WORKSHOP ON BIOGEOCHEMISTRY OF TIDAL FLATS

Introduction

Workshop rationale

In early 2001, DFG established the Research Group on *BioGeoChemistry of Tidal Flats* at the University of Oldenburg for investigations aiming at a fundamental understanding of important processes in a tidal flat system. For this purpose, biogeochemical transformations on water-column-suspended particles, at the sediment-water interface and in the sediments are being studied. Considering the hydrodynamic conditions and the related sediment transport, the influence of the different processes on the materials budget are being determined for a selected tidal flat area on the East Frisian North Sea coast (backbarrier tidal flat of Spiekeroog island). A mathematical ecosystem model will be developed for the biogeochemical processes in the tidal flat sediments and at the sediment-water interface. In addition, a tight coupling of methods for analyzing nonlinear dynamic systems with ecological problems will be used to reveal how spatial, temporal and/or spatio-temporal structures develop due to nonlinear interaction of reaction, diffusion and advection and if exceeding a critical threshold leads to the spontaneous formation of new structures or dynamics. Fig. 1 illustrates the integrated approach of this project.

After the first two years of investigations, the workshop was intended to discuss the preliminary results with an international audience studying similar problems and to focus – and possibly revise – the research objectives for the coming years.

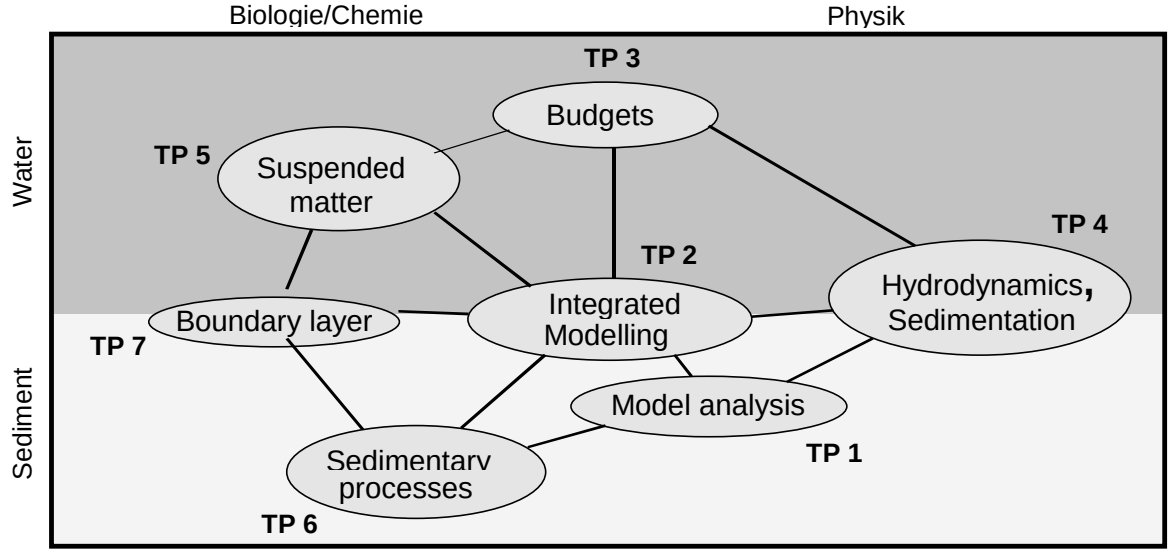

Fig. 1. The Integrated Approach

The seven sub-projects of the Research Group

Sub-Project 1 (Prof. Ulrike Feudel)
"Nonlinear Dynamics in Models for Tidal Flats: Pattern Formation, Complexity and Critical Transitions"

It is the aim of the sub-project to study pattern formation processes in a hierarchy of ecosystem models and to investigate the interaction of biogeochemical and transport processes in tidal flat sediments. The work focuses on the investigation of the formation of structures in space and time due to nonlinear interactions of reaction, diffusion and advection. Critical transitions where characteristic parameters of the system exceed threshold values leading to a spontaneous, discontinuous formation of new structures or dynamics are of particular interest. One important issue is the inhomogeneity of the medium with regard to transport characteristics and the distribution patterns of microorganisms. The influence of such inhomogeneities and non-local interactions on the pattern formation process will be studied. Additionally, the effects of stochastic influences (weather), big disturbances (extreme weather events) and the coupling of different sub-models on different spatial and time scales will be studied.

Sub-Project 2 (Prof. Wolfgang Ebenhöh)
"Integrative Modeling of Biogeochemical Processes in the Wadden Sea Sediment"

Different biogeochemical processes in the Wadden Sea sediment including exchange at the sediment-water interface are assessed in an integrative way. Mainly, two hierarchical levels are considered, the back-barrier tidal flat ecosystem and a sediment column connected to the sea water. The ecosystem model is based on established standards (ERSEM) and will integrate the hydrodynamics model of sub-project 4 as well as an aggregated version of the sediment model. Special emphasis will be given to the effects of asymmetric tidal transport of nutrients and microbial activities on suspended particles. On the level of biogeochemical sediment processes, a major task lies in developing new model equations. Additionally, the description of POM degradation as well as several transport mechanisms, including the cycling of chemical nitrogen, iron, manganese and sulfur species, are investigated. The dynamics of these element cycles is dominantly mediated by aerobic and anaerobic bacterial communities implicitly accounted for in the model. Here, the innovation lies in the description of the effect of succession and adaptation processes by means of effective variables. These, for example, represent apparent kinetic characteristics in different pathways of POM degradation or reoxidation of reduced substances. The sub-project aims at developing further coupling and aggregation methods in order to merge the two model levels as efficiently as possible. Using the results of a model sensitivity analysis, key processes of the biogeochemistry of tidal flats will be identified. In this way and by offering a frame for integrating most experimental results obtained so far, the sub-project contributes to the general coherence of the project.

Sub-Project 3 (Prof. Hans-Jürgen Brumsack, Dr. Rainer Reuter)
"Input/output budget and states of the backbarrier tidal flat water column"

The East Frisian tidal flats are continuously influenced by open marine (from the North Sea) and on-shore processes. In this sub-project, we want to elucidate whether the input/output of dissolved and particulate matter between the backbarrier and offshore areas is presently in a steady state or whether the tidal flats suffer a net loss of material. We intend to study the seasonal dynamics of seaward and landward inputs as well as their relation to the retention or mobilization of specific compounds. These questions will be addressed from three viewpoints: 1. Characterisation, quantification and input/output balance of the dissolved and particulate load between the backbarrier tidal flats and the open North Sea through the inlet on tidal and seasonal cycles, also taking into account extreme events (severe storms and sea ice), 2. Characterisation and quantification of the dissolved and particulate input from small coastal tributaries into the backbarrier tidal flat system on a seasonal scale, 3.characterisation and quantification of the biogeochemical transformation of the dissolved and particulate matter in the water column of the backbarrier tidal area.

Sub-Project 4 (Prof. Jörg-Olaf Wolff, Prof. Burghard W. Flemming)
"Hydrodynamics and Suspended Matter Budget in an Intertidal Basin of the East Frisian Wadden Sea"

The East Frisian Wadden Sea can currently be characterized by a lack of accommodation space for imported fine-grained sediments. The depositional system reacts to sea-level rise by a landward movement of existing sediments. The dominant driving forces of this process are a combination of sea-level rise, tidal currents, waves and wind-induced sea-level changes. Human activities have modified the natural system by constructing dikes for coastal protection. This has resulted in higher energy levels near the dike and hence in an ongoing elimination of finer-grained sediments. We postulate that, because of the lack of accommodation space in the Wadden Sea, the net export of fine-grained sediment (and any material associated with the fine sediment fraction) will continue and possibly accelerate in the future. The main aim of this project, therefore, is to establish a suspended-sediment budget for a typical tidal basin as a function of hydrodynamic forcing factors and, ultimately, to develop a mathematical model for its prediction. To reach this objective, a high-resolution three-dimensional circulation model will be developed which will eventually be coupled with a wave model. Both, the circulation model and the import-export model of suspended sediment will be validated by in-situ measurements. Special emphasis will be given to extreme events (e.g. ice-winters and storm surges). At the same time, the processes controlling deposition and resuspension of fine-grained sediment in the tidal basin will be investigated.

Sub-Project 5 (Pof. Meinhard Simon, Dr. Hans-Peter Grossart)
"Ecology of Suspended Particles"

This sub-project will investigate the spatio-temporal dynamics and the aggregation processes of suspended matter, its composition and microbial colonization as well as the substrate turnover in the backbarrier tidal flats of Spiekeroog island. This includes the analysis of the size structure of the suspended matter and its biochemical and microscopic composition (planktonic and benthic algae, zooplankton, detritus, mineral particles). The composition of the associated bacterial community will be analyzed with classical and molecular microbiological methods (16S rDNA clone libraries, DGGE, FISH). In order to determine the microbial turnover of the suspended matter, we will measure the biomass production of the associated bacteria and the concentration, release and turnover of amino acids and carbohydrates on the aggregated suspended matter. In addition to the field studies, we plan to carry out experiments in mesocosms and large-scale tanks under controlled conditions and simulating the tidal currents.

Sub-Project 6 (Prof. Heribert Cypionka, Prof. Jürgen Rullkötter, Dr. Henrik Sass
"Gradients and Microbial Transformations in the Anoxic Zone"

In this project, microbial and chemical processes in the Wadden Sea sediments are investigated. We study the composition and activities of the microbial communities and their influence on the sediment chemistry. Microbiological, molecular biological and geochemical approaches are used in a combined manner. Sampling will focus on the anoxic zone down to the sulfate-free layers. New methods have to be developed to deal with the bacteria of the 'shallow biosphere' and to cultivate them as efficiently as possible. Microbial and geochemical processes and fluxes are compared as a function of depth, and limiting parameters will be identified. Organic and inorganic compounds will be analyzed in order to clarify whether the present (recalcitrant) organic matter can serve as substrate for microbial growth, and whether binding to the mineral matrix limits its availability.

Sub-Project 7 (Prof. Bo Barker Jørgensen, Dr. Michael E. Böttcher
"Biogeochemical Processes at the Sediment-Water Interface of Intertidal Sediments"

In this project, the cycles of manganese, iron, and sulfur in the different sediment types will be investigated in a quantitative manner in order to understand the fluxes of matter and the biogeochemistry of the intertidal sediments. Through the interaction of geochemical and microbial processes, the decomposition of organic matter is tightly linked to the cycles of O, N, S, Mn, Fe and other elements. Manganese and iron are important for the electron transfer and are recirculated through various redox processes. However, our understanding of the role of these elements in the decomposition pathways is still poor. This project will address (1) the biogeochemical processes that are important at the sediment-water interface and in the uppermost sediment layer, (2) the mineralization rates of organic matter, (3) the influence of environmental factors on the mineralization and biogeochemical zonation, (4) the relationship between the distribution of microorganisms and the biogeochemical processes, and (5) the role of the hydrodynamic processes. All processes will be investigated with respect to their variability on tidal, day-night and seasonal scales in situ as well as in laboratory experiments.

Workshop programme

Oral presentations

Jörg-Olaf Wolff, Burghard Flemming
Tidal asymmetries, water exchanges and sediment transports in the East Frisian Wadden Sea

Hans-Jürgen Brumsack, Rainer Reuter
Geochemical and physical water column signatures of the Spiekeroog backbarrier tidal flat: Budgets and states

Timothy Shaw
Methods and models for estimating advective pore water exchange in tidal flats

Michael E. Böttcher, Dirk de Beer
Living every day with Noah's flood: Element dynamics in intertidal surface sediments of the North Sea

Lucas Stal
Biofilm formation by benthic diatoms and their influence on the stabilization of intertidal mudflats

Meinhard Simon, Hans-Peter Grossart
Tidal and seasonal variations in dynamics of microaggregates and associated bacterial communities in the German Wadden Sea

James Murray
A changing coastal sea: The Black Sea

Samantha Joye
Benthic microalgal production and nutrient dynamics in intertidal sediments

Heribert Cypionka, Jürgen Rullkötter, Henrik Sass
First steps into the shallow biosphere

Kai Finster
The activity of sulphate reducers in the rhizosphere of marine macrophytes

Ulrike Feudel
Instabilities and pattern formation in simple ecosystem models

Filip Meysman
New developments in the modelling of bioturbation in aquatic sediments

Kai Wirtz, Wolfgang Ebenhöh
Microbial and transport mechanism in the sediments: Interplay and relative importance for simulated C- and N-cycles

Bernard Boudreau
Lattice-automation modelling of bioturbation

Poster session

Carol Arnosti, Marianne Holmer
Assessing 'quality' from a microbial perspective: Contrasts between organic matter characteristics and remineralization rates and pathways

Martin Baurmann, Ulrike Feudel
Diffusion-induced pattern formation in a minimal sediment model

Knut Bernhardt, Tobias A. Sperr, Kai W. Wirtz
Reduction of a complex biogeochemical model with neural network and clustering techniques

Katja Bosselmann, Michael E Böttcher., Markus Billerbeck, Eva Walpersdorf, Dirk de Beer, Markus Hüttel, Hans-Jürgen Brumsack., Bo B. Jørgensen
Iron-sulfur-manganese dynamics in intertidal surface sediments of the North Sea.

Gerold Brink-Spalink, Emil V. Stanev, Jörg-Olaf Wolff
On numerical modelling of sediment dynamics in the East Frisian Wadden Sea

Tae Soo Chang, Alexander Bartholomä, Elke Tilch, Burghard W. Flemming
Recent development of the backbarrier tidal basin behind the island of Spiekeroog in the East Frisian Wadden Sea

Olaf Dellwig, Frank Terjung, Hans-Jürgen Brumsack, Rainer Reuter
Understanding the bioreactor Wadden Sea: A geochemical and physical approach

Niko Finke, Tori M. Hoehler, Bo B Jørgensen
Methanogenesis from methylamine and methanol at changing hydrogen concentrations

Götz Flöser
Seasonally dependent nutrient dynamics in the East Frisian Wadden Sea

Elke Freese, Jürgen Rullkötter
Characterization of organic matter in sediments from the Wadden Sea of the German Bight

Oleksiy Galaktionov
Bio-irrigation induced by Arenicola marina: classical assumptions vs numerical modelling

Thilo Gross, Wolfgang Ebenhöh, Ulrike Feudel
On the impact of interaction functions on food chain stability

Kousuke Ishii, Marc Mußmann, Rudolf Amann
Microbial community composition of Wadden Sea sediment as revealed by optimized Fluorescence In Situ Hybridization with Catalyzed Reporter Deposition (CARD-FISH)

Olaf Joerdel, Alexander Bartholomä, Burghard W. Flemming
Behaviour of suspended sediments flocs in tidal basins - A case study from the backbarrier area of Spiekeroog Island, German North Sea

Cora Kohlmeier
ECOTIM - Ecological tidal model

Sibylle Kölsch, Sven Gebhardt, Frank Terjung, Gerd Liebezeit, Rainer Reuter, Jürgen Rullkötter, Hans-Jürgen Brumsack
Freshwater discharge into the German Wadden Sea: Geochemistry of humic-rich waters

Beate Köpke, Reinhard Wilms, Bert Engelen, Heribert Cypionka, Jürgen Rullkötter, Henrik Sass
Cultivation of bacteria from a six meter long core of intertidal sediment

Gerd Liebezeit
Nutrient signatures in the Wadden Sea and adjacent terrestrial areas

Mirko Lunau, Beate Rink, Hans-Peter Großart, Meinhard Simon
How to sample marine microaggregates in shallow and turbid environments: Problems and solutions

Stephane Madani
Biogeochemical modelling of sediments from the Santa Barbara basin (California)

Beate Rink, Mirko Lunau, Heike Stevens, Susa Seeberger, Thorsten Brinkhoff, Meinhard Simon
Diversity patterns of aggregate associated and free-living bacterial communities in the German Wadden Sea

Henrik Sass, Heike Rütters, Rabea Schledjewski, Elke Freese
The influence of seasonal changes on microbial communities in the Wadden Sea

Emil V. Stanev, Jörg-Olaf Wolff
Tidal response shaped by nonlinear topographic control

Eva Walpersdorf, Ursula Werner, Lubos Polerecky, Uli Franke, Paul Bird, Dirk de Beer
Tidal dynamics of O_2, H_2S and pH in permeable sands

Ursula Werner, Lubos Polerecky, Eva Walpersdorf , Uli Franke, Markus Billerbeck, Michael E. Böttcher, Tim Ferdelman, Dirk de Beer
Organic matter degradation processes in permeable sediments – methodological approaches

Reinhard Wilms, Beate Köpke, Bert Engelen, Henrik Sass, Heribert Cypionka
Microbial community composition of the "shallow biosphere" of Wadden Sea sediments

Ralf Wöstmann, Claus Köller, Jürgen Rullkötter
Biomarkers of peat-forming plants and their signal in tidal flat sediments of the German Bight

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