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Quantifying the groundwater source of iron to redox-stratified lakes in Minnesota, U.S.A.

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Lakes with limited surface water inputs formed in glacial outwash are a common feature on the landscape in Minnesota, U.S.A. Groundwater inputs have long been assumed to be important to these “seepage”-type lakes. However, sediments deposited in ice marginal settings often exhibit complex architecture resulting in heterogeneity at a variety of scales creating the potential for complex groundwater flow patterns interacting with these lakes. The bulk chemistry and mineralogy of glacial sediments can greatly influence groundwater chemistry, with redox-sensitive elements such as iron mobilized under reducing conditions. Small but relatively deep kettle lakes are also conducive to permanent stratification (meromixis), allowing dissolved solutes including iron to build up in anoxic hypolimnetic waters. We hypothesize that if deeper, longer groundwater flow paths transporting older (vs. recent recharge), reducing groundwater intersect seepage lakes in relatively permeable glacial material, there will be a net transfer of reduced species into the lake. In such a situation, iron may behave semi-conservatively, sustaining relatively high concentrations in hypolimnetic waters.

We are investigating groundwater sources of iron into two seepage lakes in Minnesota with anoxic hypolimnia. Brownie Lake in Minneapolis and Deming Lake in Itasca State Park are meromictic and ferruginous lakes. At Brownie Lake, seepage meters and Darcy calculations informed by hydraulic conductivities measured at several scales and hydraulic gradients quantified using multilevel systems (MLS) and mini-piezometers will constrain the seepage flux. Three-dimensional variability in groundwater chemistry will be assessed with Waterloo profiling, the MLS, and mini piezometers. These results will be combined with quantification of the sedimentation flux using sediment traps and calculated burial fluxes determined on dated sediment cores to construct an iron budget for Brownie Lake. At Deming, LiDAR data will be used to estimate flow paths, and qualitative indicators of seepage (such as vegetation changes, and water column temperature anomalies) will be assessed. Mass balance of conservative ions in the lake vs. local groundwater will also inform the relative contributions of precipitation and overland flow vs. seepage.