The Journal of the Korean Society of Oceanography
Vol. 32, No. 3, pp. 128-137, September 1997

Organic Carbon, Calcium Carbonate, and Clay Mineral Distributions in the Korea Strait Region, the Southern Part of the East Sea

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This study presents results from a detailed sedimentological investigation of surface sediments obtained from the Korea Strait region, the southern part of the East Sea (Sea of Japan). The distribution of different types of bottom sediments is controlled by the recent fine-grained sediment transport and deposition combined with the lowerings of sea level during the last glacial period, forming a diverse mixture of organic-rich fine-grained and shelly coarse-grained sediments. In comparison to high organic concentration of fine-grained sediments in the inner continental shelf and slope areas, the shell-rich coarse-grained sediments on the outer shelf are discernible being further modified. These coarse-grained sediments are confirmed as relict resulting from the sediment dynamics during the lower sea levels of the last glacial period. Clay mineral distribution of the fine-grained sediments gives information about the transport mechanism. Presence of present-day current system (the Tsushima Warm Current) is most probable source for the fine-grained particles into the open East Sea from the East China Sea, indicating that Holocene sediment dynamics may be used to explain the observed distribution of surface coarse-grained shell-rich sediments.

INTRODUCTION

The East Sea (Sea of Japan; hereafter East Sea) is a semi-isolated marginal sea of northwestern Pacific Ocean. The Korea Strait serves as the only avenue to connect the East China Sea with the East Sea (Fig. 1) and plays a very sensitive and important role on the climatic change (Oba *et al.*, 1991; Keigwin and Gorbarenko, 1992). For example, the shallowness of the Korea Strait region caused almost all subaerial exposure during the last glacial maximum (LGM) to prevent the interchange between the East Sea and East China Sea. In the southeastern continental shelf of Korean Peninsula including the Korea Strait, a variety of studies on textural aspects of surface sediments and distribution of suspended particulate matter have been, thus, done by numerous academic and research groups (Park, 1985; Park and Choi, 1986; Suk, 1986; Park *et al.*, 1990; Chough *et al.*, 1991; Park and Chu, 1992; Choi and Park, 1993; Choi *et al.*, 1995).

Occurrence of coarse-grained sediments in the Korea Strait region has been the subject of much discussion, with particular attention being paid to the provenances (Park, 1985; Park and Choi, 1986; Park *et al.*, 1987; Choi *et al.*, 1995). The sediments on the outer continental shelf of the Korean Peninsula generally represent a relict feature because of the extraordinary grain size and abundance of shell remnants. Evidences of shelf relict sediments are further provided by the iron-bearing coarse-grained minerals as well as by the patchy deposits of beach gravels (Park, 1985; Choi and Park, 1993). These were formed on a subaerially exposed or much shallower shelf during the last glacial period.

Lack of sediment input through adjacent rivers in the Korea Strait region is likely to be responsible for the thin continental shelf deposits (Chough 1983). Recently, some of the fine-grained sediments delivered towards the East Sea through the Korea Strait from the Yellow Sea were reported considering the budget estimation of suspended sediments in the Yellow Sea (Wells and Huh, 1984; Wells, 1988; Lee and Chough, 1989). The clay mineral abundances in the fine-grained sediments are dominantly controlled by the circulation patterns and subsequently depositional processes. Thus, the distribution of fine-grained sediments in the modern continental shelf setting was described by the clay minerals imprinted their fingerprint from the source regions (Khim and Park, 1992; Segall and Kuehl 1992; Rao and Rao 1995).

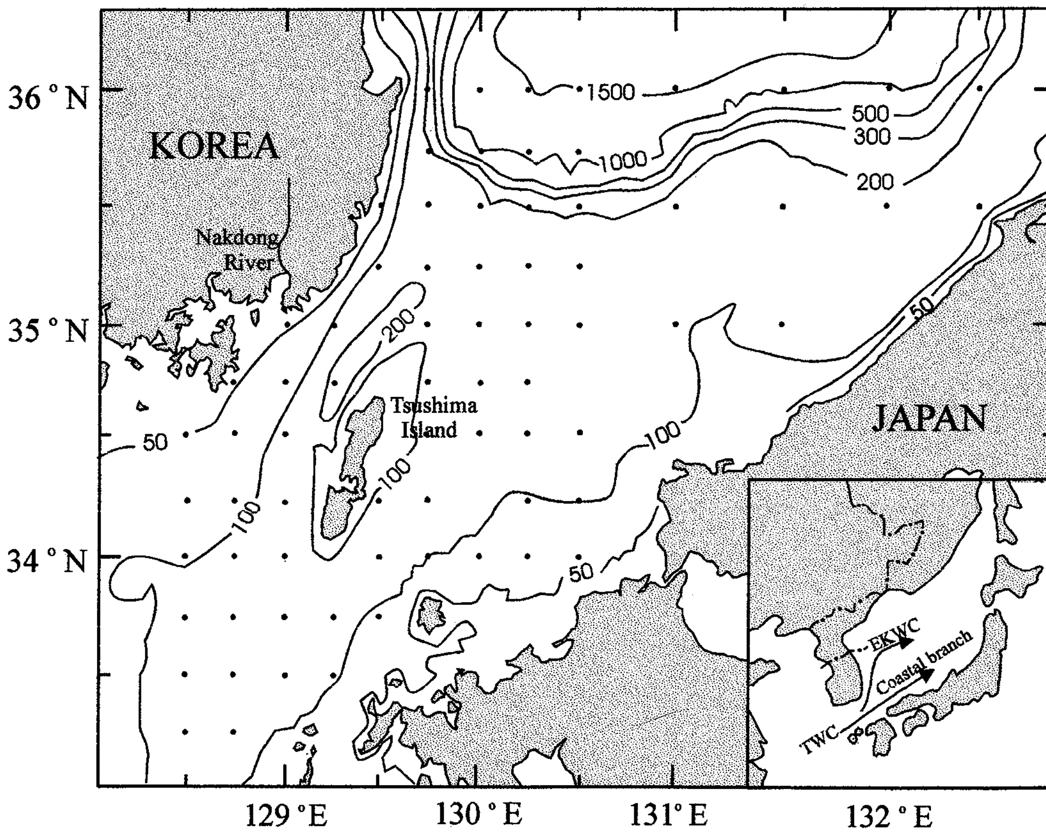

Fig. 1. Map showing the seventy-three sampling sites and bathymetry around the Korea Strait, the southern part of the East Sea. Water depths are in meters. Inset depicts the dominant current (Tsushima Warm Current) occupied in the study area and its branches (EKWC; East Korean Warm Current and Coastal branch).

In this paper, the various features of bottom sediments in the Korea Strait region, i.e., the southern part of the East Sea, are described to understand the observed distribution patterns. The principal objective of this study is to determine the factors responsible for variations in the sediment texture, associated properties and clay mineral distributions.

STUDY AREA

The East Sea is topographically a semi-isolated back-arc basin surrounded by the Japanese Islands, Sakhalin, Siberian coast, and Korean Peninsula (Fig. 1). The East Sea is morphologically connected with the North Pacific and other marginal seas (the Okhotsk Sea and the East China Sea) through the four (Tartary: 15 m, Soya: 55 m, Tsugaru: 130 m, Korea: 130 m) constricted and shallow straits. Between Korean Peninsula and Japanese Islands lies the Korea Strait with two troughs on both sides of the Tsushima Island. The trough is as much deep as 230 m in maximum. The study area includes the Korea Strait as well as nearby continental shelf (shallower than 200 m in water depth) with part of continental slope (up to 1500 m in water depth).

The study area of the present work is particularly characterized by lack of large river mouths, except the influence of the Nakdong River in the southeastern Korea (Fig. 1). The Nakdong River discharges about 10 million tons of sediments annually (Chough, 1983). Most of the drainage basin is chiefly covered by the Cretaceous sedimentary rocks with late Cretaceous granite intrusion as well as Precambrian granitic gneiss.

The primary circulation patterns in the East Sea was described by Moryasu (1972). The only important current flowing northeastward into the East Sea today is the Tsushima Warm Current, a branch of the Kuroshio Current, which enters through the Korea Strait from the East China Sea (Fig. 1; Seung and Yoon, 1995). It flows out to the North Pacific mainly through the Tsugaru Strait in the northeastern part. It has been well known that the Tsushima Warm Current splits into, at least, two branches around the Korea Strait (Kim and Legeckis, 1986). Inset of Fig. 1 shows that one branch flows along the Japanese coast (Coastal branch) controlled by the bottom topography and the other flows northward along the eastern coast of Korea (East Korean Warm Current).

MATERIALS AND METHODS

From the continental shelf and slope adjacent the Korea Strait (Fig. 1), seventy-three surface sediment samples were taken using the grab sampler on the R/V *Eardo* in May, 1993 conducted by the Korean Ocean Research and Development Institute (KORDI). Sediment samples for grain size analyses were rendered free of organic matter and calcium carbonate by treatment of H_2O_2 and HCl. Sand fractions larger than 63 μm were classified using standard sieve technique and mud fractions smaller than 63 μm were measured using Sedigraph 5000D. Bottom sediment type was categorized with the ternary diagram outlined in Folk (1968).

Sediment subsamples were dried at 60°C and ground to fine powders using an agitate mortar. A representative split of sediment powder was analyzed for particulate organic carbon (POC) by the wet-combustion method (Stickland and Parsons, 1972). The precision of POC lies within 3%. The concentration of calcium carbonate was volumetrically determined with a Bernard calcimeter through the release of CO_2 and the values are expressed as weight percent with a precision of 3%.

Texturally-oriented aggregates of the <2 μm fractions were smeared onto glass slides for clay mineral identification (Biscaye, 1965). Glycolation treatment was made by vapor-pressure exposure at 60°C for 24 hours and heated-treatment was done at 550°C. The slides were run on a Philips PW1710W X-ray diffraction system using CuKα radiation with Ni filter at 1.8°2θ/min. Major clay minerals (smectite, illite, chlorite, and kaolinite) were identified by their characteristic basal reflections following Brindley and Brown (1980). In this paper we concentrate on the main clay mineral groups within which compositional differences are not considered. Semiquantitative evaluations of the clay mineral assemblages were based on the relative proportions of the integrated peak areas. The relative percentage of each clay mineral was determined using empirically estimated weighting factors (Biscaye, 1965). All statistical and multivariate analyses were performed using the SPSS program.

RESULTS AND DISCUSSION

Surface sediment types

Generally, the various types of bottom sediments are distributed in the study area (Fig. 2). Based on the ternary diagram (Folk, 1968), the bottom sediments were divided into the four types. Sediment type 1 is composed completely of mud (silt and clay) with a little sand-sized particles. Sediment type 1 occurs along the inner shelf off the southeastern Korea as a narrow band and in the continental slope of the Ulleung Basin in the northern part of the investigated area. A band of fine-grained sediments in the inner shelf probably occurs continuously along the eastern coast of Korea (Lee *et al.*, 1989; Park *et al.*, 1990b). Park and Yoo (1988) found using the high-resolution seismic profiles that the Quaternary sediments were preserved as much as 50 m in thickness off the southeastern coast of Korea and suggested that these late Pleistocene deposits were formed by the supply of the Nakdong River. Since the late stage of the Holocene transgression at around 7000-5000 yrBP, most of sediments from the Nakdong River were trapped in the estuary and inner shelf area forming sediment type 1 (Park *et al.*, 1990a). In contrast to the inner shelf deposit, same sediment type of continental slope was interpreted to form through uniform hemipelagic sedimentation (Lee *et al.*, 1993).

Sediment type 2 comprises sandy mud and slightly gravelly sandy mud whereas sediment type 3 consists of muddy sand, slightly gravelly muddy sand, and gravelly muddy sand. Both types occupy the largest area of the sea bottom (Fig. 2); sediment type 2 can be found largely in the north of the Tsushima Island and sediment type 3 lies in the southern part of Korea Strait, both sides of the Tsushima Island and northeastern part towards Japan. These sediment types are characterized by the mixture of fine- and coarse-grained particles, which shows the poor sorting values. Salient features of the spatial distribution of sediment type 3 reflect the fine-grained sediments being provided in the study area either from the Yellow Sea through the South Sea or from the East China Sea by the Tsushima Warm Current (Wells, 1988).

Finally, sand, gravelly sand and slightly gravelly sand belong to sediment type 4. This sediment type

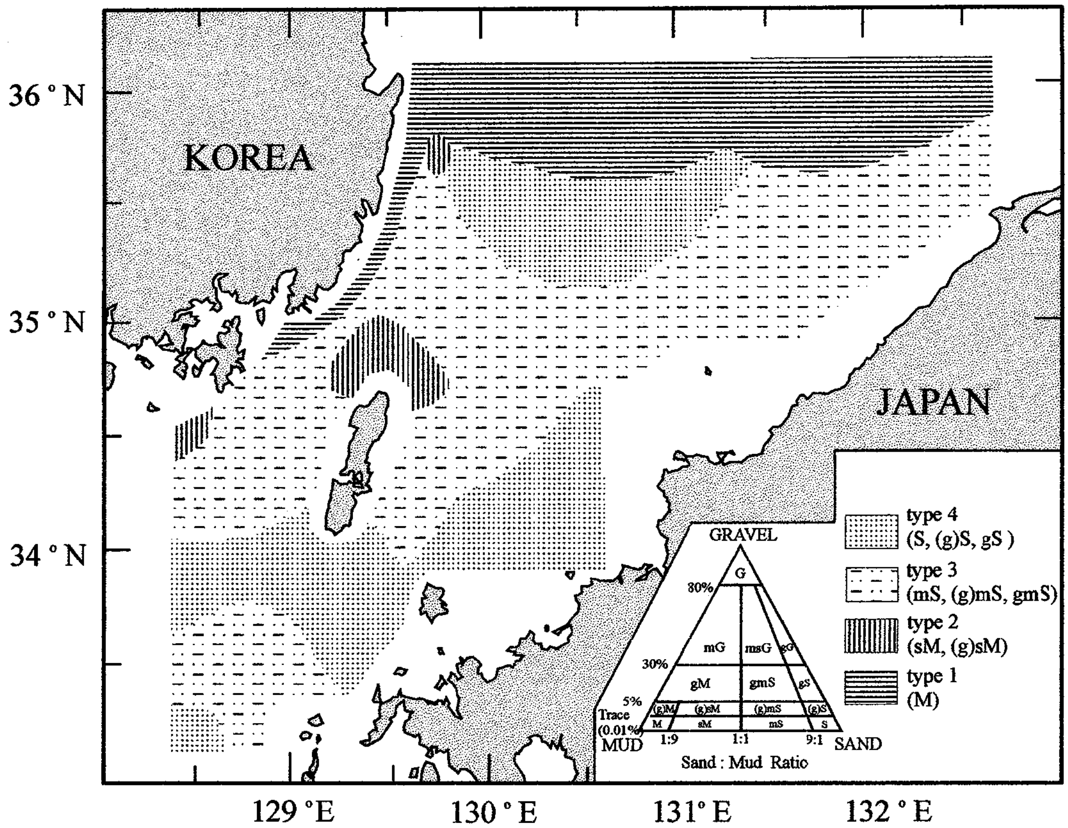

Fig. 2. Distribution pattern of the bottom sediments in the study area, which are divided into four types based on the ternary diagram of Folk (1968). Type 1 comprises the mud (M). Type 2 consists of sandy mud (sM) and slightly gravelly sandy mud ((g)sM). Type 3 includes muddy sand (mS), slightly gravelly muddy sand ((g)mS) and gravelly muddy sand (gmS). Type 4 is composed of sand (S), gravelly sand (gS) and slightly gravelly sand ((g)S).

occupies in the two distinct areas; one is the southern part of the East Sea between 100 and 200 m in water depth and the other is distributed from the entrance of the Korea Strait along the Japanese side of continental shelf (Fig. 2). The consistent occurrence of coarse sands and gravels at the water depth about 130 to 150 m near the shelf edge suggests that the sediments are relict (Park 1985; Suk, 1986). Chough *et al.* (1991) also reported similar sedimentary features from the continental shelf further south of the Korea Strait region as the relict sands formed during the early phase of Holocene sea-level rise.

POC and $CaCO_3$

Organic carbon content in marine sediments yields useful information on the depositional environment, circulation pattern, surface-water productivity, and preservation potential to diagenesis (e.g., Stein, 1991). In general, the concentrations of POC in the surface sediments of the study area are relatively low; most values are less than 3% (Fig. 3a). Due to the carbonate-free sediments used in the POC analyses, most of total carbon is derived from organic matter that has been absorbed by clay particles. An areal distribution of POC is clearly distinguished on the boundary of 35°30'N; minimum values of less than 1% occur south of 35°30'N, but north of 35°30'N more than 1% can be found.

The low concentration in the shallower southern region coincides with the coarse-grained particles of sediment types 3 and 4 (Fig. 2). However, south of 35°30'N, an area of intense organic matter accumulation with high concentration of POC was observed in the southeastern inner shelf of the Korean Peninsula. Comparatively, relatively large quantity of organic matter in this area probably result from high productivity in the surface plume (Byun, 1989). The high concentration of POC in the northern area clearly corresponds to the relationship between water depth and concentration of POC, which reflects the relationship with the fine-grained hemipelagic sediments (Fig. 4a).

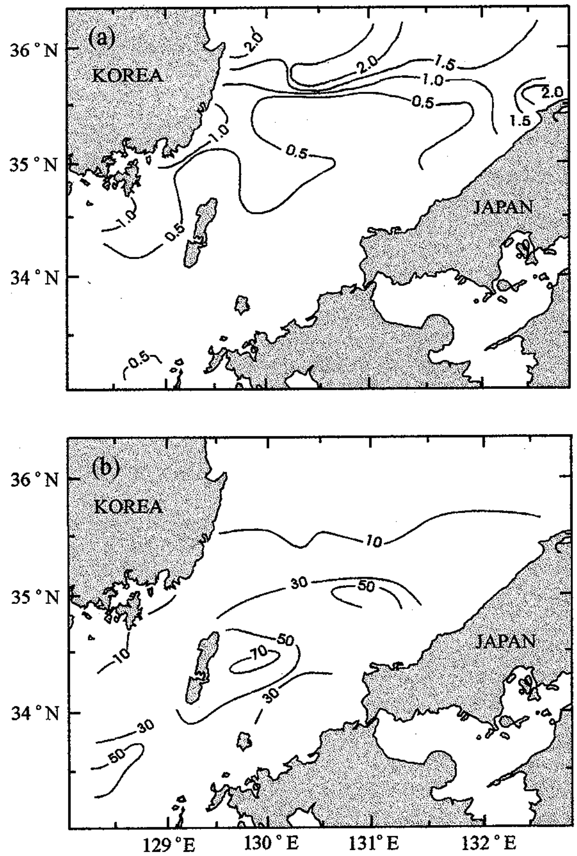

Fig. 3. Distribution of (a) POC and (b) $CaCO_3$ in the study area. Each units are in percent. The distribution of POC and $CaCO_3$ shows the mirror image, which may be responsible for the fine-grained sediments.

A negative correlation between POC and grain size is almost universally observed in the fine-grained, noncarbonate sediments in marine and lacustrine environments because of the adsorption of organic matter by clays. The higher concentration of POC in the northern part of deeper region associated with the fine-grained sediments is also seen in Fig. 4b, which shows a strongly linear correlation between grain size and POC. In the study area, where the diverse types of bottom sediments can be observed, the grain size may be the major factor to determine the amounts of POC. For example, concentrations of POC are highest in the region of fine-grained sediments and lowest in areas where coarse-grained sediments are dominant.

The content of $CaCO_3$ in the surface sediments varies up to 73% and regional variation is very great (Fig. 3b). Distribution of $CaCO_3$ content is almost opposite to POC. Three successive bull's eye pattern east of the Tsushima Island highlights the highest concentration of $CaCO_3$, among which the highest lies just east of Tsushima Island. Most of $CaCO_3$ are chiefly of biogenic origin, composed of broken shell fragments, such as mollusks, echinoid spines, bryozoans, and some microfossils; detrital carbonate is of negligible importance. However, virtually nothing is known of the detailed composition of these biogenic components. Yoon *et al.* (1993) classified the mollusk species of bottom sediments and suggested that most of species are of shallow marine. The variation of $CaCO_3$ concentration to the water depth is shown in Fig. 4c. Unlike the POC, the $CaCO_3$ contents become lower in accordance to increasing water depth. In the region deeper than 200 m, the content of $CaCO_3$ is somewhat constant no more than 10%. The dominance of coarse-grained sediments most probably reflect that these shells might be relict.

Clay minerals

Since the pioneering work of Oinuma and Kobayashi (1966), the clay mineral studies on recent

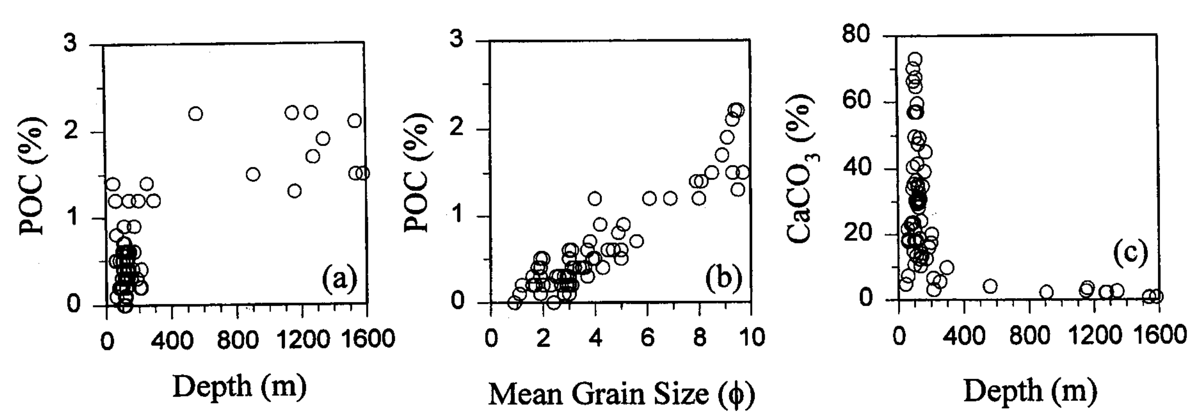

Fig. 4. Relationship between (a) POC and water depth, (b) POC and mean grain size, (c) $CaCO_3$ and water depth. POC are limited to the water depth above 200 m whereas the $CaCO_3$ are widespread shallower than 200 m. POC and mean grain size shows the linear relationship.

marine sediments in the East Sea including the adjacent marginal seas have been made by exclusively Japanese researchers (Shiozawa 1969; Sato 1972; Aoki and Oinuma 1978; Aoki *et al.* 1974, 1983; Aoki and Oinuma, 1988). In addition, a few regional studies of Korean-side research on clay minerals have been conducted (Park and Han 1985; Lee *et al.* 1989; Park *et al.* 1996). However, there is little likelihood of interpretation on the regional distribution of clay mineral with respect to the East Sea. In this study, the abundance of each clay mineral compositions is shown in Fig. 5. The results summarize that illite is the most widespread clay mineral, chlorite and kaolinite are the next subordinate, smectite is lowest in most sediment samples studied. This general trend will be discussed with the significance of the previous studies associated with the abundance of clay minerals.

In all surface sediments illite is the dominant clay mineral with concentrations between 29% and 80% (Fig. 5a). Major trend in illite concentrations is discernible in the study area. From the Korean Peninsula towards Japan, illite content decreases gradually. This distribution pattern seems to be parallel to the flow path of the Tsushima Warm Current and its two branches (Seung and Yoon, 1995). According to the previous studies (Oinuma and Kobayashi 1966; Aoki *et al.* 1983; Lee *et al.*, 1989; Park *et al.*, 1996), illite in the East Sea was interpreted to be transported largely by the Tsushima Warm Current, which delivered the fine-grained sediments from the East China Sea. However, the gradual decrease of illite is not likely to be the effect of Tsushima Warm Current. In general, the highest concentration of illite in the East Sea was reported on the Korea Plateau (Aoki *et al.* 1974). Less concentrations of illite were obtained along the Japanese coast due to the sediments discharged from the Japanese rivers (Shiozawa 1969; Aoki and Oinuma 1974). Thus, the relatively large concentration of illite in the Korea side may be attributed to the Nakdong River (Park and Han 1985; Lee and Chough 1989; Park and Chu, 1992).

The average chlorite concentration in the surface sediments is about 17% ranging between 10% and 31%. The majority of the samples falls in the range

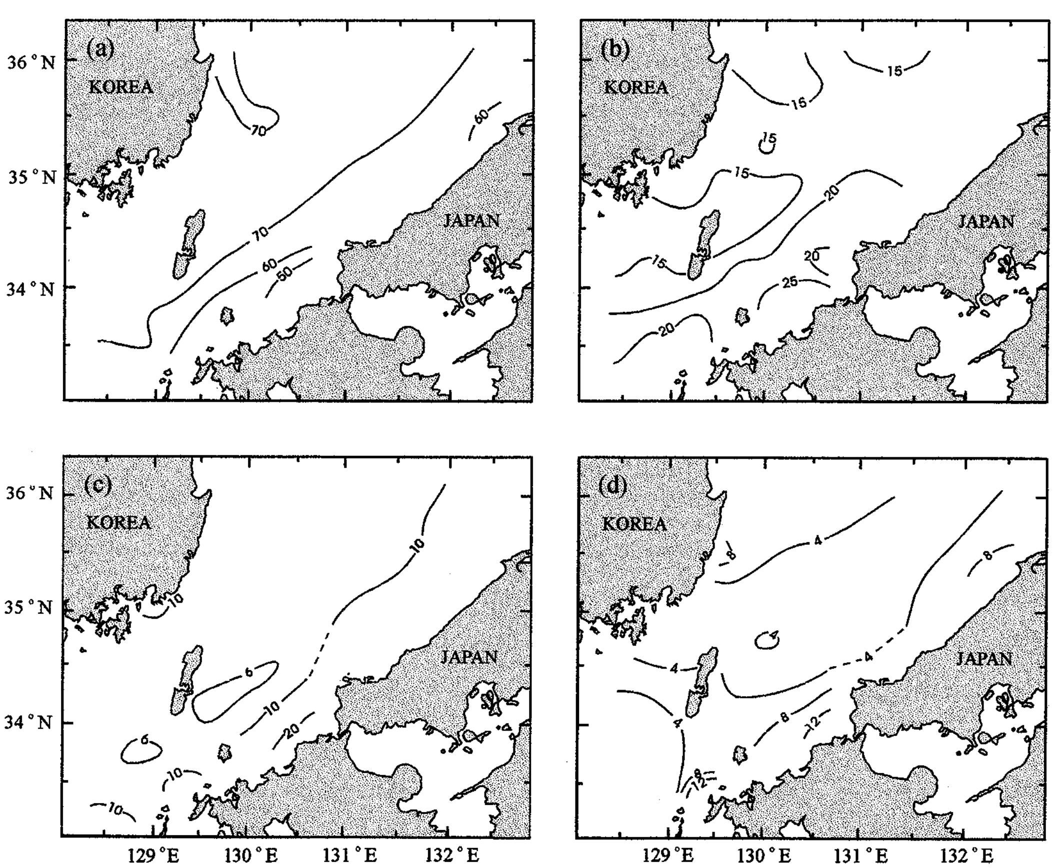

Fig. 5. Distribution of clay mineral compositions in the study area. (a) illite, (b) chlorite, (c) kaolinite, (d) smectite

of 14 to 25%. Significant regional variations in chlorite content are also apparent and opposite to that of illite. Japanese side in the Korea Strait has more concentration of chlorite than Korean side (Fig. 5b). In the East Sea, chlorite was reported as more concentration on the Japanese side than on the Asian side in accordance with the result of present study (Aoki and Oinuma 1988). The higher concentrations of chlorite on the Japanese side resulted from supplies of the fine-grained materials rich in chlorite from the Japanese rivers because of the different geological characteristics between the Japanese Islands and the Asian continent (Sato 1972; Aoki *et al.* 1974). However, it is due to the lack of large rivers in the study area that the Tsushima Warm Current has been considered to transport low concentration of chlorite from the East China Sea (Aoki *et al.* 1983). The relatively low concentration of chlorite in the west of Korea Strait implies the possible supply of chlorite-poor fine-grained sediments from the Korea. Otherwise, the distribution pattern may show the additional result at the expense of illite reduction.

Kaolinite contents vary between 5% and 20% except one station and the abundance is almost constant in surficial sediments except several ubiquitous stations (Fig. 5c). Moreover, the distribution of kaolinite content follows the similar pattern to that of chlorite. Kaolinite concentration of the easternmost East Sea was known to be relatively high, possibly because of large discharge of kaolinite from Japanese Islands (Aoki *et al.* 1974). Highest value (approximately 30%) near Japan in this study may also be contributed to the local source nearby Japanese Island. The relatively small amounts of kaolinite in the southern East Sea including the study area may be responsible for the low influx of kaolinite through the Tsushima Warm Current from the East China Sea. It also arise from dilution by large concentration of illite supplied from Korean Peninsula and from the East China Sea. Although kaolinite from the Nakdong River was not supplied to the Tsushima Warm Current but deposited within the estuary (Park and Han 1985; Park and Chu, 1992), the local abundance in the southeastern tip of Korean Peninsula may result from the Nakdong River.

Smectite in marine sediments is either formed from volcanic glass by alteration or derived from detritus and products of weathering volcanic rocks. Smectite concentrations of the sediments in the study area average 5% and the range of relative abundances is about 16% (Fig. 5d). On the whole, most of study area covers the low concentration of smectite less than 5%. However, smectite contents are found discernibly as relatively high concentration close to the Japanese coasts. The amount of smectite in the East Sea has been also reported to become relatively abundant towards the Japan. This may be attributed to the relatively high supplies of smectite from the Japanese rivers covered by volcanic materials (Aoki *et al.* 1974; Aoki and Oinuma 1988). In spite of poor discharge from the Japanese River nearby, the high concentration of smectite in this study appears to reflect Japanese local source.

Classification of sedimentary regime

In order to place the comparison on a more objective basis, we have carried out multivariate analyses on the obtained data that include grain size, content of clay minerals and others of the surface sediments from the seventy-three stations. Correlation coefficients among the eleven variables performed in the present study are summarized in Table 1. Sand content shows strongly inverse rela-

Table 1. Correlation coefficient matrix for the eleven parameters of the surface sediments in the Korea Strait region. Based on bulk (natural) data. Significant correlation (P<0.01; r>0.29; n=73) at greater than 99% confidence level are shown in bold type

	gravel	sand	silt	clay	mean	POC	$CaCO_3$	illite	chlorite	kaolinite	smectite
gravel	1.000										
sand	0.157	1.000									
silt	-0.198	-0.703	1.000								
clay	-0.196	**-0.939**	0.423	1.000							
mean	-0.332	**-0.965**	0.609	**0.965**	1.000						
POC	-0.204	**-0.824**	0.460	**0.837**	**0.830**	1.000					
$CaCO_3$	0.156	0.482	-0.109	-0.571	-0.519	-0.538	1.000				
illite	-0.089	-0.223	0.207	0.188	0.251	0.063	-0.009	1.000			
chlorite	0.236	0.497	-0.365	-0.470	-0.548	-0.397	-0.203	**-0.820**	1.000		
kaolinite	-0.074	0.015	-0.025	0.000	-0.008	0.175	-0.159	-0.770	0.238	1.000	
smectite	-0.013	-0.088	-0.055	0.138	0.083	0.165	0.336	-0.673	0.170	**0.680**	1.000

tionship with clay content, mean grain size and POC, three of which are dependent on each other. For example, clay content is inter-correlated with the mean grain size, which controls POC with correlation coefficient of 0.837 (Fig. 4b). It is wondering that $CaCO_3$ does not show good relationship to other variables. It may be due either to that $CaCO_3$ is mostly composed of biogenic fragments or to that the textural properties are obtained from carbonate-free sediments. Illite shows the opposite relation to other three clay minerals primarily because of the compositional calculation. However, kaolinite has a fairly good relationship to smectite. The areal distribution of these two minerals satisfies the statistical meaning (Fig. 5).

As shown in Table 2, the three significant factors account for about 80% of the variance. In this case, all factors retain an eigenvalue equal to or greater than 1. These loadings can be thought as composite compositional variables from the reduction of the eleven compositional variables used as input in the Q-mode analyses to three compositional variables, each expressing some compositional attribute of the sediments based on a synthesis of several measured compositional variables. However, the loadings provided no indications as to which compositional variables were synthesized into which factor (composite variables). We used the factor loadings to determine the relative contributions of each compositional variable to the Q-mode model by computing correlation coefficients between the loadings and the eleven measured variables. The results are given in Table 2.

Loadings on factor 1 correlate positively with clay content, POC and mean grain size in order of decreasing magnitude of correlation coefficient. Factor 1 loadings also correlate negatively with sand content and $CaCO_3$. The compositional variables indicative of organic-rich fine-grained sediments have all been synthesized into factor 1. Fig. 6 shows that the sediment with higher loadings (more than 1.0) for factor 1 occurs in the deeper slope region, so that this distribution is a measure of the contribution of hemipelagic sediment containing a relatively high amount of POC. Thus, factor 1 represents close dependence on mean grain size, being interpreted as reflecting the influence the modern sedimentary dynamics.

Samples with the highest loadings for factor 2 tend to contain relatively high concentrations of kaolinite and smectite negatively correlating with the content of illite. A map of higher loadings for factor 2 sediment indicates that these sediments are narrowly limited and close to the Japan (Fig. 6). Factor 2 may also be considered as the recent supply of sediment dynamics on the shelf region in case for the fine-grained sediments. However, these sediments seem to be discernible from other parts of study area. Finally, factor 3 shows the positive correlation with gravel (Table 2). The distribution of sediment samples with higher loadings for factor 3 (Fig. 6) reflects the widely scattered distribution, but these occur around the Tsushima Island. Other parts of all bottom sediments are mixed with these three compositional factor loadings.

We used Q-mode factor analysis to determine regional groupings of similar sediments on the basis

Table 2. Correlation coefficients among factor loadings for each of the three factors used in the Q-mode factor analysis. Correlation coefficients significant at the 99% confidence level are in bold type

	Factor 1	Factor 2	Factor 3
gravel	-0.291	0.004	**0.685**
sand	**-0.962**	-0.042	0.017
silt	0.560	-0.141	-0.544
clay	**0.956**	0.119	0.171
mean	**0.981**	0.039	-0.072
POC	**0.947**	0.151	0.046
$CaCO_3$	-0.619	-0.232	-0.303
illite	0.310	**-0.935**	0.046
chlorite	-0.603	0.423	0.145
kaolinite	-0.030	**0.880**	-0.215
smectite	0.039	**0.871**	-0.066
eigenvalue	5.560	2.729	1.074
percent of	46.6	22.7	9.0
cumulative percent	46.6	69.4	78.3

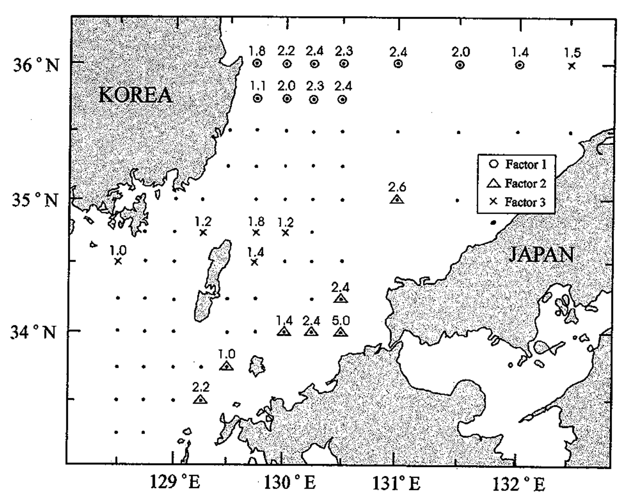

Fig. 6. Stations showing individual factors retaining an eigenvalue equal to or greater than 1. The three significant factors account for about 80% of the variance.

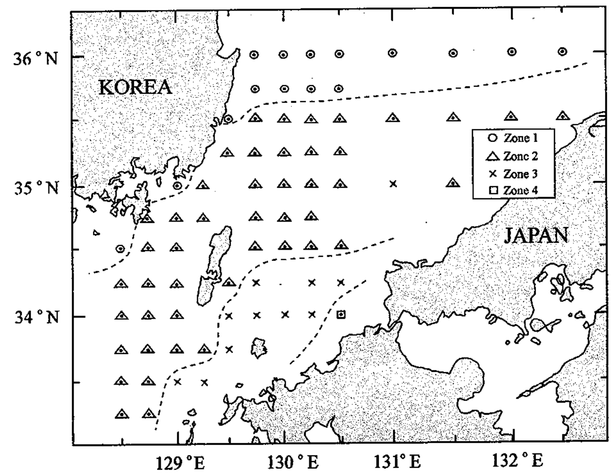

Fig. 7. Regional groupings of similar sediments on the basis of all measured compositional variables based on Q-mode cluster analyses. A variety of bottom sediment properties divides the study area into four major zones.

of all measured compositional variables. As a summary, based on the Q-mode cluster analyses, the bottom sediments in the study area can be classified possibly into four major groups (Fig. 7); 1) the fine-grained sediments in the inner shelf and slope, i.e., the most significant contribution of recent fine-grained sediment dynamics 2) the mixture of muddy and sandy sediments in the large part of central Korea Strait, creating deposition of recent fine-grained sediments on the relict coarse-grained sediments of lowered sea-level condition, 3) the separate coarse-grained sandy sediments in the Japanese-side continental shelf region, forming a relatively high concentration of $CaCO_3$ composed of biogenic shell materials, and 4) a local and distinct coastal sediment off the Japanese Island in the easternmost of Korea Strait.

CONCLUSIONS

Detailed description on the textural and associated properties and clay minerals of the bottom sediments in the Korea Strait region, southern part of the East Sea gives the following information:

(1) The surface sediments in the study area are divided into four different types based on the ternary diagram (Folk, 1968) and the distribution patterns of these sediments are likely to be influenced by the recent fine-grained sediment dynamics as well as by the relict sediments of the lowered sea-level stands.

(2) The concentration of POC in the study area is controlled by the grain size of the sediments and the contents of $CaCO_3$ shows the mirror image of POC.

(3) The distribution of clay minerals in the Korea Strait region reflect the role of the dominant flow system, the Tsushima Warm Current, and the local abundances seems to be due to the continental source.

(4) The multivariate statistic analyses follows the similar results on the differentiation of sedimentary regime to aid the interpretation on the recent depositional system.

ACKNOWLEDGMENTS

This research was carried out by the support from the Ministry of Science and Technology (BSPN 00227-733-3) to KORDI from 1990 to 1993. Laboratory works kindly helped by Ms. H.J. Cha and Mr. B.S. Kim (Seoul National University) and Ms. H.J. Choi (KORDI) are appreciated. Thoughtful comments and valuable suggestions by Dr. Jin Yong Choi (Kunsan National University) and Dr. Hee Jun Lee (KORDI) improved better understanding the early version of manuscript.

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