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Late Quaternary paleoceanographic changes in the southwestern Okhotsk Sea: Evidence from geochemical, radiolarian, and diatom records

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Abstract

High-resolution analyses of geochemical parameters (biogenic opal, calcium carbonate, organic carbon, and nitrogen) and microfossil assemblages (diatoms and radiolarians) on Core MD01-2412 clarified detailed paleoceanographic changes such as sea-ice cover and biological production in the southwestern Okhotsk Sea during the last 115 kyr. An age model of Core MD01-2412 was established based on $\delta^{18}O$ stratigraphy, accelerator mass spectrometer (AMS) ^{14}C, and tephrochronology. Sea-ice history reconstructed by siliceous microplankton records indicated that the present sea-ice condition was formed during the last 8 kyr. Only during Marine Isotope Stage (MIS) 2 was the duration of sea-ice cover in this region much longer than that of today (4–5 months a year). Two diatom species, *Thalassionema nitzschioides* and *Fragilariopsis doliolus,* revealed that the Soya Warm Current Water (SWCW) flowed into the Okhotsk Sea near the site of Core MD01-2412 during the last 12–14 kyr and during MIS 5a, and was associated with sea-level rise. Biological productivity rapidly increased during MIS 1, associated with sea-ice retreat. Two major increases of organic carbon (OC) contents (wt%) and C_{org}/N ratios were observed, and the timings of these events were 15.8–16.7 ka (Event 1) and 13.1–13.6 ka (Event 2). Corresponding to these events, the abundance of *Cycladophora davisiana*, an intermediate water dwelling radiolarian species, increased. This high *C. davisiana* abundance can be correlated to the input of terrestrial

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organic matter from the submerged shelf to the intermediate water. Apart from the radiolarians, the production of diatoms in the surface waters was suppressed by the development of well-stratified surface water along with sea-ice melting during the early Holocene. Diatom production increased gradually during the last 10 kyr with enhanced vertical mixing.
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Keywords: Okhotsk Sea; Quaternary; Sea-ice; Biological production; IMAGES

1. Introduction

Since 1995, the International Marine Past Global Changes Study (IMAGES) Program has begun to understand the mechanisms and consequences of climatic changes using long oceanic sediment cores with high sedimentation rates. During the "WEPA-MA" Cruise of the R/V *Marion Defresne* in 2001 (IMAGES VII), Core MD01-2412, which was used in this study, was obtained from the southwestern Okhotsk Sea (Fig. 1; Table 1).

The Okhotsk Sea plays a significant role in both local and global climate change for three major reasons. First, sea-ice formation is one of the most important factors in climate change since it influences the density of waters below the surface layer (e.g., brine water is rejected when sea-ice is formed) and hence affects global water circulation. Seasonally formed sea-ice is annually distributed over an extensive area of the Okhotsk Sea and its extent varies significantly with time (e.g., Lisitzin, 1972). Second, the Intermediate Water of the Okhotsk Sea

Table 1
List of sediment cores and sediment trap stations used in recent studies including this work in the Okhotsk Sea

Core ID	Lat.	Long.	Water depth (m)	Core length (cm)	Bottom age (ka)	Sedimentation rate (cm kyr-1)	Reference
Academy of sciences rise							
V34-90	48°50′N	150°28′E	1590	340	23	15	(5)
XP98-PC2	50°24′N	148°19′E	1258	1023	94	11	(7), (8), (9)
Central Okhotsk Plateau							
3	51°57′N	149°48′E	974	97	22	4	(3)
7	53°59′N	149°13′E	910	113	20	6	(3)
Off Sakhalin							
XP98-PC4	49°29′N	146°08′E	664	1128	82	13	(7), (9)
K9312	53°32′N	144°33′E	1005	687	13	53	(3)
Kuril Basin							
GGC-15	48°10′N	151°20′E	1980	325	29	11	(1), (2), (4)
Off Kamchatka							
V34-98	50°07′N	153°12′E	1175	330	19	17	(3), (5)
XP98-PC1	51°00′N	152°00′E	1107	1010	125	8	(6), (7), (8), (9)
Off Hokkaido							
HO76P1	44°32′N	145°01′E	1250	760	7.3	104	(10)
MD01-2412	44°31′N	145°00′E	1225	5811	115	46	This work

Trap station	Lat.	Long.	Water depth (m)	Mooring depth (m)	Mooring duration	Reference
SHOYO	53°19′N	149°50′E	1166	258, 1061	August 1990–August 1991	(11)
M4	53°01′N	145°30′E	1756	300, 1550	August 1998–June 2000	(9), (12), (13)
M6	49°30′N	146°28′E	804	300, 700	August 1998–June 2000	(9), (12), (13)

References: (1) Keigwin (1998), (2) Ternois et al. (2000), (3) Shiga and Koizumi (2000), (4) Ternois et al. (2001), (5) Gorbarenko et al. (2002), (6) Narita et al. (2002), (7) Seki et al. (2003), (8) Koizumi et al. (2003), (9) Okazaki et al. (2003a), (10) Kawahata et al. (2003), (11) Broerse et al. (2000), (12) Nakatsuka et al. (2002), (13) Nakatsuka et al. (2004).

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