

Landing on the sea floor

Using advanced *in situ* technologies to investigate benthic carbon cycling

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SEDIMENTS CONTROL GLOBAL CLIMATE

The ocean covers 71% of the Earth's surface and plays a major role in controlling the climate on this planet. It regulates global biogeochemical cycles of elements such as carbon, which is essential for life on Earth and important for the climate system.

When dead algae and debris, produced in the lit surface layers of the ocean, sink to the sea floor, they serve as the primary food source for the microbes and animals living there. This detritus acts as the driver for a wide range of sedimentary processes including its re-mineralisation and burial.

The intense degradation and recycling of organic matter in the sediment are important for re-fertilising the ocean surface waters with nutrients and carbon dioxide and thus for maintaining primary productivity. Burial of organic matter in marine sediments, on the other hand, is Earth's main long-term sink for carbon, and thus contributes to controlling global climate. It is essential that we understand the factors and processes that control the recycling and burial of organic matter at the seafloor.

BENTHIC BUGS

Sediment bacteria catalyse the mineralisation of organic matter to carbon dioxide and nutrients through several metabolic pathways. Aerobic bacteria are the most effective mineralisers followed by organisms living deeper down in the sediment that utilise suboxic- and anoxic respiration pathways.

Although it is well known that bacteria account for most of the organic matter mineralisation in sediments, several studies show that burrowing macrofauna also play a role in benthic mineralisation processes and oxygen dynamics. Macrofauna significantly enhances rates of organic matter mineralisation by mixing down fresh organic matter from the sediment surface and constantly reworking the sediment (= bioturbation), and by pumping oxygenated water through their burrows (= bioirrigation) to sustain their metabolic needs.

QUANTITY AND QUALITY OF ORGANIC DEBRIS

The quantity and quality of incoming biogenic debris have a profound effect on the recycling and burial rates of organic matter in the sediment. Fresh algae are more rapidly degraded than more refractory organic matter of terrestrial origin, while larger quantities of organic matter input can sustain greater activity and biomass of benthic organisms. If, however, rates of organic matter deposition become extremely high, as for example in upwelling areas, massive bacterial activity can lower oxygen concentrations in bottom waters to such an extent that most macrofauna can no longer survive in these areas.

THE ROLE OF BENTHIC LANDERS

Rates of benthic organic matter recycling and burial are more reliably measured *in situ* than from cores in the laboratory, especially in deep waters. Sediments brought up to the surface from great depths are typically subject to rapid changes in temperature and



> SAMS benthic chamber and profiling landers in the Arabian Sea

pressure that affect the microbial and faunal activity in the sediment. Measurements conducted from *in situ* benthic landers can avoid such artefacts. These deep-sea robots are used to conduct a variety of measurements and experiments on the sea floor and to bring samples and collected data back to the surface.

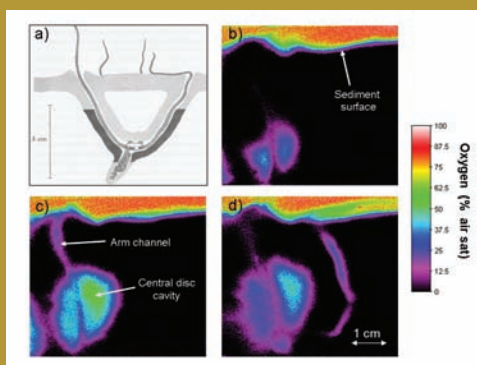
Typically, a benthic lander is deployed from a ship and sinks by its own gravity through the water column. Once it has landed smoothly on the sea floor it starts measuring the predetermined parameters. At the end of the deployment an acoustic signal tells the lander to release its ballast and return to the surface using positive buoyancy.

Different landers have different functions: Chamber landers measure fluxes of oxygen and carbon dioxide across the sediment-water interface in sediment enclosures, whereas profiling landers use fine tipped microelectrodes to measure detailed (>100 µm resolution) profiles of oxygen, pH and hydrogen sulphide in the sediment.

We also deploy planar optodes from landers. These are instruments that allow us to visualise and quantify changes in oxygen concentrations within the sediment that may for example be caused by burrowing animals (see figure).

CHALLENGES AHEAD

Since lander deployments only provide a snapshot of current conditions, a major challenge for the future is to better understand the causes of short and long term variability in the factors that control benthic carbon cycling, and to relate these to changes in global climate. By establishing networks of permanently deployed benthic observatories that integrate multiple technologies and are capable of intelligent sampling (e.g. are responsive to external physical or chemical stimuli) we could significantly enhance our understanding of the benthic carbon cycle and its importance for global climate. ●



< a) The burrowing brittlestar *Amphiuira filiformis* (after Ockelman & Muus, 1978)

b) to d) Time series of planar optode images showing the oxygen distribution around an *A. filiformis* that is injecting oxygenated bottom water into its burrow cavity.