Thermodynamic network model for predicting effects of substrate addition and other perturbations on subsurface microbial communities

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Introduction

The overall goal of this project is to develop and test a thermodynamic network model for predicting the effects of substrate additions and environmental perturbations on the composition and functional stability of subsurface microbial communities. The hypothesis is that a thermodynamic analysis of the energy-yielding reactions performed by broadly defined groups of microorganisms can be used to make quantitative and testable predictions of the change in microbial community composition that will occur when a substrate is added to the subsurface or when environmental conditions change (Fig. 1).

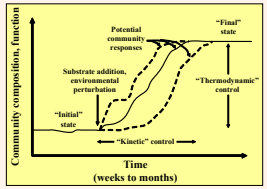


Fig. 1. Community response to substrate addition and environmental perturbation.

Approach

The network model will be used to predict the effects of substrate additions on the microbial community composition by predicting the growth of major metabolic groups of organisms (aerobes, fermenters, denitrifiers, Fe(III)/sulfate/metal reducers). Model predictions will be tested by quantifying changes in the abundance of each of these groups using a combination of functional genes and lipid analysis.

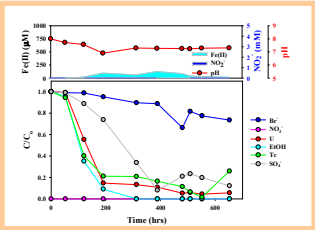


Fig. 2. Donor addition stimulates range of *in situ* microbial activities at FRC.

Group	Name	Electron acceptor(s)	Electron donor(s)
1	Aerobes	O_2	Organics[1]
2	Fermenters	Organics	Organics
3	Denitrifiers	NO_3^-, NO_2^-	Organics H_2
4	Sulfate reducers	SO_4^{2-}	Organics Acetate H_2
5	Metal reducers	Fe(III), Mn(IV), U(VI), Tc(VII)	Organics Acetate H_2
6	Methanogens	CO_2	Acetate H_2
7	Acetogens	CO_2	H_2

[1] See Fig. 4: glucose, ethanol, lactate, butyrate, propionate, and acetate

Fig. 3. Proposed network model predicts the effect of donor addition on growth of these major metabolic groups

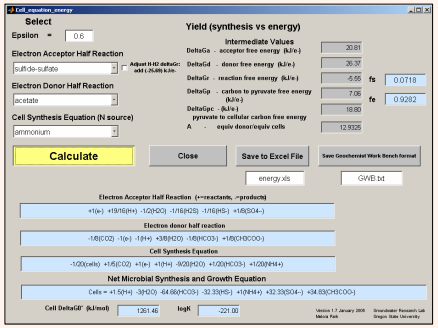
Model Development

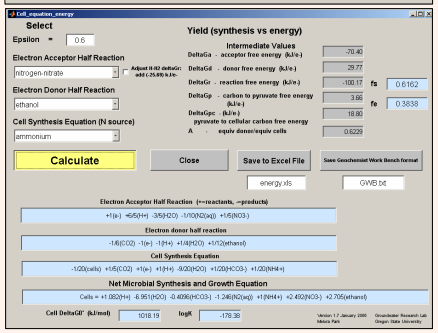
(after Rittman and McCarty, 2001)

Growth Equations

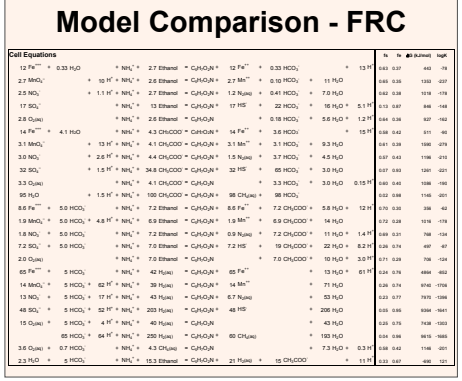
$$R_i = f_{e,i} R_{a,i} + f_{s,i} R_{c,i} - R_{d,i} \qquad (1)$$

Equation 1 is written once for every combination of donor and acceptor utilized by each metabolic group.





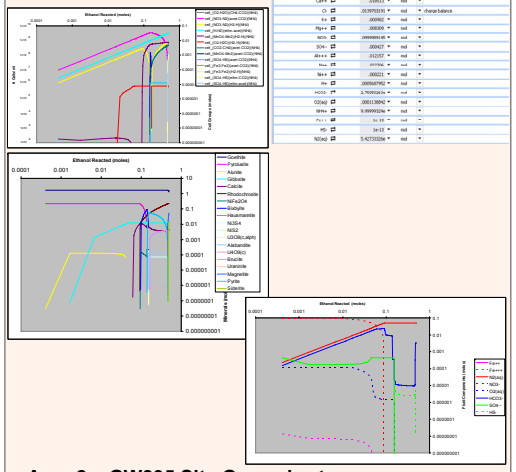
Model Comparison - FRC



Model Comparison – FRC cont.

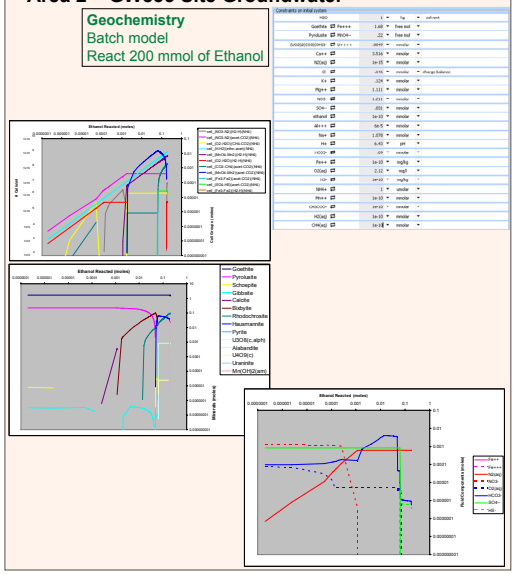
Area 1 – FW21 Site Groundwater

Geochemistry
Batch model
React 500 mmol of Ethanol

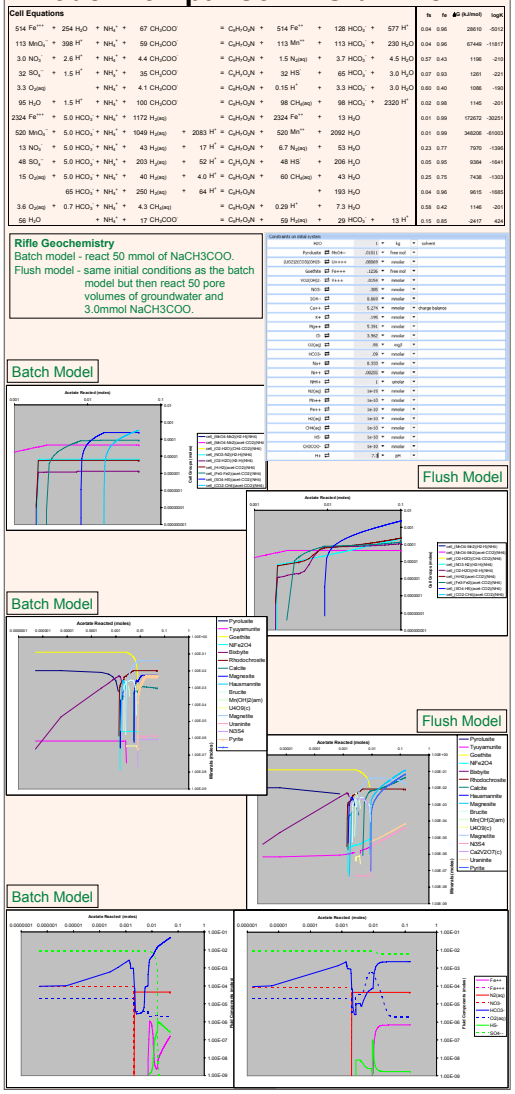


Area 2 – GW835 Site Groundwater

Geochemistry
Batch model
React 200 mmol of Ethanol



Model Comparison – Old Rifle



Acknowledgments

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