

Formation of Mineral-associated Organic Matter via Adsorption and Aggregation Pathways in Soils at the Continental Scale

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Soil organic carbon (SOC) plays a crucial role in soil health and global climate regulation, serving as a key reservoir for atmospheric carbon. Mineral-associated organic matter (MAOM), which constitutes approximately 65% of soil organic carbon, is formed through two mechanisms: adsorption of dissolved organic matter (DOM) onto mineral surfaces and aggregation of fine-sized organic particles (<53 μm) with soil minerals. These two pathways yield organic carbon pools with distinct ecological functions. Aggregated organic carbon (OC) typically exhibits a longer mean residence time than adsorbed OC and may respond differently to climate change and vegetation shifts. However, the relative contributions of adsorption and aggregation to MAOM formation, as well as the chemical composition and origins of organic carbon within each pathway, remain poorly understood. To address these gaps, we separated adsorbed and aggregated organic compounds in MAOM from soils collected at a continental scale. Using FT-ICR mass spectrometry and ^{13}C NMR spectroscopy, we characterized their chemical composition. Our results revealed that the relative contribution of adsorbed or aggregated OC to mineral-associated organic C (MAOC) varied widely (10%–95%). The adsorbed fraction was dominated by aromatic compounds (70% – 98% of MAOC), while the aggregated fraction contained primarily non-aromatic compounds with aromatics accounting for only 10%–30% of MAOC. These variations were strongly influenced by climate conditions and soil properties. Our findings highlight the equal importance of adsorption and aggregation in MAOM formation at the continental scale and challenge the prevailing notion that microbial carbon is the primary source of MAOM.