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Two modes of clay-mineral dispersal pathways on the continental shelves of the East Siberian Sea and western Chukchi Sea

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ABSTRACT: The distribution of clay-mineral abundances on the inner continental shelves of the East Siberian and western Chukchi Seas well confirms to the dominant regional circulation pattern. The clay mineralogical analysis distinctly shows the two principal sources and dispersal pathways of these clay-mineral assemblages. The latitudinal (i.e., depth dependence) and longitudinal (i.e., source dependence) transition between clay-mineral assemblages explains that the illite-rich mineral assemblage derived largely from the Kolyma River is likely transported along the inner continental shelf by the eastward-flowing Siberian Coastal Current in the East Siberian Sea. Another assemblage of smectite- and kaolinite-rich sediments mostly derived ultimately from the Yukon River extends toward the Long Strait through the Bering Strait from the northern Bering Sea. In addition, sensitive variations in the clay-mineral assemblages reflect the association with water depth, which underscores the transportation and dispersal patterns to form the modern fine-grained sedimentary blankets.

Key words: clay mineral, sediment transport, fine-grained sedimentation, East Siberian Sea, Chukchi Sea, Arctic Ocean

1. INTRODUCTION

Clay minerals in the marine environments have been regarded as an important sediment ingredient enriched in heavy metals and other pollutants because they are relatively stable without significant mineralogical and chemical transformations during transport and after deposition (e.g., Chamley, 1989; Weaver, 1989). Such particle property proves an excellent tracer for sediment transport over long distances. The investigation of the transport pathways of fine-grained sediments is of interest for two reasons. First, it is an oceanographic interest to discern the source of the fine-grained particles, and second, it is significant information to predict the dispersal pathways of pollutants that are preferentially concentrated in these fine-grained sediments. Therefore, studies on the clay-mineral assemblages yield useful clues for deciphering the sediment provenances as well as their dispersal patterns.

Fine-grained sediments of different origins can be often discriminated in terms of their clay-mineral associations, because the composition and relative abundance of clay minerals are controlled by their source rocks and weathering conditions (Grim, 1968; Chamley, 1989). The clay-mineral distribution in the continental shelf environment is largely influenced by depositional processes, especially the dominant flow patterns, and the settling of clay minerals in response to the energy conditions. A number of studies have shown that the spatial and temporal variations of clay-mineral abundances help investigate the sediment sources and provenances (Murty and Rao, 1989; Khim and Park, 1992; Segall and Kuehl, 1992; Fagel et al., 1996). In particular, clay-mineral data in the Arctic Ocean are mostly available for shelf areas of the Bering Sea, Chukchi Sea, Laptev Sea, Barents Sea and Kara Sea (Fig. 1; Wright, 1974; Naugler et al., 1974; Darby, 1975; Naidu et al., 1982; Naidu and Mowatt, 1983; Moser and Hein, 1984; Wollenburg, 1993; Stein et al., 1994; Nürnberg et al., 1994, 1995; Kalinenko et al., 1996; Wahsner et al., 1999; Dethleff et al., 2000). However, clay-mineral studies of the sediments from the East Siberian Sea and western Chukchi Sea are yet limited. The exclusive data of clay minerals in this region were reported by Silverberg (1972) who sampled very widely in space. Regional studies on the clay minerals of marine sediments from the Bering shelf demonstrated that the influence of the Yukon River extends northward through the Bering Strait to the Chukchi Sea (Naidu et al., 1982). Nevertheless, the documentation of clay-mineral data in the East Siberian Sea and western Chukchi Sea lacks a detailed study to compare the regional difference in view of sediment sources and dominant dispersal patterns of fine-grained sediments.

The primary objective of the present study is to examine the spatial variations in the clay minerals to determine the dispersal and distribution of fine-grained particles in the East Siberian and western Chukchi seas. The significance of clay-mineral assemblages was discussed to decipher the sediment sources and the sedimentary processes.

2. STUDY AREA

The Chukchi Sea has an epicontinental shelf connected with the East Siberian Sea to the west through the Long Strait (about 135 km wide and 45 m deep) and with the Bering Sea to the south through the Bering Strait (about 85 km wide and 50 m deep; Fig. 1). From the south of the Bering Strait, the more saline Bering Sea Water defined by Coachman et al. (1975) flows northward because of the sea

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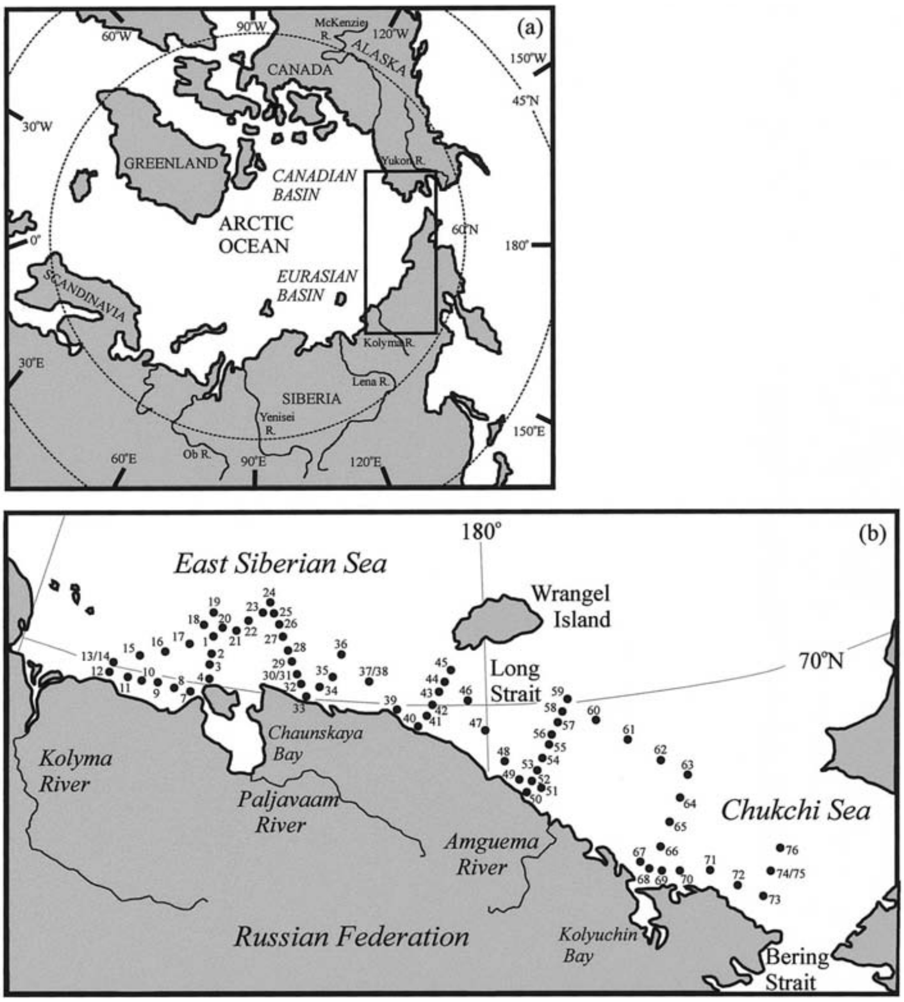

Fig. 1. (**a**) Geography of the Arctic Ocean and the distribution of major rivers discharging into the Arctic Ocean. Inset box represents the study area. (**b**) Location of sampling stations in the East Siberian Sea and western Chukchi Sea.

surface slope caused by the steric sea-level difference between the Pacific and the Arctic Ocean (Stigebrandt, 1984). The Yukon River having a drainage basin area of about 8.5×10^5 km^2 and discharging annually between 40 and 100×10^6 tons of sediments to the Bering Sea is the largest source of water and sediment discharge in the northern Bering Sea (Moser and Hein, 1984). Moser and Hein (1984) also described the Yukon Province as a vast tract of Cretaceous rocks locally veneered by Quaternary deposits and volcanic rocks. Using the remote-sensing imagery, the Yukon River-derived water was tracked continuously in the Chukchi Sea (Coachman and Aagaard, 1966).

The East Siberian Sea is the widest and shallowest epicontinental shelf, a width of which becomes narrow from west toward the Wrangel Island (Fig. 1). Depths generally are less than 50 m. The Yana-Kolyma Lowland and Chukchi Peninsula are composed of rocks of all ages, but Mesozoic ones predominate. The water entering the western Chukchi Sea through the Long Strait from the East Siberian Sea is of markedly lower salinity with variable temperatures, penetrating to a varying extent southeast as a surface flow, so-called Siberian Coastal Current flowing southeast parallel to the Siberian coast (Coachman and Shigaev, 1992; Weingartner et al., 1996; Münchow et al., 1999). Possible causes of the reduced salinity in the East Siberian Sea include the freshwater being supplied mainly by the Kolyma and Indigirka Rivers. Discharge of these rivers to the East Siberian Sea is markedly seasonal supplying most of runoff at the rate of 120 km^3/yr and 57 km^3/yr, respectively (Ivanov and Piskun, 1999). The Kolyma River enters the East Siberian Sea, but it could provide sediment for the Chukchi Sea due to the eastward current, at times, through Long Strait. The annual sediment load of the Kolyma is about 4×10^6 ton (Ivanov and Piskun, 1999), which is primarily clay and silt (Naugler et al., 1974). Most of the Siberian Coastal Current dissipates or recirculates on the Chukchi Shelf although during strongly northerly wind events it can flow further southward through the Bering Strait (Ratmonov, 1937).

The northern Bering Sea is the connection between the North Pacific and the Arctic Ocean (Fig. 1). A major north-flowing current (water mass) swings into the northern Bering Sea and then through the Bering Strait into the Chukchi Sea. Northward flow through the Bering Strait (Coachman et al., 1975) results from sea-level sloping toward the Arctic

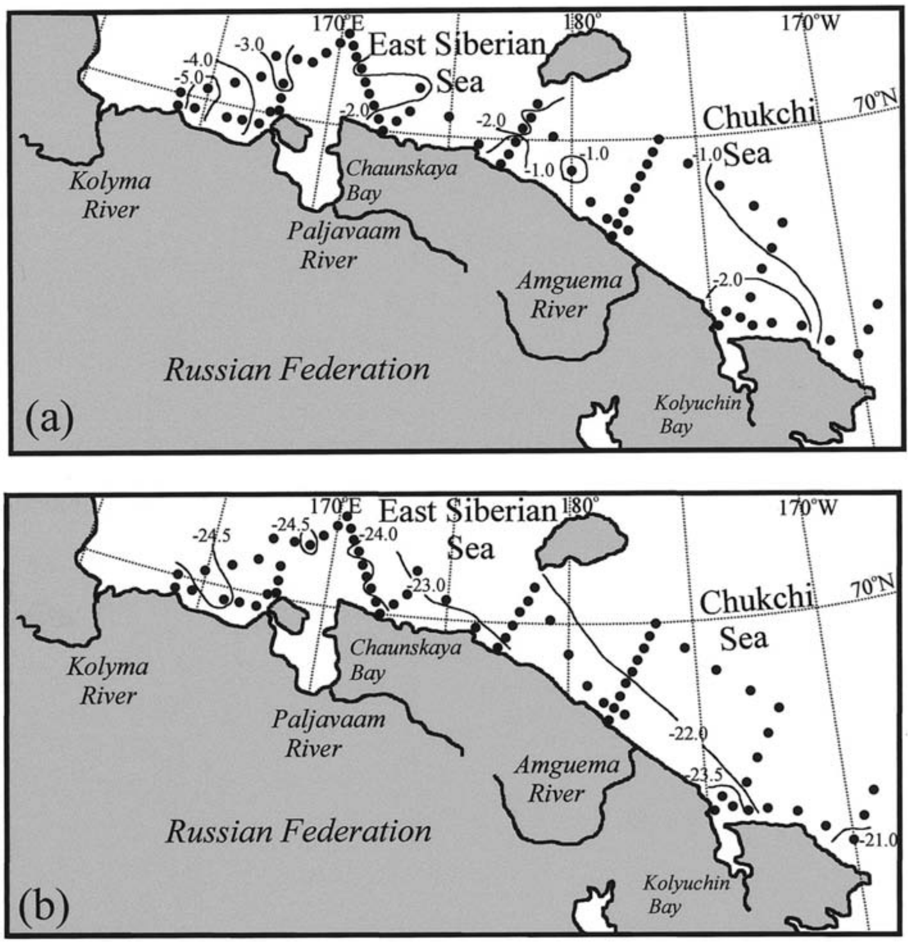

Fig. 2. (**a**) Distribution pattern of $\delta^{18}O$ values of surface water. (**b**) Distribution pattern of $\delta^{13}C$ values of sediment organic carbon. (modified from Khim et al., 2003).

Ocean (Stigebrandt, 1984). The water masses in the northern Bering Sea flow northward in almost parallel to the isobath. North of the Bering Strait, two branches are obviously bifurcated; a coastal current flows northeastward into the Beaufort Sea and another branch recirculates in the western Chukchi Sea. Evidence for a northwestward-moving plume is supported by the patterns of fine-grained bottom deposit (Coachman and Shigaev, 1992).

In August-September 1995, there was an oceanographic research cruise aboard the R/V *Alpha Helix* for studies on the East Siberian and Chukchi Sea shelves regarding sediment and water-column processes. A summary of $d^{18}O$ values for surface water and $d^{13}C$ values for organic carbon of surface sediments from both the East Siberian and Chukchi seas has resulted from this cruise (Fig. 2; Cooper et al. 1999; Münchow et al. 1999; Grebmeier and Dunton, 2000; Naidu et al. 2000; Khim et al., 2003). These $\delta^{18}O$ data indicate that the minimum $\delta^{18}O$ values of surface water occur close to the Kolyma River delta and generally increase to the east, although a secondary minimum is observed at Kolyuchin Bay on the eastern end of the Chukotka Peninsula (Fig. 2a). The $\delta^{13}C$ values of sedimentary organic carbon also show a trend increasing eastward from 24.5‰ at the Kolyma River delta to 21.0‰ in the Bering Strait, with a similar local minimum offshore of Kolyuchin Bay (Fig. 2b). These patterns reflect the extent of influence of terrestrial organic carbon on the Chukchi Sea shelf (Naidu et al., 2000).

3. MATERIALS AND METHODS

During *Alpha Helix* 189 cruise in 1995, sixty-nine sampling stations were designed to obtain the hydrographic data and to conduct hydrocasting measurements, among which at the fifty-nine stations the surficial sediments were collected using a Mctintyre grab sampler. The sampling locations are shown in Figure 1b and summarized in Table 1. In the laboratory, for the subsamples of surface sediments, grains larger than 63 μm (gravel and sand) were separated by wet sieving and classified by dry sieving. Grains smaller than 63 μm (silt and clay) were analyzed using a Micrometrics Sedigraph 5100D. After removing $CaCO_3$ by 10% HCl from the bulk sediment powders, total organic carbon (TOC) were measured using a Carlo-Erba NA-1500 Elemental Analyzer.

Among fifty-nine sediment samples, fifty-six samples were used for clay-mineral analyses. The less-than 2 μm fractions of sediments were separated and rendered free of organic mat-

Table 1. Summary of sampling locations, granulometric and clay-mineralogical data.

Station	Latitude	Longitude	Depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Mean (phi)	TOC (%)	Illite (%)	Smectite (%)	Kaolinite (%)	Chlorite (%)
2	70°26.9′N	167°59.8′E	31		10	39	51	8.3	1.1	68	4	11	17
9	69°50.1′N	165°59.9′E	32		16	42	42	7.5	1.0	75	2	9	15
12	69°50.0′N	163°59.9′E	28		44	24	32	5.8	1.1	72	2	10	16
15	70°10.1′N	164°59.8′E	17		8	57	35	7.1	0.7	74	5	10	11
17	70°30.0′N	167°00.0′E	27		18	48	34	6.8	0.6	71	3	9	18
18	70°49.7′N	167°27.0′E	31		14	52	34	7.0	0.8	77	3	8	13
19	70°02.0′N	167°41.1′E	32		8	47	45	7.8	1.0	72	2	12	14
20	70°50.0′N	168°20.8′E	39	22	8	30	40	5.5	1.1	71	3	12	14
21	70°50.1′N	168°59.9′E	37		3	44	53	8.5	1.0	74	2	8	15
22	71°00.0′N	169°30.0′E	43		2	34	64	9.3	1.3	71	4	12	12
23	71°10.0′N	169°59.9′E	43		3	40	57	8.7	1.3	71	9	9	11
24	71°18.8′N	170°20.6′E	47		4	32	64	9.3	1.3	77	2	10	10
25	71°10.1′N	170°33.9′E	36		5	39	56	8.7	1.4	75	3	12	11
26	71°00.0′N	170°49.1′E	30		10	42	48	8.0	1.0	71	3	11	15
27	70°50.0′N	171°04.0′E	28		23	40	37	6.5	1.0	67	2	16	15
28	70°40.0′N	171°20.0′E	28		14	45	41	7.7	1.0	75	3	11	12
29	70°30.0′N	171°34.0′E	26		5	46	49	8.1	1.1	73	3	11	13
31	70°20.1′N	171°49.1′E	37		25	37	38	6.9	1.1	72	1	13	14
32	70°10.0′N	172°04.1′E	27		5	46	49	8.1	1.2	69	3	15	14
33	70°00.0′N	172°20.2′E	19		25	20	55	7.8	1.3	77	1	10	12
34	70°10.1′N	172°50.2′E	31		38	31	31	6.1	0.9	75	2	11	11
35	70°20.0′N	173°19.9′E	34		55	23	22	4.8	0.8	68	6	10	15
36	70°40.1′N	173°40.2′E	37		7	54	39	7.5	1.2	64	9	10	17
38	70°17.9′N	174°55.8′E	41		17	42	41	7.4	1.3	66	5	12	17
39	69°56.4′N	176°15.3′E	16	2	43	35	20	5.5	0.6	71	4	10	15
40	69°40.0′N	177°10.1′E	19	3	73	14	10	3.1	0.3	64	3	17	17
41	69°50.0′N	177°30.0′E	36		22	34	44	7.2	1.3	63	7	11	18
42	70°00.0′N	177°44.9′E	43		19	43	38	7.2	1.3	68	10	10	12
43	70°10.1′N	178°00.1′E	44		18	40	42	7.4	1.3	67	7	11	15
44	70°20.1′N	178°16.3′E	46		20	39	41	7.3	1.3	64	8	13	15
45	70°30.0′N	178°29.8′E	46		27	36	37	6.7	1.4	65	11	10	14
46	70°03.9′N	179°14.2′E	43		15	46	39	7.3	1.2	65	6	14	15
47	69°35.9′N	179°59.9′E	47		46	24	30	5.9	0.9	63	12	10	14
48	69°08.9′N	179°14.9′W	40	7	52	18	23	5.0	0.8	69	4	11	16
49	69°55.0′N	178°36.9′W	36	23	66	5	6	0.7	0.5	69	5	13	13
51	68°44.0′N	177°51.9′W	40		64	18	18	4.5	0.7	67	7	11	15
52	68°50.0′N	178°15.1′W	37		79	9	12	3.2	0.4	63	6	13	19
53	69°00.0′N	178°00.1′W	48	15	54	14	17	3.3	0.5	63	7	13	17
55	69°20.1′N	177°30.0′W	48		32	28	40	7.2	1.4	62	13	10	15
56	69°30.0′N	177°16.0′W	50		27	32	41	7.5	1.6	65	8	13	14
57	69°40.0′N	177°00.0′W	51		6	40	54	8.4	1.6	62	9	13	16
58	69°50.0′N	176°44.9′W	52		10	34	56	8.5	1.7	64	9	13	14
59	70°00.0′N	176°30.1′W	53		9	43	48	7.9	1.6	60	13	14	13
60	69°39.0′N	175°21.8′W	53		2	38	60	9.0	–	61	11	12	16
61	69°18.1′N	174°12.0′W	51		2	42	56	8.7	2.1	60	10	14	17

Table 1. (continued).

Station	Latitude	Longitude	Depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Mean (phi)	TOC (%)	Illite (%)	Smectite (%)	Kaolinite (%)	Chlorite (%)
62	68°57.0′N	172°59.9′W	51		2	43	55	8.8	1.9	65	10	11	14
63	68°40.0′N	171°59.8′W	51		2	53	45	8.0	2.0	64	5	14	17
64	68°20.0′N	172°30.0′W	49		2	56	42	8.1	2.0	56	21	11	12
65	67°59.9′N	173°00.0′W	46		2	49	49	8.6	2.2	63	10	14	13
66	67°40.0′N	173°30.1′W	44		54	22	24	5.6	1.1	61	15	12	12
67	67°29.0′N	174°21.0′W	25		93	5	2	2.6	0.1	–	–	–	–
68	67°25.0′N	173°59.8′W	24		98	1	1	2.2	0.1	–	–	–	–
69	67°19.0N	173°36.0′W	26		94	2	4	2.8	–	69	4	13	14
70	67°17.0′N	172°52.8′W	40		62	21	17	4.7	1.1	67	2	14	17
71	67°12.0′N	171°48.1′W	45		45	32	23	5.8	–	61	7	15	18
72	66°55.0′N	170°52.9′W	41		71	17	12	4.3	0.8	61	3	20	17
73	66°40.0′N	170°00.0′W	45		71	4	5	2.6	0.3	–	–	–	–
74	67°00.0′N	169°29.9′W	49		75	16	9	3.6	0.4	66	2	16	16
76	67°20.0′N	168°59.8′W	48		48	36	16	5.1	1.0	63	10	14	13

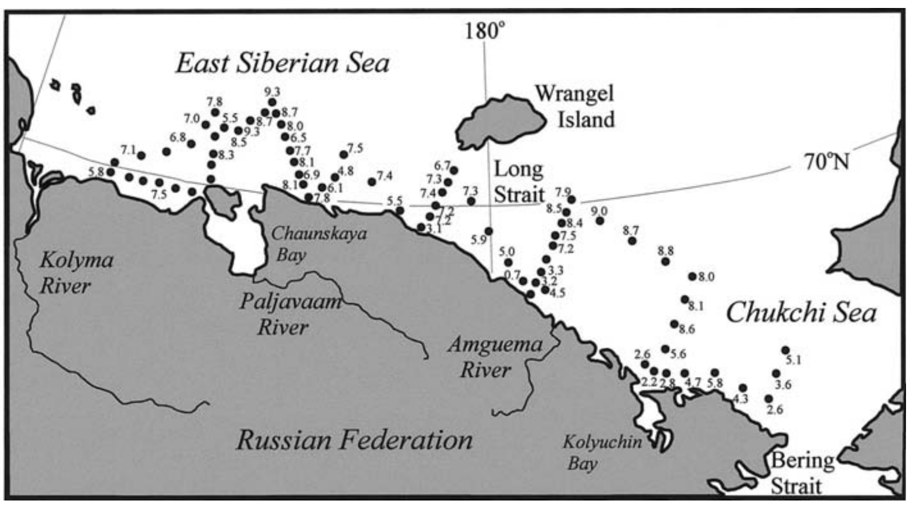

Fig. 3. Distribution of mean grain size in the study area. Unit is phi scale.

ter by treating with hydrogen peroxide. Oriented mounts of smear slides were prepared for standard Xray diffraction analysis. The air-dried and ethylene-glycol-treated slides were scanned from 3° to 30°2θ at 2°2θ/min on a Xray diffractometer (Rigaku Geigerflex) using Ni filtered CuKa radiation, equipped with an automated divergent slit. The clay minerals were identified by the basal reflections using procedures outlined elsewhere (Brindley and Brown, 1980; Moore and Reynolds, 1989). In this paper, identification was concentrated on the major clay minerals, such as smectite, illite, chlorite and kaolinite. Based on the semi-quantitative method suggested by Biscaye (1965), the integrated peak area percentages of the major clay minerals were calculated from the Xray diffractograms of the glycolated samples. The relative percentage of each clay mineral was determined by applying the weighting factors such as 1 for 17Å smectite peak, 2 for 7Å chlorite and kaolinite peak and 4 for 10Å illite peak.

4. RESULTS

Mean grain sizes of surficial sediments were shown in Figure 3. The corresponding granulomeric data were compiled in Table 1. In general, the mean grain size is relatively large in shallow depth as well as in the strait region. West of the Long Strait, the grain size decreases eastward from Kolyma River delta. The fine-grained sediments occurring in the western Chukchi Sea is likely due to the decreasing flow strength from the Bering Strait (Coachman and Shigaev, 1992). TOC contents of surficial sediments range between 0.1 and 2.2% (Table 1). The TOC contents are generally greater in western Chukchi Sea than in the East Siberian Sea. Such differentiation is attributed to the different water masses occupying the individual region. The water mass flowing from the Bering Strait is sufficiently productive to deliver the large amount of organic carbons (Hansell et al.,

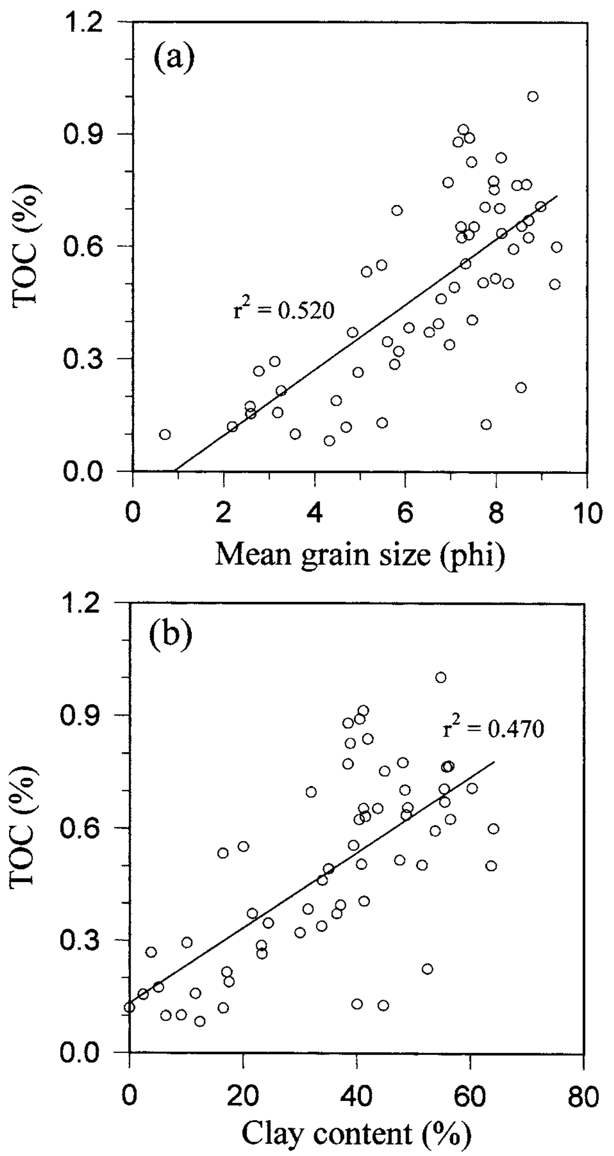

Fig. 4. (**a**) Relationship between TOC and mean grain size. (**b**) Relationship between TOC and clay content.

1993; Cooper et al., 1997), whereas the East Siberian Sea is known as relatively low productive area (Codispodi and Richards, 1968). TOC contents usually depend on sediment grain size. Most of organic matter in shallow marine sediments is closely linked to the mineral matrix, occurring as organic coating adsorbed on the surface of minerals (Keil et al., 1994). Thus, a positive correlation between TOC and mean grain size is almost universally observed in the non-carbonate sediments in marine and lacustrine environments. The relationship between mean grain size (or clay contents) and TOC is fairly positive (Fig. 4), indicating the TOC contents of sediments are largely controlled by the amounts of clay particles in sediments, although overall TOC content is mostly low.

The clay-mineral compositions of the less-than 2 μm fraction of the analyzed bottom sediments are mainly composed of illite, smectite, kaolinite, and chlorite (Table 1). Due to the complex and difficult drawing of isopleth contouring, the clay-mineralogical data are compared with respect to latitudinal (i.e., depth) and longitudinal sampling spacing (Figs. 5 and 6).

The illite content varies between 56 and 77% (Table 1). Low concentrations of illite are present in the eastern part to the Long Strait (175°W) of the study area while samples with relatively higher illite contents are found in the East Siberian Sea. Figure 5 shows the longitudinal variation of illite content, in which the eastward decreasing trend can be seen clearly, presenting that correlation coefficient (r^2) is 0.63. The relationship (r^2=0.63) between illite distribution and water depth is also illustrated in Figure 6, demonstrating that the illite is distributed to more extent in shallower areas. The smectite concentration lies in the range between 1 and 21% (Table 1). The majority of the samples fall in a range of 3 to 10%. In contrast to the illite distribution, smectite is less abundant in the East Siberian Sea whereas the relatively higher concentrations of smectite are found east of Long Strait in the western Chukchi Sea. Such distribution opposite to illite highlights the introduction of another source. In case of the relationship (r^2=0.62) between smectite and water depth, the more abundant smectite in the deeper-than-30 m stations is clearly observed (Fig. 6).

The abundance of kaolinite varies between 8 and 20% (Table 1). Kaolinite occurring in the polar regions may be derived from the weathering of older, kaolinite-bearing sediments and erosion of paleosols, because kaolinite is a very resistant mineral (Darby, 1975). Values of more than 12% are found mostly in the eastern part of study area while relatively small amounts of kaolinite less than 11% are found west of the Long Strait. The other part of the study area is occupied by intermediate contents of kaolinite. Nevertheless, the differences in the lateral distribution are fairly significant, similar to and as coherent (r^2=0.44) as smectite. However, it is apparent that the distribution is independent to the water depth (r^2=0.20; Fig. 6). The chlorite content varies within a relatively small range of 10 to 19% (Table 1). Most of samples fall within the range of 12 to 17%. The distribution of chlorite in the study area is ubiquitously random differing from the other clay minerals. Subsequently, the association of chlorite with longitude and water depth seems to be poor, presenting r^2=0.23 and r^2=0.06, respectively (Figs. 5 and 6).

5. DISCUSSION

Clay mineralogy of the surface sediments in the East Siberian Sea and western Chukchi Sea shows well-defined distribution patterns with markedly and different concentrations (Figs. 5 and 6). The most striking feature in the clay-mineral distribution in the study area is the lateral variation along and across the continental shelf. The cause for such discrimination between the clay-mineral associations can be

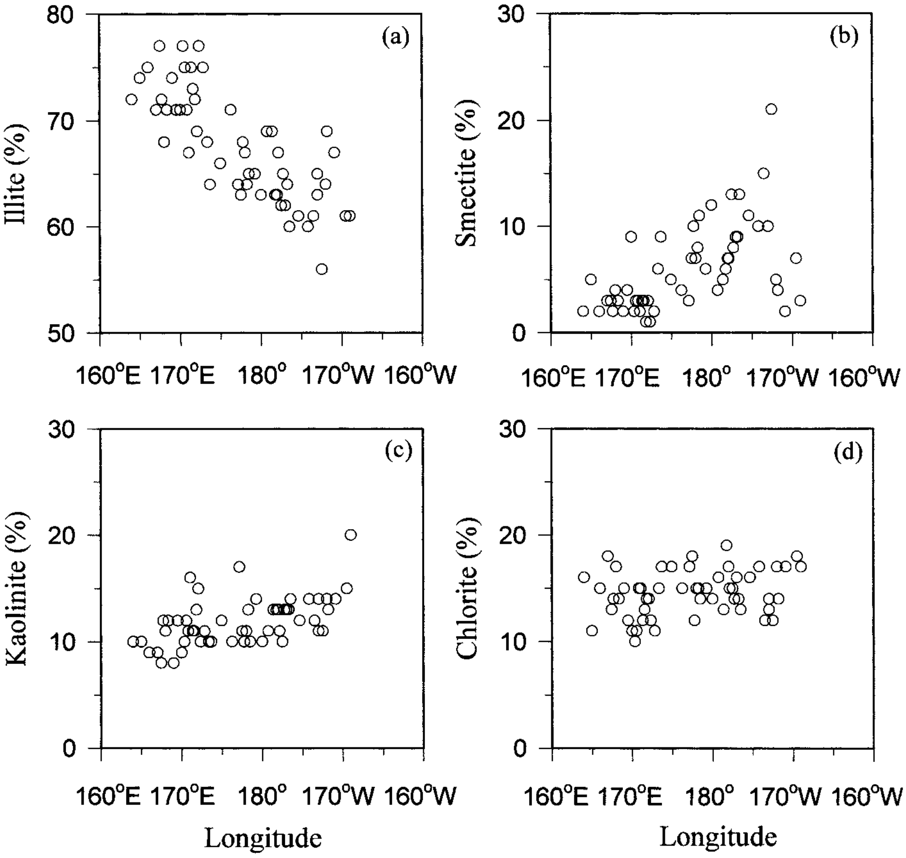

Fig. 5. Longitudinal distribution of clay minerals, (**a**) illite, (**b**) smectite, (**c**) kaolinite, and (**d**) chlorite.

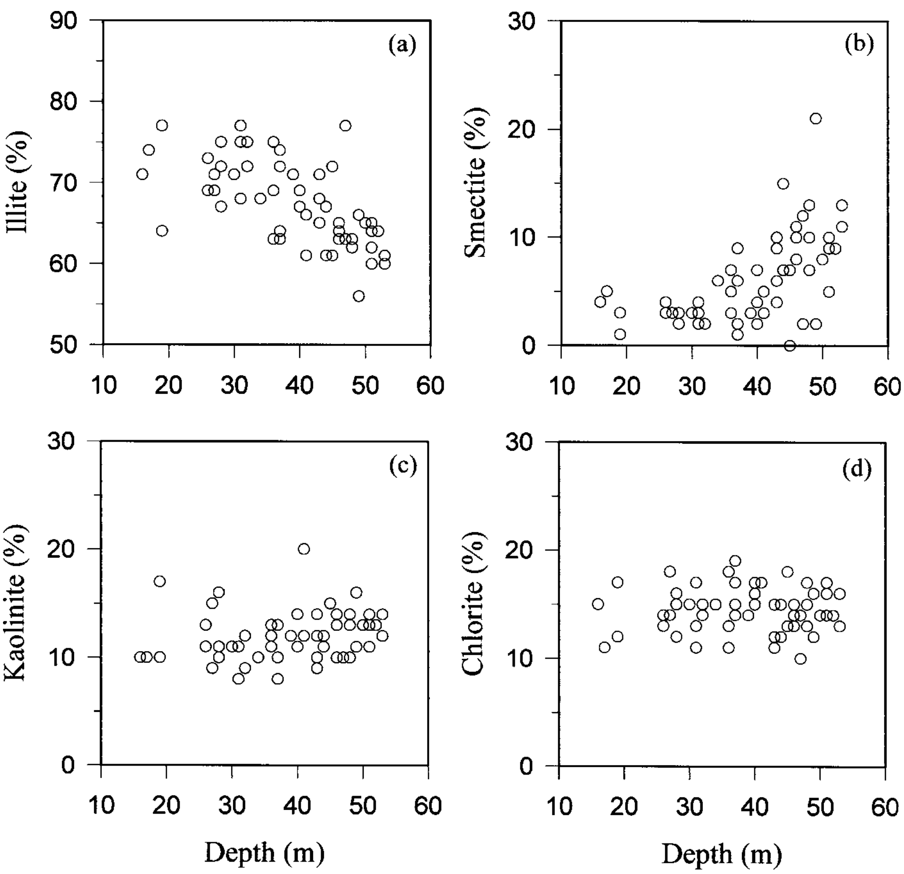

Fig. 6. Relationship between clay-mineral abundances and water depth of sampling station, (**a**) illite, (**b**) smectite, (**c**) kaolinite, and (**d**) chlorite.

sought in the dissimilar transport mechanisms of the fine-grained particles delivered into the study area from different sources. Possibly the distribution of clay minerals in this study largely reflect the regional current patterns related to the prevailing hydrodynamic regime.

The clay-mineral assemblages characteristic of a variety of rivers discharged into the western Arctic region indicated subtle but significant variations among potential sources (Nürnberg et al., 1995 Kalinenko et al., 1996; Behrends et al., 1999; Dethleff et al., 2000). The smectite concentration serves as an indicator for sediment source areas on the circum-Arctic shelves. The eastern Kara Sea and the western Laptev Sea are dominated by high smectite percentages in surface deposits from discharges of Ob, Yenisey, and Khatanga Rivers (Fig. 7). In contrast, the shelves from the eastern Laptev Sea over the Siberian and Chukchi Seas to the Canadian Beaufort Sea are characterized by relatively low smectite concentrations in surface sediments because source areas for the smectite are very limited in the western Arctic region (Darby, 1975; Naidu and Mowatt, 1983; Stein et al., 1994; Wahsner et al., 1999; Schooster et al., 2000). For example, the Yukon River which empties into the Bering Sea contains smectite in excess of 20%, while the Kolyma-Indigirka rivers into the East Siberian Sea comprise much lesser contents of smectite and more contents of illite.

High illite concentrations in the sediments around the East Siberian Sea may be attributed to the weathering and subsequent fluvial transportation by the Kolyma River (Naugler, 1967; Silverberg, 1972; Kalinenko et al., 1996). The illite distribution shows the lateral variation as a result of transport and distribution of fine-grained particles from the Kolyma and Indigirka Rivers by the eastward flowing Siberian Coastal Current (Münchow et al., 1999). These illite-rich sediments of northern Siberia are transported from the East Siberian Sea toward apparently the adjacent northwestern portion of the Chukchi Sea (Codispodi and Richards, 1968). These Kolyma River-derived sediments could account for the large area on the East Siberian Sea shelf, but the presence of the finest materials adjacent to Long Strait suggests that some clay-sized particles could also be transported from the western Chukchi Sea (Fig. 3). Thus, the clay-mineral types in the East Siberian Sea and western Chukchi Sea are distinctly distinguished, although the similarity probably reflects the general feature in the polar climate. In addition, sea ice has been proved to be an important agent in transporting large amounts of mainly fine-grained sediments across the Arctic Ocean (Wollenburg, 1993; Nürnberg et al., 1994; Reimnitz et al., 1994; Dethleff et al., 2000). However, it is unlikely that the sea ice plays a significant role in contributing to the illite contents on the shelf of the study area.

In this study area, another example for almost exclusively longitudinal variation in clay-mineral distribution comes from

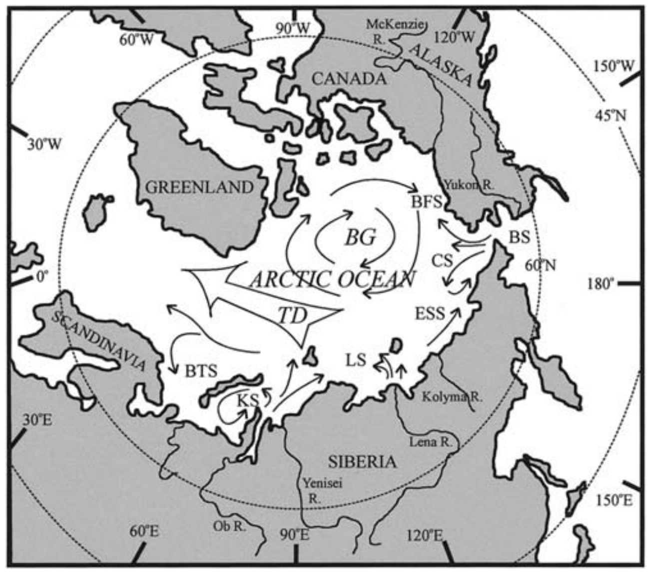

Fig. 7. Schematic transport dispersal of clay minerals in the Arctic Ocean. (modified after Reimnitz et al., 1994), TD: Transpolar Drift, BG: Beaufort Gyre, BFS: Beaufort Sea, BS: Bering Sea, CS: Chukchi Sea, ESS: East Siberian Sea, LS: Laptev Sea, KS: Kara Sea, and BTS: Barents Sea.

the smectite (Fig. 5). The smectite content increases significantly toward the western Chukchi Sea far away from the Long Strait. The very low content of smectite along the East Siberian Sea is an evidence of minimum smectite occurrence in rocks within Yana-Kolyma and Chukchi Regions. This peculiar pattern can be explained only by an input of smectite from the Bering Strait (Fig. 7). Smectite has been used to delineate fine-grained sediment dispersal pattern in the northern Bering Sea due to the abundant discharge from the Yukon River (Moser and Hein, 1984; Naidu et al., 1982). The Yukon River is the predominant source of terrigenous clay minerals for the northern portion of the Bering Sea, and more northerly transport through the Bering Strait results in significant contributions to the Chukchi Sea as well (McManus et al., 1974; Naidu and Mowatt, 1983). Apparently, the central Chukchi Sea is a major depositional repository for clay minerals derived from the Yukon River. In addition, Naidu et al. (1982) demonstrated remote-sensing imagery to specify the northward current component in the Chukchi Sea. This influx was interpreted as the water mass composed chiefly of the warmer Yukon River discharge (Coachman et al., 1975). Thus, net northward transport of Yukon River clays through the Bering Strait and significant deposition in the central portion of the Chukchi Sea is well established.

The general circulation pattern in the eastern Arctic Ocean was reflected in the smectite and illite distribution (Nürnberg et al., 1994, 1995; Reimnitz et al., 1994; Stein et al., 1994; Kalinenko et al., 1996). The distribution pattern of smectite and kaolinite clearly reflects the surface water circulation regime in the Barents and Kara Seas (Nürnberg et al., 1995; Wahsner et al., 1999). Smectite concentrations found in the Laptev Sea correlate to those in central Arctic Ocean sea ice, which provides evidence for an ice drift branch of Transpolar Drift (Fig. 7; Reimnitz et al., 1994; Wahsner et al., 1999; Dethleff et al., 2000). Concerning the distribution of clay minerals in the eastern Arctic Ocean, a clear relation between mineralogical characteristics and the mineral inventory is obvious. Likewise, in the western Arctic Ocean, the illite-enriched sediments are transported from the Kolyma River along the inner continental shelf by the eastward-flowing Siberian Coastal Current in the East Siberian Sea. The smectite- and kaolinite-rich sediments in the western Chukchi Sea are derived mostly and ultimately from the Yukon River by northward flow through the Bering Strait from the northern Bering Sea (Fig. 7).

In recent years, the variations in the vertical clay-mineral distribution in deep-sea sediments have been interpreted in terms of changes in the climatic conditions prevailing in the continental source areas, and numerous studies have been accomplished to reconstruct ancient climate and continental paleoenvironment (e.g., Thiry, 2000). The Bering Strait is very shallow and sensitive enough to the eustatic sea-level changes. Therefore, following the interglacial and glacial stages, the amounts of clay minerals passing through the Bering Strait should have fluctuated. It reflects that the distinct clay-mineral assemblage from the Bering Sea could play a key indicator to reconstruct the paleoclimate variation in the western Arctic Ocean.

6. CONCLUSIONS

Clay mineralogy of surface sediments of the East Siberian Sea and western Chukchi Sea have been analyzed in order to determine the fine-grained sediment sources and sediment-dispersal routes, with reference to the current pattern. Marked compositional differences of the clay-mineral assemblages are noted, with resultant two principal sediment sources. In this study, the rivers are the major fluvial sources that contribute clay minerals to the study area. The Kolyma River is a major fluvial system to provide illite-rich sediments to the East Siberian Sea, whereas the Yukon River is unquestionably another primary source of smectite-rich sediments for the western Chukchi Sea. The inner continental shelf sediments generally reflect the first source, indicating the dominant transportation by the Siberian Coastal Current. In contrast, the sediments on the shallow shelf of the western Chukchi Sea have a clay-mineral assemblage that reflects the output from the Bering Strait. The distribution patterns of clay minerals in the East Siberian Sea and western Chukchi Sea show that fine-grained sedimentation herein is governed by the distinct hydrographic features in the western Arctic Ocean.

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