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North Pond: A model for the biogeochemical development of an open ocean sub-seafloor sedimentary ecosystem?

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The flanks of the Mid-Atlantic Ridge are characterized by sediment-filled depressions, surrounded by high relief topography. The largest depressions are 5 km to 20 km wide and sediment thickness varies but can reach 400 m. North Pond is one such isolated sediment package along the Mid-Atlantic Ridge (22° 46' N and 46° 06' W). This sediment pond lies below the oligotrophic central North Atlantic and contains sediments that are typically less than 0.3% organic carbon. Linear sedimentation rates are approximately 0.03 m/ka. North Pond lies on 7 Ma old basement and appears to maintain active fluid circulation below the sediment package through the underlying permeable rock (Langseth et al., 1992). North Pond was revisited in Spring 2009 with the German research vessel M.S. Merian (MSM 11/1) as part of an IODP site evaluation. In addition to heat-flow, single-channel seismic and bathymetry surveys, , oxygen measurements and extensive pore water sampling (25 cm depth intervals) were performed directly on intact gravity cores. The entire sediment column down to > 8 m sediment depth contained oxygen, the deepest penetration of oxygen that has been measured in the seafloor of the Atlantic. In the central part of the sediment pond oxygen decreased continuously with depth, indicating an active aerobic microbial community while nitrate concentrations increased. In contrast, along the northern and western rims of North Pond, oxygen concentrations remained surprisingly constant with depth at values around 170 μM. These oxygen profiles, beneath the surface layer, can be explained by a balance between upward diffusion and consumption of oxygen within the sediment column. At 3 locations along the north shore, oxygen increased towards the bottom of the cores, indicating an upward supply of oxygen from the underlying basaltic basement. Nutrient profiles confirmed that, in contrast to the central part of the pond where concentration profiles (nitrate, silica) reflected diagenetic processes, the sediment cover at the edges seemed to be influenced by transport processes. Our dissolved oxygen and nutrient data measured down-core on multiple deep cores depicts an oxidant supply from the underlying, permeable ocean basin crust into the deep sedimentary biosphere. This upward diffusion of oxygen supplied from the basaltic aquifers supports abundant and active microbial communities at greater depths and provides a mechanism by which extensive biomass can be maintained in open ocean basin sediments.

Ponded sediment ecosystems overlying oceanic crust, such as North Pond, provide natural laboratories and testable model systems for the link between the deep subsurface biosphere and global biogeochemical cycles. The sediment column in the center of the pond represents the sum total of 7 to 8 Ma of sedimentation, diagenesis, and influence from sub-sediment water flow. Cores taken near the edge of North Pond are closer to the basalt aquifer and thus to the reservoir of dissolved oxygen. Over short distances diffusion is more effective and oxygen fluxes can counter balance reaction processes in the sediment cover, maintaining an oxic environment. However, at some critical sediment thickness, diffusion of of oxygen can no longer keep up with microbial mediated consumption and the centermost sediments become micro-aerophilic to anoxic, allowing for the development of a micro-aerophilic or anaerobic microbial community. Whether this model is appropriate for the development of pelagic, deep sub-seafloor habitats will be tested on an upcoming IODP drilling (http://iodp.tamu.edu/scienceops/expeditions/midatlantic_ridge_microbio.html).

References

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