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Controls on iron and sulfate reduction in Arctic fjord sediments

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Iron and sulfate reduction are quantitatively the most important pathways for anaerobic oxidation of organic matter in marine sediments. Whether iron or sulfate is used as the predominant terminal oxidant for anaerobic organic matter mineralization affects not only the geochemistry of the sediment but also the release of metals and nutrients from the sediment. In general, the terminal electron-accepting processes change with depth in the sediment, following the order of decreasing free energy of reaction. Yet, a substantial spatial overlap between iron and sulfate reduction is frequently found. Thus, it appears that the competition between iron- and sulfate-reducing microorganisms is affected by aditional factors. Most prominently, the crystallinity of the iron, that influences both the kinetics and the thermodynamics of iron reduction.

The fjords along the west coast of Svalbard provide an ideal natural laboratory to study the competition between iron- and sulfate-reducers because the glaciers discharge large amounts of iron oxides. Thus, the surface sediment of the inner parts of the fjords can be dominated by iron reduction due to the favorable energetic yeild of this process, while sulfate reduction prevails in the outer parts of the fjords further away from the iron source. We determined pore water and solid phase geochemistry, as well as the rates of organic carbon mineralization by iron and sulfate reduction in fjord sediments with differing loads of iron(III) and organic carbon. Furthermore, we performed amendment experiments in bag incubations to determine whether iron- and sulfate-reducers in the contrasting fjord sediments are limited by the availability of organic carbon or of iron(III). The results showed that carbon mineralization in apparantly well oxidized sediments with high concentrations of hematite was still partially driven by sulfate reduction. The ongoing sulfate reduction did, however, not lead to accumulation of sulfides. Addition of a small amount of poorly crystaline ferrihydrite shifted the pathway of mineralization from sulfate reduction entirely to iron reduction. Thus, the predominance of iron reduction was dependent on the reactivity of the iron oxides.