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Using stable isotopes of water to re-evaluate the recharge/discharge functions of North American bogs and fens

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In North American mires hydrologists commonly find raised bog crests and low-lying fen water tracks to be focal points for groundwater recharge and discharge, respectively. To further test these observations we synoptically surveyed vertical profiles of peat pore water δ^{18}O/δ^{2}H and major mineral solutes from a range of bog and fen landforms across the Glacial Lake Agassiz Peatlands (GLAP) of northern Minnesota. We also sampled a detailed transect through a 150 km^2 bog-fen complex in the Red Lake II peatland watershed of the GLAP. The molar ratios of Ca/Mg in the pore water beneath the Red Lake II bog crest are depleted in Mg with respect to the atmospheric average of 3.6, indicative of preferential flushing of Mg from the peat by meteoric recharge. Higher solute concentrations in the middle of the peat profile at an adjacent fen show focused groundwater discharge with Ca/Mg ratios of $\sim$1.4, similar to that of water from local wells tapping underlying glacial till. However, contrary to expectations, we find evidence that modern recharge has penetrated throughout the peat column beneath both bog and fen landforms throughout the GLAP. Landform surface features control the isotopic recharge value. These landform-specific isotope signatures propagate through vertical pore water profiles. Pore waters deeper than 0.5 m partition into discrete ranges of δ^{18}O according to three $a\ priori$ landform classifications: 1) -11.9 $\pm$ 0.4 ‰ for bog crests, 2) -10.6 $\pm$ 0.1 ‰ for $Sphagnum$ lawns, and 3) -8.8 $\pm$ 1.0 ‰ for fen water tracks. The fen water tracks have standing water at their surface that is seasonally enriched by isotope fractionating evaporation and therefore fingerprints recharge to depths $\geq$3 m. Incongruities between isotope and solute mixing trends may be related to the dual porosity nature of peat and matrix diffusion, which could supply solutes to active pore spaces following flushing by meteoric recharge. This buffering of base solutes in the deep peat may influence methanogenic bacteria that are sensitive to pH. Our results support the hypothesis that the downward transport of labile carbon substrates from the surface of northern peat basins fuels methane production in deeper peat strata.