

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

Kimberley L. Gallagher^{1,2}, Christophe Dupraz^{1,2} and Pieter T. Visscher^{1,2}

¹Department of Marine Sciences, 1080 Shennecossett Road, University of Connecticut, Groton, Connecticut 06340, USA

²Center for Integrative Geosciences, 345 Mansfield Road U-2045, University of Connecticut, Storrs, Connecticut 06269-2045, USA

Sulfate reduction (SR) has been linked to carbonate mineral precipitation and has been invoked as a possible mechanism for microbialite formation (Lyons et al., 1984; Kempe, 1990). Although there is evidence to support the contribution of SR in carbonate mineral precipitation from both field (Visscher et al., 2000; Dupraz and Visscher, 2005; Vasconcelos et al., 2006) and laboratory studies (Warthmann et al., 2000; van Lith et al., 2002; Wright and Wacey, 2005), the subject remains controversial (Castanier et al., 1999; Arp et al., 2001; Bosak and Newman, 2003; Aloisi, 2008).

Meister (2013) compared modeled results of the effects of SR under conditions of normal seawater, hypersaline lagoon, and Precambrian seawater conditions. He concluded that SR “was entirely ineffective” (Meister, 2013, p. 499) in promoting carbonate precipitation. This was based primarily on a modeled pH decrease for the SR of general organic matter (CH₂O). Although many modeling papers use this formula, we argue that this is an overly simplified view of organic matter utilization by sulfate-reducing bacteria (SRB), and disagree with his conclusion. Our specific points are:

(1) A general formula for organic matter does not appropriately reflect the variety of electron donors that can be utilized by SRB.

(2) Different electron donors for SR have different effects on pH and mineral precipitation.

SRB utilize a variety of electron donors, including hydrogen, formate, acetate, propionate, butyrate, ethanol, methanol, and lactate (e.g., Rabus et al., 2006). We used both culturing and modeling to show that the nature of the specific electron donor for sulfate reduction affects pH and saturation index (SI) (Gallagher et al., 2012). Our results for lactate (C₃H₅O₃) utilization by SRB agreed very closely with both Meister’s results (Fig. 1) and with pH modeling work by Soetaert et al. (2007). Thus, Meister’s conclusions appear consistent with ours and with these previous results. However, we also showed that utilization of other electron donors

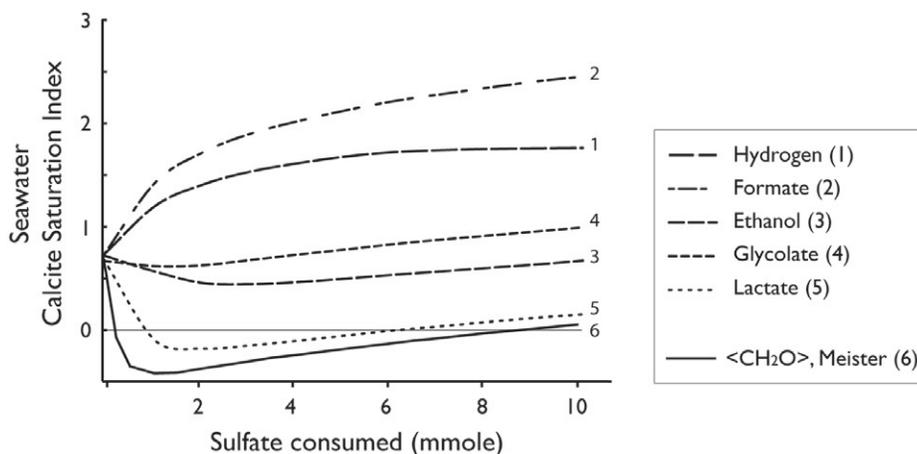


Figure 1. Comparison of the modeled effect of seawater sulfate reduction (SR) (expressed as mmole sulfate consumed) on calcite saturation index (SI) for different electron donors (Gallagher et al., 2012) and general organic matter, CH₂O (Meister, 2013). Although lactate shows an effect very similar to general organic matter, other electron donors, especially hydrogen and formate, produce dramatically different results, increasing calcite SI as a result of SR. The general organic matter curve (6) is adapted from Meister (2013, his figure 1A, p. 500). Modified from Gallagher et al. (2012) with additional curve from Meister (2013).

by SRB, specifically, hydrogen and formate, caused dramatic pH and SI increases. Our results from other electron donors (ethanol and glycolate) also differed from lactate results and from Meister’s results, though not to the extent of hydrogen and formate (Fig. 1).

We have always stated that it is net community metabolism that creates conditions favorable to mineral precipitation (or dissolution) (Visscher et al., 1998; Dupraz and Visscher, 2005), not a single microbial process. SRB are an important component of mineral precipitation because SR causes an increase in alkalinity relative to aerobic respiration (Visscher and Stolz, 2005). This effect may be further enhanced if the supply of electron donors to SRB includes, e.g., large quantities of hydrogen or formate (Gallagher et al., 2012) which also increase pH. A simple model using a generalized formula for electron donors can miss this potentially important relationship between electron donors and mineral precipitation, thereby underestimating the true role SRB play in calcium carbonate precipitation.

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