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Quality and Distribution of Frozen Organic Matter (Old, Deep, Fossil Carbon) in Siberian Permafrost

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Permafrost deposits constitute a large organic carbon (OC) pool vulnerable to degradation and potential carbon release due to global warming. Permafrost sections along coastal and river bank exposures and subsea cores in northeastern Siberia were studied for organic matter (OM) characteristics and ice content. OM stored in Quaternary permafrost grew, accumulated, froze, partly decomposed, and refroze under different periglacial environments, reflected in specific biogeochemical and cryolithological features. For the studied individual strata (Saalian ice-rich deposits, Pre-Eemian floodplain, Eemian lake deposits, Early to Middle Weichselian fluvial deposits, Middle Weichselian Yedoma, Late Weichselian Yedoma , Taberites, Holocene cover, Holocene thermokarst, Holocene thermoerosional valley and submerged lagoon and fluvial deposits) OM accumulation, preservation, and distribution are strongly linked to a broad variety of paleoenvironmental factors and specific surface and subsurface conditions before inclusion of OM into the permafrost.

OM in permafrost includes twigs, leaves, peat, grass roots, plant detritus, and particulate and dissolved OM. The vertical distribution of total OC (TOC) in exposures varies from 0.1 wt % of the dry sediment in fluvial deposits to 45 wt % in Holocene peats. High TOC, high C/N, and low d13C reflect less decomposed OM accumulated under wet, anaerobic soil conditions characteristic of interglacial and interstadial periods. Glacial and stadial periods are characterized by less variable, low TOC, low C/N, and high d13C values indicating stable environments with reduced bioproductivity and stronger OM decomposition under dryer, aerobic soil conditions. Based on TOC data and updated information on bulk densities, we estimate average OC inventories for different stratigraphic units in northeastern Siberia, ranging from 7 kg C/m^3 for Early Weichselian fluvial deposits, to 33 kg C/m^3 for Middle Weichselian Yedoma deposits, to 75 kg C/m^3 for Holocene peaty deposits.

Thus, we present one of the first in-depth studies of the complexity of OM distribution for the upper permafrost (to 100 m depth) in the northeastern Siberian Arctic, indicating that considerable variability of OM distribution between different stratigraphical units, between the same stratigraphical unit at different study sites, and even within stratigraphic units at the same site, are important factors that need to be taken into account in future inventories. Based on our own data and scarce published data on stratigraphical differences and the spatial variation of OC sequestered in late Quaternary permafrost deposits, we believe that knowledge about the quantities and qualities of this potentially significant OM pool is still too limited for extrapolating to larger spatial scales. However, combining TOC and ice content measurements with new bulk density estimates suggests that current carbon inventory values are too high.