

Iron accumulation promotes phosphate retention at redox interfaces in arctic and boreal soils

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Arctic and boreal ecosystems are experiencing pronounced warming that is accelerating decomposition of soil organic matter and releasing greenhouse gases. Future carbon storage in these ecosystems depends on the balance between microbial decomposition and net primary productivity, both of which can be limited by nutrients such as phosphorus. Phosphorus cycling in tundra and boreal ecosystems is often assumed to occur through biological pathways; however, redox-sensitive abiotic processes, e.g., phosphate adsorption to Fe oxides and organic-bound Fe(III), may exert poorly recognized control over P in these systems.

To evaluate this potential mechanism, we examined iron and phosphorus geochemistry in surface organic soils collected from areas with contrasting soil saturation and pH within four arctic and boreal ecosystems. We coupled sequential chemical extractions with synchrotron-source X-ray absorption and Mössbauer spectroscopies to investigate Fe speciation and Fe-P interactions. Iron oxides and organic-bound Fe(III) accumulated in circumneutral topographic lows where the water table was near the land surface. These low-lying soils had a high capacity to bind phosphate and low concentrations of water-soluble P. In comparison, acidic soils located primarily in topographic high positions were relatively Fe-poor with low phosphate sorption capacity and correspondingly elevated water-soluble P. On average across all sites, approximately one-third of soil P was bound to Fe-oxides as phosphate, although the stability and bioaccessibility of this P reservoir remain unknown. We contend that biological and geochemical controls over P dynamics may vary as a function of pH and redox regime, which often vary with topographic position, across rapidly changing northern landscapes.