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Interdisciplinary survey on a new type volcanism “petit spot” in northwestern Pacific:

Investigation for the distribution of the melt generation and magma extrusion fields

R/V KAIREI KR07-06, May 6th – 30th 2007
Onboard Cruise Report

Kiyoshi Baba, Natsue Abe, and shipboard scientific party

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Summary

Petit spot is a young volcanic field (< 1 Ma) that discovered on the old (~135 Ma) northwestern Pacific Plate. This volcanism does not belong to any known volcanisms because the field is far from any mid-ocean ridges, subduction zones, nor hotspots previously reported. To understand the petit-spot volcanism, we have been taking multidisciplinary surveys since 2003 by using JAMSTEC research vessels, KAIREI and YOKOSUKA (KR03-07, KR04-08, YK05-06, KR05-10, and KR06-03 cruises). Based on the analysis of the rocks sampled by these cruises, Hirano *et al*. (2006) proposed a hypothesis of the petit spot forming process that flexure of Pacific Plate near Japan Trench causes cracks in the lithosphere leading upwelling of melt from the asthenosphere. This hypothesis suggests that direct cause of the melt generation and the magma extrusion may be different and it should be examined by further observations.

The observation in this cruise aims to investigate two fields; the melt generation field and the magma extrusion field, through a multidisciplinary collaboration. The multidisciplinary survey consists of rock sampling using a remote operated vehicle (ROV) KAIKO 7000 II, seafloor electromagnetic and seismic surveys using ocean bottom electromagnetometers (OBEMs) and broad band ocean bottom seismometers (BBOBSs), heat flow measurement, and surface geophysical mapping. The rock sampling at KAIKO knolls in ocean ward slope of the Japan Trench can provide us further information about the extrusion ages and the chemical composition of the magma. The seafloor electromagnetic survey images electrical conductivity structure of the asthenosphere. These observations contribute the investigation of the extent and the physical and chemical status of the melt generation fields. The seafloor seismic survey attempts to detect earthquakes that occur in petit spot area, which contributes the investigation of the magma extrusion field at present. It is also useful for the investigation of the melt generation field through the analysis of teleseismic signals. The crustal heat flow measurements along a line connecting the petit spot area and KAIKO knolls seek thermal anomaly associated with the petit spot volcanic activity, which will constrain the history of the magma extrusion field. The mapping of bathymetry and back scatter intensity by multi-narrow beam sounding system seeks further petit spot volcanoes. The distribution of the volcanoes is fundamental information for investigating the both the melt generation and magma extrusion fields. The surface gravity and geomagnetic field measurements contribute a study for background crustal tectonics. The correlation between the magma extrusion fields and the background crustal tectonics can be investigated.

The cruise was scheduled from May 6 (departing Yokohama) to May 30 (reaching to Kamaishi). We carried out the most part of the surveys for the 25 days. The KAIKO 7000 II dives were proposed at four points and were successfully carried out at three of them. The other point was canceled because of bad sea condition. Fresh basaltic rocks, which are similar to the

petit spot alkali-basalts previously collected, were sampled abundantly from the three points. The OBEMs were successfully deployed by free fall at three sites. Their position on the seafloor was detected by acoustic measurements of the slant ranges at three points. One OBEM, which was deployed in May 2005, was tried to recover during this cruise. However, the recovery was failed because the OBEM did not respond to acoustic signals from the ship. The BBOBSs were deployed by free fall at three sites and the settled positions were successfully calibrated by the acoustic measurement. One BBOBS was not deployed because of an instrumental accident although the observation at four sites was planned originally. The seafloor electromagnetic and seismic observations continue for one year and the instruments will be recovered in 2008. The heat flow measurements were attempted at 10 sites on the survey line and succeeded at eight sites. Measurement at one site was canceled due to bad sea condition although 11 sites were planed. At three sites, sediment cores were also sampled using Piston Core system. Surface geophysical data (bathymetry, gravity, and geomagnetic field) were collected in the area near the survey sites described above and on the way of the transit although we couldn’t cover whole the planned area because of bad sea condition. No petit spot like volcano was discovered but some seamounts that larger than typical petit spot volcanoes and seem to be covered with sediments.

1. Research project

1-1. Background

Petit spot is a new type volcanic activity that discovered on the seafloor at 37.5°N, 150°E in the northwestern Pacific. The first discovery was in the ocean ward slope of Japan Trench in 1997. Basaltic rocks were sampled from knolls (KAIKO knolls) and fault escarpments and dated about 6 Ma, which is much younger than the age of background oceanic crust (~135 Ma) (Hirano *et al*., 2001). Then, small knolls were discovered in an area tracked back with the age along the Pacific Plate motion and a very young basaltic rock (< 1 Ma) was dredged from one of these knolls by following two cruises in 2003 (KR03-07) and 2004 (KR04-08) (Figure 1-1.1). These knoll were named “petit spot” because their sizes, which are so small that multi-narrow beam sounding system is necessary to discover them, and they locates far from known plate boundaries and hot spots.

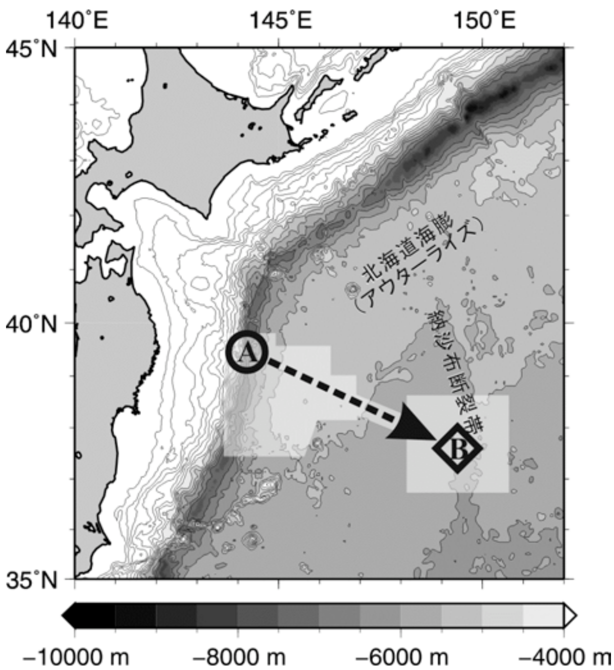

Figure 1-1.1. Bathymetry map of northwestern Pacific. A: KAIKO knolls that the young basalts were first discovered. B: the petit spot area that the youngest basalt was sampled. Shaded area indicates that bathymetry data have been obtained using multi-narrow beam sounding.

The petit spot is not belong to any known volcanisms and hence it have been questioned how the basaltic melt was generated and how it extrude on the seafloor in this area. Even the distribution or extent of the petit spot volcanoes is not fixed because the detailed bathymetry data has been limited in northwestern Pacific. Thus, we initiated a multidisciplinary collaborative study to investigate the petit spot forming process. In 2005, we had two cruises (YK05-06 and KR05-10) and carried out rock sampling at KAIKO knolls and knolls in petit spot area by a submersible vessel SHINKAI 6500, surface geophysical mapping (bathymetry, back scatter intensity, gravity, and geomagnetic field), single channel seismic survey of the petit spot knolls, and seafloor magnetotelluric survey.

1-2. Results obtained by previous studies

Distribution of the petit spot volcanoes

The petit spot volcanoes are neither equally distributed in northwestern Pacific nor distributed continuously along the line between the KAIKO knolls and the petit spot area. However, some knolls trend to align along the Pacific plate motion (Hirano *et al*., 2006).

Ages of the alkali basalts

The basalts obtained from KAIKO knolls dated 4.2, 6.0, and 8.5 Ma. Tracking backed these ages, the estimated extrusion positions are distant about 200 km each other. The age of the basalt obtained from a knoll of the petit spot area is 0.05~1.0 Ma (Hirano *et al*., 2006).

Seismic activity

Several earthquakes with magnitude of 3–5 were detected in the petit spot area for recent 30 years, according to the data collected in Japan Meteorological Agency. The positions of hypocenters are ~10 km distant from the petit spot knolls but approach to the knolls when hypocenters are reanalyzed using more realistic velocity structure for the oceanic crust and uppermost mantle.

Noble gas compositions

The petit spot basalt samples are higly radiogenic in noble gas isotope compositions, suggesting a similar source to that of mid-ocean ridge basalts (MORBs) (Hirano *et al*., 2006). Xenoliths composed of peridotite and basalt are also consistent with the MORB source origin (Yamamoto *et al*., 2003; Shimizu *et al*., 2007).

Sr, Nd, and Pb isotopes

The composition of Sr, Nd, and Pb isotopes obtained from the petit spot basalts show a feature similar to Dupal anomaly reported for basalts sampled in Indian Ocean and southern Atlantic Ocean. It is the first discover for north Pacific except for the hot spot region and suggests heterogeneous upper mantle (Machida *et al*., 2007).

Geothermal structure

Geothermal gradient obtained from the analysis of xenolith in the petit spot basalt indicates is much higher than the gradient predicted from GDH1 model (Stein and Stein, 1992).

Crustal heat flow

In ocean ward slope of Japan Trench, where is close to KAIKO knolls, anomalous heat flow values were observed, which is higher than the value for typical lithosphere older than 100 Ma (Yamano and Goto, 1999).

Electrical conductivity structure

Electrical conductivity beneath the petit spot area shows high conductivity peak at about 200 km depth. The conductivity value can be explained by temperature lower than both for dry and wet solidi of garnet peridotite.

Seismic velocity structure

Cross sections of the petit spot volcanoes were depicted through single channel seismic reflection survey (Fujiwara *et al*., 2006). A global P-wave tomography study detected a low velocity anomaly beneath the northwestern Pacific at about 400 km depth (Obayashi *et al*., 2006). The relation between the anomaly and the petit spot is not clear because of poor resolution of the tomography for the upper mantle.

1-3. Models of the petit spot formation

Hirano *et al*. (2001; 2006) proposed a hypothesis of the petit spot forming process that flexure of Pacific Plate near Japan Trench causes cracks in the lithosphere leading upwelling of melt from the asthenosphere. This hypothesis suggests that direct cause of the melt generation and the magma extrusion may be different and it should be examined by further observations.

The melt generation process possibly caused by following four cases (Figure 1-3.1); A) Everywhere of the asthenosphere is in condition that partial melt occur, B) The asthenospheric flow contains upward component due to the lithospheric flexure forming outer rise and the mantle is partially molten by the pressure release, C) The mantle is heterogeneous and only materials having lower solidus are partially molten., and D) There is a dynamic upwelling from deep in the mantle beneath the petit spot area.

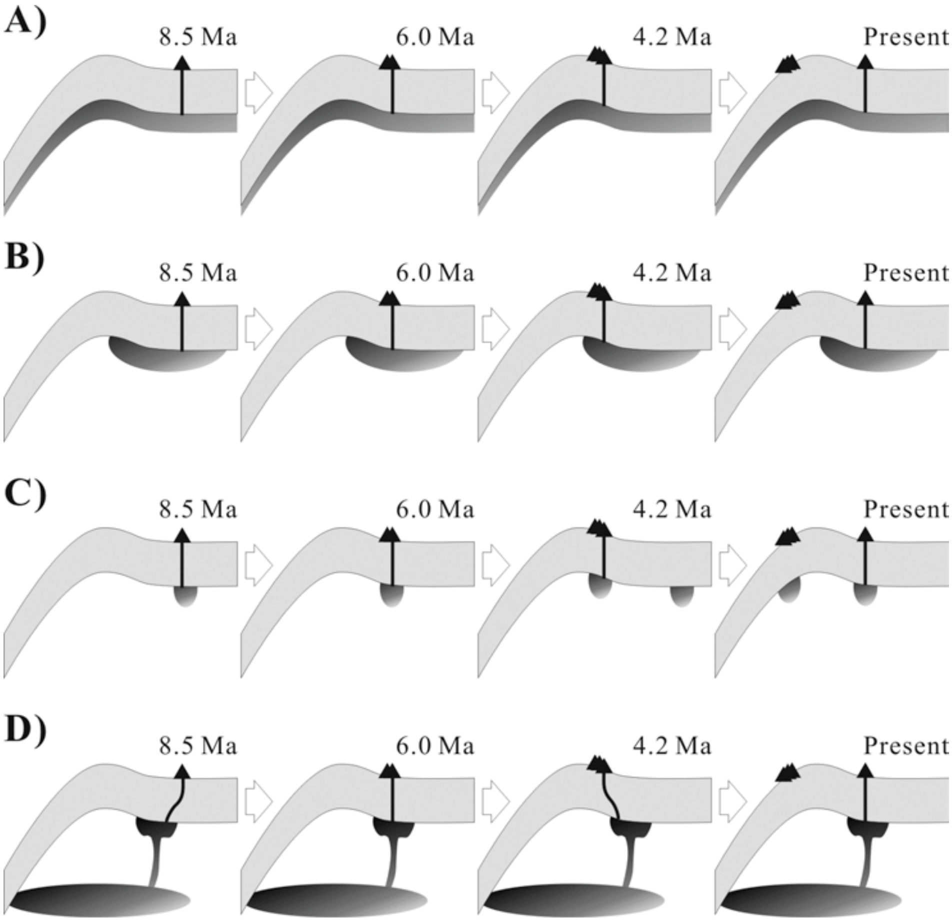

Figure 1-3.1. Four possible models to generate partial melt beneath the petit spot area.

The results of petrologic analysis indicate that the petit spot basalt was formed by melting depleted mantle as for MORB (e.g. Hirano *et al*., 2006) is not consistent with model D. The extent of magma extrusion field reconstructed from the ages of the basalts sampled in KAIKO knolls (> 400 km) is extremely large compared with typical hot spots. The electrical conductivity beneath the petit spot area indicates no partial melt under an assumption of dry peridotite. Geodynamics modeling showed that the mantle can be partially molten by model B when the mantle contains 0.01 wt% of water (Takahashi, 2007). The electrical conductivity model requires only 0.001 wt% of water and no partial melt when GDH1 for temperature is assumed although the effect of water on electrical conductivity of olivine is still controversial (Yoshino et al., 2006; Wang et al., 2006). Anomaly of Sr, Nd, and Pb isotopes in the basalt suggests model C. Model C is acceptable for the electrical conductivity.

Questions exist for the application of the hypothesis by Hirano et al. (2006) to the magma extrusion field. If the plate flexure makes the cracks that melt can rise up, there should be volcanoes continuously between KAIKO knolls and the petit spot area. Also, volcanoes may distribute equally in the 200~600 km ocean ward of the outer rise. However, no petit spot like volcanoes is discovered in such fields although the fine scale bathymetry and back scatter intensity maps are limited. There is a possibility that the magma extrusion is also associated with surface tectonic conditions. Combination of stress concentration due to the plate flexure and proximity to weak region of the lithosphere like fracture zone may work to form pass ways for the melt upwelling.

1-4. Research plan

The petit spot forming process is still controversial as seen in the previous section and hence further multidisciplinary investigation is required to obtain conclusions. The observation in this cruise aims to investigate the two fields; the melt generation field and the magma extrusion field. The multidisciplinary survey consists of rock sampling using a remote operated vehicle (ROV) KAIKO 7000 II, seafloor electromagnetic and seismic surveys using ocean bottom electromagnetometers (OBEMs) and broad band ocean bottom seismometers (BBOBSs), heat flow measurement, and surface geophysical mapping.

The rock sampling at KAIKO knolls in ocean ward slope of the Japan Trench can provide us further information about the extrusion ages and the chemical composition of the magma. The seafloor electromagnetic survey images electrical conductivity structure of the asthenosphere. These observations contribute the investigation of the extent and the physical and chemical status of the melt generation fields. The seafloor seismic survey attempts to detect earthquakes that occur in petit spot area, which contributes the investigation of the magma extrusion field at present. It is also useful for the investigation of the melt generation field through the analysis of teleseismic signals. The crustal heat flow measurements along a line connecting the petit spot area and KAIKO knolls seek thermal anomaly associated with the petit spot volcanic activity, which will constrain the history of the magma extrusion field. The mapping of bathymetry and back scatter intensity by multi-narrow beam sounding system seeks further petit spot volcanoes. The distribution of the volcanoes is fundamental information for investigating the both the melt generation and magma extrusion fields. The surface gravity and geomagnetic field measurements contribute a study for background crustal tectonics. The correlation between the magma extrusion fields and the background crustal tectonics can be investigated.

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2. Cruise log

2-1. Survey area

The survey area proposed for the experiment is a square area in northwestern Pacific bounded by 33°N, 40°N, 143°E, and 156°E (Figure 2-1.1). The youngest petit spot volcanoes locate in the central area of Box 1 while KAIKO knolls that the ages were 4~8.5 Ma (Hirano *et al*., 2006) locate in the western end of the Box 1.

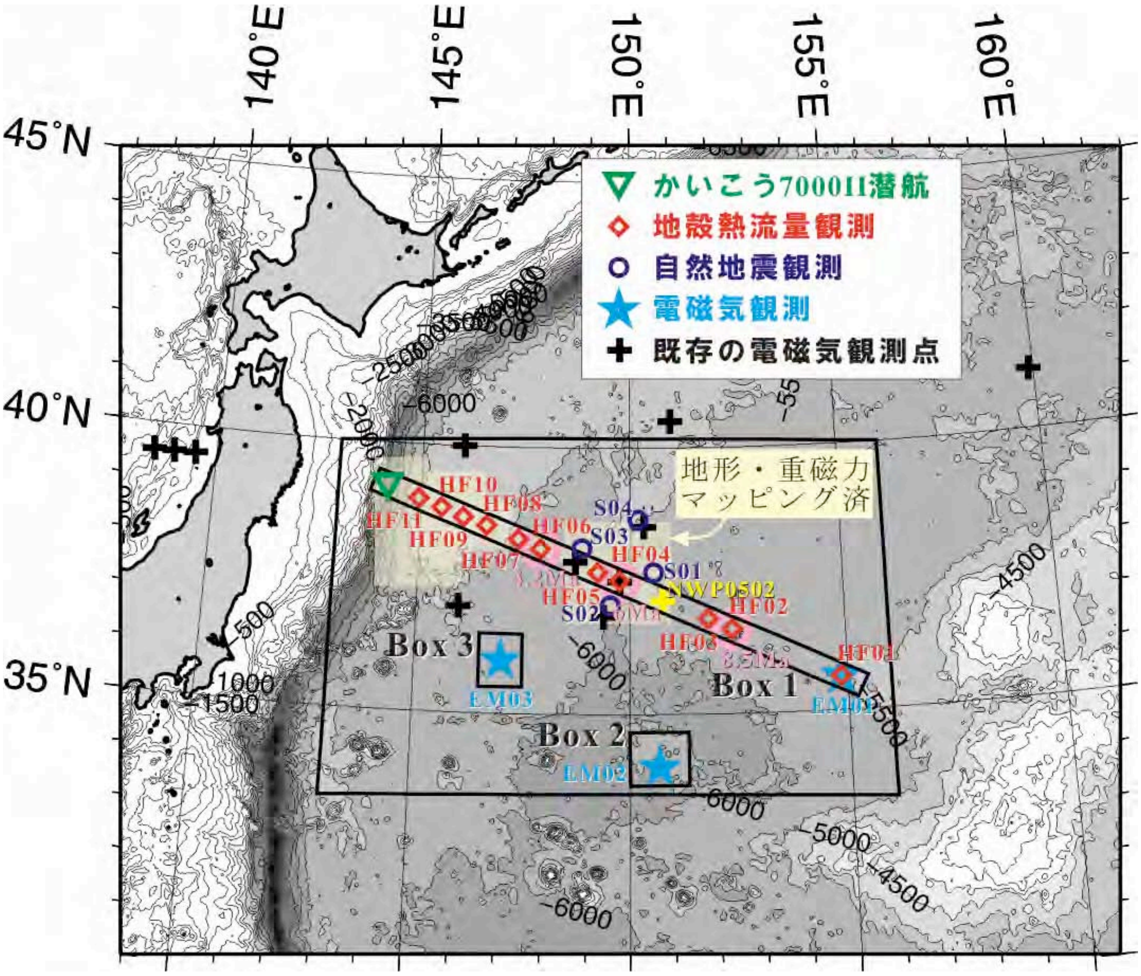

Figure 2-1.1. Bathymetry map and survey area. Box1, 2, and 3 indicate the area proposed for detailed surface geophysical mapping. Green triangle, red diamonds, dark blue circles, and light blue starts are proposed KAIKO 7000II dive point, heat flow measurement sites, BBOBS deployment sites, and OBEM deployment sites, respectively. Yellow cross is OBEM recovery sites and the other crosses are OBEM sites that data were acquired in past experiments. Yellow shaded zone indicates the area that the surface geophysical mapping data were collected in the past cruises (KR03-07, KR04-08, YK05-06, and KR05-10).

2-2. Operation log

R/V KAIREI departed Yokohama port on May 6, operated the experiments in Box 3, 2, and 1, called at Kamaishi port on May 24 for embarkation of KAIKO 7000II operating team, and then carried out the dives, and returned to Kamaishi port on May 30. The ship track of the cruise is shown in Figure 2-2.1 and the detailed operation log was listed in Table 2-2.1.

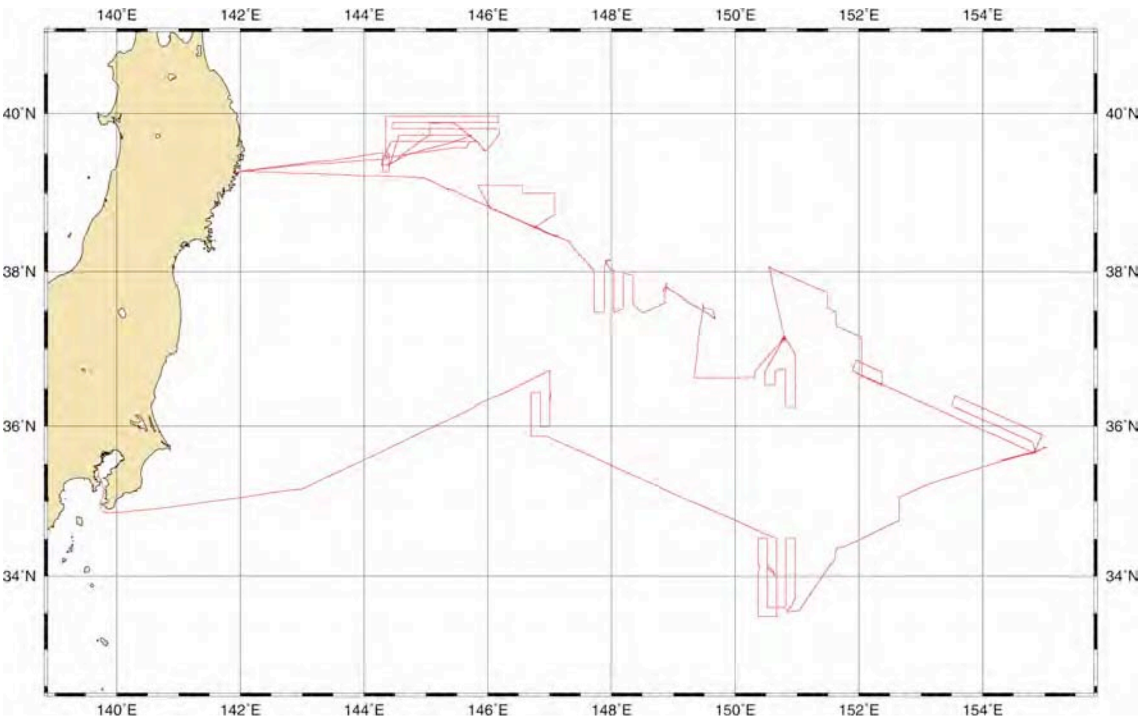

Figure 2-2.1. Ship track of KR07-06 cruise.

Table 2-2.1. Operation log of KR07-06 cruise.

Shipboard Log & Ship Track(KR0706 07/5/6 - 07/5/30)				
Date	Time	Description	Remark	Position / Weather / Wind / Sea condition (Noon)
06,May,07	9:00 10:00 12:00 14:00	embarkation science group departure from anchored at Yokosuka port section 4 on board seminar	for safety KAIREI life	5/6 12:00 35-20N, 139-40E rain SSW-3(Gentle breeze) Sea smooth
07,May,07	5:55 16:30 16:35	recovered anchor arrived at research area released XBT	35-05.0972N,142-21.4063E D=1830m	5/7 12:00 34-57N, 141-00E over cast

	16:40 0:00	set on Proton magnetometer shift ship's clock -1 hour	300m cable length	N-2(Light breeze) Sea smooth
08,May,07	8:47～10:40 10:51 11:23 11:33～12:05 13:27～14:57 15:06 15:20 18:30～19:30	carried out MBES mapping survey recovered Proton magnetometer deployed OBEM(EM03) carried out calibration for OBEM carried out calibration for OBEM set on Proton magnetometer commenced MBES mapping survey scientific meeting		5/8 12:00(JST+1h) 36-26N, 147-01E fine NW-2(Light breeze) Sea smooth
09,May,07	18:30～19:30 0:00	scientific meeting shift ship's clock -30 minutes		5/9 12:00(JST+1h) 34-51N, 149-44E fog SSE-3(Gentle breeze) Sea smooth
10,May,07	8:33 8:41 9:24 9:27～10:00 11:57～13:34 13:42 13:47～14:00 14:30 18:00 18:30～19:30	recovered Proton magnetometer finished MBES mapping survey deployed OBEM(EM02) carried out calibration for OBEM carried out calibration for OBEM set on Proton magnetometer figure eight turn commenced MBES mapping survey recovered Proton magnetometer scientific meeting	Magnetic calibration	5/10 12:00(JST+1.5h) 34-01N, 150-38E fine SE-5(Fresh breeze) Sea slight
11,May,07	9:00～10:00 18:30～19:30	on board seminar scientific meeting		5/11 12:00(JST+1.5h) 33-36N, 150-55E rain SSW-8(Gale) Sea rough

12,May,07	15:21 17:38～17:39 18:30～19:30	deployed OBEM(EM01) carried out calibration for OBEM scientific meeting		5/12 12:00(JST+1.5h) 35-41N, 154-56E fine SW-7(Near breeze) Sea rough
13,May,07	7:09～7:35 8:39 16:43 18:30～19:30	carried out SBP mapping survey commenced MBES mapping survey set on Proton magnetometer scientific meeting		5/13 12:00(JST+1.5h) 35-58N, 154-20E fine WNW-5(Fresh breeze) Sea rough
14,May,07	6:47 6:45 7:12 8:15～12:36 12:45 13:10 18:30～19:30	recovered Proton magnetometer released XBT finished MBES mapping survey carried out heat flow piston core sampling(HF01) set on Proton magnetometer commenced MBES mapping survey scientific meeting		5/14 12:00(JST+1.5h) 35-39N, 154-49E fine SSW-4(Moderate breeze) Sea smooth
15,May,07	5:24 5:24～5:41 6:38～11:12 13:08～17:31 17:44 17:58 18:30～19:30	finished MBES mapping survey carried out SBP mapping survey carried out heat flow(HF02) carried out heat flow(HF03) set on Proton magnetometer commenced MBES mapping survey scientific meeting		5/15 12:00(JST+1.5h) 36-36N, 152-13E overcast S-4(Moderate breeze) Sea slight
16,May,07	5:28 5:32 6:03	finished MBES mapping survey recovered Proton magnetometer deployed BBOBS(S04)		5/16 12:00(JST+1.5h) 37-13N, 150-46E overcast

	6:58～8:20 12:32 13:33～14:40 14:43 14:52 18:30～19:30	carried out calibration for BBOBS deployed BBOBS(S01) carried out calibration for BBOBS set on Proton magnetometer commenced MBES mapping survey scientific meeting		NNW-7(Near gale) Sea rough
17,May,07	6:54 6:57 7:15～11:19 11:41 15:44 18:03 18:30～19:30	recovered Proton magnetometer finished MBES mapping survey searched for OBEM by SSBL lowered relay unit recovered relay unit set on Proton magnetometer scientific meeting		5/17 12:00(JST+1.5h) 37-08N, 150-47E overcast SE-4(Moderate breeze) Sea smooth
18,May,07	7:59 8:03 8:40 9:48～11:03 0:00	recovered Proton magnetometer finished MBES mapping survey deployed BBOBS(S02) carried out calibration for BBOBS shift ship's clock +30 minutes		5/18 12:00(JST+1.5h) 37-30N, 149-38E overcast SSW-5(Fresh breeze) Sea moderate
19,May,07	8:10～8:43 9:10～13:40 13:48 14:20 18:30～19:30	carried out MBES SBP mapping survey carried out heat flow piston core sampling(HF05) set on Proton magnetometer commenced MBES mapping survey scientific meeting		5/19 12:00(JST+1h) 37-49N, 148-52E overcast S-4(Moderate breeze) Sea smooth
20,May,07	5:49 6:18 6:33～11:40 11:50 18:30～19:30	recovered Proton magnetometer finished MBES mapping survey carried out heat flow(HF06) scientific meeting scientific meeting		5/20 12:00(JST+1h) 38-08N, 147-55E overcast NW-6(Strong breeze) Sea rough

	21:27	finished MBES mapping survey		
21,May,07	11:20～11:40 12:35～17:05 17:13 17:23 18:30～19:30	carried out MBES SBP mapping survey carried out heat flow(HF09) set on Proton magnetometer commenced MBES mapping survey scientific meeting		5/21 12:00(JST+1h) 38-49N, 146-02E fine N-4(Moderate breeze) Sea slight
22,May,07	5:39～5:54 5:55 6:00 6:15～11:23 14:15～18:51 19:02 19:09～19:21 19:30～20:00	carried out SBP mapping survey finished MBES mapping survey recovered Proton magnetometer carried out heat flow(HF08) carried out heat flow(HF07) set on Proton magnetometer figure eight turn scientific meeting		5/22 12:00 38-31N, 146-53E fine S-3(Gentle breeze) Sea smooth
23,May,07	5:34～6:01 6:00 6:06 6:21～11:17 13:17～17:20 17:20 19:30～20:00	carried out SBP mapping survey recovered Proton magnetometer finished MBES mapping survey carried out heat flow(HF10) carried out heat flow piston core sampling(HF11) commenced proceeding to Kamaishi scientific meeting		5/23 12:00 39-07N, 145-12E fine WSW-4(Moderate breeze) Sea smooth
24,May,07	6:30 9:10 13:00～13:30 16:10 18:30～19:00	anchored at Kamaishi port section 2 embarked and disembarked science group on board seminar recovered anchor scientific meeting	for KAIKO operation	5/24 12:00 39-15N, 141-54E fine W-3(Gentle breeze) Gentle breeze

25,May,07	2:02 2:51～6:10 7:28 7:35 18:30～19:30 23:58	released XBT carried out MBES mapping survey commenced MBES mapping survey set on Proton magnetometer scientific meeting recovered Proton magnetometer		5/25 12:00 39-58N, 144-45E overcast ESE-7(Near gale) Sea rough
26,May,07	13:19 15:17 18:30～19:30	set on Proton magnetometer commenced MBES mapping survey scientific meeting		5/26 12:00 39-36N, 145-53E fog NNW-5(Strong breeze) Sea slight
27,May,07	6:54 7:11 8:34 8:39 11:12 12:30 14:55 15:07 15:53 16:11 18:30～19:00	recovered Proton magnetometer finished MBES mapping survey launched 7K II started 7K II #385 dive arrived at bottom leave the bottom surfaced 7K II recovered 7K II set on Proton magnetometer commenced MBES mapping survey scientific meeting	D=6817m D=6756m	5/27 12:00 39-20N, 144-24E overcast ENE-7(Neal gale) Sea moderate
28,May,07	6:50 6:43 8:26 8:31 11:04 13:43 15:57 16:06 16:48 17:03 18:30～19:00	recovered Proton magnetometer finished MBES mapping survey launched 7K II started 7K II #386 dive arrived at bottom leave the bottom surfaced 7K II recovered 7K II set on Proton magnetometer commenced MBES mapping survey scientific meeting	D=6909m D=6741m	5/28 12:00 39-23N, 144-18E fine NNW-5(Strong breeze) Sea moderate

29,May,07	6:45 7:13 8:26 8:32 11:02 13:38 15:51 15:59 16:30	recovered Proton magnetometer finished MBES mapping survey launched 7KⅡ started 7KⅡ#387 dive arrived at bottom leave the bottom surfaced 7KⅡ recovered 7KⅡ left research area for KAMAISHI	D=6909m D=6824m	5/29 12:00 39-27N, 144-22E fine S-3(Gentle breeze) Sea smooth
30,May,07	9:00 12:00	arrived at KAMAISHI left the ship and concluded KR0706	KR0706 scientists	

3. Participants

3-1. Onboard scientists

Kiyoshi Baba	Chief Scientist Earthquake Research Institute, the University of Tokyo
Natsue Abe	Vice-chief Scientist Institute for Research on Earth Evolution, Japan Agency for Marine-Earth Science and Technology
Naoto Hirano	Graduate School of Science, the University of Tokyo
Shiki Machida	Ocean Research Institute, the University of Tokyo
Teruaki Ishii	Hukada Geological Institute
Hideki Hamamoto	Earthquake Research Institute, the University of Tokyo
Hiroko Sugioka	Institute for Research on Earth Evolution, Japan Agency for Marine-Earth Science and Technology
Azusa Shito	Graduate School of Science, the University of Tokyo
Aki Ito	Institute for Research on Earth Evolution, Japan Agency for Marine-Earth Science and Technology
Ayu Takahashi	Graduate School of Science, the University of Tokyo
Taisuke Isobe	Graduate School of Science, Chiba University
Takahiro Yoshida	Graduate School of Science, Chiba University
Yuuki Koike	Institute for Research on Earth Evolution, Japan Agency for Marine-Earth Science and Technology
Naotaka Togashi	Marine Works Japan Co., Ltd.
Yohei Taketomo	Marine Works Japan Co., Ltd.
Ei Hatakeyama	Marine Works Japan Co., Ltd.
Satoshi Okada	Nippon Marine Enterprise Co., Ltd.

3-2.KAIKO7000Ⅱ　Operation team

Kazuyoshi Hirata	Chief ROV Operator
Tetsuya Komuku	1st ROV Operator
Atsumori Miura	2nd ROV Operator
Kiyoshi Takishita	2nd ROV Operator
Homare Wakamatsu	2nd ROV Operator
Hidek i Sezoko	2nd ROV Operator
Keigo Suzuki	2nd ROV Operator
Seiji Shigetake	3rd ROV Operator
Yudai Sakakibara	3rd ROV Operator

Yudai Tayama	3rd ROV Operator

3-3.KAIREI Crew

Sadao Ishida	Captain
Takafumi Aoki	Chief Officer
Isao Maeda	2nd Officer
Jyun Takao	3rd Officer
Kiyonori Kajinishi	Chief Engineer
Kazuhiko Kaneda	1st Engineer
Naoyuki Takahara	2nd Engineer
Takafumi Tominaga	3rd Engineer
Masamoto Takahashi	Chief Electronics Operator
Kenji Takakusu	2nd Electronics Operator
Yosuke Komaki	3rd Electronics Operator
Kingo Nakamura	Boat Swain
Kiyotugu Hosokawa	Able Seaman
Yoshiaki Kawamura	Able Seaman
Takao Kubota	Able Seaman
Tadahiko Toguchi	Able Seaman
Hiroaki Murase	Sailor
Myuta Yamazaki	Sailor
Kazuaki Nakai	No.1 Oiler
Kozo Miura	Oiler
Hiroyuki Ohishi	Oiler
Shota Watanabe	Oiler
Shota Tatsuki	Oiler
Kyoichi Hirayama	Chief Steward
Hideo Hukumura	Steward
Isao Matsumoto	Steward
Yukihide Chikuba	Steward
Tadayuki Takatsu	Steward
Ken Yamaguchi	Trainee Electronics Operator
Nao Ishizuka	Trainee Sailor
Kazuki Bandoh	Trainee Oiler
Norihito Izumi	Trainee Steward
Ryo Hujimoto	Trainee Steward

4. Observations

4-1. Surface geophysical surveys

4-1-1. Bathymetry and back scatter intensity

N. Hirano, T. Yoshida and K. Baba

System Overview

Bathymetric data were collected by a multi-beam echo sounder system, SeaBeam 2112.004 (L-3 Communications SeaBeam Instruments, Figure 4-1-1.1). SeaBeam 2112.004 collects bathymetric and side scan data to deep sea over a wide swath of up to 140. The system has sub-bottom profiler using 4 kHz echo. There are three UNIX-based workstations and one Windows-based personal computer in the system. SeaBeam 2112.004 has a vertical reference unit, which is installed in the gravimeter room, and a sound velocity-meter unit for seawater of sea surface, which is installed in the boatswain’s storeroom.

The projector array is a 14-foot long linear array positioned fore and aft along the ship's keel. It forms a downward projected acoustic beam whose maximum response is in a plane perpendicular to its axis. The system transmits an acoustic signal from projectors mounted along the keel of the ship. The acoustic signal travels through the seawater to the seafloor and is reflected off the bottom. Hydrophones mounted across the bottom of the ship receive the reflected signals. The system electronics process the signals, and based on the travel time of the received signals as well as signal intensity, calculate the bottom depth and other characteristics such as S/N ratio for echoes received across the swath. The data is logged to the hard disk for post processing which allows for additional analysis.

The beam angle is narrower, 2° in the fore/aft direction, than a traditional echo sounder, PDR. The receiver array detects and processes the returning echoes through stabilized multiple narrow athwart ship beams in a fan shape. The hydrophone array has a flat shape in the case of R/V KAIREI, although the standard SeaBeam 2000 series system has a V-shaped array. The system synthesizes 2°×2° narrow beams at the interval of 1°, and the swath width varies from 120° at depths from 1500 m to 4500 m, 100° from 4500 m to 8000 m and 90° deeper than 8500 m. The horizontal resolution of the bathymetry data depends on the depth of seafloor and ship's speed because a pinging interval increases as the depth, for example about 20 sec. at 6500 m. The accuracy of depth measurement is reported at 0.5% of the depth of seafloor.

The obtained raw data includes data records of each ping (bathymetry, side scan image, and position), nautical information and correction parameters such as sound velocity profile of seawater. There is a real-time display software to show bathymetric map on the display as well as side scan and amplitude maps.

Bathymetric surveys were conducted every night. The interval of most track lines is 8 miles.

Principal bathymetric features are shown in the following sections. Furthermore, the side scan surveys are also very important for this cruise because the area showing high acoustic reflectivity possibly explains the presence of lava flows to find the petit spot volcanoes. We describe bathymetric features in more detail after precise data processing in order to find the petit spot volcanoes and to expose a detailed tectonic history of the northwestern Pacific Plate.

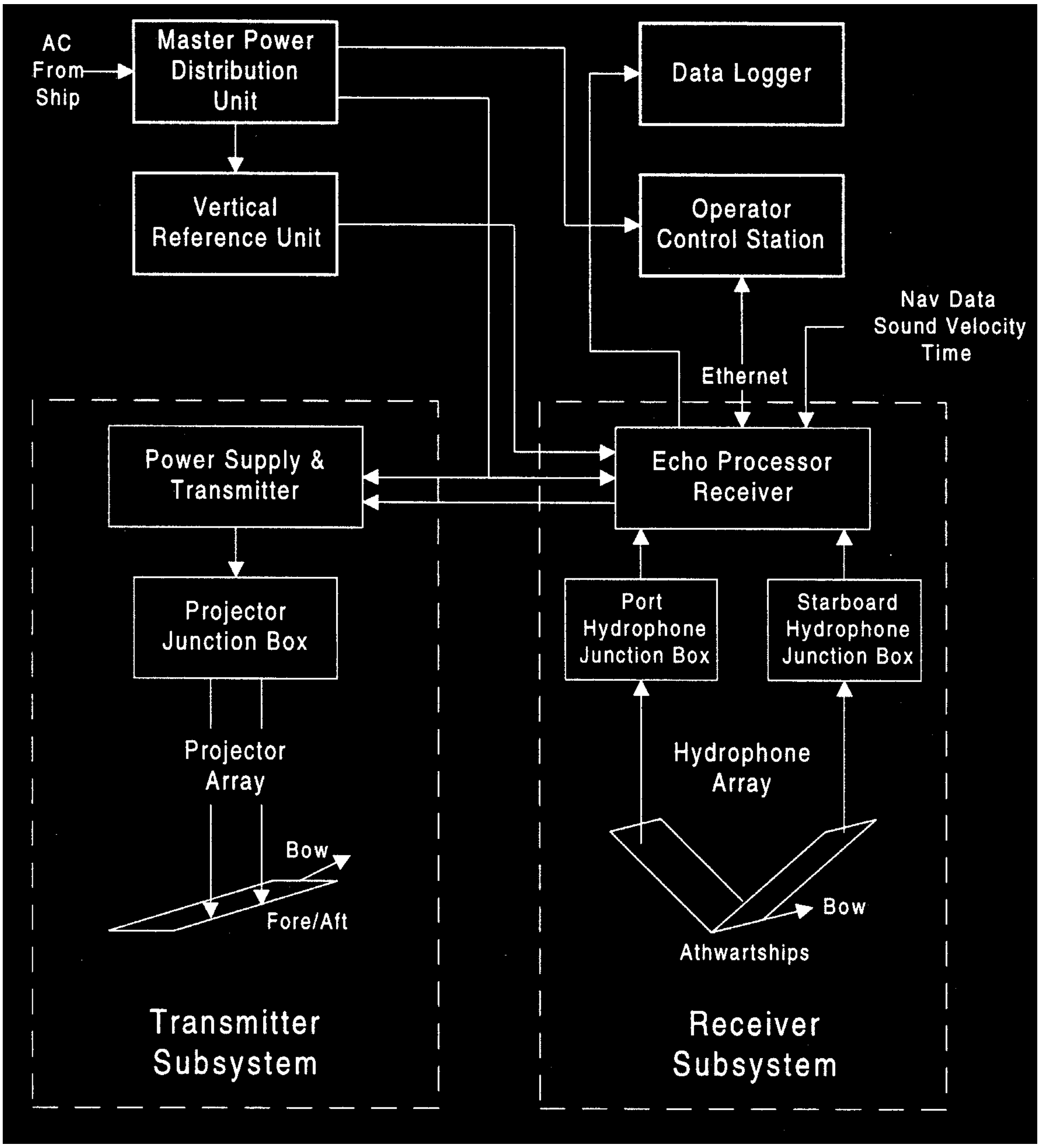

Figure 4-1-1.1. Basic diagram of the SeaBeam system

Bathymetry and Side Scan Surveys

Bathymetric and acoustically geological surveys were conducted in the research area to generate data and to produce the wide-swath contour maps and acoustic backscatter images of the seafloor. Positioning of depths on the seafloor is based on GPS and ship motion input. The horizontal resolution of the bathymetry data depends on the depth and ship speed. Data quality also depends greatly on the sea state. However, we cannot have the favorable sea condition because the cruise was scheduled on May. So the SeaBeam survey could not allow high speeds enough to achieve the scientific objectives. In addition, it was also big problem for our survey that the price of oil has been soaring. The surveys were quite limited about the ship speed to save the cost for the oil, which was only less than 10 knot. Unfortunately, we cannot conduct the surveys enough for our scientific objectives, although all cruises of the petit spot expedition have been highly depending on the bathymetric and side scan surveys since 2003. Therefore, we could not find any petit spot volcanoes during this cruise.

The data were plotted using the command “mbswath” in the MB system (Caress and Chayes, 1996). The bathymetric maps and side scan images for each box surveys are shown in Figure 4-1-1.2 to 4-1-1.8. A and B of each figure show the bathymetry and side scan image, respectively.

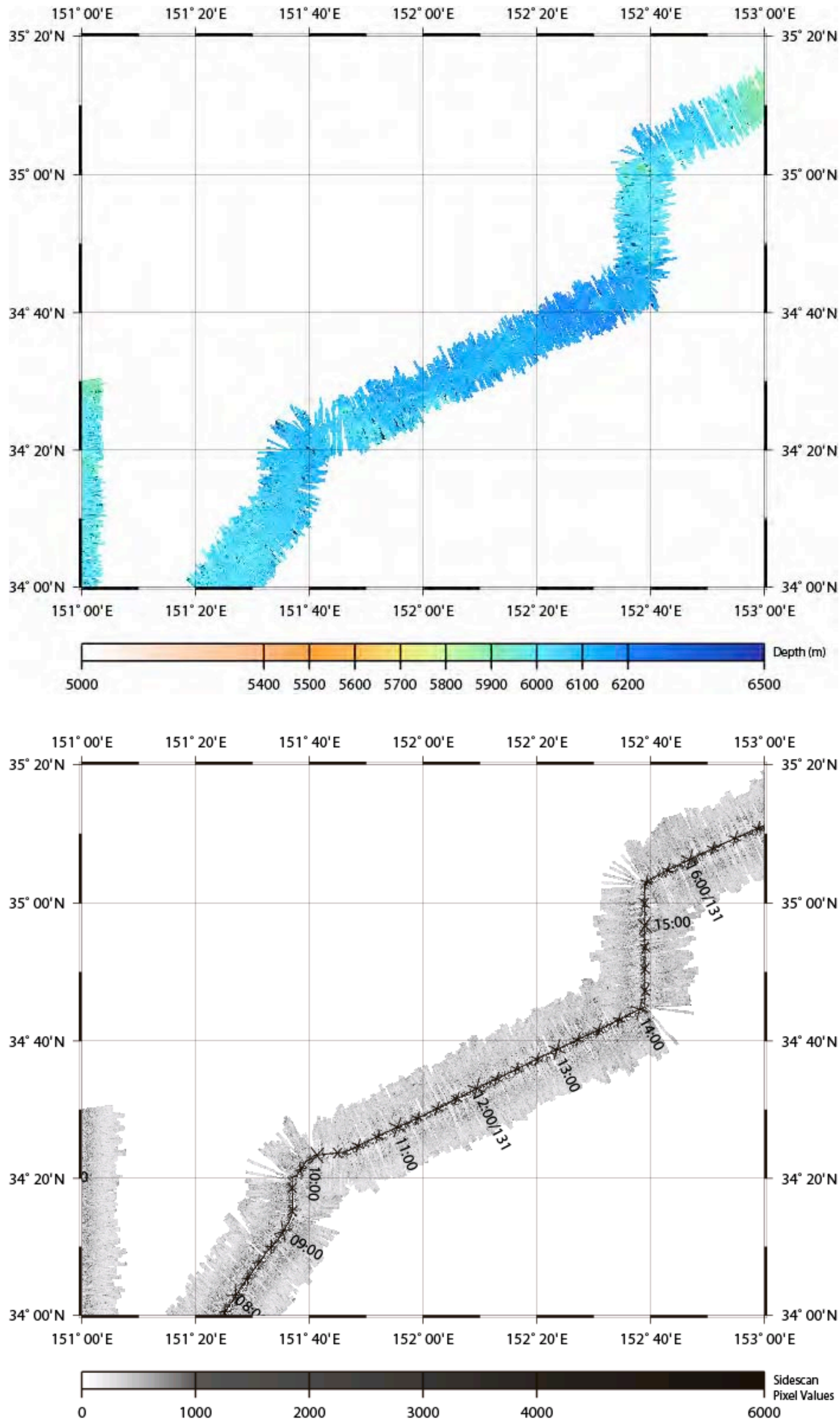

Figure 4-1-1.2. Bathymetrical map and side scan image during a box survey on 131/2007.

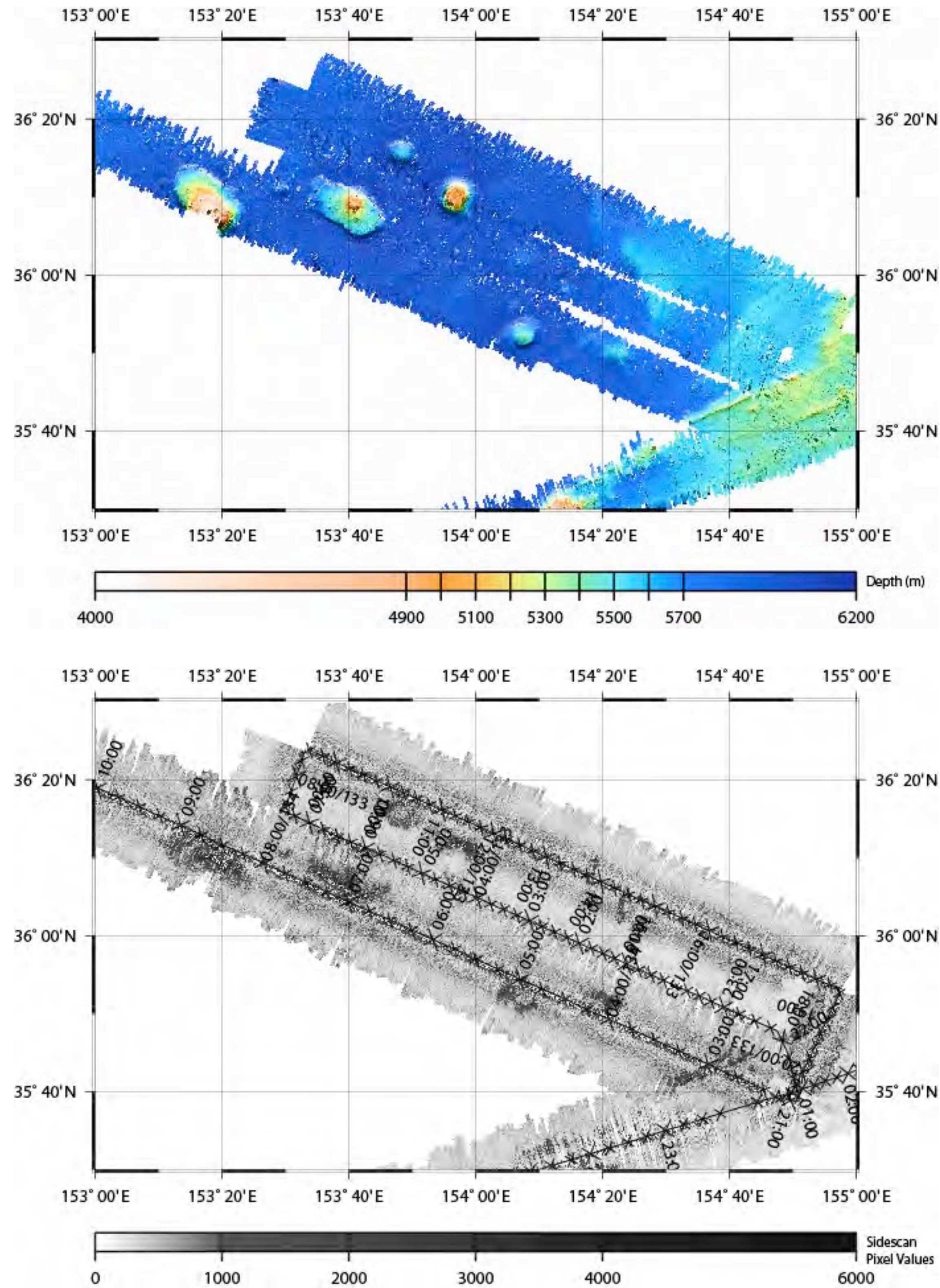

Figure 4-1-1.3. Bathymetrical map and side scan image during a box survey on 133-134/2007.

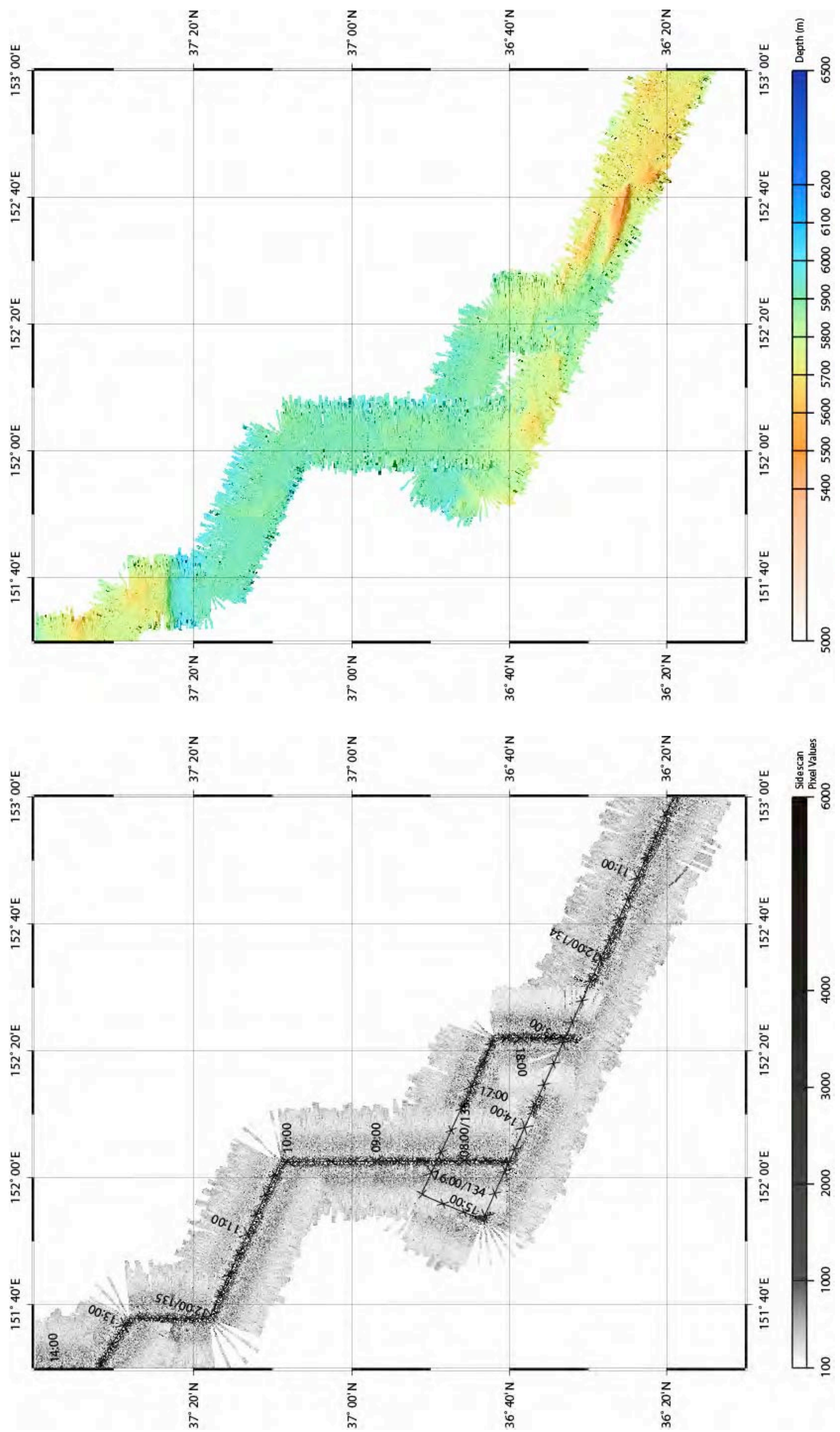

Figure 4-1-1.4. Bathymetrical map and side scan image during a box survey on 134-135/2007.

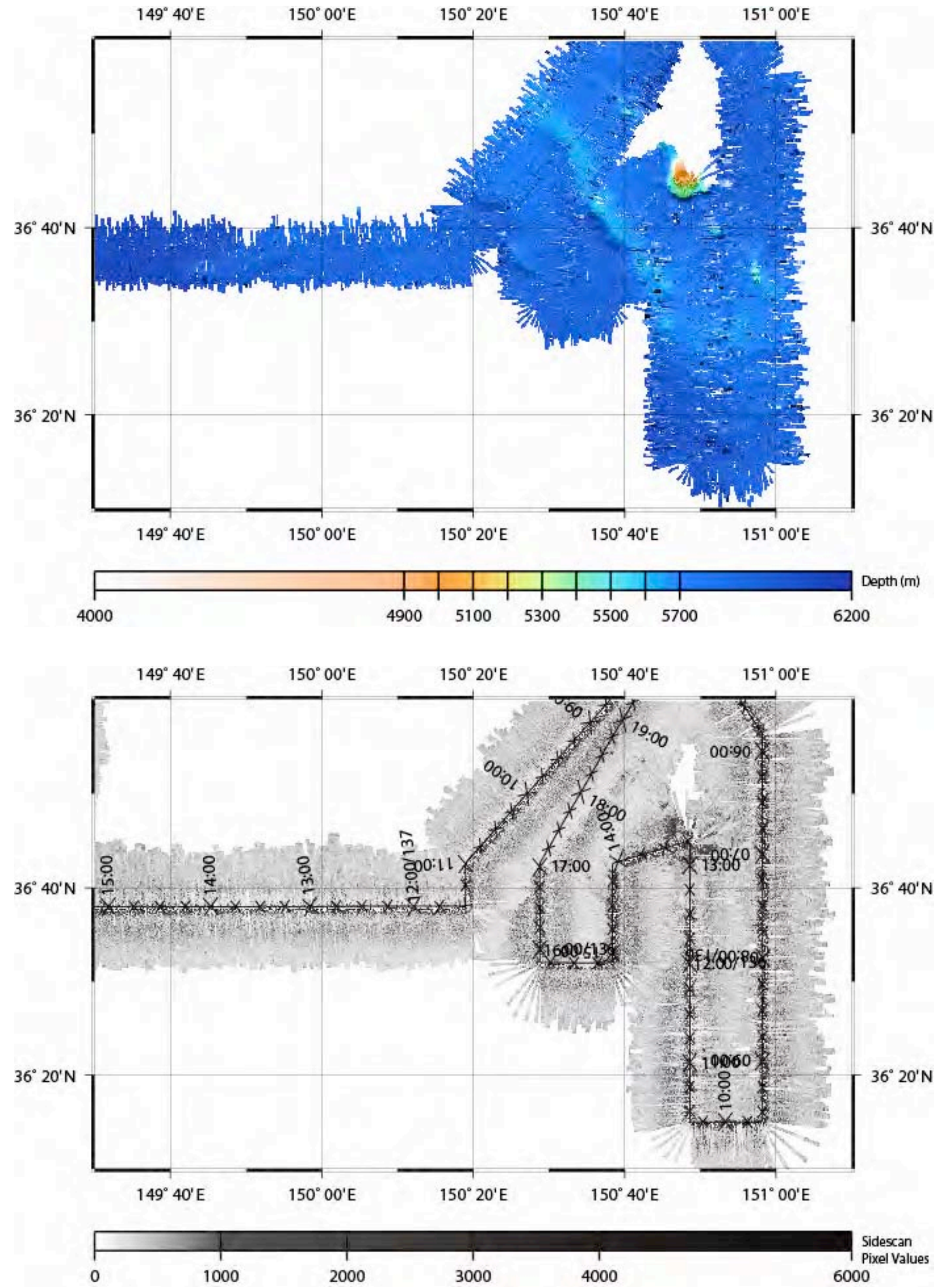

Figure 4-1-1.5. Bathymetrical map and side scan image during a box survey on 136-137/2007.

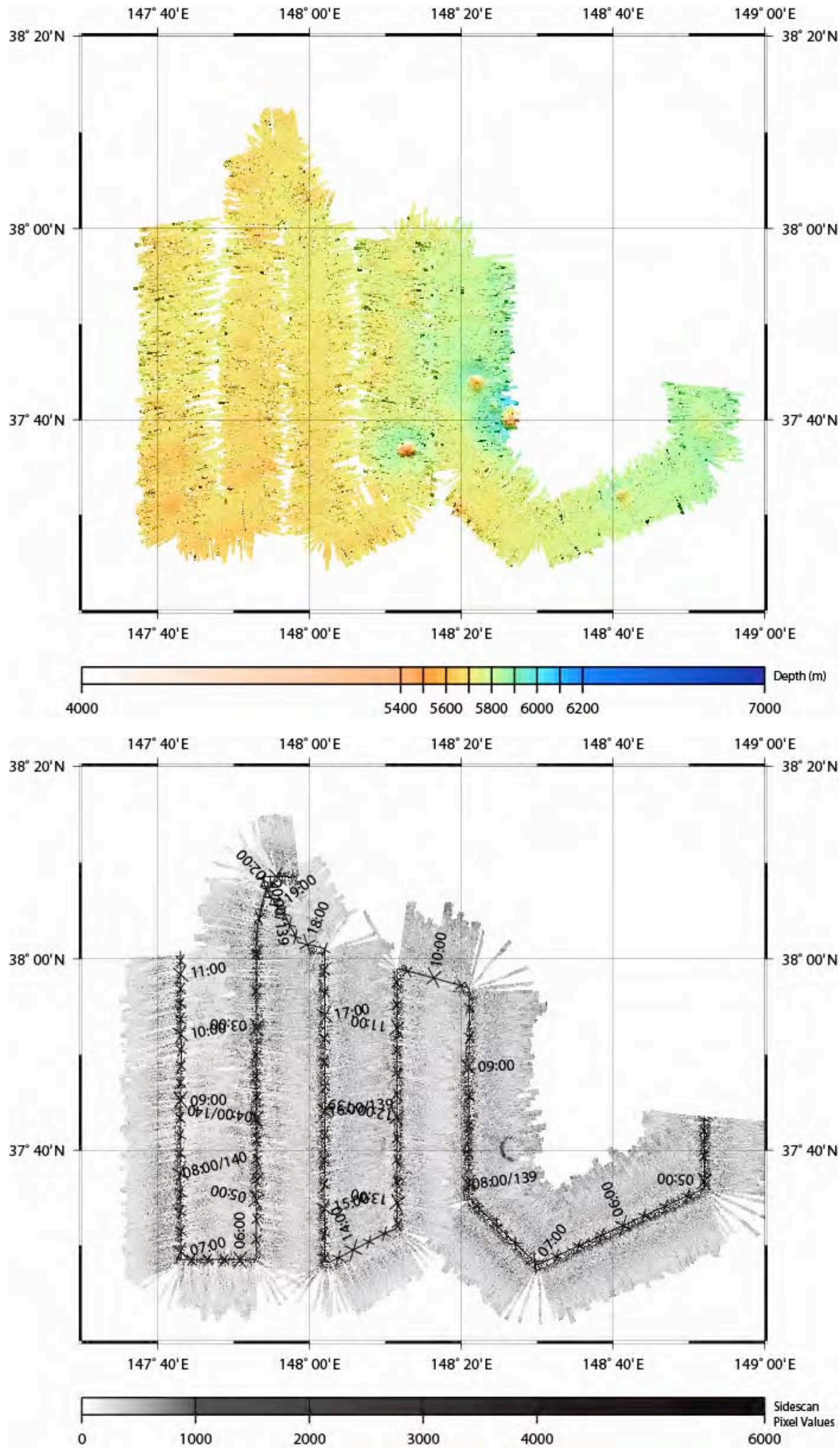

Figure 4-1-1.6. Bathymetrical map and side scan image during a box survey on 139-140/2007.

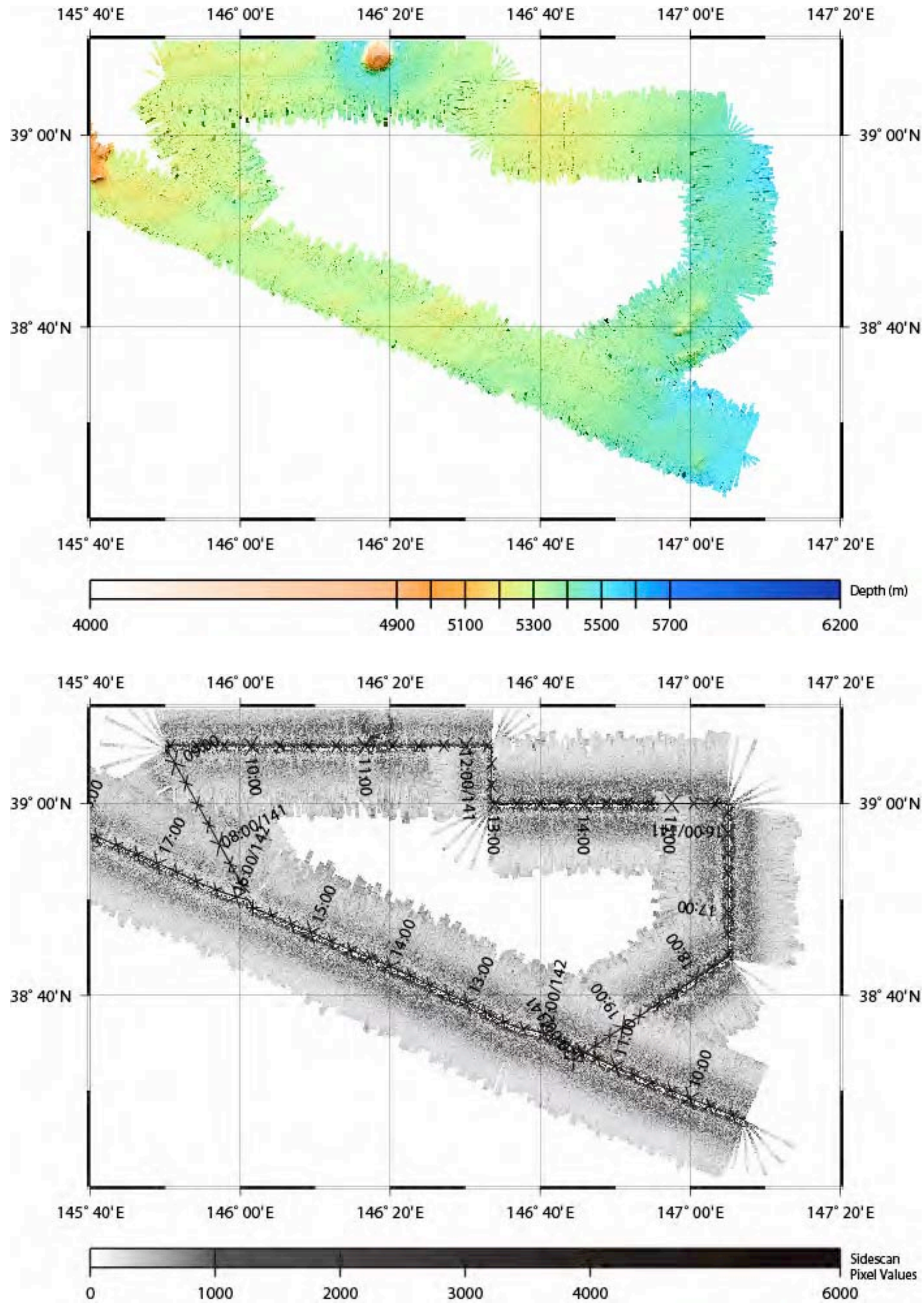

Figure 4-1-1.7. Bathymetrical map and side scan image during a box survey on 141/2007.

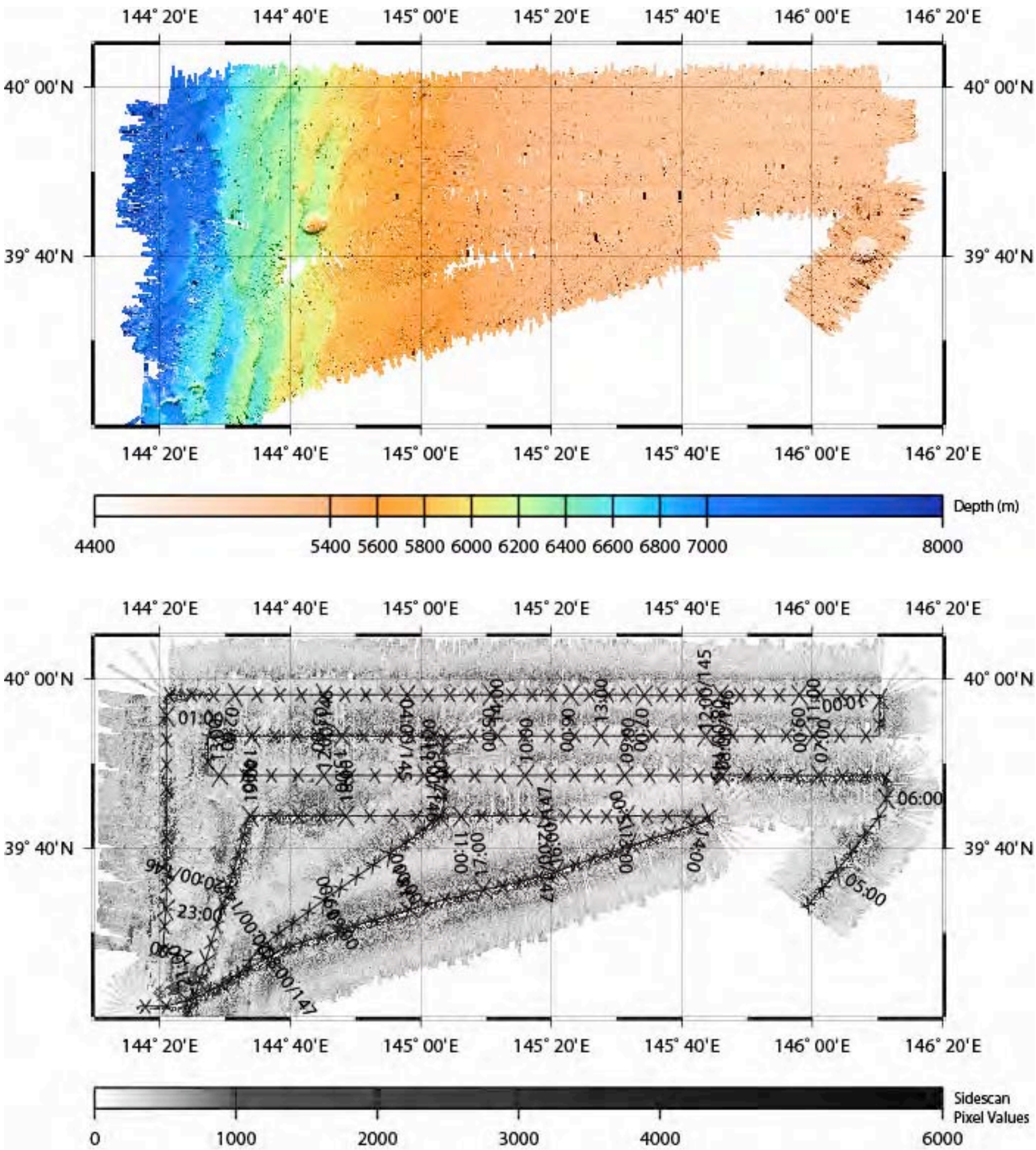

Figure 4-1-1.8. Bathymetrical map and side scan image during a box survey on 145-147/2007.

Sub-bottom profiler

Sub-bottom profiles were obtained by using the sub-bottom profiler system of SeaBeam 2112.004. The capability of the system ranges from 50 m to 11,000 m. Depth penetration varies with bottom composition and may be as much as 75 m. The system uses an array of 60 TR-109 projectors, operating at 4 kHz to form a vertical beam of 45° athwart ship and 5° fore/aft. The data is displayed on a display and EPC recorder, and stored on the hard disk and archived in standard SEGY format.

We conducted the sub-bottom profiling to take place three sites of piston cores and the eight sites for heat flow measurements. See details the heat flow’s section.

4-1-2. Description of seamounts

Y. Koike and K. Baba

We describe seamounts discovered by bathymetric mapping using SeaBeam system during this cruise. Distribution of the seamounts, their relative elevations, and the diameters were detected from the SeaBeam data (Figure 4-1-2.1).

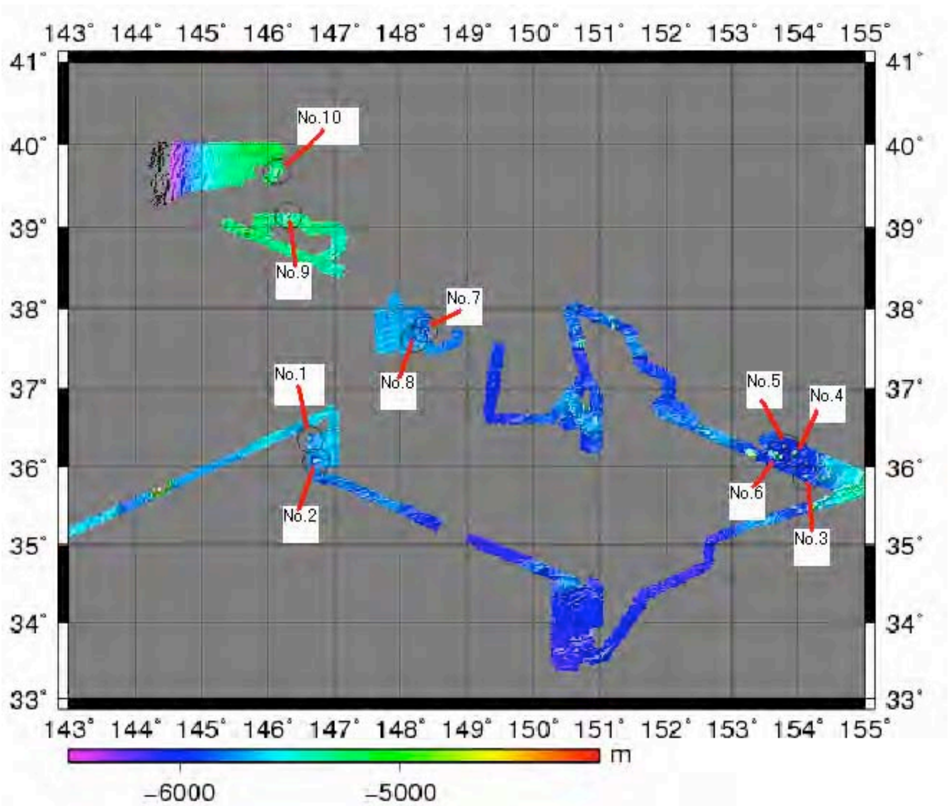

Figure 4-1-2.1. Bathymetry map obtained by SeaBeam mapping. Seamounts newly discovered in this cruise are indicated by numbers.

For calculation of the relative elevations, a profile that passes the top of seamounts from the south to the north was taken at first, and then the difference between minimum and maximum depths was calculated. The profile was divided into small sections in the vicinity of the seamount, and the diameter was calculated as the distance between two local minimum values on both sides of the maximum value (Figure 4-1-2.2).

As the results, 10 seamounts are detected (Figure 4-1-2.1, Table 4-1-2.1). Their altitudes are about 200~1000 m and the diameters are 5~11 km. There are two seamounts over 1000 m high on the east side of the Nosappu fracture zone. The seamounts may be classified into two types; seamounts like a cone and seamounts where the lengths of the major and minor axes are largely different. There are a lot of cone-like seamounts around the outer rise (No.1, 2, 7-10), and there was a seamount with the big aspect ratio (No.6) in the east of Nosappu fracture.

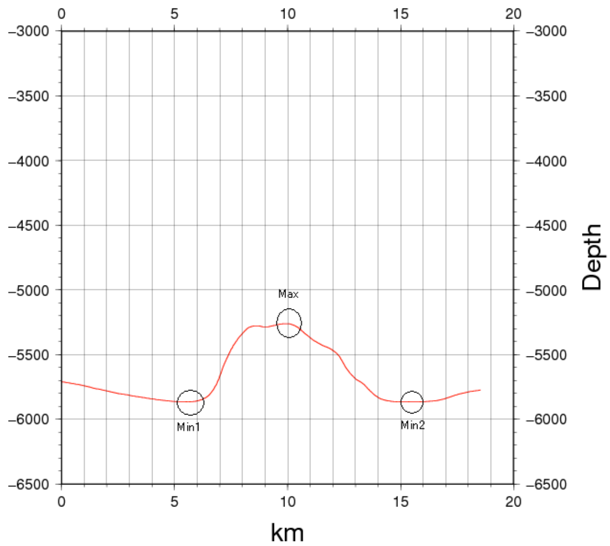

Figure 4-1-2.2. The bathymetric profile for No.2 seamount. Max indicates the top of the seamount. Min1 and Min2 indicate the minimum values on the northern and southern sides of the top, respectively.

Table 4-1-2.1 List of the seamounts.

	Longitude	Latitude	Altitude(m)	Diameter(km)
No.1	146.64	36.35	773.24	8.2
No.2	146.73	36.08	604.17	10.1
No.3	154.12	35.87	560.51	9.72
No.4	153.95	36.17	1025.66	13.2
No.5	153.8	36.26	527.45	8.55
No.6	153.68	36.15	1171.56	14.15
No.7	148.37	37.74	255.27	5.11
No.8	148.21	37.62	377.31	5.11
No.9	146.31	39.14	653.62	8.5
No.10	146.14	39.68	601.62	7.85

4-1-3. Gravity field and geomagnetic field measurements

K. Baba and T. Isobe

Objectives

Gravity and geomagnetic anomalies as well as detailed bathymetry map allows us to discuss crustal structure and its evolution through density and magnetized layer distributions. Investigation of the crustal structure and the distribution of the petit spot volcanoes in northwestern Pacific will contribute to elucidate if the background tectonics is associated with the magma extrusion in the petit spots.

Gravity field measurement

Gravity field data were measured using a shipboard gravimeter (Bodenseewerk KSS-31) with 1 mGal accuracy. The data were recorded every 1 minute, and were collected throughout the cruise. The system incorporates ship's position, speed, and heading through onboard LAN. The measured gravity value was tied to an absolute gravity value at the JAMSTEC pier, which is measured by a gravimeter (Scintrex CG-3M) with 5 μGal accuracy, before and after the cruise. The gravity anomaly will be obtained after pre-processing (readjustment of time difference, Etovos, drift, and reference gravity corrections) of the raw data.

Magnetic field measurement

Magnetic field data were collected by using a shipboard three component magnetometer (STCM) and a surface-towed proton procession magnetometer. The vector magnetic field data were collected with a sampling rate of 8 Hz throughout the cruise. "Figure-8 turn"s (a ship runs along an 8-shaped track consisting of two circles) were made for calibration of the ship's magnetic effect (Isezaki, 1986). The turns were made at two locations as listed in Table 4-1-3.1. The IGRF model was also employed as the reference magnetic field for calculation of vector geomagnetic anomaly and "Figure-8" calibration.

Table 4-1-3.1. Time and position of “Figure 8” turns.

Date & time (UTC)	Position	
May 10, 2007 03:17~03:31	34° 04’ N	150° 37’ E
May 22, 2007 09:09~09:21	38° 27’ N	147° 07’ E

The proton sensor was towed 300 m behind the ship. The geomagnetic total force data were collected every 20 seconds in transit and night time except for a few bad weather days. The total force anomaly is calculated by subtracting the International Geomagnetic Reference Field (IGRF) 10th generation (IAGA, 2005). Figure 4-1-3.1 shows the area that the total force data was collected in this cruise. Following Figure 4-1-3.2 – 4-1-3.9 shows the total force anomaly profiles superimposed on bathymetry.

References

Isezaki, N. (1986), A new shipboard three component magnetometer, *Geophysics*, **51**, 1992—1998.

International Association of Geomagnetism and Aeronomy (IAGA), Division V, Working Group VMOD (2005), The 10th-generation International Geomagnetic Reference Field, *Geophys. J. Int.*, **161**, 561—565, doi: 10.111/j.1365-246X.2005.02641.x.

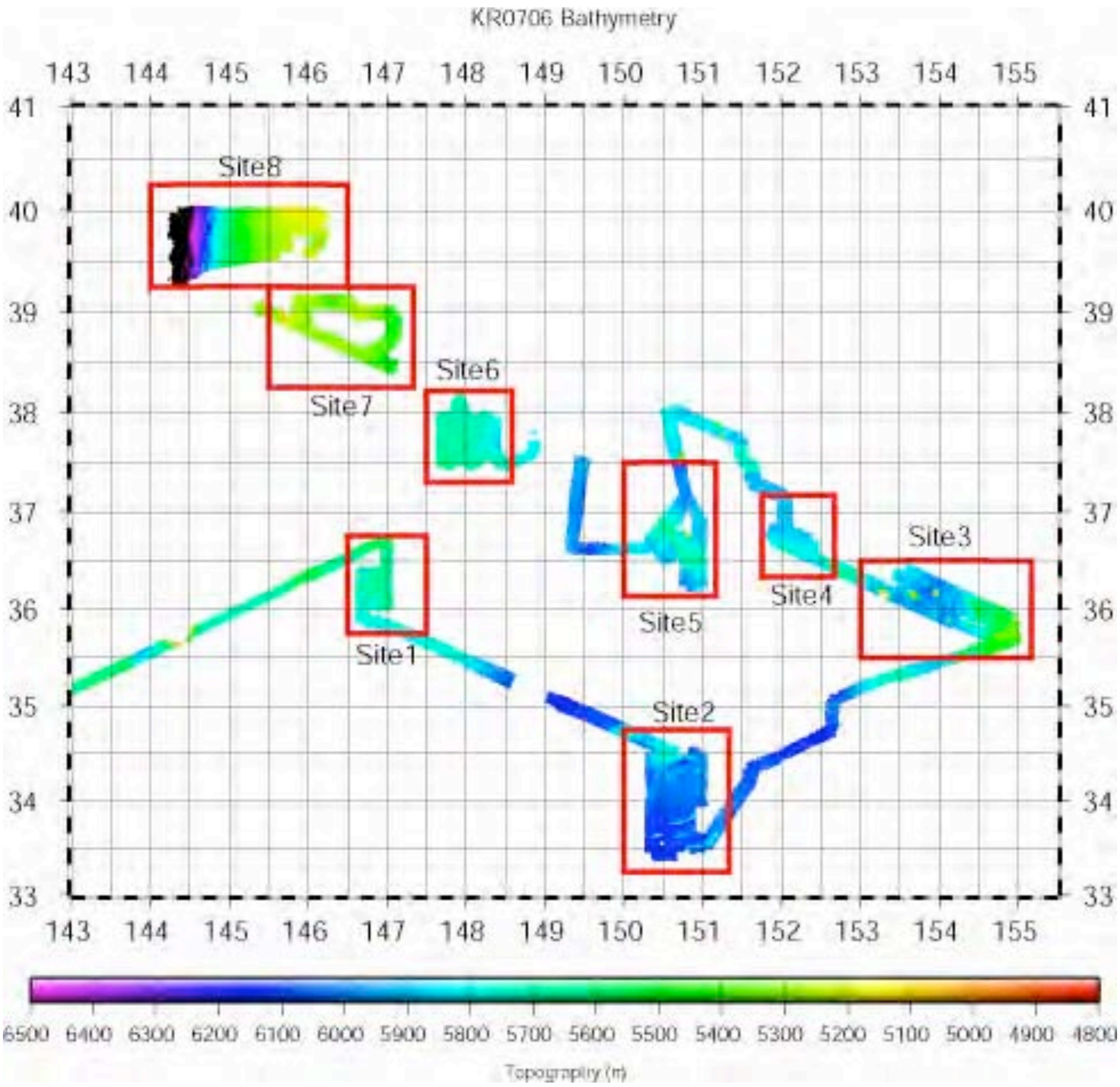

Figure 4-1-3.1. The area that the geomagnetic total force was obtained in this cruise. The total force anomaly profiles in red boxes are plotted in Figures 4-1-3.2 – 4-1-3.9.

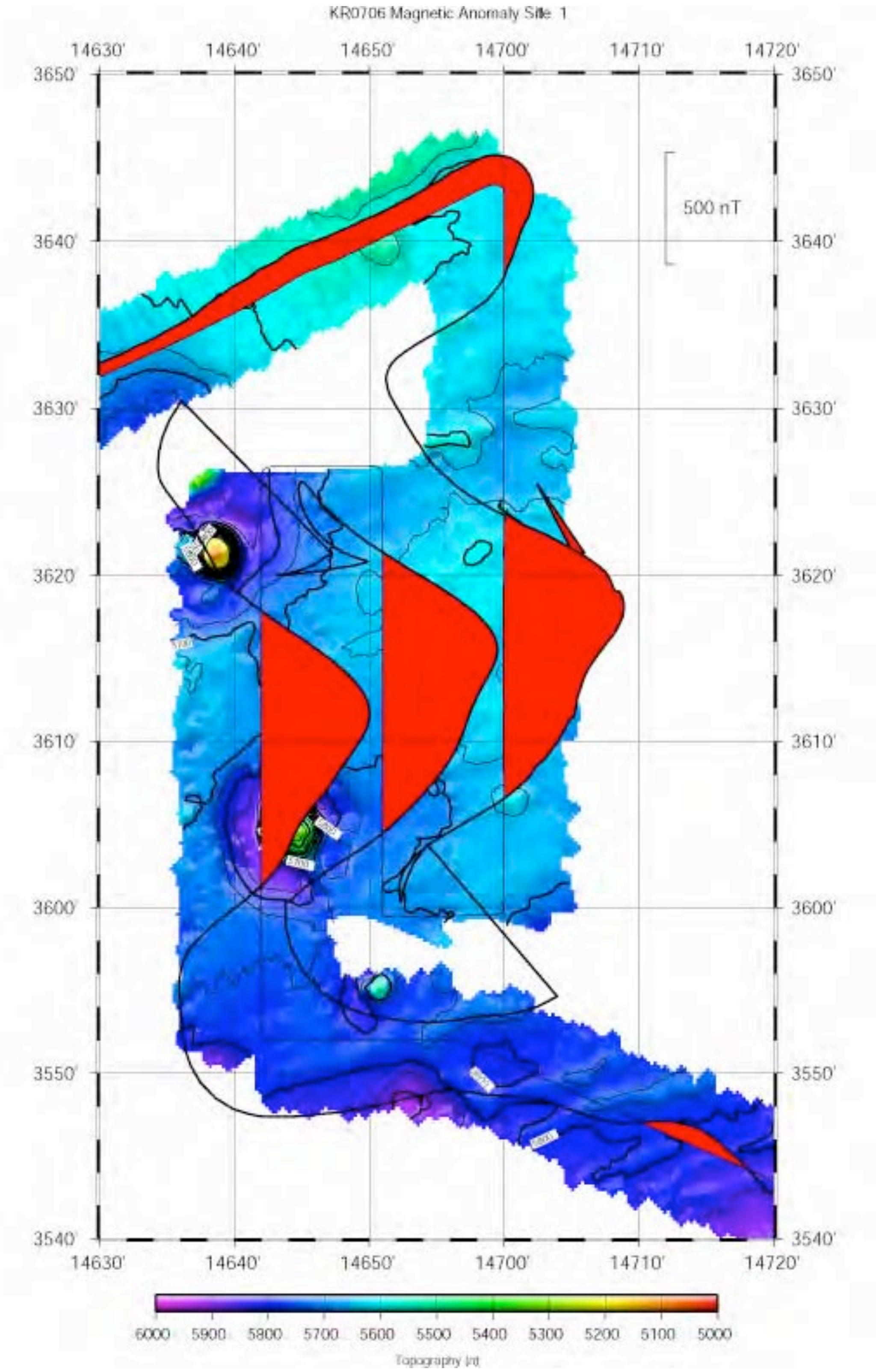

Figure 4-1-3.2. Geomagnetic total force anomaly in site 1.

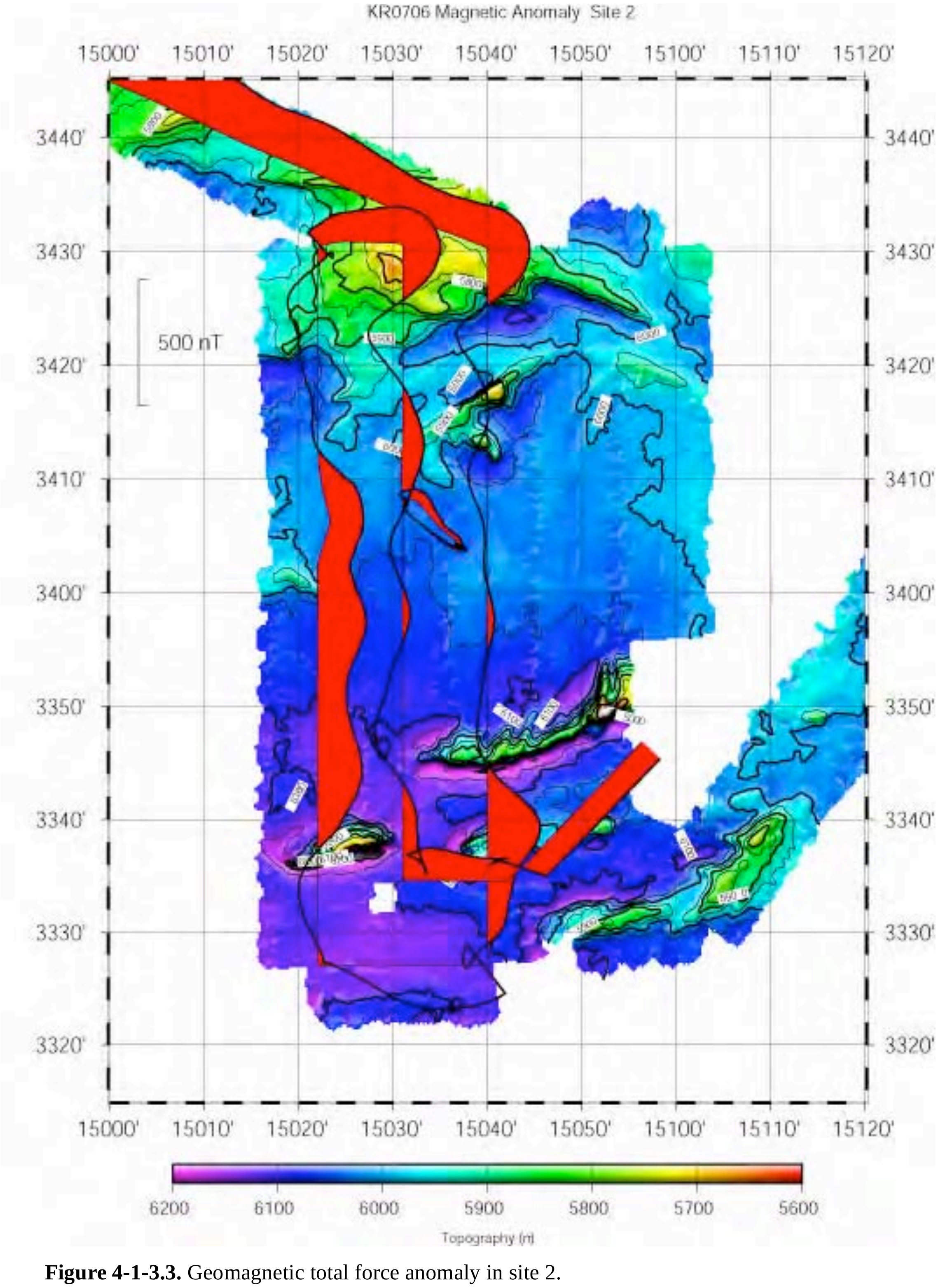

Figure 4-1-3.3. Geomagnetic total force anomaly in site 2.

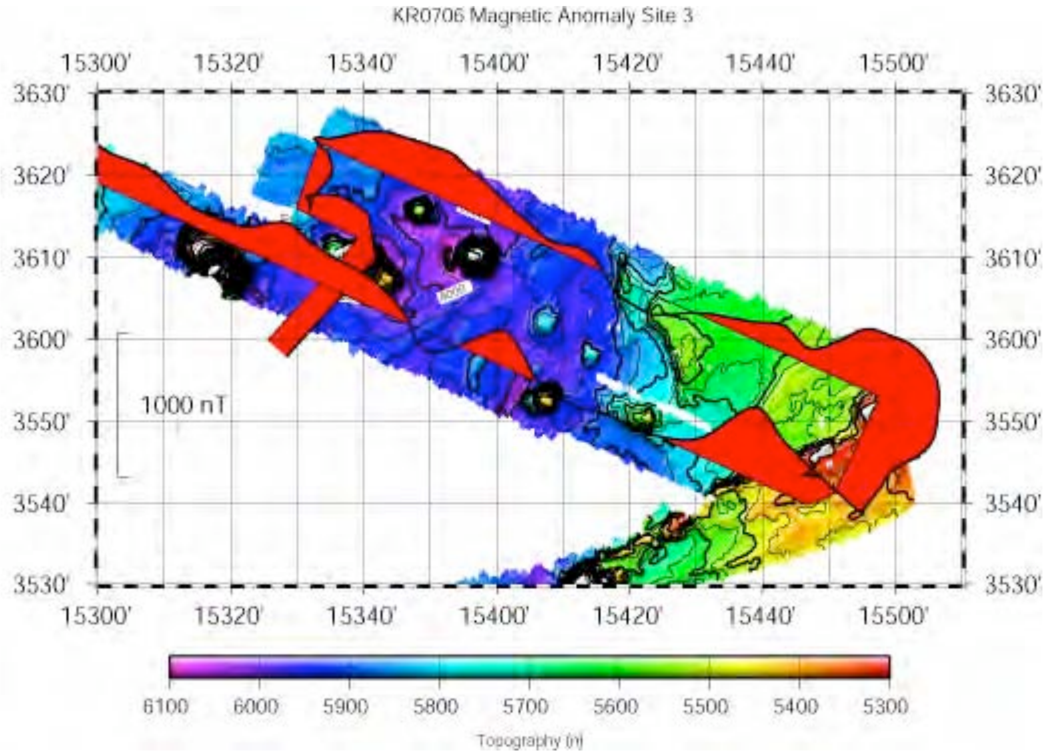

Figure 4-1-3.4. Geomagnetic total force anomaly in site 3.

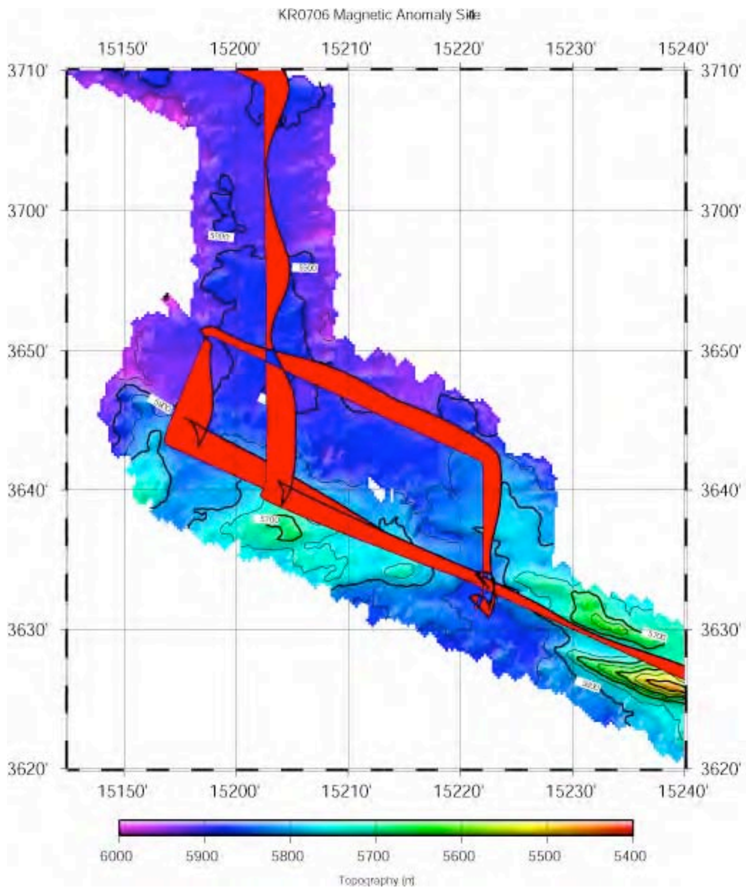

Figure 4-1-3.5. Geomagnetic total force anomaly in site 4.

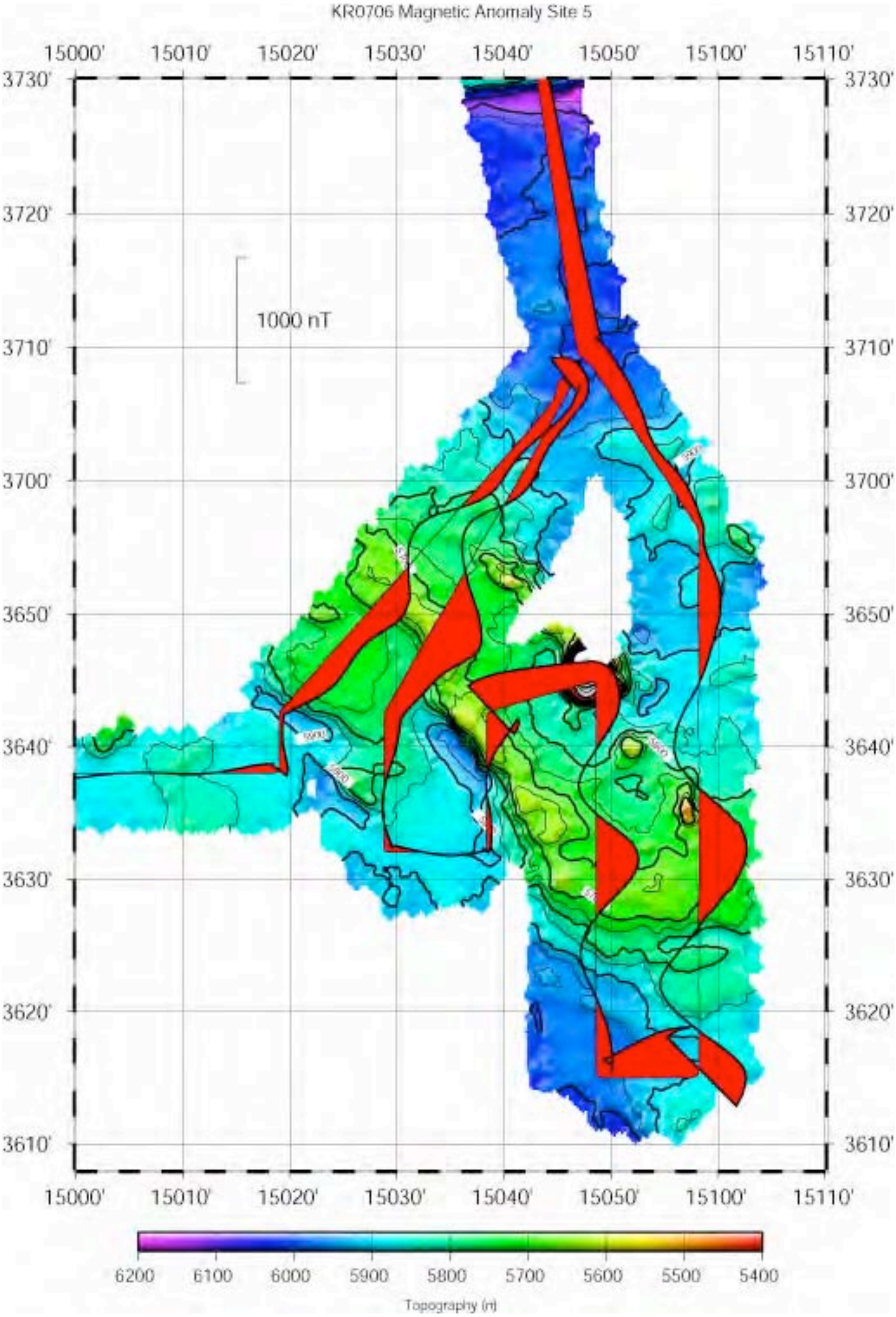

Figure 4-1-3.6. Geomagnetic total force anomaly in site 5.

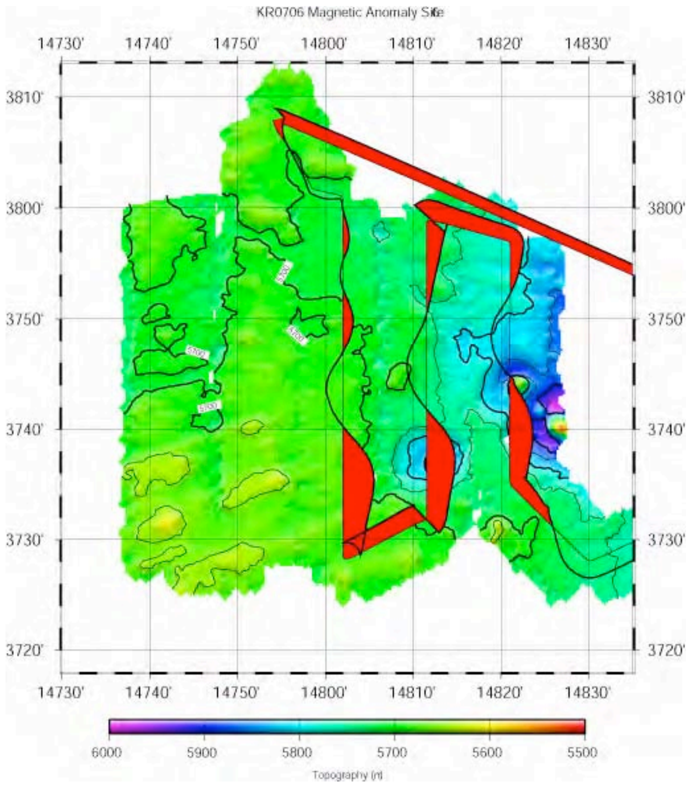

Figure 4-1-3.7. Geomagnetic total force anomaly in site 6.

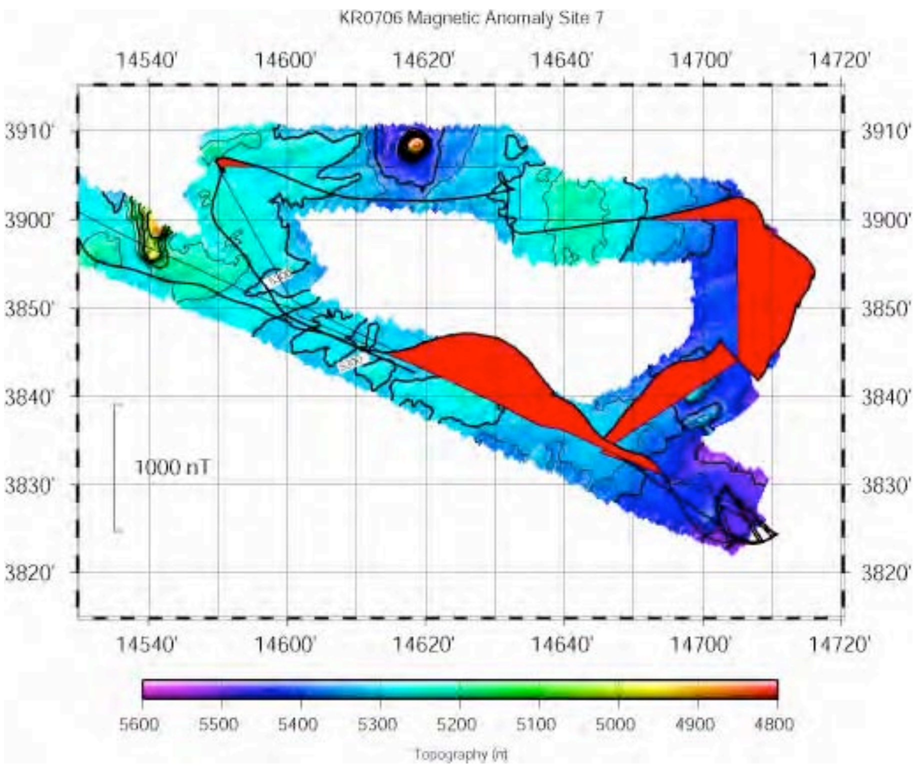

Figure 4-1-3.8. Geomagnetic total force anomaly in site 7.

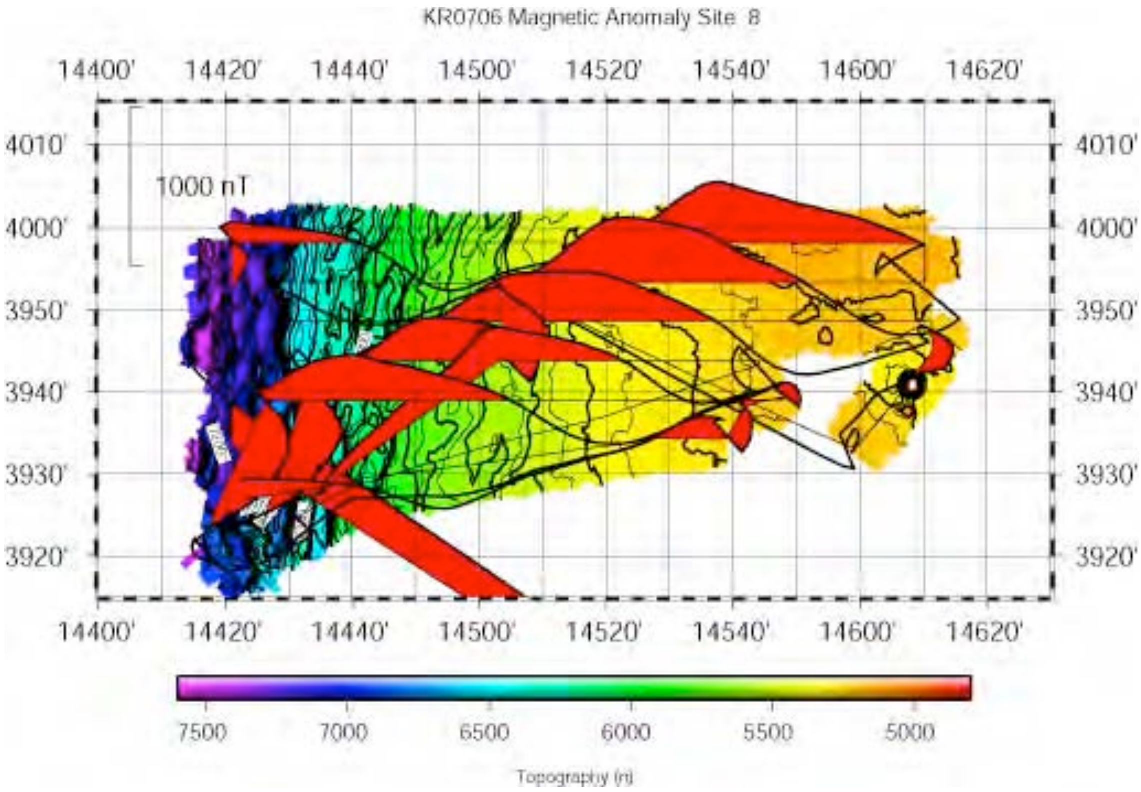

Figure 4-1-3.9. Geomagnetic total force anomaly in site 8.

4-2. Seafloor magnetotelluric survey

K. Baba

Objectives

Magnetotelluric (MT) soundings provide us an image of electrical feature of Earth's interior. Because electrical conductivity of the mantle materials is strongly dependent of temperature, partial melt, and volatiles such as water, electrical conductivity structure models estimated through seafloor MT surveys are definitely useful to discuss where the source of the petit spot volcanic activity is and its relation to the mantle dynamics. For these objectives, we have carried out a seafloor MT experiment using ocean bottom electromagnetometers (OBEMs) since 2005. We have acquired available data from seven sites so far. In this cruise, we deployed three OBEMs. The OBEM array which includes the sites that the data were collected in previous experiments covers a thousand km square of the northwestern Pacific (Figure 2-1.1). The sites set in this cruise extend the existing survey area to the south and east, which we intended to get reference structure less affected by the plate flexure. Joint analysis of these data will allow us to image the asthenospheric conductivity structure and to discuss the extent of the melt generation field.

Instruments

The OBEMs are made by Tierra Tecnica Ltd., which can measure time variations of three components of magnetic field, horizontal electric field, the instrumental tilts, and temperature. The resolutions are 0.01 nT for flux-gate magnetometer, 0.305 μV for voltmeter, 0.00026 degrees for tiltmeter, and 0.01°C for thermometer. There are two types of instrumental design (Photo 4-2.1). Type 1 OBEM equips three glass spheres housing Benthos acoustic transponder, the electromagnetometer, and a Lithium battery pack for the electromagnetometer, respectively. Type 2 OBEM is an improved version of type 1, which equips two glass spheres. An acoustic transponder and the battery pack are put together in one glass sphere. We have one type-1 OBEM (TT3) and two type-2 OBEMs (JM7 and JM8). All the OBEMs mount a radio beacon, a flash light, and a catching buoy for easy recovery.

Photo 4-2.1. Type 1 OBEM (left) and type 2 OBEM (right).

Deployment of the OBEMs

We first mapped the bathymetry in the vicinity of planned position using SeaBeam system and select flat seafloor for the final deployment point. The OBEMs were launched from deck using A-frame and sunk by their self weights. The operations were quick and smooth. We tracked the OBEMs by acoustic signals and confirmed that the OBEMs were successfully settled on the seafloor. Then, the settled positions were determined by measurements of the slant ranges at least three positions surrounding the launching point for TT3 and JM8 and by Super Short Base Line (SSBL) positioning system of R/V KAIREI for JM7. The information that will be needed for the recovery and the data analysis are listed in Table 4-2.1.

Recovery trial of the OBEM at NWP0502

Recovery of one OBEM, which was deployed at site NWP0502 (Figure 1-2.1) in 2005, was

Table 4-2.1. Information of the OBEMs deployed during this cruise.

Site	EM01	EM02	EM03
OBEM ID	JM7	JM8	TT3
Launched position	35° 38.4574' N 154° 49.1102' E	34° 01.0483' N 150° 37.9962' E	36° 25.8345' N 147° 00.7928' E
Settled position	35° 39.0379' N 154° 48.7279' E	34° 01.5747' N 150° 37.5402' E	36° 26.0197' N 147° 01.1318' E
Depth	5446 m	5964	5622 m
sampling intervals	60 s	60 s	60 s
Dipole length (N-S)	5.19 m	5.21 m	6.38 m
Dipole length (E-W)	5.20 m	5.22 m	6.38 m
Time for clock reset to GPS (TZ = ±0h)	2007-05-12 02:42:31	2007-05-09 05:01:29	2007-05-07 10:26:18
Time for recording start (TZ = ±0h)	2007-05-16 14:59:00	2007-05-14 14:59:00	2007-05-12 14:59:00
Acoustic system	Kaiyo Denshi	Nichiyu Giken	Benthos
frequency (Tx, ship side)	10.0 kHz	9.6~10.9 kHz	9.0 kHz
frequency (Rx, ship side)	13.5 kHz	10.24 kHz	12.0 kHz
Release command	3C-1	3-H	F
Radio beacon	NOVATECH	NOVATECH	Taiyo Musen
frequency	159.3 MHz	159.2 MHz	43.528 MHz
ID	N/A	N/A	JS1105
Flash light	NOVATECH	NOVATECH	Taiyo Musen

tried. The position on the seafloor was not determined when it was deployed so that we know only the position that the OBEM was launched (37° 07.7894’N, 150° 46.7774’E).This OBEM did not respond to acoustic signal in the previous cruises (KR05-10 and MR06-05 leg3). There is a possibility that the acoustic transponder mounted on the OBEM doesn’t have enough power. Thus we prepared a relay system (Photo 4-2.2). The relay system is attached on the observation wire and brought down at about 3000 m from the surface. We send a command from a transducer hanged on the starboard side of the ship with SI-II mode. Then, the relay system interprets it and sends a command it with JX mode, which the transponder mounted on the OBEM understands. If the relay system receives the response from the OBEM, it relay the response with SI-II mode to the transducer on the surface. The position of relay

Photo 4-2.2. The acoustic relay system.

system was tracked by KAIREI SSBL system and benthos transponder attached just above the relay system.

At the site NWP0502, we first sought the OBEM using hull transducer, moving on the circle centering the deploy point with radius of 1 and 1.5 nmiles. We never received the response from the OBEM. Then, we stopped at the deploy point and brought the relay system down to 3000 m depth and send the acoustic signals and the release command many times. The response was never obtained, again. The radio beacon signal was not detected although we wait for the enough time of the OBEM's surfacing. Finally we gave up the recovery of this OBEM.

Future plan

The three OBEMs deployed in this cruise will be recovered in 2008. The data will be analyzed based on the MT method. The obtained MT responses will be inverted together with the responses that were obtained by previous experiments. I will interpret the electrical conductivity model of the upper mantle obtained by the inversion analysis and contribute on the discussion of the melt generation field.

4-3. Seismological observation

H. Sugioka, A. Shito, and A. Ito

Overview

Our common target is to know what the petit-spot is and how it was born and bred there, as Hirano *et al*. (2006) proposed that the petit-spot erupt along lithospheric fractures in response to plate flexure during subduction and minor extents of asthenospheric melting and the volcanoes' tectonic alignment and age progression in the direction opposite to that of plate motion provide evidence for the presence of a small percent melt in the asthenosphere. We think that it is direct and efficient method for us to understand the mechanism of the petit-spot by the seismological knowledge. Here we suggest two points of view for approaching to the problem. (1) Where is the volcanic active source associated with the petit-spot? (2) Where is the melting area in the oceanic plate?

In order to solve them according with these views by seismological method, we deployed three broadband ocean bottom seismographs (BBOBS) around several petit-spots found that it is 4.2-8.5 million-year-old by the Ar-Ar dating method (Photo 4-3.1). Our BBOBS system includes the broadband seismometer (Guralp CMG-3T) that can measure in frequency range from 360 sec to 40 Hz. We expect to determine the hypocenters below the region and to obtain the three-dimensional structures of the seismic velocity and attenuation by using the tomographic method. There are solutions to the above two problems which we suggest. That is, the hypocenters would show the distribution of the active volcanic activity of the petit-spot and the structure of the seismic velocity and the attenuation would indicate the melting area in the oceanic plate. And more, here we add that the answer of these problems will be a key to know the origin of the lithosphere and the asthenosphere.

Broadband ocean bottom seismograph (BBOBS)

The BBOBS has been developed at the Earthquake Research Institute (ERI) of the University of Tokyo since 1999 based on the OBS with a geophone. A broadband sensor (CMG-3T for OBS, Guralp, UK) is installed on an active leveling unit developed at the ERI. The data is digitized by a 24 bit ADC with 100 Hz, and recorded on 2.5 inch HDDs with the total capacity of 80 GB. The maximum recording period of the BBOBS is 400 days. These and 70 Li cells (DD size) are fixed inside of a titanium sphere housing (D = 65 cm). The BBOBS is deployed by a free fall from the sea surface and pop up by its buoyancy in the recovery. The anchor is released by a forced electric corrosion of two thin titanium plates after receiving a command of an acoustic transponder from the ship.

Principal specifications are as following;

[Outside]	
Size	1m x 1m x 0.7m (Width x Depth x Height)
Weight in air	240kg (deployment), 150kg (recovery)
Pressure case	Titanium sphere (D=65cm, Buoyancy=70kg, Made in Russia)
Releasing mechanism	forced electric corrosion of two thin Ti plates (t=0.4mm)
Recovery control	Acoustic transponder system with recorder communication
Recovery aids	Radio beacon (160MHz band) and Xenon flasher with light switch
[Inside]	
Sensor	CMG-3T for OBS (Guralp, UK) sensor on the active leveling unit
	360s ~ 50Hz, 1500V/m/s, leveling works up to 20 deg. tilt
Analog unit	gain: 0 dB, LPF: 32Hz (4th-order Butterworth)
A/D	24bit (0~5V), 100Hz sampling, Win format like compression
Data media	two 2.5inch 40GB SCSI HDDs
RTC	0.5ppm, backuped by two DD size lithium cells (7.2V, 30Ah)
Power supply	DD size lithium cells (ElectroChem, 3.6V 30Ah)
	Sensor:32 (14.4V, 240Ah), Recorder:39 (10.8V, 390Ah)

Photo 4-3.1. Appearance (left) and inside (right) of BBOBS. See to above text for detail scription.

Deployment of BBOBS

We arranged BBOBS array to enclose both Yukawa-Kaikyu and recent seismicity. We originally planned to deploy 4 BBOBS stations in the petit-spot region. However, after the installation of the two BBOBS (S01 and S04), detaching device of a BBOBS was damaged, which cannot be recovered onboard and we gave up installing the BBOBS. Finally, we changed arrangement of the array, and deployed totally 3 BBOBS stations. The site locations are carefully chosen so that the topography should be basin or flat on the basis of the sea beam bathymetry data taken from the previous cruises. We set the recording period to be 13 months. The BBOBS were launched from KAIREI with an A-frame. After the BBOBS reached sea floor, we communicated with BBOBS using the acoustic transponder. We calibrated slant range at 3 points which are about 1 km from the launching point. Using the slant range, we located the settled position of BBOBS (Table 4-3.1, Figures 4-3.1 and 4-3.2).

Table 4-3.1. BBOBS locations.

	Launched Position		Settled Position		
ID	Latitude	Longitude	Latitude	Longitude	Depth
S01	37° 09.9808′ N	150° 46.9204′ E	37° 09.8815′ N	150° 47.2048′ E	5987.5 m
S02	37° 31.7554′ N	149° 29.3389′ E	37° 31.8902′ N	149° 29.4093′ E	5880.7 m
S04	38° 02.9582′ N	150° 32.9645′ E	38° 03.0029′ N	150° 33.0911′ E	5776.4 m

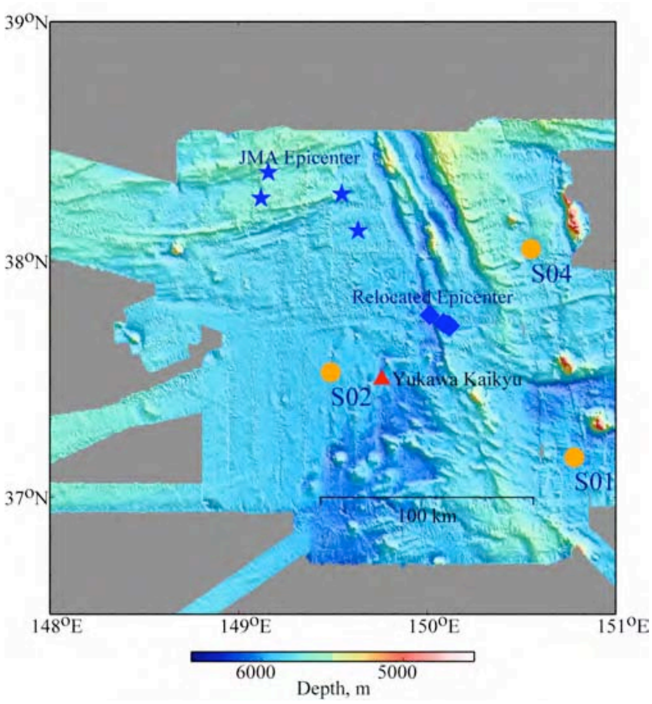

Figure 4-3.1. BBOBS array. Circles indicate BBOBS sites. Stars indicate epicenters located JMA. Diamonds are epicenters relocated by using local velocity structure for Northwestern Pacific determined by Fukano *et al*. (2007). A triangle indicates the location of Yukawa-Kaikyu.

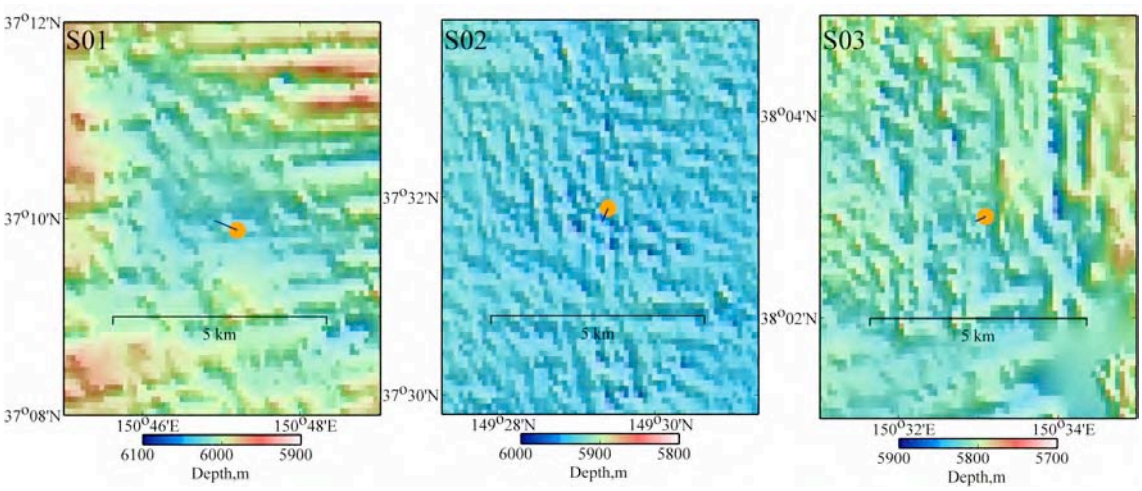

Figure 4-3.2. Topography map of BBOBS sites. Circles indicate BBOBS settled positions. The lines indicate BBOBS track from launched to settled positions.

Future plan

We plan to do the following basic analysis using the data of this observation.

(1) Hypocenter location

In order to estimate activity and exact active area of petit-spot seismicity, we will locate accurate hypocenter of local seismic event in the petit-spot region.

(2) Mechanism

In order to estimate stress field of the petit-spot region, we will try to determine mechanism of the local event.

(3) Velocity structure

The combination of the BBOBS data with previous land data will provide us improved velocity structure (e.g., seismic tomography, receiver function) in the petit-spot region.

The above (1) and (2) will be a key to understand petit-spot magma erupting region, and (3) will help investigating petit-spot magma source region.

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Acknowledgements

We are extremely grateful for helpful advices provided Drs. H. Shiobara, Y. Fukao, and D. Suetsugu. We used BBOBS designed by Drs. T. Kanazawa and H. Shiobara (Earthquake Research Institute, Univ. of Tokyo). We here thank to their great efforts.

4-4. Crustal heat flow survey

4-4-1. Heat flow measurement

H. Hamamoto

Scientific target

The Japan Trench is the place where old oceanic lithosphere, the northwestern part of the Pacific plate, is subducting beneath the northeast Japan arc. This trench-arc system is one of the best investigated subduction zones in the world. The crust and upper mantle structures and the subduction process have been studies extensively through various geophysical surveys such as reflection and refraction seismic and electromagnetic observations. Measurements of heat flow were also made both on land and at sea in the 1960s, which delineated the general pattern of heat flow distribution: low in the Japan Trench side of the arc and high in the Japan Sea side (Uyeda and Horai, 1964; Yasui *et al.*,1968). The heat flow profile across NE Japan from the trench to the back –arc was often cited as a typical heat flow distribution in subduction zones and various thermal models were presented to explain the profile (e.g. Hasebe *et al*., 1970; Toksoz, 1971).

After these studies, however, only a small number of heat flow measurements were conducted in Japan Trench area. Heat flow were especially spare on the Pacific plate seaward slope and outer rise of the trench (Yamano, 1995). These high values seem to be anomalous for the age of the Pacific plate in this area, 120 to 130 m.y. (e.g. Nakanishi *et al*., 1989), considering that reliable heat flow values obtained in old ocean basins with ages over 200 m.y. are about 50 mW/m^2 (Davis, 1989).

Another recently found feature of the study area is a group of small knolls probably of volcanic origin on the trench seaward slope on the survey line (Hirano *et al*., 2006). Hirano *et al*. (2001;2006) sampled alkali-basalt lavas from some of the knolls and obtained very young isotopic age of 4 to 8 m.y. Hirano *et al*. (2006) also found another group of small knolls on the 135 m.y. old seafloor on the eastern edge of the trench outer rise and sampled volcanic rocks younger than 1m.y. Results of chemical analysis of the samples showed that magmas of these volcanoes were formed in the asthenosphere beneath the Pacific plate. They inferred that the magmas ascended to the surface through fractures created by flexure of the plate and named this type of volcanism “petit spot”. Such intra-plate volcanism may also have affected the thermal structure of the old Pacific plate.

It is important to know whether the observed high heat flow values well reflect the temperature structure of the Pacific plate in this area, since the temperature distribution of the incoming oceanic plate is a major factor that controls the thermal structure of subduction zones. We conducted detailed heat flow measurements along a 1000 km long east-west line of seaside of the Japan Trench aiming to investigate the nature and origin of the reported high heat flow and thermal influence of intra-plate volcanism. We obtained 8 new data and found that heat flow is between about 40 and 70 mW/m^2.

Deep-sea heat flow measurement

<u>Specification of tools</u>

Heat flow is obtained as the product of the geothermal gradient and the thermal conductivity. We measured the geothermal gradient by penetrating an ordinary deep-sea heat flow probe or a heat flow piston corer into seafloor sediments. The heat flow probe has a 3 - 4.5 m-long lance, along which thermistor temperature sensors are mounted (Photo 4-4-1.1). The total weight of the probe is about 800 kg and the lance is strong enough to allow multi penetrations at each station. Temperature of the sensors and two components of the instrument tilt are measured every 30 sec. The data are recorded in the data logger and sent to the surface with acoustic pulses so that we can monitor the status of the probe on the ship.

On the KR07-06 cruise, we used two different types of temperature sensors; Ewing type sensors mounted in an outrigger fashion (Photo 4-4-1.1) and commercial compact temperature recorders (Miniaturized Temperature Data Logger, ANTARES Datensysteme GmbH (Photo 4-4-1.2)) as well. Specifications of the data logger used for the heat flow probe and HFPC and the ANTARES Miniaturized Temperature Data Logger (MTL) are summarized below:

Heat Flow Data Logger (Kaiyo Denshi Co.)

Pressure case: anodized aluminum
Pressure rating: 6000 m water depth
Number of temperature channels: 8
Temperature resolution: 1mK
Tilt: two-axis, 0 to ±45°
Data-cycle interval: 30 sec
Pinger frequency: 15.0 kHz

Miniaturized Temperature Data Logger (ANTARES Datensysteme GmbH)

Pressure case: stainless steel
Case length: 160 mm
Diameter: 15 mm
Pressure rating: 6000 m water depth
Number of temperature channel: 1
Temperature resolution: 1.2 mK at 20°C, 0.75 mK at 1°C
Sample rate: variable from 1 s to 255 min.

Photo 4-4-1.1. Deep-sea heat flow probe with Ewing type temperature sensors.

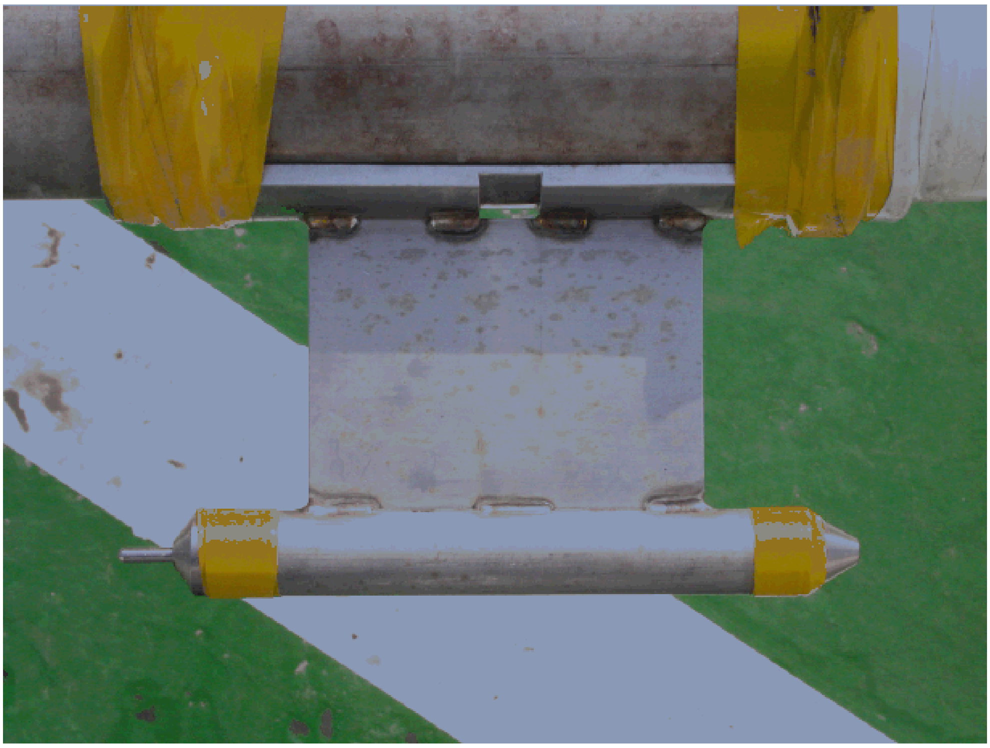

Photo 4-4-1.2. Miniaturized Temperature Data Logger (ANTARES Datensysteme GmbH)

Operations

A 15-20 m long fiber rope was put between the heat flow probe and the winch wire rope in order not to kink the wire rope during probe penetrations. An acoustic transponder was also attached 50 m above the probe for precise determination of the position of the probe (Figure 4-4-1.1). Multi-penetration heat-flow measurement operations were conducted following the procedures described below.

1. Measure water temperature 50 to 100 m above the sea floor for calibration of temperature sensors.
2. Lower the probe at a speed of about 60 m/min until it penetrates into the sediment.
3. Measure temperatures in the sediment for about 20 min. Monitor the wire tension and pay out the wire when necessary to keep the probe stable.
4. Pull out the probe and move to the next station.

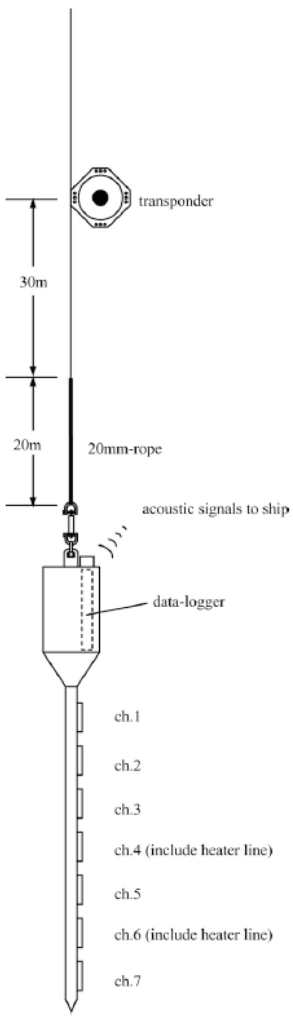

Figure 4-4-1.1. Schematic illustration of the heat flow measurement system in deep sea.

Results

We carried out heat flow measurements at three sites with the HFPC and at six sites with the deep-sea heat flow probe (Table 4-4-1.1).

Table 4-4-1.1.

Station	Lat (deg)	Lat (min)	Lon (deg)	Lon (min)	Depth (m)	Probe Length	Comment	N
HF-PC01	35	38.9452	154	48.9876	5454	5.0m	penetrated	7
HF02A	36	32.0652	152	21.5480	5867	4.5m	fell	
HF02B	36	32.0582	152	21.5781	5869	4.5m	fell	
HF03A	36	40.2532	152	2.7741	5786	3.0m	penetrated	5
HF03B	36	40.2500	152	2.7830	5790	3.0m	penetrated	5
HF-PC05	37	48.6452	148	52.6063	5867	5.0m	penetrated	7
HF06A	38	8.7518	147	58.4961	5684	4.5m	fell	
HF06B	38	8.7470	147	58.4983	5684	4.5m	penetrated	7
HF06C	38	8.7584	147	58.4951	5687	4.5m	penetrated	7
HF09A	38	49.0162	146	1.9721	5313	4.5m	penetrated	8
HF09B	38	49.9501	146	1.9721	5311	4.5m	penetrated	6
HF09C	38	48.9389	146	2.0135	5312	4.5m	penetrated	6
HF08A	38	33.5239	146	44.9387	5329	4.5m	penetrated	6
HF08B	38	33.5280	146	44.9274	5331	4.5m	penetrated	6
HF08C	38	33.4484	146	45.0752	5328	4.5m	penetrated	6
HF07A	38	26.8676	147	4.9830	5484	4.5m	penetrated	5
HF07B	38	26.8752	147	4.9567	5488	4.5m	penetrated	5
HF07C	38	26.8784	147	4.9629	5489	4.5m	penetrated	
HF10A	39	3.4577	145	21.0645	5232	4.5m	penetrated	5
HF10B	39	3.4300	145	21.0875	5234	4.5m	penetrated	5
HF10C	39	3.4342	145	21.0957	5234	4.5m	penetrated	5
HF-PC11	39	12.0211	144	57.0252	5562	4.5m	fell	

We could successfully penetrate the HF-PC core barrel or heat flow probe into sea-floor sediments at all the stations except HF-PC11. Five temperature sensors (MTL) were lost at the measurement of HF-PC11. But the core of HF-PC11 could be obtained more than 3 m. At the measurement with conventional heat flow instrument, the probe was penetrated twice or three times. the profiles appear to be linear.

In-situ thermal conductivities of sediments were measured using heat pulse method at conventional heat flow instrument. Thermal conductivity will be also measured on piston core samples in a laboratory on shore. Thermal conductivities are between about 0.8 and 1.0 in this area by in-situ measurement.

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4-4-2. Piston coring system

Y. Taketomo, N. Togashi, and E. Hatakeyama

Instrumentation

Piston corer system was used during this cruise, a heat-flow piston corer with duralumin barrel and inner core liner. This system is shown in Figure 4-4-2.1.

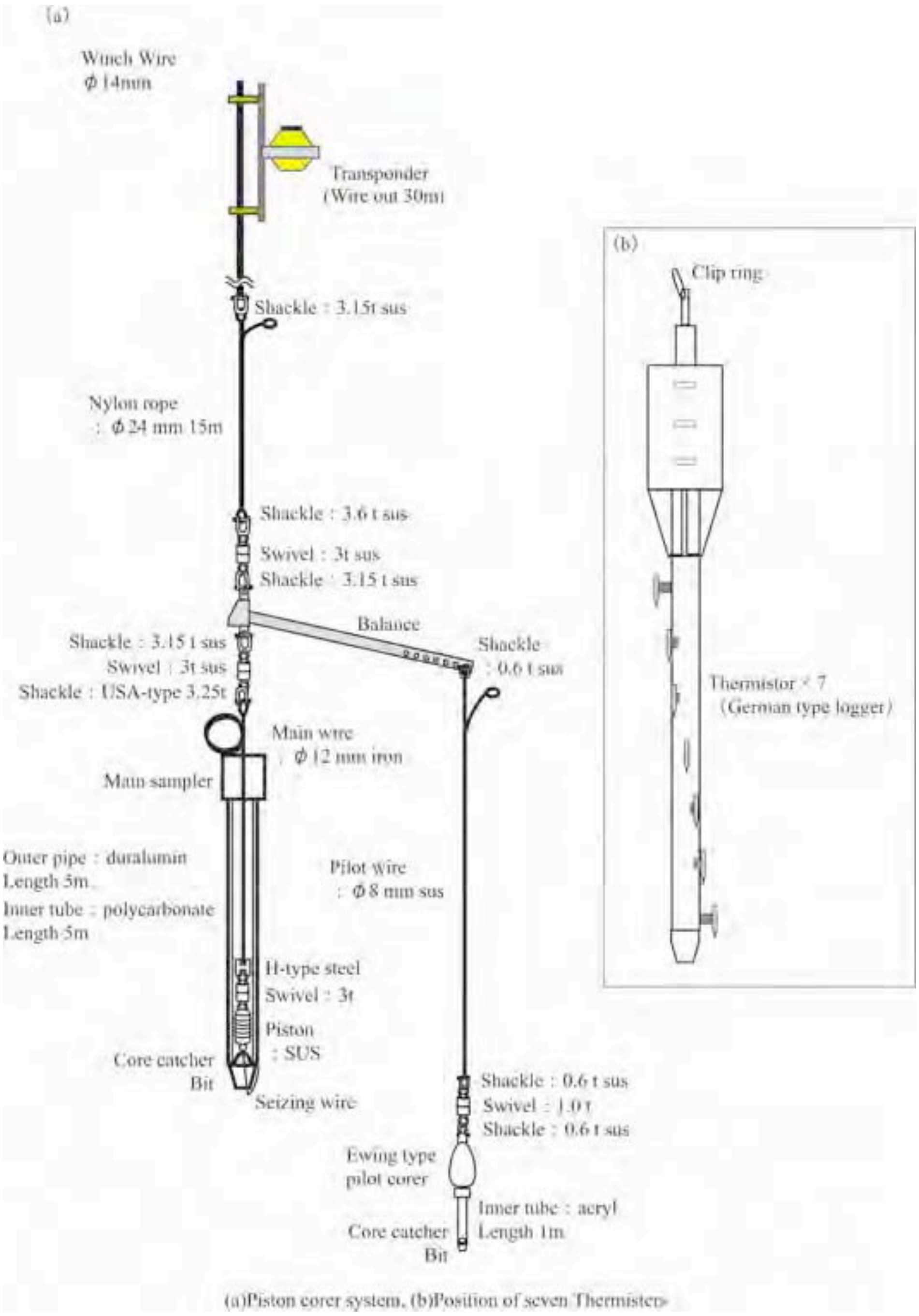

Figure4-4-2.1. Piston corer system.

Piston corer and heat flow system

The piston corer system was used for the combined operation of measuring heat flow and recovering sediments. The barrel was attached to a piston corer head of 900kg weight. This system was placed 7 thermistors to record the temperatures on the outside of barrel in a spiral. Each thermistor recorded the data by itself. To recognize the water depth and the position of this system, a transponder is placed at winch wire of 30m above the nylon rope. The duralumin barrel with this system is 5m in length and liner is used for recovering sediments. 15m nylon rope was placed between the balance and winch wire for additional wire out and/or increased tension after hitting sea bottom. Because the system must be kept in the sediment for 10～20 minutes to obtain stable temperature, additional wire out must be avoided to pulling the barrel out of the seafloor by either heaving or drifting of the ship during the measurement.

General Operation

Preparation for the piston coring

After barrels are attached to the head (weight stand), the main wire is connected, through the barrel, to the piston at the bottom of the barrel, and to the balance at the weight stand. The core catcher and bit are then attached. The balance is connected to the end of the main wire. The entire assemblage is carried under the A flame using a cart and is lifted over the edge of the deck by the main winch, A flame and capstan winches, the pilot core and it's wire are then connected to the balance. To prevent the piston moving due to water pressure from below, a large amount of water must be added into the barrel from the top of weight during the launch into the sea.　The system is then lowered through the water to the seafloor.

Aft. wheel house

When the sampling site is reached, the operation of the ship is transferred to the aft. wheel house which overlooks the aft working deck. From this room the ship can be fully managed, the winch is operated, all equipment handling is fully observed and the wire out and wire tension are displayed, all operations can easily managed. Therefore, scientists, technicians, the ship's operator and winch operator are in this room, working jointly, during the piston core operation. After stopping the ship at the site, the ship keeps its position by bow and stern thrusters throughout the operation.

Winch Operation

The piston corer starts lowering at a winch speed of 60 m/min. The corer is stopped at a depth about 100m above the seafloor for 10 minutes to reduce any pendulum motion and to calibrate the thermistors on the outside of barrel. This also reduce possible swing of the core after pullout, which could cause lose of the samples.

After 10 minutes standing 100 m above seafloor to confirm that the system is stabilized, the wire is paid out at a speed of about 20 m/min., at the same time carefully watching the pen recorder of the strain gauge tension meter. When the corer hits the bottom the tension will abruptly decrease by release of the amount of the corer weight. Therefore, it is easy to detect the bottom hit.

Immediately after confirmation that the corer hit bottom, wire out is stopped and keep the position for 10～20 minutes. And then, rewinding of the wire is started at a dead slow speed (10 m/min.) until the tension gauge indicates that the core has lifted off the bottom. The tension meter shows a small increase in tension when the corer is being pulled out of the seafloor and then a steady value. After we can recognize absolutely that the piston core is above the seafloor, the winch to keep speed is increased to 60 m/min.

Sediment core treatment

The inner tube of the piston core filled by sediments was cut into 1 m length for each section using a handy cutter. Each section was longitudinally cut into working and archives half by a splitting device.

4-5. Sediment Core Description

N. Abe, T. Kanamatsu, H. Hamamoto, Hatakeyama, T. Mori

Purpose of Piston Core study

The aims of piston coring during KR07-06 petit spot cruise are 1) to measure precise thermal conductivity of the ocean floor surface at the heat flow measurement site, 2) to investigate their paleomagnetic record at the sites, 3) to take further geological and geophysical measurement on the sediment core sample as occasion arises. There are not many sediment samples from this area, neither from plane oceanic old plate, therefore those sediment core samples are quite important to understand the evolution of the oceanic plate.

Sediment core treatment

The piston core sampling with heat flow measurement was taken three times during KR07-06 cruise. The sediment core samples were cut 1m each on board right after Piston Corer on deck each time. Cut core sections had been deposited in a refrigerator in the core laboratory on R/V KAIREI until the unloading for about a month. Then, they were cut on land at JAMSTEC

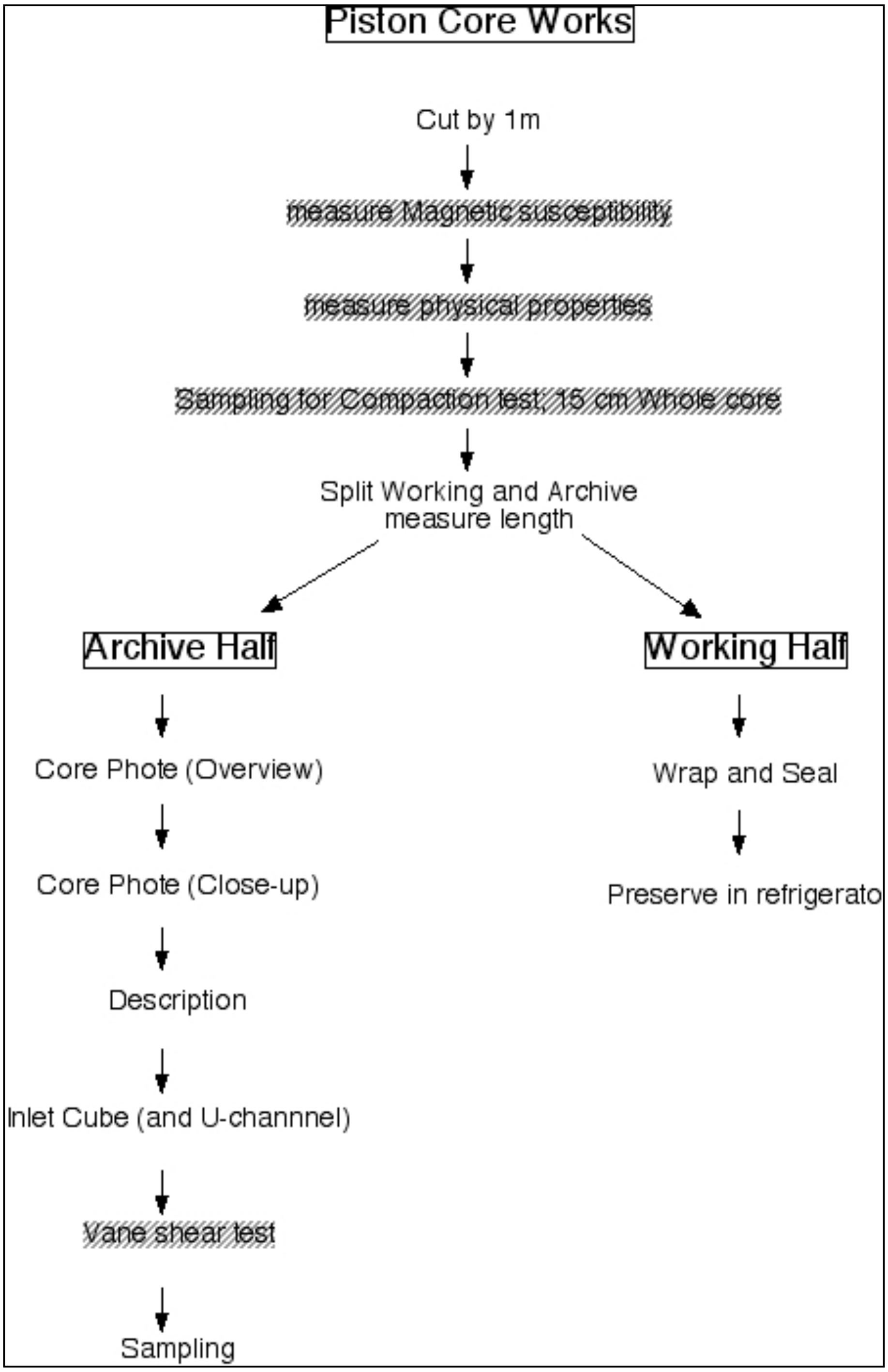

Figure 4-5.1. Piston core sample procedure.

headquarters on June 19 and 20, 2007. The cores were described after halved lengthwise and taken overview sample photographs.

Each length of sediment core samples is shown in Table 4-5.1. The core description sheets are attached as Figure 4-5.2. The sample photo (overview) and close-up photos are attached as Figure 4-5.3.

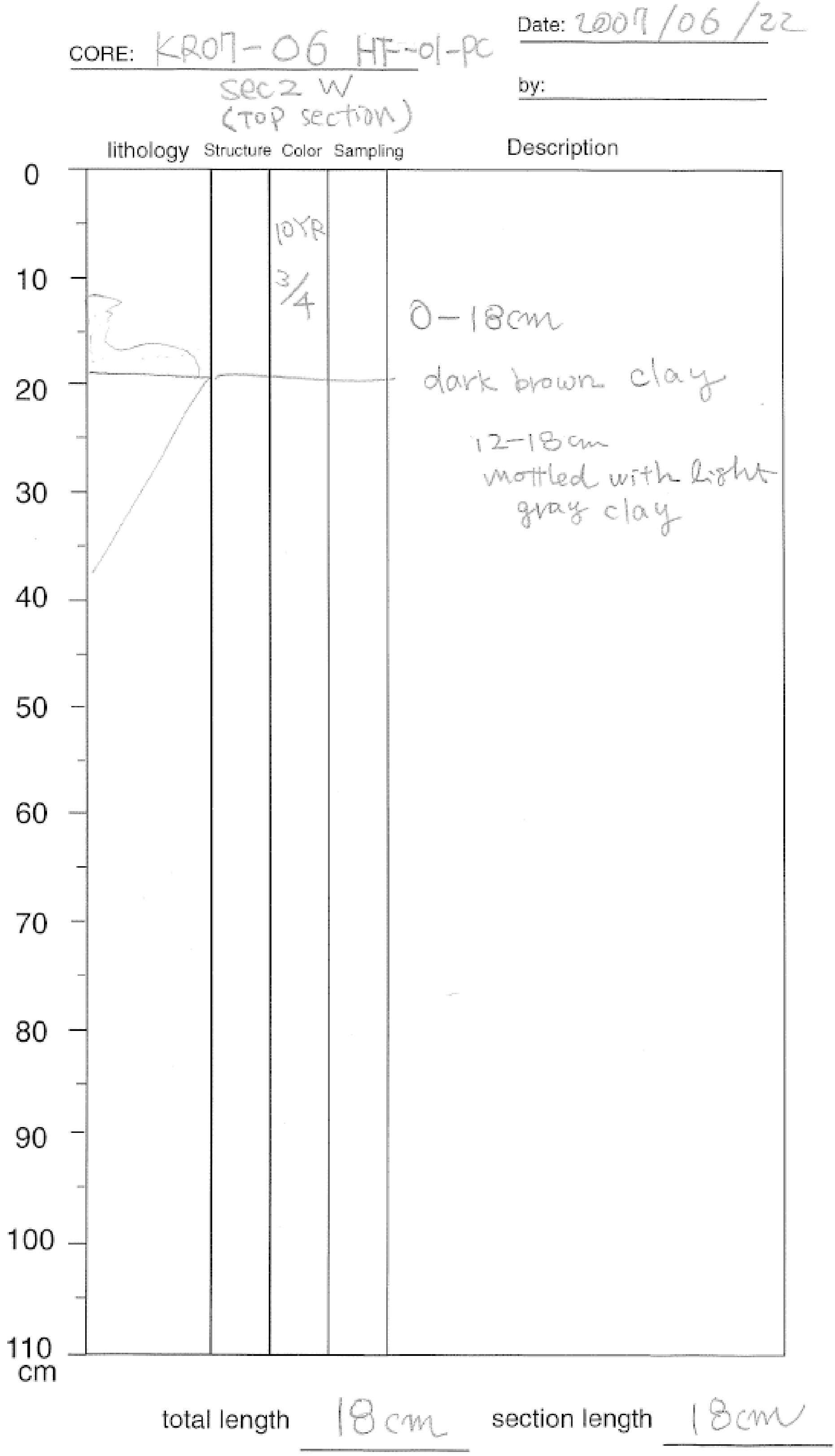
CORE: KR07-06 HF-01-PC
sec2 W
(TOP section)
Date: 2007/06/22
by:
lithology
Structure
Color
Sampling
Description
0
10
20
30
40
50
60
70
80
90
100
110
cm
10YR
3/4
0-18cm
dark brown clay
12-18cm
mottled with light gray clay
total length 18cm
section length 18cm

Figure 4-5.2.

Table 4-5.1. Sediment core sample length.

Site	HF-01-PC		HF-05-PC		HF-11-PC	
	W	A	W	A	W	A
Top section	2	2	2	2	2	2
Total length	318.1	313.5	376.2	374.7	395	395.9
Section 2	17.2	13.1	79.0	78.0	95.0	95.8
Section 3	100.6	100.1	100.0	99.8	100.2	100.2
Section 4	100.2	100.2	100.5	100.2	99.2	99.2
Section 5	100.1	100.1	96.7	96.7	100.6	100.7

W: working half, A: archive half

Figure 4-5.3a. Overview core sample photo (HF-01-PC).

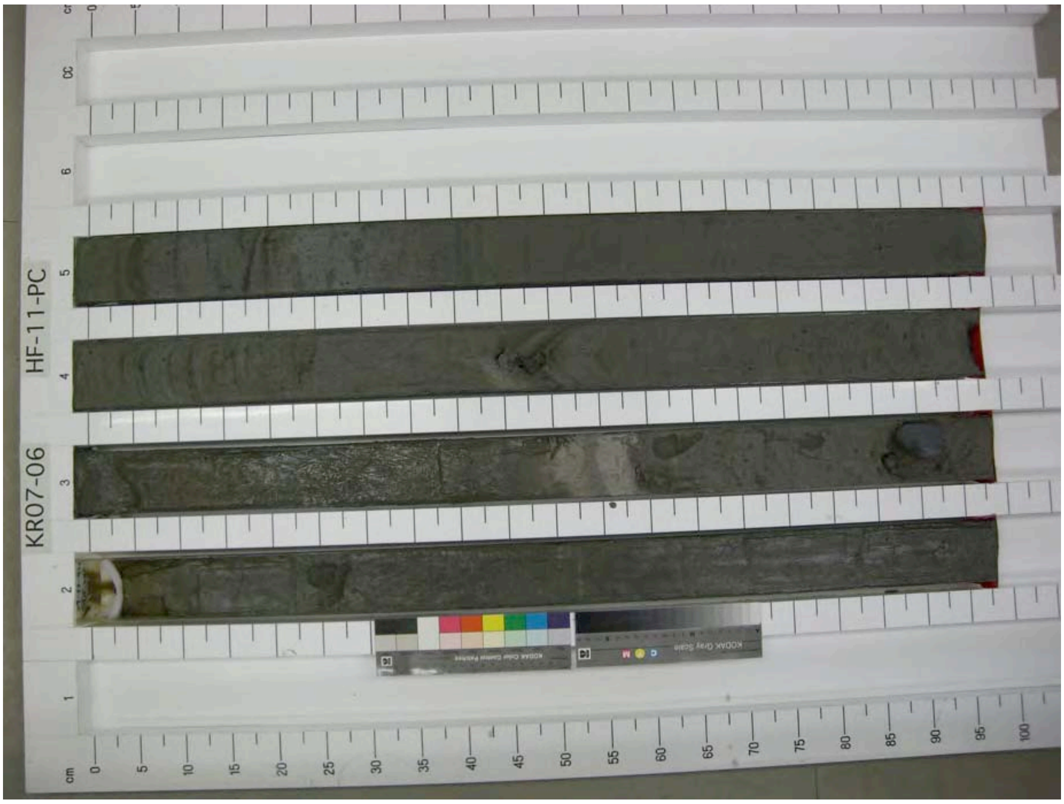

Figure 4-5.3b. Overview core sample photo (HF-05-PC).

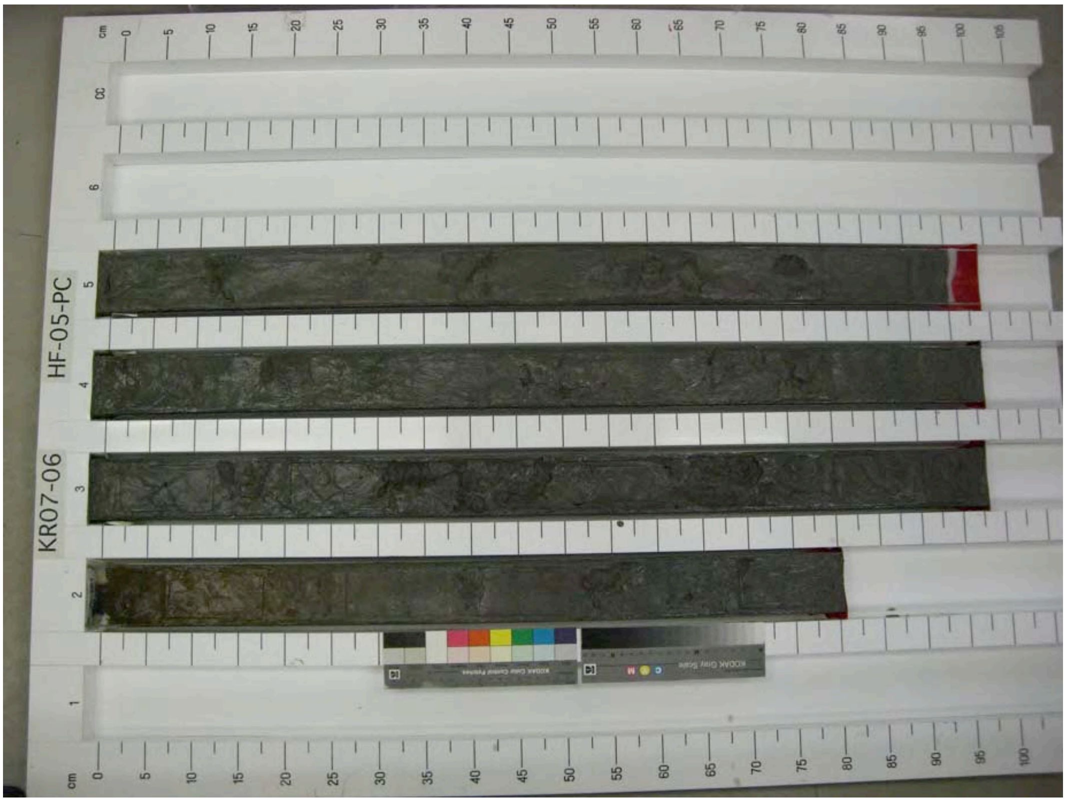

Figure 4-5.3c. Overview core sample photo (HF-11-PC).

Core descriptions

<u>A. HF-01-PC</u> (2007.6.19 cut)

Totally 313.5 cm (archive half) and 318.1 cm (working half) length sediment core was sampled at Site HF-01-PC. Dark brown to dull yellow clay and slightly reddish brown clay is sampled with several thin layers of grayish clay. Those thin layers are probably some ash layers as widespread tephra. There is a black coarse sand pod, probably Mn coated, indurate clay fragment layer at the bottom of Section 3W (95-96 cm). There is a strange pattern on the cut surface at 58-73 cm, Section 5W; brownish black laminated layer (2-3 cm thick) mottled with dull yellow clay pod with sharp contact with dull yellow clay part at 73 cm (Figure 4-5.4). There are several parts of moderately mottled by bioturbations all over this core. As understood even from the pilot core (Ewing) was overcrowded, the sediment layer on this sea floor surface is loose and unconsolidated.

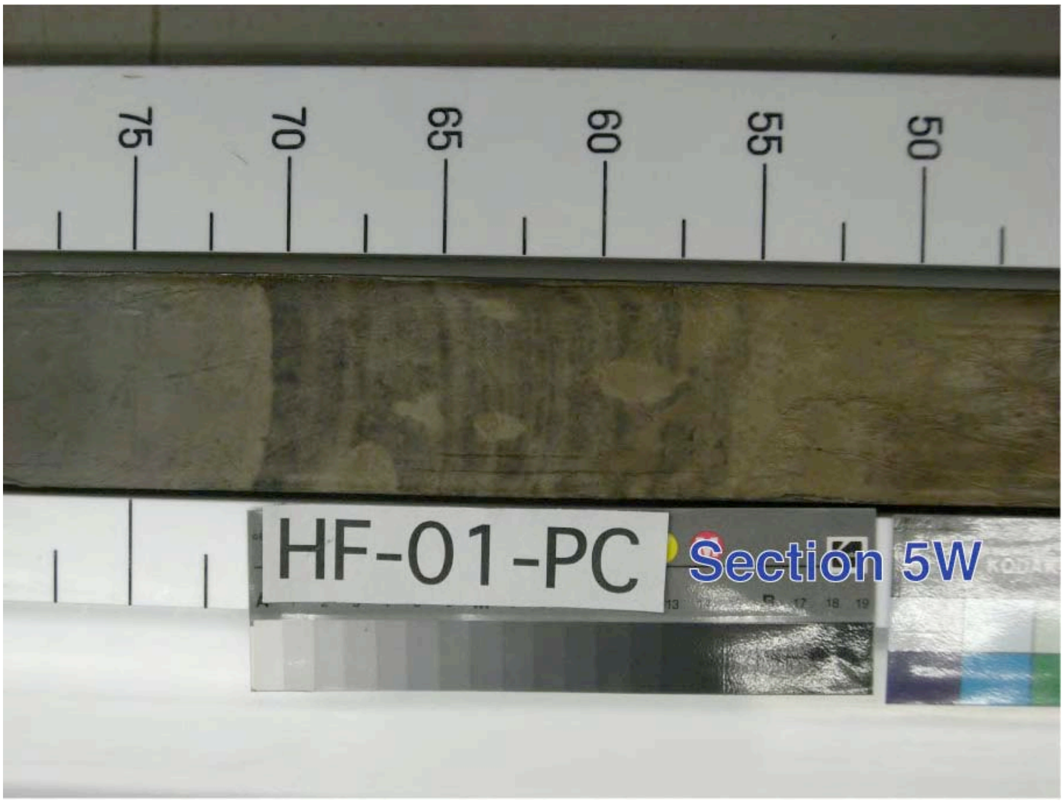

Figure 4-5.4. A strange pattern of dark brownish black laminated layer with mottle yellowish clay pods at 58-73 cm, Section 5W.

<u>B. HF-05-PC</u> (2007.6.19 cut)

Totally 374.7 cm (archive half) and 376.2 cm (working half) length sediment core was sampled at Site HF-05-PC. Grayish massive silty clay with several green colored faint bonds is sampled at this site. Only a few ten centimeter of the core at the top shows brownish black

color.

C. HF-11-PC (2007.6.20 cut)

Totally 395.9 cm (archive half) and 395.0 cm (working half) length sediment core was sampled at Site HF-11-PC. Grayish olive silty clay with several dark grayish yellow silty clay parts was sampled at this site. Various colored (gray to green) 5 mm thick bands are in Section 5W between 8 to 23 cm. Remarkably a large black round pebble (~5 cm) was sampled at the bottom of Section 3W and relatively thick light gray silty clay part as an ash layer (9 cm) is in the middle of Section 3W (Fig. 4-5-5). There are a couple of pumice pebbles (~2cm) in 46-50 cm, Section 4W. There are several ash layers between 52 cm in Section 3W to 50 cm in Section 4W.

Figure 4-5.5. A pebble and moderately thick ash layer in HF-11-PC, Section 3.

Future plan

The sediment cores will be sampled using by mini cube for paleomagnetic measurement (T. Kanamatsu). If paleontological and/or paleomagnetic datings are needed for petit spot study or heat flow modeling, the samples would be taken. Meanwhile, core sections are sealed and packed in plastic bags and stored in a refrigerator belonging to DSR group, IFREE, JAMSTEC.

4-6. Geological survey and rock sampling

N. Hirano, N. Abe, S. Machida, and T. Ishii

Remotely operated vehicle (ROV) "KAIKO7000II" was modified from "KAIKO7000" and "KAIKO" after 2006. It is a powerful tool for the geological surveys and samplings on the deep seafloor.

KAIKO7000II dove to three sites at the Kaiko Knolls lava field on the Japan Trench, oceanward slope (Figure 4-6.1), three of which are young volcanoes on the Early Cretaceous Pacific Plate erupted at 4.2, 6.0 and 8.5 Ma (Hirano *et a*l., 2006). The targets of these three dives are sampling rocks, observation of eruptive styles and discussion of the stratigraphy of the monogenic volcanoes. We expected the several type of lavas, which are flood lavas, vesicular lavas and peperites. Cretaceous basement may be also sampled along the fault wall of the horst and graven and/or as xenoliths.

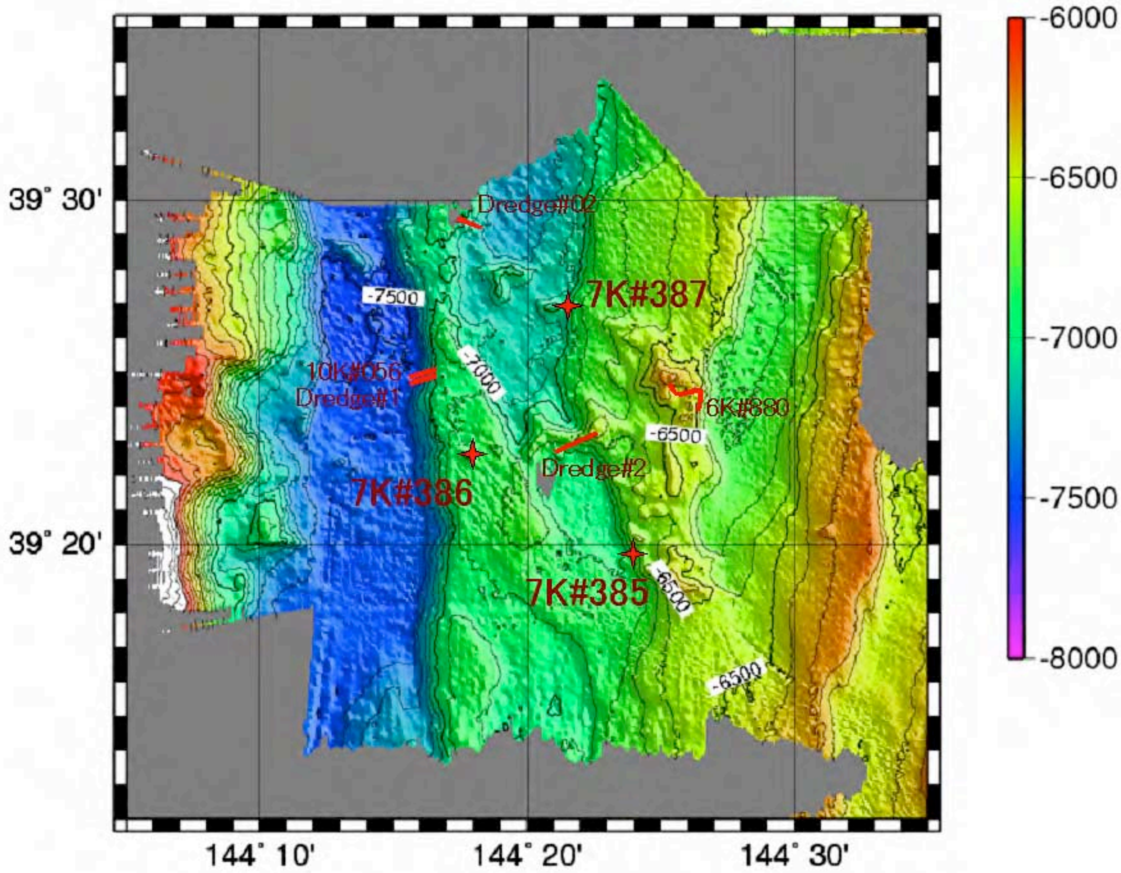

Figure 4-6.1. Bathymetrical map of the Kaiko Knolls lava field. All of hummocks show monogenetic volcanoes of petitspot disrupted by the horst and graven structure on the trench oceanward slope of the Japan Trench.

4-6-1. Dive #385: Kaiko knoll cliff

N. Abe

Date: May 27, 2007

Dive point: A fault cliff beside a petit spot knoll, Kaiko knolls, off Sanriku, the Japan Trench

On bottom: 39°19.6042’N, 144°23.9109’E, D= 6817m

Off bottom: 39°19.8497’N, 144°23.9292’E, D=6756m

Launcher Pilot: Seiji Shigetake

Pilot: Homare Wakamatsu

Co-Pilot: Hideki Sezoko

Observer: Natsue Abe

Payload

1- Sample basket

1- Sample Box

1- Rake sampler

4- Partition (to part sample basket by 4) - 4

Purposes of Dive

Dive target is a cliff (Figure 4-6.2) beside a Kaiko knoll which is considered as a kind of petit spot volcanoes. The slope is possibly formed by faulting of horst and graven structure around this area, then an exposure of the cross-section of a petit spot knoll is expected. The aim of this dive is to observe on the surface of this slope and to take rock samples from this slope.

Results

ROV Track for this Dive (#385) is shown as Figure. 4-6-2 and Dive log is attached as Table 4-6-1. Total bottom time of R/V KAIKO 7000II of Dive #385 was shorter than 1.5 hours because of the unstable weather. Vehicle was detached from Launcher at 10:58 a.m., 6688 mbsl and on the sea floor at 11:12 a.m., 6817 mbsl. The sea floor was a slope blocked by angular basaltic rubbles. The outcrop is thinly covered by sediment, but there is little cover of Mn crust (Figure 4-6.3). There are several steps on the slopes, which is repeated terraces and steep cliffs. There are white humps made of semisolid state clay on some terraces (Figure 4-6.4), which is peculiar to petit spot knolls.

Rock samples were taken by right side manipulator (Figures 4-6.3). If the rock samples are not large enough to be taken by manipulator, sampling is attempted using by a rake (Figure 4-6.5). There are some large boulders on the terrace like plane (Figure 4-6.6). There are lobe-like structure covered by thick Mn crust in a part of the cliff (Figures 4-6.7 to 4-6.10). The bottom surface of the last sampling site (Site 7KII- #385-8) was a scree slop filled with angular rubbles (Figure 4-6.11). As well as slope gradient of the cliff, the aspect of the outcrops repeatedly changes with pile of rubble, and large round clints/pillow and sediment plane with white humps. This dive had only about 250 m distance excursion and 61 m distance in elevation for 1:18 hours in the result.

Rock Samples

Described sample feature and lithology are shown in Table 4-6.2. The sampling were attempted totally 13 times including one rake scope during this dive. The collected samples are mainly basaltic lava fragments and possible pillow lavas, some volcaniclastics (basaltic small fragments) and one manganese nodule. It was hard for 7KII to take massive samples from outcrops, therefore, most of these samples are considered as boulders near the outcrops. One basaltic lava sample has a thick Mn crust (~3.5 cm; Figure 4-6.12) and others has thin (<1 cm) Mn crust. Some basaltic samples include peperite in vesicles or out of the block (Figure 4-6.13). Some basaltic lava samples show vesicle layering (Figure 4-6.13). Most of the basalt samples has a lot of olivine phenocryst (possibly xenocryst), and some clinopyroxene and orthopyroxene xenocrysts with reaction rim between the basaltic host rock. Mafic and ultramafic xenoliths can be hardly found, except for a few grains aggregate of olivine and orthopyroxene and/or olivine and clinopyroxene (Figure 4-6.14).

Sampling site and Video highlights

(1) 11:12 On the bottom, sampling Site 1 (R-01)
(2) 11:23 Sampling Site 2 (R-02 and R-03)
(3) 11:34 White humps, sampling Site 3 (R-04 and R-05 with rake)
(4) 11:51 Boulders, sampling failed
(5) 11:51 Lobe outcrop, Sampling Site 4 (R-06)
(6) 11:56 Outcrop covered with Mn crust, Sampling Site 5 (R-07 and R-08)
(7) 12:05 Lobes, sampling Site 6 (R-09 and R-10)
(8) 12:11 Sampling Site 7 (R-11)
(9) 12:18 Scratching on the surface of Mn crust
(10) 12:26 Sampling Site 8 (R-12 and R-13)
(11) 12:31 Off Bottom

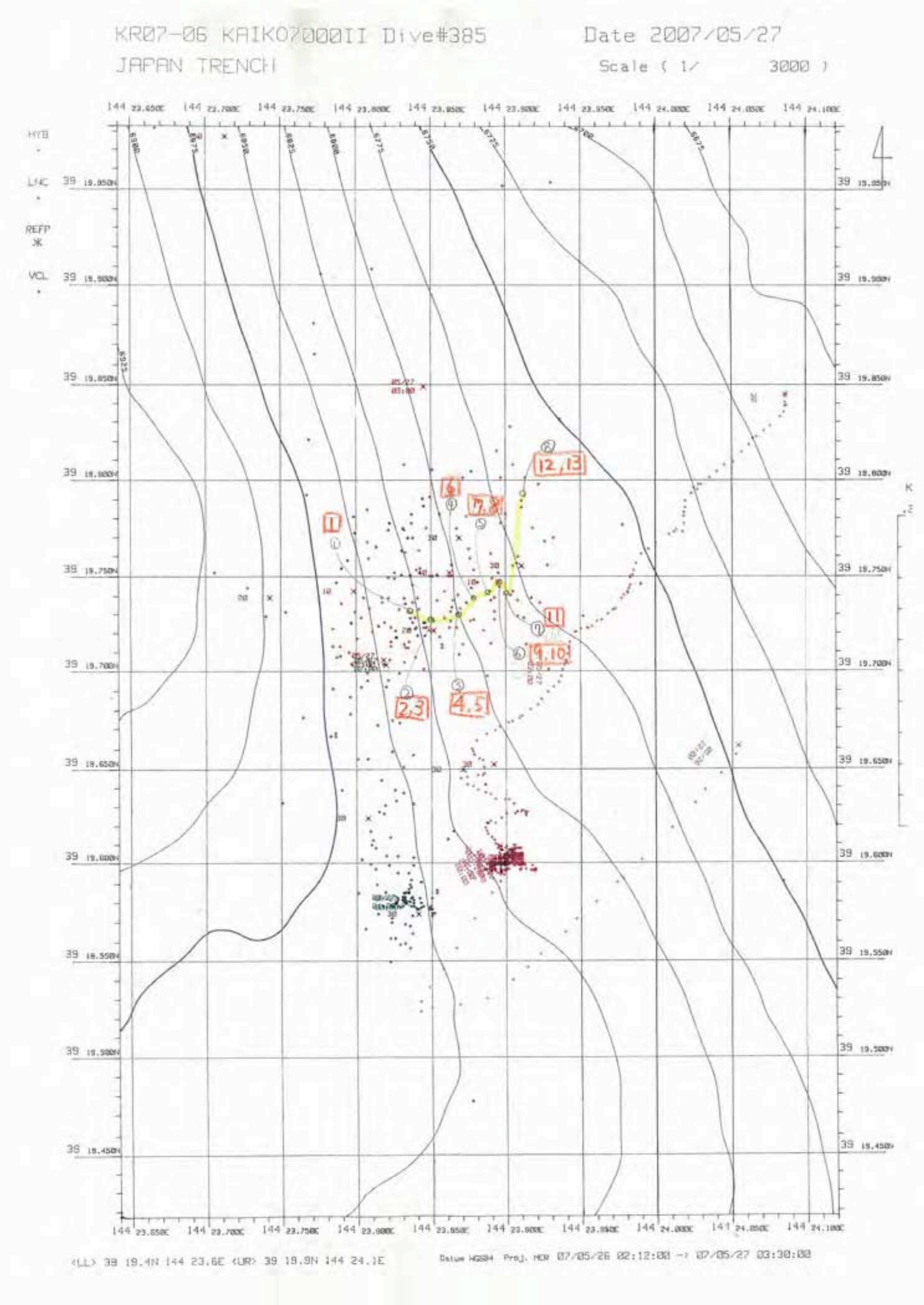

Figure 4-6.2. R/V KAIKO 7000II Dive track for Dive # 385 carried on May 27, 2007 at Kaiko knolls, the Japan Trench site. Red numbers, sampling sites. Yellow line, Dive track.

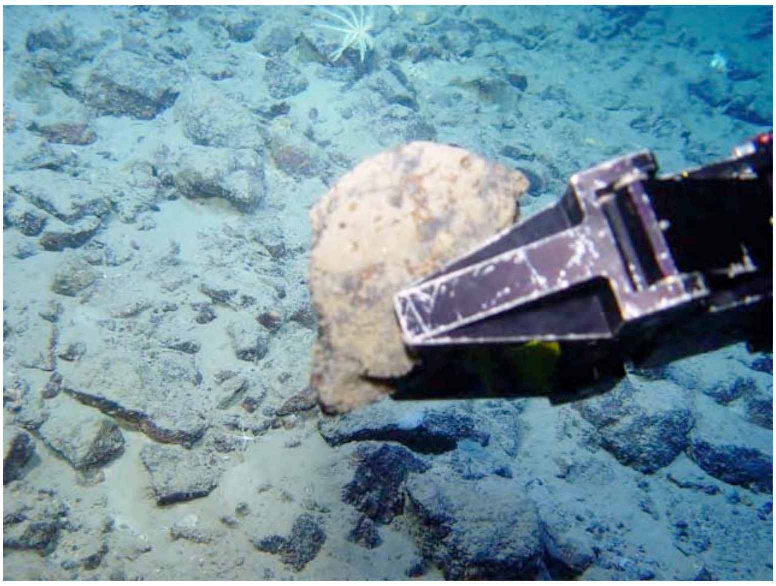

Figure 4-6.3. Sampling at the first site on the sea floor. The outcrop is filled with angular boulders. Sampling Site 1.
(11:18) DSC00378

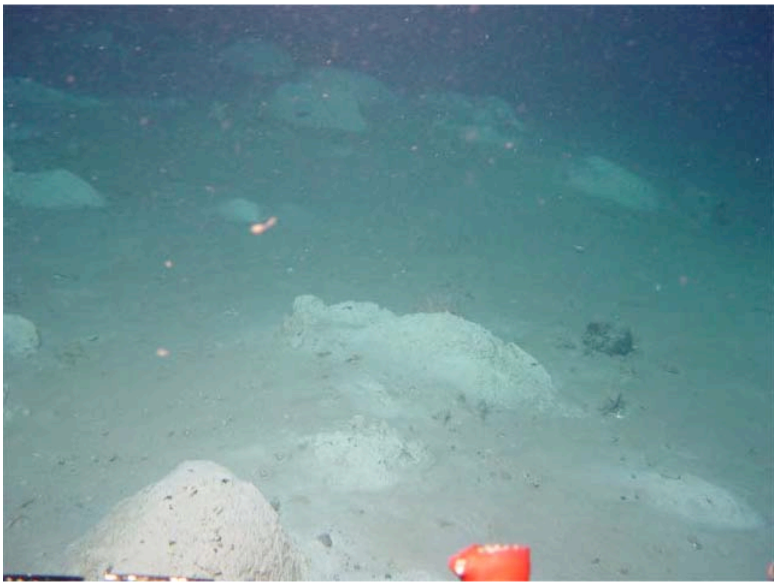

Figure 4-6.4. White humps on a terrace. They are made of semisolid state clay.
(11:39) DSC00392

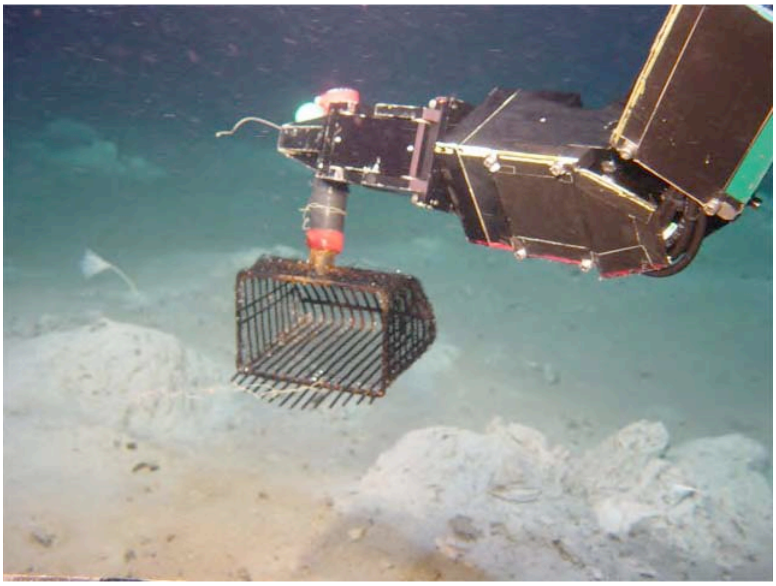

Figure 4-6.5. Small pebble sampling using by a rake. Sampling Site 3.
(11:39) DSC00399

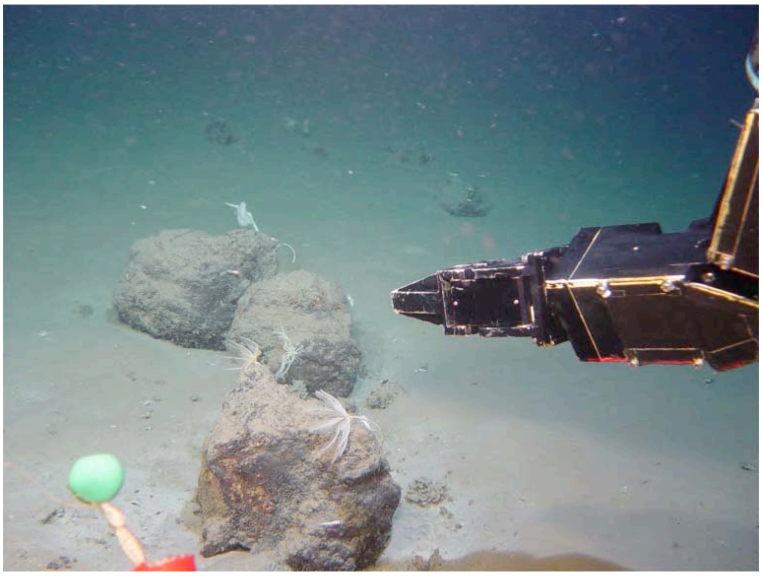

Figure 4-6.6. Boulder on a terrace.
(11:51) DSC00403

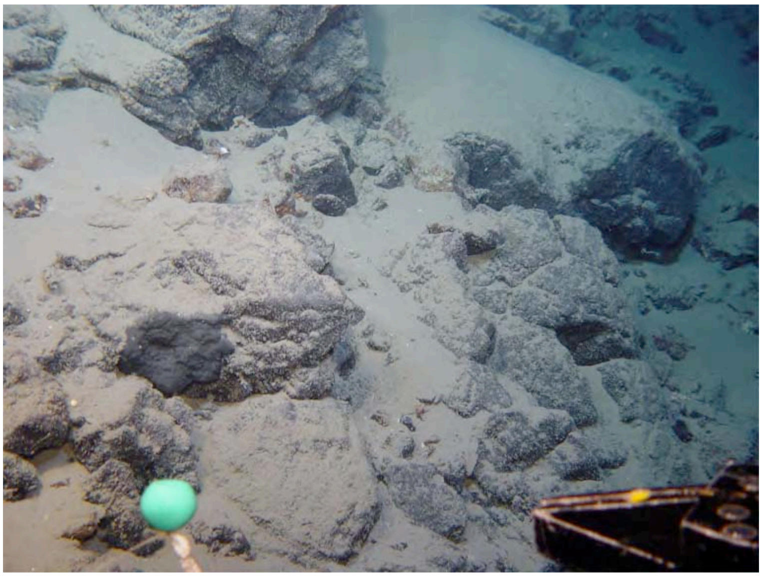

Figure 4-6.7. Outcrops covered with thick Mn crust. Sampling Site 5.
(11:57) DSC00414

Figure 4-6.8. Lobe stracture. Close to the Sampling Site 7.
(12:10) DSC00441

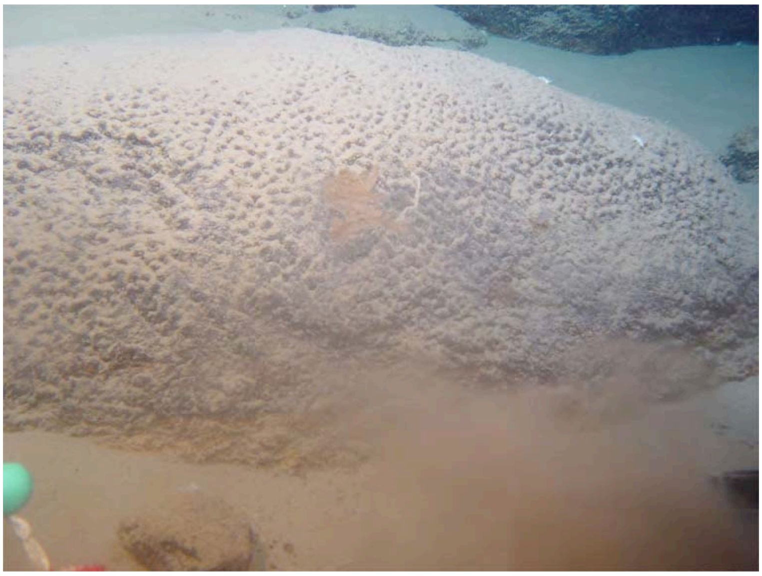

Figure 4-6.9. Scratched surface on a lobe.
(12:21) DSC00458

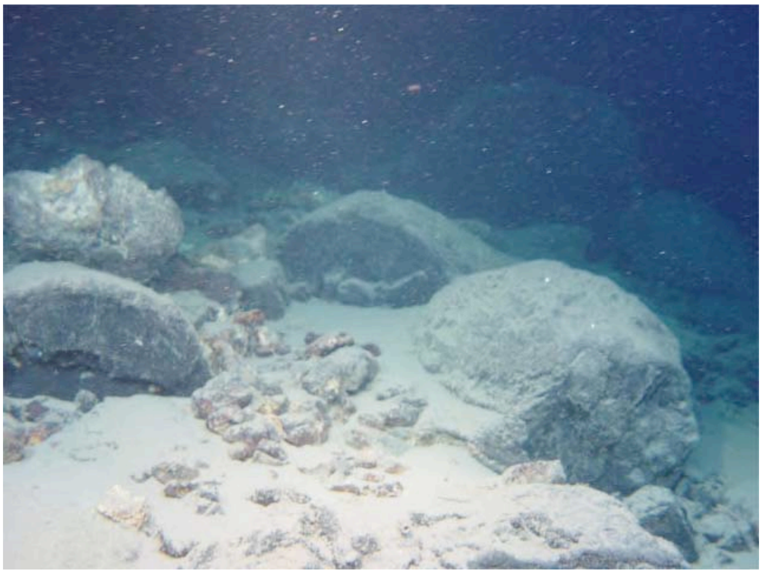

Figure 4-6.10. Outcrop with lobes and large round boulders(?). Sampling Site 6.
(12:01) DSC00419

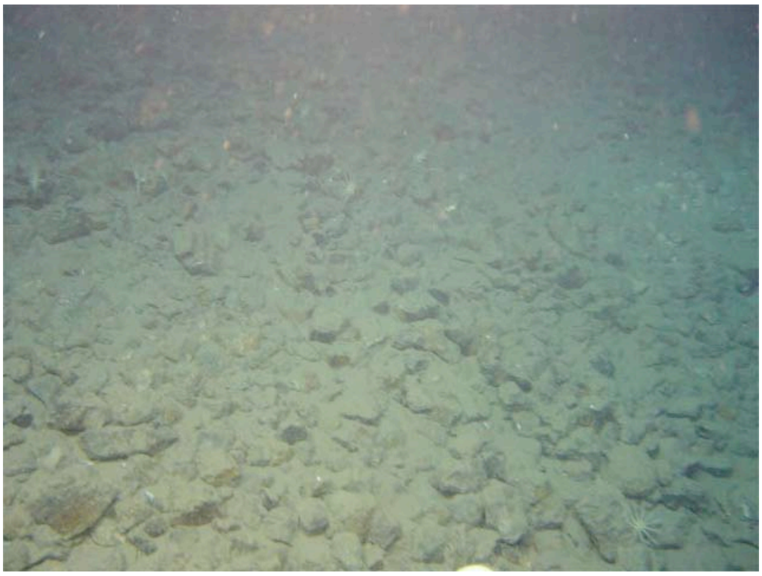

Figure 4-6.11. Last sampling Site 8 filled with angular rubbles.
(12:31) DSC00484

Figure 4-6.12. Basaltic lava sample with thick Mn crust.
(7KII #385 R-03)

Figure 4-6.13. Basaltic lava sample with vesicle layers.
(7KII #385 R-01)

Figure 4-6.14. Basaltic lava sample containing relatively large amount of mafic minerals such as olivine, orthopyroxene and clinopyroxene (?).
(7KII #385 R-08)

日付 2007.5.27 KR 0706 No. 385 No.

調査種類 かいこう調査潜航 調査海域 日本海溝 かいこう海丘群

	時刻	深度	作業内容	緯度・経度	
	08:39		着水 D=6801m	39-19.6042N 144-23.9109E	X: Y:
	08:58	150m	下降開始 深度6500mまで下降	.5780 .8425	X:-40.7m Y:-82.7m
	10:59	6673m (L)	VCL 離脱	.6987 .8323	X:182.7m Y:-97.3m
①	11:12	6817m	着底	.7304 .8350	X:241.3m Y:-93.3m
	11:17	〃	岩石採取(1個)	〃	X: Y:
②	11:26	6799m	〃 (1個)	39-19.7268 144-23.8508	X:234.7m Y:-70.7m
	:	〃	〃 (1個)	〃	X: Y:
③	11:35	6791m	〃 (1個)	.7276 .8694	X:236m Y:-44m
	11:39	6791	熊手による採泥	〃	X: Y:
	11:43	〃	〃	〃	X: Y:
④	11:53	6789m	岩石採取(1個)	.7364 .8812	X:252.3m Y:-27.0m
⑤	11:58	6778m	〃 (2個)	.7403 .8875	X:259.7m Y:-18m
⑥	12:06	6772m	〃 (2個)	.7470 .8958	X:272m Y:-6.0m
⑦	:15	6766m	〃 (1個)	.7405 .9000	X:260m Y: 0m
⑧	:27	6760	〃 (2個)	.7924 .9125	X:356m Y: 18m
	:30	6756	離底	〃	X: 〃 Y:
	:45	6593(L)	結合	.8497 .9292	X:462.0 Y: 42.0
	:48	〃	一次ケーブル巻取開始	〃	X: Y: 〃
	:				X: Y:
	:				X: Y:
	:				X: Y:
	:				X: Y:
	:				X: Y:
	:				X: Y:
	:				X: Y:

Table 4-6.1. Dive log for #385.

Table 4-6.2. Sample list for 7KII Dive #385.

by KR07-06 hard rock sampling party

Sample No.	Rock type	Lithology	Diameter (mm) L	M	S	Wt (g)	Mn (mm)	alteration	Vesicularity (%)	glass thickness (mm)	Color	phenocryst (%) Ol	Pl	Py	Remarks
7KII#385-R01	lavas	basalt	130	130	130	2650	<10	no	>20	<7	dark brown ~ black	3	-	-	layering of vesiculation, chilled margin
7KII#385-R02	lavas	basalt	185	97	62	2350	0	no	<20	<5	dark brown	10	-	-	spinel inclusion in Ol, large ol xenocryst(?) up to 10 mm
7KII#385-R03	lavas (pillow)	basalt	183	100	100	2100	<35	no	20	<5	dark brown ~ black	2			w/ peperite
7KII#385-R04	others	Mn nodule	155	110	90	1550	-	-			dark brown				
7KII#385-R05	volcaniclastics	basalt	-	-	-	75	-	-	high	-	black	-	-	-	basaltic fragments and peperite, and red chart
7KII#385-R06	volcaniclastics	basalt	105	80	50	450	0	no	20	thin	dark brown	3			fragment of lavas(?), Ol xenocryst up to 4 mm
7KII#385-R07	lavas	basalt	124	80	70	1280	3	no	25	<5	dark brown ~ black	2			layering of vesicular
7KII#385-R08	lavas	basalt	200	180	65	4300	<13	no	20	<5	dark brown ~ black	6			Ol xenocrysts up to 7mm
7KII#385-R09	lavas (pillow)	basalt	340	190	140	9000	<5	no	<20	<6	dark brown ~ black	3			one Ol grain w/opx, layering of vesicule, irregular cooling crack
7KII#385-R10	others	solid peperite	110	90	12	180					pale brown				solid peperite
7KII#385-R11	lavas	basalt	230	170	150	8200	>20	no	>20	<3	dark brown ~ brown	4			Ol xenocrysts up to 4mm crack, peperite rich part, variable size of vesicules
7KII#385-R12	lavas	basalt	190	110	110	2500	0	no	20	-	dark brown	3	<1		Opx xenocryst e/ thick reaction rim, partly covered w/peperite, ?? Crystal
7KII#385-R13	lavas	basalt	155	125	90	1900	0	no	15	<5	dark brown	3	<1		layering of vesicules, chilled margin, various size of vesicules
7KII#385-R-UNK1	volcaniclastics	basalt	75	55	30	170		weathered			dark brown - pale brown				basaltic fragment with peperite
7KII#385-R-UNK2	volcaniclastics	basalt	50	30	7	30					brown				basaltic gragment

4-6-2. Dive #386: Small knoll on ocean ward slope in the Japan Trench

S. Machida

Date: May 28, 2007

Place: A knoll (unnamed) on ocean ward slope in the Japan Trench

37° 31.10’ N, 149° 45.20’ W

Chef Pilot: T. Miura

Launcher Pilot: S. Shigetake

Vicle Pilot: H. Wakamatsu

Vicle Co-pilot: H. Sezoko

Observer: Shiki Machida (Ocean Research Institute, University of Tokyo)

Research Title

The geological and petrological investigation on a small knoll (unnamed).

Abstract

The target of dive No. 386 was selected to a small knoll (Figure 4-6.15) for investigating about volcanic stratigraphy of a petit-spot volcano on horst structure of ocean ward slope in the Japan Trench. The dive track began at the base of small knoll, and KAIKO 7000II ascended the northern slope of knoll to the summit (Figure 4-6.16). The occurrences of lava flow exhibited in limited area around the summit of knoll. The pillow lavas and the pillow robes are dominated in almost outcrops. Soft pelagic mud is commonly covered. 10 basalt lavas, 1 conglomerate, 1 manganese crust, and 2 pumice were corrected during dive (see the file “Dive #386_sample_list.xls” in Appendix). Some ridges consist of lavas were expected on NW slope and observed southern edge of summit of the knoll.

Payloads

(1) 1-Sample basket,

(2) 4-partitions in basket (to part sample basket by 4),

(3) 1-Sample container with lid in basket,

(4) 1-Rake sampler,

Purposes of Dive & Dive Plan

In order to investigate volcanic stratigraphy of small knoll on, dive is planned to start ascending the northern slope of knoll. The landing point was selected at the middle of slope, and continuously observation and sampling along the slope until reach summit of the knoll. We also planed another observation track from middle of southwestern slope of the knoll to summit. We should understand distribution of lava, some differences of the occurrence, rock type, and lava morphology.

The targets of this dive were:

1. To assess and observe the nature and composition of the small knoll,
2. Continuously sampling from lower to upper of central crater in the small knoll,
3. To observe the distribution of lava formation and lava morphology.

Summary of Dive Operation

Topography

Side scan sonar and reflectivity data (SeaBeam) collected on this and previous surveys of this area show a small hill from 6900 m to 6800 m depth with high backscatter intensity. The landing point was middle of slope on planed. Water depth of landing point is 6909 m. Water depth of most shallow point on summit of the knoll (off bottom point) is 9741 m. On the basis of sonar image collected during dive (and previous SeaBeam observations), we expected that this knoll have NW-SE trending ridge with some outcrops (maybe covered with thick sediment) on NW slope. However, we cannot approach the ridge and outcrops because no enough time for observation. Dome-like ridge is also observed along southern edge of summit of the knoll (along with 6800 m isobathic line) just before KAIKO 7000II began its return ascent to the surface. This ridge lead us to speculation that small basin, which is not observed by SeaBeam observation, may situate in centre of summit of knoll.

Geology

KAIKO 7000II descended to 6909 mbsl to the northern slope of the knoll (Stop 1). Seafloor was fully covered with pelagic sediments. We did quite observation and took some pictures on landing point. KAIKO 7000II ascended the hill from the north with moving to 160˚ direction. Outcrop was poorer along this slope; corrected one sample on the pelagic sediment seafloor at 6904 mbsl (Stop 2), and stopping again at 6895 mbsl (Stop 3) to sampling. The first sample (R01) is sandstone covered with manganese crust, and the second sample (R02) is conglomerate consist of various type of rocks, such as altered volcanic rock and red chert. Then KAIKO 7000II ascended the hill again with moving to 195˚ direction. Several number of rock fragments were observed at about 6872 mbsl at 11:37. We stopped at 6859 mbsl (Stop 4) because of large rock (outcrop?) were observed. Then, we tried sample collection during observation, but failed – observation continued up to 6830 mbsl (Stop 5). Many rock fragments and outcrops were observed from about 6844 mbsl at 11:04:35. We correct one basalt lava (R03) at 6830 mbsl (Stop 6).

After sample correction at stop 6, KAIKO 7000II move to 180˚ direction with continues observation and rock sampling. We observed huge outcrops, which made up of mostly pillow lava and lava fragmens along dive track in western part of summit of knoll. 12 samples were corrected from 7 stops (stop 7 to stop 13). At stop 7, many rock fragments were observed on almost flat seafloor, and we collected one basalt lava (R04). Stop 8 consist of outcrop of flattened lava lobes, and we collected one basalt lava sample (R05). Then, volcaniclastic rock (basalt lava) (R06) and manganese nodule (R07) were collected from stop 9, where many lobate lava flows lie over one another. One large basalt lava (R08) was collected from near the tabular outcrop (stop 10). Between stop 10 and 13, we observed dome-shape, tabular, blocky, or lobate outcrops of lava along ridge in southern edge of summit of knoll. Three stops were selected along the ridges. One basalt lava (R9) and two pumice (R10 and R11) were collected from outcrop (stop 11) consist of brecciated lava fragment near lobate lava flow on the ridge. Then, one volcaniclastic rock (basalt lava) (R12) was collected from stop 12. Finaly, three basalt lavas (R13-R15) were collected from stop 13.

The occurrences of lava outcrops of the knoll exhibited in limited area around the summit of knoll (from stop 4 to 13). This feature of outcrop occurrence is similar to that of a knoll at approximately 600 km off of ESE from the Japan Trench, which was observed by SHINKAI submersible dive (dive#879) during YK05-06 cruise using R/V Yokosuka. Then, we can consider that such limited lava occurrence is common feature of petit-spot volcanism forming small knoll.

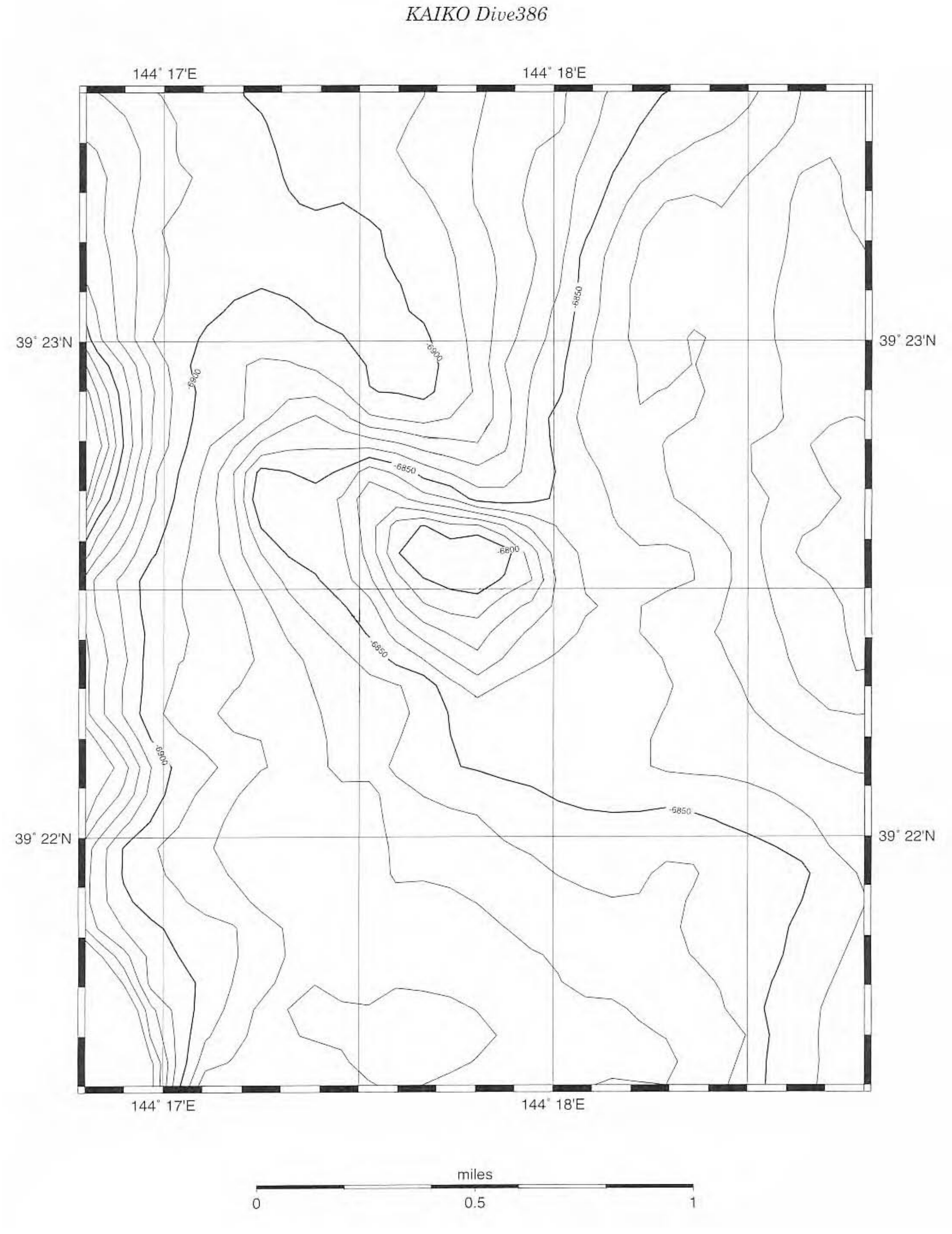

Figure 4-6.15. Bathymetric map around the #386 dive site.

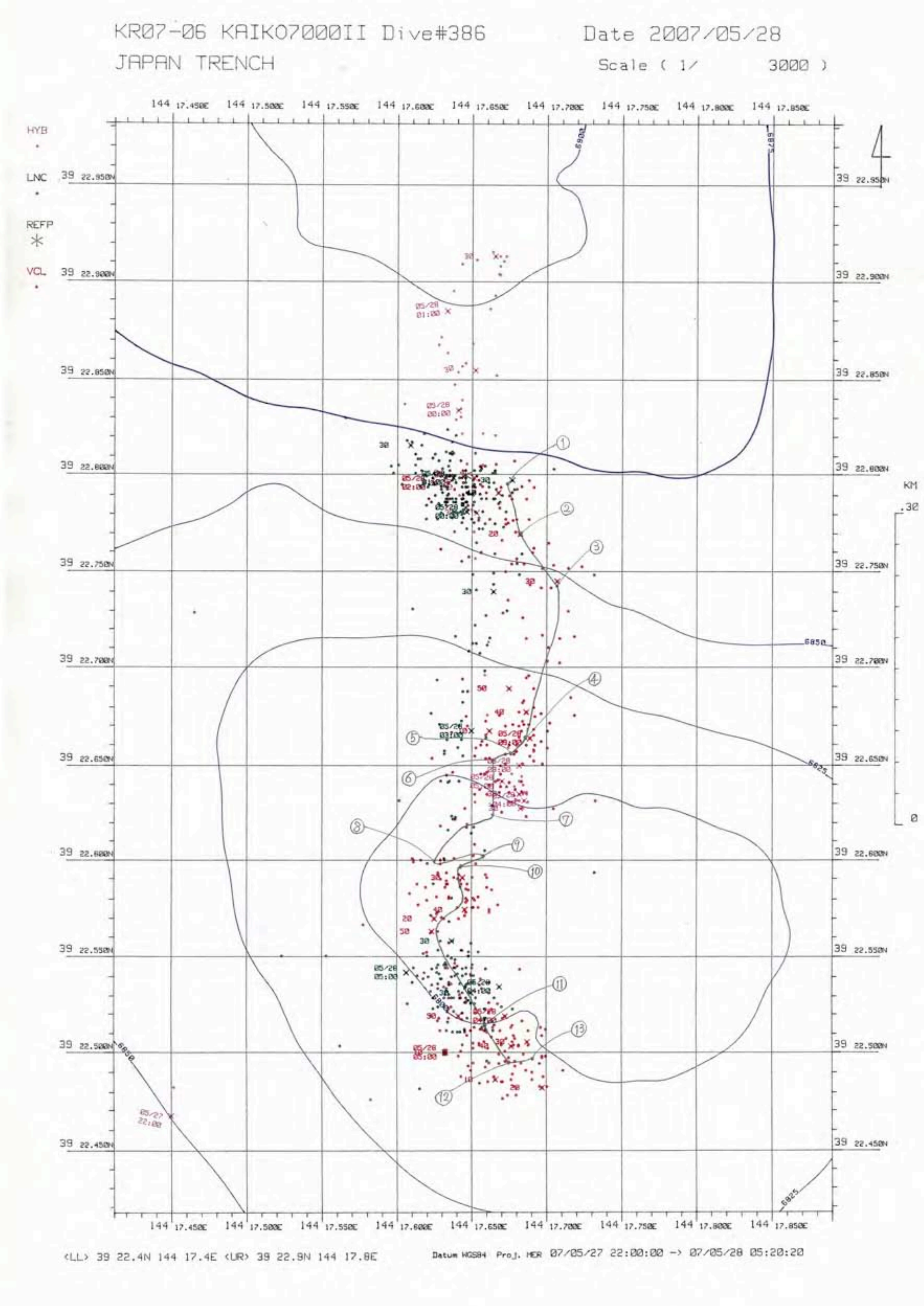

Figure 4-6.16. Dive track of #386.

4-6-3. 7KII#387 Dive: Fault escarpment disrupting a petitspot knoll

N. Hirano

Date:	May 29, 2007
Place:	Fault escarpment by horst and graven, Japan Trench oceanward slope 39°26.9' N, 144°21.5' E
Operator:	T. Miura
Launcher:	S. Shigetake
Vehicle Pilot:	H. Wakamatsu
Co-Pilot:	H. Sezoko
Observer:	N. Hirano (University of Tokyo)

Payloads

1 – sample basket
3 – partitions in the basket
1 – sample container with lid in the basket
1 – rake ("Kumade" in Japanese)

Research Title

A petitspot knoll disrupted by horst and graben

Objectives

The main objectives of this dive are

1) To make a geological cross sectional view on a small knoll on the Kaiko Knolls lava field
2) To establish the volcanic sequence erupted on the deep seafloor
3) To obtain the xenoliths from lithospheric mantle
4) To date the eruption ages of lavas of this monogenetic volcano by Ar-Ar method
5) To sample the fresh rocks in order to determine the geochemical composition of magma.

For this cruise, 4) is most important project in these objectives. The chief scientist, K. Baba, remarks the age distribution of the Kaiko Knolls lava field in his proposal of this cruise, because Hirano *et al*. (2006) described the 4.2, 6.0 and 8.5 Ma Ar-Ar ages in the Kaiko Knolls lava field and mentioned that petitspot volcanisms erupted on large area along the direction of the Pacific Plate in spite of quite small production of each volcanoes. The age distributions of petitspot give the information of eruptive sites on reconstruction of the Pacific Plate.

We planned the site of 7000 m in depth along the fault escarpment disrupting a knoll for the dive #387. The size of the knoll is 100 m in height and 1-2 km in diameter, which is a typical size of monogenetic volcano. The detail bathymetric map around the dive site is shown in

Figure 4-6.17.

Results

Firstly *KAIKO7000II* arrived at fault escarpment on 6909 m in depth. Unfortunately, we could not reach the depth, 7000 m. Talus deposits broadly covered, which are composed of fragments from likely petitspot lavas. *KAIKO* sampled 1 rock, #R-01, on this site.

Second, KAIKO conducted to navigate to the north along the fault escarpment. At 11:10am, the escarpment is most steep. The rocks, #R-02 and R-03, were sampled at 11:18am and 11:26am. Talus materials changed to fine grained rocks, probably to mud-supported fraguments of lava, at 11:30. The fraguments were also composed of fine grains rather than arrival site. *KAIKO* tried to sample a fragment as big as possible, #R-04, at 11:38am. Then *KAIKO* changed to move to the south along the escarpment. *KAIKO* sampled a fragment, #R-05, on the most southern part of the dive track after passing the arrival point.

KAIKO started to climb the escarpment to establish a geological cross sectional view of a petitspot monogenetic volcano. The outcrop was dominantly covered with pelagic mud and some rock fraguments. Then *KAIKO* sampled a lava fragment, #R-06 at 12:21. Some white rocks, probably mudstone, were scattered above this outcrop. *KAIKO* sampled again at 12:30, #R-07, 08, and 09. R-07 is basaltic lava. R-08 and 09 are white-colored mudstone, most of which were lost during rising to the sea surface. We found a large block of the breccias above this outcrop. *KAIKO* also sampled a breccia, #R-10. Then *KAIKO* restarted climbing up the escarpment. We saw an outcrop of some sill into the mudstone at 12:47. Then the outcrops were composed of all mudstone. Although *KAIKO* tried to touch the outcrop at 12:50, the mudstones were mostly soft. *KAIKO* entirely climbed up toward the top terrace of the escarpment at 12:56 and then *KAIKO* went ahead to the east. Some channels appeared at 12:59 (shallow channel), 13:00 (deep channel), 13:02 (shollow channel), 13:04 (broad channel), 13:07 (deep channel), 13:09 (steep and broad channel), 13:21 (steep and sharp channel), 13:27 (shallow channel) and 13:32 (deep channel). The steep channels at 13:21 and 13:09 may be young fracture by the recent earthquake, because no pelagic sediments filled the channels.

The #387 dive gave us some useful information about the cross section of the petitspot volcanoes and a lot of samples. Description and list of samples are shown in a file "Dive #387_sample_list.xls" in appendix. Dive track is shown in Figure 4-6.18.

Sampling site and highlights of dive #387

Time(LCL) hh	mm	ss	Dep. (m)	Lat. (deg)	Lon. (deg)	Head (Deg)	Pos. Xm	Pos. Ym	Observation	Sample	Remarks
10	50	6	6779	39. 26.9303	144. 21.5170	182.66	-56	-18.7	launching		

11	2	40	6909	39.	26.9353	144.	21.5216	61.53	65.3	-12	on bottom, blocky floor		
11	5	3	6909					54.73			sampling attempted		
11	7	45	6909	39.	26.9353	144.	21.5216	73.83	65.3	-12	sample recovered	R01	left, front
11	10	9	6909					76.12			start moving to north		
11	14	17	6912					110.37			large blocks (lava) are observed		
11	16	0	6914					186.58			sampling attempted		
11	18	18	6914	39.	26.9418	144.	21.5430	10.77	77.3	18.7	sample recovered	R02	right, rear
11	21	31	6911					5.03			moving to north		
11	22	51	6911					23.4			slope covered with blocks, sampling attempted		
11	26	9	6912	39.	26.9569	144.	21.5681	9.16	105.3	54.7	sample recovered	R03	left, rear
11	29	35	6910					340.75			start moving to north		
11	34		6911					112			sampling attempted, blocky		
11	37	30	6912	39.	26.9829	144.	21.5644	113.24	153.3	49.3	sample recovered	R04	right, rear
11	39	25	6912					185.27			moving to south		
11	46	0	6911					195			reddish dikelet		
11	51	19	6910					191.83			slope covered with small blocks		
11	55	59	6910					247.17			layered structure (lava?) is observed		
12	2	37	6909					157.22			sampling attempted		
12	5	45	6911	39.	26.9267	144.	21.5495	112.93	49.3	28	sample recovered	R05	left, front
12	9	10	6910					41.53			start climbing up the fault wall, set head angle to 40		
12	16	28	6894					79.49			still climbing up the fault wall		
12	19	13	6887					125.59			breccias against muddy floor, sampling attempted		
12	21	31	6887	39.	26.9605	144.	21.6480	127.17	112	169.3	sample recovered	R06	left, rear
12	24	12	6883					113.44			climbing up the fault wall, breccias against muddy floor		

Time(LCL) hh | mm | ss			Dep. (m)	Lat. (deg)	Lon. (deg)	Head (Deg)	Pos. Xm	Pos. Ym	Observation	Sample	Remarks
12	25	36	6880			107.25			breccias against muddy floor, sampling attempted		
12	29	0	6880	39. 26.9497	144. 21.6852	113.07	92	222.7	sample recovered	R07 (black)	right, front
12	29	17	6880			113.07			sampling attempted, white ones		
12	30	43	6881	39. 26.9497	144. 21.6852	113.08	92	222.7	sample recovered	R08 (white)	right, front
				39. 26.9497	144. 21.6852		92	222.7		R09 (white)	right, front
12	38	0	6879	39. 26.9584	144. 21.6778	124.4	188	212	a large block of breccia is observed, sampling attempted	R10	left, front
12	46	26	6877			133.76			start moving, set head angle to 130		
12	47	20	6871			104.63			slope slightly covered with white mud		
12	48	25	6865			120.27			scratched, soft sediment		
12	51	41	6864			117.99			set head angle to 120		
12	56	12	6853			110.53			a large white rectangular block (sediment) is observed		
12	57	29	6849			128.83			muddy floor		
13	0	50	6844			118.27			layered structure (white-black) is observed along cracks		
13	5	2	6839			117.88			a few shallow cracks (N-S) are observed		
13	10	37	6831			82.1			moving to east, muddy floor		
13	15	7	6830			98.96			still moving to east		
13	20	12	6826			93.57			shallow cracks (N-S) against muddy floor		
13	28	53	6825			66.37			still moving to east, muddy floor		

13	38	48	6824	39.	26.9814	144.	21.7726	170.73	150.7	348	off bottom, muddy floor		
13	52	46	6718	39.	26.9382	144.	21.8228	180.93	70.7	420	combined vehicle with launcher		

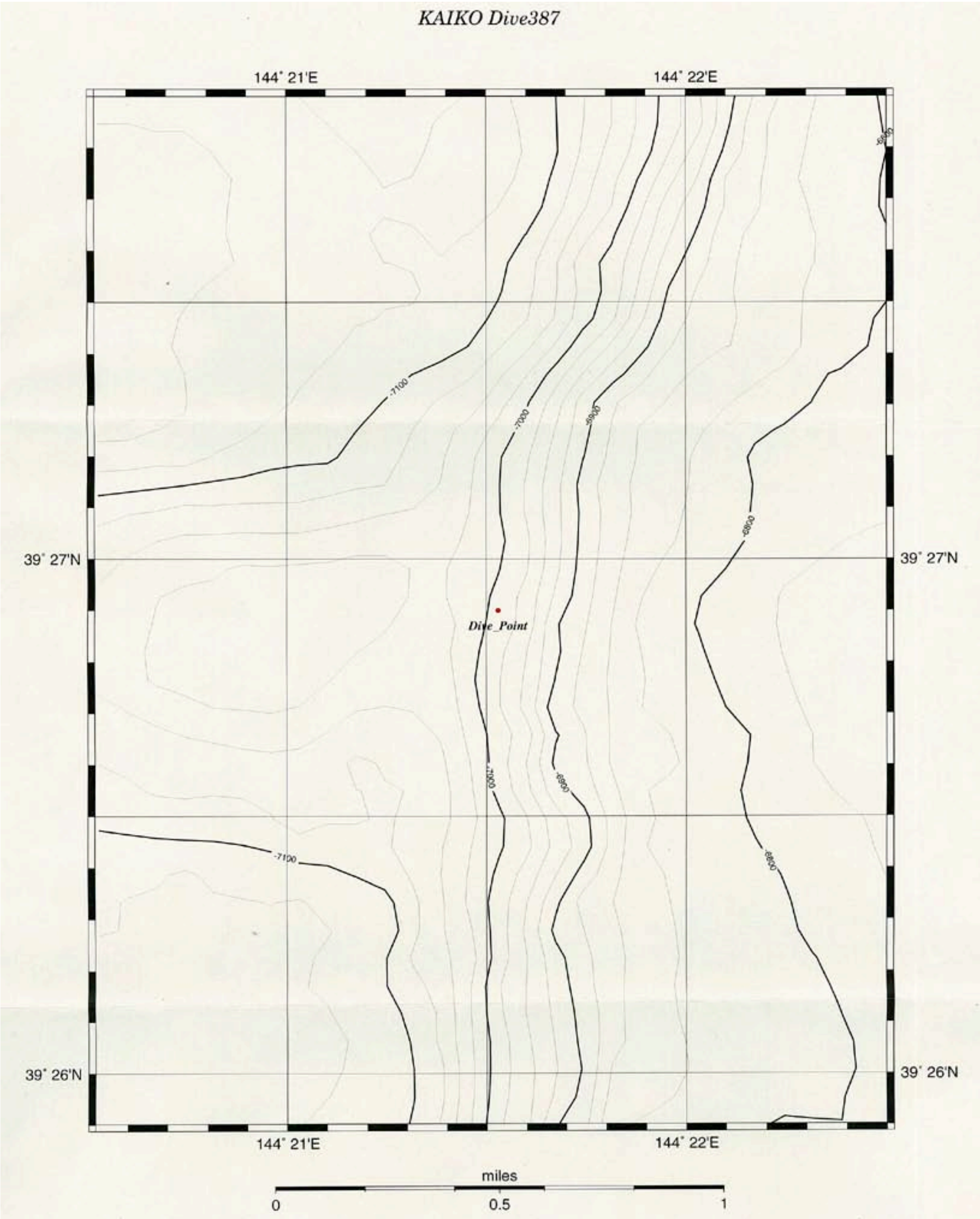

Figure 4-6.17. Detail bathymetric map around the site of the dive #387.

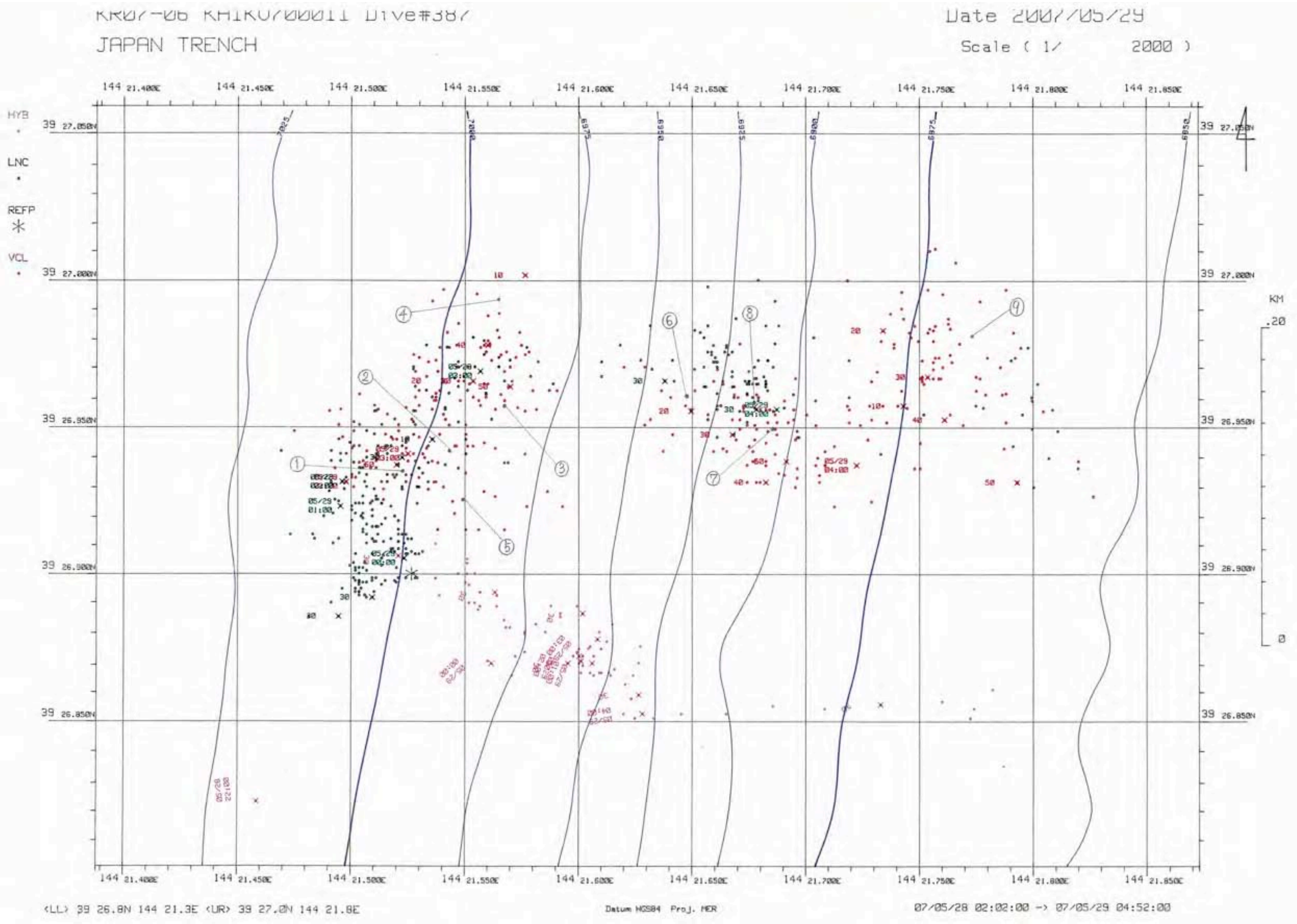

Figure 4-6.18. Dive track of 7KII#387 (red). Numbers, 1 to 9, show the sampling site.

4-6-4. Future Studies

Natsue Abe (JAMSTEC)

Main interest is mineral chemistry in the basalt. Chromian spinel with/without olivine phenocryst and also olivine xenocryst may tell us the origin of these minerals and host magma (e.g., Arai, 1994). In other words, mineral chemistry and detail description of thin sections can tell us the condition of magma formation and capture of xenocrysts; e.g., PT conditions.

If possible, in situ trace-element analysis using by LA-ICPMS or SIMS will be taken on clinopyroxene in basaltic samples, and mineral and/or melt inclusions in phenocryst/xenocryst in basalts. Then compositions of the equilibrium melt with such kind of minerals/melt inclusions will be estimated. Methods are:

- Describing thin sections using by optical microscope
- Major element analysis on minerals using by EPMA
  - ✓ To estimate the equilibrium and cooling temperature of minerals using by two pyroxene, pyroxene-olivine-spinel, and spinel-olivine geothermometors.
  - ✓ To estimate the precipitation temperature of pyroxene in the groundmass using by pyroxene geothermometor.
- Trace element analysis on minerals using by LA-ICPMS and/or SIMS
  - ✓ To estimate the source mantle composition and the degree of melting.

Shiki Machida (ORI)

SR, ND, AND PB ISOTOPES OF BASALTS FROM PETIT-SPOT VOLCANOES

My interest is bulk rock Sr, Nd, and Pb isotope compositions of basalts from “petit-spot” volcanoes. Sr, Nd, and Pb isotopes are not only basic geochemical data set for investigation of rock generation, but also important data for defining the origin of source material.

In my previous work (Machida et al., in preparation), Sr, Nd, and Pb isotopic compositions of basalt lava from petit-spot volcanoes were determined. These basalts have enriched Sr, Nd, and Pb isotope compositions, which equal to Indian and southern Atlantic mid-ocean ridge basalts with an exact Dupal isotopic anomaly (Dupal anomaly: hemispheric isotopic heterogeneity existing in southern hemisphere defined by Dupré and Allègre, 1983 and Hart, 1984), and are almost identical to the composition of EM-1 mantle endmember. This isotopic feature provides evidence for existing recycled plate materials (e.g. pyroxene-rich eclogite) in plume-unrelated upper-mantle beneath Pacific Plate. These results indicate that Earth’s upper-mantle is heterogeneous in various scales even in the apparently uniform and massive Pacific Ocean mantle domain, and suggests that recycled materials would play an important rule in existence of partial melts in the asthenosphere.

During KR07-06 cruises, many basaltic rocks were collected from petit-spot volcanoes in ocean ward slope of the Japan Trench by dive of KAIKO 7000II (Dive #385-#387). Isotope analysis using Thermal Ion Mass Spectrometer (TIMS) will be taken on basaltic rock collected from each dive site. In order to investigate about further isotopic variation of lava from petit-spot and identification of original recycled material, we got new isotopic data from petit-spot volcanoes, which we never collect samples during previous cruise. The new isotope data determined from these samples corrected in this cruse must provide additional restrictions to examine the problem for origin of source materials. Then, I confidents that I will provide key constraints on understanding nature of the Dupal signature as the problem of whole solid Earth's recycling.

CHEMICAL COMPOSITION OF OLIVINE PHENOCRYSTS IN BASALT LAVA AND NUMERICAL MELTING MODELS FOR BULK ROCK TRACE ELEMENT COMPOSITIONS

Sr-Nd-Pb isotopic compositions of petit-spot lavas indicate that the magmas would have formed by melting of recycled plate materials (EM-1) entrained by subduction and delamination. Several hypotheses have been proposed for the source of recycled material as following: (1) subcontinental lithospheric mantle, (2) continental lower-crust, (3) subducted oceanic crust and/or sediment. Recently, Sobolev et al. (2005 and 2007) reported that chemical compositions of olivine phenocrysts, such as NiO content and Mn/Fe ratio, provide key constraints for estimation of amount of recycled materials in source of mantle-derived melts.

It is important problem which materials and how much amount of materials contribute to petit-spot volcanism. In order to solve these problems, (1) I will determine chemical composition of olivine phenocrysts by electron probe micro analyzer (EPMA). Then, I use Sobolev's results as a guide for determining amount of recycled materials in source mantle of petit-spot volcanoes. In addition, (2) I will examine origin of recycled material by quantitative numerical melting model for bulk rock trace element compositions. Modeling will be conducted assuming all of proposed materials for recycling. On the basis of modeling, it will be examined which material melting reproduce trace element composition of primary magma of petit-spot. EPMA data will also use for estimation of primary magma composition for trace element modeling.

Naoto Hirano (Univ. Tokyo)

ERUPTIVE STYLES

Lavas are highly vesicular, despite 6 kbar hydrostatic pressure at eruption depth; this and the low viscosity of the lavas may form their peculiar morphology. We may observe collapsed structures of inflated pahoehoe lavas with botryoidal lavas located interstitially on the terrace below the flood lavas. The lava may form lobate structures and pyroclastic ejecta despite deep-submarine eruption conditions. Volatile contents in the quenched glass analysed by FT-IR would be helpful to estimate its contents in magma and source asthenosphere.

DETAIL DISTRIBUTION OF VOLCANOES

Using on-board data we will firstly report detail distribution of the lava field based on the back-scan image and bathymetry by the Seabeam 2112 and obtaining samples by dredges and dives. High reflection areas in the backscatter image expecting the lava field appear are shown along some irregularly topographic highs and normal faults on the subducting Pacific Plate. Previous cruises show that the lava field is composed of two type lavas; one is vesicular lavas forming some topographic highs (possibly pillow lavas) and another is underlying sheet flow (dense and flood-like lavas). The latter would be concealed by topographic highs and pelagic mud. Ar-Ar datings for lavas would be also useful to consider the tectonic environment of eruption. “Which are the Kaiko Knolls lava field in the Japan Trench accidental or common on the outer-rise?” The some dredges and seabeam data on this cruise should solve this problem.

SOURCE AND ORIGIN OF MAGMA

This theme will be the main study of the young lavas on the Japan Trench and outer-rise. We should obtain answers of two questions about the source of magmas in the mantle and the cause of eruption. Firstly we will solve the source mantle of this magma based on the geochemical studies of major and trace element compositions and radiometric isotopes. Each element compositions along the differentiation line of magma can indicate the mineralogy of source mantle, which are a tool to consider the depth in the mantle. We think that the variation of obtained rocks such as ol-bearing basalt, cpx-bearing basalt, aphyric basalt and dolerite are useful to recognize the source mineralogy and depth. Sr, Nd, Pb and He isotopes would indicate source material in the mantle (primitive or depleted mantles). The cause of eruption may be resolved by tectonophysics such as some bendings or fractures of oceanic plate. We are going to simulate some bendings of the flexural plate with decreasing pressure or fractures into lithosphere. The arrangements of lava field using backscatter on this cruise may also indicate the cause of eruption.

METHODS AND COLLABORATERS

- Ar-Ar dating (by N. Hirano, K. Nagao, A. Koppers)
- FT-IR analysis (by N. Hirano, H. Kagi)
- Microprobe analysis for quenched glasses and minerals (by N. Hirano)
- XRF (by N. Hirano, S. Machida, T. Ishii)
- Laser ablation ICPMS for bulk and glasses (by N. Hirano, T. Hirata)
- Mass spectrometry for noble gases (by J. Yamamoto, N. Hirano)
- TIMS for solid elements (by S. Machida, N. Hirano, J. Kimura)

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Appendices

Two DVDs are distributed to the onboard scientists.

KR07-06 DVD-1

- Cruise report (Folder, 265 MB)
    - KR07-06_cruise_report.pdf (PDF file, This document)
    - Appendices (Folder)
    - draft (Folder, 247 MB)
- KAIKO7KII_Dives (Folder, 2.13 GB)
    - 7K 資料 (Folder)
    - Acoustic_data (Folder)
    - CTD_launcher (Folder)
    - Dive_logs (Folder)
    - Photo (Folder)
    - Rock_samples (Folder)
    - SSS_SBP (Folder)
    - 潜航要望書(Folder)
- Misc (Folder, 541 MB)
    - PDF_papers (Folder)
    - Seminar (Folder)

KR07-06 DVD-2

- Data (Folder, 3.23 GB)
    - KR0706.xls (Excel file)
    - KR0706 重力測定追加分.xls (Excel file)
    - BBOBS (Folder)
    - Gravity (Folder)
    - MBES (Folder)
    - NAV (Folder)
    - OBEM (Folder)
    - Proton (Folder)
    - SOJ (Folder)
    - SOQ (Folder)
    - STCM (Folder)
    - XBT (Folder)