Geosciences Journal
Vol. 8, No. 4, p. 381 − 390, December 2004

Variations of terrigenous sediment supply to the southern slope of the Ulleung Basin, East/Japan Sea since the Last Glacial Maximum

Jang Jun Bahk* *Petroleum and Marine Resources Division, Korea Institute of Geoscience and Mineral Resources, Yuseong P.O. Box 111, Daejeon 305-350, Korea*
Sang-Joon Han *Marine Geoenvironment and Resources Research Division, Korea Ocean Research and Development Institute, Ansan, P.O. Box 29, Seoul 425-600, Korea*
Boo-Keun Khim *Department of Marine Science and Marine Research Institute, Pusan National University, Busan 609-730, Korea*

ABSTRACT: In order to examine the variations of terrigenous detrital components in the core (97PC-19) sediments from the southern margin of the Ulleung Basin, we detail changes in grain-size composition and contents of major elements such as detrital SiO_2 ($detSiO_2$), TiO_2, Al_2O_3, MgO and K_2O since the Last Glacial Maximum (LGM). The variations of detrital components are characterized by the significant elevations of $detSiO_2/Al_2O_3$ and TiO_2/Al_2O_3 ratios with the concomitant increase of silt to clay ratios during the last deglaciation (10−15 ka). Such a prominent increase suggests an enhanced flux of detrital quartz and Ti-bearing minerals relative to Al-rich clay minerals which can be attributed to either aeolian transport or hemipelagic advection. Similar variations of detrital components during the last deglaciation are much more pronounced in the core 95PC-1, located more proximal to the Korea Strait, as evidenced by the high sedimentation rate and sand and silt contents. However, this temporal variation is not clearly observed in ODP site 797 far from the Korea Strait. The spatial change of the detrital components among the cores suggests a primary control of hemipelagic fluxes of riverine sediments relative to aeolian dust fluxes on the variations of detrital components since the LGM. The hemipelagic fluxes were most likely derived from the paleochannels of the Nakdong River that extended onto the shelf margin of the Korea Strait during the last sea-level lowstand and increased by shore-parallel transport of paleocurrents through the Korea Strait during the early stage of the postglacial transgression.

Key words: detrital component, aeolian flux, hemipelagic flux, Ulleung Basin, East/Japan Sea.

1. INTRODUCTION

Terrigenous sediments are supplied to continental slopes and deep-sea basins by diverse processes such as aeolian transport, hemipelagic advection including river runoffs and winnowing of shelf and upper slope sediments, and gravity mass-transport of slides, slumps, debris flows and turbidity currents (Stow et al., 1996). All these processes have been significantly influenced by the late Quaternary climate variations combined with glacio-eustatic sea-level changes. For instance, rate and grain size of aeolian dust input to deep-sea basins have been related with glacial-interglacial changes in source area aridity and intensity of transporting winds (e.g., Rea and Leinen, 1988; Hovan and Rea, 1991). Shoreline regression and transgression by sea-level fluctuations fundamentally affect the sediment supply by hemipelagic advection and gravity mass-transport, as demonstrated by numerous studies from continental margins (e.g., Lee et al., 1996; Prins et al., 2000; Steinke et al., 2003). Owing to the complexity of terrigenous sediment supply, paleoclimatic interpretation of variations in terrigenous fractions of slope and deep-sea sediments requires distinction of the contributions from the different input processes.

The East/Japan Sea is supposed to have received significant aeolian dust flux from the desert regions in the northern China. The present dust flux to Japan is estimated to be 0.7–4.3 $g/cm^2/ka$ (Suzuki and Tsunogai, 1987), which is more than 30 times greater than the flux to the central North Pacific (0.0013–0.045 $g/cm^2/ka$: Suzuki and Tsunogai, 1987) and comparable to the average total mass accumulation rate of 4.1 $g/cm^2/ka$ during Quaternary at Ocean Drilling Program (ODP) site 797 (Shipboard Scientific Party, 1990) in the Yamato Basin (Fig. 1a). Recent studies on the ODP site 797 sediments revealed that the Asian dust flux (0.7–3.7 $g/cm^2/ka$) during the last 200 ka varied in harmony with millennial-scale variations of summer and winter monsoon intensities (Tada et al., 1999; Irino and Tada, 2000, 2002). In the Ulleung Basin, exposure and inundation of the relatively broad shelf between the southeast Korea and the southwest Japan by the late Quaternary sea-level fluctuations may have significantly influenced the rate and composition of sediment supply by fluvial and coastal processes to the deeper parts of the basin. The sea-level fluctuations also affected the stability of surrounding slopes of the Ulleung Basin and considerably changed the frequency of slope failure events and gravity mass-transport by debris flows and turbidity currents (Lee et al., 1996). Previous sedimentologic studies of the core sediments retrieved from the slopes and basin floor of the Ulleung basin have sufficiently identified the gravity mass-transport processes and their deposits like turbidites and debrites from hemipelagites which generally occur as bioturbated muds composed of an admixture of biogenic and terrigenous materials (Chough et al., 1984;

*Corresponding author: jjbahk@kigam.re.kr

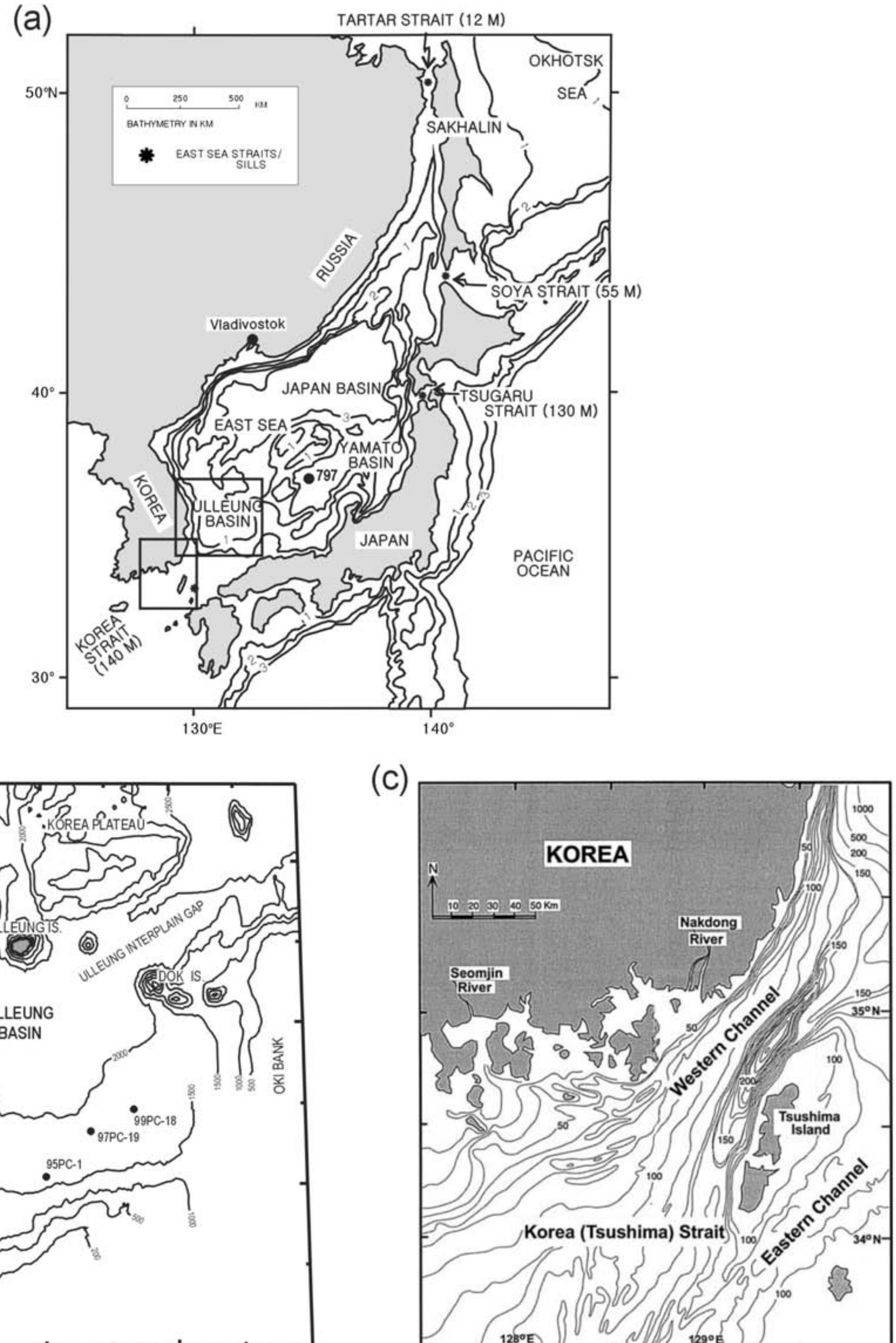

Fig. 1. (a) Physiographic map of the East/Japan Sea and the surrounding region. Note shallow sills and straits connecting the East/Japan Sea with the western Pacific. Inset boxes indicate the area expanded in (b) and (c). Location of ODP site 797 on the northern rim of the Yamato Basin is shown. (b) Bathymetry of the study area (contours in meters) and locations of piston cores. (c) Detailed bathymetery (contours in meters) of the Korea /Tsushima Strait which can be divided into a western channel as deep as 230 m and an eastern channel shallower than 120 m. Note present location of the mouth of the Nakdong River. Redrawn from Park et al. (2000).

Lee et al., 1996; Bahk et al., 2000). Distinction of the possible contributions from aeolian transport and hemipelagic advection in the hemipelagites, however, warrants further investigation of the compositional variations of the terrigenous fractions.

The purpose of this study is to estimate the relative importance of aeolian vs. hemipelagic fluxes of terrigenous sediment to the southern slope of the Ulleung Basin in the East/Japan Sea since the Last Glacial Maximum (LGM). For this purpose, we characterize variations of terrigenous detrital components in the hemipelagic sediments from the southern lower slope of the Ulleung Basin using major element contents and grain-size compositions. The compositional variations are compared to those from more proximal and distal sites to possible sources of hemipelagic fluxes from the shelf region to judge the degree of spatial variation of detrital components among the core sites. Because the East/Japan Sea is more than 2000 km apart from the aeolian dust sources in the northern China, significant spatial variations of detrital components, if present, were most likely controlled by the changes of hemipelagic fluxes from the surrounding land and shelf region, rather than those of aeolian fluxes.

2. GEOLOGICAL AND OCEANOGRAPHIC SETTING

The East/Japan Sea is a semi-enclosed marginal sea that is connected to the North Pacific and adjacent seas through four shallow and narrow straits (water depths of 12–140 m; Fig. 1a). The Tsushima Warm Current, a branch of the warm saline Kuroshio Current, enters the East/Japan Sea through the Korea/Tsushima Strait and flows out through the Tsugaru and Soya straits. A cold (< 1°C), highly oxygenated (5–6 ml/l) water mass that originates from winter cooling of surface water in the northern part occurs below the water depth of 200–300 m (Kawamura and Wu, 1998; Kim et al., 2002). Sea-level lowering by as much as 120 m during the LGM (Shackleton, 1987; Fairbanks, 1989) influenced significantly the bottom-water conditions of the East/Japan Sea, as expected from restricted exchange of surface water with open oceans. Geochemical and paleontological evidences from numerous sediment cores indicate that an anoxic bottom-water condition developed during this period (Oba et al., 1991; Crusius et al., 1999). Based on oxygen isotope composition of planktonic foraminifera, the anoxia has been ascribed to a decrease in surface-water salinity and consequently intensified water-column stratification (Oba et al., 1991; Keigwin and Gorbarenko, 1992; Gorbarenko and Southon, 2000).

In the Ulleung Basin, the southwestern part of the East/Japan Sea (Fig. 1a), slope failures occurred frequently during the late Pleistocene (Lee et al., 1996). The failures have been attributed to degradation of regional slope stability by glacio-eustatic sea-level lowering (Lee et al., 1996). A wide variety of mass-movement deposits were identified: slide and slump deposits occur mainly on the upper slope region, debris flow deposits on the lower slope and turbidites in the deeper area (Chough et al., 1985, 1997). Fine-grained turbidites derived from the slope failures alternate with hemipelagic laminated muds which formed under anoxic bottom-water conditions during the LGM (Bahk et al., 2000). The LGM sequences are overlain by hemipelagic bioturbated muds which have been deposited under generally well-oxygenated bottom-water condition since the late glacial period (Bahk et al., 2000).

The Nakdong River in the southeastern part of Korea annually discharges about 10×10^6 tons of sediments to the Korea Strait (Park et al., 1999; Fig. 1c). Since sea level reached its present position at approximately 6 ka, the deposition of suspended sediments from the Nakdong River has been mostly limited to the inner-to-mid shelf areas owing to the presence of oceanic front between the Korean Coastal Current and Tsushima Warm Current, resulting in a formation of nearshore mud belt along the southeastern coast of Korea (Park et al., 1999; Yoo and Park, 2000). During the sea-level lowstand of LGM, however, paleochannels of the Nakdong River extended onto the shelf margin at about 110–120 m depth and supplied the sediments which formed the lowstand deltaic wedges in the NE-SW-trending western channel of the Korea Strait (Yoo and Park, 1997, 2000).

3. MATERIALS AND METHODS

A piston core, 97PC-19 (36°20.3'N, 131°20.9'E; water depth 1872 m) was obtained from the southern lower slope of the Ulleung Basin, cruise aboard *R/V Onnuri* in 1997 (Fig. 1b). Previous sedimentological study of the core sediments (Bahk et al., 2000) revealed that the sediment records since the LGM can be divided into two lithologic units, Units I and II in descending order (Fig. 2). Unit II consists mostly of alternating fine-grained turbidites and dark laminated mud layers, whereas Unit I is dominated by hemipelagic bioturbated mud. In Unit I, thin dark laminated mud layers uniquely occur at 14 cm below Ulleung-Oki (U-Oki) tephra (Fig. 2). The dark laminated mud layers of Units II and I were interpreted as the layers formed by hemipelagic sedimentation under poorly oxygenated bottom-water condition (Bahk et al., 2000). The lithologic change is probably due to the variation in slope stability and degree of bottom-water oxygenation associated with the sea-level rise during the last deglaciation (Lee et al., 1996; Bahk et al., 2000). Age determinations for the core were based on the tephra layers of U-Oki and Aira-Tanzawa (AT) with well-known ages (Machida, 1999; Gorbarenko and Southon, 2000) and lithologic correlation with the nearby core 99PC-18 (36°29.5'N, 131°39.6'E; water depth 1867 m; Fig. 1b) whose chronology was well established by four AMS ^{14}C dates (Table 1; Fig. 2). Age-depth relationship for the core was constructed using the age controls and core depths after removing the thickness of turbidite and tephra layers representing near instantaneous events. The thickness of turbidite and tephra layers amount to 31% of the total.

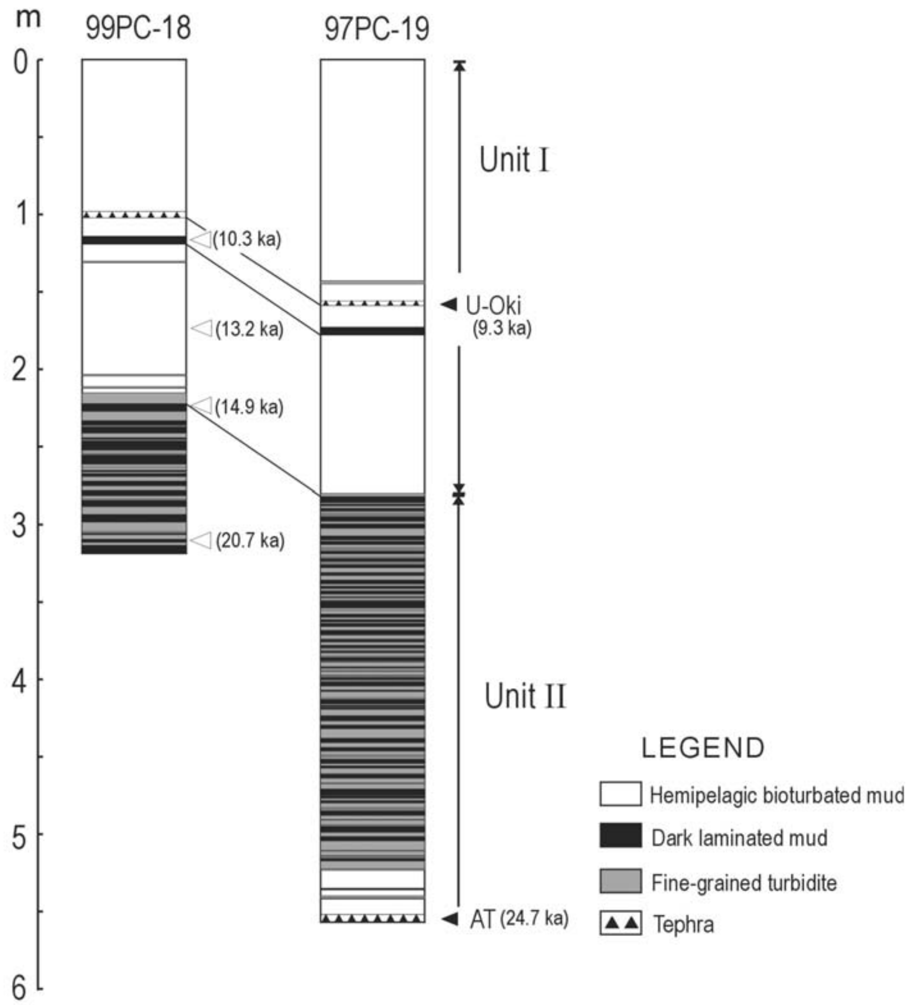

Fig. 2. Summary of sedimentary logs and correlation between cores 99PC-18 and 97PC-19. Solid arrows indicate tephra layers with known eruption ages; open arrows indicate locations of AMS ^{14}C dates. Numbers in parentheses are ^{14}C ages. Interpretation of sedimentary facies was based on Bahk et al. (2000).

Table 1. Age controls for cores 99PC-18 and 97PC-19.

[a]Corrected depth (cm)	Age control methods	AMS ^{14}C age (ka)	Lab number and reference
99PC-18			
99.5	U-Oki ash	9.3	Machida (1999)
113.5	AMS ^{14}C age	10.34±0.05	KIA 11587, Lee et al. (2003)
166.5	AMS ^{14}C age	13.21±0.08	KIA 11588, Lee et al. (2003)
212	AMS ^{14}C age	14.94±0.07	KIA 11589, Lee et al. (2003)
257.5	AMS ^{14}C age	20.66±0.13	KIA 11591, Lee et al. (2003)
97PC-19			
152.5	U-Oki ash	9.3	Machida (1999)
169	[b]Correlation	10.34	
269.5	[b]Correlation	14.94	
383	AT ash	24.7	Gorbarenko and Southon (2000)

[a] Depth corrected for the thickness of interbedded turbidite and tephra layers.
[b] Lithologic correlation between cores 99PC-18 and 97PC-19 (see Fig. 2 and text).

To focus on the compositional variations due to possible aeolian transport and hemipelagic advection, samples for geochemical analyses were collected only in the hemipelagic muds (bioturbated mud and dark laminated mud: Fig. 2) with varying intervals of 5–20 cm. Contents of 10 major elements (SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O and P_2O_5) were determined by X-Ray Fluorescence spectrometer (XRF; Model: Philips PW1480). Samples were ignited at 1000°C prior to make the fused glass disk and the loss on ignition (LOI) was obtained by the mass difference. Because the samples for XRF analysis included sea salt in pore water, total Na_2O contents were corrected for those

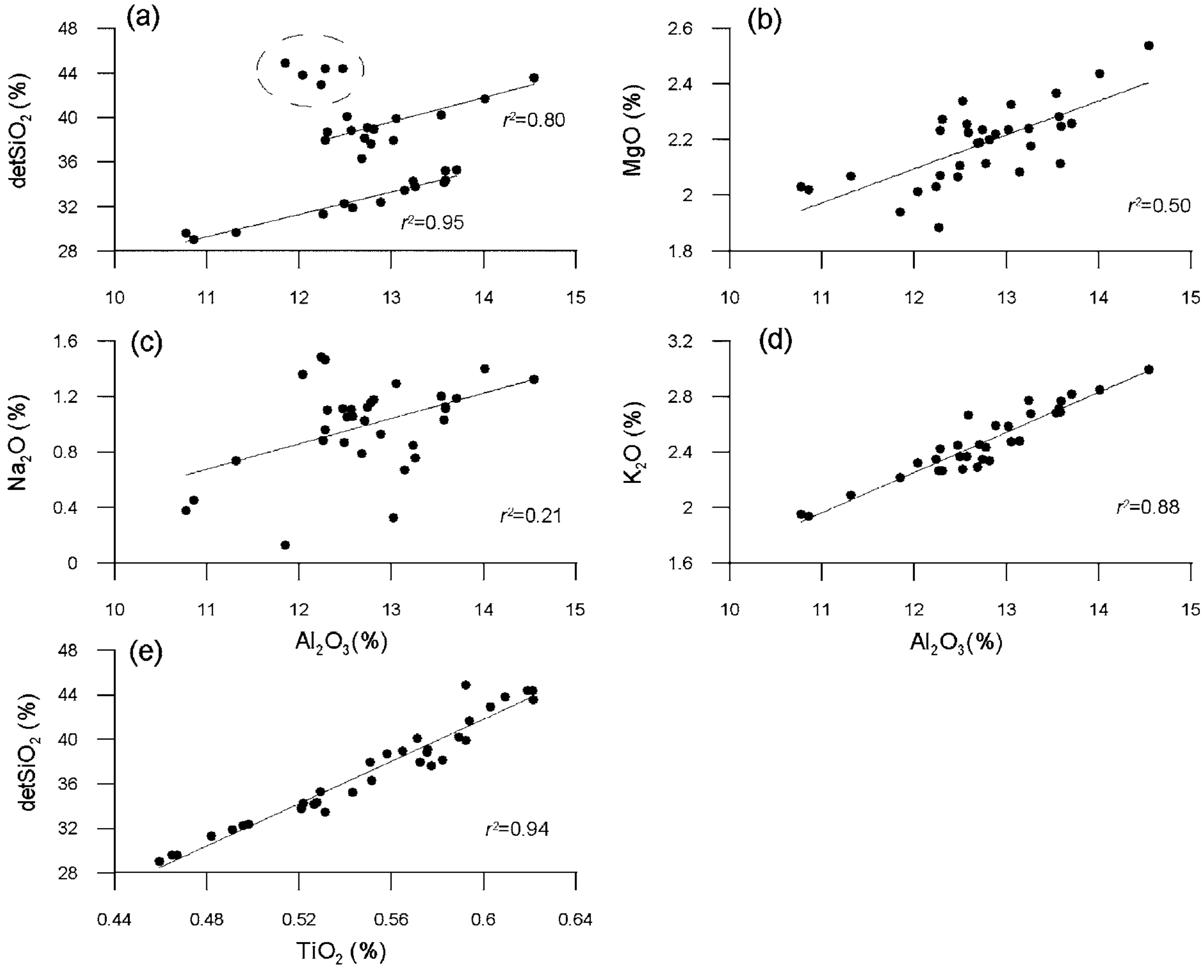

Fig. 3. (a-d) Relationships between the contents of $detSiO_2$, Na_2O, MgO and K_2O and the content of Al_2O_3. (e) Correlation between $detSiO_2$ and TiO_2. Lines in figures are best fit regressions.

from sea salt, based on measured water contents and an assumed average salinity (35‰) of pore water. Biogenic silica content ($bioSiO_2$) was analyzed at Hokkaido University by extraction with an alkaline solution (Mortlock and Froelich, 1989). Detrital SiO_2 ($detSiO_2$) was calculated by subtracting $bioSiO_2$ from total SiO_2 measured by XRF. Among the 10 major elements determined by XRF, we focused on the contents of TiO_2, Al_2O_3, MgO, Na_2O, K_2O and $detSiO_2$, which are most likely in detrital mineral phase. Other elements appear to be strongly effected either by authigenic enrichments by redox change (Fe_2O_3, MnO) or by biogenic components (CaO, P_2O_5) (Irino and Tada, 2000; Bahk et al., 2001; Lee et al., 2003). Grain-size analysis was conducted using standard sieves and a Micromeritics SediGraph 5100 for the sand and mud fractions, respectively. Prior to the grain-size analysis, organic matters and carbonates were removed by diluted H_2O_2 and HCl, respectively.

4. RESULTS

Relationships between the contents of Al_2O_3 and those of K_2O and MgO from the core 97PC-19 sediments are relatively good (Fig. 3b, d), implying that K and Mg are mainly contained in detrital aluminosilicates. Rather poor correlation of Na_2O with Al_2O_3 contents (Fig. 3c) is partly attributed to the uncertainty of sea-salt correction which may arise from the arbitrarily assumed pore water salinity (35‰). Relationship between $detSiO_2$ and Al_2O_3 contents is characterized by three groups: two groups with good positive correlations and one with almost constant and high $detSiO_2$ contents (Fig. 3a), reflecting temporal changes of $detSiO_2/Al_2O_3$ ratios (see below). The contents of TiO_2 are highly correlated with those of $detSiO_2$ (Fig. 3e).

Profile of grain-size composition shows that the core 97PC-19 sediments consist mostly of silt and clay, with relatively high silt to clay ratios particularly during the last deglaciation (10–15 ka) (Fig. 4). The contents of $detSiO_2$, TiO_2, MgO and K_2O were normalized by Al_2O_3 contents to eliminate dilution effect by biogenic components such as biogenic silica, organic carbon and biogenic calcite. Profiles of the $detSiO_2/Al_2O_3$ and TiO_2/Al_2O_3 ratios are very similar to that of the silt to clay ratios, suggesting that the variations

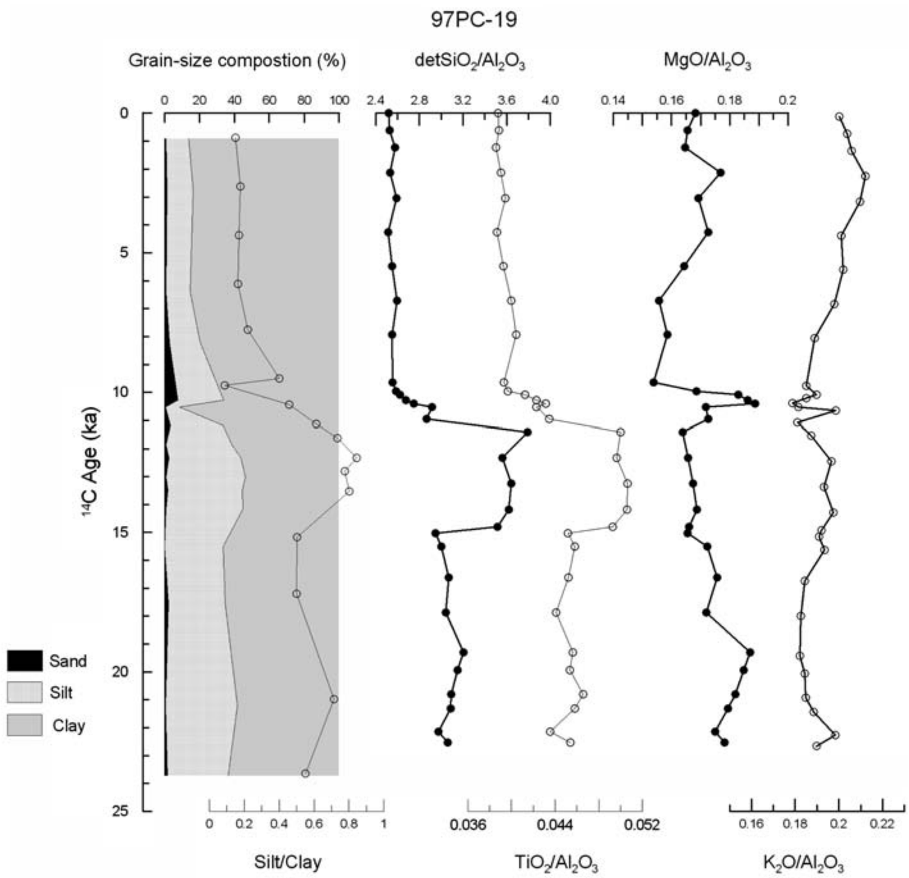

Fig. 4. Profiles of grain-size composition, silt to clay ratios and Al_2O_3-normalized contents of $detSiO_2$, TiO_2, MgO and K_2O in core 97PC-19.

of $detSiO_2$ and TiO_2 contents within detrital fractions are mainly controlled by the amounts of silt fractions (Fig. 4). It is also noteworthy that the ratios of $detSiO_2/Al_2O_3$ and TiO_2/Al_2O_3 are temporally distinct: moderate during the LGM, particularly high during the last deglaciation, and relatively low during the Holocene. The ratios of MgO/Al_2O_3 and K_2O/Al_2O_3 vary with age within relatively narrow ranges, except an excursion of MgO/Al_2O_3 at about 10.5 ka (Fig. 4).

5. DISCUSSION

To examine the origin of detrital components in the core 97PC-19, the ratios of $detSiO_2$, TiO_2, MgO and K_2O to Al_2O_3 contents are compared with those of possible source materials such as the loess in the Chinese Loess Plateau (Gallet et al., 1996; Jahn et al., 2001) and surface mud sediments in the southeastern coast of Korea (Lee et al., 1991) which were mainly derived from the Nakdong River (Fig. 5). Chinese loess samples are obviously characterized by high values of $detSiO_2/Al_2O_3$ and TiO_2/Al_2O_3 (Fig. 5a). Such distinguishably high ratios of the loess are attributed to the high contents of silt fraction (up to 60% for 0.01–0.05 mm fraction: Liu, 1988) that probably includes relatively large proportions of detrital quartz and Ti-bearing heavy minerals. In contrast, variations of MgO/Al_2O_3 and K_2O/Al_2O_3 of the loess samples generally encompass those of both the surface sediments from the Nakdong River and the 97PC-19 sediments (Fig. 5b). The biplot of $detSiO_2/Al_2O_3$ and TiO_2/Al_2O_3 illustrates that the loess can be chosen as one end member on a mixing line which may explain the compositional variability of the 97PC-19 sediments (Fig. 5a). However, because $detSiO_2/Al_2O_3$ and TiO_2/Al_2O_3 values of the surface sediments from the Nakdong River, which may represent the other end member composition for hemipelagic fluxes, are not available, contributions of aeolian dust fluxes from the loess cannot be properly estimated at the present. Moreover, composition of hemipelagic fluxes from river runoff or winnowing of shelf and upper slope sediments can vary significantly, depending on the sea-level change.

To estimate relative importance of aeolian vs. hemipelagic fluxes on the variations of $detSiO_2/Al_2O_3$ and TiO_2/Al_2O_3 ratios in the core 97PC-19 sediments, we checked the comparable data from the cores 95PC-1 (36°03.9'N, 130°59.4'E; water depth 1634 m: Hyun et al., 2001) and ODP site 797 (36°37.2'N, 134°32.4'E; water depth 2874 m: Tada et al., 1999; Irino and Tada, 2000) (Fig. 1). These cores are 44 km apart southwest (95PC-1) and 287 km northeast (ODP site 797) from the core 97PC-19, located more proximal and distal to the possible sources of terrigenous sediments from the paleo-Nakdong River, respectively (Fig. 1).

Correlations among the cores are made on the basis of the tephra layers of U-Oki (9.3 ka) and AT (24.7 ka) and upper

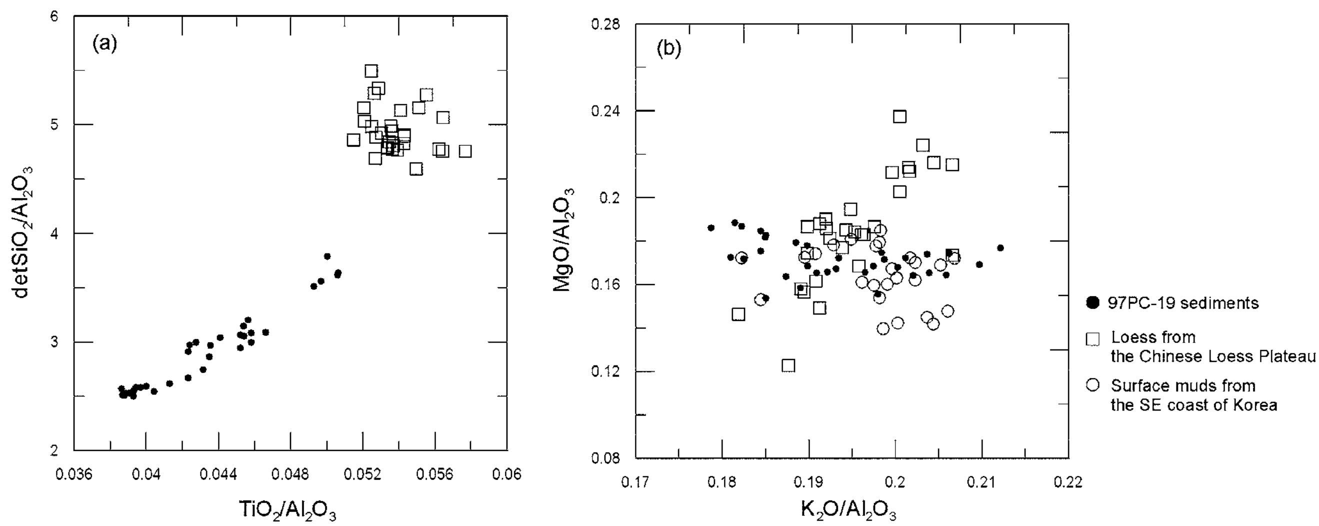

Fig. 5. Variabiltites of elemental compositions of the 97PC-19 sediments and possible source materials on the plots of (a) $detSiO_2/Al_2O_3$ vs. TiO_2/Al_2O_3 and (b) MgO/Al_2O_3 vs. K_2O/Al_2O_3. The data for the loess from the Chinese Loess Plateau are taken from Gallet et al. (1996) and Jahn et al. (2001), and those for the surface muds from the southeastern coast of Korea are from Lee et al. (1991). The $detSiO_2/Al_2O_3$ and TiO_2/Al_2O_3 for the surface muds are unavailable.

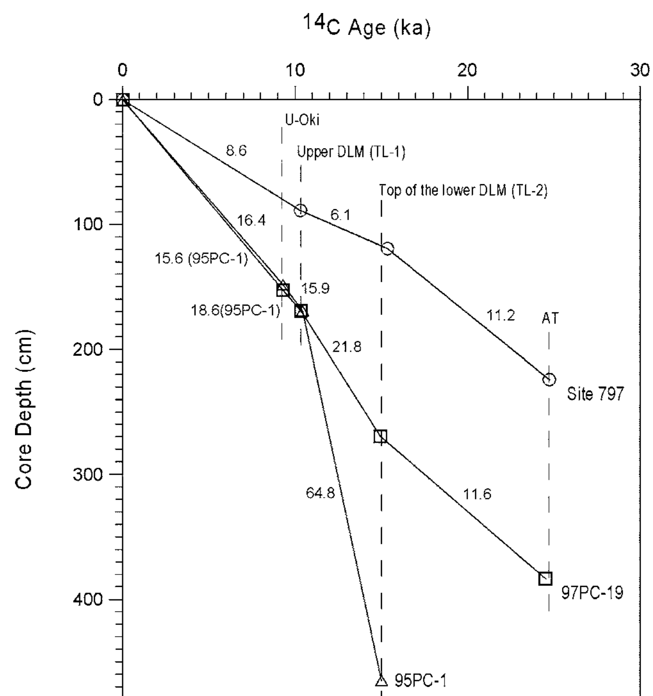

Fig. 6. Age-depth plots for cores 95PC-1, 97PC-19 and ODP site 797. For core locations, see Figure 1. The core depth for 97PC-19 sediments, which include frequent turbidite beds, was corrected for the thickness of interbedded turbidite beds. Numbers are linear sedimentation rates for each line segment in cm/ka. Dotted vertical lines denote age controls based on age-known tephra layers (U-Oki and AT) and lithologic correlation of upper and lower dark laminated mud (DLM) layers (TL-1 and TL-2 in site 797). The age controls for the 95 PC-1 are after Hyun et al. (2001) and those for the ODP site 797 are after Tada et al. (1999).

boundaries of upper and lower dark laminated mud layers (TL-1 and TL-2 in site 797) which represent basin-wide changes in bottom-water oxygenation (Fig. 6). During the last deglaciation (10–15 ka), the linear sedimentation rate (LSR) of the core 95PC-1 is about three times higher than that of the 97PC-19 (Fig. 6) and grain-size compositions of the core 95PC-1 show much higher fractions of sand (up to 23%) and silt (up to 55%) (Fig. 7). Ratios of TiO_2/Al_2O_3 in the core 95PC-1 are also remarkably high during the last deglaciation (Fig. 7). Although $detSiO_2/Al_2O_3$ ratios are not available in the core 95PC-1, variability of the ratios is expected to be similar to that of TiO_2/Al_2O_3 ratios based on the good linear correlation between $detSiO_2$ and TiO_2 contents of the core 97PC-19 sediments (Fig. 3). In the ODP site 797, however, such increases of the $detSiO_2/Al_2O_3$ and TiO_2/Al_2O_3 ratios and LSR during the last deglaciation are not observed (Figs. 6 and 7). The elevated $detSiO_2/Al_2O_3$ and TiO_2/Al_2O_3 ratios and LSR significantly decrease during the Holocene in the cores 95PC-1 and 97PC-19 sediments (Figs. 4, 6 and 7).

The variations of LSR and grain-size composition between the 95PC-1 and 97PC-19 sediments suggest that the significant increase of $detSiO_2/Al_2O_3$ and TiO_2/Al_2O_3 ratios in the 97PC-19 during the last deglaciation may have been caused by increased hemipelagic fluxes with more fractions of detrital quartz and Ti-bearing heavy minerals. The hemipelagic fluxes were most likely delivered from the paleochannels of the Nakdong River which extended onto the shelf margin of the Korea Strait at the sea-level lowstand (Yoo and Park, 1997, 2000). The ODP site 797 sediments in the Yamato Basin appear to be nearly free of the influences of hemipelagic fluxes from the Korea Strait. The relative

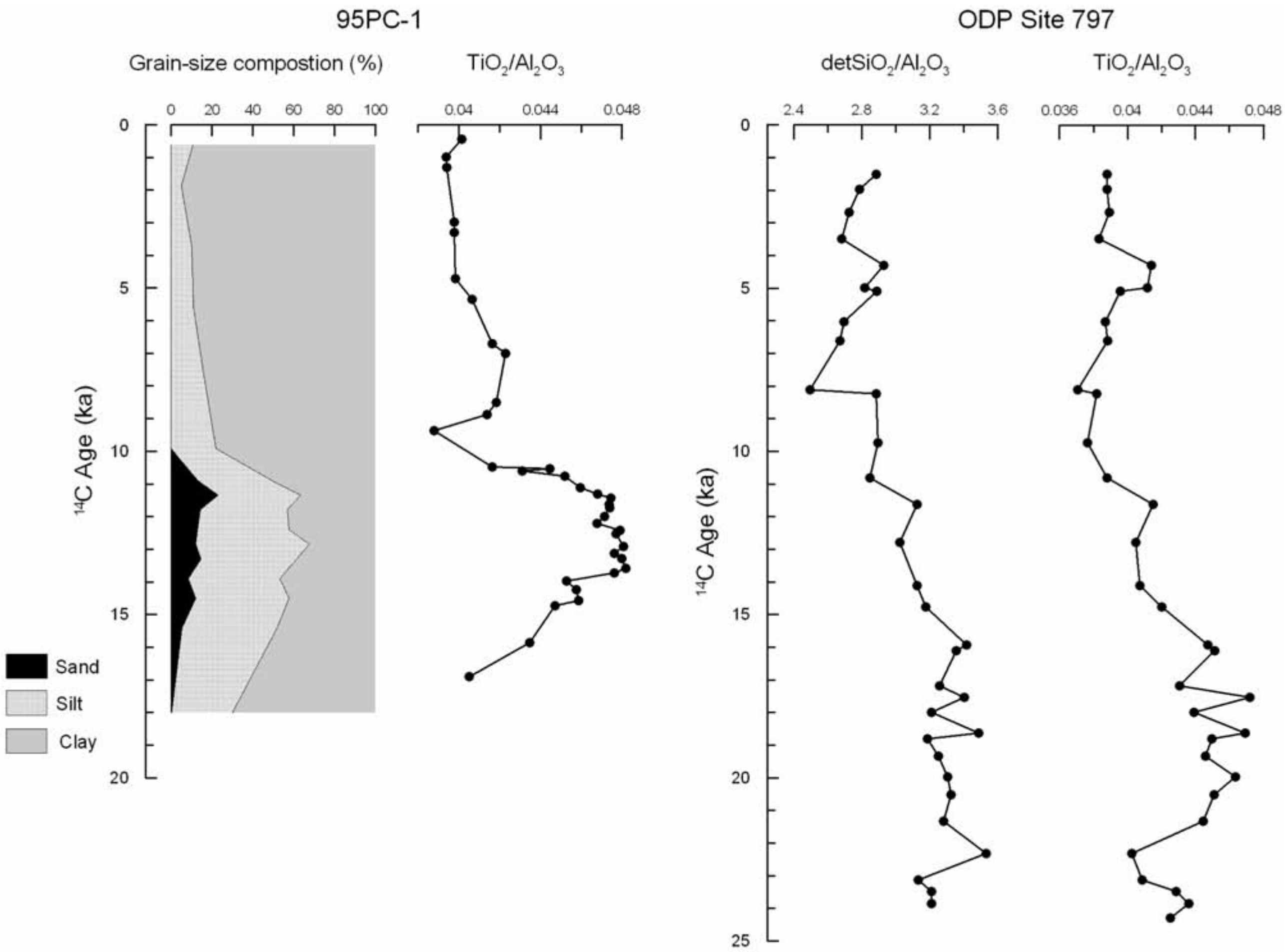

Fig. 7. Profiles of grain-size composition and TiO_2/Al_2O_3 ratios in core 95PC-1 after Hyun et al. (2001) and detSiO_2/Al_2O_3 and TiO_2/Al_2O_3 ratios in ODP site 797 sediments after Irino and Tada (2000).

decreases of detSiO_2/Al_2O_3 and TiO_2/Al_2O_3 ratios and LSR during the Holocene in both the 95PC-1 and 97PC-19 sediments also suggest that dispersal of the sediments from the Nakdong River to the deep parts of the Ulleung Basin may have been prevented by the oceanic front between the Korean Coastal Current and Tsushima Warm Current (Park et al., 1999), which may have been established since about 10 ka when the Tsushima Warm Current began to flow into the East/Japan Sea through the Korea Strait (Oba, 1991).

Compilation of high-resolution seismic profiles and sediment core data from the Korea Strait revealed that the lowstand deposits during the last glacial period consist of relict coastal deposits (beach/shoreface complex; BSC) at the shelf margin and thick deltaic deposits (lowstand deltaic wedge; LDW) in the western channel, which were formed by sediments provided through the paleochannels of the Nakdong River (Yoo and Park, 1997, 2000; Park et al., 2000). The BSC, formed during the early stage of postglacial transgression between about 12 and 15 ka, consists of reworked gravelly sand, overlying the erosional transgressive surface on sandy mud sediments of the LDW (Park et al., 2000; Yoo and Park, 2000). Both BSC and LDW show an NE-SW trending elongated distribution, parallel to the paleoshoreline. Based on this distribution pattern, Park et al. (2000) suggested substantial shore-parallel sediment transport by paleocurrent through the Korea Strait at that time. The variations of LSR and grain-size composition in the 95PC-1 and 97PC-19 sediments (Figs. 4, 6 and 7) indicate that the substantial increases in the hemipelagic fluxes were particularly associated with formation of the BSC during the early stage of the postglacial transgression (Park et al., 2000). We suspect that, even if the western channel of the Korea Strait were not completely closed during the LGM (Park et al., 2000), the shore-parallel sediment transport out of the western channel were restricted at that time.

6. CONCLUSIONS

Variations of detSiO_2/Al_2O_3 and TiO_2/Al_2O_3 ratios of the core 97PC-19 sediments since the Last Glacial Maximum show a significant increase during the last deglaciation (10–15 ka), associated with high silt to clay ratios. This suggests more input of detrital quartz and Ti-bearing minerals relative to Al-rich clay minerals at that time, which can be attributed to increased flux by either aeolian transport or hemipelagic advection. The core 95PC-1 sediments, which are more proximal to the Korea Strait, also indicate significant elevations of LSR and sand and silt contents during the last deglaciation, even much higher than those of the 97PC-19, whereas the ODP site 797 sediments from the Yamato Basin do not show such increases of detrital coarse fractions at that time. The spatial variations of LSR, grain-size composition, and detSiO_2/Al_2O_3 and TiO_2/Al_2O_3 ratios among the core sediments indicate an increased hemipelagic flux of riverine sand and silt during the last deglaciation, which were most likely delivered from the Korea Strait where paleochannels of the Nakdong River extended onto the shelf margin during the last sea-level lowstand. The increased hemipelagic flux may have been caused by shore-parallel sediment transport by paleocurrent through the Korea Strait which was related with formation of the beach/shoreface complex during the early stage of the post-glacial transgression.

ACKNWOLEDGEMENTS: This study was carried out by the grant of KORDI (PE84900) and partly supported by KOSEF (F01-2002-00-20030-0).

REFERENCES

Bahk, J.J., Chough, S.K. and Han, S.J., 2000, Origin of laminated muds and its paleoceanographic significance in the Ulleung Basin, East Sea (Sea of Japan). Marine Geology, 162, 459–477.

Bahk, J.J., Chough, S.K., Jeong, K.S. and Han, S.J., 2001, Sedimentary records of paleoenvironmental changes during the last deglaciation in the Ulleung Interplain Gap, East Sea (Sea of Japan). Global and Planetary Change, 28, 241–253.

Chough, S.K., Jeong, K.S. and Honza, E., 1985, Zoned facies of mass-flow deposits in the Ulleung (Tsushima) Basin, East Sea (Sea of Japan). Marine Geology, 65, 113–135.

Chough, S.K., Lee, G.H., Park, B.K. and Kim, S.W., 1984, Fine structures of turbidite and associated muds in the Ulleung (Tsushima) Basin, East Sea (Sea of Japan). Journal of Sedimentary Petrology, 54, 1212–1220.

Chough, S.K., Lee, S.H., Kim, J.W., Park, S.C., Yoo, D.G., Han, H.S., Yoon, S.H., Oh, S.B., Kim, Y.B. and Back, G.G., 1997, Chirp (2–7 kHz) echo characters in the Ulleung Basin. Geosciences Journal, 1, 154–166.

Crusius, J., Pedersen, T.F., Calvert, S.E., Cowie, G.L. and Oba, T., 1999, A 36 kyr geochemical record from the Sea of Japan of organic matter flux variations and changes in intermediate water oxygen concentrations. Paleoceanography, 14, 248–259.

Fairbanks, R.G., 1989, A 17,000-year glacio-eustatic sea level record: influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation. Nature, 342, 637–642.

Gallet, S., Jahn, B. and Torii, M., 1996, Geochemical characterization of the Luochuan loess-paleosol sequence, China, and paleoclimatic implications. Chemical Geology, 133, 67–88.

Gorbarenko, S.A. and Southon, J.R., 2000, Detailed Japan Sea paleoceanography during the last 25 kyr: constraints from AMS dating and $\delta^{18}O$ of planktonic foraminifera. Palaeogeography Palaeoclimatology Palaeoecology, 156, 177–193.

Hovan, S.A. and Rea, D.K., 1991, Late Pleistocene continental climate and oceanic variability recorded in northwest Pacific sediments. Paleoceanography, 6, 349–370.

Hyun, S., Huh, S. and Han, S.-J., 2001, Last Glacial Maximum-Holocene variability in geochemical records of a core sediment from the southern part of the Ulleung Basin, East Sea: implications for paleoceanographic changes. Journal of the Korean Society of Oceanography, 6, 71–80.

Irino, T. and Tada, R., 2000, Quantification of aeolian dust (Kosa) contribution to the Japan Sea sediments and its variation during the last 200 ky. Geochemical Journal, 34, 59–93.

Irino, T. and Tada, R., 2002, High-resolution reconstruction of variation in aeolian dust (Kosa) deposition at ODP site 797, the Japan Sea, during the last 200 ka. Global and Planetary Change, 35, 143–156.

Jahn, B., Gallet, S. and Han, J., 2001, Geochemistry of the Xining, Xifeng and Jixian sections, Loess Plateau of China: eolian dust provenance and paleosol evolution during the last 140 ka. Chemical Geology, 178, 71–94.

Kawamura, H. and Wu, P., 1998, Formation mechanism of Japan Sea Proper Water in the flux center off Vladivostok. Journal of Geophysical Research, 103, 21611–21622.

Keigwin, W.D. and Gorbarenko, S.A., 1992, Sea level, surface salinity of the Japan Sea, and the Younger Dryas event in the northwestern Pacific Ocean. Quaternary Research, 37, 346–360.

Kim, K.R., Kim, G., Kim, K., Lobanov, V., Pononmarev, V. and Salyuk, A., 2002, A sudden bottom-water formation during the severe winter 2000–2001: The case of the East/Japan Sea. Geophysical Research Letters, 29, 75-1–75-4 (1234, DOI 10.1029/2001GL014498).

Lee, C.-B., Park, Y.A., Kang, H.J. and Kim, D.C., 1991, Geochemical characteristics of the continental shelf and slope sediments off the southeastern coast of Korea. The Korean Journal of Quaternary Research, 5, 15–32.

Lee, H.J., Chough, S.K. and Yoon, S.H., 1996, Slope-stability change from late Pleistocene to Holocene in the Ulleung Basin, East Sea (Japan Sea). Sedimentary Geology, 104, 39–51.

Lee, K.E., Bahk, J.J. and Narita, H., 2003, Temporal variations in productivity and planktonic ecological structure in the East Sea (Japan Sea) since the last glaciation. Geo-Marine Letters, 23, 125–129.

Liu, T., 2nd ed., 1988, Loess in China. Springer-Verlag, Heidelberg, 224 p.

Machida, H., 1999, The stratigraphy, choronology and distribution of distal marker-tephras in and around Japan. Global and Planetary Change, 21, 71–94.

Mortlock, R.A. and Froelich, P. N., 1989, A simple method for the rapid determination of biogenic opal in pelagic marine sediments. Deep-Sea Research, 36, 1415–1426.

Oba, T., Kato, M., Kitazato, H., Koizumi, I., Omura, A., Sakai, T. and Takayama, T., 1991, Paleoenvironmental changes in the Japan Sea during the last 85,000 years. Paleoceanography, 6, 499–518.

Park, S.C., Yoo, D.G., Lee, C.W. and Lee, E.I., 2000, Last glacial sea-level changes and paleogeography of the Korea (Tsushiam) Strait. Geo-Marine Letters, 20, 64–71.

Park, S.C., Yoo, D.G., Lee, K.W. and Lee, H.H., 1999, Accumulation of recent muds associated with coastal circulations, southeastern Korea Sea (Korea Strait). Continental Shelf Research, 19, 589–608.

Prins, M.A., Postma, G. and Weltje, G.J., 2000, Controls on terrigenous sediment supply to the Arabian Sea during the late Quaternary: the Makran continental slope. Marine Geology, 169, 351–371.

Rea, D.K. and Leinen, M., 1988, Asain aridity and the zonal westerlies: Late Pleistocene and Holocene record of eolian deposition in the northwest Pacific Ocean. Palaeogeography, Palaeoclimatology, Palaeoecology, 66, 1–8.

Shackleton, N.J., 1987, Oxygen isotopes, ice volume and sea level. Quaternary Science Reviews, 12, 183–190.

Shipboard Scientific Party, 1990, Site 797. In: Tamaki, K., Pisciotto, K. and Allan, J. (eds.), Proceedings of the Ocean Drilling Program. Initial Reports, 127, College Station, TX (Ocean Drilling Program), p. 71–167.

Steinke, S., Kienast, M. and Hanebuth, T., 2003, On the significance of sea-level variations and shelf paleo-morphology in governing sedimentation in the southern South China Sea during the last deglaciation. Marine Geology, 201, 179–206.

Stow, D.A.V., Reading, H.G. and Collinson, J.C., 1996, Deep seas. In: Reading, H.G. (ed.), Sedimentary Environments: Processes, Facies and Stratigraphy. Blackwell Science, Oxford, p. 395–453.

Suzuki, T. and Tsunogai, S., 1987, Transport of chemical species from land to sea through atmosphere. Kaiyo Monthly, 19, 657–662. (In Japanese)

Tada, R., Irino, T. and Koizumi, I., 1999, Land-ocean linkage over orbital and millennial timescales recorded in late Quaternary sediments of the Japan Sea. Paleoceanography, 14, 236–247.

Yoo, D.G. and Park, S.C., 1997, Late Quaternary lowstand wedges on the shelf margin and trough region of the Korea Strait. Sedimentary Geology, 109, 121–133.

Yoo, D.G. and Park, S.C., 2000, High-resolution seismic study as a tool for sequence stratigraphic evidence of high-frequency sea-level changes: latest Plestocene-Holocene example from the Korea Strait. Journal of Sedimentary Research, 79, 296–309.

Manuscript received June 11, 2004
Manuscript accepted December 14, 2004