Transport, degradation and burial of organic matter released from permafrost to the East Siberian Arctic Shelf

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Abstract

Permafrost soils in the Arctic store large quantities of organic matter, roughly twice the amount of carbon that was present in the atmosphere before the industrial revolution. This freeze-locked carbon pool is susceptible to thawing caused by amplified global warming at high latitudes. The remobilization of old permafrost carbon facilitates its degradation to carbon dioxide and methane, thereby providing a positive feedback to climate change.

Accelerating coastal erosion in addition to projected rising river discharge with enhancing sediment loads are anticipated to transport increasing amounts of land-derived organic carbon (OC) to the Arctic Ocean. On its shallow continental shelves, this material may be remineralized in the water column or in the sediments, transported without being altered off shelf towards the deep sea of the Arctic Interior or buried in marine sediments and hence sequestered from the contemporary carbon cycle. The fate of terrigenous material in the marine environment, though offering potentially important mechanisms to either strengthen or attenuate the permafrost-carbon climate feedback, is so far insufficiently understood.

In this doctoral thesis, sediments from the wide East Siberian Arctic Shelf, the world's largest shelf-sea system, were used to investigate some of the key processes for OC cycling. A range of bulk sediment properties, carbon isotopes and molecular markers were employed to elucidate the relative importance of different organic matter sources, the role of cross-shelf transport and the relevance of degradation during transport and after burial.

Overall, OC released from thawing permafrost constitutes a significant proportion of the sedimentary organic matter on the East Siberian Arctic Shelf. Two sediment cores from the inner and outer East Siberian Sea recorded no substantial changes in source material or clear trends in degradation status for the last century. With increasing distance from the coast, however, strong gradients were detected towards lower concentrations of increasingly reworked land-derived OC. The time spent during cross-shelf transport was consequently found to exert first-order control on degradation. Compound-specific radiocarbon dating on terrigenous biomarkers revealed a net transport time of ~4 000 years across the 600 km wide Laptev Sea shelf, yielding degradation rate constants for bulk terrigenous OC and specific biomarkers on the order of 2-4 kyr^{-1}.

From these results, the carbon flux released by degradation of terrigenous OC in surface sediments was estimated to be ~1.7 Gg yr^{-1}, several orders of magnitude lower than what had been quantified earlier for dissolved and particulate OC in the water column. Lower oxygen availability and close associations with the mineral matrix may protect sedimentary OC from remineralization and thereby weaken the permafrost-carbon feedback to present climate change.

Keywords: *organic carbon, marine sediments, East Siberian Sea, Laptev Sea, cross-shelf transport, degradation rate constants, carbon isotopes, terrestrial biomarkers, HMW wax lipids, lignin phenols, compound-specific radiocarbon analysis.*

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