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Erosion of soil organic carbon at high latitudes and its delivery to Arctic Ocean sediments: New source to sink insight from radiocarbon dating

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Soils of the northern high latitudes store carbon over thousands of years and contain almost double the carbon stock of the atmosphere. Erosion processes can mobilise this pre-aged soil organic carbon from the landscape and supply it to rivers. If it escapes degradation during river transport and is delivered to the coastal ocean, this carbon may be sequestered for much longer periods of time ($>10^4$ yr) as a geological CO_2 sink. Despite this recognition, the erosional flux and fate of particulate organic carbon (POC) in large rivers draining the high latitudes remains poorly constrained.

Using radiocarbon activity, we quantify POC source, flux and fate in the Mackenzie River, the main sediment supplier to the Arctic Ocean. When combined with stable carbon isotopes and element ratios, the radiocarbon activity of POC allows us to distinguish inputs of POC from sedimentary rocks and quantify the average age of biospheric POC (from vegetation and soil) transported through the river system. We find that the eroded biospheric POC has resided in the basin for millennia, with a mean radiocarbon age of 5800$\pm$800 years. This is much older than large tropical rivers where we have equivalent data (Amazon River, Ganges River), and likely reflects the longer residence time of organic matter in cold, wet, high latitude soils. Based on the measured biospheric POC content and annual sediment flux, we calculate a biospheric POC flux of 2.2 (+1.3/-0.9) TgC yr^{-1} from the Mackenzie River. This is the largest input of aged organic carbon to the Arctic Ocean, more than the combined POC flux from the Eurasian Rivers.

Offshore, we use a marine core to investigate organic carbon burial over the Holocene period. Radiocarbon measurements of bulk organic carbon reveal a significant offset from benthic foraminifera radiocarbon ages throughout the core, which is dependent upon the grain size of the sediments. Organic matter in sediments $>63\mu$m are offset from foraminifera by $\sim$ 6,000 ^{14}C years, while organic matter in materials $<63\mu$m are offset by $\sim$10,000 ^{14}C years. The benthic-organic matter offsets are relatively constant down core, suggesting pre-aged soil organic matter has been eroded from parts of the Mackenzie Basin for at least 15,000 years. The ^{14}C age offsets are consistent with those seen in the modern river system, where we find fine grained sediments containing older biosperhic POC ($\sim$6-8 ka) than coarse grained materials ($\sim$3-5 ka). Together with the organic carbon content of these sediments, these measurements suggest high burial efficiencies ($>60\%$) of pre-aged terrestrial organic matter in this core over the Holocene. We postulate that erosion of organic carbon-rich, high latitude soils may result in a significant long term carbon sink.