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Natsushima Cruise Report

NT12-25

Ferromanganese Crust Deposits in the Daito Ridge and Amami Plateau, the south of the Japanese Islands: Growth Processes and On-site Resource Exploration

September 25-October 10, 2012

Japan Agency for Marine-Earth Science and Technology

(JAMSTEC)

1 . Cruise Information

The research vessel NATSUSHIMA left the Apura Port, Guam on September 25, 2012 for a study of ferromanganese crusts in the seamounts over the Philippine Sea plate, the Daito ridge and the Amami plateau, located to the south of the Japanese Islands. The cruise was set for a joint study of two adopted programs "Growth processes and compositional variations of ferromanganese crusts around the Japanese sea areas" led by Dr. A. Usui at Geology Division, Faculty of Science, Kochi University and "Continuous mapping the ferromanganese crust cover and its thickness" led by Blair Thornton at the University of Tokyo. This research cruise is a part of multi-instutional and multi-disciplinary program of a KAKEN project and KIBAN Tools project. Three typhoons and TDs pushed her away from the planned sea area and she harbored at sea twice, but it was lucky for us JAMSTEC kindly approved another additional area after the start of the cruise. The maximum 2 plus 7 dives with the hitech ROV Hyper-Dolphin 3K (JAMSTEC) was secured for each program, but unfortunately due to the bad weather only 3 dives was conducted during the 16-day cruise, with two uncompleted operation time schedule of ROV at the bottom. We could not dive at the proposed site, the Ryusei seamount.

September 25 NATSUSHIMA left Guam at 10 am

September 26-October 1 we harbored at sea due to rough sea state

October 2 ROV dive HPD#1442 at a seamount (tentatively named Tobu seamount) in the Daito Ridge, the dive was suspended at noon sharp due to rough sea

October 3-5 Diving suspended due to rough sea and strong wind

October 6 ROV dive HPD#1443 at Koniya seamount in the Amami Plateau (alternatively set on site)

October 7 ROV dive HPD#1444 at a seamount (tentatively named Tobu seamount) in the Daito Ridge, the dive was broken down at 14:20 pm due to rough sea

We unfortunately abandoned further dives due to expected much worse sea state at any proposed areas

NATSUSHIMA arrived at Naha Port, Okinawa at 9 am.

2. Participants List

The shipboard scientific party consists of scientists, supporting technical staffs, and graduate/undergraduate students of NME on board and other 8scientists in collaboration of shore-based analyses with the party. The cruise NATSUSHIMA Leg2was successfully conducted by the science party, crew members, and ROV staff with a dive of the ROV Hyper Dolphin 3K at the seamount in the scheduled period.

2.1 Scientist Party

Akira Usui (Chief Scientist)	Kochi University
Blair Thornton	The University of Tokyo
Adrian Bodenmann	The University of Tokyo
Takumi Sato	The University of Tokyo
Issei Takafuji	Link Laboratory Inc.
Yusuke Yano	Hakuyodo Co.Ltd
Keisuke Nishi	Kochi University
Kazuko Hishikawa	Kochi University
Yoshio Nakasato	Kochi University
Tomoya Niiyama	The University of Tokyo
Shota Nitahara	Tokyo University of Pharmacy and Life Science
Koichi Iijima	Japan Agency for Marine-Earth Science and Technology
Minami Inoue	Hiroshima University
Jun Fujimoto	Hiroshima University
Masashi Ito	Nippon Marine Enterprises, LTD.

2.2 Crew Member

Captain	Hitoshi Tanaka
Chief Officer	Takafumi Aoki
2nd Officer	Masato Chiba
3rd Officer	Yumihiko Kobayashi
Chief Engineer	Koji Funae
1st Engineer	Naohito Tadooka
2nd Engineer	Kenichi Shirakata
3rd Engineer	Koichi Hashimoto
Chief Electronic Operator	Yoichi Inoue
2nd Electronic Operator	Yohei Yamamoto
Boat Swain	Hatsuo Oda
Able Seaman	Shuji Takuno
Able Seaman	Yasuo Konno
Able Seaman	Nobuyuki Ichikawa
Able Seaman	Yukihito Ishii
Sailor	Hideo Ito
Sailor	Yusaku Kanada
No.1 Oiler	Masaru Kitano

Oiler	Tsuneo Harimoto
Oiler	Moriya Abe
Oiler	Toshinori Matsui
Oiler	Daiki Sato
Chief Steward	Tomihisa Morita
Steward	Koji Kirita
Steward	Kiyotaka Kosuji
Steward	Mizuki Nakano

2.3 HyperDolphin Operation Team

Submersible Operation Manager	Yoshinari Ono
1st Submersible Technical Officer	Homare Wakamatsu
1st Submersible Technical Officer	Mitsuhiro Ueki
2nd Submersible Technical Officer	Teppei Kido
2nd Submersible Technical Officer	Shigeru Kikuya
2nd Submersible Technical Officer	Atsushi Takenouchi

3. On-site observation and sampling

We dove with ROV *Hyper Dolphin 3K* two times (#1442 and #1444) at the Toubu seamount of the Daito ridge, and one time at the Koniya Seamount, the Daito ridge.

At each survey track between 2000 to 1000m water depths, we mapped successfully with the seafloor microtopograhy and thickness of ferromanganese crusts. This is the first dives of ROV for exploration of ferromanganese crusts deposits at the Amami plateau and Daito ridge, where only a few dredge hauls have been done there.

During dives #1442 and #1444, the southern slope of the seamount, the Daito ridge was studied climbing up to the crest between depths 1950m and 1400m. The average gradient is about 21 degree or less, but whole of the survey line was scarcely covered with sediments. We found 1 to 9cm thick ferromanganese crust covering mostly highly-altered volcanic rocks, probably original breccia or lava. Semi-consolidated limestones were partly consist of substrates. The surface morphology of the slopes is generally bumpy or angular where the crusts grow over the outcrops. The knobby surface structure is again characteristic for the crusts in the area, often very thinly covered with foram sands and clayey sediments.

During the dive #1443 at the southern slope of the Koniya Seamount, Amami plateau, the most steep slope of the seamount was explored between depths 1700 and 1450 m with an average gradient of 20 degree or less. The slope were mostly covered with a wide range of size and shape of slumped rocks very thinly ferromanganese-oxide encrusted. The large rock outcrops of angular surface are probably the weathered surface of granitic rock body. The area is scarcely covered with ferromanganese oxide. Other less steep slopes are generally covered with sediments, but no outcrops are observed.

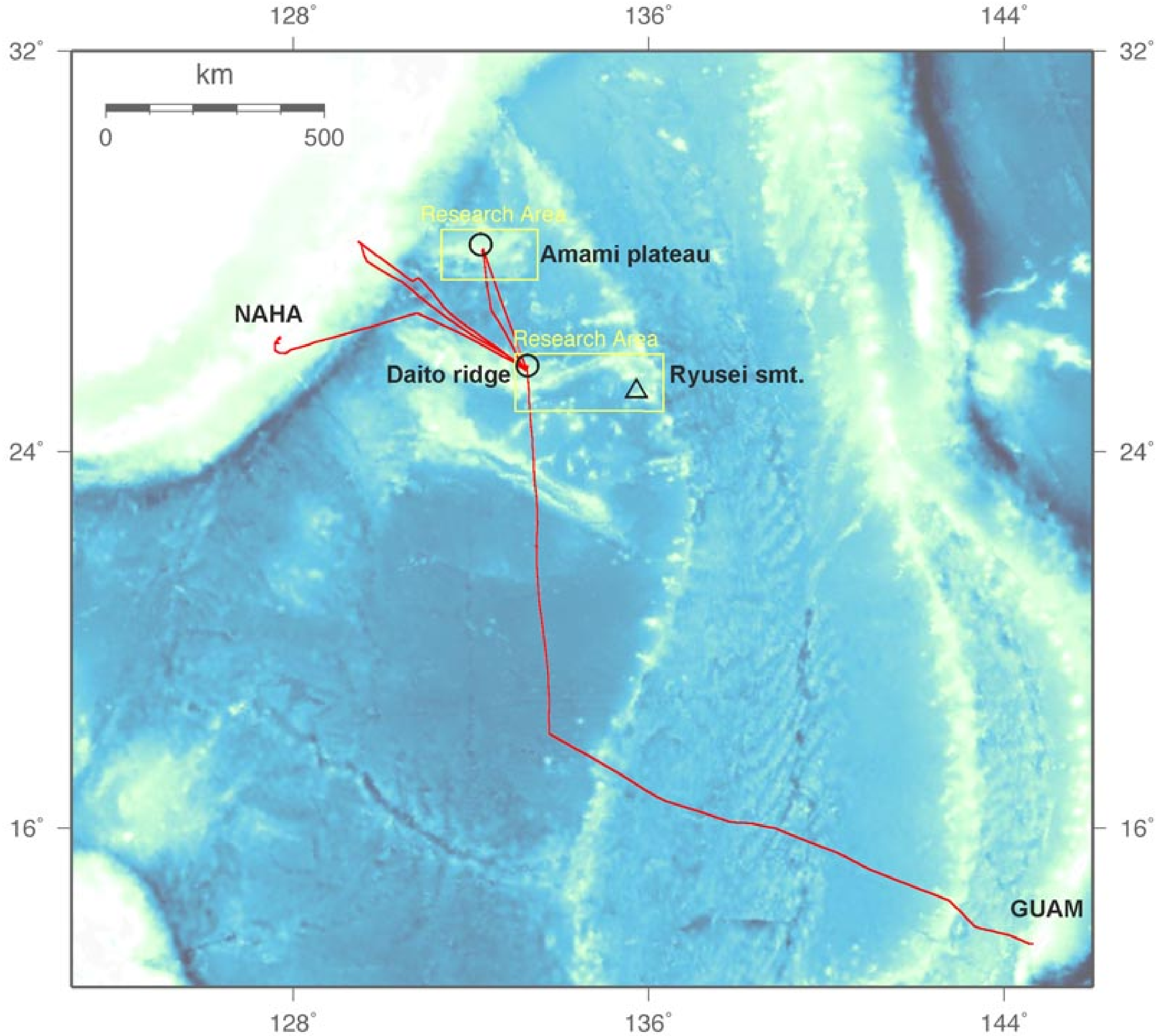
The continuous mapping the ferromanganese crust cover and its thickness was conducted as case study in the areas and the acoustic and lazer measurement of microtopography and the deposits was successfully conducted during all the three dives with more improved technique, such as gradient-tracking devices.

Date	Local Time	Note	Position/Weather/Wind/Sea condition
9.26		Sail out, proceeding to research area	09/25 12:00 (UTC+10h)
	10:00	Let go all shore lines,left GUAM.Then com'ced proceeding to research area.	13-28.8N 144-30.9E
	10:45-11:10	Carried out shipboard education for scientists.	Fine but cloudy
	13:00-15:00	Scientists meeting.	ENE-3(Gentle breeze)
			3(Sea slight)
			3(Moderate short)
			Visibly: 8'
9.27		Proceeding to research area	09/26 12:00(UTC+10h)
	M.N.	Put ship's clock aback 1hour for J.S.T.(Japanease standard time)	14-05.0N 143-07.4E
			Fine but cloudy
			East-5(Fresh breeze)
			4(Sea moderate)
			4(Moderate average)
			Visibly: 8'
9.28		Proceeding to research area	09/27 12:00(UTC+9h)
			15-10.8N 140-47.2E
			Fine but cloudy
			NE-3(Gentle breeze)
			3(Sea slight)
			4(Sea moderate)
			4(Moderate average)
			Visibly: 8'
9.29		Proceeding to research area	09/28 12:00(UTC+9h)
			16-00.4N 138-49.2E
			Fine but cloudy
			NE-4(Moderate breeze)
			3(Sea slight)
			4(Moderate average)
			Visibly: 8'
9.30		Proceeding to research area	09/29 12:00(UTC+9h)
			16-25.0N 136-56.7E
			Fine but cloudy
			NE-5(Fresh breeze)
			4(Sea moderate)
			4(Moderate average)
			Visibly:8'
10.1		Proceeding to research area	09/30 12:00(UTC+9h)
			18-51.0N 133-46.2E
			Fine but cloudy
			NNE-3(Gentle breeze)

			2(Sea smooth)
			5(Moderate long)
			Visibly:8'
10.2		Proceeding to research area	10/01 12:00(UTC+9h)
			22-48.0N 133-29.2E
			Overcast
			North-5(Freshe breeze)
			4(Sea moderate)
			5(Moderate long)
			Visibly:8'
10.3		HPD#1442_Daito Seamount	10/02 12:00(UTC+9h)
	5:00	Arrived at research area.	25-39.9N 133-15.4E
	05:00-06:06	Carried out MBES site survey.	Fine but cloudy
	6:13	Released XBT at 25-39.5239N 133-15.2994E .	North-5(Freshe breeze)
	7:18	Hoisted up HPD.	4(Sea moderate)
	7:22	Launched HPD.	4(Moderate average)
	7:32	HPD dove &started her operation#1442.	Visibly:8'
	8:36	HPD lamded on the sea bottom.(D=1900m)	
	12:00	HPD left the sea bottom.(D=1586m)	
	12:43	HPD refloated.	
	12:57	Recovered HPD & finished the operation.	
	13:00	Left research area due to rough sea.Then com'ced proceeding to AMAMI OOSHIMA.	
10.4		Arrived at off AMAMI OOSHIMA	10/03 12:00(UTC+9h)
	14:45	Arrived at off AMAMI OOSHIMA.	27-52.2N 129-39.3E
	14:50	Com'ced drifting.	Fine but cloudy
			North-6(Strong breeze)
			5(Sea rough)
			3(Moderate short)
			Visibly:8'
10.5		Proceeding to research area	10/04 12:00(UTC+9h)
	6:00	Finished drifting,then com'ced proceeding to research area(DAITO Seamount).	27-35.0N 129-30.0E
			Fine but cloudy
			North-3(Gentle breeze)
			2(Sea smooth)
			4(Moderate average)
			Visibly:8'
10.6		Suspended HPD#1443	10/05 12:00(UTC+9h)
	7:30	Arrived at research area(DAITO Seamount).	25-40.4N 133-15.3E
	14:05	Suspended HPD#1443 due to rough sea.	Cloudy
	15:10	Left DAITO Seamount,com'ced proceeding to KONIYA Seamount.	NE-5(Fresh breeze)
			4(Sea moderate)

			5(Moderate long)
			Visibly:8'
10.7		HPD#1443_KONIYA Seamount	10/06 12:00(UTC+9h)
	5:30	Arrived at research area(KONIYA Seamount).	28-05.9N 132-16.2E
	05:32-06:20	Carried out MBES site survey.	Fine but cloudy
	6:28	Released XBT at 28-05.1551N 132-16.2944E.	NE-5(Fresh breeze)
	8:09	Hoisted up HPD.	4(Sea moderate)
	8:13	Launched HPD.	3(Moderate short)
	8:23	HPD dove & started her operation#1443.	Visibly:8'
	9:47	HPD landed on the sea bottom.(D=1685m)	
	15:45	HPD left the sea bottom.(D=1480m)	
	16:32	HPD refloated.	
	16:45	Recovered HPD & finished above operation.	
	17:00	Left KONIYA Seamount,com'ced proceeding toDAITO Seamount.	
10.8		HPD#1444_DAITO Seamount	10/07 12:00(UTC+9h)
	7:50	Arrived at research area(DAITO Seamount).	25-40.4N 133-15.3E
	8:24	Hoisted up HPD.	Fine but cloudy
	8:29	Launched HPD.	NE-5(Fresh breeze)
	8:42	HPD dove & started her operation#1444.	4(Sea moderate)
	9:54	HPD landed on the sea bottom.(D=1633m)	4(Moderate average)
	14:27	HPD left the sea bottom.(D=1397m)	Visibly:8'
	15:08	HPD refloated.	
	15:22	Recovered HPD & finished above operation.	
	16:15	Left DAITO Seamount,com'ced proceeding to NAHA.	
10.9		Proceeding to NAHA	10/08 12:00(UTC+9h)
			26-31.6N 129-39.8E
			Overcast
			NE-7(Near gale)
			5(Sea rough)
			5(Moderate long)
			Visibly:6'
10.10		Proceeding to NAHA	10/09 12:00(UTC+9h)
			26-18.1N 127-40.5E
			Fine but cloudy
			NE-5(Fresh breeze)
			4(Sea moderate)
			2<Low swell long)
			Visibly:6'
10.11		Arrived at NAHA	10/10 12:00(UTC+9h)
	8:50	Sent out 1st shore line,then arrived at NAHA.	

NT12-25_Ship Track



GMT 2012 Oct 10 09:19:57 NT12-25,WGS-84,Mercator Project,(JAMSTEC/NME)

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3.1 Growth processes and metal concentration into hydrogenetic ferromanganese crusts: A case study at the Amami Plateau and Daito Ridge.

Akira Usui, Keisuke Nishi, Kazuko Hishikawa,Yoshio Nakasato (Kochi University) and
Minami Inoue, Jun Fujimoto, Aya Sakaguchi (Hiroshima University)

Objective: Ocean hydrogenetic ferromanganese crusts are potential archives of paleoceanographic and geological environments and events as well aspotential future mineral resources. However, the oceanographic or geological parameters controlling their elemental and mineralogical diversity have not been well determined with combined geochemical, mineralogical, physical and microbiological characterization on areal small-scale or microscopicscale. The ROV exploration and geological mapping proved the most elegant, accurate, and effective method for on-site geological study and geochemical analysis. We attempt to figure out the parameters related to the variations of chemical and physical characteristic of ferromanganese crusts in space and time. For this purpose, the key technique is a delicate sampling method that should provide us with undisturbed ferromanganese crust samples and on-site measurement of chemical and physical parameters. This cruise is a part of our program to characterize the geological occurrences of ferromanganese crusts from two typical areas (MinamiTorishima Island area, the Pacific and OkinoTorishima Island area, the Philippine sea) over the northwestern Pacific Ocean. We plan to describe on microscopical scale geochemical, mineralogical, and structural properties with reliable time scales, as we did at the Takuyo-Daigo seamount during the earlier cruises NT09-02, KY11-02, and NT 12-05.

Method and samples: We collected the crust samples without damage or break using the skilful and robust ROV, after continuous measurement of C-T-D-DO throughout lowering and uplifting of the vehicle as well as on the track on the bottom. In-situ samples were taken for geochemisty, mineralogy and physical engineering studies on the crusts. At each station, with approximately 200 m water-depth intervals, 30 kg samples at each site. The samples were sliced and carefully kept wet cool in a refrigerator after packing in air-tight plastic bags. To avoid chemical damage, the air-tight, wet and cool conditions are requisites for further chemical and mineralogical analyses.

Results: We have successfully mapped the occurrence of the ferromanganese deposits and substrate with physical mapping of ferromanganese crusts and microtopography during the three dives between water depths 1950m and 1400m. Total 23 ferromanganese samples (125 kg in wet total) were taken at 16 stops. The thickness of ferromanganese crusts ranges from less than 1 mm to 95 mm in maximum, whereas the Amami plateau seamount is not well covered with ferromanganese crusts. Only the steep slumped slope is partly abundant, but other less steep slopesare sediment-covered. Most of them show separated nature from the original substrate rocks but transported from shallower sea floors. The apparent rock boulders are granite, fragments of ferromanganese crusts, or manganese nodules.

The overall coverage of sea bottom with the ferromanganese oxide deposits were much more than we expected in the Daito ridge, but less in the Amami plateau. The samples were variable in thickness and in water depth. The DO varies from 2.4 (2000m) to 1.2mL/L(1200m).

Future plan: The slice samples (2 cm thickness each) are in plan to be analysed for the items below in collaboration within the shipboard scientists for the first priority, and secondly with shore-based collaborators. The samples and topics of analysis will be shared and informed to each other among the party to avoid overlapping and to secure their priority of all members.

We will first select specific key samples from several sites on the track line, and following analysis will be made mostly on the same slice or columns after discussion and negotiation.

-Bulk chemical analysis using ICP/AES and ICP/MS for about 2-3 meter intervals.
-Powder X-ray diffraction analysis for the above aliquots
-Microscopic observation on polished and thin sections for the same columns
-SEM/EDS
-EPMA/WDS
-XANES, EXAFS
-Isotopes (Be, Sr, Os)
-PGE and REE abundances
-Dating (above radiochemical, paleomagnetic, paleontological)

In order to extend the range of depth environments, we should collect more samples in the adjacent areas out of the depth range, for examples, shallower than 1000m or deeper than 3000 m. On the other hand, micro-analysis including LA/ICP-MS, SIMS, TEM observation and analysis will be considered to specify chemical and mineralogical form of useful elements and fractionation.

3.2 Microbial concentration of ferromanganese minerals

Nitahara Shota and Kato Shingo (Tokyo University of Pharmacy and Life Science and RIKEN)

Objective: Ferromanganese crust is iron and manganese oxide deposite that is widely distributed in the world. The process of concentration of ferromanganese crust is controversial (ex. accumulation of metals into Fe or Mn colloid). We think that process of concentration of ferromanganese crusts involves activity or presence of microbes. However, microbe on ferromanganese crust is still unclear, especially there is no study using molecular biology techniques.

Thus, our purpose is to clarify microbial community on ferromanganese crust, and to discuss the involvement of microbes in concentration of ferromanganese crust.

Method and samples: We collected ferromanganese crust samples without damage using manipulator, sediment with MBARI sampler and ambient seawater with NISKIN. Ferromanganese crust was divided into some particles and stored – 80 °C (molecular biology) and 4 °C (microscopy and cultivation). Sediment sample was sliced approximately 3 cm interval and stored – 80 °C (molecular biology) and 4 °C (microscopy and cultivation). Ambient seawater was filtered with 0.2 □m filter and stored – 80 °C (molecular biology).

For cultivation on board, ferromanganese crust and sediment were suspended with 0.2 □m filtered and inoculate into media for ammonia oxidizers and incubate 4 °C.

Results: We have successfully collected ferromanganese crusts, sediment and ambient seawater from Daito-Ridge and Koniya seamount. Ferromanganese crusts were divided into several pieces (surface and center). Sediment sample was sliced at interval about 2 cm. A part of samples was suspended with filtered seawater and inoculated into media for ammonia oxidizer.

Future plan: On shore study, we plan to perform following analysis using molecular biology techniques to clarify microbial community on the surface of ferromanganese crust.

i. Construct clone library of 16S rRNA gene, ammonia monooxygenase subunit A (*amoA* gene) and other functional genes based on DNA and RNA.
ii. Quantitative PCR for 16S rRNA and *amoA* gene for quantify abundance microbes and ammonia oxidizers.
iii. Cultivation ammonia oxidizing bacteria and archaea, Fe (or Mn) oxidizing bacteria and other anaerobes.
iv. Microscopic observation of ferromanganese crusts with SYBR Green I and CARD-FISH.

3.3 Mineralogical speciation of ferromanganese minerals in bottom waters

Ayaka Tokumaru and Tomoya Niiyama (Dept. Earth & Planetary Sciences, Univ. Tokyo)

Objective:

It is considered that the formation and growth of ferromanganese crusts can be mediated either by oxidative precipitation of Mn at the crust surface or by sedimentation of Mn-bearing particles in seawater. Although it is thought to have little suspended particles in deep seawater, except the vicinity of hydrothermal vents, there is a remaining possibility by taking the extremely slow growth rate of ferromanganese crusts into account that ferromanganese crusts are formed by sedimentation of Mn-bearing particles or by sequestration of aqueous Mn species. In addition, chemical and physical properties of seawater near the seamount, in general, is not well characterized enough to understand the relation between ferromanganese crusts and seawater.

The main purpose of this study are (1) to try to collect particles from ambient seawater which might be potentially involved in ferromanganese crusts and (2) to compare trace element concentrations of ferromanganese crusts and seawater near the crust surface for better understanding of the formation of ferromanganese crusts.

Method and samples:

Ambient seawater was sampled systematically by using syringe sampler and NISKIN sampler in every 50-100m water depths at a few meters above seafloor when seawater was clear, such as before landing on seafloor and during seafloor observation. The crust samples were sampled without damage or break by ROV Hyper Dolphin.

Results:

Ambient seawater sampling using syringe sampler was conducted at ten water depths during #1442-1444 dives. Seawater samples collected by Syringe sampler and NISKIN sampler were filtered (0.2μm) and stored in with 1M nitric acid at 4ºC for chemical measurement. And the filters were also stored at 4ºC. The crust samples were sliced or divided for geological analysis. After that they were packed in air-tight plastic bags, and then kept in a refrigerator at about 4ºC.

Future plan:

Scanning Electron Microscopy - Energy Dispersive X-Ray analysis (SEM-EDX) and transmission electron microscopy (TEM) are planned to characterize particles collected on a filter from syringe samplers and the surface of ferromanganese crusts. SEM-EDX analysis will reveal the presence of nanoparticles assemblages. TEM will give further details on the size, morphology and mineralogy of nanoparticles. Determination of trace metals in seawater will be carried out by inductively coupled plasma mass spectrometry (ICP-MS) with a down-sized chelating resin-packed mini-column for pre-concentration.

The synthesis of seawater data and those from ferromanganese crusts obtained during NT12-25 Cruise lead to a better understanding of the formation of ferromanganese crusts.

3.4 Acoustic and visual mapping system for survey of ferromanganese crust deposits

Objectives

One of the objectives of this cruise was to deploy an acoustic and visual mapping system designed to measure the thickness and distribution of ferro-manganese crusts and test its performance. The systems can be mounted on a mobile underwater platform, such as an autonomous underwater vehicle (AUV) or remotely operated vehicle (ROV), to continuously map the volumetric distribution of crusts while hovering over the areas of interest at low altitude. The performance of the systems has previously been demonstrated during NT10-11 and NT12-05 at Takuyo-Daigo seamount (Chief Scientist: Blair Thornton) on the flat top of the seamount.

On this cruise, the research party investigated the feasibility of extending the proposed survey strategy to the slopes of a seamount. The main motivation for this is to determine the distribution of crusts at different depths, since both changes in properties of seawater in the water column and the shape of the terrain itself are thought to play an important role in determining the thickness and distribution of manganese crusts. By combining the acoustic data with visual mapping data based on navigation information, it is possible to create a 3D colour reconstruction of the seafloor with multiple layers of information, as shown in figure 1, as a form of Geographic Information System (GIS).

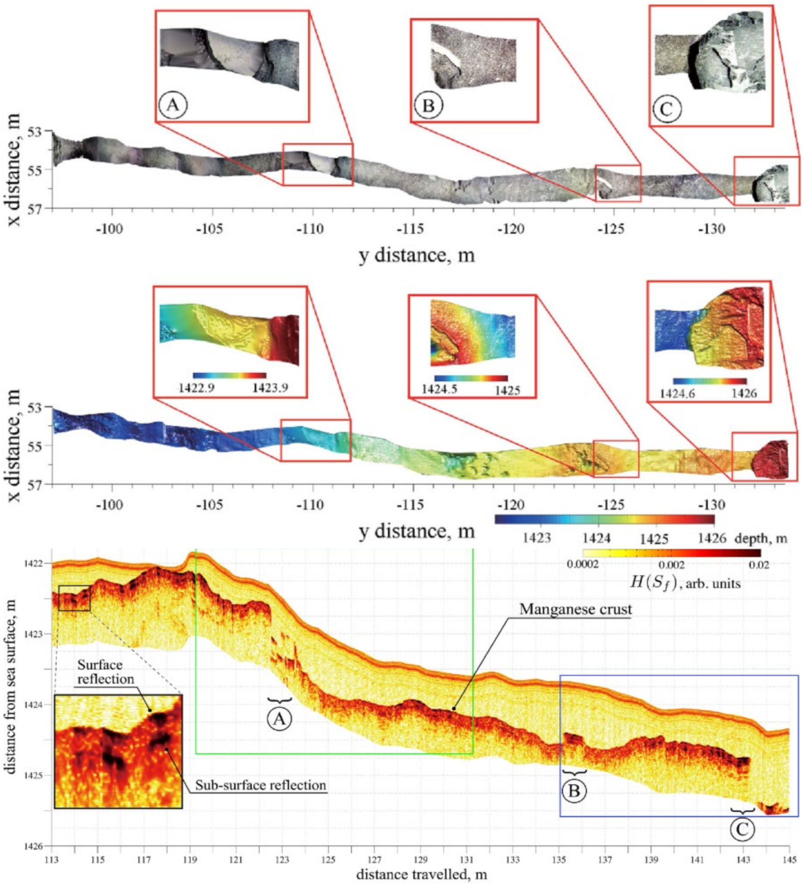


Fig.1 3D reconstruction of ferromanganese deposits based on acoustic sub-bottom and visual mapping data obtained during HPD#1144, NT10-11.

Instruments and methods

The acoustic measurement system for measuring the thickness of the ferromanganese crust and the 3D mapping devices were mounted on Hyper-Dolphin's payload box. Figure2 shows the payload box during a tank test.

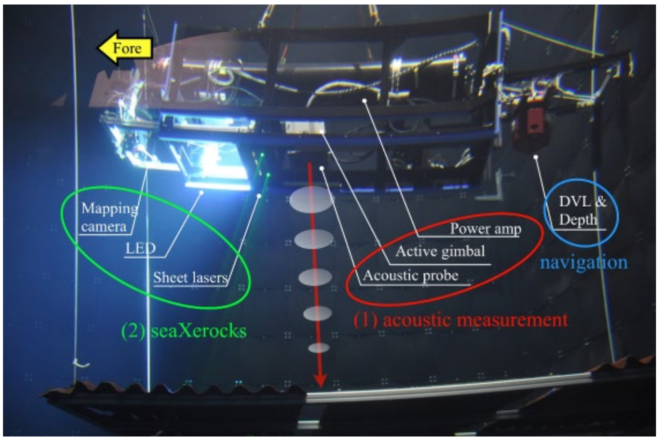


Fig.2 Configuration of payload box showing (1) the acoustic measurement system that consists of an acoustic probe, the power amplifier and the a gimbal system, (2) the SeaXerocks 3D visual mapping system that consists of a mapping camera, 2 LED panels and a sheet laser. Both systems use the information from a DVL and a depth sensorto determine the vehicle's position and orientation.

1,Gimbaled sub-surface acoustic probe

An acoustic probe has been developed to perform remote acoustic measurements of manganese crust thickness. The probe, shown in figure 3, has a diameter of 220mm, a height of 200mm and weighs 12kgs in air (6kgs in water).

The transducer consists of an annular array of 2MHz 1-3 piezoelectric composite elements for transmission,

Fig. 3 Acoustic probe developed to measure manganese crust thickness.

with a 200kHz receiver array built-in along the same axis. The probe emits a 2MHz, high frequency amplitude modulated signal in order to generate a narrow 200kHz beam that penetrates the target. This penetrating beam has a footprint of diameter 18mm on a target 1500mm away, and has no side lobes. By performing dynamic beam focusing with the array, it is possible to automatically focus the acousitc beam onto targets at a range of between 500 and 2500mm. The echoes of the low frequency component are detected using the on-axis 200kHz receiver. The oil-filled probe is pressure compensated and designed to operate at depths of up to 3000m. The housing of the power amplifier, which can be seen in figure 2, contains

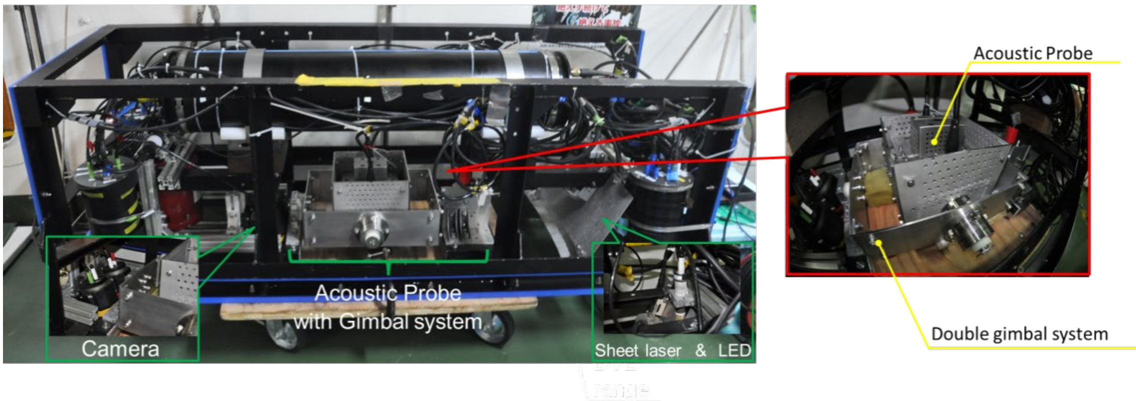


***Fig. 4**Active gimbal control mechanism (right) mounted on the payload box (left). The sheet laser and the LED panel at the bottom right of the image and one of the cameras at the bottom left of the image are used for the SeaXerocks mapping system*

the control electronics and power amplifier, used to generate a 15kW signal to drive the acoustic probe.

In order to control the angle of incidence of the sound beam, we have employed an activelycontrolled double gimbal system that holds the acoustic probe, as shown in figure 4. A system for determining the angle and direction of the slope and controlling the gimbals has been developped. The projection of the sheet laser captured by a camera is used to calculate the distance to the seafloor at two points at the front. At the back the distance from the seafloor is measured by the DVL. Figure 5 shows the schematic diagram of the algorithm to measure the slope's angle and control the gimbal's angles accordingly. First, the coordinates of two points on the laser line projection in a camera image are determined. These tell us the distance to the seafloor at the two points towards the front of the vehicle. At the same time the DVL measures the height off the seafloor at the back of the vehicle. These three points define a plane with an inclination corresponding to the average slope between these points on the seafloor. The algorithm then sends the commands to the gimbals that they adjust their angles so that the probe points vertically onto this plane.

While choosing only three points is a strongly simplified model of the actual topography, it is considered sufficient for our purposes. As the algorithm has to run in real time, the amount of information that can be processed is limited, which is the main reason why we chose to select only 3 points.

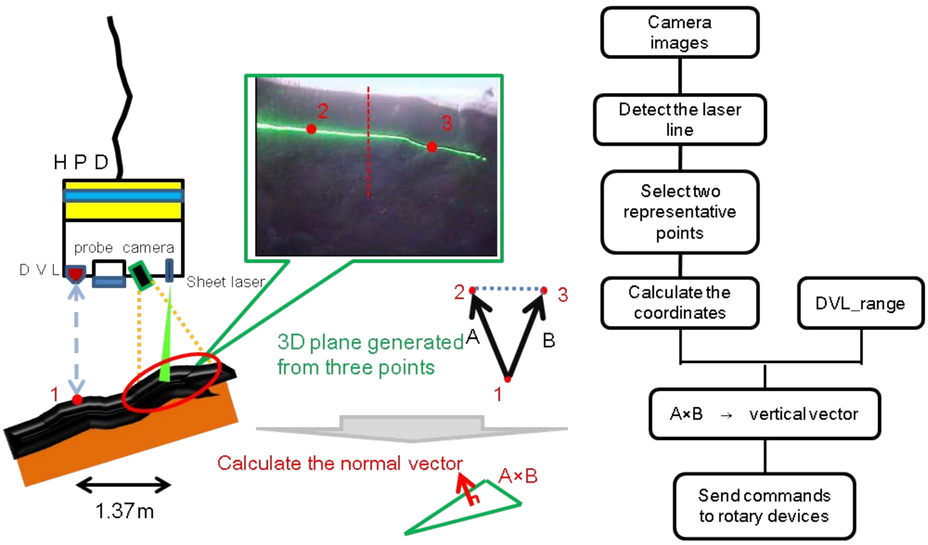


***Fig. 5**Schematic diagram of the algorithm for calculating the slope angle and sending the suitable commands to the gimbals in real-time*

2, SeaXerocks 3D visual mapping system

"SeaXerocks" is a mapping device that acquires seafloor photos, which can be used to calculate the topography and create 3D maps of the seafloor, as illustrated in figure 6. A vertically mounted sheet laser projects a line on the seafloor, making a 90° angle with the forward moving direction of the ROV, and a pair of LED panels illuminates the area in front of that line (see figure 4). A camera mounted a certain distance in front of the laser and LED panels records continuous images of the seafloor. The camera's mounting angle is adjusted so that its field of view contains the illuminated area of seafloor and extends up to the laser line projection. Throughout the dive position and orientation data supplied by a DVL and depth sensor is recorded.

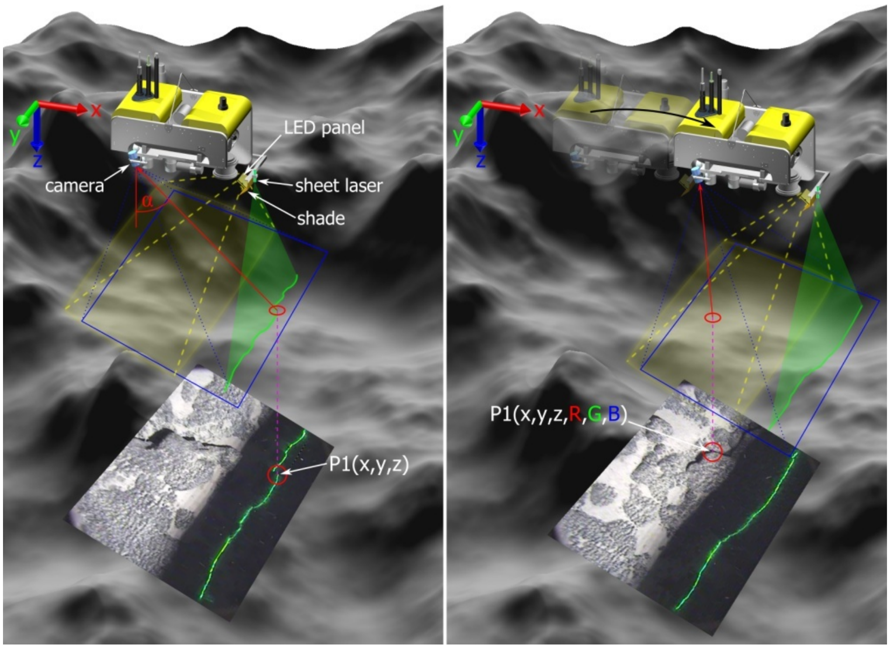


Fig. 6Illustration of SeaXerocks, used for generation of3D reconstructions of the seafloor in colour.

As the vehicle moves forwards, the projected laser line scans the shape of the seafloor, and through triangulation of the laser projections captured by each camera, it is possible to generate a detailed 3D bathymetry of the seafloor based on the vehicles position. In a second step colour information is added and after meshing the individual points, 3D reconstructions such as those shown in figure 7 and 9 can be generated. This system has been previously deployed on Hyper-Dolphin during NT10-11, KY11-02 leg 2 and NT12-05, for manganese crust surveys and in Okinawa (NT11-17) and Kagoshima Bay (NT12-07) to survey of active Hydrothermal vents, as well as for surveying a sunken whale carcass in Sagami Bay (NT12-15). The system has also been deployed on the AUV Tuna-Sand of the University of Tokyo in Kagoshima Bay (KT10-20), where it recorded the data for generating the 3D map shown in figure 7.

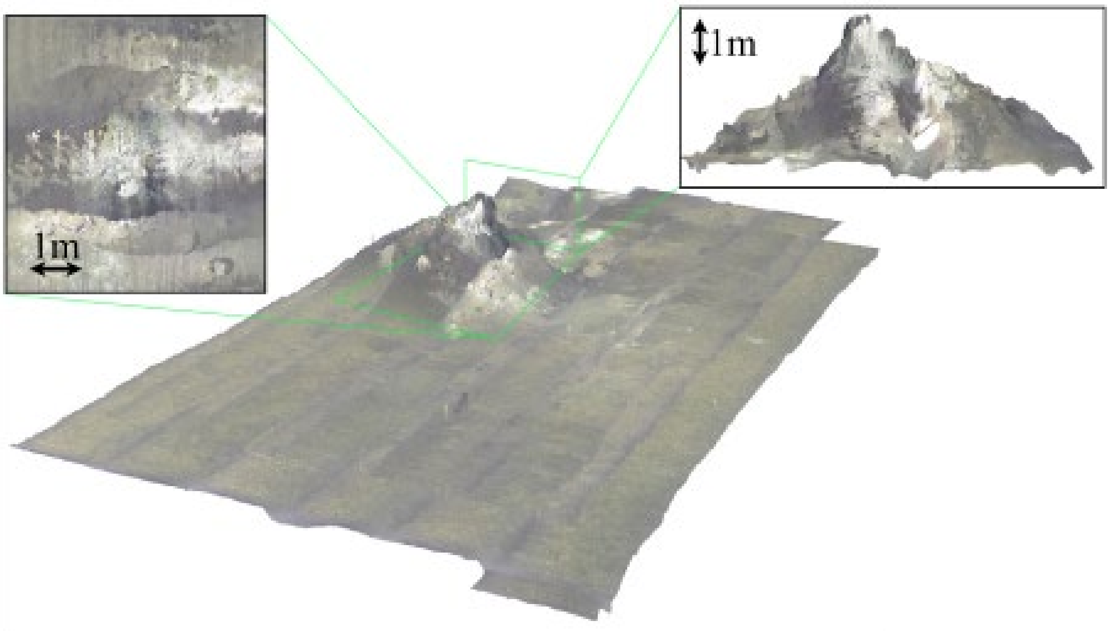


Fig. 73D reconstruction of a hydrothermal chimney and its surroundings in Kagoshima Bay.

3.4-3 ***Results***

During the dives HPD1443 and HPD1444, acoustic measurement of the crust thickness were taken and while the double gimbal system controlled the direction of the acoustic probe. Figure 8 shows the value of the angle encoders in the gimbals.

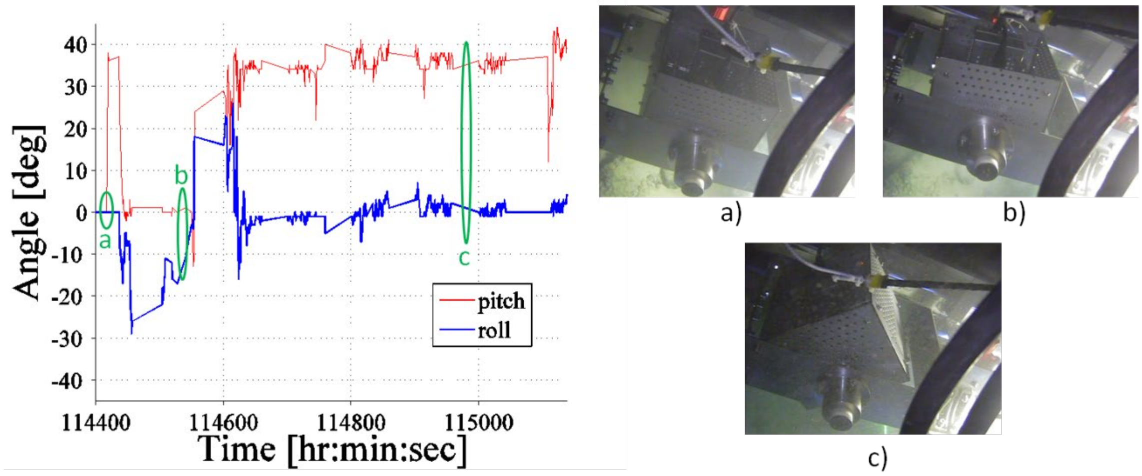


Fig. 8The graph to the left shows the anglesof the two gimbals (pitch and roll). The 3 photos at the right show the double gimbals in different positions: a) No pitch, no roll; b) no pitch but roll, c) maximum pitch and no roll

Photos of the seafloor with the laser line projection were recorded by SeaXerocks throughout all of the 3 dives and a large number of photos have already been processed and turned into coloured 3D reconstructions. Figure 9 shows the 3D reconstruction of a steep slope with relatively dense crust cover. The colour has been compensated for the absorption of light and the blue-shift in water for every point of the 3D map individually by taking into account ever point's distance from the camera and the light source at the time of recording.

The mapped area has a swath of 2m on average and covers most of the track that Hyper-Dolphin followed during the 3 dives. It will also be used to show where the acoustic measurements have been taken.

Figure 10 a) shows the raw data from an acoustic measurement recorded on the crust covered area showed in figure 9, indicating that the crust is approximately 50mm thick. Figure 10 b) shows the acoustic measurement indicating that the crust was approximately 68 mm thick, taken while the ROV had landed on the seafloor for taking the crust sample HPD1444-R1, shown in figure 10 c). The crust thickness measured on the sample agrees with the acoustic measurement.

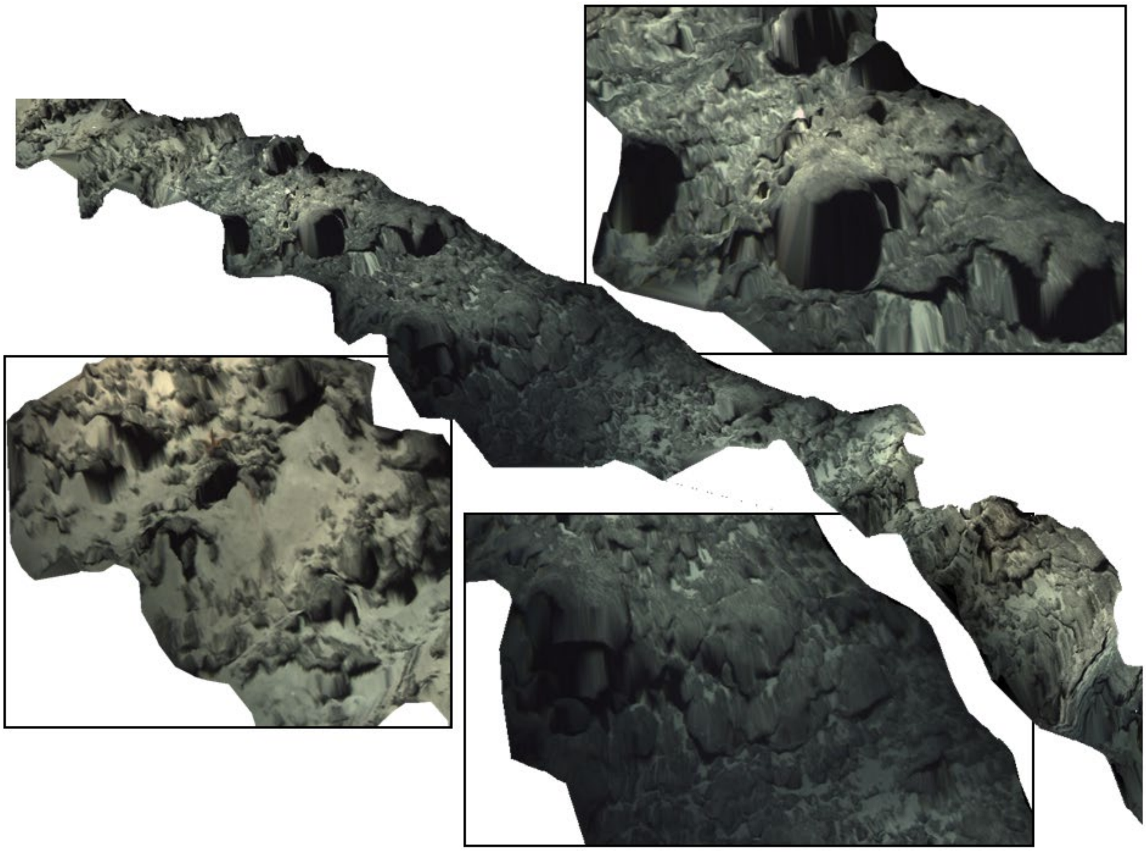
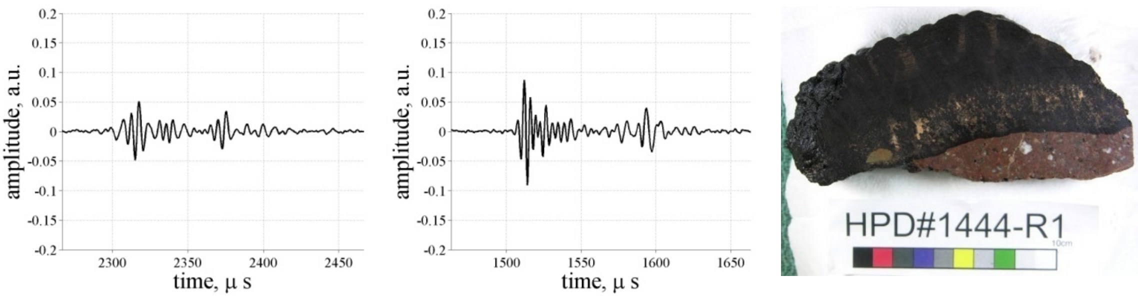


Fig. 9 3D reconstruction in colour of a slope partially covered with crust at a depth of 1625m.



a) *b)* *c)*

Fig. 10:Acoustic measurements of the crust thickness and sample taken during dive HPD#1444

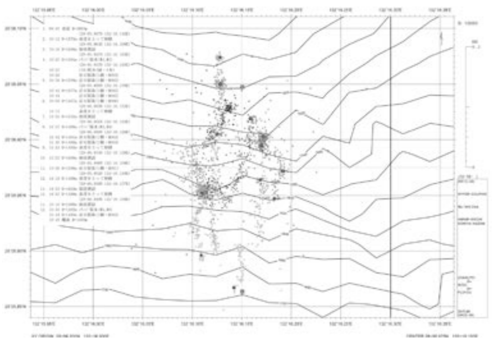
3.4-4. Conclusion and Future Plans

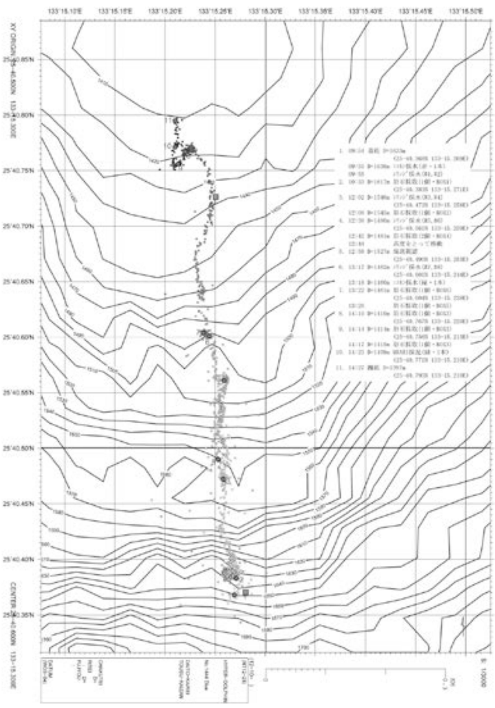
During this cruise, acoustic measurement and 3D mapping was performed in order to determine the thickness and distribution of manganese crusts. The hardware setup was similar to the one used during the cruise NT12-05, however this time the acoustic probe's angle was actively and automatically controlled by a 2 axis gimbal system, making it possible to measure the thickness of crusts also on steep slopes of varying angles. In the areas surveyed in this cruises, exposed manganese crusts were also confirmed on steep slopes in certain parts of the seamount. However, the acoustic and the 3D visual mapping device showed that the areas covered in thick, continuous crust on the surveyed seamounts are relatively small.

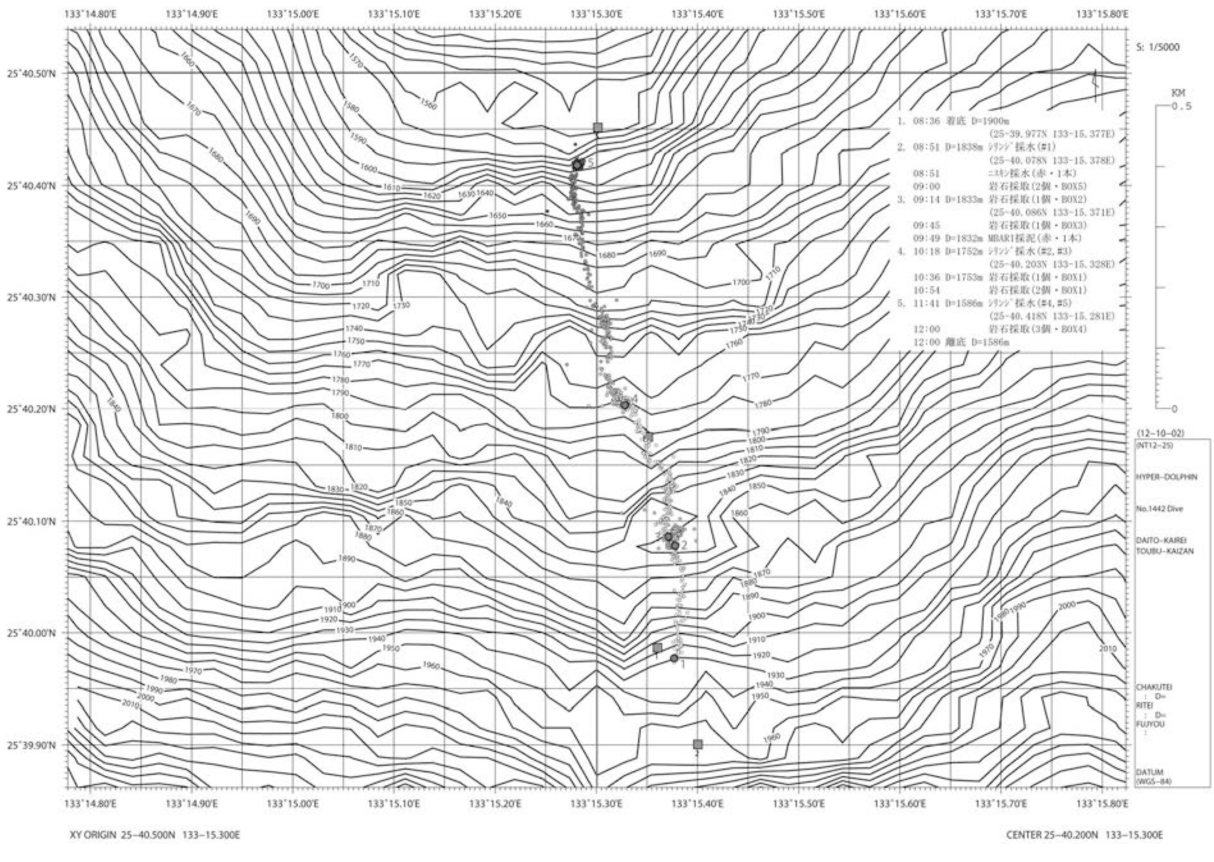
Earlier this year we surveyed manganese crusts on Takuyo-Daigo Seamount during the NT12-15 cruise and we aimed to survey crusts on Rysusei Seamount during this cruise, in order to compare the crust coverage of these two seamounts. However, because of the rough sea state it was not possible to deploy Hyper-Dolphin on Ryusei seamount as planned during this cruise. We hope to be able to measure the crust thickness with our survey device on Ryusei seamount in the future as it is thought that there is extensive crust deposit.

4. Other Research Information

See the track map of the ship NATSUSHIMA, and the track map of “Hyper Dolphin for the dives are shown as follows. Other details will be open to public in coning symposiums and printed papers.







5. Notice on Using

Notice on using: Insert the following notice to users regarding the data and samples obtained.

> This cruise report is a preliminary documentation as of the end of the cruise.
> This report may not be corrected even if changes on contents (i.e.taxonomic classifications) may be found after its publication. This report may also be changed without notice. Data on this cruise report may be raw or unprocessed. If you are going to use or refer to the data written on this report, please ask the Chief Scientist for latest information.
> Users of data or results on this cruise report are requested to submit their results to the Data Management Group of JAMSTEC.