# Fate of OC in the Arctic nearshore zone: Rapid removal and degradation due to hydrodynamic and ice-related sediment transport

Boris Radosavljevic[1, 2, 4],
Nicole Couture[3],
Ulrike Herzschuh[1,2],
Hugues Lantuit[1,2],
Christian Knoblauch[5],
Michael Fritz[1]

[1]*Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Potsdam, Germany, boris.radosavljevic@gmail.com;* [2]*Institute of Earth- and Environmental Science, University of Potsdam, Potsdam, Germany;* [3]*Northern Canada Division, Geological Survey of Canada, Ottawa, Canada;* [4]*GFZ German Research Centre for Geosciences, Potsdam, Germany;* [5]*Institute of Soil Science, University of Hamburg, Hamburg, Germany*

## Abstract

The present study investigated the fate of terrestrial carbon in shallow coastal areas. Surface sediment samples near Herschel Island, Yukon, Canada, were collected to infer sediment- and organic matter (OM) transport processes and to determine the origin and state of degradation of organic carbon. We determined total organic carbon (TOC), total nitrogen (TN), TOC:N ratios, stable carbon isotopes ($\delta^{13}C$), and grain size distributions. Sediments are predominantly silty, moderately to poorly sorted mud (<64 μm fraction). A significant correlation of TOC (mean: 1.02 % wt.) was found with mud content (silt and clay). Sediments are largely of terrestrial origin (up to 70% of the total carbon pool), yet contain up to 90% less TOC than terrestrial sediments in the area, suggesting rapid offshore transport and degradation.

**Keywords:** Arctic Ocean, organic carbon, stable isotopes, sediment chemistry, sediment transport, Beaufort Sea

## Introduction

Fluxes from the permafrost carbon pool (1300±200 Pg of carbon in the upper 3 m) occur via permafrost degradation, microbial mineralization, river discharge, and coastal erosion (e.g. Macdonald et al., 2015; Rachold et al., 2000). Particular organic carbon fluxes into nearshore areas resulting from coastal erosion are estimated at 4.9-14.0 Tg $a^{-1}$ (Wegner et al., 2015), corresponding to the annual amount discharged by rivers (Rachold et al., 2004). The nearshore zone (< 20 m depth) accounts for 20% of the shelf area in the Arctic (Fritz et al., 2017) and constitutes a key interface in the land to ocean transition, yet the fate of terrestrial carbon in the arctic nearshore is not fully understood.

We determined the patterns of sediment and OM distribution, identified responsible processes, and provide new information on the contribution and fate of terrestrial carbon in an arctic nearshore environment through the application of sedimentological and geochemical methods.

## Study Area

Nearshore areas were sampled off Herschel Island (69°36`N; 139°04`W), in particular an embayment southeast and a shallow lagoon southwest of the island. The island is composed of perennially frozen marine and glacigenic sediments (Lantuit and Pollard, 2008), ground ice contents reach up to 60-70 % by volume in the upper 10-15 m (Pollard, 1990). Coastal retreat releases significant amounts of organic carbon to the nearshore. Organic carbon contents in island sediments range from 0.6-38.9 % wt. (Couture, 2010; Fritz et al., 2012).

## Methods

Sedimentological and geochemical analyses were carried out on samples obtained using a Van Veen grab sampler during 2012 and 2013 summer expeditions by the Alfred Wegener Institute (AWI). We analyzed grain size distributions (GSDs), and bulk geochemical parameters, i.e. total organic content (TOC), nitrogen (N), and stable carbon isotope composition. Radosavljevic et al. (2016) provide a detailed methodology.

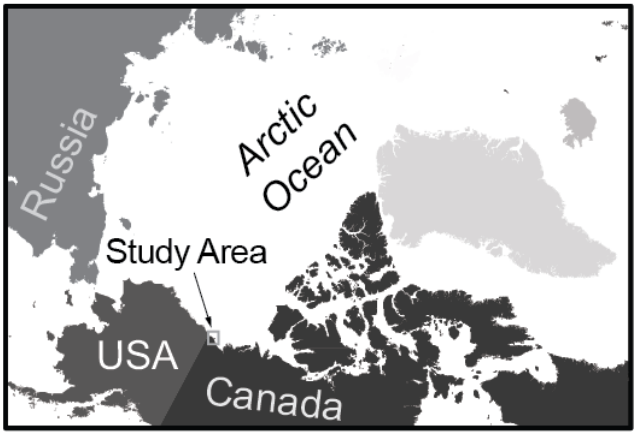


Figure 1 Location of Herschel Island in the Canadian Beaufort Sea

## Results

Approximately 200 samples were analyzed (Table 1).

Table 1 Results of grain size and bulk geochemical analyses and their standard deviations (in parentheses) shown by Thetis Bay (TB) and Workboat Passage (WBP) locations.

| | Location | | |
|---|---|---|---|
| Parameter | TB | WBP | Overall |
| mean [ϕ] | 5.30 (1.72) | 4.44 (1.23) | 5.20 (1.68) |
| sorting [σ i] | 2.07 (0.49) | 2.09 (0.35) | 2.07 (0.48) |
| TOC (% wt.) | 1.03 (0.92) | 0.97 (0.62) | 1.02 (0.88) |
| TIC (% wt.) | 1.17 (0.37) | 1.65 (0.31) | 1.23 (0.39) |
| TN (% wt.) | 0.15 (0.05) | 0.14 (0.02) | 0.15 (0.05) |
| TOC:N (atomic) | 11.06 (3.30) | 11.63 (2.24) | 11.13 (3.18) |
| $\delta^{13}C$ (‰) | -26.32 (0.38) | -26.55 (0.25) | -26.35 (0.37) |

## Discussion and Summary

The data gathered in this study show both hydrodynamic- and ice-related processes affect the spatial grain size variation. Ice processes are evident in the generally moderate to poor sorting beyond the 4 m contour. TOC concentration in nearshore sediments is ~90% lower than concentrations found in terrestrial sediments along the Yukon Coast and Herschel Island. We found a correlation with mud content since physical processes tend to focus OM in the fine fraction, where greater mineral surface area also aids sorption of OM (e.g. Blair and Aller, 2012). We conclude that while degradation occurs in the nearshore, some portion of the terrestrial carbon is transported offshore as suspended load. The isotope end member model is questionable, yet it indicates the significant contribution of terrestrial plants to benthic OM.

## Acknowledgments

This work was funded by the Helmholtz Association (grant no. VH-NG-801 to H.L.). The work of M.F. was supported by the Daimler and Benz Foundation (grant no. 32-02/15). We are grateful to Yukon Government, Yukon Parks (Herschel Island Quiqiktaruk Territorial Park), and the Aurora Research Institute for their support during this project.

## References

Blair, N. E. and Aller, R. C.: The fate of terrestrial organic carbon in the marine environment, Annu. Rev. Mar. Sci., 4, 401–423, 2012.

Couture, N.: Fluxes of Soil Organic Carbon from Eroding Permafrost Coasts, Canadian Beaufort Sea, PhD Dissertation, Department of Geography, McGill University, Montreal., 2010.

Fritz, M., Vonk, J. E. and Lantuit, H.: Collapsing Arctic coastlines, Nat. Clim Change, 7(1), 6–7, 2017.

Lantuit, H. and Pollard, W. H.: Fifty years of coastal erosion and retrogressive thaw slump activity on Herschel Island, Southern Beaufort Sea, Yukon Territory, Canada, Geomorphology, 95(1), 84–102, doi:10.1016/j.geomorph.2006.07.040, 2008.

Macdonald, R. W., Kuzyk, Z. Z. A. and Johannessen, S. C.: The vulnerability of Arctic shelf sediments to climate change, Environ. Rev., 23(4), 461–479, doi:10.1139/er-2015-0040, 2015.

Pollard, W. H.: The nature and origin of ground ice in the Herschel Island area, Yukon Territory, in Proceedings, Fifth Canadian Permafrost Conference, Québec, pp. 23–30., 1990.

Rachold, V., Grigoriev, M. N., Are, F. E., Solomon, S., Reimnitz, E., Kassens, H. and Antonow, M.: Coastal erosion vs riverine sediment discharge in the Arctic Shelf seas, Int. J. Earth Sci., 89(3), 450–460, 2000.

Rachold, V., Eicken, H., Gordeev, V. V., Grigoriev, M. N., Hubberten, H.-W., Lisitzin, A. P., Shevchenko, V. P. and Schirrmeister, L.: Modern terrigenous organic carbon input to the Arctic Ocean, in The organic carbon cycle in the Arctic Ocean, pp. 33–55, Springer., 2004.

Wegner, C., Bennett, K. E., de Vernal, A., Forwick, M., Fritz, M., Heikkilä, M., Łącka, M., Lantuit, H., Laska, M., Moskalik, M., O'Regan, M., Pawłowska, J., Promińska, A., Rachold, V., Vonk, J. E. and Werner, K.: Variability in transport of terrigenous material on the shelves and the deep Arctic Ocean during the Holocene, Polar Res., 34(1), 24964, doi:10.3402/polar.v34.24964, 2015.