Estuarine, Coastal and Shelf Science 86 (2010) 31–41

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Origin and fate of particulate organic matter in the southern Beaufort Sea – Amundsen Gulf region, Canadian Arctic

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ARTICLE INFO

Article history:
Received 5 February 2009
Accepted 10 September 2009
Available online 17 September 2009

Keywords:
organic matter
carbon
nitrogen
sediment
stable isotopes
Arctic ocean
Beaufort Sea
Amundsen Gulf
Mackenzie Shelf

ABSTRACT

To establish the relative importance of terrigenous and marine organic matter in the southern Beaufort Sea, we measured the concentrations and the stable isotopic compositions of organic carbon and total nitrogen in sediments and in settling particles intercepted by sediment traps. The organic carbon content of surface sediment in the Chukchi and southern Beaufort Seas ranged from 0.6 to 1.6% dry wt., without a clear geographical pattern. The C_{ORG}:N_{TOT} ratio ranged from 7.0 to 10.4 and did not vary significantly downcore at any one station. Values of $\delta^{13}C_{ORG}$ and $\delta^{15}N_{TOT}$ in the sediment samples were strongly correlated, with the highest values, indicative of a more marine contribution, in the Amundsen Gulf. In contrast, the organic matter content, elemental (C_{ORG}:N_{TOT} ratio) and isotopic ($\delta^{13}C_{ORG}$ and $\delta^{15}N_{TOT}$) composition of the settling particles was different from and much more variable than in the bottom sediments. The isotopic signature of organic matter in the Beaufort Sea is well constrained by three distinct end-members: a labile marine component produced *in situ* by planktonic organisms, a refractory marine component, the end product of respiration and diagenesis, and a refractory terrigenous component. A three-component mixing model explains the scatter observed in the stable isotope signatures of the sediment trap samples and accommodates an apparent two-component mixing model of the organic matter in sediments. The suspended matter in the water column contains organic matter varying from essentially labile and marine to mostly refractory and terrigenous. As it settles through the water column, the labile marine organic matter is degraded, and its original stable isotope signature changes towards the signature of the marine refractory component. This process continues in the bottom sediment with the result that the sedimentary organic matter becomes dominated by the refractory terrigenous and marine components.

1. Introduction

The changing climate in the Arctic is decreasing the extent and thickness of the ice cover, increasing the length of the ice-free season in the Arctic Ocean, and modifying the production rate and fluxes of marine organic carbon to the seafloor (Arrigo et al., 2008; Comiso et al., 2008; Haas et al., 2008; Boe et al., 2009; Lavoie et al., 2009; Overland, 2009). The changing climate is also altering the timing and magnitude of river discharge and coastal erosion, and the delivery of terrigenous organic carbon to the Arctic Ocean (Peterson et al., 2002; Déry et al., 2009; Jones et al., 2009; Spencer et al., 2009). In consequence, the relative importance of the fluxes of terrestrial and marine organic carbon to the seafloor will likely

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doi:10.1016/j.ecss.2009.09.009

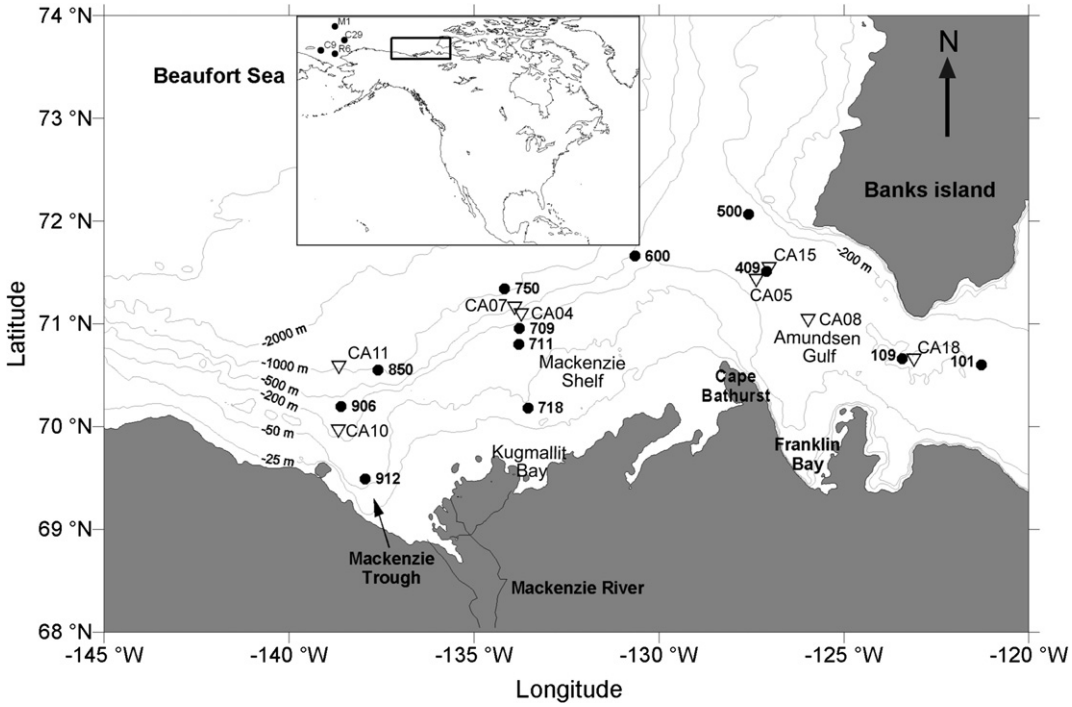

Fig. 1. Map of the CASES survey area. Stations 101, 109, 500 and 718 were sampled during Leg 2 (Oct–Nov 2003). All other stations were sampled during Leg 8 (Jun–Aug 2004). The black filled circles correspond to stations where sediment cores were retrieved. The four smaller black dots in the upper left inset correspond to stations sampled in the Chukchi Sea during the First (stations C9 and C29 – Aug 1999) and Second (stations R6 and M1 – Jul 2003) Chinese National Arctic Research Expeditions. The empty triangles refer to stations were sediment traps were deployed.

change, as will the processing and preservation of organic carbon in Arctic sediments (Katsev et al., 2006).

Shallow continental shelf regions account for about 50% of the total surface area of the Arctic Ocean, which sets the Arctic apart from other oceans (Jakobsson et al., 2004), and allows a much larger proportion of the particulate organic matter that settles through the water column to reach the seafloor without being significantly degraded (Jahnke, 1996). Outside of the Mackenzie River plume and occasional nepheloid layers, most of the particulate organic carbon encountered in the water column of the Mackenzie Shelf is marine (Goñi et al., 2005; Forest et al., 2007), even though the Mackenzie River contributes vast quantities of terrigenous organic carbon to the Beaufort Sea (Rachold et al., 2004). Despite the predominantly marine provenance of the suspended organic carbon, the shelf sediments appear to be dominated by terrigenous organic carbon (Goñi et al., 2005). The organic carbon that is ultimately preserved in Beaufort Sea sediments may thus bear little resemblance to the material settling through the water column.

The primary objective of our study was to evaluate the influence of the Mackenzie River on the composition, distribution, and reactivity of sedimentary organic carbon in the southern Beaufort Sea – Amundsen Gulf region. To this end, we traced the origin and fate of terrigenous and marine organic matter in the water column and sediment on the basis of its elemental (C_{ORG}:N_{TOT} ratio) and stable isotope ($\delta^{13}C_{ORG}$ and $\delta^{15}N_{TOT}$) composition. We also provide a reference state relative to which modifications resulting from climatic change can be evaluated.

2. Study area

The study area includes the Mackenzie Shelf, the adjacent continental slope to a depth of ~1000 m, and the Amundsen Gulf (Fig. 1).

Table 1
Sediment trap data obtained during the 2003–2004 sampling year. All results are averages over the sampling period.

Stations	Depth (m)	Sampling period	Suspended particulate matter ($mg\,m^{-2}\,d^{-1}$)	C_{ORG} ($mg\,m^{-2}\,d^{-1}$)	C_{ORG} (%)	N_{TOT} ($mg\,m^{-2}\,d^{-1}$)	N_{TOT} (%)	$\delta^{13}C_{ORG}$ (‰)	$\delta^{15}N_{TOT}$ (%)	C_{ORG}:N_{TOT} (molar ratio)
CA10	105	07 Oct 2003–08 Sep 2004	718	19.0	2.6	2.3	0.3	−26.5	5.8	9.5
CA11	102	06 Oct 2003–08 Sep 2004	323	12.7	4.0	1.7	0.5	−26.8	6.9	8.9
CA04	109	04 Aug 2003–07 Sep 2004	104	7.7	7.5	1.3	1.2	−26.0	10.3	7.1
	214	04 Oct 2003–04 Aug 2004	182	4.8	3.8	0.5	0.4	−25.5	5.7	10.1
CA07	94	04 Aug 2003–07 Sep 2004	62	7.6	12.6	1.2	1.9	−26.8	10.1	7.7
	200	04 Oct 2003–04 Aug 2004	74	3.3	4.1	0.4	0.5	−25.7	6.5	9.3
CA05	105	13 Oct 2003–28 Jul 2004	147	10.8	8.4	1.4	1.1	−26.3	15.8	8.9
CA15	108	11 Oct 2003–22 Jul 2004	81	6.2	7.6	1.0	1.2	−25.6	14.8	7.1
	212	11 Oct 2003–22 Jul 2004	58	3.0	6.0	0.5	1.0	−25.5	10.7	7.3
CA08	108	13 Oct 2003–18 Jul 2004	129	9.2	7.4	1.5	1.2	−25.3	13.8	7.1
CA18	109	14 Oct 2003–29 Jul 2004	73	8.6	12.5	1.6	2.3	−24.5	11.9	6.4
	413	14 Oct 2003–29 Jul 2004	144	3.9	2.4	0.5	0.3	−25.3	6.7	9.5