



R/V MIRAI Cruise Report

MR15-02

Strategic Innovation Program (SIP), New-generation
Technology for Ocean Resources Survey (ZIPANG in
ocean), “Deep-sea mud and seawater sampling with the
bathymetric survey around the Minamitorishima offshore”

22th, June 2015 to 17th, July 2015

Japan Agency for Marine-Earth Science and Technology
(JAMSTEC).

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1. Cruise Information

- Cruise ID: MR15-02
- Name of vessel: R/V MIRAI
- Title of the cruise: Strategic Innovation Program (SIP), New-generation Technology for Ocean Resources Survey (ZIPANG in ocean), “Deep-sea mud and seawater sampling with the bathymetric survey around the Minamitorishima offshore”
- Title of proposal: Strategic Innovation Program (SIP), New-generation Technology for Ocean Resources Survey (ZIPANG in ocean), “Extensive investigation of REY-rich mud around the Minamitorishima offshore”
- Cruise period: 22th, June 2015 to 17th, July 2015
- Ports of departure / arrival: Shimizu to Kushiro
- Research area: Minamitorishima offshore
- Research Map

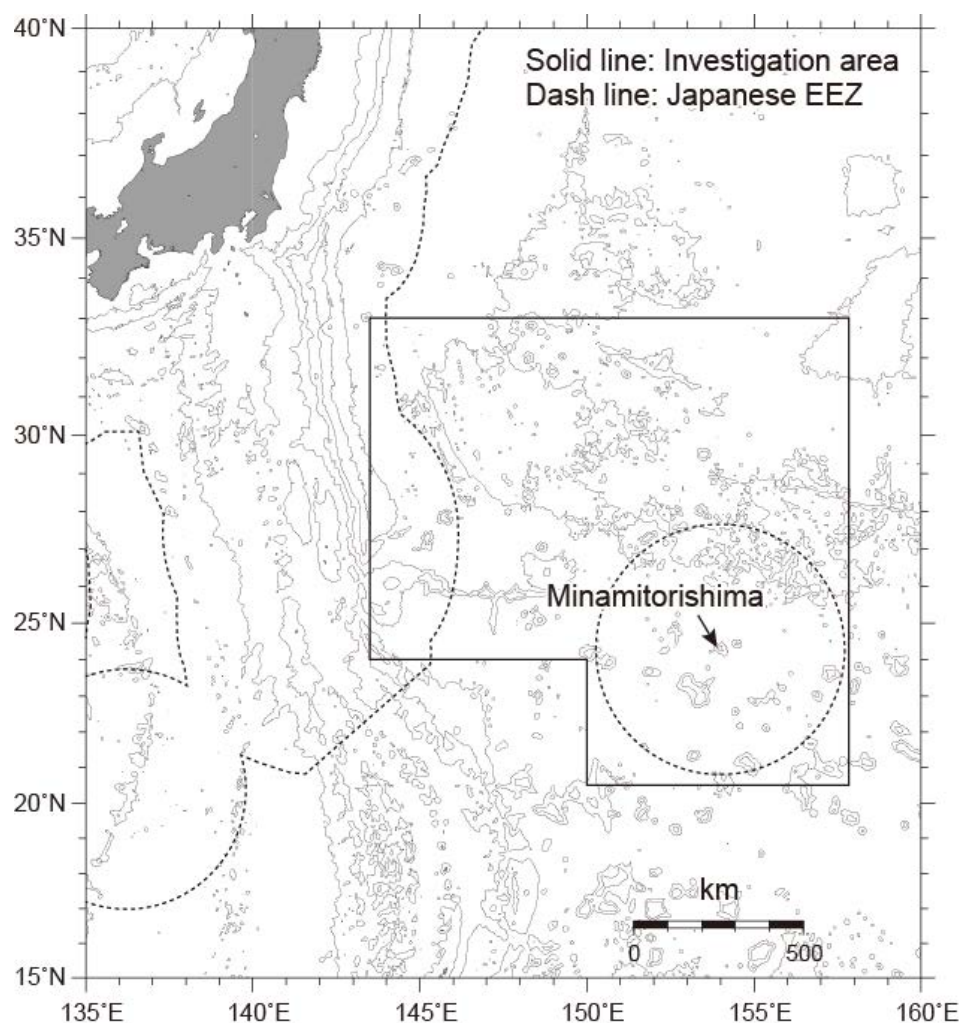


Fig. 1-1 Investigation area of the MR15-02 Cruise.

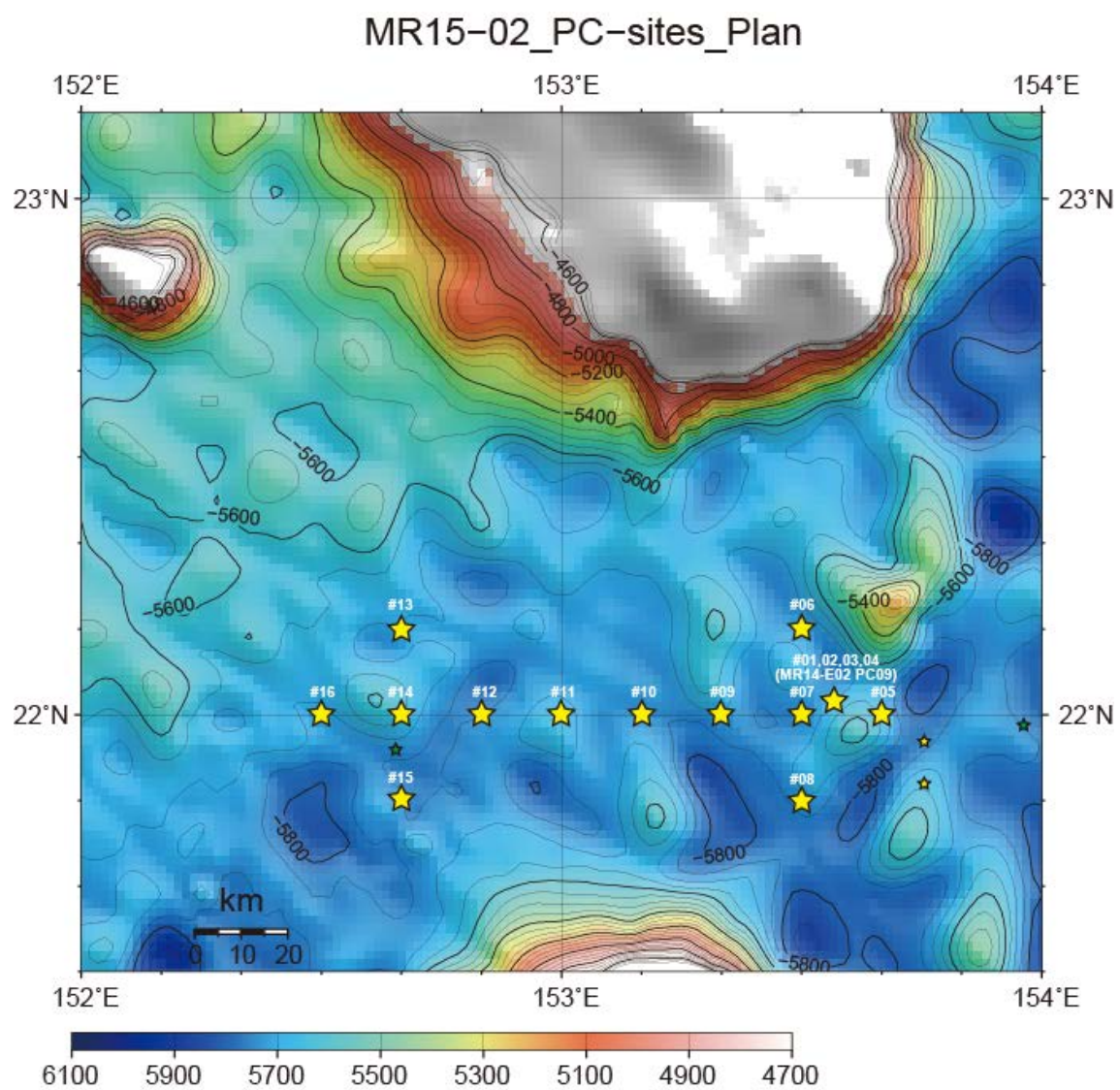


Fig. 1-2 Planned location map of the piston core sampling.

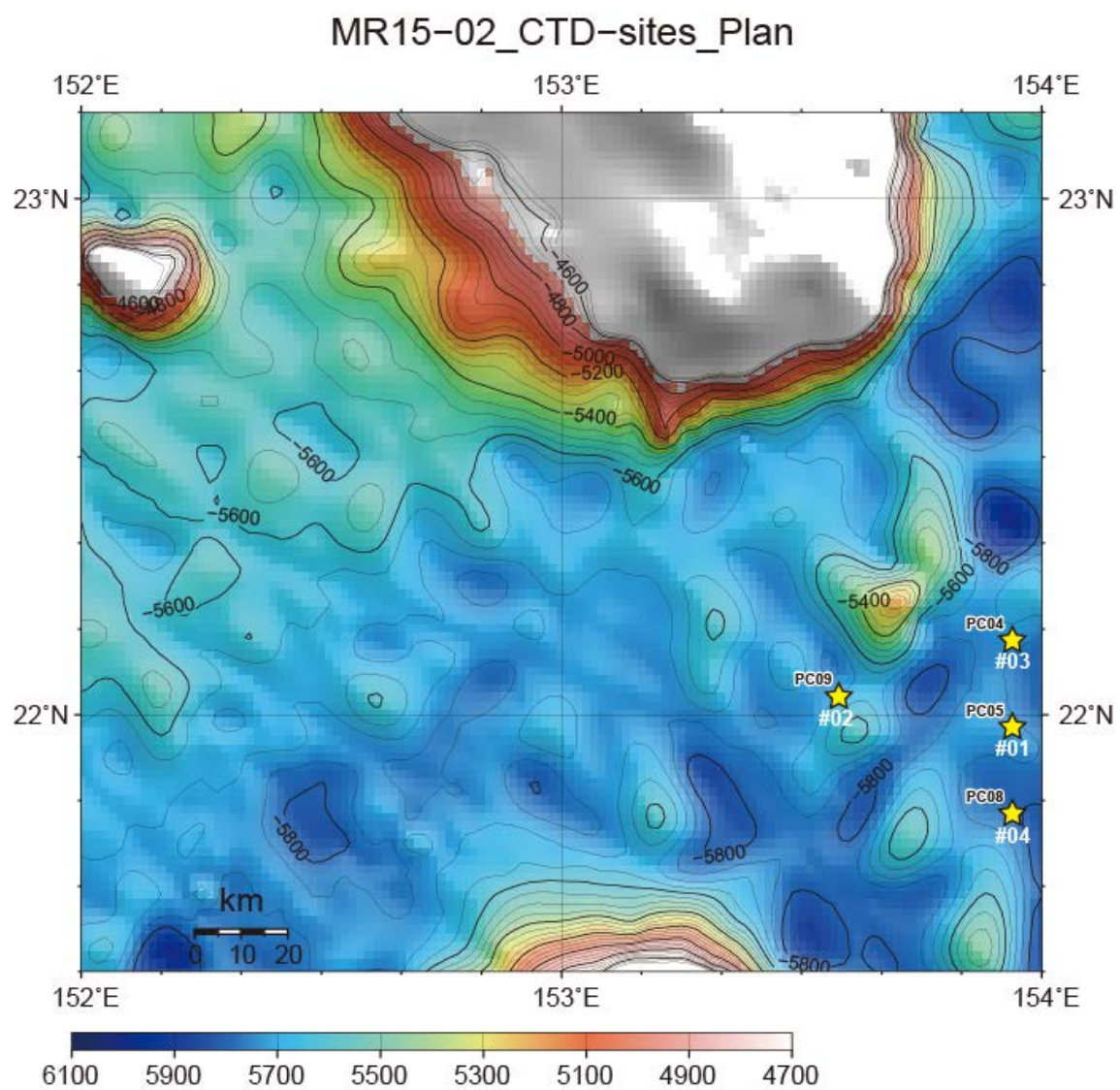


Fig. 1-3 Planned location map of the CTD seawater sampling.

2. Researchers

- **Chief scientist:**

Tatsuo Nozaki [JAMSTEC]

- **Representative of the science party:**

Katsuhiko Suzuki [JAMSTEC]

- **Science party:**

Koichi Iijima (JAMSTEC)

Ayu Takahashi (JAMSTEC)

Hiroshi Amakawa (JAMSTEC)

Shiki Machida (JAMSTEC)

Junji Torimoto (JAMSTEC)

Yusuke Fukami (JAMSTEC)

Koichiro Fujinaga (JAMSTEC)

Kazutaka Yasukawa (JAMSTEC)

Takehiro Kawasaki (JAMSTEC)

Ryo Oyama (GODI)

Kazuho Yoshida (GODI)

Yuya Mori (GODI)

Kazuhiro Yoshida (MWJ)

Akira Sou (MWJ)

Yasushi Hashimoto (MWJ)

Mika Yamaguchi (MWJ)

Hiroki Ushiromura (MWJ)

Rei Ito (MWJ)

Keisuke Takeda (MWJ)

Koki Uda (MWJ)

- **Crews:**

Captain	Hiroshi Matsuura
Chief Officer	Haruhiko Inoue
Junior 2nd Officer	Hirokazu Sugawara
2nd Officer	Nobuo Fukaura
3rd Officer	Akihiro Nunome
Chief Engineer	Yoichi Furukawa

1st Engineer	Kazuhito Ikeda
2nd Engineer	Wataru Okuma
3rd Engineer	Katsumitsu Kodama
Radio officer	Ryo Kimura
Boat Swain	Kazuyoshi Kudo
Able Seaman	Tsuyoshi Sato
Able Seaman	Takeharu Aisaka
Able Seaman	Tsuyoshi Monzawa
Able Seaman	Masashige Okada
Able Seaman	Shuji Komata
Able Seaman	Masaya Tanigawa
Able Seaman	Shohei Uehara
Sailor	Hideyuki Okubo
Sailor	Tetsuya Sakamoto
Sailor	Tenki Yamashiro
No.1 Oiler	Yoshihiro Sugimoto
Oiler	Fumito Kaizuka
Oiler	Toshiyuki Furuki
Oiler	Kazumi Yamashita
Fireman	Shintaro Abe
Fireman	Kazuya Ando
Chief Steward	Kazuhiko Hayashida
Steward	Yukio Shige
Steward	Tamotsu Uemura
Steward	Ei Hoshikuma
Steward	Tuneaki Yoshinaga
Steward	Hiroataka Yamaguchi

3. Observations

3.1 Objectives & Background

In 2011, the wide distribution of deep-sea mud bearing high total REY contents in the Pacific Ocean was reported by Kato et al. (2011_ *Nature Geoscience*) and now deep-sea REY-rich mud has been vigorously studied as “the 4th seafloor mineral resources” followed by ferromanganese nodule, hydrothermal sulfide deposit and ferromanganese crust. Research cruises dedicated only for the REY-rich mud have been conducted within the Japanese Exclusive Economic Zone (EEZ) since 2013 and extremely enriched REY-rich mud whose total REY concentration exceeds 5,000 ppm has been discovered (Iijima et al., *submitted to Geochemical Journal*; Fujinaga et al., *submitted to Geochemical Journal*; Ohta et al., *submitted to Geochemical Journal*; press released by JAMSTEC and Univ. of Tokyo in 21th, Mar. 2013). Moreover, acoustic geophysical researches have been performed by sub-bottom profiler (SBP) through the KR13-02, MR13-E02, KR14-02, MR14-E02, MR15-E01 Leg 2 and MR15-E01 Leg 3 Cruises, which classified deep-sea mud around the Minamitorishima Island into three types; (1) banded structured mud, (2) acoustically transparent irregular shaped mud and (3) acoustically transparent smooth shaped mud (Nakamura et al., *submitted to Geochemical Journal*). Petrological and geochemical studies have been done to investigate the relationship among the results of SBP survey, bulk geochemical compositions (especially total REY contents) and physical properties. In the MR15-02 Cruise, we focused to comprehend the detailed distribution of the extremely enriched REY-rich mud in the southern area of the Minamitorishima EEZ as well as geophysical researches using SBP and MBES (multi-narrow beam eco sounding system).

Fujinaga, K., Yasukawa, K., Nakamura, K., Machida, S., Takaya, Y., Ohta, J., Araki, S., Liu, H., Usami, R., Maki, R., Haraguchi, S., Nishio, Y., Usui, Y., Nozaki, T., Yamazaki, T., Ichiyama, Y., Ijiri, A., Inagaki, F., Machiyama, H., Iijima, K., Suzuki, K., Kato, Y. and KR13-02, MR13-E02 Leg 2 and KR14-02 Cruise members (*submitted*) Geochemistry of rare-earth elements and yttrium-rich muds in the Japanese Exclusive Economic Zone around Minamitorishima Island. *Geochemical Journal*, **xx**, xxx-xxx.

Iijima, K., Yasukawa, K., Fujinaga, K., Nakamura, K., Machida, S., Takaya, Y., Ohta, J., Haraguchi, S., Nishio, Y., Usui, Y., Nozaki, T., Yamazaki, T., Ichiyama, Y., Ijiri, A., Inagaki, F., Machiyama, H., Suzuki, K., Kato, Y. and KR13-02 Cruise members (*submitted*) Discovery of extremely REY-rich mud in the western North Pacific Ocean. *Geochemical Journal*, **xx**, xxx-xxx.

Kato, Y., Fujinaga, K., Nakamura, K., Takaya, Y., Kitamura, K., Ohta, J., Toda, R., Nakashima, T. and Iwamori, H. (2011) Deep-sea mud in the Pacific Ocean as a potential resource for rare-earth elements. *Nature Geoscience*, **4**, 535-539.

Nakamura, K., Machida, S., Okino, K., Masaki, Y., Iijima, K., Suzuki, K. and Kato, Y. (*submitted*)

Acoustic characterization of pelagic sediments using sub-bottom profiler: Implications for the distribution of REY-rich mud in the Minamitorishima EEZ, western Pacific. *Geochemical Journal*, **xx**, xxx-xxx.

Ohta, J., Yasukawa, K., Machida, S., Fujinaga, K., Nakamura, K., Takaya, Y., Iijima, K., Suzuki, K. and Kato, Y. (*submitted*) Grain size distributions and mineralogical features of REY-rich mud in the western North Pacific Ocean. *Geochemical Journal*, **xx**, xxx-xxx.

3.2 Methods & Instruments

3.2.1 MBES and SBP

R/V MIRAI is equipped with a Multi-narrow Beam Echo Sounding system (MBES), SEABEAM 3012 (L3 Communications ELAC Nautik GmbH) and Sub-Bottom Profiler (SBP), Bathy 2010 (SyQwest Incorporated). In order to determine an accurate sound velocity of water column for the ray-path correction of acoustic multibeam, we used Surface Sound Velocimeter (SSV) data to obtain the sea surface (6.62 m) sound velocity, and the deeper depth sound velocity profiles were calculated by temperature and salinity profiles from XBT (eXpendable BathyThermograph) data based on the equation in Del Grosso (1974).

Del Grosso, V. A. (1974) New equation for speed of sound in natural water (with comparison to other equations). *The Journal of the Acoustical Society of America*, **56**, 1084-1091.

Table 3-1 System configuration and performance of SEABEAM 3012 (12 kHz system)

Frequency:	12 kHz
Transmit beam width:	2.0 degree
Transmit power:	4 kW
Transmit pulse length:	2 to 20 msec
Receive beam width:	1.6 degree
Depth range:	50 to 11,000 m
Beam spacing:	Equi-Angle
Number of beams	301 beams
Swath width:	60 to 150 degree (max)
Depth accuracy:	< 1 % of water depth (average across the swath)

Table 3-2 System configuration and performance of SBP, Bathy 2010 (3.5 kHz system)

Frequency:	3.5 kHz (FM sweep)
Transmit beam width:	23 degree
Transmit pulse length:	0.5 to 50 msec
Strata resolution:	Up to 8 cm with 300 m of bottom penetration according to bottom type
Depth resolution:	0.1 feet, 0.1 m
Depth accuracy:	± 10 cm to 100 m, ± 0.3% to 6,000 m
Sound velocity:	1,500 m/s (fix)

3.2.2 Three-component magnetometer

The shipboard three-component magnetometer system (Tierra Technica SFG1214) is equipped on-board R/V MIRAI. Three-axes flux-gate sensors with ring-cored coils are fixed on the fore mast. Outputs of the sensors are digitized by a 20-bit A/D converter (1 nT/LSB), and sampled at 8 times per second. Ship's heading, pitch and roll are measured utilizing Inertial Navigation System (Fiber Optical Gyro) installed for controlling attitude of the Doppler radar. Ship's position (GPS) and speed data are taken from LAN every second.

3.2.3 Piston corer

Piston core sampler system (PC) consists of the weight, duralumin pipes (5 m-long per pipe), trigger which works as the balance and a pilot core sampler. The polycarbonate liner tube (5 m-long per tube) is installed inside the duralumin pipe. The inner diameter (I.D.) of liner tube is 74 mm. The outer diameter of the main winch wire is 17 mm.

In this cruise, the 1.5 ton weight was only used. The total length of duralumin pipes and liner tubes were all 15 m. The pipe length was decided based on the results of SBP site survey data. The long and sharp stainless bit was used at the end of the pipes to promote penetration of the PC into subseafloor. We used a 74 mm (I.D.) Long Type Pilot Corer (called 74 corer) for a pilot core sampler. The total weight of the PC system with the 1.5 ton weight is approximately 1.7 ton in water. The constructions of the PC system in this cruise are shown in Figure 3-1. We used a hybrid type piston which was composed of brass body. To reduce backpressure during coring to prevent liner tube deformation, the piston O-ring (size P62) was reduced to one or not used for PC04 and PC08. The hardness of the rubber plate was 45. We did not use the rubber plate for PC03. On the PC09 to 16 operations, the same rubber plate with eight V-shaped cutouts was used to prevent liner tube deformation.

The polycarbonate tubes we used as a liner tube were annealed before cruise. When we divide the core into archive and working halves, non-anneal polycarbonate tubes have transformation internally. However, annealing polycarbonate tubes can lessen transformation.

After deployment the PC, the swell compensator was started at wire out 200 or 500 m water depth depending on the sea state. After that, the winch was gradually increased the speed up to 1 m/s. The winch was stopped at a depth about 100 m above the seafloor for 3 minutes to reduce some pendulum motions of the PC system. After that, the wire was stored out at the speed of 0.3 m/s. When the wire tension decreased suddenly by the loss of the weight, we confirmed the PC hit the bottom. After that, the winch was immediately stopped and winched up at the speed of 0.2 m/s until the tension gauge indicated the PC was completely lifted off the bottom. After leaving the bottom, the winch speed was at the maximum speed (1.2 m/s).

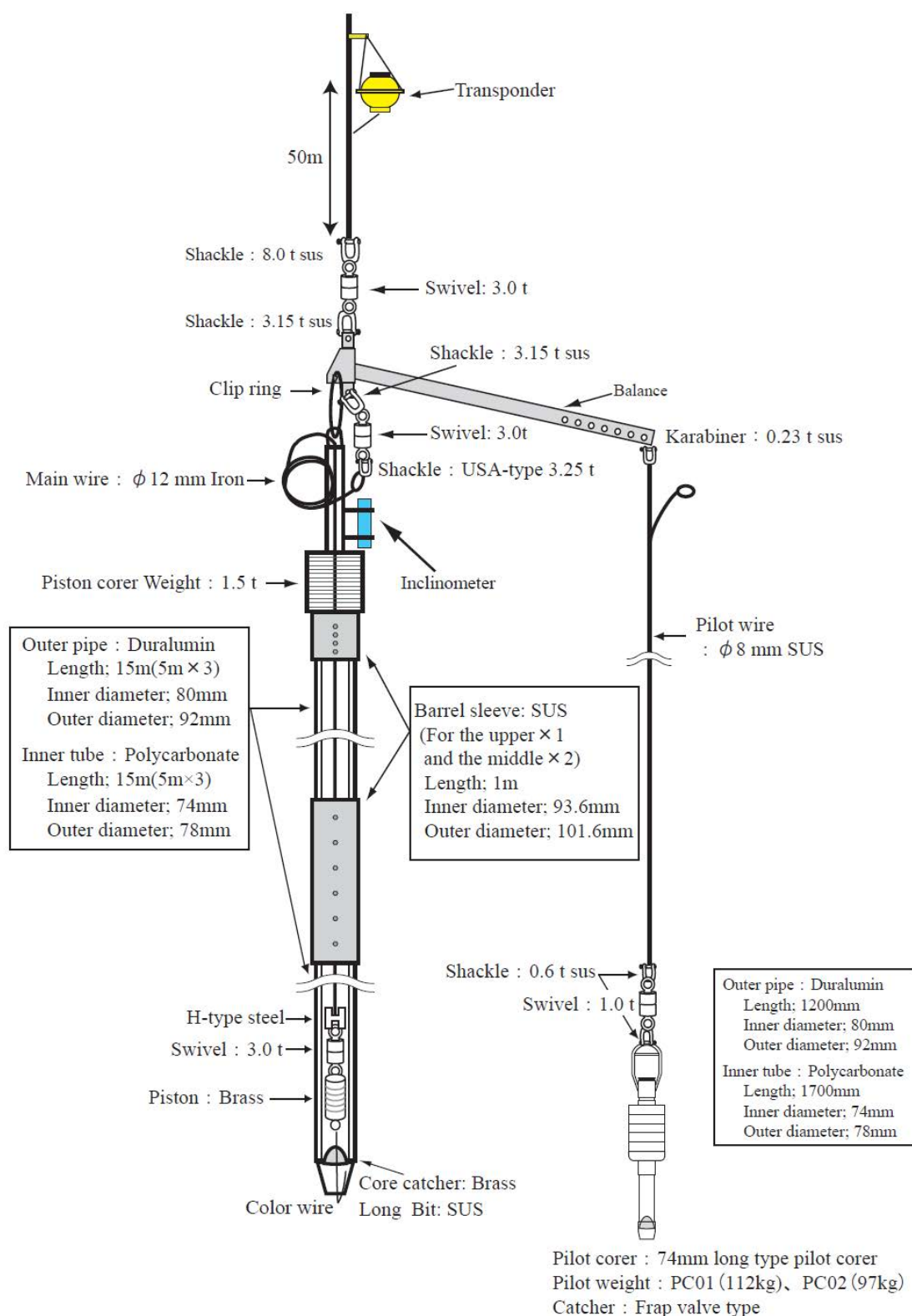


Fig. 3-1 Piston corer system with 1.5 ton weight in the MR15-02 Cruise. Outer and inner pipe lengths were all 15 m. The outer pipe length of the pilot corer was 120 cm.

3.2.4 Core flow

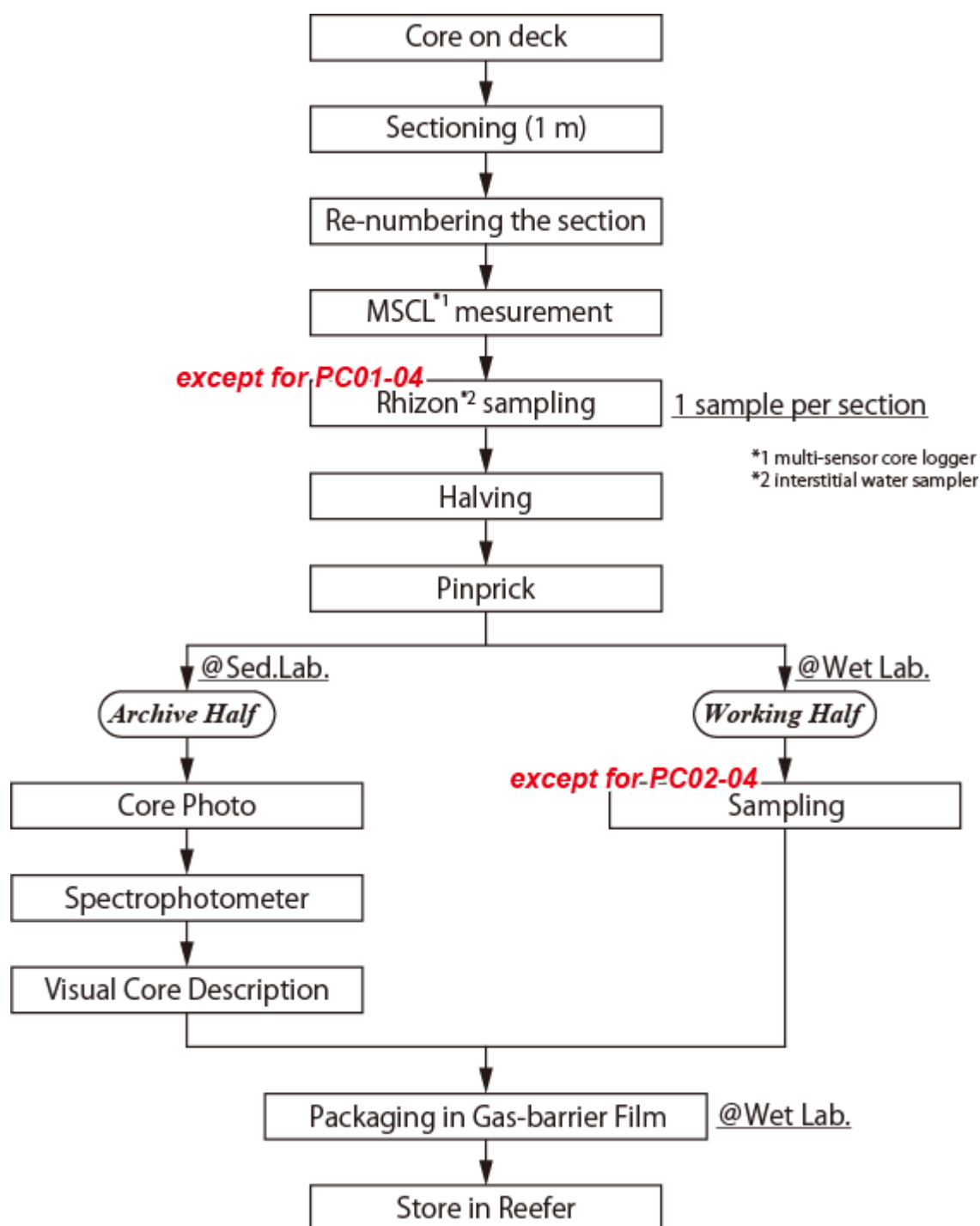


Fig. 3-2 Core flow of the MR15-02 Cruise. In this cruise, we did not measure dissolved oxygen concentration and pH of the interstitial water, and did not conduct interstitial water sampling using a squeezer for the whole-round sample.

3.2.5 CTD seawater sampler

CTD/Carousel Water Sampling System, which is a 36-position Carousel water sampler (CWS) with Sea-Bird Electronics, Inc. CTD (SBE9plus), was used during this cruise. The 12-liter Niskin Bottles were used for seawater sampling. The sensors attached on the CTD were temperature (Primary and Secondary), conductivity (Primary and Secondary), pressure and Altimeter. Salinity was calculated by measured values of pressure, conductivity and temperature. The CTD/CWS was deployed from starboard on a working deck. The CTD raw data were acquired on real time using the Seasave-Win32 (ver.7.23.2) provided by Sea-Bird Electronics, Inc. and stored on the hard disk of the personal computer. Seawater was sampled during the up cast by sending fire commands from the personal computer. We usually waited for 30 seconds to stabilize the CTD seawater sampler before sending fire commands. Raw data were processed by using SBE Data Processing-Win32 (ver.7.23.2) and SEASOFT.

3.3 Preliminary Results

We have arrived at the westernmost part of the investigation area at 23:37 (UTC), 22th June 2015 and started to geophysical survey using SBP, MBES (Fig. 3-3), gravity meter and three-component magnetometer. The ship track and survey lines of these geophysical researches are given in Figures 3-3, 3-4(A) and 3-4(B).

The sea state during this cruise was relatively calm and all planned PC coring, CTD seawater sampling and geophysical survey operations could be performed. We obtained sixteen piston cores and fifteen pilot core samples (Fig. 3-4) to investigate the detailed distribution of the extremely REY-rich mud in the southern and southeastern part of the Minamitorishima EEZ. Owing to the hybrid-type piston with an appropriate selection of the O-ring size, rubber plate hardness, core lengths of all piston core samples exceeded 10 m with a relatively higher recovery rate of 69 to 87% (Table 3-3) than those of previous cruises for REY-rich mud in the Minamitorishima offshore. Moreover, we obtained totally 144 seawater samples from 4 sites with 19 different water depths by CTD seawater sampler (Fig. 3-4 and Table 3-4). During this cruise, we could comprehend the detailed distribution of the extremely REY-rich mud in the southern part of the Minamitorishima EEZ by the microscopic observation of core samples and density based on the MSCL data. The total length of the SBP and MBES survey exceeded 6,800 km and we could obtain appropriate sample and data sets to understand the relationships between some typical acoustic structures of REY-rich mud and actual core physical/geochemical data. Detailed results of MSCL, core photo image, core color reflectance (CCR), visual core description (VCD) with more than 640 smear slides and geophysical data will be reported at the academic conference or as an peer-reviewed international scientific paper in the near future.

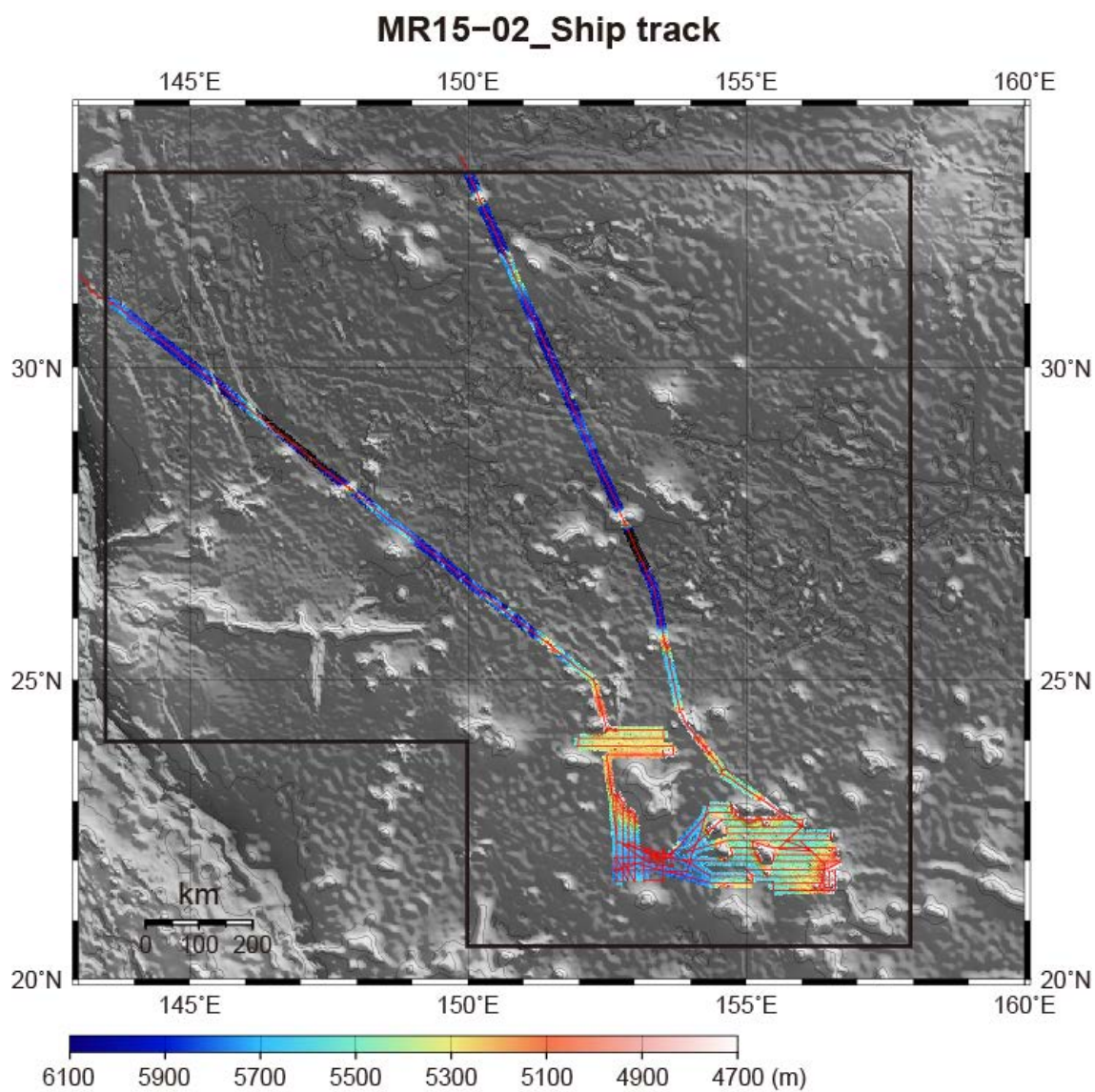


Fig. 3-3 Shiptrack of the MR15-02 Cruise in the investigation area.

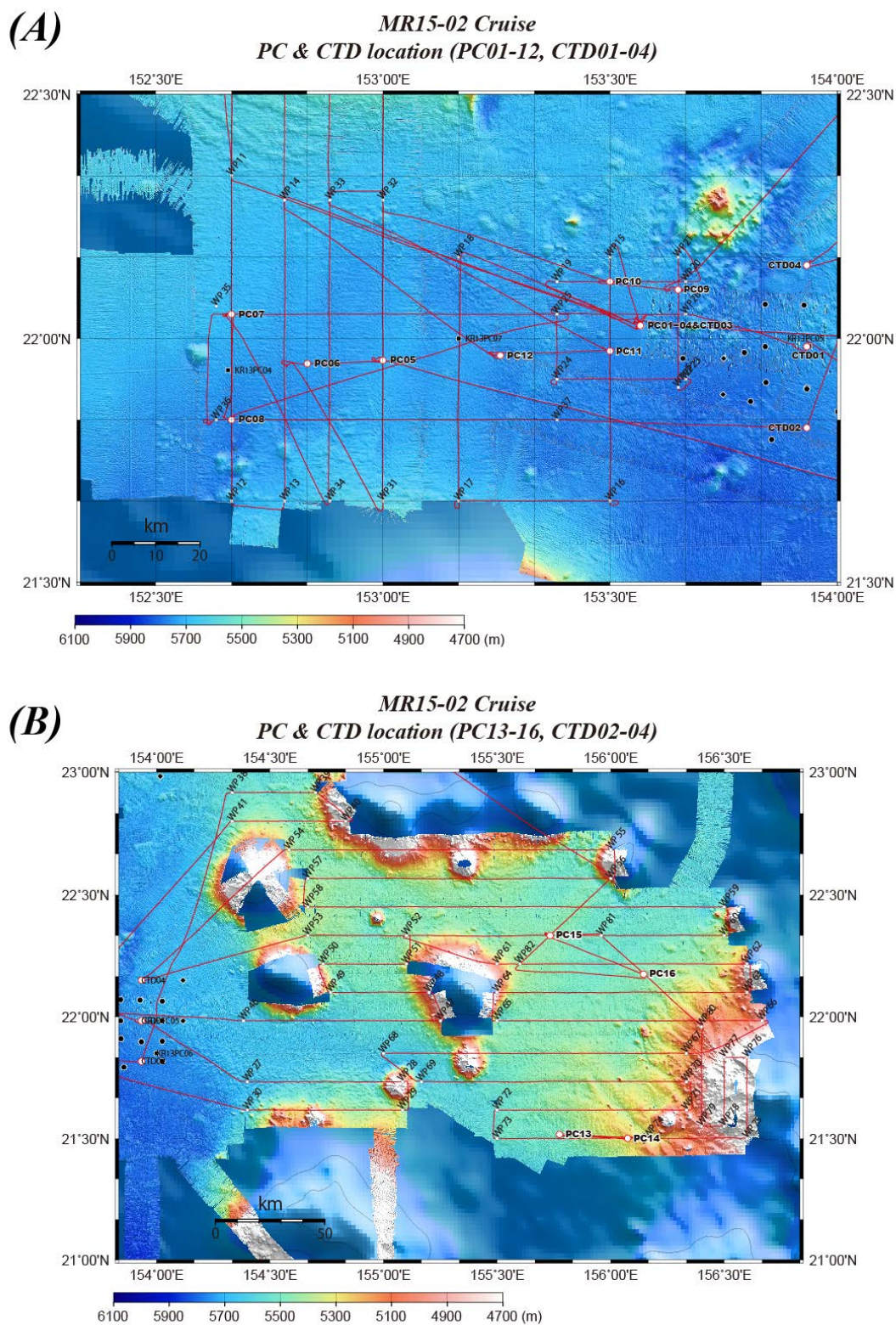


Fig. 3-4 Location map of the piston core and CTD-seawater sampling sites during the MR15-02 Cruise. (A) PC01-12 and CTD01-04, (B) PC13-16 and CTD02-04.

Table 3-3 Location, water depth, corer type and core length (recovery rate) of sixteen piston core samples. Outer and inner pipe lengths were all 15 m. The outer pipe length of the pilot corer was 120 cm. Since the transponder was broken during the down cast of the PC15 operation, the sampling position of PC15 is only based on the ship GPS.

Coring Site		MR15-02									
Date (UTC)	Core ID	Location	Water Depth	Position			Corer type		Core length (m)		Tension MAX
yyyymmdd			(m)	Latitude	Longitude	Type	Type*	Weight	PC	PL	(t)
20150626	PC01	Minamitorishima offshore	5,738	22-01.6085N	153-34.0013E	Transponder	IN PC	1500 kg	12.30 / 15	0.96	7.6
20150627	PC02	Minamitorishima offshore	5,737	22-01.6081N	153-34.0052E	Transponder	IN PC	1500 kg	12.13 / 15	0.98	7.5
20150627	PC03	Minamitorishima offshore	5,737	22-01.6360N	153-34.0248E	Transponder	IN PC	1500 kg	11.61 / 15	1.12	7.5
20150628	PC04	Minamitorishima offshore	5,738	22-01.6099N	153-34.0065E	Transponder	IN PC	1500 kg	12.34 / 15	0.84	7.6
20150629	PC05	Minamitorishima offshore	5,707	21-57.3327E	153-00.0156E	Transponder	IN PC	1500 kg	11.74 / 15	0.75	7.5
20150630	PC06	Minamitorishima offshore	5,723	21-56.8208N	152-47.0011E	Transponder	IN PC	1500 kg	12.39 / 15	0.96	7.7
20150630	PC07	Minamitorishima offshore	5,691	22-03.0016N	152-40.0061E	Transponder	IN PC	1500 kg	12.62 / 15	1.18	7.4
20150701	PC08	Minamitorishima offshore	5,747	21-50.0114N	152-39.9798E	Transponder	IN PC	1500 kg	10.64 / 15	0.81	7.8
20150702	PC09	Minamitorishima offshore	5,740	22-06.0064N	153-38.9968E	Transponder	IN PC	1500 kg	12.53 / 15	1.05	7.4
20150703	PC10	Minamitorishima offshore	5,710	22-07.0000N	153-29.9631E	Transponder	IN PC	1500 kg	11.87 / 15	0.48	7.6
20150703	PC11	Minamitorishima offshore	5,754	21-58.4792N	153-29.9763E	Transponder	IN PC	1500 kg	11.54 / 15	0.00	8.1
20150704	PC12	Minamitorishima offshore	5,741	21-57.9234N	153-15.1987E	Transponder	IN PC	1500 kg	10.28 / 15	0.70	8.2
20150709	PC13	Minamitorishima offshore	5,482	21-30.9733N	155-46.5008E	Transponder	IN PC	1500 kg	12.47 / 15	1.12	7.3
20150710	PC14	Minamitorishima offshore	5,280	21-29.9879N	156-04.4941E	Transponder	IN PC	1500 kg	13.12 / 15	0.80	7.3
20150710	PC15	Minamitorishima offshore	5,459	22-19.9909N	155-44.05540E	Ship	IN PC	1500 kg	11.65 / 15	1.65	7.3
20150711	PC16	Minamitorishima offshore	5,446	22-10.5111N	156-08.6701E	Transponder	IN PC	1500 kg	11.34 / 15	1.19	8.2
* "IN" is Inner type corer, "OUT" is Outer type corer											
** Position of PC15 is Ship's position.											

Table 3-4 Location and water depth of four CTD seawater sample sets.

Sewarer Sampling Site		MR15-02				
Date (UTC)	Seawater ID	Location	Water Depth	Position		
yyyymmdd			(m)	Latitude	Longitude	Type
20150629	CTD01	Minamitorishima offshore	5,705.8 to 9.8	21-59.190N	153-56.046E	Ship
20150702	CTD02	Minamitorishima offshore	5,731.9 to 9.6	21-49.188N	153-56.100E	Ship
20150705	CTD03	Minamitorishima offshore	5,693.4 to 10.4	22-01.926N	153-34.116E	Ship
20150706	CTD04	Minamitorishima offshore	5,681.5 to 10.4	22-09.318N	153-56.346E	Ship

4. Notice on Using

This cruise report is a preliminary documentation as of the end of the cruise. This report may not be corrected even if changes on contents (i.e. taxonomic classifications) may be found after its publication. This report may also be changed without notice. Data on this cruise report may be raw or unprocessed. If you are going to use or refer to the data written on this report, please ask the Chief Scientist for latest information. Users of data or results on this cruise report are requested to submit their results to the Data Management Group of JAMSTEC.