

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung,
Forschungsstelle Potsdam, Sektion für Periglazialforschung
&
Universität Potsdam,
Institut für Erd- und Umweltwissenschaften

Fate of organic matter mobilized from eroding permafrost coasts

Dissertation
zur Erlangung des akademischen Grades
"doctor rerum naturalium"
(Dr. rer. nat.)
in der Wissenschaftsdisziplin "Geomorphologie"

eingereicht an der
Mathematisch-Naturwissenschaftlichen Fakultät
der Universität Potsdam

von
George Tanski

Potsdam, den 24.04.2017

Table of contents

Abstract..... V

Zusammenfassung..... VII

Abbreviations and nomenclature..... IX

1. Introduction 1

 1.1 Scientific background..... 2

 1.1.1 Permafrost and ground ice..... 2

 1.1.2 Organic carbon pools and fluxes into the Arctic Ocean..... 3

 1.1.3 Climate warming and permafrost thaw 5

 1.1.4 Permafrost degradation and coastal erosion 6

 1.1.5 Study area Yukon coast and *Qikiqtaruk*..... 7

 1.2 Knowledge gaps 9

 1.3 Aims and objectives 10

 1.4 Thesis structure and author’s contribution 10

2. Eroding permafrost coasts release low amounts of dissolved organic carbon (DOC) from ground ice into the nearshore zone of the Arctic Ocean 13

 2.1 Abstract 14

 2.2 Introduction 14

 2.3 Study area..... 16

 2.4 Methods..... 17

 2.4.1 Field work..... 17

 2.4.2 DOC concentration..... 18

 2.4.3 DOC flux estimation..... 19

 2.5 Results 22

 2.5.1 Segmentation of the coast – literature synthesis..... 22

 2.5.2 DOC concentration..... 23

 2.5.3 DOC stocks and fluxes 24

 2.6 Discussion 27

 2.6.1 DOC concentrations in ground ice 27

 2.6.2 DOC fluxes from the YC..... 30

 2.6.3 DOC fluxes and the Arctic carbon budget..... 30

 2.7 Conclusion and Outlook..... 32

 2.8 Acknowledgements 33

3. Transformation of terrestrial organic matter along thermokarst-affected permafrost coasts in the Arctic.....	34
3.1 Abstract	35
3.2 Introduction	36
3.3 Study area.....	38
3.3 Methods.....	39
3.3.1 Field work.....	39
3.3.2 Sedimentology, stratigraphy, and vegetation	42
3.3.3 Organic matter	43
3.3.4 Statistics.....	44
3.3.5 Transformation of organic matter.....	44
3.3.6 Fate of organic matter in the nearshore zone.....	46
3.4 Results	46
3.4.1 Sedimentology, stratigraphy, and vegetation	46
3.4.2 Organic matter	48
3.4.3 C/N-ratios and $\delta^{13}\text{C}$	51
3.4.4 Biomarkers	54
3.5 Discussion	56
3.5.1 Transformation of organic matter in the disturbed zone	56
3.5.2 Fate of organic matter in the nearshore zone.....	60
3.5.3 Environmental impact of the RTS.....	61
3.6 Conclusion.....	62
3.7 Acknowledgements	62
4. Rapid greenhouse gas release from eroding permafrost coasts	64
4.1 Summary	65
4.2 Background	65
4.3 Study site	67
4.4 Sampling and incubation set up.....	67
4.5 Findings and discussion.....	68
4.6 Conclusion.....	71
4.7 Methods.....	71
4.7.1 Incubation conditions	71
4.7.2 Gas measurements.....	72
4.7.3 Geo- and hydrochemical analysis.....	72
4.8 Acknowledgements	73

5. Synthesis	74
5.1 Mobilization of permafrost OC pools by coastal erosion.....	76
5.2 Transformation of permafrost OM on transit from land to sea	79
5.3 Fate and pathways of permafrost OC in the nearshore zone	82
5.4 Conclusion and outlook.....	84
References	86
Appendix I: Dissolved organic carbon (DOC) in Arctic ground ice	A-1
I-1 Abstract.....	A-2
I-2 Introduction.....	A-2
I-3 Study area and study sites.....	A-4
I-4 Material and methods	A-10
I-4-1 Laboratory analyses.....	A-10
I-4-2 Statistical methods.....	A-11
I-5 Results	A-11
I-5-1 DOC and DIC concentrations.....	A-11
I-5-2 Correlation matrix	A-13
I-5-3 Principal components	A-14
I-5-4 Univariate Tree Model (UTM).....	A-15
I-6 Discussion.....	A-17
I-6-1 DOC stocks in ground ice and relevance to carbon cycling.....	A-17
I-6-2 Carbon sequestration and origin in relation to inorganic geochemistry	A-19
I-6-3 DOC mobility and quality upon permafrost degradation	A-21
I-7 Conclusions and outlook.....	A-24
I-8 Acknowledgements.....	A-24
Appendix II: Supplementary material for Chapter 2	A-26
II-1 Supplementary table – Ground ice and geochemical data.....	A-27
II-2 Supplementary table – Coastal segments and DOC flux.....	A-31
Appendix III: Supplementary material for Chapter 3	A-33
III-1 Normalized Differenced Vegetation Index map	A-34
III-2 Photograph of a massive ice bed in a RTS.....	A-35
III-3 Calculation of biomarker proxies.....	A-36
III-4 Supplementary table – Summary of geochemical data	A-37
III-5 Supplementary table – Summary of statistical analysis	A-42
Appendix IV: Supplementary material for Chapter 4	A-45
IV-1 Design of the incubation experiment	A-46
IV-2 Photograph of a standard incubation set up	A-47
IV-3 Conversion of gas amounts into mass.....	A-47

Table of contents

IV-4 Total and daily aerobic CH ₄ production	A-48
IV-5 Histogram summarizing OC losses and CO ₂ emissions.....	A-49
IV-6 Supplementary table – Summary of TOC, DOC, and pH data	A-50
IV-7 Supplementary table – Summary of TN, TOC/TN, and δ ¹³ C-TOC data	A-51
IV-8 Supplementary table – Summary of total CO ₂ and CH ₄ production data	A-52
IV-9 Supplementary table – Comparison of incubation set ups	A-52
IV-10 Supplementary table – Summary of daily CO ₂ production data	A-53
IV-11 Supplementary table – Summary of daily CH ₄ production data	A-54
Acknowledgements – Danksagung.....	A-55
Eidesstaatliche Erklärung	A-57