Iron oxides as carbon and nutrient traps in soils

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Redox gradients influence biogeochemical processes that control carbon storage (decomposition, plant growth)

Polygonal ground on the North Slope of Alaska
ngee-arctic.ornl.gov; Photo credit Chonggang Xu

Arctic tundra near Utqiagvik, Alaska


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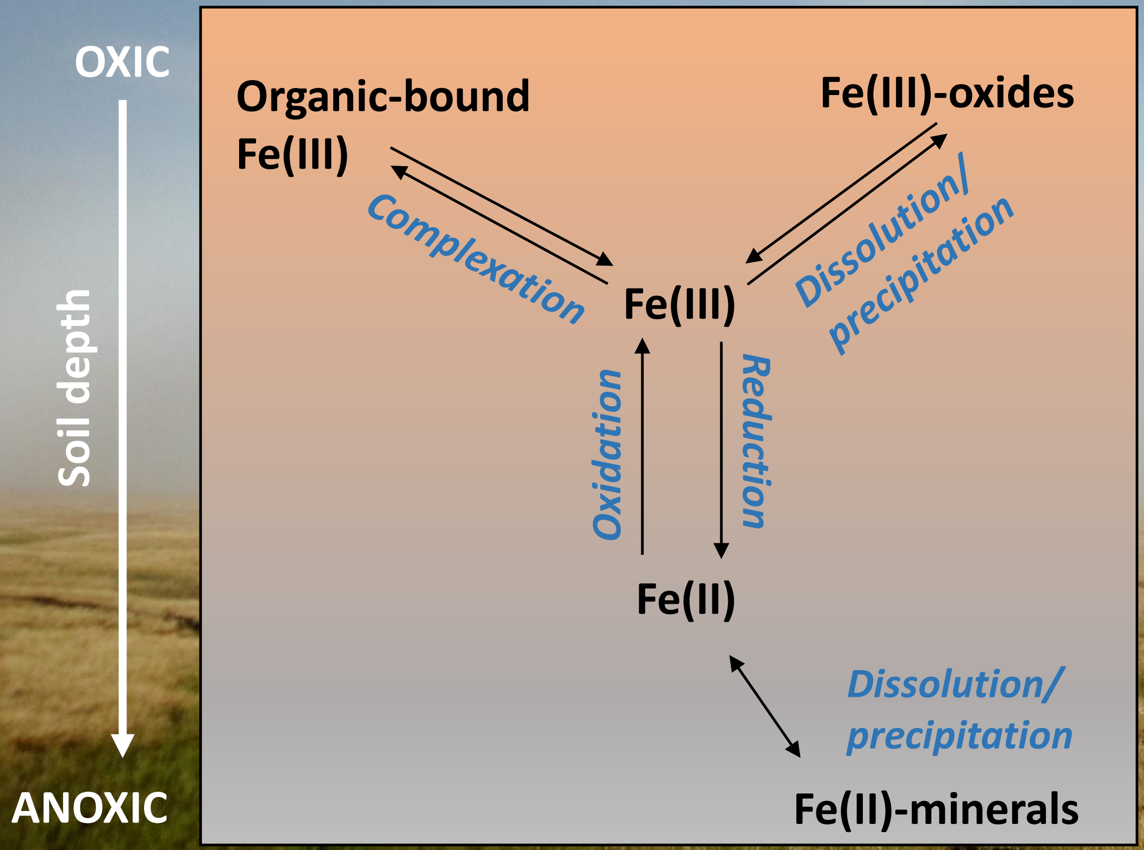
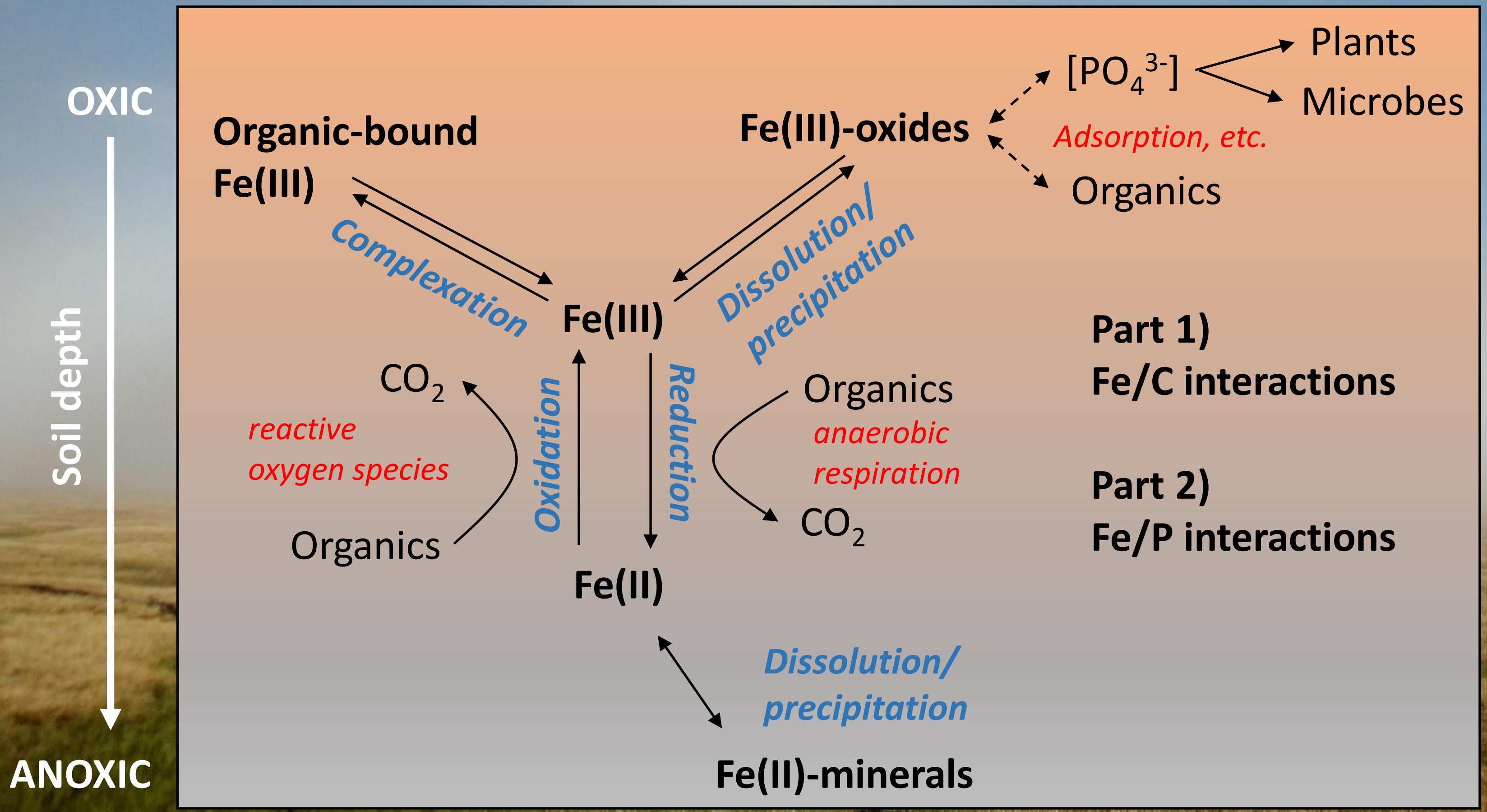
Fe redox cycling in the arctic tundra



Objective: explore how Fe cycling influences C & nutrient cycling

Fe redox cycling may help degrade organic molecules, while Fe oxides serve as potential traps for labile C and phosphate

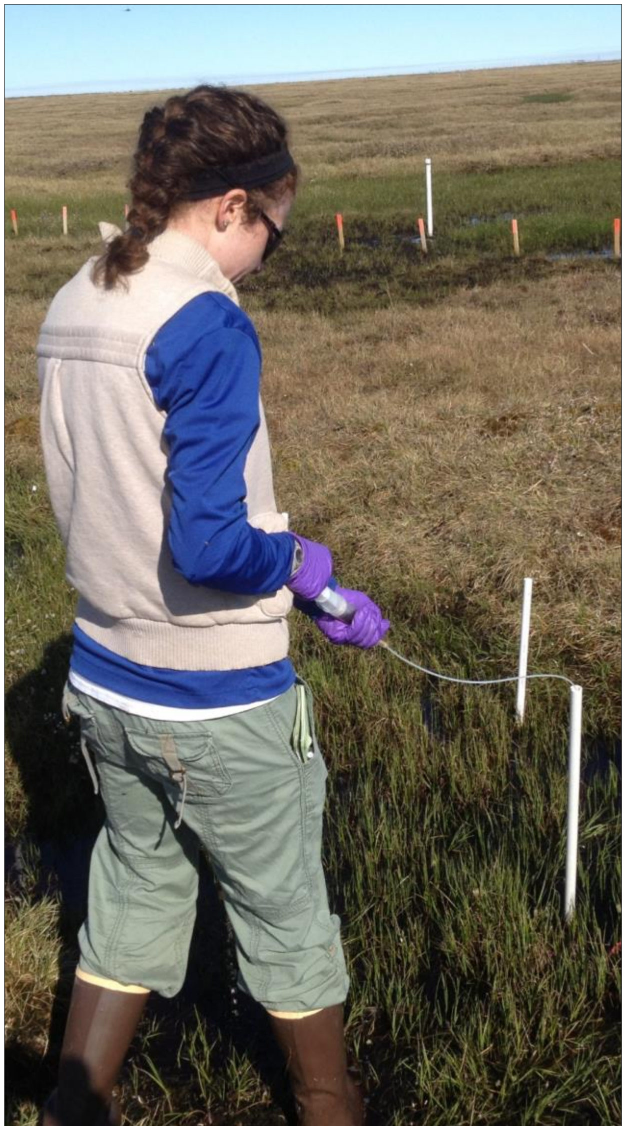


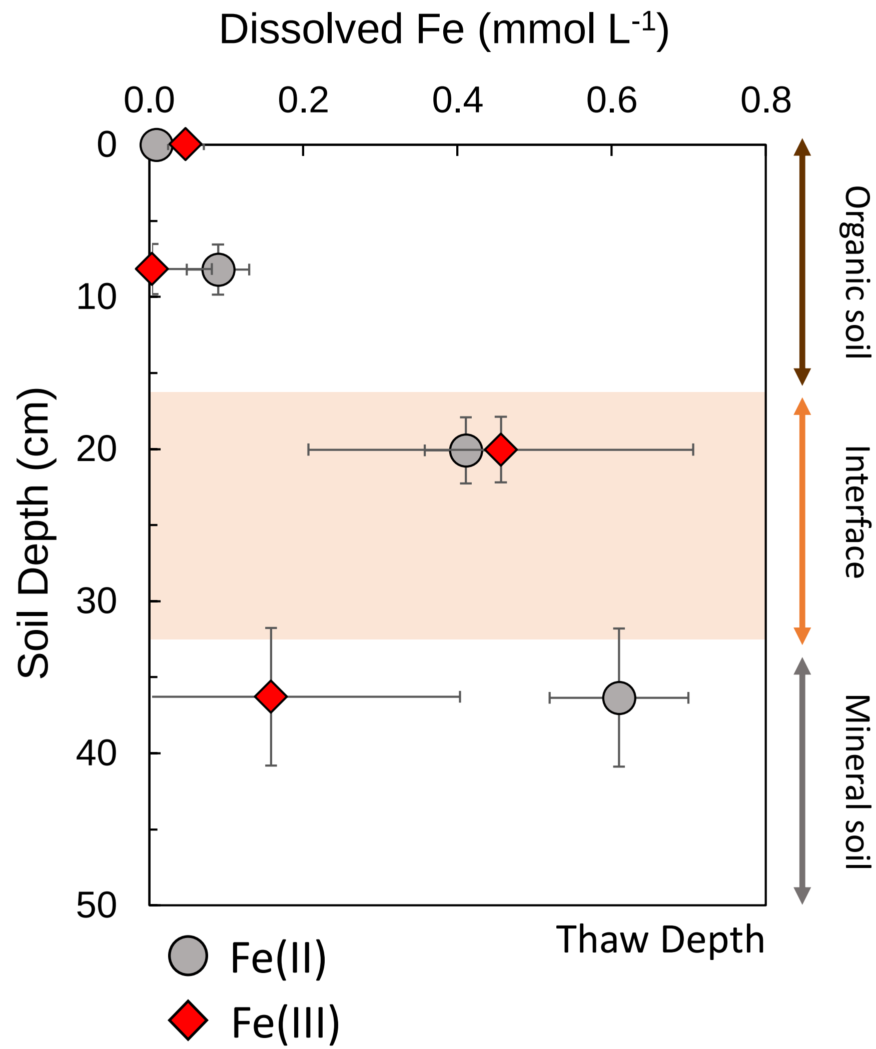
Part 1) Fe/C interactions

Part 2) Fe/P interactions

What is the geochemical distribution of Fe in this landscape?

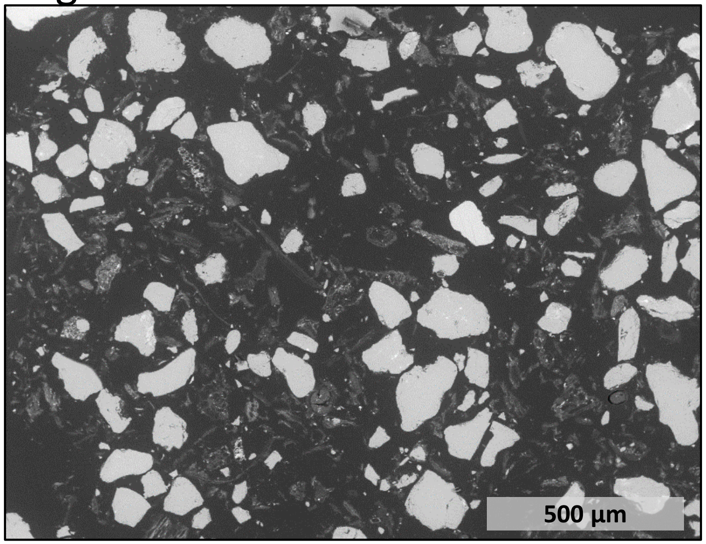
- Vertical redox gradients drive Fe cycling
- High Fe(II) at depth; Oxidized Fe(III) peaks at the redox interface





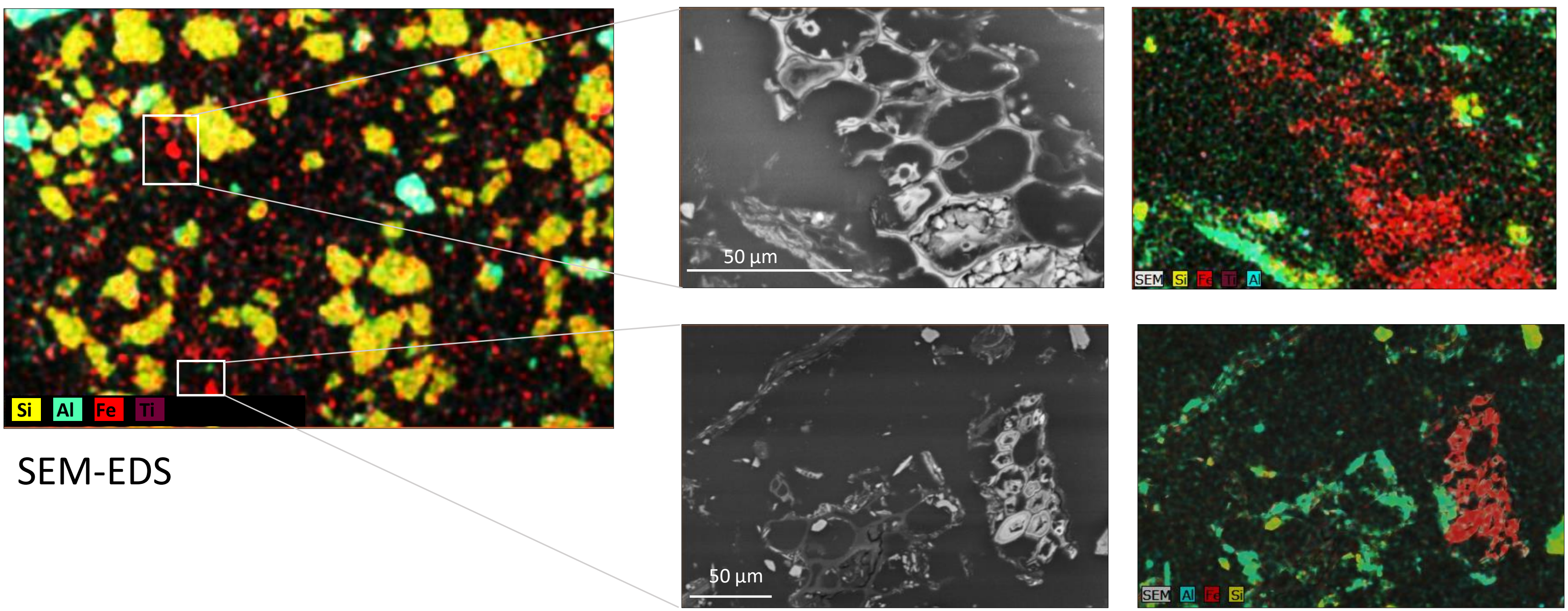
Herndon et al. (2015) *Biogeochemistry*

Organic Horizon



Surface organic soils accumulated Fe

- High concentrations of poorly crystalline iron oxides
- Fe oxides adsorbed labile organic molecules, stabilized soil aggregates, and coated POM

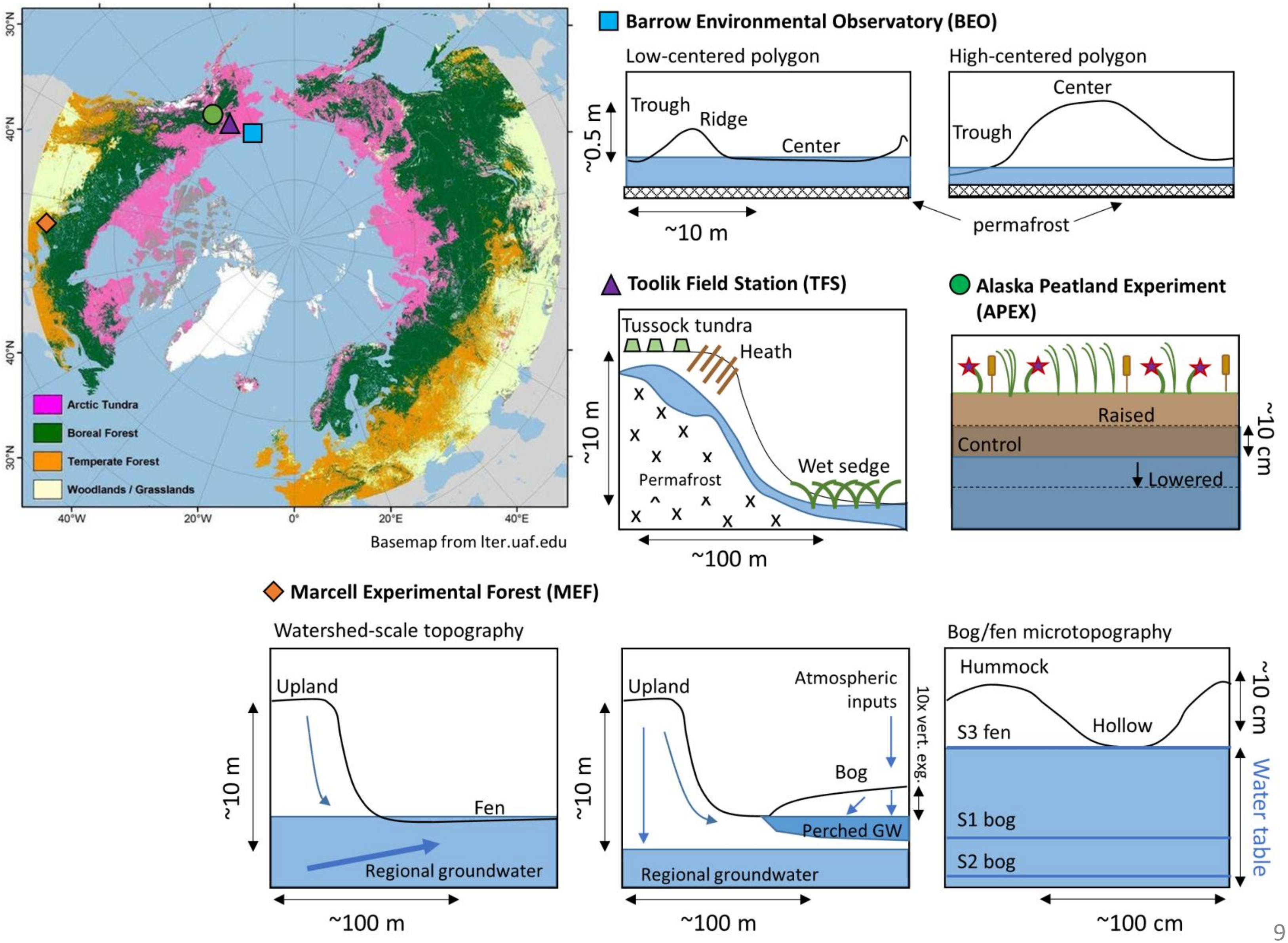


SEM-EDS

Herndon et al. (2017) *Geochim. Cosmochim. Acta*

How does Fe redox cycling influence P availability?

Investigated Fe/P associations across hydrologic/redox gradients



Organic-rich surface soils collected from regions of variable saturation

- Depth < 20 cm
- Organic content = 77 ± 20%
- pH = 4.5 ± 1.1
- n = 3 per site

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- Phosphate sorption index (PSI)

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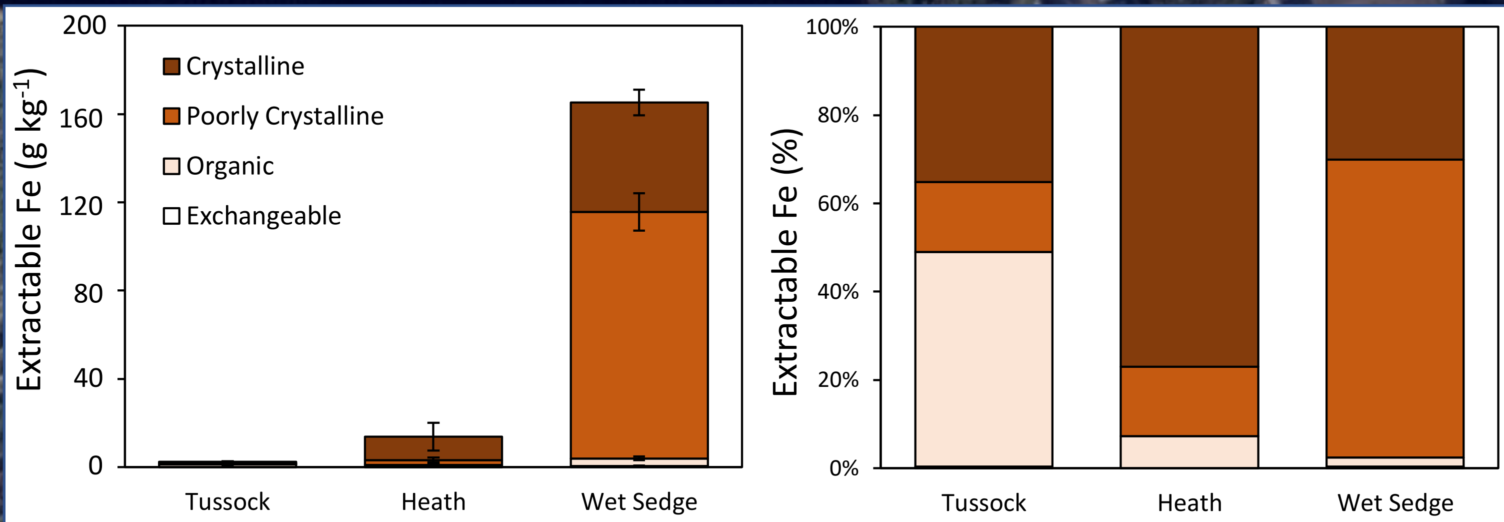
3) *How much P is being sequestered by Fe oxides?*

- Sequential P extractions: Water-soluble → Bound to Fe oxides → Organic-P → Apatite fractions

Toolik Lake sites

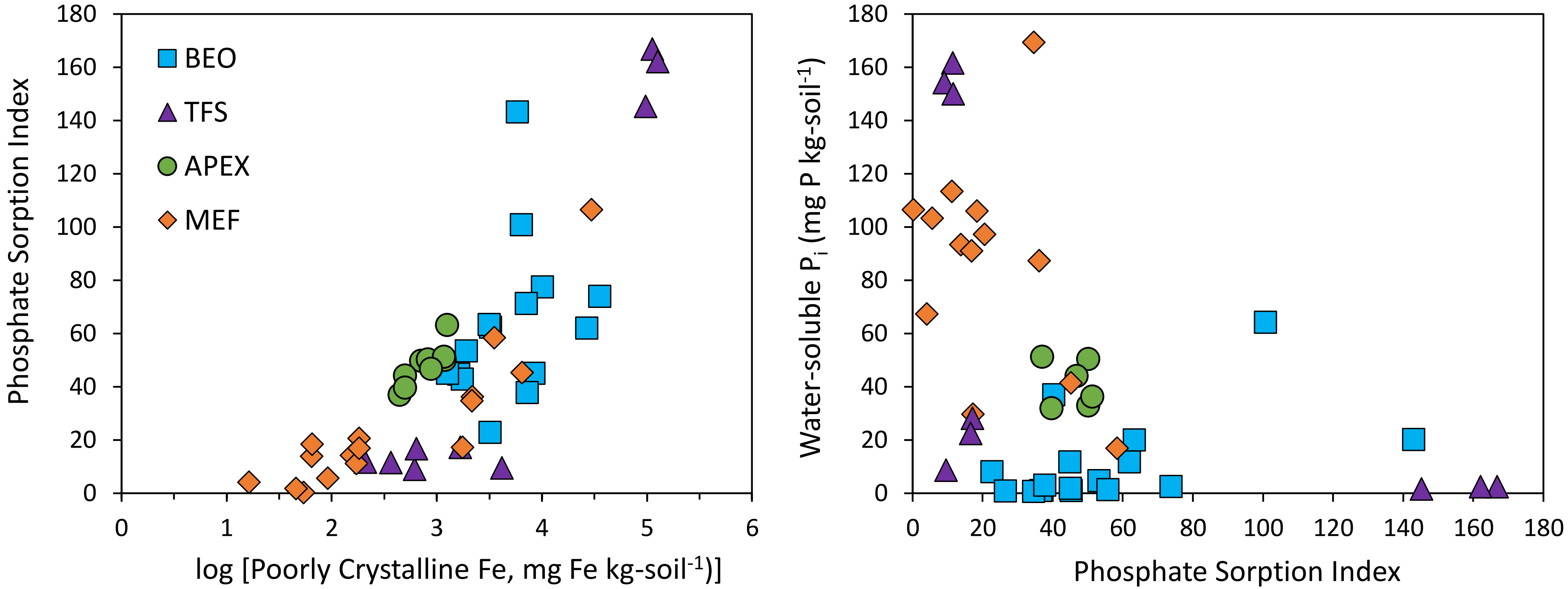
- Upland, acidic soils were Fe poor and contained organic-bound/crystalline Fe
- Lowland, circumneutral soils were Fe-rich and contained poorly crystalline Fe oxides



Herndon et al. (2019) JGR-Biogeosciences

Low-lying soils potentially serve as phosphate traps on the landscape

- Soils with high concentrations of poorly crystalline Fe oxides had a *high capacity to bind phosphate* and *low soluble phosphate*



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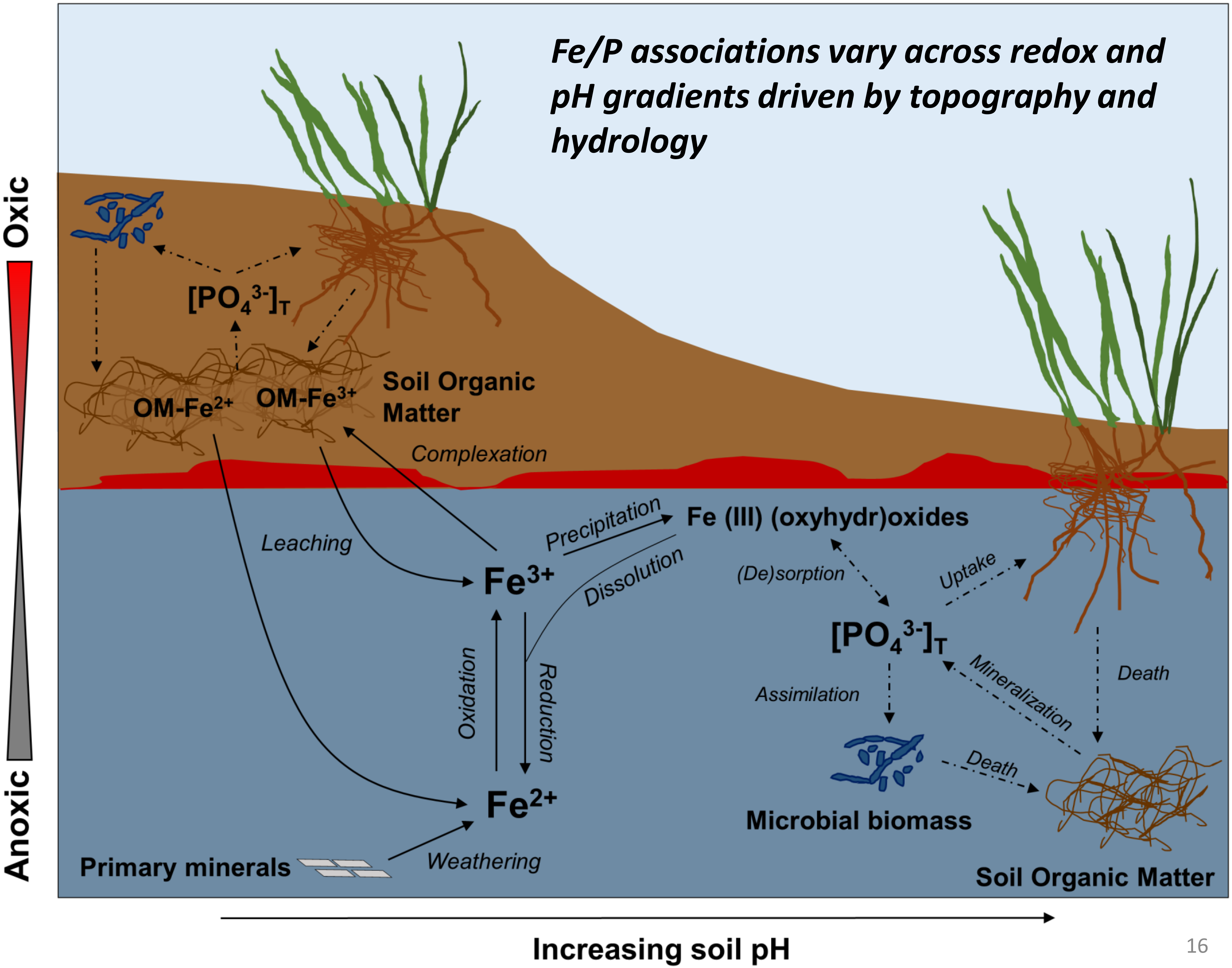
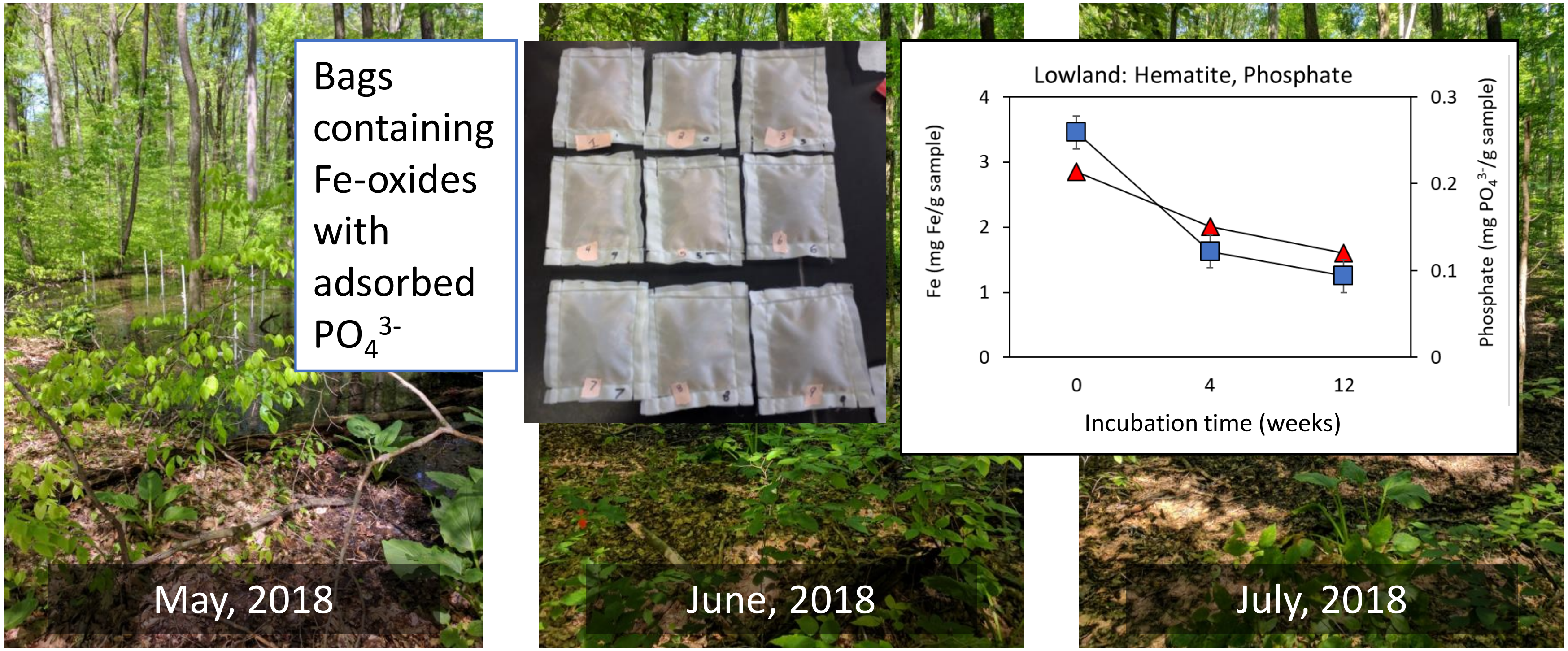
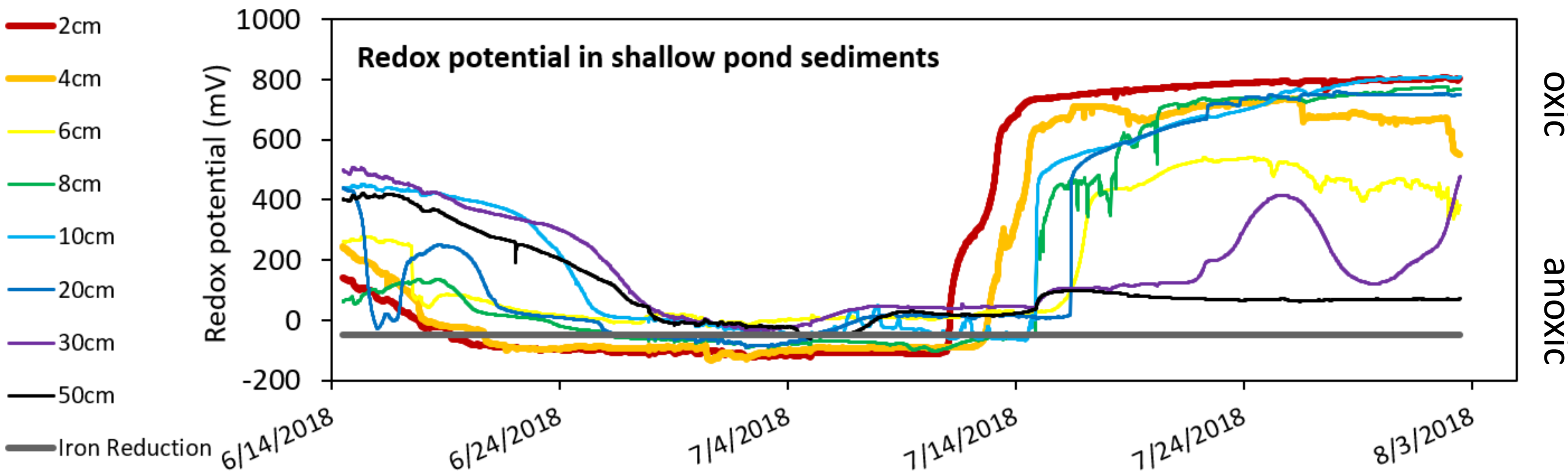

Fe/P associations vary across redox and pH gradients driven by topography and hydrology
Oxic
Anoxic
[PO4 3-]T
OM-Fe2+
OM-Fe3+
Soil Organic Matter
Complexation
Leaching
Precipitation
Fe (III) (oxyhydr)oxides
Dissolution
Fe3+
Oxidation
Reduction
Fe2+
(De)sorption
Uptake
[PO4 3-]T
Mineralization
Death
Assimilation
Death
Microbial biomass
Soil Organic Matter
Primary minerals
Weathering
Increasing soil pH

How do we measure temporal dynamics?





Slide by Max Barczok (PhD student/Kent State)

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People

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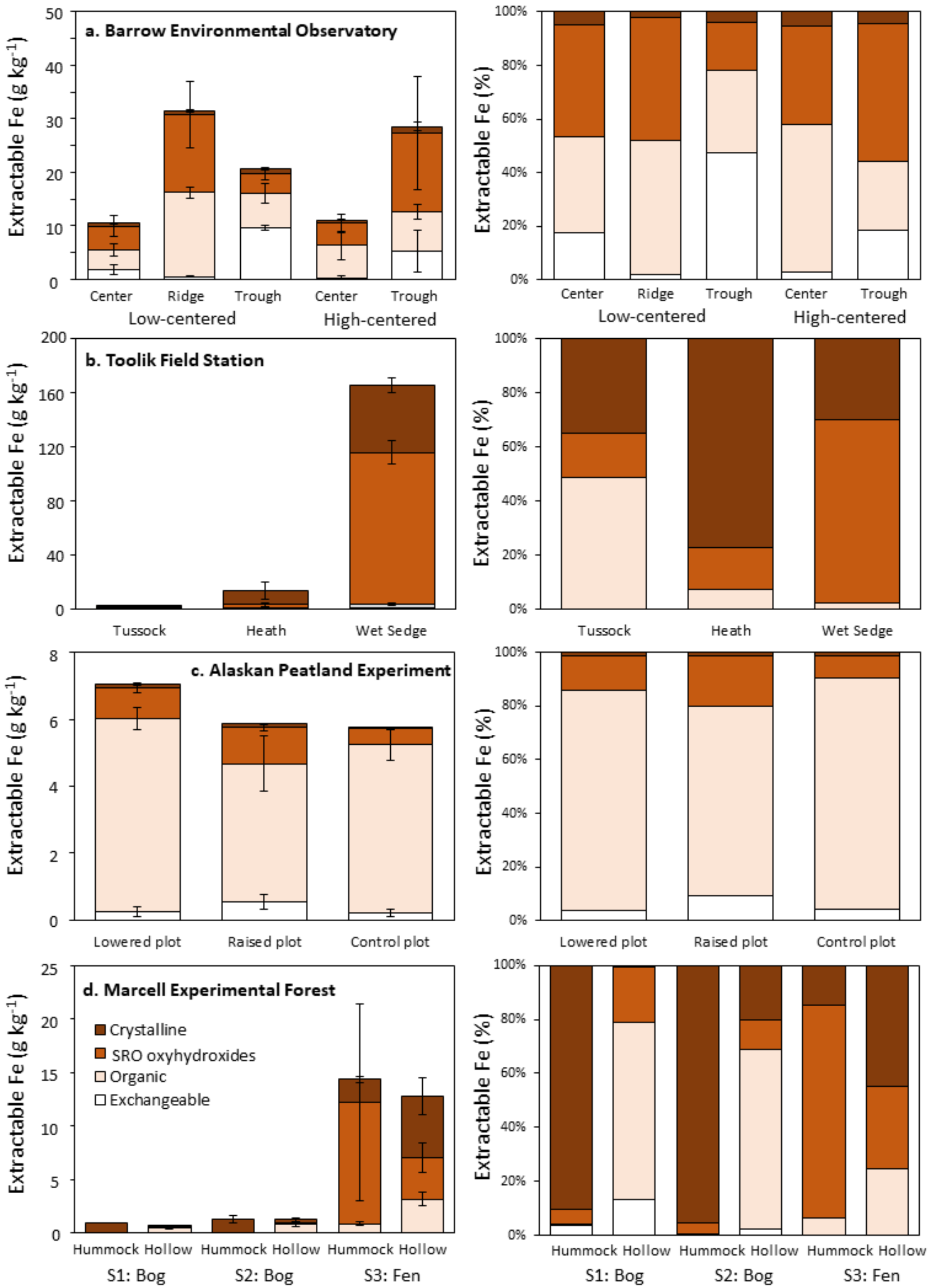
APS 12-BM; March 2018

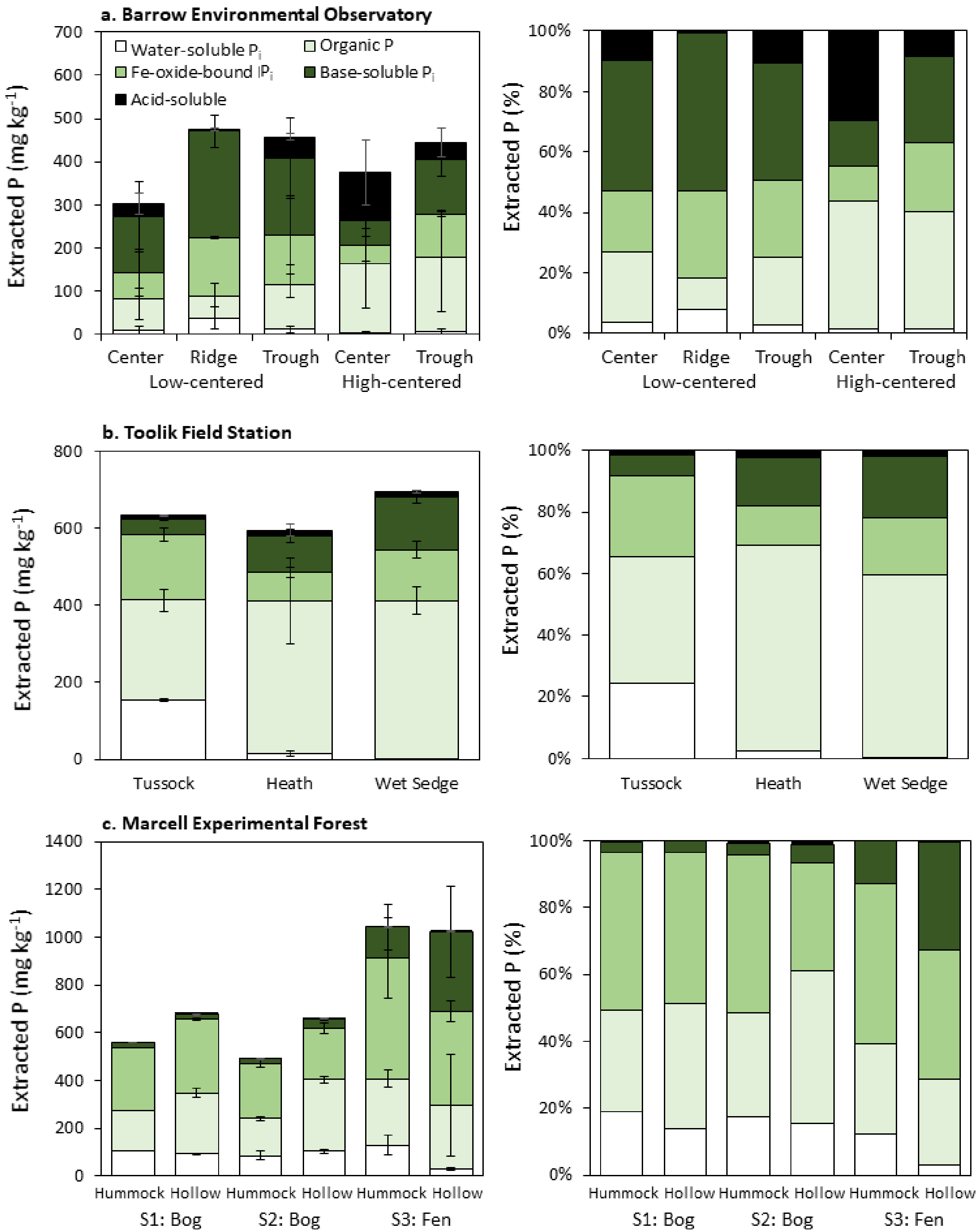
APEX; July 2016

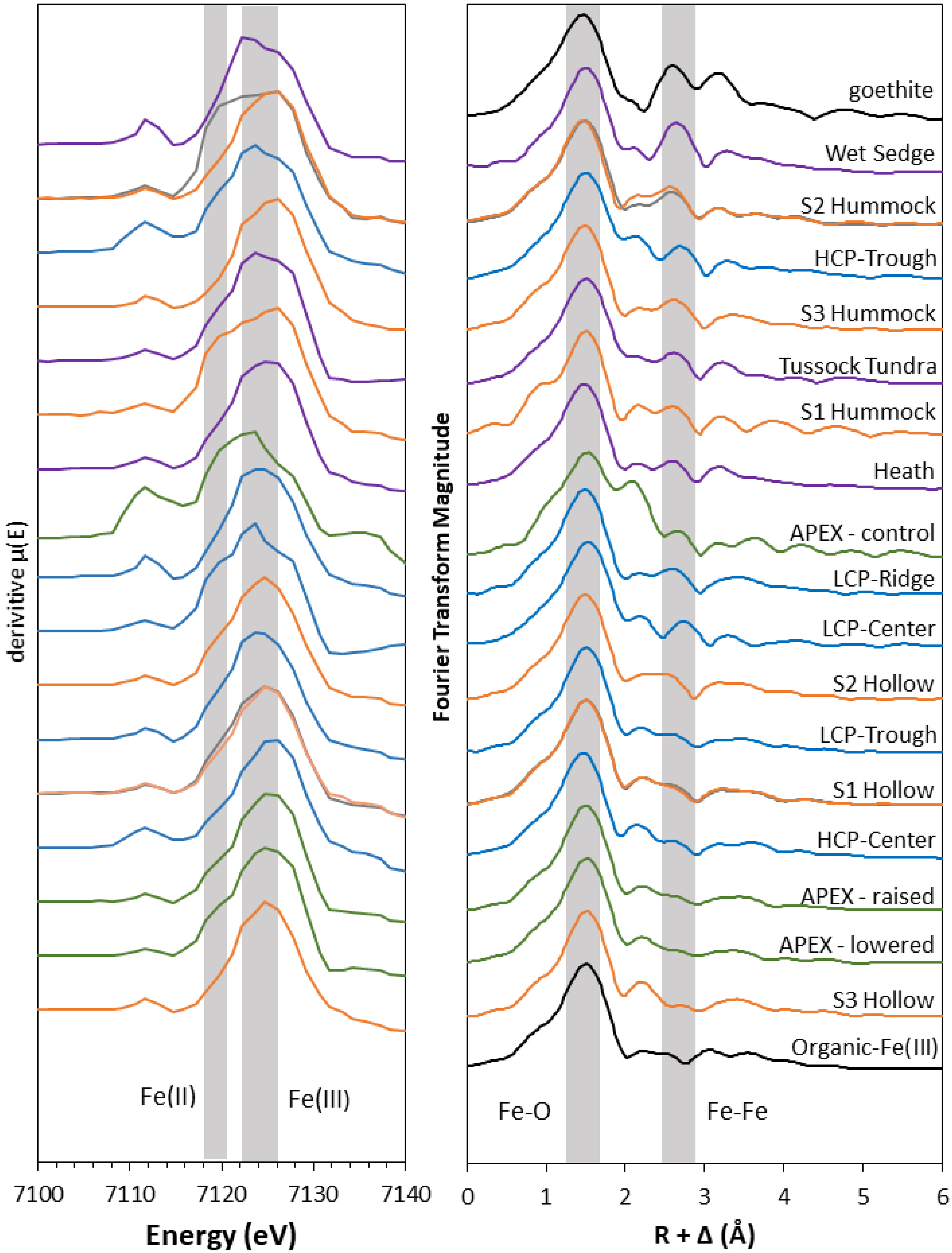
Arctic tundra near Utqiagvik, Alaska

Sequential Fe extractions



Sequential P extractions





Fe K-edge X-ray Absorption Spectroscopy

- Soils contained primarily Fe(III)
- Varying proportions of organic-bound or oxide Fe among soils generally confirmed trends seen in sequential extractions

Marcell: Fens contained high concentrations of Fe (oxyhydr)oxides while bogs contained little Fe, primarily as organic-bound/crystalline Fe