

CRUISE REPORT

R/V HAKUHO-MARU KH-23-10

December 13, 2023 – December 23, 2023
(Naha to Naha)



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

Huatung Basin and Gagua Ridge

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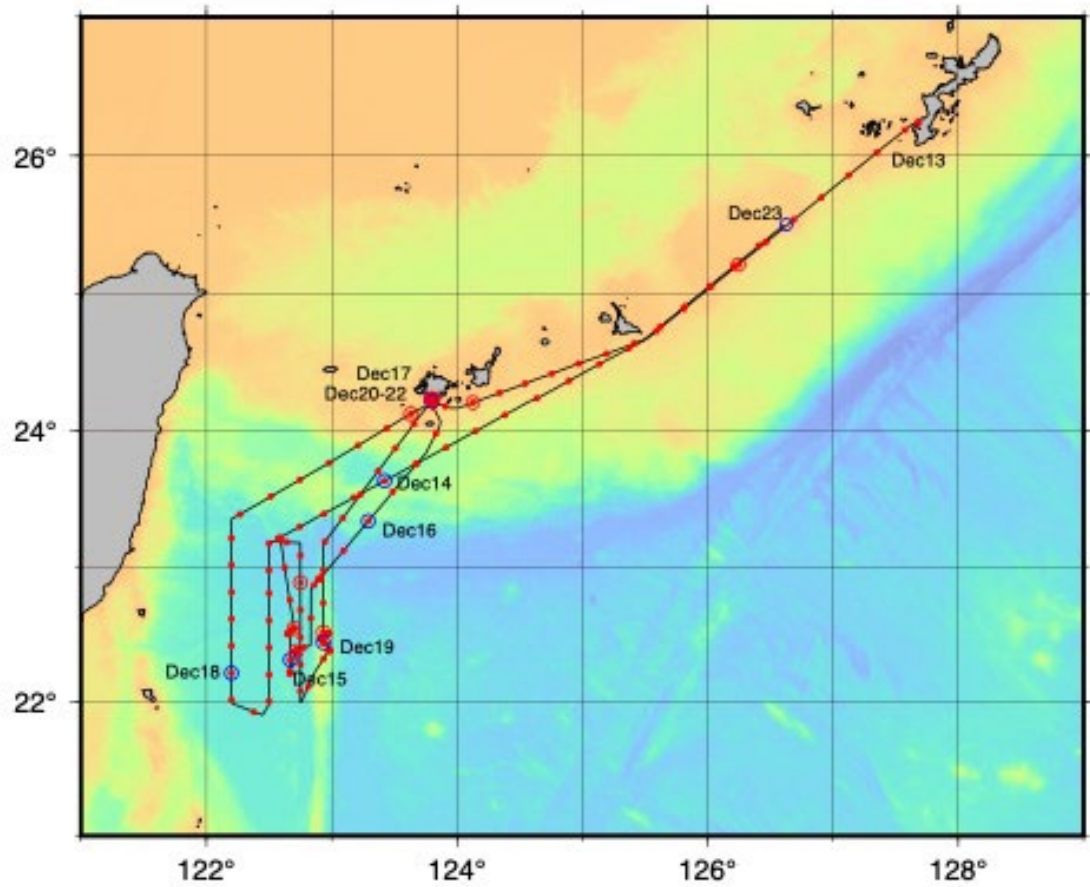
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Cruise Summary

During the KH-23-10 cruise of the research vessel *Hakuho-maru*, geological, geophysical, and biological surveys were conducted in the Huatung Basin and Gagua Ridge to the east of Taiwan. The origins and formation history of the Huatung Basin and Gagua Ridge, which constitute northwestern sections of the Philippine Sea Plate, remain unclear. Investigating their formation age and tectonics is crucial for understanding the origin of the Proto-Philippine Sea Plate as the basement of the Izu-Bonin-Mariana Arc. Additionally, this region is important for the study of paleoceanography and benthic organisms in the upstream Kuroshio region.

The expedition was originally planned for 12 days from December 13 to 24, 2023, departing from and returning to Naha. However, due to adverse sea conditions caused by a strong winter-type pressure system in the middle of the voyage, the expedition was shortened by one day and. The ship arrived at Naha Port on December 23. Despite the reduction in survey days, seven dredge sampling, two piston corer sampling, and one each of multiple corer and VMPS sampling were conducted. In addition, a total of 260 nautical miles of shipboard geophysical survey were carried out, obtaining seafloor topography, magnetic, and gravity data.



KH-23-10 survey ship track

Cruise Narrative

	12/13 Wed	12/14 Thur	12/15 Fri	12/16 Sat	12/17 Sun	12/18 Mon
0				Geophysical survey (L4) 12 knt		
1						
2			Transit	Transit		
3			Dredge (D02) D3 site, 4900 m	Dredge (D04) D7 site, 5000 m		Geophysical survey (L1) 12 knt
4						
5						
6						
7				Transit to Iriomote Is.		
8			Transit			
9						
10			Dredge (D03) D5 site, 4800 m			Transit
11		XCTD				
12		Site survey P1				Geophysical survey (L2) 12 knt
13	Naha Pier			Shelter at Iriomote Is.		
14	Transit to survey area	Piston (PC01) P1 site, 5500 m	Site survey P5			
15			Piston (PC02) P5 site, 5000 m			
16						
17						
18		Transit				Figure 8
19						Transit
20			Multi (MC01) P5 site, 5000 m		Transit to survey area	Geophysical survey (L3) 12 knt
21		Dredge (D01) D2 site, 5000 m			Deploy Proton mag.	
22						
23						
24			Transit			

	12/19 Tue	12/20 Wed	12/21 Thur	12/22 Fri	12/23 Sat
0					
1					
2	Transit				
3	Recover				
	Proton mag.				
4	VMPS				
	500, 100 m				
5					
	Dredge (D05)				
6	D15 site, 3400 m				
		Shelter at			
7		Iriomote Is.			
8					
9	Transit				
	Site survey				
10	P8				
	Multi (MC02)				
11	P8 site, 2800 m				
12					
	Transit				
13					
	Dredge (D06)				
14	D10 site, 3100 m				
15					
16					Naha Pier
	Transit				
17	Dredge (D07)				
	D14 site, 3400 m				
18					
19					
20				Transit to Naha	
	Transit to				
21	Iriomote Is.				
22					
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 the initiation of subduction in the Izu-Bonin-Mariana (IBM) Arc. Subduction of the Pacific Plate is postulated to have occurred synchronously along the PSP margin around 52 Ma, leading to the formation of the current IBM Arc (Ishizuka et al., 2011).

To investigate the crustal structures of the PSP, we have conducted multiple research cruises since 2007 in regions where remnants of the PSP are potentially exposed: the Daito Ridges (YK10-04, KR13-15, and KH-20-6 cruises), the Izu-Bonin forearc (KH-07-02, KR08-07, KR09-04, YK09-06, YK11-07, and KH-14-5 cruises), and the Kyushu-Palau Ridge and Palau Basin (YK10-14, YK13-08, and YK15-12 cruises).

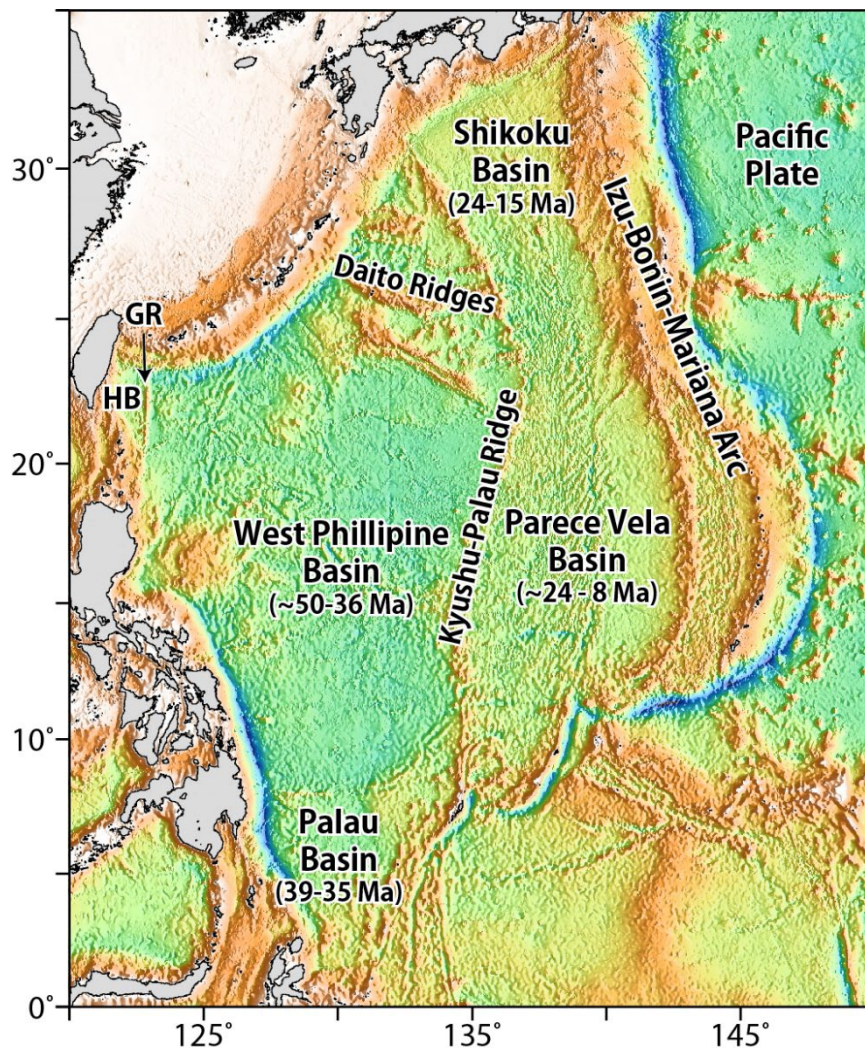


Figure 1. Basins, arc and ridges within the current Philippine Sea Plate. HB: Huatung Basin, GR: Gagua Ridge.

Submersible and ROV observations, along with rock sampling, have revealed that parts of these regions, especially in the Daito Ridges (Figure 1), expose deep crustal sections of continental rocks, encompassing various volcanic, plutonic, metamorphic, and ultramafic rocks (e.g., Morishita et al., 2018). Geochemical analysis and radiometric dating of these

rocks clearly indicate that the PSP predominantly consists of Mesozoic arc rocks. These findings, along with tectonic reconstructions 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 the formation of backarc basins since the Eocene.

Unresolved questions remain regarding the crustal structure of the PSP at the Huatung Basin and Gagua Ridge, located at the northwestern margin of the current Philippine Sea Plate (Figure 1). Deschamps et al. (2000) suggested that the Huatung Basin was formed in the Early Cretaceous, based on magnetic anomaly modeling and radiometric dating of MORB-like gabbro collected at the southern part of the basin. If so, the Huatung Basin is the only known oceanic domain in the PSP, indicating that the PSP was a complex of continental and oceanic crusts. However, Doo et al. (2014) and Kuo et al. (2009) suggested a much younger post-Eocene spreading of the basin based on a reinterpretation of magnetic anomalies and evidence of thin lithosphere under the basin. If the basin 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). However, dredge sampling conducted in 1980 recovered andesite and metamorphic rocks, suggesting a more complex crustal structure. More recently, Qian et al. (2021) reported Early Cretaceous basaltic andesite with arc-like geochemical affinity from central Gagua Ridge, proposing that the ridge is a rifted block from the southern China (Cathaysian) craton.

Therefore, we propose to conduct geological and geophysical surveys in the Huatung Basin and Gagua Ridge to constrain the ages and crustal structures of these regions.

The main objectives of KH-23-10 cruise are to conduct extensive geological, geophysical, and biological survey in the Huatung Basin and Gagua Ridge in order to reach the following targets:

1. Constraining the formation age and crustal structure of the Huatung Basin and Gagua Ridge
2. Investigation of past variability of the Kuroshio Current through paleoceanographical studies
3. Understanding sediment transport and deposition from Taiwan Island to the Huatung Basin via the Ryukyu Trench
4. Promoting taxonomic and biogeographical understanding of benthic organisms in the upstream region of the Kuroshio Current

2. Geophysics

2.1 General

The objective of geophysical mapping in KH-23-10 cruise are 1) confirm the magnetic boundaries of the Huatung Basin using vector magnetic anomalies, and 2) map the eastern Huatung Basin including the enigmatic topographic highs west of the Gagua Ridge. We conducted three N-S lines (70~80 miles each) in the Huatung Basin, one N-S line along the eastern Gagua Ridge, and also conducted underway geophysics on the transit lines. The track line and list of the survey lines are shown in Figure 2 and Table 1, respectively.

Table 1. Survey Lines

Way point	Lon	Lat	distance [nm]	Speed [kt]	Course [°]	Date	Time (UTC)
L1 N	122°12'E	23°20'N				2023Dec17	18:23
L1 S	122°12'E	22°00'N	80	12	180°	2023Dec18	01:03
L2 S	122°30'E	22°00'N				2023Dec18	02:59
L2 N	122°30'E	23°10'N	70	12	0°	2023Dec18	8:58
L3 N	122°45'E	23°10'N				2023Dec18	10:30
L3 S	122°45'E	22°00'N	70	12	180°	2023Dec18	16:24
L4 S	122°56'E	22°30'N				2023Dec19	11:53
L4 N	122°56'E	23°10'N		12	0°	2023Dec19	

*L4 line: no proton magnetometer survey

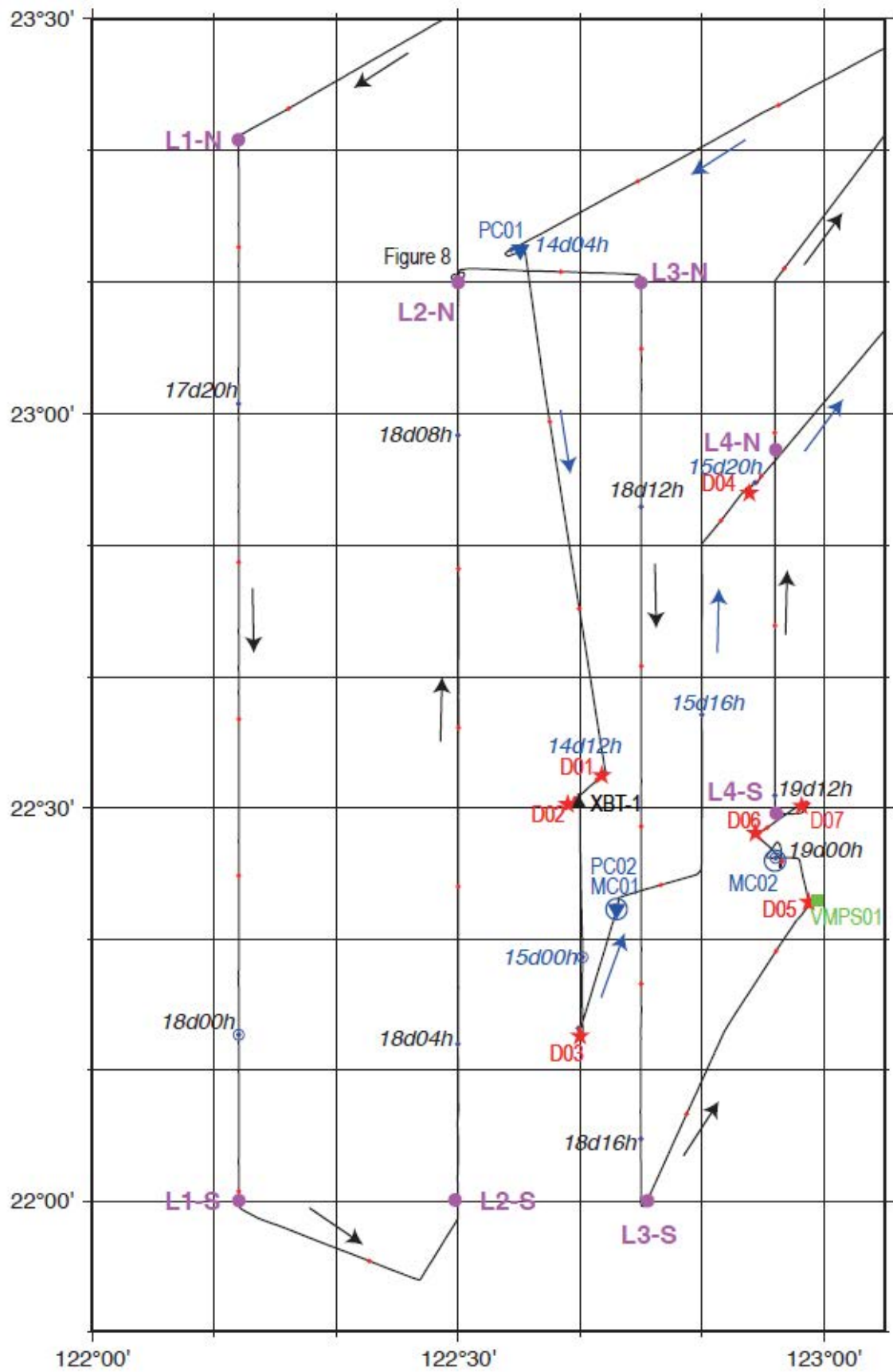


Figure 2. Track chart and survey lines and stations.

2.2 Instruments and Operation notes

2.2.1 Multibeam sonar

Seafloor bathymetry and backscatter are measured using the hull-mounted multibeam echo sounder EM124 (12kHz, Kongsberg Maritime). The system consists of acoustic arrays of transmitters and receivers on the ship's hull, control CPUs, motion sensor Seapath380-5+(Kongsberg) (Figure 3), and real-time surface velocity meter Oceanographic AML-1 (AML).

The standard runtime setting during KH-23-10 is shown in Table.2.

Table 2. MBES Operation parameter setting

Model	EM124
Operation frequency	12kHz
Beam angle	2°x 2°
Swath range	120°
Max depth points	512
Sounding pattern	Equidistance
Pulse	
Swath mode	Dual, Dynamic

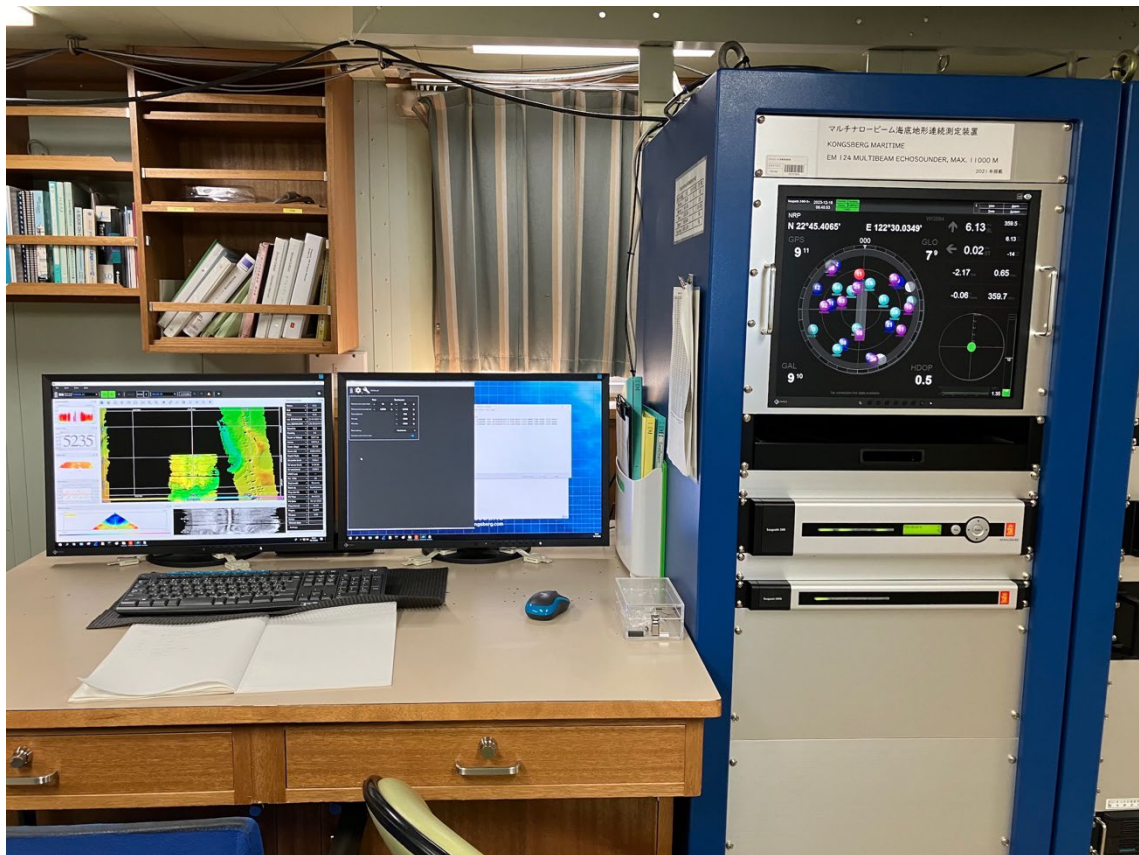


Figure 3. MBES Kongsberg EM124 control unit in Lab-1.

The pinging and recording were continuously done within the survey area and transit, except for P01 and D04 sites. The data quality is generally good, and we can get ~11km swath width along all tracks in the Huatung Basin. The ship speed is 12knot on three main survey lines. The vertical structures of sound velocity were determined by one XCTD (XCTD-1) and one XBT (XBT-1) measurements (Figure 2, Table 3). The maximum depths of these measurements were 1800-2000m, respectively. We used the Levitus table for deeper water column. We stopped logging during the operations of piston and multiple coring. We also stopped logging during dredge D04. During D05~D07 operations, we tried to narrow the depth gate and succeeded to keep bottom detection and to get better sounding data.

Table 3. Measurements of vertical temperature profile

	Date	Time(UTC)	Lon	Lat	Max depth [m]	probe
XCTD-1	2023Dec14	02:03	122°56.2'E	23°23.4'N	2001	CT-4
XBT-1	2023Dec14	22:51	122°39.9'E	22°31.0'E	1833	T-05

2.2.2 Sub-bottom profiler

Sub-bottom profiles were obtained by SyQwest BATHY-2010 Chirp Sub Bottom Profiler (Figure 4). The specification and operation parameters are shown in Table 4. The profiles were recorded almost all time. The ship speed was reduced near the sediment sampling points for the site survey. The data were saved both raw data (*.odc) and seg format data (*.seg).

Table 4 Operation setting of sub-bottom profiler

Operation Mode	FM
Pulse Window	Hamming
Power Level	0~16
Sweep bandwidth	1-3.5kHz
Sound velocity	1500m
Zoom range/Gain	Depend on water depth
Bottom tracking gain	0dB

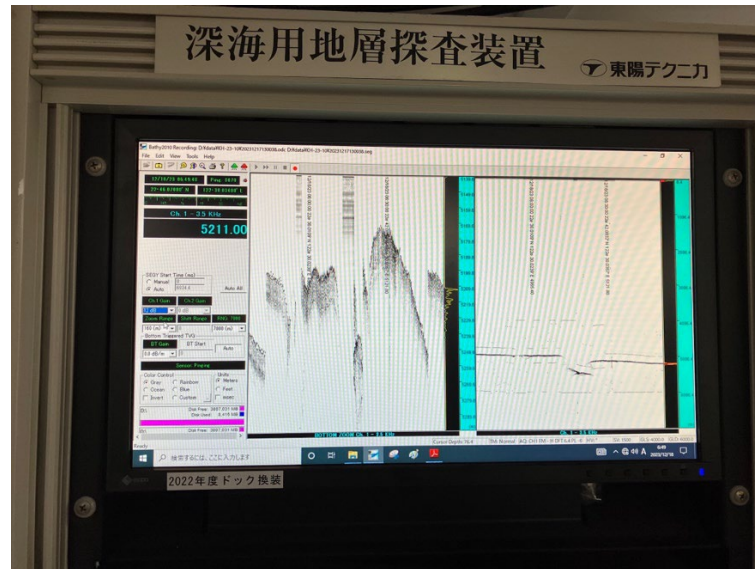


Figure 4. Monitor of sub-bottom profiler control unit (Lab-3).

2.2.3 Magnetics

Total magnetic field was measured by proton precession magnetometer PR-745 (Kawasaki Geol. Eng. Co.). The sensor was towed 300m behind the ship's stern (approximately 360m from the ship's GPS sensor), and excitation interval was 20 sec. Magnetometer and recording computer were installed in Lab-3 (Figure 5a). The measurement was done only along survey lines L1, L2 and L3, and high-quality data was collected. The magnetometer winch was broken in the previous leg (KH-23-9), so we deployed and recovered the sensor by manpower (Figure 5b).



Figure 5(a) left: proton magnetometer and logging computer (Lab-3),
(b) right: sensor towed behind the ship.

Vector magnetic field was measured by shipboard three component magnetometer (STCM). The fluxgate sensor SBM-89 (Gauss) was installed on the compass deck (Figure 6a), the magnetometer unit (Hakuho system, Clover Tech) was in Lab-1 (Figure

6b), and the logging/monitoring system was in Lab-3 (Figure 6c). The sampling frequency is 10Hz and ship's attitude (SyPath, 10kHz) and navigation data were merged and logged. We collected data from departure at Naha on Dec.14 to arrival at Naha on Dec.24.

We conducted one figure-eight operation near the northern end of the survey area (Figure 2, Table 5).

Table 5. Operation log of figure-eight turn

	Date	Time(UTC)	Lon	Lat	Start head	speed
fig8-1	2023Dec18	09:00-09:20	122°30.0'E	23°10.4'N	0°	10kt

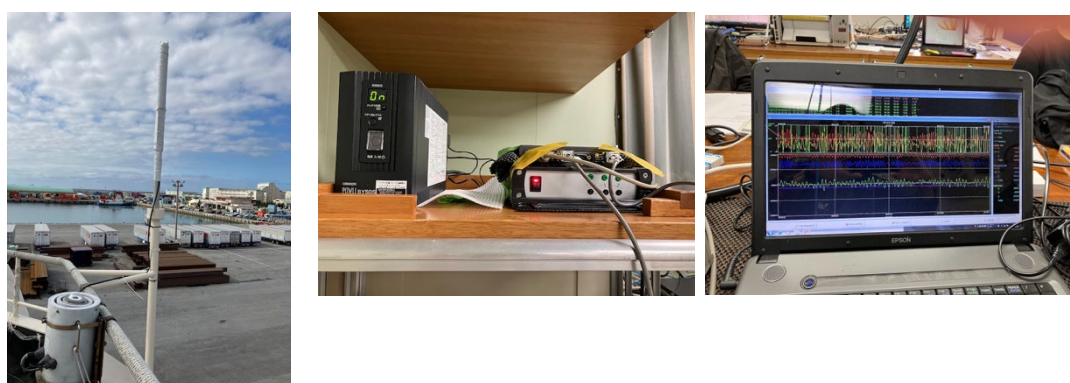


Figure 6(a) left: sensor on compass deck (b) center: magnetometer in Lab-1and (c) right: log/monitor unit in Lab-3

2.2.4 Gravity

Gravity field data were recorded by the shipboard gravimeter D-004 (Lacoste&Romberg type, ZLS Co.), installed in Lab-9 (Figure 7, Table 6).

Table 6. Specification of gravimeter on R/V Hakuho-maru

Range	7000mGal
Drift	3mGal or less per month
Static repeatability	0.2 mGal
Gyro	ZLS FOG
Sampling rate	10sec

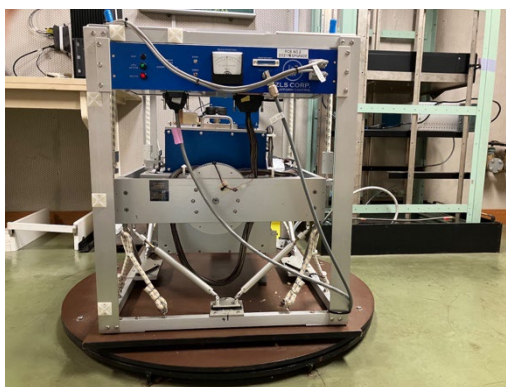


Figure 7 gravimeter in Lab-9

Absolute gravity tie was done at Naha port, before and after KH-23-9, using portable gravimeter CG-5 (AUTOGRAB, SCHINTREX). The details are shown in Table 7. The drift of shipboard gravimeter is less than 0.002[mGal/day].

Table 7(a). Gravity Measurements at Naha port

Date	Time (UTC)	Station	Pier height [m]	Draft [m]	Lab-9 height[m]	CG-5 height[m]	Corr. [mGal]
2023Dec9	02:25	Naha pier4-2	2.58	5.9	4.191	0.165	1.3475
2023Dec9	04:56	Naha pier4-2	2.13	6	4.191	0.165	1.2655
2023Dec24	0:56	Naha pier3-3	2.76	5.7	4.191	0.169	1.3696
2023Dec24	2:44	Naha pier3-3	2.80	5.75	4.191	0.168	1.3970

Table 7(b). Measurement at reference station Naha Ferry Terminal

Date	Time(UTC)	CG-5 Gravity [mGal]	Absolute gravity at station [mGal]	Absolute gravity at Lab.9 [mGal]	ZLS gravity [mGal]
2023Dec9	03:25	4763.8330	979110.09	979110.64	2615.73
2023Dec24	01:55	4764.0450	979110.09	979110.76	2615.87

3. Dredge Survey

3.1 General

We conducted 7 dredge surveys during the KH-23-10 cruise in the Gagua Ridge and Huatung Basin (Figure 8) based on two major scientific objectives:

1. Understand the detailed crustal structures of the Gagua Ridge.
2. Understand the timing of the Huatung 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.

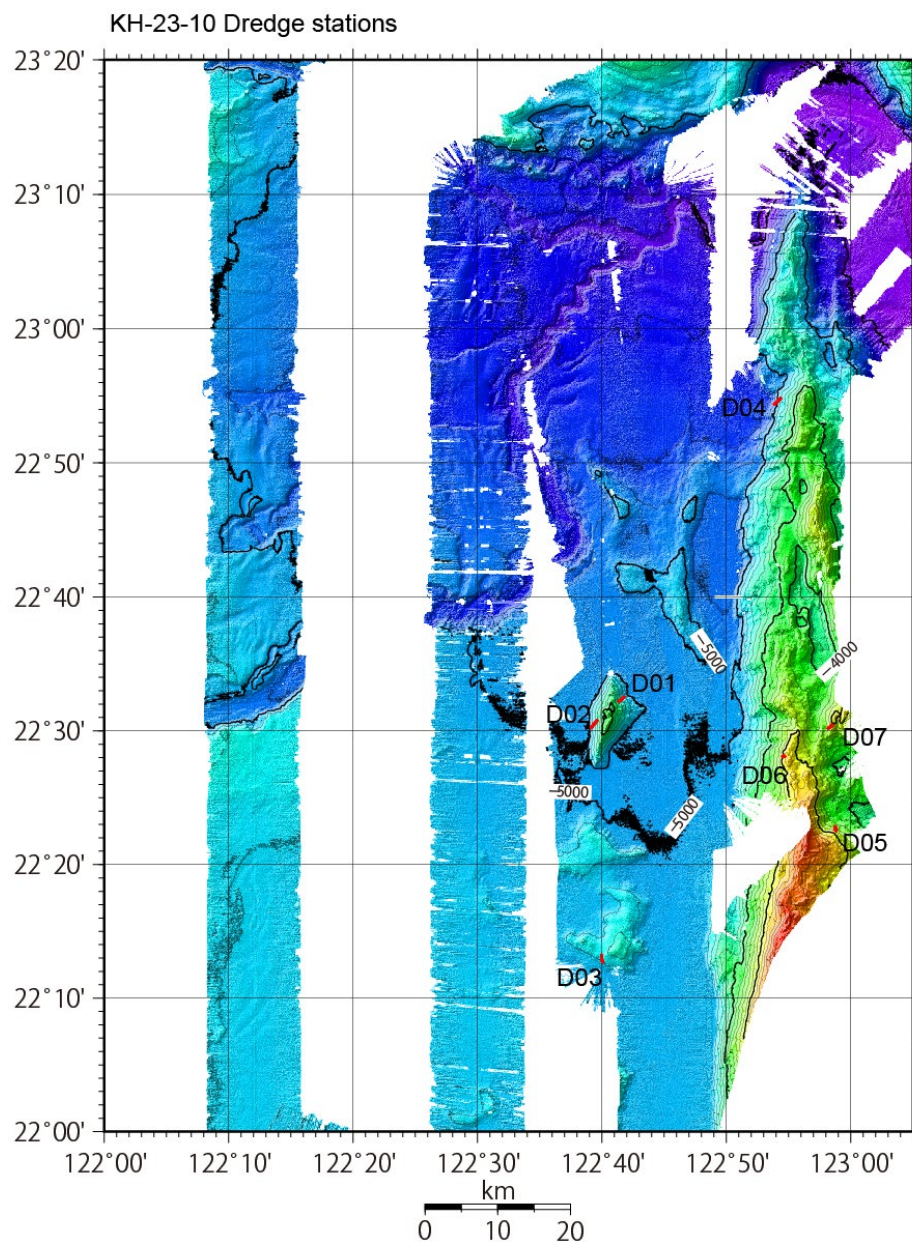


Figure 8. Dredge sites during the KH-23-10 cruise.

3.2 Instrument and operation notes

The dredge systems used during the KH-23-10 cruise are as illustrated in Figure 9. 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; Gyaico-type chain-bag dredge and Satsuki-type box-shaped dredge. The dredge assemblage was connected to the ship-board No.1 winch wire (14 mm in diameter). The assembly of each dredge is summarized in Table 8. Operation procedures of the dredge were as follow:

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 polyethylene and nylon mesh bags inside the dredge (Figure 10). We also installed an RBR SOLO depth logger inside the camera sledge to monitor precise movements of the dredge at the seafloor.
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.

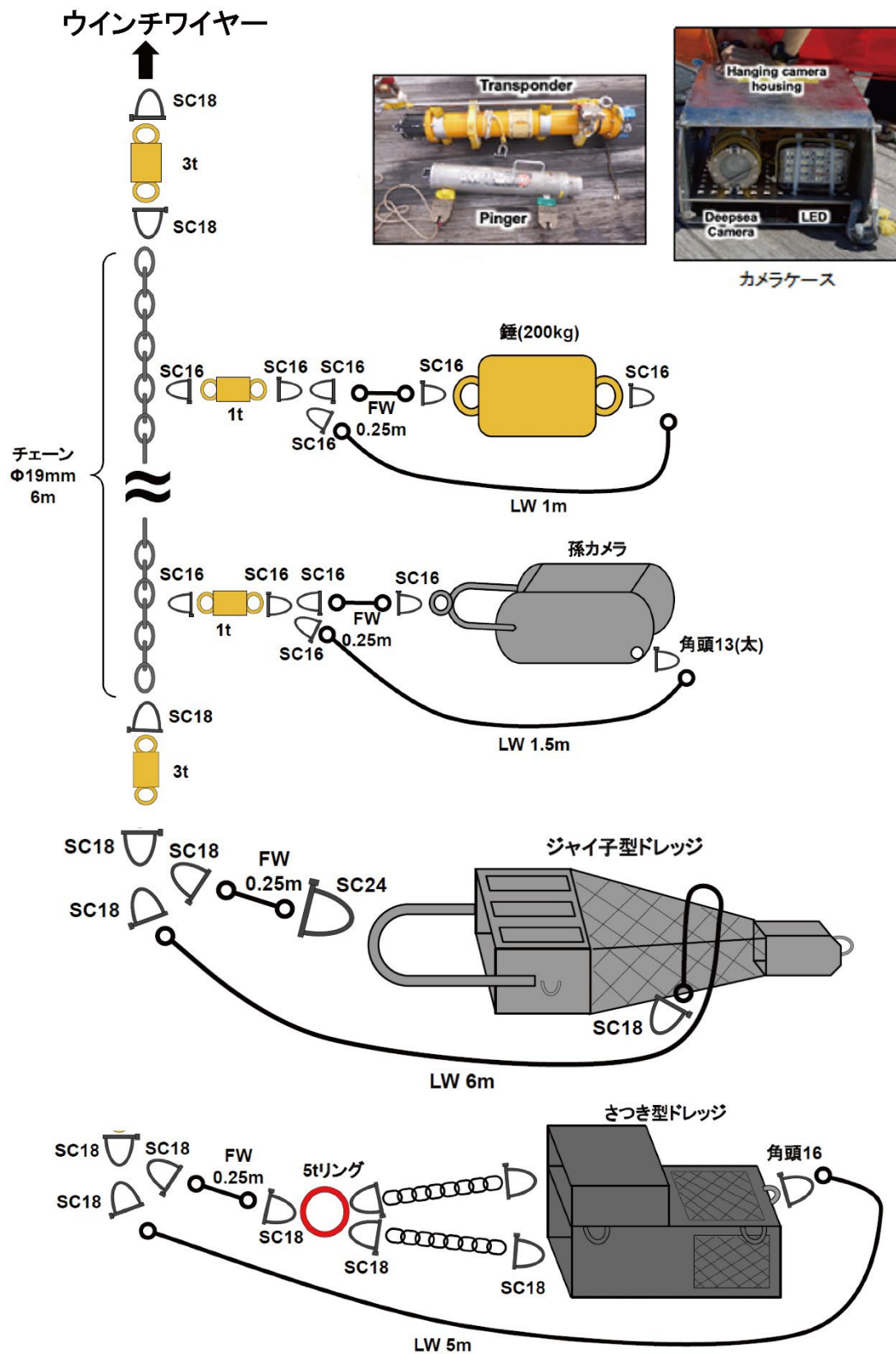


Figure 9. Detailed assembly of dredge systems used in KH-23-10 cruise.

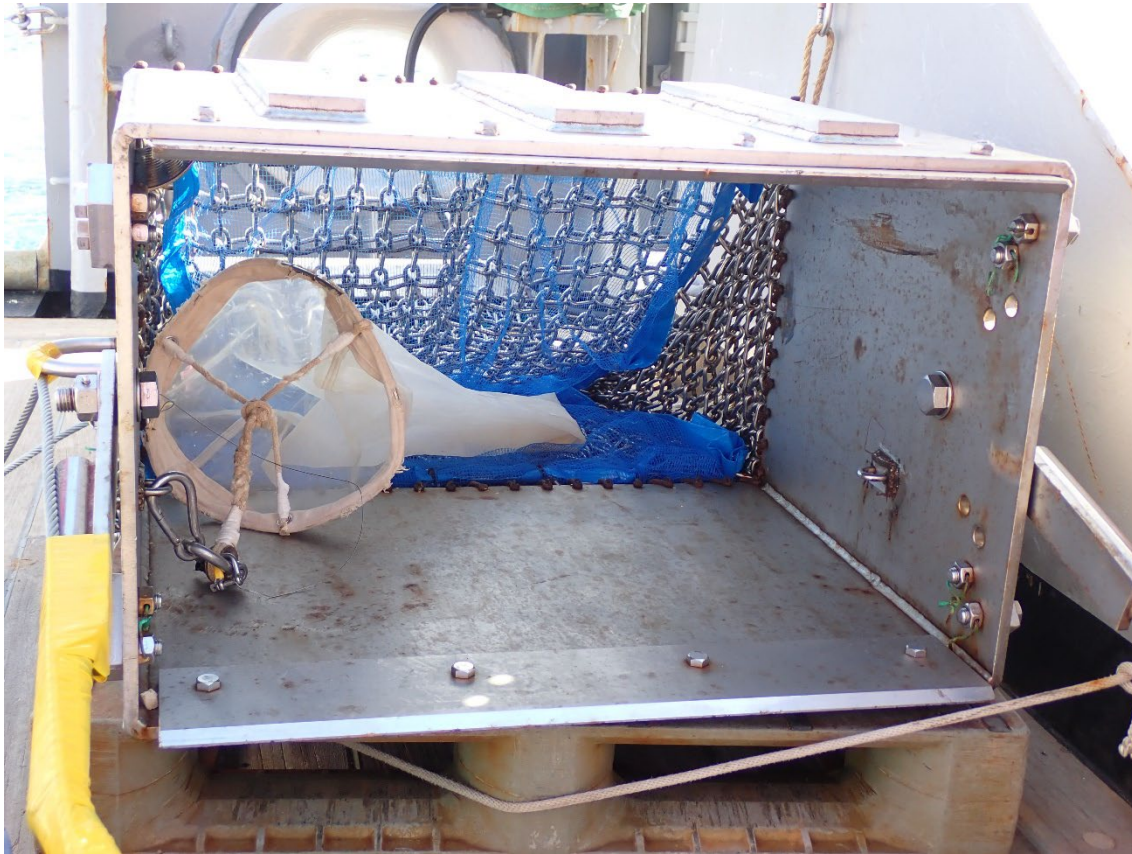


Figure 10. Nylon mesh bags installed in the Gyaico-type dredge for benthos sampling.

Dredge No.	Site No.	Lat.		Long.		Depth m	Fuse Wire (FW)		Fracture strength of fuse wire (tf)	Life Wire (LW)		Fracture strength of life wire (tf)	Dredges	Pinger	Transponder	Camera
		N	E				Φ	Length		Φ	Length					
D01	D2	22	31.80	122	42.00	4755	8A	0.25m	3.22	9G	6m	3.78	Gyaiko	200m	400m	Y
D02	D3	22	29.60	122	39.60	4306	8A	0.25m	3.22	9G	6m	3.78	Gyaiko	200m	400m	Y
D03	D5	22	12.47	122	40.22	4880	8A	0.25m	3.22	9G	6m	3.78	Gyaiko	200m	400m	Y
D04	D7	22	54.38	122	53.90	5150	8A	0.25m	3.22	9G	5m	3.78	Satsuki	200m	400m	Y
D05	D15	22	22.82	122	58.77	3500	9A	0.25m	4.07	10G	5m	4.67	Satsuki	200m	400m	Y
D06	D10	22	28.10	122	54.45	3100	9A	0.25m	4.07	10G	5m	4.67	Satsuki	200m	400m	Y
D07	D14	22	30.17	122	58.18	3380	9A	0.25m	4.07	10G	5m	4.67	Satsuki	200m	400m	Y

Table 8. Dredge assembly list

3.3 Survey results

Sample recovery of the dredge hauls was generally good except for D01 and D03, mostly collecting at least several rocks on each dredge.

The position and depth of the dredge sites are summarized in Table 9. The total weight of the recovered rocks was approximately 350 kg. Individual dredge sites are described in the following section.

Date	St. No.	SP/EP	Time (JST)	Depth (m)	Lat. (°N)	Lon. (°E)	Wireout (m)	Lithology	Total weight (kg)
2023/12/14-12/15	D01	on bottom	22:54	4790	22.5424	122.6967	4876	Basalt, sandy silt stone, silt stone and Mn-crust	~0.1
		off bottom	0:48	4764	22.5416	122.6961	4762		
2023/12/15	D02	on bottom	4:44	4900	22.5039	122.6521	4907	Basalt (ol-cpx and ol), volcanic rock clast, mudstone and wood fragments	7.30
		off bottom	6:05	4460	22.5128	122.6600	4659		
2023/12/15	D03	on bottom	11:40	4790	22.2119	122.6680	4799	Weathered glassy basalt lava	<0.1
		off bottom	12:33	4689	22.2205	122.6662	4765		
2023/12/16	D04	on bottom	4:08	5150	22.9066	122.8980	5143	microgabbro, tonalite, diorite, metabasalt, andesite and muddy sand	71.3
		off bottom	5:12	4826	22.9134	122.9061	5044		
2023/12/19	D05	on bottom	6:19	3495	22.3806	122.9794	3554	Andesite, andesite lapilli stone, andesite lapilli tuff, brecciated andesite, dacite, dacite tuff and dacite lapilli tuff	7.86
		off bottom	7:19	3436	22.3757	122.9805	2772		
2023/12/19	D06	on bottom	14:09	3106	22.4683	122.9088	3253	Basalt, andesite, andesite lapilli tuff, brecciated andesite, andesite autobreccia, andesite tuff breccia and dacite tuff breccia	32.1
		off bottom	14:49	2864	22.4683	122.9114	2976		
2023/12/19	D07	on bottom	17:51	3371	22.5030	122.9700	3482	limestone, foraminifer limestone, calcareous sandstone and pumice	226.2
		off bottom	19:00	3105	22.5069	122.9750	3105		

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

4. Understanding benthic fauna in Huatung Basin and Gagua Ridge

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The Kuroshio Current strongly affected the high biodiversity formation of marine benthic fauna of the northwestern Pacific. Huatung Basin and Gagua Ridge located the upper stream of the Kuroshio Current from the southwestern Japan, and it presumed their benthic fauna of highly connected each other. However, the deep-sea benthic fauna of Huatung Basin, especially at abyssal depths, was still poorly explored. The present study aims to understand basic benthic biodiversity at the abyssal seafloor of Huatung Basin and Gagua Ridge, and to compare benthic fauna of each area.

4.1 Benthic and pelagic metazoan sampling

We conducted biological samplings via geological dredges at seven sites, Cast No. D01, D02, and D03 in Huatung Basin, Cast No. D04-D07 in Gagua Ridge, a vertical multiple plankton sampler (VMPS), Cast No. V01 and V02 at single site at Gagua Ridge, and multiple corer (MC) at two sites in Huatung Basin and Gagua Ridge, Cast No. MC01 and MC02. For geological dredges, we attached one or two plankton nets with a mesh size of 350 μ m inside the collecting bags in all dredges, and we laid polyethylene mesh inside the collecting chain bags for Gyaiko type dredge. For Satsuki type, we set a steel collecting bucket laid inside 1 mm sized nylon mesh.

As a result, sediment was collected at all the dredge casts. The sediment supernatant was filtered through a 350 μ m net. The remaining sediments were then separated using several metal mesh sieves, 16 mm, 10 mm, 4 mm, 2 mm, and 1 mm. Those particles trapped inside the plankton nets were processed separately. The debris and organisms were sorted under microscopes or naked eye on board. Samples were photographed where possible, and then preserved 80% or 99% ethanol. We also collected several specimens from dredge sediments: Cnidaria, Annelida, Mollusca, Nematoda, Crustacea, and Echinodermata. For the VMPS samples, we are screened and picked metazoan samples under microscopes or naked eye on board. VMPS samples were also preserved in 70% or 99% ethanol. By the MC samples, we got sediment samples at the first site, Cast No. MC01. At the second site, Cast No. MC02, we could not obtain core sample because of hard substrate. For the MC sample treatment, at first, we removed supernatant water for eDNA sampling (see the next subsection), and the remained sediment cut the upper 2 cm layer was sampled and frozen -20°C for metazoan meiofauna. The sediment samples will be proceeded onshore.

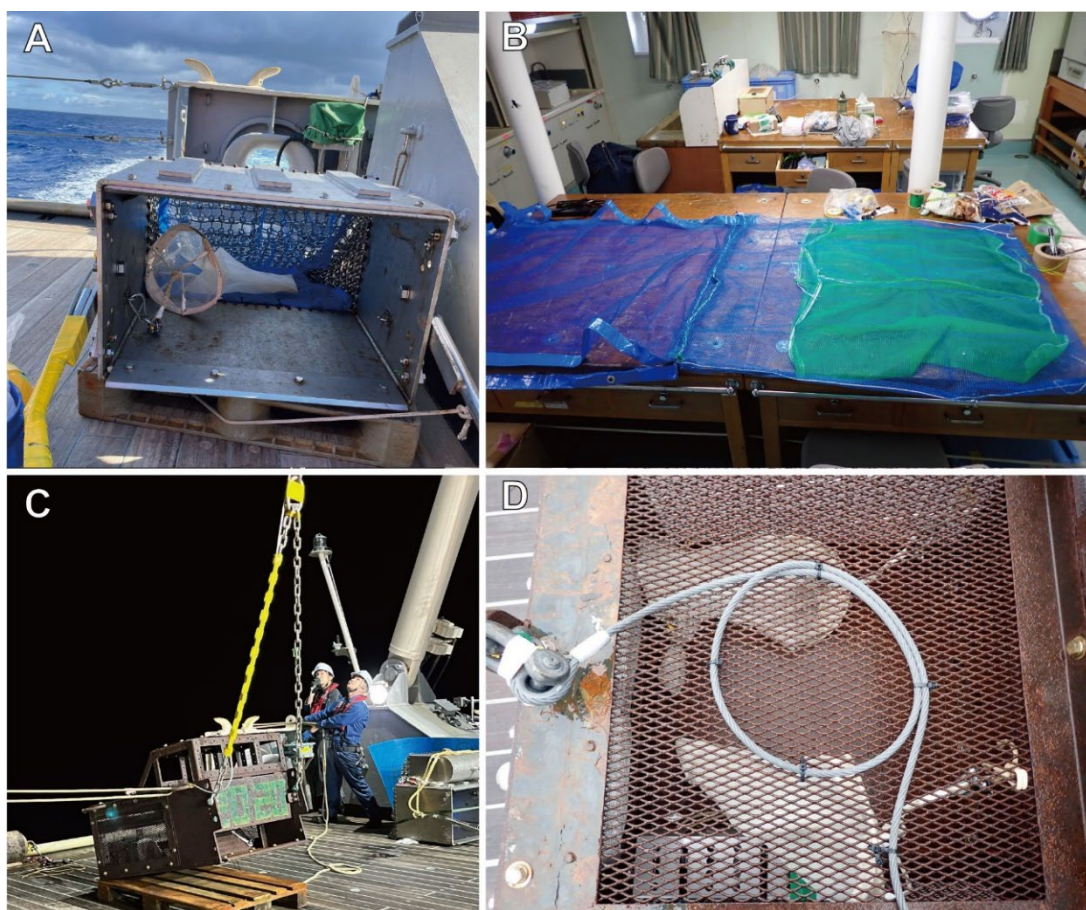


Figure 11. Attached biological sampling nets inside rock dredges. A. Laid polyethylene nets and an installed plankton net inside the Gyaiko type rock dredge. B. Polyethylene net for Gyaiko type rock dredge. C. Statsuki type rock dredge installed a plankton net and a steel collecting bucket. D. Plankton nets and a steel collecting bucket attached inside the Statsuki type rock dredge.

4.2 Sampling for environmental DNA (eDNA)

We also conducted environmental DNA samplings from supernatant water of core collected by MC at the Gagua Ridge, Cast No. MC01. All tubes and buckets designated for use in the experiment underwent a thorough cleaning process before collecting seawater from the core. The process involves a wash with 10% bleach, followed by tap water to remove residual bleach and a rinse of MilliQ water prior to utilization. Subsequently, to initiate the seawater collection, the tubes were rinsed with seawater sourced from the core. The seawater was then siphoned to a 5 L water container carefully to prevent disturbance of the surface of the sediment layer. Once transferred to a controlled environment in the hood, the seawater was filtered using a 0.45 μm Sterivex filter positioned on the inlet side, employing a new and unused syringe. The filtration duration was calculated to quantify the volume of seawater processed. Filtration ceased once sediment blockage impeded further water passage through the filter outlet. Upon complete removal of seawater from the filter, the outlet side was sealed, and RNA later was added to the filter. To ensure comprehensive coverage, the filter was gently spun, facilitating exposure to the RNA later. Following this, the inlet side

was sealed, and the filter was then stored in a -20 ° C freezer for preservation. To standardize, 5 L of MilliQ water was filtered as a blank filter. DNA extraction will be done for all the used filters after sending back to the lab.

5. Sediment

5.1 General

We conducted two piston core and two multiple core sampling during the KH-23-10 cruise in the Huatung Basin and Gagua Ridge based on the following objectives:

1. Understanding the characteristics of deep-sea turbidites and sediment source of the northern Huatung Basin
2. Understanding past oceanographic condition of Kuroshio and the subtropical gyre

5.2 Instrument and operation notes

A piston core system used during the KH-23-10 cruise is composed of 600 kg weight and SUS pipes (Figure 12). Two 6 m SUS pipes are connected by tube joint. As a pilot, 75-core sampler and weight “Apollo” were used for PC01 and PC02, respectively. Wire lengths are 16 m for both main and pilot wires.

A multicore system is used to collect surface sediment with 4 short pipes (60 cm) and 4 long pipes (100 cm). Total weight of multicore system is ~600 kg. Deep-sea camera is attached to frame to record surface condition and sampling process.

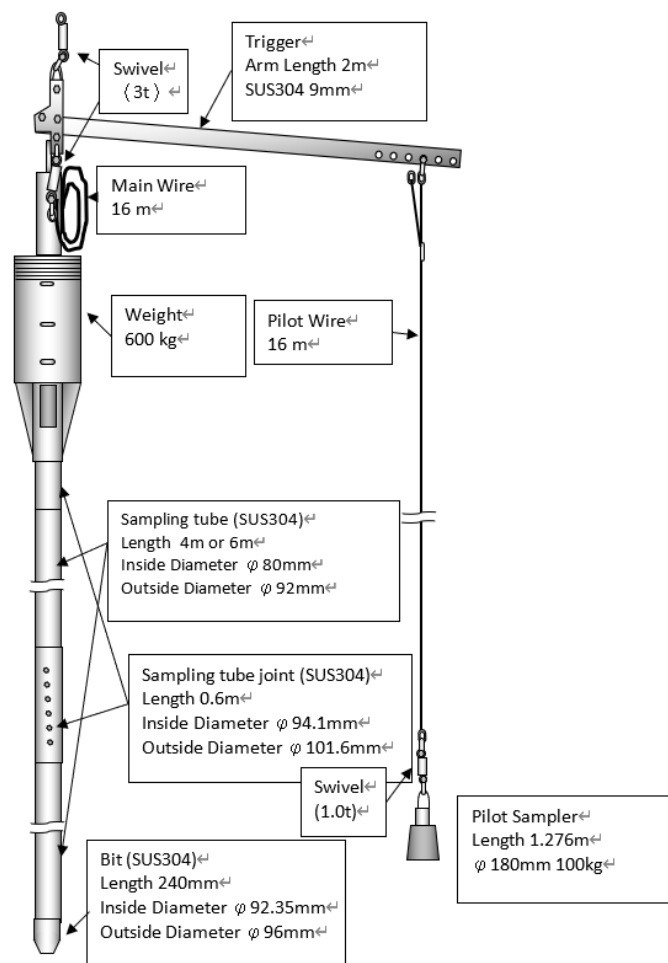


Figure 12: Schematic diagram showing piston coring system.

5.3 Survey results

5.3.1 KH-23-10-PC01

Site P1 is in the north flank of the Hualien Canyon and south of accretionary wedge. Cores from the site P1 will help to understand the characteristics of deep-sea turbidites and sediment source(s) of the north Huatung Basin. Also, we will compare the P1 turbidites with Ryukyu Trench turbidites east of Gagua Ridge. Previous studies (Hsiung et al., 2021; 2023) indicate that the turbidites in the western Ryukyu Trench may include Taiwan-sourced sediments.

Piston core PC01 is located in 23-12.4750', 122-35.1059' in 5,381 m water depth. In PC01 and PL01, total ~650 cm (including caps and before splitting) long piston core with ~30 cm long pilot core was obtained. Lithology from the piston core catcher was massive sand to very fine sand. Lithology of the PL01 was massive fine sand to very fine sand which was similar to the uppermost main piston core.

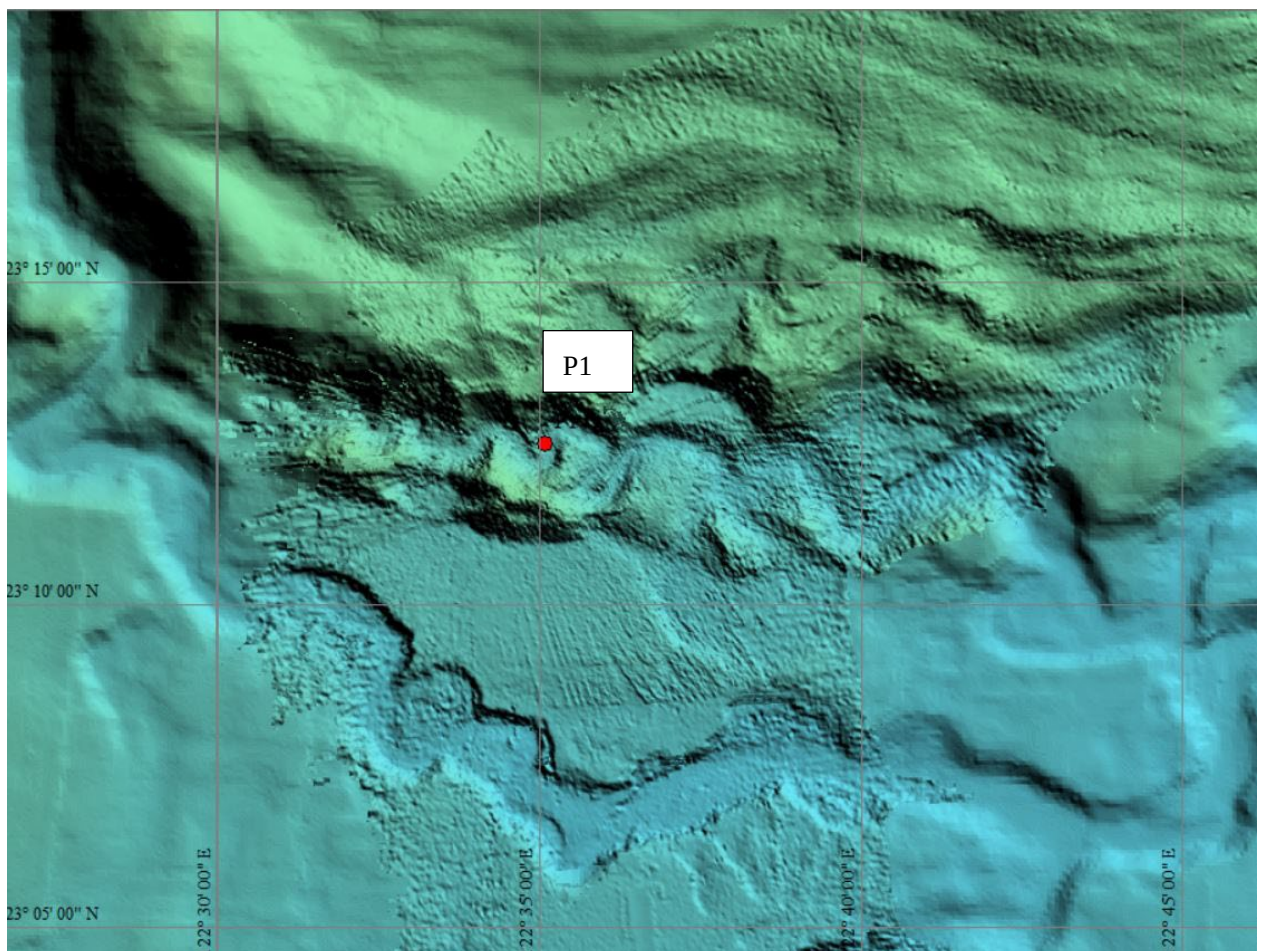


Figure 13. Site location of P1, where piston core KH-23-10-PC01 was retrieved.

5.3.2 KH-23-10-PC02

Due to bad weather the planned sites P2, P3 and P4 were canceled. Site P5 is situated in a small basin west of the Gagua Ridge. The site was initially selected due to its distance from the main submarine canyons in the Huatung Basin, which may therefore yield hemipelagic sediments with little include from turbidites. It was expected that this hemipelagic sediment core may be used to reconstruct past changes in the Kuroshio Current and North Pacific subtropical gyre.

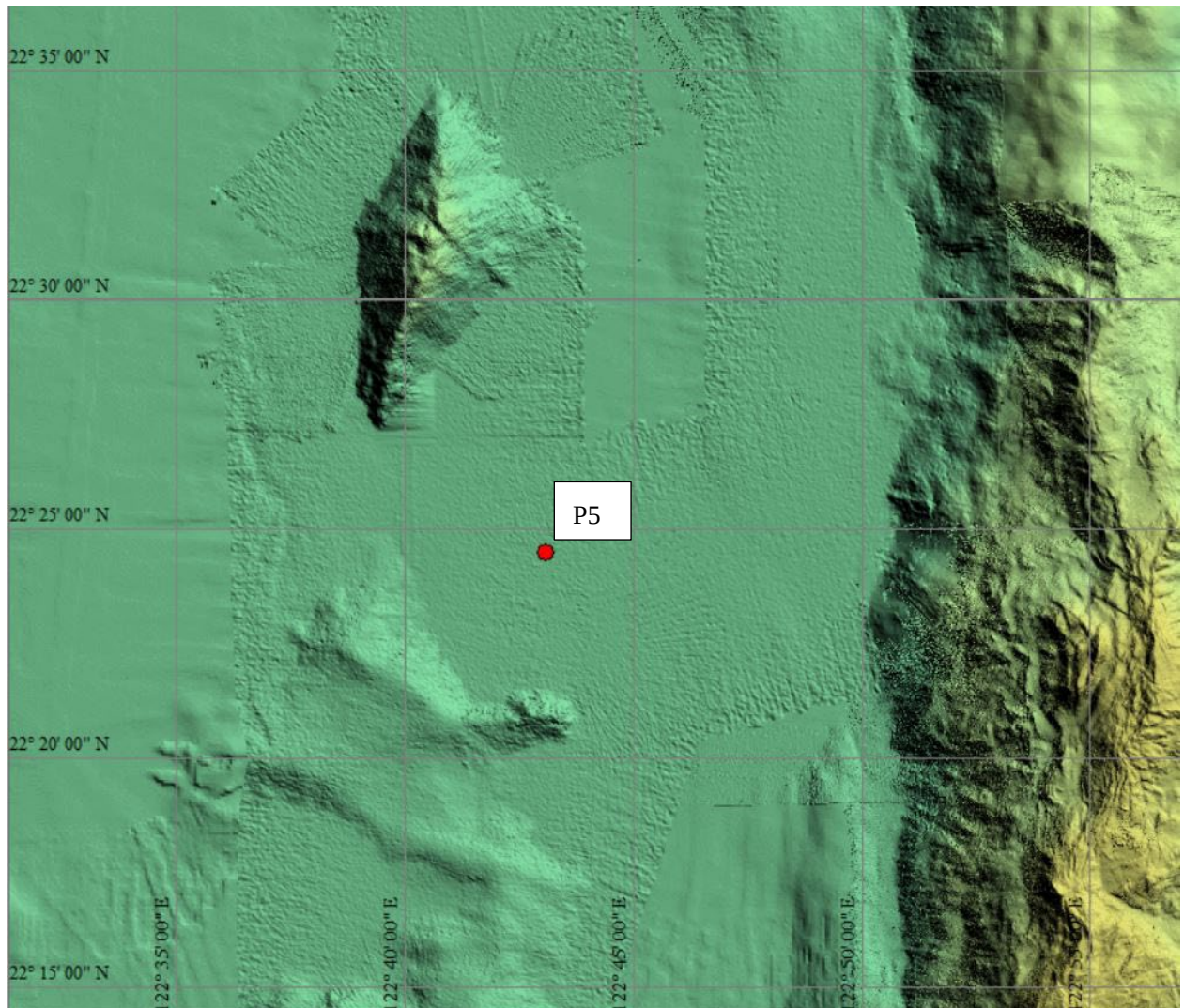


Figure 14. Site location of KH-23-10-PC02, where piston core KH-23-10-OC02 and multicore KH-23-10-MC01 were retrieved.

The piston core retrieved from the P5 location is named KH23-10-PC02. As a multicorer deployment was planned, no pilot corer was deployed with the piston core. Instead a weight (“Apollo”) was used. The site is located at 22°N 22.456’N, 122°43.012’E (water depth 4997 m). The core barrel was bent in the mid-section. The entire sediment core was only retrieved after the core barrel (section 8 and 9) was cut into several shorter sections. Cutting generated

plenty of small shredded pieces of PVC (from the core tube) and metal (from the core barrel), which were then scattered and embedded in adjacent sediments. Care should thus be exercised when performing geochemical analysis on these sections. Also noteworthy is that the piston was placed on deck with the bent part pointing upward, thus the sediments in the upper part of the core flowed backward into the empty section (sections 4 and 5). The total sediment recovery was ~ 8m. The original sections 5–12 were with sediments. The core was not split on board thus the lithology throughout the core was unknown. From the core catcher the sediment appeared to be homogenously clayey.

5.3.3 KH-23-10-MC01

A multicorer, with 4 long (100 m) and 4 short (60 cm) cores, was deployed at site P5. From the deep-sea camera attached to the frame of the multicorer, the seafloor appears to be flat with fine sediments and a lebenspurren of indeterminate origin. The arm of the multicorer was released while the corer was still in the sediments, thus the bottom cap of the arm scraped in additional sediments when the corer was closed. Nonetheless, from the video it could be observed that these additional sediments from the surface of the seabed were completely washed out during the ascent to the shipboard, thus they did not compromise the fidelity of the sedimentary sequence.

5.3.4 KH-23-10-MC02

Due to bad weather the originally planned P6 and P7 were abandoned as they were too far south. Instead, a back-up site was sought in the northern part of the Gagua Ridge. P8 site was decided based on the backscatter and sub-bottom profile, which suggested that the site is covered by a sediment layer and the seafloor was not as hard as the peak of the ridge; based on previous survey the peak of the ridge is consisted mostly of manganese crust. The main objective of this site is to retrieve sediments from seafloor located above the carbonate compensation depth where the preservation of the calcite shells of planktonic foraminifera is possible.

KH-23-10 MC02 site is located on the northeastern flank of the Gagua Ridge at 22°25.9918'N, 122°56.5069'E (water depth 2784 m; Figure 16). Unfortunately, the deployment did not recover any sediment. Deep-sea camera video showed that the bottom of the site was covered by rocks. As a result, the KH-23-10-PC03 operation was canceled due to a lack of time to conduct a new site survey.

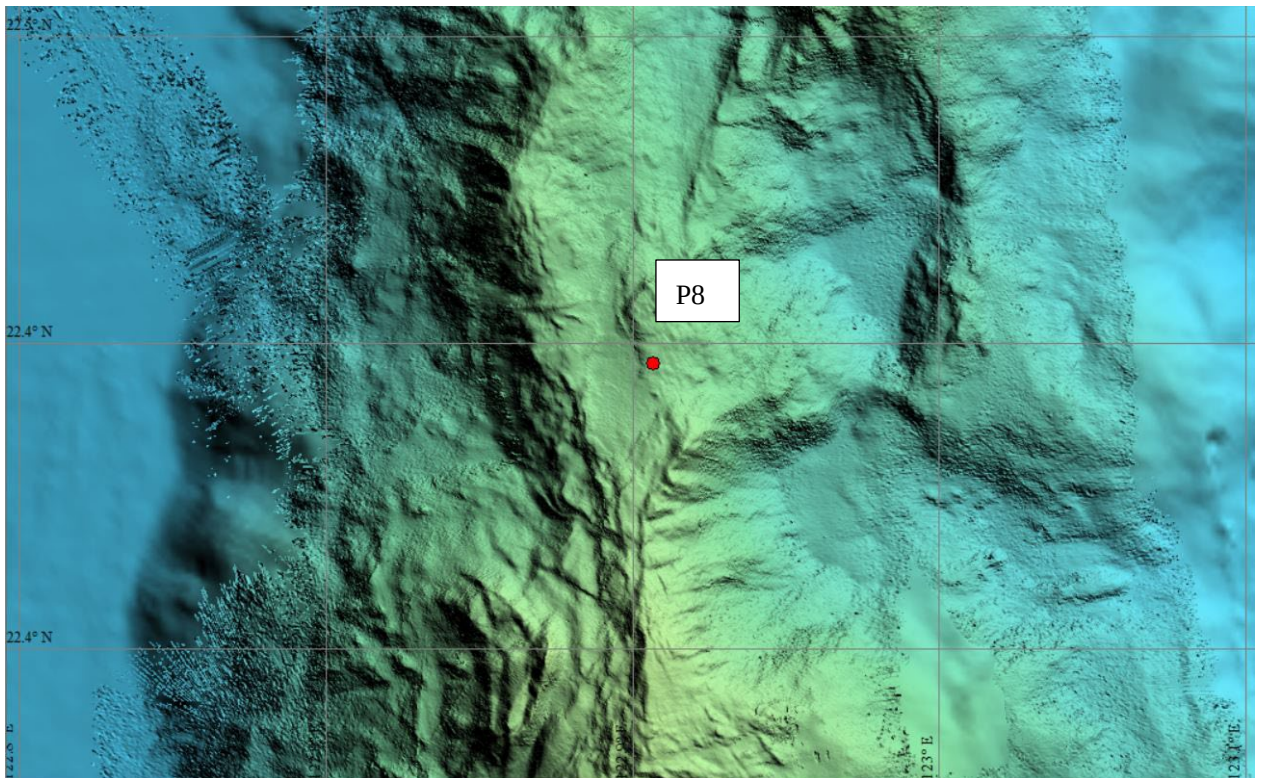


Figure 16. Site location of P8, where the failed multicorer deployment KH-23-10-MC03 was attempted.

6. Plankton Sampling

Plankton sampling was conducted using the Vertical Multiple-opening Plankton Sampler (VMPS) of Tsurumi-Seiki Co., Ltd. (Figure 18). The VMPS equipped four plankton nets (100 μ m mesh, NXX13) and temperature and depth sensors. Two VMPS casts were done at the same location (D05 site) with nets closing at different water depths (Table 11). The collected planktons were immediately fixed with ethanol (99.5%) and stored in refrigerator ($\sim 4^{\circ}\text{C}$).

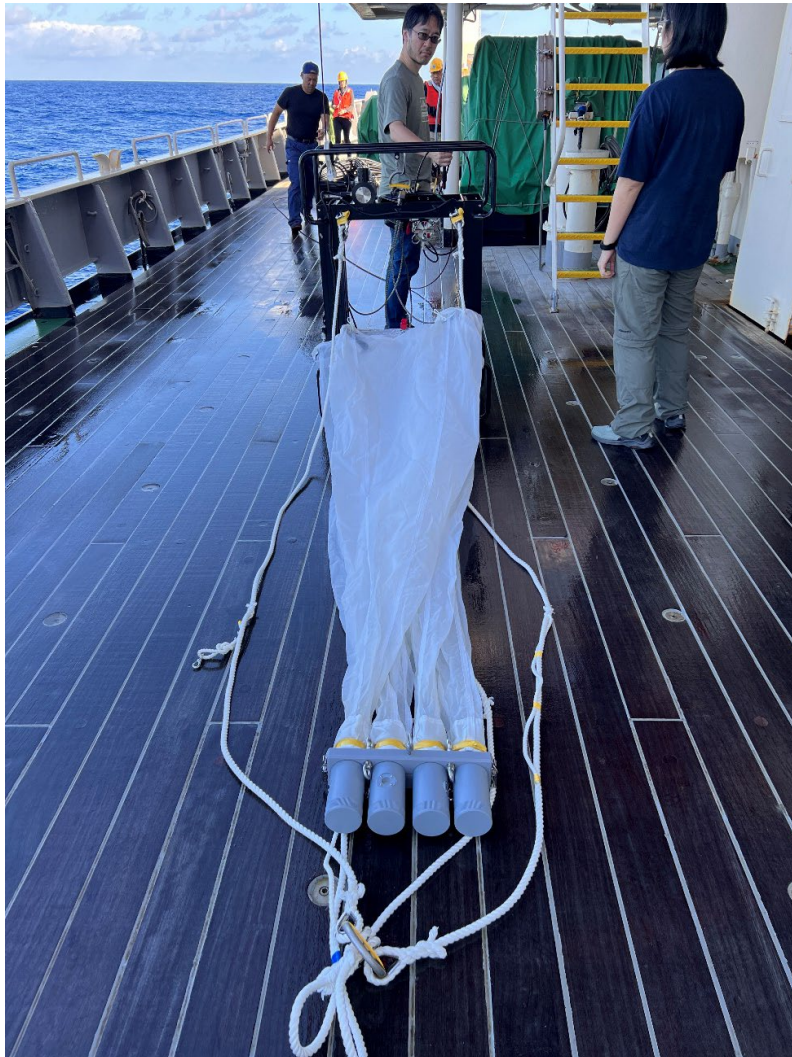


Figure 18. VMPS used during the KH-23-10 cruise.

Cast No.	Start Position (WGS84)	Time (JST)	End Position (WGS84)	Time	Net closing depths (m)
1	22°22.784'N, 122°58.955'E	Dec. 19 3:39	22°22.992'N, 122°58.719'E	Dec. 19 4:13	500, 300, 200, 100
2	22°22.991'N, 122°58.767'E	Dec. 19 4:28	22°23.026'N, 122°58.740'E	Dec. 19 4:40	100, 50, 25, 0

Table 11. VMPS sampling details

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