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Distribution of detrital minerals and sediment color in western Arctic Ocean and northern Bering Sea sediments: Changes in the provenance of western Arctic Ocean sediments since the last glacial period

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ABSTRACT

This paper describes the distribution of detrital minerals and sediment color in the surface sediments of the western Arctic Ocean and the northern Bering Sea and investigates the relationship between mineral composition and sediment provenance. This relationship was used to determine the provenance of western Arctic Ocean sediments deposited during the last glacial period. Sediment color is governed by water depth, diagenesis, and mineral composition. An a*–b* diagram was used to trace color change during diagenesis in the Arctic Ocean sediments. The mineral composition of surface sediments is governed by grain size and provenance. The feldspar/quartz ratio of the sediments studied was higher on the Siberian side than on the North American side of the western Arctic Ocean. The (chlorite + kaolinite)/illite and chlorite/illite ratios were high in the Bering Sea but decrease northwards in the Chukchi Sea. Thus, these ratios are useful for provenance studies in the Chukchi Sea area as indices of the Beaufort Gyre circulation and the Bering Strait inflow. The sediments deposited during the last glacial period have a lower feldspar/quartz ratio and a higher dolomite intensity than Holocene sediments on the Chukchi Plateau, suggesting a greater contribution of North American grains during the last glacial period.

1. Introduction

Changes in the system of currents regulate the fate of sea ice in the Arctic Ocean, and are involved in the processes of global climate change via the ice-albedo feedback and the delivery of freshwater to the North Atlantic Ocean (Miller et al., 2010; Screen and Simmonds, 2010). The system of currents in the Arctic Ocean consists of the Beaufort Gyre (BG) and the Transpolar Drift (TPD), which are driven by surface winds (Proshutinsky and Johnson, 1997; Rigor et al., 2002). The Beaufort Sea exports much of its ice to the eastern Arctic Ocean via the BG. The TPD carries the sea ice from the eastern Arctic Ocean to the Atlantic via the Fram Strait. The Bering Strait inflow (BSI) is also an important element that transports heat and freshwater from the Bering Sea to the Chukchi Sea (e.g., Weingartner et al., 2005; Woodgate and Aagaard, 2005; Woodgate et al., 2005a,b; Shimada et al., 2006). Shimada et al. (2006) suggested that the inflow of warm Pacific water causes catastrophic changes in sea ice stability in the western Arctic Ocean.

The mineral composition of sediments has been used to reconstruct the ocean circulation, sea ice drift, and iceberg

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Table 1
Surface sediment samples.

Leg	Core	Latitude (°N)	Longitude (°E)	Water depth (m)	Location	Lithology
ARA03B	41	82.3200	171.5200	2758	Makarov basin	Clayey silt
ARA03B	18	79.0000	174.0000	2452	Makarov basin	Clayey silt
ARA03B	16	78.5000	−177.7500	1228	Arlis plateau	Clayey silt
ARA02B	06[a]	78.0055	−168.3589	453	Chukchi plateau	Clayey silt
ARA02B	09	77.9999	−179.3347	1577	Arlis plateau	Clayey silt
ARA02B	11	77.9997	173.9981	1596	East siberian slope	Clayey silt
ARA02B	08	77.9991	−175.6784	1375	Arlis plateau	Clayey silt
ARA03B	19	77.9700	173.0400	1091	East Siberian slope	Clayey silt
ARA03B	30	77.0800	−172.2900	2013	Chukchi Abyssal plain	Clayey silt
ARA03B	29	77.0100	−177.3600	1396	Arlis plateau	Clayey silt
ARA02B	15	76.4023	−179.3416	1803	Arlis plateau	Clayey silt
ARA02B	16A	76.3994	−176.2174	337	Chukchi Abyssal plain	Clayey silt
ARA02B	16B	76.3994	−176.2174	1073	Chukchi Abyssal plain	Clayey silt
ARA02B	18A	76.2885	−167.1604	435	Chukchi plateau	Clayey silt
ARA02B	18B	76.2885	−167.1604	406	Chukchi plateau	Clayey silt
ARA03B	28	76.2200	−179.8400	1179	Arlis plateau	Clayey silt
ARA02B	13[a]	76.0040	174.0003	340	East Siberian slope	Clayey silt
ARA01B	25	76.0008	−159.0007	820	Northwind ridge	Clayey silt
ARA01B	21	75.9981	−156.0156	920	Northwind ridge	Clayey silt
ARA01B	27	75.9695	−160.0028	2100	Northwind ridge	Clayey silt
ARA03B	27	75.5200	178.7800	678	East Siberian slope	Clayey silt
ARA01B	32	75.4963	−163.0149	1920	Northwind Abyssal plain	Clayey silt
ARA03B	26	75.3700	177.2900	354	Arlis plateau	Clayey silt
ARA02B	03B	75.1165	−166.3405	455	Chukchi plateau	Clayey silt
ARA02B	03A[a]	75.1079	−166.3405	423	Chukchi plateau	Clayey silt
ARA01B	13	75.0175	−156.0072	3900	Northwind ridge	Clayey silt
ARA01B	08	75.0006	−159.0005	1993	Northwind ridge	Clayey silt
ARA01B	05	74.9987	−159.0167	940	Northwind ridge	Clayey silt
ARA02B	02[a]	74.2989	−167.6520	320	Chukchi slope	Silt
ARA01B	04	73.7349	−167.0042	43	Chukchi shelf	clayey silt
ARA02B	01B	73.6343	−166.5065	119	Chukchi shelf	Silt
ARA02B	01A[a]	73.6314	−166.5183	123	Chukchi shelf	Silt
MR06	12EX	73.5998	−166.0007	53	Chukchi shelf	Sandy silt
ARA01B	03	73.5193	−166.0163	113	Chukchi shelf	Silt
ARA01B	01	73.1289	−168.0156	72.5	Chukchi shelf	Silt
MR06	12	72.4322	−166.9642	51	Chukchi shelf	Sandy silt
MR06	13	72.0007	−165.9995	46	Chukchi shelf	Sandy silt
MR06	14	70.9997	−165.9975	43	Chukchi shelf	Sandy silt
MR06	15	69.9998	−168.0002	48	Chukchi shelf	Sandy silt
MR00	15	69.7562	−138.1627	163	Mackenzie estuary	
MR06	16	68.5005	−167.9992	54	Chukchi shelf	Silty sand
MR06	17	66.9998	−166.9992	40	Chukchi shelf	Sandy silt
MR06	18	63.9998	−169.0030	35	Bering shelf	Sand
MR06	B52	63.9000	−166.2000		Bering shelf	
MR00	7	63.5017	−165.4998	21.3	Bering shelf	
MR06	19	63.0003	−167.4990	33	Bering shelf	Sand
OS	5	62.9600	−164.9200		Yukon estuary	Sand
OS	P2	62.8800	−165.0800		Yukon estuary	Sand
OS	1	62.8500	−164.9600		Yukon estuary	Sand
OS	P1	62.8400	−164.8800		Yukon estuary	Sand
MR06	22	62.0052	−176.0027	98	Bering shelf	Sandy silt
MR06	21	62.0007	−172.0005	56	Bering shelf	Silty sand
MR06	23	60.1587	−179.4633	1004	Bering slope	Silty sand
MR06	25	60.0748	−179.4632	1158	Bering slope	Silty sand
MR06	26	59.9997	−176.0000	132	Bering shelf	Sandy silt
MR06	30	58.5002	−172.0002	101	Bering shelf	Sandy silt
MR06	31	58.3832	−170.0007	74	Bering shelf	Silty sand
MR06	32	57.0003	−167.5005	77	Bering shelf	Sand

[a] Whole core analyzed (rather than just core top as for other samples).

discharge in the Arctic Ocean (e.g., Bischof et al., 1996; Bischof and Darby, 1997; Vogt, 1997). Spatial variation in mineral composition is found in Arctic shelf sediments. Accordingly, we can potentially identify the provenance of sediments by analyzing their mineral composition (e.g., Naidu et al., 1982; Naidu and Mowatt, 1983; Stein et al., 1994; Bischof et al., 1996; Vogt, 1997; Wahsner et al., 1999; Kalinenko, 2001; Stein, 2008; Ortiz et al., 2009; Darby et al., 2011; Nwaodua et al., 2014). Using the spatial variability of detrital minerals, the ocean circulation and ice drift patterns have been reconstructed to reveal late Pleistocene changes (Stein et al., 2010a,b), glacial–interglacial contrasts (Bischof and Darby, 1997; Phillips and Grantz, 2001; Vogt et al., 2001; Darby and Bischof, 2002), and Holocene changes in the TPD and BG configuration (Darby and Bischof, 2004; Darby et al., 2012) and the Bering Strait inflow (Ortiz et al., 2009).

The Chukchi Sea is located in the region where the BSI meets the BG circulation. Thus, the Chukchi Sea and the adjacent seas are suitable areas in which to investigate the evolution of the BG circulation and the BSI. In the present study, we examined the distribution of detrital minerals in surface sediments from the western Arctic Ocean, the Bering Sea, and the Yukon and Mackenzie River estuaries with the aim of determining the relationship between