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# Dynamics of organic matter decomposition during iron redox fluctuations in soils

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It is well-understood that iron redox dynamics can lead to both organic matter persistence—through the stabilization of organic matter in iron mineral associations or in Fe-cemented aggregate structures—as well as organic matter decomposition—through microbial respiration on ferric iron and through the production of hydroxyl radicals during the oxidation of ferrous iron (i.e., Fenton chemistry). However, we do not understand how the relative impact of each of these processes manifests during redox fluctuations. For instance, we do not understand how the net decomposition of organic matter via Fenton chemistry during the oxidation of ferrous iron compares with the net protection of organic matter via newly formed short-range-ordered (SRO) ferric minerals; nor do we understand how much of that recently-protected organic matter will be lost during a transient anoxic event. Certainly, some of the key parameters determining the balance of iron-mediated OM protection vs. decomposition include the timescales of the redox fluctuations (the duration of the oxic or anoxic periods), the rates of iron oxidation, and critically, the dynamics of the resident microbial community. Here, we explore these parameters using upland soils from the Calhoun and Luquillo Critical Zone Observatories in laboratory experiments. (1) We quantified Fe-stimulated OM protection vs. decomposition by amending $^{13}$C-labeled dissolved OM (DOM) and $^{57}$Fe-labeled $Fe^{II}_{aq}$ to soil slurries incubated under either static oxic or fluctuating redox conditions. (2) We tracked the rates of Fe reduction, CO2 production, and CH4 production from soils during multiple redox fluctuations with three different lengths of O2 exposure and equal lengths of anoxia. From these experiments we find that (1) the addition of iron only conferred net protection to newly added organic matter and only under strict oxic conditions, whereas in treatments without added DOC or that were exposed to transient anoxia, the addition of iron stimulated net organic matter decomposition. (2) That the length of $O_2$ exposure altered the balance of Fe reduction and methanogenesis during the anoxic periods with longer O2 exposure suppressing Fe reduction and enhancing methanogenesis. These findings suggest iron redox dynamics will likely tend to enhance organic matter decomposition in soils. But, importantly, these studies have specifically focused on localized iron dynamics and biogeochemical coupling with organic matter by using well-mixed systems. Spatial heterogeneity and soil structural features have yet to be evaluated in this context.