# N cycling in deeply oxygenated sediments: Rates, sensitivities, and lacustrine-marine connections

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Sediments are major contributors to the global cycling of N, particularly through the denitrification reaction that removes the biologically reactive nitrate to $N_2$. Deeply oxygenated environments, such as in the deep ocean, differ from coastal sediments in that they are sources rather than sinks of nitrate to the water column. We characterized the N fluxes and transformation rates in the sediments of Lake Superior, the largest freshwater lake by area, where oxygen penetration exceeds several centimeters. The N cycle there suggests interactions with the cycles of other elements that have been underexplored in freshwater, such as nitrate-dependent oxidation of ferrous iron. The results on rates, which reveal remarkable similarity between the freshwater and marine nitrogen cycling, indicate that phenomenological relationships established for the rates of denitrification in coastal regions (e.g., with sediment oxygen uptake) cannot be extended to the open ocean. The depth of oxygen penetration appears to be a useful predictor. Similarly to the global ocean, large lakes exhibit strong offshore-nearshore gradients in denitrification: high-sedimentation areas nearshore contribute disproportionately strongly to the reactive N removal. The rates of sediment denitrification are sensitive to factors such as sedimentation rate and fluxes of organic carbon. Thus, changes in the trophic status of large lakes, e.g. in response to regulating P inputs from their watersheds, may markedly shift their nitrogen budgets and affect the exports of N into the coastal ocean.