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Geochemical characterization of coastal permafrost and estimation of organic matter fluxes to the Beaufort Sea via shoreline erosion near Drew Point, Alaska

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Background

Arctic coastlines are vulnerable to increased erosion rates due to increases in permafrost temperature, declines in sea ice extent, and increases in the length of the ice-free season. The long-term annual mean erosion rate along the Alaskan Beaufort Sea coast is 1.7 m [1].

Permafrost soils along the Beaufort Sea coast contain large stores of organic carbon (OC) and nitrogen (N). When these soils erode into the ocean, OC can be buried in nearshore sediments, transported off-shore as particulate organic carbon, or leached to produced dissolved organic carbon. Rapid decomposition of OC may quickly release greenhouse gases such as CO_2 and CH_4 to the atmosphere[2]. Terrestrial OC is also an important food subsidy for nearshore marine food webs[3].

Coastal erosion is likely a substantial source of OC to the Beaufort Sea. Quantifying historical fluxes of OC provides insight on future changes to regional and global carbon cycling.

Study Site: Drew Point, Alaska

Our study area, shown in **Figure 1**, is located approximately 100 km east of Utqiagvik, AK (formally known as Barrow). The coastline is characterized by exposed bluffs reaching elevations of 1.6-7.1 m. Surface permafrost has been subject to thaw-lake cycles throughout the Holocene.

Here, erosion rates have doubled since the mid 20th century, with annual rates averaging 17.2 m in the past decade[4].

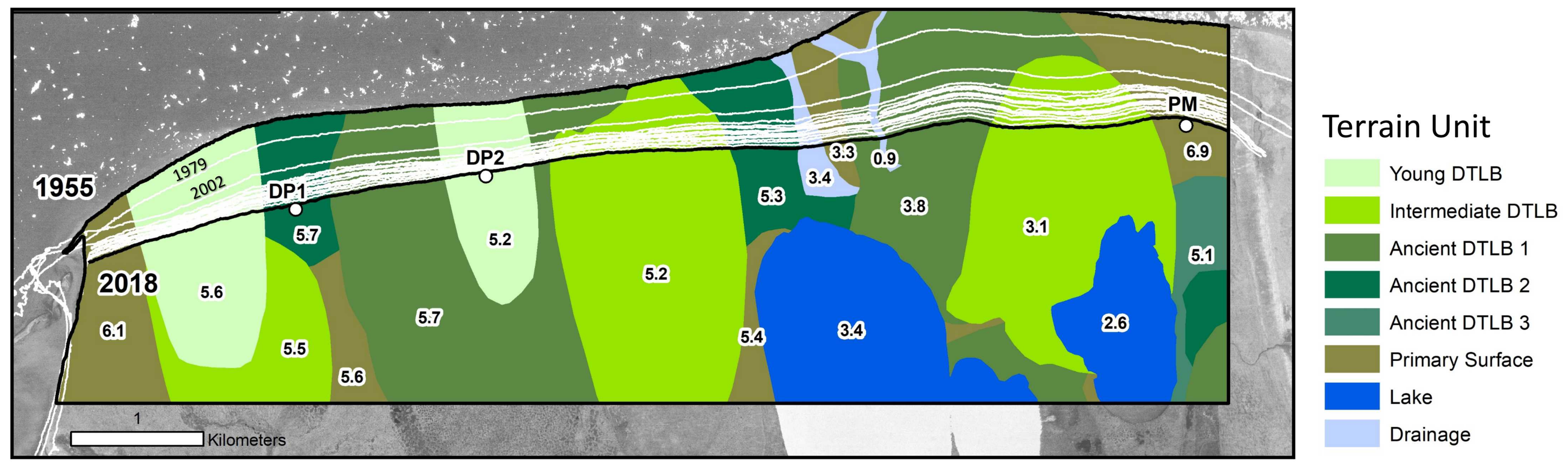

Figure 1. Map of study coastline near Drew Point, AK. Note coastline loss from 1955 to 2018. Landscape geomorphology is classified by age of drained thermokarst lake basins (DTLB), or as primary surface that has not been reworked by thaw-lake cycles. Numbers indicate average elevation (m) of each terrain unit. DP1, DP2, and PM indicate locations of permafrost cores.

Methods

Three permafrost cores, spanning from the tundra surface to below sea level, were subsectioned for geochemical and soil bulk density analyses. Using these data, in combination with geospatial analysis of landscape geomorphology, shoreline change, and elevation, we estimated fluxes of eroding OC from 1955 to 2018.

Results

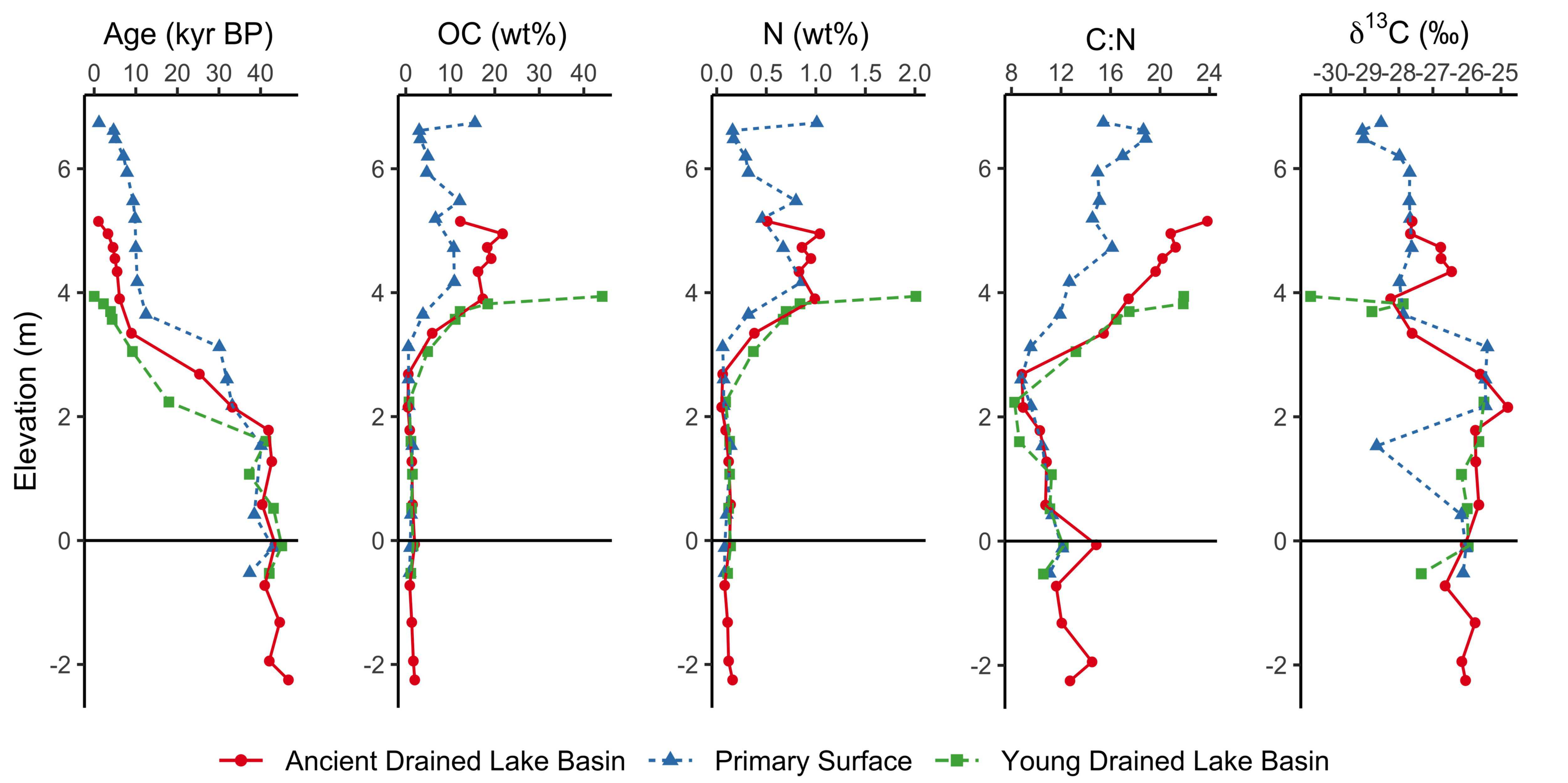

Figure 2. Radiocarbon dated bulk soil organic carbon, organic carbon (wt %), total nitrogen (wt %), carbon to nitrogen mass ratio (C:N), and δ^{13}C (‰) depth profiles for three permafrost cores. Colors and symbols indicate the terrain unit each core was sampled from. Black horizontal lines indicate mean local sea level.

A cryopeg, perennially unfrozen permafrost at temperatures below 0°C due to high salinity, was found at sea level and below.

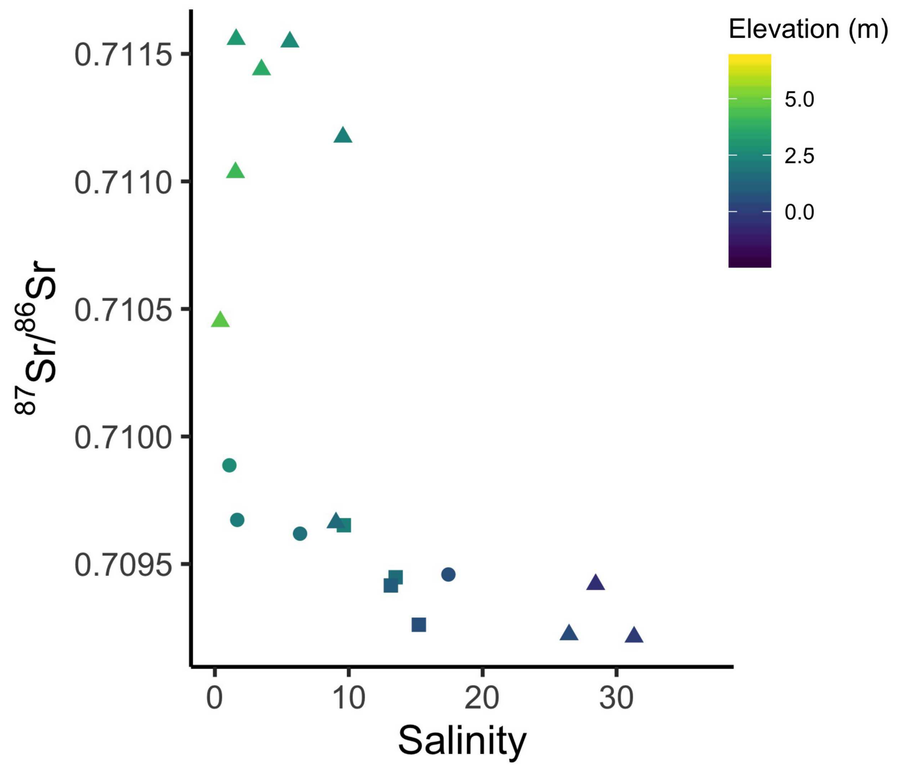

Figure 3. Relationship between porewater ^{87}Sr/^{86}Sr (‰) and porewater salinity (psu). Color indicates elevation (m) and symbols indicate the terrain unit each core was sampled from (see Fig 2).

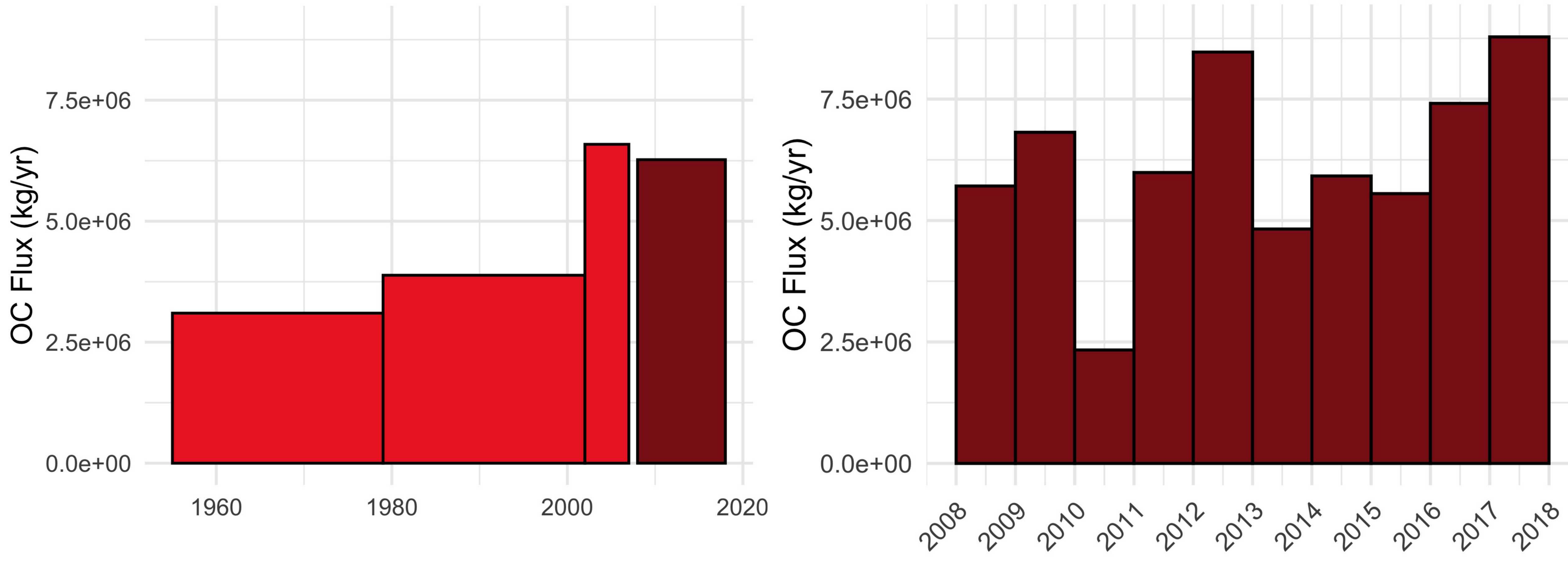

Figure 4. Estimation of organic carbon fluxes to the ocean (kg OC/yr), over four time steps from 1955 to 2018, and over annual time steps from 2008 to 2018.

Discussion

- Eroding soil OC ranges in age from modern to 47 kyr BP, with rapid accumulation of organic-rich soils since 12 kyr BP (**Figure 2**).
- Permafrost cores show that bluffs store as much as 220 kg OC m^{-2}.
- %OC, C:N, and δ^{13}C results from permafrost cores (**Figure 2**) indicate relict marine sediments below an elevation of ~3 m, deposited during the Simpsonian marine transgression (Flaxman member of the Gubik formation)[5].
- ^{87}Sr/^{86}Sr data (**Figure 3**) suggest that high salinity porewaters at depth are due to a combination of brine rejection during ice formation and residual seawater from relict marine sediments.
- Erosion rates and OC fluxes are notably greater during the past two decades, compared to historical data (1955-2007) (**Figure 4**).
- We estimate that annual OC fluxes from this 9 km coastline averaged ~6 Mg over the past decade (**Figure 4**). This is on the same order of magnitude as annual particulate organic carbon fluxes from the Sagavanirktok (~2.7 Mg) and Kuparuk (~1.5 Mg) Rivers, the second and third largest rivers that drain into the Alaskan Beaufort Sea[6].

Acknowledgements

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