

## BACKGROUND

Hydrogen ( $H_2$ ) is vital in the energy transition as a clean alternative to fossil fuels, requiring **large-scale storage** solutions like Underground Hydrogen Storage (UHS). UHS uses geological formations such as depleted oil and gas reservoirs, salt caverns, and aquifers to store significant amounts of  $H_2$ , ensuring supply and demand balance and integrating renewable energy sources effectively.

The **interplay** between microbial activities and geochemical reactions in UHS is complex and dynamic. Microbial processes like Methanogenesis (MET), Acetogenesis (ACE), and Sulfate Reduction (SRB) use dissolved  $H_2$ , affecting the geochemical equilibrium and pH. Geochemical reactions, in turn, influence microbial activity by supplying necessary ions. The reservoir's mineralogy significantly impacts these interactions. Understanding this interdependence is crucial for predicting  $H_2$  loss, byproduct generation, and the long-term impact on storage integrity.

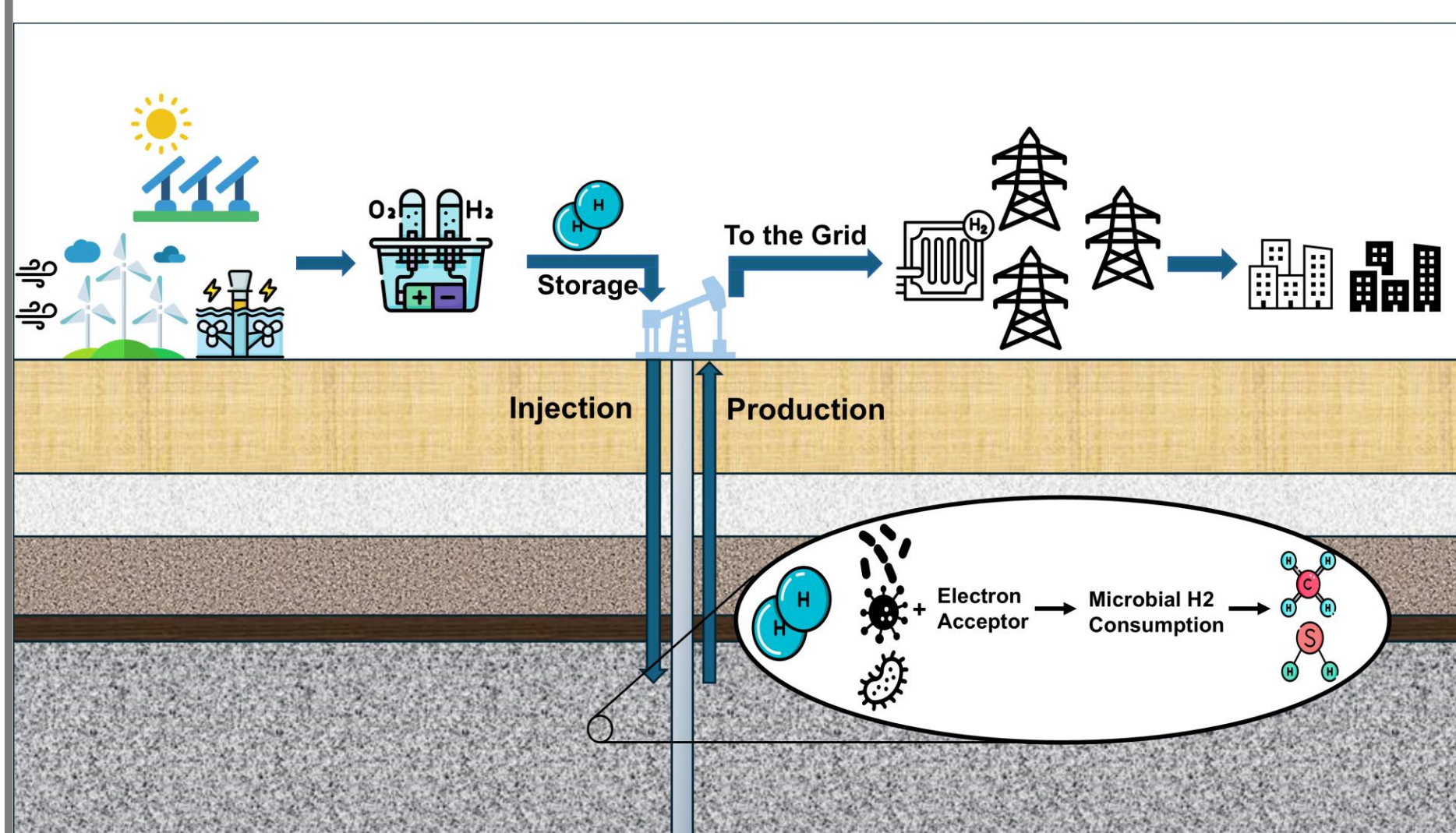


Fig 1. UHS in Energy Transition.

## WHY / PURPOSE

### Objectives:

- Address Bio-Geochemical Knowledge Gaps in UHS.
- Develop a Multi-Physics Model for UHS.

### Why?

- ✓ Hydrogen Loss
- ✓  $H_2$  Purity after Withdrawal
- ✓  $H_2$  Recovery
- ✓ Corrosion due to  $H_2S$  Formation

### Approach:

- ❑ Developing a Reactive Transport Model.
- ❑ Coupling Bio-Geochemical Reactions with Fluid Flow.

### References:

- 1- A. Shojaei, S. Ghanbari, G. Wang, E. Mackay., [Interplay between microbial activity and geochemical reactions during underground hydrogen storage in a seawater-rich formation](#)
- 2- A. Shojaei, S. Ghanbari, G. Wang, E. Mackay., [Integrated Modelling of Bio-Geochemical Aspects in Underground Hydrogen Storage: Implications for Reservoir Selection and Performance](#)

## METHODOLOGY

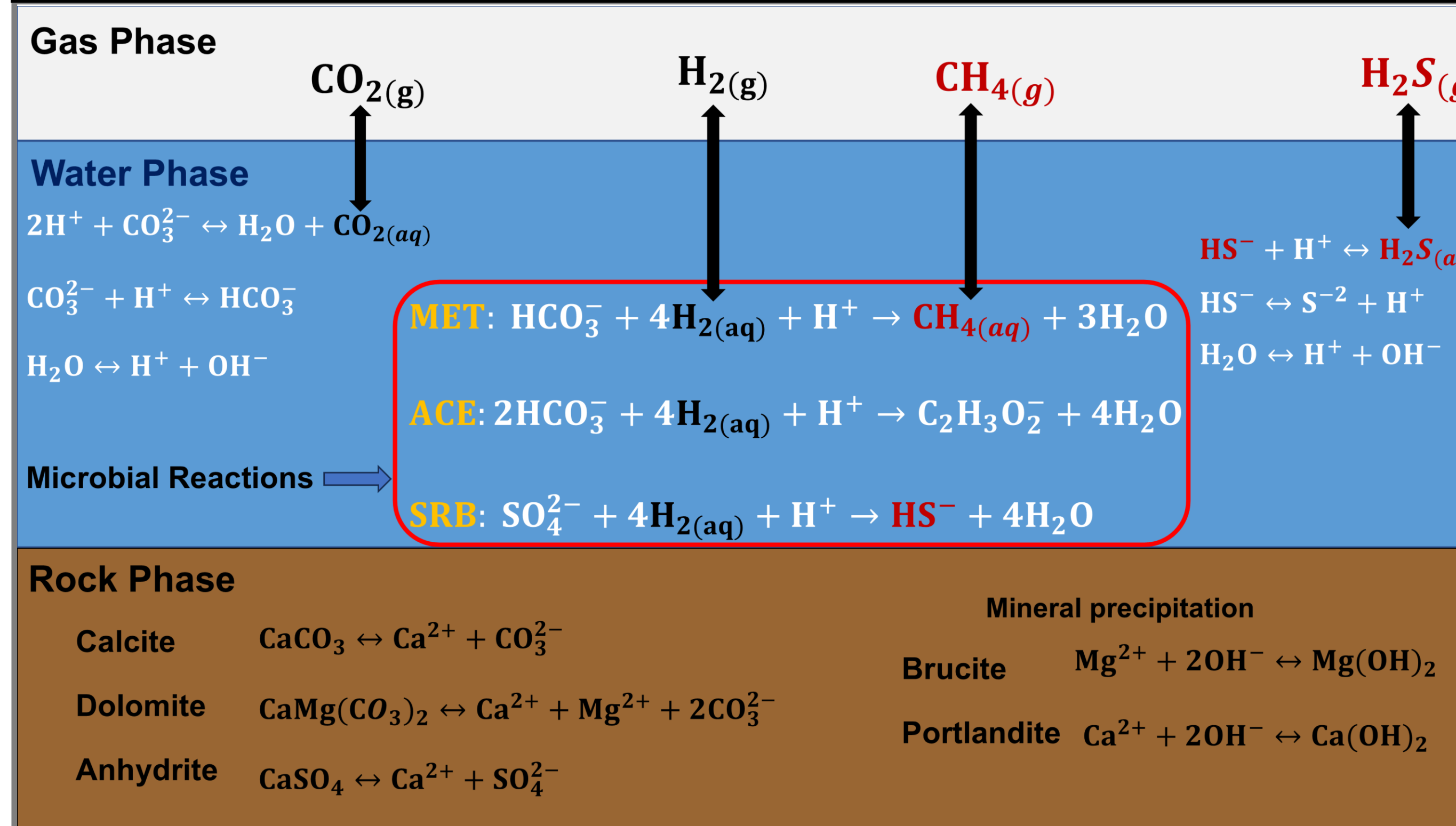


Fig 2. Bio-Geochemical Modeling of UHS.

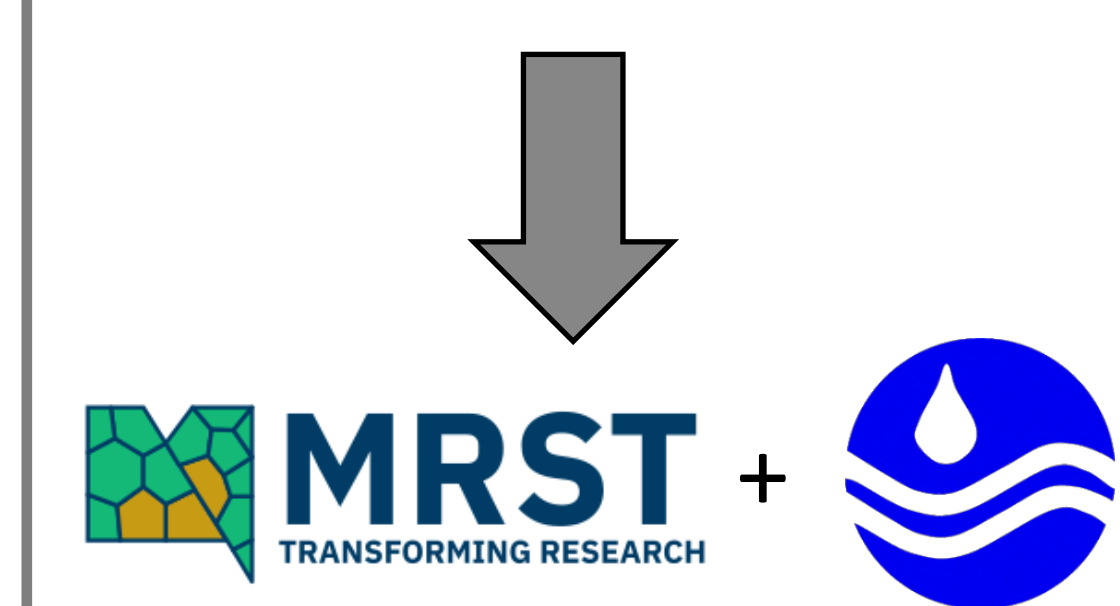
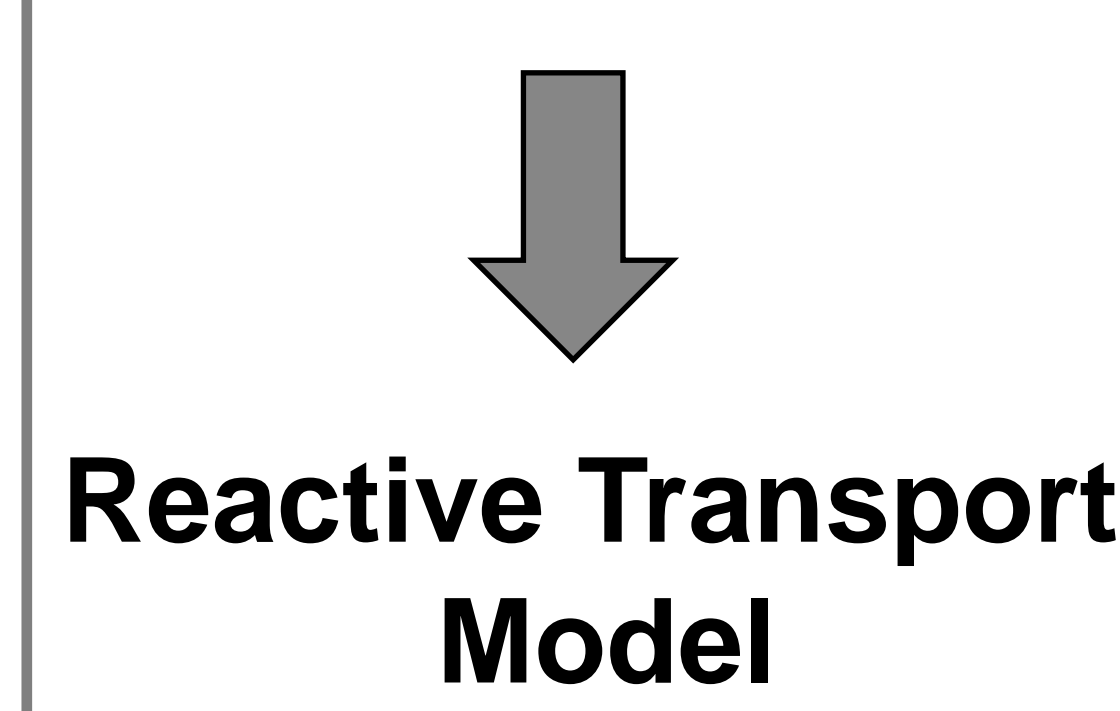
- ❑ Geochemical Reactions
- ❑ Equilibrium

### Microbial Reactions

- ❖ Kinetic
- ❖ Dual Monod Rate Model
- ❖  $r_s = -\frac{\mu_{max} C_D}{Y K_D + C_D} \frac{C_A}{K_A + C_A} X$
- ❖  $r_x = -Y r_s - bX$
- ❖ pH-Temp-Salinity Dependency
- ❖  $r_{s,corrected} = r_s \cdot \tau(T) \cdot \rho(pH) \cdot \varepsilon(TDS)$
- ❖  $0 \leq \tau(T) \leq 1, \tau(T_{opt}) = 1$
- ❖  $0 \leq \rho(pH) \leq 1, \rho(pH_{opt}) = 1$
- ❖  $0 \leq \varepsilon(TDS) \leq 1, \varepsilon(TDS_{opt}) = 1$

Microbial Reactions Consume C(4) and S(6)  
Geochemical Reactions Provide C(4) and S(6)

### Dynamic of UHS



### Algorithm

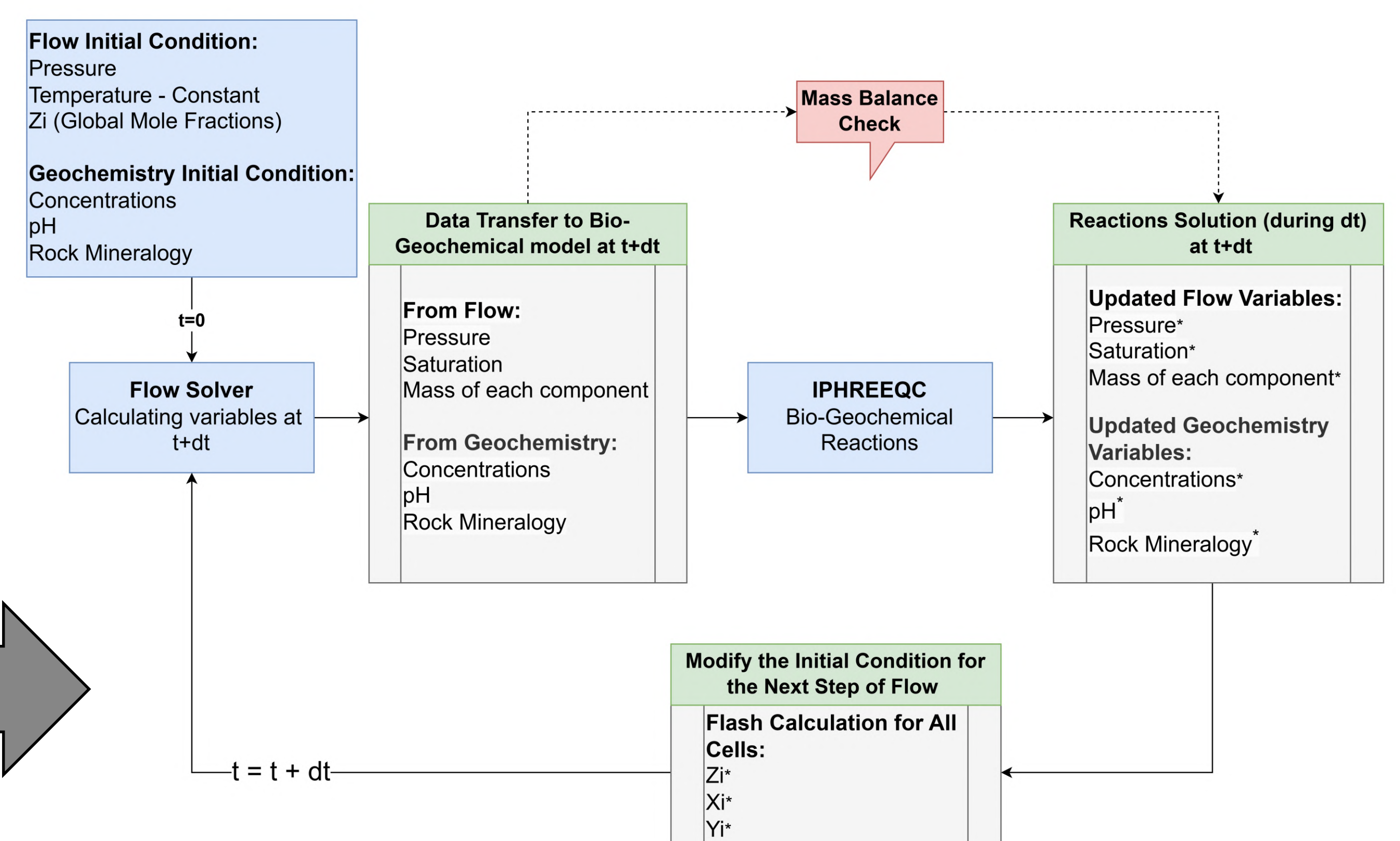


Fig 3. Framework of the Coupling Transport Equation with the Bio-Geochemical Model.

## RESULTS

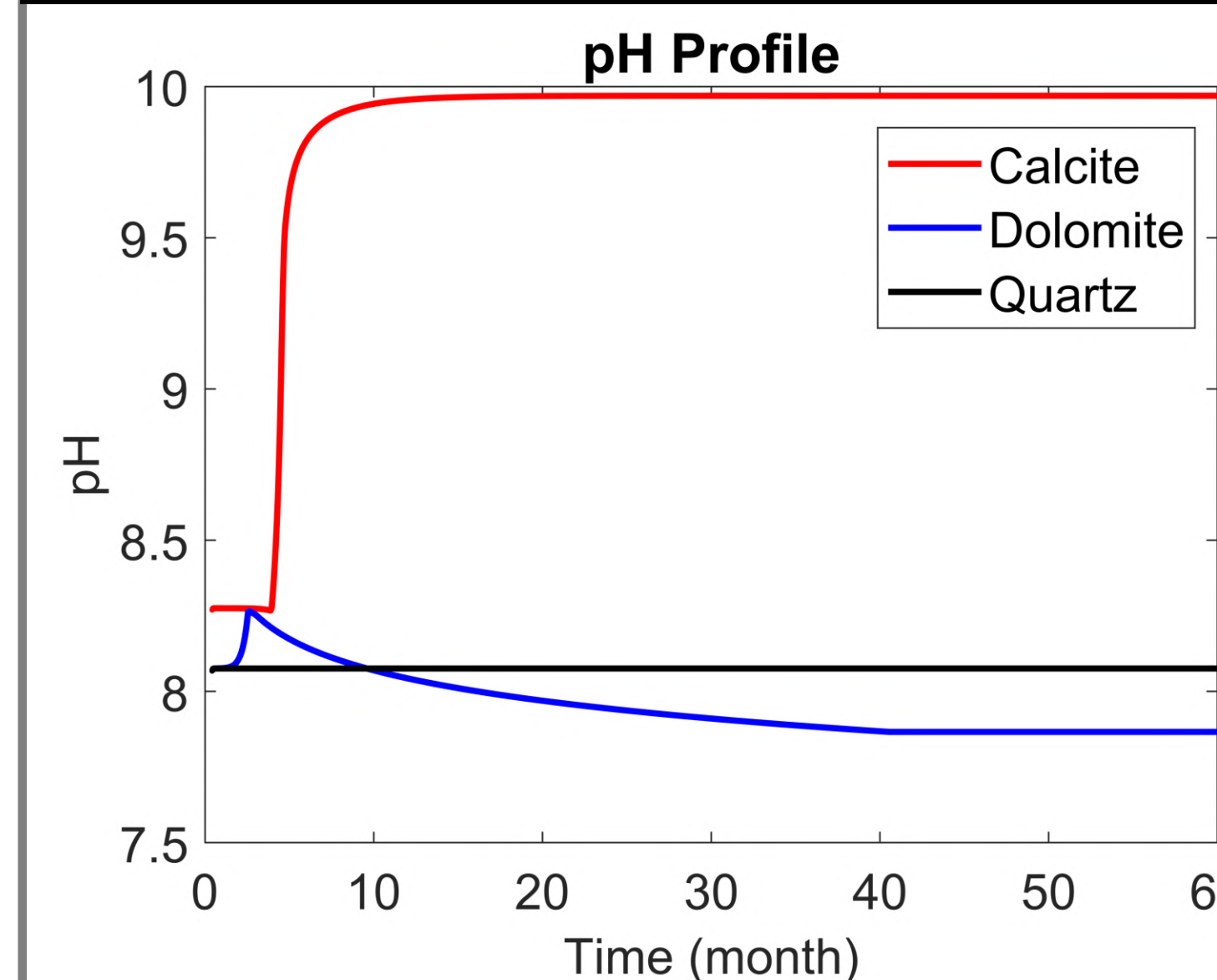
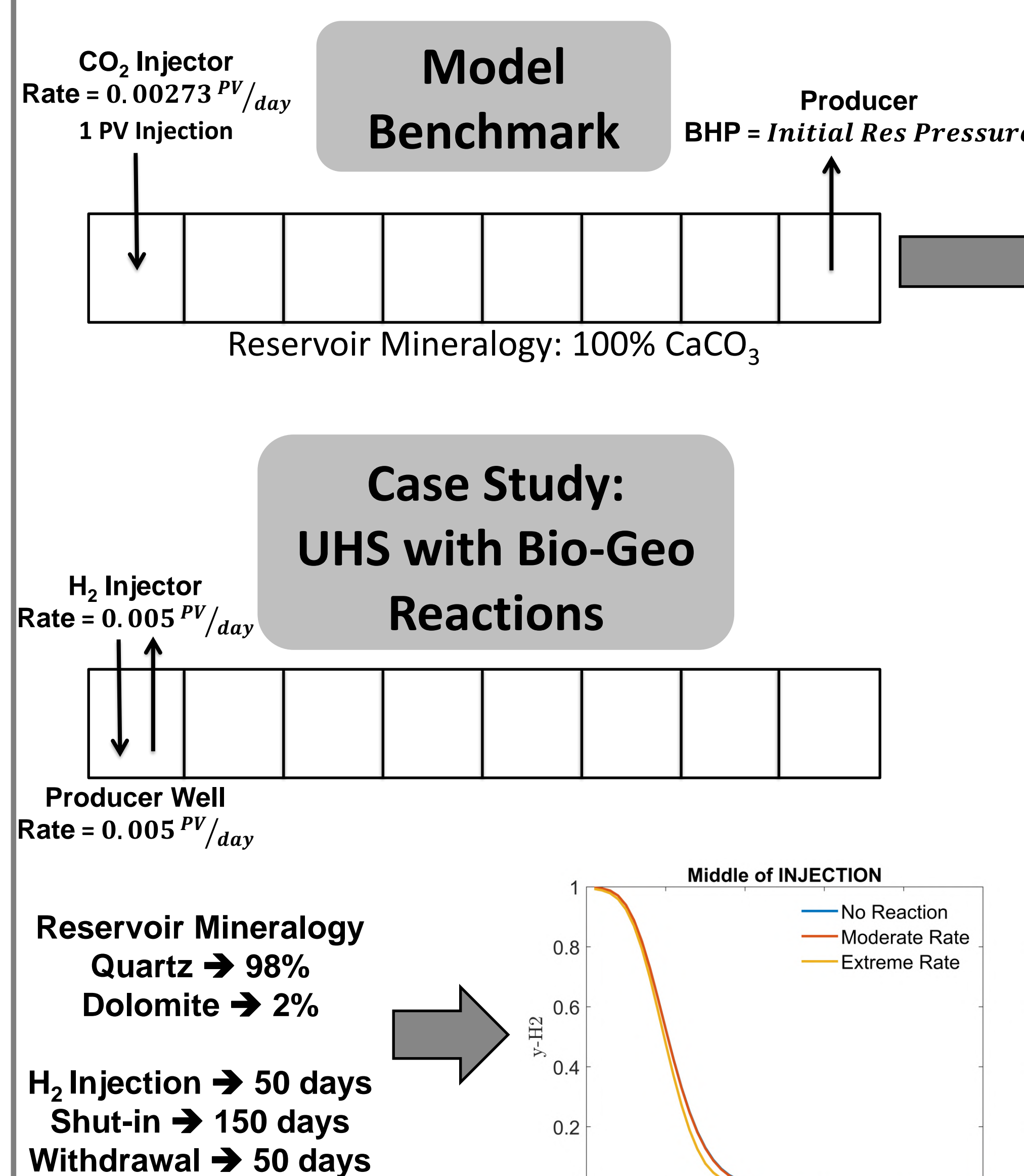


Fig 4. pH Response in Different Rock Mineralogies.



- Strong Interplay between Microbial and Geochemical Reactions.
- Equilibrium Disruption due to Microbial Activities.
- The Role of pH on System Response.
- The Importance of Site Screening and Selection.

Fig 5. Benchmark Results - Geochemistry Properties in CMG-GEM and Our Model.

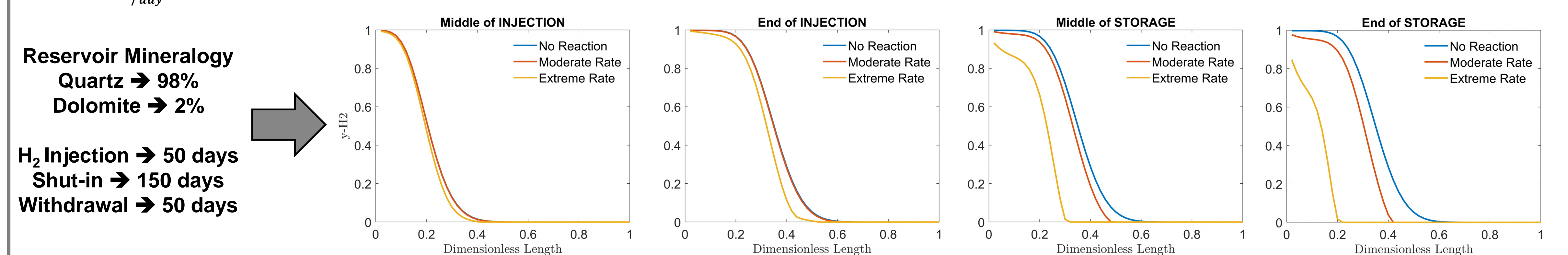


Fig 6.  $H_2$  Mole Fraction in the Gas Phase in I) No Microbial Reaction, II) Moderate Microbial Condition, and III) Extreme Microbial Condition Cases.