Title: Spatial Variation in Microbial Processes Controlling Carbon Mineralization within Soils and Sediments

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Approximately 3300 Pg of carbon (C) are stored in soils as organic matter, which is three-times the amount stored in the atmosphere. An important control on soil organic matter (SOM) storage is the mineralization (oxidation) rate, which is affected by climatic factors (particularly temperature and rainfall) influencing microbial metabolic rates as well as SOM chemistry, mineral-organic associations, and physical protection. What remains elusive is to what extent constraints on microbial metabolisms induced by the respiratory pathway, and specifically the electron acceptor in respiration, control overall rates of carbon mineralization in soils. The complex physical structure of soils and sediments results in an abundance of redox environments even within seemingly aerobic systems. Therefore, factors limiting oxygen diffusion and availability such as soil texture and aggregate size (soil structure) may be central controls on microbial C mineralization rates. Here, we are combining laboratory studies with in-field measurements to examine if soil structure and carbon availability interact to impose respiratory constraints on organic matter mineralization rates and thus storage.

In model aggregates, we determined the distribution of operative microbial metabolisms and their cumulative impact on SOM transformations and overall oxidation rates across soil redox gradients. In both saturated and unsaturated systems, microsensor measurements in combination with gas flux measurements showed that particle size exerts a strong control on the extent of the anaerobic volume, thereby causing an overall decrease in OM oxidation rates. Density separations and C 1s NEXAFS spectroscopy showed that the formation of persistent anaerobic microsites resulted in the preferentially preservation of reduced (electron-rich) organic carbon compounds (both dissolved and particulate), a result corroborated by field measurements across multiple sites. Metabolic profiling showed that volume-specific aerobic respiration rates are an order of magnitude larger than those for anaerobic respiration, with Fe reduction contribution more than 75% of the overall metabolism. However, our results also indicate that diffusion limitations imposed by small particle sizes not only negatively impacted aerobic respiration but also anaerobic respiratory pathways, suggesting that the predictive power of 'soil texture' used in current soil C cycling models may not only be grounded in mineral protection mechanisms, but also in diffusion limitations creating anaerobic microsites. Collectively, our results suggest that anaerobic microsites are an underappreciated OM protection mechanism in soils (upland and lowland). Because this mechanism appears to be most important for organic carbon compounds thought to be inherently available for microbial catabolism, it may be particularly vulnerable to changes in environmental conditions due to climate change.