Utilization, release, and long-term fate of ancient carbon from eroding permafrost coastlines

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Abstract

About 34% of global coast lines are underlain by permafrost. Rising temperatures cause an acceleration in erosion rates of up to 10s of meters annually, exporting increasing amounts of carbon and nutrients to the coastal ocean. The degradation of ancient organic carbon (OC) from permafrost is an important potential feedback mechanism in a warming climate. However, little is known about permafrost OC degradation after entering the ocean and its long term-fate after redeposition on the sea floor. Some recent studies have revealed CO_2 release to occur when ancient permafrost materials are incubated with sea water. However, despite its importance for carbon feedback mechanisms, no study has directly assessed whether this CO_2 release is indeed derived from respiration of ancient permafrost OC. We used a multi-disciplinary approach incubating Yedoma permafrost from the Lena Delta in natural coastal seawater from the south-eastern Kara Sea. By combining biogeochemical analyses, DNA-sequencing, ramped oxidation, pyrolysis and stable and radiocarbon isotope analysis we were able to: 1) quantify CO_2 emissions from permafrost utilization; 2) for the first time demonstrate the amount of ancient OC contributing to CO_2 emissions; 3) link the processes to specific microbial communities; and 4) characterize and assess lability of permafrost OC after redeposition on the sea floor. Our data clearly indicate high bioavailability of permafrost OC and rapid utilization after thawed material has entered the water column, while observing only minor changes in permafrost OC composition over time. Microbial communities are distinctly different in suspended Yedoma particles and water. Overall, our results suggest that under anthropogenic Arctic warming, enhanced coastal erosion will result in increased greenhouse gas emissions, as formerly freeze-locked ancient permafrost OC is remineralized by microbial communities when released to the coastal ocean.