doi : 10.17596/0002787

R/V Yokosuka “Cruise Report”

YK16-01

Cross-ministerial Strategic Innovation Promotion Program (SIP), Next-generation Technology for Ocean Resources Exploration (ZIPANG in ocean), “Extensive investigation of ferromanganese nodules”

Around Minamitorishima Island

Apr.08,2016-Apr.26,2016

Japan Agency for Marine-Earth Science and Technology

(JAMSTEC)

Contents

1. Cruise Information

Cruise ID: YK16-01

Name of vessel: R/V Yokosuka

Title of the cruise: Cross-ministerial Strategic Innovation Promotion Program (SIP), Next-generation Technology for Ocean Resources Exploration (ZIPANG in ocean), “Extensive investigation of ferromanganese nodules”

Title of proposal: Cross-ministerial Strategic Innovation Promotion Program (SIP), Next-generation Technology for Ocean Resources Exploration (ZIPANG in ocean), “Extensive investigation of ferromanganese nodules”

Cruise period: April 8 to 26, 2016

Ports of departure: Harumi Pier, JAMSTEC

Ports of arrival: Harumi Pier, JAMSTEC

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

Research maps

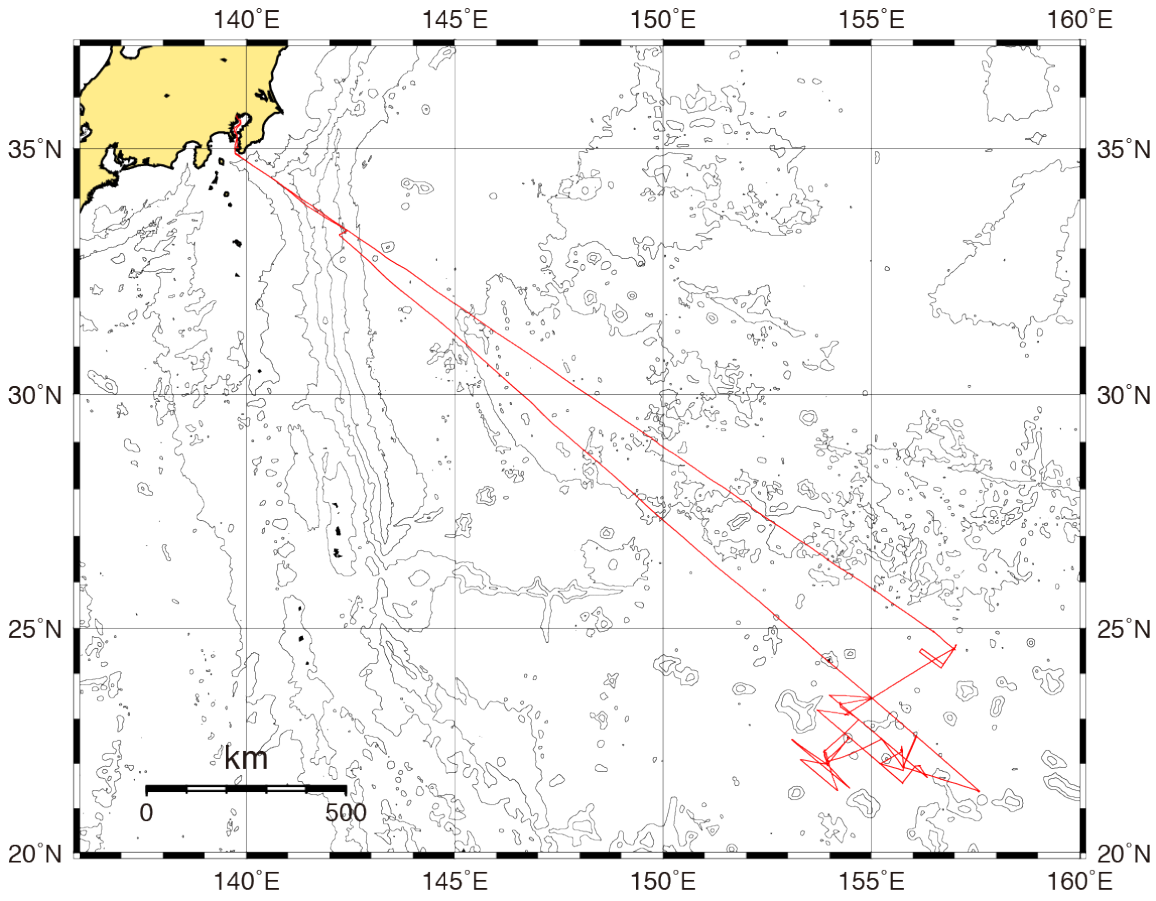

Figure 1-1. Ship track during the cruise YK16-01.

2. Researchers

Chief Scientist Shiki Machida Research Scientist, JAMSTEC

Chief scientist of the project on

"Extensive investigation of ferromanganese nodules"

RePresentative of Scientice Party

Eiichi Kikawa JAMSTEC

Onboard Researchers

Vice-chief Scientist	Koichi Iijima	Engineer, JAMSTEC
Scientist	Hirofumi Yamamoto	Senior Engineer, JAMSTEC
Scientist	Tatsuo Nozaki	Scientist, JAMSTEC
Scientist	Junji Kaneko	Engineer, JAMSTEC
Scientist	Junichiro Ohta	JSPS Post-Doc. Fellow, JAMSTEC
Scientist	Koichiro Fujinaga	Senior Res. Scientist, Chiba Inst. Tech.
Scientist	Kazutaka Yasukawa	Assistant professor, the Univ. Tokyo
Scientist	Yutaro Takaya	Visiting Scientist, JAMSTEC
Scientist	Teruaki Ishii	Visiting Professor, Shizuoka Univ.
Scientist	Ryo Shimomura	Student (Master's), the Univ. Tokyo
TV crew	Keisuke Fujishima	NHK
TV crew	Toshio Kurosaki	NHK
TV crew	Yoshiyuki Umehara	NHK
Marine Technician	Satomi Minamizawa	Nippon Marine Enterprises, Ltd.

Shore-based Researchers

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

3. Observation

by Shiki Machida

3.1. Background

Ferromanganese (Fe-Mn) nodules and crusts, and REY-rich mud (deep-sea sediment containing high concentrations of rare-earth elements and yttrium (REY)) have been considered a potential resource for metals, such as Ni, Cu, Co, Li, and REY that are important in contemporary technology (e.g., Hein *et al.*, 2013; Kato *et al.*, 2011; Hein *et al.*, 2010). Recently, it is further considered that these three types of "oxide deposits" are also key to understanding of palaeoenvironmental change (e.g., Machida *et al.*, 2016; Hyeong *et al.*, 2013; Han *et al.*, 2003; Jeong *et al.*, 2000).

Large Fe-Mn nodules have been found to be densely distributed on a seamount approximately 300 km east of Minamitorishima Island, in the Japanese Exclusive Economic Zone (Figs. 3-1 and 3-2). On this seamount, a geological survey has been conducted using the *Shinkai 6500* submersible (dive No. 6K 1207) during cruise YK10-05 of *R/V Yokosuka* in 2010. Machida *et al.* (in press) subsequently reported results of geological survey and geochemical analyses of collected samples from Site 6K 1207. They revealed two major important findings as follows. (1) Seafloor with extremely strong acoustic reflectivity is densely covered with the Fe-Mn nodules, a feature that should be noted in future exploration. (2) Textural and compositional changes over the growth history of the nodules are quite similar to those of the Fe-Mn crust on large seamounts in the western Pacific. Therefore, the Fe-Mn nodules formed solely by hydrogenetic Fe-Mn-(oxyhydr)oxide precipitation having a high potential as a future metal resource.

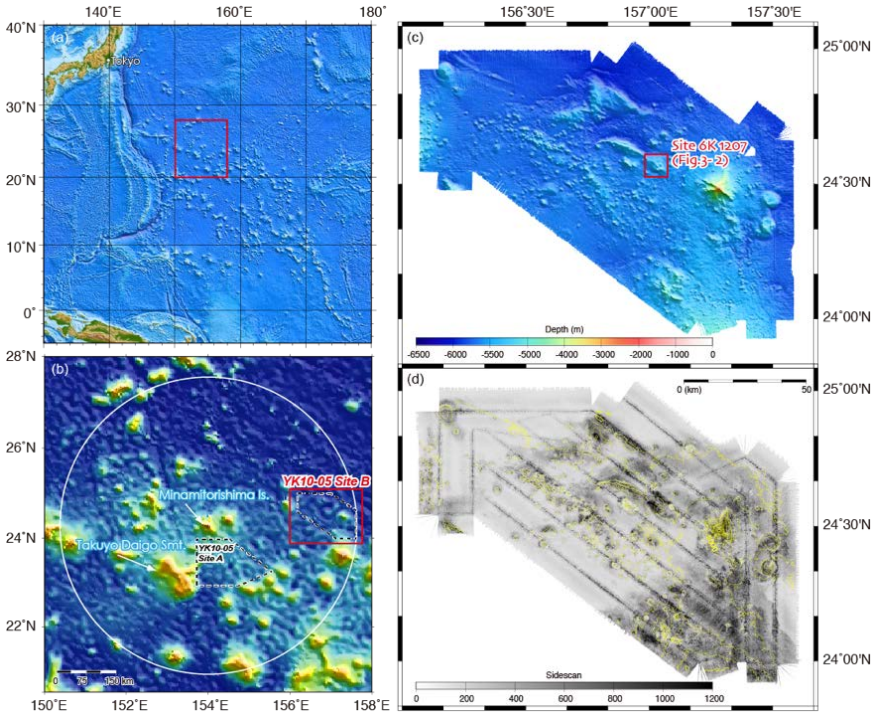

Figure 3-1. Maps of the Fe-Mn nodule field modified after Machida *et al.* (2016).

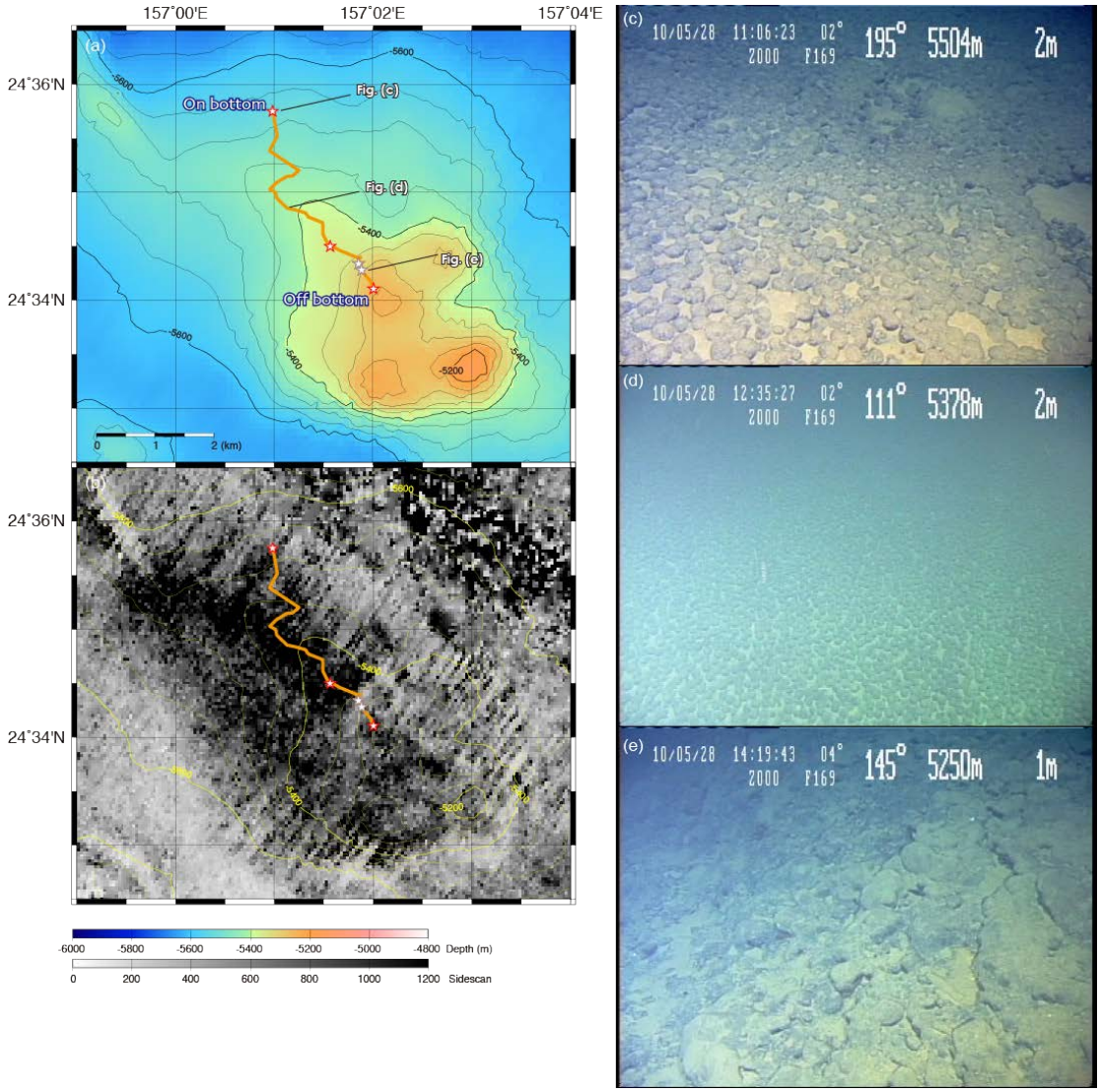

Figure 3-2. Maps and photographs of Site 6K 1207 modified after Machida *et al.* (2016). Orange line illustrates the survey track of *Shinkai 6500* dive No. 6K 1207. Red and gray stars respectively indicate sampling site for nodule and crust samples.

In precise data of bathymetry and acoustic reflectivity, using Multi narrow Beam Echo Sounder (MBES), acquired by the Japan Coast Guard around Minamitorishima Island (Oikawa and Morishita, 2009). These data indicate that regions showing high acoustic reflectivity are widespread especially in southeastern quarter of EEZ around Minamitorishima Island, not only Site 6K 1207 (Okino, personal communication). Such feature was also identified by our recent investigations using MBES (Figs. 3-3 and 3-4) during seven cruises YK10-05 of *R/V Yokosuka*, KR13-02 and KR14-02 of *R/V Kairei*, and MR13-E02, MR14-E02, MR15-E01, and MR15-02 of *R/V Mirai*. Although all of regions showing acoustic reflectivity is considered as potential for dense nodule field, we do not have any observation yet.

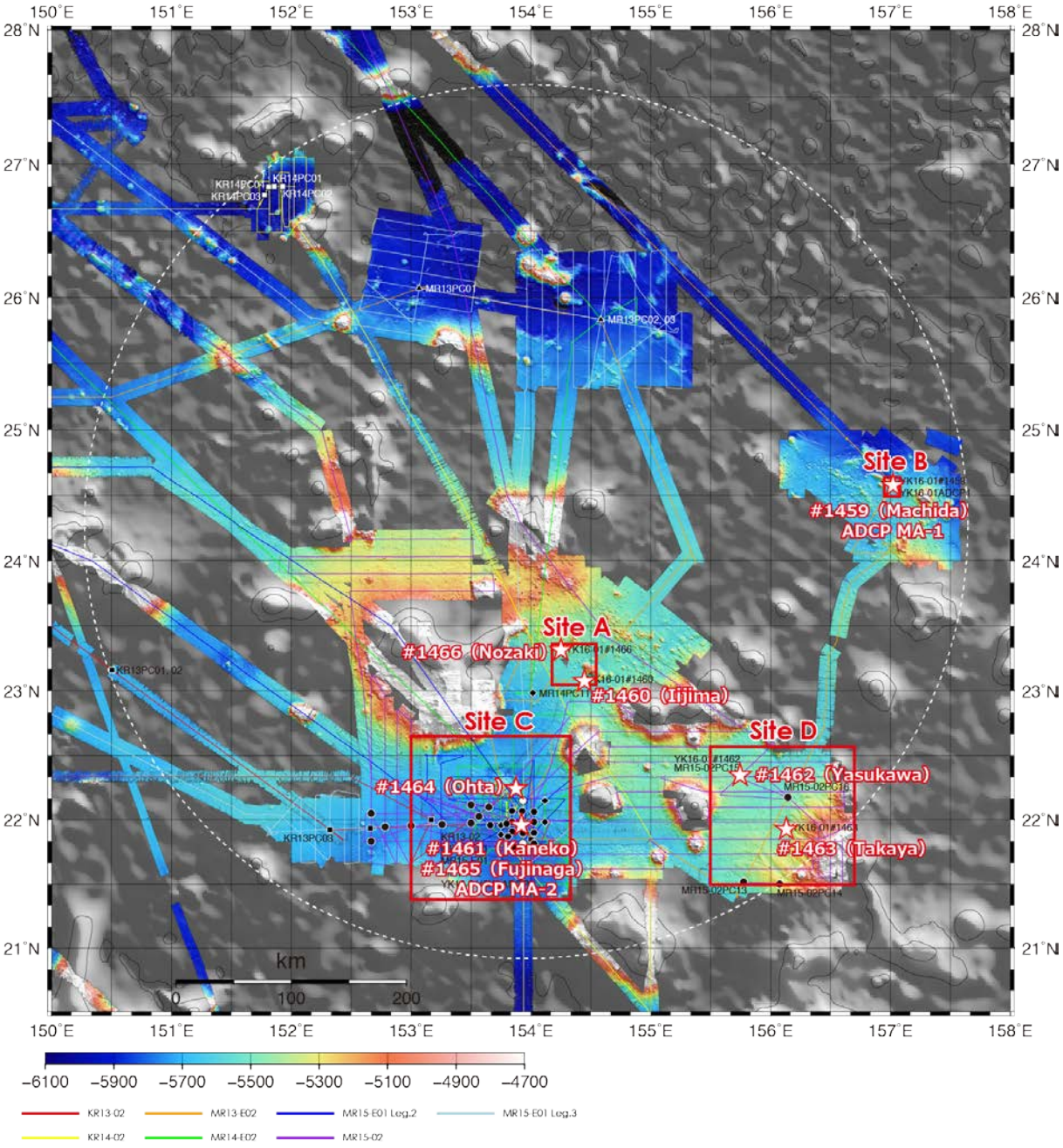

Figure 3-3. Map showing location of survey area during cruise YK16-01. Topographic data by MBES were collected during previous cruises YK10-05, KR13-02, MR13-E02, KR14-02, MR14-E02, MR15-E01 Legs. 2 and 3, and MR15-02. Symbols with annotation indicate piston core during previous cruises and 6K dive and ADCP sites of this cruise. Background topographic data are from ETOPO 1.

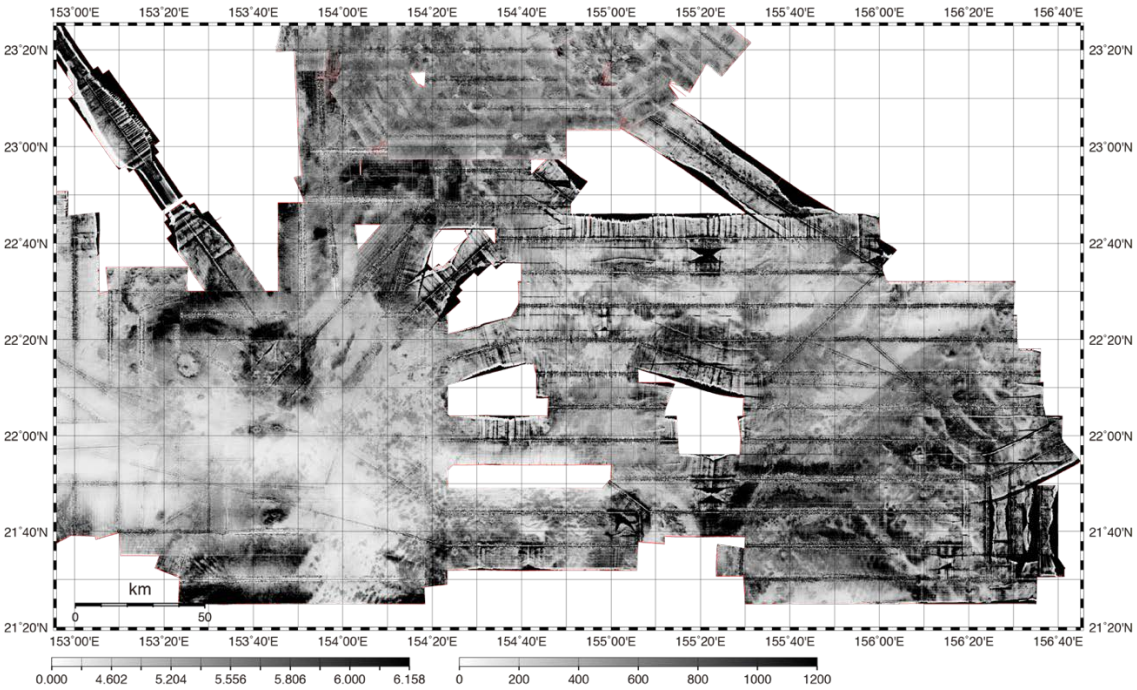

Figure 3-4. Map of acoustic reflectivity of the seafloor in the southeastern region of the Minamitorishima EEZ. Data were collected by MBES during previous cruises YK10-05, MR14-E02, MR15-E01 Legs. 2 and 3, and MR15-02. Color scale for this map (left) corresponds to that of Figs. 3-1d and 3-2b (right).

In contrast, recent geological investigations using a sub-bottom profiler and a piston corer reveals that the seamount at Site 6K 1207 is situated within an area of T_I echo type (Nakamura et al., 2016), which corresponds to the region where REY-rich mud is directly exposed on the seafloor (Iijima *et al.*, 2016). Furthermore, Yasukawa *et al.* (2015) showed that Fe-Mn-(oxyhydr)oxides contribute to form REY-rich mud as a critical component of REY-enrichment in sediment cores drilled from the Indian Ocean. Accumulation of micro-ferromanganese nodules was also observed in the REY-rich mud cored from the Minamitorishima EEZ (Iijima *et al.*, 2016). These acoustic and mineralogical observations suggest that a geologic and genetic relationship between the Fe-Mn nodules and REY-rich mud in the Minamitorishima EEZ.

Previous studies for deep-sea mineral resources individually focused on the origin of each resource. However, our recent observations on (1) petrological similarity between Fe-Mn nodules and crusts, and (2) coexistence of Fe-Mn nodules and REY-rich mud, especially within southeastern quarter of EEZ around Minamitorishima Island, suggest a genetic relationship among these three types of oxide deposits. We thus need comprehensive geological and geochemical studies to understand genesis of “the Oxide Deposit Trinity” (nodules, crusts, and REY-rich mud) on the basis of a new unified framework.

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3.2. Cruise Objectives

The objective of this cruise is to elucidate the features on distribution of Fe-Mn nodules on the seafloor showing high acoustic reflectivity. The following items will be done in southeastern part of the Minamitorishima EEZ (Fig. 3-3).

1. Observation of nodule fields: Detailed megascopic observation and recording of high-resolution visual image will be done to quantitatively define morphological features and density of distributions of nodules on the basis of dive using *Shinkai 6500*.
2. Nodule and sediment sampling: Sampling of surface nodules and pelagic sediment below nodules will be done for comprehensive geochemical and geochronological analysis.
3. Geology of nodule fields: To identify geological features of nodule field and determine the extremely-REY-rich mud (which is potentially distributed below nodule field), acoustic stratigraphy will be observed in detail using SBP equipped on *Shinkai 6500*. MBES and shipboard SBP data also contribute to interpretation on geology of studied area.
4. Magnetics and Gravity: 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 and CTD data also will be used to recalculate seafloor depth.
5. Direction and speed of deep-sea current: Acoustic Doppler Current Profiler (ADCP) will be deployed to determine flow direction and speed of deep-sea current in the Fe-Mn nodule field and on sediment with few Mn nodules.

3.3. Activities

3.3.1. Cruise Log

2016/04/08 Tokyo Bay (35-19.8N, 139-42.5E)

Weather: Cloudy / Wind direction: NE/ Wind force: 3 / Wave scale: 1 /Swell scale: 0 / Visibility: 8 miles (12:00 JST)

09:00	onboard
10:00	let go all shore line, left HARUMI, proceeded to research area
10:30-11:10	carried out education and training for scientist
16:40	pray for safety of cruise to KONPIRASAN

2016/04/09 Northwest off Torishima Island (31-51.3N, 145-02.1E)

Weather: Cloudy / Wind direction: South/ Wind force: 3 / Wave scale: 2 /
Swell scale: 3 / Visibility: 8 miles (12:00 JST)

09:00-09:40	Crews, SHINKAI 6500 team and scientists meeting
09:45-10:00	SHINKAI 6500 team and scientists meeting
10:00-11:00	carried out briefing about SHINKAI 6500
14:30-15:30	scientific meeting
18:00-20:30	scientific meeting

2016/04/10 East off Ogasawara Islands (28-21.8N, 150-53.3E)

Weather: Fine but cloudy / Wind direction: SSW / Wind force: 5 / Wave scale: 3 /Swell scale: 3 / Visibility: 8 miles (12:00 JST)

09:00-10:00	practiced Life boat, fire and callision station drill
18:00-19:00	scientific meeting
M.M.	Put ship’s clock ahead 60’ m for S.M.T.

2016/04/11 Northeast off Minami-torishima Island (24-57.2N, 156-26.3E)

Weather: Fine but cloudy / Wind direction: SSE / Wind force: 4 / Wave scale: 2 /Swell scale: 1 / Visibility: 8miles (12:00 JST+1h)

09:00-10:00	carried out seminar for crews
12:15-12:36	carried out figure eight turn
14:45	arrived at research area (Site B)
14:56	released XBT @ 24-32.8770N, 156-58.3942E
15:17-16:01	carried out MBES site survey for dive#1459
16:32	deployed ADCP mooring systems (MA-1)
16:49	launched Proton magnetometer

17:51 ADCP mooring systems landed on the sea bottom
17:52-18:21 carried out calibration of ADCP mooring systems
(24-35.7566N, 157-00.9457E, Depth=5518.78m)
19:00 scientific meeting
20:25 commenced to MBES and SBP mapping survey

2016/04/12 Around the Minami-torishima Island (24-35.7N, 157-01.0E)
Weather: Fine but cloudy / Wind direction: SSW / Wind force: 4 / Wave scale: 3 /Swell scale: 1 / Visibility: 8 miles (12:00 JST+1h)
03:28 finished MBES and SBP mapping survey
06:35 recovered Proton magnetometer
09:07 SHINKAI 6500 dove and started her operation #1459
11:32 SHINKAI 6500 landed on the sea bottom (Depth = 5499m)
14:58 SHINKAI 6500 left the sea bottom (Depth = 5590m)
17:16 recovered SHINKAI 6500 and finished her operation
17:45 commenced proceeding to Site A
20:58 commenced to MBES and SBP mapping survey
20:30-21:40 scientific meeting

2016/04/13 Around the Minami-torishima Island (23-05.0N, 154-26.0E)
Weather: Fine but cloudy / Wind direction: NNE / Wind force: 3 / Wave scale: 3 /Swell scale: 3 / Visibility: 8 miles (12:00 JST+1h)
05:00 arrived at Site A
05:14 released XBT @ 23-05.2405N, 154-22.2975E
05:33-06:12 carried out MBES site survey for dive#1460
09:07 SHINKAI 6500 dove and started her operation #1460
11:30 SHINKAI 6500 landed on the sea bottom (Depth = 5527m)
14:53 SHINKAI 6500 left the sea bottom (Depth = 5555m)
17:29 recovered SHINKAI 6500 and finished her operation
18:10 commenced proceeding to Site C
18:14 launched Proton magnetometer
18:30 commenced to MBES and SBP mapping survey
19:30-20:20 scientific meeting

2016/04/14 Around the Minami-torishima Island (21-59.0N, 153-56.1E)
Weather: Fine but cloudy / Wind direction: SE / Wind force: 5 / Wave scale: 4 /Swell scale: 3 / Visibility: 8 miles (12:00 JST+1h)
05:10 arrived at Site C

05:22 released XBT @ 22-06.5658N, 153-56.8756E
05:31 finished MBES and SBP mapping survey
05:46-06:31 carried out MBES site survey for dive#1461
06:45 recovered Proton magnetometer
07:40 suspended SHINKAI 6500 submergence due to rough sea
08:56-09:40 carried out MBES site survey
11:25 deployed ADCP mooring systems (MA-2)
12:48 ADCP mooring system landed on the sea bottom
13:00 launched Proton magnetometer
13:12-13:37 carried out calibration of ADCP mooring systems
(21-59.0197N, 153-56.2705E, Depth= 5733.58m)
13:39 commenced MBES and SBP mapping survey
18:00 scientific meeting

2016/04/15 Around the Minami-torishima Island (21-59.1N, 153-56.2E)

Weather: Fine but cloudy / Wind direction: ESE / Wind force: 5 / Wave scale: 3 /Swell scale: 3 / Visibility: 8 mile (12:00 JST+1h)

03:26 finished MBES and SBP mapping survey
06:35 recovered Proton magnetometer
09:02 SHINKAI 6500 dove and started her operation #1461
11:31 SHINKAI 6500 landed on the sea bottom (Depth = 5728m)
14:54 SHINKAI 6500 left the sea bottom (Depth = 5729m)
17:24 recovered SHINKAI 6500 and finished her operation
17:45 commenced proceeding to Site D
18:04 launched Proton magnetometer
18:15 commenced MBES and SBP mapping survey
19:30 scientific meeting

2016/04/16 Around the Minami-torishima Island (22-20.0N, 155-44.0E)

Weather: Fine but cloudy / Wind direction: SE / Wind force: 3 / Wave scale: 2 /Swell scale: 3 / Visibility: 8 miles (12:00 JST+1h)

02:19 finished MBES and SBP mapping survey
05:00 arrived at Site D
05:11 released XBT @ 22-17.3712N, 155-44.4862E
05:42-06:28 carried out MBES site survey for dive#1462
06:38 recovered Proton magnetometer
09:01 SHINKAI 6500 dove and started her operation #1462
11:20 SHINKAI 6500 landed on the sea bottom (Depth = 5453m)

15:05 SHINKAI 6500 left the sea bottom (Depth = 5443m)
17:37 recovered SHINKAI 6500 and finished her operation
18:00 launched Proton magnetometer
20:00 commenced MBES and SBP mapping survey

2016/04/17 Around the Minami-torishima Island (21-57.1N, 156-06.7E)
Weather: Fine but cloudy / Wind direction: East / Wind force: 5 / Wave scale: 3 /Swell scale: 3 / Visibility: 8 miles (12:00 JST+1h)
02:46 finished MBES and SBP mapping survey
02:47-03:07 carried out figure eight turn
05:28-06:09 carried out MBES site survey for dive#1463
06:35 recovered Proton magnetometer
09:02 SHINKAI 6500 dove and started her operation #1463
09:20-09:45 scientific meeting
11:19 SHINKAI 6500 landed on the sea bottom (Depth = 5458m)
15:15 SHINKAI 6500 left the sea bottom (Depth = 4928m)
17:37 recovered SHINKAI 6500 and finished her operation
18:00 launched Proton magnetometer
19:33 commenced MBES and SBP mapping survey

2016/04/18 A round the Minami-torishima Island (21-39.0N, 156-40.6E)
Weather: Fine but cloudy / Wind direction: East / Wind force: 5 / Wave scale: 4 /Swell scale: 3 / Visibility: 8 miles (12:00 JST)
02:47-03:07 carried out figure eight turn
03:12 finished MBES mapping survey
06:39 recovered Proton magnetometer
07:50 suspended SHINKAI6500 submergence due to rough sea
08:00 launched Proton magnetometer
08:00-08:45 scientific meeting
16:05 released XBT @ 21-21.9610N, 157-35.1244E
16:22 commenced MBES and SBP mapping survey

2016/04/19 Around the Minami-torishima Island (22-51.7N, 155-45.8E)
Weather: Fine but cloudy / Wind direction: East / Wind force: 5 / Wave scale: 3 /Swell scale: 3 / Visibility: 8 miles (12:00 JST)
03:15 finished MBES mapping survey
06:50 suspended SHINKAI6500 submergence due to rough sea
07:00 commenced proceeding to Site C

08:00-08:30 scientific meeting
09:51 commenced MBES and SBP mapping survey

2016/04/20 Around the Minami-torishima Island (22-15.4N, 153-51.4E)

Weather: Fine but cloudy / Wind direction: East / Wind force: 4 / Wave scale: 3 /Swell scale: 3 / Visibility: 8 mile (12:00 JST+1h)

01:45 finished MBES and SBP mapping survey
06:00 arrived at Site C
06:33 recovered Proton magnetometer
08:59 SHINKAI 6500 dove and started her operation #1464
11:29 SHINKAI 6500 landed on the sea bottom (Depth = 5778m)
14:59 SHINKAI 6500 left the sea bottom (Depth = 5761m)
17:29 recovered SHINKAI 6500 and finished her operation
18:11 launched Proton magnetometer
21:39 commenced MBES and SBP mapping survey

2016/04/21 Around the Minami-torishima Island (21-59.1N, 153-56.2E)

Weather: Fine but cloudy / Wind direction: NE / Wind force: 4 / Wave scale: 3 /Swell scale: 3 / Visibility: 8 mile (12:00 JST+1h)

03:50 finished MBES and SBP mapping survey
06:33 recovered Proton magnetometer
09:03 SHINKAI 6500 dove and started her operation #1465
11:32 SHINKAI 6500 landed on the sea bottom (Depth = 5727m)
15:02 SHINKAI 6500 left the sea bottom (Depth = 5679m)
17:41 recovered SHINKAI 6500 and finished her operation
18:15 commenced proceeding to Site A
18:22 launched Proton magnetometer
23:38 commenced MBES and SBP mapping survey

2016/04/22 Around the Minami-torishima Island (21-59.1N, 153-56.2E)

Weather: Fine but cloudy / Wind direction: ESE / Wind force: 5 / Wave scale: 3 /Swell scale: 3 / Visibility: 8 mile (12:00 JST+1h)

02:55 finished MBES and SBP mapping survey
05:00 arrived at Site A
05:09 released XBT @ 23-14.7247N, 154-16.9404E
05:29-06:15 carried out MBES site survey for 1466 dive
06:33 recovered Proton magnetometer
09:01 SHINKAI 6500 dove and started her operation #1466

11:15 SHINKAI 6500 landed on the sea bottom (Depth = 5476m)
15:00 SHINKAI 6500 left the sea bottom (Depth = 5267m)
17:23 recovered SHINKAI 6500 and finished her operation
18:11 launched Proton magnetometer
20:48 commenced MBES and SBP mapping survey

2016/04/23 Northwest off the Minami-torishima Island (25-28.5N, 152-26.5E)
Weather: Fine but cloudy / Wind direction: WSW / Wind force: 3 / Wave scale: 2 /Swell scale: 1 / Visibility: 8 mile (12:00 JST+1h)
05:28 finished MBES and SBP mapping survey
06:25 recovered Proton magnetometer
06:30 proceeded to YKDT's F.F. point (OFF Boso)
09:00-10:00 scientific meeting
10:00-17:00 Lab. clean up

2016/04/24 East off Ogasawara Islands (29-42.0N, 146-58.8E)
Weather: Fine but cloudy / Wind direction: ESE / Wind force: 5 / Wave scale: 3 /Swell scale: 3 / Visibility: 8 mile (12:00 JST+1h)
Transit for YKDT F.F. point
08:00 scientific meeting
11:00-12:00 engine room tour
13:00-14:00 carried out seminar for crews
15:00-16:00 sampling party

2016/4/25 Off Boso (33-19.2N, 142-20.7E)
Weather: Fine but cloudy / Wind direction: ESE / Wind force: 5 / Wave scale: 3 /Swell scale: 3 / Visibility: 8 mile (12:00 JST+1h)
08:00 arrived at YKDT winch F.F.
08:00-08:10 scientific meeting
08:30-14:20 carried out YKDT winch F.F.
13:30-16:00 scientific meeting & seminar
14:30 left F.F. point for HARUMI pier
M.M. Put ship's clock aback 60' m for S.M.T. in J.S.T.

2016/4/26 Harumi pier
10:00 arrived at HARUMI Port
11:00 disembarked YOKOSUKA
finished YK16-01 cruise

3.3.2. 6K Dive

YK16-01 cruise operated the eight dives 6K#1459 to 6K#1466 in Sites A, C, and D (Fig. 3-3). The dive logs, related information and corrected samples, are confidential matters.

3.3.3. Multibeam Survey

Multi-narrow beam echo sounder (EM122, Kongsberg Maritime, Inc.) surveyed bathymetry and acoustic reflectivity of western Pacific, was powerful tool to seach the ferromanganese nodules during YK16-01. The track lines are shown in Fig. 1-1. The data are confidencial matters.

3.3.4. Magnetometers & Gravity Meter

During the YK16-01 cruise, geophysical surveys, whose items included were gravity and geomagnetics, were conducted aboard the R/V Yokosuka around Sites A, C, and D (Fig. 3-3). 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.

3.3.5. Acoustic Doppler Current Profiler

To investigate water current velocity above the two apparently different seafloor, Mn nodule field (MA-1; Fig. 3-3) and sediment with few Mn nodules on abyssal plain (MA-2; Fig. 3-4), we deploied two acoustic doppler current profiler (ADCP) system. The measurement system will be retrieved in November 2016 by R/V Mirai cruise and hopefully deployed another place during the cruise.

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.