High-Resolution Molecular Profiling of Permafrost Soil Organic Carbon Composition and Degradation

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Microbial degradation of soil organic matter (SOM) is a key process for terrestrial carbon (C) cycling, though the dynamics of these transformations remain unclear at the molecular level. As part of the Next Generation Ecosystem Experiment (NGEE-Arctic) research, this study reports the application of ultrahigh resolution Fourier transform ion cyclotron resonance mass spectrometry (FTICR-MS) to profile molecular components of Arctic SOM collected from the surface water and the mineral horizon of a low-centered polygon soil at Barrow Environmental Observatory (BEO) (Barrow, AK). Soil samples were subjected to anaerobic warming experiments for a period of 40 days, and the SOM was extracted with water and 0.1 M NaOH and analyzed before and after the incubation to determine the components of organic C that were degraded over the course of the study. A CHO index based on molecular composition data was utilized to codify SOM components according to their observed degradation potential. Carbohydrate- and lignin-like compounds in the water-soluble fraction (WSF) demonstrated a high degradation potential, while structures with similar stoichiometries in the base-soluble fraction (BSF) were not readily degraded. The WSF of SOM also shifted to a wider range of measured molecular masses including an increased prevalence of larger compounds, while the size distribution of compounds in the BSF changed little over the same period. Additionally, the molecular profiling data indicated an apparently ordered incorporation of organic nitrogen in the BSF immobilized as primary and secondary amines, possibly as components of N-heterocycles, which may provide insight into nitrogen immobilization or mobilization processes in SOM. Our study represents an important technical advancement for studying Arctic SOM with improved understanding of the detailed molecular properties of soil organic C and, ultimately, the ability to accurately represent SOM in climate models that will predict the impact of climate change on soil C and nutrient cycling.