

## Two opposing effects of sulfate reduction on carbonate precipitation in normal marine, hypersaline, and alkaline environments

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In their Comment, Gallagher et al. (2013) challenge the interpretation of my recent modeling study (Meister, 2013) that sulfate reduction is not the process that induces carbonate precipitation in microbial mats. They argue that using  $\text{CH}_2\text{O}$  as organic carbon substrate does not adequately describe the composition of electron donors used for sulfate reduction. They base their criticism on calculations of carbonate saturation indices (SI), using a similar model to that used by Meister (2013), during sulfate reduction with a variety of intermediate compounds as electron donors, including glycolate, ethanol, formate, and hydrogen (Gallagher et al., 2012). Use of these electron donors rather than  $\text{CH}_2\text{O}$  results in much higher SI.

While the plots shown by Gallagher et al. (2013) are consistent with previous studies (e.g., Soetaert et al., 2007; Meister, 2013), I argue that consideration of individual substrates for sulfate reduction is a too simplistic way to explain the SI evolution within a microbial mat. Activity in a microbial mat is a joint venture (van Gernerden, 1993) as also noted by Gallagher et al. (2013). Dissolved organic compounds are intermediates in a complex network of fermentative and terminal electron accepting reactions, whereby fermentation also produces  $\text{CO}_2$ . Culture experiments, in which these intermediates are artificially added, therefore do not reproduce the pH and SI in microbial mats. These compounds may be produced and consumed at high rates in microbial mats, but if we assume that no intermediates are added from or lost to the outside of the mat, then the pH evolution is constrained by the overall reaction stoichiometry for sulfate reduction.

The problem ultimately boils down to what bulk organic substrate is available to drive sulfate reduction. Assuming an organic matter composition with a stoichiometry close to modern Redfield ratios [ $\text{CH}_2\text{O}(\text{NH}_3)_{0.125}$ ]

results in an initial lowering and slow recovery of carbonate saturation, which according to the model would not induce carbonate precipitation as a result of sulfate reduction in a microbial mat. If sulfate reduction is coupled to the degradation of extracellular polymeric substances (EPS) (Visscher et al., 1998, 2000) consisting largely of carbohydrates with a bulk composition similar to  $\text{CH}_2\text{O}$ , the resulting pH and SI would be even lower. To assess the effects on the SI and pH of organic matter degradation with sulfate as a terminal electron acceptor, we have to consider the overall process stoichiometry. I thank Gallagher et al. (2013) for providing the opportunity to debate this issue more directly.

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