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Analysis of marine environmental changes based on dinoflagellate cyst biostratigraphy in the East China Sea

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와편모조류 시스트의 층서학적 분석을 통해서 본 동중국해 환경 변화

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동중국해의 정점 St. 11에서 채집한 주상 퇴적물 시료들의 분석을 통하여 얻은 와편모조류 시스트의 층서학적 분석 결과를 이용하여 당 해역의 고해양학적 환경 변화를 유추하였다. 조사된 시스트 군집의 특성으로는 총 16속 24종의 시스트가 동정되었으며, 주상 퇴적물의 맨 아래쪽 시료를 방사성 연대 측정한 결과 약 1만년 이내에 형성된 퇴적물임을 알 수 있었다. 시스트 출현을 분석한 결과 본 정점에 해수가 유입된 시기는 지금으로부터 약 9000년 전이었다. 그리고, 약 8300년 전부터 6000년 전 사이에 시스트 농도의 급격한 변동이 있었는데, 이는 이시기의 대마난류의 발달에 기인한다고 생각된다.

We reconstructed history of environmental changes recorded in dinoflagellate cyst biostratigraphy, analyzing St. 11 core sediment samples collected from the East China Sea. Radiocarbon (^{14}C) measurement revealed that the sediment samples were restricted in the last 10000 years. Total of 24 cyst species in 16 genera were observed in the St. 11 core. Seawater soaked the St. 11 site 9000 yr BP, based on occurrence of marine dinoflagellate cysts, more than 477 cysts/g. Abrupt increase of cyst concentration continued roughly from 8300 to 6000 yr BP, probably resulted from development of the Tsushima Current.

Key words : dinoflagellate cyst biostratigraphy, palaeoenvironmental changes, the East China Sea

INTRODUCTION

Dinoflagellates are increasingly utilized in gaining paleoceanographic information from the cyst analysis because these marine planktonic algae contain genera and species that produce hypnozygotic cysts, resistant to bacterial decay, and hence with fossilization potential (Harland, 1988). Wilpshaar and Leereveld (1994) concluded that changes in physical and chemical features of water masses are reflected in the distribution patterns of dinoflagellate cysts, therefore, quantitative analysis of dinoflagellate cyst assemblages may provide information regarding paleoenvironments.

Matsuoka (1994) described Holocene dinoflagellate cyst assemblages in a core taken from Mine Bay of Tsushima Island, Japan, east part of the East China Sea. Xu and Oda (1999) reconstructed surface water history in the East China Sea, based on planktic foraminiferal evidence since 36 kyr BP. Nevertheless, few investigations have been carried out to clarify paleoenvironmental conditions in the East China Sea. In this paper, we reconstructed history of environmental changes recorded in dinoflagellate cyst assemblages, analyzing the St. 11 core collected from the East China Sea.

MATERIAL AND METHODS

Eighteen sediment samples were obtained from the St. 11 core in length of 2 m by a piston corer equipped in a R/V of Nagasaki Maru belonging to Nagasaki University, May 1996. The location of the site was 31° 44′ 54″ N and 126° E (Fig. 1). The water depth at the site was 76 m.

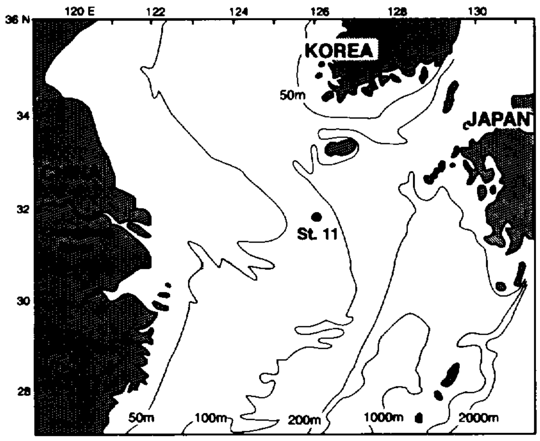

Fig. 1. Site map of boring the St. 11 core in the East China Sea.

Sediment samples were taken with cubes (diameter 2.4 cm). Cubes put into the sediments of the core to cut an even thickness of 2.4 cm. Cubes were selected to take totally 18 sediment samples throughout the St. 11 core (Table 1). All sediment samples were preserved at a refrigerator until chemical treatment following Cho and Matsuoka (2001) for a microscope experiment. The original sample was divided into two, one for measuring water content rate and the other for dinoflagellate cyst analysis in order to prevent decay of cysts due to oven dry. The former was weighed in wet condition and then oven dried at 70°C for a day. The latter was also weighed in wet condition, and processed with 10% hydrocloric acid (HCl) and 47% hydrofluoric acid (HF) to dissolve calcium carbonate and silicate materials, respectively. The chemically treated sample was placed in a 100 ml beaker, and mixed with distilled water to make slurry. The slurry was sonicated for 30 seconds in Sharp Ultrasonic Cleaner. Then the slurry was sieved through two different meshes with 125 and 20 μm openign sized, and the residue on the latter was suspended with 10 ml distilled water and kept in a vial. Dinoflagellate cysts were identified and enumerated in 1 ml of the final slurry under an inverted microscope (Olympus IX70) at 200, 400 and 600 times magnification. Cyst concentration in the sediment was expressed as number of cysts per gram of dry sediment (cysts/g).

Table 1. Radiocarbon (^{14}C) data of sediments taken from the St. 11 core. Every 1000 ages of a depth was calculated from the values expressed with an asterisk, which were measured by ^{14}C method

Bottom depth (-m)	^{14}C age (yr BP)
0.214	1000
0.41	*1940+ -90
0.428	2000
0.642	3000
0.856	4000
1.07	5000
1.284	6000
1.498	7000
1.712	8000
1.926	9000
1.99	*9230+ -130

Radiocarbon (^{14}C) measurement to shell fragments of mollusks estimated the ages of core sediments. In the St. 11 core, 0.41 and 1.99 m in depth had radiocarbon ages of 1940 ± 90 and 9230 ± 130 yr BP. respectively. On the basis of these ages. radiocarbon ages of the sediment samples of the core were calculated and expressed in Table 2.

Table 2. Sediment depth in the St. 11 core according to sample no. from 1 to 18

sample no.	depth (-m)		
1	0	~	0.024
2	0.095	~	0.119
3	0.214	~	0.238
4	0.333	~	0.357
5	0.452	~	0.476
6	0.571	~	0.595
7	0.69	~	0.714
8	0.809	~	0.833
9	0.928	~	0.952
10	1.047	~	1.071
11	1.166	~	1.19
12	1.285	~	1.309
13	1.404	~	1.428
14	1.523	~	1.547
15	1.642	~	1.666
16	1.761	~	1.785
17	1.88	~	1.904
18	1.999	~	2.023

RESULTS AND DISCUSSION

Assemblages of dinoflagellate cysts in the St. 11 core consisted of the following 6 cyst-based groups: gonyaulacoid. tuberculodinioid. calciodinellid. protoperidinioid. diplopsalid and gymnodinioid. Total of 24 species in 16 genera consisted of the groups (Table 3). Among them. the gonyaulacoid group occupied ranging from 71.4% and 96.3% in the relative abundance throughout the core. The cyst concentration had a prominent peak at the horizon of 1.761 to 1.785 m (sample no. 16: 1348 cysts/g) around 8300 yr BP. Species number ranged from 6 to 12 without so significant difference throughout the core. The age of the sediment at the bottom of the core was within 10000 yr BP.

Dinoflagellate cyst biostratigraphy based on the cyst concentration through the St. 11 core was depicted in Fig. 2. Abrupt increase of cyst concentration in the core began at 8300 yr BP. where cyst concentration was changed from 409 (sample no. 17) to 1348 cysts/g (sample no. 16). The abrupt increases of the cyst concentrations continued roughly to 6000 yr BP (sample no. 12). The abrupt increases of cyst concentration in the core from 8300 to 6000 yr BP might imply the marine environmental change. Broecket et al. (1988) concluded that the abruptness in the biological change (eg. planktonic foraminifera) according to time was due to a change in climate. Matsuoka (1992) suggested the development of the Tsushima Current at 8000 yr BP. based on increase of dinoflagellate cysts obtained from the sediment core at Mine Bay of Tsushima Island. The abrupt increase of cyst concentration at 8300 yr BP in the core may be resulted from development of the Tsushima Current.

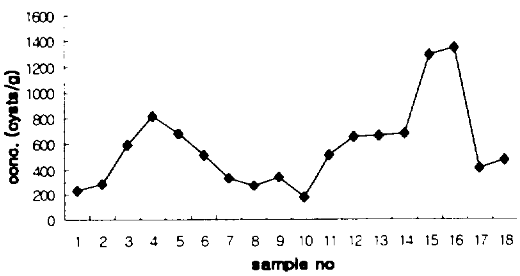

Fig. 2. Dinoflagellate cyst biostratigraphy based on the cyst concentration (cysts/g) through the St. 11 core.

Among the observed cysts. *T. vancampoae* clearly increased within the period from 8300 to 6000 yr BP in the core. *Tuberculodinium vancampoae* has been used as an indicator of the Tsushima Current. because this current is a main branch of the Kuroshio Current. which originates from the North Equatorial Current in the western Pacific and carries warm and saline water flowing east of Taiwan and entering the Okinawa Trough towards

Table 3. Dinoflagellate cyst composition and concentrations at the St. 11 core

species. sample no.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Gonyaulacoid group																			
Alexandrium	sp. 1 (ellipsoid)	12	4	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
Impagidinium	spp.	0	0	0	0	0	0	0	10	0	0	10	8	0	0	10	0	0	0
Lingulodinium	*machaerophorum*	4	4	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	14
Spiniferites	*bentorii*	0	0	0	0	0	0	0	10	11	0	0	8	0	0	10	15	0	0
	bulloideus	104	130	282	502	368	246	134	21	139	27	289	301	275	378	680	622	79	246
	hyperacanthus	0	0	33	19	9	10	0	0	16	27	0	0	21	0	20	0	8	14
	mirabilis	0	4	0	0	0	10	19	10	11	9	0	25	32	0	60	37	0	28
	ramosus	15	8	66	116	60	59	19	21	27	18	31	33	21	0	30	89	24	21
	spp.	58	97	166	116	205	118	86	103	16	37	62	184	190	204	360	437	236	98
Operculodinium	*centrocarpum*	8	17	25	0	17	30	10	31	11	9	31	25	63	10	60	74	31	21
	crassum	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
	israelianum	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
Tuberculodinioid group																			
Tuberculodinium	*vancampoae*	4	0	0	29	0	0	10	21	32	0	52	33	0	61	20	37	8	0
Calciodinellid group																			
Scripssiella	*trocoidea*	15	13	17	10	26	30	57	41	64	46	41	42	32	10	20	30	16	14
Protoperidinioid group																			
Brigantedinium	*majusculum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0
	spp.	4	0	0	10	0	0	0	0	0	0	0	0	21	0	0	0	8	14
Protoperidinium	spp.	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0
Quinquecuspis	*concretum*	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Selenopemphix	*quanta*	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	0	0
Stelladinium	*reidii*	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Votadinium	*calvum*	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diplopsalid group																			
Diplopelta	*parva*	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diplopsalis	*lenticula*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Gymnodinioid group																			
Polykrikos	sp. (reticulum)	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL (cysts/g)		232	282	598	812	684	512	335	268	337	174	515	661	667	683	1290	1348	409	477

the north (Jian et al., 2000). The variation of the concentration of *T. vancampoae* probably indicates the movement of the warm Tsushima Current.

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