Deep Sea and Sub Seafloor Frontier (DS³F)

Workshop Report

Work Package 2

"Sedimentary seafloor and sub-seafloor ecosystems:
past, present, & future links"

Zurich, Switzerland
January 26-28, 2011

Organizers:
Tim Ferdelman and Judy McKenzie

I. *General information*

Work Package 2

Sedimentary seafloor and sub-seafloor ecosystems: past, present, & future links

26-28 January 2011
Zürich, Switzerland

Organisers
Timothy G. Ferdelman (MPI)
Judith McKenzie (ETH)

Local host
Judith McKenzie (ETH)

II. **Agenda**

Wednesday 26. January 2011

Arrival, registration at Hotel Uto Kulm
Welcome (Judy McKenzie/Tim Ferdelman)
19:00 General Introduction to DS3F (Tim Ferdelman)
20:00 Seminar Dinner

Thursday 27 January 2011
08:00 – 17:00 Seminar (12 persons)

Breakfast and Coffee to 09:00
09:00 Scientific presentations I (20-30 minutes each)
10:30 Coffee
11:00 Scientific presentations II
13:00 Lunch (12 persons)
14:00 Scientific presentations III
16:00 Coffee
16:30 Scientific presentations IV
20:00 "Gornergrat" (Raclette-Grill Dinner)

Friday 28 January 2011
08:00 – 12:00 Seminar (11 persons)

Breakfast and Coffee to 09:00
09:00 Rachel James: Report from the INVEST Meeting (September 2009, Bremen)
00:30 Open discussion
10:30 Coffee
11:00 Formulation of Workshop output
13:00 Lunch (11 persons)
14:00 End of workshop

III. Workshop

A. Background and Objectives

We sought to bring together a broad coalition of scientists who have interest in how sub-seafloor processes intersect with biogeochemical processes at the seafloor or in the deep ocean. While the text of the Coordinated Action itself may appear to be very focused on scientific drilling, we hope that we can make clear that deep sub-surface science depends heavily on understanding surface and deep ocean processes. This represents a chance for the European deep ocean community to link deep-ocean, surface sediment, and deep sub-surface oriented scientists, and to build a critical mass of people and ideas at the intersection of these fields. The idea is have a solid basis for discussion and for making well-thought through proposals, i.e, we should make this more than just a "talking shop".

For Work Package 2, a group of 13 scientists from ten European countries were invited to form the Level 3 (see Description of Work) Working Group.

WP2 Scientists

Person	*Institute*	*Attendance*
Judy McKenzie	ETH Zurich, Switzerland	yes
Tim Ferdelman	MPI Bremen, Germany	yes
Rachel James	NOC, Southhampton, UK	yes
Filip Meysman	NIOO Yserke;	yes
Karline Soetaert	Netherlands	unable to attend
Ronny Glud	Southern Danish U., Odense, Denmark	yes
Caroline Slomp	U. Utrecht, Netherlands	unable to attend
Giovanni Aloisi	CNRS /LOCEAN, Paris, France	yes
Daniel Conley	U. Lund, Sweden	yes
Gian Marco Luna	CONISMA, Italy	yes
R. Danovaro	CONISMA, Italy	unable to attend
Achim Kopf	MARUM, Germany	unable to attend
Francisca Martinez Ruiz	Granada, Spain	yes
Anneleen Foubert	Leuvan, Belgium	yes
Martine Buatier	Besançon, France	yes
Tina Treude	IFM-GEOMAR,Kiel, Germany	yes
Gretchen Früh-Green	ETH Zürich WP1 Representative	Thursday attendance

We envisioned that the contributors would be willing to participate in the initial workshop and follow-up workshops with members from the other work packages, and to

contribute to a final white paper. The white paper will be targeted towards the EC with the expectation of enhancing support for deep sea and deep sub-seafloor science.
The workshop consisted of one day of scientific presentations and discussion, followed by a half-day of further discussion and preparation of science report output.

B. List of Scientific presentations
(Thursday from 09:00 to 19:30 & one on Friday Morning) (20-30 minutes each)

Tim Ferdelman: *WP-2 Sedimentary Seafloor and sub-seafloor ecosystems: past, present & future links*
Ronny Glud : *Mineralization from coastal to hadal sediments*
Filip Meysman: *Faunal activity and organic matter processing in marine sediments: a global perspective*
Tim Ferdelman : *North Pond: A model for the biogeochemical development of an open ocean sub-seafloor sedimentary ecosystem?*
Franicsca Martinez Ruiz: *Using mineralogical and geochemical proxies for paleoceanographical reconstruction: role of bacteria in mineral precipitation in seawater*
Annaleen Foubert: *Diagenesis in cold-water coral reef ecosystems and the potential palaeo-environmental implications*
Martine Buatier: *Clay minerals: a key for deciphering fluid-sediment interatctions in deep sea sediments?*
Giovanni Aloisi: *Submarine weathering of silicates*
Daniel Conley: *Land-sea fluxes and the silica cycle*
Gian Marco Luna: *Viral activity in deep sea sediments*
Tina Treude : *The deep-seafloor and global change: understanding potential consequences of seafloor warming for deep-sea ecosystems*
Rachel James: *A talk of two halves: fate of methane released from gas hydrates with Arctic sediments; and the utility of Cr isotopes as a proxy for past changes in ocean oxygenation*
Rachel James: *Report from the INVEST Meeting (September 2009, Bremen)*

III. Workshop Output

The surface sedimentary seascape ecosystem

A. Overall messages:

After a full day of talks and both formal and informal discussion, the group quickly agreed that we are still on the verge of exploring a vast, virtually unexplored, ecosystem – essentially what we referred to as the sediment seascape ecosystem. Seascape is a key word, because the suffix *–scape* effectively transmits the idea of standing in front of a wide expanse, whose distant feartures only come into focus with detailed and proper exploration. Three main themes quickly came to the fore – these were: *diversity*, *exploration*, and *discoveries*.

1. Diversity
First, the deep-sea seascape is much more diverse and heterogeneous than previously thought, both at small and large scales. A tendency is to thing of the deep abyssal seafloor

as a monotonous expanse of slow sediment accumulation. This may be true for large regions, where single samples or cores are representative of the ocean seafloor. However, developments in seafloor imaging, geophysics and understanding of deep sub-seafloor hydrology suggest that there may be a significant interaction between seafloor roughness, sediment accumulation and sediment biogeochemistry. One important idea is that of "patchiness". Recent deep-sea studies suggest that a characteristic patch size is on the order of 1-2 cm. For instance, identifying key zones is important because a significant fraction of sedimentary total oxygen utilization (stoichimetrically linked to organic carbon mineralization) can be attributed to diagnostic hotspots.

2. Exploration
Second, the deep seafloor is mostly unexplored and highly undersampled. To a large extent, sediment biogeochemists and geologists have been literally poking about in the dark, although newer tools have started to illuminate surprising aspects of the seafloor. The enhanced ability to image and direct sampling efforts over the last decade has led to a more concerted effort to sample more difficult targets, e.g. near seamounts and outcrops, on cold-water coral-bearing ledges, near gas seeps and mud volcanos.

3. Discovery
Recent exploration has led to the third point: that there have been a series of stunning discoveries from the seafloor environments, and we are sure that there are more surprises in the store. Some examples include the recognition of the role of alternative physiologies in meiofauna, for instance, the discovery of nitrogen storage and dentrifying metabolisms in meiofauna. Such linkage between various metabolisms has implications for not only element cycling, but also for palaeo-oceanographic reconstructions, e.g. foraminifera. Paradigm changing has also been the discovery of microbial redox processes electrically linked over space by nanowires. The first indications of the importance of viruses in organic matter turnover in deep sea sediments have also just been glimpsed. Vast sedimentary regions underlying the South Pacific Gyre, the world's largest gyre system, are comprised of oxic sediments, and likely never become anoxic.

B. **Getting to know and understand our largest ecosystem:**

1. Unexplored habitats
We have mapped the general biological, geochemical and sedimentological trends at basin-scales, but the difficult-too-sample and potentially key environments have been ignored. These unexplored habitats include but are not restricted to: trenches, areas around seamounts, sediment ponds on mid-ocean ridges, sedimentary areas opening under ice in the arctic. Part of the problem has been access. For instance, hadal biogeochemistry of the deep ocean trenches is scarcely explored. Although they represent only 1% of the ocean floor, they focus sediment and corresponding rates of carbon turnover are significantly higher than on the abyssal plans. Likewise, sediment trapped in "ponds" at on the mid-ocean ridges, is influenced from both below and above (sub-seafloor crustal aquifer flow). These sediments serve as the kernal for future development of the deep-biosphere.

2. Food web operation in a food-limited world

Broad trends in faunal activity in the deep sea have been established, with faunal activity and consequent sediment mixing decreasing with increasing depth. Globally, more than 80% of deep-sea sedimentary O_2 consumption can be attributed to microbes. The population dynamics of deep-sea fauna are still poorly understood. For instance, the deep-sea may be more prone to boom-bust cycles. There is interest in how changing nutrient and oxygen concentrations over time may have effects on benthic faunal activity. Furthermore, elucidating faunal activity over geological time, e.g. the Cambrian explosion, has implications for our understanding of changing seawater chemistry.

3. Impact of virus on microbe/fauna interactions

Recent studies have highlighted the important role of viruses in surface sediment ecosystems. If the high content of extracellular DNA may be attributed to viruses in sediments was also discussed (source of P cycling?). Another important and exciting aspect was the link between viral infection and mineral formation (e.g. microbial driven calcification.).

C. The ocean floor in a rapidly changing world

1. Sediments as proxy archives for past oceans and climates

The seafloor acts as an active diagenetic filter for the deep archive of proxies used to deconvolute past ocean and climate states. This is a tremendously large and changing field (best represented by WP6), but a few issues were discussed. For instance, we still do not understand one of the most fundamental proxies – barite. The mechanism of barite precipitation in seawater is not fully understood and there may be a link to bacterial processes also in surface sediments. know the mechanism of barite ppt in seawater – link to nutrient cycling, perhaps in sediment surface. Two newer ideas were also introduced. Clays can be used as as indicators of fluid-sediment interaction and/or bacterial induced diagenesis, and Cr isotopes appear to be an excellent proxy for low oxygen environments. Also, local deep seas such as the Western Mediterranean are very sensitive to climate variability and are good testing grounds.

An important issue that arose is consideration of non-steady state or multi-stage diagenesis. Many of the environments of interest have complicated sedimentation, or fluid-flow imprints. Enhancing our ability to understand non-steady state diagenetic systems is important for interpreting geological records such as in cold-water coral mounds. “Geobiophysics” describes a new approach combining dynamic diagenesis and petrophysics.

2. Feedback between climate and the seafloor

A clear and measurable feedback with implications for surface sediments is gas hydrate and methane reserve destabilization. Deep venting on Arctic shelves has been observed. Where oxidation takes place will have an effect on ocean alkalinity, i.e. aerobic oxidation adds CO_2, whereas AOM coupled to sulfate reduction, adds DIC and increases alkalinity.

Another important issue is the role of sedimentary carbonates as a buffer against ocean acidification. Sedimentary $CaCO_3$ dissolution is key for global models addressing ocean acidification, but the effects of respiratory activity (microbial and faunal) on carbonated dissolution is very poorly parmeterized.

Changes in ocean productivity and food input (natural changes and impact of ocean fertilization)

Changes in nutrient cycling and carbon fluxes have had and will continue to impact deep-sea sediments. Perhaps, the last open ocean environment not to be impacted by dramatic changes in atmospheric nitrogen deposition is the South Pacific gyre. Understanding of the basic nutrient cycles in the water column and in surface sediments is rapidly evolving. For instance, just recently N_2 fixation in anoxic marine sediments has been observed. The extent of this process is not constrained.

4. The ocean floor as a dynamic environment for global element cycles

The role microbial and biogeochemical processes in clay and silicate diagenesis may be significant for controls of alkalinity and pH in the deep sediments and the deep ocean "twilight" zone. Alteration of clays and silicate minerals will also potentially play a role in the regulation of P in deep sea sediments. Although, Si is usually associated with clays and silicate minerals, a significant fractions of Si cycling is driven by fluxes of Si associated with land-derived biomass. Alterations in the fluxes and weathering of Si, will affect the regulation of diatom distributions in the ocean and their ultimate flux into the sediments.

D. Resources, reservoirs, economics and society

It was agreed upon that curiosity driven research on the seafloor seascape is most likely to provide the most insight, but that this exploration and discovery process has important societal and economic ramifications. Some of these were:

- Biodiversity and genetic reservoir (bioprospecting)
- Methane production and storage
- Geo-engineering
- Resource mining (e.g. manganese nodule)
- Deep sea fishery impact on the sediment ecosystems
- Geohazards (landslides)

E. Link to WP7 and WP8

1. *Technological/platform needs*
2.

Several technological requirements for sub-seafloor sampling and measurements identified.

- Coring technology (sample permeable/complicated sediments)
- In situ measurements / conditioning / recovery
- In situ sampling; "cheaper, cleverer and faster"
- Under ice sampling

Simple and flexible cabled observatories and development of long term monitoring devices (e.g. osmo pumps, eddy correlation flux measurements) are very useful and should be promoted. The importance, also, of importance of in situ work should not be underestimated, because surface deck experimentation is always problematic. Whole core techniques, e.g. NMR, CT scanning, are currently being developed and will continue to add insight.

2. Data Interpretation

We came to the conclusion that needs concerning data archiving and interpretation need to be stressed. The most useful model approaches are the representation of surface sediments in Earth System Models of Intermediate Complexity (EMICS). Furthermore, model intercomparison and standardization of modeling procedures for data interpretation need to be incorporated into upcoming programs.

3. Unlocking the drawers: data rescue and archiving

Massive amounts of high quality data exist, but are difficult to access. Although most international and national funding agencies require databank deposition, the incentives to do so are poor. It is time-consuming (i.e. expensive) and there is little to no reward for doing so (i.e., data reports are not usually citable in a citation index). Incentives for data archiving and database participation (DOI for datasets and funding) need to be provided to make this activity more efficient.