Quantitative Chemical Mass Transfer in Coastal Sediments During Early Diagenesis

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LONG-TERM GOALS

The long-term goals are to understand the fundamental mechanisms of biogeochemical processes that occur during early diagenesis, and to use that understanding to develop a predictive capability for assessing biogeochemical, physicochemical, and geotechnical consequences.

OBJECTIVES

This study is a collaborative effort between Dr. Samuel Bentley (Louisiana State University), Dr. Carla Koretsky (Western Michigan University), Dr. Dawn Lavoie (Naval Research Laboratory), and myself originally started in 1997 under ONR322GG funding. We focused on further data collection and initiating the synthesis of results during FY01. My specific objectives were:

1. Sub-millimeter characterization of the dynamics of redox fluctuation in the immediate vicinity of burrows in laboratory mesocosms and field test sites using direct analysis and numerical models.
2. Millimeter-scale characterization of the response of sedimentary microbial community to the redox dynamics using direct analysis and numerical models.

APPROACH

1. **Laboratory data collection:** Static characterization of pore water chemistry and dynamic characterization of redox environment near burrows were to be conducted in benthic mesocosms.

2. **Field data collection:** Static characterization of pore water chemistry and dynamic characterization of redox environment near burrows were to be conducted at field test sites in Mississippi Sound (with Bentley and Lavoie), Scheldt Estuary (with Koretsky and Philippe Van Cappellen, Utrecht University), and Skidaway Marsh (with Joel Kostka, Florida State University).

3. **Reaction-transport (RT) modeling:** A deterministic bioirrigation model in which the depth-dependent distribution of burrows, burrow flushing frequencies, and metabolite production by macrofauna are explicitly considered, was to be developed and applied to the data from benthic mesocosms. The model also was to become the basis for a new RT model whose forcings include dynamic burrow ventilation and seasonal sedimentation dynamics.

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14. ABSTRACT
The long-term goals are to understand the fundamental mechanisms of biogeochemical processes that occur during early diagenesis, and to use that understanding to develop a predictive capability for assessing biogeochemical, physicochemical, and geotechnical consequences.

15. SUBJECT TERMS

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WORK COMPLETED

All planned activities of laboratory data collection, field data collection, and RT modeling (see above) were completed.

RESULTS

The burrow walls created by burrowing macrofauna in aquatic sediments are sites of intense chemical mass transfer. A temporally dynamic, 2D multicomponent diffusion-reaction model, parameterized using the actual measured data, depicted the magnitude and time dependency of chemical mass transfer in the immediate vicinity of burrow walls as well as at the water-sediment interface. The simulation results illustrate that sediment particles, pore water, and microorganisms within a few millimeters of burrow walls experience significant oscillation in pH (as much as two pH units, see figure 1) and dissolved oxygen concentration (between saturation and near anoxia) whereas such oscillation is absent at water-sediment interface. The geochemical oscillation is expected to affect the net stability of mineral phases, activities and community structures of microorganisms, and rates and magnitudes of microbial diagenetic reactions.

IMPACT/APPLICATIONS

The fundamental and temporally dynamic description of chemical mass transfer in littoral sediments enables us to predict the mobility and bioavailability of metal and organic contaminants, as well as the erosion and resuspension potential of the sediments. Consequently, the results will lead to environmental and coastal optics-related applications.

TRANSITIONS

N/A

RELATED PROJECTS

1. Co-funded efforts by Bentley, Koretsky, and Lavoie

2. Biogeochemistry of salt-marsh sediments, by Dr. Joel Kostka (Florida State University)

PUBLICATIONS (FY01 ONLY)

Bentley, S. J., Furukawa, Y., and Vaughan, W. C. (2000) Record of event sedimentation in Mississippi Sound. *Transactions---Gulf Coast Association of Geological Societies* **50**, 715-723.

Furukawa, Y. (2001) Biogeochemical consequences of macrofauna burrow irrigation. *Geochemical Transactions*, submitted.

Furukawa, Y., Bentley, S. J. and Lavoie, D. (2001) Bioirrigation modeling in experimental benthic mesocosms. *Journal of Marine Research* **59**, 417-452.

Furukawa, Y., Socki, R., Elrod, L., and Bissada, A. (2001) Two-dimensional numerical modeling of geochemical interactions between infauna and sediments during early diagenesis of burrowed carbonate sediments in Dry Tortugas, Florida. *Geochimica et Cosmochimica Acta*, submitted.

Lavoie, D., Watkins, J., and Furukawa, Y. (2001) Microwave processing of sediment samples. (In: Microwave Techniques and Protocols. Eds., R. T. Giberson and R. S. Demaree Jr). Humana Press, p.123-137.

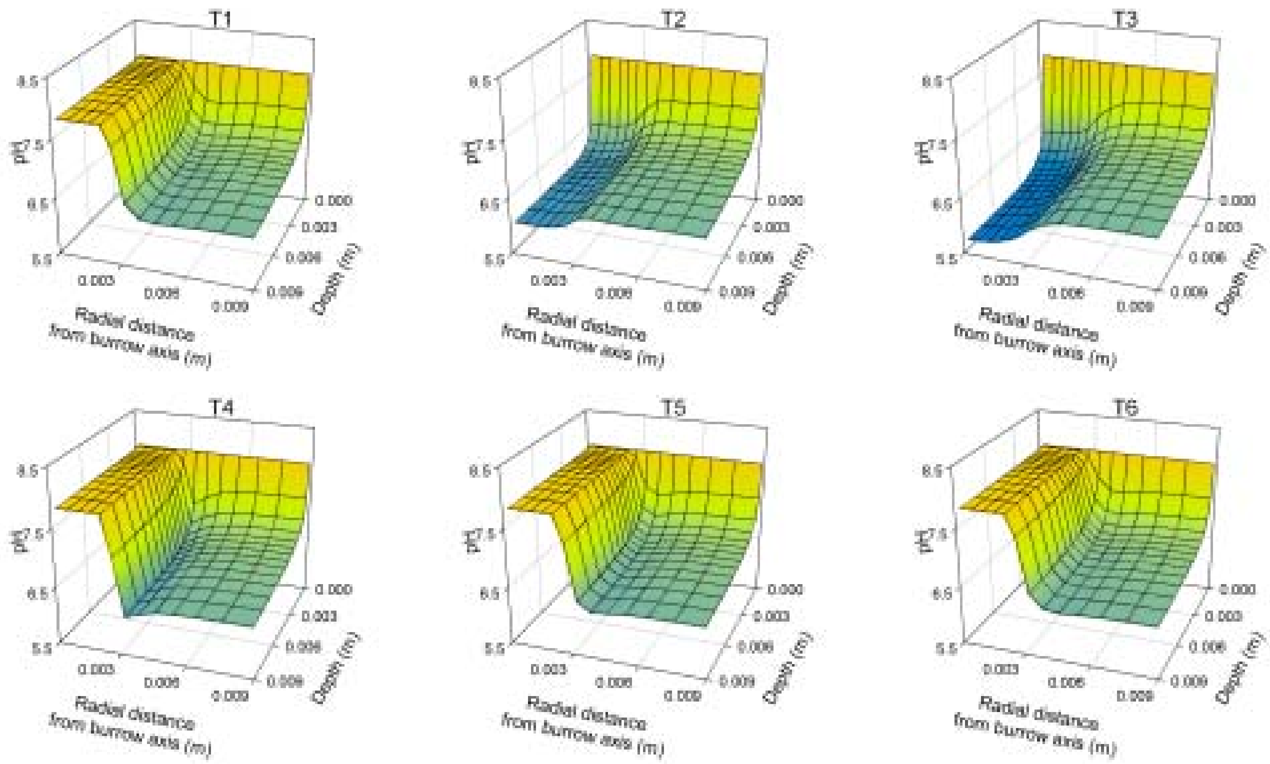

Figure 1: Model-calculated evolution of pH near WSI and burrow wall during each rest-ventilation cycle (~1,200 seconds) of a burrowing Macrofauna, N. diversicolor. At the beginning of each rest period (T1), the pH along burrow wall is 8.0. It decreases during the rest period, as seen at halfway into the rest period (T2), and at the end of the rest period (T3) when the pH at burrow wall is as low as 6.9. Immediately following the rest period, the macrofauna begins ventilation (T4) to maintain the pH level within burrow cavity, as seen at halfway into the ventilation period (T5) and at the end of each rest-ventilation cycle (T6).