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Carbon Budget of a Ferruginous Meromictic Lake with Ebullitive Methane Fluxes

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Meromictic ferruginous (Fe-rich, anoxic, and permanently stratified) lakes offer a unique analog to evaluate the biogeochemical dynamics during the Earth's past when oceans were characterized by similar redox conditions. This study investigated carbon cycling within ferruginous and meromictic Brownie Lake in Minneapolis, MN. Previous works have reported an active methane cycling in this system with ebullitive losses of methane. Water column concentrations and stable carbon isotopes of methane ($\delta^{13}C_{CH4}$), dissolved and particulate organic carbon ($\delta^{13}C_{DOC}$, $\delta^{13}C_{POC}$), and dissolved inorganic carbon ($\delta^{13}C_{DIC}$), along with concertation profiles of major nutrients, anions, and cations were collected over several years.

The increasing ammonium and DIC concentrations with depth below the chemocline (~4 m below the surface) indicate organic matter remineralization by microbial heterotrophy. However, the increasing $\delta^{13}C_{DIC}$ values and methane concentrations with depth suggest active methanogenesis below the chemocline. The DOC concentration profile below the chemocline did not show comparable variation with DIC and CH_4 concentrations, suggestive that only a portion of the organic carbon pool is available for methanogenesis and the existence of a sizeable recalcitrant DOC pool. A noticeable depletion of $\delta^{13}C_{DIC}$, $\delta^{13}C_{DOC}$, and $\delta^{13}C_{POC}$ along with enrichment in $\delta^{13}C_{CH4}$ at 3m depth suggests strong aerobic methane oxidation above the chemocline impacting the organic and inorganic carbon pools. Estimated CH_4 storage yielded 33.46 g C m^{-2}, a very high amount when compared to other lakes with similar surface area (5 ha). Further, the correlation between dissolved Fe concentrations with concentrations of DOC, DIC, CH_4, NH_4, P, and $\delta^{13}C_{DIC}$, and $\delta^{13}C_{POC}$ suggests an active role of iron in carbon cycling. Ongoing works aim to quantify the carbon sources and sinks in the system, and evaluate the proportion of exported POC mineralized by heterotrophy, converted to methane, or buried in sediments. These results will contribute to our evolving understanding of the role of methane biogeochemistry in the Precambrian ferruginous oceans.