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Relevance of mineral-organic associations in cryoturbated permafrost soils

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Enhanced microbial decomposition of deep buried organic matter (OM) increase the release of $CO_2$and $CH_4$from high latitude ecosystems, thus being an uncertain but potentially crucial positive feedback to global warming. The role of soil minerals as stabilization agents of OM against microbial attack gain in importance as soon abiotic soil conditions will change in permafrost soils. We investigated changes in storage and turnover of soil organic carbon (OC) and total nitrogen (TN) associated with minerals in 27 cryoturbated permafrost soils from the west to the east Siberian Arctic. Furthermore, we studied the mineral composition and the potential of OM to interact with soil minerals via different binding mechanisms. Mineral-associated organic matter (MOM) was separated from particulate plant debris by density fractionation in sodium polytungstate (density cut-off 1.6 g cm^{-3}). Their apparent ^{14}C ages were determined by accelerator mass spectrometry and potential mineralization rates were analyzed in a 180 days incubation experiments at 5 and 15˚C. The mineral composition was analyzed by X-ray diffraction and selective extractions. Desorption experiments (stepwise extraction with KCl and NaH_2PO_4) using the permafrost soils as well as reference soils from temperate regions (three Stagnolsols from Germany) were performed to study OM sorbed to mineral surfaces or complexed with polyvalent metal ions. The proportion of OC associated with minerals (MOC) ranged from 5.1 to 14.9 kg m^{-2} (average: 11.0 kg m^{-2}), corresponding to $\sim$55% from the total soil OC storage (average: 20.2 $\pm$ 8.0 kg m^{-2}) in the first meter of the Cryosols. In contrast to temperate soils, where maximum MOC concentrations are present in topsoils, cambic, or spodic horizons, cryoturbation in permafrost soils leads to high MOC concentrations within the whole solum. Cryoturbated OM-rich pockets in the subsoil store 18% (2.0 $\pm$ 1.3 kg m^{-2}) of the MOC while another 34% (3.8 $\pm$ 3.5 kg m^{-2}) was located in the uppermost permafrost. In topsoil horizons, mineralization rates showed a similar pattern for MOM and the bulk soil controls. In contrast, even higher MOM respiration rates then the bulk control were found in the cryoturbated OM-rich pockets and permafrost horizons. These findings deviate from temperate soil environments where MOM is considered to contribute to a 'stabilized pool' with mean residence times from hundreds to thousands of years. Statistical analysis indicated that mineral-organic interactions primarily occurred with poorly crystalline Fe and Al phases and Fe/Al-OM complexes. However, the minor desorption of organic polyelectrolytes by NaH_2PO_4 in permafrost soils indicated that significantly lower amounts of OC were bound by ligand exchange to Fe and Al minerals or the edges of clay minerals in permafrost soils compared to the temperate reference soils. Therefore, stabilization of OM by mineral surfaces or polyvalent metal ions appears to be of minor relevance in arctic environments compared to temperate soils.