☒ **Talk** ☐ **Poster**

Laboratory for Observing (An)oxic Microsites in Soils (LOAMS)

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Redox reactions underlie several biogeochemical processes and are typically spatiotemporally heterogeneous in soils and sediments. However, redox heterogeneity has yet to be incorporated into mainstream conceptualizations and models of soil biogeochemistry. Anoxic microsites, a defining feature of soil redox heterogeneity, are non-majority oxygen-depleted zones in otherwise oxic environments. Neglecting to account for anoxic microsites can generate major uncertainties in quantitative assessments of greenhouse gas emissions, carbon sequestration, as well as nutrient and contaminant cycling at the ecosystem to global scales. However, only a few studies have observed/characterized anoxic microsites in undisturbed soils, primarily, because soil is opaque and microsites require µm-cm scale resolution over cm-m scales. Consequently, our current understanding of microsite characteristics does not support model parameterization.

To address this gap, we developed a platform combining multiple-energy X-ray fluorescence (XRF) 2D mapping at multiple scales and algorithm-driven image analysis to reliably detect, quantify, and provide characterization of redox microsites using solid-phase “forensic” evidence. This method was validated in Fe-rich sediment cores with artificially injected microsites [1], where we established a systematic processing workflow to eliminate false positives arising from synchrotron-based multi-energy XRF maps of Fe.

Our approach enables rapid screening of large core sections (cm–m scale) at high spatial (50–100 µm) and energy resolution, facilitating efficient identification and characterization of redox microsites. To date, this platform has revealed a direct link between the spatial distribution of Fe(II)-enriched microsites and methane flux at the soil surface along a floodplain-to-hillslope transect in a mountainous watershed (Colorado, USA). These findings also provide direct evidence of anoxic microsites in predominantly oxic soils such as the toeslope, where anaerobic conditions are not typically expected. By overlaying X-ray maps of multiple redox-sensitive elements with varying redox potentials, we expect to detect and characterize microsites with distinct internal biogeochemical functions. For example, in rice paddy soils, Fe(III)-rich microsites formed near roots during alternate wetting and drying cycles were found to inhibit arsenic (As) transport in sediment, while Fe(III)-plaques accumulated on root under continuous flooding conditions promoted As(III) migration into roots.

We anticipate that this approach will significantly advance our understanding of soil redox heterogeneity and improve the accuracy of predictions regarding its impact on soil-scale biogeochemistry.

References

[1] Noël V., Boye K., Naughton H., Lacroix E., Aeppli M., Kumar N., Fendorf S., and Webb S. (2024) X-ray chemical imaging for assessing redox microsites within soils and sediments. *Frontiers in Environmental Chemistry, 5.*