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R/V Hakuho-maru "Cruise Report"
KH-19-6 Leg 4

Integrated investigation for marine earth sciences in the Weddell Sea and the South Pacific: Fulfillment of R/V Hakuho-maru 30th anniversary expedition

Atlantic sector of Southern Ocean

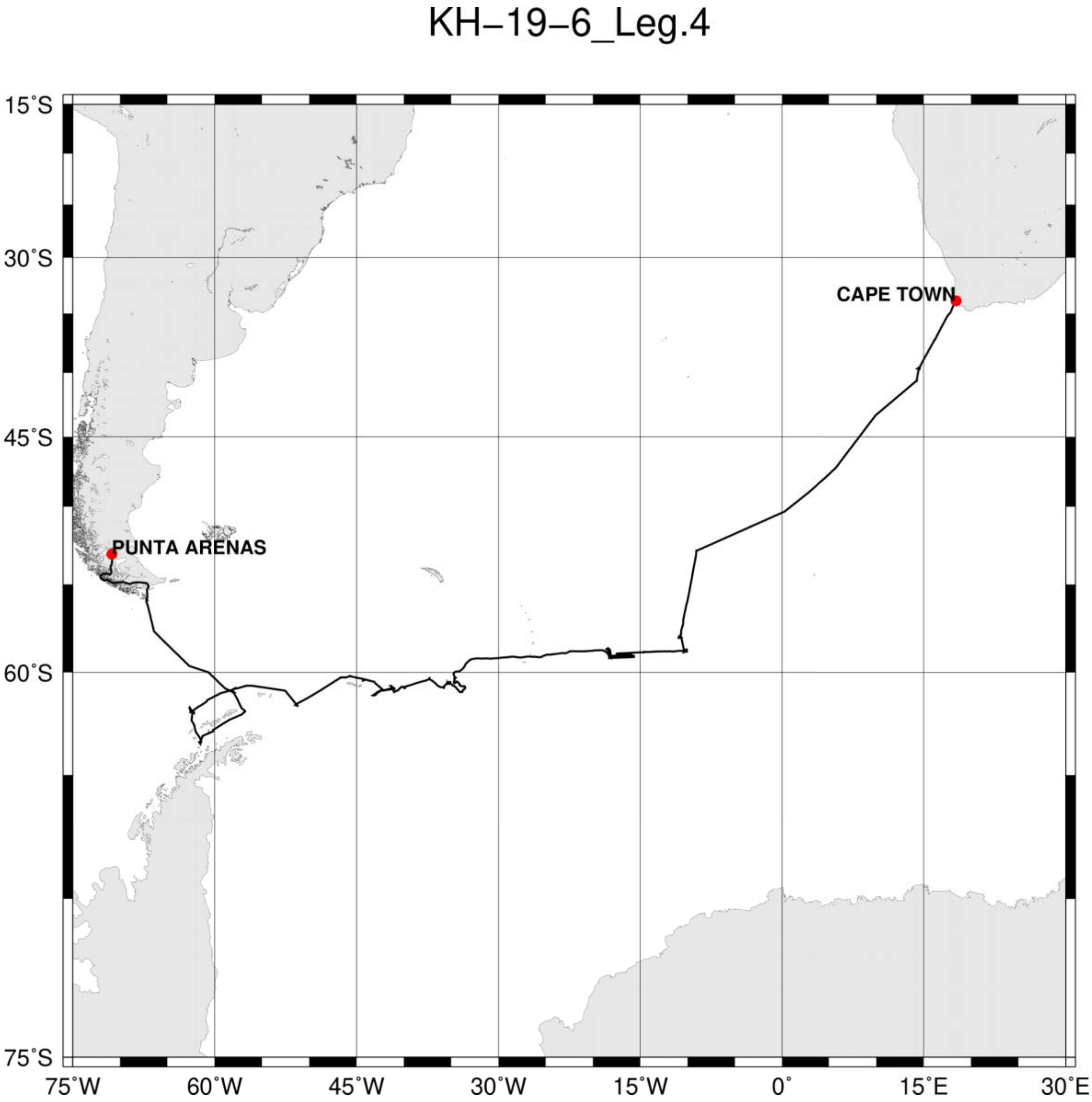
Dec. 19, 2019 - Jan. 16, 2020

Joint Usage/Research Center for Atmosphere and Ocean Science
(JURCAOS)
Japan Agency for Marine-Earth Science and Technology
(JAMSTEC)

Contents

1. Cruise Information

● Cruise ID: KH-19-6 Leg 4
● Name of vessel: R/V Hakuho-maru
● Title of cruise: Integrated investigation for marine earth sciences in the Weddell Sea and the South Pacific: Fulfillment of R/V Hakuho-maru 30th anniversary expedition
● Chief Scientist [Affiliation]: Minoru Ikehara [Kochi University]
● Cruise period: Dec. 19, 2019 - Jan. 16, 2020
● Ports of departure / call / arrival: Punta Arenas to Cape Town
● Research area: Atlantic sector of the Southern Ocean
● Research map



1-1. Shipboard Scientists of KH-19-6 Leg 4

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	Takanori KAGOSHIMA	AORI, The University of Tokyo	
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	Chihiro OHSHIMA	AORI, The University of Tokyo	
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	Hayao YOKOCHI	Graduate School, Kindai University	
	Akito OGAWA	Graduate School, The University of Tokyo	
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	Shimpei HIRUTA	National Museum of Nature and Science	
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	Yumiko HARIGANE	Geological Survey of Japan, AIST	
	Koji SEIKE	Geological Survey of Japan, AIST	
	Hiroaki KOGE	Geological Survey of Japan, AIST	
	Hidetaka NOMAKI	X-star, JAMSTEC	
	Iona MCINTOSH	Marine Geodynamics, JAMSTEC	
	Heather RITCHIE	X-star, JAMSTEC	
	Kaoru KUBOTA	X-star, JAMSTEC (now: Kobe University)	
	Naoto JIMI	Biosicence, National Institute of Polar Research	
	Mike WEBER	Bonn University	
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Technical Staff	Yuji FUWA	Marine Work Japan Ltd.	

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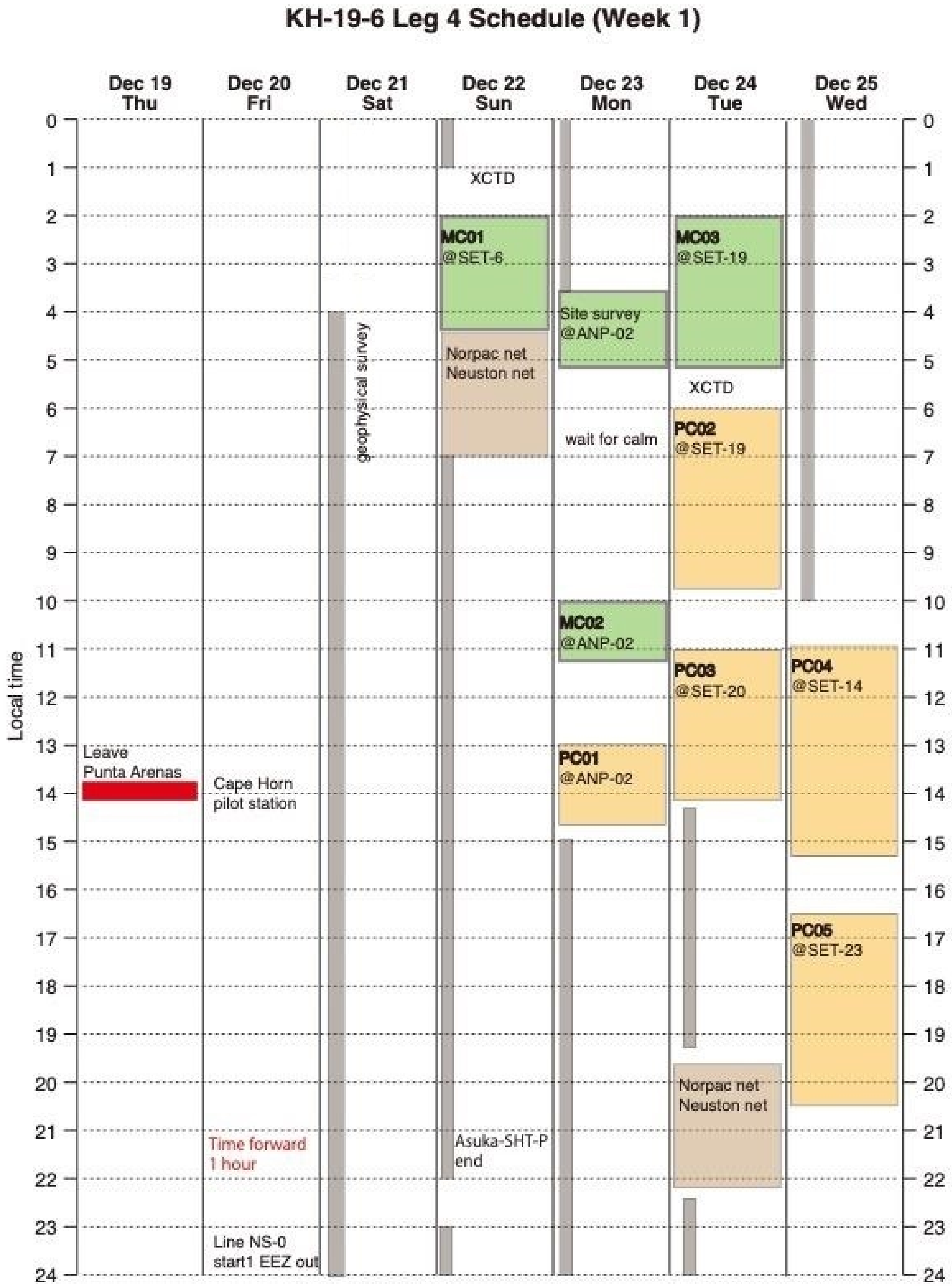
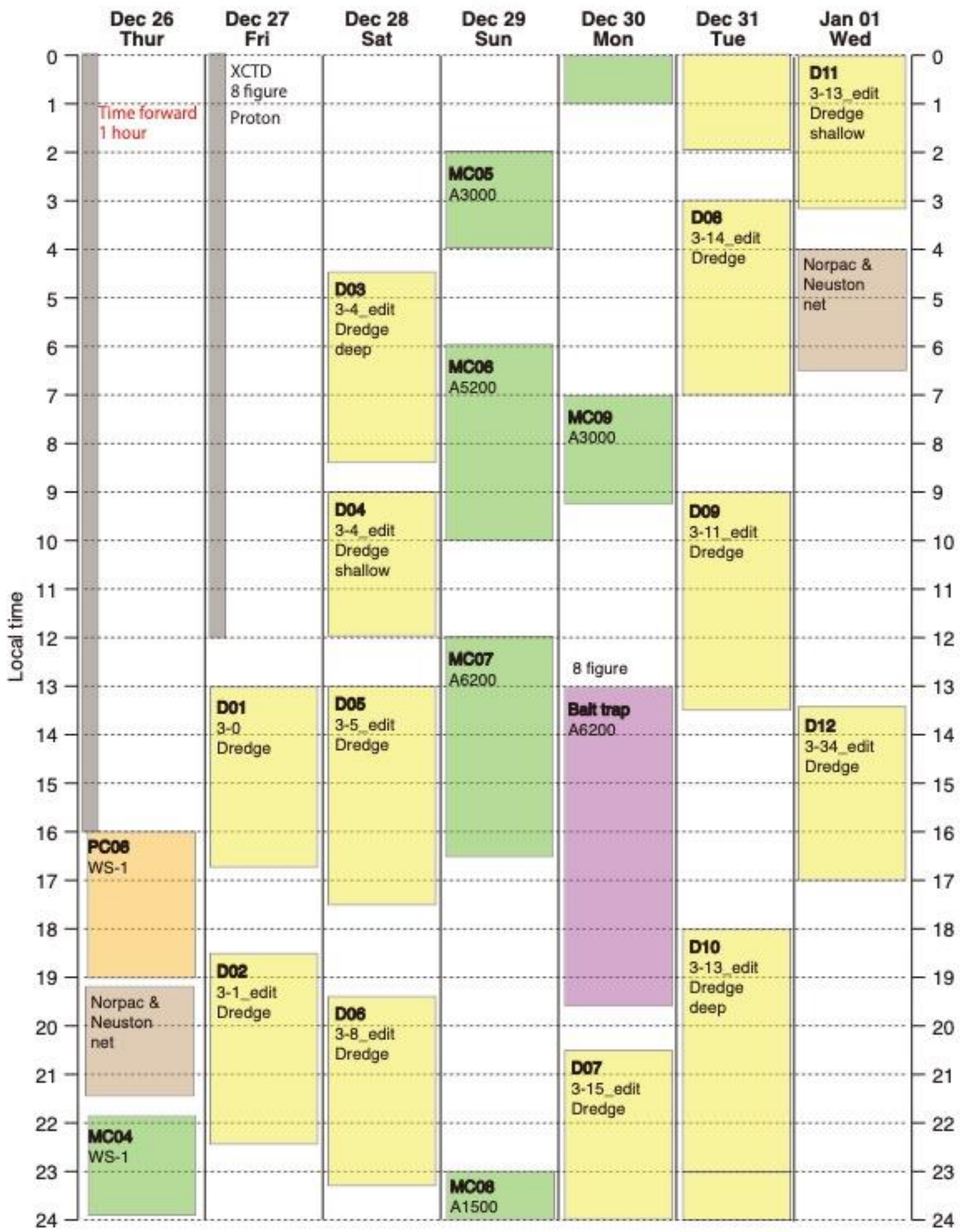
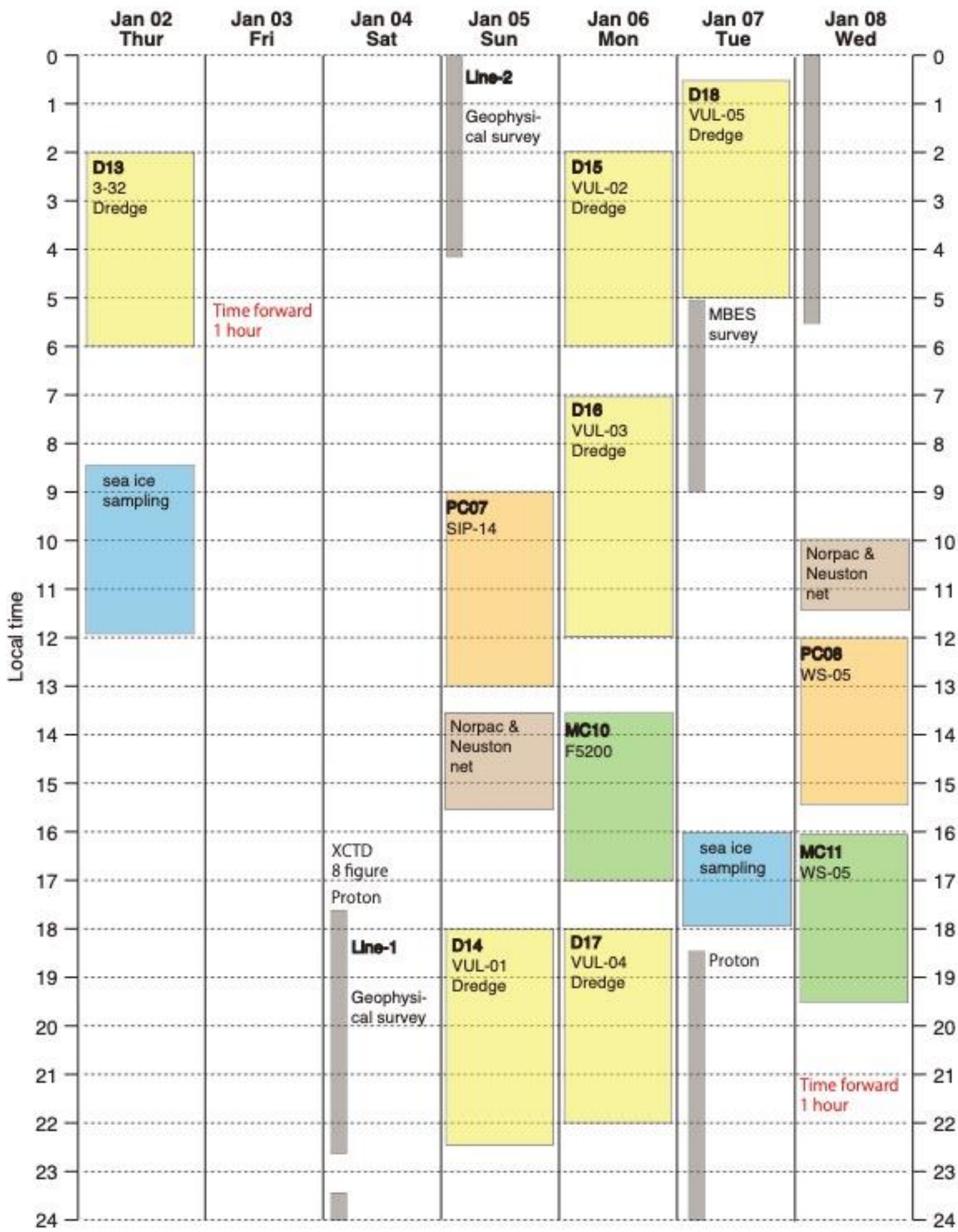
1-3. Summary of operation schedule of KH-19-6 Leg 4



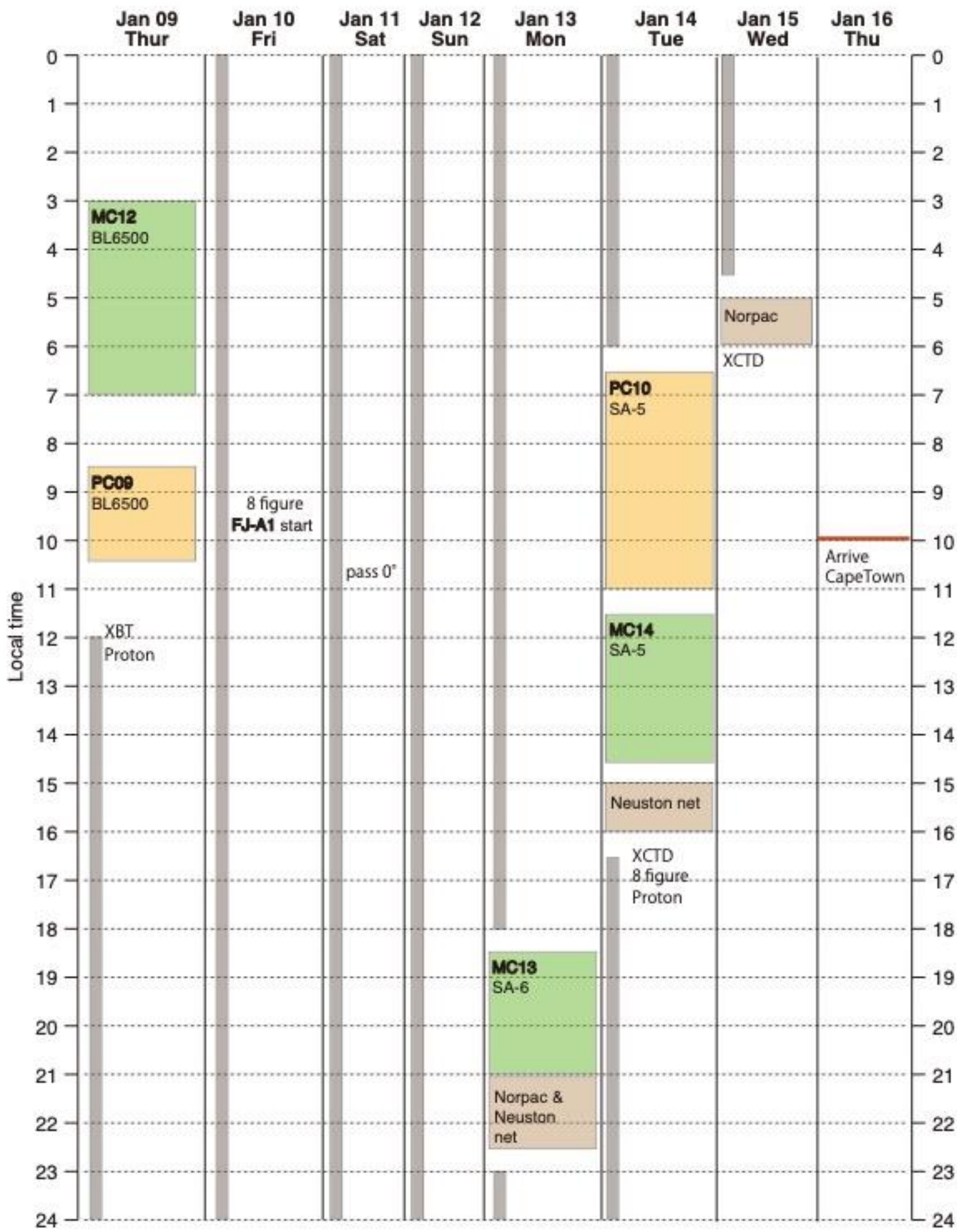
KH-19-6 Leg4 Schedule (Week 2)



KH-19-6 Leg 4 Schedule (Week 3)



KH-19-6 Leg 4 Schedule (Week 4)



2. Research Proposal and Science Party

2-1. Paleoceanographic investigation of the Weddell Gyre history

- Representative of Science Party [Affiliation]
  - Minoru Ikehara [Kochi University]
- Science Party (List) [Affiliation]
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  - Miho Sasaoka [Kochi University]
  - Kodai Kato [Kochi University]
  - Mutsumi Iizuka [Hokkaido University]
  - Ryuichi Seto [Hokkaido University]
  - Mike Weber [Bonn University]
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  - Kaoru Kubota [JAMSTEC]
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  - Osamu Seki [Hokkaido University]
  - Masanobu Yamamoto [Hokkaido University]
  - Yoshimi Kubota [National Museum of Nature and Science]
  - Akira Ijiri [JAMSTEC]
  - Toshitsugu Yamazaki [The University of Tokyo]
  - Yuki Morono [JAMSTEC]
  - Yukiko Kozaka [Nagoya University]
  - Li Lo [National Taiwan University]

2-2. Linkage between climate and tectonics in the Scotia Sea and South Sandwich trench

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- Shipboard Science Party (List) [Affiliation]
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  - Yuichi Okuma [The University of Tokyo]
  - Jinyu Zhou [The University of Tokyo]
  - Chihiro Ohshima [The University of Tokyo]
  - Ippei Yamamoto [The University of Tokyo]
  - Osamu Ishizuka [AIST]
  - Yumiko Harigane [AIST]
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  - Iona McIntosh [JAMSTEC]
  - Heather Ritchie [JAMSTEC]
  - Naoto Jimi [National Institute of Polar Research]
  - Marcel Ortler [University of Innsbruck]
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2-3. Distribution of microplastics in the Southern Ocean

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Hayao Yokochi [Kinki University]
Minoru Ikehara [Kochi University]

2-3.1. Background
The distribution of microplastics in the open ocean of the southern hemisphere is largely unknown. This R/V Hakuho-maru world-round cruise “HEAW30” provides a great opportunity to investigate a current status of microplastic contamination in the Southern Ocean. In the present study, we conducted microplastic surveys through south of Chile to South Africa.

2-3.2. Materials and Methods
Neuston net sampling for surface microplastic analysis
Floating microplastic samples were collected at 8 stations using a neuston net with a rectangular mouth opening of 75 cm height and 100 cm width, equipped a 333 µm mesh opening net with a collecting bottle at the cod end. At each station, the net was towed three times for 20 min each along the surface of the starboard side, if possible. The trawl speed ranged between 1 and 2 knots. A flow meter was installed at the net mouth to estimate the volume of water filtered during each tow. The collected samples were fixed with 5% formalin and stored at room temperature until analysis.

Seawater sampling for subsurface microplastic analysis
Subsurface (~5 m depth below sea surface) microplastic samples were collected using a pumped seawater system of the ship throughout the cruise except any foreign exclusive economic zones. The pumped seawater was continuously filtered through a 333 µm mesh screen and then 100 µm mesh screen at a flow rate between 4 and 7 L/min. These meshes were collected and replaced approximately every 24 hours, and the collected meshes were wrapped with an aluminum foil and stored at 4°C until analysis.

Sediment core sampling for benthic microplastic analysis
To obtain samples of microplastics from the deep-sea floor, a multiple corer equipped with aluminum sampling tubes was used at 7 stations. The top 10 cm of sediment cores were sliced at every 1 cm depth interval with a metal spatula and then frozen in combusted glass bottles until analysis.

2-3.3. Future plan
Microplastic samples from the neuston net, the pumped seawater and sediment cores will be subjected to enumeration and identification of plastic types using a microscope and a FT-IR. The microplastics will also be weighed for mass calculation. The distribution, density and concentration of microplastic in this study will be compared with the previous reports from the Southern Ocean.

2-4. Do submarine volcanism in mid-ocean ridges impact global climate change?

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● Science Party (List) [Affiliation]
● Shore-based Science Party (List) [Affiliation]
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Kyoko Okino [The University of Tokyo]

2-5. Diversity and ecology of zooplankton in the Weddell Sea

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● Shipboard Science Party (List) [Affiliation]
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Hidetaka Nomaki [JAMSTEC]

● Shore-based Science Party (List) [Affiliation]
Atsushi Tsuda [The University of Tokyo]
Junya Hirai [The University of Tokyo]
Fang Chen [The University of Tokyo]

2-6. Deep-sea benthic organisms and their activities in the Antarctic Ocean

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● Science Party (List) [Affiliation]
Koji Seike [AIST]
Heather Ritchie [JAMSTEC]
Naoto Jimi [NIPR]
Akito Ogawa [The University of Tokyo]
Shimpei Hiruta [NMNS]
● Shore-based Science Party (List) [Affiliation]
Chong Chen [JAMSTEC]
Mauricio Shimabukuro [IFREMER]
Daniela Zeppilli [IFREMER, Daniela]

2-6.1. Background
Deep-sea floor is one of the vast ecosystem on the Earth, and plays important roles on biogeochemical cycles.

2-6.2. Materials and methods
In this cruise, we investigated distributions of benthic organisms and their activities through multiple corer samplings, dredge samplings, and a baited-camera sampling attached to a rock-dredge. Different sizes (from microbes to megabenthos) and classes (bacteria, archaea, and eukaryotes) of organisms will be analyzed using the samples retrieved during this cruise.

3. Research/Development Activities

3-1. Underway Geophysics

Hiroaki Koge (AIST), Zhou, Jinyu (AORI, UTokyo)

3-1-1. Instruments

Following instruments equipped with the R/V *Hakuho-maru* were utilized for shipboard geophysical observation in the KH-19-6 cruise; a multi-narrow beam echo sounder (MBES); proton precession magnetometer (PPM), shipboard three-component magnetometers (STCM), shipboard gravimeter, and sub-bottom profiler (SBP).

The seafloor bathymetry was observed using the MBES (SeaBeam3020, L3 Communications ELAC Nautik). Its operating frequency and maximum number of beams is 20 kHz and 301, respectively. The SeaBeam3020 system is consist of acoustic arrays of transmitters and receivers on the bottom of the ship and is controlled by the software "Hydrostar" installed on a Windows computer at the Lab. 1 (Fig. 3-1-1a). Auto swath width, auto intervals, and equi-beam-angle modes were applied in this cruise. The seawater sound velocity structure was determined by vertical profiles of several CTD cast observations, in which seawater conductivity (equivalent to salinity), temperature, and depth were measured.

Gravity field data were obtained from the shipboard gravimeter (D-004, LaCoste & Romberg, ZLS Co.). The system time drift is 3 mGal or less per month, static repeatability is 0.2 mGal, and measurement range is 7000 mGal. The gravimeter is operated using the software UltraSys installed in a computer at the Lab. 9 (Fig. 3-1-1c). Gravity fields are measured every 10 seconds. The control system basically consists of remote and host computers. The former performs all real-time activity associated with controlling the platform and gravity meter as well as maintaining the system clock. The latter receives the data, computes the cross-coupling correction, and performs the final filtering before archiving the data. The instrument drift is corrected using on shore gravity field data measured by a portable gravimeter (CG-5 AUTOGRAV, SCHINTREX).

The total and vector magnetic fields are measured using the PPM (PR-745, Kawasaki Geol. Eng. Co). The PPM measurements were performed every 20 seconds when the proton sensor (Fig. 3-1-1d) was towed 330 m away from the ship. Measured magnetic data are merged with longitude, latitude, and time data from the ship GPS and recorded on a laptop computer at the Lab 3. (Fig. 3-1-1e).

The vector magnetic fields were measured using two sets of STCMs; the STCM-AORI (SBM-89, GAUSS), and STCM-KOBE (SFG-1211, Tierra Technica). Both measurements are performed continuously with sampling frequency of 8 Hz during the cruise. The three fluxgate sensors orthogonally aligned to each other were rigidly fixed in the compass deck (Fig. 3-1-1f). Measured data are merged with attitude data (heading, pitch, and roll) and are recorded in a laptop computer set at the Lab. 1 (Figs. 3-1-1f, 3-1-1g). Attitude data were obtained by a gyro of the OCTANS installed in the Lab. 9 (Fig. 3-1-1b) for the STCM-AORI, and by a ring-laser gyro (RLG, Nihon Koku-densi Kogyo) installed in the Lab. 1 for the STCM-KOBE (Fig. 3-1-1h).

The sub-seafloor structure was observed using the SBP (Bathy2010, SyQwest Inc.). Operating acoustic wave is 3.5 or 12 kHz chirp. This system consists of acoustic sensor on the bottom of the ship and is controlled by the software installed on a Windows computer at the Lab. 3 (Fig. 3-1-1i).

3-1-2. Operation note

The detailed observations were summarized in Table1 and its index map Figure 3-1-2. Here we mainly describe the state of the equipment in the observation.

During this cruise, we successfully obtained the observation data on Seabeam2030 (bathymetry), Bathy2010 (SBP), STCM- KOBE, and gravimeter. The measurements and data recording were continuously conducted along ship tracks with average speed of generally 12–15 kt except within the exclusive economic zones of other countries.

The STCM-AORI was down in the end of observation at South Shetland, and failed the observation in the other area. We tried to restart every once a few days, but the condition did not recover.

On the other hand, the proton magnetometer in an excitation system was unable to work in the end of observation at South Shetland, but it recovered. In transit to South Orkney area, we tested the recovered PPM for checking the system condition, and the result was well. And finally, the observations of the Vulcan fracture zone and Mid-Atlantic ridge were very successful. The cause of the PPM failure seems in the circuit of “supercap”. The failure in supecap was likely to occur if the power supply was not turned on for a long time. In this cruise, the observation was carried out by the procedure in which the power was kept on, and only the excitation switch was turned on during the PPM observation. And the procedure worked well. In order to avoid damage to the machine, we set in the UPS power supply in the PPM system, which was originally used for the STCM-AORI.

Seawater sound velocity profile (SVP) were obtained by XCTD/XBT, and applied to acoustic depth ranging of the MBES system (Fig. 3-1-4). We analyzed MBES data using the software “CARIS” during the cruise (Fig. 3-1-7).

The figure-8 turns for the STCM data correction were performed seven times in this cruise (Table 1). The STCM data quality was fine (Fig. 3-1-5).

The gravity measurement was made continuously through the entire length of the cruise. In order to estimate the absolute gravity value considering the gravimeter drift. The data quality of the shipboard gravimeter (Gravity and Spring tension) was not good (Fig. 3-1-6).

3-1-3. Preliminary results

The preliminary result and the quality of the data was summarized in with Figure 3-1-3 to -6.

The operation of proton procession magnetometer showed the successful signal level (average ~55-65) during the observation, for the aim of revealing temporal change of the mid-ocean ridge and fracture zone activity.

The SVP data were renewed at eight times (Table 1). The shipboard XCTD/XBT system has error, the observation of #1, #4 #9 XCTD result included a lot of noise, and finally #10 XBT cannot contact between PC and the launcher (Fig. 3-1-4). Radio team of R/V *Hakuho-maru* checked the system with the test probe twice (both XCTD and XBT) and #11XBT. We concluded the cause of error was based on the damage of cable.

3-1-4. Future Works and Data Distribution

Underway geophysical mapping of bathymetry, magnetics and gravity was continuously conducted in this cruse. Multibeam bathymetry, total and vector magnetic fields, gravity, and sub-bottom profiler data along the ship tracks will be analyzed at first after the cruise.

In this cruise, PPM observation was conducted in the any chance of the transit. Therefore, it could make us to obtain the data with the much longer transect before the prediction.

In addition, the observations using three-component magnetometer could be conducted over the wide area not only in the spreading system of the plate tectonics but also the convergence system such as the subduction in South shetland, which is the subduction zone of convergence, so more comprehensive study on plate tectonics can be expected.

Specific scientific target area was set to the Southeast Indian Ridge for the aim of revealing temporal change of the mid-ocean ridge activity.

Acknowledgement;

Watching is important part of Underway Geophysics. We appreciate any member who join watching; T. Kagoshima, H. Kobayashi, Y. Okuma, C. Oshima, M. Iizuka, R. Seto, A. Ogawa, I. Yamamoto, Y. Kato, M. Sasaoka, K. Kato, S. Hiruta, N. Jimi, H. Ritchie, K. Kubota, M.Ortler

Table 3-1-1. The operation log of the shipboard geophysical observations.

UTC				Latitude	Longitude	Event	Note
Date			Time				
2019	Dec	21	7:01	58 18.458S	65 22.998W	Start recording; STCM-AORI, STCM-KOBE, Gravimeter, SBP, and MBES	Cleared out EEZ. Proton magnetometer didn't work until 27th.
2019	Dec	21	7:23	58 20.974S	65 18.237W	#1 XCTD	First XCTD was broken, we finished the operation with second one.
2019	Dec	21	19:59	60 00.029S	60 39.828W	Entered Antarctic Sea	
2019	Dec	21	16:03	61 03.815S	57 56.977W	#2 XCTD	
2019	Dec	22	4:11	61 03.665S	57 58.794W	STCM-AORI suddenly made error.	
2019	Dec	22	7:23	61 03.829S	57 57.975W	We gave up the STCM-AORI.	
2019	Dec	22	11:16	61 19.412S	57 40.554W	#1 8 Shape rotation right turning started	End at 11:36
2019	Dec	23	22:54	62 40.362S	62 09.924W	#2 8 Shape rotation right turning started	End at 23:14
2019	Dec	24	7:29	61 58.998S	62 19.352W	#3 XCTD	
2019	Dec	27	0:52	61 40.422S	51 25.700W	#4 XCTD	
2019	Dec	27	1:08	61 39.992S	51 27.239W	#3 8 Shape rotation right turning started	End at 1:28
2019	Dec	27	1:39	61 39.073S	51 26.503W	#0 Proton survey started	End at 13:15, 60 22.049S 046 57.570W This is for checking the equipment and the
2019	Dec	30	13:30	60 51.117S	41 04.504W	#4 8 Shape rotation right turning started	End at 13:50, this point is based on complex geology and will be unfit for 8 figure
2020	Jan	2	8:44	60 31.817S	35 10.708W	#5 XCTD	
2020	Jan	3	3:30	59 50.962S	33 51.230W	Stop all recording.	Entered EEZ of SGSSI
2020	Jan	4	11:10	58 49.219S	19 53.866W	Restart all recoeding.	Cleared out EEZ of SGSSI
2020	Jan	4	16:17	59 14.175S	18 14.986W	#6 XCTD	
2020	Jan	4	16:29	59 14.195S	18 13.245W	#1 Proton survey Start	
2020	Jan	4	16:45	59 14.248S	18 10.154W	#5 8 Shape rotation right turning started	End at 17:05
2020	Jan	4	17:30	59 13.909S	17 59.962W	Entered LINE-OKINO 1	End at 23:13, 59 13.909S, 15 45.023W
2020	Jan	4	23:13	59 06.996S	15 44.960W	Entered LINE-OKINO 2	End at 04:20, 59 10.003S, 18 00.093W
2020	Jan	5	4:46	59 10.104S	18 05.661W	#1 Proton survey End	
2020	Jan	7	4:55	59 06.409S	15 58.336W	#2 Proton survey Start	
2020	Jan	7	5:38	59 03.092S	15 58.268W	Entered LINE 3	End at 9:02, 59 04.800S, 17 24.993W
2020	Jan	7	9:41	58 59.036S	17 25.008W	Entered LINE-OKINO 3	End at 12:47, 58 56.999S, 16 00.913W
2020	Jan	7	16:19	58 56.252S	14 32.156W	#2 Proton survey End	
2020	Jan	7	18:14	58 53.912S	14 32.571W	#3 Proton survey Start	
2020	Jan	8	6:37	58 55.106S	10 22.895W	#3 Proton survey End	
2020	Jan	9	11:03	58 07.428S	10 48.278W	#7 XBT	
2020	Jan	9	11:15	58 06.438S	10 47.915W	#4 Proton survey Start	
2020	Jan	10	8:39	52 58.306S	9 04.861W	#8 XCTD	
2020	Jan	10	8:53	52 57.087S	9 04.587W	#6 8 Shape rotation right turning started	End at 9:13
2020	Jan	10	9:33	52 53.967S	8 59.895W	Entered FJA1	End at 9:31, Jan 11, 50 23.991E 0 00.006E
2020	Jan	13	16:19	40 38.383S	14 14.885E	#4 Proton survey End	
2020	Jan	13	20:32	40 40.556S	14 14.566E	#5 Proton survey Start	
2020	Jan	14	3:58	39 37.967S	14 27.721E	#5 Proton survey End	
2020	Jan	14	6:00	39 39.178S	014 27.418E	#9 XCTD1, #10 XBT1	drum cable might be broken, #9 was noisy data and #10 didn't work.
2020	Jan	14	13:50	-	-	#7 8 Shape rotation right turning started	End, 14:51
2020	Jan	14	14:26	39 37.425S	14 29.458E	#6 Proton survey Start	
2020	Jan	15	2:40	37 16.247S	16 08.460S	#6 Proton survey End	
2020	Jan	15	4:07	37 13.927S	16 11.867E	#11 XBT	#11 didn't work.
2020	Jan	15	4:20	37 09.670S	16 15.120E	Stop all recording.	Entered EEZ of South Africa

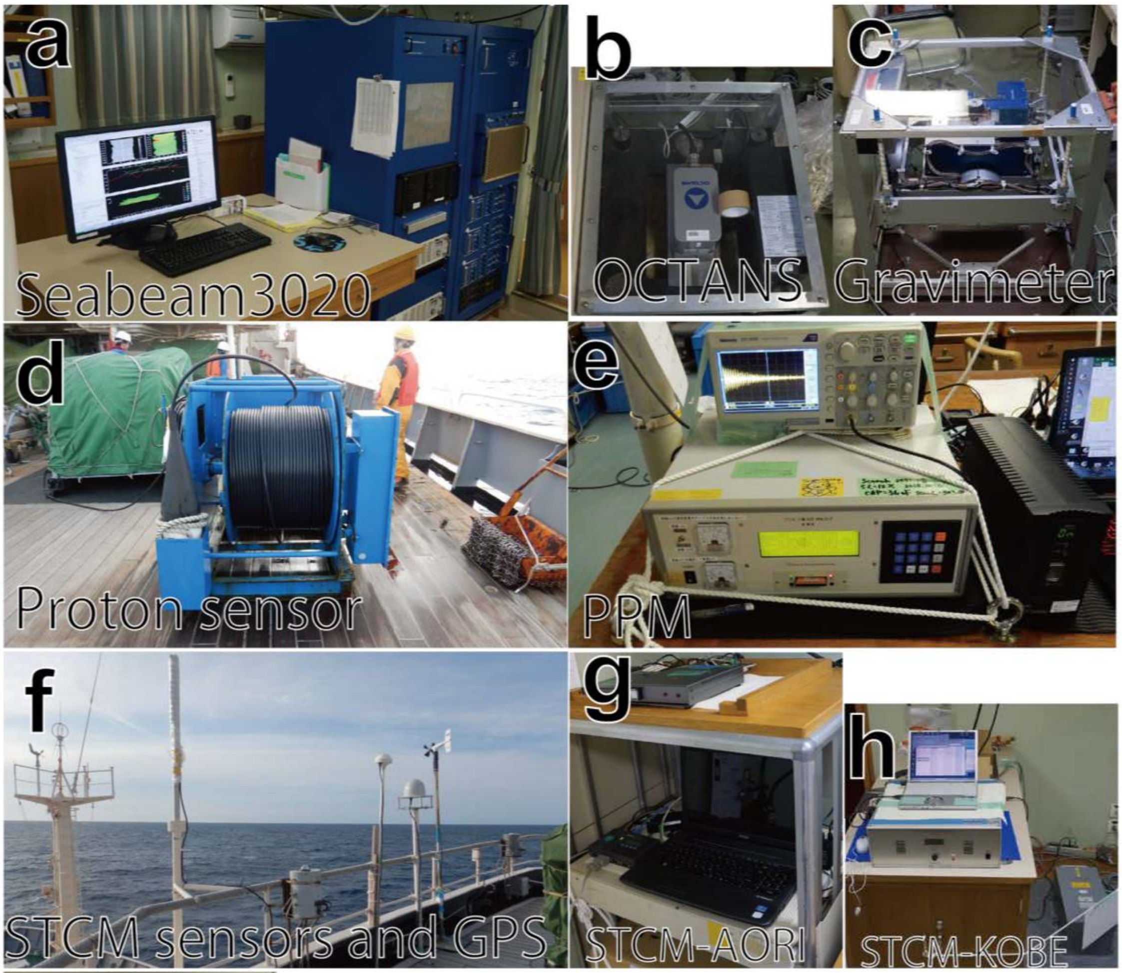

Figure 3-1-1. Photo images of (a) the SeaBeam3020 system in the Lab.1, (b) gyro compass of OCTANS in the Lab.9, (c) shipboard gravity meter in the Lab.9, (d) proton procession magnetometer (PPM) sensor on the deck, (e) PPM controller and recording PC in the Lab.3, (f) GPS sensor and fluxgate sensor of two sets of shipboard three-component magnetometer (STCM), STCM-AORI and STCM-KOBE, on the compass deck, (g) STCM-AORI controller and recording PC in the Lab.1, (h) STCM-KOBE controller and recording PC, and ring laser gyro (RLG) in the Lab.1, and (i) sub-bottom profiler of the Bathy2010 in the Lab.3.

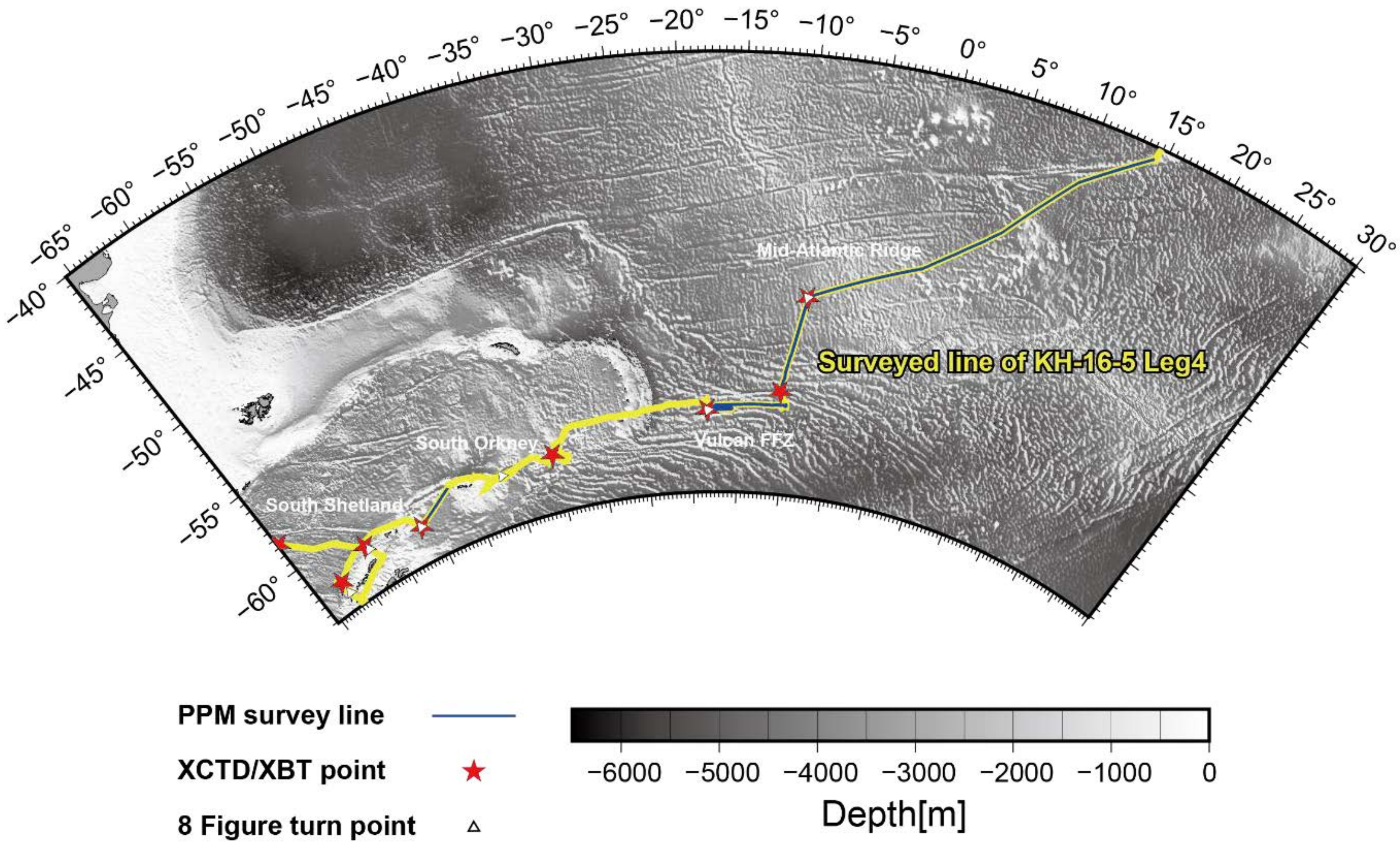

Figure 3-1-2. Surveyed area during the KH-19-6 Leg4 cruise.

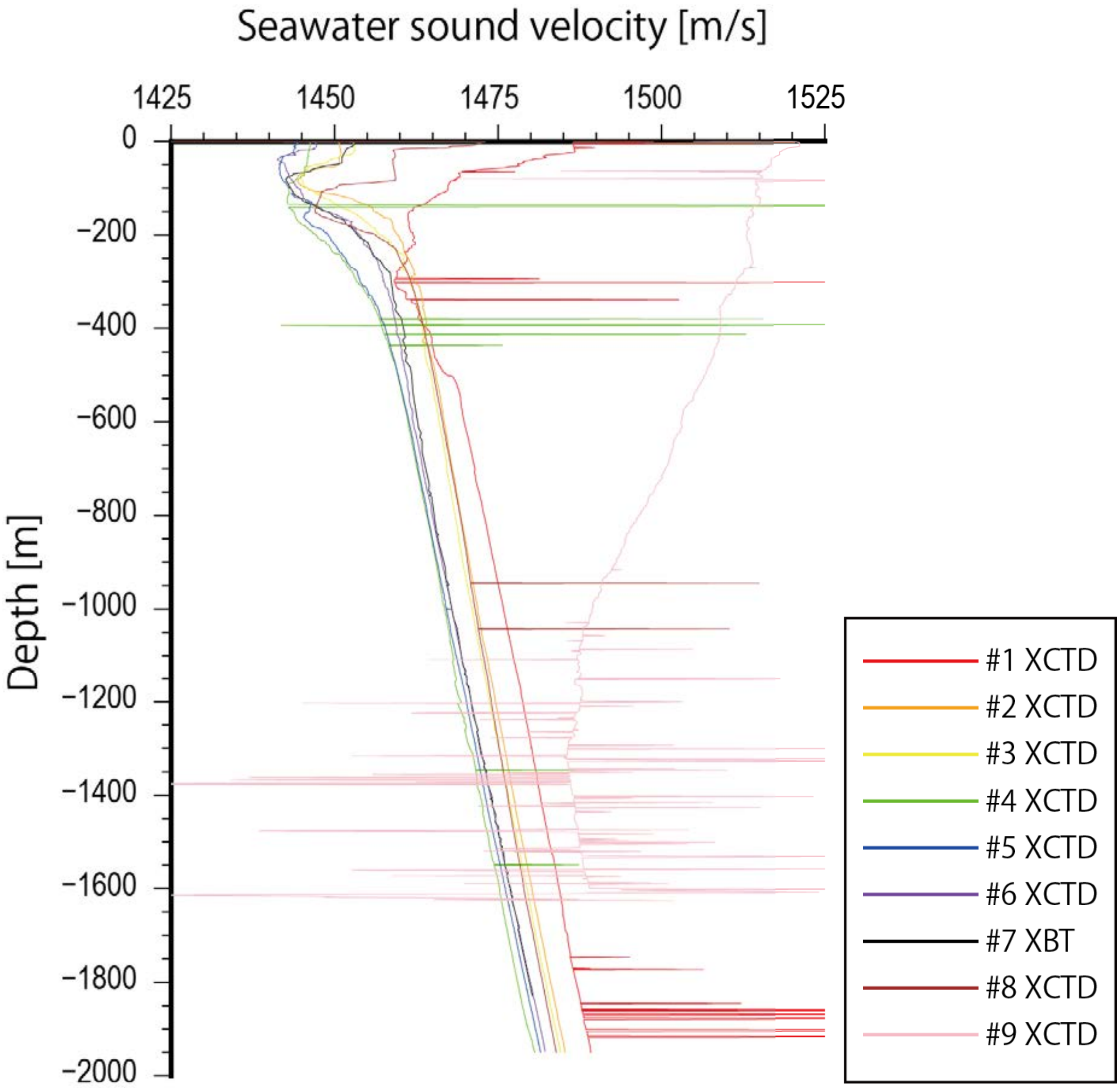

Figure3-1-4. Seawater sound velocity profiles obtained during ten times of XCTD/XBT observations at #1-#9.　#10, #11 had no signal.

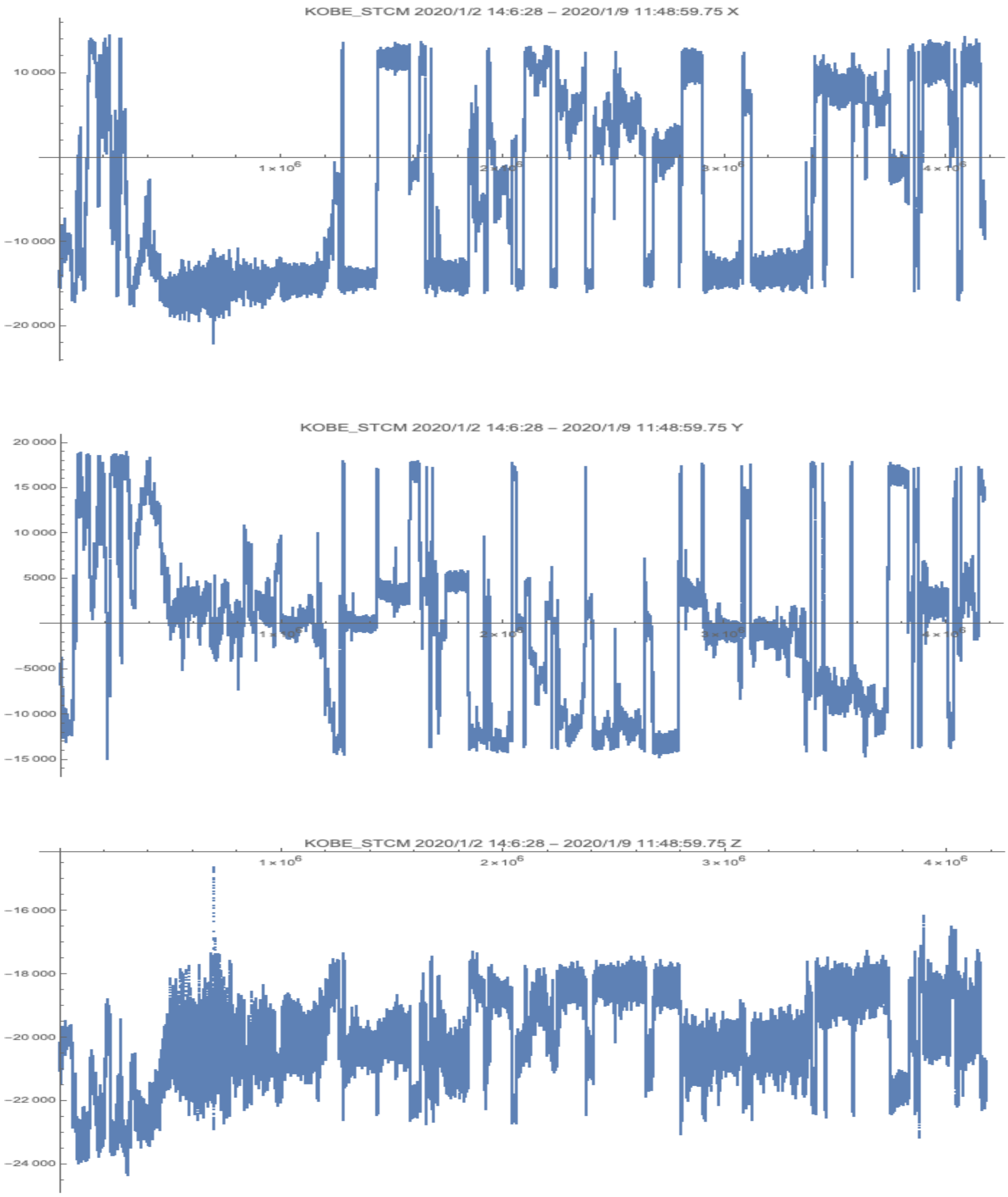

Figure 3-1-5. The shipboard three-component magnetometers (KOBE-STCM) in 2^{th} -9^{th} January 2020.

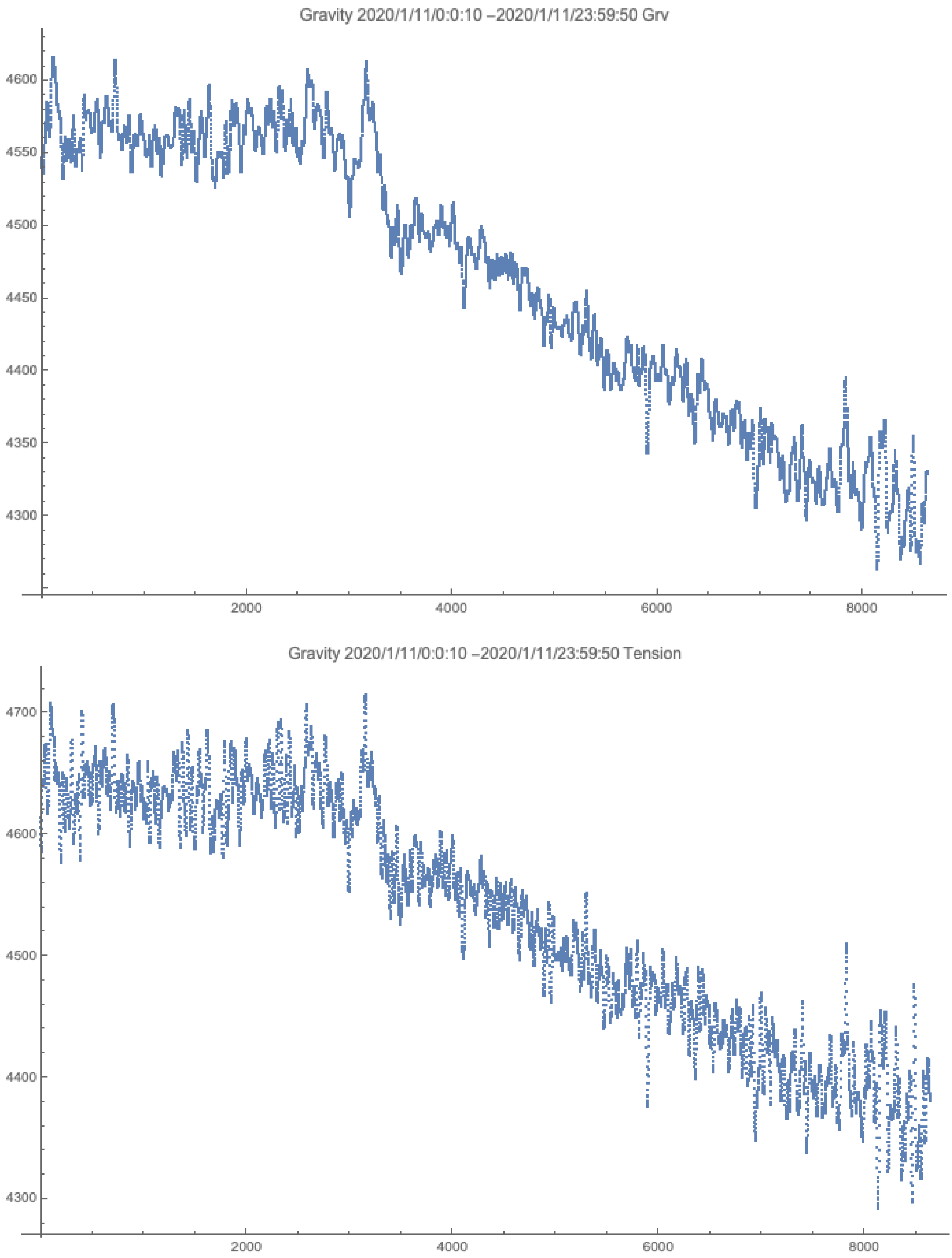

Figure 3-1-6. The shipboard gravimeter parameter (Gravity and Spring tension) obtained in 11th January 2020.

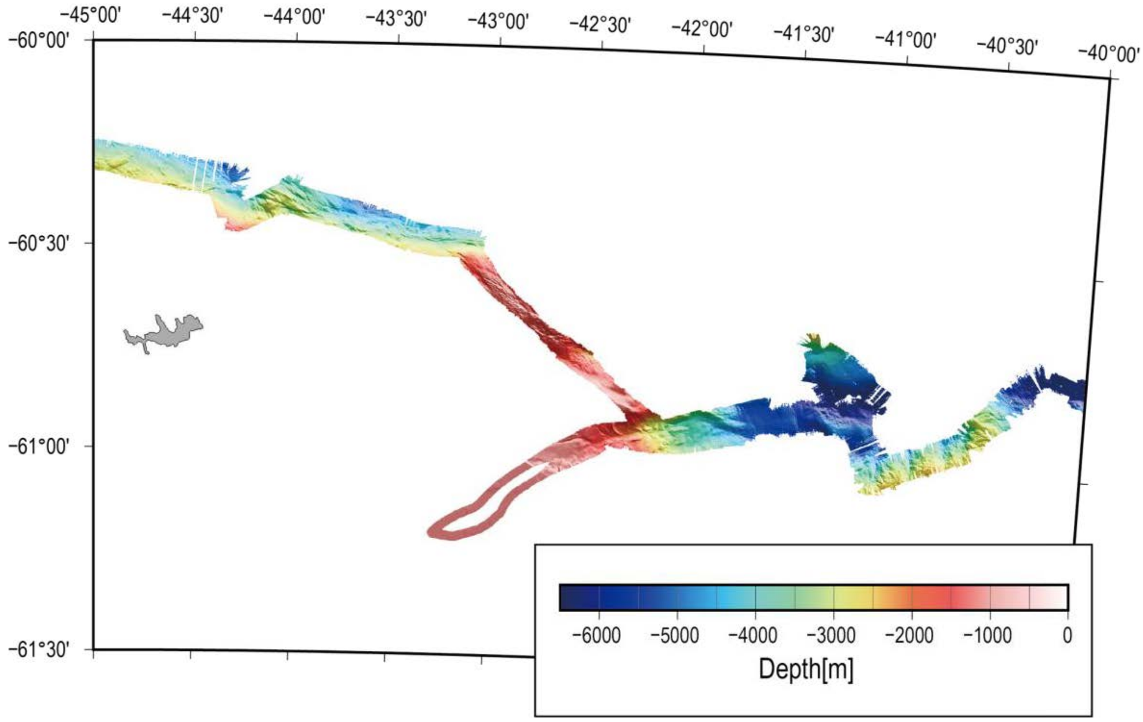

Figure 3-1-7. The cleaned bathymetry; example in South Orkney area.

3-2. Piston core sampling

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3-2-1 Instruments and Method

Piston corer system and operation

A piston corer was used to obtain sediment samples during this cruise. It consists of a 900 kg-weight, a total 14 m-long (4 m x 2 + 6 m) or 12 m long (6 m x 2) stainless steel barrel and polyvinyl chloride (PVC) inner pipe, a core bit, a core catcher, a wired piston cylinder inside and a trigger arm (all belonging to AORI). The inner diameter of inner pipe is 74 mm. Either a 1-m long gravity corer "75-gravity corer" (belonging to AORI), a 100-kg weighed multiple-type corer "Asyura" (belonging to Kochi University), or a 100-kg cone-shape weight "Apollo" were used as pilot weight. The multiple-type pilot corer consists of a stainless-steel frame and three sub-corer attachments containing three 0.6-m long acrylic resin tubes and self-closing lids at both ends of each tube, which enables us to collect short sediment cores and bottom water without disturbance at the sediment surface. The inner diameter of each acrylic resin tube is 80 mm.

The winch wire was gradually let out at the speed of 1.0 m/s. Except for operation of PC01 and PC09, a transponder was attached 50 m above the corer to monitor the accurate location of coring. The winch was stopped at the depth approximately 50 m above the seafloor for three minutes to reduce pendulum motion of the corer system, and then the wire was stored out at the speed of 0.3 or 0.5 m/s, depending on sea condition. When the wire tension decreased suddenly, we confirmed the corer arrived at the seafloor. We stopped the wire out immediately and waited for a few seconds. Then the winch wire was wound at the speed of 0.2 m/s until the tension gauge indicated the piston corer left the seafloor. Then the wire was wound at the speed of 1.0 m/s until the corer came up to the ship.

After core retrieval on deck, we performed the following procedures. The core bit and core catcher were removed to obtain the core catcher samples. The inner pipes were pulled out from the core barrels and cut into 1-m long sections. The whole-round sections are capped at the top and bottom ends and stored at cool temperature (6 °C) in the Lab. No. 10. Magnetic susceptibility of whole sediment cores was measured onboard at 1-cm resolution, except for core PC10.

3-2-2 Coring Sites

Sediment cores were collected using a piston corer (PC) at sites on the Bransfield Strait (PC01), South Shetland Trench (PC02, 03, 04 and 05), Powell Basin (PC06), north of Vulcan Fracture Zone (PC07), south of Bullard Fracture Zone (PC08) and north of Agulhas Ridge (PC10) (Figure 3-2-1, Table 3-2-1). These sites were chosen carefully with the help of bathymetry and sub-bottom profiles. Details of each site are described below.

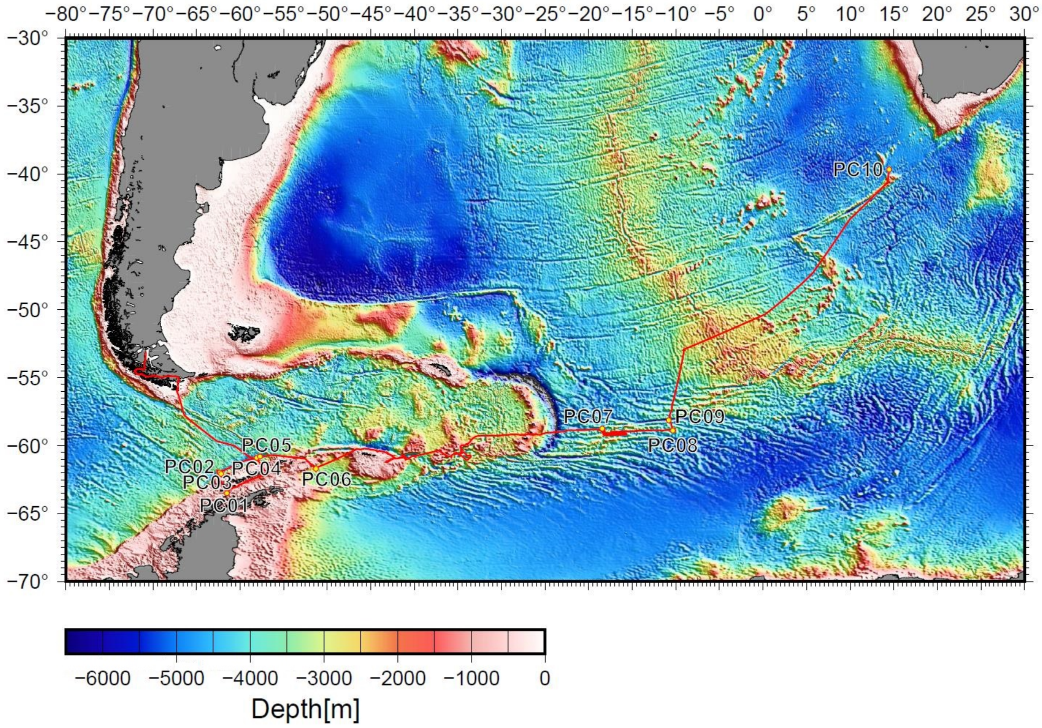

Figure 3-2-1. Locality of piston core sites operated during KH-19-6 Leg 4.

Table 3-2-1. Basic information of all piston core samples. PC09 was retrieved with no core recovery, due to a trigger malfunction in the seawater.

Core number	Day and time of touch bottom (UTC)		Latitude	Longitude	Type of position (S=Ship, TP=Transponder)	Area	Station	Water Depth (m)	Total core length (m)	section number
	Day	Time								
PC01	Dec. 23, 2019	15:51	63°30.5151′ S	61°31.8366′ W	S	Bransfield Strait	ANP-02	1053	10.31	11
PC02	Dec. 24, 2019	9:57	61°59.0221′ S	62°19.411′ W	TP	Bottom of South Shetland Trench	SET-19	4731	10.94	11+PL (24 cm)
PC03	Dec. 24, 2019	14:44	62°03.9779′ S	62°11.9343′ W	TP	Landward slope of South Shetland Trench	SET-20	3803	2.13	3 + PL (91 cm)
PC04	Dec. 25, 2019	15:21	60°54.0136′ S	58°5.0243′ W	TP	Bottom of South Shetland Trench	SET-14	5217	11.2	12
PC05	Dec. 25, 2019	20:36	60°47.5775′ S	57°42.5286′ W	TP	Seaward slope of South Shetland Trench	SET-23	4775	11.23	12 + PL (75 cm)
PC06	Dec. 26, 2019	18:27	61°41.9928′ S	51°18.0113′ W	TP	Powell Basin	WS-01	2857	12.28	13
PC07	Jan. 5, 2020	11:05	58°45.0446′ S	18°26.4848′ W	TP	North of Vulcan Fracture Zone	SIP-14	4401	12.55	13 + PL (31 cm)
PC08	Jan. 8, 2020	13:54	58°53.0301′ S	10°20.0723′ W	TP	South of Bullard Fracture Zone	WS-05	3947	11	11
PC09	Jan. 9, 2020	-	58°07.6516′ S	10°48.7878′ W	S	Bullard Fracture Zone	BL6500	6508	0	0
PC10	Jan. 14, 2020	7:10	39°38.2465′ S	14°28.4717′ E	TP	North of Agulhas Ridge	SA-5	4604	12.28	13 + PL (36 cm)

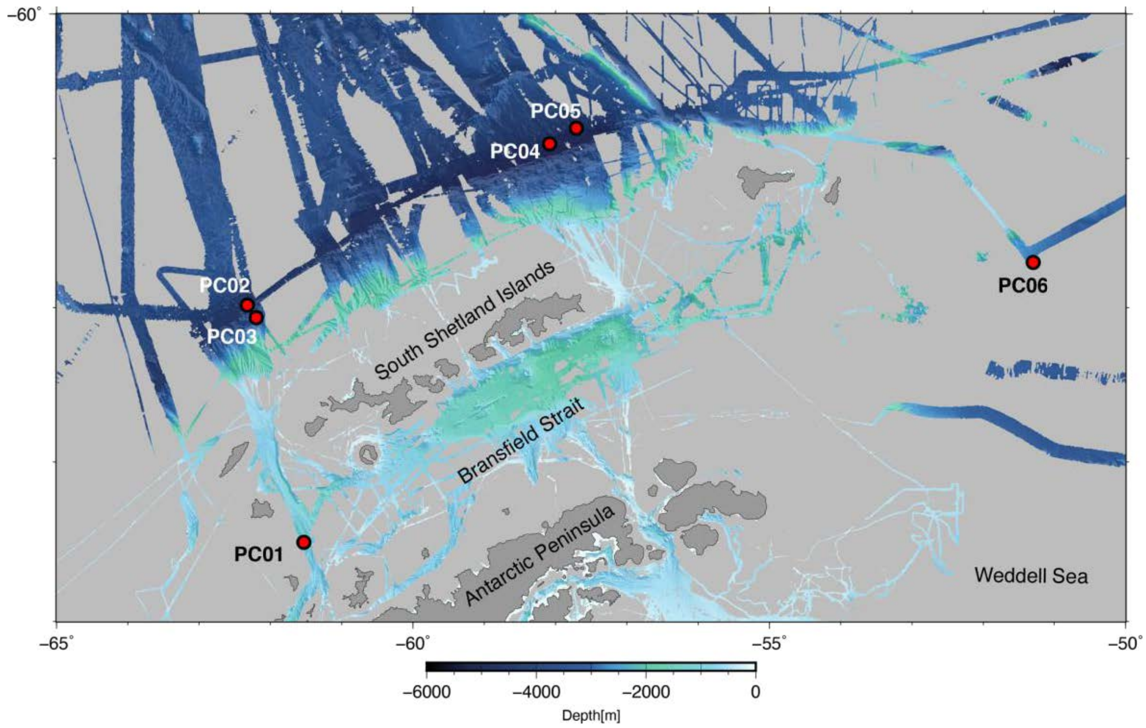

Figure 3-2-2. Locality of piston core sites around the South Shetland Islands.

Bransfield Strait

・ *Site ANP-02 (**PC01**: 63°30.5151'S, 61°31.8366'W, 1053 m water depth)*

Site ANP-02 is located at the Western Bransfield basin bundle, which is formed by giant ice streams from the Antarctic Peninsula (Canals et al., 2000). Bundle structures reveal the very dynamic behavior of ice caps in the northern Antarctic Peninsula during the last glacial maximum. PC01 (a 12-m piston core with 75-type pilot corer) was sampled from Site ANP-02 with recovery of 10.31 m. We expect to reconstruct past variability of ice streams from the Antarctic Peninsula Ice Sheet.

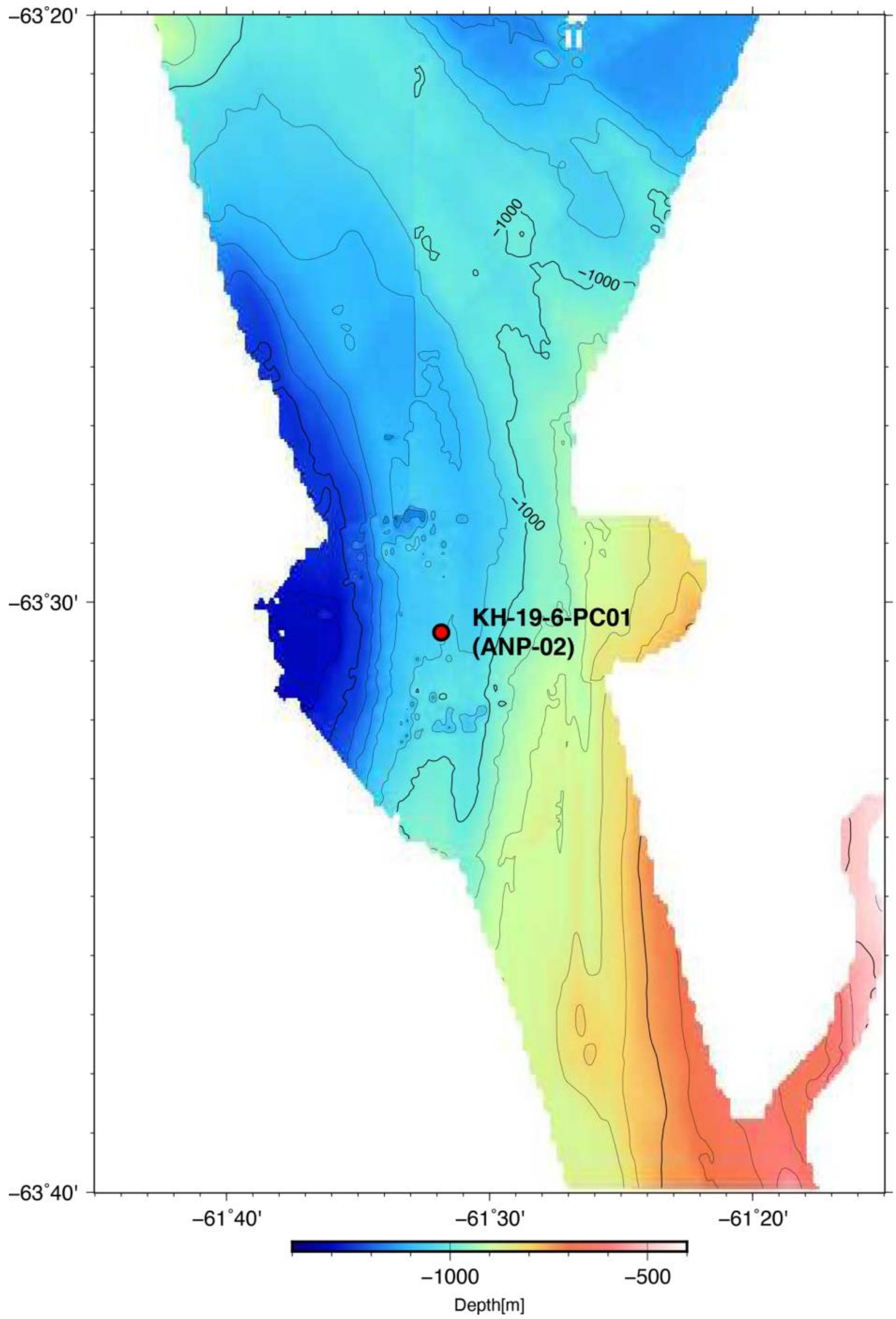

Figure 3-2-3. Location map of piston core KH-19-6-PC01 (Site ANP-02) in the Western Bransfield basin.

South Shetland Trench

The South Shetland Trench is the southernmost deep-sea trench of the world, where subduction of Former Phoenix Plate beneath the Antarctic Plate has almost been terminating (~1 cm/yr of convergent rate; Taylor et al., 2008). To explore sediment dynamics of Antarctic arc-trench system, four piston cores were sampled from the South Shetland Trench.

- *Site SET-19 (**PC02**: 61°59.0221'S, 62°19.411'W, 4731 m water depth)*

Site SET-19 is located at the bottom of the western part of South Shetland Trench. Although the trench axis has an almost flat topography, the water depth becomes gradually shallower from east to west. To compare east-west sediment variation in the South Shetland Trench, PC02, a 12-m piston core with 75-type pilot corer was sampled from Site SET-19 with a recovery of 10.94 m.

- *Site SET-20 (**PC03**: 62°03.9779'S, 62°11.9343'W, 3803 m water depth)*

Site SET-20 is located at the small basin in the lower terrace of forearc slope in the western part of South Shetland Trench. Two submarine canyons flow into the basin. This site was cored to understand the influx of forearc sediment into the South Shetland Trench. However, penetration of PC03 (a 12-m piston corer with 75-type pilot corer) was inhibited by a gravel layer, which destroyed a core bit, resulting in only 2.13 m core recovery.

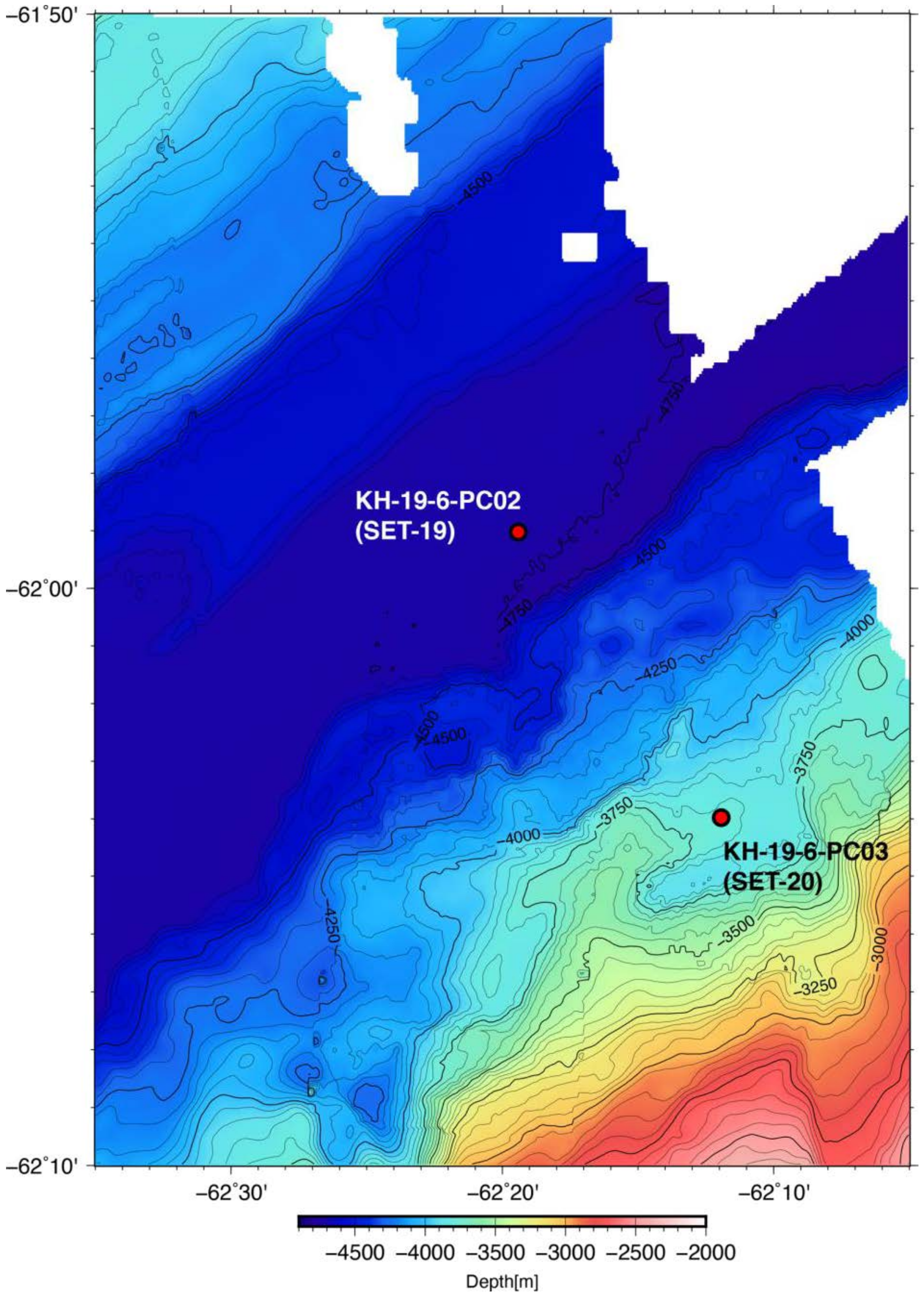

Figure 3-2-4. Location map of two piston core KH-19-6-PC02 (Site SET-19) and KH-19-6-PC03 (Site SET-20) in the western part of South Shetland Trench.

- *Site SET-14 (**PC04**: 60°54.0136'S, 58°5.0243'W, 5217 m water depth)*

PC04 from Site SET-14 (a 12-m piston core with 75-type gravity corer) was sampled at the bottom of the eastern part of South Shetland Trench, where the deepest water depth is recorded along the trench axis. We expect that the comparison between PC02 and PC04 would lead to better understandings of east-west sediment variation and sediment transportation pattern along the trench.

- *Site SET-23 (**PC05**: 60°47.5775'S, 57°42.5286'W, 4775 m water depth)*

PC05, a 12-m piston core with 75-type gravity corer, was sampled from the seaward slope terrace of the eastern part of South Shetland Trench. Site SET-23 was newly settled during the cruise to obtain the information of incoming sediment on the Former Phoenix Plate.

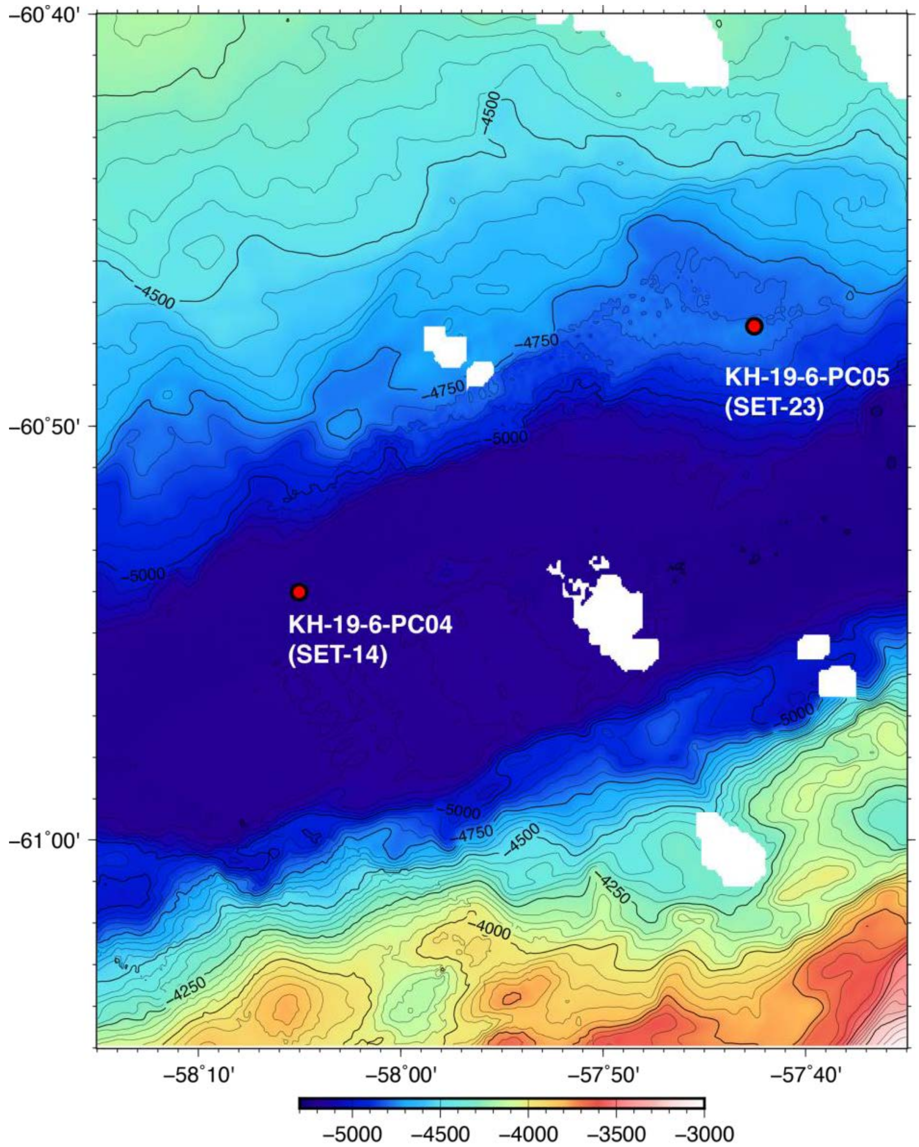

Figure 3-2-5. Location map of two piston core KH-19-6-PC04 (Site SET-14) and KH-19-6-PC05 (Site SET-23) in the eastern part of South Shetland Trench.

Powell Basin

- *Site WS-01 (**PC06**: 61°41.9928'S, 51°18.0113'W, 2857 m water depth)*

Site WS-01 is located at the northwestern Powell Basin, northern Weddell Sea. Sediment wave structures are found at the base of continental slope in water depths of 2800-3100 m, along outflow region for Weddell Sea Deepwater (e.g., Howe et al., 1998). PC06 (a 14-m piston core with Asyura pilot corer) recovered a sediment record of 12.28 m. We expect to reconstruct past variability of Weddell Sea Deepwater and Weddell Gyre circulation.

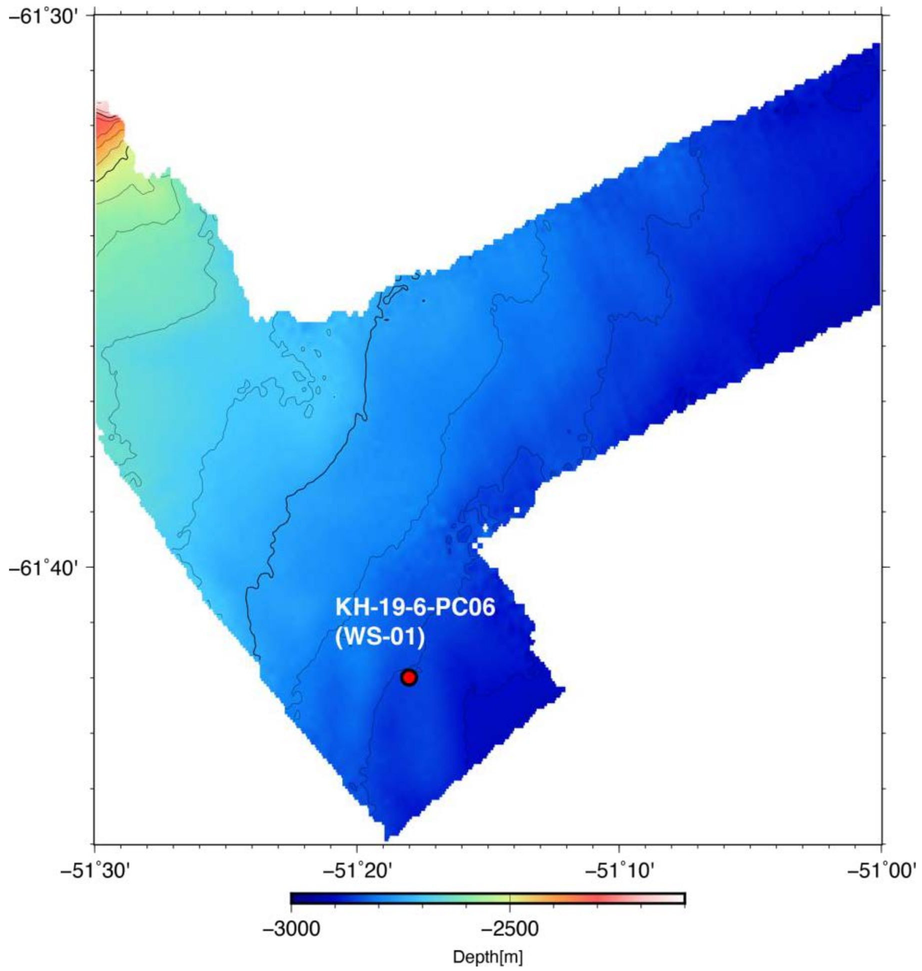

Figure 3-2-6. Location map of piston core KH-19-6-PC06 (Site WS-01) in the Powell Basin, northern Weddell Sea.

North of Vulcan Fracture Zone

- *Site SIP-14 (**PC07**: 58°45.0446'S, 18°26.4848'W, 4401 m water depth)*

Site SIP-14 is located ~10 mile east from original Site SIP-4. Site on the South American Plate (or Sur Microplate) was selected to explore the nature of incoming sediments being subducted to the South Sandwich Trench. PC07 (a 14-m piston core with Asyura pilot corer) was sampled from Site SIP-14 with recovery of 12.55 m. Core site is suitable for detection of past variability of Antarctic Circumpolar Current (ACC) and Weddell gyre.

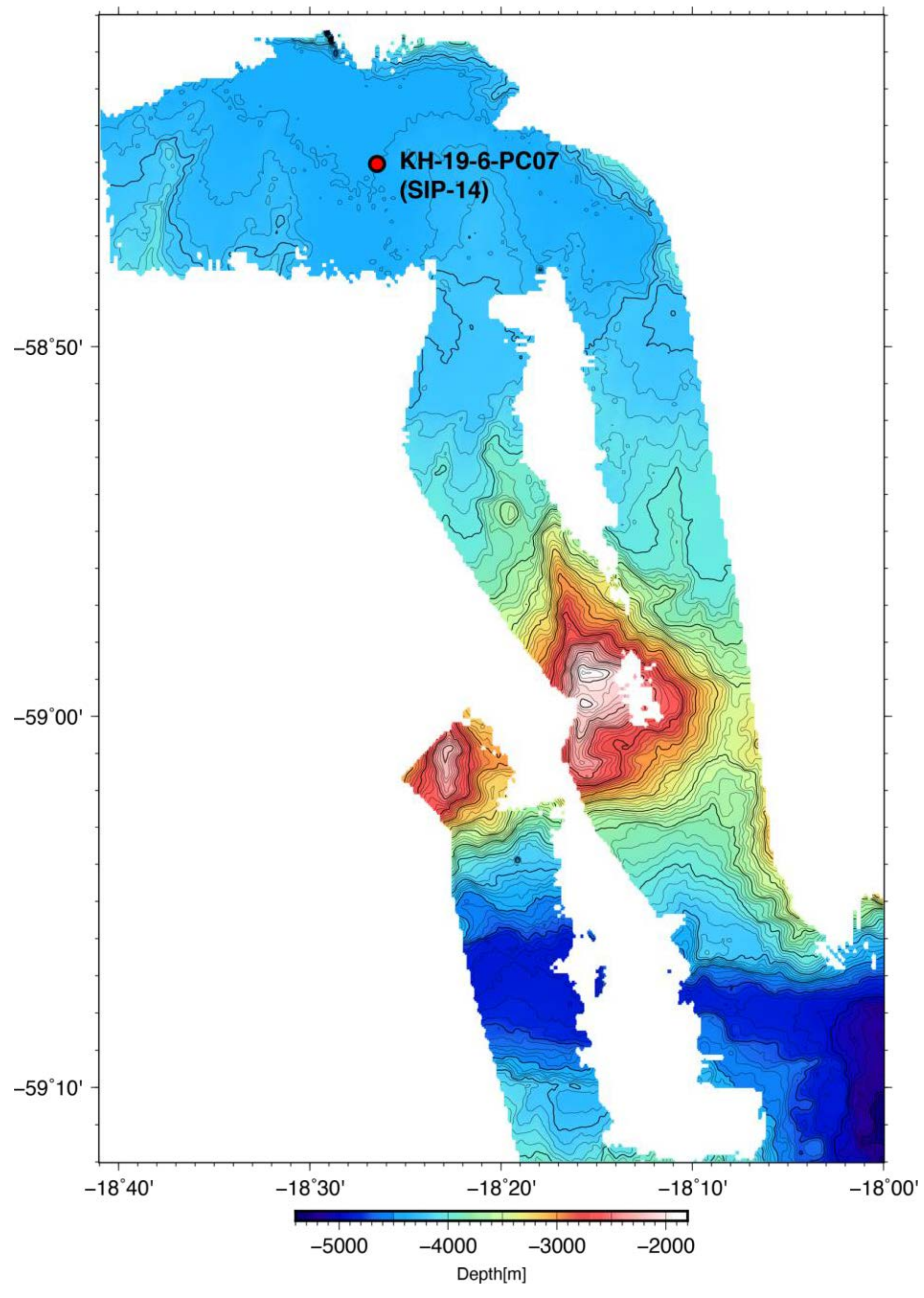

Figure 3-2-7. Location map of piston core KH-19-6-PC07 (Site SIP-14) in north of Vulcan Fracture Zone.

South of Bullard Fracture Zone

- *Site WS-05 (**PC08**: 58°53.0301'S, 10°20.0723'W, 3947 m water depth)*

Site WS-05 is located at the south of Bullard Fracture Zone of the Atlantic-Antarctic Ridge. PC08 (a 14-m piston core with Asyura pilot corer) was sampled from Site WS-05 with recovery of 11 m. Site is located on the far northeastern branch of the Weddell Gyre. The hope is that this site records both the outflow to the northeast and the inflow into the southeastern Weddell Gyre.

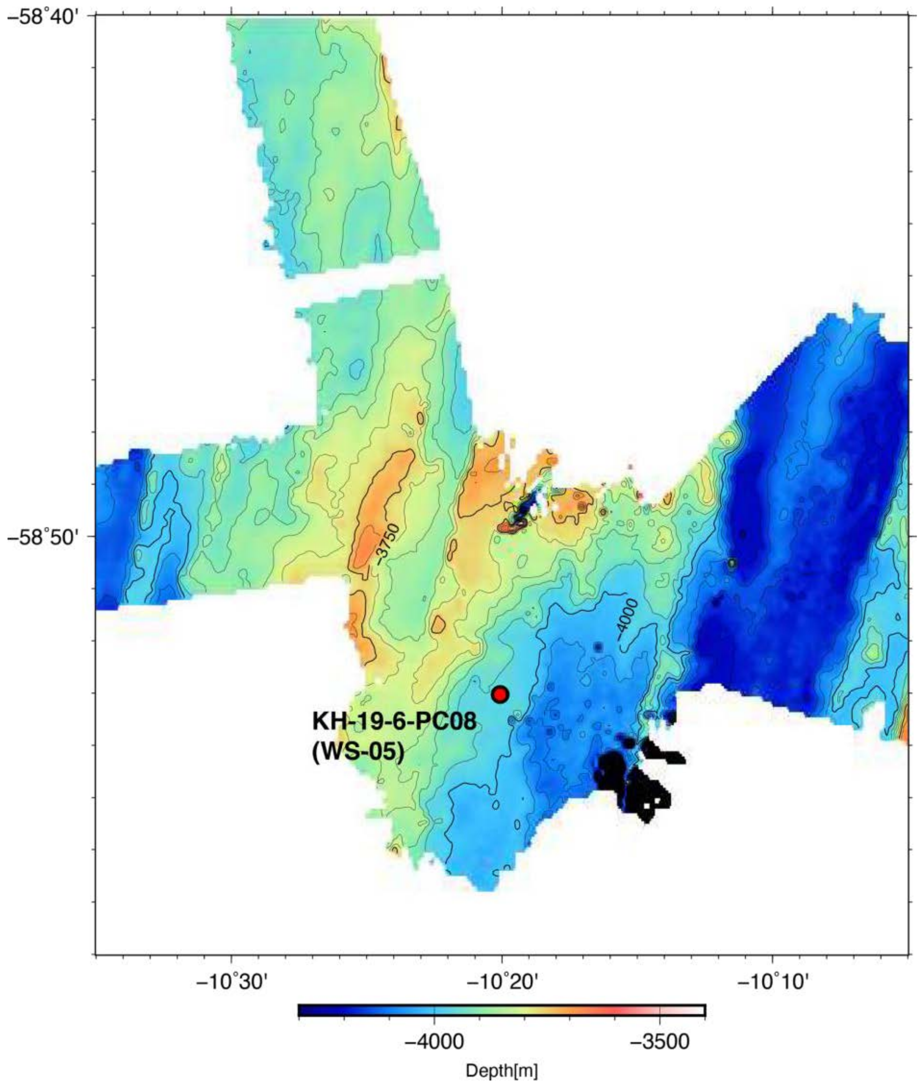

Figure 3-2-8. Location map of piston core KH-19-6-PC08 (Site WS-05) in south of Bullard Fracture Zone.

Bullard Fracture Zone

・ *Site BL-6500 (**PC09**: 58°07.6516'S, 10°48.7878'W, 3947 m water depth)*

Bullard Fracture Zone is a transform fault which offsets American-Antarctic Ridge, the spreading axis between South American Plate (or Sur Microplate) and Antarctic Plate. The water depth within the fracture zone exceeds ~6500 m, which is ~3000 m deeper than surrounding abyssal plane. To understand sedimentation process of a deep, narrow and isolated sedimentary basin in the Southern Ocean, piston coring operation was conducted on January 9. However, tension meter recorded an abrupt positive spike up to 6 tons (~3.5 ton larger than the average tension at that time) at a wire length of ~2700 m. Operation was suspended at the wire length of 2799 m, and the corer was retrieved on deck, with the piston at the top of the inner tube. The situation was interpreted that the trigger (~100kg "Apollo" weight) malfunctioned in the seawater because of the high heave condition. Hence, coring was cancelled at this site.

North of Agulhas Ridge

・ *Site SA-5 (**PC10**: 39°38.2465'S, 14°28.4717'E, 4604 m water depth)*

Site SA-5 is located at the north of Agulhas Ridge, which is much influenced by Agulhas

Retroflection (Agulhas Return Current). The Agulhas system around southern Africa forms a key component of the global ocean circulation, and feeds the upper arm of the Atlantic meridional overturning circulation (AMOC) through the leakage of warm, saline waters from the Indian Ocean to the Atlantic (Beal et al., 2011). PC10 (a 14-m piston core with Asyura pilot corer) was sampled from Site SA-5 with recovery of ~13 m. We expect to reconstruct past variability of Agulhas Retroflection.

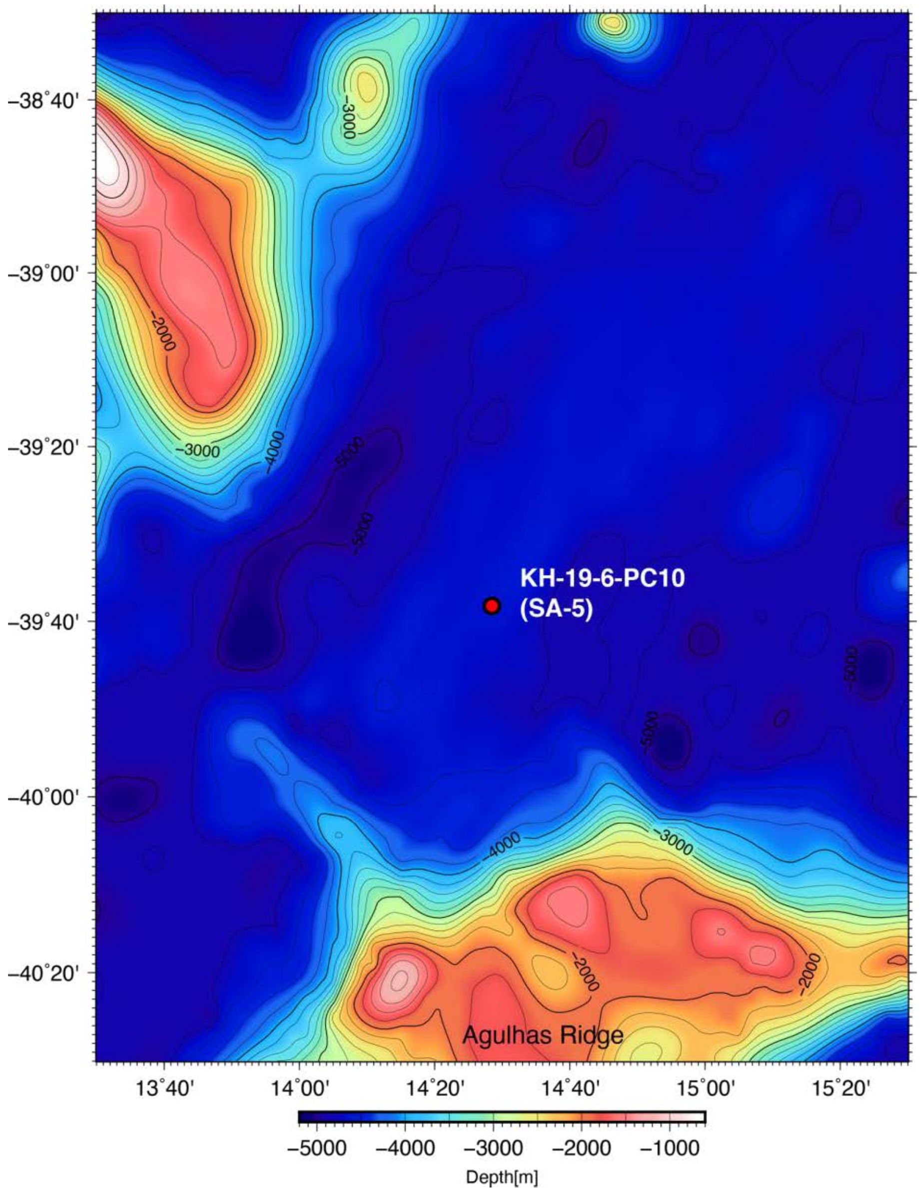

Figure 3-2-9. Location map of piston core KH-19-6-PC10 (Site SA-5) in north of Agulhas Ridge.

3-2-3 Preliminary results

Cores retrieved during KH-19-6 Leg 4 were not split on board. Only magnetic susceptibility (MS) measurement were conducted at 1-cm increments onboard on cores PC01–PC08.

Magnetic Susceptibility Measurement

The results of the measurements with a Bartington MS-2 sensor are shown in Figure 3-2-2. Some sites (e.g., PC05, 07, and 08) show low MS and variability typically found in open marine settings.

Other sites have higher average MS values pointing to more terrigenous input (e.g., PC01 and 04). Some sites show segments with very high values in excess of ~600 10^{-5}SI (e.g., PC02, 03, and 06), which is typically found only in basaltic or volcanic settings. Postcruise analysis will have to reveal the exact nature of variability.

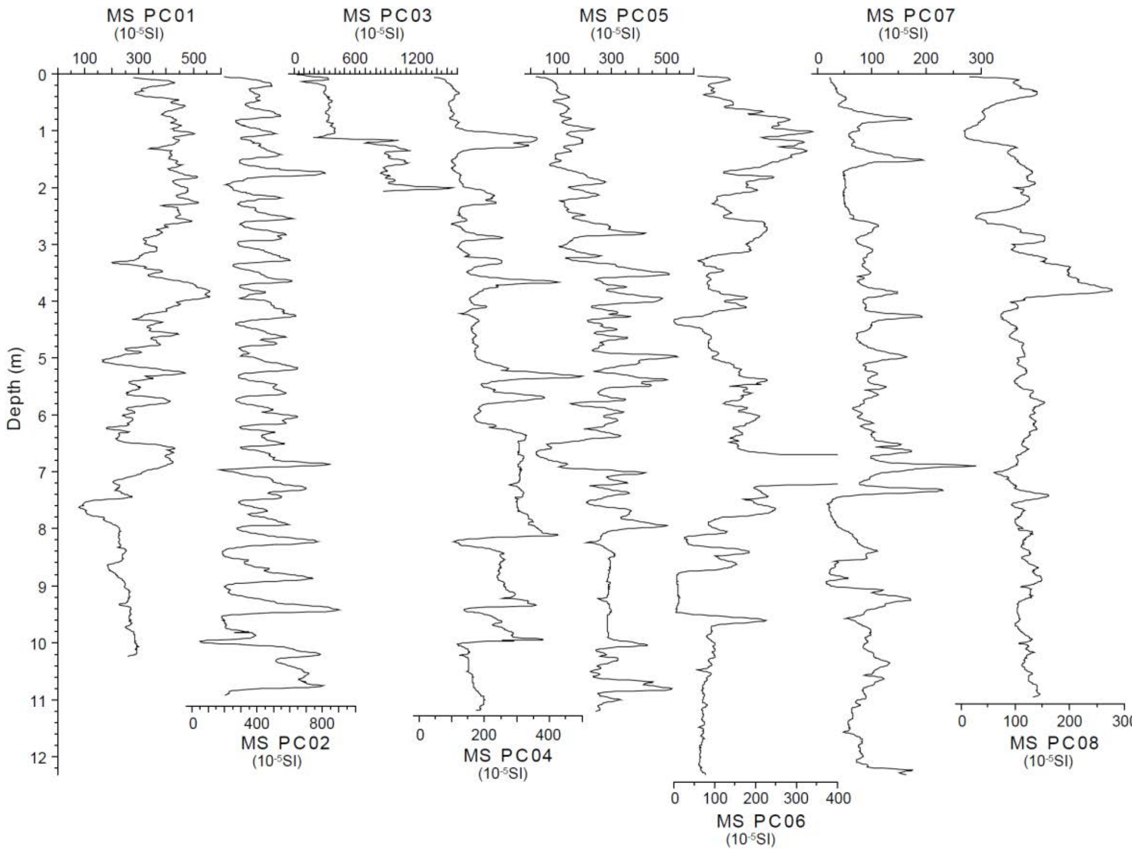

Figure 3-2-10. Magnetic susceptibility (MS) versus sediment depth, measured on cores PC01 to PC08 onboard Hakuho-maru during Expedition KH-19-6 Leg 4. Note that scales are different for each site to display best the internal variability. However, each tick mark indicates 50 instrument units (10^{-5}SI) for comparison.

3-2-4 Future Works

All sediment samples obtained during this cruise will be sent to the Center for Advanced Marine Core Research, Kochi University and stored in the refrigerator. Cores will be scanned by X-ray CT scanner, to obtain internal structures of cores before splitting. Non-destructive Multi-Sensor Core Logger (MSCL) analysis for density, velocity, and MS measurement is also planned using whore-round core sample.

Core splitting, description and sampling party is scheduled in early June of 2020. Cores will be split into working- and archive-halves using a splitting devise with nylon or stainless lines. Archive-half sections will be provided for photographs, color reflectance measurements with a reflectance photospectrometer and visual core description of lithology. Working-half sections will be used for postcruise research on sedimentology, paleoceanography, physical properties, geochemistry, and micropaleontology.

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3-3. Multiple core sampling

H Nomaki, K Seike, T Kagoshima, H Ritchie, M Sasaoka, and helps from dredge team

3-3.1. Instruments and Method

Surface sediment samples were collected with a Barnet-type multiple corer to minimize a sediment disturbance during the corer penetration into sediments. The multiple corer equipped eight 60-cm long core tubes with an inner diameter of 82 mm. Specific core tubes were used for certain scientific objectives.

In some multiple corer deployments, we attached a deep-sea camera and a temperature and dissolved oxygen sensor to a stainless frame of the multiple corer. The camera was pre-programmed to record up to 2 hours of video during the multiple corer sampling on the seafloor. The sensor recorded during entire multiple corer deployments; i.e. before the multiple corer deployment to the recovery on deck.

After recovery of the multiple corer onboard, we retrieved sediments with overlying seawater and kept chilled either outside the deck or in a cold room. Each sediment core was processed subsequently with an appropriate protocol for each scientific purpose.

3-3.2. Operation notes

We carried out 14 multiple corer deployments during the Leg 4 (Table 3-3-1). Two deployments (MC05 and MC09) among 14 were failed due to mechanical problems or bottom substrate problems. A deployment MC08 collected only gravels and intact sea urchins. A deployment MC12 retrieved surface ~5cm of sediments, thus not suitable for some scientific purposes. Typically 25 cm to 35 cm length (thickness) of layered sediments were obtained and used for several different scientific analyses as noted in the next chapter.

3-3.3. On board processing and preliminary results

In the cold-room laboratory, dissolved oxygen (DO) concentrations across the sediment–water interface were measured with a microelectrode (Unisense, Denmark) immediately after core recovery.

Porewater was extracted by either pressurization or centrifuging and the extracted water samples were preserved accordingly. Cores for sedimentary structure analyses was kept intact in a cold room. Other cores were sliced into pre-determined sediment depths and preserved in a cold room or in a freezer.

3-3.4. Future Works and Data Distribution

Following analyses will be performed by on-board scientists and their collaborators: sedimentological analyses, micropaleontological analyses, geochemical analyses, porewater nutrient concentrations, organic matter quantity and quality, microbial abundances and diversity, metazoans abundances and diversity, helium isotopes, microplastics abundances.

Table 3-3-1. Basic information of all multiple core samples, and sample distribution.

Date(UTC)		22-Dec-19	23-Dec-19	24-Dec-19	26-Dec-19	29-Dec-19	29-Dec-19	29-Dec-19	30-Dec-20	30-Dec-19	6-Jan-20	8-Jan-20	9-Jan-20	13-Jan-20	14-Jan-20
Time(UTC)		5:37	12:52	5:32	23:38	5:01	9:41	15:36	1:01	9:13	15:33	16:59	3:50	17:39	11:08
Cast No		**MC01**	**MC02**	**MC03**	**MC04**	**MC05**	**MC06**	**MC07**	**MC08**	**MC09**	**MC10**	**MC11**	**MC12**	**MC13**	**MC14**
Station name		**SET6**	**ANP2**	**SET19**	**WS01**	**A3000**	**A5200**	**A6200**	**A1500**	**A3000**	**F5200**	**WS5**	**BL6500**	**SA-6**	**SA-5**
Latitude		61d3.78S	63d30.43S	61d58.97S	61d41.38S	60d56.90S	60d52.50S	60d51.02S	60d57.94S	60d56.55S	59d06.33S	58d53.02S	58d07.51S	40d37.99S	39d38.16S
Longitude		57d59.03W	61d31.94W	62d19.55W	51d25.35W	42d7.73W	41d36.04W	41d2.23W	42d26.38W	42d7.79W	16d31.49W	10d20.02W	10d55.06W	14d14.98E	14d28.85E
Water depth (m)		4166	1062	4731	2716	3011	5251	6271	1538	3019	5602	3961	6516	2280	4597
Operation notes						Failed, Frozen?			Only gravels and a sea urchin	Failed			~5cm thickness	~10cm thickness	
Camera		N	N	Y(failed)	(not focused	N	Y	N	N	N	Y	N	Y	Y	Y
Temp&DO Sensor		N	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Sedimentology, Paleoceanograpy	M Ikehara	2	2	2	ashura×2						1	ashura×2		2	1
Microfossils	Y Kubota		1		ashura							ashura		1	1
Sedimentology, Paleoceanograpy	A Yamaguchi	1		1									failed	1	Ashura
Microplastics	R Nakajima	1	1	1	1						1	1			1
O2 conc, porewater nutrients	H Nomaki	1	1		1		1	1			1	1	1		1
Meiofauna	H Nomaki				1		1	1			1	1	1		
Microbes, Meiofauna	H Nomaki	0.5	0.5		0.5		1	1			1	1	1		0.5
Organic matters, Meiofauna	H Nomaki	0.5	0.5		0.5		1	1			1	1	1		0.5
Burrows	K Seike (K Kubota)	1	1	2	1		1	1			1	2		2	2
He isotopes	T Kagoshima	1	1	1	1		1	1			1	1	failed		
Metazoans	N Jimi et al.			1	2		2	2	Sea urchin etc				2	2	1
Total		8	8	8	8		8	8	0		8	8	6	8	8

3-4. Dredge

3-4-1. Personnel

Kenichiro Tani (National Museum of Nature and Science)
Shimpei Hiruta (National Museum of Nature and Science)
Osamu Ishizuka (Geological Survey of Japan/AIST)
Yumiko Harigane (Geological Survey of Japan/AIST)
Iona McIntosh (Japan Agency for Marine-Earth Science and Technology)
Naoto Jimi (JSPS postdoctoral fellow/National Institute of Polar Research)
Philip Leat (The University of Tokyo)
Akito Ogawa (The University of Tokyo/National Museum of Nature and Science)
Chihiro Ohshima (The University of Tokyo)
Yuuji Fuwa (Marine Works Japan. Ltd)

3-4-2. Objectives

We conducted 18 dredge surveys during the KH-19-6-Leg 4 cruise based on two major scientific objectives:

1. Understanding the crustal structures and ages of the South Orkney microcontinent including those of the surrounding Bruce and Discovery Banks (Fig. 3-4-1; D01 to D13)
2. Tracing the temporal variation of oceanic crust formation along the Vulcan Fracture Zone, American-Antarctic Ridge (Fig. 3-4-2; D14 to D18)

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.

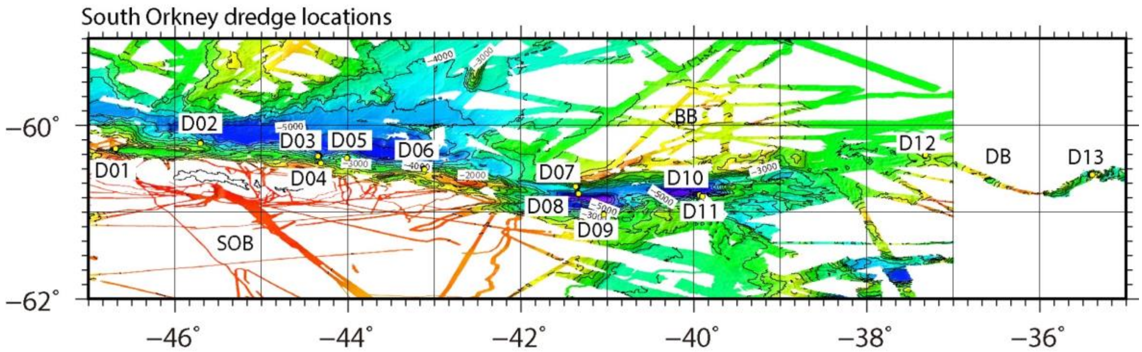

Figure 3-4-1. Bathymetry map in the vicinity of the South Orkney Islands. Bathymetric data is a combination of compiled data from British Antarctic Survey (Abrahamsen 2019; Fremand 2019) merged with newly acquired SEABEAM data during the KH-19-6-Leg 4 cruise. Yellow circles indicate the dredge stations conducted during the KH-19-6-Leg 4 cruise. SOB: South Orkney Bank, BB: Bruce Bank, DB: Discovery Bank.

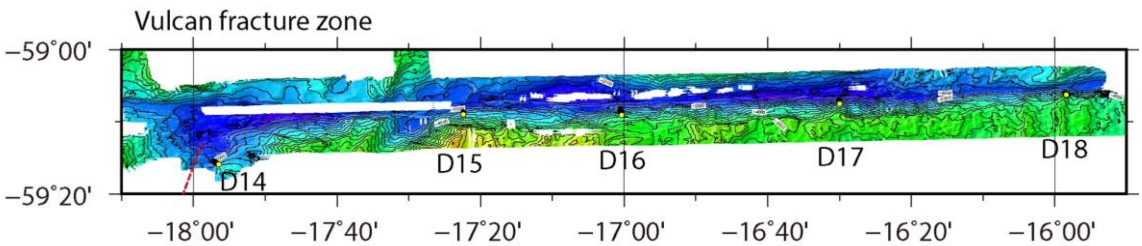

Figure 3-4-2. Bathymetry map of the Vulcan Fracture Zone. Bathymetric data is newly acquired SEABEAM data. Yellow circles indicate the dredge stations conducted during the KH-19-6-Leg 4 cruise. Red dotted line represents estimated location of the current spreading center.

3-4-3. Instrument and Methods

The dredge systems used during the KH-19-6-Leg 4 are as illustrated in Figure 3-4-3. 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 two types of dredge; Satsuki-type box-shaped dredge and barrel-type 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 various altitudes aiming to find optimal position for better signal recovery. We tested at 250 m above wire end (D02, D03, and D04), 300 m above (D01 and 05), and 400 m above (D06). We found that 400 m above the wire end was optimal and used this position from D06 onwards.

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 5 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.

7. 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). Both a barrel-type dredge (D01 and D02) and a box-shaped, Satsuki-type, dredge (D03 to D18) were used. To obtain better recovery of the benthos that are sampled with the rocks, we installed 350 μm nylon mesh bags inside the dredge (Fig. 3-4-4). We also installed an RBR SOLO depth logger inside the dredge to monitor precise movements of the dredge at the seafloor.

8. Following the regulation of Hakuhomaru, fuse wires of 6.3 mm (23 kN of breaking force) and life wires of 8 mm (29.3 kN of breaking force) were used for sites deeper than 4000 m. For sites shallower than 4000 m, we used fuse wires of 9 mm (37.1 kN of breaking force) and life wires of 10 mm (45.8 kN of breaking force).

9. 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.

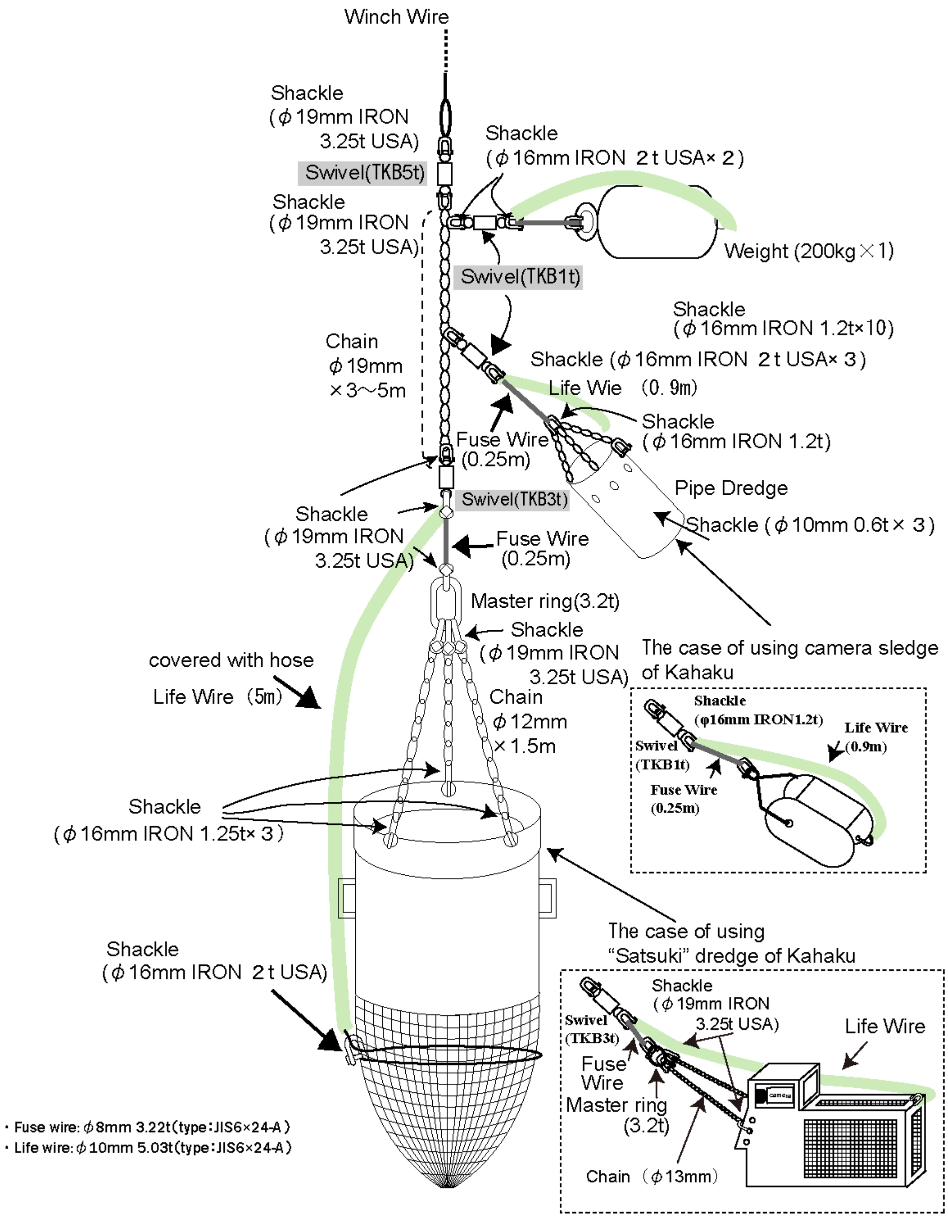

Figure 3-4-3. Detailed assembly of dredge systems used in KH-19-6-Leg 4 cruise.

Figure 3-4-4. Nylon mesh bag installed in the barrel-type dredge for benthos sampling (D01).

3-4-4. Survey results

South Orkney Islands (D01 to D13)

The main target for dredging in the vicinity of the South Orkney Islands was to recover rock samples from basement outcrops suitable for radiometric dating and for petrological and geochemical analyses. We chose three topographic highs along the South Scotia Ridge: South Orkney Bank, Bruce Bank, and Discovery Bank for dredging (Fig. 3-4-1). They are considered to represent submerged continental fragments once connecting South America and the Antarctic Peninsula, separated during the formation of the Scotia Plate since the Oligocene (e.g. Lodolo et al., 2010 EPSL). Understanding the detailed geology of these crustal blocks thus would provide critical constraints on tectonic development of the Scotia-Antarctica plate boundary.

Among the dredges conducted in the South Orkney Bank (D01 to D06, and D09), the predominant rock type which we considered as being collected in situ was metasedimentary rocks experiencing various degrees of low-grade metamorphism and deformation. This was most prominent in the central part of the bank (D06). Volcanic rocks (basalt-andesite) were collected at the eastern part of the bank (D09).

We conducted two dredges in the southern scarp of the Bruce Bank (D07 and D08). These two sites were selected to survey deeper (D08, 5835 – 5545 mbsl) and shallower (D07, 3979 – 3565 mbsl) parts of the same slope. Various rock types were collected in D07, including one peridotite sample, but we considered it likely that only the metasedimentary rocks and suites of basaltic rocks were collected in situ, based on their morphology and predominance among the collected samples. We recovered semi-consolidated mudstone from D08.

Two dredges were conducted at the northern wall of the eastern Bruce Deep (D10 and D11). These two sites were selected to survey deeper (D10, 5835 – 5129 mbsl) and shallower (D11, 4313 – 3881 mbsl) parts of the same slope. Gabbroic rocks were recovered at both sites.

We were unable to survey the main structure of the Discovery Bank due to the presence of icebergs in the area. Instead, we dredged a conical seamount located on the northwestern part of the bank (D12) and a small topographic high located south of the bank (D13). Various rock types were collected in D12, including significant amounts of non-igneous rocks (metasedimentary and metamorphic rocks). We considered that they are most likely to be drop stones and that only the suites of basaltic rocks in the dredge would represent the outcrop(s). However, further geochemical and petrographical analyses are required to confirm our shipboard conclusion. Metasedimentary rocks and several clasts of basalts were recovered at D13.

Vulcan Fracture Zone

The main research goal in surveying the Vulcan Fracture Zone was to conduct systematic sampling of the oceanic lithosphere along the transform fault, aiming to detect temporal variation of the magmatism during oceanic crust formation at the mid-oceanic ridges. We conducted geophysical survey (bathymetric and geomagnetic surveys) before dredging and chose five dredge sites (D14 to D18), roughly 25 to 30 km apart, along the north-facing wall of the fracture zone (Fig. 3-4-2). D14 is in the current spreading center.

The predominant rock type collected in the area was basalt. We also obtained fresh basaltic glass in D14, and various gabbroic rocks in D17.

The position and depth of the dredge sites are summarized in Table 1. The total weight of the recovered rocks was 679 kg. Individual dredge sites are described in the following. Details of benthos collected from these dredge sites are described in a different section.

Table 3-4-1. The position and depth of the dredge sites.

Date	St. No.	SP/EP	Time (UST)	Depth (m)	Lat. (°S)	Lon. (°W)	Wireout (m)	Lithology	Total weight (kg)	Dredge assembly
2019/12/27	D01	on bottom	15:29:09	2789	60.2795	46.6831	2789	schist, volcanic rock and mud clast	0.92	Barrel-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	16:55:43	2034	60.2677	46.6883	2023			
2019/12/27	D02	on bottom	22:13:15	3849	60.1986	45.7020	3841	schist, metasediment rock, sandstone, amphibolite, volcanic rock, qtz vein	6.40	Barrel-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	23:44:26	3229	60.2123	45.7077	3470			
2019/12/28	D03	on bottom	6:42:00	4841	60.3490	44.3261	4825	mica schist, metasediment rock, sandstone (coarse- and fine-grained), porphyritic andesite, quartzite, plutonic rock	9.25	Satsuki-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	7:57:51	4319	60.3585	44.3459	4551			
2019/12/28	D04	on bottom	11:23:04	2459	60.4330	44.3114	2438	sandstone (coarse- and fine-grained), brecciated sandstone, metasediment rock, amphibolite, volcanic rock	10.1	Satsuki-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	12:06:31	2214	60.4385	44.3153	2255			
2019/12/28	D05	on bottom	15:46:21	3439	60.3723	44.0068	3460	sandstone	1.35	Satsuki-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	16:30:07	3297	60.3782	44.0112	3414			
2019/12/28-2019/12/29	D06	on bottom	21:57:31	3184	60.4956	43.1239	3332	cataclasite, black schist, green schist, metasandstone, metasediment rock, sandstone, manganese	207	Satsuki-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	23:09:48	2328	60.5092	43.1160	2717			
2019/12/30-2019/12/31	D07	on bottom	23:52:34	3979	60.7193	41.0448	4076	basalt, andesite, tuff, dunite, gabbro, amphibolite, granodiorite, granite, quartzite, mafic geiss, metasediment rock, metasandstone, metamorphosed mudstone, sandstone, siltstone, conglomerate	95.3	Satsuki-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	1:12:56	3565	60.7072	41.3689	3827			
2019/12/31	D08	on bottom	5:35:28	5835	60.7996	41.3333	5824	volcanic rock, siltstone	3.36	Satsuki-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	6:22:58	5545	60.7899	41.3343	5804			
2019/12/31	D09	on bottom	11:49:37	3905	61.0152	41.0408	3870	basalt, andesite, volcanic rock, gabbro, granodiorite, granite, gneiss, schist, quartzite, greenschist, metasediment rock, metasandstone, sandstone	46.4	Satsuki-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	13:01:40	3471	61.0309	41.0394	3722			
2019/12/31	D10	on bottom	21:07:35	5835	60.7903	39.9343	5759	gabbro, olivine gabbro	0.2	Satsuki-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	22:10:12	5129	60.8052	39.9312	5354			
2019/12/31-2020/1/1	D11	on bottom	2:28:37	4313	60.8163	39.9077	4293	gabbro	0.1	Satsuki-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	3:23:05	3881	60.8205	39.9009	3938			
2020/1/1	D12	on bottom	15:43:34	1945	60.3554	37.3273	1994	gabbro, microgabbro, granite, basalt, andesite, dacite, volcanic rock, amphibolite, quartzite, metasandstone, metasediment rock, sandstone, manganese	129	Satsuki-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	16:43:04	1619	60.3445	37.3223	1690			
2020/1/2	D13	on bottom	4:14:59	2455	60.5651	35.4120	2479	gabbro, microgabbro, granite, basalt, altered volcanic rock, fault breccia, gneiss, metasandstone, metasediment rock, sandstone	92.2	Satsuki-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	5:05:59	1912	60.5688	35.3947	2036			
2020/1/5	D14	on bottom	20:02:38	5026	59.2571	17.9541	5012	basalt, basalt glass, granite, sandstone	23.1	Satsuki-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	21:15:58	4548	59.2653	17.9411	4736			
2020/1/6	D15	on bottom	3:29:06	4779	59.1450	17.3738	5003	basalt (with gabbroic inclusion)	1.25	Satsuki-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	4:29:39	4451	59.1503	17.3734	4555			
2020/1/6	D16	on bottom	8:59:51	4839	59.1387	17.0087	4865	baslt, dolerite, silicic volcanic rock, gabbro, diorite, granite, cataclasite, sandstone, Mn crust, manganese	2.65	Satsuki-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	10:49:50	3964	59.1511	17.0059	4083			
2020/1/6	D17	on bottom	19:53:12	5312	59.1172	16.5013	5273	olivine gabbro, olivine basalt, basalt, dolerite	13.4	Satsuki-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	21:16:06	4431	59.1253	16.4991	4627			
2020/1/7	D18	on bottom	2:07:29	4183	59.1009	15.9751	4356	basalt, diorite	50.4	Satsuki-type dredge with 200 kg weight and hanging camera (7000 m)
		off bottom	3:16:13	3802	59.1044	15.9738	3877			

3-5. Plankton net sampling

Takuya Ohnishi (Tokyo Univ.), Hayao Yokochi (Kindai Univ.) and Hidetaka Nomaki (JAMSTEC)

Background

Zooplankton are ubiquitous and abundant in the pelagic ocean, playing a significant role in marine food webs and in biogeochemistry. They are also highly diverse and sensitive to environmental changes; therefore, investigating their diversity is important to understand changes in marine environments and ecosystems. During KH-19-6 cruise aboard the R.V. Hakuho-Maru, zooplankton samples were obtained to assess both species-level and genetic-level diversity of zooplankton using molecular technique.

In order to reveal population structure and gene flow of key zooplankton in pelagic oceans, Norpac net with 100 µm mesh size was vertically towed to collect zooplankton at the depth of 0–200 m. Bulk samples were preserved in 99% ethanol. Key zooplankton species will be picked up from bulk zooplankton, and mtCOI sequences and genome-wide SNP data will be obtained foe each species. The results in the Weddell Sea and the South Pacific will be compared with those in the North Pacific and the Indian Ocean, which were collected during previous research cruises aboard on the R.V. Hakuho-maru. Other bulk samples collected by Norpac net with 335 µm or 100 µm mesh sizes were frozen at –20°C or store in RNAlater. These samples can be used to investigate diets and evolution of functional genes in a local population of key zooplankton species.

Instruments and Method

Zooplankton samples were obtained during the KH-19-6 cruise (Table 3-5-1). The samples were collected with vertical hauls of Norpac net from 200 m depth (Fig. 3-5-1). The net has four rings with a ring diameter of 45 cm with mesh sizes of 100 or 335 µm. A flow-meter was equipped in the mouth of the ring to estimate the water volume filtered. Samples were preserved immediately after collection using four different methods (formalin, ethanol, RNAlater and frozen at –20°C).

Table 3-5-1. Sample locations

Date	Time	Latitude	Longitude
22-Dec.-19	5:26	61°03.75’S	57°58.06’W
24-Dec.-19	17:05	61°50.22’S	62°39.46’W
26-Dec.-19	19:13	61°41.67’S	51°18.53’W
1-Jan.-20	4:15	60°47.88’S	39°57.79’W
5-Jan.-20	13:04	58°45.04’S	18°26.65’W
8-Jan.-20	10:19	58°52.95’S	10°20.05’W
13-Jan.-20	9:00	40°38.27’S	14°14.99’E
15-Jan.-20	4:59	37°14.03’S	16°10.33’E

Figure 3-5-1. Norpac net

Future Works

Euphausiids and copepods are important in the oceanic ecosystem as they could link higher and lower trophic levels with prey consisting of detritus, phytoplankton, and a variety of small zooplankton. They are important food resources for fish and some sea birds. Thus, understanding their feeding ecology is helpful and necessary to clarify the matter and energy flow through the oceanic ecosystem.

3-6. Sea water sampling

Y. Kato (Kochi Univ.), M. Iizuka (Hokkaido Univ.)

3.6.1. Instruments and Method

During the cruise, we collected surface seawater containing living plankton and organic matters using seawater pumps, which are located at left side of the R/V Hakuho-Maru (~5 m water depth). This seawater sampling aims to obtain biogeographic/ecological data of the marine plankton as well as geochemical data of seawater in the Southern Ocean. Types and details of the sampling are as follows.

Living plankton sampling

To estimate the standing stock of the marine plankton and to assess its reliability as paleo-proxy (e.g., oxygen isotope), living plankton (planktic foraminifera and diatom) was collected from research seawater. Seawater was filtered using the special hand-nets (20 μm and 63 μm opening) and the fractions of >63 μm and 20–63 μm were intended for studies of foraminifera and diatom, respectively. Total volume of seawater was recorded using the flowmeter (Fig. 3-6-1). At each sampling point, about 1 to 3 m^3 of seawater was filtered through for about two hours depending on the abundance of plankton. Collected samples were stored in a 120 mL or 300 mL bottle and filled with 50 to 90% ethanol. Samples were stored in a cold room (~ 4C°).

Sea water sampling

To evaluate the distribution of hydrogen and oxygen isotopes of seawater, research seawater was collected into two bottles (50 mL each). They were filled with sea water and stored in a cold room (~ 4C°).

Membrane filter sampling

To understand the biogeographic distribution of coccolith, diatom, and chrysophytes in the Southern Ocean, research seawater was filtered through the 0.45 μm mesh membrane filter. Three filters were used (1L, 2L, 2L each) for each station and then dried and stored in a cold room (~ 4C°). In several stations where the abundance of phytoplankton was extremely high, additional membrane filter was used to filter 0.5 L of seawater.

Particulate organic matter sampling

To evaluate the spatial distribution and compositions of marine biomarkers such as alkenones (coccolith-marker) and brassicasterol (diatom-marker) in the Southern Ocean, we collected suspended particle organic matters (POM) in research seawater. About 20L of research seawater was filtered by means of Whatman GF/F 47 mm filters (pre-combusted glass fiber filter). When the filter was clogged with the POM, another filter was used (at most four filters). The POM samples were stored in dark at about -20 C°.

3.6.2. Operation notes

Seawater sampling was successfully carried out during the cruise. Sampling of living plankton, sea water, membrane filter, and POM were performed twice a day (local time: 7:00 and 17:00). A total of 41 sampling points is summarized below (Fig. 3-6-2. And Table 3-6-1).

3.6.3. Preliminary results

Plankton abundance was significantly high in the region south of winter sea-ice limit (Stations 510–533). The result is likely to reflect high primary production caused by ice-edge blooming. Abundance of plankton remarkably dropped when crossing through the Subtropical Front (i.e., plankton abundance in Station 540 is much lower than that in Station 539), which indicates entirely different structure of water mass and/or plankton communities. In several sites such as Stations 502–504, the filters (i.e., membrane filters and GF/F filters) ware clogged with only a small amount of seawater, which implies high abundance of plankton, despite the fact that the living plankton sampling using special hand-nets caught less abundant planktons. The contradiction could be explained by assuming that plankton community in the region is mainly comprised of small diatoms (> 20μm).

3.6.4. Future Works and Data Distribution

All samples collected will be stored in Kochi University. For living plankton samples, standing stock, assemblage, and isotope signature of foraminifera and diatom will be investigated. Oxygen and hydrogen isotopes of sea water samples will be measured. For membrane filter samples, we aim at studying spatial distribution of coccolith, diatom, and chrysophytes. Analyses of the POM samples include nitrogen and carbon isotopes of bulk organic matters, phytoplankton biomarkers, terrestrial plant biomarker, and bacteria biomarker. All data will be available 2–3 years after the cruise.

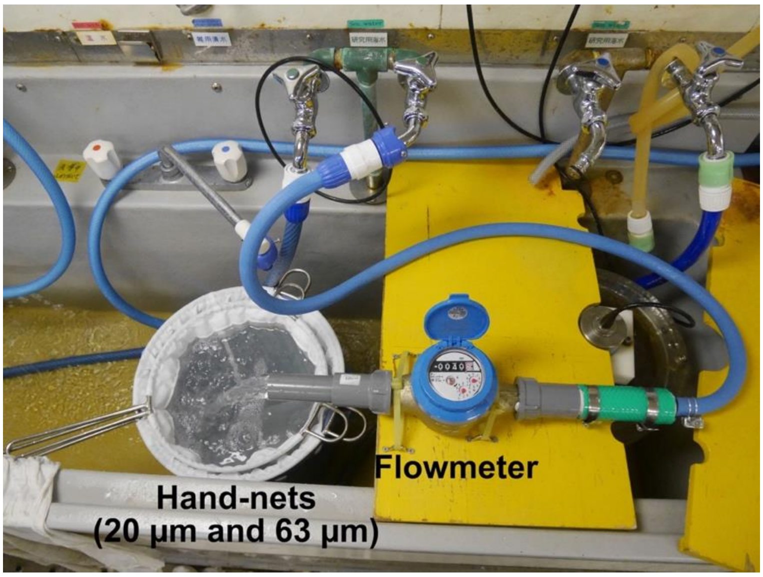

Fig. 3-6-1. Living plankton sampling system comprising the special hand-nets (20 μm and 63 μm opening) and the flowmeter.

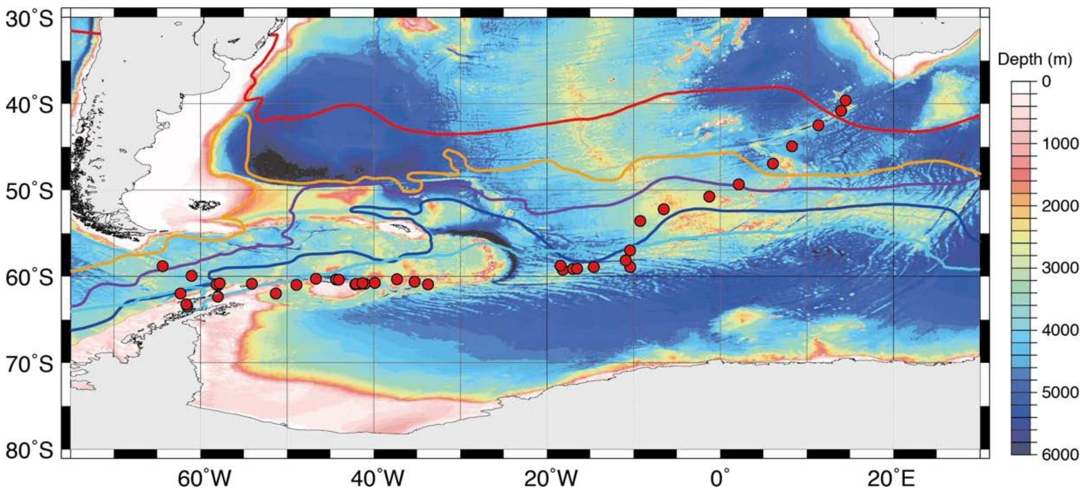

Fig. 3-6-2. Map showing seawater sampling stations during KH-19-6 Leg 4. The oceanographic fronts (Orsi et al., 1995) and winter sea-ice limit (Fetterer et al., 2017) are also indicated. Red: Subtropical Front, orange: Subantarctic Front, purple: Polar Front, Blue: Southern Antarctic Circumpolar Current Front, light-blue: winter sea-ice limit.

Table 3-6-1. Seawater sampling stations during KH-19-6 Leg 4. Sampling at Station 525 was cancelled because the ship had entered the Exclusive Economic Zone (EEZ).

Station	Date	Net sampling starts at:					Net sampling ends at:					Filtered water volume (hand-net sampleing) (L)	Number of membrane filters			Number of GF/F filters	Total water volume for POM sampleing (L)	Note
		Time (GMT)	Latitude	Longitude	Water temp. (°C)	Salinity	Time (GMT)	Latitude	Longitude	Water temp. (°C)	Salinity		2L	1L	0.5L			
501	2019/12/21	10:10	58° 48.33' S	64° 23.78' W	3.6	34.0	12:10	59° 8.64' S	63° 43.39' W	4.0	34.0	1180	2	1	0	2	20	
502	2019/12/21	19:05	59° 56.26' S	61° 3.00' W	0.4	33.9	21:10	60° 11.67' S	60° 15.35' W	1.2	33.7	1077	2	1	0	2	20	
503	2019/12/22	9:03	61° 2.89' S	57° 59.46' W	0.3	33.9	11:05	61° 17.80' S	57° 42.53' W	0.3	33.9	1771	2	1	0	2	20	
504	2019/12/22	19:04	62° 19.92' S	57° 59.51' W	1.3	34.1	21:14	62° 31.66' S	58° 48.32' W	1.5	34.1	1754	1	3	0	6	20	
505	2019/12/23	9:07	63° 30.39' S	61° 32.13' W	0.4	34	11:27	63° 30.40' S	61° 32.22' W	0.3	34.0	2112	1	2	2	3	20	
506	2019/12/23	19:15	63° 14.55' S	61° 38.29' W	0.3	34	21:15	62° 59.22' S	62° 0.31' W	0.5	34.0	2069	0	1	2	2	10.5	
507	2019/12/24	9:06	61° 59.02' S	62° 19.49' W	1.1	33.9	11:18	61° 58.69' S	62° 19.95' W	1.1	33.9	2434	2	1	0	2	20	
508	2019/12/25	9:07	60° 54.89' S	58° 9.33' W	0.5	33.8	11:20	60° 54.06' S	58° 8.82' W	0.9	33.8	1913	2	1	0	1	20	
509	2019/12/25	19:10	60° 47.72' S	57° 47.71' W	1.4	33.8	21:21	60° 47.74' S	57° 42.83' W	1.5	33.9	2204	2	1	0	1	20	
510	2019/12/26	8:10	60° 50.94' S	54° 3.78' W	-0.1	34.3	10:10	60° 54.62' S	53° 13.54' W	0.6	34.4	2079	2	1	1	2	20	
511	2019/12/26	18:03	61° 58.81' S	51° 18.03' W	-0.5	33.9	20:07	61° 41.59' S	51° 18.68' W	-0.4	33.7	2156	2	1	0	2	20	
512	2019/12/27	8:02	60° 58.81' S	48° 55.81' W	-0.5	34.3	10:04	60° 43.89' S	48° 7.57' W	-0.4	34.1	1571	2	1	0	2	20	
513	2019/12/27	18:01	60° 16.29' S	46° 40.42' W	-0.1	33.8	20:01	60° 14.48' S	45° 56.45' W	-0.2	33.6	2703	2	1	1	4	20	
514	2019/12/28	8:13	60° 21.48' S	44° 20.71' W	-0.1	33.6	10:14	60° 25.81' S	44° 18.71' W	-0.3	33.5	1652	2	1	1	3	20	
515	2019/12/28	18:01	60° 22.85' S	44° 2.15' W	0.1	33.5	20:23	60° 29.43' S	43° 8.42' W	-0.1	33.6	2329	2	1	1	3	20	
516	2019/12/29	8:12	60° 52.52' S	41° 36.08' W	-0.6	33.4	10:04	60° 52.48' S	41° 35.99' W	-0.7	33.4	1387	2	1	1	2	20	
517	2019/12/29	18:01	60° 51.10' S	41° 0.94' W	-0.7	33.5	20:06	60° 52.31' S	41° 4.21' W	-1.2	33.4	4279	2	1	0	3	20	
518	2019/12/30	8:08	60° 56.42' S	42° 7.65' W	-0.4	33.4	10:18	60° 56.66' S	42° 7.48' W	-0.5	33.4	1535	2	1	1	2	20	
519	2019/12/30	18:03	60° 51.03' S	42° 2.20' W	-0.8	33.5	20:05	60° 51.20' S	41° 2.19' W	-0.9	33.5	1823	2	1	0	2	20	
520	2019/12/31	8:09	60° 46.96' S	41° 19.26' W	-0.3	33.3	10:24	61° 0.69' S	41° 2.56' W	-1.0	33.4	1662	2	1	0	2	20	
521	2020/1/1	8:01	60° 45.42' S	39° 52.08' W	-0.9	33.5	10:15	60° 37.42' S	38° 59.50' W	-0.9	33.4	1689	2	1	0	2	20	
522	2020/1/1	18:04	60° 20.24' S	37° 18.32' W	-0.3	33.2	20:04	60° 27.24' S	36° 58.35' W	-0.6	33.2	2006	2	1	1	4	20	
523	2020/1/2	8:08	60° 36.68' S	35° 16.20' W	-0.8	32.9	9:29	60° 31.11' S	35° 6.44' W	-0.7	32.8	1020	2	1	1	3	10	
524	2020/1/2	18:05	60° 55.19' S	33° 43.24' W	-0.8	33.2	19:52	60° 44.05' S	33° 42.73' W	-0.9	33.1	1000	1	2	1	3	10	
526	2020/1/4	17:00	59° 13.91' S	18° 10.36' W	0.1	33.3	19:13	59° 12.86' S	17° 14.48' W	-0.2	33.3	2483	2	1	1	4	12	
527	2020/1/5	7:09	58° 45.96' S	18° 26.68' W	0.1	33.7	9:02	58° 44.99' S	18° 26.65' W	0.6	33.6	1293	2	1	0	3	17.5	Site PC07
528	2020/1/6	7:11	59° 8.11' S	17° 0.62' W	0.0	33.3	8:54	59° 8.29' S	17° 0.53' W	0.5	33.3	5276	2	1	1	3	20	
529	2020/1/6	17:09	59° 6.37' S	16° 31.25' W	0.4	33.6	18:56	59° 7.03' S	16° 30.10' W	0.5	33.6	1000	1	1	1	4	3.5	
530	2020/1/7	17:00	58° 55.36' S	14° 35.64' W	0.3	33.7	18:34	58° 54.34' S	14° 25.23' W	0.1	33.7	1004	1	1	1	4	8	
531	2020/1/8	7:06	58° 54.37' S	10° 22.34' W	-0.3	34	8:44	58° 52.89' S	10° 19.97' W	0.2	34.0	1387	0	2	1	4	12.5	Site MC10
532	2020/1/9	6:10	58° 7.58' S	10° 54.53' W	0.6	33.7	7:51	58° 7.53' S	10° 48.94' W	0.5	33.6	1018	0	2	1	4	11.5	
533	2020/1/9	16:01	56° 59.03' S	10° 24.84' W	0.7	33.7	17:39	56° 35.22' S	10° 16.01' W	0.9	33.7	1443	1	2	1	4	15.5	
534	2020/1/10	6:02	53° 35.83' S	9° 14.22' W	1.2	33.8	7:42	53° 11.43' S	9° 6.81' W	1.9	33.8	1363	2	1	1	3	20	
535	2020/1/10	15:59	52° 13.50' S	6° 31.30' W	2.1	33.8	17:50	52° 2.17' S	5° 49.92' W	2.4	33.8	1639	2	1	0	2	17.5	
536	2020/1/11	6:03	50° 45.66' S	1° 16.03' W	3.3	33.8	7:09	50° 38.84' S	0° 51.91' W	3.5	33.8	1062	2	1	1	2	20	
537	2020/1/11	16:07	49° 21.60' S	2° 8.50' E	4.3	33.8	17:56	49° 4.06' S	2° 42.25' E	4.3	33.8	1426	2	1	1	2	20	
538	2020/1/12	6:08	46° 55.90' S	6° 5.86' E	5.8	33.9	7:45	46° 36.08' S	6° 27.89' E	6.4	33.8	1211	2	1	1	4	20	
539	2020/1/12	16:08	44° 55.78' S	8° 16.44' E	7.2	33.9	17:54	44° 34.61' S	8° 38.84' E	8.3	34.1	1461	1	2	1	4	13.5	
540	2020/1/13	5:08	42° 29.36' S	11° 19.87' E	10.2	34.2	6:47	42° 2.66' S	11° 46.45' E	10.4	34.2	1600	2	1	0	2	20	
541	2020/1/13	15:03	40° 48.99' S	13° 57.86' E	17.9	35.5	16:59	40° 38.10' S	14° 15.01' E	18.1	35.5	2101	2	1	0	2	20	
542	2020/1/14	5:01	39° 37.87' S	14° 28.47' E	20.9	35.5	6:24	39° 37.99' S	14° 28.99' E	21.1	35.5	1426	2	1	0	2	20	Site PC11

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3-7. Microscale bacterial diversity

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Introduction

Bacteria are now recognized as key players in marine biogeochemical processes. However, the findings are only based on the context of macro- and mesoscale oceanographic features. As the diversity and functions of bacteria (about one micrometer cell size) are defined by processes and interactions occurring in much smaller scale, it is needed to focus on bacterial dynamics at microscale, not at larger scale. Therefore, it is absolutely important to investigate their diversity and functions at microscale for better understanding of marine biogeochemical processes.

In this cruise, we collected on-board pumping seawater samples at a certain interval of latitude and longitude to explore bacterial diversity at microscale in order to understand a role of bacteria in marine biogeochemical processes. To collect the microscale water samples, we used a microscale water sampling (MWS) device. Using this MWS device, we can collect 96 samples (one microliter each) at once. Additionally, we performed a microcosm experiment to investigate the microscale dynamics of bacteria during a phytoplankton bloom at several stations.

Methods: Microscale bacterial dynamics analyses

On-board pumping seawater samples were collected into a polycarbonate box at 7 stations (Table 3-7-1), which was subsampled in duplicate using the MWS devise. The subsamples were put into 96-well plate containing 15 microliters of DNA-free distilled water at each well and stored at -80°C until further processing in the lab. Additionally, a small amount of aliquot water samples was fixed with glutaraldehyde at 4°C for several hours, flash-frozen in liquid nitrogen and stored at -80°C until further analysis in the lab. This is for flowcytometric counting of prokaryotes.

For the microcosm experiment, on-board pumping seawater samples were additionally collected at four stations (Table 3-7-1). After the sampling, HCl was added to the water samples in polycarbonate boxes (duplicate of 700 mL each) in order to adjust to pH 7.60 and then f/2 medium. The water samples without pH adjustment (duplicate of 700 mL each) were also prepared as a control. The samples were incubated for six days in an on-deck incubator flowing surface seawater. After the 6-day-incubation, all boxes were incubated in a dark condition for another six days. *In vivo* chlorophyll fluorescent and pH were measured every day. Microscale subsamples (obtained by using MWS device) and flowcytometric subsamples were collected every three days.

Future plans

Microscale samples will be subjected to direct PCR amplification of 16S rRNA gene and sequencing, which provides the data on microscale bacterial diversity and dynamics. Prokaryotic abundance will be also measured. This analysis aims to revealing spatial and temporal dynamics of bacteria at microscale, which will also contribute to better understandings of marine biogeochemical processes.

Table 3-7-1. Sampling stations for microscale bacterial diversity.

Leg	Station	Date	Latitude	Longitude	Incubation
4	MS15	191221	60 11.861 S	60 15.017 W	Yes
	MS16	191227	61 19.295 S	50 07.963 W	No
	MS17	191231	60 47.694 S	39 56.118 W	Yes

MS18	200104	58 48.794 S	19 05.143 W	No
MS19	200108	58 53.076 S	10 05.447 W	No
MS20	200111	50 29.819 S	00 20.149 W	No
MS21	200113	43 28.143 S	09 48.559 E	No

3-8. Sea ice sampling

Minoru Ikehara (Kochi University)

Sea ice samples were collected at a site (60°33.9'S, 35°24.7'W) near dredge site D13 in the Scotia Sea on 2 January 2020. Two blocks of sea ice were collected with a special net (Fig. 3-8-1), which is produced by a square flame (1.7 m length) and net. Sea ice blocks were broken into pieces. Samples were stored in clean plastic box in a storage (-20°C) during the cruise. Sea ice samples will be analyzed for diatoms, planktonic foraminifers, and organic geochemistry.

Figure 3-8-1. A special sea ice net.

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Cape Town

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