Chronic downward flow of seawater in bacterial mats – mechanisms and biogeochemical significance

EVAN A. SOLOMON[1], LAUREN KOWALSKI[1], THERESA L. WHORLEY[1]

[1]University of Washington, Seattle, WA, esolomn@uw.edu

Fluid flow at seeps drives the interaction among anaerobic oxidation of methane (AOM), communities of micro- and macrobiota, and the precipitation of authigenic carbonates and sulfides. Hydrogen sulfide is produced through AOM and rises to the seafloor where it is a substrate for sulfide-oxidizing microbial mats. Downward fluid flow has been observed in clam fields at seep sites, however previous coring and short-term (~30 days) fluid flow meter studies have indicated that bacterial mats are exclusively associated with strong upward advection of pore water. Here we report long-term (2 years) net downward transport of seawater at multiple locations within bacterial mats at southern Hydrate Ridge, offshore Oregon.

Continuous measurements of fluid flow rates and time-series depth profiles of fluid composition were made by three Mosquito fluid flow meters deployed across a bacterial mat site from July 2013 to July 2015 as part of the Ocean Observatories Initiative Cabled Array. All three Mosquitos (hereafter M1, M2, and M3) recorded highly variable vertical flow rates with flow polarity reversals occurring over periods of days to weeks. M1, M2, and M3 measured a net downward flow of 25±1, 68±4, and 57±3 cm/yr, respectively. Despite the continuous supply of SO_4 through downward flow, SO_4 concentrations were <5 mM between ~12-50 cmbsf.

We contend the fluid flow records are a surface manifestation of subsurface gas dynamics. We propose that water is driven out of the sediments by rising gas bubbles and is replaced by the drawdown of overlying bottom water rich in electron acceptors. Surface pore waters are undersaturated with respect to methane and ascending methane bubbles shrink upon crossing the sulfate-methane transition, further enhancing the downward flow of seawater. In this conceptual model, it is not advection of CH_4-rich pore water sustaining the mat community, but rather the dissolution of gas bubbles providing dissolved methane close to the seafloor. This is coupled to the strong downward flux of SO_4-rich seawater, which greatly enhances HS^- production through AOM and diffusive HS^- fluxes to the benthic communities. This coupled gas transport-partial gas dissolution-seawater circulation process significantly increases solute transport leading to enhanced biogeochemical turnovers and sustaining microbial mat communities in a downward aqueous flow regime.