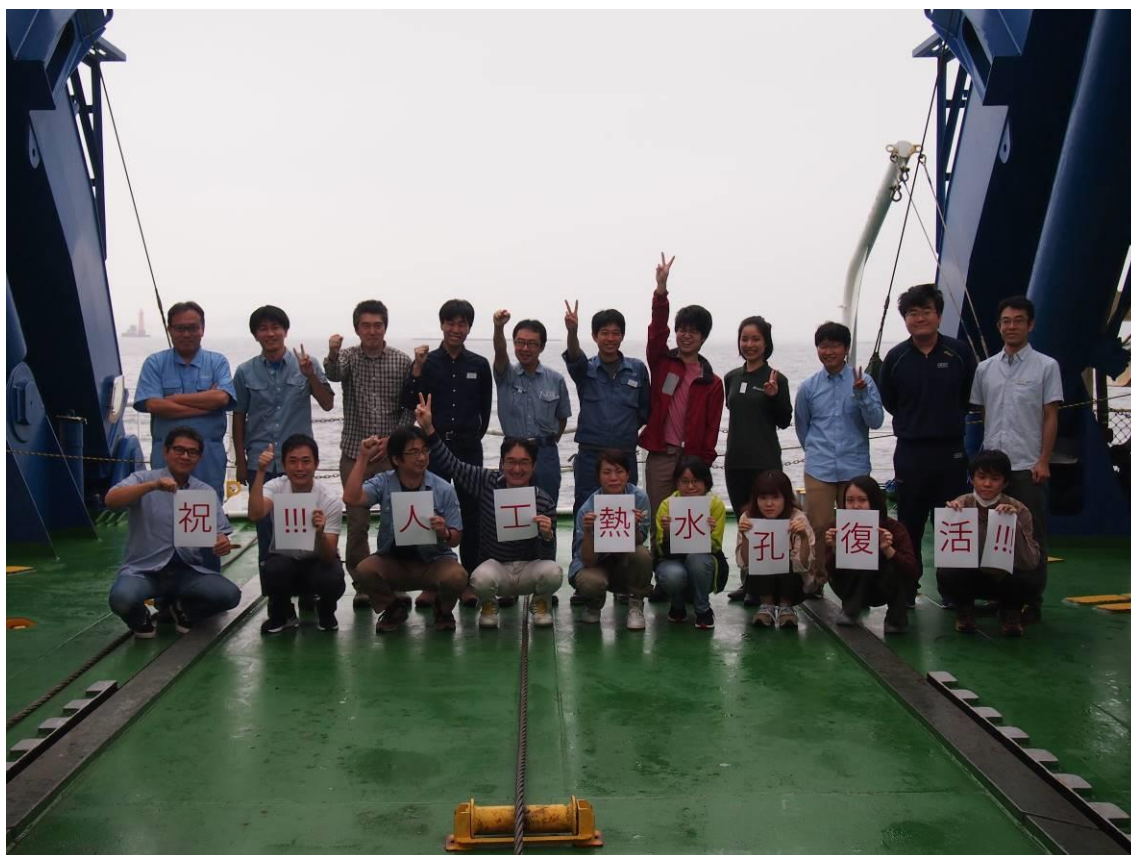




R/V Kairei Cruise Report

KR20-12



New application project of the scientific deep-sea drilling hole;
Rejuvenation of the artificial hydrothermal vent and formation of
the platform for *in-situ* deep-sea scientific and engineering
experiments

14th Oct. 2020 – 24th Oct. 2020

Japan Agency for Marine-Earth Science and Technology
(JAMSTEC)

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1. Cruise Information

- Cruise ID: KR20-12
- Name of vessel: R/V Kairei
- Title of the cruise: New application project of the scientific deep-sea drilling hole; Rejuvenation of the artificial hydrothermal vent and formation of the platform for *in-situ* deep-sea scientific and engineering experiments.
- Title of proposal: (JS20-03) New application project of the scientific deep-sea drilling hole; Rejuvenation of the artificial hydrothermal vent and formation of the platform for *in-situ* deep-sea scientific and engineering experiments. (JS20-02) New application project of the scientific deep-sea drilling hole; Study on electric function in artificial hydrothermal vents.
- Cruise period: 14th October 2020 to 24th October 2020
- Ports of departure and arrival: Naha to Yokosuka HQ (Nissan Communal Wharf)
- Research area: Iheya-North Knoll, southern flank of Iheya Minor Ridge and Izena Hole at Middle Okinawa Trough
- Research Map:

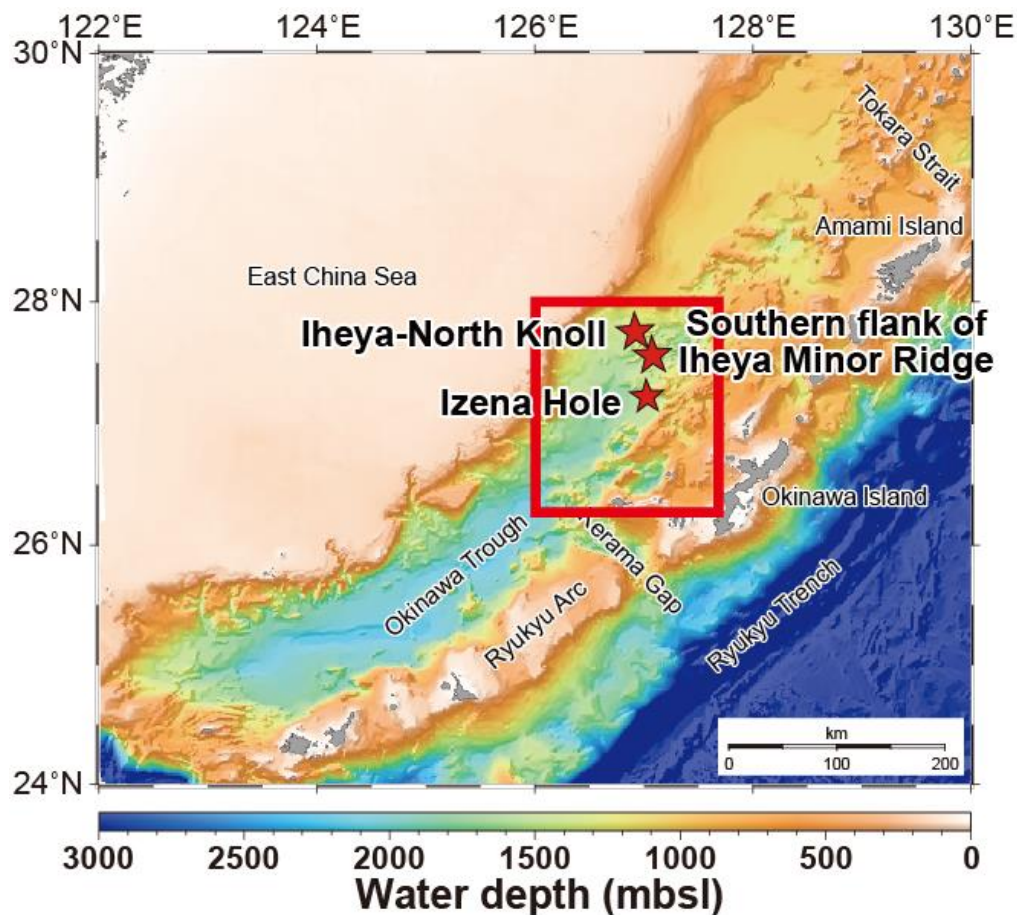


Fig. 1-1 Investigation area map of the cruise KR20-12.

2. Researchers and Crews

● Chief scientist

Tatsuo Nozaki (JAMSTEC)

● Representative of the scientific party

Tatsuo Nozaki (JAMSTEC)

● Scientific party

Masayuki Watanabe (JAMSTEC)

Koichi Iijima (JAMSTEC)

Kazuya Kitada (JAMSTEC)

Ieyoshi Shimizu (JAMSTEC)

Tomonori Ihara (JAMSTEC / Tokyo Univ. of Marine Science and Technology)

Toshiro Nagase (JAMSTEC / Tohoku Univ.)

Keita Omori (JAMSTEC / Tohoku Univ.)

Makiko Tomita (JAMSTEC / Okayama Univ. of Science)

Jun-ichiro Ishibashi (JAMSTEC / Kyushu Univ.)

Yushi Itatani (JAMSTEC / Kyushu Univ.)

Mizuki Ishida (JAMSTEC / Univ. of Tokyo)

Yusuke Kuwahara (JAMSTEC / Univ. of Tokyo)

Masahiro Yamamoto (JAMSTEC)

Satoshi Wakai (JAMSTEC)

Hiroyuki Kashima (JAMSTEC)

Hiromi Watanabe (JAMSTEC)

Kosuke Shimoniida (JAMSTEC / Yokohama City Univ.)

Runa Kobayashi (JAMSTEC / Yokohama City Univ.)

Noeru Kato (JAMSTEC / Yokohama City Univ.)

● Kairei Crew Members:

Master	Takafumi Aoki
Chief Officer	Takeshi Egashira
2nd Officer	Tatsuya Nozawa
3rd Officer	Eri Shiraishi
Jr. 3rd Officer	Taiga Yamamoto
Chief Engineer	Minoru Tsukada
1st Engineer	Kazunori Noguchi

2nd Engineer	Ryuzo Mikami
3rd Engineer	Kazuki Ono
Chief Electronics Operator	Takatomo Shirozume
2nd Electronics Operator	Kazumi Ugajin
3rd Electronics Operator	Keisuke Oi
Boat Swain	Hideo Isobe
Quarter Master	Shuichi Yamamoto
Quarter Master	Tsuyoshi Chimoto
Quarter Master	Saikan Hirai
Quarter Master	Kenta Nasu
Sailor	Hotaka Honjo
Sailor	Yohei Hidaka
No.1 Oiler	Yukihiro Yamaguchi
Oiler	Shinya Sugi
Oiler	Toru Hidaka
Assistant Oiler	Fubuki Homma
Assistant Oiler	Tsuyoshi Uchiyama
Assistant Oiler	Aoi Dantsuka
Chief Steward	Kiyotaka Kosuji
Steward	Tsuyoshi Nagatomo
Steward	Norio Takaku
Steward	Kina Abe
Steward	Keito Sato

● Kaiko Operation Team

Submersible Op. Manager	Seiji Shigetake
1/Submersible Tec. Officer	Homare Wakamatsu
1/Submersible Tec. Officer	Tomoe Kondo
1/Submersible Tec. Officer	Teppei Kido
2/Submersible Tec. Officer	Shota Ihara
2/Submersible Tec. Officer	Taiken Yamaguchi
3/Submersible Tec. Officer	Naoki Sato
3/Submersible Tec. Officer	Kunihiro Iwata

● Marine Technician

Chief Observation Engineer	Morifumi Takaesu
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3. Observation

3.1 Objectives & Background

There are several active deep-sea hydrothermal sites in the Okinawa Trough within the Japanese Exclusive Economic Zone (EEZ). Cu-Pb-Zn-rich sulfide deposits occurring at these hydrothermal sites are considered to be a modern analogue of the Kuroko-type volcanogenic massive sulfide (VMS) deposits on land (e.g., Halbach et al., 1989, 1993, 1997; Ishibashi et al., 2015; Nozaki et al., 2016; Yeats et al., 2017). In 2010, the international drilling research cruise of the IODP Expedition (Exp.) 331 was conducted at the Iheya-North Knoll, middle Okinawa Trough (Takai et al., 2011, 2012; Yanagawa et al., 2016), whose main purpose of this expedition was unravelling “Deep-Hot Biosphere”. The massive sulfide core was successfully obtained from the western flank of the North Big Chimney (NBC) Mound (Yeats et al., 2017) and four artificial hydrothermal vents were formed during this drilling expedition (Takai et al., 2012). Semi-annual ROV dive expeditions were performed to observe and collect fluid/rock samples from these artificial hydrothermal vents (Kawagucci et al., 2013). On the bare hole artificial hydrothermal vent at the NBC Mound (Hole C0016A), rapid growth of chimney which became a 15 m height in 25 months was observed (Kawagucci et al., 2013; Nozaki et al., 2016). The sulfide-rich part of this rapidly grown chimney on the artificial hydrothermal vent has a similar chemical composition to that of high-grade Kuroko VMS ore on land (Nozaki et al., 2016). These observations inspired us “cultivation of seafloor mineral deposits” by controlling mixture and quench processes between hydrothermal fluid and ambient cold seawater through the Kuroko-ore cultivation apparatus which was collaboratively developing by the Research and Development (R&D) Center for Submarine Resources and the Center for Deep Earth Exploration (CDEX) at JAMSTEC. Totally three unique apparatuses have been installed at two hydrothermal sites, Original Site at the Iheya-North Knoll (Hole C9024A) and Noho Site at the southern flank of the Iheya Minor Ridge (Hole C9017B) in the Okinawa Trough during the cruise CK16-01 (Exp. 908) as well as at the Noho Site (Hole C9017A) during the cruise CK16-05 (Exp. 909).

During the cruise NT16-02, we conducted an *in-situ* function test of various hydraulic tools for the future recovery operation of the Kuroko-ore cultivation apparatus using a ROV. The isolated hydraulic power unit (IHPU), hydraulic short drill and chisel were used at Hole C0014G of the Iheya-North Knoll, so as to remove a sulfide scale within the steel pipe on the corrosion cap, and then to install a temporal flowmeter after rejuvenation of hydrothermal fluid discharge. In this dive expedition, seawater invaded into the IHPU and its controlling electric circuit. Thus, the IHPU became out of order and we failed to install the temporal flowmeter at Hole C0014G. Based on the many important and precious experiences during the cruise NT16-02, the IHPU was repaired/improved, and ROV hydraulic tools including the IHPU functioned well during the cruises CK16-01, CK16-05, KR16-17, KR18-02C and KR18-14 Leg 1 cruises, which means that our ROV

hydraulic tools became technically robust. In the cruises KR16-17 and KR18-02C, we successfully recovered three Kuroko-ore cultivation apparatuses installed at Holes C9017A, C9017B and C9024A during the cruises CK16-01 and CK16-05 using the IHPU with other ROV hydraulic tools. In the latest cruises of KR18-14 Legs 1 and 2, another Kuroko-ore cultivation apparatus equipped with a P/T sensor was installed on the natural hydrothermal vent for (1) *in-situ* mineral precipitation experiment, (2) chemical reaction experiment of pumice and pyrite fragments with hydrothermal fluid and (3) gold adsorption experiment from hydrothermal fluid. Moreover, two electrotrophic microbes enrichment systems (EMESs) were installed on a seafloor at the Original Site, Iheya-North Knoll, because artificial hydrothermal vents are useful for an *in-situ* electric power generation experiment due to the different electric potential between hydrothermal fluid and seawater (Yamamoto et al., 2013, 2017) and are one of the best targets to conduct the *in-situ* incubation experiment of electrotrophic microbes. However, three artificial hydrothermal vents equipped with casing pipe and corrosion cap/guide base are now clogged by scale deposits (Nozaki et al., *in press*) which have to be periodically removed for the future various *in-situ* experiments.

Thus, in this cruise of KR20-12, as a metallogenic study on seafloor hydrothermal deposit by Research Institute for Marine Resources Utilization (MRU), JAMSTEC and microbial study under the extreme condition by Institute for Extra-cutting-edge Science and Technology Avant-garde Research (X-star), JAMSTEC, followings are our main purposes; (1) retrieving the Kuroko-ore cultivation apparatus on the natural hydrothermal vent, (2) deploying and retrieving *in-situ* pumice reaction apparatus, (3) flow rate measurement of hydrothermal fluid using ultrasonic wave, (4) scale removal and rejuvenation of hydrothermal discharge from artificial hydrothermal vents using a hydraulic drill, and then installment of simplified flow meter and deep-sea electricity generation apparatus, (5) installment of corrosion ladder box and metal rods together with retrieving EMESs and electric potential measurement by deep-sea potentiostat system (D-POTE).

Halbach, P., Hansmann, W., Koëppel, V. and Pracejus, B. (1997) Whole-rock and sulfide lead-isotope data from the hydrothermal JADE field in the Okinawa back-arc trough. *Mineralium Deposita*, **32**, 70-78.

Halbach, P., Nakamura, K., Wahsner, M., Lange, J., Sakai, H., Kaselitz, L., Hansen, R.-D., Yamano, M., Post, J., Prause, B., Seifert, R., Michaelis, W., Teichmann, F., Kinoshita, M., Marten, A., Ishibashi, J., Czerwinski, S. and Blum, N. (1989) Probable modern analogue of Kuroko-type massive sulphide deposits in the Okinawa Trough back-arc basin. *Nature*, **338**, 496-499.

Halbach, P., Pracejus, B. and Marten, A. (1993) Geology and mineralogy of massive sulfide ores from the central Okinawa trough, Japan. *Economic Geology*, **88**, 2210-2225.

Ishibashi, J.-i., Ikegami, F., Tsuji, T. and Urabe, T. (2015) Hydrothermal activity in the Okinawa Trough back-arc basin: geological background and hydrothermal mineralization. *In*: Ishibashi,

- J.-i., Okino, K. and Sunamura, M. (eds) Subseafloor biosphere linked to hydrothermal systems. Springer, New York, 337-359.
- Kawagucci, S., Miyazaki, J., Nakajima, R., Nozaki, T., Takaya, Y., Kato, Y., Shibuya, T., Konno, U., Nakaguchi, Y., Hatada, K., Hirayama, H., Fujikura, K., Furushima, Y., Yamamoto, H., Watsuji, T., Ishibashi, J. and Takai, K. (2013) Post-drilling changes in fluid discharge, mineral deposition patterns and fluid chemistry for the seafloor hydrothermal activity in the Iheya-North hydrothermal field, Okinawa Trough. *Geochemistry Geophysics Geosystems*, **14**, 4774-4990.
- Nozaki, T., Ishibashi, J.-I., Shimada, K., Nagase, T., Takaya, Y., Kato, Y., Kawagucci, S., Watsuji, T., Shibuya, T., Yamada, R., Saruhashi, T., Kyo, M. and Takai, K. (2016) Rapid growth of mineral deposits at artificial seafloor hydrothermal vents. *Scientific Reports*, **6**, 22163.
- Nozaki, T., Nagase, T., Torimoto, J., Takaya, Y., Ishibashi, J.-i., Shimada, K., Watanabe, M., Masaki, Y., Iijima, K., Kitada, K., Saitoh, M., Yokoyama, T., Akiyama, K., Sakurai, N., Saruhashi, T., Kyo, M., Kumagai, H. and Maeda, L. (*in press*) Formation of highly Zn-enriched sulfide scale at a deep-sea artificial hydrothermal vent, Iheya-North Knoll, Okinawa Trough. *Mineralium Deposita*, **xx**, xxx-xxx. <https://doi.org/10.1007/s00126-020-01022-3>.
- Takai, K., Mottl, M. J., Nielsen, S. H. and the Expedition 331 Scientists (2011) Proceedings of Integrated Ocean Drilling Program 331, Tokyo (Integrated Ocean Drilling Program Management International, Inc.).
- Takai, K., Mottl, M. J., Nielsen, S. H. H. and the IODP Expedition 331 Scientists (2012) IODP Expedition 331: Strong and Expansive Subseafloor Hydrothermal Activities in the Okinawa Trough. *Scientific Drilling*, **13**, 19-27.
- Yamamoto, M., Nakamura, R., Kasaya, T., Kumagai, H., Suzuki, K. and Takai, K. (2017) Spontaneous and widespread electricity generation in natural deep-sea hydrothermal fields. *Angewandte Chemie International Edition*, **56**, 5725-5728.
- Yamamoto, M., Nakamura, R., Oguri, K., Kawagucci, S., Suzuki, K., Hashimoto, K. and Takai, K. (2013) Generation of electricity and illumination by an environmental fuel cell in deep-sea hydrothermal vents. *Angewandte Chemie International Edition*, **52**, 10758-10761.
- Yanagawa, K., Ijiri, A., Breuker, A., Sakai, S., Miyoshi, Y., Kawagucci, S., Noguchi, T., Hirai, M., Schippers, A., Ishibashi, J.-i., Takaki, Y., Sunamura, M., Urabe, T., Nunoura, T. and Takai, K. (2016) Defining boundaries for the distribution of microbial communities beneath the sediment-buried, hydrothermally active seafloor. *The ISME Journal*, **11**, 529-542.
- Yeats, C. J., Hollis, S. P., Halfpenny, A., Corona, J.-C., LaFlamme, C., Southam, G., Fiorentini, M., Herrington, R. J. and Spratt, J. (2017) Actively forming Kuroko-type volcanic-hosted massive sulfide (VHMS) mineralization at Iheya North, Okinawa Trough, Japan. *Ore Geology Reviews*, **84**, 20-41.

3.2 Dive Information & Preliminary Results

3.2.1 Dive KK#852 (15th October 2020) at the Original Site, Iheya-North Knoll

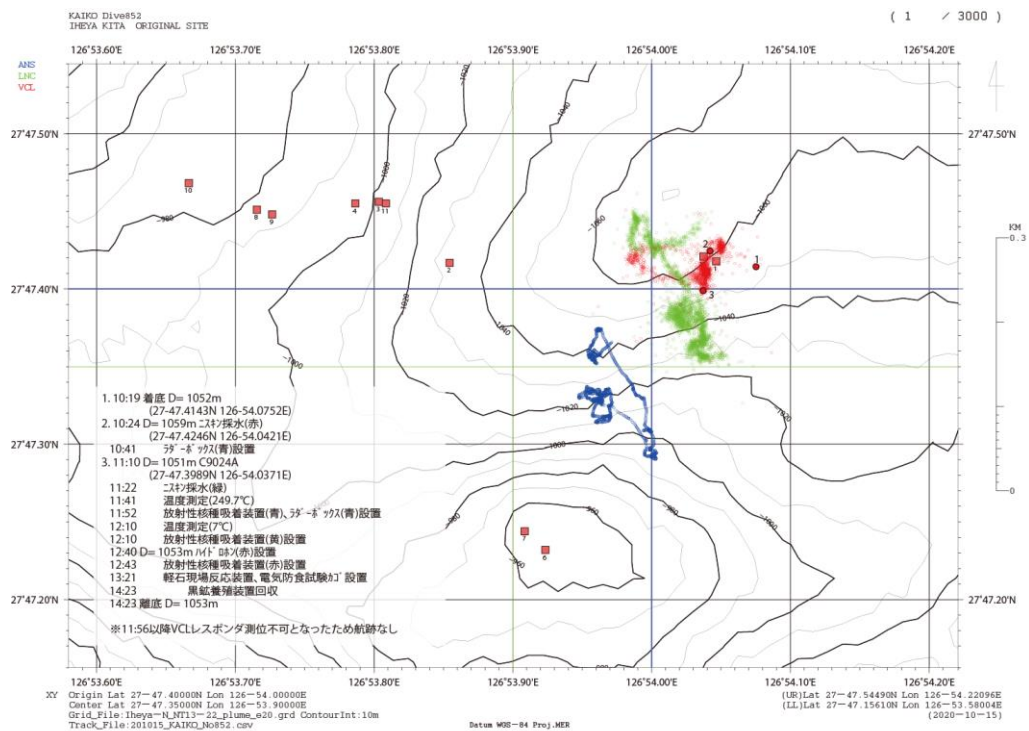


Fig. 3-1 Dive track and operation list of the dive KK#852 on a bathymetric map.



Fig. 3-2 Payload of the dive KK#852 in the sample basket.

Payload:

Thermometer for hydrothermal fluid x 1, gamma-ray detector x 1, portable three-component magnetometer x 1, corrosion ladder box x 2, hydrophone x 2, radioactive nuclear species adsorption apparatus x 3, recovery hook x 2, cutter x 1, *in-situ* pumice reaction apparatus x 2, electric corrosion proof test box x 1, isolated hydraulic power unit (IHPU) x 1, hotstab x 1, Niskin water sampler x 2, magnet x 4.

Operation:

During moving downward to seafloor, the oil leak test was conducted by using the IHPU and hotstab at the water depth of 300 and 600 mbsl (meters below sea level). Owing to improvement and replacement of the O-ring, no oil leakage was observed from the hotstab. Then, the ROV landed at seafloor, followed by Niskin water sampling (red), installment of corrosion ladder box (red) and hydrophone (blue) (Fig. 3-3) only several meter away from four concrete boxes put on a seafloor during the cruise KR18-14 Leg 1 in Oct. 2018 (Fig. 3-4). After putting the hydrophone on a seafloor, the ROV moved to the artificial hydrothermal vents of Holes C9024A and C0014G to observe the clogging of the vent pipe. The vent pipe of Hole C9024A was completely clogged, however vigorous hydrothermal discharge was observed from the vent pipe of Hole C0014G without any scale removal operation (Fig. 3-5). The vent pipe of Hole C0014G was completely clogged during cruised KR18-14 Legs 1 and 2 in Oct. to Nov. in 2018, and hydrothermal discharge was naturally rejuvenated again for some unknown reasons. Then, the ROV moved to the natural hydrothermal vent near Hole C9024A, followed by Niskin water sampling (green), putting radioactive nuclear species adsorption apparatus (blue) and corrosion ladder box (blue) on the natural hydrothermal vent (Fig. 3-6) whose maximum temperature of hydrothermal fluid was 249.7 °C. At another natural hydrothermal vent near Hole C9024A ($T_{\max} = 7.6$ °C), two more radioactive nuclear species adsorption apparatuses (yellow and red) and one more hydrophone (red) were put on a seafloor (Fig. 3-7). During these operations at ca. a.m. 11:56, the responder of ROV became out of order and we cannot acoustically trace the precise position of the ROV. Due to such a trouble, to finish the dive KK#852 as soon as possible, we gave up to install *in-situ* pumice reaction apparatus and electric corrosion proof test box during this dive, which were temporally put on the ROV platform of Hole C9024A (Fig. 3-8). Finally, after short observation of the hydrothermal fluid effluence of Hole C0014G, the Kuroko-ore cultivation apparatus installed on a natural hydrothermal vent near Hole C9024A was recovered using manipulator and two recovery hooks (Figs. 3-9 and 3-10).

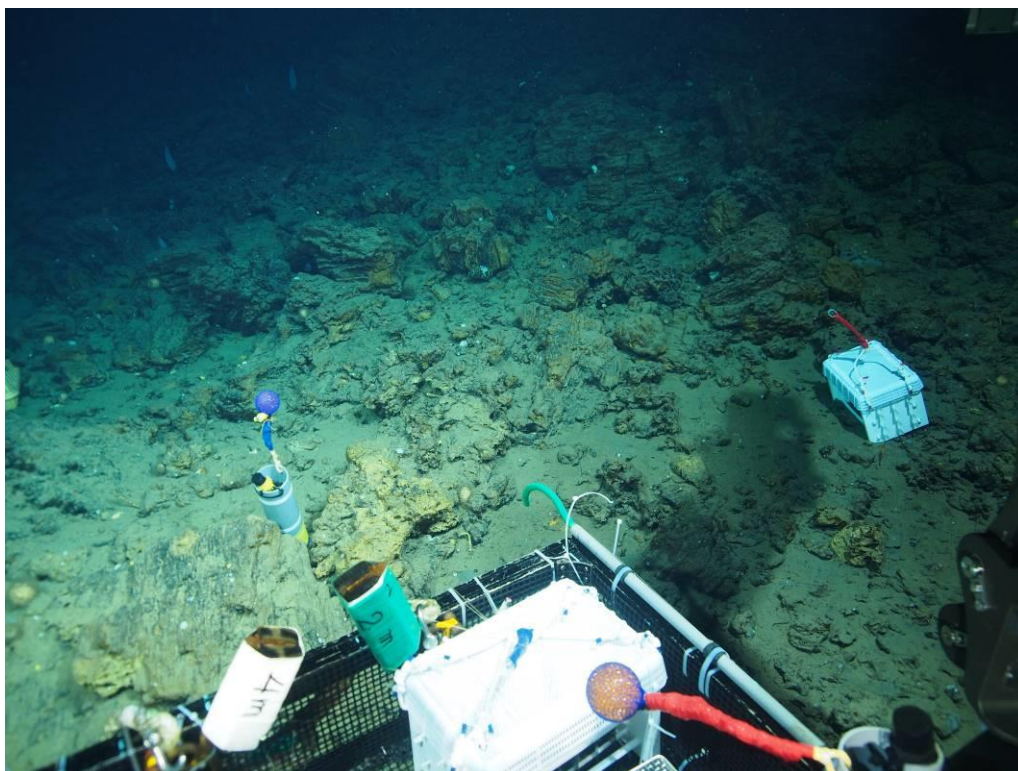


Fig. 3-3 Corrosion ladder box and hydrophone put on a seafloor.

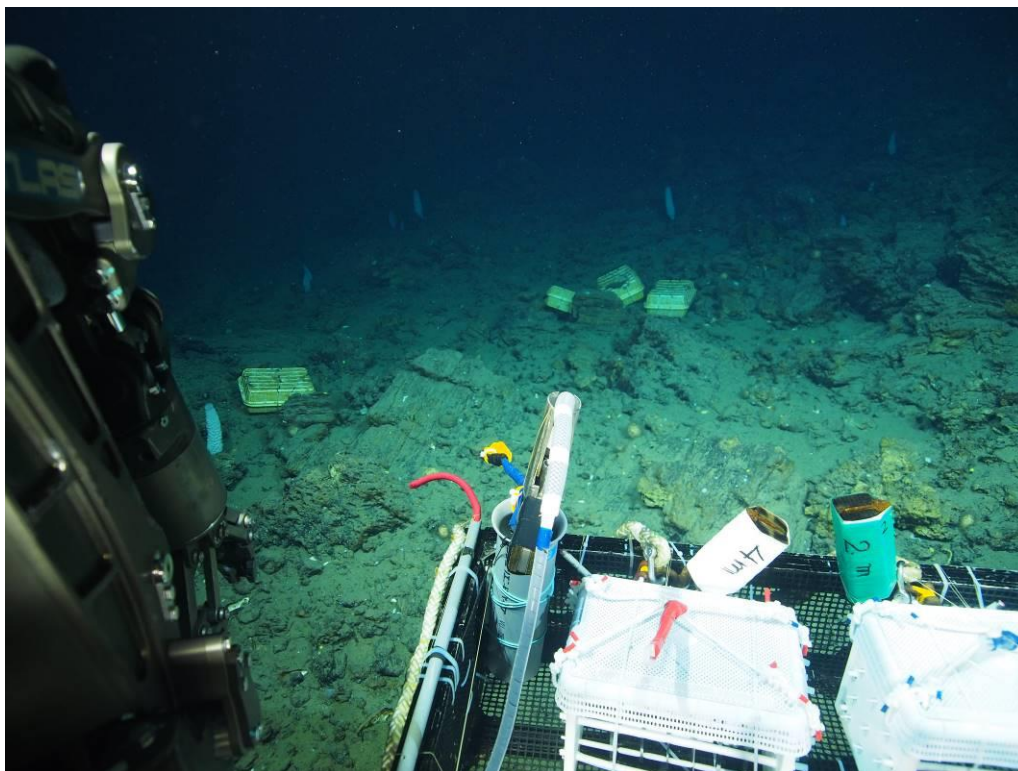


Fig. 3-4 Four concrete boxes put on a seafloor during the cruise KR18-14 Leg 1.

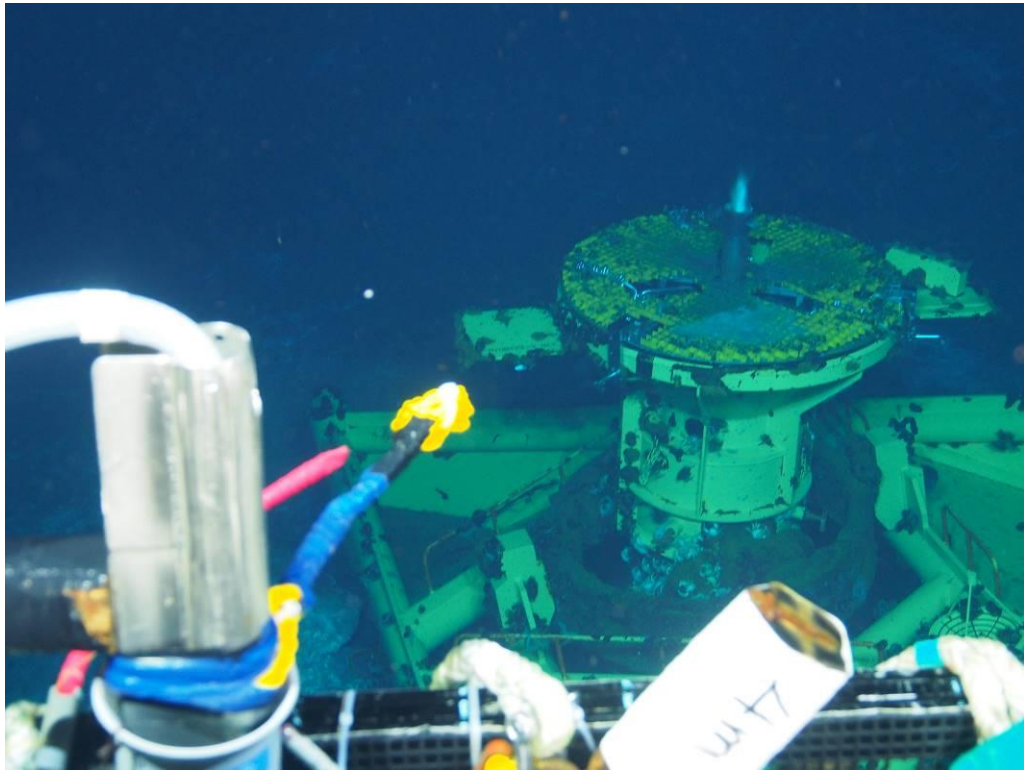


Fig. 3-5 Hydrothermal fluid discharge from Hole C0014G was rejuvenated without any scale removal operation.

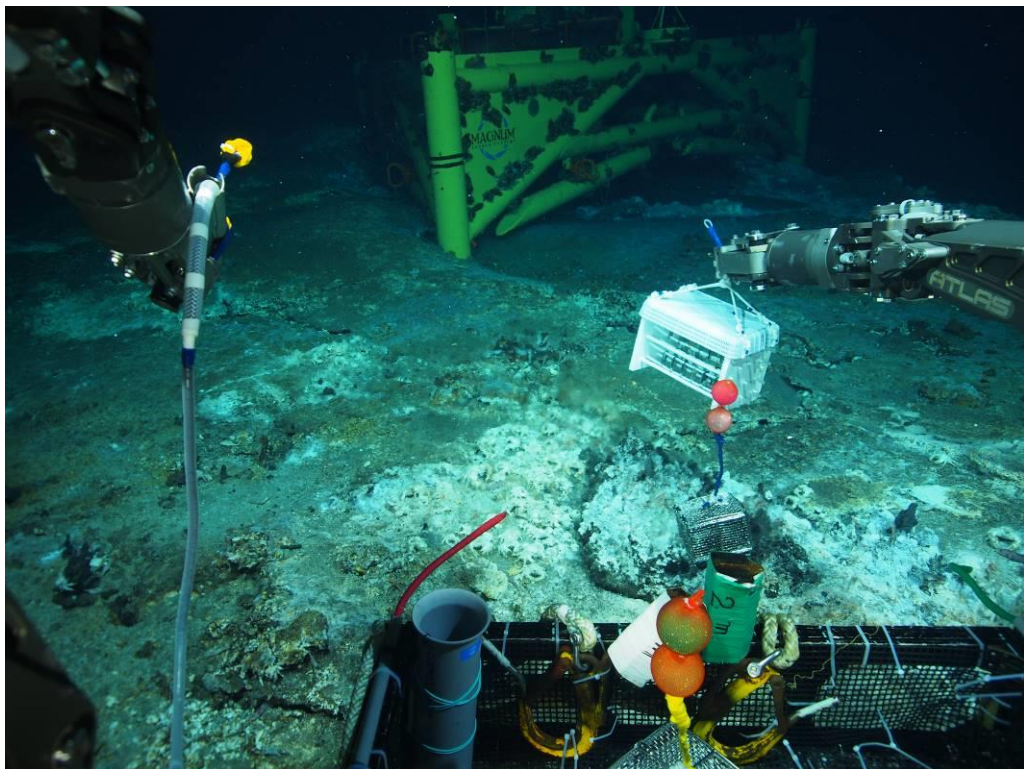


Fig. 3-6 Radioactive nuclear species adsorption apparatus and corrosion ladder box were put on the natural hydrothermal vent near Hole C9024A.

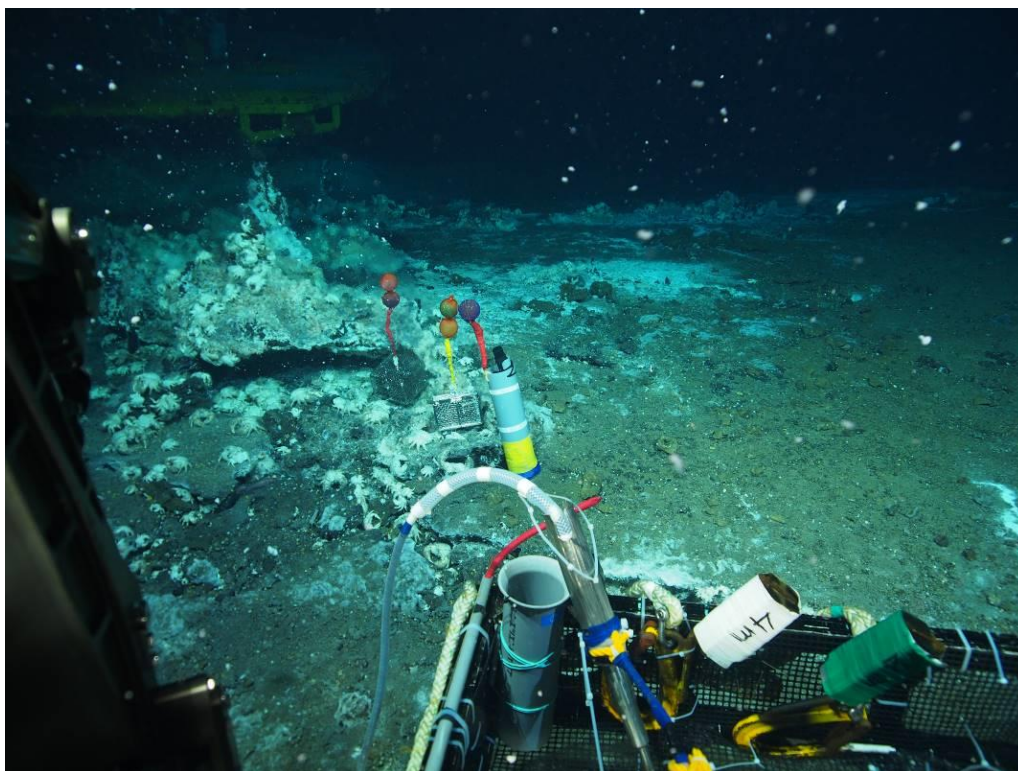


Fig. 3-7 Two more radioactive nuclear species adsorption apparatuses and hydrophone were put on another natural hydrothermal vent near Hole C9024A.

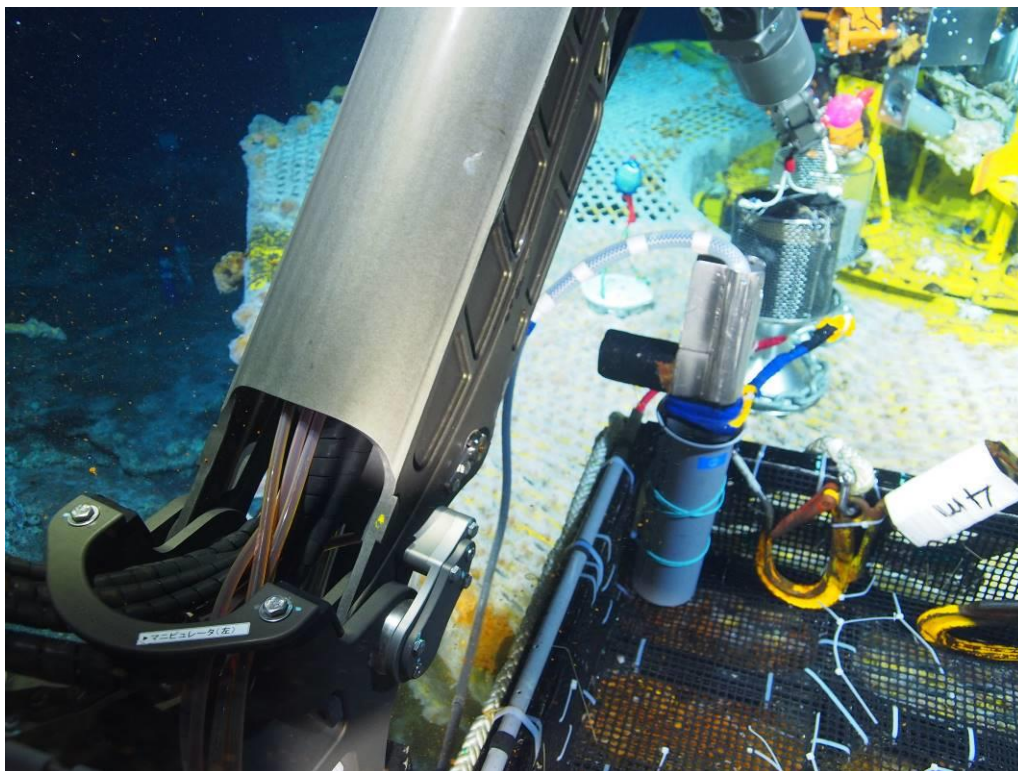


Fig. 3-8 *In-situ* pumice reaction apparatus and electric corrosion proof test were temporally put on the ROV platform of Hole C9024A.

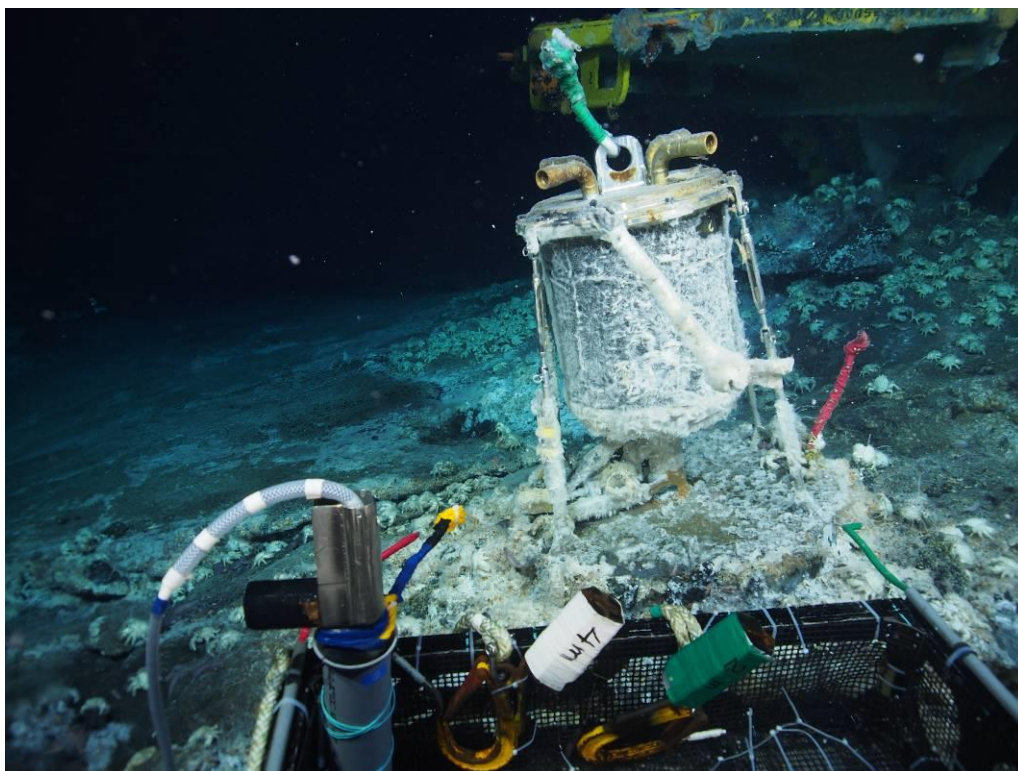


Fig. 3-9 Kuroko-ore cultivation apparatus installed on a natural hydrothermal vent during the cruise KR18-14 Leg 1.

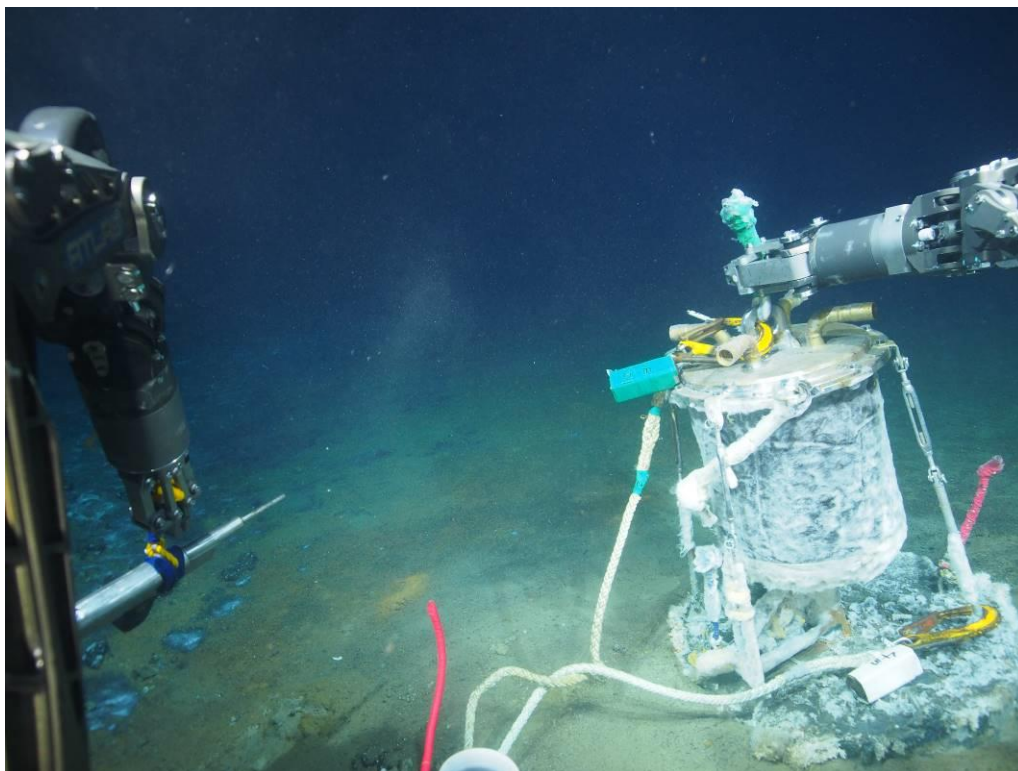


Fig. 3-10 Kuroko-ore cultivation apparatus was retrieved by using two recovery hooks.

3.2.2 Dive KK#853 (16th October 2020) at the Original Site, Iheya-North Knoll

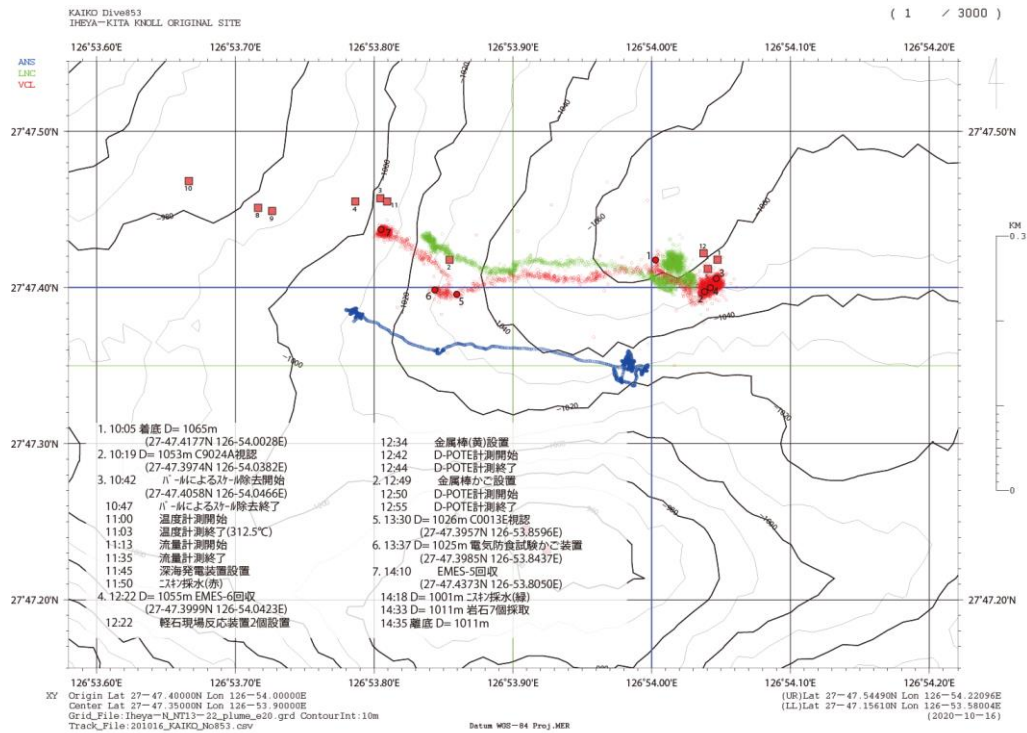


Fig. 3-11 Dive track and operation list of the dive KK#853 on a bathymetric map.

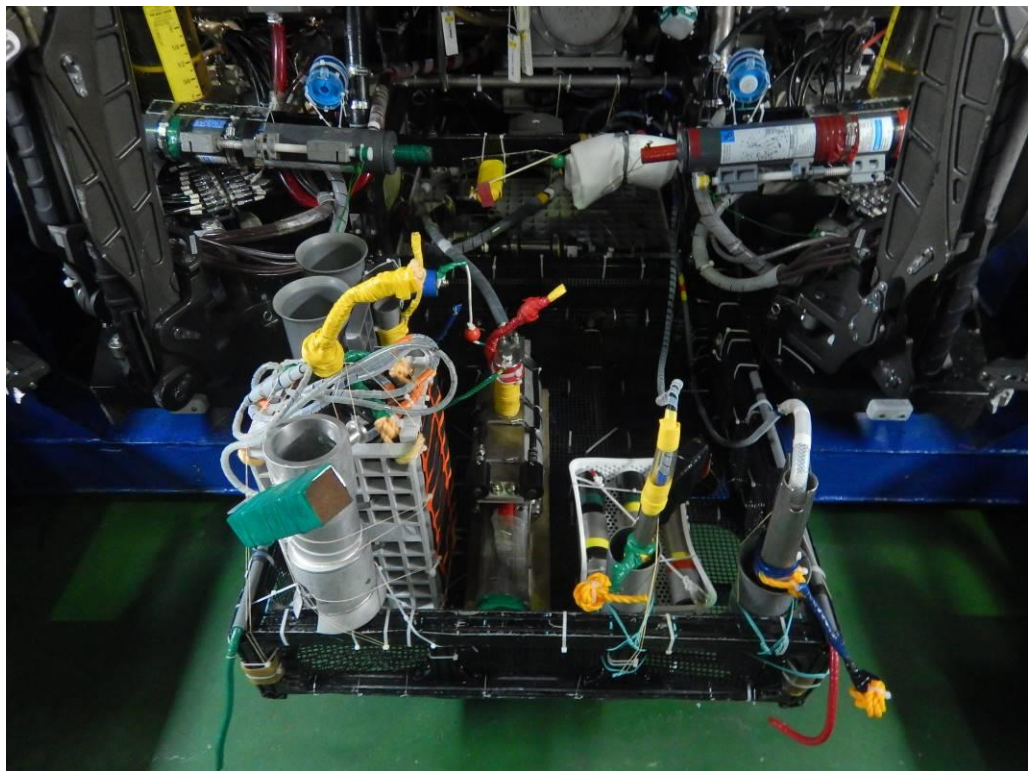


Fig. 3-12 Payload of the dive KK#853 in the sample basket.

Payload:

Thermometer for hydrothermal fluid x 1, ultrasonic wave hydrothermal fluid flowmeter x 1, gamma-ray detector x 1, deep-sea potentiostat system (D-POTE) x 1, portable three-component magnetometer x 1, deep-sea electricity generation apparatus x 1, metal rod x 3 and metal rod box 1 set (including metal rod x 3), long pinch bar x 1, isolated hydraulic power unit (IHPU) x 1, Niskin water sampler x 2, magnet x 4, scabbard for EMES retrieving x 2.

Operation:

At first, the ROV moved to Hole C0014G to pick and remove the scale deposit within the steel vent pipe using a long pinch bar (Fig. 3-13). The long pinch bar was inserted into the steel vent pipe about 50 cm depth. After the temperature measurement of hydrothermal fluid ($T_{\max} = 312.5\text{ }^{\circ}\text{C}$), the movie of hydrothermal fluid discharge was captured for ca. 5 min (Fig. 3-14), followed by hydrothermal flow rate measurement using ultrasonic wave (Fig. 3-15) and installment of the deep-sea electricity generation apparatus (Fig. 3-16). Then, the ROV moved toward Hole C9024A to recover the EMES and install *in-situ* pumice reaction apparatus and electric corrosion proof test box. After Niskin water sampling (red), the EMES-6 installed on a seafloor during the cruise KR18-14 Leg 2 was recovered (Fig. 3-17). Next, two *in-situ* pumice reaction apparatuses were picked up from the ROV platform of Hole C9024A and were put on the same natural hydrothermal vent where the Kuroko-ore cultivation apparatus was installed from cruises KR18-14 Leg 1 to KR20-12 (Fig. 3-18). Metal rod (yellow) was inserted into the seafloor in front of the two *in-situ* pumice reaction apparatuses and its electric potential was measured by using a D-POTE (Fig. 3-19), followed by installment of metal rod box on a seafloor and electric potential measurement by D-POTE. Then, the ROV picked up the electric corrosion proof test box from the ROV platform of Hole C9024A and move to Hole C0013E that is another artificial hydrothermal vent, which is completely clogged now. The electric corrosion proof test box was put on the top of the steel vent pipe of Hole C0013E (Fig. 3-20), and the ROV moved to the eastern flank of the NBC Mound. Here, the EMES-5 installed on a seafloor during the cruise KR18-14 Leg 2 was recovered (Fig. 3-21), followed by Niskin water sampling (green). Finally, seven rock samples were collected by manipulator around the place of EMES-5 (Fig. 3-22) and finished this dive survey.

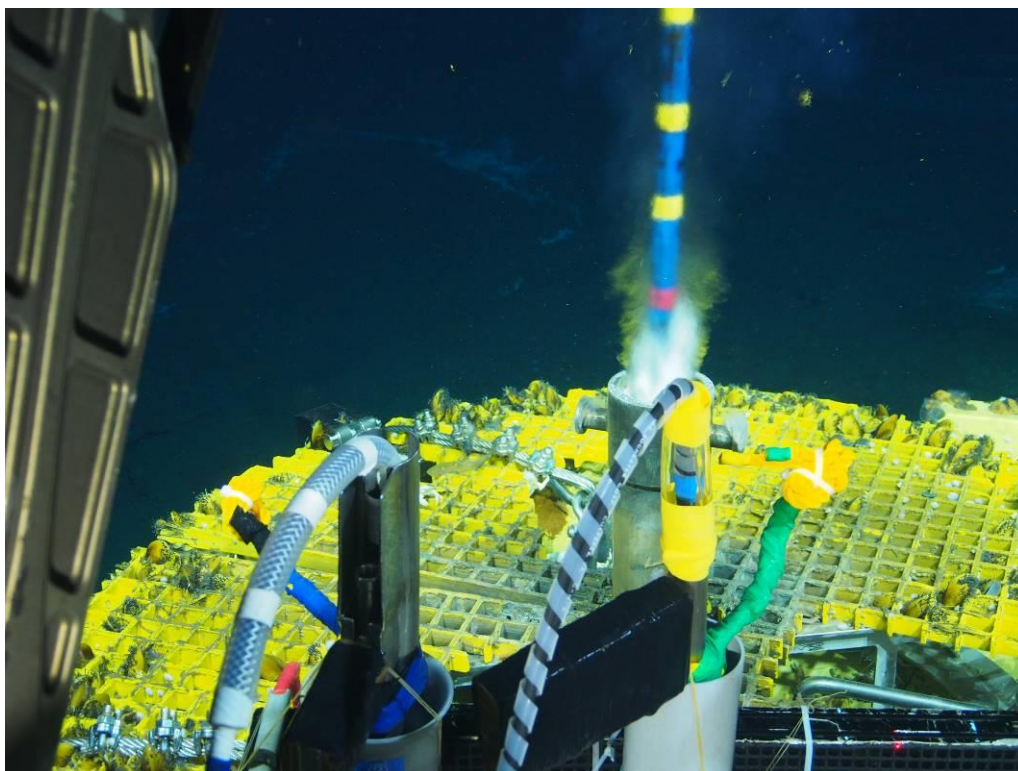


Fig. 3-13 Long pinch bar was inserted into the steel vent pipe of Hole C0014G to pick and remove the scale deposit.

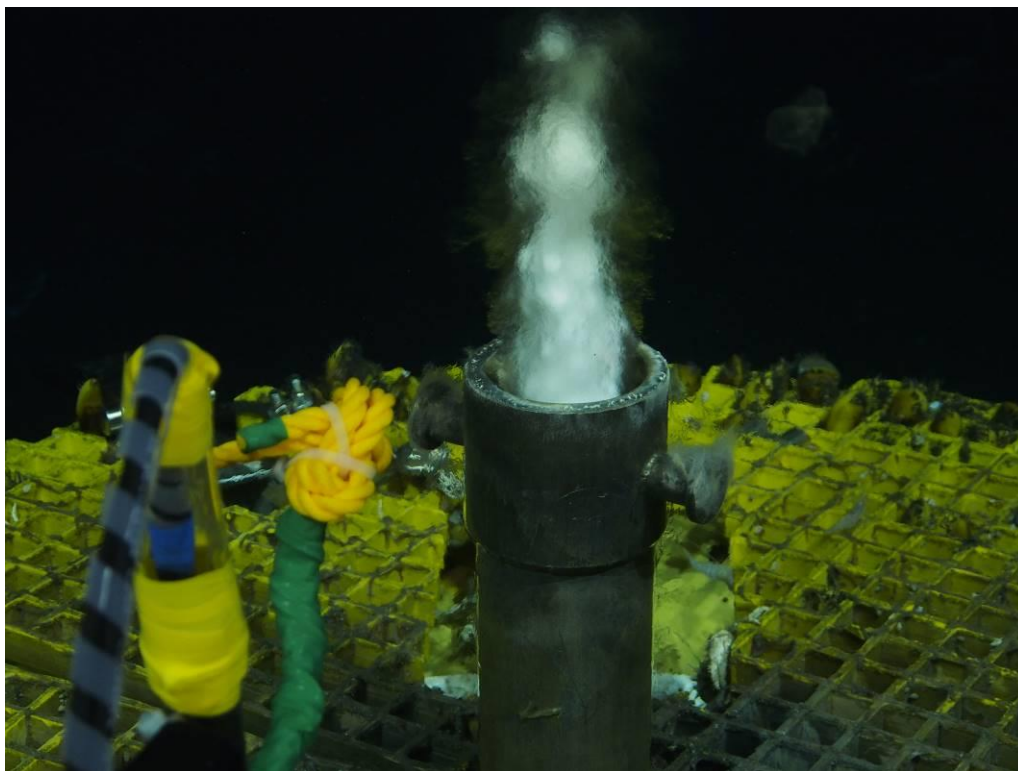


Fig. 3-14 Flame structure of the hydrothermal fluid discharge at Hole C0014G.

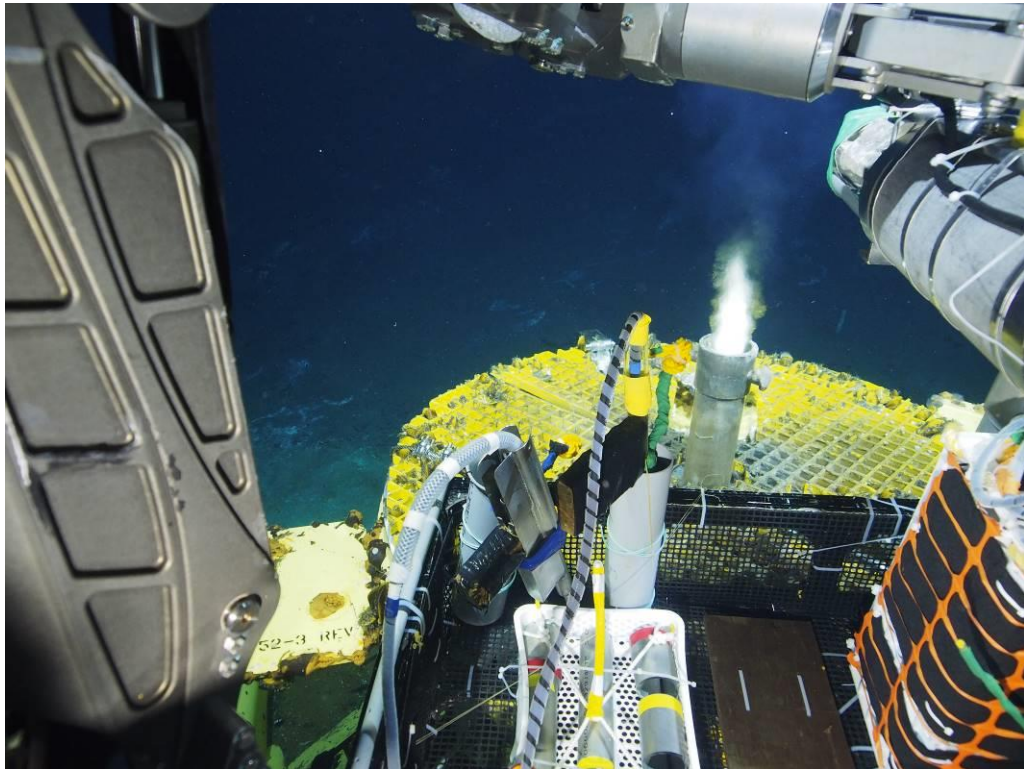


Fig.3-15 Hydrothermal fluid flow rate measurement by using ultrasonic wave.

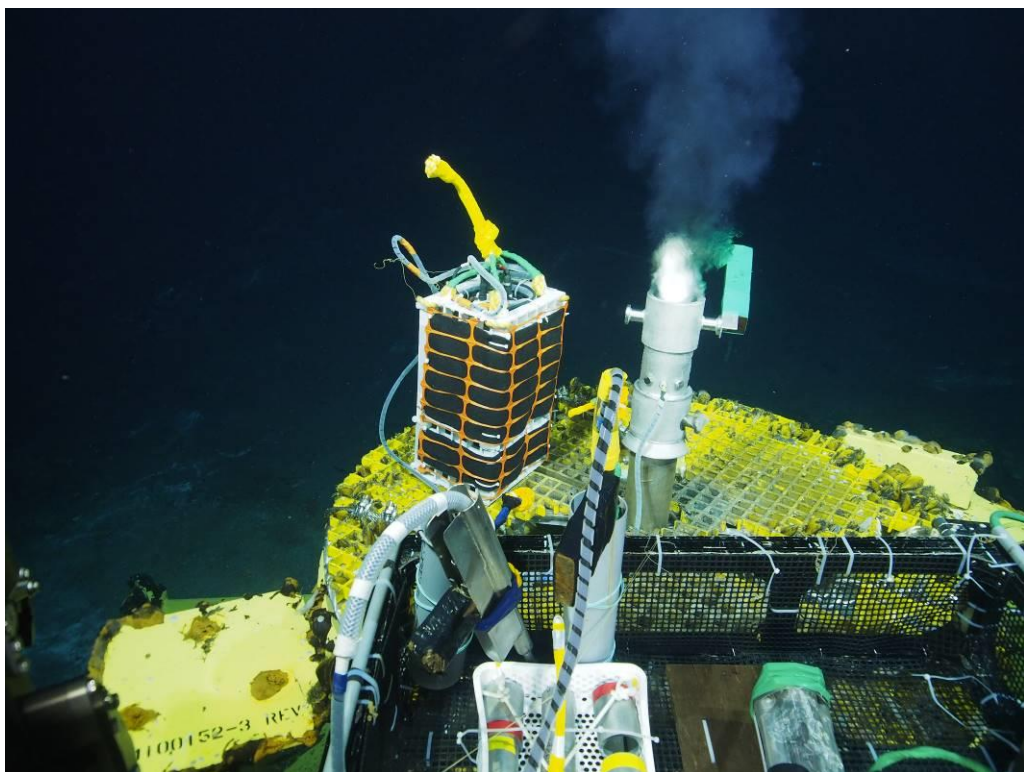


Fig. 3-16 Installment of the deep-sea electricity generation apparatus on the corrosion cap of Hole C0014G.

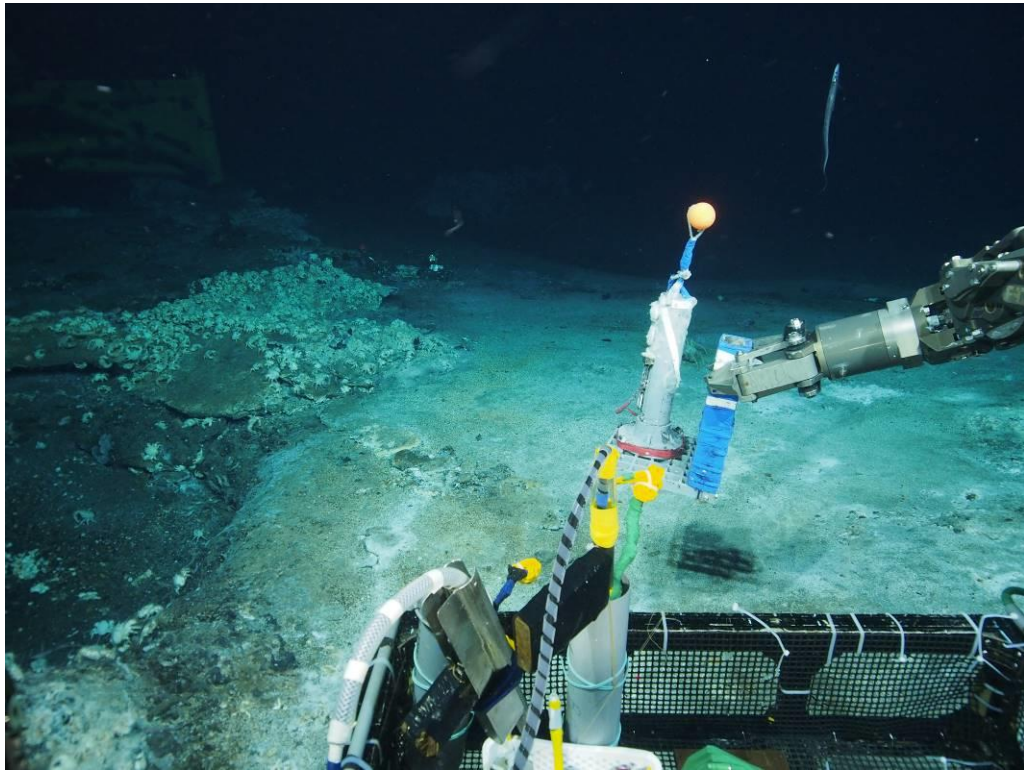


Fig. 3-17 Retrieving the EMES-6 which was put on a seafloor during the cruise KR18-14 Leg 2.

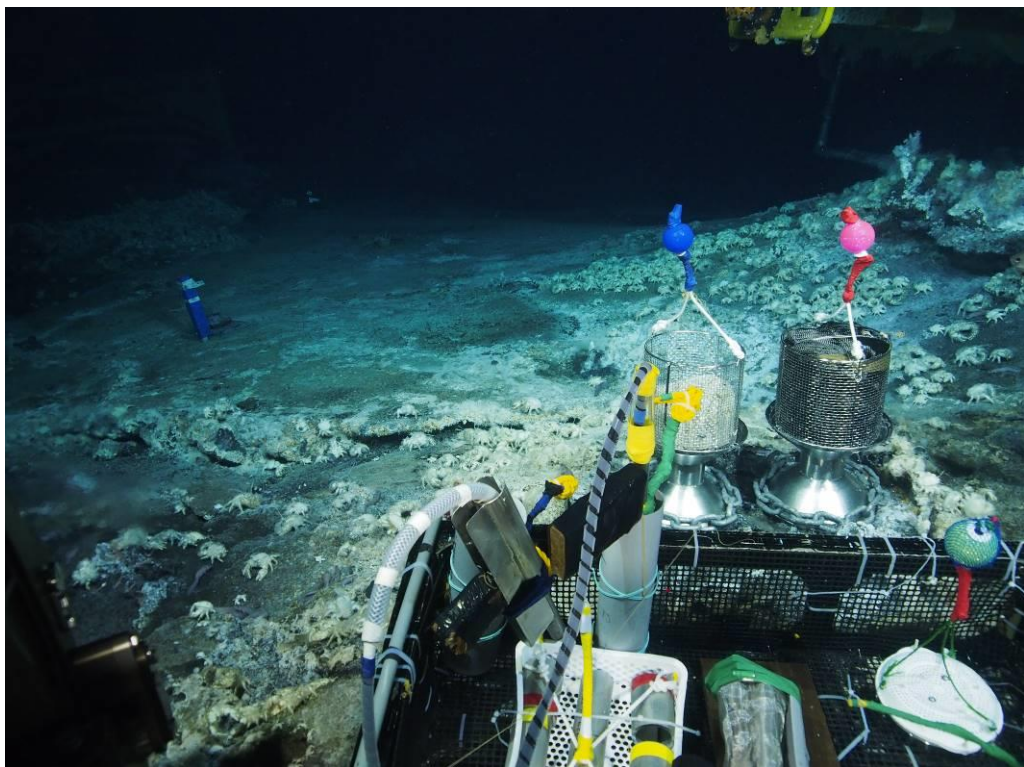


Fig. 3-18 Two *in-situ* pumice reaction apparatuses were put on the same natural hydrothermal vent where the Kuroko-ore cultivation apparatus has been installed.

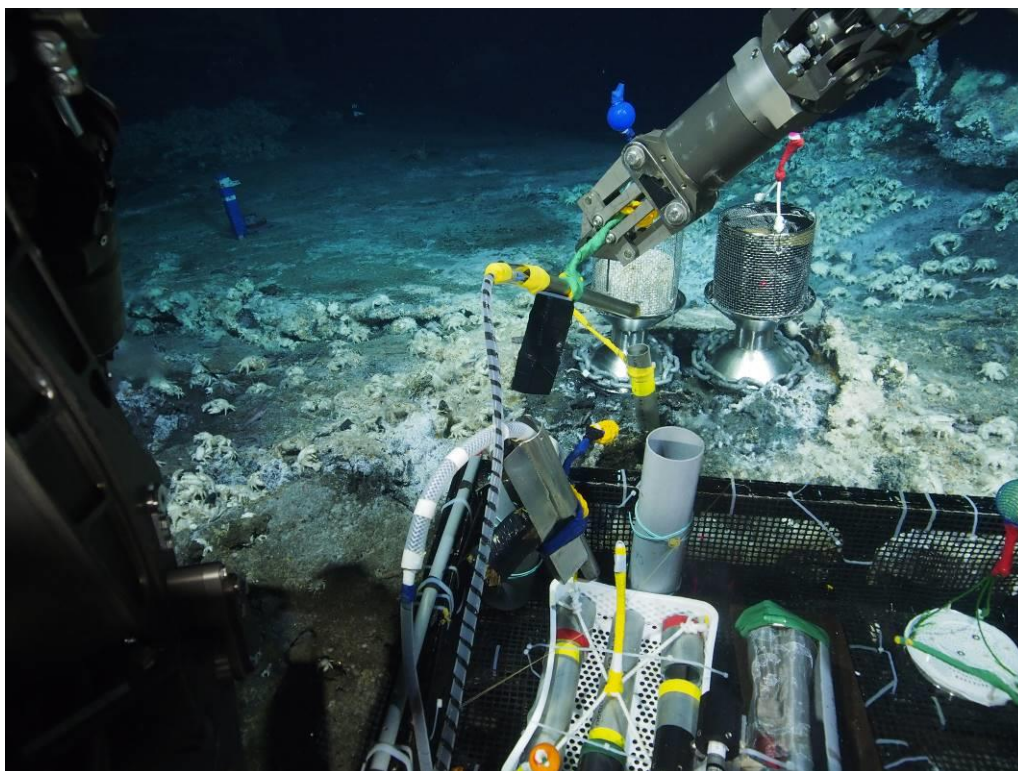


Fig. 3-19 Electric potential of metal rod was measured by D-POTE.

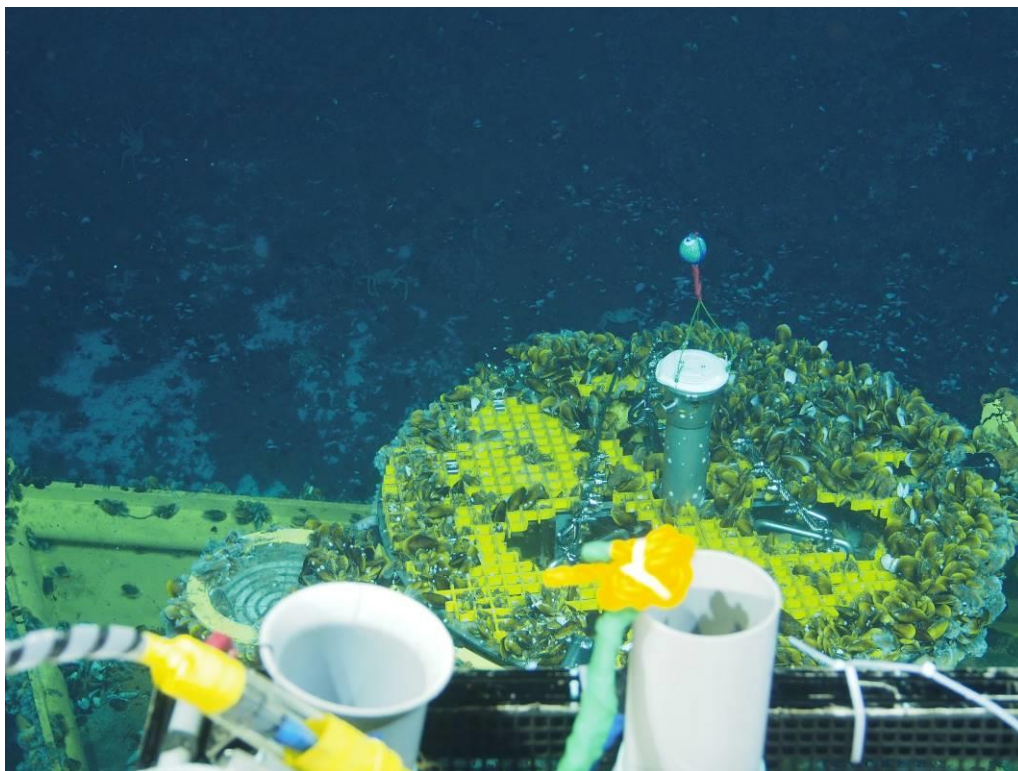


Fig. 3-20 Electric corrosion proof test box was put on the top of the steel vent pipe of Hole C0013E.

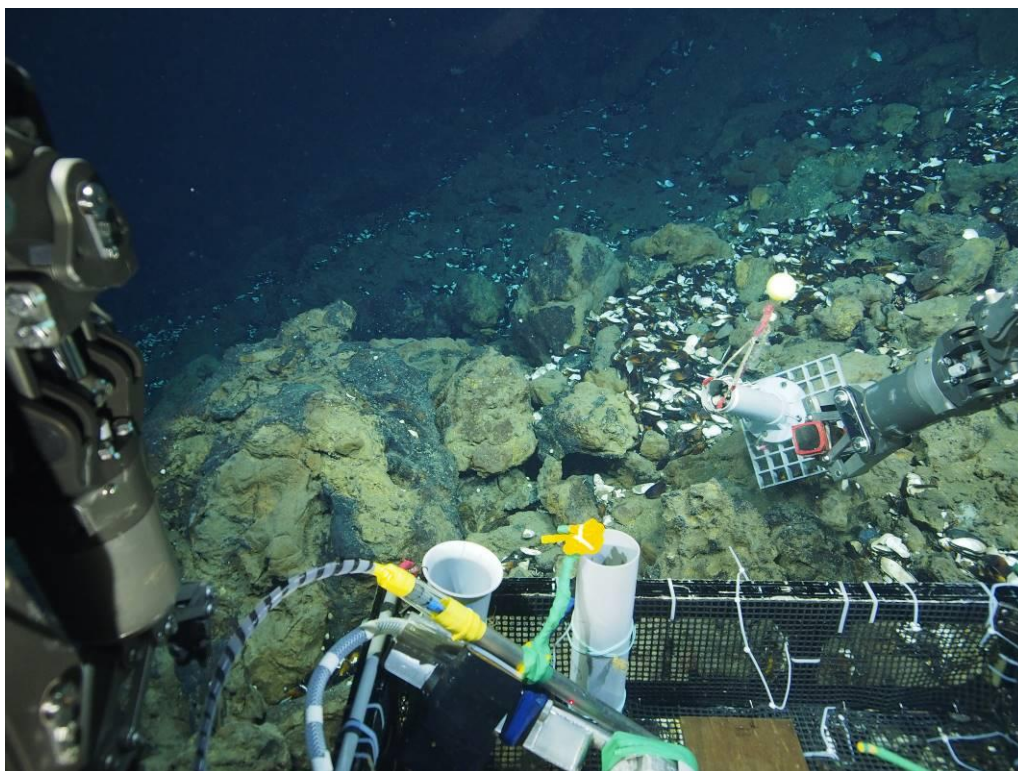


Fig. 3-21 Retrieving the EMES-5 which was put on a seafloor during the cruise KR18-14 Leg 2.



Fig. 3-22 Rock sampling at the eastern flank of the NBC Mound.

4. 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 cruise.

This report is not necessarily corrected even if there is any inaccurate description (i.e. taxonomic classifications). This report is subject to be revised without notice. Some data on this report may be raw or unprocessed. If you are going to use or refer the data on this report, it is recommended to ask the Chief Scientist for latest status.

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