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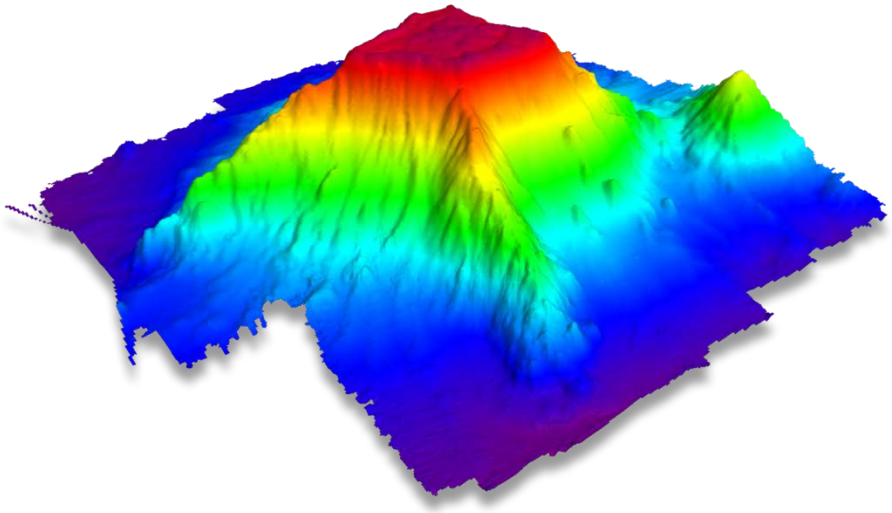
R/V Kairei Cruise Report

KR17-07C

Investigation of hydrothermal deposits and hydrogenetic ferromanganese crusts on "The Scientific Research of Cause of Formation of Marine Mineral Resources"

April 23, 2017 – May 1, 2017

Takuyo-Daisan Seamount



Japan Agency for Marine-Earth Science and Technology
Kochi University
Ibaraki University
Tsukuba University

Contents

1. Cruise Information

- Cruise ID: KR17-07C
- Name of vessel: R/V Kairei
- Cruise period: 2017/04/23-2017/05/01
- Departure / arrival: JAMSTEC at Yokosuka – JAMSTEC at Yokosuka
- Research area: Takuyo-Daisan Seamount
- Research Map

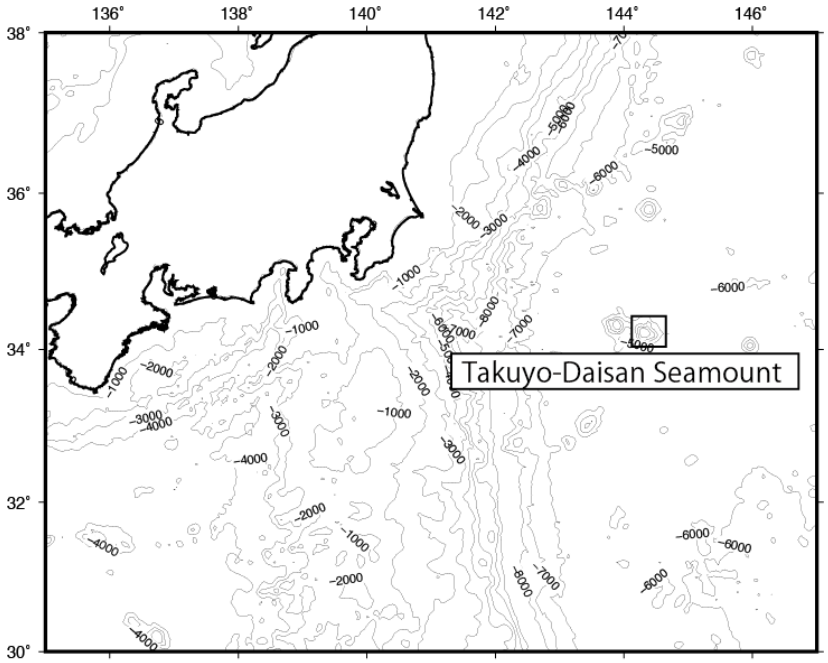


Fig. 1. Location of Takuyo-Daisan Seamount.

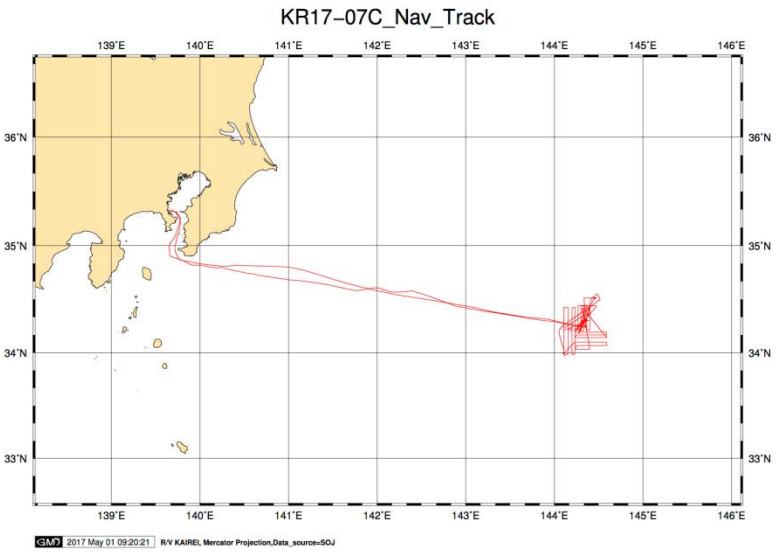


Fig. 2. Navigation track of this cruise.

- R/V KAIREI CREW

Captain	TAKAFUMI AOKI
Chief Officer	TATSUO ADACHI
2nd Officer	TAKESHI MURAMATSU
3rd Officer	YUKI ITO
Jr.3rd Officer	HAYATO OOMOTE
Chief Engineer	MINORU TSUKADA
1st Engineer	TAKASHI OTA
2nd Engineer	YOSHINOBU HIRATSUKA
3rd Engineer	YUNA KAINO
Chief Electronics Operator	HIROYASU SAITAKE
2nd Electronics Operator	TOSHIHIKO YUASA
3rd Electronics Operator	RYUJI ONIKUBO
Jr.3rd Electronics Operator	KAZUMI UGAJIN
Boat Swain	KAZUO ABE
Quarter Master	YASUO KONNO
Quarter Master	SHUICHI YAMAMOTO
Quarter Master	YOSHIAKI MATSUO
Quarter Master	DAISUKE YANAGITANI
Sailor	OSAMU MARUO
Sailor	TAKUMI MIURA
No.1 Oiler	JUNJI MORI
Oiler	RYOTA SUZUKI
Oiler	MASAKI TANAKA
Oiler	TAKUYA WATANABE
Oiler	DAIKI SATO
Assistant Oiler	KOUSEI AKIBA
Chief Steward	KAZUHIRO HIRAYAMA
Steward	HIDEO FUKUMURA
Steward	JUN SATO
Steward	SHINOBU OHYU
Steward	KOKI SHINOHARA

- Kaiko Mk-VI Operation Team

Submersible Op. Manager	HOMARE WAKAMATSU
2/Submersible Tec. Officer	TOMOE KONDO
2/Submersible Tec. Officer	KIYOSHI TAKISHITA
2/Submersible Tec. Officer	SEIJI SHIGETAKE
2/Submersible Tec. Officer	SHOTA IHARA
2/Submersible Tec. Officer	KEN YATSU
2/Submersible Tec. Officer	TAKUMA GOTO

2. Researchers

- Title of the cruise: Investigation of hydrothermal deposits and hydrogenetic ferromanganese crusts on "The Scientific Research of Cause of Formation of Marine Mineral Resources"
- Chief scientist: Shingo Kato [JAMSTEC]
- Representative of the science party: Eiichi Kikawa [JAMSTEC]
- Science party on board

SHINGO KATO	Japan Agency for Marine-Earth Science and Technology
HIROSHI AMAKAWA	Japan Agency for Marine-Earth Science and Technology
SATOSHI TOKESHI	Japan Agency for Marine-Earth Science and Technology
YUSUKE FUKAMI	Japan Agency for Marine-Earth Science and Technology
SAKIKO KIKUCHI	Japan Agency for Marine-Earth Science and Technology
AKIRA USUI	Kochi University
DAIKI SUZUSHIMA	Kochi University
YURIKO YAMAUCHI	Kochi University
ANNA NAGAOKA	Kochi University
GO-ICHIRO URAMOTO	Kochi University
TAKASHI ITO	Ibaraki University
MASAKI SAITO	Ibaraki University
KOHEI SEKI	Ibaraki University
JUNPEI INAGAKI	Tsukuba University
TOSHIMASA NASU	Nippon Marine Enterprises, LTD

3. Observation

3.1. Overview of the observation

Ferromanganese crusts, which cover basal rocks such as basalt and limestone, are widely distributed on the slope of flat-top seamounts (guyots) in the northwest Pacific (e.g., Usui et al., 2016). The ferromanganese crusts have been paid attention as potential of mineral resources containing Co, Ni, Pt and REE. Previously, systematic sampling of crusts using a remotely operated vehicle (ROV) has been performed at the water depth of 5500 m or shallower on the Takuyo-Daigo Seamount as a model seamount for crust research, indicating that thick ferromanganese crusts are generally present at outcrops on the slope of the seamount. Geological, geochemical and microbiological analyses of the crusts have shown some trends along water depths. It is hypothesized that these trends are common for ferromanganese crusts in the northwest Pacific. To assess this hypothesis, more data accumulation from other seamounts are needed.

The Takuyo-Daisan Seamount is a guyot located near the main island of Japan. Ferromanganese crusts have been found on the seamount by previous investigations using dredges. However, little is known about the details of the ferromanganese crusts such as spatial distribution, thickness, and geochemical and microbiological characteristics due to lacking of systematic sampling using a ROV. In this cruise (KR17-07C), ferromanganese crusts were found along water depths ranged from 1400 m to 5500 m in the Takuyo-Daisan Seamount. A number of crust samples were successfully collected using the ROV *Kaiko Mk-IV*. Surrounding sediments and bottom seawater were also collected as references. In addition, electromagnetic velocity meters and in situ colonization-absorption instruments were deployed at each depth. Dissolved oxygen concentration, pH, temperature and salinity were measured using sensors equipped with the ROV during each dive. Multidisciplinary analyses (including geological, mineralogical, geochemical, and microbiological approaches) of the collected samples will help us to understand the cause of formation of the ferromanganese crusts. Although we had planed to investigate a hydrothermal field of the Bayonnaise Knoll in this cruise, we abandoned it due to a warning of a volcanic eruption around this field.

3.2 Seafloor observation and sampling

A. Usui, G. Uramoto, Y. Yamauchi, D. Suzushima, A. Nagaoka (Kochi Univ.),
T. Ito, M. Saito, K. Seki (Ibaraki Univ.)

During the five dives (dive #743 to #747), we observed occurrence of hydrogenetic ferromanganese crusts and nodules at various depths through the Northern Ridge of the Takuyo-Daisan seamount. Dive #743 was conducted at shallow part of the Northern Ridge to flat plain of the Takuyo-Daisan seamount between 1842 m and 1412 m in water depth. The main bottom surfaces were rock, gravels and sediments. The degree of roughness of rock surface was poor commonly. Many rocks and gravels are

coated with manganese oxide. Many manganese crusts are broken secondary and made slab and debris. Whitish basement rocks (limestone or phosphatized limestone) exposed without manganese oxide coating. During this dive, 11 manganese crust samples were collected. The Mn-oxide thickness of most of the crusts is 5 to 60 mm. Basements of the crusts show variety in rock type, i.e. basalt, rudist fossil, limestone and phosphatized limestone.

Dive #744 was conducted at the Northern Slope of the Takuyo-Daisan seamount between 3199 m and 3137 m in water depth. The main surface is sediments and rock. All rocks are coated with manganese oxide without remark of broken and secondary movement of manganese crusts. During this dive, three manganese crust samples were collected. All crusts have very thick oxide layers of 60 - 130 mm.

Dive #745 was conducted at the Northern Slope of the Takuyo-Daisan seamount between water depth 4290 m and 4282 m. The main bottom surface was rock with smooth and flat surface coated with manganese oxide. In this dive, four manganese crust samples were collected. The thickness of the manganese oxides is 25 - 55 mm. The basement rocks are weathered volcanic rocks.

Dive #746 was conducted at the Northern Slope of the Takuyo-Daisan seamount between 5515 m and 5425 m in water depth. The main surfaces are rocks, gravels and sediments with current ripples. All rocks and gravels are coated with manganese oxide. Limited numbers of manganese nodules are distributed on the sediment surfaces. During this dive, three manganese crusts were taken. The oxide thickness varies from 12 to 50 mm. All crusts have weathered volcanic rock as substrate. In addition, approximately 10 cm long sediment was taken by push corer at the depth 5515 m. Lithology of the sediment is clayey sand and some of sand-sized fractions are comprised by manganese micronodules. Siliceous microfossils including diatoms are also observed by smear slide analysis, suggesting that age of sediment sample can be determined by using such microfossil assemblages.

Dive #747 was conducted at the Northern Slope of the Takuyo-Daisan seamount between 2794 m and 2487 m in water depth. The main bottom surfaces were rock and sediments. All rocks are coated with manganese oxide. Many manganese nodules with various size occur on sediments. Totally six manganese crust samples were taken during this dive. The thickness of manganese oxide is 30 to 95 mm. The basement rocks consist of weathered volcanic rock.

We plan to analyze the rock and sediment samples in collaboration with SIP/JAMSTEC and share the data and progress of analysis and related data if appropriate. Most of samples will be archived in refrigerator at Kochi Core Center, Kochi University.

3.3. Water depth profile of seawater

H. Amakawa and S. Kato (JAMSTEC)

Water depth profile of temperature, salinity, dissolved oxygen (DO) concentration and pH was determined using a combined sensor (Fig. 3). Preliminary representative results were shown in Fig. 4.

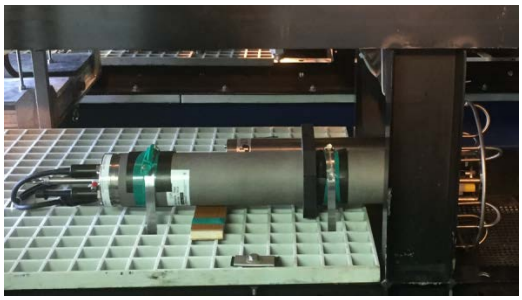


Fig. 3. Photo of the CTD-DO-pH sensor.

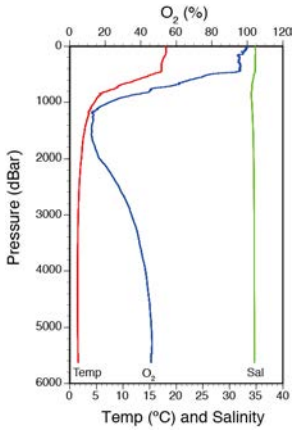


Fig. 4. Water depth profile of temperature and O_2 for the Takuyo-Daisan Seamount (Dive#746).

3.4. in situ adsorption and incubation experiments using Fe/Mn (oxyhydr)oxides

S. Kikuchi, T. Kashiwabara, S. Kato, S. Tokeshi, K. Fukami, Y. Amakawa (JAMSTEC), J. Inagaki (Tsukuba Univ.)

Marine ferromanganese crusts have gained attention as potential future resources for a variety of elements such as rare earth elements, Co, and Te. However, mechanisms of their formation on the deep-sea seafloor and the enrichment of trace elements from seawater are still unclear. The purpose of our project is to understand chemical/biological reactions at the seawater/ferromanganese oxide interface responsible for incorporation of trace elements.

In this cruse, we have set up in situ adsorption and incubation experimental systems called “HOSHIGAKI” on slopes of five water depths (Table 1). The HOSHIGAKI consists of titanium frame hanging acrylic cells which entrapping various minerals. This system allows us to examine ongoing chemical/biological reactions on each surface of constituent minerals with modern seawater. We also have placed electromagnetic current direction and velocity profiler near HOSHIGAKI to estimate the total volume of specific elements passed by them. In the next cruise, we are planning to collect these instruments to investigate adsorption reactions of trace elements and microbial communities on each constituent mineral under different water depth, which may lead to explain the enrichment of elements into natural ferromanganese crusts.

Table 1. Location for in situ adsorption and incubation experiments

Dive No.	Instrument	Water depth	Latitude	Longitude
#743	HOSHIGAKI L	1483 m	34-14.6464N	144-18.4952E
#743	HOSHIGAKI S	1483 m	34-14.6464N	144-18.4952E
#743	Current direction and velocity profiler	1483 m	34-14.6464N	144-18.4952E
#744	HOSHIGAKI L	3202 m	34-19.3634N	144-20.3056E
#744	HOSHIGAKI S	3202 m	34-19.3634N	144-20.3056E
#744	Current direction and velocity profiler	3202 m	34-19.3634N	144-20.3056E
#745	HOSHIGAKI L	4290 m	34-22.4755N	144-21.2949E
#745	HOSHIGAKI S	4290 m	34-22.4755N	144-21.2949E
#745	Current direction and velocity profiler	4290 m	34-22.4755N	144-21.2949E
#746	HOSHIGAKI L	5514 m	34-24.5925N	144-23.1735E
#746	HOSHIGAKI S	5514 m	34-24.5925N	144-23.1735E
#746	Current direction and velocity profiler	5514 m	34-24.5925N	144-23.1735E
#747	HOSHIGAKI L	2753 m	34-17.9038N	144-20.6424E
#747	HOSHIGAKI S-1	2753 m	34-17.9038N	144-20.6424E
#747	HOSHIGAKI S-2	2753 m	34-17.9038N	144-20.6424E

3.5. Geochemical analysis and dating of crusts

S. Tokeshi, Y. Fukami, H. Amakawa, T. Kashiwabara (JAMSTEC),
A. Usui (Kochi Univ.), T. Itoh (Ibaraki Univ.)

The ferromanganese crusts have been considered to be chemical precipitates that mostly consist of Fe and Mn oxide and hydroxide minerals (e.g. Hein et al., 2000). The continuous accumulation of elements from ambient seawater makes the ferromanganese crusts suitable as archives for the isotopic composition of the present seawater (Amakawa et al., 2017). In addition, they preserve the record of seawater chemical compositions over millions of years (Frank, 2002). It is thus essential to get the geochemical record from the ferromanganese crust samples, in order to understand the elemental source of ocean, the accumulation mechanism, and environmental and oceanographic conditions of the past.

The ferromanganese crusts sampled from the Takuyo-Daisan seamount will be sliced parallel to the basement at several-mm intervals up to the crust surface, and be subsequently pulverized by a mortar to decipher the geochemical record in the samples. We have planned to determine major, trace elements

(ppm to ppb orders such as highly siderophile elements), and radiogenic and stable isotopic compositions for the each surface and slice powders of the ferromanganese crusts and basements. Relative date for the sliced crust samples is estimated by fitting their 187Os/188Os ratio to a secular variation of marine Os isotopic compositions (Klemm et al., 2005). 10Be/9Be dating will be also determined for the crust samples. In future, we will determine geochemical signatures for the several minerals in the HOSHIGAKI-cells after colleting the HOSHIGAKI units deployed on the Takuyo-Daisan seamount in this cruise.

3.6. Mineral-microbiological analysis of nanoparticles in seawater

G. Uramoto (Kochi Univ.) and S. Kato (JAMSTEC)

It has been considered that precipitation of ferromanganese minerals from seawater is one of important mechanisms for formation of Mn crusts on seafloor. However, formative processes of ferromanganese (micro-)particles in seawater is still unclear. In order to examine the origin of component minerals of Mn crusts, in this cruise, the suitability of the application of the tangential flow filtration system for the separation of mineral (micro-)particles in seawater was examined. Approximately 1 litter of seawater, that were taken from just above the seafloor using NISKIN bottle samplers, was processed and approximately 20 ml of filtered water was obtained using Vivaflow 50 cassette (Sartorious, Germany) for subsequent processing by density concentration using heavy metal solution, and mineral analyses by electron microscopy and X-ray micro-computed tomography.

3.7. Microbiological analysis

S. Kato (JAMSTEC)

Our previous studies have shown that microbes are rich and phylogenetically diverse on Mn crusts collected from the Takuyo-Daigo Seamount, Ryusei Seamount, and Daito Ridge (Nitaraha et al., 2011; Nitaraha et al., 2017). However, it is still unclear whether such microbiological characteristics are general or specific. To this end, in this cruise, we collect Mn crusts for DNA/RNA analyses, microscopy and cultivation, and also collect surrounding sediments and seawater as references. Furthermore, to reveal what microbes are initially attached to basement rocks and whether and how the microbes contribute to trigger the formation of Mn crusts, we deployed in situ colonization devices on the seafloor, which will be recovered after a year or later. The microbiological analyses/experiments will provide insights into mechanism of formation of Mn crusts.

Samples of Mn crusts were collected at water depths ranged from 1500 m to 5500 m (Table 2). To minimize microbial contaminations from surface seawater when we brought Mn crust samples from the seafloor and deployed *in situ* colonization devices to the seafloor, we used a sealable “biobox” made of aluminum with a 0.2-um-pore-size membrane filter unit to balance internal pressure (Fig. 5). The

collected Mn crusts were trapped in the biobox on the seafloor. We collected sediments using a push-core sampler and bottom seawater using NISKIN bottle samplers (6 L) equipped with the ROV around the sampling points of the Mn crusts as references.

Table 2. Sample list for microbiological analysis

Dive #	Date	Latitude	Longitude	Depth (m)	Sample name	Sample
#743	2017/4/23	34-15.0081N	144-18.7978E	1839	W1	Seawater
		34-14.6464N	144-18.4952E	1483	R6,R7	Mn crust
#744	2017/4/24	34-19.4217N	144-20.3294E	3198	W1	Seawater
		34-19.4217N	144-20.3294E	3199	C1	Sediment
		34-19.3565N	144-20.3089E	3200	R1	Mn crust
#745	2017/4/25	34-22.4755N	144-21.2949E	4287	W1	Seawater
		34-22.4717N	144-21.3046E	4290	R1	Mn crust
#746	2017/4/27	34-24.5925N	144-23.1735E	5514	C1	Sediment
		34-24.4424N	144-23.1699E	5507	R1	Mn crust
#747	2017/4/28	34-17.9456N	144-20.6898E	2792	W2	Seawater
		34-17.8758N	144-20.6242E	2748	R1	Mn crust

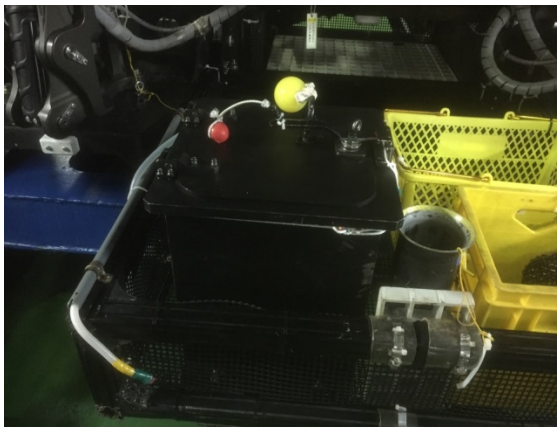


Fig. 5. Biobox equipped with the ROV *Kaiko Mk-IV*.

Microbes in the seawater (approx. 6 L) were collected on 0.2 μm-pore-size membrane filters by filtration. The Mn crusts were crashed into small pieces by a sterile hummer and chisel in a clean booth. The filters and subsamples of Mn crusts and sediments were stored at -80ºC for DNA/RNA analysis. For cultivation, some subsamples were stored in glass bottles filled with filtered seawater at 4ºC. Stable isotope tracer experiments were performed to show metabolic activity of microbes on board. The other pieces of the samples were fixed with formalin or glutaraldehyde at 4ºC for microscopy.

3.8. Cruise log

日付 Date	時間 Local Time	内容 Note	特記事項 Description	本船位置／気象／海象 Position/Weather/Wind/Sea condition
23-Apr-17		**Scientists onboard.**		12:00 (UTC+10h)
	08:00	Scientists onboard.		OFF South NOJIMAZAKI
	09:00	Let go all shore lines & left YOKOSUKA for Research area.		34-51.0N,139-50.7E
	09:40-10:20	Carried out Shipboard education & traning for scientist.		Fine but coudy
	11:00-11:30	KAIKO team briefing.		NNE-4 Moderate breeze
	13:00-14:00	Scientists meeting.		2 Light breeze
	18:00-18:30	Scientists meeting.		2 Sea smooth
				Visibly: 8'
24-Apr-17		**KAIKO Mk-IV Dive#743.**		12:00 (UTC+10h)
	04:30	Arrived at research area.	Area = Takuyo Daisan Kaizan	Takuyo Daisan Kaizan
	05:08	Released XBT.	34-14.5775N,144-21.5305E	34-14.9N,144-18.7E
	05:34-05:54	Carried out MBES site survey.		Cloudy
	08:32	Hoisted up "KAIKO Mk-IV".		NNE-5 Fresh breeze
	08:37	Launched "KAIKO Mk-IV" then it dove & Com'ced her operation.	Dive No.743	4 Sea moderate
	10:19	"KAIKO Mk-IV" landed on the sea bottom.	Depth = 1,842m	3 Moderate short
	14:44	"KAIKO Mk-IV" left the sea bottom.	Depth = 1,412m	Visibly: 8'
	15:56	Hoisted up "KAIKO Mk-IV".		
	16:07	Recovered "KAIKO Mk-IV" & finished the operation.		
	17:25	Com'ced MBES mapping survey & SBP survey.		
	18:00-18:30	Scientists meeting.		
25-Apr-17		**KAIKO Mk-IV Dive#744.**		12:00 (UTC+10h)
	03:52	Finished MBES mapping survey & SBP survey.		Takuyo Daisan Kaizan
	08:52	Hoisted up "KAIKO Mk-IV".		34-19.5N,144-20.4E
	08:58	Launched "KAIKO Mk-IV" then it dove & Com'ced her operation.	Dive No.744	Cloudy
	11:16	"KAIKO Mk-IV" landed on the sea bottom.	Depth = 3,199m	ESE-4 Moderate breeze
	14:00	"KAIKO Mk-IV" left the sea bottom.	Depth = 3,131m	2 Sea smooth
	16:03	Hoisted up "KAIKO Mk-IV".		2 Low swell long
	16:11	Recovered "KAIKO Mk-IV" & finished the operation.		Visibly: 8'
	17:39	Com'ced MBES mapping survey & SBP survey.		
	18:00-18:30	Scientists meeting.		
26-Apr-17		**KAIKO Mk-IV Dive#745.**		12:00 (UTC+10h)
	00:16	Finished MBES mapping survey & SBP survey.		Takuyo Daisan Kaizan
	02:18-02:40	Carried out eight figure running.		34-22.3N,144-21.4E
	07:33	Hoisted up "KAIKO Mk-IV".		Over cast
	07:38	Launched "KAIKO Mk-IV" then it dove & Com'ced her operation.	Dive No.745	South-6 Strong breeze
	10:12	"KAIKO Mk-IV" landed on the sea bottom.	Depth = 4,290m	4 Sea moderate
	11:41	"KAIKO Mk-IV" left the sea bottom.	Depth = 4,282m	3 Moderate short
	13:56	Hoisted up "KAIKO Mk-IV".		Visibly: 8'
	14:04	Recovered "KAIKO Mk-IV" & finished the operation.		
	16:14	Com'ced MBES mapping survey & SBP survey.		
	18:00-19:00	Scientists meeting.		
27-Apr-17		**Suspended KAIKO MK-IV diving operation.**		12:00 (UTC+10h)
	00:23	Finished MBES mapping survey & SBP survey.		Takuyo Daisan Kaizan
	09:00-10:00	Scientists meeting.		34-05.0N,144-14.0E
	10:30	Suspended KAIKO MK-IV diving operation, due to rough sea.		Rain
	10:58	Com'ced MBES mapping survey & SBP survey.		North-6 Strong breeze
	12:41	Released XBT.	33-59.5283N,144-13.7891E	4 Sea moderate
	13:00-14:00	Scientists meeting.		4 Moderate average
	18:12	Finished MBES mapping survey & SBP survey.		Visibly: 2'
	18:00-18:15	Scientists meeting.		
28-Apr-17		**KAIKO Mk-IV Dive#746.**		12:00 (UTC+10h)
	07:31	Hoisted up "KAIKO Mk-IV".		Takuyo Daisan Kaizan
	07:37	Launched "KAIKO Mk-IV" then it dove & Com'ced her operation.	Dive No.746	34-05.0N,144-14.0E
	10:30	"KAIKO Mk-IV" landed on the sea bottom.	Depth = 5,514m	Rain
	13:28	"KAIKO Mk-IV" left the sea bottom.	Depth = 5,425m	North-6 Strong breeze
	14:30-15:45	Scientists meeting.		4 Sea moderate
	16:08	Hoisted up "KAIKO Mk-IV".		4 Moderate average
	16:16	Recovered "KAIKO Mk-IV" & finished the operation.		Visibly: 2'
	18:00-18:30	Scientists meeting.		
	18:25	Com'ced MBES mapping survey & SBP survey.		
	20:04-20:25	Carried out eight figure running.		
29-Apr-17		**KAIKO Mk-IV Dive#747.**		12:00 (UTC+10h)
	02:45	Finished MBES mapping survey & SBP survey.		Takuyo Daisan Kaizan
	08:30	Hoisted up "KAIKO Mk-IV".		34-17.9N,144-20.5E
	08:34	Launched "KAIKO Mk-IV" then it dove & Com'ced her operation.	Dive No.747	Blue sky
	10:37	"KAIKO Mk-IV" landed on the sea bottom.	Depth = 2,794m	WSW-5 Fresh breeze
	14:18	"KAIKO Mk-IV" left the sea bottom.	Depth = 2,487m	3 Sea slight
	16:02	Hoisted up "KAIKO Mk-IV".		2 Low swell long
	16:09	Recovered "KAIKO Mk-IV" & finished the operation.		Visibly: 8'
		Com'ced MBES mapping survey & SBP survey.		
	18:30-19:00	Scientists meeting.		
	21:40	Finished MBES mapping survey & SBP survey.		
	21:45	Left research area for YOKOSUKA.		
30-Apr-17		**Proceeded to YOKOSUKA.**		12:00 (UTC+10h)
	09:00	Scientists meeting.		OFF South-East NOJIMAZAKI
	15:20	Let go anchor , arrived at off YOKOSUKA.		34-49.7N,140-00.4E
	18:00-19:00	Scientists meeting.		Fine but cloudy
				SSW-5 Fresh breeze
				3 Sea slight
				2 Low swell long
				Visibly: 8'
1-May-17		**Arrived at YOKOSUKA.**		
	09:00	Sent out 1st shore line, arrived at YOKOSUKA,completed KR17-07C.		

3.9. Dive information

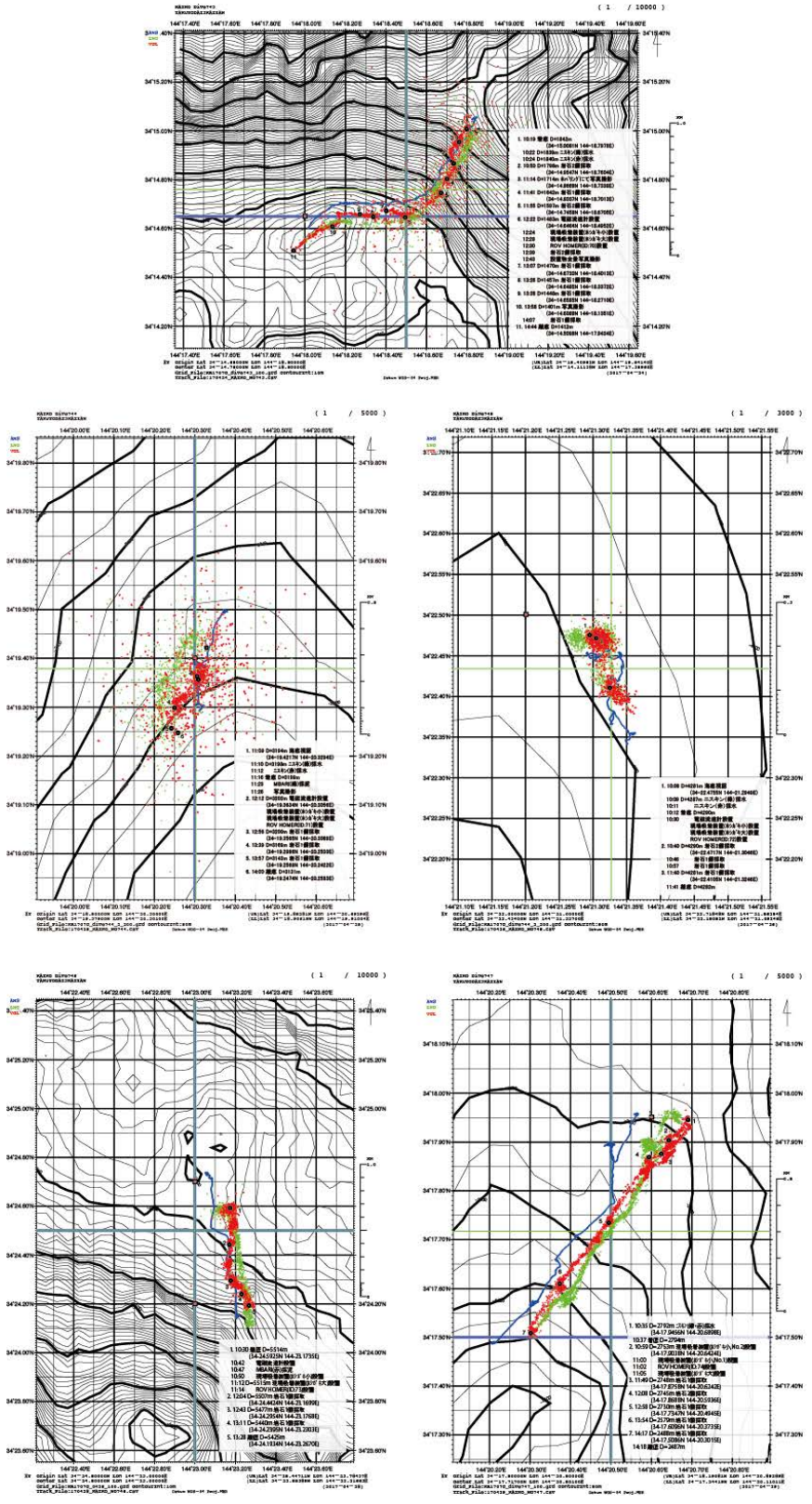


Fig. 6. Dive track for each dive.

Acknowledgement

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