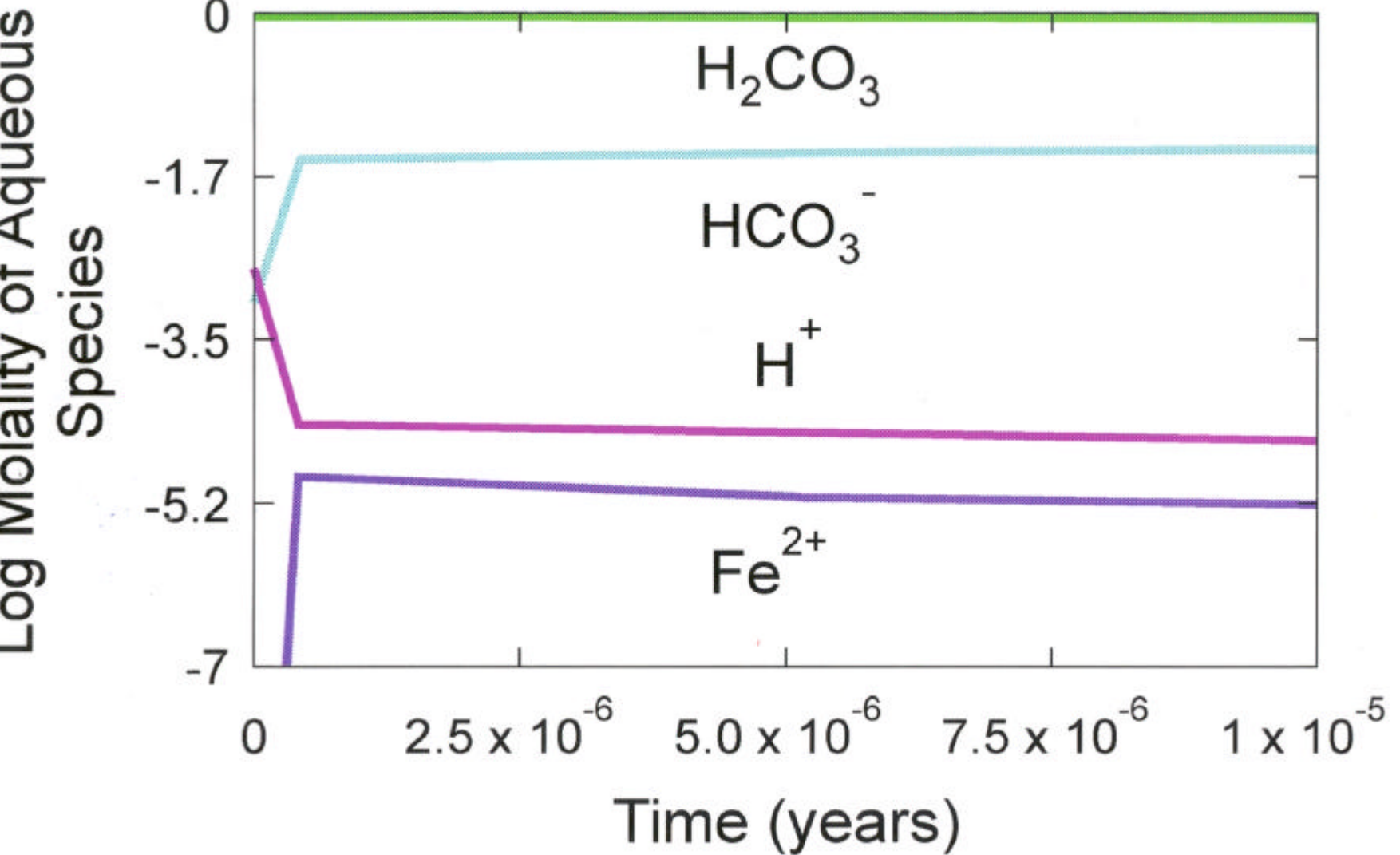
- Calcite is fast
- Silicates are slow

Nisku Carbonate CO₂ Reaction Summary (1 molal CO₂)

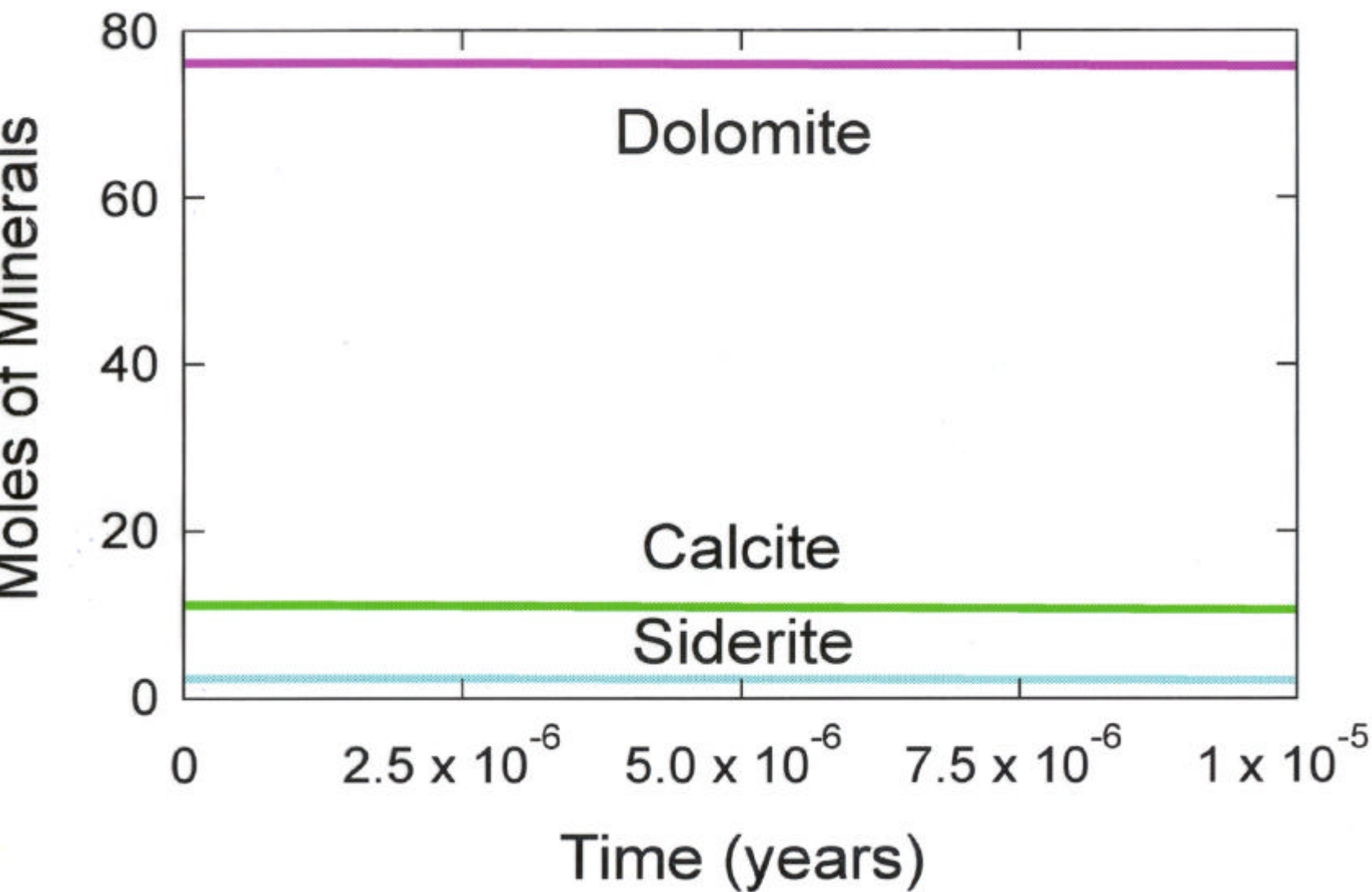
P_{CO₂}: 87 → 86 bars



Nisku Aquifer (CO₂)

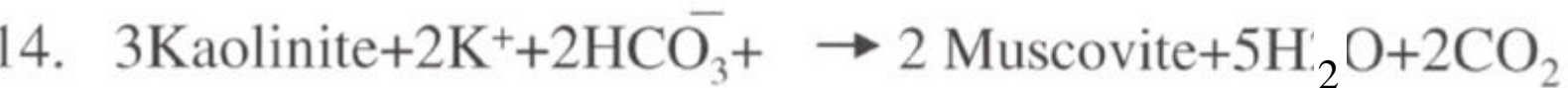
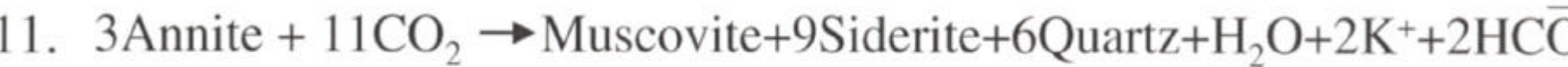


Nisku Aquifer (CO₂)

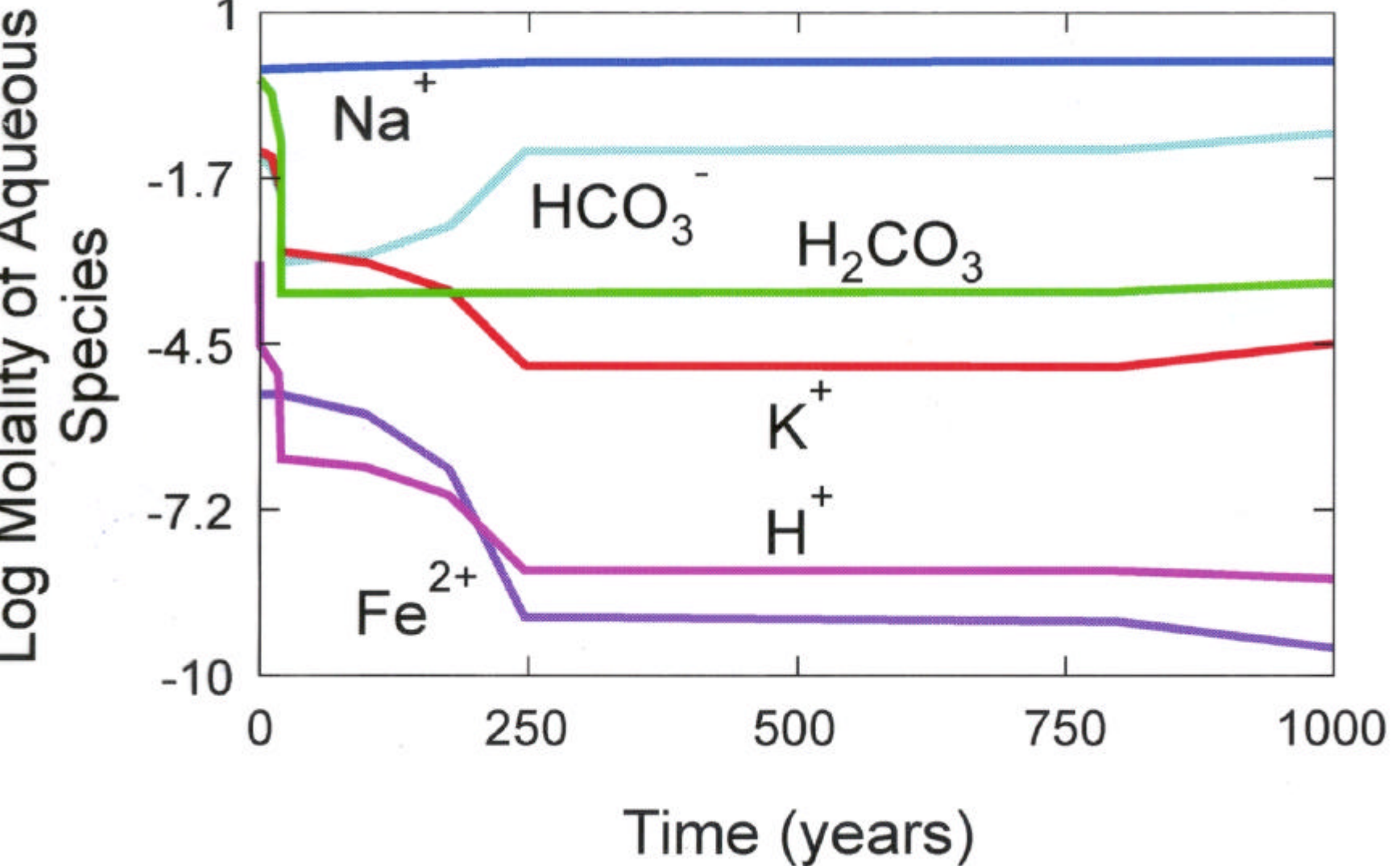


Glauconitic Sandstone CO₂ Reaction Summary (1 molal CO₂)

P_{CO2} : 87 → 0.02 bars

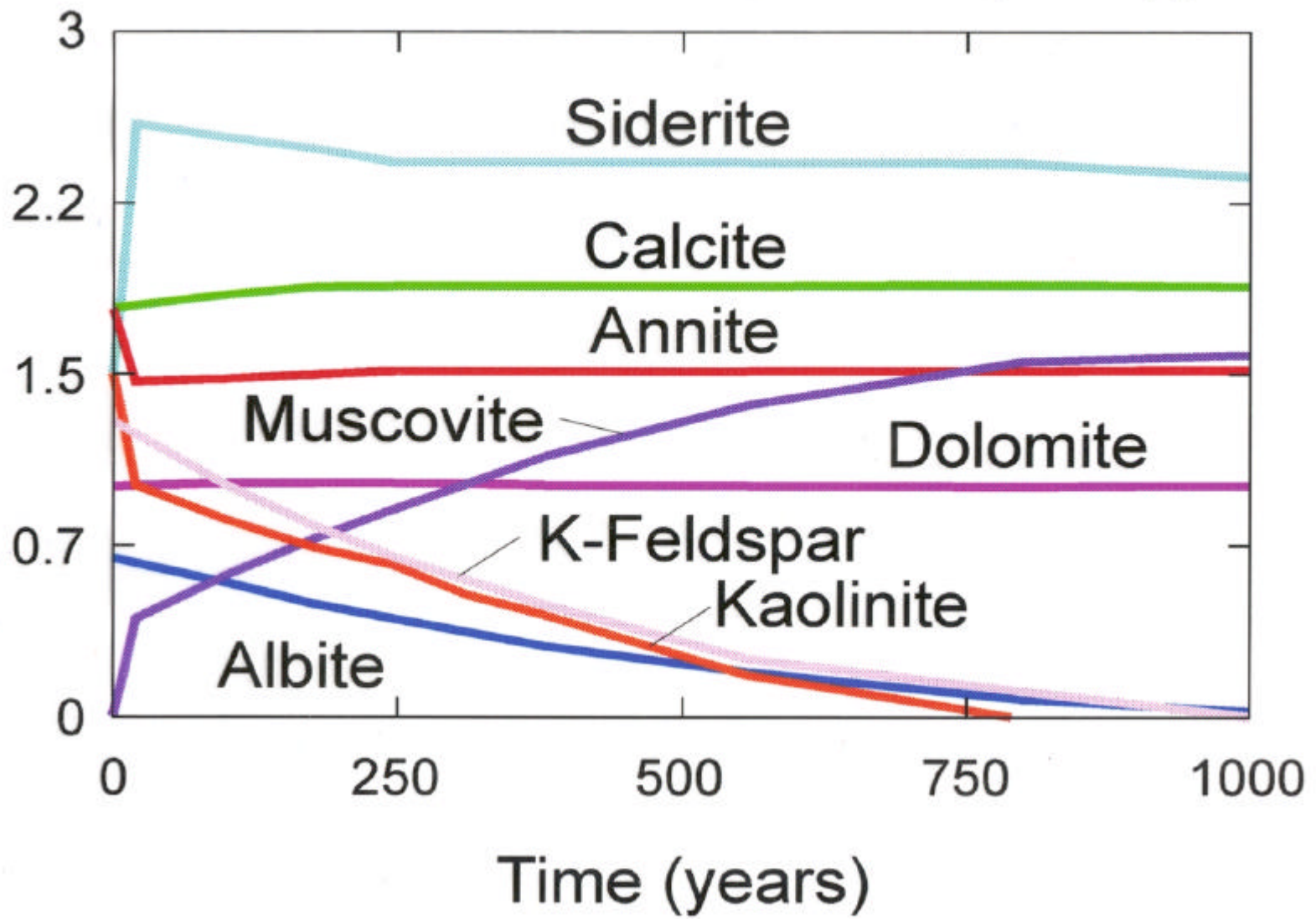


Glauconitic Aquifer (CO₂)



Glauconitic Aquifer (CO₂)

Moles of Minerals



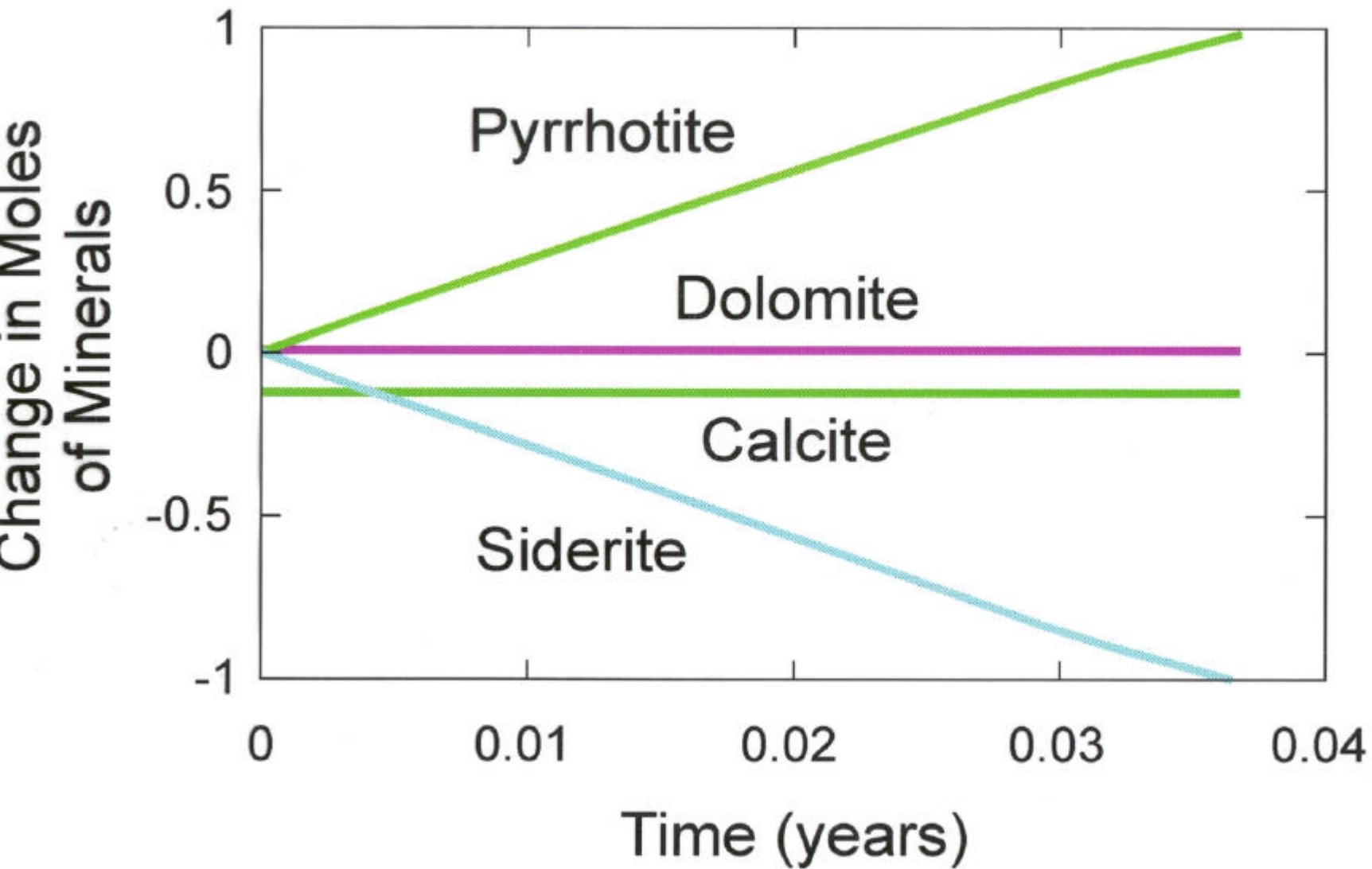
Nisku Carbonate H₂S Reaction Summary (1 molal H₂S)

$P_{\text{H}_2\text{S}}$: 30 → 0.03 bars

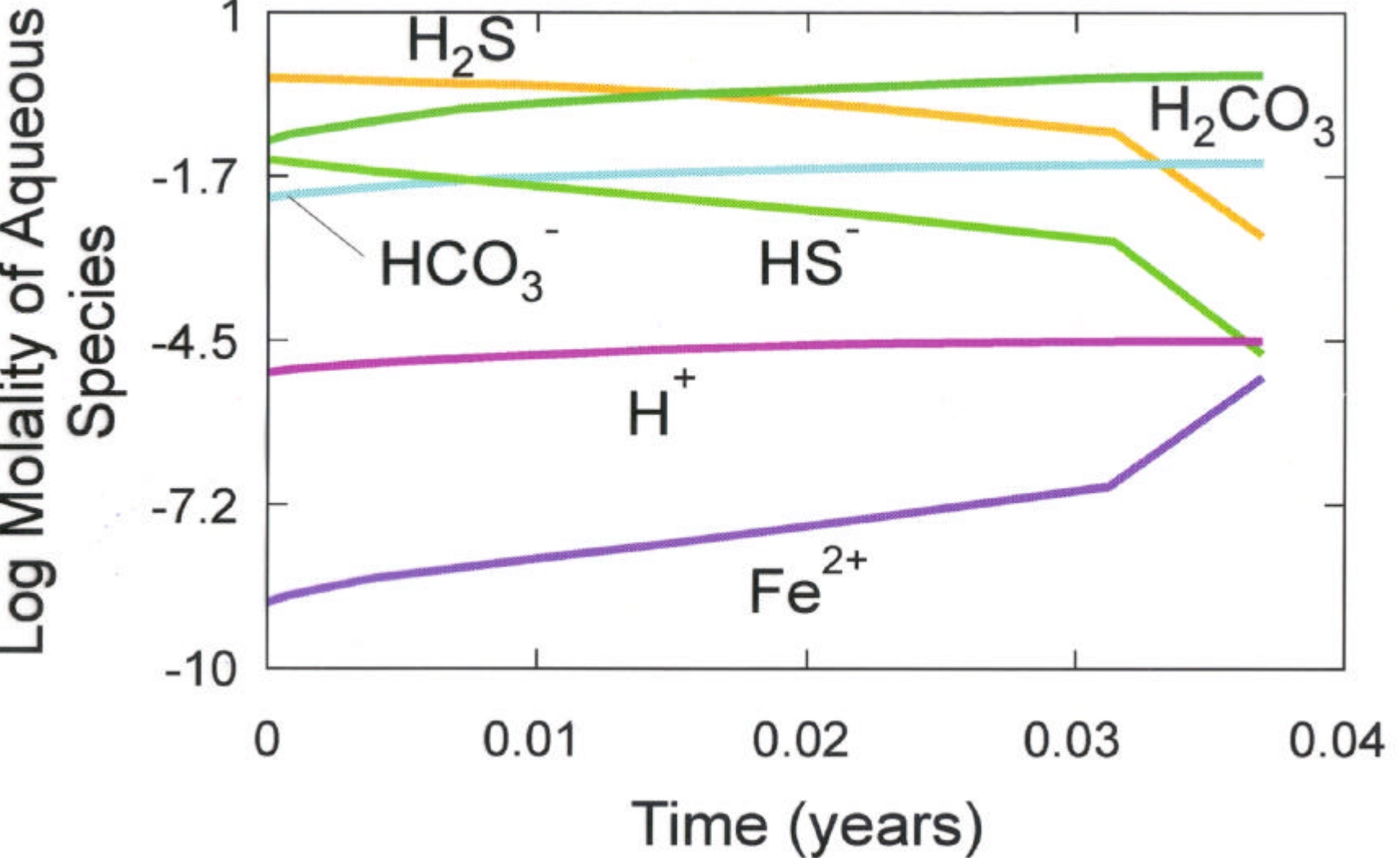
P_{CO_2} : 0.01 → 100 bars

2. Siderite + H₂S → Pyrrhotite + H₂O + CO₂

Nisku Aquifer (H_2S)



Nisku Aquifer (H_2S)



Glaucconitic Sandstone H₂S

Reaction Summary (1 molal H₂S)

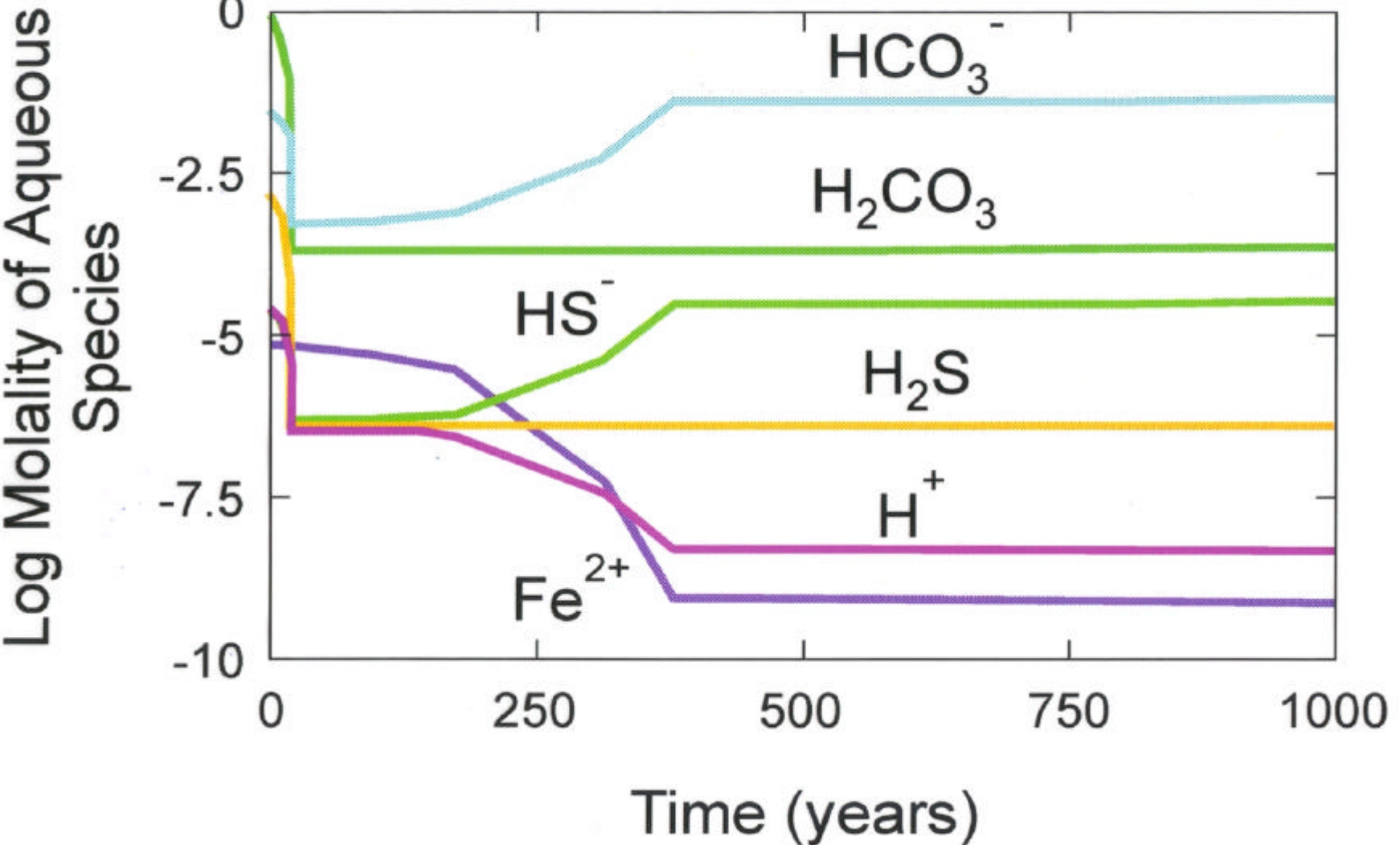
P_{H_2S} : 30 → 0.03 → 0.00001bars

P_{CO_2} : 0.01 → 100 → 0.02bars

Reaction 2

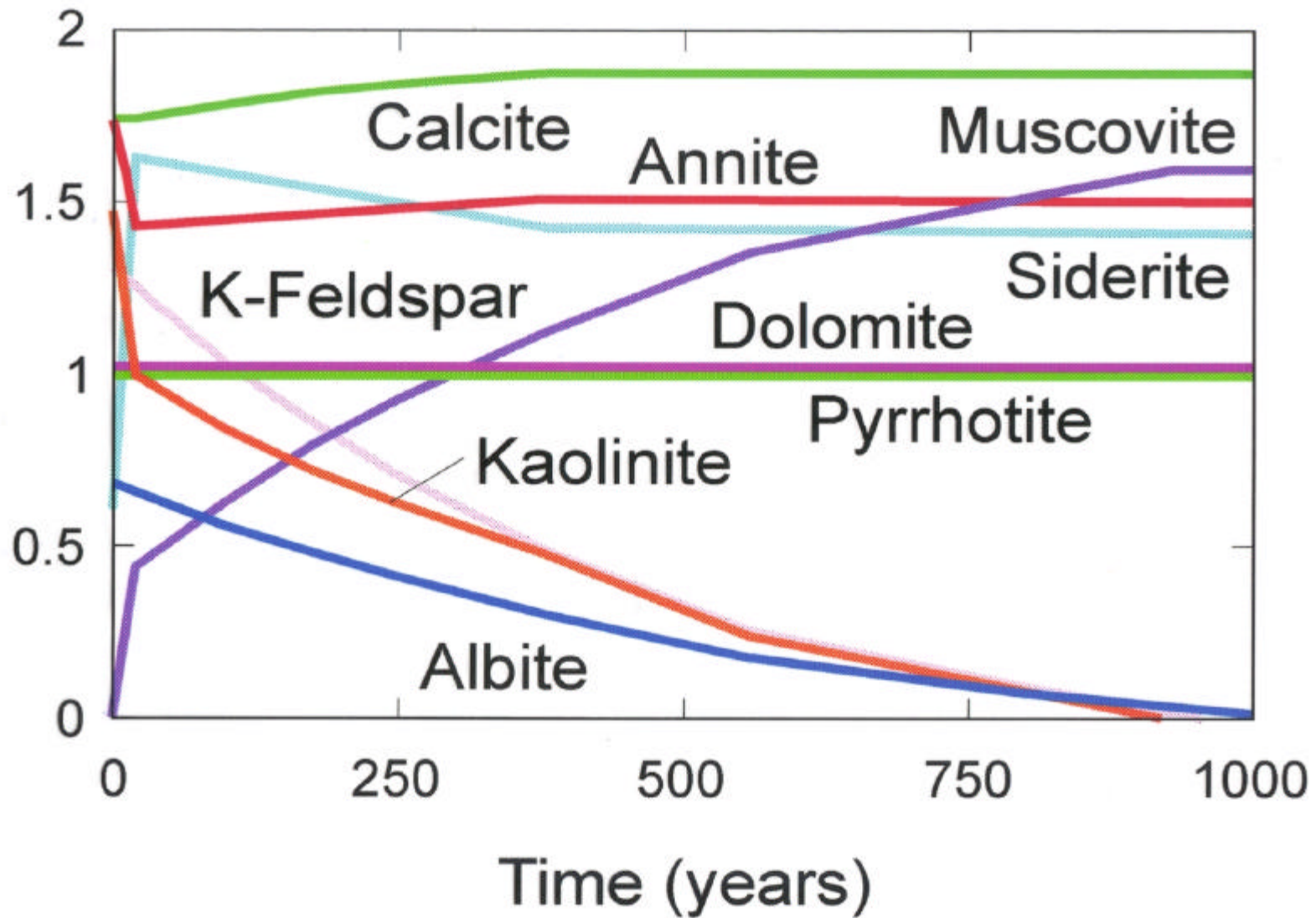
Reactions 11, 12, 13, 14

Glaucconitic Aquifer (H_2S)



Glauconitic Aquifer (H_2S)

Moles of Minerals



CO₂ (1molal) = P_{CO2} of 87 bars

Nisku Carbonate

P_{CO2} : 87 → 86 bars

Glaucconitic Sandstone

P_{CO2} : 87 → 0.02 bars

H_2S (1molal) = $P_{\text{H}_2\text{S}}$ of 30 bars

Nisku Carbonate

$P_{\text{H}_2\text{S}}$: 30 \longrightarrow 0.03 bars

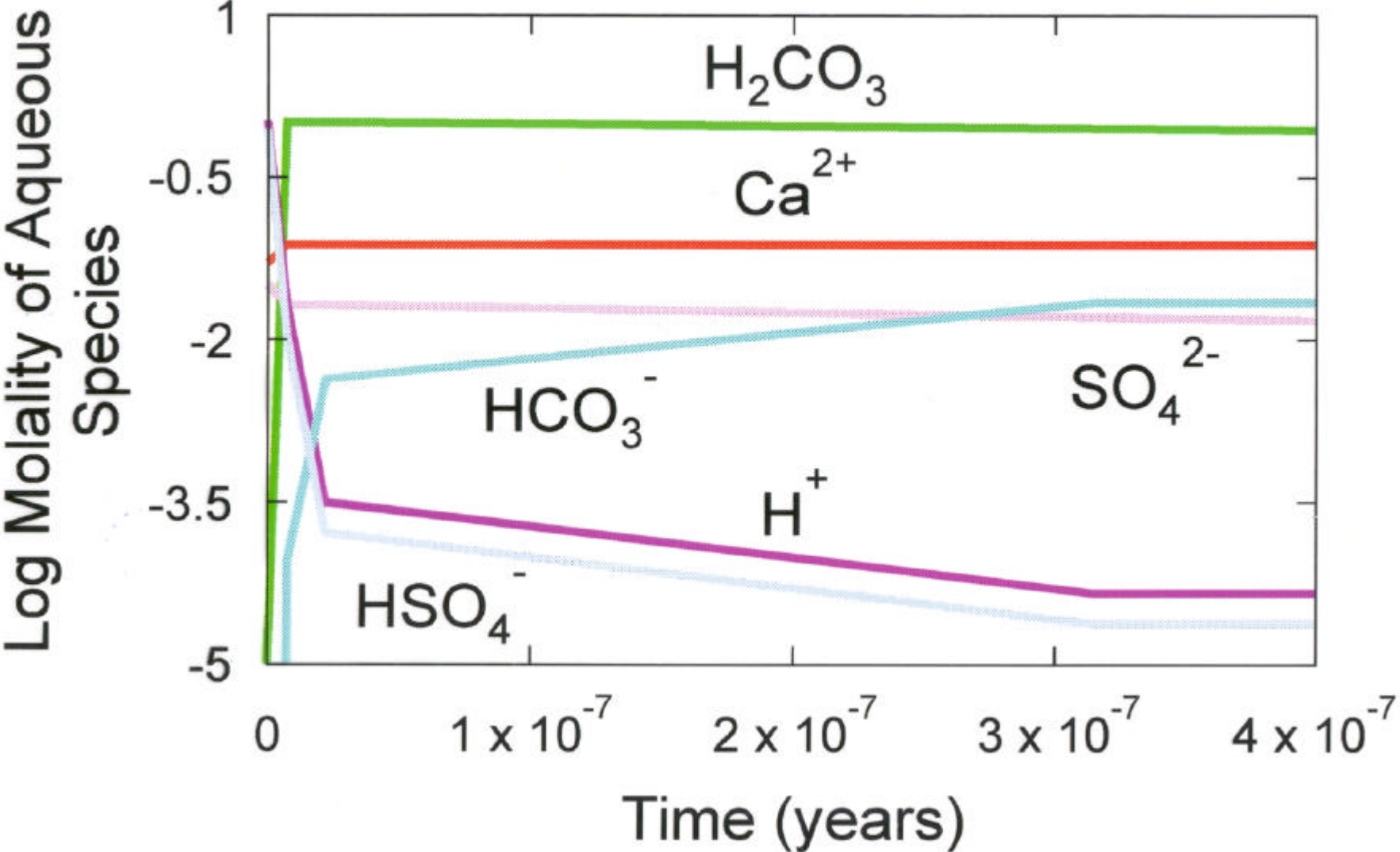
P_{CO_2} : 0.01 \longrightarrow 100 bars

Glaucconitic Sandstone

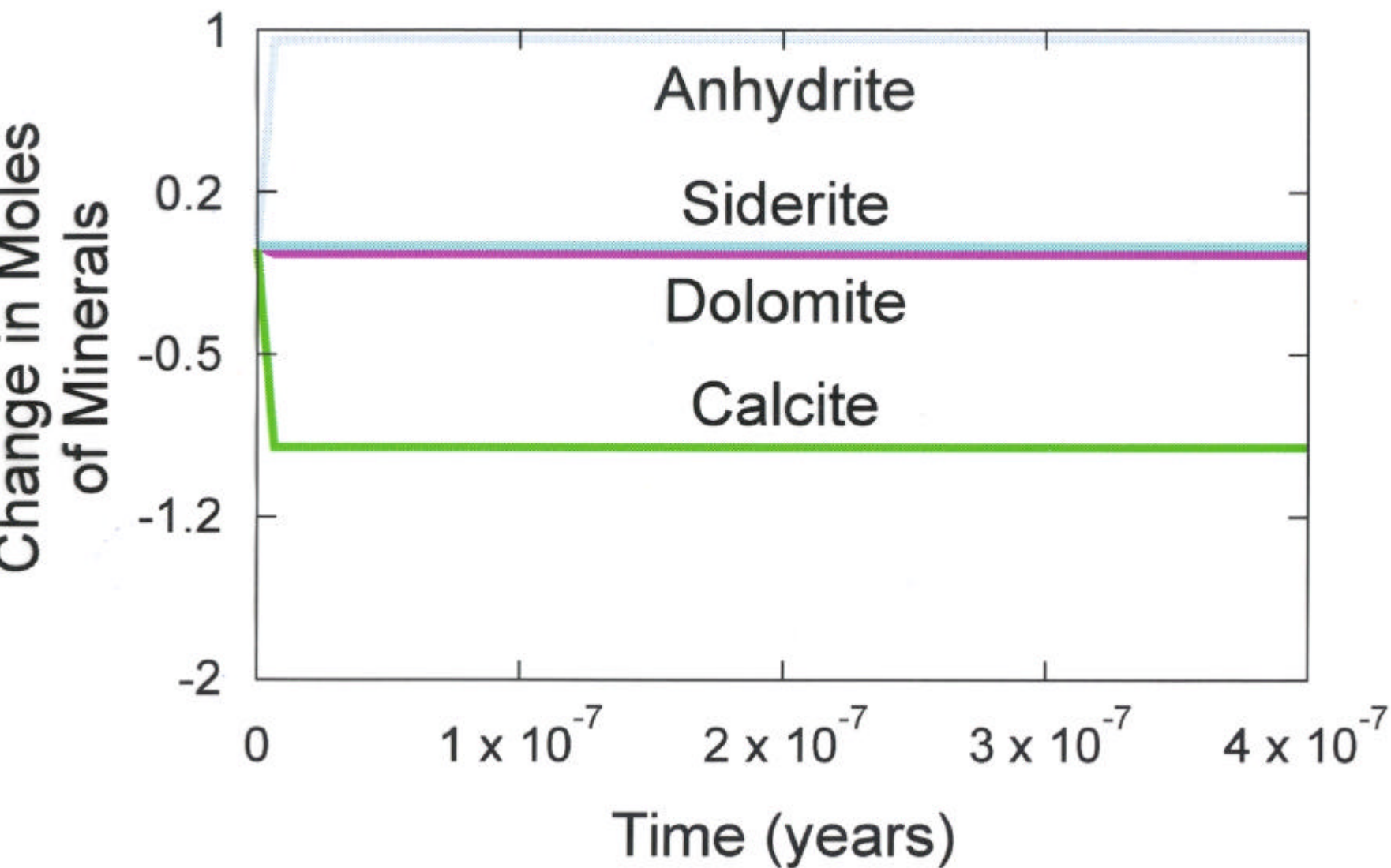
$P_{\text{H}_2\text{S}}$: 30 \longrightarrow 0.03 \longrightarrow 0.00001 bars

P_{CO_2} : 0.01 \longrightarrow 100 \longrightarrow 0.02 bars

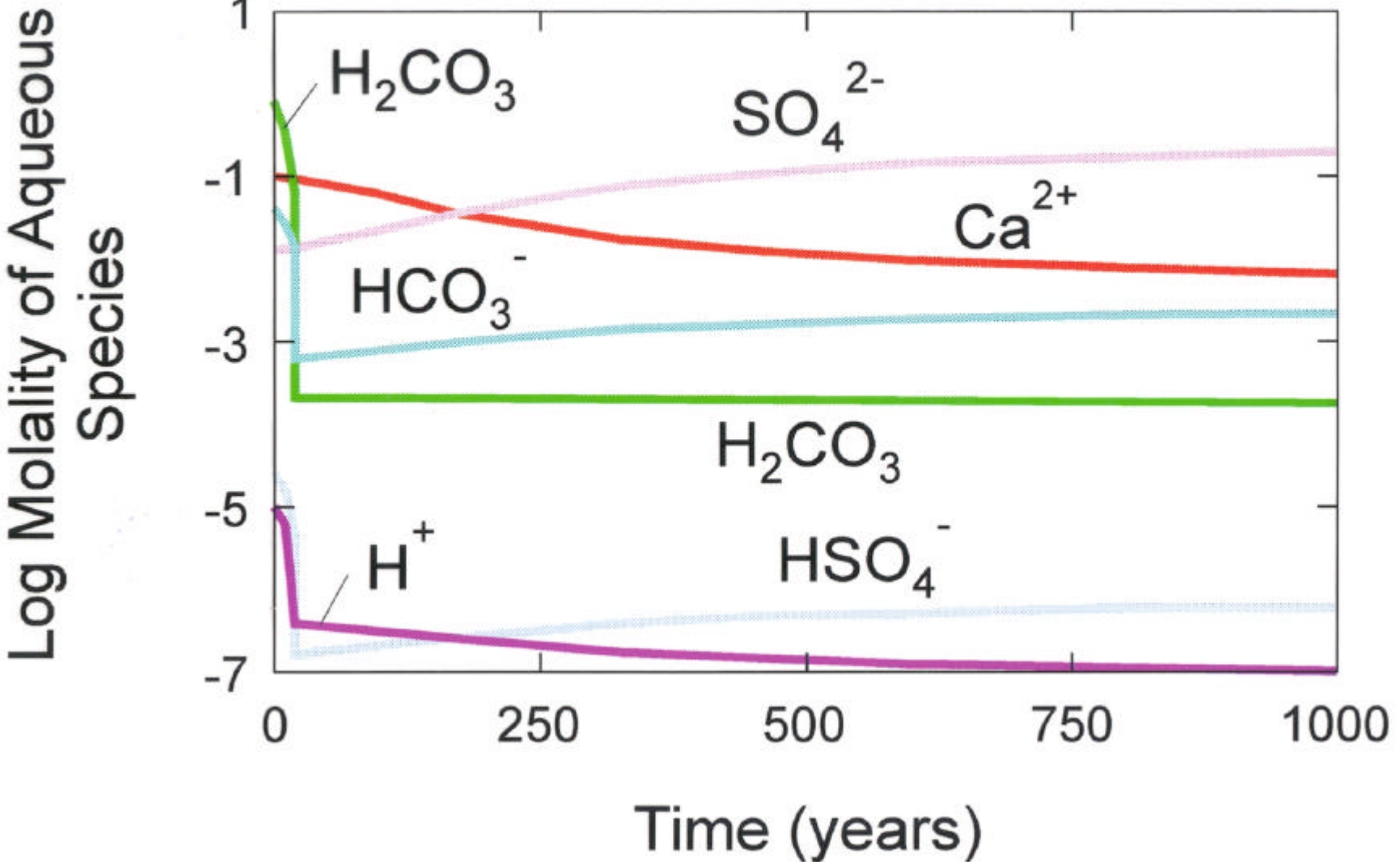
Nisku Aquifer (SO_2)



Nisku Aquifer (SO_2)



Glaucconitic Aquifer (SO_2)



Glaucconitic Aquifer (SO₂)

Moles of Minerals

