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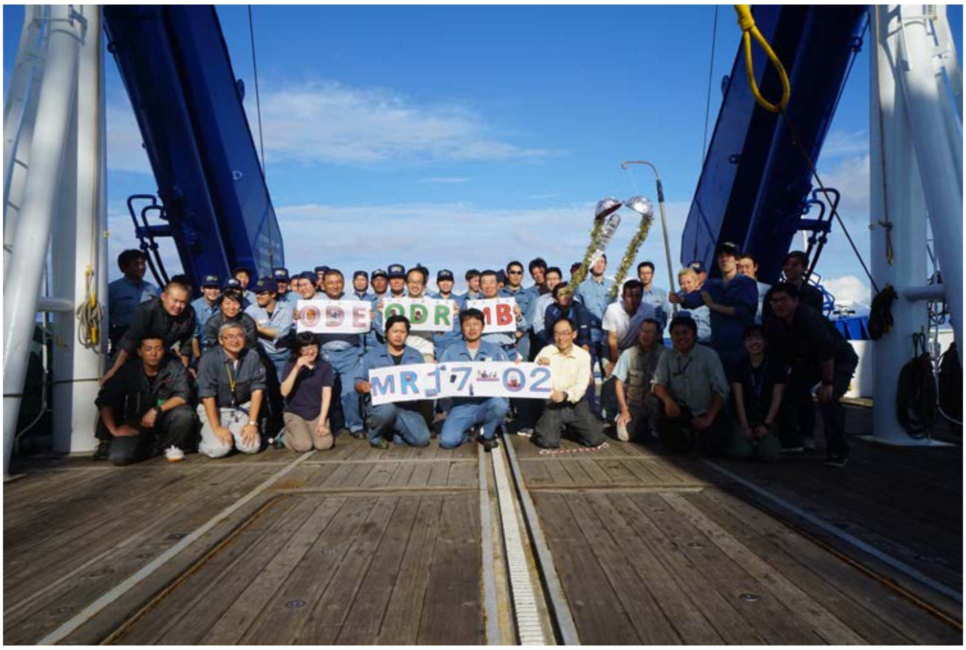
MIRAI Cruise Report

MR17-02

Tectonics leading to and following subduction initiation

Oki-Daito Ridge area

May 20 2017 – May 27, 2017
(Nakagusuku to Nakagusuku)
Japan Agency for Marine-Earth Science and Technology
(JAMSTEC)



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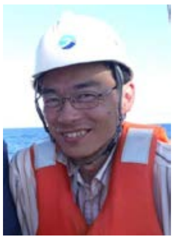

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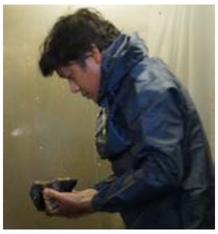

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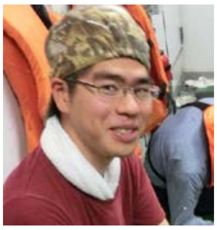
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1st Engineer	Jun	Takahashi
Jr.1st Engineer	Syuichi	Hashide
2nd Engineer	Kenta	Ikeguchi
3rd Engineer	Akihiro	Demura
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Boatswain	Yosuke	Kuwahara
Quarter Master	Kazuyoshi	Kudo
Quarter Master	Tsuyoshi	Sato
Quarter Master	Takeharu	Aisaka
Quarter Master	Tsuyoshi	Monzawa
Quarter Master	Shuji	Komata
Sailor	Hideyuki	Okubo
Sailor	Tetsuya	Sakamoto
Sailor	Yasunobu	Kawabe
Sailor	Shinya	Kojima
Sailor	Toshiya	Saga
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Oiler	Fumihito	Kaizuka
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We are grateful to Captain Haruhiko Inoue and the excellent crew of the Mirai, for their outstanding efforts to make this scientific program successful. We also thank JAMSTEC for their support of this project.

1. Cruise objectives

Title of the cruise/proposal:

Tectonics leading to and following subduction initiation

Robust tectonic reconstruction of the evolving Philippine Sea Plate for the period immediately before and after subduction initiation at ~52 Ma to form the Izu-Bonin-Mariana (IBM) arc is prerequisite to understand cause of subduction initiation (SI) and test competing hypotheses for SI such as spontaneous or induced nucleation. Understanding of nature and origin of overriding and subducting plates is especially important because plate density is a key parameter controlling SI based on numerical modeling (e.g., Leng and Gurnis 2015). There is increasing evidence that multiple geological events related to changing stress fields took place in and around Philippine Sea plate about the time of SI ~52 Ma (Ishizuka et al., 2011). For our understanding of the early IBM arc system to increase, it is important to understand the pattern and tempo of these geological events, particularly the duration and extent of seafloor spreading in the proto arc associated with SI, and its temporal relationship with spreading in the West Philippine Basin.

The MR17-02 cruise aimed to investigate origin and age of formation of ocean basins in and around the Daito Ridge group. Especially ocean basins which potentially existed in the period of SI to form the IBM arc were the major targets of this cruise, because ocean crust of these basins might be part of overriding plate when subduction of Pacific plate initiated to form IBM arc. Since gravitational instability between the neighboring plates is supposed to be a critical factor for subduction initiation, it is important to understand characteristics (age, origin, crustal structure) of overriding plate to test hypotheses of subduction initiation. Recovery and characterization of ocean crust of these basins will provide crucial information about the possible basement of the IBM arc and critical constraints to evaluate models for subduction initiation along the Pacific margin.

2. Geological background

2.1. Daito Ridge group and Kyushu-Palau Ridge

The Daito Ridges region is a complex array of ridges and basins (Fig. 1a,b). This comprises three remnant arcs: the Amami Plateau, the Daito and Oki-Daito Ridges, and two ocean basins among these ridges (the Kita-Daito and Minami-Daito Basins).

The Oki-Daito Ridge (Fig. 1a), which is one of the major target of this study, is WNW–ESE trending ridge characterised by crust ranging from 20 to 23 km in thickness, based on its seismic velocity structure (Nishizawa et al., 2014), and is supposed to be another Mesozoic remnant arc (Tani et al., 2012). Another important characteristics of the Oki-Daito Ridge is occurrence of extensive escarpment and lineament in NW-SE direction. Seismic experiments show that crustal thickness and seismic velocity structure significant change at the NW-SE escarpment along the Oki-Daito Ridge.

A wide bathymetric high west of the Oki-Daito Ridge is the Oki-Daito Rise, which partially overlaps the western part of the Oki-Daito Ridge (Fig. 1a). The rise is characterised by much thinner crust (10–15 km) compared to the Oki-Daito Ridge, and occurrence of basalts with ocean-island basalt (OIB)–like geochemical characteristics with an age range between 40 and 44 Ma (Ishizuka et al., 2013).

Remnant arc terranes of the Daito Ridges region are divided by intervening basins of the Kita-Daito and Minami-Daito Basins (Fig. 1a,b). The Kita-Daito Basin, separating the Amami Plateau and the Daito Ridge, has a thin crust of 4 to 6 km based on seismic structure (Nishizawa et al., 2013). Nishizawa et al. (2014) inferred that this basin could be a backarc ocean crust. The Minami-Daito Basin, located between the Daito and Oki-Daito Ridges, has abundant bathymetric highs, and has a crust of 7 – 10 km thick (Nishizawa et al., 2014). Deep Sea Drilling Project (DSDP) at Site 446 in the western part of the basin and shallow drilling at a seamount in the basin recovered basalts which clearly have OIB–like geochemical characteristics (Hickey-Vargas, 1998 ; Ishizuka et al., 2013). These basalts show $^{40}Ar/^{39}Ar$ ages of 43 – 51 Ma. Age of formation of the Kita-Daito and Minami-Daito Basin has not been known.

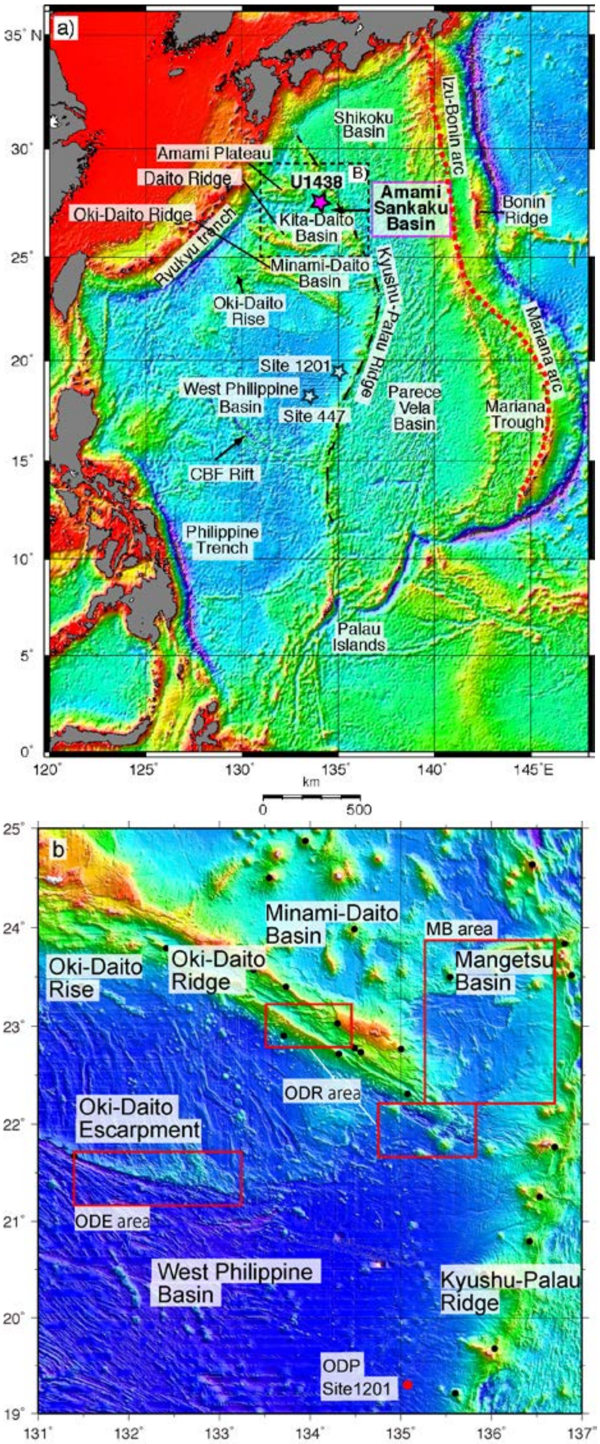

Fig.1a Map of Philippine Sea Plate with major tectonic features. b. Survey area of MR17-02 cruise.

Oki-Daito Escarpment (ODE) is a major tectonic lineament in the northern WPB. The trend of abyssal hills of the WPB is discontinuous across this escarpment. WNW-ESE, while trend is close to NNW-SSE to N-S. This implies that the basin north of

ODE has different spreading history from other part of the WPB. Hilde and Lee (1984) interpreted magnetic anomaly data of the basin, and insisted that this part of the basin could correspond to the oldest part of the WPB, but Deschamps and Lallemand (2002) considered that interpretation of magnetic anomaly of this part the basin is highly questionable. No reliable age constraints have been obtained from this part of the basin.

Mangetsu Basin is bounded by KPR in its eastern margin, and by Oki-Daito Ridge in its western margin (Fig. 1b). There are abyssal hill-like NNW-SSE-trending ridges in this basin. Eastern part of the basin shows smooth seafloor, which strongly implies that this part of the basin has been covered with sediment shed from KPR. The trend of abyssal hill suggests that spreading axis was subparallel to the KPR. However, since no rocks from this basin have been recovered, age and origin of this basin remains unknown.

2.2. IODP Exp. 351 in the Amami Sankaku Basin (ASB)

IODP Exp. 351 was conducted to recover detailed geological information when subduction initiated as well as basement of Izu-Bonin-Mariana arc (Fig. 1a).

Drill site of Exp. 351 is located in Amami Sankaku Basin (ASB) which corresponds to the reararc area of Kyushu-Palau Ridge, i.e., reararc of ancient Izu-Bonin-Mariana arc.

The Kyushu-Palau Ridge is a remnant arc separated from the IBM arc by backarc spreading of Shikoku and Parece-Vela Basins initiated at c. 25 Ma. West of the drill site is Mesozoic arc terrane of Daito Ridge group. Igneous basement of this drill site could correspond to basement of the Izu-Bonin-Mariana arc.

Igneous basement of this drill site consists of basaltic lava flows. The ASB basalts and the FAB from the IBM forearc share geochemical characteristics. The ASB basalts have lower Ti/V compared to MORB and most of the younger Philippine Sea ocean crust. This is one of the important geochemical characteristics of FAB, possibly due to melting at higher oxygen fugacity condition than MORB. Primitive mantle normalised spidergrams indicate that basement basalts show significant depletion in LREE and highly-incompatible elements. This characteristics is remarkably similar to that of forearc basalt from IBM arc.

Age of the basement basalt was determined by ArAr dating. Several samples from different level of the basement gave well-defined and consistent ages of Middle Eocene. This age of basaltic crust overlaps with the age range of forearc basalt (c. 52-48 Ma) of the IBM arc, i.e., period of seafloor spreading associated with subduction initiation.

Based on this age constraints and geochemical similarity of the basement basalts to forearc basalts, we proposed tectonic model for the period of subduction initiation of the IBM arc. One of the key feature of this model is, based on the possible wide distribution of "forearc basalt" type magmatism, the area affected by seafloor spreading associated with subduction initiation is supposed to be wider than previously expected, which means spanning from forearc to reararc area of the future IBM arc. In this scenario, most of the IBM arc volcanoes formed on ocean crust which formed at subduction initiation.

3. Methods

To accomplish our scientific goal described above, we conducted 1)bathymetric mapping, 2)geomagnetic and gravity survey, 3)dredge sampling using research vessel. Detailed description of methods and results are described in the following sections. Ship track during this cruise is shown in Fig. 2.

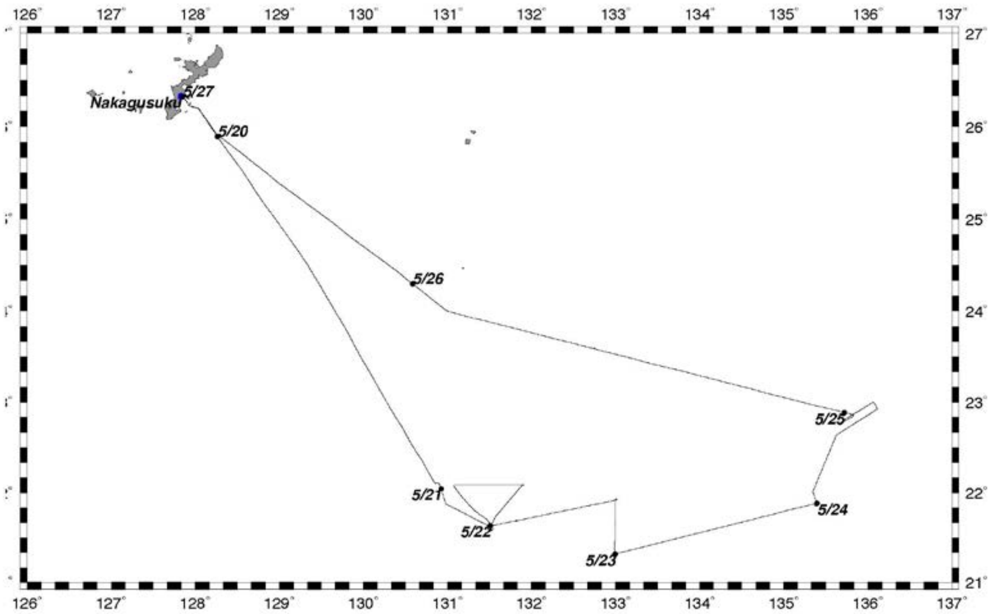

Fig.2 Ship track during MR17-02 cruise.

4.Operations and data processing information

Data and samples from the dredge operation and geophysical survey were archived as customary. Brief sample descriptions are included in Section 5. Samples distributed to the scientific party are listed in Appendix A. Standard data products were provided to the shipboard scientific party.

5. Dredge sampling results

We accomplished dredge sampling at 4 stations in total (Fig. 3, Table 1: 2 sites in Oki-Daito Escarpment (ODE) area (D01, D02), 1 site in Oki-Daito Ridge (ODR) area (D03, D04), and 1 site in Mangetsu Basin (MB) area (D05).

D01: This dredge was conducted on the steep escarpment of Oki-Daito Escarpment at 131°30.6'E. This part of escarpment has a relief of 900m. This dredge started around 6200m deep and climbed the steep slope to top of the escarpment at around 5350m. Small bites up to about 1 ton were consistently observed along the track of the dredge.

Total 128 kg of samples were recovered. Major rock types are aphyric basalt, ol basalt and microgabbro, which mostly occur as angular to subangular clast of conglomerate with matrix of silt. Some basalt clasts have altered chilled margin. These samples are expected to represent ocean crust of northern most part of the West Philippine Basin.

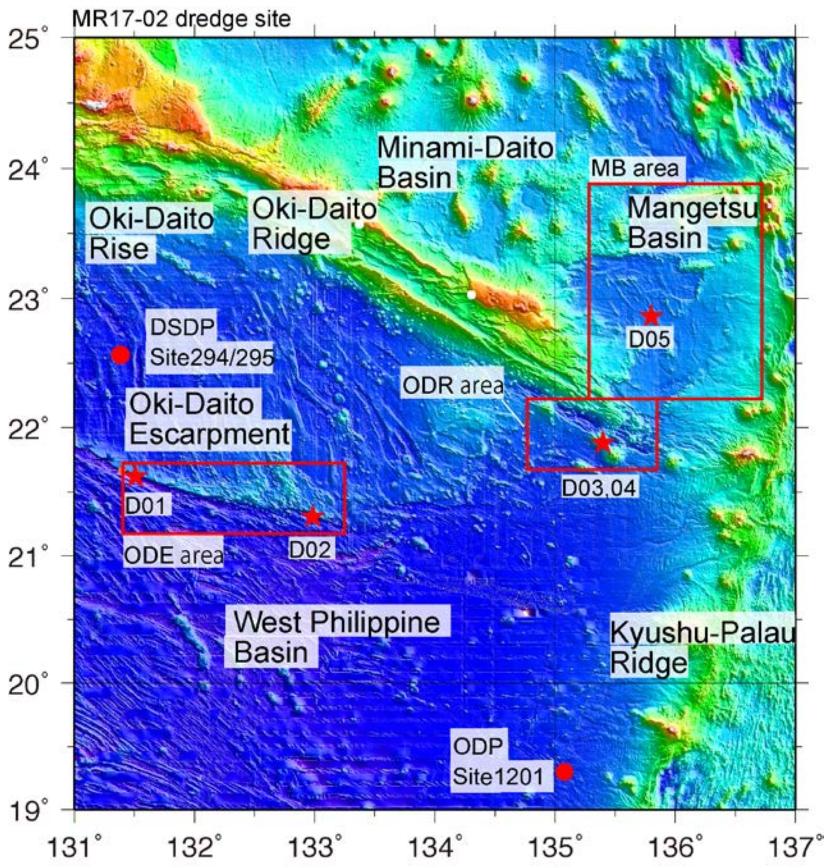

Fig.3 Dredge sampling stations during MR17-02 cruise.

D02: This dredge haul was placed on the steep slope of Oki-Daito Escarpment 160km ESE of D01 site. At this dredge haul, the relief of the escarpment is around 500m. In this area, the escarpment mainly transects broad volcanic zone with abundant small volcanic edifices. However, the dredge site itself appears to correspond to one of the abyssal hills of the northern part of the West Philippine Basin.

The dredge started on a gentle slope at around 5800 m deep. In the earlier part of the dredge, only a few bites were observed. But in the later half of the dredge on the steepest part of the slope, there were many bites up to around 2 tons. Total weight of the recovered samples was 95.7kg. Most of the recovered samples are Mn-oxides nodule of less than several cm in diameter. Subordinate amount of Mn-oxides crusts were recovered. Some of them have substrate with them. Most of the substrate are mudstone, however, one sample (R03) has substrate of aphyric basalt. Three shark teeth were also recovered. These teeth have Mn-oxides crust, and probably derived from an extinct spieces thrived in Miocene (Calcalodon, Megalodon).

D03: This dredge haul was conducted at a seamount SE of Oki-Daito Ridge. This seamount is transected and offset by NW-SE trending faults. This dredge aimed to collect igneous rock samples from the fault scarp of this seamount to obtain age constraint on the formation of the NW-SE trending fault system, and age and origin of magmatism which formed this seamount.

The dredge landed at the foot of a fault scarp at around 5080 m deep and climbed up the scarp. In the earlier part of the dredge, no bite was observed. After the dredger was landed again, many bites were observed (max 2.6t). After recovery, it was found that the fuse was broken, and the dredger was empty. Only mud with Min-oxides was found in the spaces between the plates of the dredger.

D04: Since D03 failed to recover rock samples, D04 was conducted at the same site as D03. We used cylindrical dredge this time. Again there are many bites in the upper slope. The bites were adjusted not to exceed 6 ton (baseline is around 4.5 ton). This time, total 29 kg of samples were recovered. Blocks of lapilli stone, and fragment of volcanic sandstone were mainly recovered. Lapilli stone is mainly composed of ol basalt with subordinate amount of pl and cpx phenocrysts. Some clasts have chilled margin. Small number of Mn-oxides crusts were also recovered.

D05: This dredge haul was conducted on a NNW-SSE-trending ridge in the Mangetsu Basin, west of Kyushu-Palau Ridge. Relative height of this ridge is around 400m, and it shows asymmetric feature, i.e., its western slope is much steeper than the eastern slope. This might imply that this ridge is a tilted block formed by rifting. The dredge was conducted on the western slope of the ridge. There are a number of increase in tension, but the net increase was small, and rate of increase was very low, which implied that the dredger was on muddy floor. In fact, the dredger came back with full of mud. The mud contained pumice, scoria and a few pieces of rock fragments.

Table 1 MR17-02 Cruise Dredge summary

Date (UTC)	Dredge number	Location	On the bottom				Off the bottom				Depth (m)		Tension max. (t)	Survey time
			Lat. (SOQ*)	Lon. (SOQ*)	Lat. (SOJ)	Lon. (SOJ)	Lat. (SOQ*)	Lon. (SOQ*)	Lat. (SOJ)	Lon. (SOJ)	On the bottom	Off the Bottom		
2017/5/21~22	D01	OKIDAITO Escarpment	21-37.1513 N	131-30.5234 E	21-37.2218 N	131-30.4530 E	21-37.7491 N	131-30.7294 E	21-37.8752 N	131-30.7596 E	6,136	5,318	6.2	1h45min.
2017/5/22~23	D02	OKIDAITO Escarpment	21-18.3051 N	132-59.0837 E	21-18.4953 N	132-59.2279 E	21-18.8764 N	132-59.5195 E	21-19.0860 N	132-59.6537 E	5,791	5,283	6.7	1h33min.
2017/5/23~24	D03	OKIDAITO Ridge	21-52.9252 N	135-23.9035 E	21-52.8526 N	135-23.8443 E	21-52.7517 N	135-23.5231 E	21-52.6781 N	135-23.3845 E	5,050	4,418	7.2	1h30min.
2017/5/24	D04	OKIDAITO Ridge	21-52.8688 N	135-23.8816 E	21-52.8665 N	135-23.8932 E	21-52.8067 N	135-23.5291 E	21-52.8189 N	135-23.4464 E	5,056	4,370	6.1	2h1min.
2017/5/24~25	D05	Mangetsu Basin	22-51.5827 N	135-48.0134 E	22-51.5310 N	135-47.9282 E	22-51.7176 N	135-48.6103 E	22-51.7631 N	135-48.8185 E	5,320	4,930	5.1	1h29min.

*SOQ = Transponder's position, SOJ = Ship's position

6. Collected samples

List of collected samples is shown here (Table 2).

Table 2 List of samples collected by dredging during MR17-02 cruise.

MR17-02-D01	May 22 2017	Lat.:21°37.1513'N	Long.:131°30.5234'E	Water Depth (m):6136	CRUISE TOTAL	255.4							
sample No.	rock type	shape	size X (cm)	size Y (cm)	size Z (cm)	weight(kg)	colour	alteration	Mn coating (mm)	Glass rim (mm)	phenocrysts	vesiculation	Memo
D01-R01	rubble in mud	subangular	50	37	15	25	yellowish brown		40				Planar angular clasts are dark brown-colored coarse-grained basalt and flake of small heavily altered glass.
D01-R02	rubble in mud	subangular	30	27	14	10	yellowish brown		35				Clasts are gabbro, heavily altered glass and aphyric basalt. poorly-sorted
D01-R03	hyaloclastite	subangular	27	16	16	5	brownish gray	altered	25			<0.1%	hyaloclastite includes (tuff breccia size) altered glass and aphyric basalt (<0.1% vesiculation and moderately altered).
D01-R04	aphyric basalt	angular	13	10	10	1.5	brownish gray	moderately altered	1.5			<0.1%	coarse-grained
D01-R05	aphyric basalt	angular	14	8	7	1	gray	weakly altered	4	2	cpx and pl glomerocryst, microphenocryst	<0.1%	chilled margin, altered glass
D01-R06	gravel bearing mudstone	subangular	13	10	8	1			18				
D01-R07	pebble in mud	subangular	24	14	7	1.5	yellowish brown		8				Mud includes pebbles. Almost all pebbles are Mn-nodule. Core of Mn-nodule Is coarse-grained basalt (altered) and gabbro (fresh).
D01-R08	rubble in mud	subangular	18	15	9	2	yellowish brown		50				Clast is aphyric basalt with chilled margin (heavily altered glass is 3 mm thickness).
D01-R09	rubble in mud	subangular	11	9	6	1	yellowish brown		3				Clasts are aphyric basalt (gray colored) and Mn-nodule.
D01-R10	aphyric basalt	angular	7	6.5	5	0.5	gray	moderately altered	1	2		<0.1%	chilled margin, altered glass
D01-R11	aphyric basalt	subangular	7	6	5.5	0.5	gray	moderately altered	7	4			chilled margin, heavily altered glass
D01-R12	coarse-grained basalt	subangular	9	6	5	0.2	brownish gray	heavily altered	6				
D01-R13	medium-grained phyric basalt	subangular	7.5	5.5	4	0.2	gray	weakly altered	1.5		cpx and pl glomerocryst	<0.1%	
D01-R14	coarse-grained basalt	angular	6.5	5	4	0.2	brownish gray	altered	1				
D01-R15	microgabbro	subangular	7.5	5.5	4	0.1	brownish gray	moderately altered	4				
D01-R16	olivine basalt	subangular	5.5	4.5	3.5	0.1	brownish gray	heavily altered	film			0.50%	olivine is heavily altered.
D01-R17	brown mud	subangular	7	7	4	0.1	brown						
D01-R18	aphyric basalt	subangular	6.5	5	2.5	0.1	gray	weakly altered	4			0.20%	
D01-R19	olivine basalt	subangular	6.5	5	3	0.1	brownish gray	moderately altered	3		cpx and pl glomerocryst, microphenocryst	<0.1%	heavily altered olivine (orange color)
D01-R20	basalt	angular	5	4	3	0.1	brownish gray	altered	film		cpx and pl glomerocryst, microphenocryst	<0.1%	
D01-R21	basalt	angular	5	4	2	0.1	brownish gray	altered	film		cpx and pl glomerocryst	<0.1%	
D01-R22	aphyric basalt	subangular	8	5	2	0.1	gray	moderately altered	2			5%	
D01-R23	aphyric basalt	angular	5	4	3	0.1	brownish gray	altered	1			<0.1%	
D01-R24	aphyric basalt	subangular	5.5	5	2.5	0.1	gray	altered	0.5		cpx and pl glomerophyric		rapid growth of plagioclase
D01-R25	aphyric basalt	subangular	6.5	3	2	0.1	gray	altered	film				
D01-others						77.5							pebbles (many Mn-nodules), rubbles and Mn-crusts
						128.2							

MR17-02-D02	May 23 2017	Lat.:21°18.3051'N	Long.:132°59.0837'E	Water Depth (m):5791									
sample No.	rock type	shape	size X (cm)	size Y (cm)	size Z (cm)	weight(kg)	colour	alteration	Mn coating (mm)	Glass rim (mm)	phenocrysts	vesiculation	Memo
D02-R01	Mn-crust	subangular	20	16	4	1.5	black		45				
D02-R02	Mn-crust	subangular	15	9	7.5	1	black		40				
D02-R03	sparsely phyric olivine basalt	subangular	10	7.5	7	1	gray	moderately altered	25		altered ol: <0.2%	<0.1%	olivine in the groundmass
D02-R04	Mn-coated mud	subrounded	10	10	3	0.7	brown		25				
D02-R05	Mn-coated mud	subangular	10	7	4	0.6	brown		13				
D02-R06	Mn-crust	subangular	8.5	7	5	0.3	black		60				
D02-R07	rubble in mud	subangular	8	6.6	5.5	0.4	yellowish brown		13				Clast is siltstone.
D02-R08	Mn-coated mud	subrounded	7	6	4	0.4	brown		8				
D02-R09	Mn-coated mudstone	subrounded	9	7	3.5	0.5	brown		2				
D02-R10	Mn-nodule	rounded	7	5.5	3.5	0.4	black						
D02-R11	Mn-crust	angular	16	14	4.5	1	black		30				planar
D02-R12	Mn-coated mudstone	rounded	7.5	5.5	4	0.5	brown		12				
D02-R13	Mn-coated mud	rounded	8	6	4.5	0.4	brown		10				
D02-R14	Mn-coated mud	rounded	7.5	5.5	4.5	0.3	brown		5				
D02-R15	Mn-coated mud	rounded	7.5	5.5	4.5	0.3	brown		7				
D02-R16	pebble in mud	subrounded	7.5	5.5	4.5	0.2	yellowish brown		8				Pebbles are Mn-nodule (~2 cm). Tiny Mn-nodule's core is gabbro or diorite.
D02-R17	Mn-coated mud	subangular	8.5	6	3.5	0.4	brown		4				
D02-R18	Mn-coated mud	subrounded	5.5	5	4	0.3	dark brown		20				
D02-R19	Mn-coated mud	subangular	10.5	4.5	3	0.3	brown		9				
D02-R20	shark tooth	angular	4.5	4.5	2	0.1	black		1				
D02-R21	shark tooth	angular	3	1.5	1	0.05	black		1				
D02-R22	shark tooth	angular	3.5	2.5	1	0.05	black		1				
D02-others						85							pebbles
						95.7							

MR17-02-D03	May 24 2017	Lat.:21°52.9252'N	Long.:135°23.9035'E	Water Depth (m):5050									
sample No.	rock type	shape	size X (cm)	size Y (cm)	size Z (cm)	weight(kg)	colour	alteration	Mn coating (mm)	Glass rim (mm)	phenocrysts	vesiculation	Memo
D03-others	mud					0.05							There is no sample. Mud cames from a corner of dredge.
						0.05							

MR17-02-D04	May 24 2017	Lat.:21°52.8688'N	Long.:135°23.8816'E	Water Depth (m):5056									
sample No.	rock type	shape	size X (cm)	size Y (cm)	size Z (cm)	weight(kg)	colour	alteration	Mn coating (mm)	Glass rim (mm)	phenocrysts	vesiculation	Memo
D04-R01	siliceous sandstone	angular	54	17	16	10	pale yellow		1				medium-grained
D04-R02	lapilli stone	subangular	22	20	16	6	dark brown	moderately altered	film			10-20%	Lapilli size scoria. Scoria is ol (5%)-aug(10%) basalt (porphyritic).
D04-R03	coarse lapilli stone	subangular	30	17	9	4.5	dark brown	moderately altered	1			~10-20%	highly porphyritic pl-bearing ol (5%)-aug (25%) basalt coarse-grained lapilli size scoria
D04-R04	siliceous sandstone	angular	18	10	6	1	pale yellow		film				framboidal Mn-oxide surface
D04-R05	Mn and mud mixture	subangular	15	10	5	1	black		20				
D04-R06	siliceous sandstone	angular	13	8	8	0.6	pale yellow	film					framboidal Mn-oxide surface
D04-R07	lapilli stone	subangular	13	9	3.5	0.6	brownish gray-brown-yellowish brown	heavily altered	1			20%	large lithis clast (~7 cm) in lapilli stone Lithic clast and scoria (~10% vesiculation) are highly porphyritic ol (5%)-aug (25%) basalt. no chilled margin in lithic clast
D04-R08	siliceous sandstone	subangular	12	6.5	4	0.4	pale yellow		1				framboidal Mn-oxide surface
D04-R09	Mn-nodule in mud	subangular	11	7.5	7	0.5	black-yellowish brown		6				
D04-R10	Mn-crust	subangular	11	9	6	0.5	black		25				
D04-R11	Mn-crust	subangular	12	9	4	0.6	black		25				
D04-R12	medium lapilli stone	planar	12	10	2.5	0.5	yellowish brown	heavily altered	1				medium-grained finely-vesiculated ol-aug basalt scoria
D04-R13	siliceous sandstone	subangular	10	7.5	4.5	0.4	pale yellow		film				hydrofracturing framboidal Mn-oxide film
D04-R14	medium lapilli stone	subangular	12	6.5	4.5	0.4	brownish gray	heavily altered	30			5%	ol-aug basalt scoria
D04-R15	medium lapilli stone	angular	12	7	4.5	0.2	brown-yellowish brown	heavily altered	film			<5%	framboidal Mn-oxide film ol (10%)-basalt scoria
D04-R16	medium lapilli stone	subangular	11	7	6	0.5	brown-yellowish brown	heavily altered	1			15%	aug-ol basalt scoria
D04-R17	ol-aug basalt	angular	7.5	6	5	0.3	gray	moderately altered	film				framboidal Mn-oxide film
D04-R18	Mn-coated mud	subrounded	9.5	6.5	4	0.3	brown		5				
D04-R19	lapilli stone	angular	8	5	3	0.1	dark brown-brown	heavily altered	0.5			3%	ol-aug basalt scoria
D04-R20	medium lapilli stone	subangular	10	5.5	3	0.1	dark brown-brown	heavily altered	3			5%	ol-aug basalt scoria
D04-R21	Mn-crust	subangular	7.5	5	3	0.1	black						
D04-R22	medium lapilli stone	subangular	7	7	4	0.1	brown	heavily altered	film			5%	framboidal Mn-oxide film aug-ol basalt
D04-R23	siliceous sandstone	subangular	6	5	3	0.1	pale yellow		film				
D04-R24	lapilli stone	subangular	5	4.5	3.5	0.1	brownish gray	heavily altered	film			5%	framboidal Mn-oxide film ol-aug basalt with chilled margin amygdaloidal zeolite
D04-R25	Mn-coated mud	subrounded	7	5	4	0.1	brown						
D04-R26	Mn-coated mud	subangular	6	5	3	0.1	brown		13				
D04-R27	basalt scoria	subrounded	6.5	4.5	3	0.05	black	fresh			pl		well vesiculated
D04-others	rock fragments					0.05							
						29.2							

MR17-02-D05	May 25 2017	Lat.:22°51.5827'N	Long.:135°48.0134'E	Water Depth (m):5320									
sample No.	rock type	shape	size X (cm)	size Y (cm)	size Z (cm)	weight(kg)	colour	alteration	Mn coating (mm)	Glass rim (mm)	phenocrysts	vesiculation	Memo
D05-R01	basalt scoria	subangular	7.5	5	4	0.2	dark gray		film				well vesiculated
D05-R02	basalt scoria	subangular	6	5	2	0.1	black						well vesiculated
D05-R03	basalt scoria	subangular	4.5	4.5	4	0.1	black						well vesiculated
D05-R04	basalt scoria	subrounded	5.5	3.5	2.5	0.05	black						well vesiculated
D05-R05	basalt scoria	subangular	5	4.5	2.5	0.05	black						well vesiculated
D05-R06	woody pumice	subangular	4	4	3	<0.05	gray						
D05-R07	basalt scoria	subangular	4	3	3	0.1	black						well vesiculated
D05-R08	basalt scoria	subangular	5	3	2.5	<0.05	black						well vesiculated
D05-R09	basalt scoria	subrounded	4.5	3.5	2	<0.05	dark gray	altered					well vesiculated
D05-R10	basalt scoria	subangular	4	4	1.5	0.05	black		film				well vesiculated
D05-R11	moderately vesiculated pumice	subangular	4.5	3	1.5	<0.05	gray	altered					
D05-R12	woody pumice	subangular	3.5	3	3	<0.05	dark gray	altered					
D05-R13	moderately vesiculated pumice	subangular	3	3	2.5	<0.05	gray	altered					
D05-R14	altered ol-basalt scoria	subangular	2	1.5	0.5	<0.05	dark brown	altered					
D05-R15	poorly-vesiculated ol basalt with minor amount of pl	subangular	2	1.5	0.7	<0.05	dark gray	moderately altered	1				
D05-R16	altered aphyric basalt	angular	2	1.5	0.5	<0.05	dark green	altered	film				pl and px/amp
D05-R17	poorly-vesiculated porphyritic basalt with pl and px phenocrysts	subangular	2	1.5	1	<0.05	dark brown	moderately altered	film				phenocrysts(pl and px) are fresh
D05-S01	mud					0.1							
D05-others	pebble-sized scoria and pumice					1.5							
						2.25							

7. Geophysical survey

A geophysical survey including bathymetry, magnetic, and gravity anomalies has been conducted during the MR17-02 cruise in oceanic basins around the Oki-Daito Ridge. The purposes of the geophysical survey in this cruise are (1) to understand mode and rate of spreading of these oceanic basins, (2) to reveal temporal relationship between major tectonic features and volcanic activity, (3) to obtain a high-resolution bathymetric map for selecting sites suitable for dredge.

Personnel
Osamu Ishizuka (Geological survey of Japan, AIST) : Principal Investigator
Taichi Sato (Geological survey of Japan, AIST) : Principal Investigator
Ryo Kimura (NME)
Noriyuki Hayashi (NME)
Yutaro Murakami (NME)

7.1. Swath Bathymetry

(1) Introduction

R/V MIRAI is equipped with a Multi-narrow Beam Echo Sounding system (MBES), SEABEAM 3012 Upgrade Model (L3 Communications ELAC Nautik). The objective of MBES is collecting continuous bathymetric data along ship's track to make a contribution to geological and geophysical investigations.

(2) Data Acquisition

MBES survey was conducted during the MR17-02 cruise from 19th May 2017 to 27th May 2017.

To get accurate sound velocity of water column for ray-path correction of acoustic multi-beam, Surface Sound Velocimeter (SSV) for sea surface (6.62m) and XCTD for the deeper depth were used. Surface sound velocities were directly observed by the instrument. Sound velocity profiles were calculated from temperature and salinity, and depth profiles from XCTD data using the equation in Del Grosso (1974) during the cruise.

Table 3 System configuration and performance of SEABEAM 3012 system.

Frequency	12 kHz
Transmit beam width	1.6 degree
Transmit power	20 kW
Transmit pulse length	2 to 20 msec.
Receive beam width	1.8 degree
Depth range	100 to 11,000 m
Beam spacing	0.5 degree athwart ship

Swath width	150 degree (max) 120 degree to 4,500 m 100 degree to 6,000 m 90 degree to 11,000 m
Depth accuracy	Within < 0.5% of depth or +/-1m, whichever is greater, over the entire swath.(Nadir beam has greater accuracy; typically within < 0.2% of depth or +/-1m, whichever is greater)

Table 4. List of XCTD observations

No.	Date [YYYY/MM/DD]	Time [hh:mm]	Latitude [degN]	Longitude [deg]	Depth [m]	SST [deg-C]	SSS [PSU]	Probe S/N
1	2017/05/21	02:16	22-06.2180	130-51.7463	5854	25.200	34.703	12099602
2	2017/05/23	05:35	21-18.6573	132-57.7565	5727	28.630	34.315	16027276
3	2017/05/23	20:00	21-51.4532	135-17.5848	5550	27.841	34.899	16027279
4	2017/05/24	18:50	22-51.7858	135-49.1809	5096	27.615	34.455	16027280

(3) Preliminary Results

Figure 1 shows the preliminary result of the seafloor bathymetry during the cruise. For the operations of dredge in this cruise, underway geophysical data were used to explore detailed bathymetry and structure of the seafloor near the dredge sites (Fig. 4).

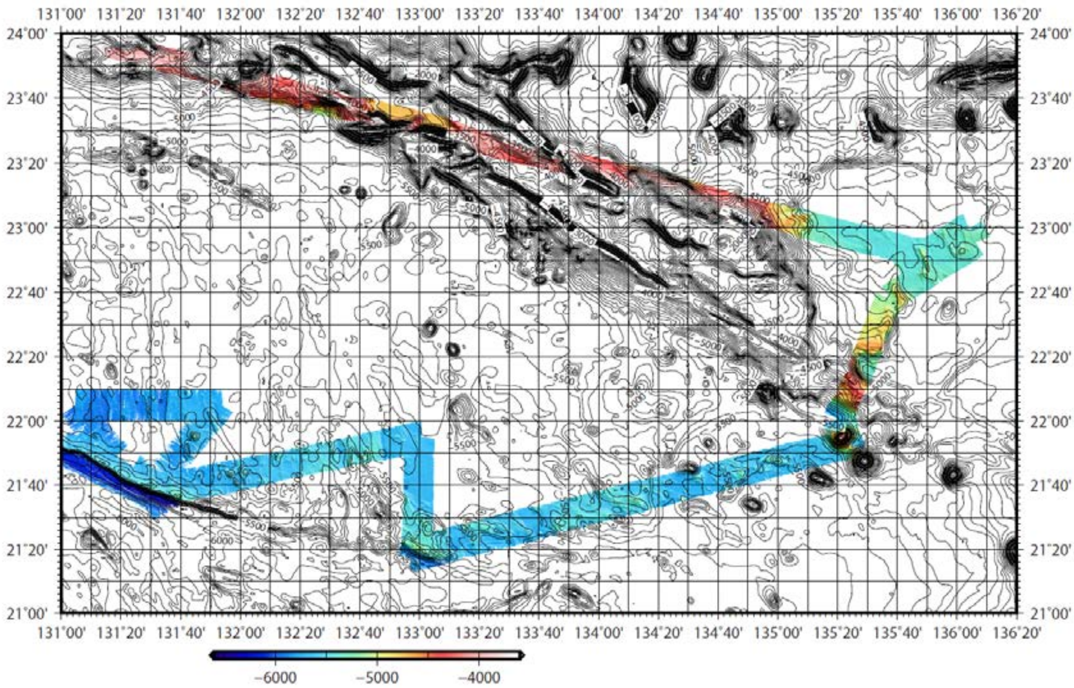

Fig. 4 Seafloor bathymetry of MR17-02 cruise

(4) Data Archives

Bathymetric data obtained during this cruise will be submitted to the Data Management Group (DMG) in JAMSTEC after the expiration of the data.

7.2. Sea surface magnetic survey

7.2.1. Total magnetic force magnetometer

(1) Introduction

Measurement of total magnetic force on the sea is required for the geophysical investigations of marine magnetic anomaly caused by magnetization in upper crustal structure. We measured total geomagnetic field during the MR17-02 cruise from 19th May 2017 to 27th May 2017.

(2) Data Acquisition

Cesium marine magnetometer (Geometrics Inc., G-882) was used and the data was 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 and the distance from system position to stern is 80 m. Table 5 shows system configuration of MIRAI cesium magnetometer system. Preliminary results of main track lines are shown in Fig.5 and 6.

Table 5 System configuration of cesium magnetometer.

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

(3) Data Archive

Total magnetic force data obtained during this cruise was submitted to the Data Management Group (DMG) of JAMSTEC after the expiration of the data.

7.2.2. Three-component magnetometer

(1) Introduction

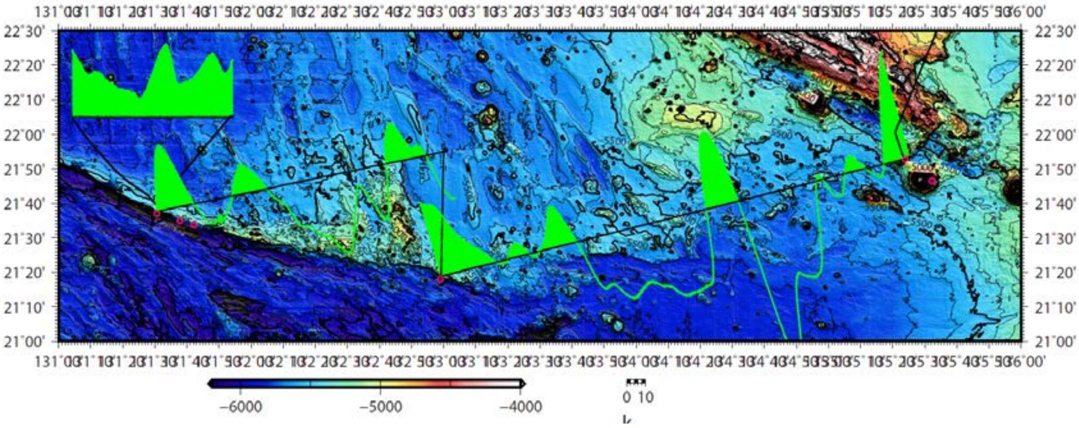

Fig. 5 Observed total field magnetic anomaly around Oki-Daito Escarpment.

Measurement of magnetic force on the sea is required for the geophysical investigations of marine magnetic anomaly caused by magnetization in upper crustal structure. We measured geomagnetic field using a three-component magnetometer during the MR17-02 cruise from 19th May 2017 to 27th May 2017.

(2) Data acquisition

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

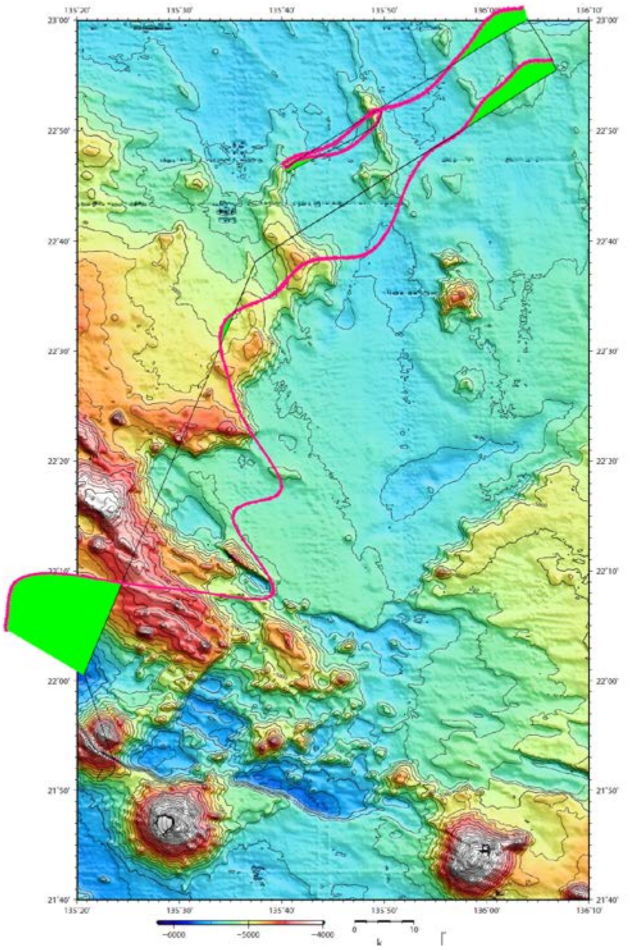

Fig. 6 Observed total field magnetic anomaly in the Mangetsu Basin.

(3) Figure-eight turn

For calibration of the ship's magnetic effect, we made a "figure-eight" turn (a pair of clockwise and anti-clockwise rotation). This calibration was carried out as below.

1st: 22th May. 2017, 08:24 – 08:34 UTC around at 21-41.2N, 131-49.1E

2nd: 25th May. 2017, 16:23 – 16:44 UTC around at 22-35.4N, 132-44.8E

(4) Principle of ship-board geomagnetic vector measurement

The relation between a magnetic-field vector observed on-board, Hob, (in the ship's fixed coordinate system) and the geomagnetic field vector, F, (in the Earth's fixed coordinate system) is expressed as:

$$Hob = A\ R\ P\ Y\ F + Hp \quad (a)$$

where R, P and Y are the matrices of rotation due to roll, pitch and heading of a ship, respectively. A is a 3 x 3 matrix which represents magnetic susceptibility of the ship, and Hp is a magnetic field vector produced by a permanent magnetic moment of the ship's body. Rearrangement of Eq. (a) makes

$$R\ Hob + Hbp = R\ P\ Y\ F \quad (b)$$

where R = A-1, and Hbp = -R Hp. The magnetic field, F, can be obtained by measuring R, P, Y and Hob, if R and Hbp are known. Twelve constants in R and Hbp can be determined by measuring variation of Hob with R, P and Y at a place where the geomagnetic field, F, is known.

(5) Data Archives

These data obtained in this cruise will be submitted to the Data Management Group (DMG) of JAMSTEC, after the expiration of the data.

7.3. Sea surface gravity

(1) Introduction

The gravity is an important parameter to estimate the density structure of the sub-seafloor. We collected gravity data at the sea surface during the MR17-02 cruise from 19th May 2017 to 27th May 2017.

(2) Parameters

Relative Gravity [CU: Counter Unit] [mGal] = (coef1: 0.9946) * [CU]

(3) Data Acquisition

We measured relative gravity using LaCoste and Romberg air-sea gravity meter

S-116 (Micro-g LaCoste, LLC). The gravimeter is installed on Gravity meter room (4.8m from the base line). Sampling rate is 1 sec and QC gravity is filtered by 120 sec Exact Blackman filter. To convert the relative gravity to absolute one, we used 979114.12 mGal as the absolute gravity, which is measured at Nakagusuku port in 2003.

(4) Preliminary Results

Absolute gravity shown in Table 4.

Table 4. List of absolute gravity

No	Date	UTC	Port	Absolute Gravity [mGal]	Sea Level [cm]	Draft [cm]	Gravity at Sensor *1 [mGal]	L&R*2 Gravity [mGal]
#1	2017/5/17	22:59	NAKAGUSUKU	979114.12	244	635	979115.11	11399.75
#2	2017/5/27	7:10	NAKAGUSUKU	979114.12	316	618	979115.29	11399.36

*1: Gravity at Sensor = Absolute Gravity + Sea Level*0.3086/100 + (Draft-530)/100*0.2222

*2: LaCoste and Romberg air-sea gravity meter S-116 6-53

(5) Data Archives

Surface gravity data obtained during this cruise will be submitted to the Data Management Group (DMG) in JAMSTEC, after the expiration of the data.

8. Shore-based studies

A comprehensive work plan for the rock samples was developed by the shipboard scientific party. This work will include major element analyses, trace element analyses, geochronology studies, mineral analyses, petrographic characterization, and stable and radiogenic isotope characterization. The work will be completed at the Geological Survey of Japan/AIST, Kanazawa University, Tokai University, Nation museum of science and other possible collaborators. Analytical responsibilities include:

Volcanic rocks:

Petrological, geochemical and geochronological study on volcanic rocks will be conducted to reveal age, magmatic processes and magma sources

.

•Whole rock chemical composition (XRF, ICP-MS): GSJ

•Mineral chemistry (major elements: EPMA): GSJ, Kanazawa Univ.

•Ar/Ar dating (GSJ)

•Radiogenic isotopes (Sr, Nd, Pb, Hf?): GSJ etc.

•Melt inclusion studies, if applicable (Kanazawa, GSJ)

•FT-IR study on fresh glass for H_2O concentrations (Kanazawa)

•Description of volcanic textures for marginal part of subaqueous volcanic rocks (Tokai University).

•Clay-minerals and rock alteration process (Tokai University).

Volcaniclastic rocks

•SHIRMP zircon U-Pb dating

•LA-ICP-MS zircon trace element analyses

•LA-ICP-MS analyses on other minerals and glass

• FT-IR study on fresh glass for H_2O concentrations (Kanazawa)

2) XRF and EPMA analysis on relative fresh clast and glass will be conducted at GSJ and Kanazawa University..

Sedimentary rocks

•Description of sediments and sedimentary rocks (Tokai University, National Museum of Science).

•Description and age dating of micro-fossils (Tokai University).

• Zircon U-Pb dating (National Museum of Science)

•LA-ICP-MS zircon trace element analyses (National Museum of Science)

Geophysical data

•Bathymetric and magnetic data will be merged with existing data and synthesized at GSJ and Tokai University.

Other shore-based studies include:

•Volcanic and geologic synthesis will be done at GSJ, National Museum of Science, Kanazawa University and Tokai University.

•Links between ocean basin structure and characteristics of magma will be extensively investigated with shore-based collaborators.

9. 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

Appendix A. Sample distribution list

Dredge: MR17-02 D01 **Date: 2017/05/22**

	GSJ				Kanazawa Univ.				Tokai Univ.				Kahaku				Archive
	Chip	Slab	Block	Whole	Chip	Slab	Block	Whole	Chip	Slab	Block	Whole	Chip	Slab	Block	Whole	
R01																○	
R01A			○				○				○						○
R01B			○				○										
R01C			○				○										
R01D			○				○										
R01E			○				○				○						
R01F			○				○										
R01G			○				○										
R01H			○				○										
R01I			○				○				○						
R02			○								○					○	
R03			○													○	
R04			○													○	
R05			○				○				○						
R06																○	
R07																○	
R08			○				○				○						
R09				○1/2												○1/2	
R10				○													
R11				○1/2												○1/2	
R12				○1/2												○1/2	
R13				○													
R14				○1/2												○1/2	
R15				○													
R16				○1/2												○1/2	
R17																○	○
R18				○1/2												○1/2	
R19				○1/2												○1/2	
R20				○1/2												○1/2	
R21				○1/2												○1/2	
R22				○													
R23				○1/2												○1/2	
R24				○1/2												○1/2	
R25				○1/2												○1/2	
Others																○	

Dredge: MR17-02 D02 **Date: 2017/05/23**

	GSJ				Kanazawa Univ.				Tokai Univ.				Kahaku				Archive
	Chip	Slab	Block	Whole	Chip	Slab	Block	Whole	Chip	Slab	Block	Whole	Chip	Slab	Block	Whole	
R01																O	
R02																O	
R03			O			O			O							O	
R04																O	
R05																O	
R06																O	
R07				O1/2												O1/2	
R08																O	
R09																O	
R10																O	
R11																O	
R12																O	
R13																O	
R14																O	
R15																O	
R16																O	
R17																O	
R18																O	
R19																O	
R20																O	
R21																O	
R22																O	
Others																O	

Dredge: MR17-02 D03 **Date: 2017/05/24AM**

	GSJ				Kanazawa Univ.				Tokai Univ.				Kahaku				Archive
	Chip	Slab	Block	Whole	Chip	Slab	Block	Whole	Chip	Slab	Block	Whole	Chip	Slab	Block	Whole	
Others																O	

Dredge: MR17-02 D04　　Date: 2017/05/24PM

	GSJ				Kanazawa Univ.				Tokai Univ.				Kahaku				Archive
	Chip	Slab	Block	Whole	Chip	Slab	Block	Whole	Chip	Slab	Block	Whole	Chip	Slab	Block	Whole	
R01			O								O					O	
R02			O				O				O					O	
R03			O				O				O					O	
R04			O								O					O	O
R05																O	
R06			O								O					O	O
R07		O							O								
R08			O								O					O	O
R09																O	
R10																O	O
R11																O	O
R12			O								O					O	
R13			O								O					O	
R14			O								O					O	
R15			O								O					O	
R16			O								O					O	
R17			O								O						
R18																O	O
R19			O								O					O	
R20			O								O					O	
R21																O	O
R22			O								O					O	
R23			O1/2													O1/2	
R24			O								O						
R25																O	
R26																O	
R27																O	
Others																O	

Dredge: MR17-02 D05　　Date: 2017/05/25

	GSJ				Kanazawa Univ.				Tokai Univ.				Kahaku				Archive
	Chip	Slab	Block	Whole	Chip	Slab	Block	Whole	Chip	Slab	Block	Whole	Chip	Slab	Block	Whole	
R01																o	
R02																o	
R03																o	
R04																o	
R05																o	
R06																o	
R07																o	
R08																o	
R09																o	
R10																o	
R11																o	
R12																o	
R13																o	
R14																o	
R15				o													
R16				o													
R17				o													
S01												o					
Others																o	