

## Soil Architecture Controls Organic Carbon Turnover in Hawaiian Forest Soil

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Soil represents one of the largest dynamic stocks of carbon on earth; understanding soil organic carbon (SOC) oxidation and stabilization mechanisms are critical to forecasting changes in atmospheric greenhouse gas concentrations. Although our understanding of SOC processing has advanced over the last decade, most work has not considered soil architecture. To evaluate the chemical and biological controls imposed by physical structure and its changes with depth within a soil profile, we investigated the potential contrast in SOC deposited by advective-dominated transport along preferential flow paths (PFP) compared to that deposited by diffusive-dominated transport within the soil matrix at millimeter resolution in soils of the Pu'u Eke rainforest on Kohala, Hawaii. Specifically, the <sup>14</sup>C age and chemistry of SOC, the abundance of short-range ordered (SRO) minerals, the level of mineral protection and microbial population changes were assessed as a function of soil profile depth and distance from PFPs into peds.

Carbon content, C:N ratios, and <sup>14</sup>C are similar with respect to both depth and distance from PFPs. Carbon is youngest and most abundant at PFPs and at the surface, and it is progressively older away from PFPs and with depth. C:N molar ratios are lowest at the PFP and increases as a function of distance from the PFP, indicating that C is most microbially processed at PFPs. Spectroscopic analyses as well as permanganate oxidizable assays confirm that C becomes more chemically labile as a function of distance from PFPs.

Increasing abundance of SRO mineral fraction with depth explains greater mineral-induced protection of C, which is the dominant mode of C sequestration at the site. In addition to mineral protection, however, anaerobic conditions, exemplified by the abundance of *nirK* gene (normalized to mass of DNA) and methanogens, exert metabolic constraints that substantially decrease C turnover away from PFPs.

Our work highlights the role of spatial variability imposed by soil architecture in controlling SOC accumulation and stability. We conclude that micro-scale variation in the chemistry and mineralogy of soil substrate is linked to SOC oxidation rates.