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Characterizing the export of fossil carbon from permafrost soils of Spitsbergen using compound-specific radiocarbon dating

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Permafrost soils in the circumpolar Arctic regions contain vast amounts of carbon stored as organic matter, which could potentially be mobilized during the climate warming expected to be particularly severe in these regions. Deeper thawing of permafrost soils may result in degradation and erosion of previously freeze-locked organic matter, followed by transport to the ocean and respiration to CO_2. We studied a small catchment area covered by permafrost soils on the island of Spitsbergen at approximately 78°N, Svalbard archipelago. Total organic carbon (TOC) in a soil profile of the annually thawed active layer exhibits increasing radiocarbon ages with depth of 5800 conventional radiocarbon years (14C yrs BP) in 0 to 30 cm depth to 26000 14C yrs BP at 60-85 cm. However, in this region known for its occurrence of carboniferous and tertiary coals, these ages are likely biased by variable relative contributions of fossil coal particles.

Compound-specific radiocarbon ages of short-chain (C16) and long-chain (C26 and C28) fatty acids, which are derived mainly from bacteria and recent tundra vegetation, respectively, aree substantially younger than TOC, but still reach values between 2280 14C yrs BP for C16 in the uppermost 0-30 cm and 8350 14C yrs BP for C26 fatty acids in the 30-60 cm soil depth interval. Obviously, several different carbon pools contribute to TOC in the soil profile, and carbon turnover is slow.

Radiocarbon dating of long-chain (C26-C28) fatty acids recovered from core-top sediments of the Bayelva river draining the catchment and from shallow water fjord sediments directly off the river mouth yields 14C ages of 10800 and 7900 yrs BP, respectively. As the C16 fatty acids in marine sediments are primarily attributed to marine phytoplankton, its modern in the marine sediment age clearly identifies it as a recent sediment, in which old terrestrial plant material is deposited. Apparently, this terrigenous material is buried near shore, as 14C ages of long-chain fatty acids from three core-top sediments recovered from deeper in the adjacent Kongs Fjord as well as from two locations in the Isfjord further South contain long-chain fatty acids of 2850 to 3700 14C yr co-occurring with modern or very recent short-chain fatty acids. At all of these locations, substantial amounts of older, likely fossil carbon contributes to TOC as attested by bulk sediment radiocarbon ages of 3800 to 7900 yrs BP.

Overall our data imply that export of fossil terrigenous organic carbon derived from permafrost soils occurs and is likely to integrate over the annually thawed depth, i.e. the active layer. However, the average age of exported soil-derived organic matter seems to vary between locations, and the oldest age of exported material is observed in a shallow water setting with very high sedimentation rates. This may imply that in recent times covered by the uppermost centimeters of the shallow water sediment, mobilization of older material has already started compared to the time intervals represented by the core-tops of deeper water fjord sediments, which likely accumulate at lower rates. Alternatively, differences in the oxygenation of waters overlying the respective sediments or the length of transport of particles toward the location of sediment deposition may lead to preservation of different signals.