Diffusion-dependent anaerobic microsites constrain soil carbon turnover

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Particle-size distribution (or texture) is an important predictor of long-term soil organic carbon (SOC) storage and its sensitivity to global change impacts in current terrestrial ecosystem models. Positive correlations between texture and SOC persistence have long been attributed to protective associations between clay-sized minerals and organic compounds that prevent microbial and enzymatic access – a mechanism commonly referred to as 'mineral protection'.

Here we show that the protective effect of texture is not only due to mineral protection, but also to the formation of anaerobic microsites. Combining micro-scale laboratory experiments with field-scale observations, we find that oxygen diffusion limitations within clay-rich domains create anaerobic microsites within seemingly well-aerated soils, shifting microbial metabolism to less efficient anaerobic SOC oxidation pathways. Kinetic and thermodynamic constraints reduce SOC oxidation rates within these anaerobic microsites by an order of magnitude relative to aerobic rates, and caused the preservation of bioavailable, polymeric and reduced organic compounds. Lifting these metabolic constraints through increased soil aeration (e.g., changing precipitation patterns or land use) may stimulate microbial oxidation of this inherently bioavailable SOC pool. Models that attribute the effects of texture merely to 'mineral protection' may therefore underestimate the vulnerability of soil C to global change impacts.