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R/V MIRAI Cruise Report

MR16-07

Cross-ministerial Strategic Innovation Promotion Program (SIP), New-generation Technology for Ocean Resources Exploration (ZIPANG in ocean), “Extensive investigation of REY-rich mud with the geophysical survey around the Minamitorishima offshore”

Nov.01,2016-Nov.25,2016

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

Contents

1. Cruise Information

Cruise ID: MR16-07

Name of vessel: R/V Mirai

Title of the cruise: Cross-ministerial Strategic Innovation Promotion Program (SIP), New-generation Technology for Ocean Resources Exploration (ZIPANG in ocean), "Extensive investigation of REY-rich mud with the geophysical survey around the Minamitorishima offshore"

Title of proposal: Cross-ministerial Strategic Innovation Promotion Program (SIP), New-generation Technology for Ocean Resources Exploration (ZIPANG in ocean), "Extensive investigation of REY-rich mud with the geophysical survey around the Minamitorishima offshore"

Cruise period: November 1 to 25, 2016

Port of departure: Sekinehama Pier, JAMSTEC

Port of arrival: Shimizu Pier

Research area: Southern region and out of the Japanese Exclusive Economic Zone around Minamitorishima Island, Northwestern Pacific.

Research Map

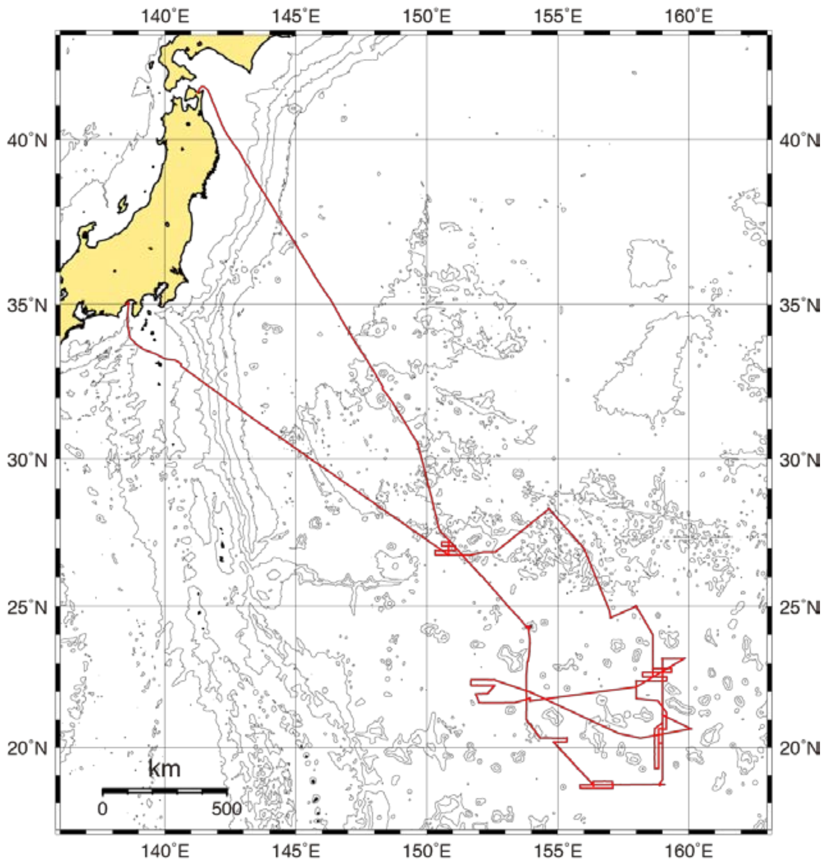

Figure 1-1. Ship track during the cruise MR16-07.

2. Researchers

Chief Scientist	Shiki Machida	Research Scientist, JAMSTEC

Chief scientist of the project on
"Extensive investigation of REY-rich mud"

Representative of the Science Party	Shiki Machida	Research Scientist, JAMSTEC

Onboard Researchers

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Scientist	Ayu Takahashi	Scientist, JAMSTEC
Scientist	Yoichi Usui	Scientist, JAMSTEC
Scientist	Honami Sato	JSPS Post-Doc. Fellow, JAMSTEC
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Scientist	Kazutaka Yasukawa	Assist. professor, the Univ. Tokyo
Scientist	Ryo Shimomura	Student (Master's), the Univ. Tokyo
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Marine Technician	Yuji Fuwa	Marine Works Japam, Ltd.
Marine Technician	Mika Yamaguchi	Marine Works Japam, Ltd.
Marine Technician	Takehiro Kanii	Marine Works Japam, Ltd.
Marine Technician	Yohei Katayama	Marine Works Japam, Ltd.
Marine Technician	Yoshitaka Ukihashi	Marine Works Japam, Ltd.

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Scientist	Taichi Sato	Researcher, AIST
Scientist	Kentaro Nakamura	Assoc. Professor, the Univ. Tokyo
Scientist	Yasuhiro Kato	Professor, the Univ. Tokyo

3. Observation

3.1. Background

In 2011, the wide distribution of deep-sea mud bearing high total REY (rare earth elements and yttrium) 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 hydrothermal sulfide deposit, ferromanganese nodule, 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 6,000 ppm has been discovered (Iijima et al., 2016; Fujinaga et al., 2016; Ohta et al., 2016; 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 Legs 2 and 3, and MR15-02 Cruises, which classified deep-sea mud around the Minamitorishima Island into three type facies (Nakamura et al., 2016). The O-type facies is acoustically opaque and highly reflective, without visible structures beneath the top surface. The T-type facies is acoustically transparent, with a basal reflector from the acoustic basement. This face is subdivided into irregular (TI) and smooth (TS) types according to the topography of its upper surface. 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.

3.2. Cruise Objectives

The objective of this cruise is to elucidate the features on distribution of REY-rich mud. The following items will be done in southern part of and off the Minamitorishima EEZ (Fig. 3-3).

1. <u>Sediment sampling</u>: Sampling of pelagic sediment using piston corer will be done for comprehensive geochemical and geochronological analysis.
2. <u>Magnetics and Gravity</u>: Surface tow and shipboard magnetic survey will be done to estimate age of the seafloor in the survey area on the basis of magnetic lineation. Shipboard gravity survey using shipboard gravitymeter will be carried out to define structure of basement of the survey area. MBES data also will be used during magnetic and gravity analyses. XBT data also will be used to recalculate seafloor depth.
3. <u>Direction and speed of deep-sea current</u>: Acoustic Doppler Current Profiler (ADCP) will be deployed to determine flow direction and speed of deep-sea current in the survey area. We have deployed two mooring ADCP systems at sites MA-01 and 02 in cruise YK16-01 in April 2016. They will be retrieved during this cruise.

3.3. Activities

3.3.1 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). 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).

The data are confidencial matters.

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.

3.3.2 Magnetometer

(1) 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 (Differential GNSS) and speed data are taken from LAN every second.

(2) 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. The system configuration of MIRAI cesium magnetometer system is listed as follow.

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

The aim of geophysical surveys was to provide a detailed geophysical characterization of the lithosphere in the western Pacific, which will be used to unravel tectonic evolution and crustal structure. Shipboad gravity anomaly will be used for analysis the crustal structure combined with bathymetry data. The data are confidencial matters.

3.3.3 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. In addition, the polycarbonate liner tube (5m-long per tube) is inside of 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, 1.5 t weight was used. The total length of duralumin pipes and liner tubes were 15 m. We used three type pilot Corers. The total weight of the PC system is approximately 1.7 ton in water. The constructions of the PC system in this cruise are showed in figs. 1, 2, and 3. In addition, the polycarbonate tubes we used as 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. Moreover, Hybrid piston was used. This is composing of one O-rings (size: P62) and one rubber plate.

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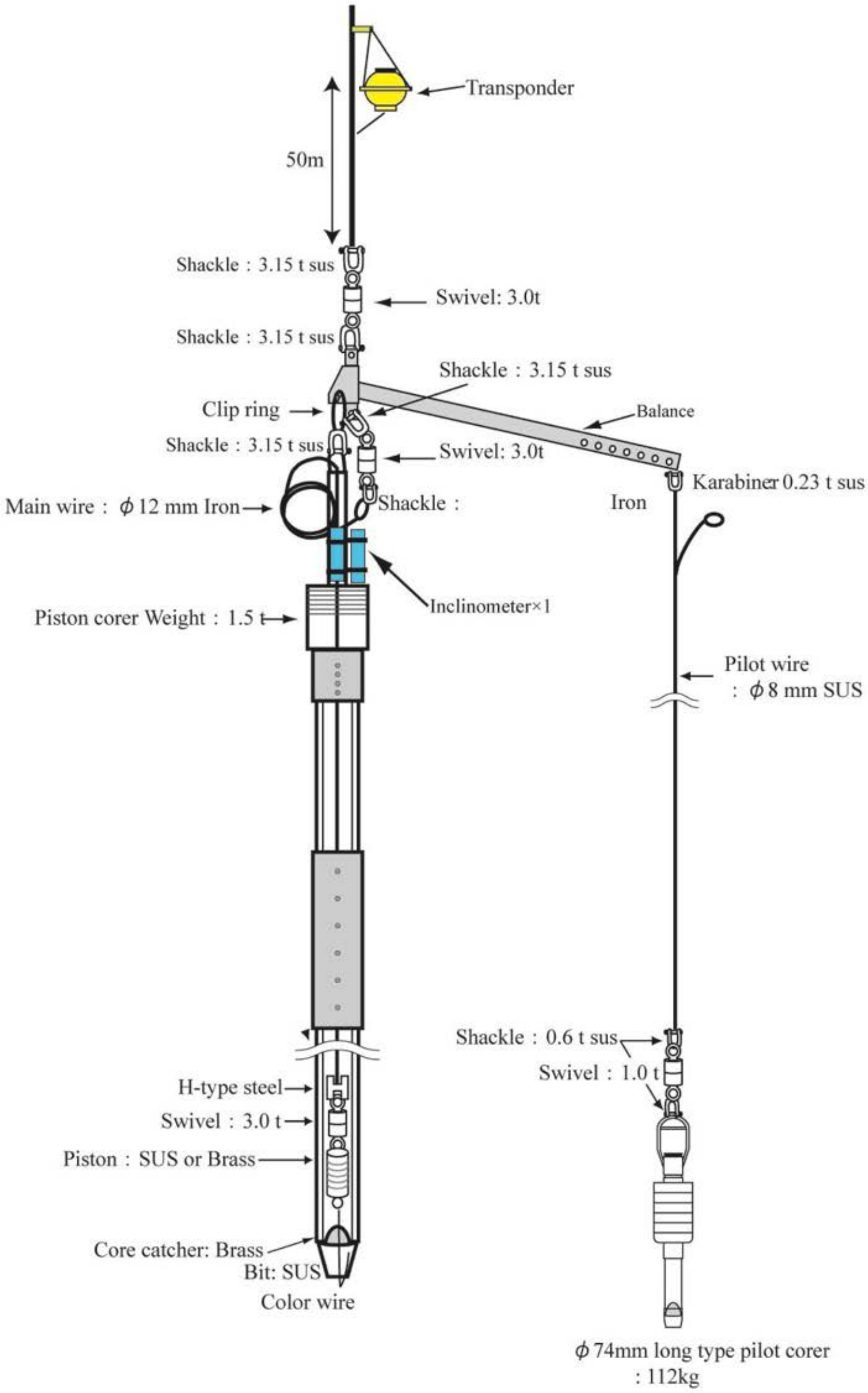

Figure 3-1. Piston corer system with 1.5 ton weight for PC01 during the cruise MR16-07. Outer and inner pipe lengths were all 15 m. The outer pipe length of the pilot corer was 120 cm.

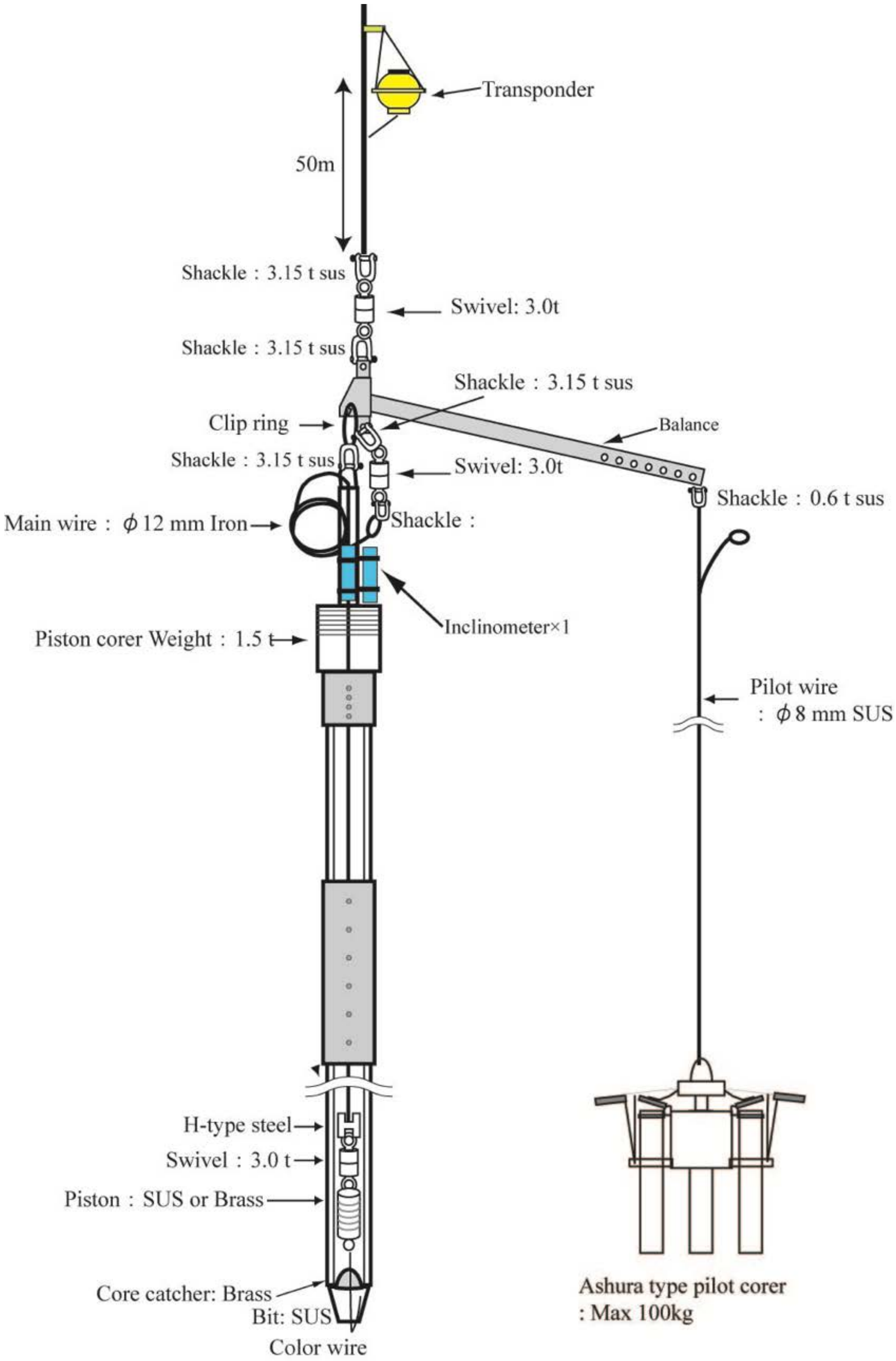

Figure 3-2. Piston corer system with 1.5 ton weight for PC02 and PC03 during the cruise MR16-07. Outer and inner pipe lengths were all 15 m. The outer pipe of the Ashura type pilot corer was not used.

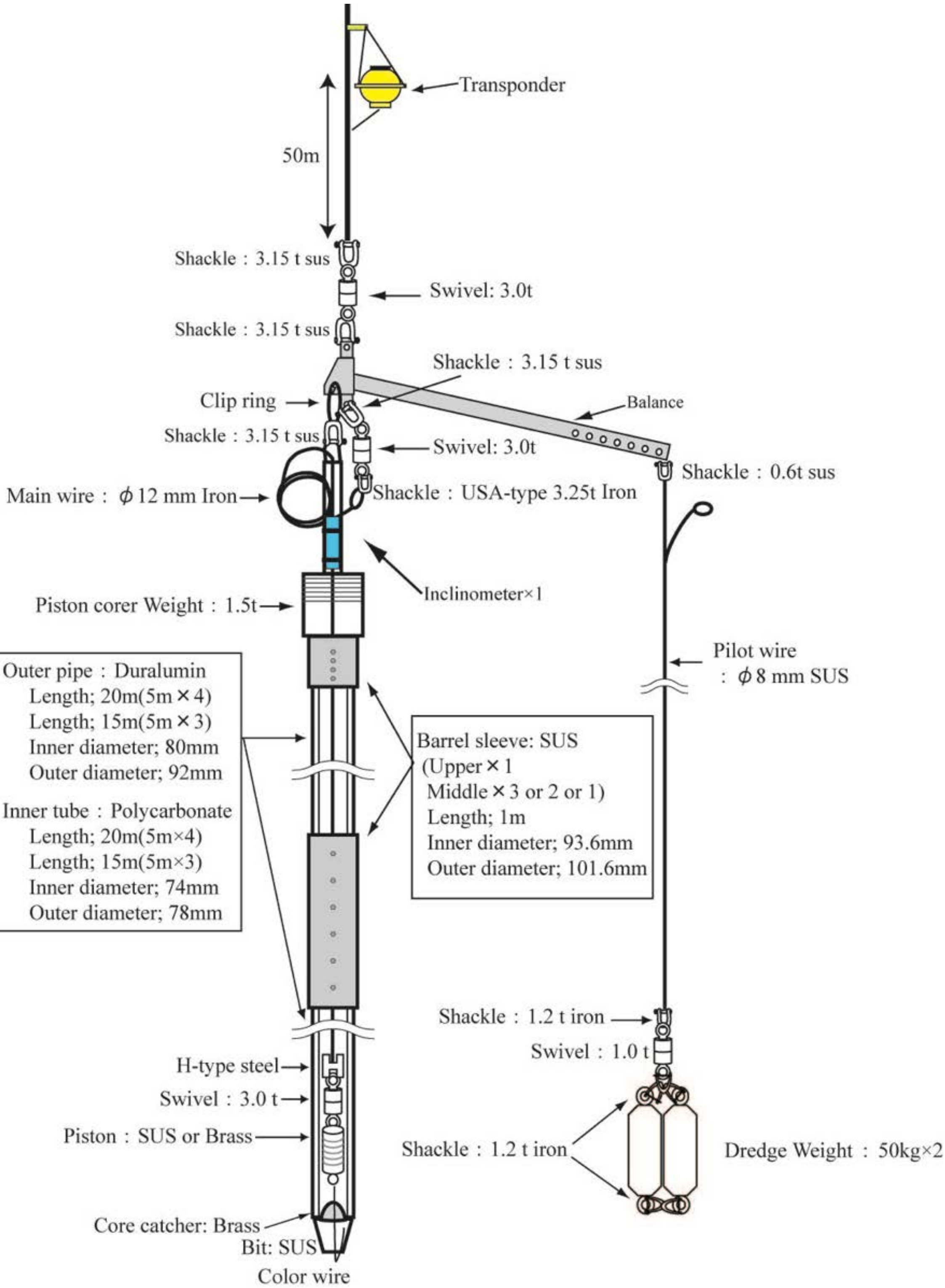

Figure 3-3. Piston corer system with 1.5 ton weight for PC04, PC05, PC06, PC07, PC08, PC09, PC10, PC11 and PC12 during the cruise MR16-07.

The gamma-ray attenuation (GRA), the P-wave velocity (PWV), and the magnetic susceptibility (MS) of whole-core samples are measured using multi-sensor core logger (MSCL). Whole-core samples are kept in the laboratory for the night to equalize the sediment temperature with the room temperature. Measurement interval was every 2 cm for all cores. GRA is measured by a gamma ray source and a detector, which are mounted on the center sensor stand. A narrow beam of gamma ray is emitted by Cesium-137 (^{137}Cs, energies principally at 0.662 MeV). The detector comprises a scintillator (a 2” diameter and 2” thick NaI crystal). The photon of gamma ray is collimated through 5 mm diameter in rotating shutter at the front of the housing of ^{137}Cs. These photons pass through the center of the whole core and are detected the scintillation detector on the other side. The detector comprises a scintillator (a 2” diameter and 2” thick NaI crystal). The calibration of GRA assumes a two-phase (the minerals and the interstitial water) system model for sediments. Aluminum has an attenuation coefficient similar to common minerals and is used as the mineral phase standard. Pure water is substituted as the interstitial-water phase standard. The actual standard consists of a telescoping aluminum rob (five elements of varying thickness) mounted in a piece of core liner and filled with pure water. GRA was measured with 10 seconds counting. PWV is measured two oil filled the Acoustic Rolling Contact (ARC) transducers, which are mounted on the center sensor stand with the gamma system. These transducers measure the velocity of P-wave through the whole core and the pulse amplitude. MS is measured by the loop sensor of 100 mm diameter made by the Bartington Instruments Ltd.. An oscillator circuit in the sensor produces a low intensity (approx. 80 A/m RMS) non-saturating, alternating magnetic field (0.565 kHz). MS was measured with 1 second.

3.3.4. Acoustic Doppler Current Profiler

Thorough 2013 to 2015, many research cruises of piston coring were carried out around Minami-torishima Island. We recognized that the seafloor sediment in this field could be categorized into some types, such as soft sediment, soft sediment with Mn nodules, stiff sediment. Concerning with distribution and formation of REY-rich mud, factor(s) of the variation for *in-situ* sediments must be resolved.

We focused on bottom current just above the seafloor which may affect them directly and forcibly. Therefore, we started to observe it using a mooring system equipped with: downward-looking high-frequency ADCP (Teledyne RD Instruments Workhorse Sentinel 1200 kHz) for few meters to the seafloor, upward-looking low-frequency ADCP (Workhorse Sentinel 300 kHz) for dozens of meters from the ADCP, and electromagnetic current meter (ECM, JFE Advantech INFINITY-Deep AEMD-USB) at the altitude of ADCPs (Figs. 3-4 and 3-5). In April 2016, we have deployed two mooring ADCP systems at sites MA-01 and 02 during the cruise YK16-01. We achieved the two retrieving and three deploying of the mooring ADCP system in this cruise.

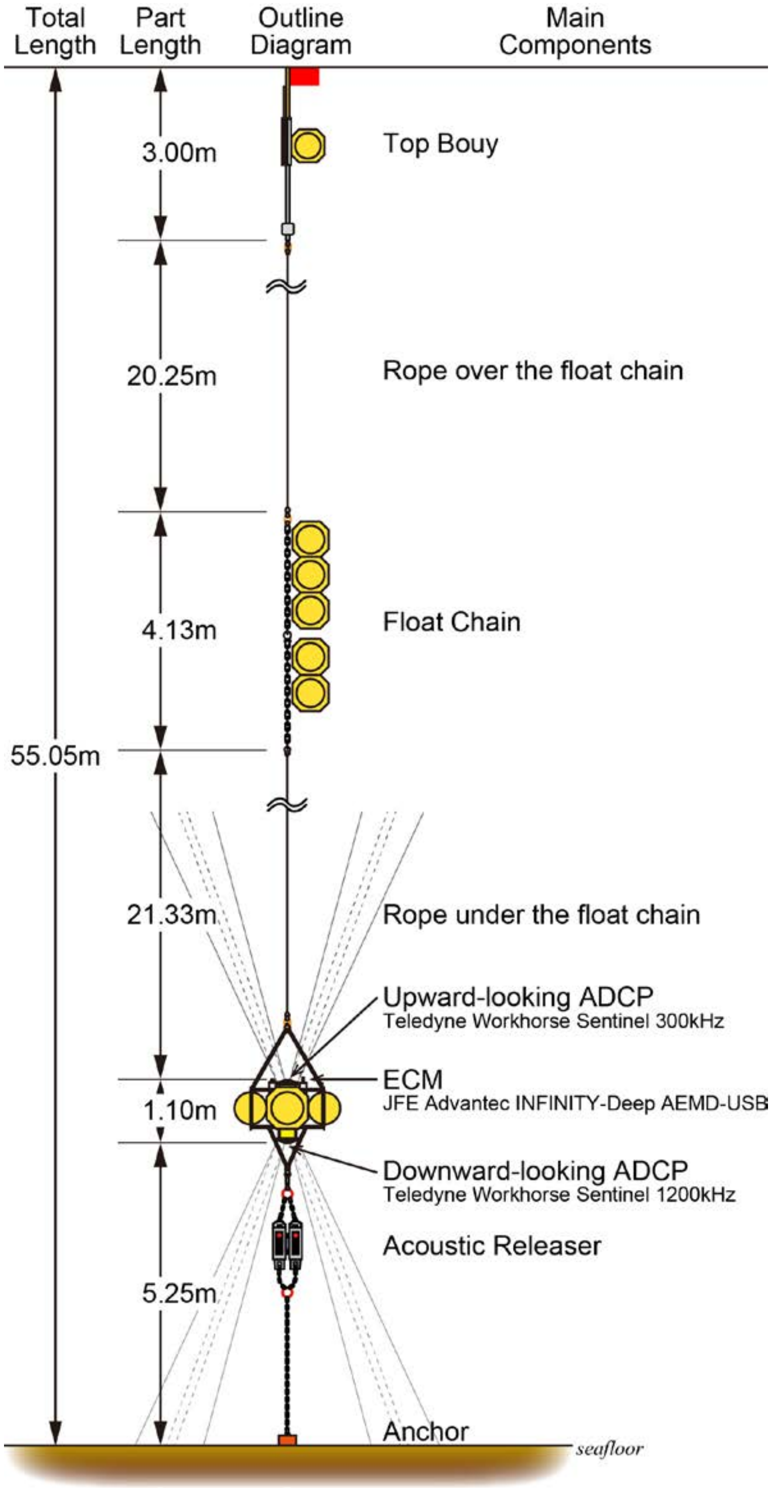

Figure 3-4. Schematic view of main components and the length of the mooring system. Pair of gray dash lines represents approximate direction of acoustic beam (20°) with 5° range represented by gray solid lines.

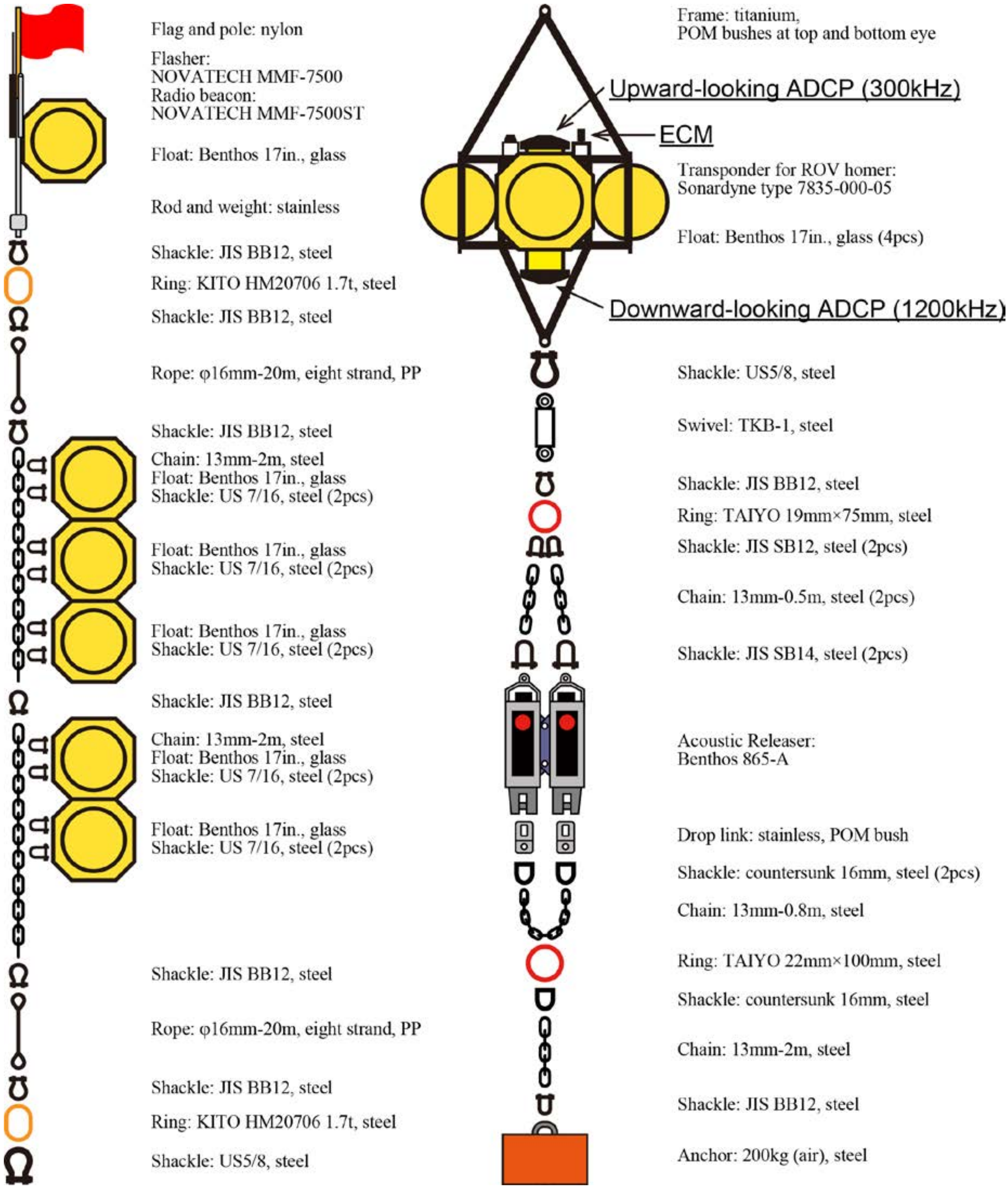

Figure 3-5. Specification of all parts consists of the mooring ADCP system.

3.4 Preliminary Results

We have arrived at the northernmost part of the investigation area at 19:26 (UTC), 2nd November 2016 and started to geophysical survey using SBP, MBES, gravity meter, and magnetometer. The ship track and survey lines of these geophysical researches are given in Fig. 3-6.

The sea state during this cruise was relatively calm and all planned PC coring, except for PC01, ADCP retrieving and deploying, and geophysical survey operations could be performed (Tables 3-1 and 3-2). We obtained twelve piston cores and no pilot core samples (Fig. 3-6) to investigate the detailed distribution of the extremely REY-rich mud in the southern part of and off the Minamitorishima EEZ. Owing to the hybrid-type piston with an appropriate selection of the O-ring size, rubber plate hardness, core lengths of piston core samples, from PC02 to PC11, exceeded 10 m (Table 3-1). During this cruise, we could comprehend the detailed distribution of the extremely REY-rich mud in the southern part of and off 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 8,500 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 360 smear slides and geophysical data will be reported at the academic conference or as a peer-reviewed international scientific paper.

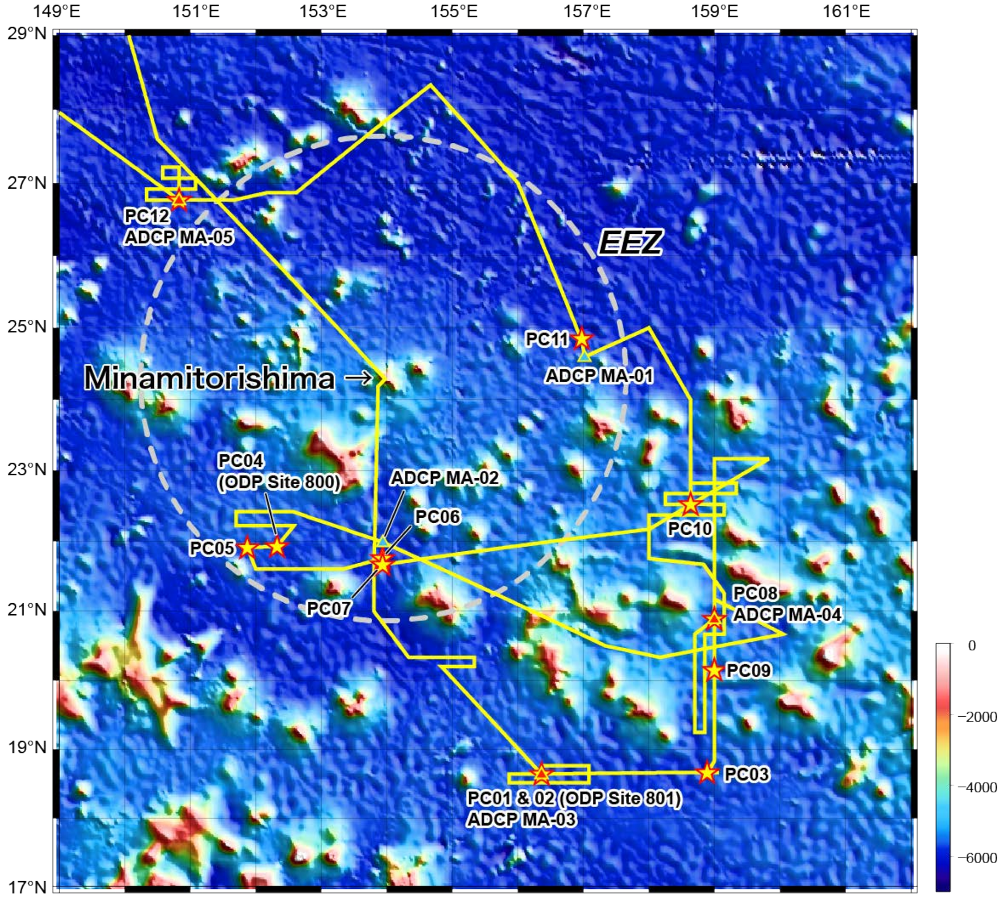

Figure 3-6. Map showing location of survey area during the cruise MR16-07.

Table 3-1. Summary of PC coring during the cruise MR16-07.

Date (UTC)	Core ID	Location	Water Depth

The mooring ADCP systems were successfully retrieved; at MA-01 on 19th November and at MA-02 on 11th November, 2016. The locations are shown in Table 3-2 and the measurement parameters are shown in Table 3-3. Benthos 865-A acoustic releasers SN821 at MA-01 and SN875 at MA-02 were enabled and certainly released the anchor. The position of ascending releasers were tracked by its transponders using super short baseline (SSBL), the ascending speed was about 71.4 m/min. (1.19 m/sec.) so that it took about 80 minutes to be arrived to the sea surface. Snapshots of the recovery at site MA-01 are shown in Fig. 3-7. After recovering the system on deck, the ADCPs and ECM were cleaned by freshwater, and immediately connected to a laptop PC to retrieve the data. Finally, both upward-looking and downward-looking ADCPs and the ECM clearly recorded the bottom current situation. Figs. 3-8 and 3-9 show preliminary results from the sensors at MA-01 and MA-02.

Three mooring systems were deployed at MA-03, 04 and 05 on 8, 15 and 22 November 2016 respectively. Descending position of the releasers in the water column were tracked by its transponders using SSBL, the descending speed was about 70 m/min. (1.17 m/sec.) so that it took about 80 to 90 minutes to be landed on the seafloor. After recognition of stable depth of transponders, SSBL calibration for landed position was carried out to determine precise location of the system. The location and results of SSBL calibration are shown in Table 3-4, the location map is shown in Fig. 3-6. Snapshots of the deployment at site MA-04 are shown in Fig. 3-10.

The system composition was as same as sites MA-01 and 02 (Figs. 3-4 and 3-5). However, the transducer for ROV homer was not equipped in newly deployed sites because we confirmed that the acoustic releasers are highly reliable still in 6,000 meters deep water depths through the successful recoveries at sites MA-01 and 02. Fresh bones of Pacific saury placed in a mesh laundry bag is attached to a pillar of the main frame at sites MA-03 and 04, to exam chemical adsorption to biogenic calcium phosphate. The measurement parameters are shown in Table 3-5 for MA-03 and Table 3-6 for MA-04 and 05 (ECM is not equipped at site MA-03). The parameters for MA-03 is almost same as MA-01 and 02 since the recovery was not carried out before the deployment at site MA-03 thus we had no information to improve the measurement at that time. For MA-04 and 05, some parameters were revised to cover more wide range between the 1200 kHz ADCP and the seafloor, and to sustain the measurement at least 1 year because these systems will be recovered in December 2017.

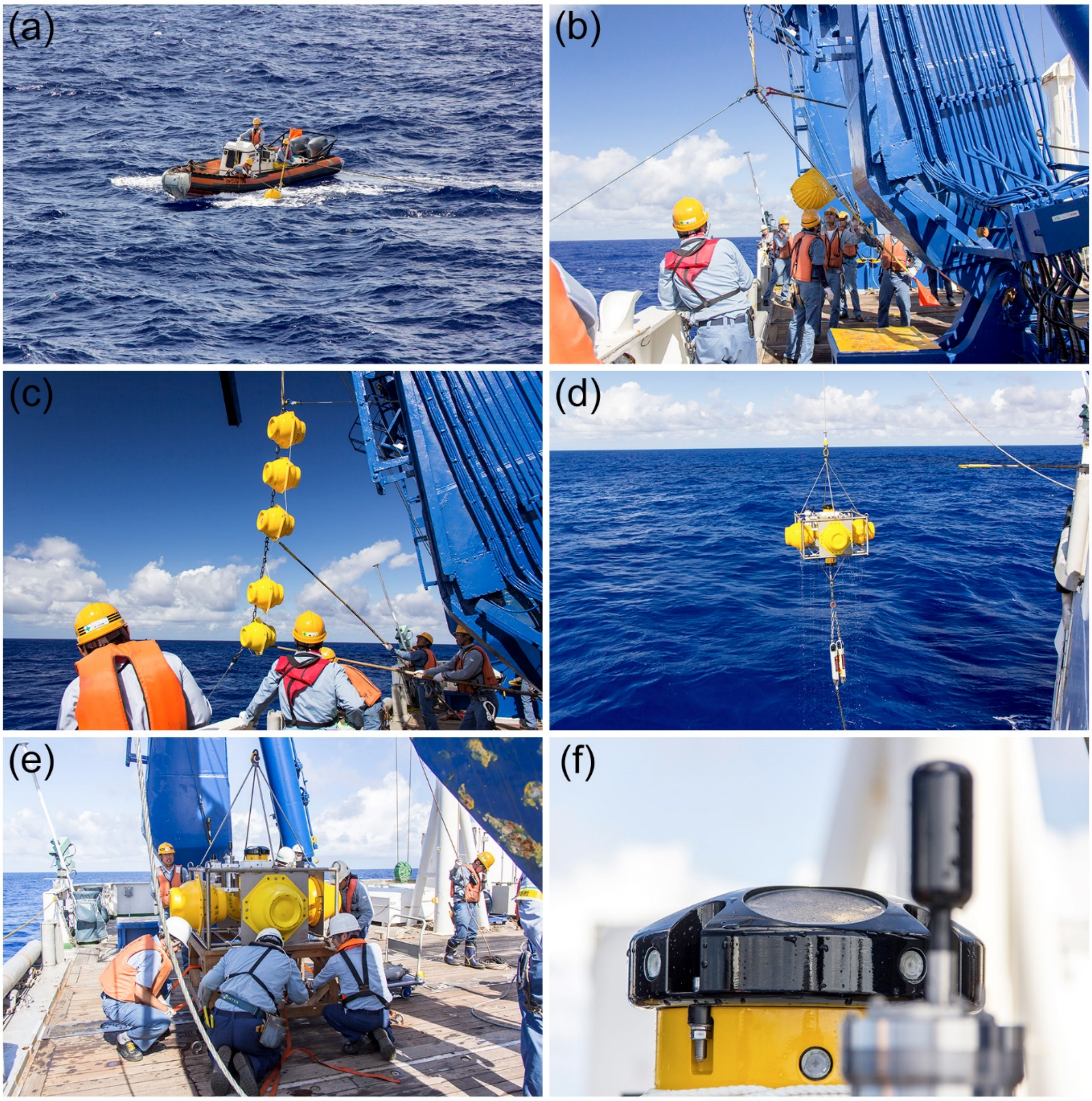

Figure 3-7. Snapshots of a recovery of the mooring ADCP system at site MA-01 on 19 November 2016. (a) Hooking the top buoy to connect it to hauling rope. (b) Firstly the top buoy was recovered. (c) Secondly five floating buoys were recovered. (d) The main frame with parallel acoustic releasers was exposed above the sea surface. (e) Finally the whole system was recovered on deck. (f) A kind of biofilm was covered on the sensor of ADCP. A black bar connected to steel-colored pressure tight case is the sensor of ECM.

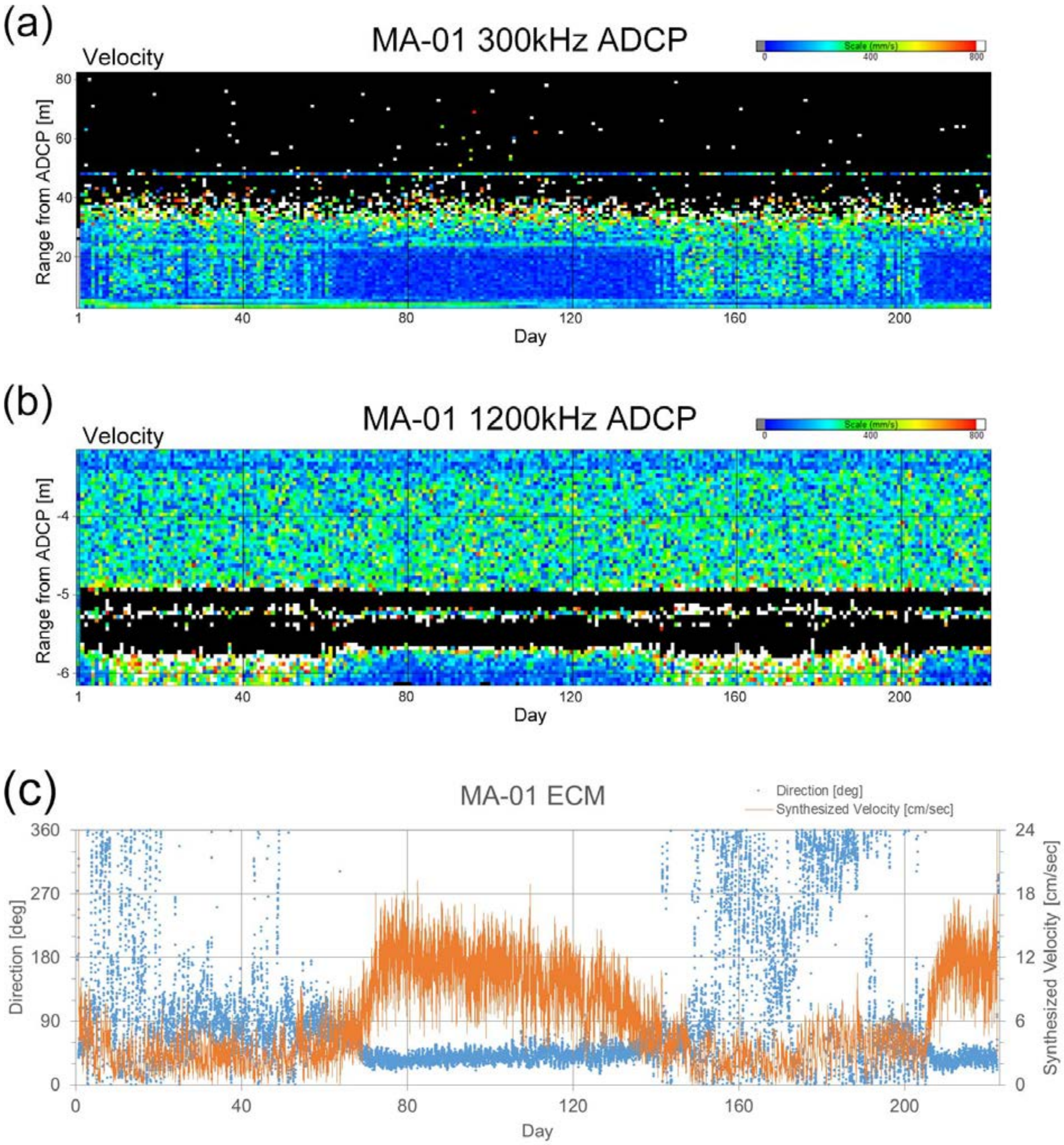

Figure 3-8. Preliminary results of bottom current situation at site MA-01. (a) Velocity magnitude (80 pings averaged) obtained by upward-looking 300 kHz ADCP, ranges from 3.21 to 82.21 meters above the sensor. (b) Velocity magnitude (400 pings averaged) obtained by downward-looking 1200 kHz ADCP, ranges from 3.17 to 6.12 meters below the sensor. The seafloor is about -4.9m. (c) 20 pings averaged synthesized current velocity (orange line) and the direction (blue dots) obtained by ECM, at an altitude of the sensor of upward-looking ADCP.

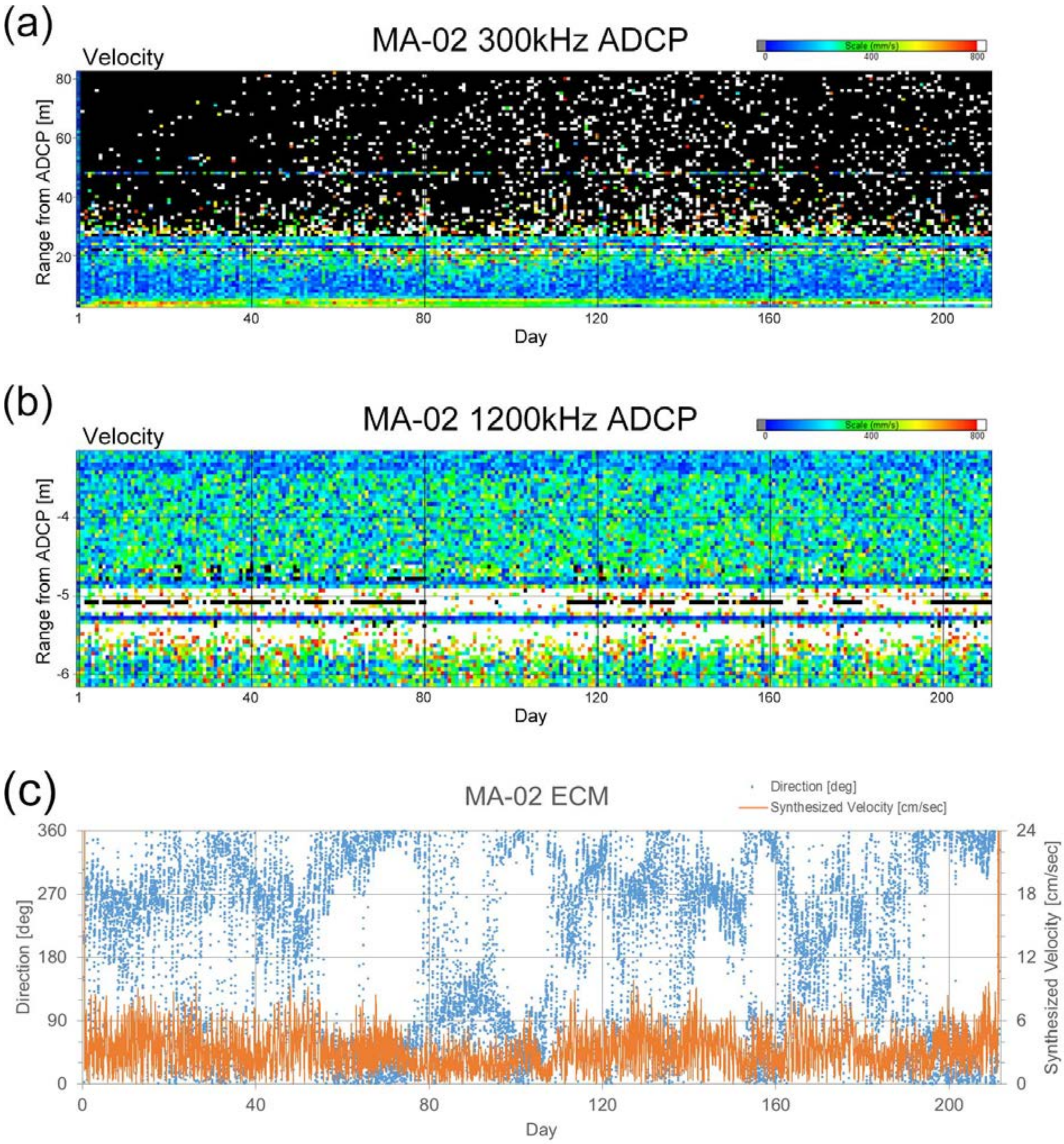

Figure 3-9. Preliminary results of bottom current situation at site MA-02. (a) Velocity magnitude (80 pings averaged) obtained by upward-looking 300 kHz ADCP, ranges from 3.21 to 82.21 meters above the sensor. (b) Velocity magnitude (400 pings averaged) obtained by downward-looking 1200 kHz ADCP, ranges from 3.17 to 6.12 meters below the sensor. The seafloor is about -4.9m. (c) 20 pings averaged synthesized current velocity (orange line) and the direction (blue dots) obtained by ECM, at an altitude of the sensor of upward-looking ADCP.

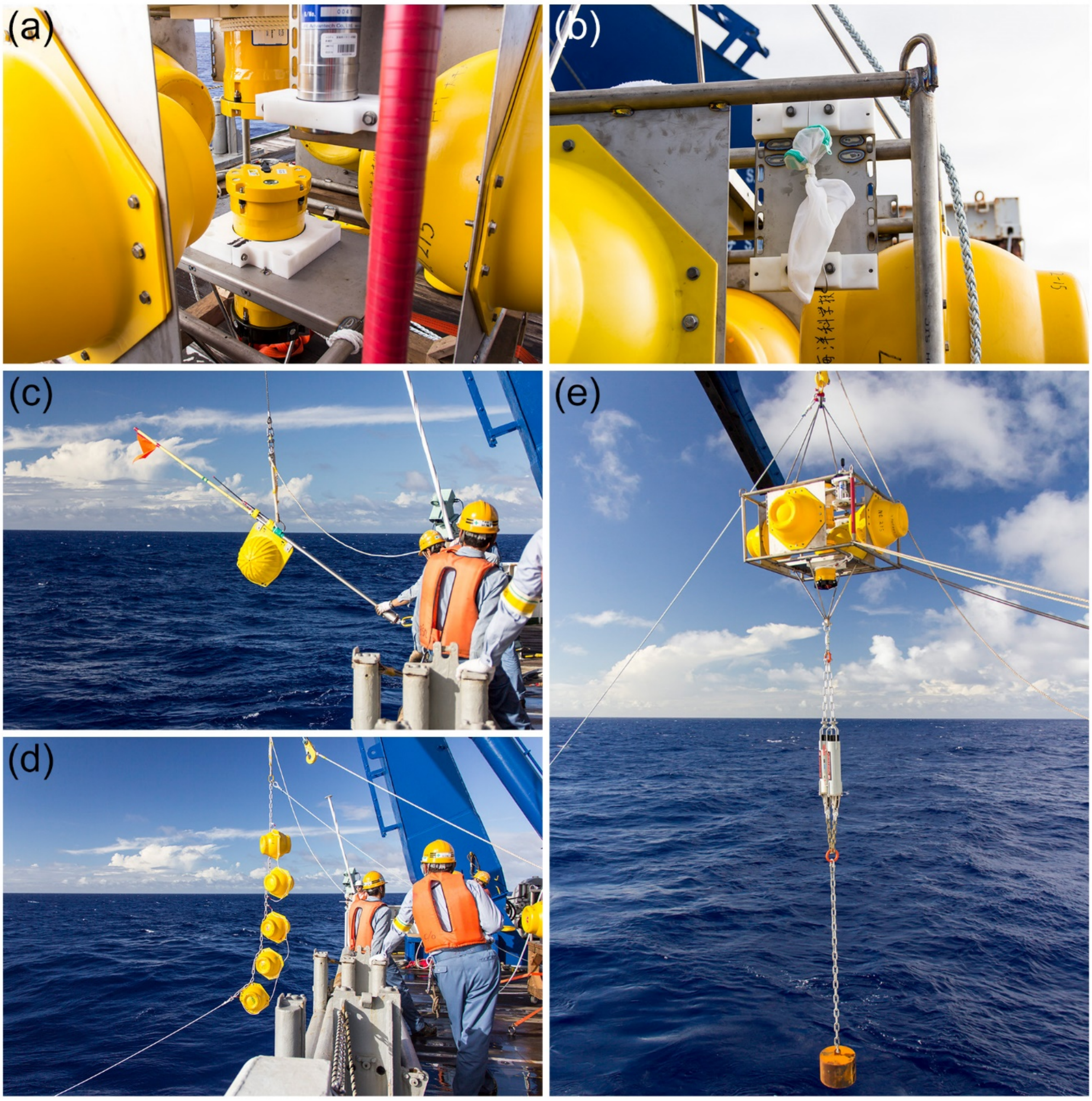

Figure 3-10. Snapshots of a deployment of the mooring ADCP system at site MA-04 on 15 November 2016. (a) Two oppositely oriented ADCPs (center), ECM (steel-colored pressure tight case) and four glass floats (placed at four walls). (b) Fresh fish bone in a mesh laundry net was attached. (c) Firstly the top buoy was released. (d) Secondly five floating buoys were released. (e) A whole view of fundamental part of the measurement system; anchor ~ acoustic releaser ~ downward-looking ADCP ~ upward-looking ADCP and ECM.

Table 3-2. Location of sites MA-01 and 02.

	MA-01	MA-02
Deployed date*1	11 April 2016	14 April 2016
Area	East off Minami-torishima Island	Southeast off Takuyo-Daigo Seamount
Feature of the seafloor*2	Huge amount of Mn nodules.	Silty clay, few Mn nodules.
Longitude	24°35.7566' N	21°59.0197' N
Latitude	157°00.9427' E	153°56.2705' E
Water Depth*3	5518.78 m	5733.58 m
Transmit frequency*4 and serial number of acoustic releasers	13.5 kHz for SN821 15.5 kHz for SN918	14.0 kHz for SN875 14.5 kHz for SN817

*1 Local time, UTC+10. *2 Observation by a diver in manned underwater vehicle "*SHINKAI 6500*".
*3 Obtained by super short baseline (SSBL) *4 Receive frequency is 13.0 kHz for all of them.

Table 3-3. Measurement parameters of ADCPs and ECM for sites MA-01 and 02.

	Sentinel 1200kHz	Sentinel 300kHz	INFINITY-Deep
Depth cell size	0.05 m	1.00 m	-
First cell range	3.17 m	3.21 m	-
Number of depth cell	60	80	-
Pings per ensemble	400	80	(20) *1
Estimated Std. Dev.	2.25 cm/s	1.52 cm/s	-
Time per ping	1.00 sec.	2.00 sec.	(1.00 sec.) *2
Time per ensemble	1 hrs. *3	30 min. *4	20 min.

*1 Sampling number. *2 Sampling interval.*3 Pinging starts every hour on the hour. *4 Pinging starts every hour and half hour on the hour. For those of all instruments, the local time UTC+10 was adopted in the internal calendars.

Table 3-4. Location and SSBL calibration results of sites MA-03, 04 and 05.

	MA-03	MA-04	MA-05
Deployed date*1	8 November 2016	15 November 2016	22 November 2016
Area	ODP site 801, far southeast off Minami-torishima Island	Northern gateway of "D" basin, far southeast off Minami-torishima Island	West off MIT guyot, far northwest off Minami-torishima Island
Feature of the seafloor*2	REY-rich mud (SBP) Soft sediment (PC)	REY-rich mud (SBP) Soft sediment (PC)	Surface mud (SBP) Stiff sediment (PC)
Longitude	18°38.4876' N	20°52.9970' N	26°45.9961' N
Latitude	156°21.4696' E	159°00.0636' E	150°49.6771' E
Water Depth*3	5,686 m	5,589 m	5,806 m
Transmit frequency*4 and serial number of acoustic releasers	15.5 kHz for SN819*5 15.0 kHz for SN878	14.0 kHz for SN875*5 14.5 kHz for SN817	13.5 kHz for SN821*5 15.5 kHz for SN918
Survey points for calibration	58	77	76
Standard deviation of position	X=67.38 m, Y=74.44 m, Z=13.14 m	X=65.82 m, Y=73.06 m, Z=22.72 m	X=62.02 m, Y=76.87 m, Z=16.80 m

*1 Local time, UTC+10. *2 SBP: estimation from a result of sub-bottom profiler, PC: top sediment obtained by piston corer.

*3 Obtained from bathymetric survey by multibeam echo sounder (MBES) *4 Receive frequency is 13.0 kHz for all of them. *5 Used for SSBL calibration.

Table 3-5. Measurement parameters of ADCPs for site MA-03.

	Sentinel 1200kHz	Sentinel 300kHz
Depth cell size	0.05 m	1.00 m
First cell range	3.17 m	3.70 m
Number of depth cell	60	80
Pings per ensemble	404	80
Estimated Std. Dev.	2.24 cm/s	1.52 cm/s
Time per ping	1.00 sec.	2.00 sec.
Time per ensemble	1 hrs. *1	30 min. *2

*1 Pinging starts every hour on 5 minutes past the hour. *2 Pinging starts every half hour.

For those of all instruments, the local time UTC+10 was adopted in the internal calendars.

Table 3-6. Measurement parameters of ADCPs and ECM for sites MA-04 and 05.

	Sentinel 1200kHz	Sentinel 300kHz	INFINITY-Deep
Depth cell size	0.10 m	1.00 m	-
First cell range	0.82 m	3.70 m	-
Number of depth cell	60	80	-
Pings per ensemble	400	60	(10) *1
Estimated Std. Dev.	1.55 cm/s	1.75 cm/s	-
Time per ping	1.00 sec.	2.00 sec.	(1.00 sec.) *2
Time per ensemble	1 hrs. *3	30 min. *4	20 min.

*1 Sampling number. *2 Sampling interval.*3 Pinging starts every hour on 5 minutes past the hour. *4 Pinging starts every hour and half hour on the hour. For those of all instruments, the local time UTC+10 was adopted in the internal calendars.

4. Notice on Using

Notice on using: Insert the following notice to users regarding the data and samples obtained.

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.