Enzymatic Activity Determines the Stoichiometric Consistency of C/N in Anaerobic Sediments

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The ratio of organic carbon to total nitrogen is frequently reported in studies of ancient organic-rich sediments where it is used to infer paleoproductivity, redox conditions, macronutrient availability, and organic matter sources. Commonly, the ratio of organic C to organic N and the absolute abundance of inorganic N are highly consistent within sample suites from specific locations, independent of time and total organic matter content. The sedimentary biogeochemical process that underlies this relationship has not been mechanistically detailed. We propose a mechanism based upon the observed ecological stoichiometry of modern anaerobic sediments to account for the pattern of C/N in Late Devonian shales. Bacterial heterotrophy in organic-rich anaerobic sediments is frequently limited by the availability of labile carbon. In response, bacterial heterotrophs invest scarce C and N to produce alkaline phosphatases in order to alleviate C limitation by hydrolysis of organophosphates. This suggests that sediment organic C/N may represent a threshold beyond which the investment of intracellular C and N in the production of alkaline phosphatase no longer results in a stoichiometrically favorable return on the investment. The observation that organic C/N varies across sites in inverse proportion to median total phosphorus abundance is consistent with the fact that alkaline phosphatase expression is inversely proportional to porewater phosphate concentration. As a result, sediment organic C/N is consistent at a given basinal site because the flux of bio-available P (a product of terrestrial weathering) at that site is relatively consistent over long time spans.