

Recycling versus Inaccessibility: Which mechanisms stabilize organic carbon at mineral surfaces?

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In the last two decades physico-chemical fractionation of soil organic matter (SOM) revealed mineral-associated organic matter (OM) as the oldest (i.e. most-stable) SOM fraction. Such results conflict with short-term incubation experiments demonstrating that microbial uptake outcompetes sorption and that even sorbed compounds are highly accessible to decomposition. Thus, the high apparent age of mineral-associated organic carbon (C) must result from additional processes that have yet to be identified.

Awareness of the important role that microbial OM recycling plays in terrestrial C transformations originated within the field of biogeochemistry within the last years. However, microbial recycling cannot be unequivocally differentiated from stabilization of untransformed OM by sorption based on ¹³C or ¹⁴C natural abundance and/or short-term pulse-labeling approaches. Long-term experiments based on uniformly-labeled glucose first indicated microbial recycling as a relevant process in soil C dynamics. Recently, 1) a position-specific labeling approach and 2) moiety-specific isotope analysis demonstrated the relevance of lipid recycling in terrestrial as well as marine C cycling. Novel metabolic tracing techniques provide the unique opportunity to observe metabolic cycling of sorbed OM, i.e. to assess the relevance of recycling at mineral surfaces. Therefore, position-specific labeling of sorbed versus free amino acids was combined with compound-specific isotope analysis of microbial biomarkers. Nearly all microbial groups took up sorbed low molecular weight organic compounds to a similar extent as the respective free compounds from soil solution, clearly opposing direct stabilization. Sorption shifted microbial metabolism from catabolic to anabolic use of the respective C – a clear indication that sorbed compound recycling partially explains the high apparent age of the mineral-associated OM.

Although quantitative assessment of recycled versus directly stabilized C is not yet possible, these results support the strong relevance of microbial OM recycling, especially within microhabitats located on mineral surfaces.