



## R/V MIRAI Cruise Report

MR15-E01 Leg 2

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

Mar. 14, 2015 to Mar. 28, 2015

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

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## 1. Cruise Information

- Cruise ID: MR15-E01 Leg 2
- 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 sampling around the Minamitorishima offshore”
- Title of proposal: Investigation of the REY-rich mud distribution around the Minamitorishima offshore
- Cruise period: 14th, Mar. 2015 to 28th, Mar. 2015
- Ports of departure / arrival: Naha to Futami (Chichijima Island)
- Research area: Minamitorishima offshore
- Research Map

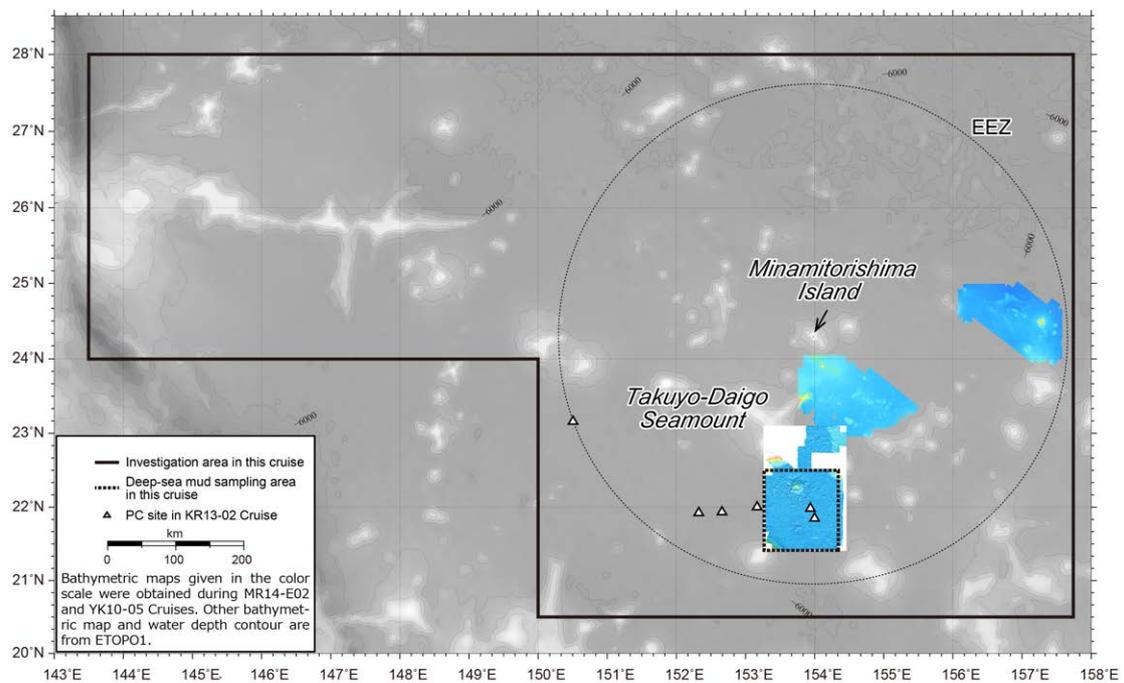


Fig. 1-1 Investigation marine area map of the MR15-E01 Leg 2 Cruise

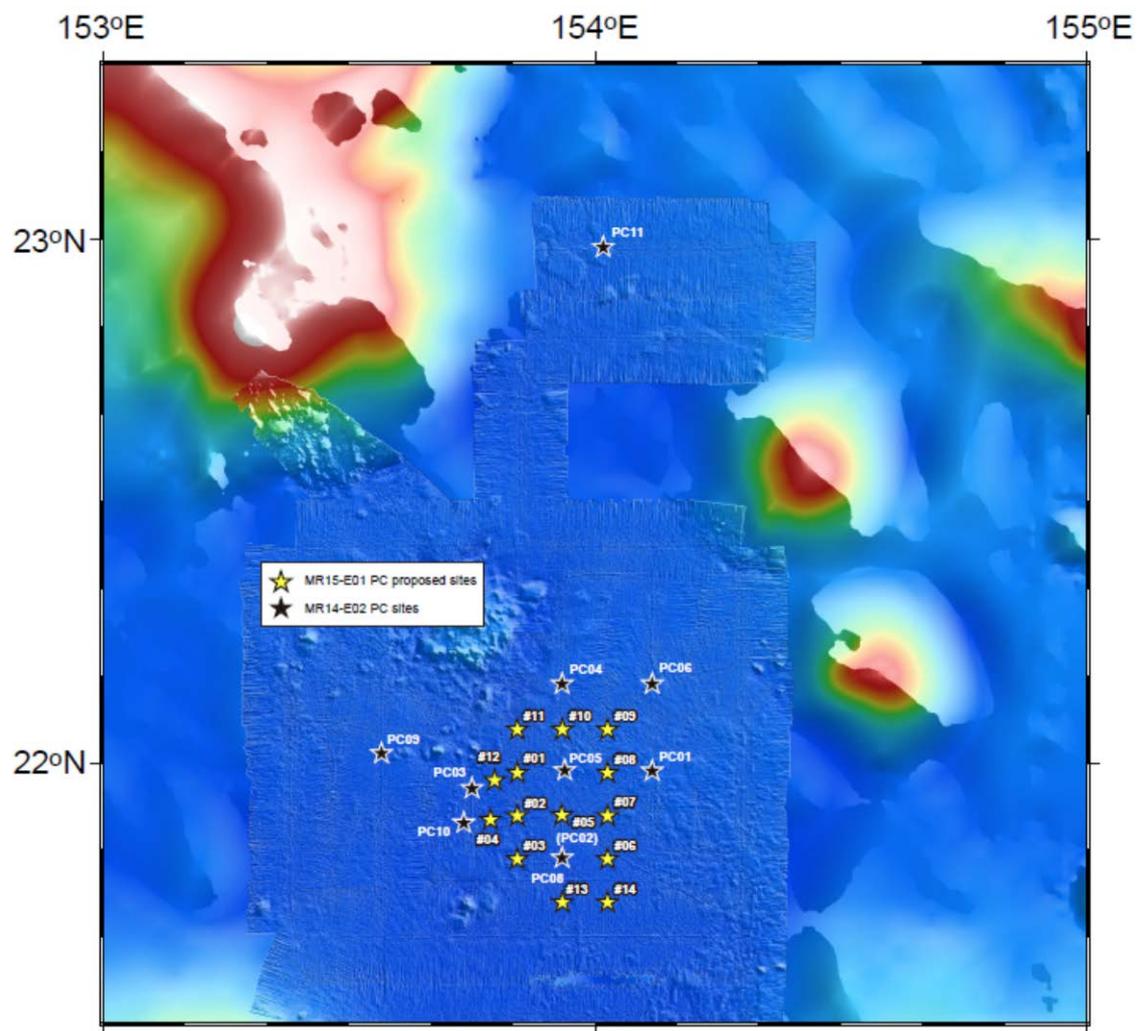


Fig. 1-2 Proposed location map of the piston core sampling.

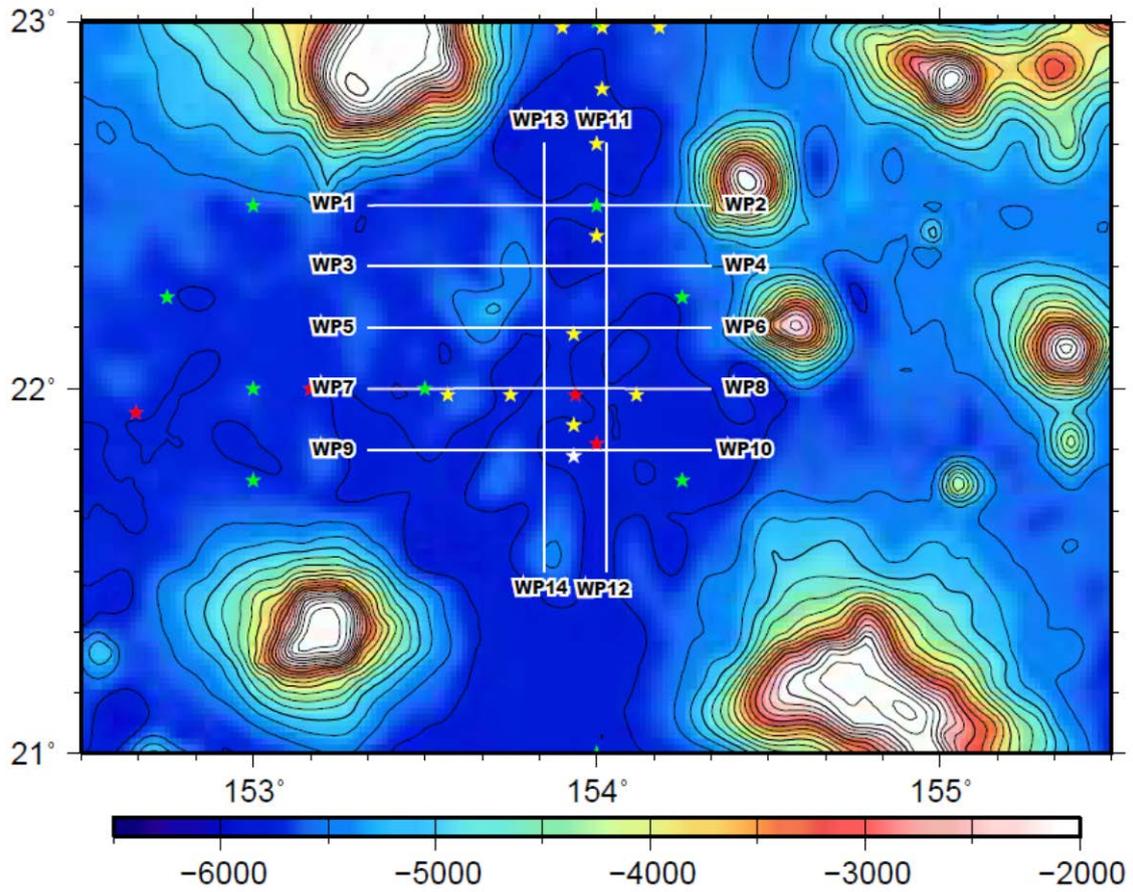


Fig. 1-3 Proposed SBP (sub-bottom profiler), MBES (multi-narrow beam eco sounding system) and cesium magnetic meter survey lines which enclose the piston core sampling site.

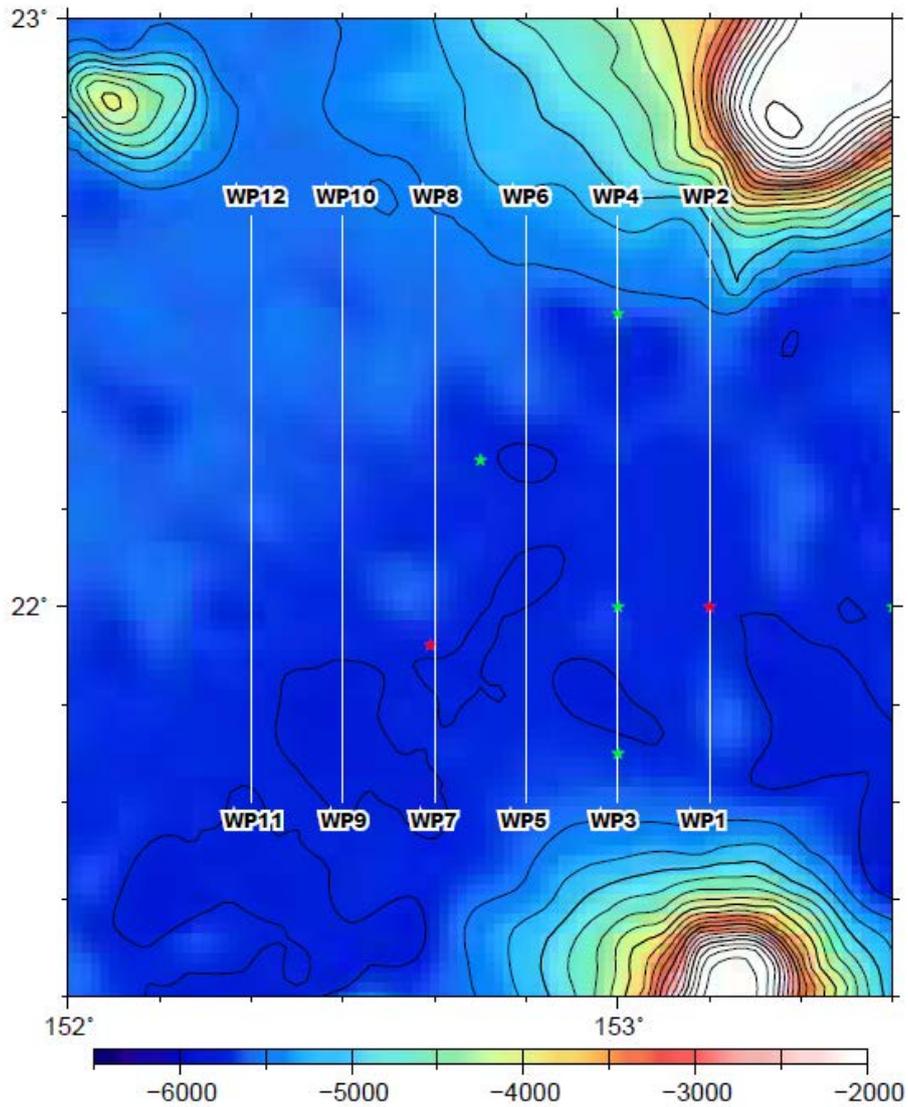


Fig. 1-4 Proposed SBP, MBES and cesium magnetic meter survey lines ca. 100 km western from the piston core sampling site. These survey lines were prepared for the bad sea state condition when we could not perform piston core sampling.

## **2. Researchers**

- **Chief scientist:**

Tatsuo Nozaki [JAMSTEC]

- **Representative of the science party:**

Katsuhiko Suzuki [JAMSTEC]

- **Science party:**

Koichi Iijima (JAMSTEC)

Yuka Masaki (JAMSTEC)

Hiroshi Amakawa (JAMSTEC)

Shiki Machida (JAMSTEC)

Yoichi Usui (JAMSTEC)

Satoru Haraguchi (JAMSTEC)

Koichiro Fujinaga (JAMSTEC)

Yutaro Takaya (JAMSTEC)

Kazutaka Yasukawa (JAMSTEC)

Kazutaka Oya (JAMSTEC)

Daiki Niikuma (JAMSTEC)

Shinya Okumura (GODI)

Yutaro Murakami (GODI)

Koichi Inagaki (GODI)

Hayashi Hiroyuki (MWJ)

Yusuke Sato (MWJ)

Keiko Fujino (MWJ)

Yasushi Hashimoto (MWJ)

Yasumi Toyoda (MWJ)

Mika Yamaguchi (MWJ)

- **Crews:**

Captain                      Toshihisa Akutagawa

Chief Officer              Takeshi Isohi

2nd Officer                Nobuo Fukaura

Junior 2nd Officer        Hirokazu Sugawara

3rd Officer                Akihiro Nunome

Junior 3rd Officer        Satohiro Tanaka

Chief Engineer	Shigeru Fujita
1st Engineer	Kazuhito Ikeda
2nd Engineer	Jun Takahashi
3rd Engineer	Katsumitsu Kodama
Radio officer	Ryo Kimura
Boat Swain	Yosuke Kuwabara
Able Seaman	Tsuyoshi Sato
Able Seaman	Tsuyoshi Kadosawa
Able Seaman	Shuji Komata
Able Seaman	Kaito Murata
Able Seaman	Masaya Tanigawa
Sailor	Shohei Uehara
Sailor	Tomohiro Shimada
Sailor	Ryoya Chishima
Sailor	Tetsuya Sakamoto
Sailor	Hideyuki Okubo
No.1 Oiler	Yoshihiro Sugimoto
Oiler	Kazumi Yamashita
Oiler	Fumito Kaizuka
Fireman	Kazuya Ando
Fireman	Shintaro Abe
Fireman	Hiromi Ikuta
Chief Steward	Ryotaro Baba
Steward	Tamotsu Uemura
Steward	Yukio Shige
Steward	Yukio Chiba
Steward	Toshiyuki Asano

### **3. Observation**

#### **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 since 2013 and extremely enriched REY-rich mud whose total REY concentration reaches ca. 7,000 ppm has been discovered (Iijima 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 MR13-E02, KR14-02 and MR14-E02 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-E01 Leg 2 Cruise, we focused to comprehend the detailed distribution of the extremely enriched REY-rich mud in the southern east from the Minamitorishima Island as well as geophysical researches using SBP, MBES (multi-narrow beam echo sounding system) and cesium magnetic meter.

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.

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.

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.

#### **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), Bathym2010

(SyQwest Incorporated). In order to determine accurate sound velocity of water column for 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 data by 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 Sub-bottom Profiler, Bathym2010 (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 Magnet meter

#### 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 a Doppler radar. Ship's position (GPS) and speed data are taken from LAN every second.

#### Cesium marine magnetometer

We measured total geomagnetic field using a cesium marine magnetometer (Geometrics Inc.,

G-882) and recorded by G-882 data logger (Clovertech Co., Ver.1.0.0). The G-882 magnetometer uses an optically pumped Cesium-vapor atomic resonance system. The sensor fish towed 500 m behind the vessel to minimize the effects of the ship's magnetic field.

Table 3. System configuration of MIRAI cesium magnetometer system

Dynamic operating range:	20,000 to 100,000 nT	
Absolute accuracy:	< ±2 nT throughout range	
Setting:	Cycle rate;	0.1 sec
	Sensitivity;	0.001265 nT at a 0.1 second cycle rate
	Sampling rate;	1 sec

### 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, both 1.5 ton and 2.36 ton weight were used. The total length of duralumin pipes and liner tubes were 15 m or 20 m. The pipe length was decided based on the results of SBP site survey data. The long and sharp bit was used at the end of the pipes to promote penetration of the PC. 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 is approximately 1.7 ton or 2.6 ton in water. The constructions of the each PC system in this cruise are showed in Figs. 3-1 and 3-2. 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 for 1.5 ton weight and P63 for 2.36 ton weight) was reduced to one. The hardness of the rubber plate was 45.

The polycarbonate tubes we used as a liner tube were annealed before cruise. When we divide the core in half, 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 m water depth. After that, winch was gradually increased to the speed of 1 m/s. The winch was stopped at a depth about 100 m above the seafloor for 3 minutes to reduce some pendulum motion 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).

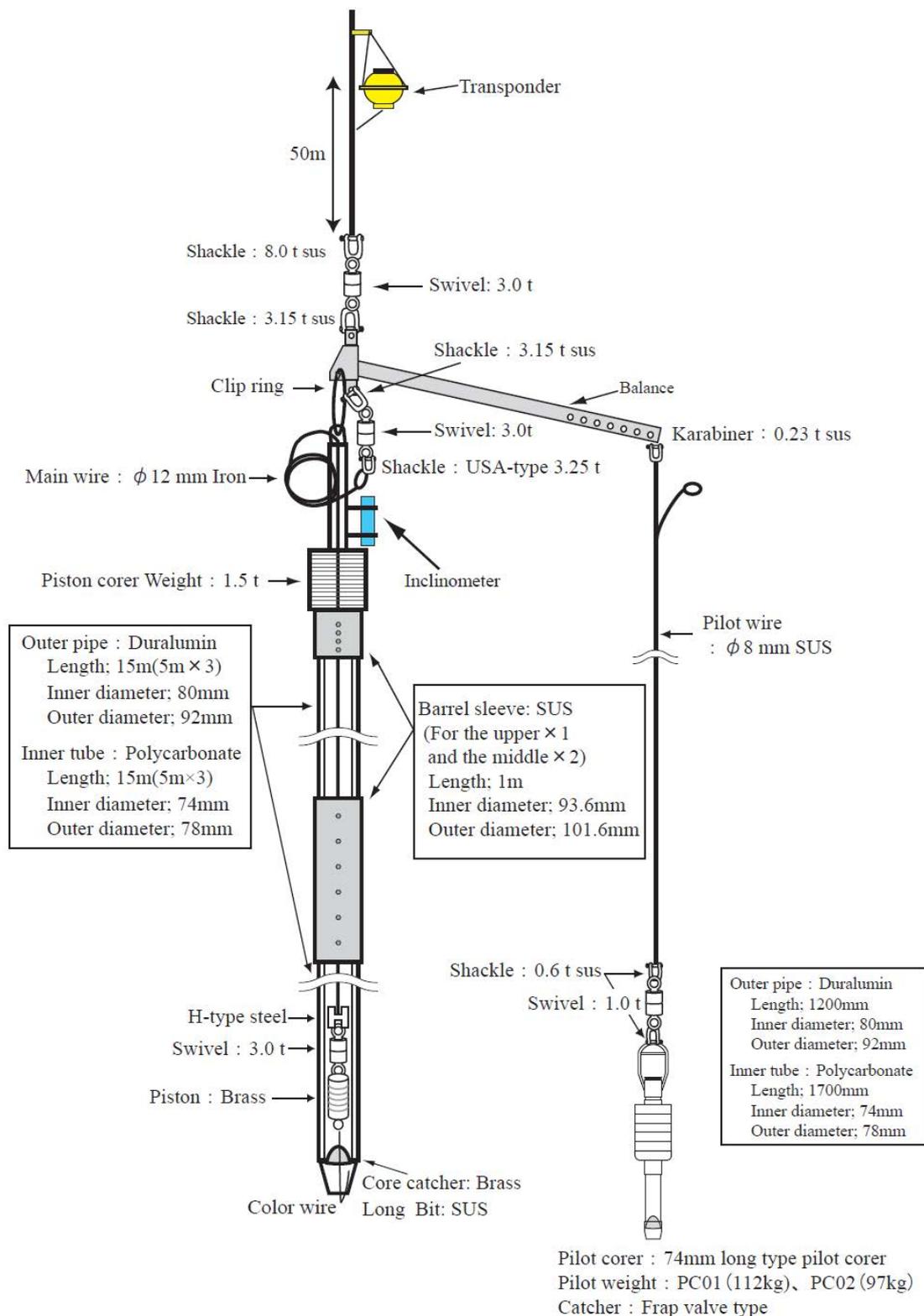


Fig. 3-1. Piston corer system with 1.5 ton weight in the MR15-E01 Leg 2 Cruise. Outer and inner pipe lengths of PC10 were 20 m. The outer pipe length of PCPL04 was 700 mm.

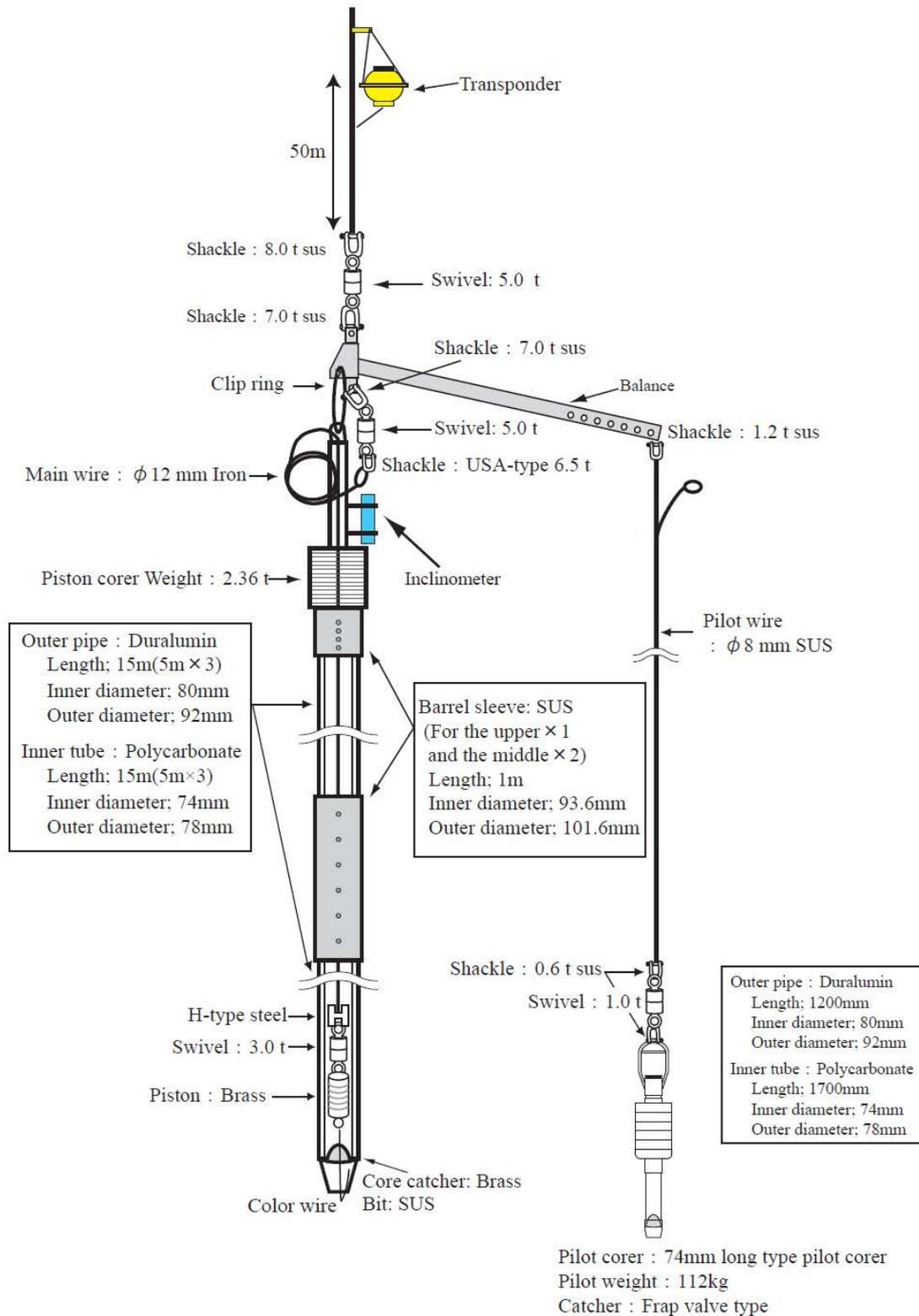


Fig. 3-2 Piston corer system with 2.36 ton weight in the MR15-E01 Leg 2 Cruise.

### 3.2.4 Core flow

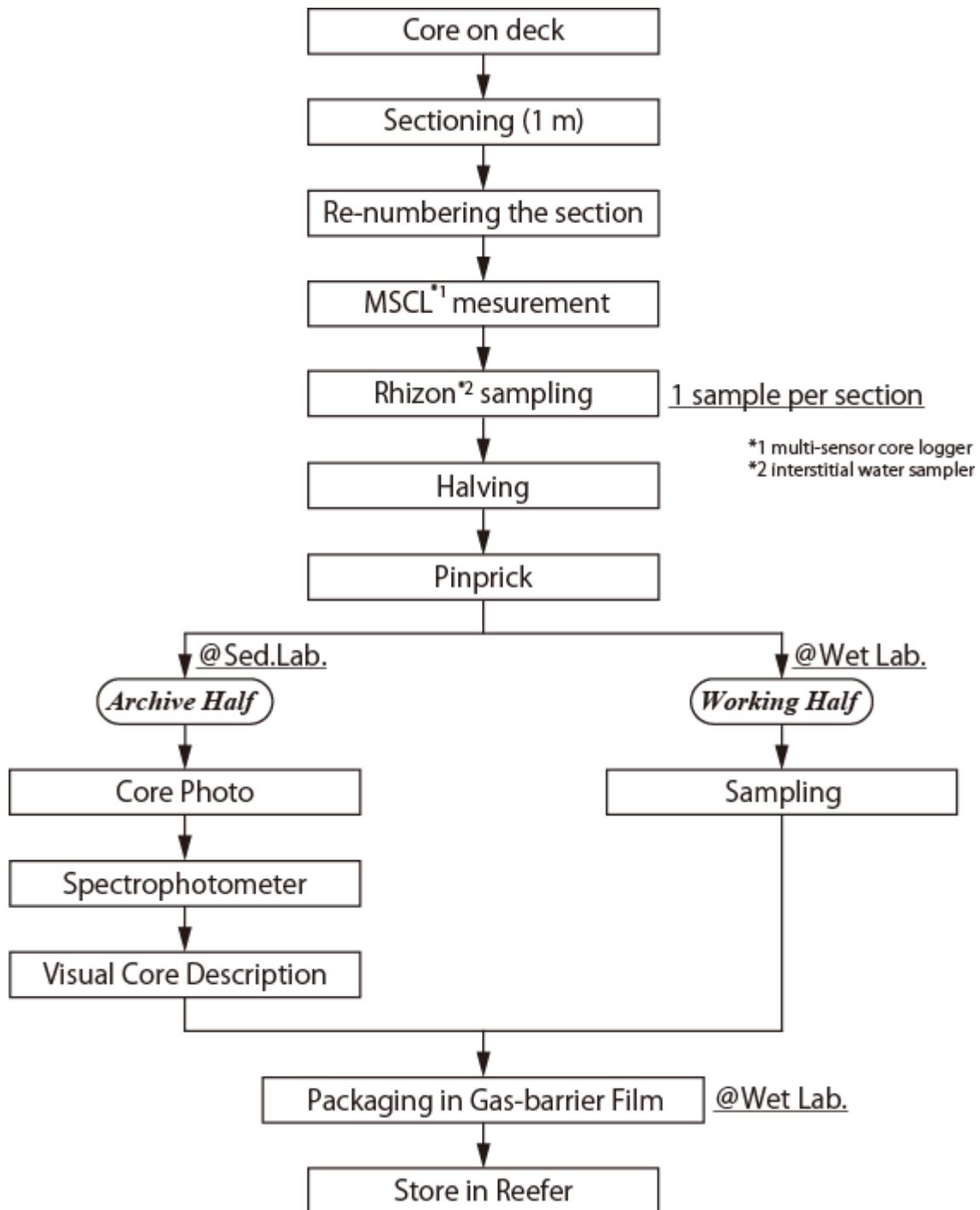


Fig. 3-3 Core flow of the MR15-E01 Leg 2 Cruise. In this cruise, we did not measure dissolved oxygen concentration and pH of the interstitial water, and did not conduct interstitial water sampling using a squeezer for the whole-round sample.

### 3.3 Preliminary Results

We have arrived at the western part of the investigation ocean area at 15:37 (UTC), 16th Mar. 2015 and started to geophysical survey using SBP and MBES (Fig. 3-4). Total geomagnetic field was started to be measured at 02:09 (UTC), 18th Mar. 2015. The cesium magnetic meter was recovered before the piston core sampling operation and then thrown again into the seawater after finishing the PC sampling operation. This cesium magnetic meter operation was repeated from 18th Mar. 2015 to 24th Mar. 2015 (Fig. 3-5).

The sea state during this cruise was very calm and PC sampling operation was conducted continuously from 18th Mar. 2015 to 25th Mar. 2015. We obtained thirteen piston and pilot core samples (Fig. 3-6) to investigate the detailed distribution of the extremely REY-rich mud. Owing to the hybrid-type piston with an appropriate selection of O-ring size, rubber plate hardness, core lengths of all piston core samples exceeded 10 m with relatively higher recovery rate (Table 3-3) than those of previous cruises for REY-rich mud in the Minamitorishima offshore. During this cruise, we could obtain many samples below (i.e., older / deeper) the extremely REY-rich mud which exhibited a banded structure with subordinate bioturbation. Because such a banded mud below the extremely REY-rich mud showed yellowish and brownish color, we called this mud as “tiger banded mud” on board. Detailed results of MSCL, core photo image, color measurement (CCR) and visual core description (VCD) with more than 400 smear slides will be reported at the academic conference or as an international scientific paper in the near future.

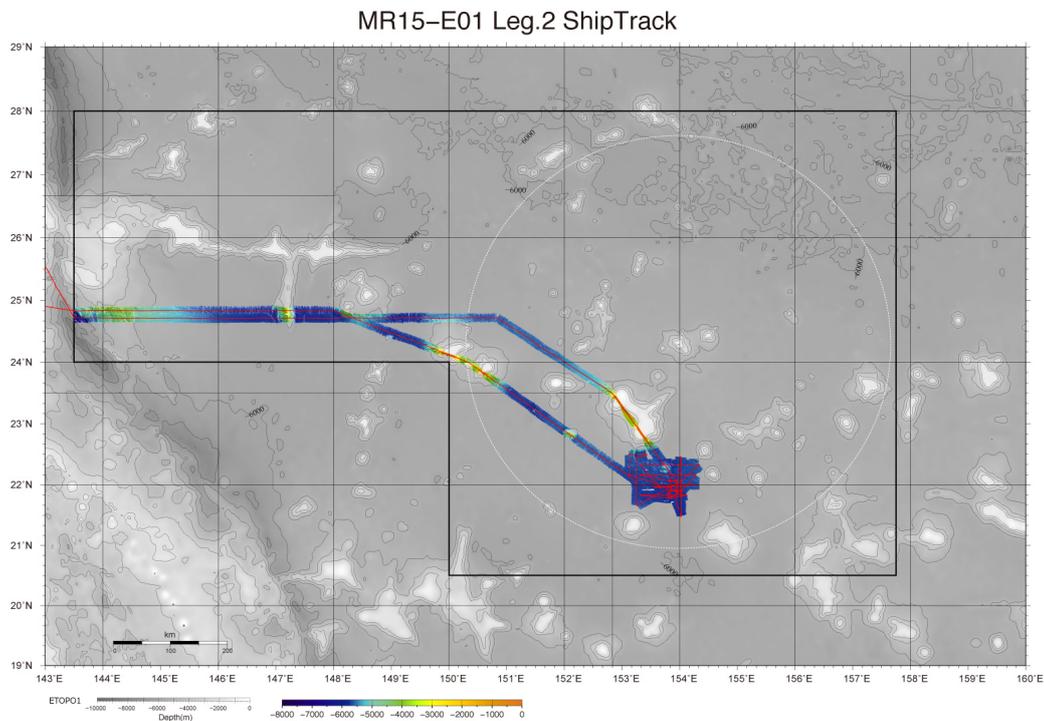


Fig. 3-4 Shiptrack of the MR15-E01 Leg 2 Cruise in the investigation marine area.

### MR15-E01\_Leg.2\_Survey-Lines

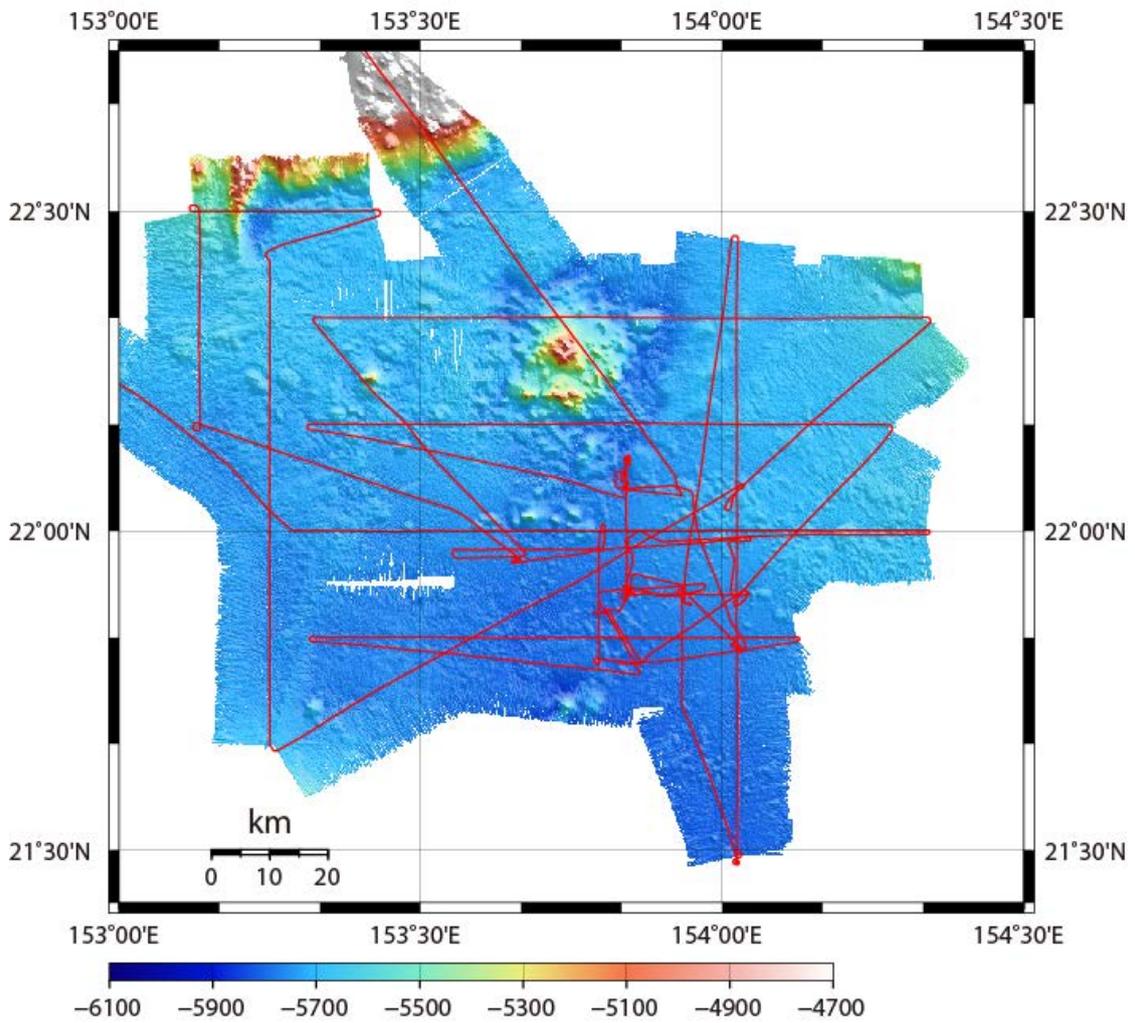


Fig. 3-5 Survey line of SBP, MBES and cesium magnetic meter.

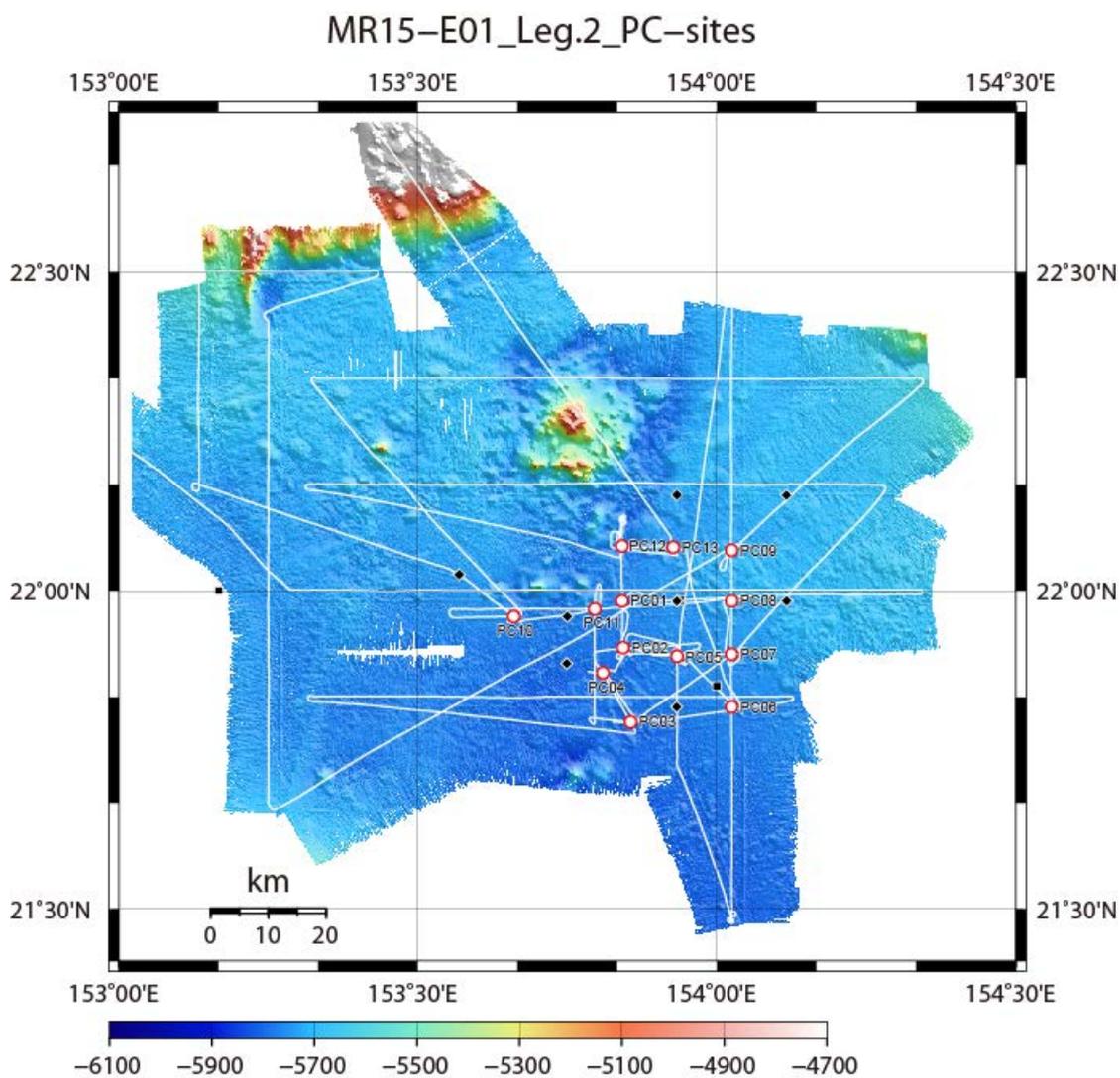


Fig. 3-6 Location map of the piston core sampling sites during the MR15-E01 Leg 2 Cruise.

Table 3-3 Location, water depth, corer type and core length (recovery rate) of thirteen piston core samples. Outer and inner pipe lengths of PC10 were 20 m. The outer pipe length of PCPL04 was 700 mm.

Coring Site		MR15-E01 Leg2									
Date (UTC)	Core ID	Location	Water Depth	Positon			Corer type		Core length (m)		Tension MAX
yyyymmdd			(m)	Latitude	Longitude	Type	Type*	Wegiht	PC	PL	(t)
20150318	PC01	Around Minamitorishima	5,759	21-59.0027N	153-50.5056E	Transponder	IN PC	1,500 kg	12.871 / 15	0.356	7.5
20150319	PC02	Around Minamitorishima	5,805	21-54.5504N	153-50.5904E	Transponder	IN PC	2,360 kg	13.327 / 15	0.604	8.6
20150319	PC03	Around Minamitorishima	5,795	21-47.5884N	153-51.3625E	Transponder	IN PC	1,500 kg	12.759 / 15	1.066	7.4
20150320	PC04	Around Minamitorishima	5,794	21-52.2491N	153-48.5244E	Transponder	IN PC	2,360 kg	11.752 / 15	1.111	8.4
20150320	PC05	Around Minamitorishima	5,756	21-53.8391N	153-56.0060E	Transponder	IN PC	1,500 kg	12.462 / 15	0.154	7.2
20150321	PC06	Around Minamitorishima	5,764	21-48.9981N	154-01.4930E	Transponder	IN PC	2,360 kg	11.150 / 15	1.087	8.2
20150321	PC07	Around Minamitorishima	5,748	21-53.9987N	154-01.4834E	Transponder	IN PC	1,500 kg	12.755 / 15	0.821	7.4
20150322	PC08	Around Minamitorishima	5,722	21-59.0065N	154-01.5074E	Transponder	IN PC	2,360 kg	10.979 / 15	1.511	8.0
20150323	PC09	Around Minamitorishima	5,699	22-03.7921N	154-01.5021E	Transponder	IN PC	1,500 kg	10.593 / 15	1.262	8.0
20150323	PC10	Around Minamitorishima	5,766	21-57.5755N	153-39.6260E	Transponder	IN PC	1,500 kg	12.267 / 20	0.260	7.9
20150324	PC11	Around Minamitorishima	5,770	21-58.2732N	153-47.7461E	Transponder	IN PC	1,500 kg	12.985 / 15	0.243	7.4
20150324	PC12	Around Minamitorishima	5,777	22-04.2191N	153-50.5017E	Transponder	IN PC	1,500 kg	11.234 / 15	0.885	7.6
20150325	PC13	Around Minamitorishima	5,719	22-04.1094N	153-55.6448E	Transponder	IN PC	1,500 kg	11.848 / 15	1.014	7.3

\* "IN" is Inner type corer.

#### **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.