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Advective flow as an early diagenetic agent in coastal marine sediments

Thomas Riedel, Karsten Lettmann, Melanie Beck, Bernhard Schnetger, and Hans-Jürgen Brumsack
(riedel@icbm.de) Mirocbiogeochemistry, ICBM, Oldenburg, Germany

Offshore intertidal sand and mud flats are subject to tidally forced ground water flow leading to circulation and subsequent discharge of ground waters to the coastal ocean. These waters have passed organic-rich, relatively young sediments that harbor active microbial communities. A number of biogeochemical processes alter the chemical composition of the circulating sea water of which the most prominent one is microbial sulphate reduction. As a result of these processes discharging ground waters are strongly enriched in certain trace metals (Mn, Ba, V), nutrients (Ammonia, Dissolved inorganic carbon (DIC), Phosphate, Silicate) and depleted in others (such as Mo, U). Advective flow therefore drives a biogeochemical alteration of sea water. So far, pore water chemistry indicates that tidal creek margins, where advective flow is most significant, show stronger chemical gradients compared to sites from the central tidal flat, where diffusion appears to dominate.

To investigate the role of advection we mapped the geochemistry down to 2.5 meters sediment depth along a transect from the creek to the central tidal flat using push-point samplers that allow almost artifact-free in-situ sampling of pore waters. Additionally a recently developed hydrogeological simulation of the creek margin was applied to calculate ages of the sampled pore waters. The simulation was calibrated by comparison of measured in-situ pressure heads with simulated ones. Sample ages obtained were used to quantify averaged production or depletion rates for trace metals, nutrients and sulphate.

Our results demonstrate that sites dominated by advection generally show higher rates of turnover for almost all species investigated. Averaged production rates for Ba, Mn, ammonia or DIC appear to be 10 to more than 30 times higher when advection dominated the subsurface flow regime.

Based on these findings we speculate whether advective ground water flow in marine sediments may be regarded as a geological agent, a view traditionally held for terrestrial aquifers. Reasons may be that (1) the distribution of reagents such as hydrogen sulfide produced from microbial reduction of sulphate in the sediments is enhanced by flow and dispersion; (2) microbial activity may be stimulated because flow maintains a steady resupply of electron donors and acceptors in the subsurface.