

## Sulphate reduction in surface sediments of the South-East Atlantic continental margin (Benguela upwelling)

T. G. Ferdelman

Max-Planck-Institute for Marine Microbiology, Celsiusstr. 1,  
D-28359 Bremen, Germany

H. Fossing

National Environmental Research Institute, Dept. of Lake and  
Estuarine Ecology, Vejsovej 25, P.O. Box 314, DK-8600,  
Denmark

K. Neumann

Max-Planck-Institute for Marine Microbiology, Celsiusstr. 1,  
D-28359 Bremen, Germany

H. D. Schulz

Fachbereich (5) Geowissenschaften, University of Bremen,  
Klagenfurterstrasse, D-28334 Bremen, Germany

The benthic remineralization of organic carbon exerts an important influence on the flux and distribution of carbon and nutrients throughout the ocean – especially along continental margins. The distribution of oxygen, the fluxes of dissolved inorganic carbon, dissolved organic carbon, and nutrients as well as the balance between water column particulate organic carbon flux and the burial of organic carbon in the sediments is determined by the rate and pathway of organic carbon remineralization. In the deep ocean beyond the continental margins,  $O_2$  fluxes account for the sum total of benthic remineralization (Jahnke, 1996; Cai and Reimers, 1995). However, anaerobic processes begin to play a quantitatively important role in organic carbon remineralization in continental margin sediments, where organic matter is buried or becomes mixed beyond the zone where dissolved oxygen is present through diffusion or bio-irrigation. Jahnke (1996) has suggested that continental margin sediments within the deep ocean (sediments > 1000 m water depth) remineralize approximately 40% of the particulate organic carbon flux to the deep ocean; anaerobic remineralization of organic carbon in these continental margin sediments may, thus, have a significant impact on the fluxes of carbon and associated nutrient elements on the deep ocean.

The oxidation of organic carbon by dissimilatory sulphate reducing bacteria is thought to be the principal terminal process of anaerobic respiration in continental margin sediments (Jørgensen, 1982; Canfield *et al.*, 1993; Thamdrup and Canfield, 1996). Fortunately, and in contrast to the measurement of most other respiratory processes in marine sediments, a robust and relatively simple method for the determination of dissimilatory sulphate reduction

exists with the application of the  $^{35}SO_4^{2-}$  tracer method to undisturbed whole-cores of sediment (Jørgensen, 1978; Fossing and Jørgensen, 1989). Yet, in spite of its relative ease of measurement and its importance to anaerobic carbon degradation, the number of continental slope and rise sites below 500 m water depth where sulphate reduction rates have been directly measured by the  $^{35}S$  tracer method are few. Here, we report on sulphate reduction rates from the continental margin of south-west Africa that form part of the Benguela upwelling system. These data comprise, to our knowledge, the most extensive data set of sulphate reduction rates yet determined for any continental slope.

Sulphate reduction rates in the surface sediments from 17 stations from an along-slope transect (*c.* 1300 m) and from a cross-slope transect (855 to 4766 m) were determined in the continental margin sediments of the Benguela Upwelling system. Profiles at all sites in the upwelling area showed increasing sulphate reduction rates from near zero at the surface to a peak near 2 to 5 cm (up to  $28.9 \pm 2 \text{ nmole cm}^{-3} \text{ d}^{-1}$ ) and then decreasing exponentially with depth to near background rates at 10 to 20 cm depth ( $< 2 \text{ nmole cm}^{-3} \text{ d}^{-1}$ ). Depth-integrated sulphate reduction rates were greatest at 1300 m and decreased exponentially with water depth. Along the transect following the 1300 m isobath, depth-integrated sulphate reduction rates were highest in the north Cape basin ( $1.16 \pm 0.23 \text{ mmol m}^{-2} \text{ d}^{-1}$ ), decreased over the Walvis Ridge ( $0.67 \pm 0.02 \text{ mmol m}^{-2} \text{ d}^{-1}$ ), and were lowest in the south Angola Basin ( $0.31 \pm 0.23 \text{ mmol m}^{-2} \text{ d}^{-1}$ ). This pattern was consistent with the strength of coastal upwelling intensity. Depth-integrated sulphate reduction rates were also strongly correlated with surface organic

carbon concentrations. Sulphate reduction was estimated to account for between 26 and 78% of the published rates of total oxygen consumption for these sediments; therefore, a significant fraction of organic matter degradation was remineralized anaerobically through sulphate reduction.

Although aerobic and anaerobic respiration rates were estimated to be roughly equivalent for the upwelling impacted sediments, modelling of the sulphate reduction rate profiles suggested that the inherent kinetics of aerobic respiration were much faster than those for anaerobic respiration. The differences in the predicted rates of anaerobic respiration based on sulphate reduction rate profiles versus anaerobic respiration from published DOU measurements suggests that there are two classes of  $C_{org}$  being decomposed in these sediments. The first is a rapidly decomposing material at the sediment-water interface that is principally consumed by aerobic respiration. The second is more refractory

material that is mixed down from the surface sediment and also includes a large fraction of organic material laterally transported downslope or from the shelf. An alternative hypothesis is that the kinetics of aerobic degradation are inherently faster than those of anaerobic degradation.

## References

- Cai, W.-J. and Reimer, C.E. (1995) *Deep-Sea Res.*, **42**, 1681–99.
- Canfield, D.E., Thamdrup, B., and Hansen, J.W. (1993) *Geochim. Cosmochim. Acta*, **57**, 3867–83.
- Fossing, H. and Jørgensen, B.B. (1989) *Biogeochem.*, **8**, 205–22.
- Jahnke, R.A. (1996) *Glob. Biogeochem. Cyc.*, **10**, 71–88.
- Jørgensen, B.B. (1978) *Geomicrobiol. J.* **1**, 29–47.
- Thamdrup, B. and Canfield, D.E. (1996) *Limnol. Oceanogr.*, **41**, 1629–50.