

白鳳丸研究航海報告

- * 航海番号 KH-20-6次研究航海
- * 航海名称 花東海盆の形成発達史：フィリピン海プレートの起源全容解明に向けて
Tectonic development of the Huatung Basin: Understanding the origin of the Philippine Sea Plate
- * 観測海域 大東海嶺・北大東海盆
Daito Ridge and Kita-Daito Basin
- * 航海期間 令和2年11月19日（木）～令和2年12月2日（水）
- * 出港日時・場所 11月19日13時晴海ふ頭
- * 入港日時・場所 12月2日10時海洋研究開発機構岸壁
- * 寄港期間・場所 なし
- * 研究課題
 1. 花東海盆の形成発達史：フィリピン海プレートの起源全容解明に向けて
 2. ドレッジ試料の船上物性測定と陸上実験に基づいた Gaugua 海嶺の地殻構造の制約
- * 主席研究員（氏名・所属・職名）
谷 健一郎・国立科学博物館・研究主幹
- * 研究内容，主調査者，観測項目
 1. フィリピン海プレートの起源解明に関する研究，谷 健一郎，岩石ドレッジ
 2. 大東海嶺・北大東海盆の地殻構造に関する研究，沖野 郷子，地球物理航走観測
（海底地形・重力・地磁気）
 3. ドレッジ試料の船上物性測定による地殻構造の解明，長瀬 薫平，岩石試料の物性計測
（空隙率・弾性波速度・電気比抵抗）

* 乗船研究者氏名・所属・職名

谷 健一郎・国立科学博物館地学研究部・研究主幹

沖野 郷子・東京大学大気海洋研究所・教授

石塚 治・産業技術総合研究所/海洋研究開発機構・主任研究員

針金 由美子・産業技術総合研究所・主任研究員

楠橋 直・愛媛大学大学院理工学研究科・准教授

植田 勇人・新潟大学理学部・准教授

奈良 幸明・新潟大学大学院自然科学研究科・大学院学生

古川 祐希・新潟大学大学院自然科学研究科・大学院学生

井上 倫瑠・新潟大学大学院自然科学研究科・大学院学生

鈴木 望夢・新潟大学大学院自然科学研究科・大学院学生

當山 凜太郎・新潟大学理学部・学部生

下岡 和也・愛媛大学大学院理工学研究科・大学院学生

相田 和之・愛媛大学大学院理工学研究科・大学院学生

山本 一平・東京大学大気海洋研究所・大学院学生

内山 涼多・東海大学大学院海洋学研究科・大学院学生

長瀬 薫平・広島大学大学院先進理工系科学研究科・大学院学生

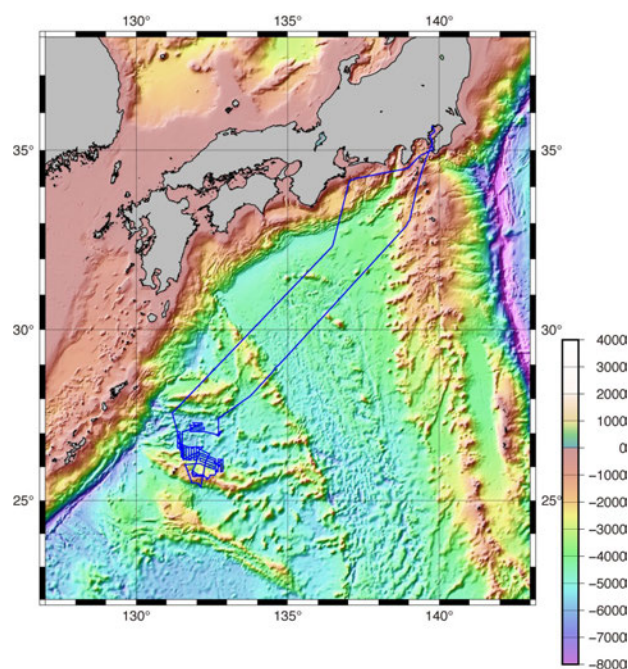
田村 千織・東京大学大気海洋研究所・技術専門職員

竹内 誠・東京大学大気海洋研究所・技術専門職員

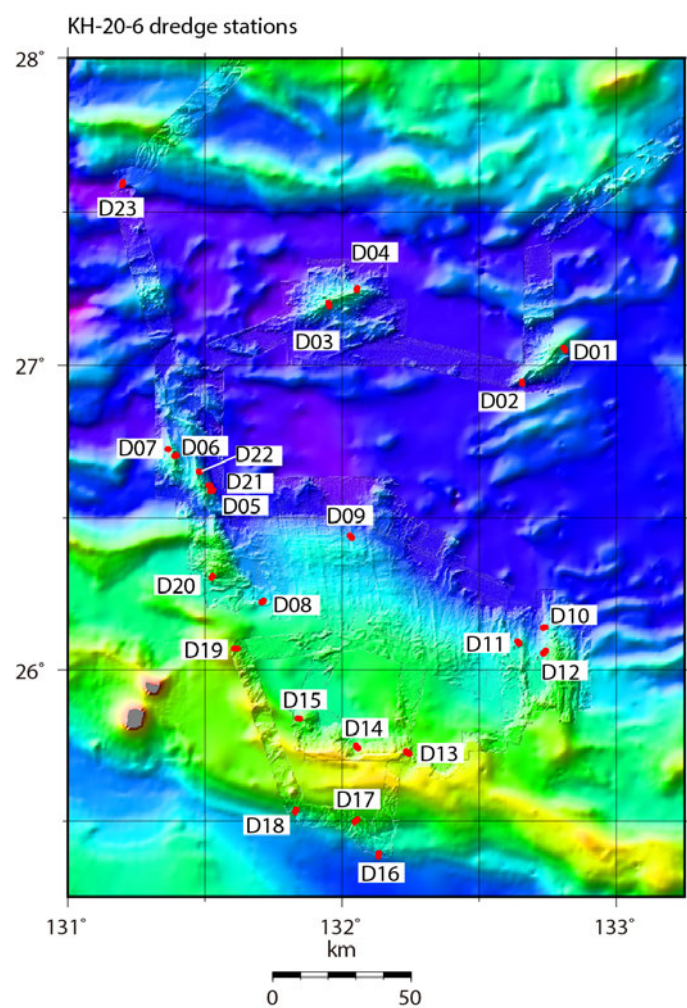
片山 陽平・株式会社マリン・ワーク・ジャパン・観測技術員

小松 亮介・株式会社 MOL マリン・観測技術員

* 航跡・測点図



航跡図



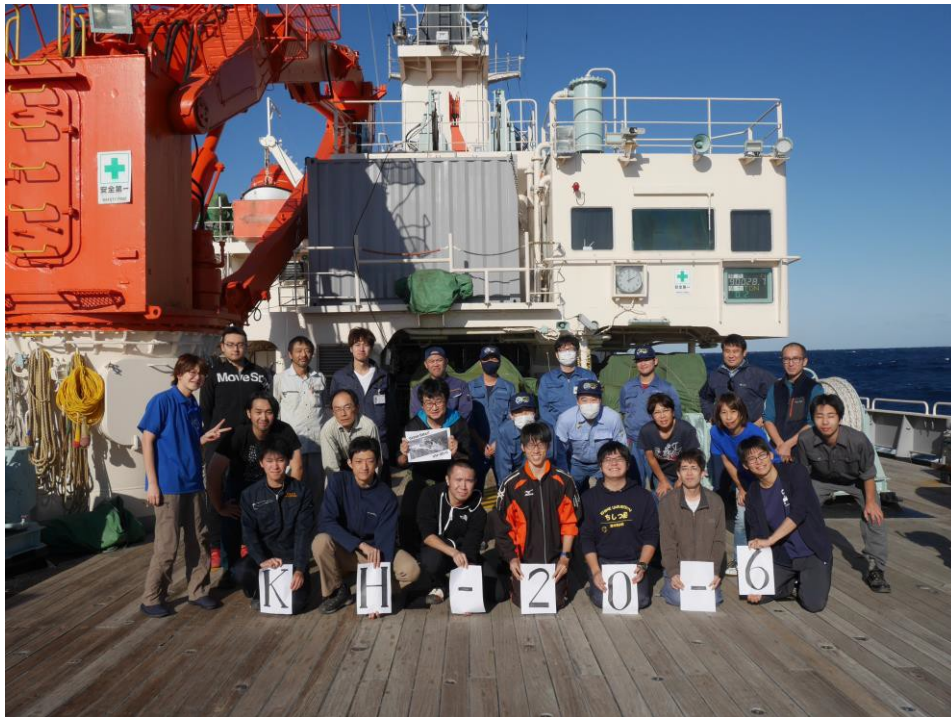
測点図

* 研究活動・観測の詳細や成果等について

CRUISE REPORT

R/V HAKUHO MARU KH-20-6

**November 19, 2020 – December 2, 2020
(Tokyo to Yokosuka)**



**"Tectonic development of the Huatung Basin:
Understanding the origin of the Philippine Sea Plate"**

Daito Ridge and Kita-Daito Basin

Table of Contents

List of scientific party.....	ii
Acknowledgements.....	vi
Cruise Summary.....	vii
Cruise Narrative.....	ix
1 Scientific objectives and backgrounds.....	1
2 Underway Geophysics	
2.1 Operation Notes	
2.1.1 General.....	4
2.1.2 Bathymetry.....	6
2.1.3 Magnetism.....	8
2.1.4 Gravity.....	10
2.2 Preliminary Results	
2.2.1 Bathymetry.....	12
2.2.2 Magnetic anomalies.....	20
2.2.3 Gravity anomalies.....	22
3 Dredge Survey	
3.1 General.....	24
3.2 Instruments and operation notes.....	25
3.3 Survey Results.....	27
4 References.....	28

List of scientific party:*Shipboard Scientific Party:*

Kenichiro TANI (Principal Investigator, Chief Scientist)

Senior Curator, Department of Geology and Paleontology, National Museum of Nature and Science

Osamu ISHIZUKA (Vice-Chief Scientist)

Senior Scientist, Research Institute of Earthquake and Volcano Geology, National Institute of Advanced Industrial Science and Technology

Kyoko OKINO

Professor, Department of Ocean Floor Geoscience, Atmosphere and Ocean Research Institute, University of Tokyo

Hayato UEDA

Associate Professor, Department of Geology, Niigata University

Nao KUSUHASHI

Associate Professor, Department of Earth's Evolution and Environment, Ehime University

Yumiko HARIGANE

Senior Scientist, Research Institute of Geology and Geoinformation, National Institute of Advanced Industrial Science and Technology

Chiori TAMURA

Technical Specialist, Field Research Support Section, Atmosphere and Ocean Research Institute, University of Tokyo

Makoto TAKEUCHI

Technical Specialist, Field Research Support Section, Atmosphere and Ocean Research Institute, University of Tokyo

Michiru INOUE

Graduate Student, Graduate School of Science and Technology, Niigata University

Yuki FURUKAWA

Graduate Student, Graduate School of Science and Technology, Niigata University

Komei NARA

Graduate Student, Graduate School of Science and Technology, Niigata University

Nozomu SUZUKI

Graduate Student, Graduate School of Science and Technology, Niigata University

Rintaro TOYAMA

Undergraduate Student, Faculty of Science, Niigata University

Kazuya SHIMOOKA

Graduate Student, Graduate School of Science and Engineering, Ehime University

Kazuyuki SODA

Graduate Student, Graduate School of Science and Engineering, Ehime University

Ryota UCHIYAMA

Graduate Student, The Graduate School of Marine Science & Technology, Tokai University

Ippei YAMAMOTO

Graduate Student, Atmosphere and Ocean Research Institute, University of Tokyo

Kumpei NAGASE (Principal Investigator)

Graduate Student, Graduate School of Advanced Science and Engineering, Hiroshima University

Yohei KATAYAMA

Marine Technician, Marine Works Japan Ltd.

Ryosuke KOMATSU

Marine Technician, MOL Marine Co., Ltd.

Shore-based Scientific Party:

Dr. Chih-Chieh SU

Associate Professor, Institute of Oceanography, National Taiwan University

Dr. Ho-Han HSU

Assistant Professor, Institute of Oceanography, National Taiwan University

Dr. Jih-Hsin CHANG

Assistant Professor, Institute of Oceanography, National Taiwan University

Dr. Char-Shine LIU

Professor Emeritus, Institute of Oceanography, National Taiwan University

Dr. Kan-Hsi HSIUNG

Scientist, Research Institute for Marine Geodynamics, Japan Agency for Marine-Earth
Science and Technology

Dr. Betchaida D. Payot

Assistant Professor, National Institute of Geological Sciences, University of the
Philippines

Mr. Akito Ogawa

Graduate Student, Department of Biological Sciences, Graduate School of Science,
University of Tokyo/National Museum of Nature and Science

R/V Hakuho Maru crew:

Captain	Kazuhiko KASUGA
Chief Officer	Naoto SAKAI
First Officer	Makoto SATO
Second Officer	Tetsuro NAKAMURA
Jr. Second Officer	Shuhei TAKASE
Third Officer	Shuta UEHARA
Jr. Third Officer	Kodai MORI
Boatswain	Shintaro NISHIDATE
Associate Boatswain	Yukio KAWANA
Associate Boatswain	Hiroyuki OGAWA
Associate Boatswain	Myuta YAMAZAKI
Quarter Master	Naoki KATO
Quarter Master	Takumi MIYAGI
Quarter Master	Masashi ANDO
Sailor	Koki UCHIYAMA

Chief Engineer	Takashi TANAKA
First Engineer	Hironori FUNATSU
Jr. First Engineer	Goro MIYAMOTO
Second Engineer	Yasuhiro SAKUMA
Jr. Second Engineer	Kohei HANADA
Third Engineer	Yudai YOKOYAMA
No. 1 Oiler	Yoshihiko ISHII
No. 2 Oiler	Takahiro YAMANAKA
No. 3 Oiler	Sakae YOSHIDA
No. 4 Oiler	Koji TAKEDA
No. 6 Oiler	Keishiro KAI
No. 7 Oiler	Soma HAYASHIDA
No. 7 Oiler	Reo SHINZATO
Machine Man	Shoya KOBAYASHI

Chief Electronics Officer	Yohei YAMAMOTO
Electronics Officer	Takumi YAMAGUCHI
Associate Steward	Takumi HAYASHI
Associate Steward	Kosuke NAKANO
Steward	Koichi TSUKAMOTO
Steward	Masaaki YAMAMOTO
Steward	Kenji KANI

Acknowledgements

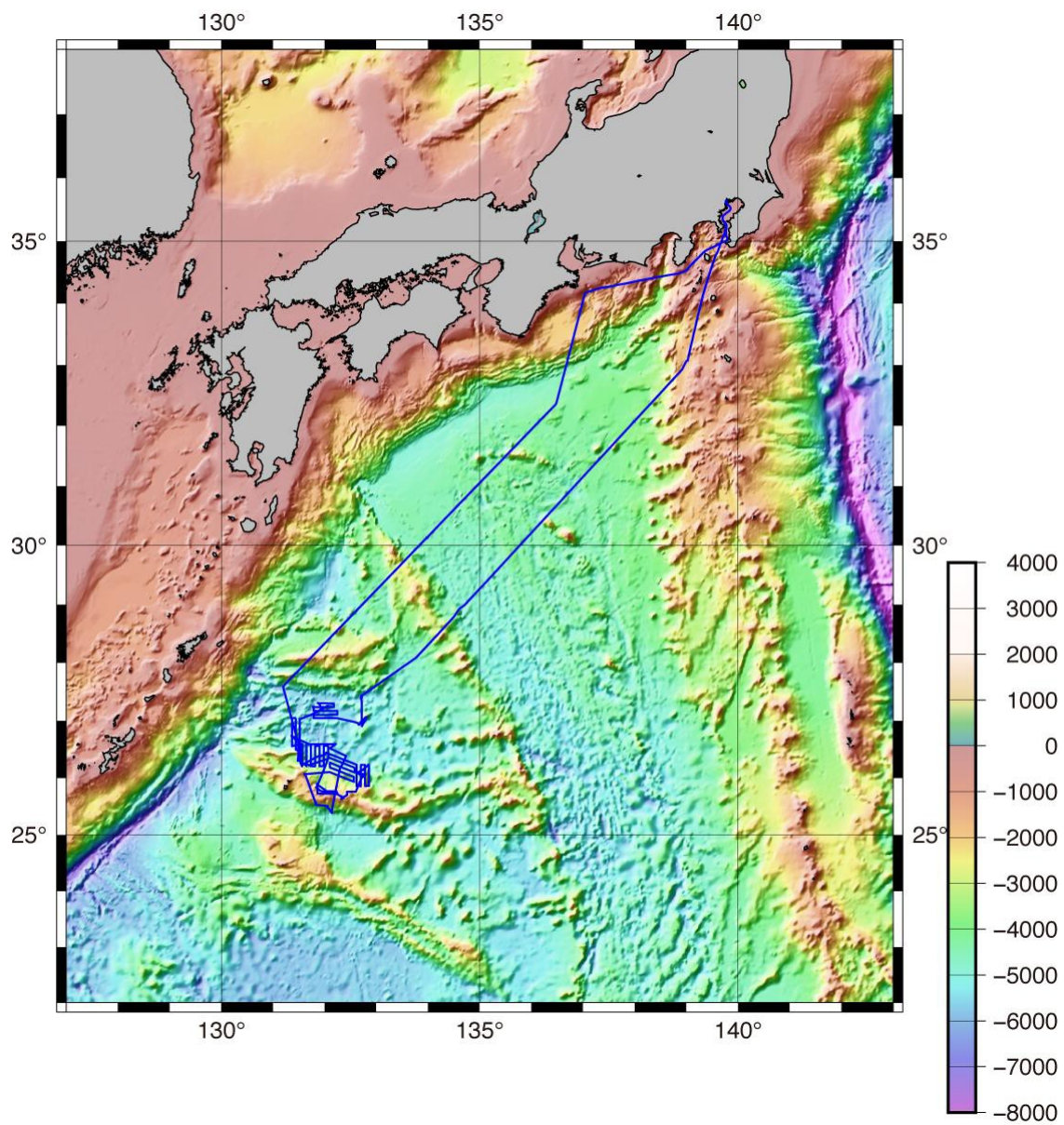
We are grateful to Captain Kazuhiko Kasuga and the crews of the R/V Hakuho Maru for their professional and outstanding supports to make this scientific cruise successful. We also thank ship operation division of JAMSTEC and administrative staffs of AORI for their supports to make this cruise happen at the difficult time of corona pandemic.

Cruise Summary

R/V Hakuho Maru KH-20-6 cruise was held from November 19, 2020 to December 2, 2020, embarking at the Harumi pier in Tokyo and disembarking at the JAMSTEC pier in Yokosuka. The chief targets of this cruise were to understand the geology and crustal structure of the proto-Philippine Sea Plate which existed prior to the initiation of subduction at Izu-Bonin-Mariana Arc. For these purposes, we have selected Huatung Basin and Gagua Ridge, located east of Taiwan, as our primary survey areas in 2017. The survey was planned and prepared in collaboration with the Institute of Oceanography, National Taiwan University (NTUIO). However, due to the travel restriction between Japan and Taiwan as a result of global spread of novel coronavirus (COVID-19), participants from NTUIO were unable to travel to Japan to join the cruise. This resulted in denial of Hakuho Maru to enter Taiwanese exclusive economic zone to conduct a research cruise in the Huatung Basin and Gagua Ridge. Therefore, we alternatively conducted our survey in the Daito Ridge and Kita-Daito Basin, located in the northwestern Philippine Sea. These areas were also expected to potentially expose crustal sections of the proto-Philippine Sea Plate.

In addition to the scientific members of our research proposal, Mr. Kumpei Nagase from the Hiroshima University joined the cruise as an independent principal investigator to analyze physical properties of the dredged samples.

The surveys during the KH-20-6 cruise were very smooth and successful. We completed all the planned surveys, including 23 dredge hauls, collected rocks and sediment samples weighing more than ~920 kg in total. Collected samples range from ultramafic rocks, gabbro, metamorphic rocks, sedimentary rocks, to volcanic rocks. These samples will provide critical geological constraints of the proto-Philippine Sea Plate and post-Eocene development of the backarc basins to generate current Philippine Sea Plate. In addition, we conducted a total ~850 miles of geophysical survey. Newly acquired bathymetry, geomagnetic and gravity data will provide important information of the crustal structures and tectonic processes in the area. We also conducted a YouTube Broadcast event as an outreach program on November 28, introducing the life on the research vessel and conducted a short lecture on collected geological/biological samples to public.



KH-20-6 survey ship track

Cruise Narrative

	11/19 Thur	11/20 Fri	11/21 Sat	11/22 Sun	11/23 Mon	11/24 Tue	11/25 Wed
0							
1							
2					Geophysical survey	Geophysical survey	Geophysical survey
3				Geophysical survey			
4							
5							
6							
7							
8							
9							
10					Dredge: D05 Daito Ridge 4784-4460 m		Dredge: D10 Kita-Daito Basin 4458-3948 m
11							
12						Dredge: D08 Kita-Daito Basin 3941-3566 m	
13	Harumi Pier		Geophysical survey	Dredge: D03 Tete Smt. 3773-3031 m			
14							
15							
16	Abandon ship drill		Dredge: D01 Kanami Smt. 4019-3486 m		Dredge: D06 Kita-Daito Basin 3903-3326 m		Dredge: D11 Kita-Daito Basin 3910-3334 m
17							
18							
19				Dredge: D04 Tete Smt. 4031-3622 m		Dredge: D09 Kita-Daito Basin 4404-4218 m	
20							
21			Dredge: D02 Kanami Smt. 4968-4553 m		Dredge: D07 Kita-Daito Basin 4021-3707 m		
22							Dredge: D12 Kita-Daito Basin 3666-3315 m
23							
24							

Local time

	11/26 Thur	11/27 Fri	11/28 Sat	11/29 Sun	11/30 Mon	12/1 Tue	12/2 Wed
0							
1							
2					Dredge: D23 Kita-Daito Basin 5544-5106 m		
3		Geophysical survey					
4	Geophysical survey						
5			Dredge: D19 Daito Ridge 2276-1894 m	Dredge: D20 Kita-Daito Basin 3033-2493 m			
6							
7							
8							
9							
10		Dredge: D16 Daito Ridge	Geophysical survey	Dredge: D21 Kita-Daito Basin 4681-4691 m			JAMSTEC Pier
11	Dredge: D13 Daito Ridge 2143-1564 m	4603-4183 m					
12							
13							
14							
15	Dredge: D14 Daito Ridge 2424-2098 m		Outreach Youtube Live				
16		Dredge: D17 Daito Ridge 2944-2694 m		Dredge: D22 Kita-Daito Basin 4038-3845 m			
17							
18							
19							
20							
21	Dredge: D15 Daito Ridge 2789-2416 m						
22		Dredge: D18 Daito Ridge 3462-3034 m					
23							
24							

1. Scientific objectives and backgrounds

Little is known about the Proto-Philippine Sea Plate (PSP), which existed as a counterpart to the Pacific Plate during subduction initiation of the Izu-Bonin-Mariana (IBM) Arc. Subduction of the Pacific Plate is postulated to have occurred synchronously along the PSP margin at around 52 Ma to generate current IBM Arc (Ishizuka et al. 2011).

To investigate the crustal structures of the PSP, we have conducted multiple research cruises since 2007 in the regions where remnants of the PSP are potentially exposed: Daito Ridges (YK10-04 and KR13-15 cruises), Izu-Bonin forearc (KH-07-02, KR08-07, KR09-04, YK09-06, YK11-07 and KH-14-5 cruises), Kyushu-Palau Ridge and Palau Basin (YK10-14, YK13-08 and YK15-12 cruises).

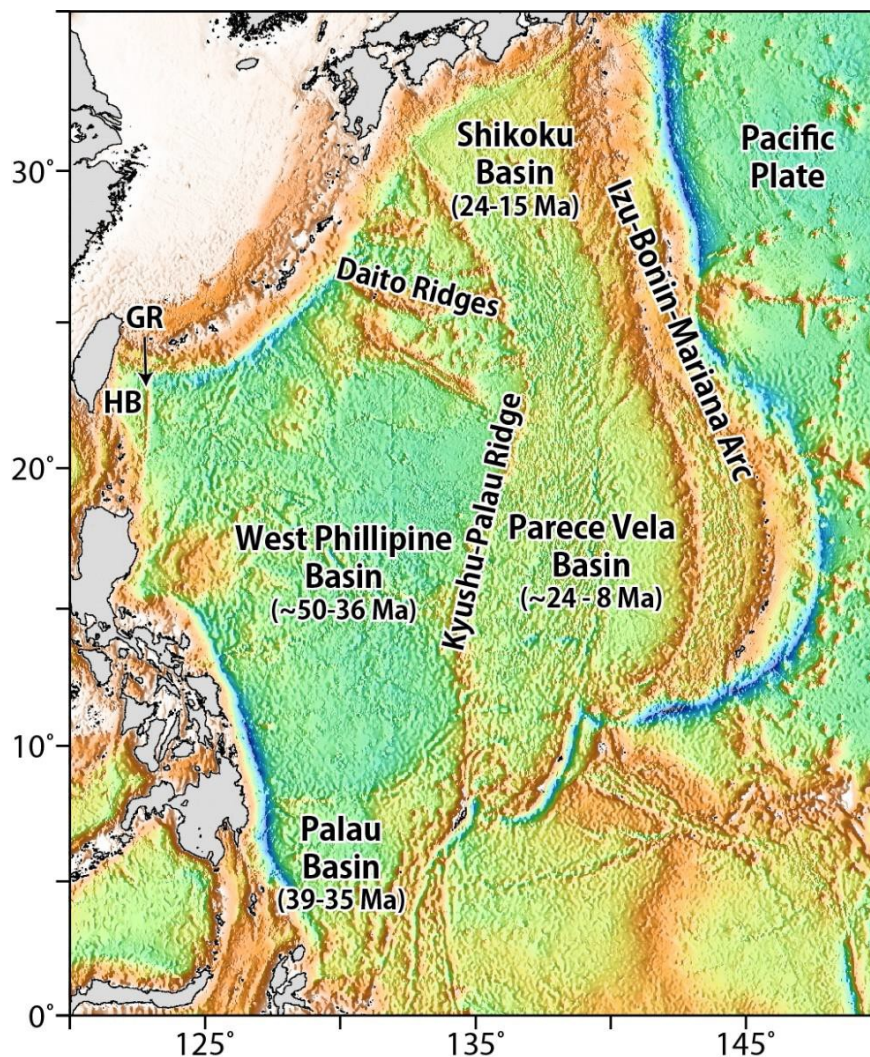


Figure 1. Basins, arc and ridges within the current Philippine Sea Plate. HB: Huatung Basin, GR: Gagua Ridge.

Submersible and ROV observations and rock sampling revealed that parts of these regions, especially in the Daito Ridges (Figure 1), expose deep crustal sections of continental rocks, spanning various volcanic, plutonic, metamorphic, and ultramafic rocks (e.g. Morishita et al. 2018). Geochemistry and radiometric dating of these rocks clearly indicate that the PSP

consists predominantly of Mesozoic arc rocks. Furthermore, amphibolite collected at the Southern Kyushu-Palau Ridge during the YK10-14 cruise yielded Cambrian protolith zircons, suggesting that even older continental fragments may exist within the PSP.

These findings and tectonic reconstruction of the PSP (Deschamps and Lallemand 2002) suggest that subduction of the IBM Arc initiated at the continental margin of Southeast Asia, and later acquired its intra-oceanic-like setting through formation of the backarc basins since the Eocene.

However, there are unresolved questions regarding the crustal structure of the PSP at Huatung Basin and Gagua Ridge, located at the northwestern margin of the current Philippine Sea Plate (Figure 1). Deschamps et al. (2000) suggested that Huatung Basin was formed in the Early Cretaceous, based on modeling of magnetic anomalies and radiometric dating of MORB-like gabbro collected at the southern part of the basin. If so, Huatung Basin is the only known oceanic domain in the PSP, indicating that the PSP was a complex of continental and oceanic crusts.

On the contrary, Doo et al. (2014) and Kuo et al. (2009) indicated much younger post-Eocene spreading of the basin based on reinterpretation of the magnetic anomalies and thin lithosphere under the basin. If the basin is formed after the Eocene, it is most likely part of the IBM backarc basins. Gagua Ridge, comprising the western margin of the basin, was interpreted to be oceanic crust uplifted along a transform fault (Deschamps et al. 1998), but dredge sampling conducted in 1980 recovered andesite and metamorphic rocks, suggesting a more complex crustal structure.

We therefore proposed to conduct geological and geophysical surveys in the Huatung Basin and Gagua Ridge, aiming to constrain the ages and crustal structures of these region. However, due to the global spread of novel coronavirus (COVID-19), we were unable to conduct the schedule survey as these areas were in the Taiwanese exclusive economic zone. Instead, we decided to conduct our survey in the alternative sites in the Daito Ridge and Kita-Daito Basin (Figure 2).

2. Underway Geophysics

2.1. Operation Notes

2.1.1. General

Underway geophysical mapping was conducted during KH-20-6 cruise in the Kita Daito Basin and Daito Ridge areas. Distribution of track lines and geophysical operations are shown in Figure 3 and 4. The survey line list and operation log note are in Appendix.

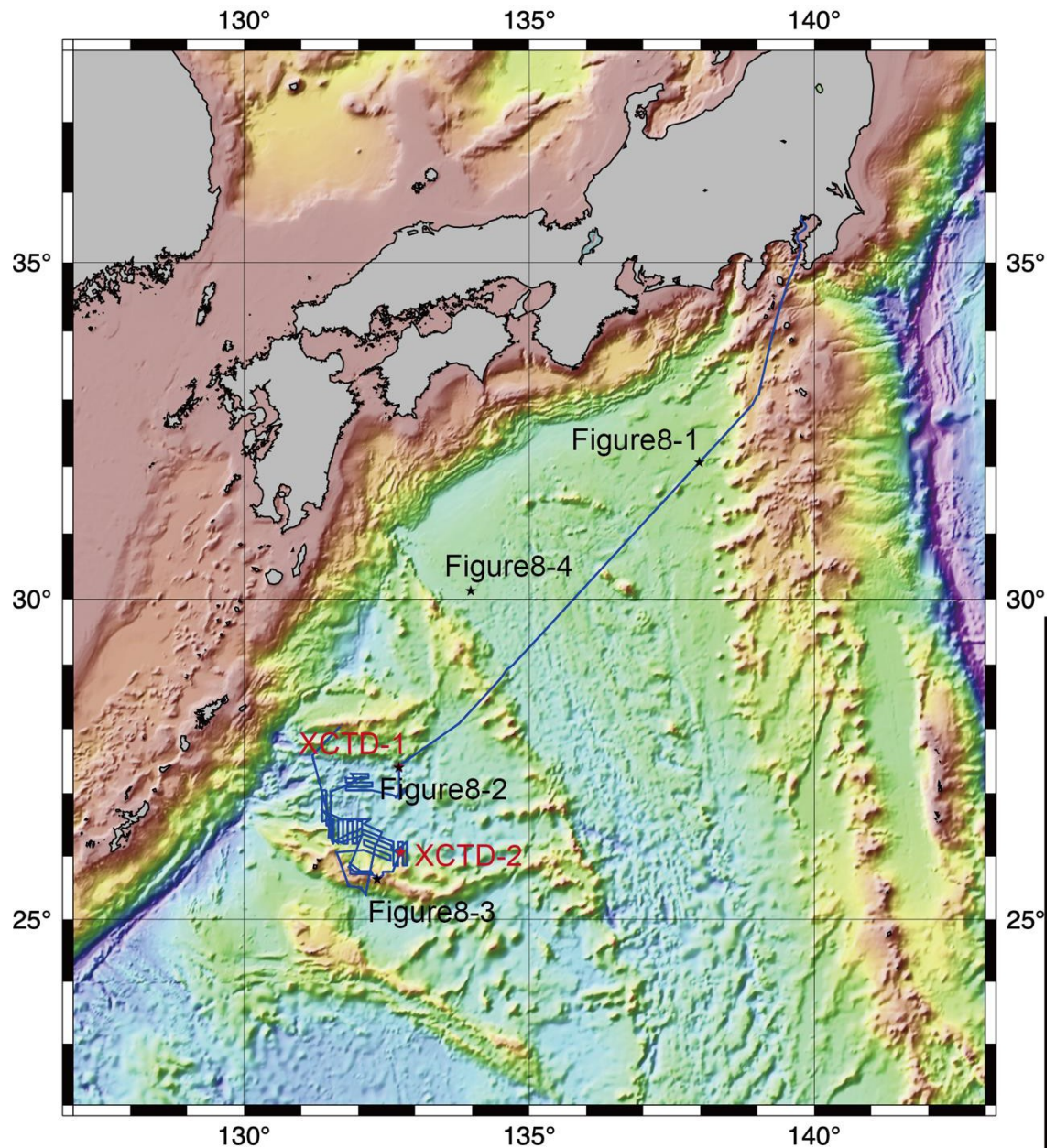


Figure 3. KH-20-6 survey area and track. Red circles and black stars indicate the loci of figure eight turns and XCTD operations, respectively. Observation log note is in Appendix.

2.1.2. Bathymetry

Seafloor bathymetry is measured using the hull-mounted multibeam echo sounder SeaBeam2120 (L3 communications). The system consists of acoustic arrays of transmitters and receivers on the ship's bottom, surface velocity meter, and controller at Lab.-1 (Figure 5). The major specification is listed in Table.

Table 1. Multi narrow beam echo sounder specification

Model	SEA BEAM 2120
Operating frequency	20 kHz
Number of beams	151
Transmitter array length	5.2 m
Receiver array length	4.75 m
Accuracy	0.3% for water depth
Beam width	1°



Figure 5. SeaBeam system in Hakuho Maru Lab-1.

The pinging and recording were continuously done within the survey area. The swath width is determined automatically, from 90° to 120°. The receiver gain is fixed 36dB. The data quality was not so bad, but the outer beams frequently provided erroneous depths. From November 28 afternoon to November 29 morning, the sea status was not good and most pings are lost (Lines B15 and B16). The data editing (cleaning) is done by using CARIS HIPS and SIPS ver 11.0.

The vertical structure of sound velocity was determined by two XCTD measurements (Figure 6, Table 2). The maximum depth of XCTD measurements is about 1500m, and the deeper profiles are from WOA18 database.

Table 2. XCTD operations

	Date	Lon	Lat	Max depth	probe
XCTD-1	2020/11/21 02:01	132°43.17E	27°24.94N	1438m	XCTD-2
XCTD-2	2020/11/25 16:28	132°44.58E	26°03.87N	1558m	XCTD-2

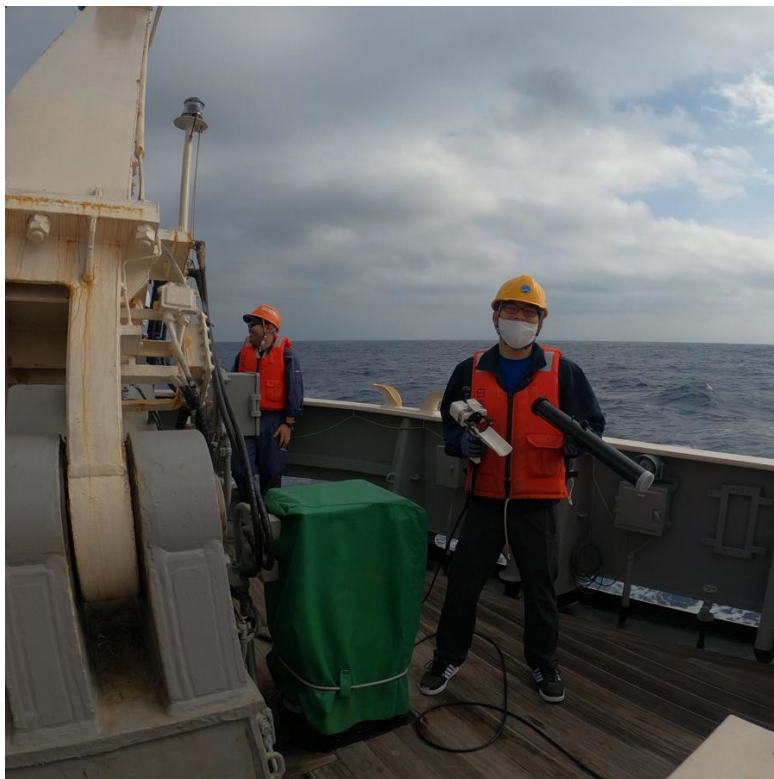


Figure 6. Deployment of XCTD probe on main deck.

2.1.3. Magnetics

Total magnetic field is measured by proton precession magnetometer PR-745 (Kawasaki Geol. Eng. Co, Table 3). The magnetometer and recording computer are installed in Lab-3. The sensor is towed 290 m behind the ship (Figure 7, approximately 350m from the ship's GPS sensor) and the measurements are performed every 20 seconds.

Table 3. Proton precession magnetometer specification

Model	PR745
Range	30000-65000 nT
Measurement resolution	0.1 nT
Sampling rate	30 sec
Towing cable length	330 m

The system runs robustly during the cruise and provides high quality data without any spike noises. The standard deviation is less than 1 and the signal level is more than 70% for almost all period.

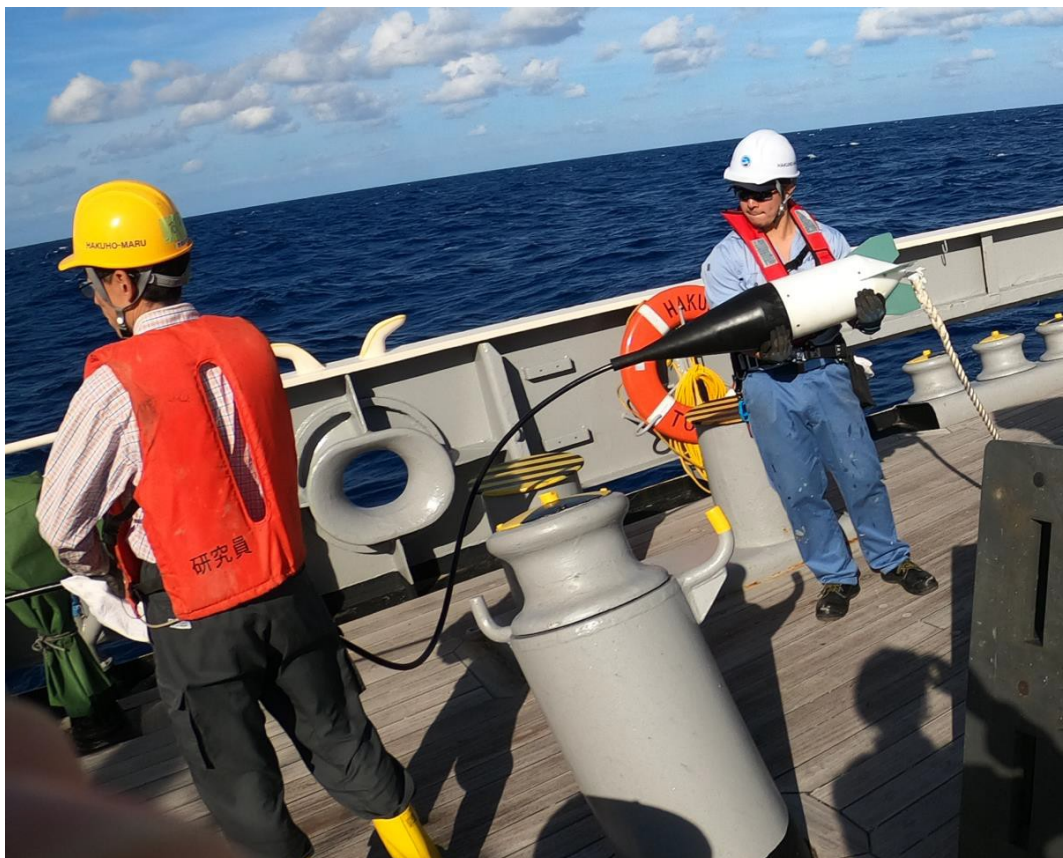


Figure 7. Recovery of proton precession magnetometer sensor on main deck.

Vector magnetic field is measured by shipboard three component magnetometer. The fluxgate sensor SBM-89 (Gauss) is installed on the compass deck (Figure 8). The

magnetometer unit (Geomag3, Terra Technica) is installed in Lab-1. The new magnetometer unit (A/D converter) was used at the beginning of the survey, but spike noises were observed during figure eight turn and course change. Though the cause of spikes was unsolved, the unit is replaced and the old unit is used after 03:18 on November 21. The old unit works well and no spike noises are observed. The sampling frequency is 5Hz and the ship attitude data from OCTANS (10Hz) are merged. The specifications of magnetometers are listed in Table4.

Table 4. Shipboard three-component magnetometer specification

Data loggin software	Geomag 3
Sensor	3-axes fluxgate
Sampling rate	5Hz
Gyro	Octans
Coordindate	X: bowward Y: starboard Z: downward

The logging is continuously done from departure at Harumi on Nov. 19 to arrival at Yokosuka (JAMSTEC) on Dec. 2. Four figure eight turns are done at different latitudes in order to estimate the ship's magnetization (Table 5). The details of operation and calculated matrices are shown in Appendix. The preliminary ship magnetization matrix estimated by first two figure eight operations is in Table 6. This matrix is used in real-time correction during the survey after 02:07 on Nov. 23. The filtered files (C files) before this time are calibrated by using temporary matrix and should not be used.

Table 5. Figure eight turns operation for STCM calibration

	Date	Time	Lon	Lat	Start Head	speed
fig8_1	2020/11/19	23:06-23:26	137°59.08E	32°03.9N	225°	8kt
fig8_2	2020/11/21	2:33-2:53	132°42.76E	27°23.8N	170°	8kt
fig8_3	2020/11/25	19:32-19:52	132°20.02E	25°38.47N	225°	7.6kt
fig8_4	2020/11/30	11:10-11:30	133°58.51E	30°07.62N	45°	7.8kt

Table 6. Preliminary ship magnetization matrix (fig8_1+fig8_2)

1.0285	0.0142	0.0058	958
0.0121	1.1195	-0.0359	80
0.0907	-0.0474	0.9374	-7841

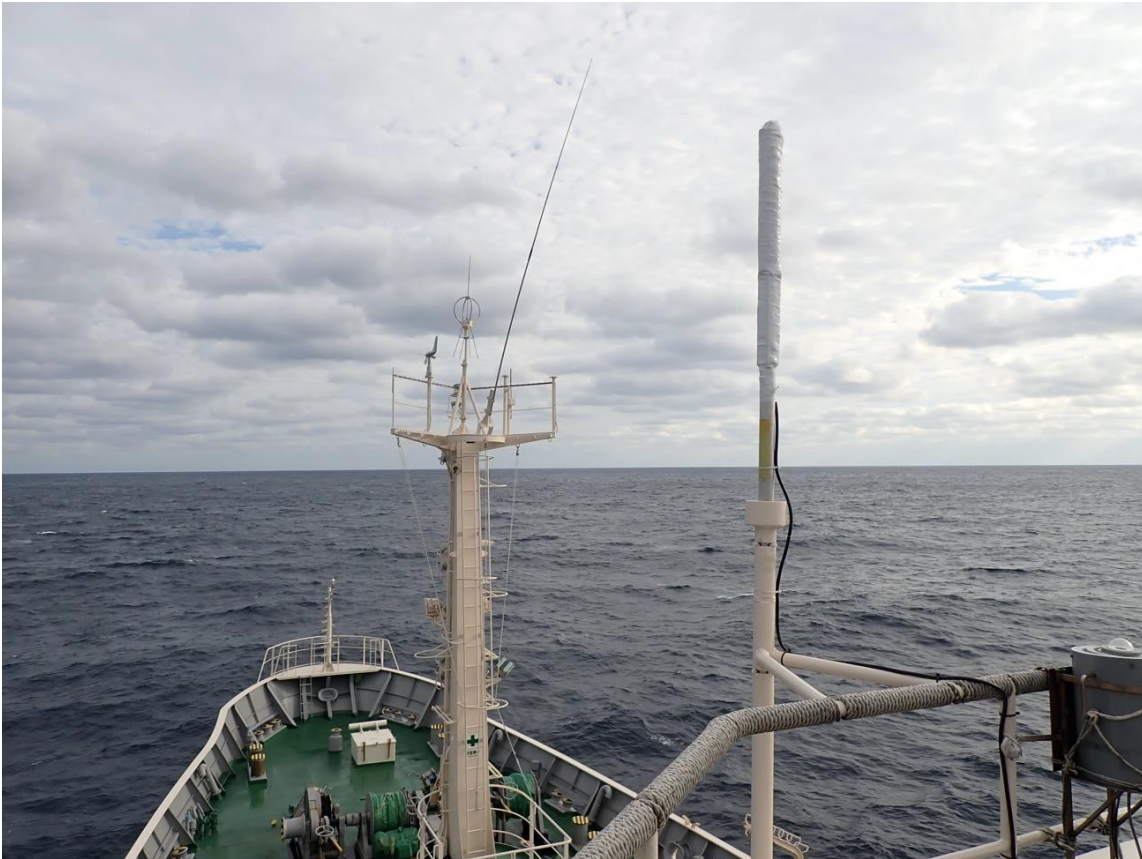


Figure 8. Shipboard three component magnetometer sensor on compass deck.

2.1.4. Gravity

Gravity field data are recorded by the shipboard gravimeter D-004 (LaCoste & Romberg, ZLS Co.), installed in Lab-9 (Figure 9). The major specifications are listed in Table 7. The portable gravimeter CG-5 (AUTOGRAV, SCHINTREX) is also used for measurements at Harumi and JAMSTEC ports.

Table 7. Shipboard gravity meter specification.

Model	ZLS D-004 Metal zero length spring
Range	7000 mGal
Drift	3 mGal or less per month
Static repeatability	0.2 mGal
Gyro	ZLS FOG
Sampling rate	10 sec

Absolute gravity tie is done at Harumi port, using HJ-pier base station. The details are shown in Table 8. Drift correction will be done after the cruise using the measurement at JAMSTEC pier on 2 December. Measurement log sheets are in Appendix.

Table 8. Absolute gravity tie information.

Date	Station	Pier height [m]	Draft [m]	Lab-9 height [m]	CG-5 height [m]	Corr. [mGal]
2020/11/19	Harumi HJ Pier	2.3	6	4.19	0.18	1.32

Date/Time	CG-5 gravity [mGal]	Absolute gravity at station [mGal]	Absolute gravity at Lab.9 [mGal]	ZLS digital gravity [mGal]
2020/11/19 11:05	7382.9150	979773.804	979775.13	3243.7

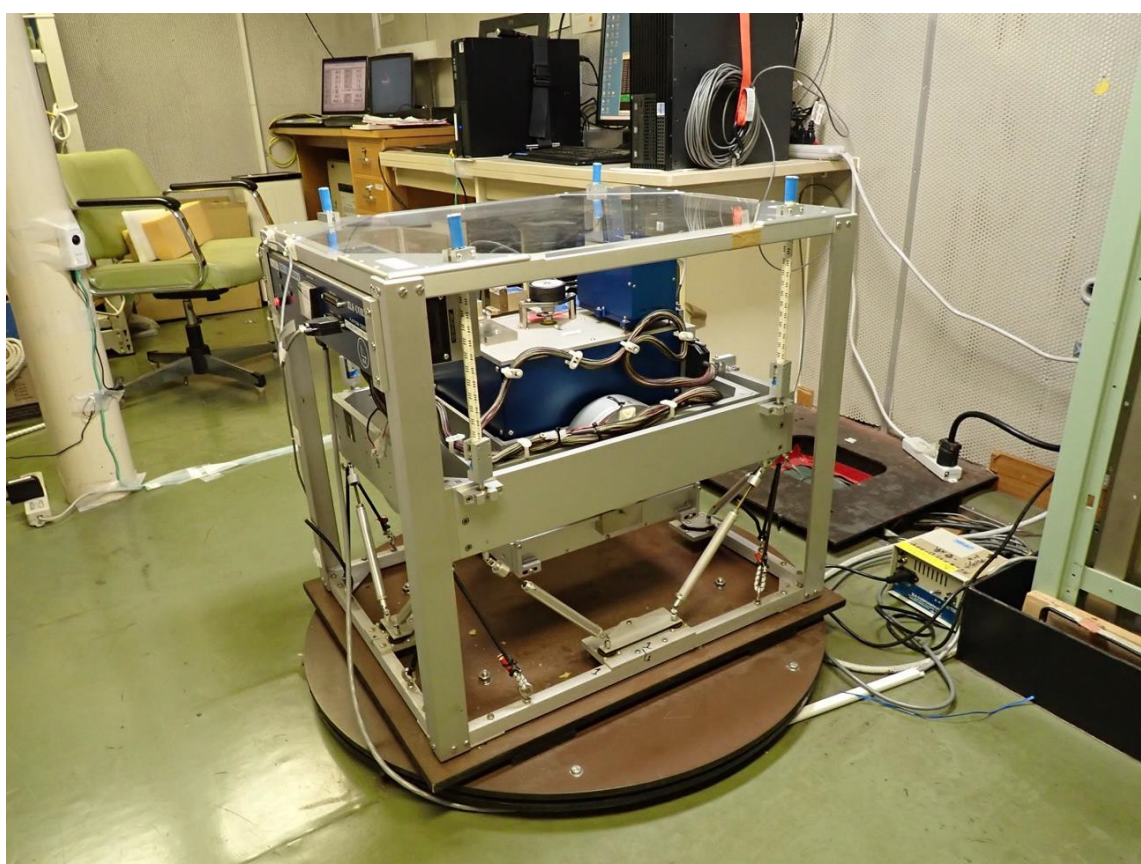


Figure 9. Ship gravimeter in Hakuho Maru Lab-9.

2.2. Preliminary Results

Gravity and vector magnetic field data were collected continuously from Harumi port to JAMSTEC pier. Multibeam bathymetry data were recorded south of 30°N. Total magnetic field data was collected along survey lines and transit lines between dredge sites. Survey lines are shown in Figure 3.

2.2.1. Bathymetry

Total 850 miles of multibeam survey was done during KH-20-6. The erroneous data are manually deleted using CARIS HIPS and SIPS and the cleaned data are exported as ascii xyz file. Then 100m-interval grid is created by GMT near neighbor algorithm. Another grid file where NaN values are replaced by JTOPO30 bathymetry is also created. These data are shown in Figure 10 and 11, respectively.

The focused survey areas with dredge hauls are; K: Kanami Seamount, A: Tete Seamount, B: Corrugated northern flank of Daito Ridge, C: N-S lineated high, E: Daito Ridge. The closeup views (shaded relief and 50m contours) are presented in Figures 12(a-e).

Kanami and Tete seamounts extend NE-SW direction, that is oblique to the general E-W trend of rift structure. Area B is characterized with almost N-S trending corrugations. The height of these corrugations is ~50m, and minor ridges of same trend are extended from the main Daito Ridge. The corrugated surface area corresponds to the area showing high P wave velocity in shallow subsurface (Nishizawa et al., 2014). The top of the Daito Ridge is flat and two conical seamounts are located in the northern flank. They are cut or controlled by NW-SE to E-W trending faults.

KH-20-6 Bathymetry ALL

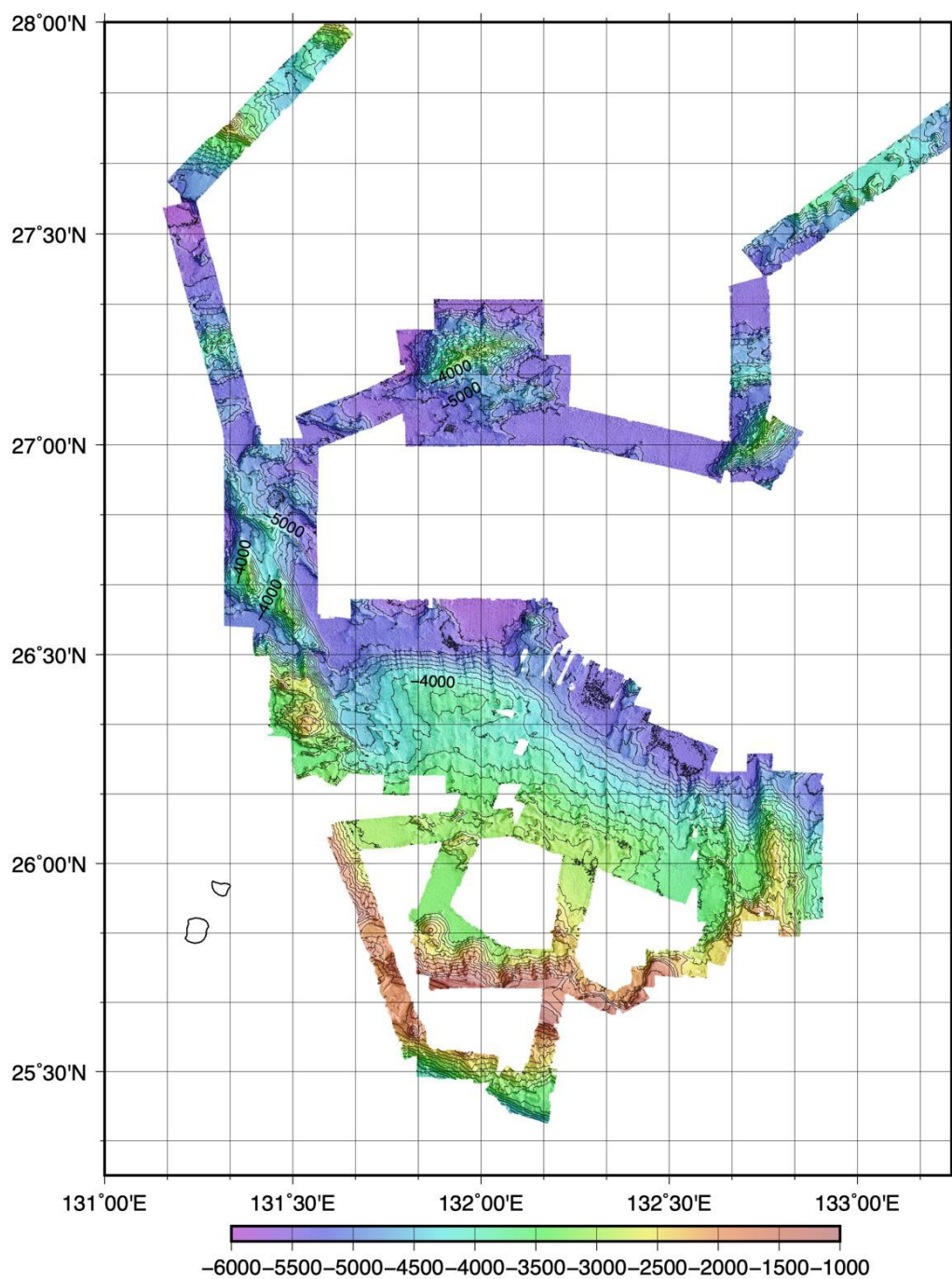


Figure 10. Multibeam bathymetry collected during KH-20-6.

KH-20-6 Bathymetry ALL + JTOPO30

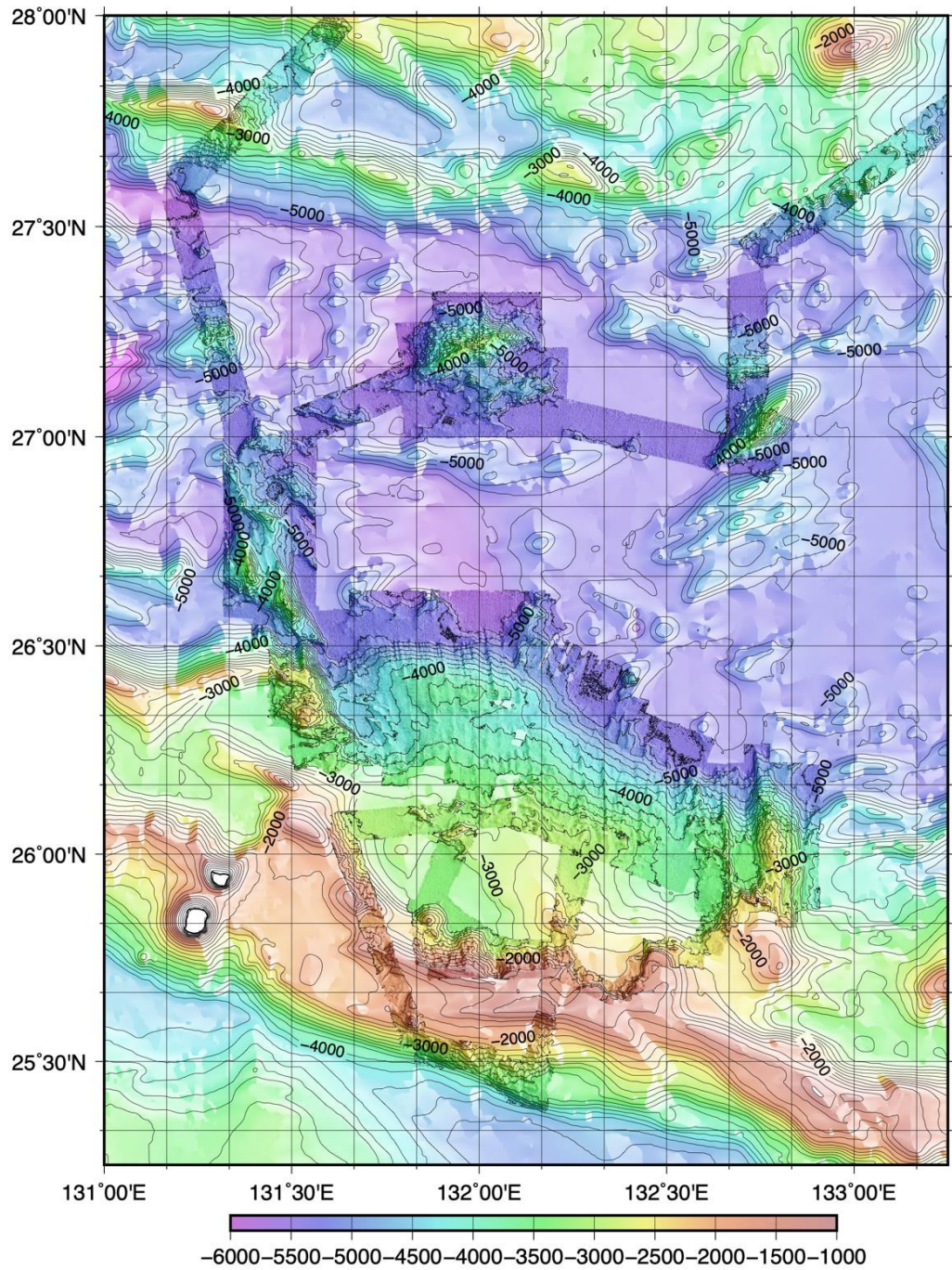


Figure 11. Multibeam bathymetry collected during KH-20-6 overlays JTOPO30 data.

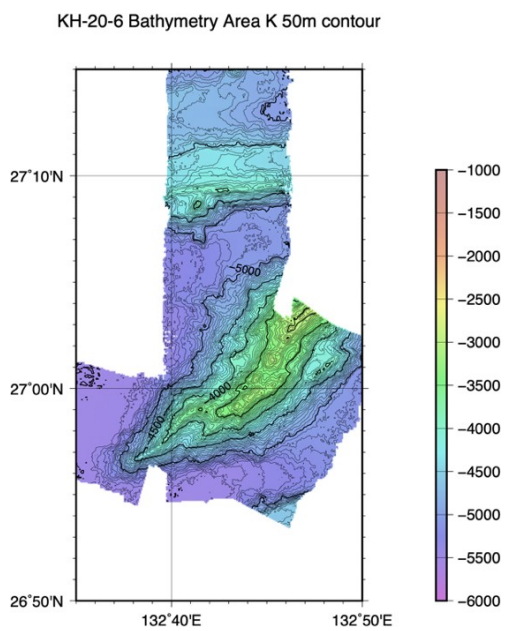
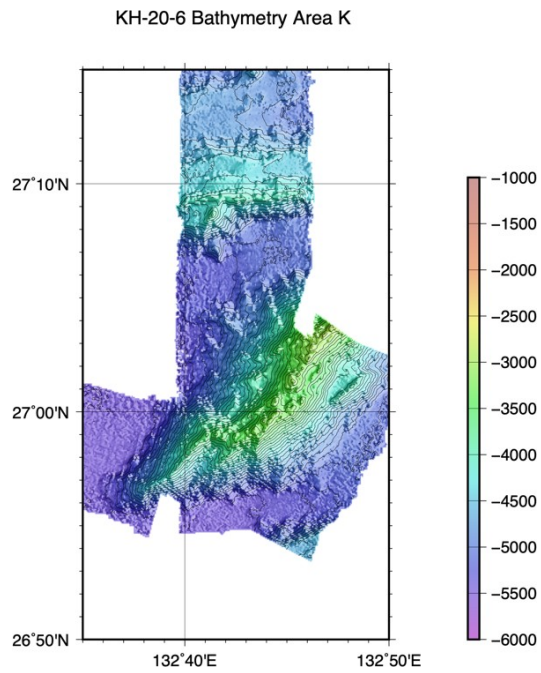
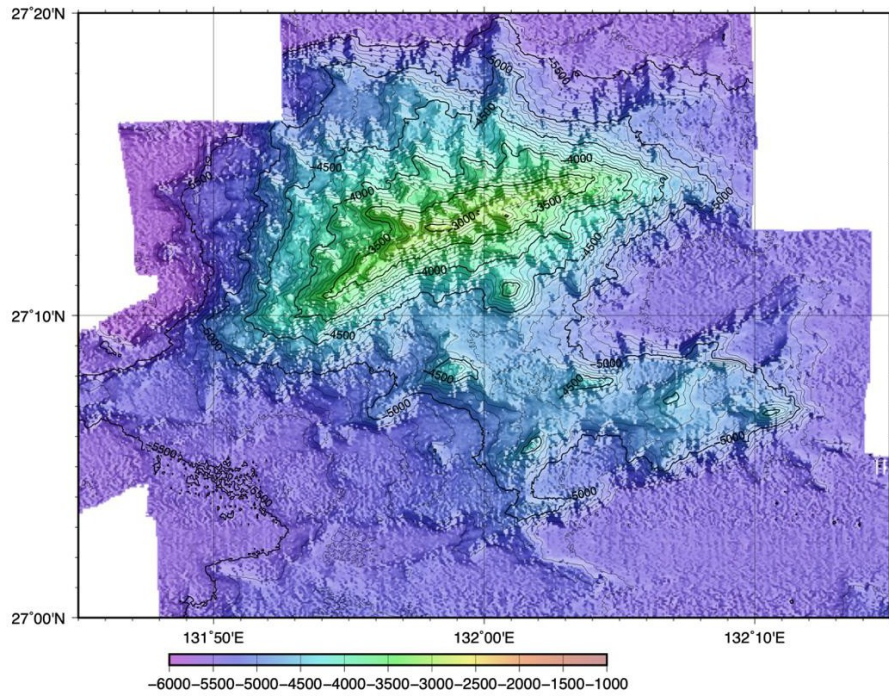


Figure 12(a). Multibeam bathymetry across Kanami Seamount (area K). (top) Shaded bathymetry with 100m contours and (bottom) 50m contours.

KH-20-6 Bathymetry Area A



KH-20-6 Bathymetry Area A 50m contour

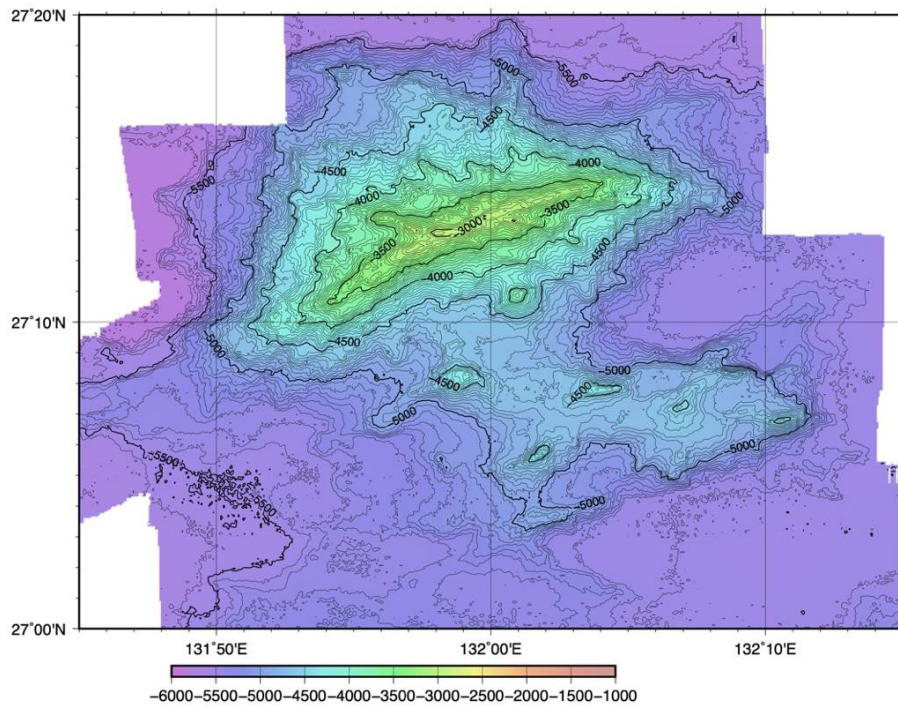


Figure 12(b). Multibeam bathymetry of Tete seamount (area A). (top) Shaded bathymetry with 100m contours and (bottom) 50m contours.

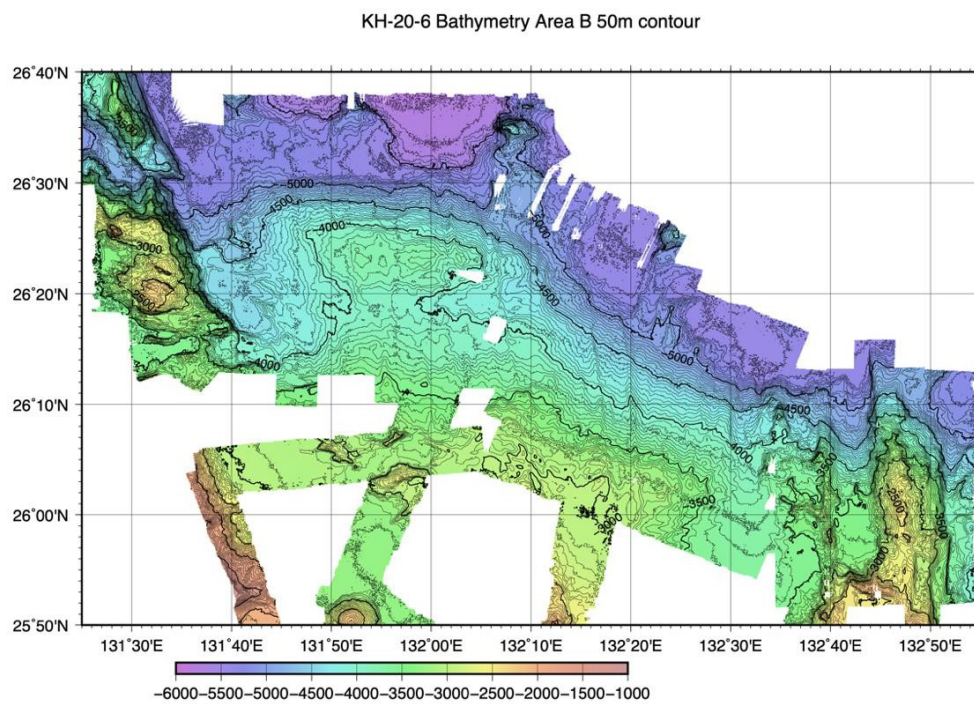
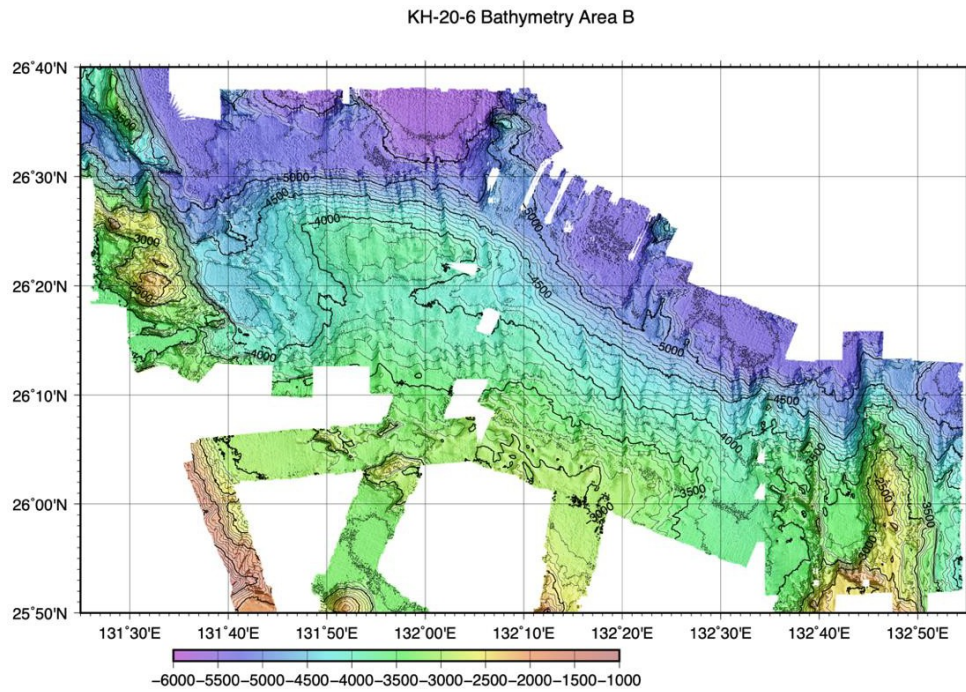


Figure 12(c). Multibeam bathymetry of corrugated surface (area B). (top) Shaded bathymetry with 100m contours and (bottom) 50m contours.

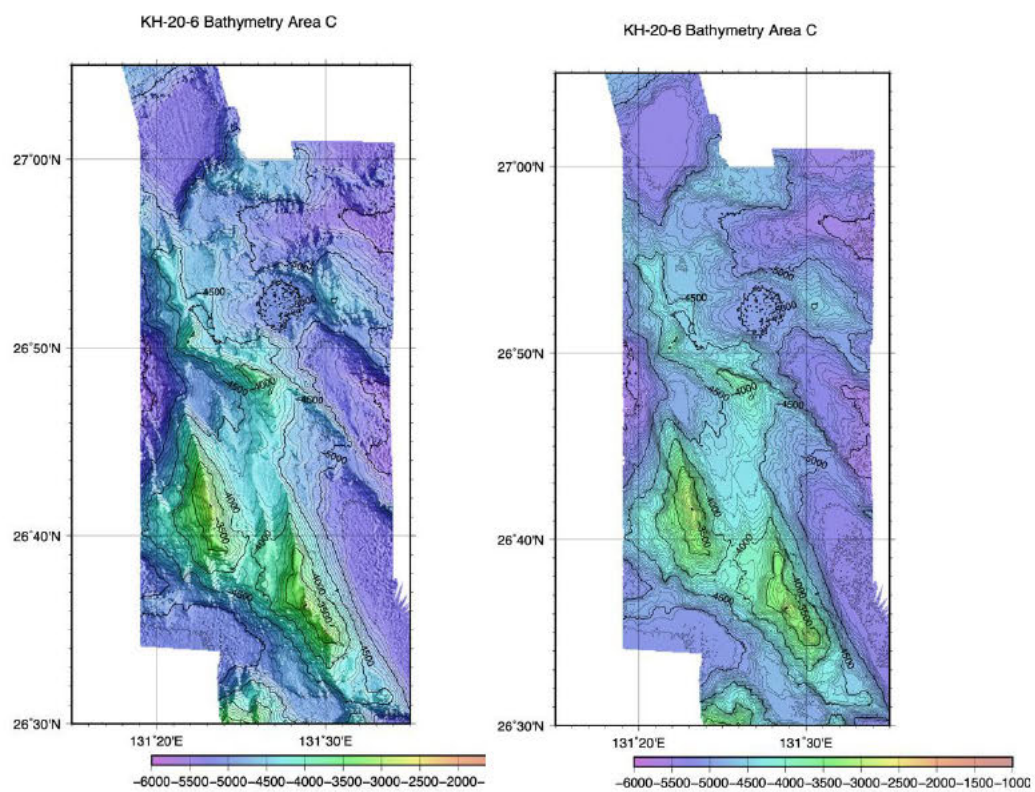


Figure 12(d). Multibeam bathymetry of anomalous elongated/faulted high (area C). (left) Shaded bathymetry with 100m contours and (right) 50m contours.

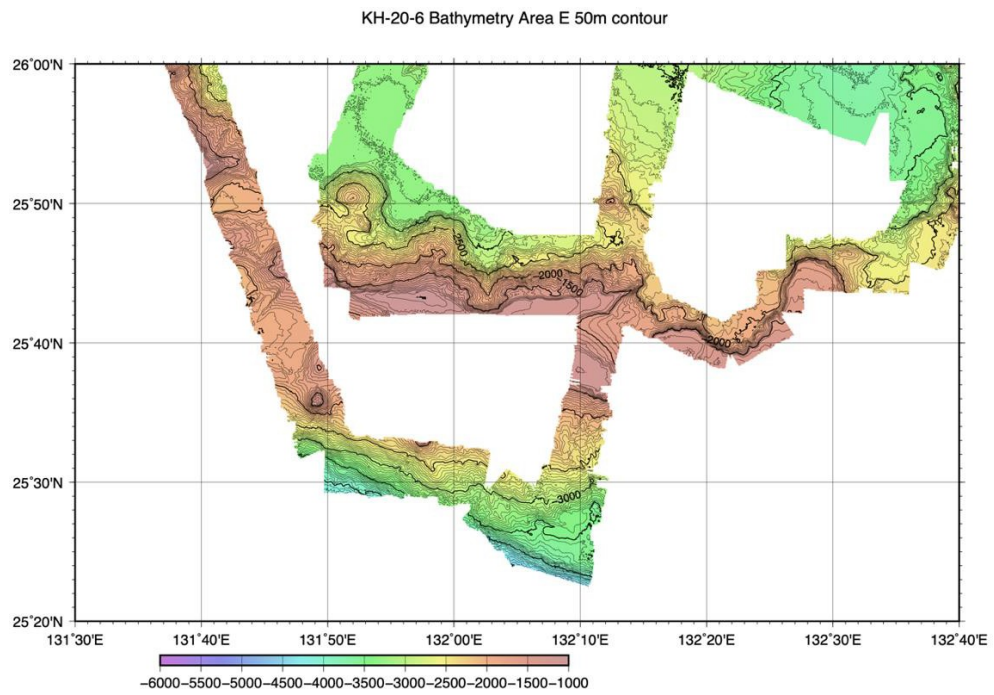
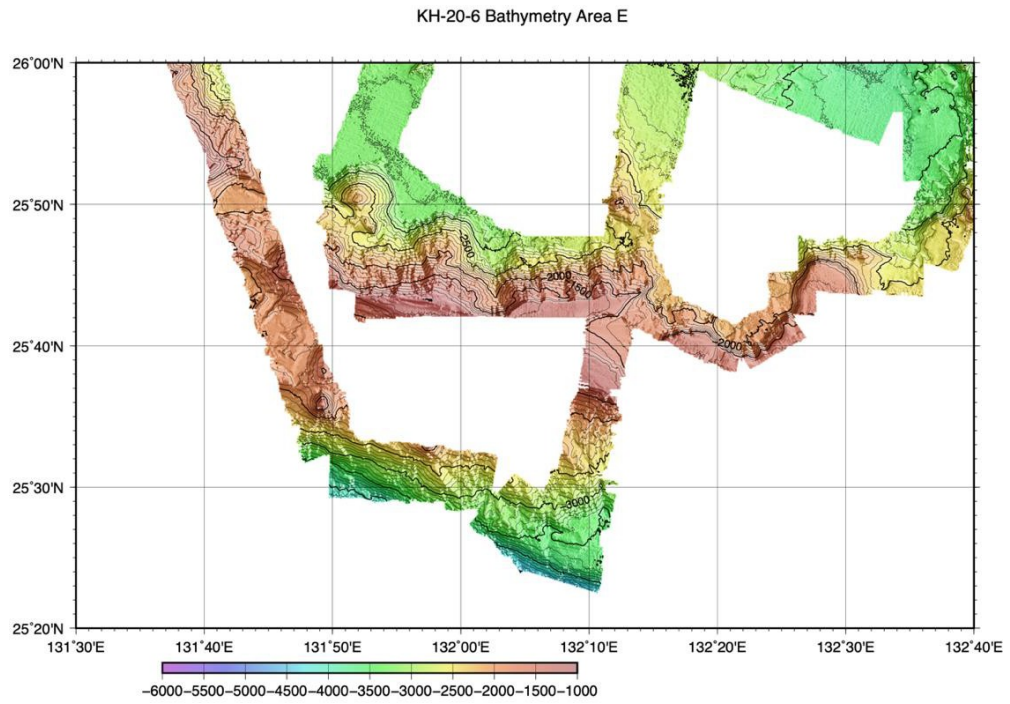


Figure 12(e). Multibeam bathymetry of Daito Ridge (area E). (top) Shaded bathymetry with 100m contours and (bottom) 50m contours.

2.2.2. Magnetic anomalies

Total magnetic field strength data collected by proton magnetometer is re-combined with appropriate position data taking the cable length into account. Then the magnetic anomalies are calculated by subtracting IGRF2020 field. Figure 13 shows the magnetic anomaly distribution along track lines in the survey area. The anomaly pattern near the Tete seamount (Area A) clearly shows the dipole type anomaly, where the negative anomaly is located above the topographic high and the positive anomaly is in the south, suggesting positively magnetized body. Area B shows generally negative anomalies. The relationship with corrugated structure remains unsolved. The top of the Daito Ridge also shows negative anomaly, associated with high positive anomalies on the southern flank.

Vector magnetic field collected by shipboard three component magnetometer will be processed after the cruise. The estimated ship magnetization matrices are in Appendix.

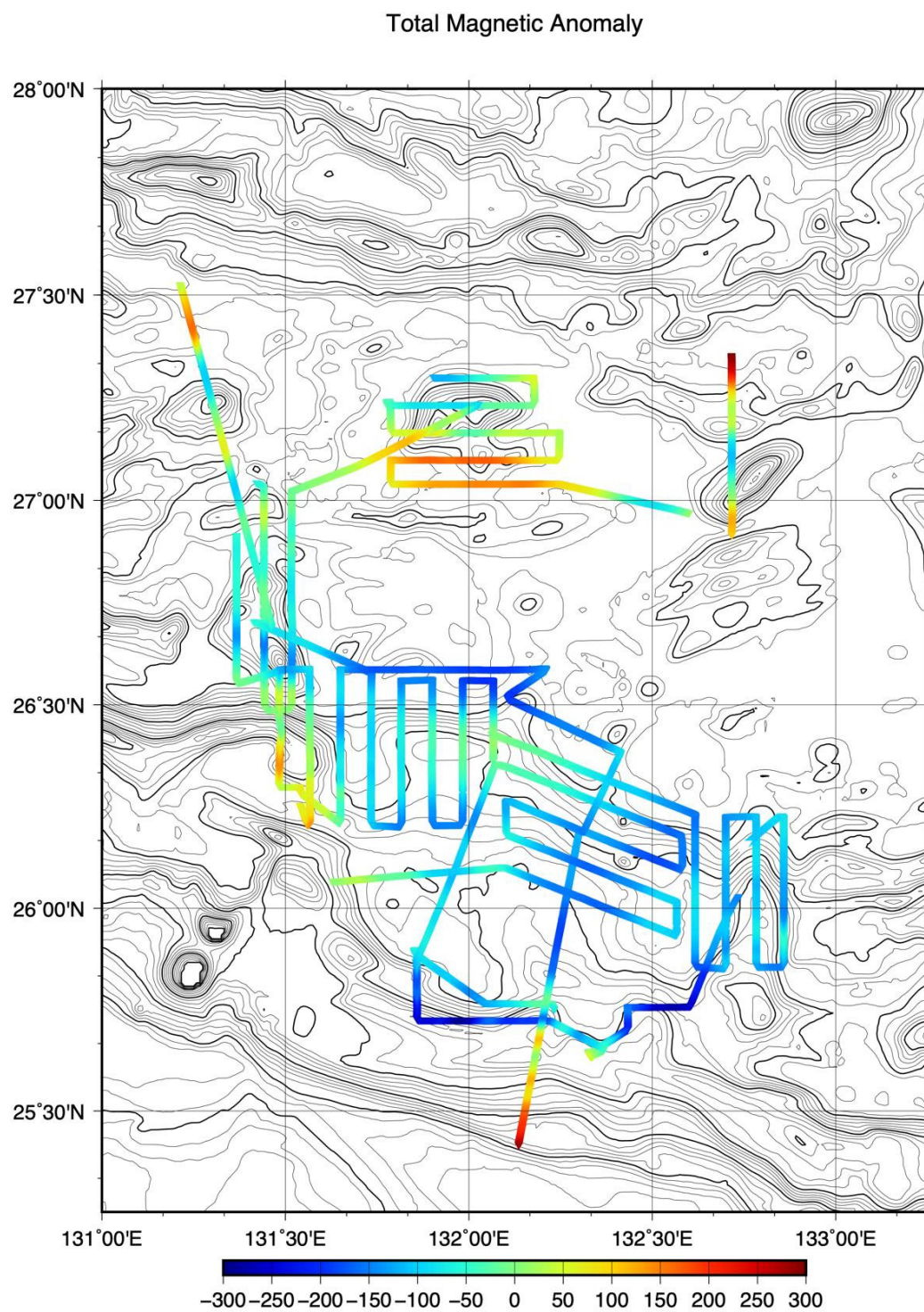


Figure 13 . Total magnetic anomalies. Unit is [nT]

2.2.3. Gravity anomalies

Shipboard gravimeter data are tied to absolute gravity value at Harumi pier and 5 minutes time delay for digital filtering are applied. Smoothed velocity (300 sec median filter) is used for Etovos correction. The comparison with satellite gravity anomaly shows that the derived free-air anomaly values generally fits satellite anomalies during cruising but some offsets exist when the ship speed is very low (during dredge operation) (Figure 14). This issue should be investigated.

Figure 15 shows the free-air anomalies along track lines. The distribution generally reflects topographic variation.

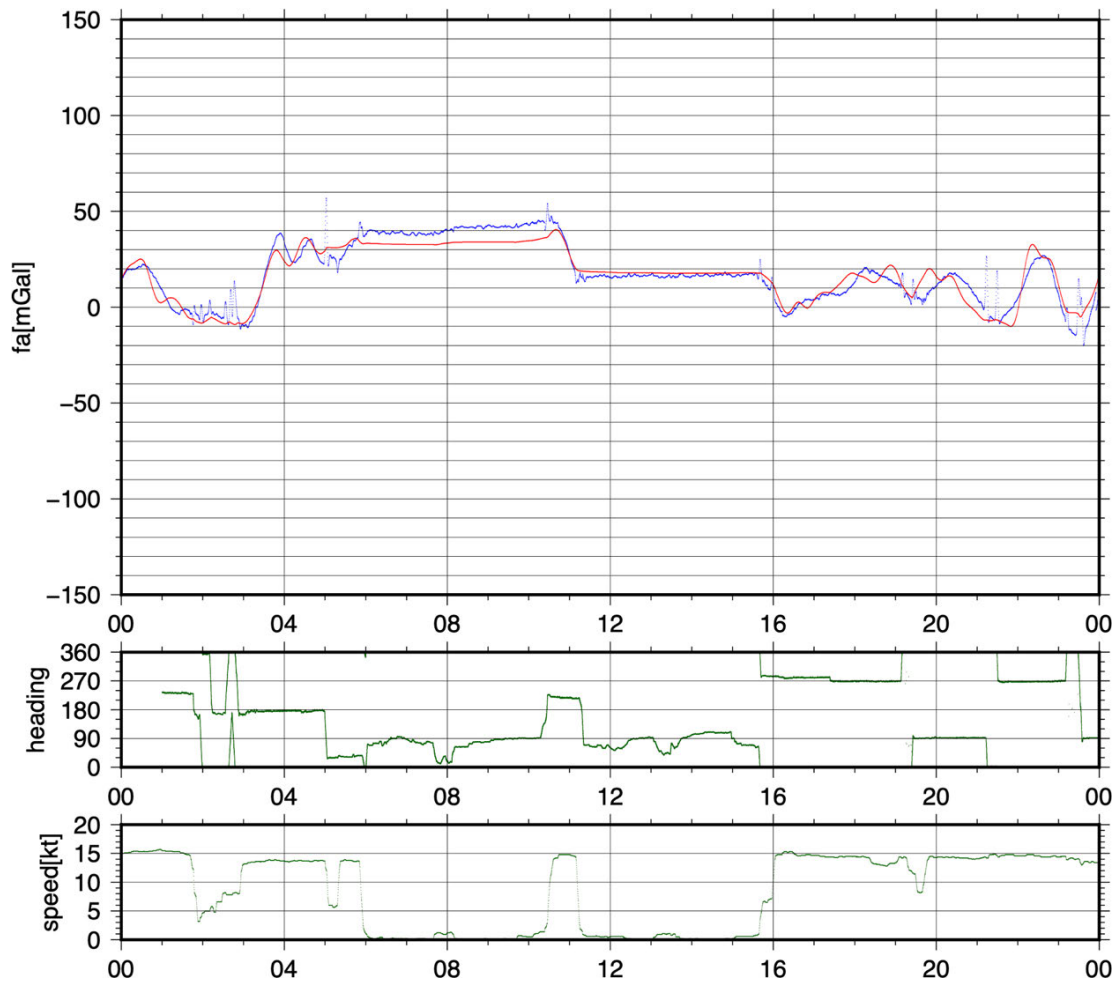


Figure 14. Comparison with satellite gravity anomaly (red) and derived free-air gravity anomaly (blue) on 21 November.

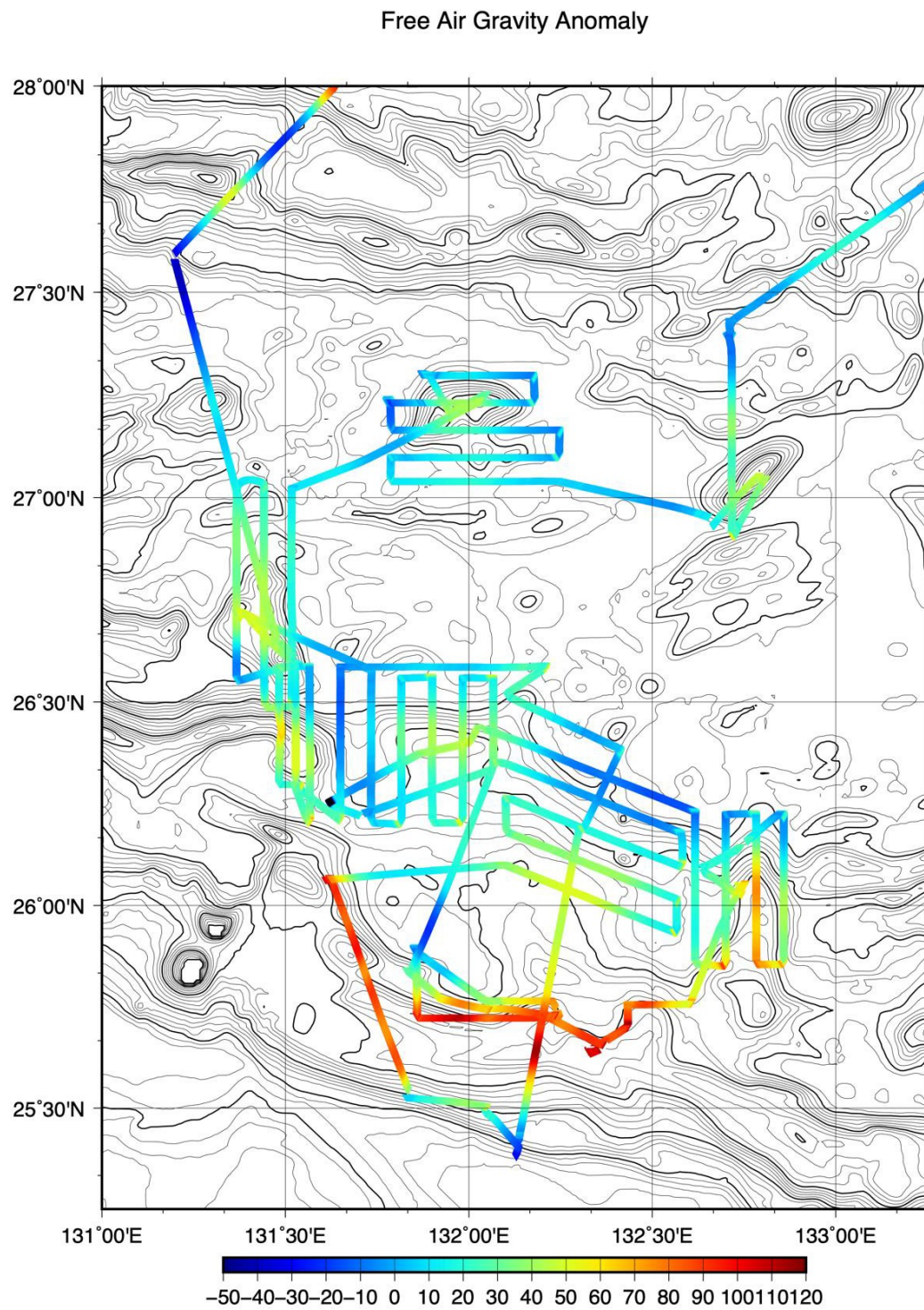


Figure 15. Free-air gravity anomalies along track lines. Unit is [mGal].

3. Dredge Survey

3.1. General

We conducted 23 dredge surveys during the KH-20-6 cruise in the Daito Ridge and Kita-Daito Basin (Figure 16) based on two major scientific objectives:

1. Understand the detailed crustal structures of the Daito Ridge.
2. Understand the timing of the Kita-Daito Basin formation and its origin.

Along with rock sampling, we have simultaneously studied benthos that were brought on deck with the rocks and sediments. As part of the dredging, we also attached a video camera to the chain above the dredge to capture images of undersea outcrops during dredging. We have also mounted an additional camera on top of the dredge (Satsuki-type) on D23 for a technical test.

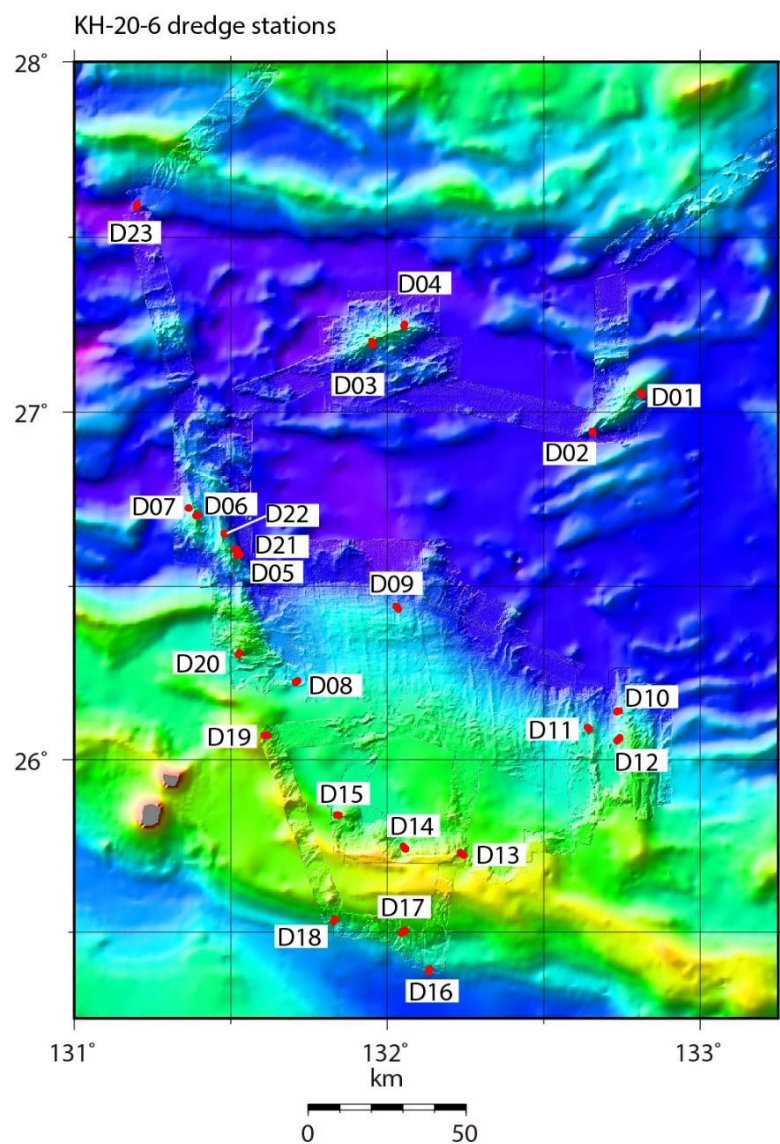


Figure 16. Dredge sites during the KH-20-6 cruise.

3.2. Instrument and operation notes

The dredge systems used during the KH-20-6 cruise are as illustrated in Figure 17. The chief components of the system are a transponder, a pinger, a chain, a 200-kg weight, a camera sledge, fuse wires, life wires, and three types of dredge; Gyaico-type chain-bag dredge, Miyamon-type box-shaped dredge and Satsuki-type box-shaped dredge. The dredge assemblage was connected to the ship-board No.1 winch wire (14 mm in diameter).

1. The transponder is used to estimate the position of the dredge system. It was attached to the winch wire at 400 m above its end.
2. The pinger is used to estimate the altitude of the winch wire during dredging. It is attached to the winch wire approximately 200 m above its end.
3. The chain is used to stabilize the dredge on the sea floor during operation. It is 6 m long and 19 mm in diameter. It is connected to the winch wire by shackles (3.25 ton) and a swivel (5 ton).
4. The weight keeps the dredge on the sea floor during operation. A weight of 200 kg was used and connected to the chain by a fuse wire (0.25 m long), a life wire covered with a hose (2.3 m long), shackles (1.2 ton), and a swivel (1 ton).
5. The camera sledge (Mago-camera) is connected to the chain by a fuse wire (0.25 m long), a life wire covered with a hose (1.5 m long), shackles (1.2 ton), and a swivel (1 ton). We used a 7000 mbsl-rated undersea video camera and LED light system.
6. The dredge is connected to the chain by a fuse wire (0.25 m long), a life wire covered with a hose (4.6 m long), shackles (2 ton; 3.25 ton), a swivel (3 ton), and a master ring (5 ton). To obtain better recovery of the benthos that are sampled with the rocks, we installed 350 μ m nylon mesh bags inside the dredge (Figure 18). We also installed an RBR SOLO depth logger inside the dredge to monitor precise movements of the dredge at the seafloor (a logger containing data from D01 to D19 was lost at D19 with the dredge).
7. Following the regulation of Hakuho Maru, fuse wires of 6.3 mm (1.84 kN of breaking force) and life wires of 8 mm (2.99 kN of breaking force) were used for sites deeper than 5500 m. For sites shallower than 5500 m, we used fuse wires of 8 mm (2.99 tf of breaking force) and life wires of 9 mm (3.78 tf of breaking force).
8. The ship position was kept still above the starting point of the dredge during the lowering of the dredge assembly. The assembly was lowered at a full speed of 1 m/sec until the dredge was approximately 50 - 100 m above the seafloor, and then slowed down to a rate of 0.3 m/sec until the dredge touched the seafloor. As soon as the dredge landed on the seafloor, which was indicated by a decrease in wire tension, the winch was stopped. Then the dredge was pulled by the ship towards the end point at 0.5 – 1.0 knot (SOG). The position of the dredge and its movement was monitored by the transponder and pinger signals. If the ship reached the end point, or the distance between the ship and the transponder exceeded ~800 m, or the pinger altitude from the sea floor became lower

than 100 m, the wire was wound up at a rate of 0.3 m/sec until the dredge left the bottom.

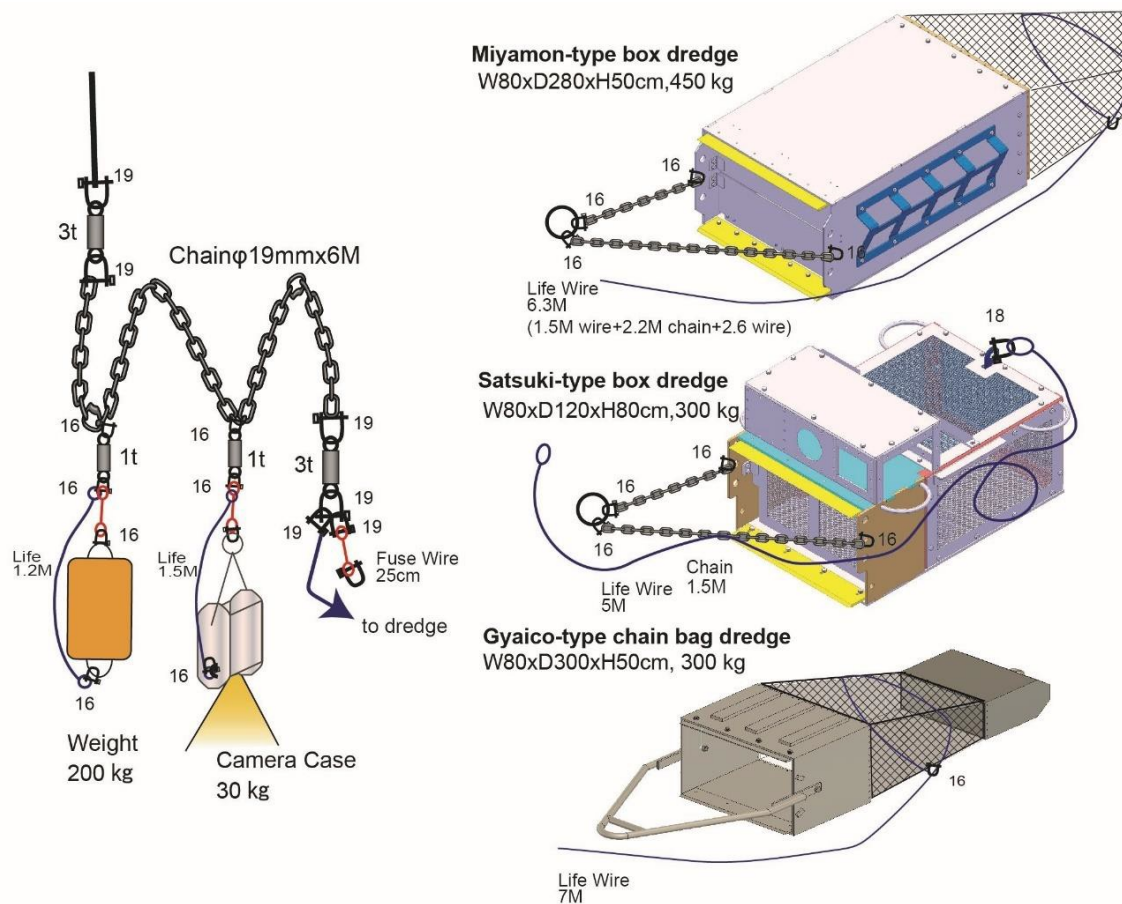


Figure 17. Detailed assembly of dredge systems used in KH-20-6 cruise.



Figure 18. Nylon mesh bag installed in the Gyaico-type dredge for benthos sampling.

3.3. Survey results

Sample recovery of the dredge hauls was generally good except for D08 and D20, mostly collecting at least several rocks on each dredge. D08 failed to land at the seafloor due to extremely steep slope and a dredge was lost on D20.

The position and depth of the dredge sites are summarized in Table 9. The total weight of the recovered rocks was approximately 920 kg.

Date	St. No.	SP/EP	Time (JST)	Depth (m)	Lat. (°N)	Lon. (°E)	Wireout (m)	Lithology	Total weight (kg)	Dredge assembly
2020/11/21	D01	on bottom	7:37:58	4019	27.0497	132.8137	4035	basalt, mudstone, mud, conglomerate, Mn crust	126.5	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	8:55:02	3486	27.0575	132.8078	3496			
2020/11/21	D02	on bottom	13:12:31	4968	26.9395	132.6571	5148	mudstone, Mn crust	6.23	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	13:52:19	4553	26.9462	132.6557	4812			
2020/11/22	D03	on bottom	4:55:49	3773	27.1926	131.9543	3807	pillow basalt lava block, mudstone, phytic basalt, fragment, scoria, pumice	50.68	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	7:00:14	3031	27.2047	131.9503	3135			
2020/11/22	D04	on bottom	10:59:16	4031	27.2531	132.0555	4198	basalt lava, mudstone, Mn crust, conglomerate, scoria	9.1	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	11:44:52	3622	27.2466	132.0542	3950			
2020/11/23	D05	on bottom	1:35:42	4784	26.5920	131.5311	4931	mudstone, Mn crust	18.76	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	4:06:30	4460	26.5907	131.5250	4423			
2020/11/23	D06	on bottom	8:08:51	3903	26.7047	131.3975	3865	Mn-oxides crust, mudstone	1	Myamori-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	9:28:25	3326	26.7036	131.3893	3349			
2020/11/23	D07	on bottom	12:40:45	4021	26.7255	131.3638	4071	none	0.0	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	13:11:51	3707	26.7252	131.3678	3788			
2020/11/24	D08	on bottom	3:52:59	3941	26.2279	131.7148	3942	lapilli tuff with basalt-andesite lava and polymictic clast, basalt-andesite clast, Mn-oxides crust, pumice	49.65	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	5:05:07	3566	26.2234	131.7061	3670			
2020/11/24	D09	on bottom	10:36:18	4404	26.4428	132.0290	4418	pumice, scoria	0.105	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	12:03:32	4218	26.4341	132.0361	4341			
2020/11/25	D10	on bottom	2:10:17	4458	26.1387	132.7332	4534	schist, mudstone	34.89	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	3:45:39	3948	26.1414	132.7426	4142			
2020/11/25	D11	on bottom	7:48:14	3910	26.0940	132.6393	3926	pumice, scoria, Mn crust	3.27	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	9:26:22	3334	26.0880	132.6463	3456			
2020/11/25	D12	on bottom	13:44:36	3666	26.0538	132.7338	3680	pumice, serpentinite, mafic schist fragments	0.16	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	15:01:03	3315	26.0635	132.7435	3524			
2020/11/26	D13	on bottom	2:00:03	2143	25.7238	132.2455	2107	dacite, andesite, mudstone, volcaniclastic conglomerate, sandstone	94.56	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	3:43:38	1564	25.7317	132.2337	1636			
2020/11/26	D14	on bottom	6:33:06	2424	25.7491	132.0504	2406	faul gauge, peridotite, serpentinite, cataclastic, mudstone	31.8	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	8:31:11	2098	25.7443	132.0565	2194			
2020/11/26	D15	on bottom	12:13:00	2789	25.8403	131.8373	2837	serpentinite (breccia), calcareous mudstone-sandy mudstone, gabbro, limestone,	74.99	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	13:28:22	2416	25.8389	131.8467	2594			
2020/11/27	D16	on bottom	2:07:54	4603	25.3838	132.1322	4630	serpentinite (harzburgite, dunite), gabbro, dolerite, dolerite breccia, Mn crust	74.3	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	3:50:13	4183	25.3942	132.1351	4338			
2020/11/27	D17	on bottom	7:33:20	2944	25.4971	132.0455	2995	basalt, sandstone, chert, serpentinite	1.75	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	10:14:33	2694	25.5022	132.0533	2628			
2020/11/27	D18	on bottom	13:45:21	3462	25.5306	131.8295	3501	mudstone, basalt, conglomerate, breccia	12.5	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	15:17:29	3034	25.5391	131.8331	3129			
2020/11/27	D19	on bottom	20:12:18	2276	26.0697	131.6187	2349	dredge lost	-	Gyaico-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	21:48:30	1894	26.0703	131.6049	1946			
2020/11/28	D20	on bottom	20:41:26	3033	26.3027	131.5246	3032	Mn crust	0.486	Myamori-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	21:54:54	2493	26.3089	131.5283	2607			
2020/11/29	D21	on bottom	2:15:49	4681	26.6055	131.5214	4770	psamitic schist, mafic schist, siliceous schist, black schist, quartz or albite vein, mudstone	5.46	Myamori-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	4:19:47	4691	26.6062	131.5212	4577			
2020/11/29	D22	on bottom	8:13:24	4038	26.6519	131.4826	3963	metadolomite, metabasalt, amphibole schist	11.62	Myamori-type dredge with 200 kg weight and hanging camera (5500 m)
		off bottom	9:30:22	3845	26.6529	131.4795	3795			
2020/11/29	D23	on bottom	17:48:25	5544	27.5863	131.1976	5624	basalt, lapilli tuff, lapilli stone	27.19	Satsuki-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	19:17:05	5106	27.5961	131.2011	5299			

Table 9. The position and depth of the dredge sites.

References

- Ishizuka, O., Tani, K., Reagan, M. K., Kanayama, K., Umino, S., Harigane, Y., Sakamoto, I., Miyajima, Y., Yuasa, M., & Dunkley, D. J. (2011). The timescales of subduction initiation and subsequent evolution of an oceanic island arc. *Earth and Planetary Science Letters*, 306(3), 229–240.
- Deschamps, A. E., Lallemand, S. E., & Collot, J.-Y. (1998). A detailed study of the Gagua Ridge: A fracture zone uplifted during a plate reorganisation in the Mid-Eocene. *Marine Geophysical Researches*, 20, 403–423.
- Deschamps, A., Monié, P., Lallemand, S., Hsu, S.-K., & Yeh, K. Y. (2000). Evidence for Early Cretaceous oceanic crust trapped in the Philippine Sea Plate. *Earth and Planetary Science Letters*, 179(3), 503–516.
- Deschamps, A., & Lallemand, S. (2002). The West Philippine Basin: An Eocene to early Oligocene back arc basin opened between two opposed subduction zones. *Journal of Geophysical Research*, 107(B12).
- Doo, W.-B., Hsu, S.-K., Yeh, Y.-C., Tsai, C.-H., & Chang, C.-M. (2015). Age and tectonic evolution of the northwest corner of the West Philippine Basin. *Marine Geophysical Researches*, 36(2), 113–125.
- Kuo, B.-Y., Chi, W.-C., Lin, C.-R., Chang, E. T.-Y., Collins, J., & Liu, C.-S. (2009). Two-station measurement of Rayleigh-wave phase velocities for the Huatung basin, the westernmost Philippine Sea, with OBS: implications for regional tectonics. *Geophysical Journal International*, 179(3), 1859–1869.
- Morishita, T., Tani, K.-I., Soda, Y., Tamura, A., Mizukami, T., & Ghosh, B. (2018). The uppermost mantle section below a remnant proto-Philippine Sea island arc: Insights from the peridotite fragments from the Daito Ridge. *The American Mineralogist*, 103(7), 1151–1160.

Notice on Using

This cruise report is a preliminary documentation as of the end of cruise.
This report is not necessarily corrected even if there is any inaccurate description (i.e. taxonomic classifications). This report is subject to be revised without notice. Some data on this report may be raw or unprocessed. If you are going to use or refer the data on this report, it is recommended to ask the Chief Scientist for latest status.
Users of information on this report are requested to submit Publication Report to Cooperative Research Cruise office.

E-mail: kyodoriyo@aori.u-tokyo.ac.jp