**The Pivotal Role of Heterogeneity in the Persistence of Soil Organic Matter**

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The dual goals of predicting soil-climate feedbacks and informing local land management, e.g., for carbon sequestration place new demands on our understanding of soil biogeochemical dynamics. Particular challenges for these 21st century goals include (1) capturing biogeochemical responses to novel and highly transient conditions; (2) representing interacting processes to inform fine-scale manipulations affecting soil organic carbon (SOC) stocks (e.g., for next-generation sequestration); and (3) explaining the observed spectrum of SOC residence times. Progress has been made in identifying important processes and conditions, but we lack an integrating framework for SOC dynamics and have difficulty explaining how the interplay of very fast reactions lead to the very long SOC residence times we observe. We hypothesize that heterogeneity in soil conditions—molecular, spatial, and temporal—is a fundamental cause of slow decomposition rates and posit that representing these three dimensions of heterogeneity will result in models that predict very long residence times and as well as reproducing other important dynamics. These concepts will be viewed in light of results from soil experiments that impose highly transient conditions. To make such a framework useful, it needs a scaling schema. Oliver Chadwick's work from molecular to pedon to landscape scale (and over time!) builds the functional connection from soils to scaling approaches adapted from geophysics, hydrology, and pedology.