



Physicochemical properties and stability of thousand-year-old soil organic matter in boreal paleopodzols

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Soil organic matter (SOM) stabilization mechanisms are key to predict carbon (C) cycle responses to climate change, especially in critically sensitive ecosystems, such as the arctic and boreal ecosystems of Scandinavia (IPCC 2007). Interactions between organic matter and soil mineral components can be of particular importance. Their impacts on SOM stability are however not fully resolved. In this study, we present an exhaustive physicochemical characterization of SOM and soil mineral components of boreal paleopodzols formed over several thousands of years in northern Sweden. We also test the hypothesis that old SOM in these environments is strongly associated to mineral surfaces.

This work was specifically focused on two relict podzolic profiles capped by more recently developed podzolic profile. Each of the three profiles consisted of a well developed E-horizon and of an underlying B-horizon enriched in secondary weathering products.

Soil C age was greater with increasing depth, with the deepest horizon dating from the mid-Holocene. Organic C loadings, expressed in terms of C mass per mineral surface area, decreased from 0.52 to 0.31 mg C m⁻² from deep to the deepest B horizons. A monolayer coating model could thus be used to suggest that C was mainly bonded to unsaturated mineral surfaces. Scanning electron microscopy and energy dispersive X-ray spectroscopy showed that, unlike in younger B-horizon, the oldest C of the deepest B-horizon did not accumulate in clusters. It was instead distributed more homogeneously at the micrometer scale with soil mineral particles. X-ray photoelectron spectroscopy moreover showed that the top 1-10 nm of the mineral surfaces contained proportions of aliphatic-C, ether/alcohol-C, and amide-C that varied greatly amongst the three B horizons but not among the three E horizons. Different composition of SOM remained in deep E and B horizons, thereby suggesting a selective SOM preservation process that is controlled by the properties of the mineral matrix. Our findings therefore support the concept that soil mineral surfaces impact SOM stability. The importance of SOM-mineral surfaces complexation was demonstrated further through combined temperature-programmed desorption mass spectrometric Fourier transform infrared (TPD-MS-FTIR) experiments pointing to highly resilient forms of SOM associated to mineral particle surfaces.

In summary, our study suggests organic matter sorption on mineral surfaces is important for SOM preservation at the millennial scale. Predicting the long-term fate of C in boreal regions should consequently account for such types of organo-mineral associations.