General features of sediment cores collected during the R/V "MIRAI" cruise MR97-02

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Multiple and piston cores were collected at three sites during the R/V "MIRAI" cruise MR97-02 (Nov.10-Dec.5, 1997) in the northern North Pacific.

In this paper, we report basic data on coring site locations, coring operation and some geological data: visual core descriptions, color reflectance spectra, magnetic susceptibility, gamma ray attenuation, P-wave velocity, and water content, which are important in order to understand the paleoenvironment.

Key Words：　R/V "MIRAI", MR97-02, Northern North Pacific, Sediment, Geological data,

「みらい」慣熟航海 MR97-02において採取された海底堆積物の概要

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1997年11月10日～12月5日の期間において，第一回目の「みらい」慣熟研究航海である物質循環調査観測が行われた。調査海域は二酸化炭素の吸収域の一つとして，物質循環研究の分野で注目されている北西部北太平洋である。本航海で3本の柱状海底堆積物が採取された。ここではそれら堆積物の基本的なデータ（記載，色彩測定，帯磁率，P波速度，含水率）についての報告を行う。

キーワード：「みらい」慣熟航海，MR97-02，海底堆積物，北西部北太平洋

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1 Introduction

The glacial-interglacial changes in circulation and hydrography of the Pacific Ocean may have significantly affected global climate change, because the Pacific dominates the world ocean volumetrically and is the end-member of the modern circulation regime. The North Pacific Intermediate Water (NPIW), originaing from the marginal seas of the North Pacific (Tally, 1991[1]), accumulate CO_2 actively. Additionally, the high latitude area of the North Pacific might play an important role as an effective sink of CO_2 over the geological period.

The MR97-02 cruise was the virgin cruise of the R/V "MIRAI" and the first investigation of a JAMSTEC project on a "Biogeochemical Study of Northern North Pacific and its Adjacent Seas" in the northwestern North Pacific. Sediment coring was one of the important observations of this cruise as well as CTD measurement, water sampling and sediment trap deployment.

The primary objective of sediment coring is to investigate the temporal change of paleocean (primary productivity, sea surface temperature, flux of particulate matter, transport process and flux of terrigenous materials and ice-rafted materials) in the northwestern North Pacific through the Quaternary period.

This is a report compiled from geological routine data of sediment cores. The principal data are:

- Visual core descriptions-To obtain geological information such as sedimentation structure, micro fossil assemblage, past volcanic activity.
- Color reflectance spectra-To determine (i) component materials such as pelagic clay and biogenic materials, and (ii) past changes in redox conditions and amounts of transition metals such as manganese and iron.
- Magnetic susceptibility-To determine (i) paleo flux of magnetic minerals such as terrigenous materials, and (ii) past volcanic activity.
- Gamma ray attenuation-To estimate bulk density of sediment.
- P-Wave velocity-To obtain information about sedimentation structure.
- Water content

These data provide valuable information on past phenomena and environmental changes, which are further investigated by future studies such as radio and stable isotope analysis, cosmogenic nuclides analysis, micro fossil assemblage analysis, and analysis of inorganic and organic geochemistry.

2 Location of coring sites

Sediment cores were obtained using multiple and piston core samplers at three sites: St. KNOT (44°N, 155°E) located at off the Kuril Islands, beneath the subtropical-subarctic boundary, St. 7S on the Detroit seamount situated beneath the Subarctic Gyre, and St. 8S on the Suiko seamount situated beneath the subarctic front. The latter two stations are located along the Emperor seamount chain (Fig. 1 and Appendix: operation summary). KNOT is an abbreviation of Kyodo North Pacific Ocean Time Series Station. At St. KNOT, observations of hydrography, chemistry, and biology have been repeated to investigate the biogeochemical cycle in the northwestern North Pacific since November 1997. St. 7S was also situated beneath a time series sediment trap mooring site (50°N, 165°E). St. 8S was designed in order to obtain a high resolution record of late Quaternary sedimentation, paleoproductivity, and other paleoceanographic conditions.

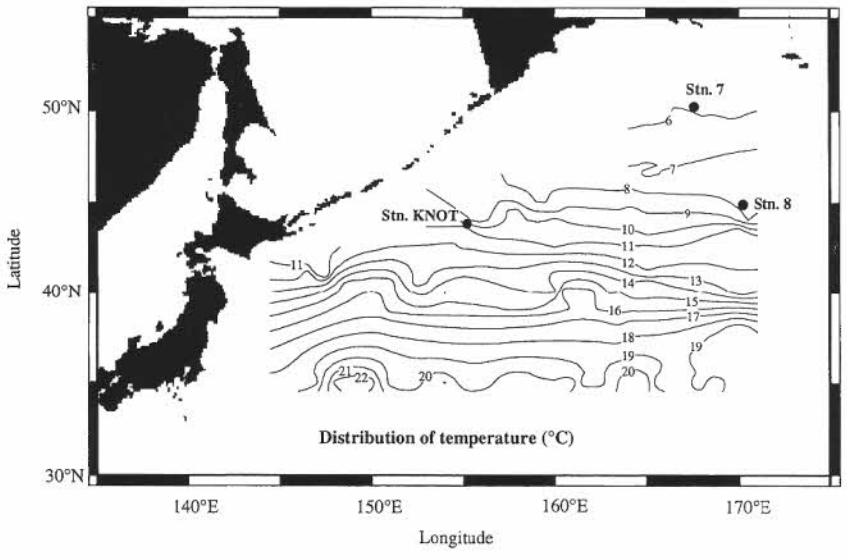

Fig. 1 Location map of multiple and piston cores during the cruise MR97-02.Contour indicates underway data of sea surface temperature from November 10 to December 6 during this cruise.

図 1 MR97-02 航海の海底堆積物採取海域図。等温線は同航海中での表層海水温の連続測定データ（11月10日～12月6日）

3 Coring operation on the R/V "MIRAI"

3.1 Multiple core sampler

A multiple core sampler produced by Rigosha Co. Ltd. was used. This core sampler consists of a main body of 600kg-weight and 8 sub-core samplers (I.D. 73 mm and length of 60cm).

3.2 8m-long stainless-steel piston corer

A piston core sampler consists of a 500kg weight, a total 8 m-long stainless-steel pipe (4m×2) with inner pipes, and a pilot core sampler. The diameter of the inner pipe is 75mm. We used two types of pilot core samplers: one is the "Ashura" multiple pilot core sampler, which consists of a 80kg weight, three sub-cores of 60 cm length and 73mm I.D., and the other is a Yuing-type gravity core sampler, which consists of a 50kg weight, and inner pipe with 30mm I.D. and 100cm length.

3.3 Site survey

Prior to coring, sampling sites were surveyed with the 12kHz SEA BEAM 2100 Multibeam Bathymetric Survey System with a 4kHz Sub-Bottom Profiler manufactured by SeaBeam Instruments, Inc. U.S.A. in order to take a sea-bottom topographic and sub-bottom profiling information for reliable coring. Figures 2 through 4 are the local topographic contour maps at each coring station.

3.4 Positioning system

A WGS 84 global positioning system (GPS) of Tokyo datum and a Benthos XT-6000 transponder (sending: 14.5kHz, receiving: 13.0kHz) mounted on a main wire at 25m above the coring equipment, were used to determine geographic position and depth of coring. Latitude and longitude between hit and pull-out times were averaged and adopted as a cored position. Water depth was carefully estimated from the transponder's maximum depth or at the moment when a corer was pulled-out.

3.5 Sampling Procedures

Three piston and three multiple cores of sediment were obtained. Piston cores were marked and cut into 1 m-length sections. The ends of each section were capped with urethane board, then marked with colored tapes, white for the section

MR9702 St. KNOT

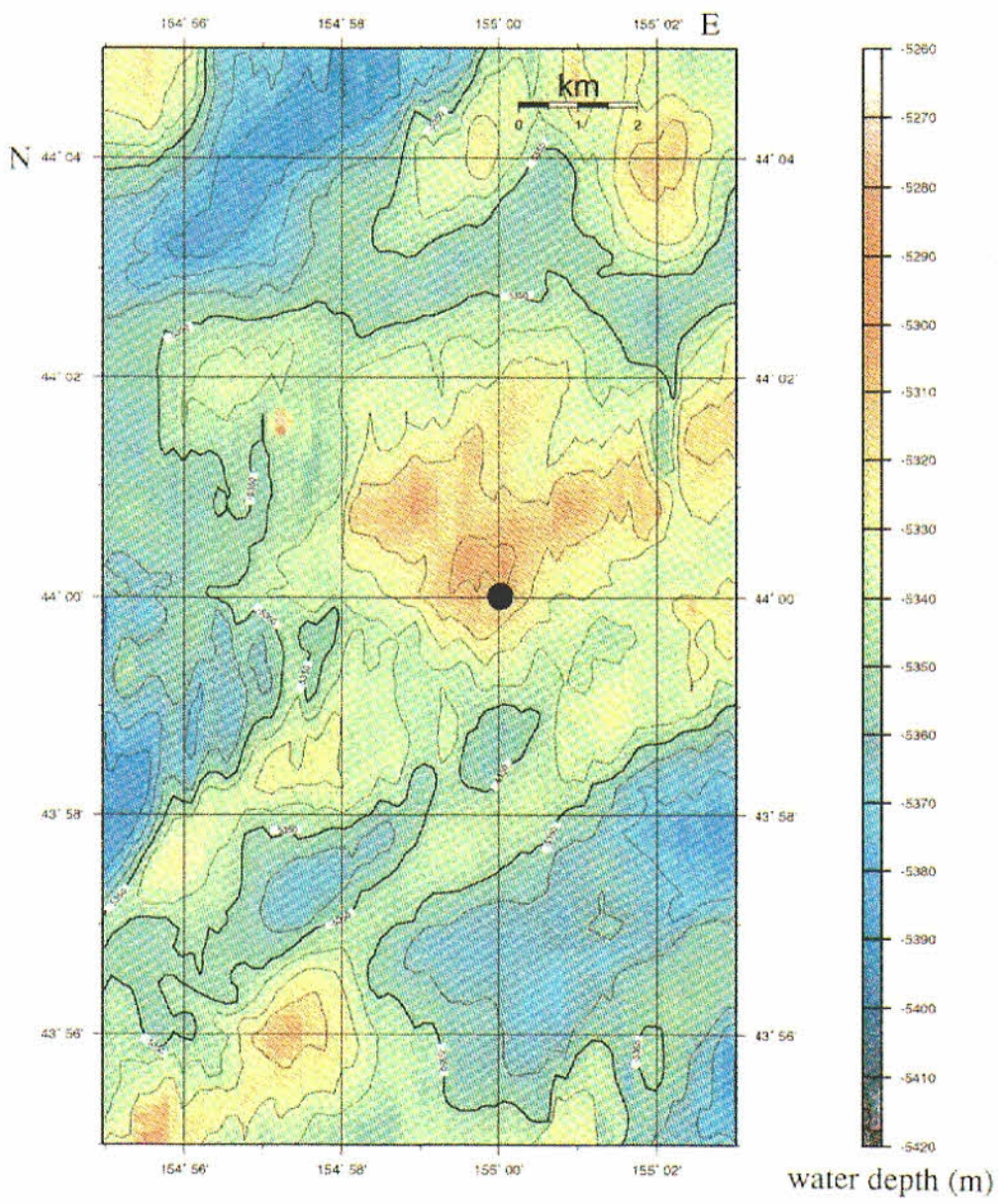

Fig. 2 Location point of sediment cores at St. KNOT
図 2 St. KNOT の採泥点

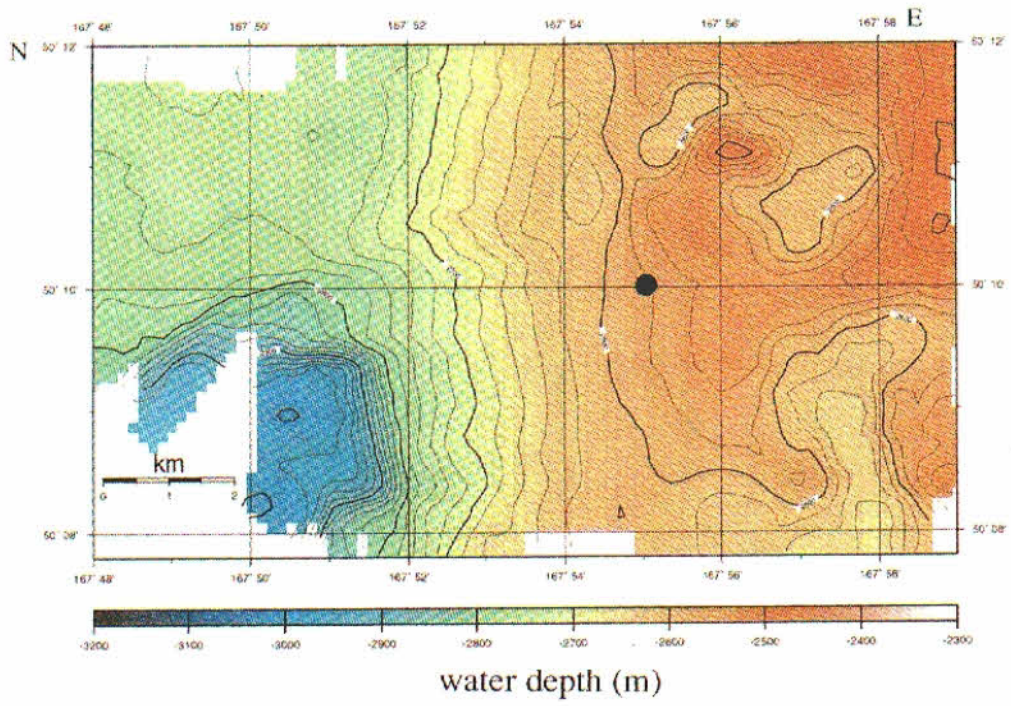

Fig. 3 Location point of sediment cores at St. 7S
図 3 St. 7S の採泥点

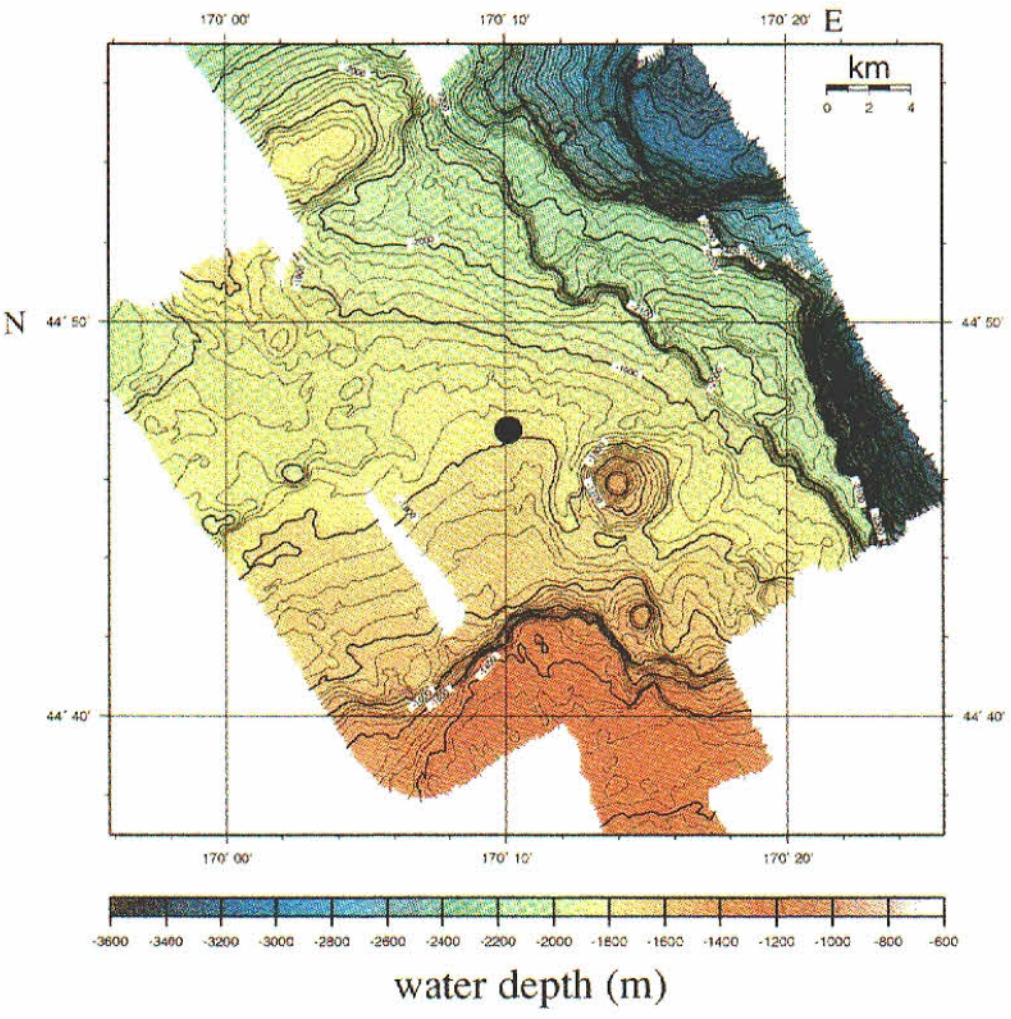

Fig. 4 Location point of sediment cores at St. 8S
図 4 St. 8S の採泥点

top and red for the bottom.

Each section was run through a Multisensor core logger (MSCL), and then split lengthwise into working and archive halves with a cutter and a fishing line. After splitting, the length of the cored sediment in each section and core-catcher were accurately measured.

Archive halves of cores were first described visually. Smear slides were made from samples taken from the archive halves. Sediment color was described based on standard Munsell notation and measured using Minolta CM-2010 color

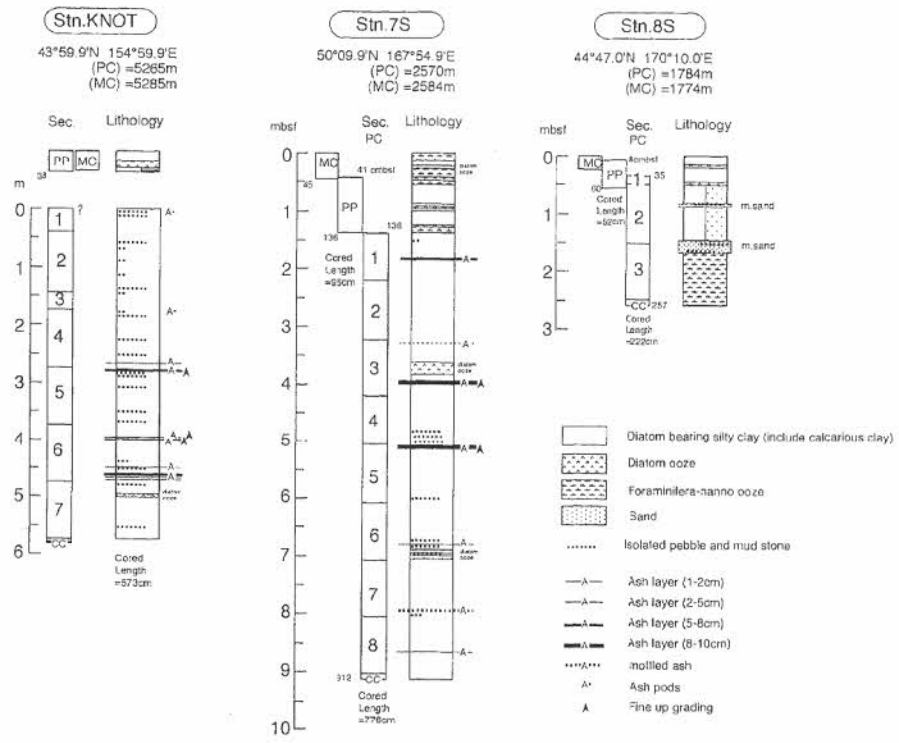

Fig. 5　Lithologic summary of cored sediments obtained during the cruise MR97-02.
図 5　MR97-02 航海で得られた堆積物の記載データ

Table 1　Summary of section lenghth and core depth. Core depth below sea floor (in cmbsf) calculated from lothologic correlation among the multiple core (MC), pilot core (PP), and piston core (PC) sediments. More than 50 cm of core gap exists between PP and PC, Section 1 from St. KNOT.
表 1　MR97-02 航海で採取されたコアの長さ及び分割されたセクションの長さのまとめ。コア長（cmbsf）は記載の記録を基に求められている。また，St. KNOTのパイロットコアとピストンコアの間には約50 cmの不連続部分が存在する。

	Core	Sec.	Interval Top		Bot.	depth Top	thick	Color		glass type
1	KNOT-PC	1	5	-	11	5	6	light gray (7.5YR8/1) to dull brown (7.5YR6/3)	thin bedded volcanoclastic ash ball	pm>>bw
2	KNOT-PC	4	3	-	6	177	1	light gray (5Y8/1)	f.ash	
3	KNOT-PC	4	93	-	95	267	2	gray (N7/0)	f.ash	
4	KNOT-PC	5	6	-	10	278	4	gray (N7/0)	upward finning volcanoclastic ash; heavy minerals common; erosional bottom contact	
5	KNOT-PC	6	23	-	25	395	2	dark greenish gray (7.5GY3/1)	upward finning volcanoclastics	-
6	KNOT-PC	6	27	-	29	399	2	dark olive gray (5GY3/1)	upward coarsening and finning volcanoclastics	-
7	KNOT-PC	6	78	-	79	450	1	light gray (2.5Y8/1)	f. ash	bw>pm
8	KNOT-PC	6	86	-	90	458	4	gray (5Y6/1)	m.-f. ash	
9	KNOT-PC	6	94	-	95	466	1	yellowish gray (2.5Y6/1)	m.-f. ash	bw>>pm
10	KNOT-PC	6	96	-	98	468	2	yellowish gray (2.5Y6/1)	m.-f. ash	bw>>pm
11	7S-PC	1	44		48	44	4	grayish olive (7.5Y5/2)	f.-m.ash	pm, bw
12	7S-PC	2	5		8	185	3	olive black (7.5Y3/1)	bioturbated both top and bottom contact	pm
13	7S-PC	2	77		84	257	7	brownish gray (10YR6/1)	f.-m. ash, upward fine graded, sharp bottom contact and bioturbated upper contact.	
14	7S-PC	5	1		8.5	368	7.5	gray to olive gray (5Y6/1 to 7.5Y4/2)	upward fine graded m.-f. ash.	
15	7S-PC	6	73		75	540	2	light gray (5Y7/1)	f. ash	
16	7S-PC	7	87		97	655	10	reddish black (10R2/1)	scattered ash patch	
17	7S-PC	8	60		62	727	2	light gray to grayish yellow (10YR7/1 to 2.5Y6/2)	upward fine graded m.-f. ash.	bw>>pm

reflectance spectroscopy. The whole cores were photographed with color film. Close-up photographs were also taken at some intervals with particular features. After these processes, slab samples of 1cm-thick were taken for soft X-ray analysis using a plastic case of length 20 cm and width 5 cm. Then archive halves of cores were sub-sampled for organic geochemical analysis. After this process, archive halves of the cores were placed into plastic bags, then sealed and kept in a refrigerator aboard the R/V "MIRAI" (4℃). After the cruise finished, the archive halves were stored at JAMSTEC under 4℃.

Working halves of the cores were continuously sub-sampled for index physical properties and paleomagnetic analysis using plastic containers of 22.5mm×22.5mm×22.5mm (7 cc). Water content was also measured using those cube samples. After measurement of the wet weight, the cube samples were dried at 60℃ for 24hours, and then the dry weight was measured. The weight loss of sample materials is regarded as water content of the sediment. For pilot cores, the water content was not measured. The water content

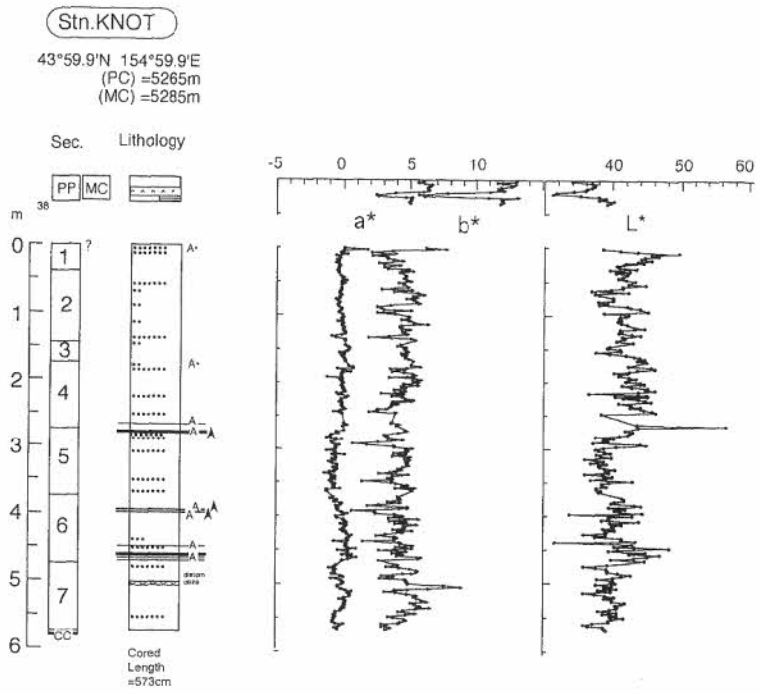

Fig. 6 Downcore fluctuations of color indices for sediment cores from St. KNOT.
The L* value indicates lightness and corresponds to black (L*=0) and white (L*=100).
The indices of a* and b* mean red to green value and yellow to blue value, respectively.

図 6 St. KNOT 堆積物の色彩測定の鉛直分布。L*の値は明るさを示し，黒（L*=0）から白（L*=100）までをデジタル値として測定。また，a*及びb*はそれぞれ赤から緑と黄色から青までの色彩値を示す

measurement of sediment cores was carried out on shore at JAMSTEC and Kochi University.

The same interval as a cube sample was sub-sampled for age determination (^{14}C and $\delta^{18}O$ methods). Cored materials of working halves were completely sub-sampled on board for microfossil assemblage analysis, radioisotope analysis and trace metal analysis. The cube samples for index physical properties will be used for future micropaleontological study.

4 Instruments for geological data on R/V "MIRAI"

4.1 Color reflectance

Color reflectance spectra of all half core sediments were measured through sealing polyvinylethylen sheet, using color reflectance spectroscopy (Minolta Co., Ltd.; model CM2010), which can measure wavelengths from 400 to 700 nm in every 10 nm. The standardization of color for the colorimeter was done with a white color standard plate. The probe area had a circle of 8 mm in diameter. The color measurement was carried out at 2 cm, excluding the direct reflectance specular component.

Color reflectance data of the sediment is indicated by the indices L*, a* and b*. The L*-value indicates brightness of the sediment. When the sediment is light in color, the L* shows a higher value (max.=100). Conversely, darkish colored sediment shows a somewhat lower L* value (min.=0). The a* value indicates color ranging between red and green. Higher values of a* correspond to red color and lower ones to green. In the case of b*, higher values correspond to yellow color and lower values to blue color.

4.2 Multisensor core logger

Magnetic susceptibility, gamma ray attenuation and P-wave

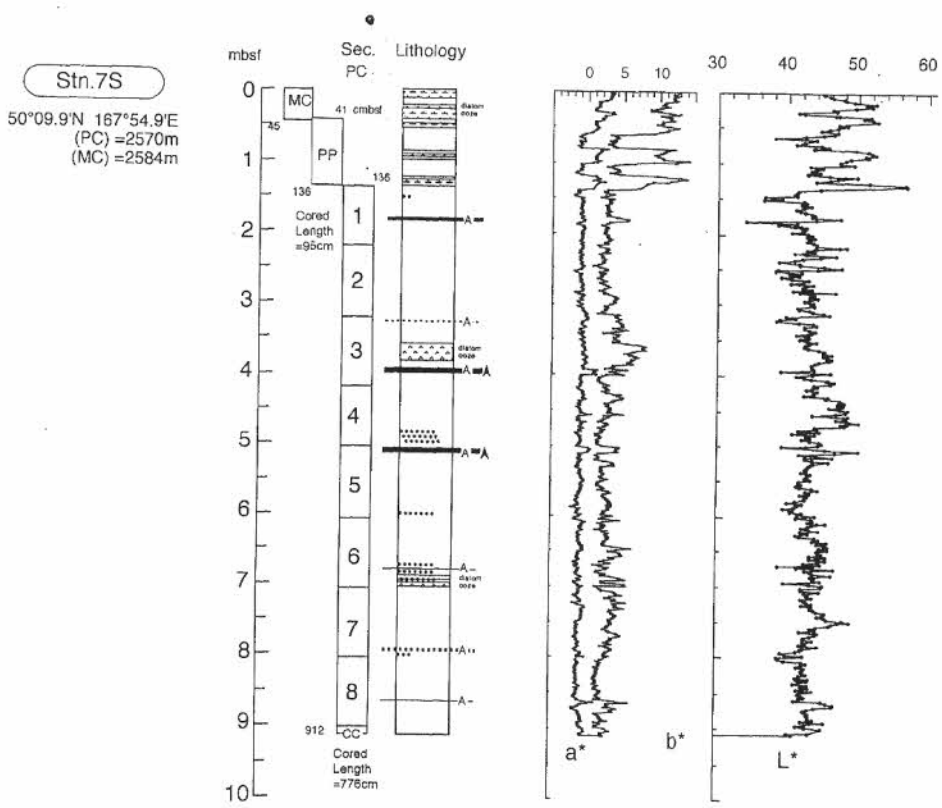

Fig. 7 Downcore fluctuations of color indices for sediment cores from St. 7S.

図 7 St. 7S 堆積物の色彩測定の鉛直分布

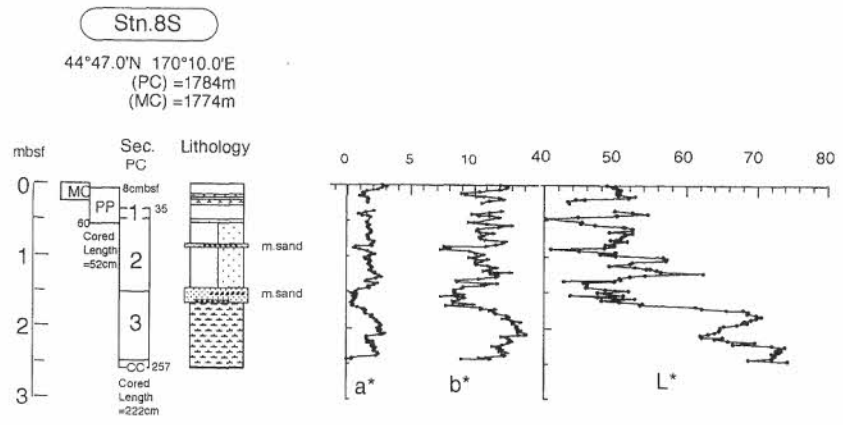

Fig. 8 Downcore fluctuations of color indices for sediment cores from St. 8S.

図 8 St. 8S 堆積物の色彩測定の鉛直分布

velocity were measured on whole-core sections using the onboard GEOTEK MSCL. All the data were taken at 2 cm intervals from all the multiple, pilot and piston cores.

The system is designed to be operated primarily under computer control. The equipped sensors are: (i) P-wave transducers to measure the velocity of P-wave in the core. (ii) A gamma ray source and detector for measuring the attenuation of gamma rays through the core, which is related to density and porosity of the sediments. (iii) A magnetic susceptibility sensor to determine the amount of magnetically susceptible material present in the sediments.

Two additional measurement sensors are also equipped to measure core diameter and temperature for correction of P-wave velocity and density (from the gamma ray attenuation measurements).

Table 2 Summary of volcanoclast ash layers in sediments.

表 2 堆積物中に存在する火山灰層のまとめ

Cruise	Station	Core	Section	Length (cm)	Core depth (cm) Top		Bottom	(cmbsf) Top		Bottom
MR97-02	KNOT	MC	A	37	0	-	37	0	-	37
	KNOT	PP	A	38	0	-	38	0	-	38
	KNOT	PP	B	22	0	-	22	0	-	22
	KNOT	PP	C	12	0	-	12	0	-	12
	KNOT	PC	1	42	0	-	42			
			2	104	42	-	146			
			3	28	146	-	174			
			4	98	174	-	272			
			5	100	272	-	372			
			6	100	372	-	472			
			7	100	472	-	572			
			CC	1	572	-	573			
	7S	MC	A	45	0	-	45	0	-	45
	7S	PP		95	0	-	95	41		136
	7S	PC	1	80	0	-	80	136	-	216
			2	100	80	-	180	216	-	316
			3	100	180	-	280	316	-	416
			4	87	280	-	367	416	-	503
			5	100	367	-	467	503	-	603
			6	101	467	-	568	603	-	704
			7	99	568	-	667	704	-	803
			8	99	667	-	766	803	-	902
			CC	10	766	-	776	902	-	912
	8S	MC	C	28	0	-	28	0	-	28
	8S	PP		52	0	-	52	8	-	60
	8S	PC	1	15	0	-	15	35	-	50
			2	100	15	-	115	50	-	150
			3	97	115	-	212	150	-	247
			CC	10	212	-	222	247	-	257

Magnetic susceptibility was measured using a loop sensor with a 15 cm diameter and is expressed as volume-specific values. The gamma ray attenuation data are expressed in counts per second; the data was not converted to bulk density at this time, because a standard sample for calibration was not available for this test leg. For gamma ray emission, a 2.5 mm collimator hole was used for cores from St. KNOT, and a 5 mm collimator hole for cores from St. 7S and 8S. Therefore, the gamma-ray counts of the cores from St. 7S and 8S are nearly tripled compared to St. KNOT. P-wave velocity could not be measured at some intervals where P-wave was not well transferred from the transducer to cores.

4.3 Soft X-ray photograph

The PRO-TEST 150 (SOFTEX) soft X-ray photograph system was used to observe the structure of sediment samples. The sediment sub-samples for soft X-ray were taken from the archive cores using a special plastic case (20 cm long, 5 cm wide and 1 cm thick). Four to five sub-samples were set on an X-ray firm, and then soft X-rays (45kVp, 3mA) were irradiated through for 160 seconds.

A total of 100 slaves were subsampled and those for soft X-ray were photographed using 31 negative films. The negative films were developed using an onboard automatic development system of Fujifilm Co. Ltd. (FIP-1400). The developed negative films will be utilized for interpreting the sediment structure as well as the visual core descriptions.

5 Results

5.1 Visual core descriptions

Visual core descriptions of St. KNOT, 7S and 8S are summarized in Fig. 5. Section lengths and total core lengths of core samples are summarized in Table 1. The down-core variations of color reflectance (L*, a* and b* values) of each piston core sample are shown in Figs. 6 through 8, with a lithological summary. Additionally, volcanic ash layers in the sediment cores are separately summarized in Table 2.

5.1.1 St. KNOT

(1) Multiple core (MC)

Dark brown to grayish-yellowish-brown colored radiolarian-bearing diatomaceous mud with diatom dominates the whole core. A brown-black mud layer bearing sulfide particles exists at 18-24 cm below the sea floor (cmbsf). The

main components of the top 22 cm of cored sediments were diatom and organic particles. Lithogenic fragments including quartz grains increase with depth below 22 cm.

(2) Piston core (PC) and Pilot core (PP)

Sediments recovered by the "Ashura" multiple type pilot corer show similar lithological character to MC. "Ashura" recovered three cores, A through C, of 38 cm, 22 cm and 12 cm in length, respectively.

PC recovered at St. KNOT is 573 cm in length. A comparison of the three cores, MC, PP and PC, based on the visual inspection, suggests that more than 40 cm of the surface sediment of PC was probably lost and the top (a few tens of cm) of recovered sediments was slightly disturbed during the coring process. PC sediments were partitioned into 7 sections and core catcher (CC) samples (Table 1). PC mainly consists of olive-gray to gray (5Y5/1 to 10Y5/1) colored diatom-bearing silty clay and diatomaceous clay. The abundance of biosilicious skeleton is variable, and has a negative correlation with lithogenic fragments. Grayish-olive (7.5Y4/2) diatomaceous ooze occurs at 30-36 cm of Section 7, exhibiting gradational and sharp contacts to upper and lower layers, respectively. Isolated pebbles with greenish-black to dark greenish-gray (10G4/1 to 10GY3/1) clay occur throughout the core, especially at 12-13 cm of Section 1, at 21-22 cm of Section 2, at 11-12 cm and 80 cm of Section 4, at 8-25 cm, 37 cm, 77-81 cm, and 95-96 cm of Section 5. The size of pebbles ranges from a few millimeter to 2 cm. Pumices and shells also exist. Isolated mudstones, 1-5 cm in diameter, are also contained at 1 cm of Section 1, at 90-95 cm of Section 2, at 4-8 cm, 50-55 cm, 77-80 cm and 93-95 cm of Section 4, at 92-95cm of Section 5. A total of 8 volcanoclastic ash layers occur in Sections 4 through 6 of this core (Table 2). Fine to medium ash at 6-10 cm in Section 5 and coarse volcanoclastic ash layers at 23-25 cm and 27-29 cm of Section 6 show upward finning and exhibit sharp erosional lower contact. Magnetic susceptibility of MSCL shows significant peaks at 6-10 cm in Section 5 and 23-25 cm and 27-29 cm of Section 6 (see MSCL chapter and Fig.9).

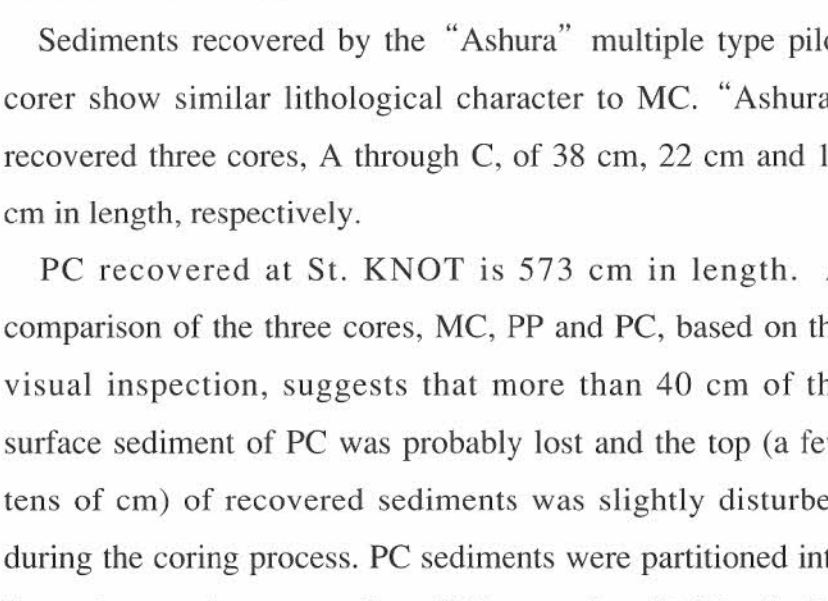

Fig. 9 Depth variations of magnetic susceptibility, gamma ray attenuation and P-wave velocity for sediment cores from St. KNOT.

図 9 St. KNOT 堆積物の帯磁率，ガンマ線透過率，P 波速度の鉛直分布

5.1.2 St.7S

(1) MC

Six cores of 45 cm, 42.5 cm, 29 cm, 27 cm, 26 cm, and 24 cm long (7S-MC-A through -F) were obtained. They consist of dull yellow foraminifera, diatom, calcareous nanno ooze and light gray diatom-bearing silty calcareous nanno ooze.

In the MC-A subcore, olive-black colored diatom-bearing calcareous clay occurred between 26 cm and 30 cm, showing sharp lower and upper bioturbated contacts. Foraminiferal tests fill in a burrow between 22 cm and 29 cm, which is grayish-olive.

(2) PC and PP

A 776 cm length of PC and a 93 cm length of PP were recovered. PP shows an alternation of yellowish-gray to grayish-olive calcareous nanno and diatom-bearing foraminifera ooze and gray colored calcareous clay. Grayish-olive colored portions at 10-16 cm, 54-60 cm, and 76-83 cm are diatomaceous, and yellowish-gray colored are calcareous. Pebble and/or mud mottles occur within gray colored clay beds. Based on visual inspection, the top 4 cm of PP is able to correlate to the bottom portion of MC-A.

The PC consists of slightly to moderately bioturbated diatom-bearing silty clay with ash layers. Foraminifera nanno ooze in the top 1 cm of Section 1 suggests that the gap between PC and PP is less than a few centimeters. The upper portion of this core is partly calcareous. A grayish-olive (7.5Y5/3) diatomaceous ooze layer occurring at 41-68 cm of Section 3 exhibits graduated top and bottom contacts. Dark bluish-gray (5PB4/1) moles, possibly manganese oxide, occur in Sections 6 and 8. Isolated pebbles and mudstone mottles with greenish-black to dark greenish-gray (10G4/1 to 10GY3/1) clay occur through this core at 8-10 cm of Section 1, at 20-30 cm of Section 3, at 27-30 cm, 39 cm, and 60-83

cm of Section 4, at 11-15 cm, 58-61 cm, 84-85 cm, 96 cm, and 98-100 cm of Section 5, at 60-80 cm, 90-94 cm, and 99-100 cm of Section 6, at 13 cm and 99 cm of Section 7 and at 1-4 cm and 37 cm of Section 8. The size of pebbles and mudstone mottles ranges from a few millimeter to 3 cm.

This core contains 7 ash layers within Sections 1 through 8 (Table 2). Most of the ash layers exhibit a lower sharp contact and an upper bioturbated contact except the brownish mottled ash layers at 5-8 cm of Section 3, and at 87-97 cm of Section 7. Fine to medium ash layers at 77-84 cm of Section 3, and at 1-8.5 cm of Section 5 show fine upgrading. Magnetic susceptibility of MSCL shows significant peaks at all ash layers (see MSCL chapter and Fig.11).

5.1.3 St. 8S

(1) MC

Sediments ranging from 23 to 28 cm in length were recovered (MC-A through -G), and consist mainly of yellowish-gray calcareous nanno and foraminifera ooze. About 10 to 15 cm in depth from the top of the subcores appear gray to grayish-olive, slightly bioturbated, diatomaceous facies.

(2) PC and PP

A 222 cm length of PC and a 93 cm length of PP were recovered. PP consists of calcareous nanno and foraminifera ooze with diatom, and shows an alternation of olive colored diatomaceous intervals and light gray calcareous intervals. An isolated pebble occurring at 27-29 cm, shows subangular shape. Comparison of the textures of the cores suggests that the surface 8 cm of PP was lost during the recovery of the core.

PC was divided into Sections 1 through 3, and CC. The upper portion of this core contains sandy calcareous nanno foraminifera ooze and muddy medium sand layers at 36-43 cm of Section 1, and at 96 cm Section of 1, through Section 2 at 23 cm with subangular to subrounded andesitic and basaltic rock fragments (0.5 to 8 cm). The lower portion of this core, 23 cm above the bottom of Section 2, contains light gray to grayish-yellow diatom and clay-bearing calcareous nanno ooze. Diatom within this calcareous ooze consists of a monospecific assemblage of *Coscidiscuc marginartus*, which never dominated in sediments from other stations.

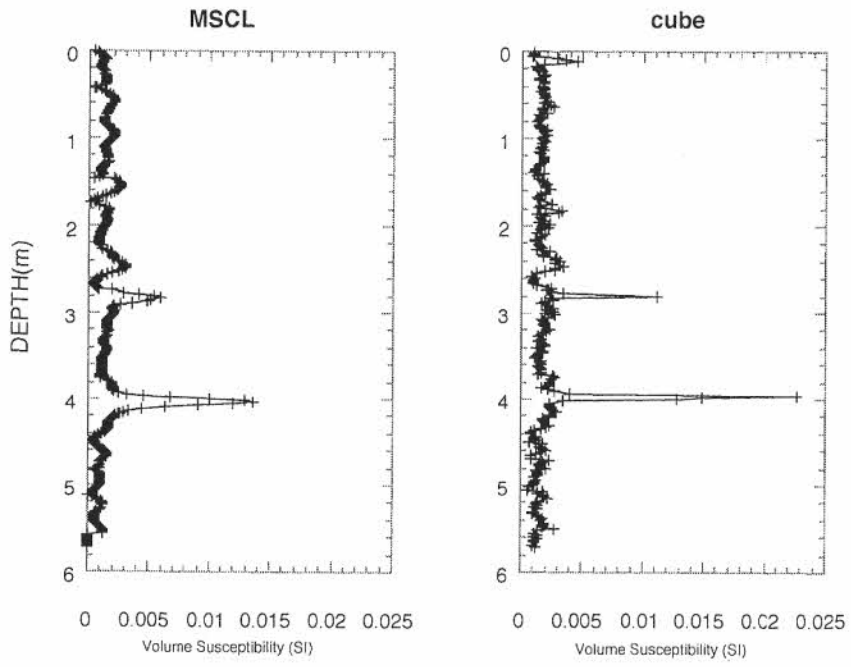

Fig. 10 Comparison of magnetic susceptibility data measured using multisensor core logger (MSCL) and discrete samples (cube) for piston core from St. KNOT.

図 10 St. KNOT 堆積物の帯磁率をマルチセンサーコアロガーで連続して測定した場合とプラスチックキューブ状にして手分析した場合の比較

5.2 Multisensor core logging

5.2.1 St. KNOT

Magnetic susceptibility and gamma ray attenuation are generally inversely proportional to each other in the PC (Fig. 9). The inverse proportionality suggests that high bulk density (low gamma ray attenuation) intervals are associated with high content of magnetic materials. For example, the two most prominent susceptibility peaks at about 2.8 and 4.0 m in depth correlate to sharp troughs in the gamma ray attenuation. These peaks correspond to ash layers identified by visual core descriptions. Some other minor peaks are also due to ash layers, or may be related to dropstones or detrital material. Plastic caps sealing the ends of sections gave low magnetic susceptibility and high gamma ray attenuation values. However, such data are not omitted to avoid overeditting. P-wave velocity could be measured only in part of Section 6.

Magnetic susceptibility data taken with MSCL were compared using discrete cube samples (Fig. 10). The 2.25 cm-sized cube samples were collected from the piston core in a back-to-back manner. The depth variations are quite similar to each other and the baseline values are consistent in the range of 0.001-0.002 SI. However, peaks in MSCL data are somehow broader and lower compared to the equivalent peaks in discrete sample data. This suggests that MSCL data are convoluted and smoothed due to the broad sensor region of the MSCL loop sensor.

5.2.2 St. 7S

The depth variation of magnetic susceptibility of the piston core is a mirror image of gamma ray attenuation (Fig. 11). For this core section, breaks do not obscure the variations because we used thin plastic covers to seal the ends of sections. Some ash layers identified by visual core descriptions are recognized as peaks in magnetic susceptibility and troughs in gamma ray attenuation (e.g., at about 0.45 cm and 2.6 cm in depth). A basalt dropstone (5.6 cm in size) corresponds to a peak of magnetic susceptibility at about 0.1 m in depth. P-

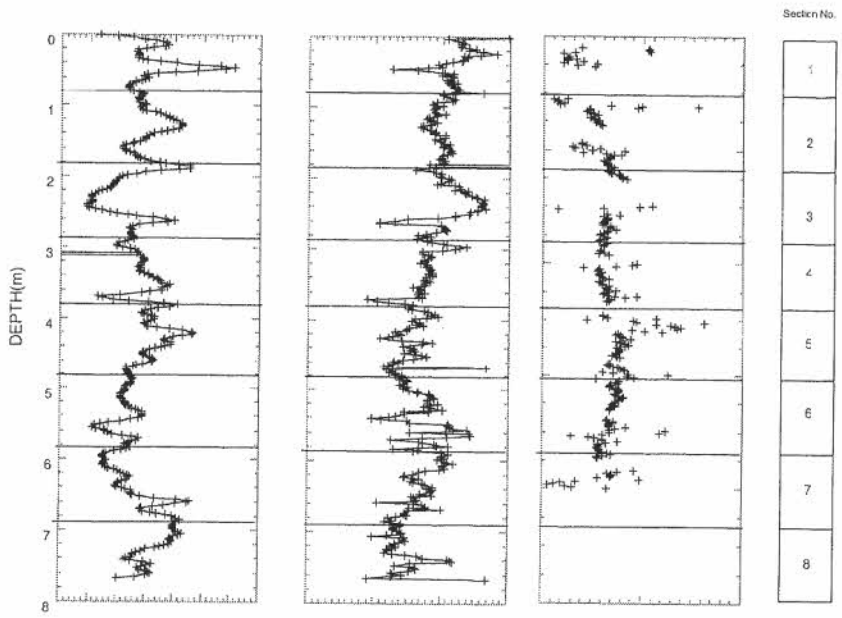

Fig. 11 Depth variations of magnetic susceptibility, gamma ray attenuation and P-wave velocity for sediment cores from St. 7S.

図 11 St. 7S 堆積物の帯磁率，ガンマ線透過率，P 波速度の鉛直分布

wave velocity data could be collected from most sections for this piston core, although the data points are scattered.

5.2.3 St. 8S

For the PC, a peak in magnetic susceptibility and a trough in gamma ray attenuation at 0.6 m in depth are due to a large (5.8 cm in size) basalt dropstone (Fig. 12). Zero or negative values of magnetic susceptibility below 1.4 m are observed for an interval of calcareous ooze. P-wave velocity data were taken only from a short interval of Section 3.

According to the calculated depth displacement, we plotted the three gamma ray attenuation variations by shifting the depth axis (Fig. 13). Peaks and troughs are quite well correlated between the three cores, verifying the visual correlation. Such a inter-core correlation can provide a complete composite section from the exact sediment surface recovered by a multiple corer to the deeper part of a piston

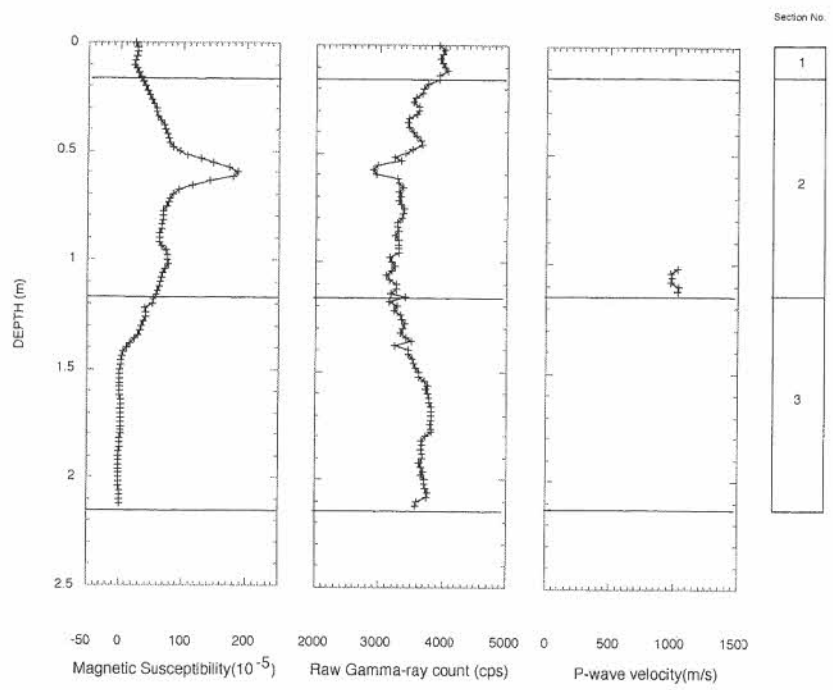

Fig. 12 Depth variations of magnetic susceptibility, gamma ray attenuation and P-wave velocity for sediment cores from St. 8S.

図 12 St. 8S 堆積物の帯磁率，ガンマ線透過率，P 波速度の鉛直分布

core.

5.3 Water content

The vertical variations of water content at three stations suggest that the water content change is closely related to the lithological change.

5.3.1 St. KNOT

The water content of MC is plotted against the depth below the sea floor (Fig. 14), however the cmbsf is unknown for the PC, because the surface sediment was lost at the piston coring. Therefore, the water content of PC is plotted against the depth of sediment (cm). The water content of MC and PC ranges from 27.3 to 64.5%. Some layers with low water content (*ac.* 27-30%) are found in the PC. They correspond to the volcanoclastic ash layers and the layers containing many mud stones, respectively (Figs. 5 and 14).

5.3.2 St. 7S

The water content is plotted against cmbsf for both MC and PC. The water content of MC and PC ranges from 34.2 to 81.4%. Some layers with low water content (ac. 30%) at 180, 380-390, 510, and 670 cmbsf correspond to the volcanoclastic ash layers. The peaks at 10 (81.4%) and 30 cmbsf (57%) of MC correspond to the foraminifera nanno ooze layers (Figs. 5 and 14).

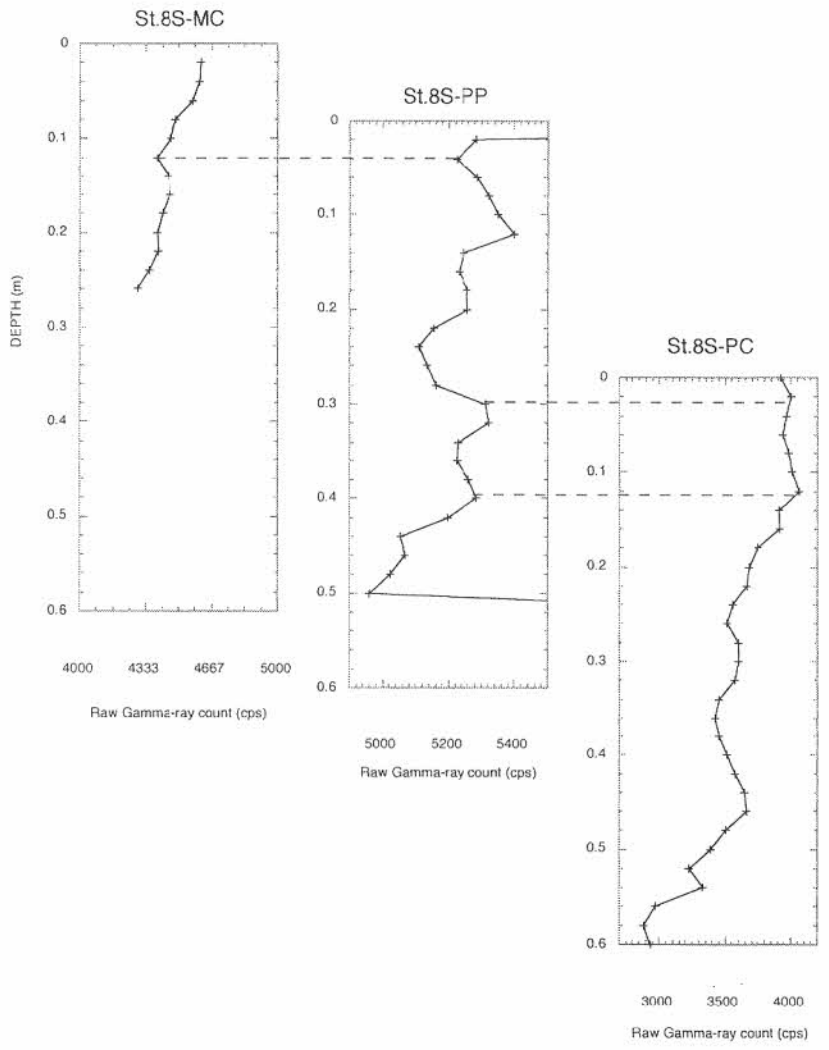

Fig. 13 Correlation of gamma rey attenuation for tha multiple core (MC), the pilot core (PP) and the piston core (PC) from St. 8S. Broken lines show corresponding peaks or troughs between different cores.

図 13 ガンマ線透過率のデータを元にSt. 8S のマルチプルコア，パイロットコア及びピストンコアを連続的に繋げた図。破線は各コア間で照合され得る部分の位置を示す

5.3.3 St. 8S

The water content is plotted against cmbsf for both MC and PC. The water content of MC and PC ranges from 27.8 to 57.3%. A relatively low water content (ac. 30-40%) layer from 60 to 150 cmbsf corresponds to the sand layer. On the other hand, the layer from 170 to 250 cmbsf has a relatively high water content of 50-60% and corresponds to the foraminifera nanno ooze layer (Figs. 5 and 14).

6 Acknowledgment

We are grateful to captain Akamine, chief officer Ukekura and crew members of R/V "MIRAI" for their help in the coring operation and sampling the sediment during the cruise MR97-02. We also wish to express our thanks to Dr. Kusakabe, chief scientist of this cruise, for his supporting all of the operations and suggestions for improvements in the manuscript.

Reference

1) Tally L.D.: An Okhotsk Sea water anomaly: Implications for ventilation in the North Pacific. Deep-Sea Research, 38(A), 171-190. (1991)

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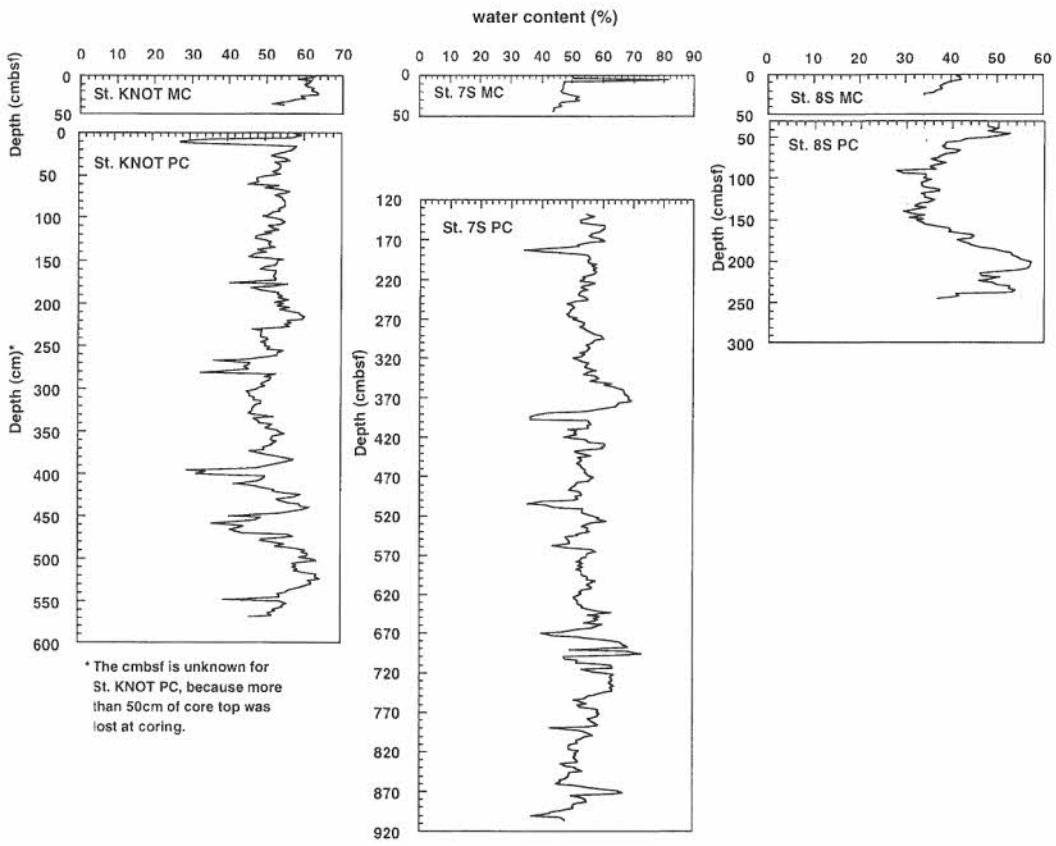

Fig. 14 Vertical profiles of water content data of sediment cores.

図 14 堆積物の含水率の鉛直分布

Operation Summary

Stn.KNOT Multiple coring

Cruise	MR97-02	Date	Nov. 14, 1997
Station	KNOT		
Latitude (TOKYO Datum)	43-59.83'N	Longitude (TOKYO Datum)	154-59.89'E
Latitude (WGS)	44-00.00029'N	Longitude (WGS)	154-59.59246'E
Location	Western North Pacific	Weather	overcast
Sea Condition	smooth-wavelets, moderate sw	Wind	2.1m/s, 348deg
Bottom	flat	Instrument	Multiple corer
Length of Core Pipe	60 cm ×4	Length Main Line	-
I.D. of Pipe	73 mm	Length Trriger Line	-
I.D. of Inner Tube		Length Main Wire	-
Wall Thickness	3 mm	Length Trriger Wire	-
Material	Acrylic	Core Head Wt.	600 kg
Swell Compensator	on	Trigger Wt.	-
Response at Hit	undistinct	Response at Pull-out	undistinct
Time Lowered	16:37	Uncorrected Water Depth	5300 m
Time Hit	18:14	Uncorrected Water Depth	5300 m
Tention at Hit	4.4 kft	Tention at Pull-out	5.6 kft
Cored Length	-	Wire-out at Hit	5379 m
Method of Storage	refrigeration	Trriger Cored Length	-
No. of Pipe Filled	-		
Length of Cores in Pipe	coreA 37 cm, coreB 37cm, coreC 35cm, coreD 7cm		
Sampling	coreA: 1/2 Harada (JAMSTEC), 1/2 Muraki (Hokkaido Tokai Univ.), coreB: 1/2 Narita (Hokkaido Univ.), coreC: Iwai (Kochi Univ.), soft X ray, cubes, 1/4 archives, coreD: Honda (JAMSTEC)		
Remark:			

Appendix.1

Stn.KNOT Piston coring

Cruise	MR97-02	Date	Nov. 15, 1997
Station	KNOT		
Latitude (TOKYO Datum)	43-59.89'N	Longitude (TOKYO Datum)	154-59.88'E
Latitude (WGS)	44-00.06028'N	Longitude (WGS)	154-59.58245'E
Location	Western North Pacific	Weather	rain
Sea Condition	smooth-wavelets, moderate swell	Wind	8.8m/s, 82deg
Bottom	flat	Instrument	Piston corer
Length of Core Pipe	8 m (4 m×2)	Length Main Line	22.6m
I.D. of Pipe	80 mm	Length Trriger Line	15.7m
I.D. of Inner Tube	75 mm	Length Main Wire	14.7 m
Wall Thickness		Length Trriger Wire	14.7m
Material	Stainless Steel	Core Head Wt.	500 kg
Swell Compensator	on	Trigger Wt.	80 kg
Response at Hit	undistinct	Response at Pull-out	clear
Time Lowered	5:27	Uncorrected Water Depth	5300 m
Time Hit	7:09	Uncorrected Water Depth	5300 m
Tention at Hit	4.5 kft	Tention at Pull-out	6.7 kft
Cored Length	572 cm	Wire-out at Hit	5370 m
Method of Storage	refrigeration	Trriger Cored Length	12, 22, 38 cm
No. of Pipe Filled	2		
Length of Cores in Pipe	sec.1: 42 cm, sec.2: 104 cm, sec.3: 28 cm sec.4: 98 cm, sec.5: 100 cm, sec.6: 100 cm, sec.7: 100 cm		
Sampling (sampling depth: 2.25cm each)	ac.23cc: Harada, ac.14 cc: Muraki, ac. 9cc: Narita, ac. 14 cc: 2 cubes (7cc each: Kanamatsu, Iwai), ac. 1cc: Fukuma soft X ray (case size: 5cm × 20cm ×1cm), ac.20cc: archives		
Remark: "Ashura" type corer, which has three subtubes (60 cm long), was used for trriger.			

Appendix.2

Stn.7S Multiple coring

Cruise	MR97-02	Date	Nov. 23, 1997
Station	7S		
Latitude (TOKYO Datum)	50-09.62'N	Longitude (TOKYO Datum)	167-54.43'E
Latitude (WGS)	50-9.78738'N	Longitude (WGS)	167-54.03937'E
Location	north western North Pacific	Weather	overcast
Sea Condition	smooth-wavelets, moderate swell	Wind	12.7m/s, 243.0deg
Bottom	slope	Instrument	Multiple corer
Length of Core Pipe	60 cm ×8	Length Main Line	-
I.D. of Pipe	73 mm	Length Trriger Line	-
I.D. of Inner Tube	-	Length Main Wire	-
Wall Thickness	3mm	Length Trriger Wire	-
Material	Acrylic	Core Head Wt.	600 kg
Swell Compensator	off	Trigger Wt.	-
Response at Hit	undistinct	Response at Pull-out	undistinct
Time Lowered	4:47	Uncorrected Water Depth	-
Time Hit	5:50	Uncorrected Water Depth	-
Tention at Hit	1.3 tonf	Tention at Pull-out	7.8 tonf
Cored Length	-	Wire-out at Hit	2665 m
Method of Storage	refrigeration	Trriger Cored Length	-
No. of Pipe Filled	-		
Length of Cores in Pipe	coreA: 45 cm, coreB: 42.5 cm, coreC: 27 cm coreD: 26 cm, coreE: 29 cm, coreF: 24 cm		
Sampling	coreA: softX ray, cubes, Iwai (Kochi Univ.), Fukuma (JAMSTEC), archives coreB:Muraki, coreC: Sato (Hokkaido Univ.), coreD:archive coreE:Harada (JAMSTEC), coreF:archive		
Remark:			

Appendix.3

Stn.7S Piston coring

Cruise	MR97-02	Date	Nov. 23, 1997
Station	7S		
Latitude (TOKYO Datum)	50-09.88'N	Longitude (TOKYO Datum)	167-54.89'E
Latitude (WGS)	50-10.04738'N	Longitude (WGS)	167-54.49930'E
Location	north western North Pacific	Weather	overcast
Sea Condition	smooth-wavelets, moderate swell	Wind	14.0m/s, 265.0deg
Bottom	slope	Instrument	Piston corer
Length of Core Pipe	8 m(4 m×2)	Length Main Line	22.6m
I.D. of Pipe	80 mm	Length Trriger Line	16m
I.D. of Inner Tube	75 mm	Length Main Wire	14.7 m
Wall Thickness		Length Trriger Wire	14.7m
Material	Stainless Steel	Core Head Wt.	500 kg
Swell Compensator	off	Trigger Wt.	80 kg
Response at Hit	undistinct	Response at Pull-out	undistinct
Time Lowered	7:36	Uncorrected Water Depth	2570 m
Time Hit	8:39	Uncorrected Water Depth	2570 m
Tention at Hit	2.7 tonf	Tention at Pull-out	3.6 tonf
Cored Length	776 cm	Wire-out at Hit	2573 m
Method of Storage	refrigeration	Trriger Cored Length	95 cm
No. of Pipe Filled	2		
Length of Cores in Pipe	sec.1: 80 cm, sec.2: 100 cm, sec.3: 100 cm, sec.4: 87 cm sec.5: 100 cm, sec.6: 101 cm, sec.7: 99 cm, sec.8: 99 cm, cc: 10cm		
Sampling	ac.23cc: Harada, ac.14 cc: Muraki, ac. 9cc: Narita, ac. 14 cc: 2 cubes (7cc each: Kanamatsu, Iwai), ac. 1cc: Fukuma soft X ray (case size: 5cm × 20cm ×1cm), ac.20cc: archives		
Remark: Gravity type corer(Yuing) was usen for trriger.			

Appendix.4

stn.8S Multiple coring

Cruise	MR97-02	Date	Nov. 26, 1997
Station	8S		
Latitude (TOKYO Datum)	44-47.02'N	Longitude (TOKYO Datum)	170-10.05'E
Latitude (WGS)	44-47.22910'N	Longitude (WGS)	170-09.69012'E
Location	north western North Pacific	Weather	overcast
Sea Condition	smooth-wavelets, moderate swell	Wind	7.2m/s, 4.9deg
Bottom	slope	Instrument	Multiple corer
Length of Core Pipe	60 cm ×8	Length Main Line	-
I.D. of Pipe	73 mm	Length Trriger Line	-
I.D. of Inner Tube	-	Length Main Wire	-
Wall Thickness	3mm	Length Trriger Wire	-
Material	Acrylic	Core Head Wt.	600 kg
Swell Compensator	off	Trigger Wt.	-
Response at Hit	clear	Response at Pull-out	clear
Time Lowered	22:10	Uncorrected Water Depth	1774 m
Time Hit	22:52	Uncorrected Water Depth	1774 m
Tention at Hit	2.0 tonf	Tention at Pull-out	3.0 tonf
Cored Length	-	Wire-out at Hit	1775 m
Method of Storage	refrigeration	Trriger Cored Length	-
No. of Pipe Filled	-		
Length of Cores in Pipe	coreA: 26 cm, coreB: 28.5 cm, coreC: 28 cm, coreD: 28 cm coreE: 28.5 cm, coreF: 26.5 cm, coreG: 23 cm		
Sampling	coreA: Sato (Hokkaido Univ.), coreB: softX ray, cubes, Iwai (Kochi Univ.), Fukuma (JAMSTEC), archives, coreC:archive, coreD:Muraki, coreE:Harada (JAMSTEC), coreF:archive, coreG:archive		
Remark:			

Appendix.5

Stn.8S Piston coring

Cruise	MR97-02	Date	Nov. 26, 1997
Station	8S		
Latitude (TOKYO Datum)	44-46.99'N	Longitude (TOKYO Datum)	170-10.00'E
Latitude (WGS)	44-47.19910'N	Longitude (WGS)	170-09.64012'E
Location	north western North Pacific	Weather	overcast
Sea Condition	smooth-wavelets, moderate swell	Wind	9.7m/s, 36.5deg
Bottom	slope	Instrument	Piston corer
Length of Core Pipe	8 m(4 m×2)	Length Main Line	20.73m
I.D. of Pipe	80 mm	Length Trriger Line	16m
I.D. of Inner Tube	75 mm	Length Main Wire	12.83m
Wall Thickness		Length Trriger Wire	14.7m
Material	Stainless Steel	Core Head Wt.	500 kg
Swell Compensator	off	Trigger Wt.	80 kg
Response at Hit	undistinct	Response at Pull-out	undistinct
Time Lowered	0:04	Uncorrected Water Depth	1784 m
Time Hit	0:53	Uncorrected Water Depth	1784 m
Tention at Hit	2.1 tonf	Tention at Pull-out	2.8 tonf
Cored Length	222 cm	Wire-out at Hit	1752 m
Method of Storage	refrigeration	Trriger Cored Length	52 cm
No. of Pipe Filled	1		
Length of Cores in Pipe	sec.1: 15 cm, sec.2: 100 cm sec.3: 97 cm, cc: 10cm		
Sampling	ac.23cc: Harada, ac.14 cc: Muraki, ac. 9cc: Narita, ac. 14 cc: 2 cubes (7cc each: Kanamatsu, Iwai), ac. 1cc: Fukuma soft X ray (case size: 5cm × 20cm ×1cm), ac.20cc: archives		
Remark: Gravity type corer (Yuing) was used for trriger.			

Appendix.6