LAGUNA (汽水域研究) 7，15～21 頁（2000 年 3 月）
LAGUNA 7，p.15−21 (2000)

The Holocene environmental change of the estuary of Nagdong River, southern Korea

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Abstract : A total of 79 species of benthic foraminifera belonging to 49 genera and 60 species of diatoms belonging to 35 genera are identified from the core samples of the deltaic sediments in Nagdong Estuary. On the basis of benthic foraminiferal fauna and diatom flora, the deltaic sediments of the cores can be divided into three environmental intervals : the upper Interval I bay environment ; the middle Interval II offshore bay environment ; the lower Interval III is bay environment. The sea−water had advanced into Nagdong Estuary already earlier than 7133 yr.B.P. This marine transgression may be correlated with the Jomon Transgression in the Japanese Islands. Sea−level fluctuation occurred after around 7000 yr.B.P., which might be due to the vertical movement of the land of Nagdong Estuary.

Key words : Nagdong Estuary, Holocene environment, micropaleontology, marine transgression

Introduction

Nagdong River is the longest river in southern Korea, and its estuary (Nagdong Estuary) is underlain with broad and thick deltaic sediments. In the marginal area of the estuary, many kitchen middens are distributed, which contain Neolithic and Proto−historic times. Yoon and Yee (1985) and Lee and Yoon (1992) reported the result of the investigation of Sugari Kitchen midden, which is located in the west−central margin of the estuary. Yoon and Yee (1985) studied Site 3 of Neolithic Time and Site 5 of Proto−historic Time, and discussed the sea−level changes of the estuary. They concluded that comparing with the present sea−level, the sea−level was about 5 m higher around 4500 yr.B.P., rose to 7.5 m higher around 3400 yr.B.P., fell to 5 m higher around 1900 yr.B.P. and rose again to 6.5 m higher around 1700 yr.B.P. Lee and Yoon (1992) reported the molluscan assemblages of Site 3 of Neolithic Time, and stated that the lowermost stratigraphic units ranging from 4450 yr.B.P. through 4250 yr.B.P. are terrestrial deposits and the upper units ranging from 4250 yr.B.P. through 2950 yr.B.P. are embayment deposits which were influenced by fresh water.

The present article deals with the environmental change near the bay−mouth of the Nagdong Estuary, analyzing the foraminiferal fauna and diatom flora, which were detected in the drilling cores. The drillings were carried out to investigate the foundation of an industrial complex.

Micropaleontological analysis

1. Materials and Methods

Cores Sp−23 and Sp−39 located near the bay−mouth of the Nagdong Estuary (Fig. 1) are consist of silt or silty clay and clay. A total of 29 samples were collected for the examination of foraminifera and diatoms, which comprise 11 samples from the 13 to 31 m−long silt or clay core of Sp−23 and 18 samples from the 13 to 54 m−long silty clay or clay core of Sp−39 (Fig. 2).

For picking foraminifera, the samples were washed,

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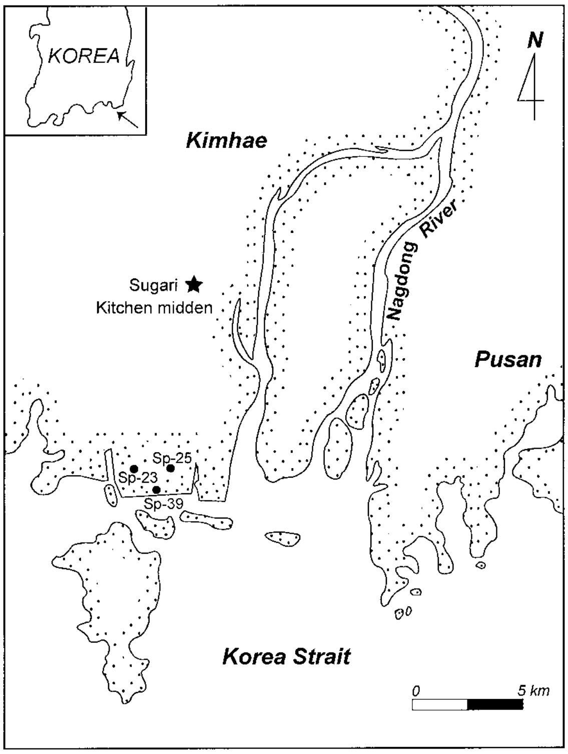

Fig. 1 Location of drilling cores in the study area and Sugari Kitchen midden.

using 74 μm (200 mesh) sieve with tap water, and dried in an oven for 24 hours, and then, fossils were picked under the binocular microscope. For the examination of the fossil diatoms, samples were placed in an oven at 60 ℃ for 24 hr and 3 g of dried−up materials were boiled in a 100 ml beaker with about 10 ml of hydrogen peroxide solution (15%) for several seconds and then left to stand for 24 hr after diluting with distilled water. After pouring off the suspension, the residue were diluted with 50 ml of distilled water and homogenized for about 3 seconds in an ultrasonic washer. Using a micropipette, 0.25ml of this solution was placed on a cover glass, dried on a hot plate at 50℃, and then mounted on a glass slide using Canada balsam.

2. Results

2−1. Benthic Foraminiferal Fauna

A total of 27 samples were collected from the cores Sp −23 and Sp−39. Of these 27 samples, 5 samples from the section 41 to 54 m of the core Sp−39 do not contain benthic foraminifera, and the other 22 samples contain generally abundant and well − preserved fossil foraminifera. From 22 samples, a total of 79 species of benthic foraminifera belonging to 49 genera are picked (Tab. 1).

Core Sp−23 : From 9 samples of the section 15 to 31 m, 60 species belonging to 38 genera of benthic foraminifera are identified. The fossil foraminifera are generally well preserved and abundant. As a whole, the most dominant species of this core are *Elphidium advenum* and *Pseudorotalia gaimardii*. However, a little change of the benthic foraminiferal fauna is identified through the core. In the lowermost part of the core (29−31 m), *P. gaimardii* is not yielded, and the dominant species are *Buccella frigida* and *Elphidium clavatum*. *Ammonia beccarii*, *E. advenum* are common, and *Elphidium somaense* is associated. *Elphidium subincertum* and *E. reticulosum* are occurred characteristically, that is dissimilar to the other samples in this core. In the middle part of the core (19−27 m), the dominant species are *E. advenum* and *P. gaimardii*. *A. beccarii*, *A. ketienziensis angulata*, *B. frigida*, *E. clavatum*, *E. somaense*, *Pseudononion japonicum* and *Pseudoparrella tamana* are associated. *Bolivina robusta*, *Quinqueloculina* spp., *Rosalina* spp. and *Spiroloculina* sp. are the minor species. In the upper part of the core (15−17 m), the dominant species are *P. gaimardii* and *E. advenum*. *B. frigida*, *E. clavatum*, *E. somaense*, *E. subincertum* and *Quinqueloculina seminulum* are common. *A. ketienziensis angulata*, *P. japonicum*, *P. tamana* and *Spiroloculina* sp. are associated. The agglutinated foraminifera such as *Ammobaculites* sp., *Haplophragmoides columbiensis* and *Trochammina* spp. are occurred characteristically as minor species.

Core Sp−39 : Seventy−nine species belonging to 47 genera of benthic foraminifera are identified from 13 of 18 samples of the section 13 to 54 m. Five samples of the section 41 to 54 m do not contain any of foraminifera. Preservation and abundance of the fossils is generally good and abundant except for the samples from the section 39 to 54 m. The sample 39 m yields well−preserved benthic foraminifera but, poor in abundance. As in the core Sp−23, the most dominant species are *E. advenum* and *P. gaimardii*, throughout the core, and the change of the benthic foraminiferal fauna is identified, also. As mentioned above, the lower part of the core (41−54 m) is barren zone. In the lower−middle part (37−39 m), the sample 39 m has only two species, *Ammonia beccarii* and *Buccella frigida*. The dominant species from the sample 37 m are *E. somaense* and *E. clavatum*. *Pseudoparella naraensis*, *Globocassidulina depressa* and *Rosalina globularis* are common, and *E. advenum* is associated. In the upper−middle part (21−35 m) of this core, *E. advenum* and *P. gaimardii* are dominant. *A. ketienziensis angulata*, *B. robusta*, *B. frigida*, *P. japonicum*, *E. clavatum* and *A. beccarii* are common. *E. somaense*, *Nonionella stella*, *Spiroloculina* sp. and *Quinqueloculina seminulum* are associated. *Cibicides lobatulus*, *Fissurina* spp., *Gaudryina* sp., *P. naraensis* and *Rosalina* spp. are occurred as minor species. In the upper part (13−19 m), the dominant species are *E.*

Table 1 Occurrence chart of benthic foraminifera from the core Sp−23 and Sp−39.

Sample No \ Species	*Ammobaculites* sp.	*Ammonia beccarii*	*Ammonia ketienziensis angulata*	*Angulogerina* sp.	*Anomalinoides glabrata*	*Anomalinoides* spp.	*Astrononion* spp.	*Bolivina robusta*	*Bolivina* sp.	*Buccella frigida*	*Buccella* sp.	*Bulimina marginata*	*Bulimina* sp.	*Buliminella elegantissima*	*Cassidulina* spp.	*Cibicides lobatulus*	*Cymbaloporetta bradyi*
Sp-23																	
15.0-15.8	9	7	15	-	-	2	-	-	-	20	-	-	-	-	-	-	-
17.0-17.8	5	5	2	-	2	1	1	4	1	12	-	1	-	3	-	-	-
19.0-19.8	-	8	11	-	-	-	-	2	-	26	-	-	1	-	-	1	-
21.0-21.8	-	25	10	1	-	-	2	3	3	13	-	-	1	-	1	2	-
23.0-23.8	-	15	17	-	-	-	-	5	-	8	-	4	-	-	1	-	1
25.0-25.8	-	5	7	-	-	1	4	4	1	19	-	-	2	-	1	3	-
27.0-27.8	-	7	14	-	-	5	3	7	1	17	-	4	4	-	1	3	-
29.0-29.8	-	17	-	-	-	3	1	1	1	21	-	-	-	-	-	-	-
31.0-31.8	-	38	-	-	-	3	-	-	-	60	-	-	-	3	-	-	-
Sp-39																	
13.0-13.8	9	14	4	-	-	-	-	-	-	29	-	1	-	-	-	-	-
15.0-15.8	3	19	-	-	-	-	-	-	-	40	1	-	-	-	-	-	-
17.0-17.8	3	7	3	-	-	-	1	-	-	15	-	-	-	-	-	-	-
19.0-19.8	4	10	2	-	-	1	-	2	-	14	-	-	1	-	-	-	-
21.0-21.8	-	12	21	-	-	1	2	3	1	17	-	4	1	-	-	2	-
23.0-23.8	-	8	17	-	-	3	2	6	-	12	-	1	-	-	1	1	-
25.0-25.8	-	10	10	1	-	1	2	9	-	6	-	2	-	2	1	3	-
27.0-27.8	-	-	17	-	-	-	1	1	1	28	-	-	-	-	-	5	-
29.0-29.8	-	11	16	-	-	-	1	16	-	19	-	1	5	-	1	5	-
31.0-31.8	-	6	8	-	-	1	1	5	-	25	-	1	1	-	2	10	-
35.0-35.8	-	5	23	1	-	1	6	14	-	20	-	4	-	-	-	5	-
37.0-37.8	-	3	-	1	3	-	4	5	2	6	-	-	-	2	2	-	-
39.0-39.8	-	5	-	-	-	-	-	-	-	13	-	-	-	-	-	-	-
41.0-41.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
44.0-44.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46.0-46.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48.0-48.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
54.0-54.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sample No \ Species	*Elphidium advenum*	*Elphidium clavatum*	*Elphidium crispum*	*Elphidium jenseni*	*Elphidium reticulosum*	*Elphidium somaense*	*Elphidium subincertum*	*Elphidium subgranulosum*	*Elphidium* spp.	*Fissurina* spp.	*Gaudryina* sp.	*Globocassidulina depressa*	*Globocassidulina subglobosa*	*Globocassidulina venustas*	*Guttulina* sp.	*Gyroidinoides nipponicus*	*Hanzawaia nipponica*	*Haplophragmoides columbiensis*
Sp-23																		
15.0-15.8	31	7	-	-	-	7	11	-	3	-	-	-	-	-	-	-	-	-
17.0-17.8	27	7	1	-	-	14	16	1	-	11	-	-	-	-	-	-	-	7
19.0-19.8	43	7	-	-	-	3	1	3	-	-	-	-	-	-	-	-	-	3
21.0-21.8	32	15	-	-	-	13	-	-	-	3	-	2	1	-	-	-	-	-
23.0-23.8	49	7	-	-	-	-	-	2	-	1	2	-	-	-	-	-	-	-
25.0-25.8	46	7	-	-	-	8	-	1	1	2	4	-	1	-	-	-	-	-
27.0-27.8	46	25	-	-	-	18	-	-	1	-	5	1	1	-	-	1	-	-
29.0-29.8	31	108	9	-	-	11	2	-	3	3	-	1	-	-	-	1	-	-
31.0-31.8	13	47	-	-	12	8	24	-	-	-	-	-	1	-	-	-	-	-
Sp-39																		
13.0-13.8	10	13	-	-	6	-	32	1	-	-	-	-	-	-	1	-	-	-
15.0-15.8	42	4	-	1	-	-	50	2	3	-	-	-	-	-	-	-	-	-
17.0-17.8	51	15	-	-	-	2	39	1	1	-	-	-	-	-	-	-	-	-
19.0-19.8	41	14	-	-	-	9	3	3	2	-	-	-	-	-	-	-	-	7
21.0-21.8	40	22	-	-	-	3	4	2	3	2	-	-	3	-	-	-	-	-
23.0-23.8	58	3	-	-	-	3	-	1	1	-	-	1	1	-	-	-	-	-
25.0-25.8	48	4	-	-	-	6	-	-	2	4	5	-	3	-	-	-	-	-
27.0-27.8	66	6	2	-	-	8	-	-	3	1	3	-	-	-	-	-	-	-
29.0-29.8	40	18	1	-	2	9	-	-	1	5	5	-	1	-	-	1	-	-
31.0-31.8	59	8	5	-	-	-	-	-	-	3	2	-	1	-	-	1	-	-
35.0-35.8	47	11	-	1	-	5	-	1	1	6	-	1	1	-	-	-	-	-
37.0-37.8	10	38	1	-	1	40	-	-	2	7	-	13	3	5	-	1	1	-
39.0-39.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41.0-41.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
44.0-44.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46.0-46.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48.0-48.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
54.0-54.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sample No \ Species	*Lagena* spp.	*Lenticulina* sp.	*Melonis* sp.	*Miliolinella* spp.	*Neoconorbina stachi*	*Nonion japonicum*	*Nonionella stella*	*Pararotalia minuta*	*Patellina corrugata*	*Pseudoeponides nipponicus*	*Pseudononion japonicum*	*Pseudoparella naraensis*	*Pseudoparella pulchella*	*Pseudoparella tamana*	*Pseudoparella* spp.	*Pseudorotalia gaimardii*	*Pullenia* spp.	*Quinqueloculina contorta*
Sp-23																		
15.0-15.8	-	-	-	4	-	-	1	-	-	-	2	-	-	2	-	46	-	3
17.0-17.8	2	-	-	-	-	-	1	-	-	-	7	3	-	18	2	30	1	-
19.0-19.8	1	-	-	-	-	-	2	1	-	-	5	-	-	9	-	48	-	-
21.0-21.8	1	-	-	-	-	-	3	-	-	-	12	-	2	15	-	13	-	-
23.0-23.8	1	-	-	-	-	-	4	-	-	-	8	1	-	10	-	54	-	-
25.0-25.8	4	-	-	-	-	1	1	-	-	-	1	1	-	4	-	52	-	-
27.0-27.8	1	1	-	-	-	-	-	-	-	-	6	5	-	1	-	19	-	-
29.0-29.8	2	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	1	-
31.0-31.8	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-
Sp-39																		
13.0-13.8	2	-	-	2	-	-	7	-	-	-	4	-	-	-	-	13	-	-
15.0-15.8	-	-	-	1	-	-	5	-	-	-	-	-	-	-	-	18	-	-
17.0-17.8	-	-	-	4	-	-	7	-	-	-	4	-	-	-	-	17	-	-
19.0-19.8	-	-	-	-	-	-	3	-	-	-	5	-	-	7	-	65	-	-
21.0-21.8	-	-	-	-	-	2	11	-	-	-	8	2	-	14	-	25	-	-
23.0-23.8	1	1	-	-	-	-	5	-	-	-	9	-	-	4	-	58	-	-
25.0-25.8	3	-	-	1	-	-	11	-	-	-	13	7	1	40	-	40	-	-
27.0-27.8	3	2	-	-	1	-	-	-	-	-	12	-	-	-	-	25	-	-
29.0-29.8	3	-	-	5	-	-	-	-	1	-	4	2	-	1	-	13	-	-
31.0-31.8	-	-	-	2	-	-	2	-	-	-	8	6	2	1	-	5	-	-
35.0-35.8	2	-	-	2	-	-	2	-	-	1	10	2	2	-	-	6	-	-
37.0-37.8	1	1	1	3	-	-	-	-	-	-	5	19	3	1	-	-	1	-
39.0-39.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41.0-41.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
44.0-44.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46.0-46.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48.0-48.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
54.0-54.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sample No \ Species	*Quinqueloculina elongata*	*Quinqueloculina lamarkiana*	*Quinqueloculina seminulum*	*Quinqueloculina subaggutinata*	*Quinqueloculina vulgaris*	*Quinqueloculina* sp.	*Rectobolivina raphana*	*Reophax* spp.	*Reussella* sp.	*Rosalina australis*	*Rosalina bradyi*	*Rosalina globularis*	*Rosalina* spp.	*Sigmoilopsis* sp.	*Spiroloculina communis*	*Spiroloculina cushimani*	*Spiroloculina* sp.	*Textularia conica*	*Textularia foliacea loceabica*	*Triloculina* sp.	*Trochammina* spp.	*Tosaia* sp.	*Uvigerinella glabra*	*Valvulineria* sp.	*Virgulina* sp.	Miscellaneous	TOTAL
Sp-23																											
15.0-15.8	-	-	10	-	-	-	-	2	-	-	-	-	-	3	1	-	7	-	2	-	1	-	-	-	-	-	196
17.0-17.8	-	4	12	-	-	-	2	-	-	-	-	-	2	2	-	-	-	-	-	-	6	-	-	-	-	1	214
19.0-19.8	-	9	7	-	-	-	-	-	-	2	-	-	-	1	1	-	6	-	1	-	-	-	-	2	-	-	204
21.0-21.8	-	-	2	-	-	-	-	-	-	-	2	3	1	1	-	-	5	-	-	-	-	-	1	1	-	-	189
23.0-23.8	1	-	-	-	1	-	1	-	-	-	1	3	2	5	-	-	5	-	-	-	1	-	1	-	-	-	211
25.0-25.8	-	2	1	-	1	-	-	-	-	-	4	1	5	2	-	-	4	-	3	-	-	-	-	-	-	-	204
27.0-27.8	-	1	1	-	-	-	2	-	-	-	-	2	3	1	-	-	1	-	-	-	-	-	-	-	-	1	209
29.0-29.8	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	2	-	-	-	224
31.0-31.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	211
Sp-39																											
13.0-13.8	-	3	10	-	-	-	1	-	1	-	-	-	-	2	1	-	1	-	-	1	1	-	-	-	-	-	169
15.0-15.8	1	1	3	-	-	1	2	2	-	-	1	-	1	-	1	1	-	-	-	-	-	-	-	-	-	-	203
17.0-17.8	-	14	12	-	-	-	2	-	-	-	-	-	-	-	3	5	-	-	-	-	3	-	-	-	-	-	209
19.0-19.8	-	2	1	2	-	-	2	-	-	-	-	-	-	-	-	-	2	-	2	-	3	-	-	-	-	4	211
21.0-21.8	-	-	1	-	1	-	-	-	-	-	2	-	1	1	-	-	5	-	-	-	-	-	-	-	-	-	216
23.0-23.8	1	1	6	-	-	-	-	-	-	-	-	-	1	2	-	-	4	-	1	-	-	-	-	-	-	-	213
25.0-25.8	-	2	1	1	-	-	2	-	-	1	-	-	5	2	-	-	-	-	1	-	-	-	3	-	1	-	254
27.0-27.8	-	1	-	-	-	-	-	-	-	-	-	-	3	5	-	-	10	-	1	-	-	-	-	1	-	1	207
29.0-29.8	-	4	2	-	-	-	-	-	1	-	1	6	8	1	-	-	-	-	5	-	-	-	1	-	1	1	218
31.0-31.8	11	1	7	-	-	-	-	-	-	-	3	-	6	2	1	-	6	-	-	-	-	-	-	-	-	-	202
35.0-35.8	-	4	7	-	1	1	-	-	1	-	1	10	3	2	1	-	1	1	2	-	-	-	-	-	1	1	217
37.0-37.8	-	-	1	-	-	-	-	-	-	-	-	11	1	2	-	-	-	-	-	1	-	2	-	-	1	2	206
39.0-39.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18
41.0-41.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
44.0-44.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46.0-46.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48.0-48.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
54.0-54.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2 Occurrence chart of diatoms from the core Sp−23 and Sp−39

	Species \ Sample No.	Sp-23											Sp-39																	
		13.0	15.0	17.0	19.0	21.0	23.0	25.0	27.0	29.0	31.0	34.0	13.0	15.0	17.0	19.0	21.0	23.0	25.0	27.0	29.0	31.0	35.0	37.0	39.0	41.0	44.0	46.0	48.0	54.0
Brackish- to Marine-water species	*Actinocyclus curvatulus*	-	-	3	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	4	2	1	2	-	5	-	2	-	2	-
	A. ehrenbergii	12	-	-	-	-	2	2	2	-	-	-	-	3	-	4	-	-	-	-	-	4	2	-	2	-	2	4	2	-
	Actinoptychus senarius	-	-	4	-	-	4	2	4	5	4	-	-	7	5	4	7	8	3	6	2	-	2	3	8	11	7	8	8	9
	A. splendens	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Arachnoidiscus sp.	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Biddulphia aurita	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2	-	-	-	-	-
	Caloneis crassa	-	-	10	-	-	2	-	-	2	-	13	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cocconeis scutellum	-	-	17	-	-	-	2	-	-	-	27	5	-	4	9	-	-	-	-	8	2	2	-	-	7	3	4	-	-
	Cocconeis sp.	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Coscinodiscus asteromphalus	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	4	2	-	-	-	-	-	-	-	3
	C. jounesianus	36	11	14	-	4	-	4	-	2	4	-	31	22	12	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-
	C. marginatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	8	2	-	-	-
	C. radiatus	-	-	2	-	-	2	-	4	-	4	26	-	-	8	8	-	-	-	4	2	2	-	-	-	-	-	8	-	-
	Cyclotella striata	15	13	4	25	77	26	14	16	17	23	12	-	12	11	8	17	15	39	15	20	39	14	9	5	10	13	-	4	-
	C. striata v. ambigua	6	-	-	-	-	-	12	4	-	-	-	-	-	-	-	-	4	8	6	4	-	2	3	-	5	2	9	-	-
	Diploneis bombus	-	-	-	-	2	2	2	2	3	4	-	-	-	8	8	7	-	-	6	4	2	4	5	5	-	2	-	4	6
	D. smithii	6	9	10	-	3	12	4	2	4	21	-	-	8	13	15	-	4	-	2	-	2	6	-	-	-	9	-	2	34
	D. chersonensis	-	-	-	-	-	-	6	4	-	-	-	-	-	-	-	-	-	-	2	-	-	-	3	-	-	-	-	-	-
	Diploneis sp.	-	-	2	-	-	-	-	2	-	-	-	-	7	-	-	-	-	-	11	2	2	8	-	-	-	-	-	-	25
	Gramatophora marina	-	-	-	-	8	-	4	2	7	6	26	-	5	5	-	7	-	-	-	3	2	2	-	2	-	2	-	-	-
	Gramatophora sp.A	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gramatophora sp.B	-	-	3	8	4	4	-	-	-	-	-	-	3	-	-	-	8	-	-	-	-	-	-	-	-	3	-	-	-
	Hanzschia amphioxys.	6	-	6	-	-	-	-	-	2	-	-	5	-	-	4	-	-	-	1	-	-	-	-	-	-	-	-	-	-
	Hyalodiscus sp.	19	12	-	16	9	-	4	2	-	-	-	-	5	-	-	9	-	-	-	3	-	6	-	7	-	6	-	-	-
	Licmophora sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	2	2	-	-	-	-	-	-	-	-	-
	Melosira sp.	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Navicula grimmei	-	9	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	N. viridula	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Navicula sp.	3	-	4	-	-	-	-	-	-	-	-	-	7	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Nitzschia cocconeisformis	6	-	-	-	-	2	-	-	-	-	-	-	-	5	4	5	-	3	2	-	-	-	-	-	-	-	-	-	-
	N. diclamia	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	N. granulata	-	-	5	13	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	7	4	2	-
	N. panduriformis	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Nitzschia sp.	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
	Paralia sulcata	7	99	31	78	71	109	82	50	143	117	41	52	62	67	35	97	121	133	63	56	97	82	69	99	59	92	121	78	76
	Pleurosigma sp.	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-	-	-	2	-	2	-	-	2	-	-	-	-	-
	Rhaphoneis surirella	11	-	-	-	-	-	-	2	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	4	17	5	-	2	4
	Rhizosolenia alata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
	R. setigera	-	-	-	15	7	-	-	2	-	-	-	-	-	-	-	-	-	-	-	4	2	2	-	-	-	-	-	-	-
	Rhizosolenia sp. A	-	-	-	-	-	4	-	2	-	-	-	5	-	-	-	-	-	-	2	-	-	-	2	-	-	-	-	-	-
	Rhizosolenia sp. B	-	-	7	-	-	1	5	7	-	-	-	-	3	5	-	9	4	3	1	2	2	2	-	-	-	-	-	2	-
	Surirella fastuosa v. recedens	-	-	2	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	3	6	-	-	-	-	-	-	-	-	-
	Surirella sp.	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Synedra spp.	13	9	5	-	-	-	-	1	-	-	-	12	-	17	9	7	-	-	1	1	-	-	-	-	1	-	-	20	-
	Thalassiosira eccentrica	-	-	-	-	-	2	-	3	-	-	-	-	4	-	-	-	-	-	5	2	2	-	6	-	-	-	-	2	-
	T. lineata	-	-	3	-	-	-	4	8	5	-	16	-	-	-	-	-	-	-	6	10	4	6	7	10	9	8	4	5	-
	Thalassionema nitzschioides	7	16	5	44	12	19	35	59	8	17	39	17	11	5	44	23	34	11	53	56	28	56	84	43	26	15	27	28	14
	Thalassiothrix longissima	-	-	-	-	-	2	2	14	-	-	-	-	4	-	3	11	-	-	1	4	-	2	2	4	5	2	-	-	-
	Trachyneis aspera	-	-	3	-	3	6	8	-	-	-	-	-	-	-	4	-	-	-	2	2	-	-	2	-	4	-	-	-	-
	Triceratium sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Fresh-water species	*Achnanthes brevipes*	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	6	4
	A. hauckiana	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
	Amphora sp.	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
	Cymbella spp.	19	-	15	-	-	-	-	1	-	-	-	29	23	9	21	-	-	-	-	-	-	-	-	-	12	7	-	14	15
	Epithemia sp.	2	3	2	-		1	1	1	1	-	-	1	1	1	1	1	-	-	-	1	-	-	1	-	-	-	-	-	-
	Eunotia diodon v. diodon	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	6	-	-	-
	E. exigua v. exigua	-	11	2	-	-	-	-	-	-	-	-	7	7	-	-	-	-	-	-	-	-	-	-	-	8	-	-	2	-
	E. rostellata v. rostellata	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gomphonema parvulum v. parvulum	12	-	17	-	-	-	-	-	1	-	-	32	-	6	19	-	-	-	-	-	-	-	-	-	13	-	11	9	10
	G. truncatum v. truncatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
	Meridion circulare	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
	Rhopalodia gibberula v. gibberula	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total diatom valves	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200

advenum and *E. subincertum*. *A. beccarii*, *B. frigida*, *E. clavatum*, *P. gaimardii* are common, and *N. stella*, *Q. lamarkiana*, *Q. seminulum* and *P. japonicum* are associated. The agglutinated foraminifera such as *Ammobaculites* sp., *Haplophragmoides columbiensis* and *Trochammina* spp. are occurred as minor species.

2−2. Diatom Flora

Sixty species of diatoms belonging to 35 genera are identified from 29 samples of the core Sp−23 and Sp−39 (Tab. 2). Preservation is bad and the abundance is poor in upper parts of two cores. Therefore, it is difficult to identify the species of some diatoms. The dominant species of two cores are brackish− to marine−water

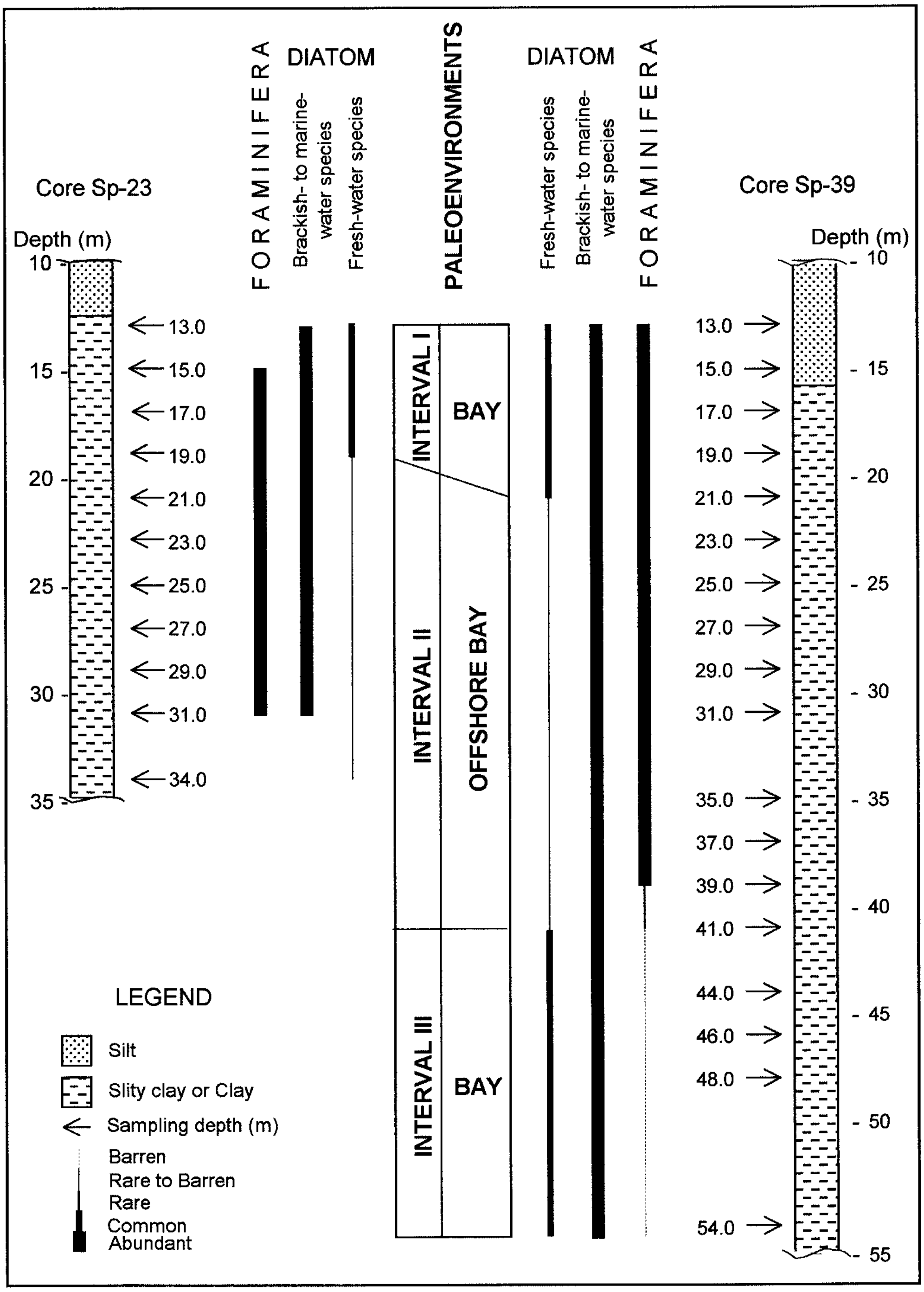

Fig. 2 Abundance of microfossils and paleoenvironment inferred from the core Sp−23 and Sp−39

diatoms, *Coscinodiscus jounesianus*, *Cyclotella striata*, *Diploneis smithii*, *Gramatophora marina*, *Paralia sulcata*, and *Thalassionema nitzschioides*. Fresh−water diatoms, *Achnanthes brevipes*, *A. hauckina*, *Amphora* sp., *Cymbella* spp., *Epithemia* sp., *Eunotia diodon v. diodon*, *E. exigua v. exigua*, *E. rostellata v. rostellata*, *Gomphonema parvulum v. parvulum*, *G. truncatum v. truncatum*, *Meridion circulare* and *Rhopalodia gibberula v. gibberula* are occurred from the upper part (13 ~17 m) of the core Sp−23, upper part (13 ~19 m) and lower part (41 ~54 m) of the core Sp−39, respectively.

Age Dating

Radiocarbon dating method using the benzene liquid scintillation was performed on the oyster shell collected from the horizon 26.5 m of the core Sp−25 in Nagdong Estuary. The carbon in sample was synthesized to the benzene through the sample preparation, $SrCO_3$, SrC_2, C_2H_2 and C_6H_6 synthesizing process. Age dating was calculated by Wallac 1415 Liquid Scintillation Counter. The operation of the age dating was conducted at the Yosu University in Korea.

The result of radiocarbon dating is estimated to be 7133±179 yr.B.P. (Fig. 3)

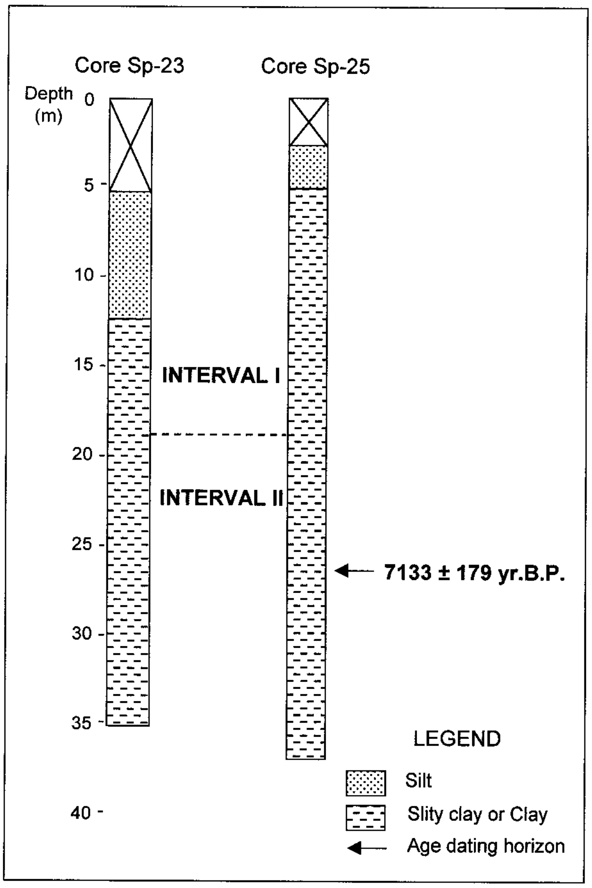

Fig. 3 Stratigraphic correlation between the core Sp−23 and Sp−25.

Discussion

1. Paleoenvironments

Elphidium advenum, the most dominant foraminifera from all samples, is widely distributed species in a shallow environment. *B. frigida*, *E. clavatum*, *N. stella*, *P. tamana*, *Bolivina* spp., *Fissurina* spp. and *Lagena* spp. are indicators of muddy offshore in the inner area in Tokyo Bay (Kosugi et.al.,1991). *A. beccarii* and *P. japonicum* are inner shelf species affected by coastal waters of the off Southern Akita of Japan (Matoba et.al., 1992). *P. gaimardii* is subtropical species (Hasegawa, 1993) and widespread species of the bay mouth through central bay of the Tanabe bay (Chiji et.al.,1968) and Hiroshima Bay with *Quinqueloculina* spp. and *Rosalina* spp. (Kosugi et.al., 1991). *E. subincertum* is widespread species on the sandy and muddy substratum and 35~30‰ in salinity in the inner bay area of the Tokyo Bay (Kosugi et.al., 1991). *A. ketienziensis angulata* which is known as open shallow−sea species is occurred in the outer bay and bay mouth of the Matsushima Bay (Matoba, 1970). *B. robusta*, which is associated species with offshore surface water, distributes shallower part and the bay mouth of the Tsuruga Bay (Inoue, 1986). *E. somaense* is occurred from the outer bay and bay mouth of the Matsushima Bay (Matoba, 1970), and the central part of the Hiroshima Bay (Kosugi et.al., 1991). However, this species was regarded as the indicator of innermost bay area within Tokyo Bay (Kosugi et.al., 1991).

Diatoms, *Coscinodiscus jounesianus*, *Cyclotella striata*, *Diploneis smithii*, *Gramatophora marina*, *Paralia sulcata*, and *Thalassionema nitzschioides* are *brackish*− to marine−water species (Laws, 1988). *Achnanthes brevipes*, *A. hauckina*, *Amphora* sp., *Cymbella* spp., *Epithemia* sp., *Eunotia diodon v. diodon*, *E. exigua v. exigua*, *E. rostellata v. rostellata*, *Gomphonema parvulum v. parvulum*, *G. truncatum v. truncatum*, *Meridion circulare* and *Rhopalodia gibberula v. gibberula* are fresh−water species (Patrick et al., 1966, 1975 ; Round et al., 1990).

On the basis of benthic foraminiferal fauna and diatom flora, core Sp−23 and Sp−39 are divided 3 intervals, I, II, III, in descending order in the core.

Interval I : The upper parts of the core Sp−23 and Sp−39 (13~17 m and 13~19 m, respectively) belong to this interval. *E. advenum*, *P. gaimardii* and *E. subincertum* are abundant. The foraminiferal fauna in this interval shows the shallow or bay environments. With the brackish− to marine−water diatoms, the fresh−water diatoms such as *Cymbella* spp., *E. exigua v. exigua* and *Gomphonema parvulum v. parvulum* are abundant also. Therefore, this interval was formed under the bay environment affected by the fresh waters.

Interval II : This interval is the lower part (19~34 m) of the core Sp−23 and middle part (21~39 m) of the core Sp−39. In all samples from two cores, the dominant species are brackish− to marine−water diatoms such as P. sulcata, *C. striata* and *T. nitzschioides*. On the other hand, the fresh−water diatoms are not yielded. The relatively higher frequency of outer bay and bay mouth or central bay species such as *P. gaimardii*, *A. ketienziensis angulata*, *B. robusta* and *P. tamana*, etc. and the occurrence of *N. stella*, *Fissurina* spp., *Lagena* spp., *Quinqueloculina* spp. and *Rosalina* spp. as a minor species indicate the offshore environments. In the lower part of this interval, that is, the lowermost part of the core Sp−23 and the lower−middle part of the core Sp−39, the foraminiferal fauna is dissimilar from other part of this interval. It is supposed that this part is the transition zone from the environment of the interval I to that of interval II.

Therefore, the deposition of this interval was under the offshore bay environment. During this period, the effects of the fresh waters were decreased than that of interval I, and probably it is considered that there was the fluctuation of the sea level in this period.

Interval III : The lower part (41~54 m) of the core Sp−39 belongs to this interval. In the core Sp−23, this interval is not identified because of the short length of the core. This interval does not yield any foraminifera. However, judging from the presence of brackish− to marine−water diatoms, it is probable that foraminifera lived, but are not preserved. Brackish−to marine−water diatoms, *Actinoptychus senarius*, *Diploneis smithii*, *P. sulcata* and *T. nitzschioides* are occurred in association with the fresh−water diatoms, *Achnanthes brevipes*, *Cymbella* spp., *Eunotia diodon v. diodon*, and *Gomphonema parvulum v. parvulum*, etc. Therefore, the sediments of this interval were deposited under the bay environment strongly affected by fresh waters during the lower sea level.

2. Sea−level fluctuation in Nagdong Estuary

The radiocarbon dating with the oyster shell collected from the horizon 26.5 m of the core Sp−25 (Fig. 3) indicates that sea−water already had advanced into Nagdong Estuary earlier than 7133 yr.B.P. This marine transgression may be correlated with the Jomon Transgression in the Japanese Islands (Assoc. Geol. Collabor. Japan, 1996, p. 597).

Yoon and Yee (1985) reported that comparing to the present sea−level, the sea−level of Nagdong Estuary was 5 m higher around 4500 yr.B.P., 7.5 m higher around 3400 yr.B.P., 5 m higher around 1900 yr.B.P. and 6.5 m around 1700 yr.B.P. This fact suggests sea−level fluctuation occurred in Nagdong Estuary. Since around 7000 yr.B.P., the sea−level continuously rose to 7.5 m higher than present sea−level, the highest sea−level in Nagdong Estuary, around 3400 yr.B.P. The sea−level fluctuation in Nagdong Estuary after around 7000 yr.B.P. might not be originated by the rise and fall of the se−level itself but probably due to vertical movement of the land of Nagdong Estuary.

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