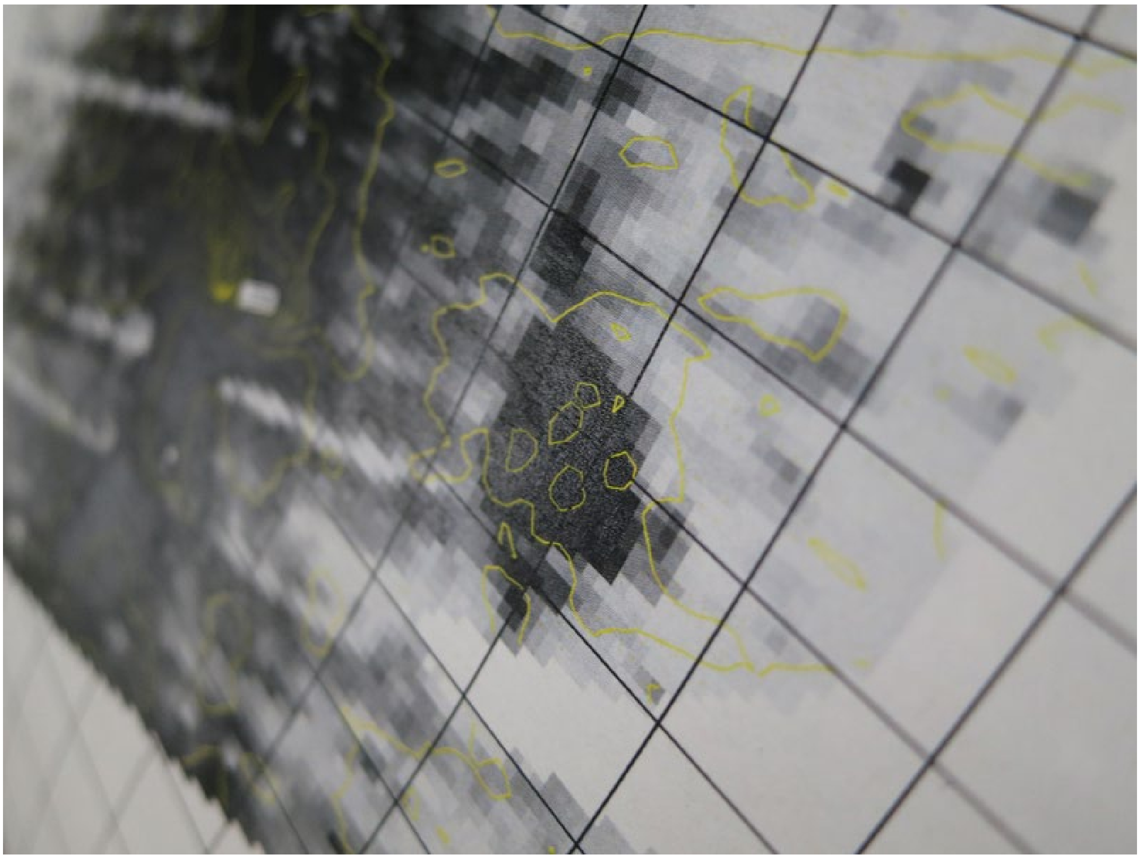
doi : 10.17596/0002928

YOKOSUKA Cruise Report YK14-05

"Petit-spot distributions along deformation of subducting plate"



Northwestern Pacific off Japan Trench

April 10 to 24, 2014

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

Contents Pages

1. Cruise Information

Cruise ID:	YK14-05
Name of vessel:	R/V YOKOSUKA
Title of the cruise:	Lithospheric structures and petit-spot volcanoes
Title of proposal:	Petit-spot distributions along deformation of subducting plate
Cruise period:	April 10 to 24, 2010
Ports of call:	Yokosuka Branch, JAMSTEC to Funabashi Port
Research area:	Japan Trench to outer-rise, Northwestern Pacific, off the Miyagi & Fukushima Prefectures
Research maps:	Figs. 1-1.

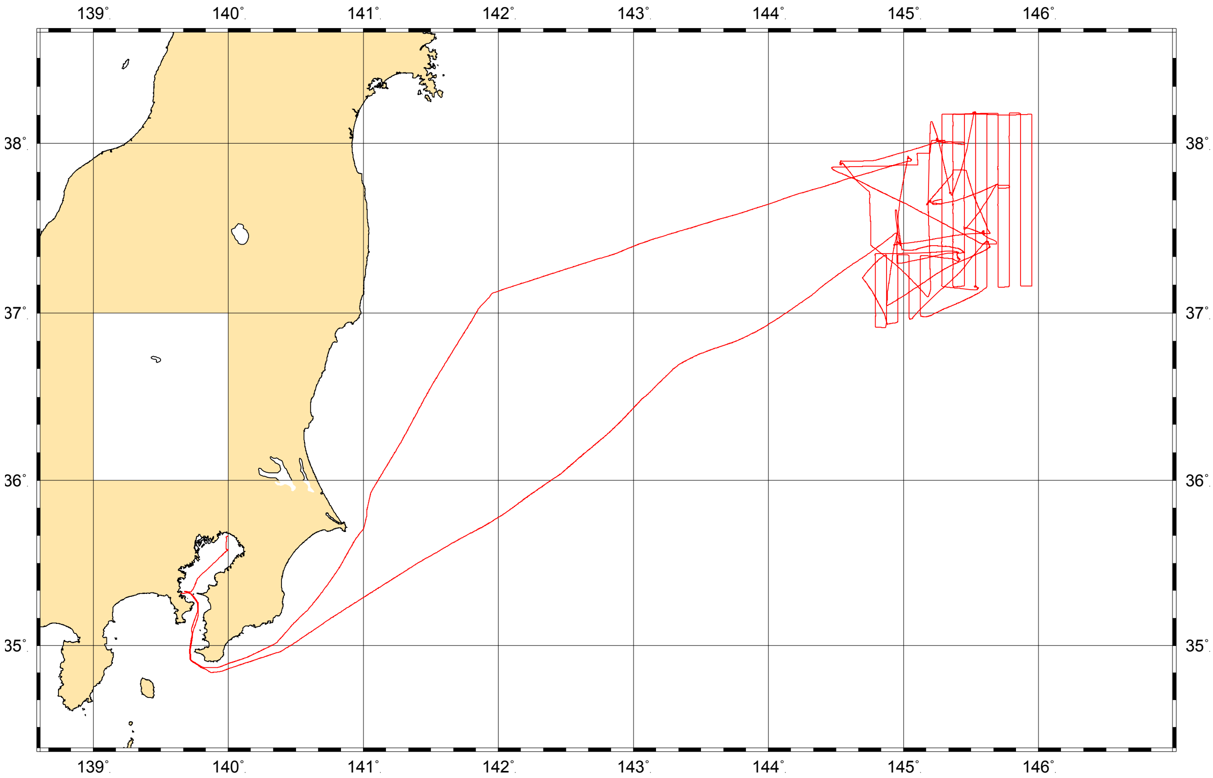


Fig. 1-1. Cruise track during the YK14-05 research cruise.

2. Researchers & Crews

Chief Scientist Naoto HIRANO Assistant Professor, Tohoku University

Chief researcher of the project on

"Petit-spot distributions along deformation of subducting plate"

Science Party (Onboard Researchers)

Vice-chief Scientist	Teruaki ISHII	Researcher, Fukada Geological Institute
Scientist	Junji YAMAMOTO	Assistant Professor, Hokkaido University
Scientist	Shiki MACHIDA	Research Assistant, Waseda University
Scientist	Yuki SATO	Postgraduate Student, Tohoku University
Scientist	Takaomi KAWANO	Undergraduate Student, Tohoku University
Scientist	Yoichi SUZUKI	Undergraduate Student, Tohoku University
Scientist	Arashi TAKI	Undergraduate Student, Tohoku University
Scientist	Nana UKYO	Undergraduate Student, Tohoku University
Scientist	Taku YUTANI	Undergraduate Student, Tohoku University
Marine Technician	Hisanori IWAMOTO	Nippon Marine Enterprises, Ltd.

Science Party (Shore-based Researchers)

Scientist	Masao NAKANISHI	Associate Professor, Chiba University

Crews of the R/V YOKOSUKA

Captain	Eiko UKEKURA
Captain	Yoshiyuki NAKAMURA
Chief Officer	Naoto KIMURA
2nd Officer	Takeshi EGASHIRA
3rd Officer	Tomohiro YUKAWA
Chief Engineer	Tadashi ABE
1st Engineer	Wataru KUROSE
2nd Engineer	Ken'ichi SHIRAKATA
3rd Engineer	Kota KATAOKA
Chief Elect. Op.	Hiroyasu SAITAKE
2nd Elect. Op.	Misato HATA
3rd Elect.Op	Takatomo SHIROZUME
BoatSwain	Kozo YATOGO
Quarter Master	Yasuo KONNO

Quarter Master	Hatsuo ODA
Quarter Master	Daisuke YANAGITANI
Sailor	Sho SUZUKI
Sailor	Yoshihiro OGAWA
Sailor	Shinya KOJIMA
No.1 Oiler	Junji MORI
Oiler	Shinya SUGI
Oiler	Keita FUNAWATARI
Oiler	Tatsuomi CHINO
Assistant Oiler	Ryo MATSUUCHI
Chief Steward	Yukio TACHIKI
Steward	Toru MURAKAMI
Steward	Kazuma SONODA
Steward	Mizuki NAKANO
Steward	Yoshie HIDAKA

Shinkai 6500 Operation team

SubmersibleOp. Manager	Toshiaki SAKURAI
Deputy Submersible Op. Manager	Yoshitaka SASAKI
1/Submersible Tec.Officer	Kazuki IIJIMA
1/Submersible Tec.Officer	Tetsuya KOMUKU
1/Submersible Tec.Officer	Mistuhiro UEKI
1/Submersible Tec.Officer	Keita MATSUMOTO
2/Submersible Tec.Officer	Hirofumi UEKI
2/Submersible Tec.Officer	Keigo SUZUKI
2/Submersible Tec.Officer	Fumitaka SAITO
2/Submersible Tec.Officer	Yudai TAYAMA
2/Submersible Tec.Officer	Masaya KATAGIRI

3. Objectives & Activities

3-1. Objectives & Background

by Naoto Hirano

Tiny submarine volcanoes, known as petit-spots, occur in regions of plate flexure prior to subduction and seamount-loading (Hirano *et al.*, 2006, 2013). They are the forth volcanic zone on Earth, because the anomalously young alkali-basalt lavas (0 to 8 Ma Ar-Ar ages) were found on the subducting, ~130 Ma Pacific Plate without any hotspot. Volcanic eruption of the newly discovered lava field occurred on the plate convexly flexed portions on outer-rise off Japan Trench based on the present absolute motion of the Pacific Plate (Gripp and Gordon, 1990). The eruption ages of petit-spot volcanoes in this region represent monogenetic eruptions over a period of >9 Myr over a large area, and the eruptions are related to the outer rise bathymetry. The surface morphology and distribution of petit-spot monogenetic volcanoes are influenced by the stress field in the lithosphere. The magmas produced by the accumulation of melt originating from asthenosphere just below the site of plate-flexure, are able to rapidly ascend to the surface from the base of the lithosphere (Fig. 3-1) (Hirano *et al.*, 2006; 2011; Valentine & Hirano, 2011). Based on their model, petit-spot volcanoes could be ubiquitous in the ocean basins, as a constant source of small-degree mantle melts may presently be stored in the asthenosphere, ready to escape to the surface whenever and wherever the oceanic plate flexes.

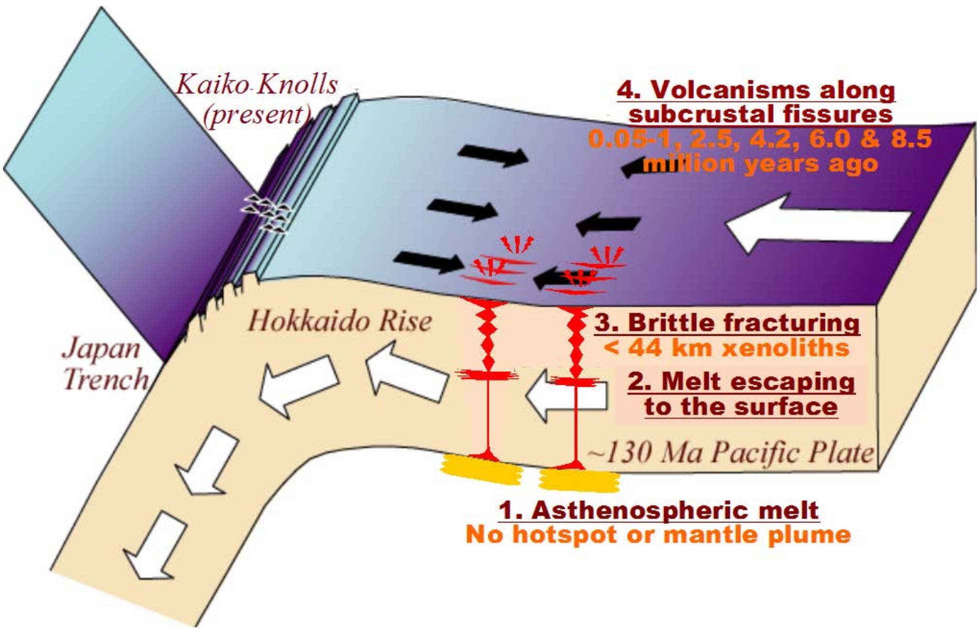


Fig. 3-1. Model of petit-spot volcanoes modified after Hirano *et al.* (2006).

As monogenetic petit-spot volcanoes are too small to be detected by satellite altimetry, our study absolutely requires a research vessel equipped for shipboard acoustic multibeam surveys. The areas where we have already surveyed are still limited, only 36 % of Japan Trench to outer-rise off the southern Japan Trench (36°N to 40°N) (Okumura & Hirano, 2013). But it is clear that spatial distributions of petit-spot are still enigmatic. Although submarine tiny volcanoes should appear homogeneously on the submarine surface wherever the plate is flexing, the area of volcanoes and lavas have not found around already reported areas of Sites A, B and C off Tohoku, Japan (Fig. 3-2) (Hirano et al., 2006). The additional local reasons in lithosphere, therefore, could be necessary to occur the petit-spot volcanoes. Here we conducted the nine submersible dives at the Site C conducted by JAMSTEC submersible Shinkai6500 on this April in order to know the distributions of petit-spot controlled by the tectonic fabrics of seafloor.

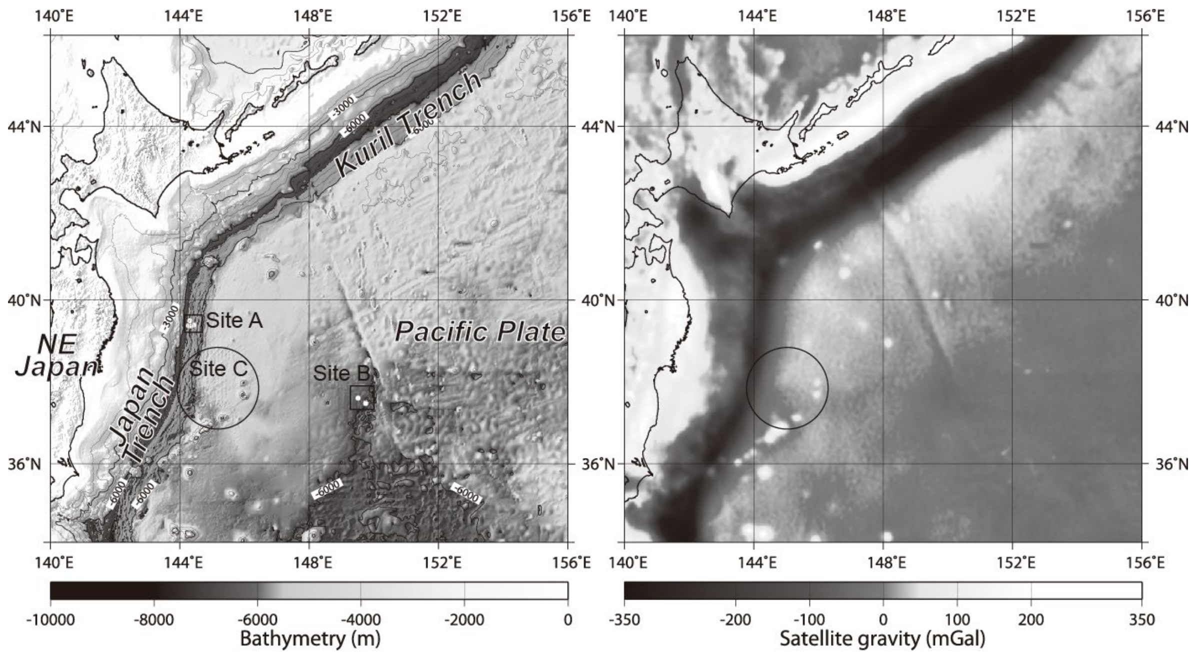


Fig. 3-2. Bathymetric map (left) and satellite gravity (right) of NW Pacific plate. White circles shown in left figure are the site of petit-spot volcanoes already reported. Survey area of this cruise show the circle (Site C).

The size of most volcanic cones in Site C is a few hundred meters in height and a few km in diameter. Their morphological characteristics are very similar to petit-spot volcanoes already studied in the Site A and B. Strongly vesicular and undifferentiated lavas for petit-spot may have occurred the peculiar eruption on the abyssal plain. We observed the eruption style using the submersible Shinkai 6500 as well.

3-1-1. Lithospheric morphology

Three principal tectonic fabrics appear on subducting Pacific Plate off the Japan Trench, which are

1) ridge-perpendicular fabrics,
2) ridge-parallel abyssal hills,
3) horst and graben structures.

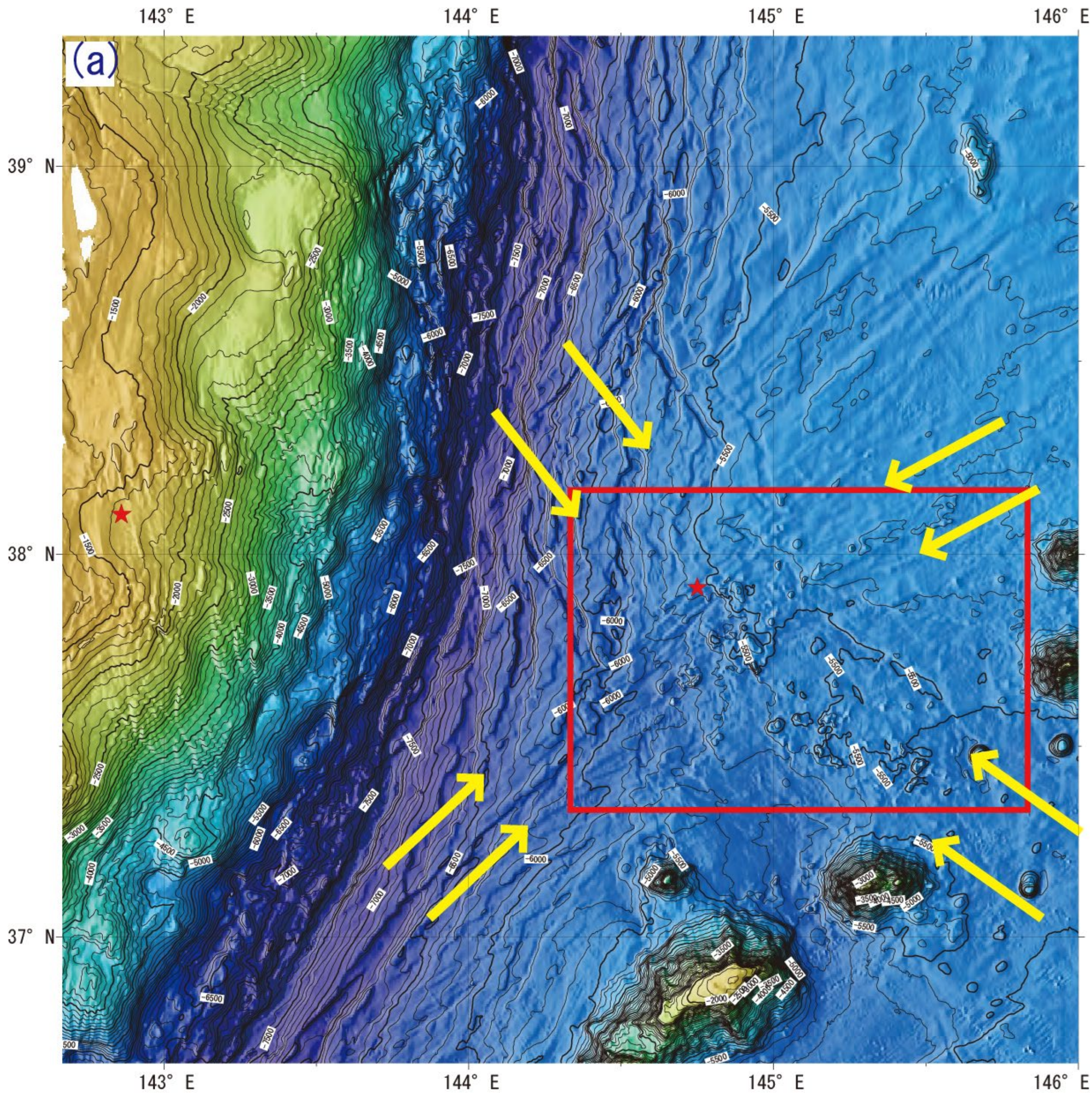


Fig 3-3. Bathymetric map around southern Japan Trench off NE Japan (Nakanisihi et al., 2011). Red square is more detail figure on Fig. 3-4. Yellow arrows show the fabrics #1 and #2.

At the trench oceanward slope, fabric#1 is approximately parallel to neighbor Nosappu and Kashima fracture zones (Nakanishi, 1993). The trends of Japan Trench axis are changed from N-S in the north to NE-SW in the south here, where the structures of fabric#3 are complicatedly intersecting (Fig. 3-3) (Nakanishi et al., 2011). As fabric#1 and #2 along petit-spot distribution are clearly original structure before subduction-related outer-rise, the petit-spot eruptions might be related to re-activation of traditional structures due to the subduction-related bending of NW Pacific Plate (Fig. 3-4).

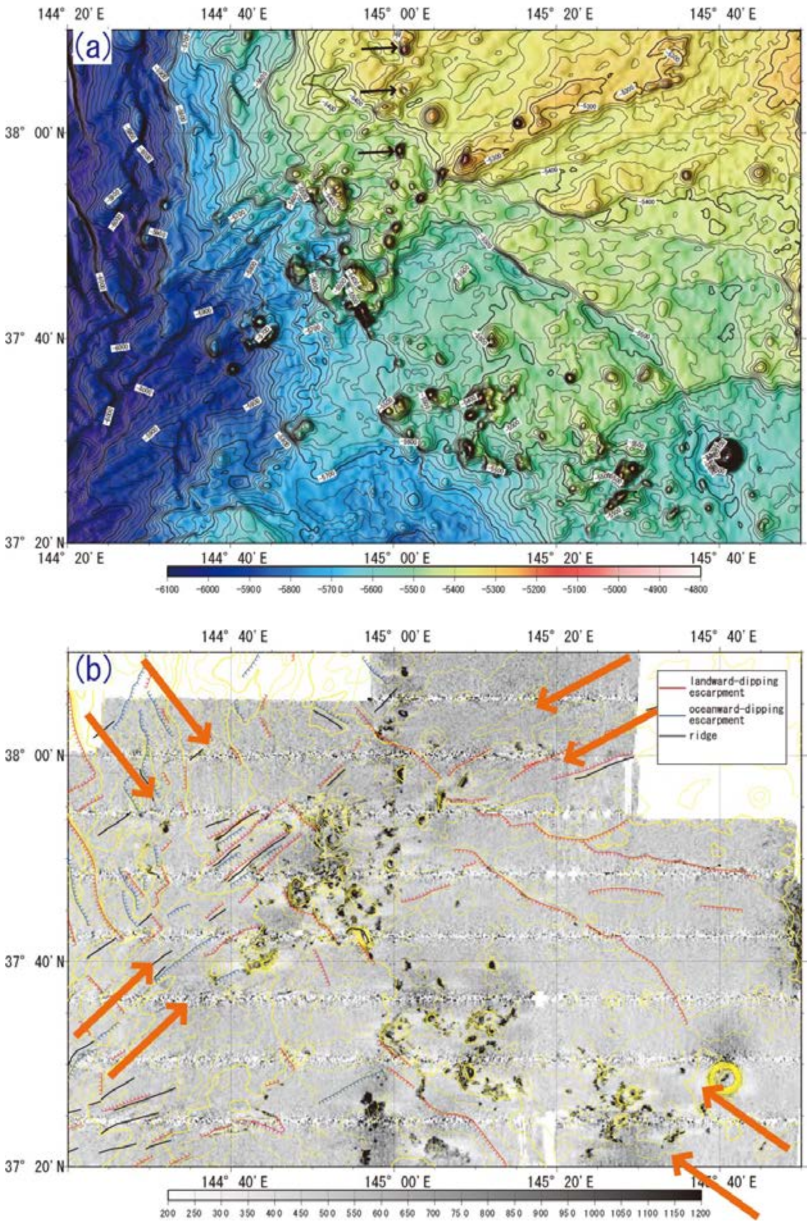


Fig. 3-4. Bathymetric map (a) and acoustic reflective map (b). Back arrows show the knolls already surveyed by Kaiko, KR07-07 cruise, JAMSTEC. Orange-colored arrows show the fabric #1 and #2.

3-1-2. What is Asthenosphere?

The plate tectonics theory suggested by Morgan (1968) totally explained the phenomena on solid Earth (e.g. earthquake, volcanoes, paleo-magnetic anomaly and continental motion). A tectonic plate moves around the nearly spherical surface of Earth as excellent approximation to be rigid, represented simply as rigid body rotations. The dynamics of the Earth's interior is reflected in process at the Earth's surface. Lithospheric plates experience stress due to mantle convection, based on the overlaying rigid plate (lithosphere) on the ductile asthenosphere, which is the engine of the plate tectonics.

The asthenosphere is considered coincidental with the low-velocity zone of the upper mantle. The flowing asthenosphere carries the lithosphere of the Earth, including the continents. Although geoscientists had originally believed that asthenosphere will be melting when the plate tectonics theory suggested, a model that the hydrogens in water in determining the structure of the lithosphere and asthenosphere boundary (LAB) behave as the role of phase transformation in controlling the density and plastic flow properties of Earth's materials. So, the asthenosphere is not necessarily melting (Karato, 1990; Karato and Jung, 1998). However, several studies recently supported the melting hypothesis in their physical property, multicomponent experiment, and shear-wave velocity (e.g. Sakamaki et al., 2013; Sifré et al., 2014; Beghein et al., 2014). So, this is still enigmatic about "What is asthenosphere?" and "Which is that melting or not?".

Hirano et al. (2006) proposed that the melt from the asthenosphere could have escaped along plate fractures that occur in the flexing outer-rise of the Pacific Plate (Fig. 3-1). The most important process of the petit-spot is not to follow any heat supplies regionally from the deep mantle such as the hotspot in spite of the oceanic intra-plate volcano. Some geochemical evidences also show the petit-spot magma from the shallower mantle. Noble gas isotopes of the present samples indicate that the magma was derived from the similar source to that of mid-oceanic ridge basalt (MORB). The abundance of heavy rare earth element (HREE), moreover, indicate that the magma came from the garnet-bearing mantle, where the asthenosphere is easily considered as a source of magma (Hirano et al., 2006). A new kind of volcano, petit-spot, would show one of evidence for melting of asthenospheric mantle, because the petit-spot magma escaped to the surface from asthenosphere along the fractures of the bending lithosphere. The petit-spot, therefore, is unique window to understand the subducting plate and underlying asthenosphere.

3-1-3. Ubiquitous petit-spot

Such tiny volcanoes are ubiquitous in regions of plate flexure worldwide, and have been recently reported from the Tonga Trench (Hirano *et al.*, 2008), the Basin and Range province (Valentine & Hirano, 2010), south of Greenland (Uenzelmann- Neben *et al.*, 2012), the Chile Trench (Hirano *et al.*, 2013), an accretionary complex in Costa Rica (Buchs *et al.*, 2013), and Java Trench (Taneja et al., 2014).

It thus is important to search for other examples of petit-spot volcanoes. This may help us to address some important first order questions. For example, are the petit-spot volcanoes observed by Hirano *et al.* (2006) isolated features or are they a phenomenon that always accompanies plate flexure? In this cruise, we will look at acoustic reflective data (i.e., sidescan data) that was collected during modern shipboard bathymetrical surveys. These reflectivity data provide us with a powerful tool to help locate the petit-spot volcanoes, because they are too small to be reliably detected by multibeam bathymetry, as they are only 1 to 2 km in diameter and only a few hundred meters in height.

3-2. Activities

3-2-1. Cruise Log

by Iwamoto

Date	Local Time	Description	Note	Position/Weather/ Wind/Sea condition
10-Apr-14	08:30	scientists onboard		4/10 12:00 (JST)
	10:00	departure from JAMSTEC, Yokosuka		34-58.4N,139-43.1E
	11:00-11:30	lecture for life of shipboard life and safety		fine but cloudy
	13:00-13:45	scientists meeting		South-3 (gentle breeze)
	15:00-15:35	scientists and 6K team meeting		2 (sea smooth)
	16:40-17:00	pray to KONPIRASAN for safety cruise		1 (Low swell sea)
				Visibly: 6'
11-Apr-14		Transit to research area		4/11 12:00 (JST)
	12:30	arrived at research area		37-19.5N,144-41.6E
	12:33	released XBT		fine but cloudy
	13:16-16:28	MBES survey for 6K dive		West-6 (strong breeze)
				3(sea slight)
				2(Low swell long)
				Visibly: 8'
12-Apr-14	09:12	launching SHINKAI 6500 (6K#1385Dive)		4/12 12:00 (JST)
	11:39	SHINKAI landing (5,750m)		37-25.0N,144-58.4E
	14:30	SHINKAI leave the bottom (5,646m)		fine but cloudy
	16:29	SHINKAI come up to surface		WNW-5 (fresh breeze)
	17:00	finish SHINAKI operation		3(sea slight)
	19:30-20:05	scientists meeting		3 (Moderate short)
	20:10-20:40	MBES survey for 6K dive		Visibly: 8'
	23:26-	MBES survey		
13-Apr-14	-05:12	MBES survey		4/13 12:00 (JST)

Date	Local Time	Description	Note	Position/Weather/ Wind/Sea condition
	08:58	launching SHINKAI 6500 (6K#1386Dive)		37-28.7N,145-35.6E
	11:21	SHINKAI landing (5,571m)		fine but cloudy
	15:01	SHINKAI leave the bottom (5,382m)		North-4 (moderate breeze)
	16:55	SHINKAI come up to surface		3 (sea slight)
	17:20	finish SHINAKI operation		2(Low swell long)
	18:01-19:00	MBES survey for 6K dive		Visibly: 8'
	19:40-19:55	scientists meeting		
	23:49-	MBES survey for 6K dive		
14-Apr-14	-04:44	MBES survey for 6K dive		4/14 12:00 (JST)
	09:00	launching SHINKAI 6500 (6K#1387Dive)		37-53.6N,144-32.0E
	10:00-10:25	scientists meeting		fine but cloudy
	11:31	SHINKAI landing (5,889m)		ESE-2 (light breeze)
	15:04	SHINKAI leave the bottom (5,694m)		2 (sea smooth)
	17:06	SHINKAI come up to surface		1 (Low swell sea)
	17:30	finish SHINAKI operation		Visibly: 8'
	19:45-20:05	scientists meeting		
	-19:21	MBES survey for 6K dive		
15-Apr-14	-02:23	MBES survey for 6K dive		4/15 12:00 (JST)
	02:23-04:25	MBES survey		37-42.5N,145-20.9E
	08:58	launching SHINKAI 6500 (6K#1388Dive)		fine but cloudy
	11:19	SHINKAI landing (5,436m)		SW-3 (gentle breeze)
	15:00	SHINKAI leave the bottom (5,348m)		2 (sea smooth)
	16:56	SHINKAI come up to surface		1 (Low swell sea)
	17:22	finish SHINAKI operation		Visibly: 8'
	19:30-20:00	scientists meeting		
	19:55-20:13	eight figure turns		
	20:22-	MBES survey		

Date	Local Time	Description	Note	Position/Weather/ Wind/Sea condition
16-Apr-14		Dive was postponed		4/16 12:00 (JST)
		MBES survey		38-04.0N,145-57.0E
	01:24-01:47	eight figure turns		fine but cloudy
	18:00-18:45	scientists meeting		NW-4 (moderate breeze)
				3 (sea slight)
				2(Low swell long)
				Visibly: 8'
17-Apr-14	-05:00	MBES survey		4/17 12:00 (JST)
	8:56	launching SHINKAI 6500 (6K#1389Dive)		37-39.7N,145-11.6E
	11:17	SHINKAI landing (5,446m)		fine but cloudy
	15:09	SHINKAI leave the bottom (5,201m)		SSE-5 (fresh breeze)
	15:15-16:00	scientists meeting		3 (sea slight)
	17:01	SHINKAI come up to surface		1 (Low swell sea)
	17:27	finish SHINAKI operation		Visibly: 8'
	20:30-21:05	scientists meeting		
	20:02-	MBES survey		
18-Apr-14	-05:55	MBES survey		4/18 12:00 (JST)
	8:59	launching SHINKAI 6500 (6K#1390Dive)		38-01.2N,145-14.8E
	11:13	SHINKAI landing (5,316m)		overcast
	15:09	SHINKAI leave the bottom (5,109m)		NNE-5 (fresh breeze)
	17:04	SHINKAI come up to surface		3 (sea slight)
	17:27	finish SHINAKI operation		1 (Low swell sea)
	19:30-20:10	scientists meeting		Visibly: 8'
	18:52-	MBES survey		

Date	Local Time	Description	Note	Position/Weather/ Wind/Sea condition
19-Apr-14	-05:55	MBES survey		4/19 12:00 (JST)
	8:57	launching SHINKAI 6500 (6K#1391Dive)		37-19.3N,145-24.4E
	11:19	SHINKAI landing (5,580m)		cloudy
	15:01	SHINKAI leave the bottom (5,387m)		NNE-6 (strong breeze)
	16:59	SHINKAI come up to surface		3 (sea slight)
	17:35	finish SHINAKI operation		2 (Low swell long)
	19:10-19:15	scientists meeting		Visibly: 8'
	20:17-	MBES survey		
20-Apr-14	-02:55	MBES survey		4/20 12:00 (JST)
	8:59	launching SHINKAI 6500 (6K#1392Dive)		37-23.3N,145-38.0E
	11:26	SHINKAI landing (5,551m)		fine but cloudy
	15:03	SHINKAI leave the bottom (5,501m)		North-4 (moderate breeze)
	16:59	SHINKAI come up to surface		2 (sea smooth)
	17:26	finish SHINAKI operation		2 (Low swell long)
	19:50-20:30	scientists meeting		Visibly: 8'
	20:30-	MBES survey		
21-Apr-14	-01:53	MBES survey		4/21 12:00 (JST)
	8:57	launching SHINKAI 6500 (6K#1393Dive)		37-55.2N,145-02.0E
	11:24	SHINKAI landing (5,425m)		cloudy
	15:01	SHINKAI leave the bottom (5,189m)		South-6 (strong breeze)
	16:51	SHINKAI come up to surface		3 (sea slight)
	17:20	finish SHINAKI operation		2 (Low swell long)
	19:50-20:30	scientists meeting		Visibly: 8'
		transit to Yokosuka No.4		

Date	Local Time	Description	Note	Position/Weather/ Wind/Sea condition
22-Apr-14		transit to Yokosuka No.4		4/22 12:00 (JST)
	09:00-10:00	ship tour		35-28.0N,140-49.0E
	13:00-13:30	onboard seminar		overcast
	18:30-19:30	scientists meeting		NNE-5 (fresh breeze)
	19:50	arrived at Yokosuka No.4		3 (sea slight)
				2 (Low swell long)
				Visibly: 8'
23-Apr-14	08:20-09:45	scientists meeting		4/23 12:00 (JST)
	13:20	heave anchor, for off Chiba		35-19.7N,139-40.6E
	15:30	arrived at off Chiba		fine but cloudy
	16:00-17:00	scientists meeting		ESE-2 (light breeze)
				2 (sea smooth)
				1 (Low swell sea)
				Visibly: 7'
24-Apr-14	09:00	arrived at Funabashi, Chiba		4/24 12:00 (JST)
	10:00	SHINKAI on ground		Funabashi
	13:30	scientists left ship		

3-2-2. 6K Dive Logs

YK14-05 cruise operated the nine dives 6K#1385 to 6K#1393 (see Fig. 1-3), NW Pacific off NE Japan.

3-2-2-1. 6K#1385 Dive

by Ishii, Sato & Yutani

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
9:03	0				launching		
9:13	0				completely sank		
9:56	2000						
10:18	3000						
10:43	4034		-60	180			
11:07	5000		0	-50			
11:31	5688		34	57			
11:39	5750		70	-380	on bottom; gravel-mixed muddy floor		
11:46					sampling attempted		
11:53	5750		80	-382	samples recovered	R01, R02	13
						C01(B)	3
12:00	5749		10	-370			
12:02		140			moving; set head angle to 140		
12:03		120	-40	-300	moving; set head angle to 120		
12:04	5744		-50	-290			
12:08					sampling attempted		
12:18	5745		-120	-230	samples recovered	R03, R04, R05	11
12:22		200			moving; set head angle to 200		
12:23	5741		-120	-260	pillow lava appeared		
12:28					sampling attempted		
12:33	5739		-290	-340	samples recovered	R06, R07	10
12:36	5737	300			moving; set head angle to 300		
12:40	5737		-270	-430			
12:47	5748		-150	-600			
12:50	5747				sampling attempted		
13:01	5739		-100	-700	samples recovered	R08, R09	14
13:04	5725	270			moving; set head angle to 270		
13:07	5691		-80	-870			
13:11	5679		-110	-880			
13:13			-100	-940			
13:17	5670	340			moving; set head angle to 340		
13:21	5677		-20	-1000			
13:22					sampling attempted		
13:28	5678		-20	-1020	samples recovered	R10, R11	15
13:32	5673	340			moving; set head angle to 340; descend gently here		

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
13:34	5680		10	-1070	ascend gently here		
13:41	5638		140	-1190			
13:44		10			moving; set head angle to 10		
13:48	5609		240	-1200			
13:50	5602				sampling attempted		
13:57	5602		310	-1260	samples recovered	R12, R13, R14	2
14:02	5597	20			moving; set head angle to 20		
14:06	5640		440	-1220			
14:09	5647				sampling attempted		
14:12	5648		500	-1270	put a marker No. 165		
14:23	5648		500	-1270	samples recovered	R15, R16, R17, R18	5
14:30	5646				off bottom		
16:30	0				surfaced		

*Center Lat. 37-25.0N Lon. 144-58.2E

3-2-2-2. 6K#1386 Dive

by Machida, Kawano & Taki

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
8:50	0		-	-	launching		
9:00	0		-	-	completety sank		
9:20	1000						
9:33	1550						
9:42	2000						
9:54	2500						
10:06	3020						
10:17	3500						
10:30	4000		-900	40			
10:31		30			moving; set head angle to 30		
10:38			-840	110			
10:42	4500		-790	110			
10:53			-560	290			
10:54	5000				stopped moving		
11:12							
11:21	5571		-630	240	on bottom; gravel-mixed muddy floor		
11:22					sampling attempted		
11:32					sample recovered	SC01 R01	9 11
11:35	5570						
11:41	5560		-450	160			
11:45	5553		-340	150			

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
11:48	5545		-280	120			
11:54	5526				sampling attempted		
12:01			-260	70		R02,03,04	13
					moving; along the slope		
12:08	5523		-190	150	sampling attempted		
12:15	5523				sample recovered	R05,06	12
						R07	10
12:15					moving; along the slope		
12:20	5520		-160	180			
12:28	5503				sampling attempted		
12:36	5503		-40	220	sample recovered	R08,09	8
						SC02	
12:38					moving; along the slope		
12:46	5492		100	200			
12:55	5500				sampling attempted		
12:59	5499		170	210	sample recovered	R10	3
13:17			290	190			
13:29	5488		380	160			
13:39	5484				sampling attempted		
13:50	5483		420	160	sample recovered	R11,12,13, 14	1
13:52		240			moving; set head angle to 240		
14:14	5381				sampling attempted		
14:27	5380		440	-80	sample recovered	R15,16,17	5
14:29		180			moving; set head angle to 180		
14:42					sampling attempted		
14:52					(whale appeared in front of yokosuka)		
15:00	5383					R18	4
15:01			250	-20	off bottom		
15:09	5000						
16:31	1000						
16:54	0				surfaced		

*Center Lat. 37-29.2N Lon. 145-35.5E

3-2-2-3. 6K#1387 Dive by JYamamoto, Ukyo & Suzuki

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
9:00					completely sank		
9:21	1000						
9:43	2000						
9:54	2500						
10:07	3000						
10:18	3500						
10:30	4000		1670	620			
10:39		200			moving; set head angle to 200		
10:43			1620	660			
10:44	4580						
10:50			1320	470			
10:54			1150	430			
10:56	5000						
11:09	5500		1280	550			
11:22							
11:31	5889		1400	560	on bottom; gravel-mixed muddy floor		
11:33		280			moving; set head angle to 280		
11:40	5894		1380	520			
11:49			1190	300			
11:50	5912						
11:53	5915						
11:56	5915		1180	280	sample recovered	R01	2
		180			moving; set head angle to 180		
12:06					sampling attempted		
12:12			1080	230	sample recovered(Mud)	C01(R02)	blue
12:13	5917	180			moving; set head angle to 180		
12:20	5920		940	280			
12:21		220			set head angle to 220		
12:35	5888		780	240	sample recovered	R03,04	3
12:42	5859		680	230			
12:50	5840		660	250	sample recovered	R05,06	5
12:57					like pahoehoe lava? byHirano		
12:57					sampling attempted		
13:03	5827		670	310	sample recovered (dolphin appeared in front of yokosuka)	R07,08,09	13
~13:12					sampling attempted		
13:21	5816		630	300	sample recovered	R10.11.12	14
13:30	5773		780	310	sampling attempted		
13:36	5765		780	310	sample recovered	R13,14,15,16	8
		180	580	330	moving; set head angle to 180		

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
13:44	5730	200			set head angle to 200		
13:49	5709		200	290			
13:56	5722		0	210			
14:05	5713		-170	-20			
14:07					sampling attempted		
14:11	5713		-180	0	sample recovered	R17	13
						R18,19	11
14:16	5658		-280	-210			
14:22					sampling attempted		
14:23	5645		-300	150	sample recovered	R20	10
14:26	5642	160			moving; set head angle to 160		
14:28			-360	280			
14:31	5661		-340	430			
14:38			-440	580			
14:41	5736						
14:42	5744		-450	570			
14:46	5768						
14:48	5737		-380	430			
14:50					sampling attempted		
14:55	5725		-360	400	sample recovered	R21,21	6
14:59					sampling attempted?		
15:03					sample recovered	R23,24	7
15:03	5694				off bottom		
	5678		-380	370			
15:09	5450						
15:18	5000						
15:37	4000						
16:19	2000						
16:53	500						
17:05					surface		

*Center Lat. 37-53.0N Lon. 144-32.0E

3-2-2-4. 6K#1388 Dive

by Hirano, Sato & Yutani

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
8:47	0				launching		
8:58	0				completely sank		
9:20	1000						
9:42	2000						
10:06	3000						
10:30	4000		-80	-530			
10:43	4500		-140	-500			

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
10:56	5000		-190	-420			
10:59		180			set head angle to 180		
11:05			-460	-390			
11:19	5436		-540	-280	on bottom; gravel-mixed muddy floor		
11:24					sampling attempted		
11:33	5437		-520	-260	sample recovered	R01, R02 R03	8 10
11:35		45			set head angle to 45		
11:46			-320	-40			
11:55					sampling attempted		
11:59	5418		-200	180	sample recovered	R04,05,06, 07,08,09	11
12:01		0			set head angle to 0		
12:13	5387		-110	130	sample recovered	R10, 11, 12, 13	12
12:22					sampling attempted		
12:33	5378		50	120	sample recovered	R14. R15	13
12:36	5375	340			set head angle to 340		
12:46	5376				sampling attempted		
13:02	5368		100	70	sample recovered	R16, R17	14
13:06			100	60			
13:10					flying along the ridge		
13:15	5348		120	-40			
13:22	5335		90	-140			
13:29					sampling attempted		
13:40	5329		50	-190	sample recovered	R18	7
13:44					set head angle to 270		
13:51			0	-400			
13:57		90	-60	-430	sethead angle to 90		
14:05					sampling attempted		
14:08	5422		-60	-400	sample recovered	R19, 20	15
14:17			-70	-300			
14:24	5430		-40	-220			
14:38			-20	-180	sample recovered	R21,22,23, 24,25,26	5
14:40	5329	0			set head angle to 0		
14:43	5326	90			set head angle to 90		
14:54	5329	180	20	-100	put a marker No. 166; set head angle to 180		
14:58	5344				battery1 lost		
14:59	5348				off bottom		
16:56	0				surfaced		

*Center Lat. 37-42.5N Lon. 145-21.0E

3-2-2-5. 6K#1389 Dive by Ishii, Kawano & Taki

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
8:47	0		-	-	launching		
8:57	0		-	-	completety sank		
9:07	500						
9:18	1000						
9:40	2000						
10:03	3000						
10:06		310			set head angle to 310		
10:15	3500		90	-540			
10:22			190	-630	stop sailing		
10:27	4000						
10:40	4500						
10:49			300	-580			
10:50		230			moving; set head angle to 230		
10:52	5000						
10:56			190	-750			
11:06			240	-760	stop sailing		
11:17	5446		300	-750	on bottom; muddy floor		
11:20		135			moving; set head angle to 135		
11:26			240	-670			
11:30	5410	110	180	-610	moving; set head angle to 110		
11:41	5354				sampling attempted		
12:00					sample recovered	R01,02,03	11
						R04	1
12:02	5348		170	-490	sample recovered	R05	11
12:04		200			moving; set head angle to 200		
12:11	5349	105	110	-500	moving; set head angle to 105		
12:20	5275		90	-380			
12:22	5267	90			moving; set head angle to 90		
12:40	5198				sampling attempted		
12:45					(whale appeared in front of yokosuka)		
12:53	5197		110	-190	sample recovered	R06	12
12:55		180			moving; set head angle to 180		
12:59	5206		-10	-180	moving; jump to X=-300		
13:05	5228		-300	-140			
13:07					down to bottom		
13:17	5395	30	-360	-110	moving; set head angle to 30		
13:19		10			moving; set head angle to 10		
13:25	5341		-270	-70			
13:30	5311		-220	-60			
13:35	5303				on bottom		
13:44	5305		-180	-70	sample recovered	R07	left
13:52	5290				sampling attempted		
13:55	5290		-120	-60	sample recovered	R08,09	13

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
						R10	14
13:58	5285						
14:04	5256	20			moving; set head angle to 20		
14:09	5236		-50	-20			
14:18	5211	40			moving; along the crack		
14:23					on bottom, sampling attenmpted		
14:33		30	30	-30	sampling failed		
14:39	5199	90	80	-30	moving; set head angle to 90		
14:47	5213		100	80			
14:55					sampling attempted		
15:01			90	120	put a marker No. 167		
15:05			90	130	sample recovered	R11	3
						R12	15
15:08	5201				off bottom		
15:22	4500						
16:49	500						
17:00	0				surfaced		

*Center Lat. 37-39.5N Lon. 145-12.0E

3-2-2-6. 6K#1390 Dive

by Machida, Suzuki & Ukyo

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
8:49					launching		
8:58					completety sank		
9:19	1000						
9:41	2000						
9:53	2500						
10:05	3000						
10:17	3500						
10:30	4000		480	-190			
10:38		280	470	-150	moving; set head angle to 280		
10:42	4500		480	-180			
10:49	4700		500	-340			
10:56	5000		540	-490			
11:06							
11:13	5316		550	-450	on bottom; gravel-mixed muddy floor		
11:24					sampling failed		
11:26	5314				moving		
11:36					sampling attempted		
11:41	5295		480	-350	sample recovered	R01,02	12
					set head angle to 120		

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
11:44					moving; set head angle to 160		
11:55					sampling attempted		
12:13	5241	160	390	-210	sampling failed ,too soft		
12:22	5194		330	-230			
12:33					sampling attempted		
12:46	5170		280	-200	sample recovered	R03	5
		160			moving; set head angle to 160		
13:03	5115				sampling attempted		
13:07	5115		210	-130	sample recovered *broken to three pieces	R04	11
	5111	160			moving; set head angle to 160		
13:11	5109				sampling attempted		
13:18	5113		200	-130	sample recovered	R05,06(R05-08?)	3
13:20					moving; set head angle to 160		
13:22			220	-300			
13:31		280	220	-380	moving; set head angle to 280		
13:34					sampling attempted		
13:39	5210		210	-340	sample recovered	R07,08(R08,09?)	10
13:39		20			moving; set head angle to 20		
13:46					sampling attempted		
13:49		120	-200		sampling failed		
14:00	5165		-190	-250	sample recovered	R09(R10?)	2
14:01							
14:31	5184		280	-240			
14:42			220	-170	sarch the point of sampling		
14:55	5133		240	-160	sample recovered	R10(R11?)	13
15:09	5109				sample recovered	R11(R12?)	14
15:13					off bottom		
15:32	4000						
17:00					surfaced		

*Center Lat.38-01.0N Lon. 145-15.2E

3-2-2-7. 6K#1391 Dive

by Yamamoto, Sato & Yutani

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
8:49	0				laumching		
8:58	0				completely sank		
9:18	1000						
9:41	2000						
10:04	3000						
10:28	4024		-1890	20			

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
10:33		30			set head angle to 30		
10:41	4550		-1650	190			
10:52	5000						
11:10	5500		-1600	290			
11:19	5580		-1600	290	on bottom; gravel-mixed muddy floor		
11:21		270			set head angle to 270		
11:24	5578						
11:28	5580		-1610	200			
11:29	5582						
11:32	5583				sampling (by scoop) attempted		
11:37	5582		-1640	220	sample recovered	SC01	9
11:39					sampling attempted		
11:43	5582				samples recovered	R02, 03	13
11:44		270			set head angle to 270		
11:46		180			set head angle to 180		
11:47					sampling attempted		
11:56	5582		-1680	180	sample recovered	R04	on 14 and 15
12:03	5568		-1690	160	sample recovered	R05	14
12:06	5565	130					
12:12	5547				sampling attempted		
12:16	5547		-1720	210	sample recovered	R06	10
						R07	11
12:18		110			set head angle to 110		
12:22	5519	150	-1720	270	set head angle to 150		
12:27	5507		-1770	340			
12:33	5505	0	-1750	300	set head angle to 0		
12:37	5536		-1620	340			
12:41	5533				sampling attempted		
12:48			-1560	340	samples recovered	R08, 09	12
12:51	5531	0			set head angle to 0		
12:54			-1520	320			
12:56	5522		-1500	320			
12:59					sampling attempted		
13:06	5520		-1490	290	sample recovered	R10	3
						R11	5
13:09		340			set head angle to 340		
13:16	5520		-1250	190	heading to S8		
13:26	5509		-660	20			
13:35			-170	-230			
13:43	5527		-160	-330			
13:52	5535		490	-500			
14:00	5552		770	-640			
14:07	5559		1010	-710			

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
14:08	5555	0			set head angle to 0		
14:14	5562		1260	-730			
14:22	5551		1460	-650	sampling attempted		
14:35	5544		1480	-620	sample recovered	R12	6
14:37		40			set head angle to 40		
14:41	5518				sampling attempted		
14:42			1540	-610	sample recovered	R13	1
14:53	5430						
14:55	5427		1610	-530	sample recovered; set head angle to 40	R14	2
15:00	5387		1650	-500	off bottom		
16:58	0				surfaced		

*Center Lat. 37-20.4N Lon. 145-24.2E

3-2-2-8. 6K#1392 Dive

by Hirano, Kawano & Taki

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
8:51	0				launching		
9:00	0				completety sank		
9:11	500						
9:21	1000						
9:44	2000						
10:32	4000						
10:57	5000		-1700	-180			
10:58		90			moving; set head angle to 90		
11:03		90			moving; set head angle to 90		
11:04			-1640	-50	stop sailing		
11:15			-1640	-80	down to bottom		
11:26	5551		-1630	-120	on bottom; gravel-mixed muddy floor		
11:28		100			moving; set head angle to 100		
11:32	5550	110			moving; set head angle to 110		
11:34			-1670	30			
11:41	5542				sampling attempted		
11:45					sampling failed; too soft	R00	
11:51		110			moving; set head angle to 110		
11:52	5496				sampling attempted		
11:56					sampling failed		
11:59	5495	110	-1750	210	sample recovered	R01	15
12:06	5464				sampling attempted		
12:13	5460	110	-1760	260	sample recovered	R02	14
12:17					sampling attempted		
12:26	5437	110	-1770	290	sample recovered	R03,04	13

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
12:31					sampling attempted		
12:42	5418		-1780	330	sample recovered	R05	11
						R06	12
12:45	5415	350			moving to point 2; set head angle to 350		
12:50	5418	350	-1560	200			
13:00	5461		-1000	60			
13:11			-500	-60			
13:24			70	-170			
13:25		0			moving; set head angle to 0		
13:32	5495		430	-220			
13:40	5491		900	-250	sail at an altitude of 104 meters		
13:44			1170	-250	stop sailing; down to bottom		
13:46		0			reaction on the rador		
13:49	5548		1320	-280			
13:53			1390	-290			
13:56	5613	45			moving; set head angle to 45		
13:57	5610	45	1430	-250			
13:59					on bottom, sampling attempted		
14:02	5606				on bottom, sampling attempted		
14:05			1460	-250	sample recovered	R07	10
14:07		45			moving slow, sampling attempted		
14:09	5600				on bottom, sampling attempted		
14:16	5600		1470	-240	sampling (by scoop) attempted	SC01	8
14:17		0			moving; set head angle to 0		
14:25	5540		1600	-240			
14:34	5523				on bottom, sampling attempted		
14:38	5523	0	1720	-230	sample recovered	R08	9
14:45					on bottom, sampling attempted		
14:48	5503		1760	-240	sample recovered	R09	5
15:02	5501				sample recovered	R10	2
15:03	5493		1780	-260	off bottom		
15:23	4500						
15:33	4000						
17:00	0				surfaced		

*Center Lat. 37-24.5N Lon. 145-38.2E

3-2-2-9. 6K#1393 Dive

by Yamamoto, Kawano & Taki

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
8:58					completety sank		
9:19	1000						
9:41	2000						
10:05	3000						
10:29	4000		1080	-980			
10:32		320			moving; set head angle to 320		
10:41	4500		1300	-1150			
10:53	5000		1390	-1190			
11:05					down to bottom		
11:12	5420		1390	-1270	on bottom;		
11:14		140			moving; set head angle to 140		
11:22					sampling attempted		
11:25	5398		1300	-1210	sample recovered	R01	7
11:30	5398				sample recovered	R02	3
11:34	5398				sample recovered	R03	7
		140			set head angle to 140		
		140			moving; set head angle to 140		
11:40					sampling attempted		
11:44					sampling failed		
11:47					sampling attempted		
11:54	5354				sample recovered	R04	1
11:56		140			moving; set head angle to 140		
12:01					sampling attempted		
12:05			1240	-1160	sampling failed		
12:10		230			moving; set head angle to 230		
12:15			1130	-1280			
12:18		110			moving; set head angle to 110		
12:22					sampling attempted		
12:26					sampling failed		
12:26			1100	-1280	moving; set head angle to 110		
12:38					sampling attempted		
12:47	5362	110	1070	-1170	sample recovered	R05,06,07	8
					sample recovered Mud?	C01	red
12:50	5345				sampling attempted		
12:52		140	1070	-1160	sample recovered	R08	13
12:59					sampling attempted		
13:02	5240	110	1070	-1080	sample recovered	R09	12
13:05		120			moving to point 2; set head angle to 120		
13:13			880	-680			
13:16		130					
13:22			580	-270			
13:35			110	310			
13:37	5314	135					

Time (JST)	Dep. (m)	Head (Deg)	Pos. X(m)	Pos. Y(m)	Description	Sample	Box
13:44	5324		-250	700			
13:50	5324		-420	880			
13:53		109	-530	980	stop sailing; down to bottom		
14:00	5292		-590	970	sampling attempted		
14:03	5286		-610	960	sample recovered	R10,R11, R12	14
14:20					sampling attempted		
14:30	5245		-670	960	sample recovered	R13,R14	10
14:31		190			moving; set head angle to 190		
14:33					sampling attempted		
14:38	5239		-680	960	sample recovered	R15,R16	15
14:47					sampling attempted		
14:59			-820	900	sample recovered	R17	5
						R18,R19	2
						R20	left
15:00	5189						
15:01					off bottom		
17:00					surfaced		

*Center Lat. 37-54.30N Lon.145-02.80E

3-2-3. Multibeam Survey

Multi-narrow beam echo sounder: MBES (EM122, Kongsberg Maritime, Inc.) surveyed bathymetry and acoustic reflectivity, which was powerful tool to search the volcanoes and to decide the dive sites during YK14-05. The track lines are shown in Figs. 1-1 and 1-2.

The data of acoustic reflectivity provide us with a powerful tool to help locate the petit-spot volcanoes, because they are too small to be reliably detected by multibeam bathymetry, as they are only 1 to 2 km in diameter and only a few hundred meters in height.

3-2-4. Magnetometers & Gravity Meter

During the YK14-05 cruise, geophysical surveys, whose items included were gravity meter (Type S-63, LaCoste & Romberg Gravity Meters Inc.), a ship borne 3 axis magnet meter (Type SFG-1212, Tierra Technica Inc.), and a proton magnet meter (Type STC 10, Kawasaki Geological Engineering Co., Ltd.) conducted aboard the R/V Yokosuka. The aim of the geophysical surveys was to provide a detailed geophysical characterization of the lithosphere and seamounts in the western Pacific on and off-axis ridge flanks, which will be used to unravel tectonic evolution and crustal structure.

Shipboard gravity anomaly will be used for analysis of the crustal structure combined with bathymetry and seismic reflection data. Analysis of lithospheric flexure and deformation using satellite derived gravity anomaly combined with the shipboard gravity anomaly may be helpful as well.

4. Observations

4-1. R/V Yokosuka

R/V YOKOSUKA is designed serve as the mother vessel for SHINKAI 6500 and Autonomous Underwater Vehicle (AUV) URASHIMA. It has silent engine, an advanced acoustic navigation systems and an underwater telephone for its state of the art operations.

There are 5 laboratories on Yokosuka, No.1-No.4 laboratories and No.1 Study room. No.1 Lab. has dry space. The permanent installations are an video editing system, a PC and a printer. No.2 Lab. has semi-dry and wet space. There are two freezers (-40 & -80 deg.C), a incubator, a Milli-Q, and a fumigation chamber at dry one, and wet one has a rock saw. No.3 Lab. has dry space with storage. No.4 Lab. has semi-dry and wet space. No.1 Study room has dry space, there are a gravity meter, a data acquisition system of gravity meter, a 3 axis fluxgate magnet meter and also a proton magnet meter, a work station for data processing, and a A0 size plotter.

The general specifications of R/V YOKOSUKA

Length overall	105.2 m
Beam overall	16.0 m
Depth	7.3 m
Draft	4.5 m
Gross tonnage	4,439 tons
Service speed	16knot
Main propulsion system Diesel engines	2,206kW x 2
Main propulsion method	Controllable pitch propeller x 2

4-2. MBES, Magnetometers, and Gravity Meter

YOKOSUKA is equipped with various kinds of underway geophysical equipment, a multi narrow beam echo sounder: MBES (EM122, Kongsberg Maritime, Inc.), a gravity meter (Type S-63, LaCoste & Romberg Gravity Meters Inc.), a ship borne 3 axis magnet meter (Type SFG-1212, Tierra Technica Inc.), and a proton magnet meter (Type STC 10, Kawasaki Geological Engineering Co., Ltd.). The specifications of these instruments are listed below.

The specifications of EM122

Measurement depth (m)	20 ~ 11,000
Measurement frequency (kHz)	12
Measurement method	cross fan beam style
Beam numbers	288
Mesurement point	432
Pulse lengths	2/5/15msec CW(～2000m)
	100msec FM(2000m～)
Beam width (deg.)	2
Beam interval (deg.)	2
Swath width (deg.)	150 (Max)
Sampling rate (msec.)	0.33
Roll (deg.)	±15
Pitch (deg.)	±10
Yaw (deg.)	±10

The specifications of Gravity Meter

Measurement range (m Gal)	12,000
Drift	3mGal per month or less
Stabilized platform	
Platform pitch(deg.)	±22
Platform roll(deg.)	±25
Platform period(min.)	4 to 4.5
Beam interval(deg.)	1
Control system	
Recording rate(Hz)	1
Serial out put	RS-232

System performance

Resolution (mGal)	0.01
Static repeatability (mGal)	0.05
50,000m Gal horizontal acceleration (mGal)	0.25
100,000m Gal horizontal acceleration (mGal)	0.50
100,000m Gal vertical acceleration (mGal)	0.25
Dimension (cm)	71×56×84
Weight (kg)	Meter:86, UPS:30

<u>The specifications of Three Axis Magnet Meter</u>

System	ring core fluxgate
Number of component directly	3 axes
Cable length (m)	50
Sensor dimension (mm)	φ280×130H
Measurement range (nT)	±100,000
Resolution (nT)	1

<u>The specifications of Proton Magnet Meter</u>

Measurement range (nT)	3 ~ 7 x 10**4
Resolution (nT)	0.01
Sampling rate	10sec, 20sec, 1min, manual, external
Time of applying field(sec.)	3 to 10
Sensor dimension (mm)	φ200×1050
Weight (kg)	28.6(in the air), 6.2(in the sea)

4-3. 6K Dives

The submersible, Shinkai 6500, conducted the nine dives to eleven petit-spot volcanoes on the Site C (Hirano et al., 2008) off NE Japan, NW Pacific (Fig. 4-3), where the observation and rock samples was implied the volcanic history and various volcanic products.

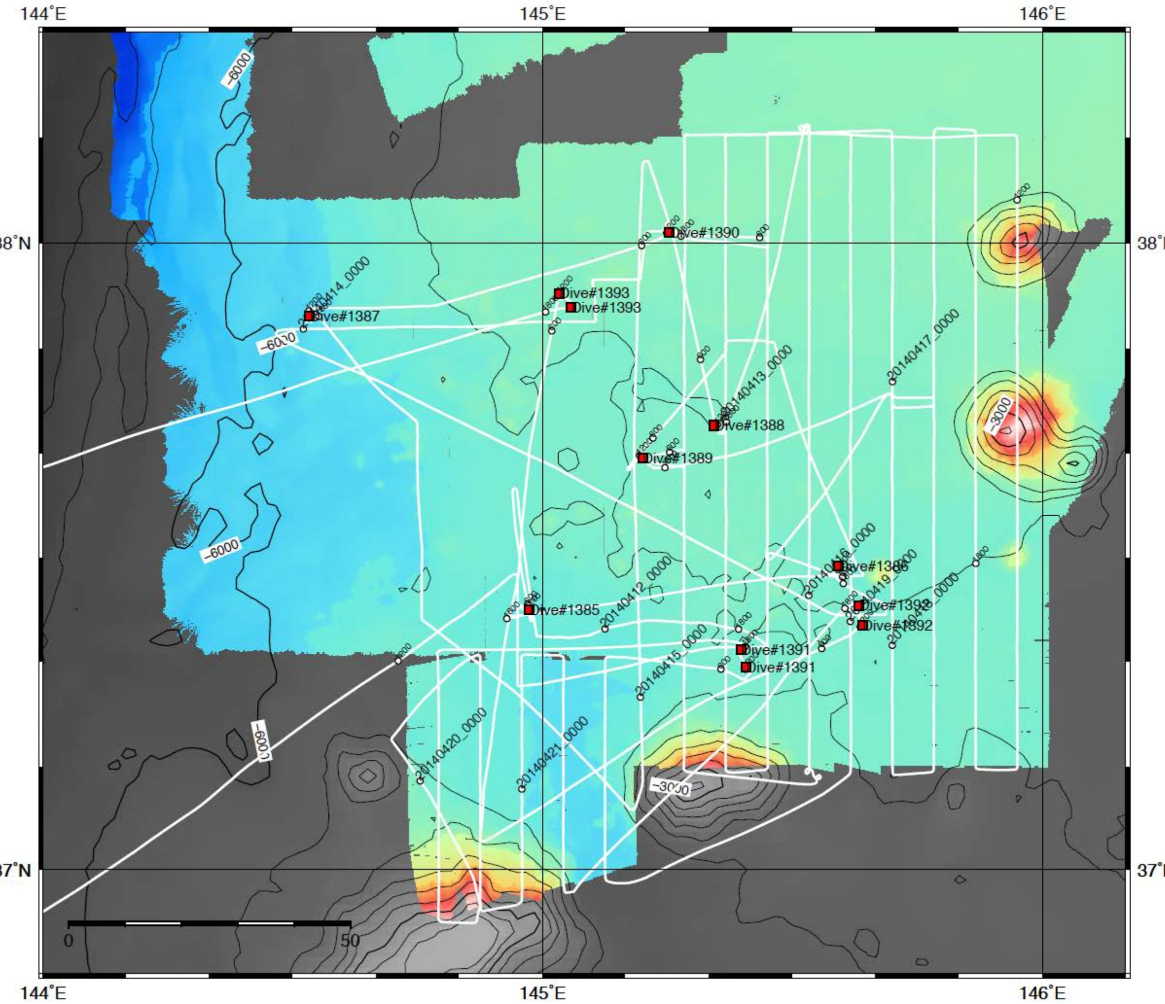


Fig. 4-3. Closed-up map of research area and the nine dive sites of 6K#1385 to 6K#1393 by submersible *Shinkai6500*.

4-3-1. 6K#1385: Flat lava field with high acoustic reflection by T. Ishii

Date: 12 (Saturday) April, 2014

Place: Off Tohoku in Western Pacific, small seamounts field at north of Bosei seamount. 27°25.00' N, 144°58.40' E

Pilot: Hirofumi UEKI

Co-pilot: Tayama YUDAI

Observer: Teruaki ISHII (Fukada Geological Institute)

The purposes of the SHINKAI 6500 dive (Dive 6K#1385) were to investigate the geological nature of the flat lava field (about 100 m high and 1000 m wide x 2000 m long, see Fig. 4.3.1-1 and -2) with high acoustic reflection, that is, to make clear the origin of the flat lava field, the geological characteristics of constituting rocks of the flat lava field and lithology of rocks comprising it; and to evaluate whether any recent volcanic activity has taken place in this area.

The SHINKAI 6K landed on the seafloor in the southeastern lowermost hillside of the flat lava field. The seafloor throughout the dive truck was occasionally covered in thin manganese crusts overlapped very thin soft pelagic sediment. Many small boulders (Fig. 4.3.1-3) probably originated from volcanic activity were observed throughout the SHINKAI 1385 dive truck locating of the eastern side toward the top of the flat lava field (Fig. 4.3.1-2). On the basis of observations on the shape of small boulders, they are assumed as pillow lava, pillow robe, lava tube and pillow breccia.

We tried sampling with the strong SHINKAI's manipulators to get pebbles and cobbles but it was not so difficult to yank off even large rock piece from the seafloor, because all rock pieces were relatively loosely connected by manganese coating. All of recovered 16 samples (6K1385R03-R18) were basaltic rocks with thin manganese coating containing. Outflowing 2 samples (R01, R02) from sample basket during pull up SHINNKAI from sea surface may be pumice (and/or sedimentary rock) coated by thin manganese crust, because they have low density.

On the basis of geological observations on seafloor and lithological consideration on collected rocks, we can assume that the main edifice of the flat lava field were induced by volcanic eruption(s) of basaltic magma with very low viscosity during relatively resent geological time (less than one million years ago?) on the Cretaceous Pacific Plate.

Video Highlights

(1) 11:39 – 11:53 (camera #1 or #2): Stop01. We arrive at the landing site at 5750m deep. The site was fully covered with soft pelagic sediment and boulders were observed (Fig. 4.3.1-3); take 2 manganese and soft pelagic sediment coated rocks (sample 6K1385R01 and R02).
(2) 12:08 – 12:20 (camera #1 or #2): Stop02. The site was covered in thin manganese crusts with very thin soft pelagic sediment and boulders showing pillow lava and lava flow features were observed (Fig. 4.3.1-4) at 5745 m deep; take 2 rock samples (sample R03, R04).
(3) 12:28 – 12:33 (camera #1 or #2): Stop03. The seafloor was fully covered in thin manganese crusts and huge boulder showing pillow lava features were observed(Fig. 4.3.1-5) at 5739 m deep; take 3 rock samples (sample R05, R06, 07).
(4) 12:50 – 13:02 (camera #1 or #2): Stop04. The seafloor was covered in thin manganese crusts and gravel showing pillow breccia features were observed (Fig. 4.3.1-6) at 5747 m deep; take 2 rock samples (sample R08, R09).
(5) 13:22 – 13:30 (camera #1 or #2): Stop5. The assumed southern summit showed boulder scattered field like appearance. Huge boulder showed pillow lava feature (Fig. 4.3.1-7) at 5678 m deep; take 2 rock samples (sample R10, R11).
(6) 13:50 – 13:57 (camera #1 or #2): Stop6. The seafloor was covered in thin manganese crusts and gravel showing pillow breccia features were observed (Fig. 4.3.1-8) at 5602 m deep; take 3 rock samples (sample R12, R13, R14).
(7) 14:09– 14:30 (camera #1 or #2): Stop7. We arrived at real summit of the high at 5647 m. Boulder and gravels showed pillow lava and pillow breccia features (Fig. 4.3.1-9) at 5648 m deep; take 4 rock samples (sample R15, R15, R17, R18); setting up #165 event marker.
(8) 14:30 (camera #1 or #2) left bottom at 5648 m.

Purposes of Dive

1. To determine the geological and lithological nature of the high back-scattered area observed in sidescan sonar data between 5750 m and 5650 m.
2. To investigate the origin of the flat lava field, that is, topographic high about 100 m high and 1000 m wide x 2000 m long .
3. To evaluate mode of emplacement of the lavas forming the edifice (the lava morphology and eruptive mode).

4. To collect rock samples from this previously unsampled area for further geological, volcanological and petrological investigations.

Payload

2 – sample baskets with 15 partitions in total
1 – sample container (3 partitions) with lid
1 – scoop for collecting lava pebbles buried in the soft sediment
2 – push cores for collecting soft sediment
2 – M-type sampler for collecting jelly material
2 – event markers (#165 and #166)

Summary of Dive Operations

Dive Plan

Dive #1385 site was initially targeted because of its topographic low feature that produce a high back-scattered area in sidescan sonar data. In order to investigate the stratigraphy of the flat lava field, the landing point of the dive was selected at the base of southeastern slope of the flat lava field. Continuous observing and sampling along the slope toward the summit were expected.

Topography

Sidescan sonar and reflectivity data (SeaBeam) collected on this and previous surveys of this area show a small NS-elongated hill (with 1000m wide x 2000m long) from 5750 m to 5650 m depth; about 100 m high from base to summit. The top of the hill is flattened. (Fig. 4.3.1-1 and -2).

Geology

The SHINKAI 6500 landed on the seafloor at 5750 m at 11:39 in the lower southeastern foot of the high, where two samples were taken. SHINKAI ascended the hill toward southern summit about 5678 m deep shown in the map (Fig. 4.3.1-1 and -2). Sampling had been continued up to 5648 m. SHINKAI finished its ascent of the hill and took additional samples. SHINKAI left the flatten summit of the high at 5648 at 14:30.

The first landed seafloor was so fully covered in pelagic sediment that bioturbation was also very rich. We observed boulders with some animals on the surface (Fig. 4.3.1-3). We took 2 samples (Stop 1, sample 6K1385R01, R02). We attempted sampling with push core to get soft sediment. We began a course at 120°at 12:03 toward the eastern toe of the high (Fig. 4.3.1-1 and -2). SHINKAI stopped for sampling at 12:08, and recovered 3 small rock samples (Stop 2, sample R03, R04, R05). After the sampling, we moved with course at 200°. We observed huge boulders with 1 to 2 m scale, but could not encounter obvious outcrop of igneous rock. Those huge boulders were assumed as pillow lobe and /or pillow lava.We stopped to take two sample at 12:33 at this depth of 5739 m (Stop 3, sample R06, R07).

We began new course at 300° at 12:37. SHINKAI stopped for sampling at 12:50 at 5739 m and recovered two samples (Stop 4, sample R08, R09). After the sampling, we moved with new course at 270°, and we stopped to take two samples at 13:22 at 5677 m (Stop 5, sample R10, R11). After the sampling, we start to move at 340° and changed course at 10° at southern end of assumed summit area. We stopped moving at 13:50 at 5602 m, and we took three samples (Stop 6, sample R12, R13, R14).

After the sampling, we moved with new course at 20°, and we stopped to set up #165 event marker at 14:12, and we took four samples at 14:23 at 5647 m (Stop 7, sample R15, R16, R17, R18).

We left bottom at 14:30 at 5646 m.

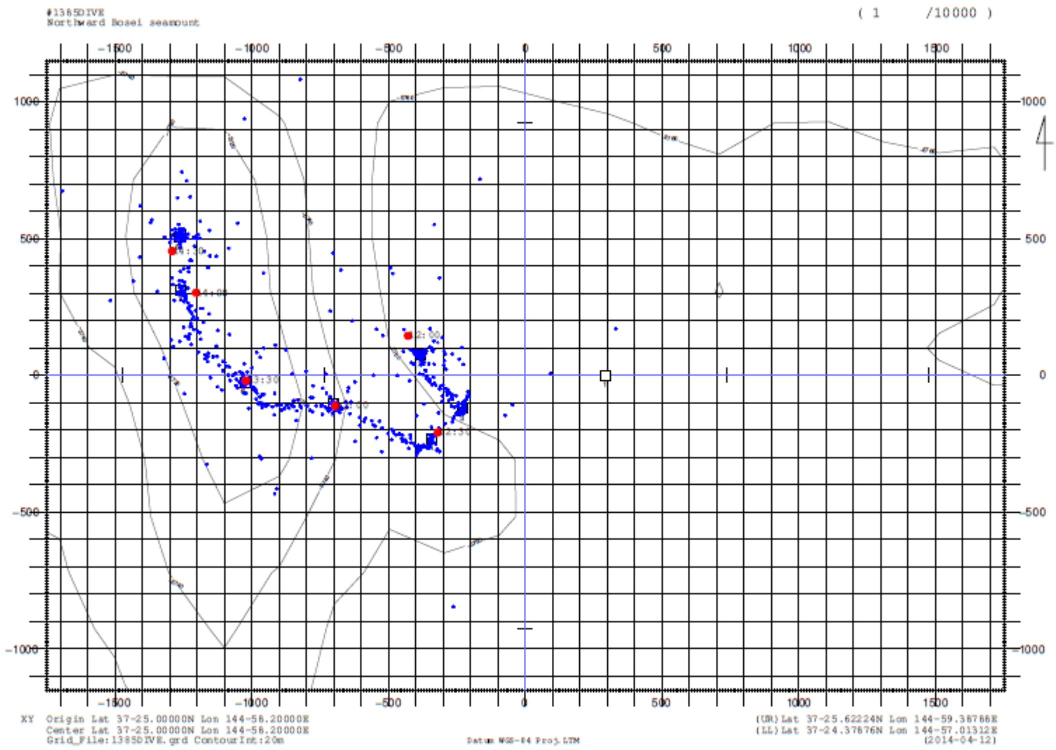


Fig. 4.3.1-1. Detail bathymetric map around the Dive6K#1385 site. The flat lava field (27°25.00' N, 144°58.40' E) with high back-scatters was confirmed by the site-survey of this dive.

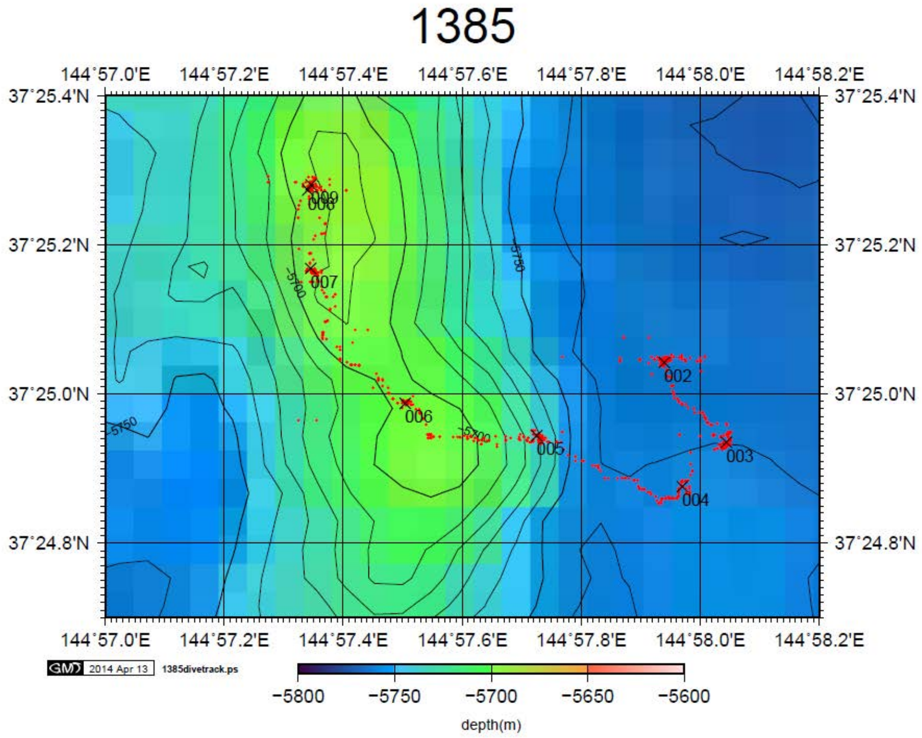


Fig. 4.3.1-2. The SHINKAI 6500 dive (Dive 6K#1385) track shown in the 20 m contour map.

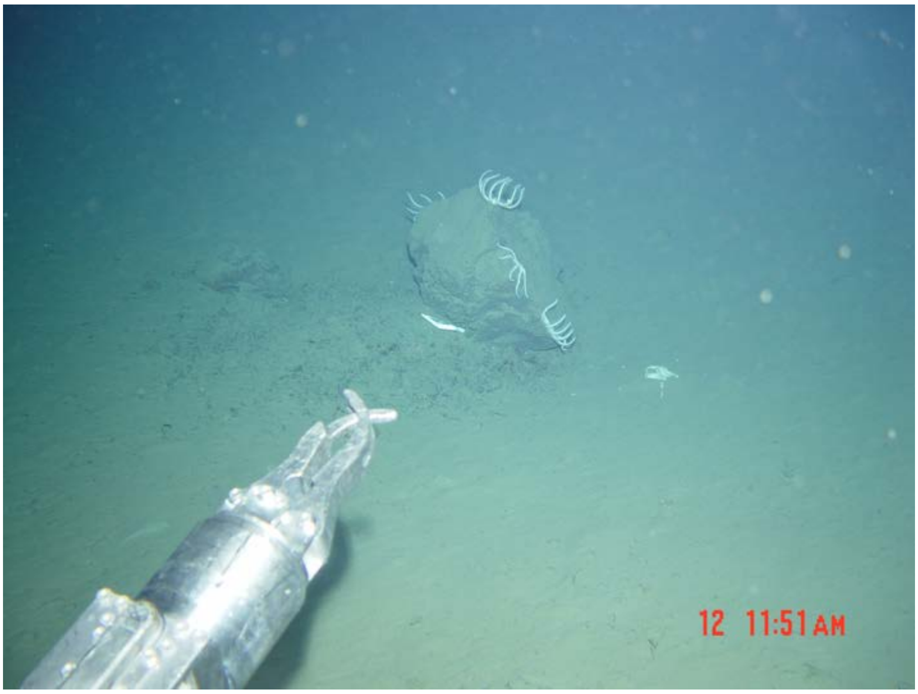


Fig. 4.3.1-3. The subangular boulder covered in manganese crusts and soft pelagic sediment showing some animals on the surface (Stop 1, Depth = 5750 m).

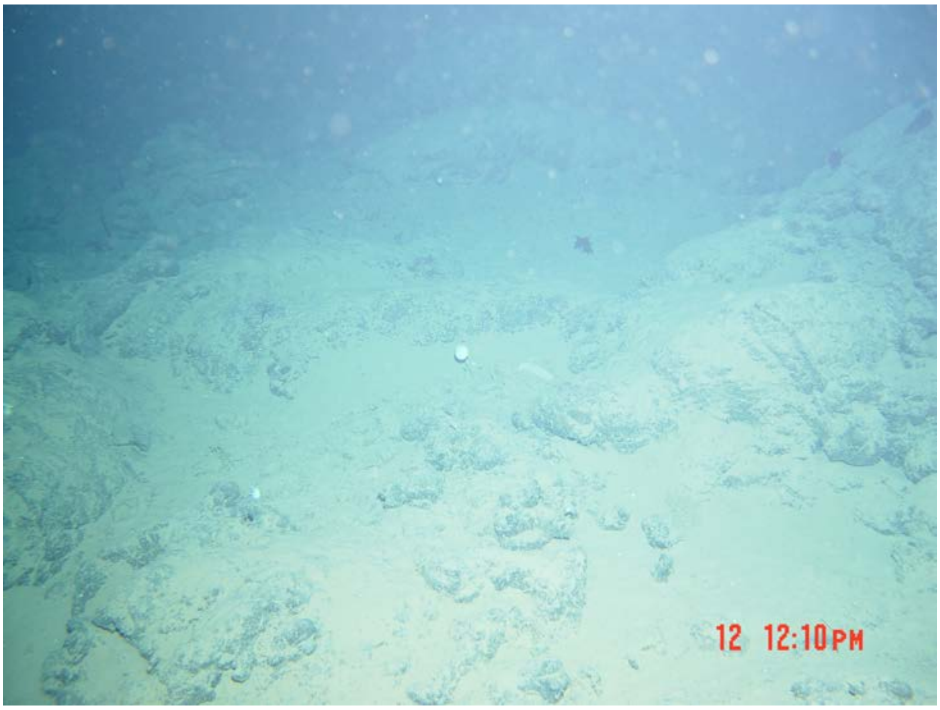


Fig. 4.3.1-4. The boulder and gravels showing lava flow and/or pillow lava features (Stop 2, Depth = 5745 m).

Fig. 4.3.1-5. Huge boulder of pillow lava covered very thin pelagic sediment (Stop 3, Depth = 5739 m).

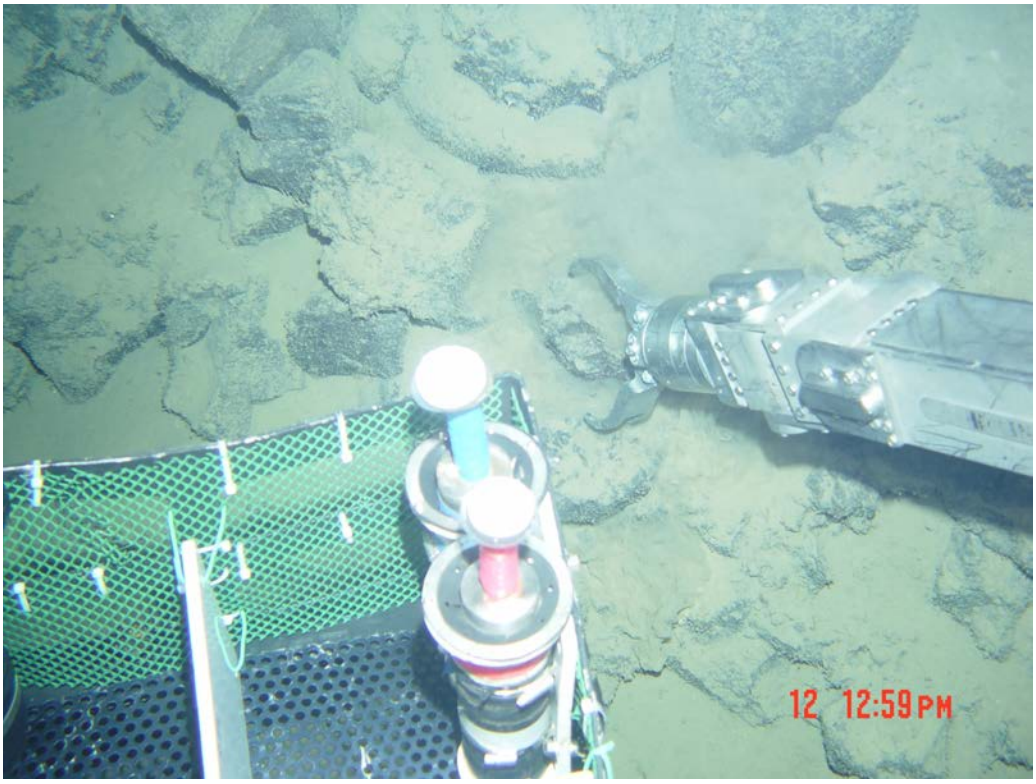


Fig. 4.3.1-6. The boulder and gravels showing lava flow and/or pillow lava features (Stop 4, Depth = 5747 m).

Fig. 4.3.1-7. The boulders showing pillow lava and lava flow features (Stop 5, Depth = 5678 m).

Fig. 4.3.1-8. The boulder and gravels showing pillow breccia and/or pillow lava features (Stop 6, Depth = 5602 m).

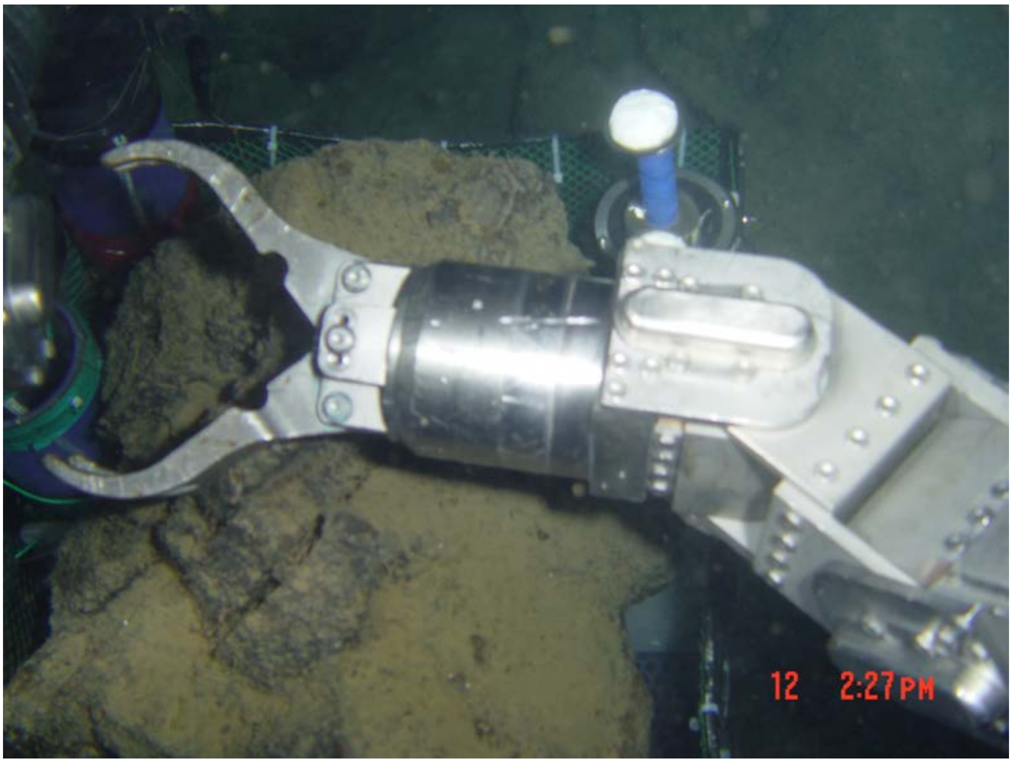


Fig. 4.3.1-9. The boulder showing pillow lava features was sampled (Stop 7, Depth = 5646 m).

4-3-2. 6K#1386: a easternmost knoll in this area

by S. Machida

Date:	13 April, 2014
Place:	W Pacific, NE of Bosei seamount
	37° 29.20' N, 145° 35.50' E
Pilot:	Matsumoto Keita
Co-pilot:	Komuku Tetsuya
Observer:	Machida Shiki (Waseda University)

Purposes of Dive

1. To determine the nature of the high back-scattered area observed in sidescan sonar.
2. To evaluate the rock morphology and eruptive or emplacement style of the rock forming the topographic high and its flanks.
3. To collect rock samples from this previously unsampled area for further geologic and petrologic investigations.

Payload

2 – sample baskets
1 – sample container with lid
1 – scoop for lava pebbles
2 – push cores
1 – tumbler mud sampler with flap (M-type sampler)
2 – marker

Video Highlights

(1) 11:12 – 11:21 (camera #1) Arriving at the landing site:

- Fragmented rock blocks and gravel-mixed muddy floor.
- Sampling#1 at 11:56 (SC01 and R01), which were gravels and a tabular lava block (Figures 4-3-2-3 and 4-3-2-4).

(2) 11:22 – 11:54 (camera #1) Gravel-mixed muddy floor:

(3) 11:54 – 12:01 (camera #1) Rocky floor under thick mud layer:

- Sampling#2 at 12:01 (R02, R03, and R04).

(4) 12:12 – 13:51 (camera #1) Moving along the slope, rocky floor and gravel-mixed muddy floor were alternately observed:

- Sampling#3 at 12:15 (R05, R06, and R07).
- Sampling#4 at 12:36 (SC02, R08, and R09).

- Sampling#5 at 12:59 (R10).
- Sampling#6 at 13:50 (R11, R12, R13, and R14).

(5) 13:52 – 14:29 (camera #1) Climbing slope, rocky floor under thick mud layer:

- Sampling#7 at 14:27 (R15, R16, R17, R18).

(6) 12:51 – 13:30 (camera #1) Moving on the summit of knoll, rocky floor under thick mud layer:

- Sampling#8 at 13:03 (R19, R20, R21, R22).

Summary

Dive #1386 started in southeastern area, fully covered in soft pelagic sediment with some manganese crusts and lava fragments (and maybe pumices) (Figures 4-3-2-3 and 4-3-2-4). The base of the southern side of the topographic high contained outcrop of rounded rocks and outcrops. Dune-like structure was typically observed on muddy floor (Figure 4-3-2-5). Oblong shaped rock outcrops and gravel-mixed muddy floor were alternately observed along the slope; these outcrops show flow-like structure down going to bottom of slope (lava flow?), however, could not be sampled in-situ. Two rock samples of conglomerate including lava fragments (R05 and R06) were corrected at the sampling point No. 3 (12:15). All the way through slope to the summit of knoll, oblong shaped rock outcrops and gravel-mixed muddy floor were alternately observed. The top of the hill contained sheet-shaped rocks, most likely manganese crust, or sedimentary deposits covered by manganese, and manganese nodules (Figures 4-3-2-7 and 4-3-2-8). Ridge of blocky rock was observed along eastern side of the top. On the basis of observations and rock sampling, we can assume that uplifting (maybe caused by lava injection) of sedimentary rock consisting oceanic plate form this topographic high.

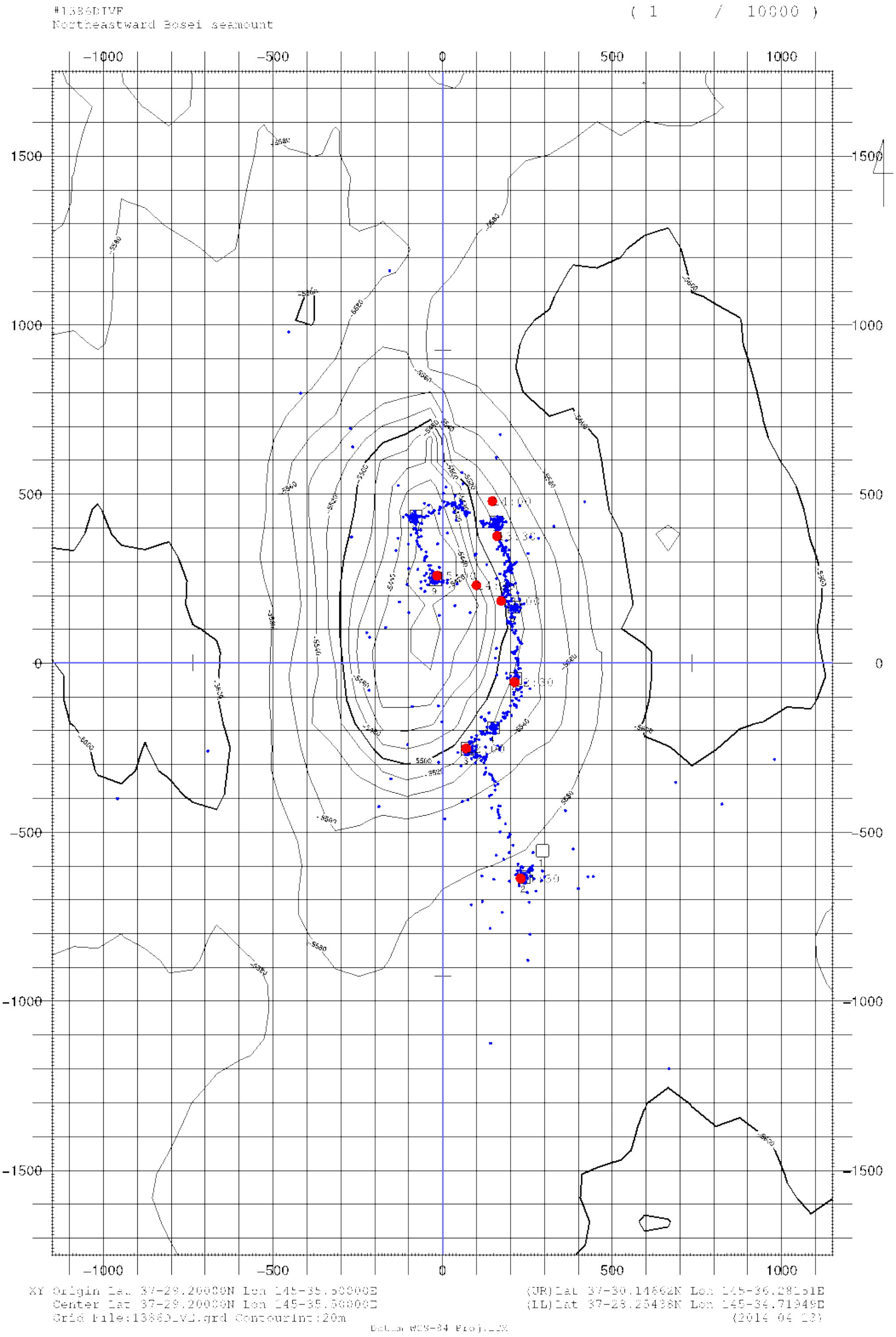


Figure 4-3-2-1. 6K#1386 dive track on the 20 m contour map.

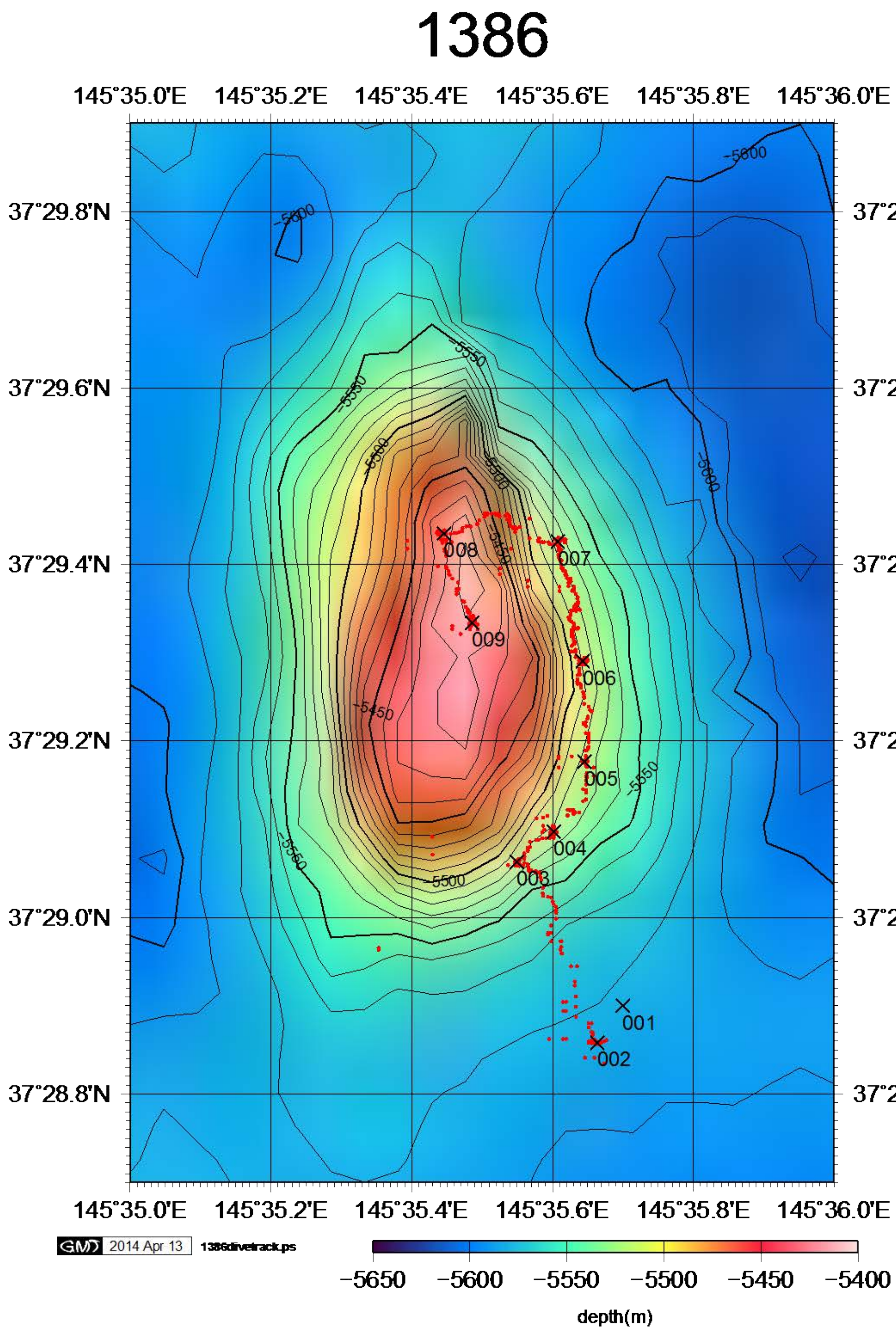


Figure 4-3-2-2. Detail bathymetric map around the dive#1386 site.

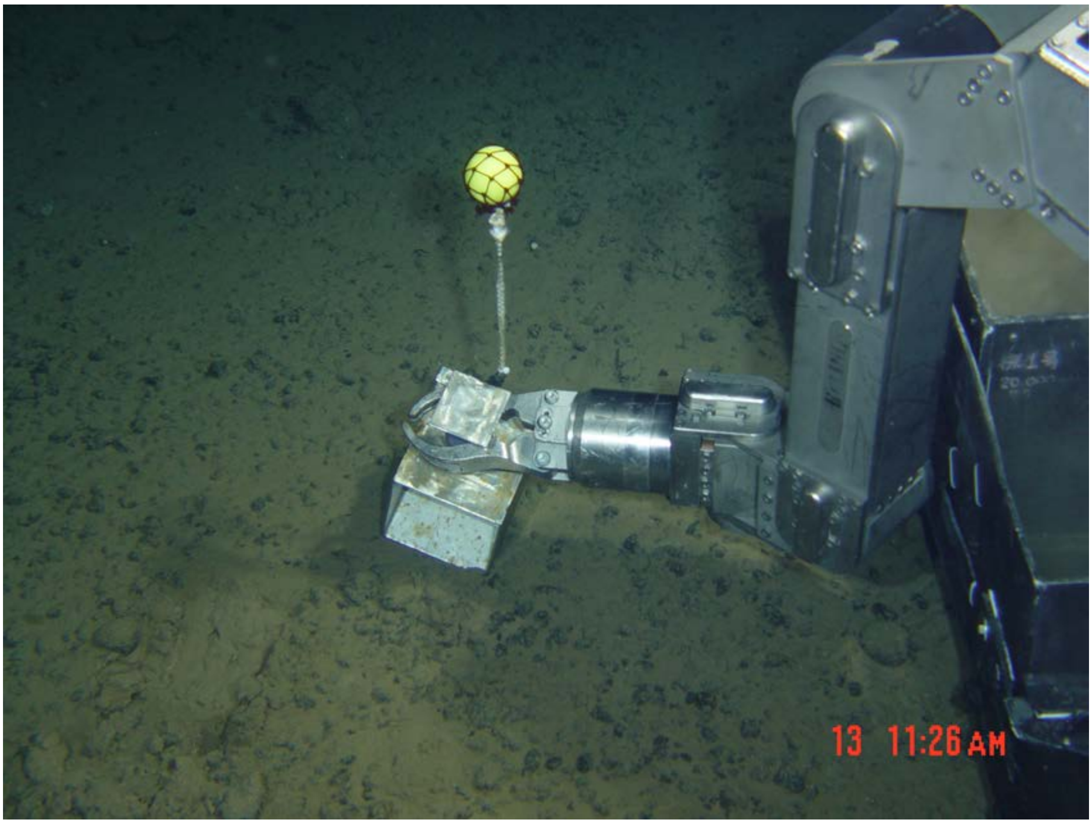


Figure 4-3-2-3. Soft pelagic sediment with some manganese crusts (SC01).

Figure 4-3-2-4. Lava fragment (R01) on soft pelagic sediment.

Figure 4-3-2-5. Dune-like structure of muddy slope.

Figure 4-3-2-6. Outcrop of oblong shaped rock (pillow breccia).

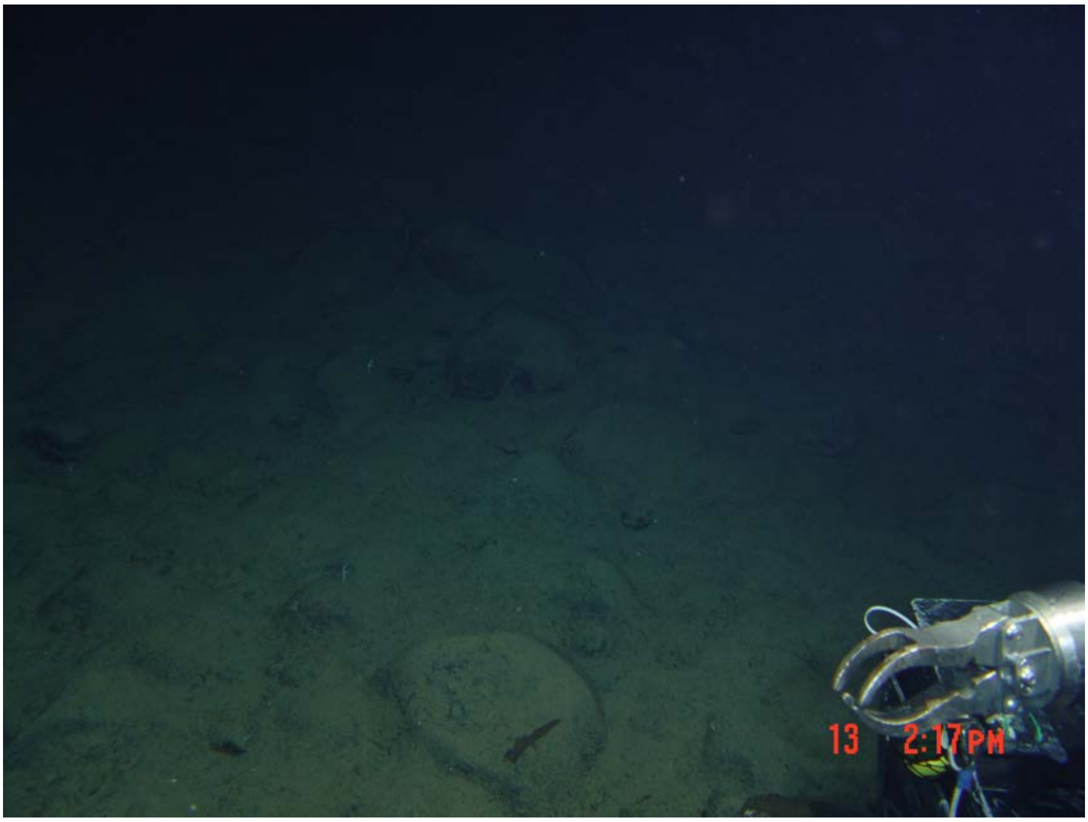


Figure 4-3-2-7. Sheet-shaped rocks, most likely manganese crust, on the top of knoll.

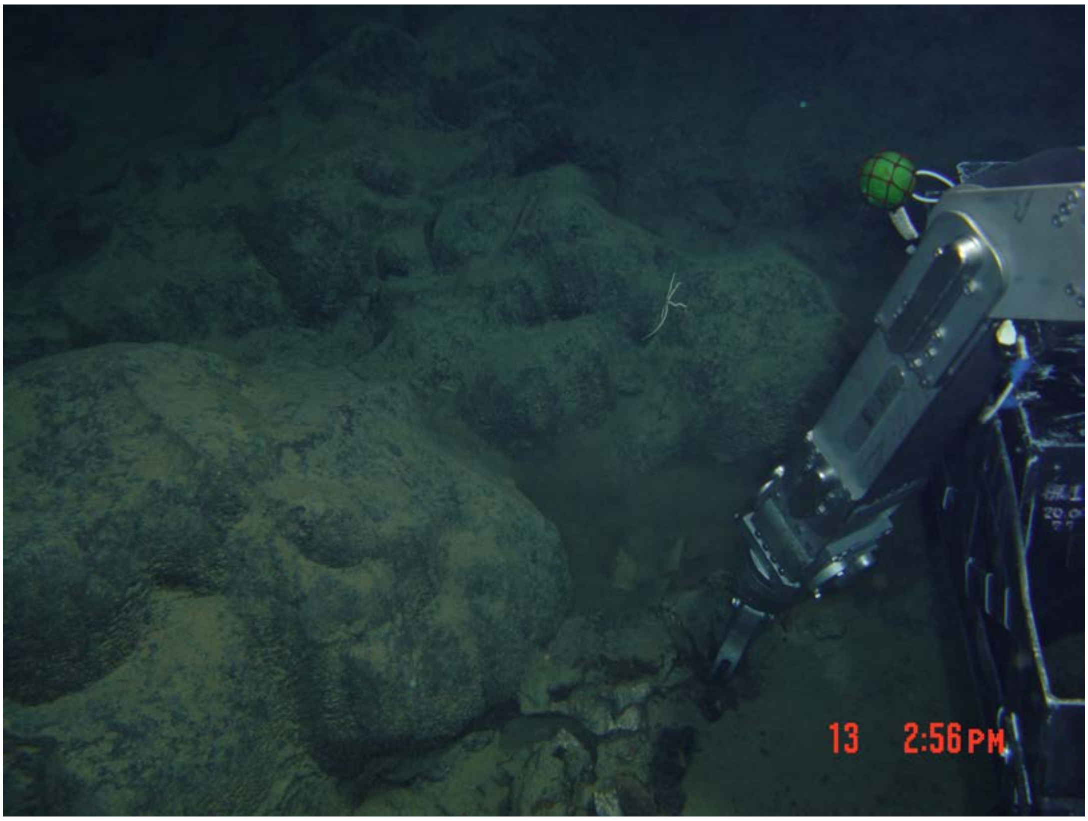


Figure 4-3-2-8. Blocky outcrop on the top of knoll.

4-3-3. 6K#1387: a westernmost knoll in this area

by J. Yamamoto

Date: 14 April, 2014
Place: W Pacific, W of Ryofu knoll
38° 01.10' N, 145° 15.50' E
Pilot: Iijima Kazuki
Co-pilot: Saito Fumitaka
Observer: Yamamoto Junji (Hokkaido University)

Purposes of Dive

1. To determine the nature of the high back-scattered area observed in sidescan sonar.
2. To evaluate the rock morphology and eruptive or emplacement style of the rock forming the topographic high and its flanks.
3. To collect rock samples from this previously unsampled area for further geologic and petrologic investigations.

Payload

2 – sample baskets
1 – sample container with lid
1 – scoop for lava pebbles
2 – push cores
1 – good for manganese
1 – marker

Video Highlights

(1) 11:30 – 11:56 (camera #1) Arriving at the landing site:

- Fragmented rock blocks and gravel-mixed muddy floor.
- Sampling#1 at 11:56 (R01), which was a tabular block.

(2) 11:56 – 12:02 (camera #1) Gravel-mixed muddy floor:

(3) 12:03 – 12:11 (camera #1) A whitish layer under thin mud:

- Sampling#2 at 12:10 (C01 as R02) (Figure 4-3-3-3).

(4) 12:12 – 12:26 (camera #1) Gravel-mixed muddy floor:

(5) 12:27 – 12:50 (camera #1) Rocky floor under thick mud layer:

- Sampling#3 at 12:34 (R03), at 12:36 (R04), at 12:50 (R05, R06).

(6) 12:51 – 13:30 (camera #1) Rocky wall covered by pillow lava (Figure 4-3-3-4):

- Sampling#4 at 13:03 (R07, R08, R09), at 13:21 (R10, R11, R12).

(7) 13:30 – 13:39 (camera #1) Collapsed lava wall (Figure 4-3-3-5):

- Sampling#5 at 13:36 (R13, R14, R15, R16).

(8) 13:40 – 13:54 (camera #1) Gravel-mixed muddy floor:

(9) 13:55 – 13:58 (camera #1) Rocky floor under thick mud layer:

(10) 13:59 – 14:18 (camera #1) Collapsed lava wall:

- Sampling#6 at 14:11 (R17, R18, R19).

(11) 14:19 – 14:25 (camera #1) Rocky wall covered by pillow lava:

- Sampling#7 at 14:23 (R20).

(12) 14:26 – 14:48 (camera #1) Jump to eastern base of the knoll

(13) 14:49 – 15:03 (camera #1) Collapsed lava wall:

- Sampling#8 at 14:55 (R21, R22).
- Sampling#9 at 15:02 (R23, R24), which are parts of a radial joint of a pillow lava (Figure 4-3-3-6).

Summary

Dive #1387 started in northern area, then climbed the north side of slope of a knoll (Figure 4-3-3-1). The purposes of the dive were to investigate the nature of the knoll showing extremely high acoustic reflectivity; the structure of rocks on the topographic high and type of rocks comprising it; and evaluate whether any recent volcanic activity has taken place in this area (Figure 4-3-3-2).

The base of the knoll was covered by thick mud, but rocky lava walls were emerged at the flank. Some of the walls were collapsed, thus were easily collected by Shinkai. As clearly indicated by a radial joint of a lava tube (figure 4-3-3-6), the knoll was formed by eruption at sea bottom.

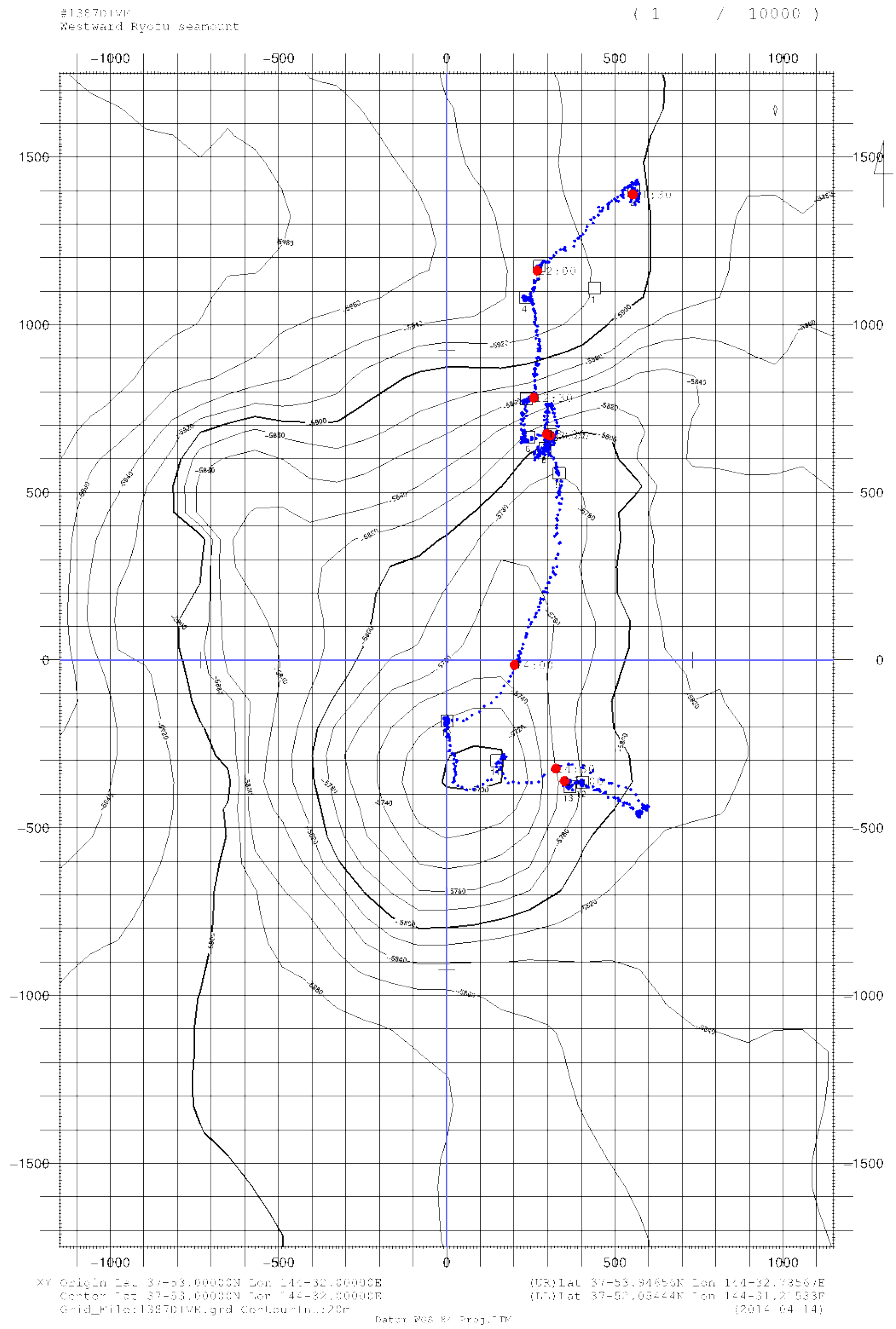


Figure 4-3-3-1. 6K#1387 dive track on the 20 m contour map.

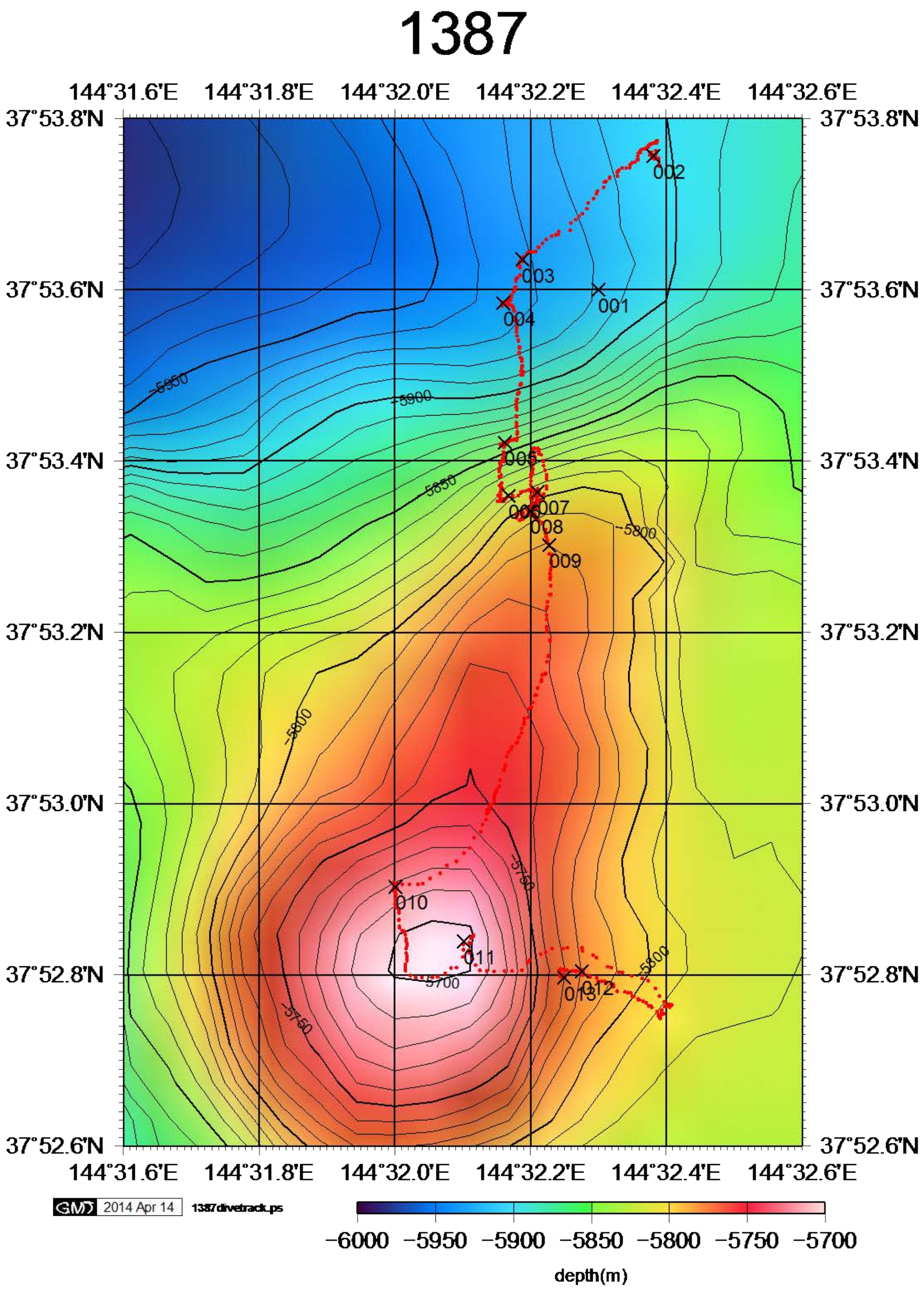


Figure 4-3-3-2. Detail bathymetric map around the dive#1387 site.

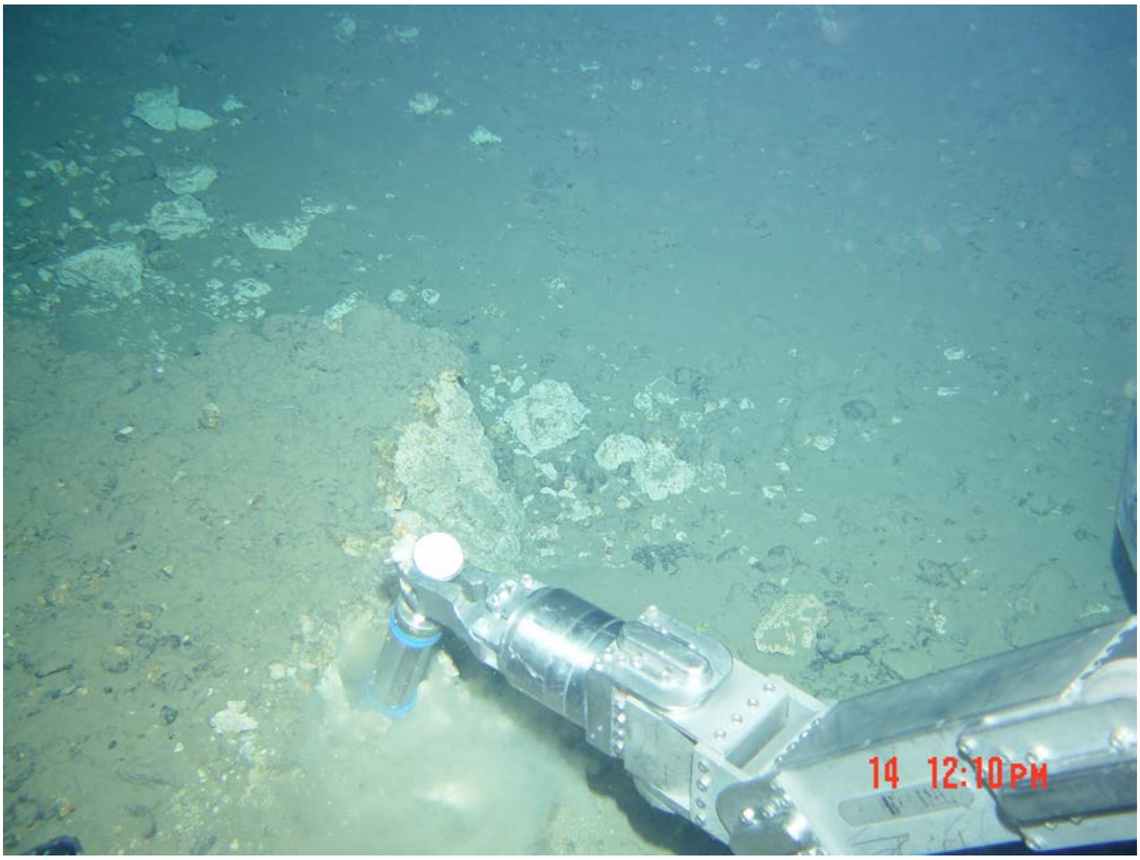


Figure 4-3-3-3. A whitish mud layer.

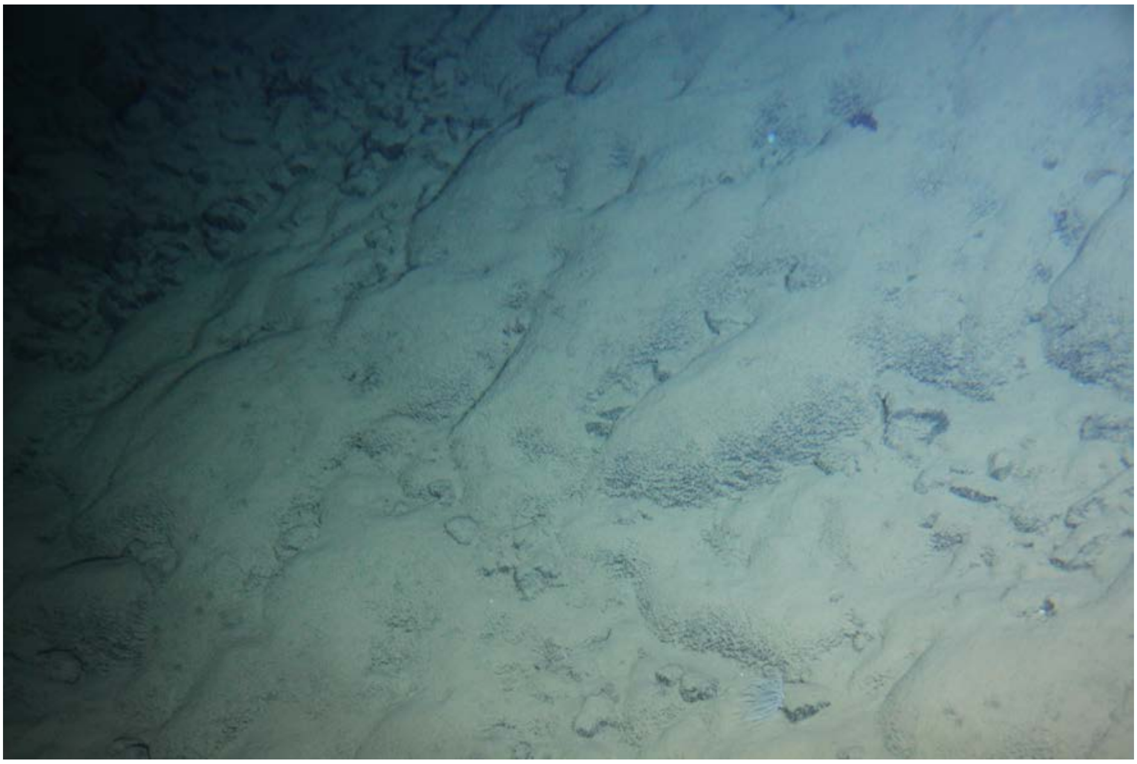


Figure 4-3-3-4. Rocky wall covered by pillow lava.

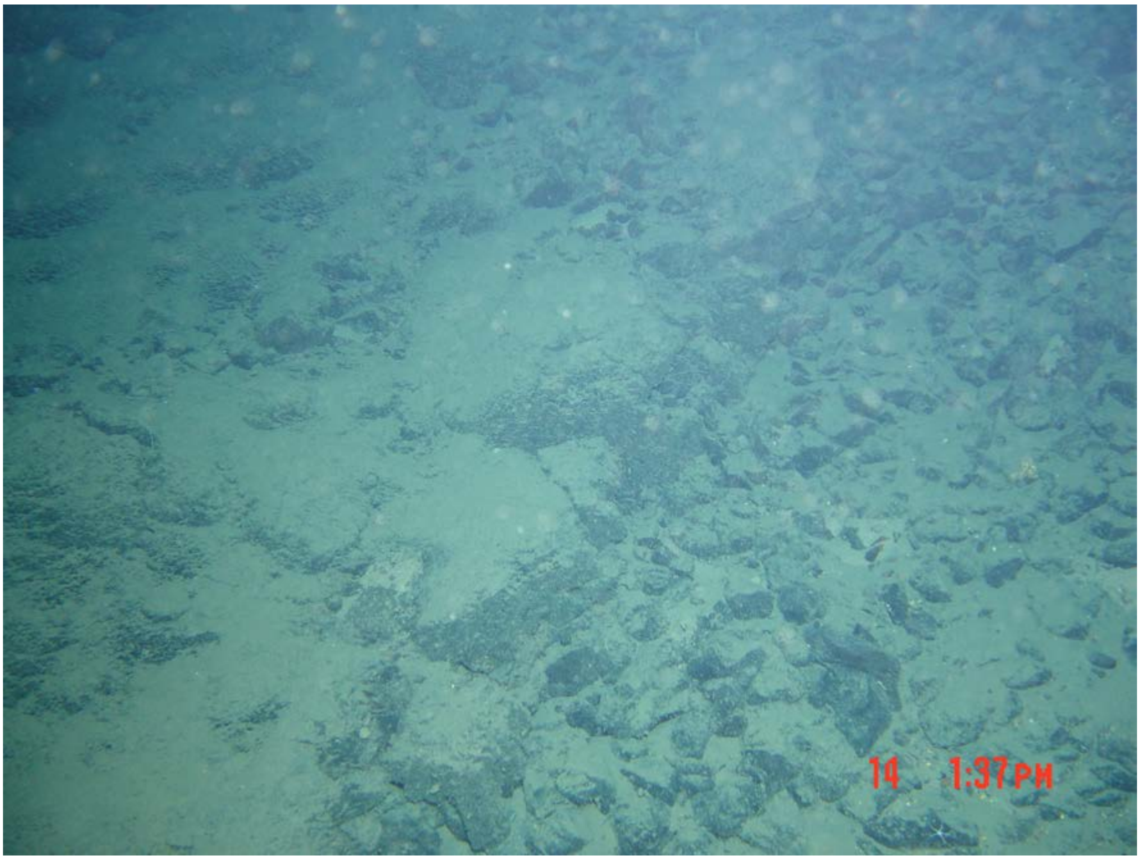


Figure 4-3-3-5. Collapsed lava wall.

Figure 4-3-3-6. A radial joint of a pillow lava.

4-3-4. 6K#1388: Manganese petit-spot

by N. Hirano

Date: 15 April, 2014
Place: NW Pacific Basin, SW of Ryofu Seamount
37° 42.6' N, 145° 20.6' E
Pilot: Ueki, Hirofumi
Co-pilot: Katagiri, Masaya
Observer: Hirano, Naoto (Tohoku University)

Purposes of Dive

1. To determine the nature of the high back-scattered area observed in sidescan sonar.
2. To evaluate the rock morphology and eruptive or emplacement style of the rock forming the topographic high and its flanks.
3. To collect rock samples from this previously unsampled area for further geologic and petrologic investigations.

Payload

2 – sample baskets
1 – sample container with lid
1 – scoop for lava pebbles
2 – push cores
2 – tumblers with flap (M-type sampler)
2 – markers

Video Highlights

(1) 11:14 – 11:15 (camera #1) Arriving at the landing site:
・ Scattered pebbles on pelagic mud with some sea cucumbers.
(2) 11:22 – 11:23 (camera #1) White fish:
(3) 11:24 – 11:28 (camera #1) Sampling#1 at 11:25:
・ Quite irregular shape materials.
(4) 11:32 – 11:33 (camera #1) Sampling#2 at 11:33:
・ A stone on pelagic mud.
(5) 11:47 – 11:47 (camera #1) Huge and yellow sea-cucumber:
(6) 11:50 – 11:51 (camera #1) Pebbles covered with pelagic sediments, white fish:
(7) 11:52 – 11:53 (camera #1) Rounded pebbles covered with pelagic sediments:
(8) 11:55 – 11:59 (camera #1) Sampling#3, 6 rocks, at 11:59:

(9) 12:07 – 12:14 (camera #1) Sampling#4, 4 rocks, at 12:13:

- Huge blocks in mud.
- Blocky rubbles and mud floor.
- Difficult to gain the sample.

(10) 12:17 – 12:18 (camera #1) Rounded rocks and sometimes huge blocks in mud:

(11) 12:20 – 12:21 (camera #1) Submersible went down the valley:

- Deep and narrow valley.

(12) 12:22 – 12:25 (camera #1):

- Huge blocks and rounded pebbles underling tabular wall.

(13) 12:26 – 12:33 (camera #1) Sampling#5, 2 rocks, from huge blocks:

(14) 12:47 – 13:01 (camera #1) Sampling#6, 2 rocks:

(15) 13:03 – 13:05 (camera #1) Scattered nodules at terrace underlying blocky valley:

(16) 13:21 – 13:21 (camera #1) White fish:

- Huge blocks and scattered nodules on floor.

(17) 13:22 – 13:28 (camera #1) Bumpy floor:

(18) 13:28 – 13:28 (camera #1) Sampling#7 at 13:41:

(19) 13:57 – 13:58 (camera #1) Scattered pebbles in mud:

(20) 14:04 – 13:58 (camera #1) Sampling#8, 2 rocks, at 14:08:

- Huge blocks and scattered nodules on floor.

(21) 14:12 – 14:23 (camera #1) Blocky rubbles again:

(22) 14:24 – 14:34 (camera #1) Much nodules on the floor:

(23) 14:26 – 14:38 (camera #1) Sampling#9, 6 rocks, at 14:38:

(24) 14:30 – 14:32 (camera #1) Red shrimp:

(25) 14:51 – 13:01 (camera #1) Placed the marker#166:

<u>*Summary*</u>

Dive #1388 started in the flat basin, to the north of the nearby small topographic high (Figure 4-3-4-1). The purposes of the dive were to investigate the nature of the knoll showing high acoustic reflectivity; the structure of rocks on the topographic high and type of rocks comprising it; and evaluate whether any recent volcanic activity has taken place in this area.

The basin at the beginning of the dive was composed of some pebbles in pelagic mud. Side and top of knoll are composed of mainly huge, blocky and angular rocks with much manganese nodules. Manganese was quite thick during all place. Orange colored materials, possibly palagonitic hyaloclastite, were found and sampled in thick manganese.

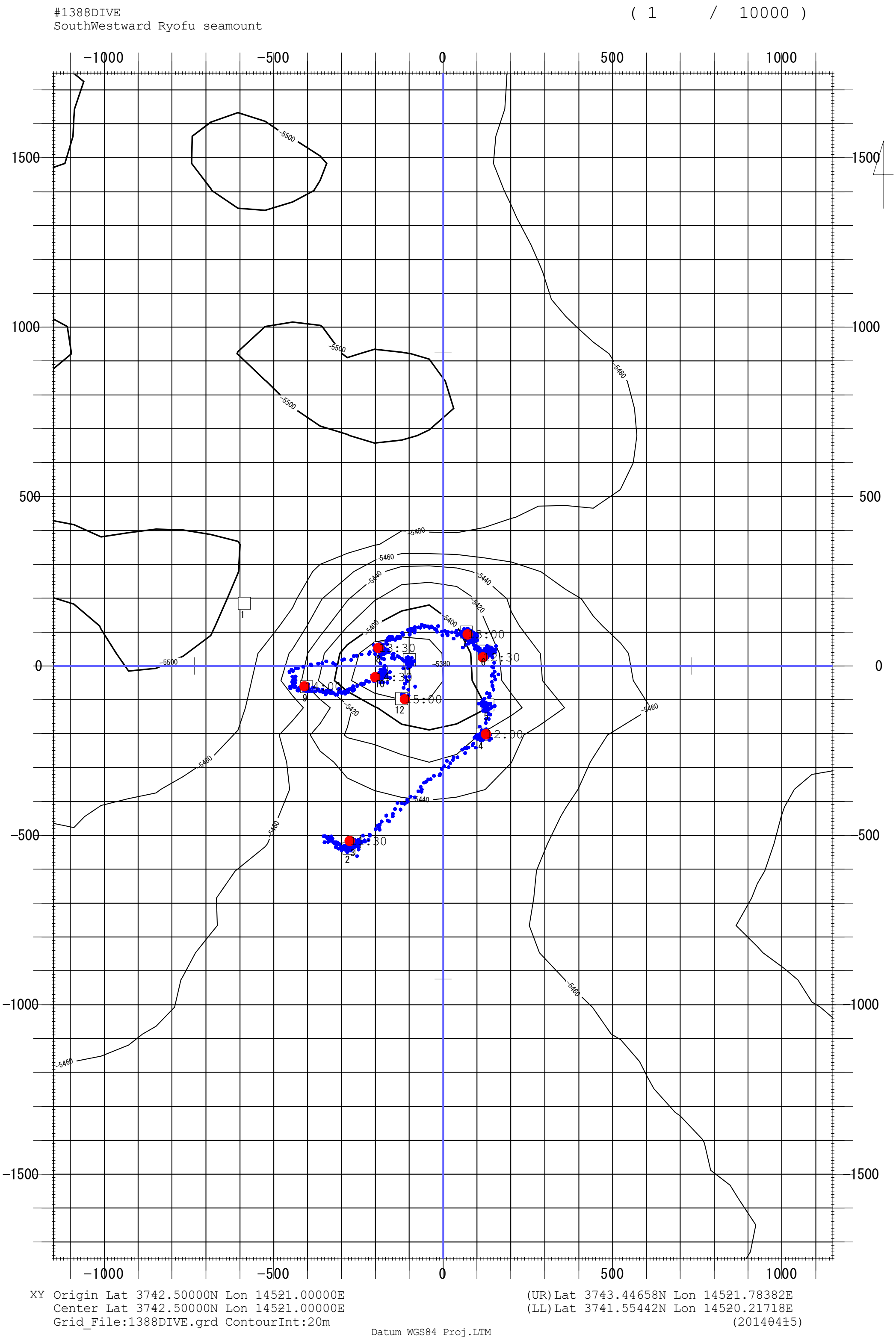


Figure 4-3-4-1. 6K#1388 dive track on the 20 m contour map.

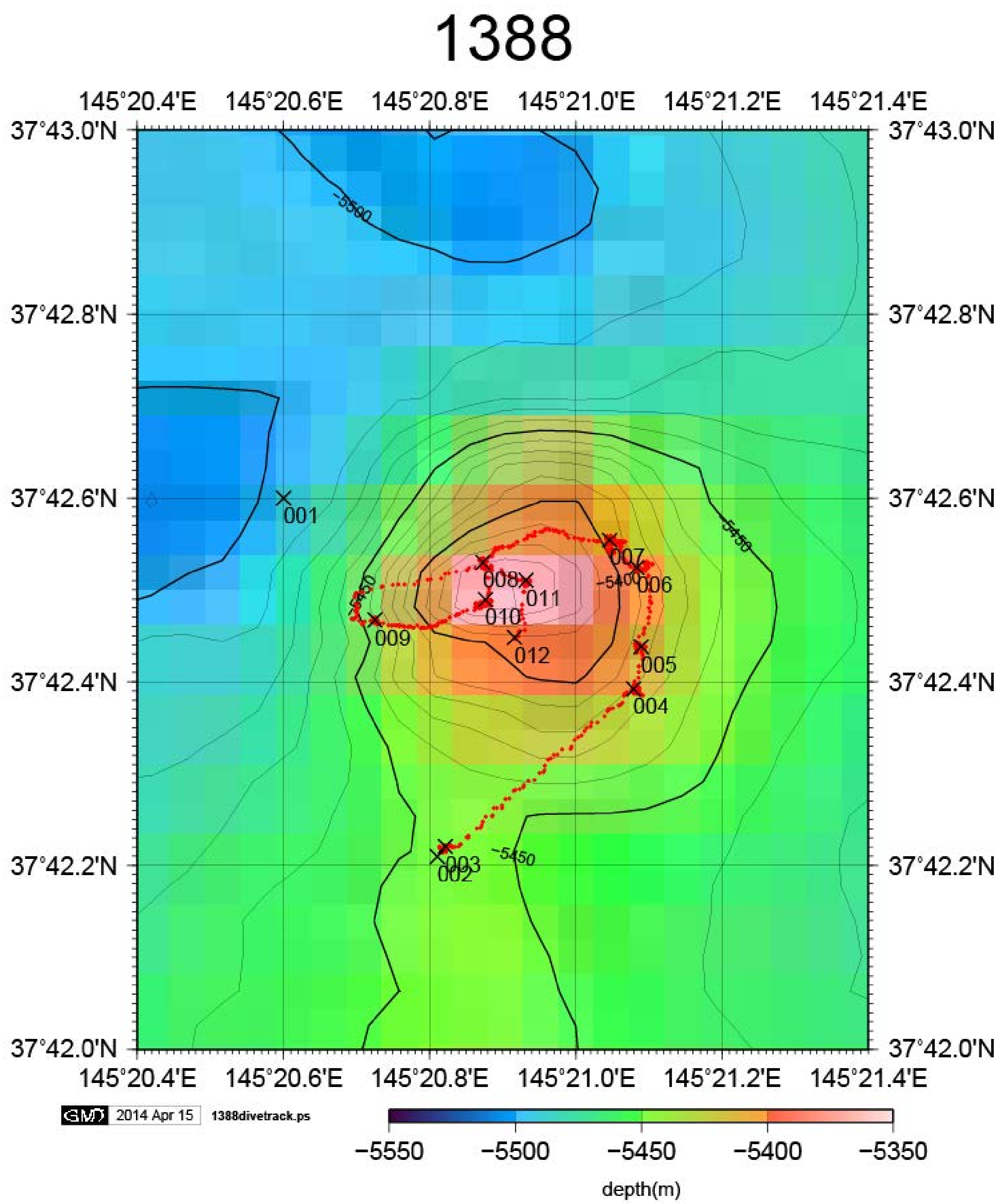


Figure 4-3-4-2. Detail bathymetric map and sampling stops of dive#1388 site.

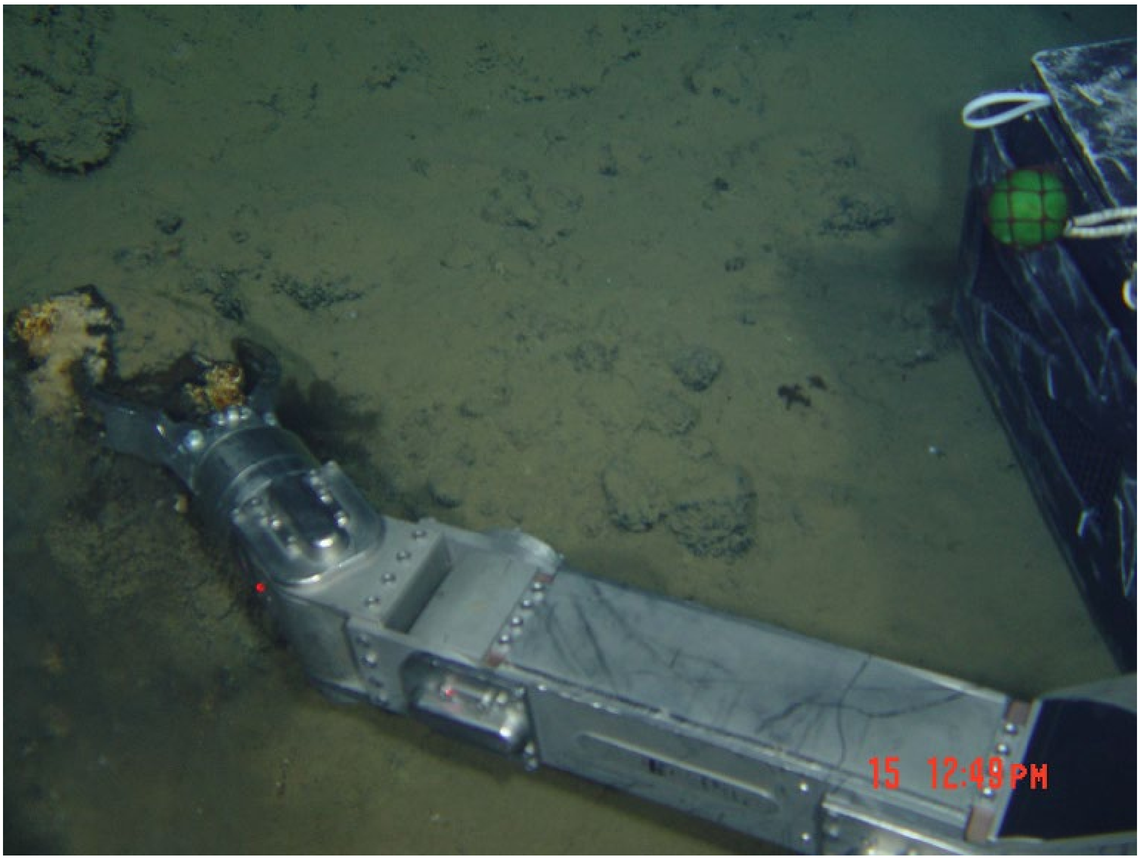


Figure 4-3-4-3. Orange colored materials, possibly palagonitic hyaloclastite, into thick manganese.

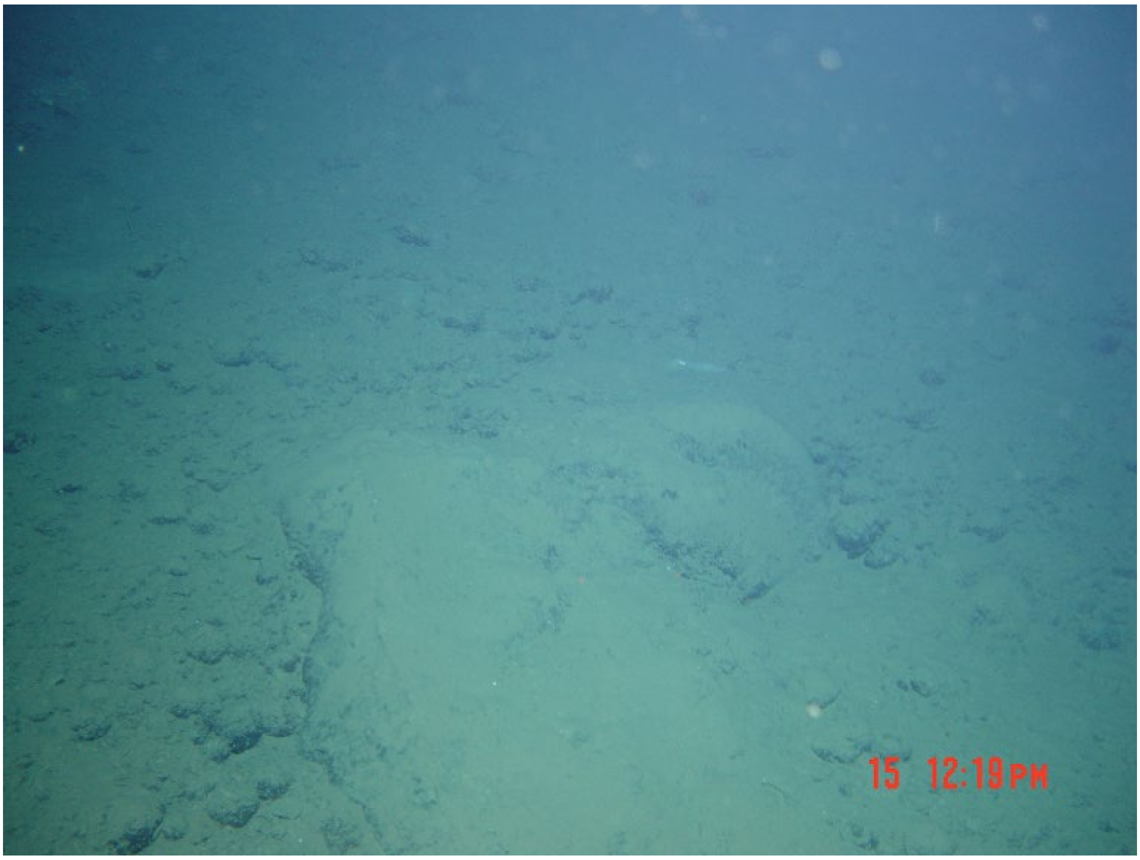


Figure 4-3-4-4. Manganese nodules on the floor composed of blocky wall.

4-3-5. 6K#1389: Small Knoll with high acoustic reflection by T. Ishii

Date: 17 (Thursday) April, 2014

Place: Off Tohoku in Western Pacific, small seamount (petit-spot) field at west of Ryosei seamount.
37°39.60' N, 145°11.50' E

Pilot: Kenta MATSUMOTO

Co-pilot: Keizo SUZUKI

Observer: Teruaki ISHII.
(Fukada Geological Institute)

The purposes of the SHINKAI 6500 dive (Dive 6K#1389) were to investigate the geological nature of the small knoll (about 200 m high and 1000 m diameter, see Fig. 4.3.5-1 and -2) with high acoustic reflection, that is, to make clear the origin of the knoll, the geological characteristics of constituting rocks of the knoll and lithology of rocks comprising it; and evaluate whether any recent volcanic activity has taken place in this area.

The SHINKAI landed on the seafloor in the western lowermost hillside of the small knoll. The seafloor throughout the dive truck was fully covered in manganese crusts with very thin soft pelagic sediment. Many boulders probably originated from volcanic activity were observed throughout the SHINKAI 1389 dive truck locating of the western and southern side toward the top of the knoll (Fig. 4.3.5-2). On the basis of observations on the shape of huge boulders, they are assumed as pillow lava, pillow robe, lava tube and pillow breccia.

We tried sampling with the strong SHINKAI's manipulators to rock samples but it was so difficult to yank off even small rock piece from the seafloor, because all rock pieces were very tightly connected each other by manganese crusts. Recovered 12 samples were coated by manganese crusts and they are pumice (8 samples), sedimentary rock (2 samples) and volcanic rock (2 samples).

On the basis of geological observations on seafloor and lithological consideration on collected rocks, we can assume that the main edifice of the small knoll were induced by volcanic eruption(s) relatively resent geological time (several millions years ago?) on the Cretaceous Pacific Plate.

Video Highlights

(9) 11:17 – 11:20 (camera #1 or #2) arrive at the landing site. The site was fully covered pelagic soft sediment and boulder was not observed (Depth = 5446 m).

(10) 11.40 – 12.04 (camera #1 or #2), sampling (Stop 1). The site was fully covered in manganese crusts with very thick soft pelagic sediment and subrounded boulders were observed (Fig. 4.3.5-3, Depth = 5348 m); take 5 manganese coated rocks (sample 6K1389R01, R02, R03, R04, R05).

(11) 12:40 – 12:55 (camera #1 or #2) sampling (Stop 2). The seafloor was fully covered in manganese crusts & pelagic soft sediment and huge boulder showing lava flow features were observed (Fig. 4.3.5-4, Depth = 5197? m); take 1 manganese coated rocks (sample R06).

(12) 13:35 – 13:44 (camera #1 or #2) sampling (Stop 3). The seafloor was fully covered in manganese crusts & pelagic soft sediment (Fig. 4.3.5-5, Depth = 5305 m); take 1 manganese coated huge rock (sample R07).

(13) 13:50 – 13:55 (camera #1 or #2) sampling (Stop 4). The seafloor was fully covered in manganese crusts & pelagic soft sediment (Fig. 4.3.5-6, Depth = 5290 m); take 3 manganese coated rocks (sample R08, R09, R10).

(14) 14:20 – 14:33 (camera #1 or #2) sampling but not succeeded. The seafloor was fully covered in manganese crusts & pelagic soft sediment. Outcrops showing pillow lava and lava flow features were observed (Fig. 4.3.5-7, Depth = 5211 m). We tried to take a piece of rock samples from the marginal part of pillow, but we fail to sampling.

(15) 14:54 – 15:05 (camera #1 or #2) sampling (Stop 5 and 6). The assumed summit showed boulder scattered field like appearance. The seafloor was fully covered in manganese crusts & pelagic soft sediment (Fig. 4.3.5-8, Depth = 5201 m); take 2 manganese coated rocks (sample R11, R12). Setting up #167 event marker.

(16) 15:09 (camera #1 or #2) left bottom at 5201m.

<u>Purposes of Dive</u>

3. To determine the geological and lithological nature of the high back-scattered area observed in sidescan sonar data between 5450 m and 5200 m.
4. To investigate the origin of the small knoll, that is, topographic high about 160 m high and 1000 m diameter.
3. To evaluate mode of emplacement style of the rocks forming the edifice (the lava morphology and eruptive mode).
4. To collect rock samples from this previously unsampled area for further geological, volcanological and petrological investigations.

Payload

2 – sample baskets with 15 partitions in total
1 – sample container (3 partitions) with lid
1 – scoop for collecting lava pebbles buried in the soft sediment
2 – push cores for collecting soft sediment
2 – M-cores for collecting jelly material
2 – event markers (#167 and #168)

Summary of Dive Operations

Dive Plan

Dive #1389 site was initially targeted because of its topographic feature that produce a high back-scattered area in sidescan sonar data. In order to investigate the stratigraphy of the knoll, the landing point of the dive was selected at the base of western slope of the knoll and continuous observing and sampling along the slope toward the summit were expected. Another route locating south of the knoll was also expected to observe along V-shaped valley, if we have enough time for investigation.

Topography

Sidescan sonar and reflectivity data (SeaBeam) collected on this and previous surveys of this area show a small conical hill from 5450 m to 5240 m depth; about 200 m high from base to summit. The top of the hill is flattened.

Geology

The SHINKAI 6500 landed on the seafloor at 5446 m at 11:17 in the lower western flank of the high, where no sample was taken. SHINKAI ascended the hill toward eastern summit about 5200 m deep shown in the map (Fig. 4.3.5-1 and -2). Sampling had been continued up to 5200 m. SHINKAI moved to the new start point of another route locating south of the knoll. SHINKAI ascended again the hill along V-shaped valley. SHINKAI finished its ascent of the knoll and took additional samples at 5273 m. SHINKAI left the summit of the high at 5201 at 15:08.

The first landed seafloor was covered by pelagic sediment so that bioturbation was commonly observed. We could not see boulders as well as gravels. We did not try sampling at the first landing point.

We began a course at 135° at 11:20 and at 110° at 11:30 toward the summit of the high. SHINKAI stopped for sampling at 11:41, and recovered 5 rock samples (Stop No 01, sample No. 6K1389R01, R02, R03, R04, R05) coated with manganese crusts at 12:02. After the sampling, we moved at the same direction. We observed huge boulders with 1 to 2 m scale covered by manganese crusts, but could not encounter obvious outcrop of igneous rock. Those huge boulders were assumed as pillow lava and /or lava flow. We stopped to take one sample at 12:40 at this depth of 5197m (Stop 2, sample R06). We then started to move down at 12:55 with a course 180° and stopped moving at 13:07 at 5395m for landing at the start point of the second course.

We began new course at 30° at 13:17 and change a course at 10° at 13:19. SHINKAI stopped for sampling at 13:35 at 5305m and recovered relatively huge one sample (Stop 3, R07). After the sampling, we moved at the same direction, and we stopped to take 3 samples at 13:55 at 5290 m (Stop 4, R08, R09, R10). After the sampling, we moved at 20° along the bottom of V-shaped valley. We then tried to take a piece of rock samples from the marginal part of huge pillow, but we failed sampling at 14:33 at 5211 m.

We moved again along course at 30° and changed course at 90° at assumed a east-west trending ridge at 5199 m deep. We stopped moving at 12:55 at 5263 m, and set up #167 event marker, because we assumed that we arrived at the summit of the knoll according to topographic chart prepared for navigation of this dive (Fig. 4.3.5.1-2). The assumed summit showed boulder scattered field like appearance. The seafloor was fully covered in manganese crusts & pelagic soft sediment. We took 2 manganese coated rocks (Stop 5, Stop 6, sample R11, R12).

We left bottom at 15:09 at 5201 m.

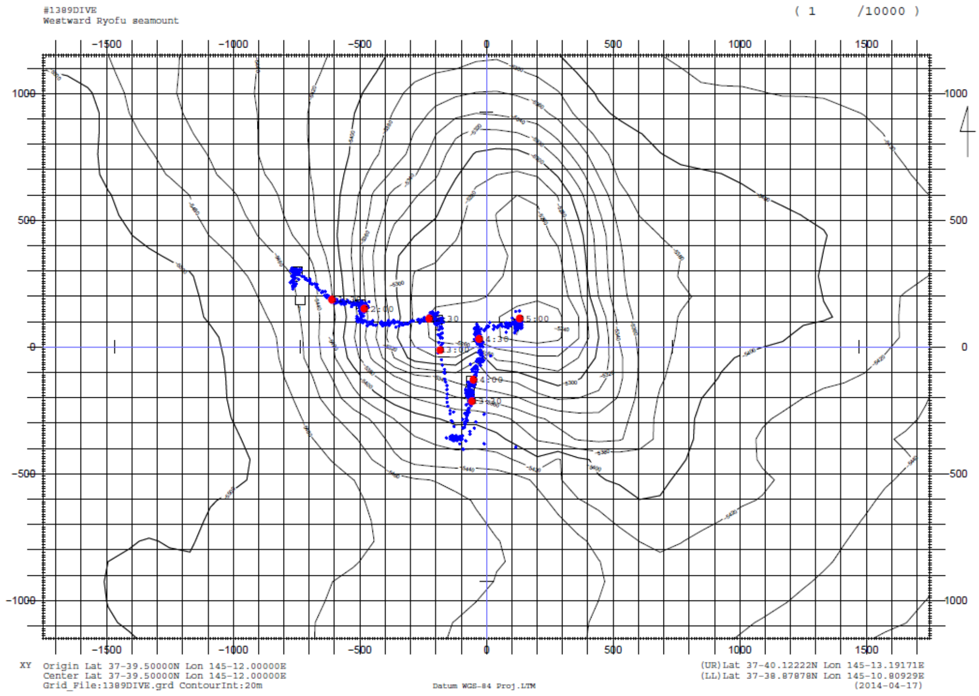


Fig. 4.3.5-1. Detail bathymetric map around the Dive6K#1389 site. The small knoll (37°39.60' N, 145°11.50' E) with high back-scatters was confirmed by the site-survey of this dive.

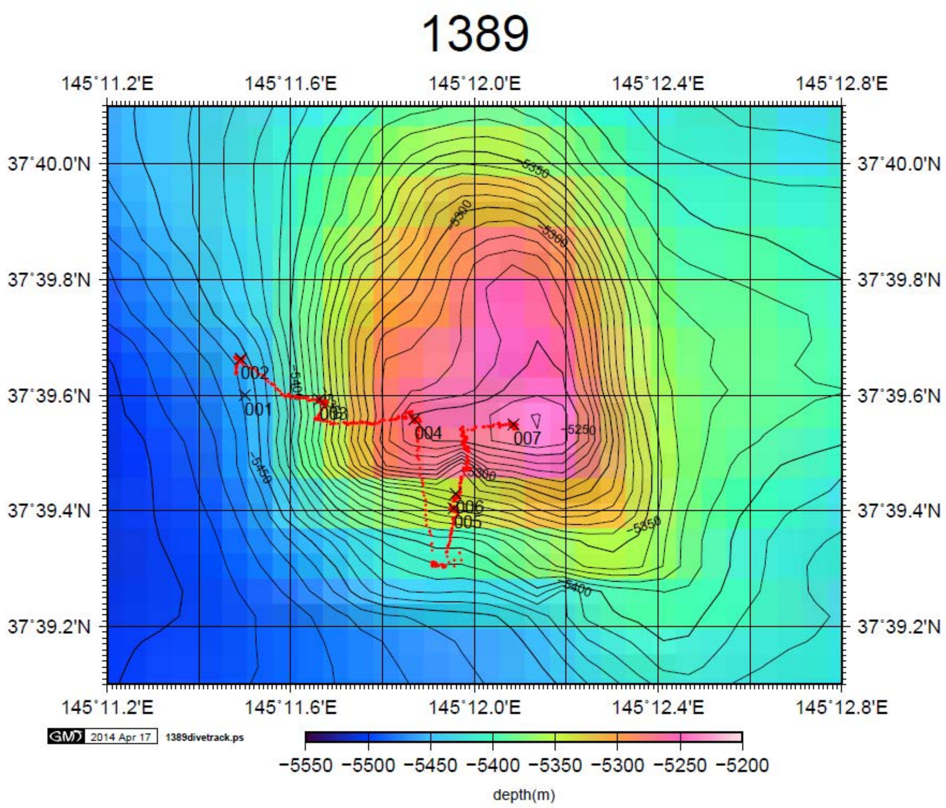


Fig. 4.3.5-2. The SHINKAI 6500 dive (Dive 6K#1389) track shown in the 20 m contour map.

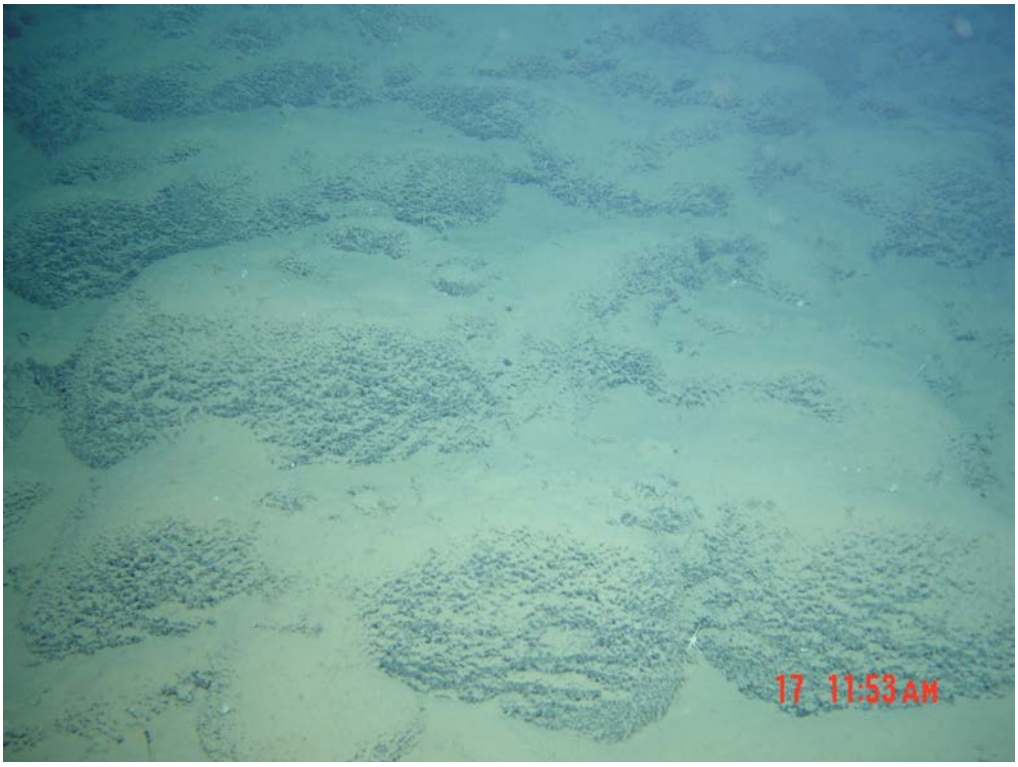


Fig. 4.3.5-3. The subrounded boulders covered in manganese crusts with very thick soft pelagic sediment showing pillow lava and lava flow features (Stop 1, Depth = 5348 m).

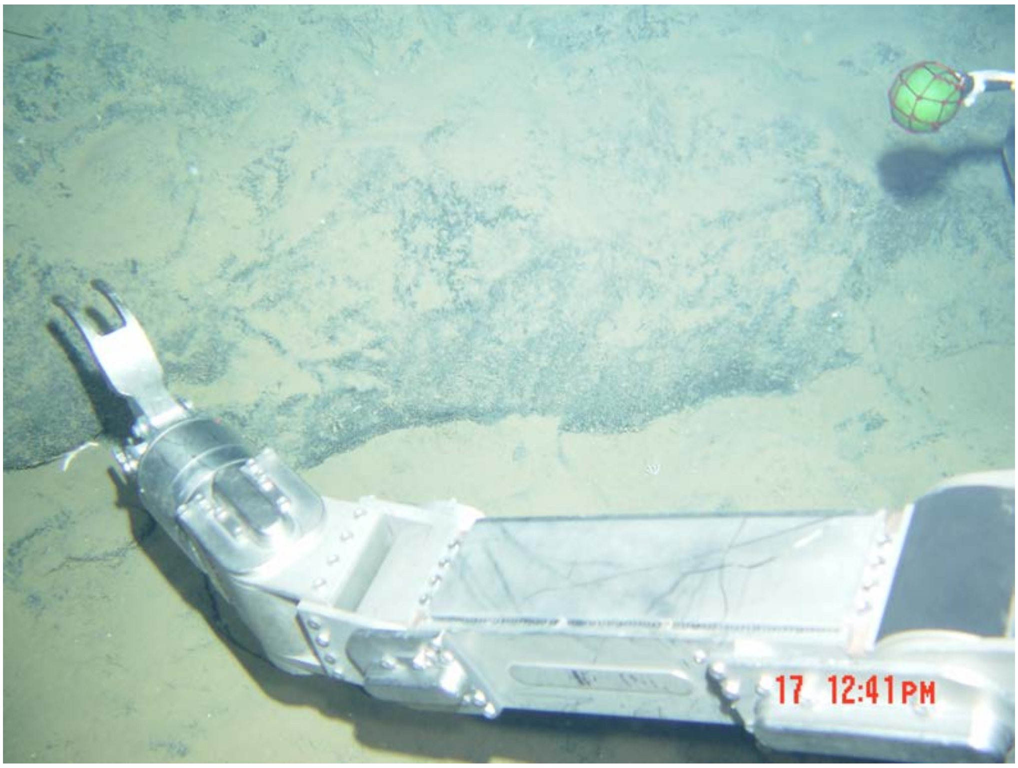


Fig. 4.3.5-4. The boulder showing lava flow features (Stop 2, Depth = 5197? m).

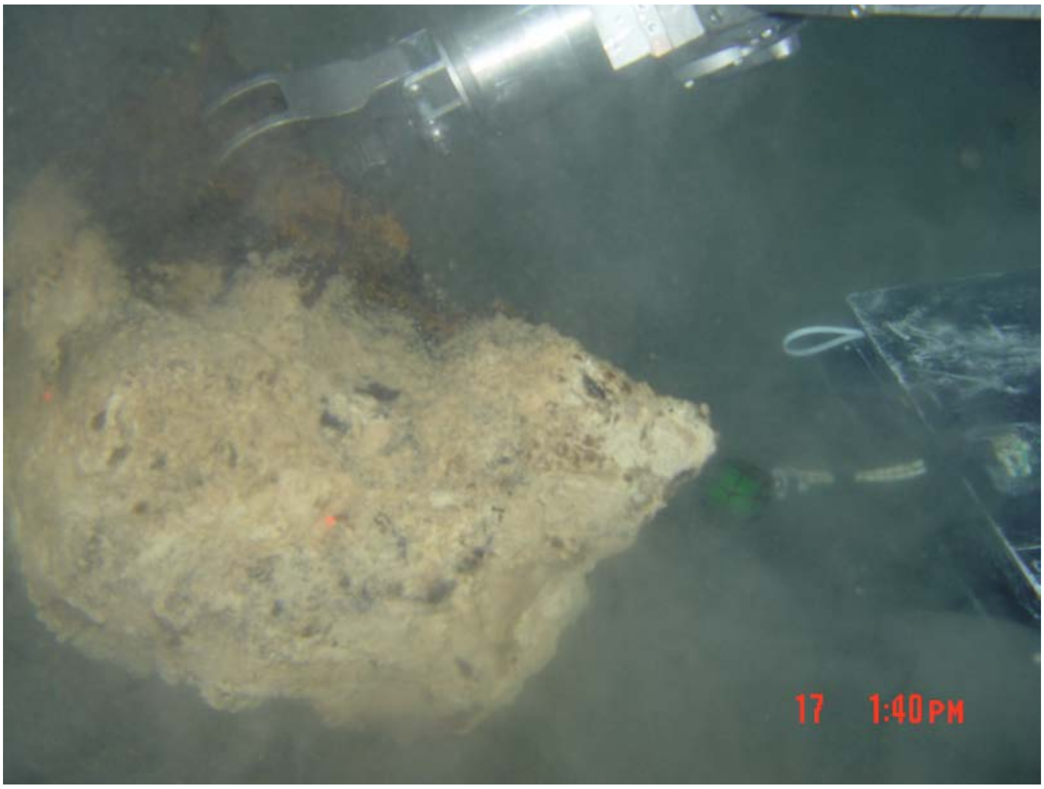


Fig. 4.3.5-5. The huge boulder covered pelagic sediment was recovered (Stop 3, Depth = 5305 m).

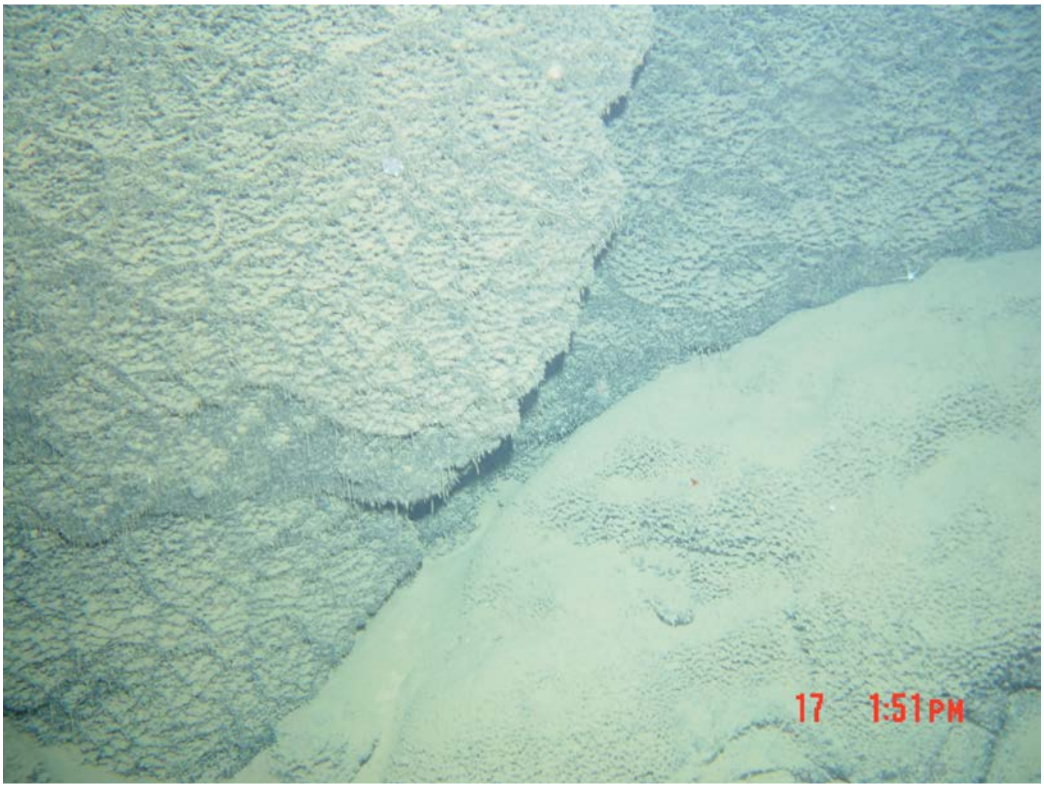


Fig. 4.3.5-6. The boulder showing features of manganese coated surface (Stop 4, Depth = 5290 m).

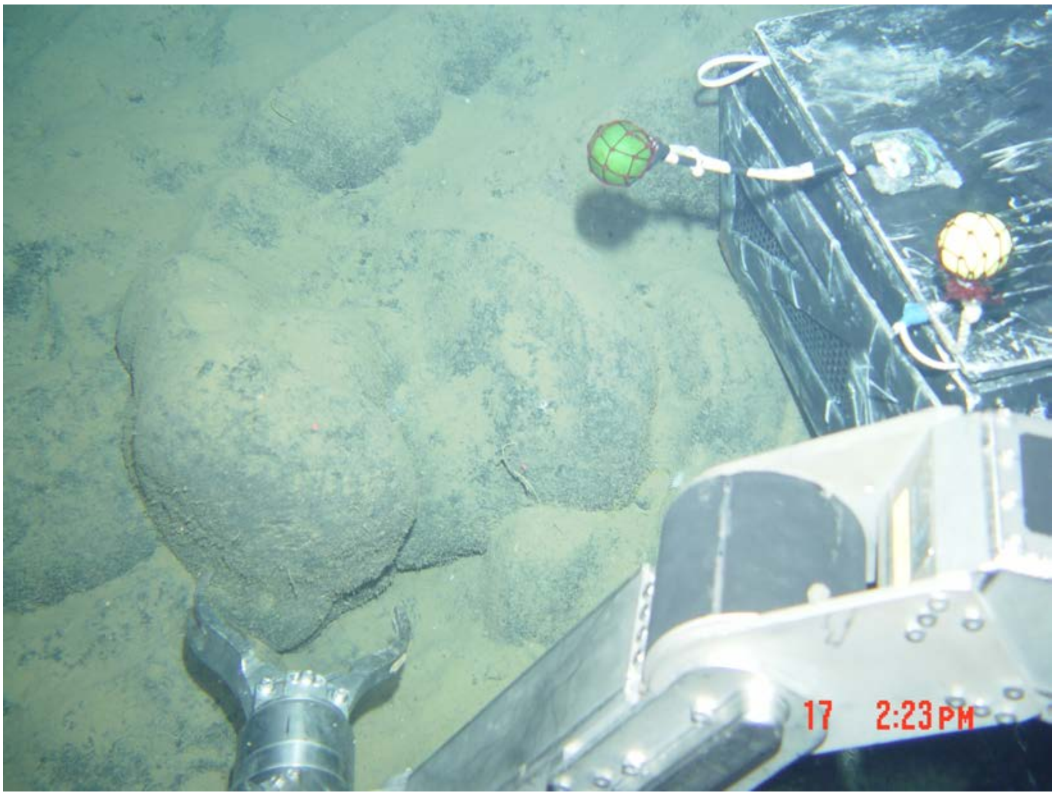


Fig. 4.3.5-7. The boulders showing pillow lava and lava flow features (Depth = 5211 m).

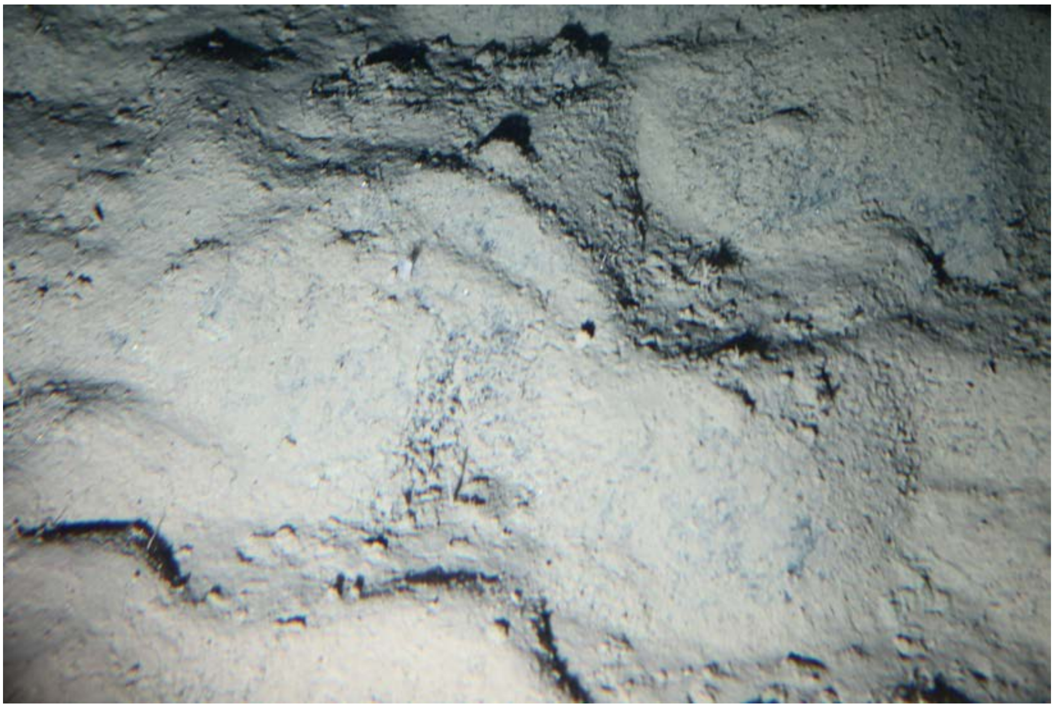


Fig. 4.3.5-8. The seafloor was fully covered in manganese crusts & pelagic soft sediment (Stop 5 and 6, Depth = 5201 m).

4-3-6. 6K#1390: a northernmost knoll in this area — by S. Machida

Date: 18 April, 2014

Place: W Pacific, W of Ryofu seamount
38° 01.00' N, 145° 14.80' E

Pilot: Iijima Kazuki

Co-pilot: Katagiri

Observer: Machida Shiki (Waseda University)

Purposes of Dive

1. To determine the nature of the high back-scattered area observed in sidescan sonar.
2. To evaluate the rock morphology and eruptive or emplacement style of the rock forming the topographic high and its flanks.
3. To collect rock samples from this previously unsampled area for further geologic and petrologic investigations.

Payload

2 – sample baskets
1 – sample container with lid
1 – scoop for lava pebbles
2 – push cores
1 – tumbler mud sampler with flap (M-type sampler)
2 – marker

Video Highlights

(1) 11:06 – 11:24(camera #1) Arriving at the landing site:

- Fragmented rock blocks and gravel-mixed muddy floor.
- Sampling attempted, but pumice and soft manganese crust (including soft sediment) were collected, then they were released.

(2) 11:24 – 11:36 (camera #1) Gravel-mixed muddy floor:

(3) 11:36 – 11:41 (camera #1) Rocky floor under thick mud layer:

- Sampling#1 at 11:41 (R01 and R02), which were tabular blocks.

(3) 11:41 – 12:46 (camera #1) Rocky floor under thick mud layer:

- Sampling#2 at 11:50, throw up (pumice).
- Steep cliff, fully covered by manganese crust, was observed.
- Sampling#3 at 12:46 (R03), just above steep cliff.

(4) 12:46 – 13:08 (camera #1) Rocky floor under thick mud layer near the summit of knoll:

- Sampling#4 at 12:55, throw up (hard to collect).
- Sampling#4 at 13:08 (R04, R05, R06, and R07).

(5) 13:08 – 13:31 (camera #1) Jump to west:

(6) 13:31 – 13:39 (camera #1) Rocky floor under thick mud layer:

- Sampling#5 at 13:39 (R08 and R09).

(7) 13:39 – 13:58 (camera #1) Rocky floor under thick mud layer:

- Small cliff, and tabular blocks (lava?) were observed.
- Sampling#6 at 13:58 (R10), above small cliff.

(8) 14:00 – 14:48 (camera #1) Back to small cliff, and observing:

(9) 14:48 – 15:13 (camera #1) Rocky floor under thick mud layer:

- Sampling#7 at 14:55 (R11).
- Sampling#8 at 15:09 (R12).

<u>*Summary*</u>

Dive #1386 started in southeastern area, fully covered in soft pelagic sediment with some manganese crusts and pumices (Figure 4-3-6-3). The base of the southern side of the topographic high contained outcrop of rounded rocks and outcrops. Oblong shaped rock outcrops (Figure 4-3-6-4) and gravel-mixed and dune-like structured muddy floor were alternately observed along the slope. Outcrops show flow-like structure down going to bottom of slope (lava flow?), however, hard to sample in-situ. Thick manganese crusts and manganese conglomerates including lava fragments were recovered. Steep cliff was observed middle of slope (Figure 4-3-6-5), which may correspond to fault-like topographic feature observed on western side of this knoll (Figures 4-3-6-1 and 4-3-6-2).

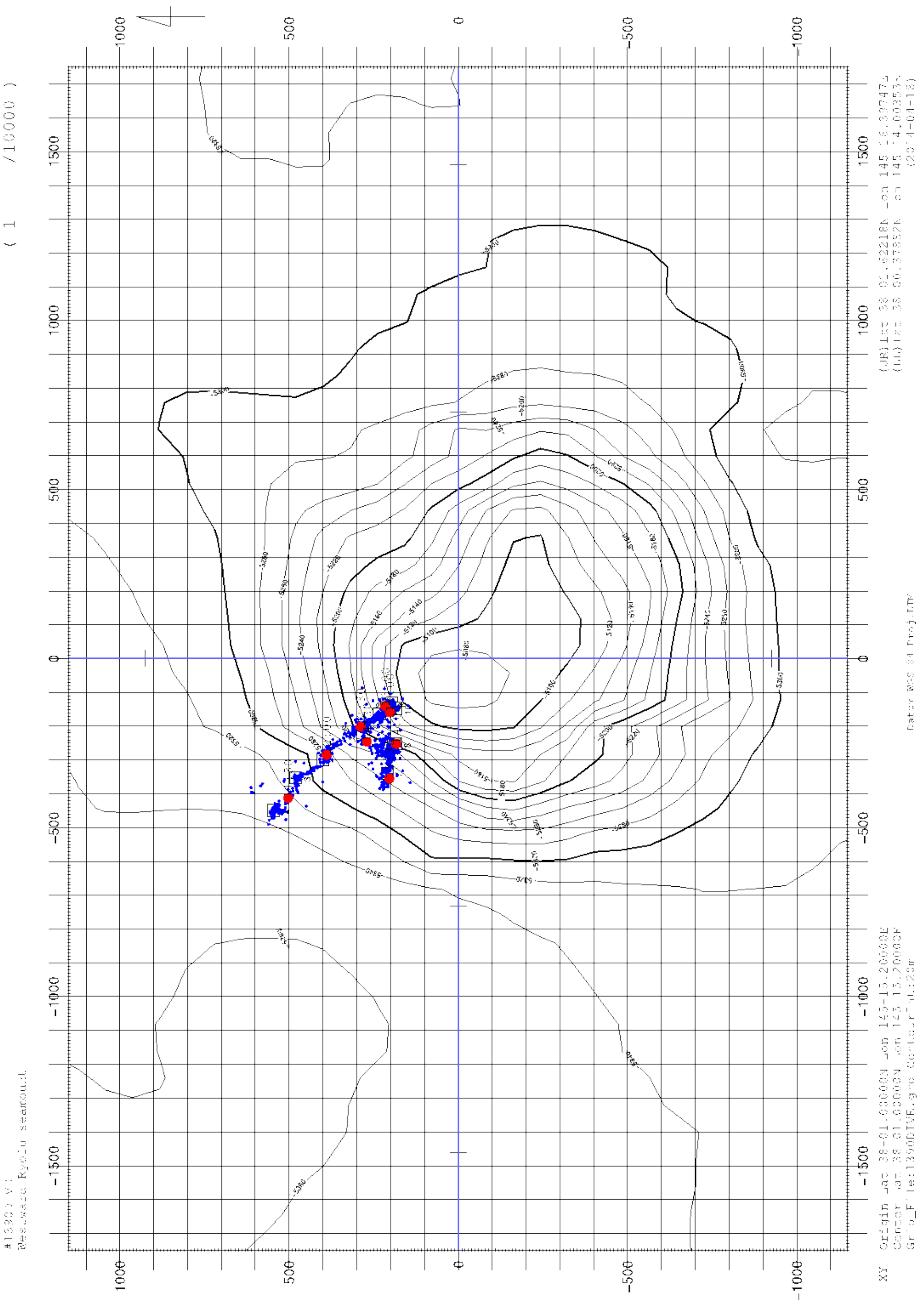


Figure 4-3-6-1. 6K#1390 dive track on the 20 m contour map.

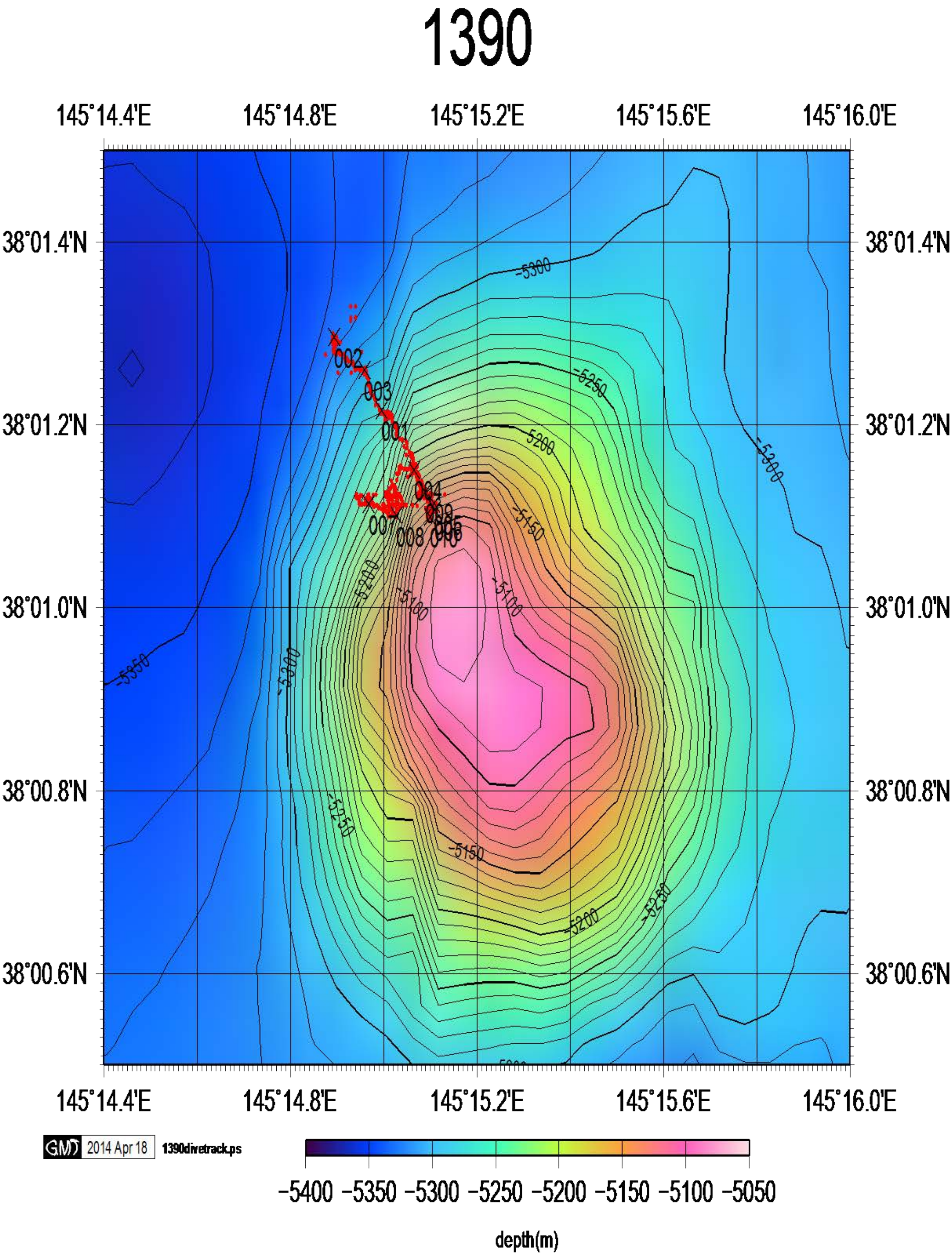


Figure 4-3-6-2. Detail bathymetric map around the dive#1390 site.

Figure 4-3-6-3. Soft pelagic sediment with some manganese crusts and pumices.

Figure 4-3-6-4. Outcrop of oblong shaped rock.

Figure 4-3-2-5. Cliff which was observed at middle of the slope.

4-3-7. 6K#1391: a westernmost knoll in this area by J. Yamamoto

Date: 19 April, 2014
Place: W Pacific, NE of Bosei knoll
37° 19.5' N, 145° 24.5' E
Pilot: Ueki Hirofumi
Co-pilot: Komuku Tetuya
Observer: Yamamoto Junji (Hokkaido University)

Purposes of Dive

1. To determine the nature of the high back-scattered area observed in sidescan sonar.
2. To evaluate the rock morphology and eruptive or emplacement style of the rock forming the topographic high and its flanks.
3. To collect rock samples from this previously unsampled area for further geologic and petrologic investigations.

Payload

2 – sample baskets
1 – sample container with lid
1 – scoop for lava pebbles
2 – push cores
1 – good for manganese
1 – marker

Video Highlights

(1) 11:19 – 11:28 (camera #1) Arriving at the landing site:

- Landed almost at the center of concave area.
- Fragmented rock blocks and gravel-mixed muddy floor.

(2) 11:29 – 11:46 (camera #1) Gravelly floor with lava blocks:

- Sampling#1 at 11:37 (SC01 as R01) (Figure 4-3-7-3).

(3) 11:47 – 12:19 (camera #1) Lava blocks (Figure 4-3-7-4):

- Sampling#2 at 11:43 (R02, R03).
- Sampling#3 at 11:56 (R04), which was a huge lava fragment with quenched surface ripped out from outcrop. It reaches a weight of 74 kg.
- Sampling#4 at 12:01 (R05).
- Sampling#5 at 12:16 (R06, R07), which were collected from aggregates of lava

fragments (Figure 5-1-5-5).

(4) 12:20 – 12:39 (camera #1) Travelling toward a high land at the southwest of the landing site:

(5) 12:40 – 13:07 (camera #1) Rocky cliff:

- We reached flank of the high land covered by Pillow lavas (Figure 4-3-7-6).
- Sampling#6 at 12:48 (R08, R09).
- Sampling#7 at 13:06 (R10, R11).

(6) 13:07 – 14:24 (camera #1) Jump to the other knoll at the north-northwest of previous one:

(7) 14:25 (camera #1) Arriving at the other knoll:

(8) 14:25 – 15:00 (camera #1) Rocky wall covered by pillow lava (Figure 4-3-7-7):

- Sampling#8 at 14:35 (R12)
- Sampling#9 at 14:42 (R13)
- Sampling#10 at 14:55 (R14)

<u>*Summary*</u>

Dive #1391 started to land at the center of a concaved area, then travelled along southern sloop of the hole and climbed up eastward. Subsequently we jumped to the other knoll locating at north-northeast of the previous one (Figure 4-3-7-1). The purposes of the dive were to investigate the nature of the area showing extremely high acoustic reflectivity; the structure and type of rocks comprising it; and evaluate whether any recent volcanic activity has taken place in this area (Figure 4-3-7-2).

The concave area around the landing site was covered by rock fragments or gravel, and sloop was covered by collapsed lava fragments, which were likely from some high lands surrounding the concave area. These observations imply that the concave area was a volcanic crater. The rocks were coated by manganese crust, but still showed angular shape, suggesting relatively young eruption activity. On the other hand, rocks of the other knoll locating at north-northeast of the previous one were coated by thick manganese crust and showed smooth rock surface. Though it would be a volcanic knoll because of cylindrical rock surface, eruption age is older than that of previous one.

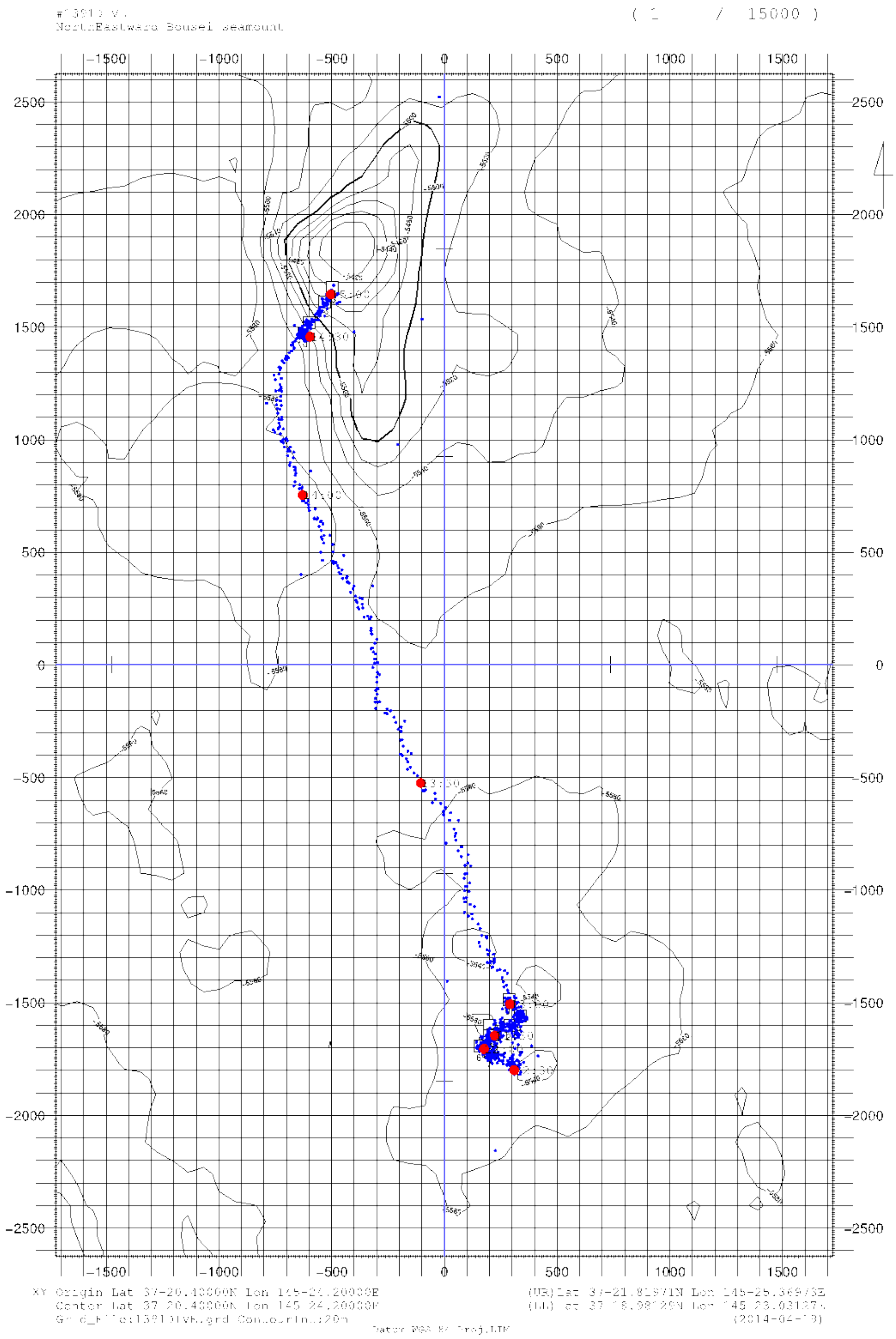


Figure 4-3-7-1. 6K#1391 dive track on the 20 m contour map.

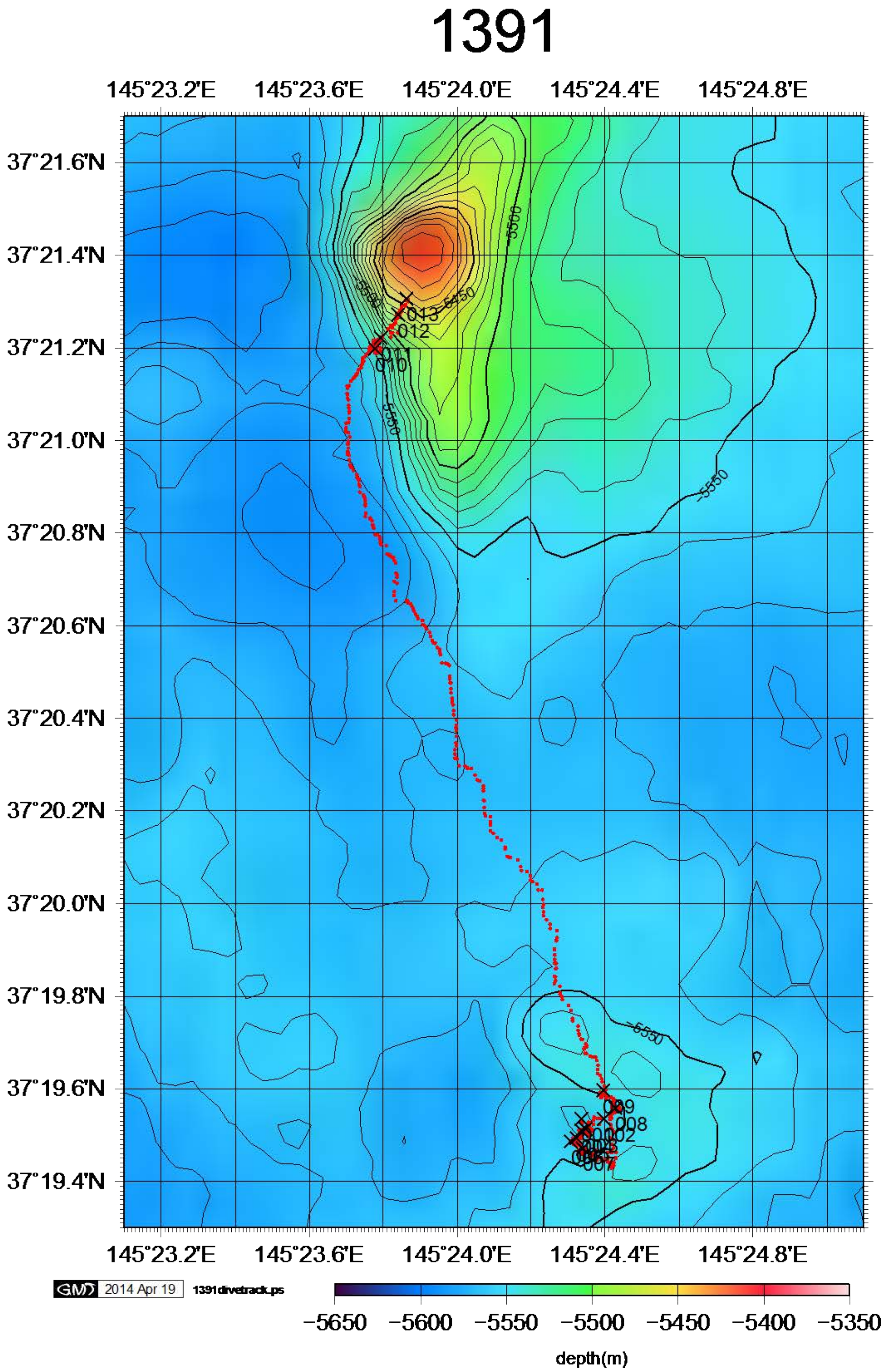


Figure 4-3-7-2. Detail bathymetric map around the dive#1391 site.

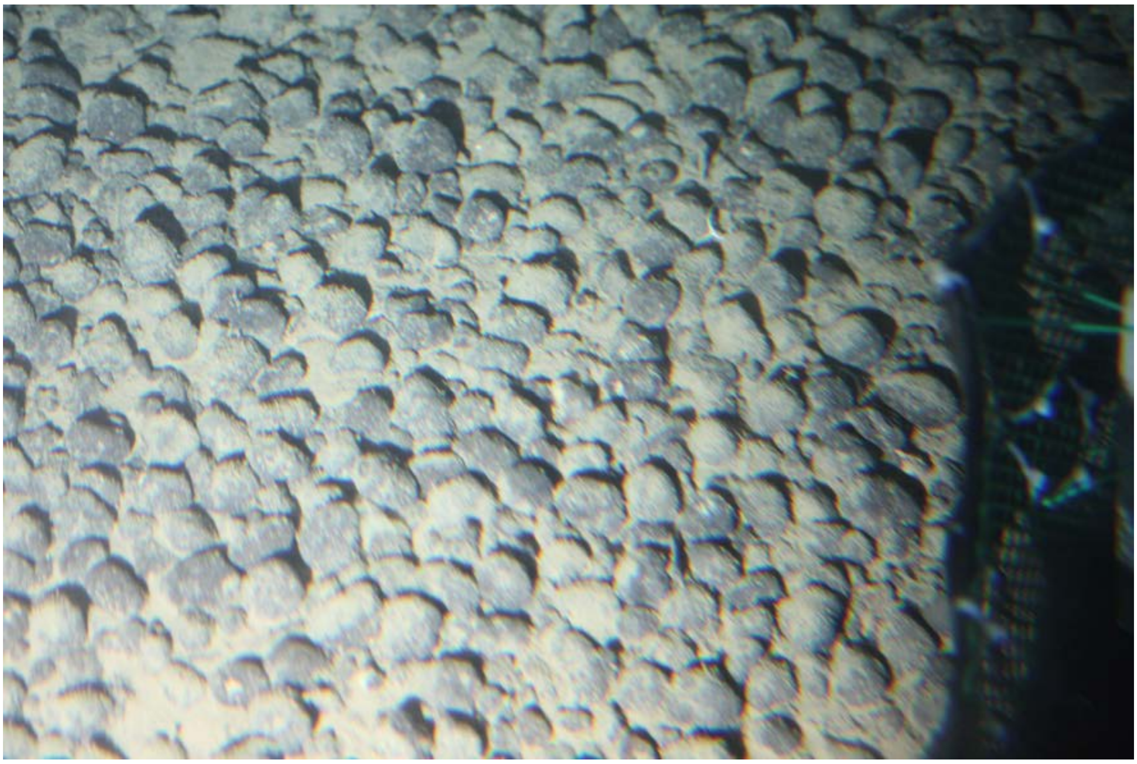


Figure 4-3-7-3. Conglomerate or gravelly floor.

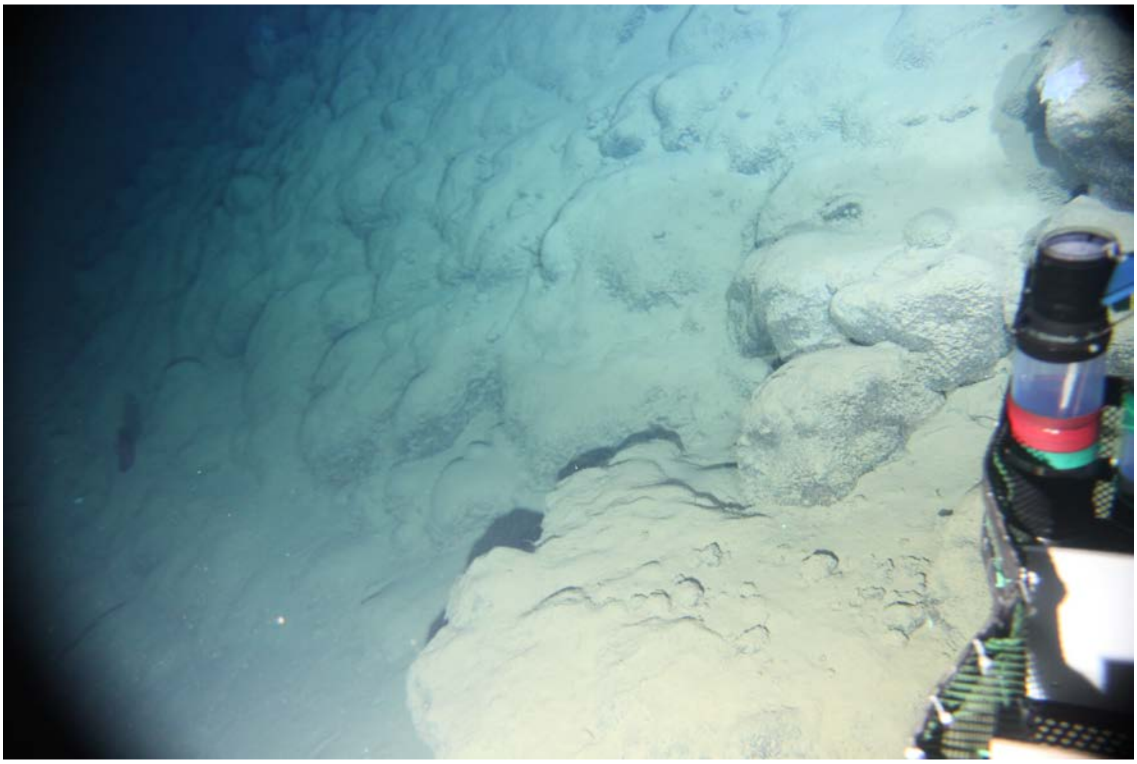


Figure 4-3-7-4. Rocky wall covered by pillow lava.

Figure 4-3-7-5. Collapsed lava wall.

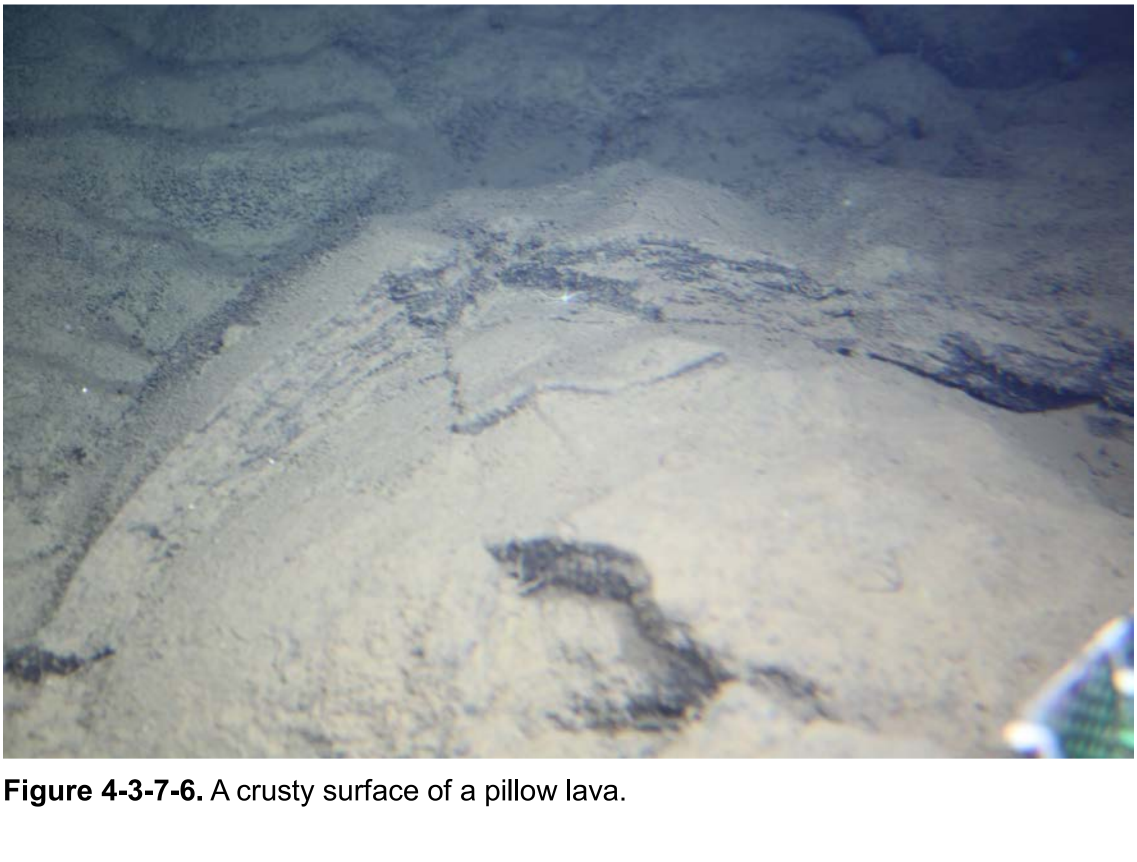


Figure 4-3-7-6. A crusty surface of a pillow lava.

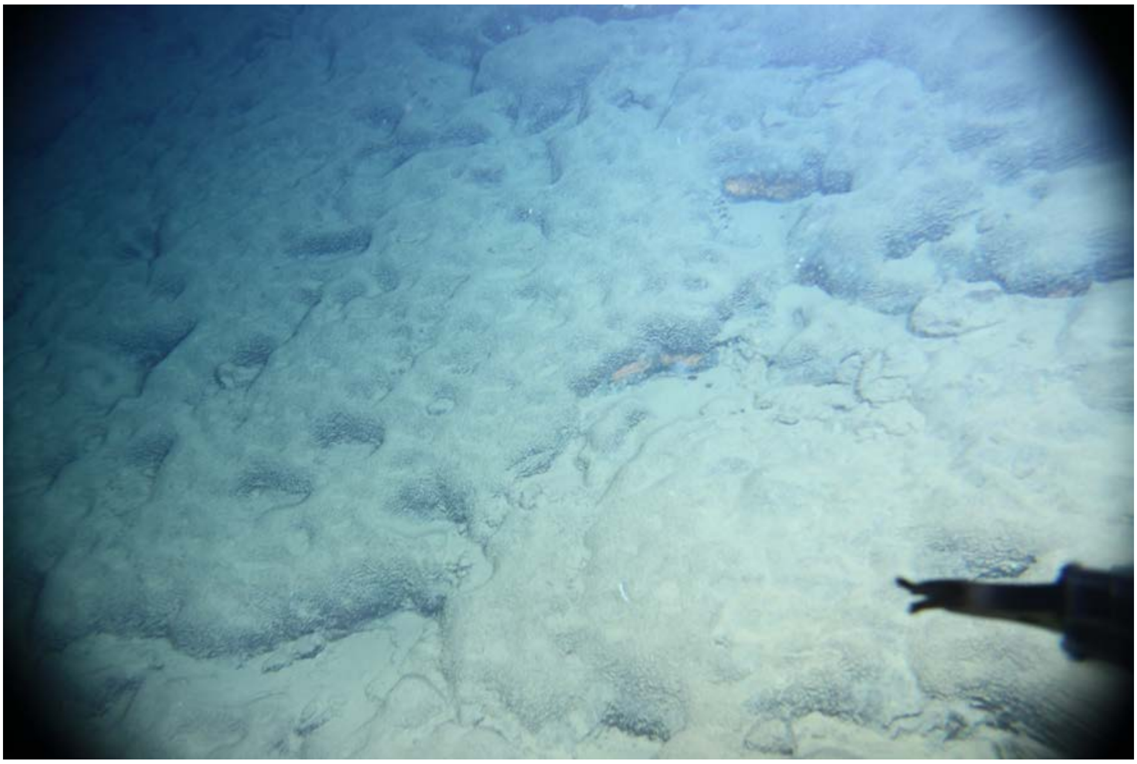


Figure 4-3-7-7. Rocky wall covered by pillow lava.

4-3-8. 6K#1392: Manganese petit-spot

by N. Hirano

Date: 20 April, 2014
Place: NW Pacific Basin, NE of Bosei Seamount
37° 42.6' N, 145° 20.6' E
Pilot: Sasaki, Yoshitaka
Co-pilot: Tayama, Yudai
Observer: Hirano, Naoto (Tohoku University)

Purposes of Dive

1. To determine the two tiny knolls, chracterised by the nature of the high back-scattered area observed in sidescan sonar.
2. To evaluate the rock morphology and eruptive or emplacement style of the rock forming the topographic highs and its flanks.
3. To collect rock samples from this previously unsampled area for further geologic and petrologic investigations.

Payload

2 – sample baskets
1 – sample container with lid
1 – scoop for lava pebbles
2 – push cores
2 – tumblers with flap (M-type sampler)
2 – markers

Video Highlights

(1) 11:21 – 11:12 (camera #1) Arriving at the landing site:
・ Scattered pebbles on pelagic mud with some sea cucumbers.
(2) 11:19:20 (camera #1) Red shrimp:
(3) 11:34:40 – 50 (camera #1) White fish:
(4) 11:38 – (camera #1) Wall rocks on gentle slope:
(5) 11:41 – 11:45 (camera #1) Sampling abandonment:
・ Soft mud into manganese.
(6) 11:51 – 11:55 (camera #1): Sampling abandonment
・ Rounded blocks of manganese cement.
(7) 11:57 – 11:59 (camera #1): Sampling#1 at 11:59

(6) 12:06 – 12:13 (camera #1) Sampling#2 at 12:13:

・ Mud with probably hyaloclastite (orange and glay colored) into manganese.

(7) 12:15:50 – 58 (camera #1) Red shrimp:

(8) 12:18 – 12:26 (camera #1) Sampling#3, 2 rocks, at 12:26:

(9) 12:30 – 12:42 (camera #1) Sampling#5 #4, at 12:42:

(10) 12:43 – 13:55 (camera #1 #2) Traveled north, the next target of knoll:

(11) 13:56 – (camera #1) Arriving at the landing site #2:

・ Scattered pebbles on pelagic mud.

・ Soon, the gentle slope composed of blocks filled by debris.

(12) 14:00 – 14:06 (camera #1) Sampling#6, 3 rocks, from wall, at 14:06:

(13) 14:09 – 14:15 (camera #1) Sampling#7 by scoop twice:

・ Debris.

(14) 14:22 – 14:23 (camera #1) Some cracks in smooth slope:

(15) 14:33 – 14:38 (camera #1) Sampling#8 at 14:38:

(16) 14:45 – 14:28 (camera #1) Sampling#9 at 14:48:

・ Line structure in the blocky wall.

(17) 14:54 – 15:01 (camera #1) Sampling#10 at 13:41:

・ Liner crack on the brocky wall.

・ Blocks in ditch along liner crack, which extends northeast straight.

(18) 14:54:58 (camera #2) Picture of the ditch.

(19) 15:02 (camera #1) Leave the floor:

Summary

Dive #1392 started in the flat basin, to the west of the southern small topographic high (Figure 4-3-8-1). The purposes of the dive were to investigate the nature of two knolls showing high acoustic reflectivity; the structure of rocks on the topographic highs and type of rocks comprising it; and evaluate whether any recent volcanic activity has taken place in this area.

The basin at the beginning of the dive was composed of some pebbles in pelagic mud. Side and top of knoll are composed of mainly huge, blocky and angular rocks with much manganese nodules. Manganese was quite thick during all place. Orange colored materials, possibly palagonitic hyaloclastite.

The second knoll of northern area is composed of blocky wall cemented manganese. The both were hard to sample the rocks because manganese cemented and soft materials inside. Some pebbles like debris were sampled by scoop. An strakght cracks made ditch and the subsidence blocks in the ditch (Fig. 4-3-8-5), NE straight in direction. We were fortunately success to samples the inside rocks from the dich at the last stop.

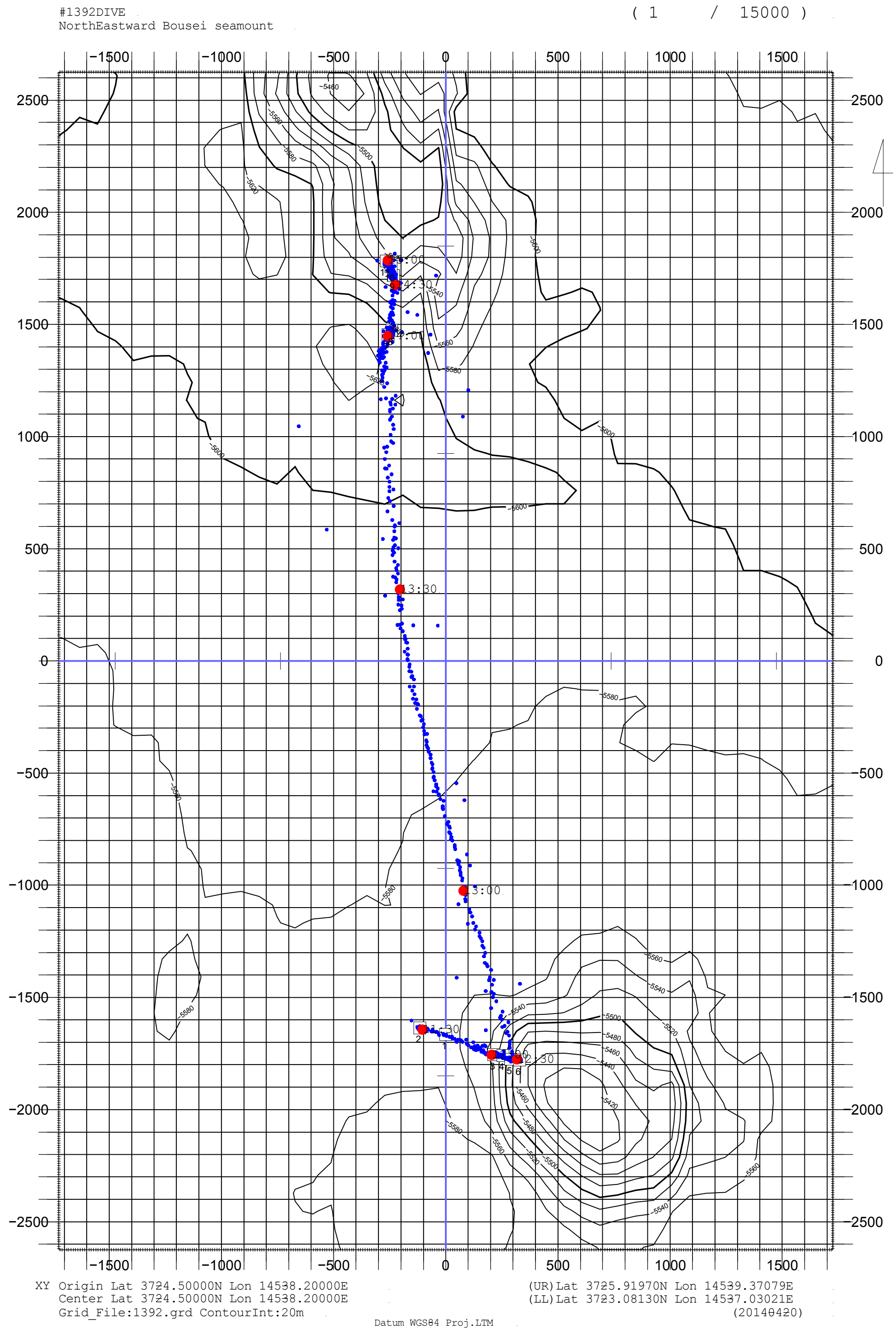


Figure 4-3-8-1. 6K#1392 dive track on the 20 m contour map.

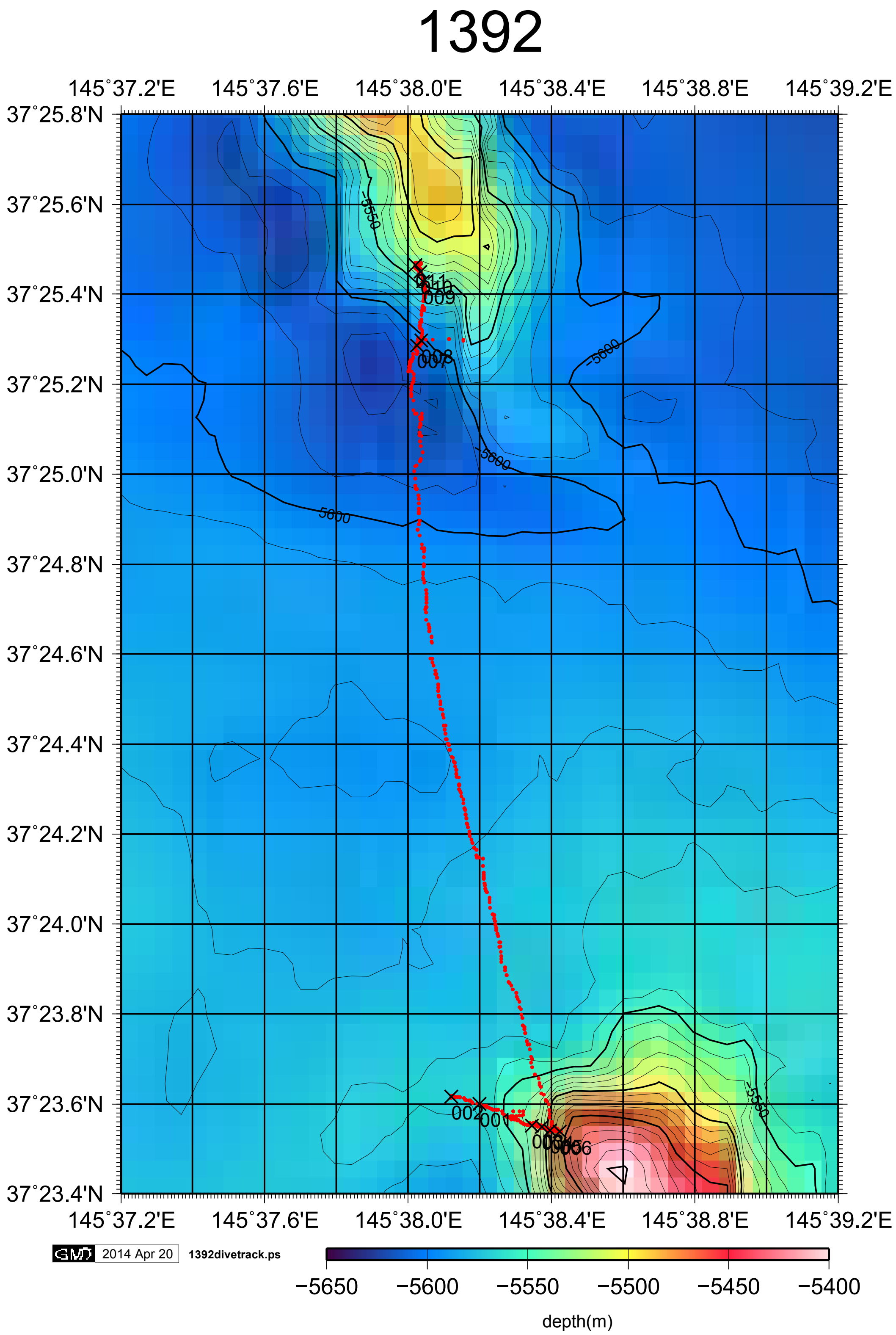


Figure 4-3-8-2. Detail bathymetric map and sampling stops of dive#1392 site.

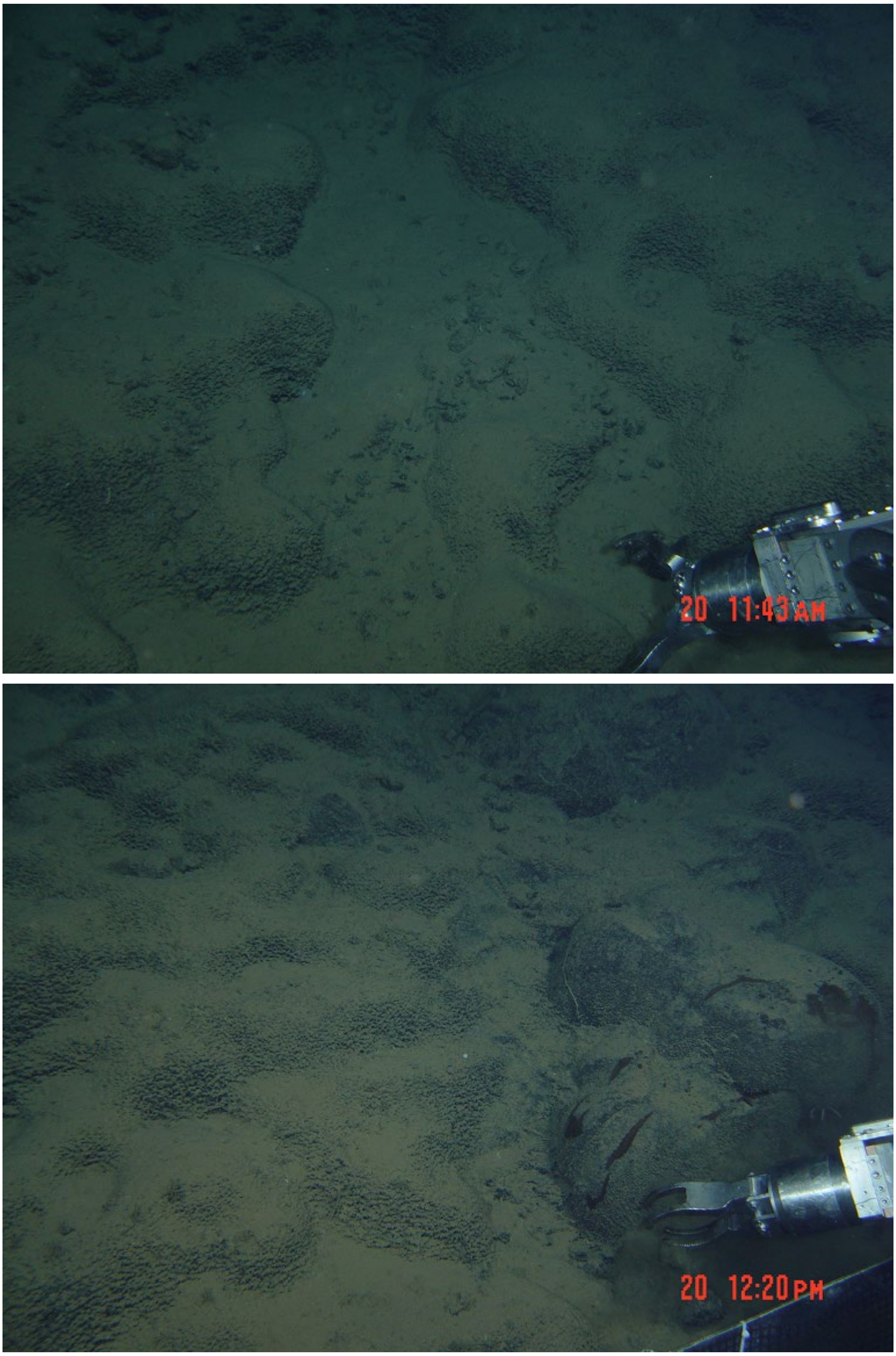


Figure 4-3-8-3. Brocky and cemented wall at the southern knoll.

Figure 4-3-8-4. Manganese wall and debris-like pebbles at the northern knoll.

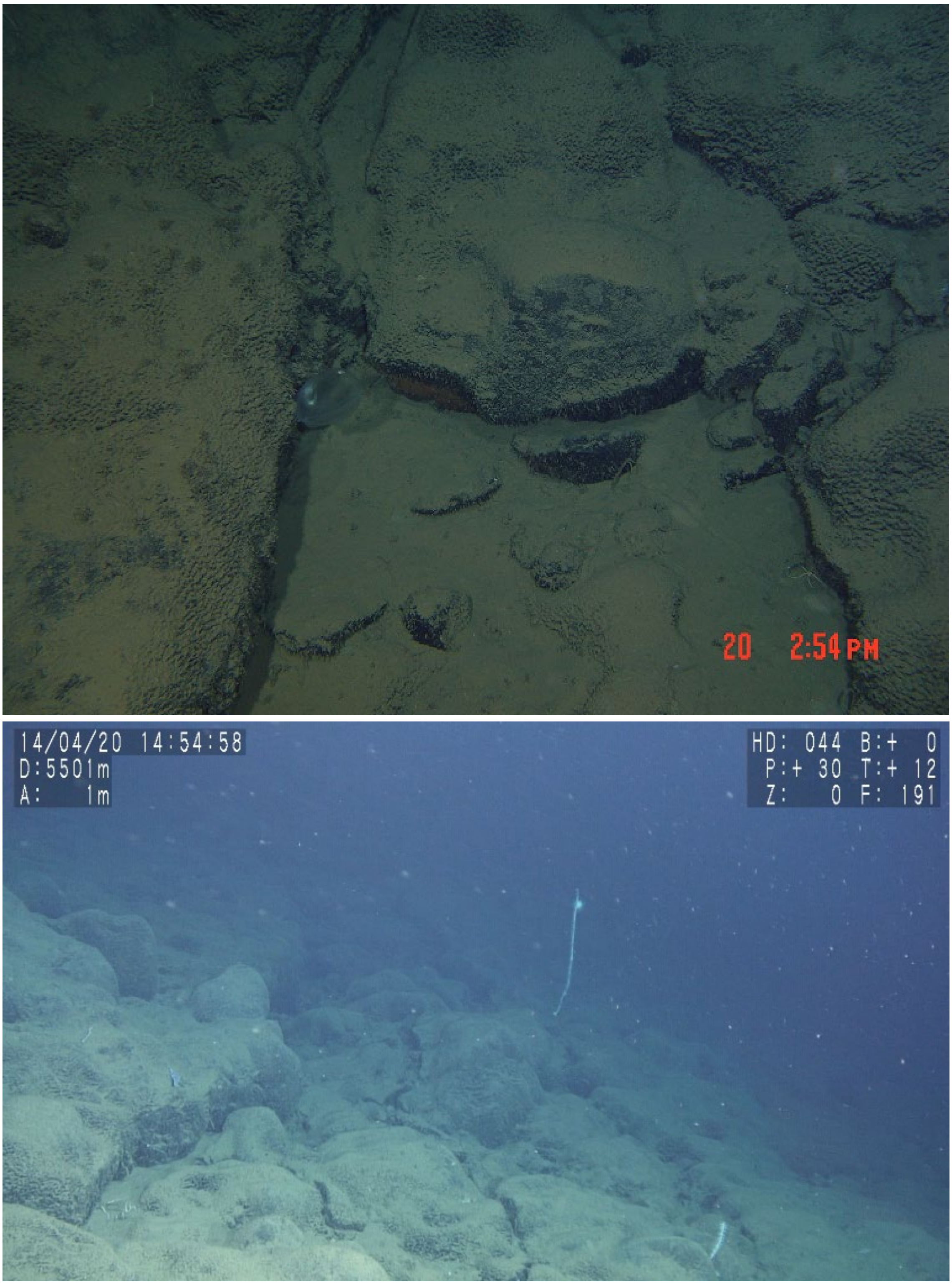


Figure 4-3-8-5. The cracked ditch of manganese wall.

4.3.9. 6K#1393: a westernmost knoll in this area

by J. Yamamoto

Date: 21 April, 2014

Place: W Pacific, W of Ryofu knoll
37° 55.0' N, 145° 02.0' E

Pilot: Saito Fumitaka

Co-pilot: Suzuki Keigo

Observer: Yamamoto Junji (Hokkaido University)

Purposes of Dive

1. To determine the nature of the high back-scattered area observed in sidescan sonar.
2. To evaluate the rock morphology and eruptive or emplacement style of the rock forming the topographic high and its flanks.
3. To collect rock samples from this previously unsampled area for further geologic and petrologic investigations.

Payload

2 – sample baskets
1 – sample container with lid
1 – scoop for lava pebbles
2 – push cores
1 – good for manganese
1 – marker

Video Highlights

(1) 11:12 – 11:19 (camera #1) Arriving at the landing site:

- Landed at northwestern flank of a knoll.
- Muddy floor.

(2) 11:20 – 11:35 (camera #1) Sheer cliff and lava tube:

- Vertical cliff and lava tube were emerged (Figure 4-3-9-3).
- Sampling#1 at 11:25 (R01), 11:30 (R02), 11:34 (R03).

(3) 11:36 – 11:58 (camera #1) Rugged rock surface (Figure 4-3-9-4):

- Wavy rock surface covered by thick mud layer.
- Sampling#2 at 11:54 (R04).

(4) 11:59 – 12:04 (camera #1) Boghole:

- A hole was emerged (Figure 4-3-9-5).
- We failed to collect any rock fragments.

(5) 12:05 – 12:19 (camera #1) Jump to east flank of the knoll:

(6) 12:20 – 14:24 (camera #1) East flank of the knoll:

- Landed again at base of the knoll.
- Wavy rock surface was visible, which was analogous to that observed in the first attack.
- Occasionally tubular rocks were visible (Figure 4-3-9-6).
- Sampling#3 at 12:47 (R05, R06, R07, C01), which were probably manganese nodules and surrounding mud
- Sampling#4 at 12:52 (R08), 13:02 (R09).

(7) 13:02 – 13:57 (camera #1) Travelling toward the other knoll at the southeast of the previous one.

(8) 13:58 – 15:00 (camera #1) Arriving at the other knoll:

- Wavy rock surface was visible (Figure 4-3-9-7), which was similar to that of previous knoll.
- Sampling#5 at 14:03 (R10, R11, R12).
- Sampling#6 at 14:30 (R13, R14).
- Sampling#7 at 14:38 (R15, R16).
- Sampling#8 at 14:59 (R17, R18, R19, R20).

Summary

The purposes of dive #1393 were to investigate the nature of the area showing extremely high acoustic reflectivity; the structure and type of rocks comprising it; and evaluate whether any recent volcanic activity has taken place in this area (Figure 4-3-9-2). Overall we found difficulty in sampling because rocks in the area showed smooth and wavy surface. It was almost impossible to pick rock off from outcrops.

The dive started to land at northwestern flank of a knoll, then climbed up southeastward. After two-hour exploration of the knoll we jumped to the other knoll locating at southeast of the previous one (Figure 4-3-9-1). Though we attempted to collect rock sample from outcrop many times, we have never succeeded it.

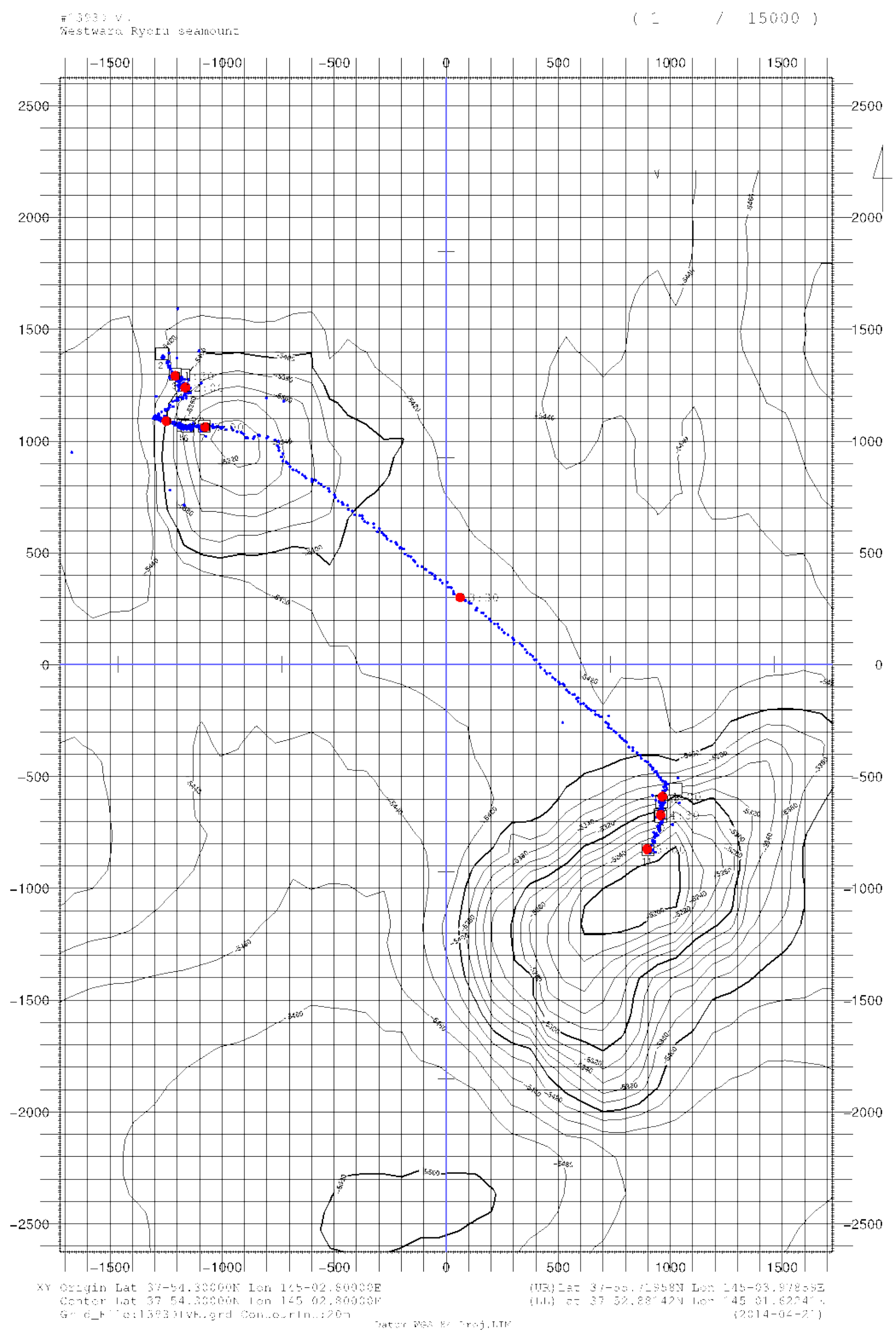


Figure 4-3-9-1. 6K#1393 dive track on the 20 m contour map.

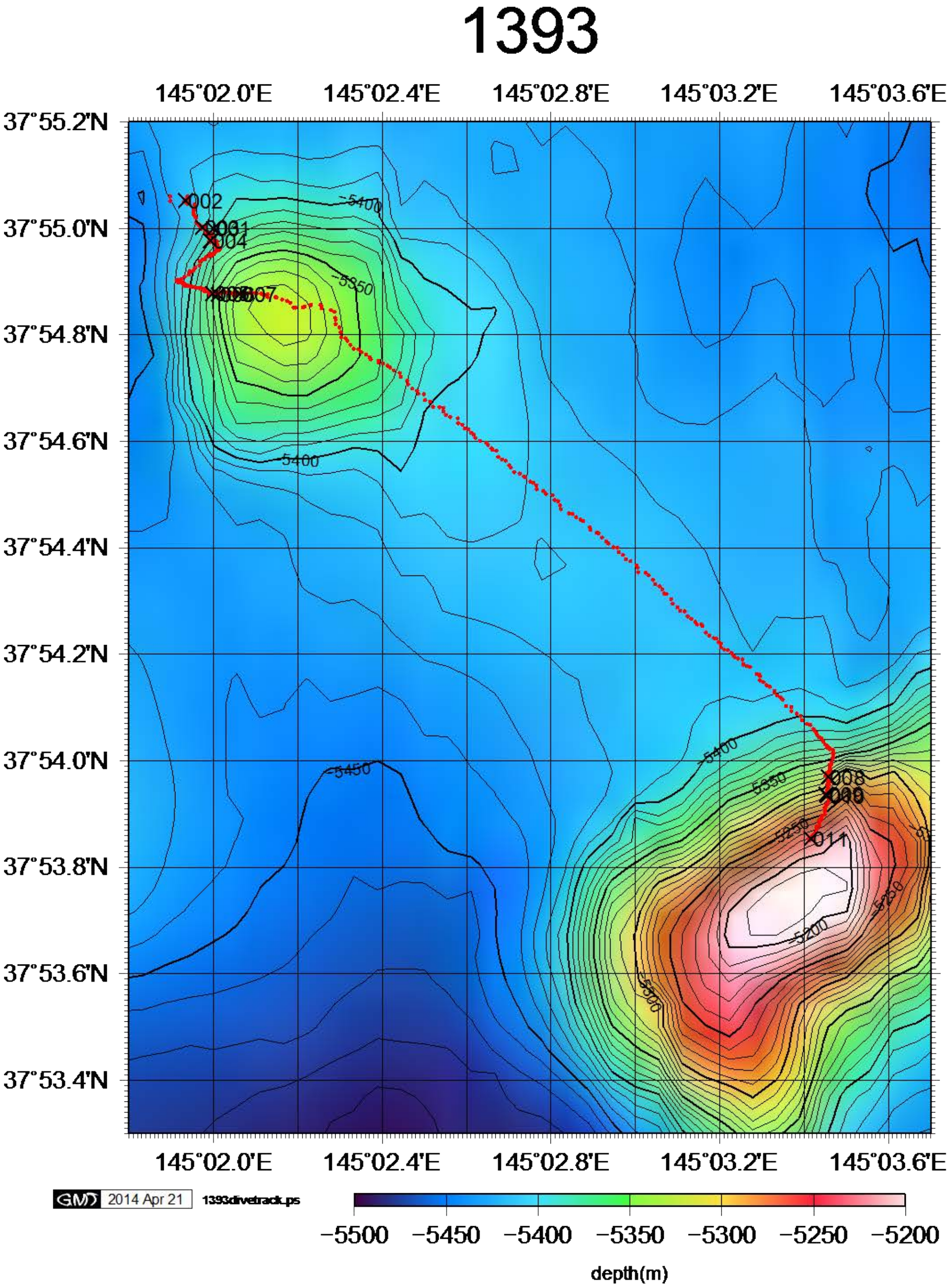


Figure 4-3-9-2. Detail bathymetric map around the dive#1393 site.

Figure 4-3-9-3. Vertical cliff (left) and lava tube (right).

Figure 4-3-9-4. Wavy rock surface covered by thick mud layer.

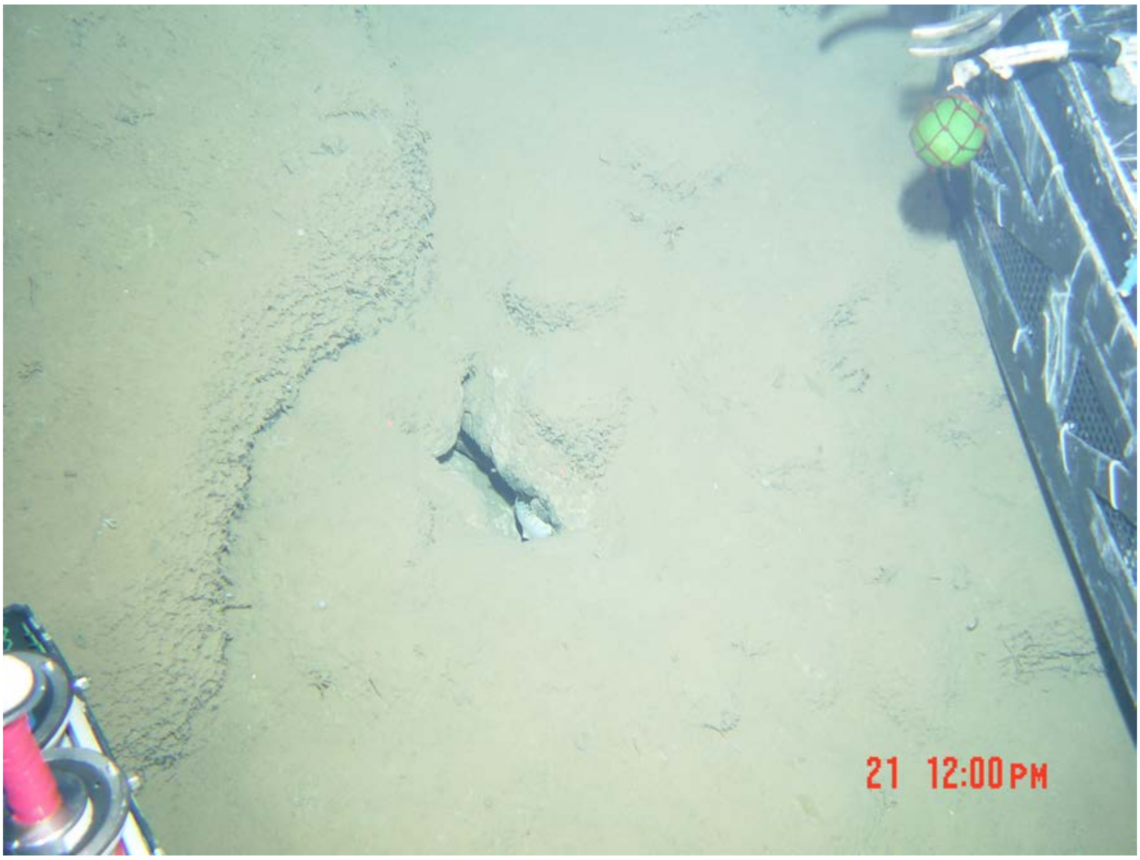


Figure 4-3-9-5. Boghole.

Figure 4-3-9-6. Tubular rocks like pillow lava.

Figure 4-3-9-7. Wavy rock surface covered by thick mud layer.

4-4. Geophysical Surveys

4-4-1. MBES   by N. Hirano & M. Nakanishi

MBES surveys were conducted throughout all the survey tracks (Fig. 1-1) during YK14-05 cruise. Surveyed ship-tracks were designed to fill gaps of the previous bathymetric measurement by the JAMSTEC after 2011. Fortunately, much data could be accomplished due to good weather conditions during the entire of the cruise, although all the geophysical surveys were cancelled due to bad weather only at the last day of the cruise.

Detailed survey was carried out over each submersible's dive site. Measurements of the sound velocity profile in the water column using an expendable bathothermograph (XBT) were made at 11 Friday, the second day of cruise. The multi-narrow beam echo sounder provides a detailed morphological characterization of the seafloor, which will be used to unravel tectonic evolution and crustal structure in the northwestern Pacific.

Figs. 4-4-1 and 4-4-2 show a bathymetric map and acoustic reflectivity of the research area (around the Marcus Island), respectively. The figures revealed detailed morphology and reflective geology of the knolls surrounded by the Cretaceous oceanfloor of northwestern Pacific. The knolls are a few km in diameter.

See the data in folder "DataYK" - "MBES_SeaBeam" in detail.

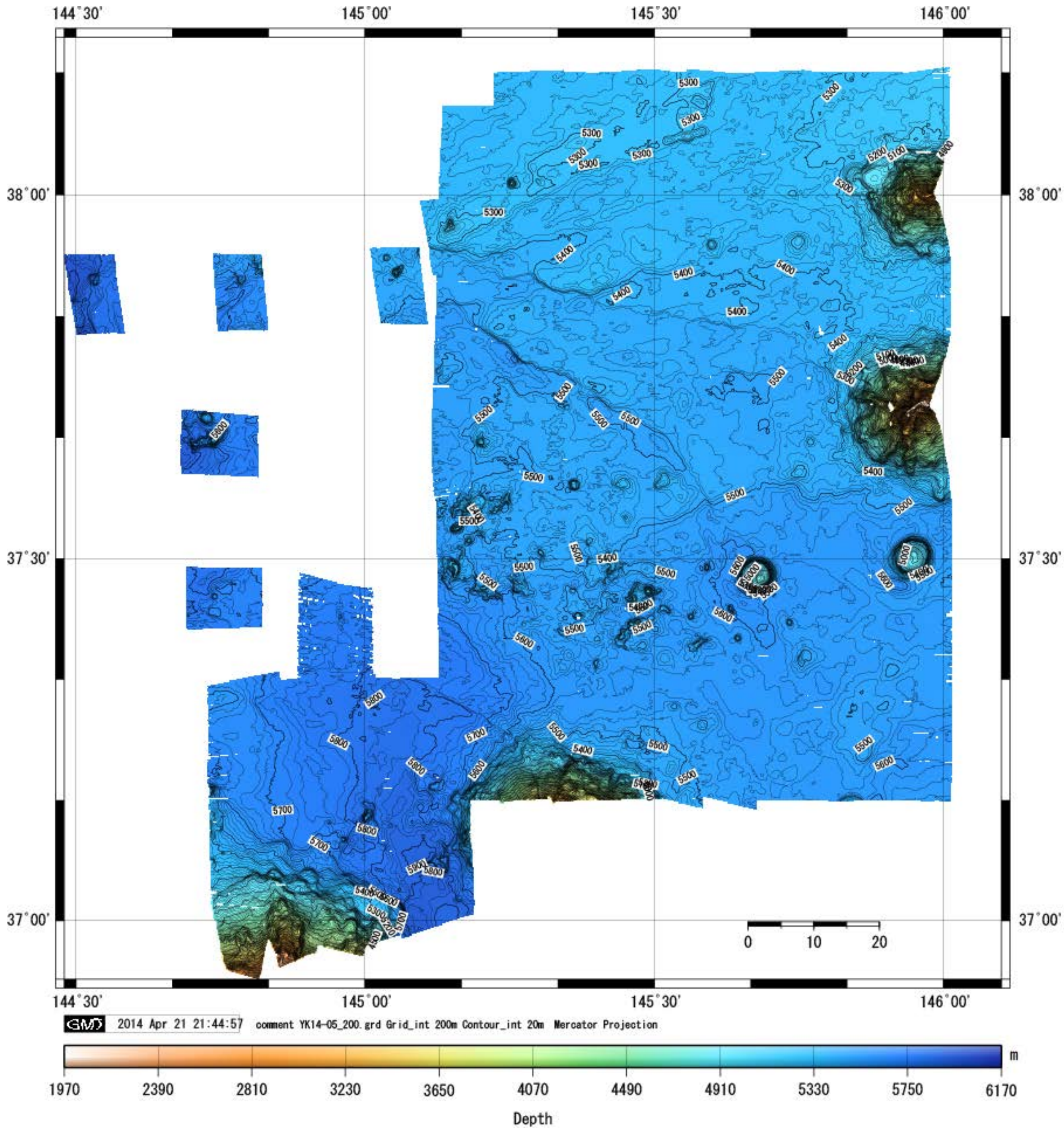


Fig. 4-4-1. MBES bathymetric data of research areas.

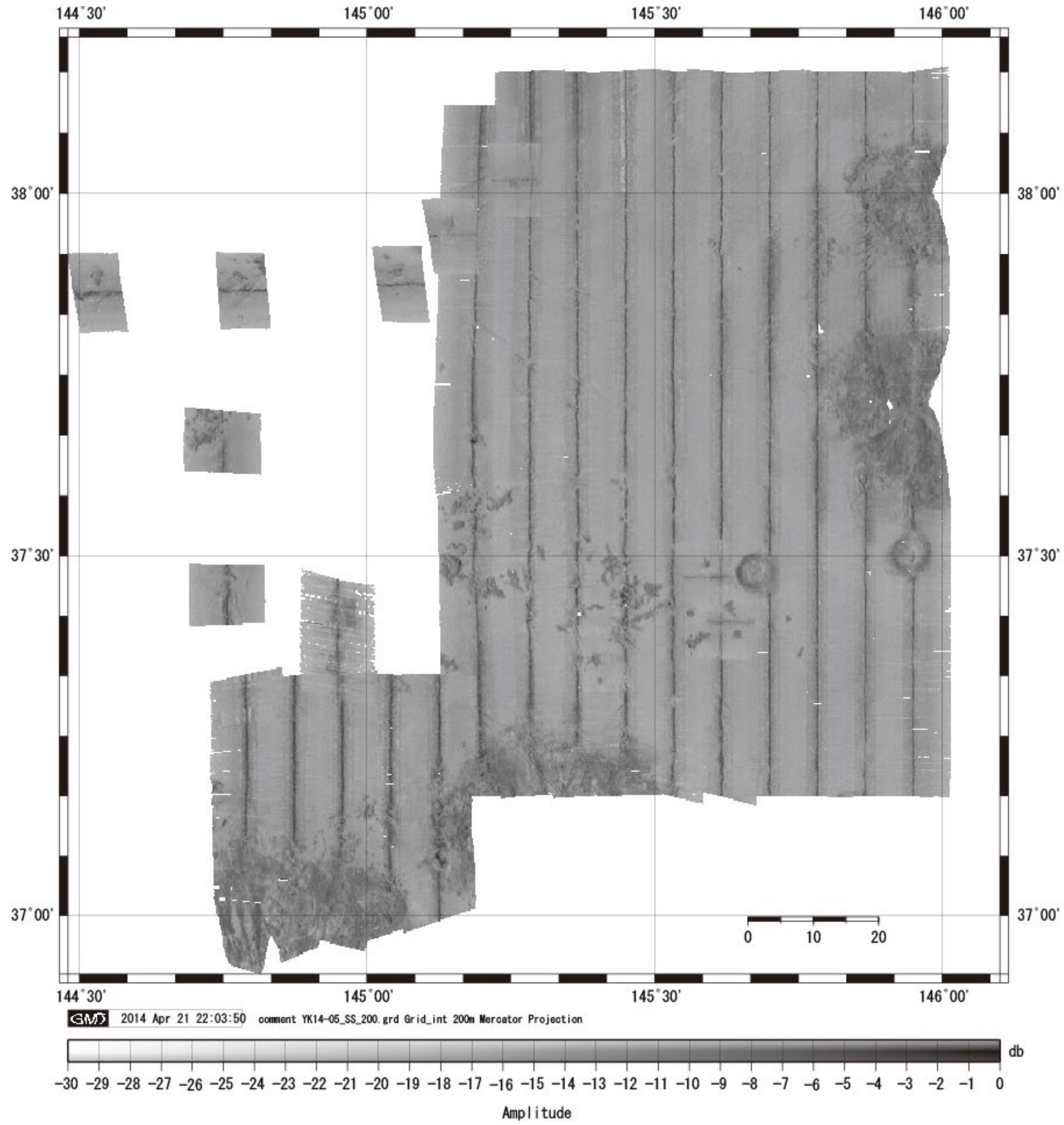


Fig. 4-4-2. MBES acoustic reflectivity of the research areas.

4-4-2. Magnetic and Gravity Surveys

by M. Nakanishi & N. Hirano

The geophysical surveys, whose items included were gravity and geomagnetics, were conducted aboard the R/V Yokosuka. The aim of the geophysical surveys was to provide a detailed geophysical characterization of the lithosphere in the northwestern Pacific on and off-axis volcanic flanks, which will be used to unravel tectonic evolution and crustal structure.

Geomagnetic total force data were obtained by using a surface-towed proton precession magnetometer PROTO10 (Kawasaki Geol. Eng. Co.). The sensor was towed 300 m behind the ship. The data were collected every 20 seconds in transit and at nighttime MBES surveys (Figure 1-1). After positioning correction taking into account the sensor cable length, the geomagnetic total force anomaly was calculated by subtracting the International Geomagnetic Reference Field (IGRF) 9th generation [IAGA, 2003] as the reference field. Vector magnetic field data, on the other hand, were collected using a shipboard three-component magnetometer, Tierra Tecnica SFG-1212. The 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 IGRF 9th model was also employed as the reference magnetic field for calculation of vector geomagnetic anomaly and "Figure-8" calibration. Magnetic vector anomalies will be utilized to map the strike directions of lineated magnetic boundaries, which are commonly representing lithological boundaries, geomagnetic reversals, or topographic offsets of magnetized layers due to faults.

Onboard gravity measurements were made using a LaCoste & Romberg S-63 air-sea gravity meter. 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 (10898.5 mGal) was tied to an absolute gravity value at the JAMSTEC pier in Yokosuka (979758.7 mGal) before departure. The "gravity tie" will be conducted again after arrival at the pier to estimate sensor drift of the gravity meter. Therefore, gravity data processing (readjustment of time difference, Etovos, drift, and reference gravity corrections) should be required onshore. Shipboard gravity anomaly will be used for analysis of the crustal structure combined with bathymetry and seismic reflection data. Analysis of lithospheric flexure and deformation using satellite derived gravity anomaly combined with the shipboard gravity anomaly may be helpful.

See the data in folder “DataYK” - “Ship's_Data” in detail.

5. Future Studies & Research Interest

5-1. Naoto Hirano

The main target of the cruise is totally understanding the interrelation between volcanic distributions and eruptive geochronology. The petit-spot eruptions might be related to re-activation of traditional structures due to the subduction-related bending of NW Pacific Plate. Other questions about asthenosphere and origin of petit-spot eruption are important target as well.

See the chapter 3-1.

Methods are:

・Petrography:
corroborated work with Dr. Ishii and onboard students

・Analyzing the onboard geophysical data:
corroborated work with Dr. Nakanishi, Chiba University.

・Electron microprobe analysis for quenched glasses and minerals:
corroborated work with Department of Earth Science, Tohoku University

・XRF:
corroborated work with Dr. Machida, onboard scientist

・Ar-Ar dating:
corroborated work with Prof. Nagao, Dr. Sumino and the Radioactive Isotope Center, University of Tokyo, and the Research Reactor Institute, Kyoto University

・Laser ablation ICPMS for bulk and glasses:
corroborated work with Kyoto and Kanazawa Universities

・Noble gases isotopic analysis:
corroborated work with Dr. J.Yamamoto, onboard scientist

・TIMS for solid elements:
corroborated work with Dr. Machida, onboard scientist

・FTIR analysis of glass:
corroborated work with Dr. Okumura, Tohoku University

5-2. Teruaki Ishii

Powder petrology is recently very popular among geosciences, that is, rock samples are crushed to powder instantly without detailed mineralogical and petrological considerations. Igneous petrology on the basis of mineralogical investigations including several rock forming minerals should be more emphasized to create petrological new horizon among geosciences.

During YK14-05 cruise, we collected about 50 basaltic igneous rock samples including hyaloclastite by SHINKAI 6500 from petit-spot type volcanoes. Those rocks include lithologically primitive through intermediate to fractionated rocks. It is very important to estimate of the fractional crystallization sequences among those recovered rocks, on the bases of the mineralogical and petrological investigations using constituting minerals.

We also recovered about 30 pumices during YK14-05 cruise. Unfortunately it is not clear that those specimens may or may not contribute petit-spot studies, but it is very important to identify the source volcanoes of those pumices. If some of those pumices were insitu igneous products, it will be very interesting.

5-3. Junji Yamamoto

Debates on the presence of partial melts in the asthenosphere have intensified in recent years. The occurrences of a seismic low velocity zone and a high electric conductive layer in upper mantle, for example, have supported partial melting in the asthenosphere, which is also consistent with the experimentally determined peridotite solidus in the presence of H_2O and CO_2 (Wyllie, 1988). However, recent studies suggest that partial melts are not required to explain seismic observations (Faul and Jackson, 2005; Stixrude and Lithgow-Bertelloni, 2005; Priestley and McKenzie, 2006). Because of their geochemical signature of mid-ocean ridge basalts, petit-spot magmas are likely to be derived from partial melts in the ambient asthenosphere (Hirano et al., 2006), so a good understanding of how petit-spots actually form can provide entirely new insight into the physical state of the normal upper mantle.

Petit-spot volcanoes are tiny seamounts erupting off the fore bulge of the downgoing Pacific plate (Hirano et al., 2001; 2004; 2006). Though they are volumetrically minor, petit-spot magmas are invaluable samples of asthenospheric partial melts beneath a mature oceanic lithosphere. If petit-spot volcanoes are polygenetic with a long active period, their genesis indicates melt accumulation at the lithosphere-asthenosphere boundary. On this point recovery of peridotite xenoliths in the present cruise are notable success. These xenoliths can constrain how the oceanic lithosphere is affected by petit-spot formation. As long-standing volcanism at old oceanic plate is expected to affect the geotherm, the thermal structure of oceanic plate deduced from the peridotite xenoliths could potentially test the occurrence of the melt at the base of lithosphere.

Our approach is as follows. At first, a state-of-the-art spectroscopic geobarometry based on fluid inclusion reveals a local geotherm within 140-Ma Pacific plate, which could be higher than expected from conventional plate cooling models. Second, we will devise a simple fluid mechanical model to relate petit-spot formation, the observed lithospheric geotherm, and melt migration in the asthenosphere, and our model constrains melt porosity in the asthenosphere. Consequently these results enables us to discuss the connection between the physical state of asthenosphere and the global age-depth relation of ocean basins. We believe that the approaches will have a broad impact on both geochemistry and geophysics.

References:

Faul U H, Jackson I (2005) The seismological signature of temperature and grain size variations in the upper mantle. Earth Planet Sci Lett 234:119–134.

Hirano N, Kawamura K, Hattori M, Saito K, Ogawa Y (2001) A new type of intra-plate volcanism; young alkali-basalts discovered from the subducting Pacific Plate northern Japan Trench. Geophys Res Lett 28:2719–2722.

Hirano N, Yamamoto J, Kagi H, Ishii T (2004) Young olivine xenocryst-bearing alkali-basalt from the oceanward slope of the Japan Trench. Contrib Mineral Petrol 148:47–54.

Hirano N, Takahashi E, Yamamoto J, Machida S, Abe N, Ingle S, Kaneoka I, Hirata T, Kimura J, Ishii T, Ogawa Y, Suyehiro K (2006) Volcanism in response to plate flexure. Science 313:1426–1428.

Priestley K, McKenzie D (2006) The thermal structure of the lithosphere from shear wave velocities. Earth Planet Sci Lett 244:285–301.

Stixrude L, Lithgow-Bertelloni C (2005) Mineralogy and elasticity of the oceanic upper mantle: Origin of the low-velocity zone. J Geophys Res 110:B03204.

Wyllie P J (1988) Solidus curves mantle plumes and magma generation beneath Hawaii. J Geophys Res 93:4171–4181.

5-4. Shiki Machida

School of Creative Science and Engineering, Waseda University
Volcanic rock petrology, geology, tectonics, mantle dynamics, solid earth recycling

Magma genesis of petit-spot volcanoes in the NW Pacific

My interest is bulk rock geochemistry of basalts corrected from petit-spot volcanoes. Major and trace element and Sr, Nd, and Pb isotopic compositions will be determined to define the nature of magma source and its melting conditions. These data, together with experimental studies, will clarify the differences of source rock petrology and melting conditions for petit-spot volcanism. We thus get important aspects for the nature of Earth's mantle heterogeneity, as well as origin of intra-plate volcanism unrelated to mantle plumes.

I will determine (1) major elements, trace elements, and isotopic compositions using X-ray Fluorescence Analysis (XRF), Inductively Coupled Plasma Mass Spectrometry (ICP-MS), and Thermal Ion Mass Spectrometry (TIMS) or multi corrector type ICP-MS, respectively. Recently, we defined that alkaline basalt lava from petit-spot volcanoes in the NW Pacific (i) has extreme EM-1-like Sr–Nd–Pb isotopic compositions (Machida et al., GCA, 2009), and (ii) can be classified into three distinct groups, on the basis of features on trace element compositions (Machida et al., Geology, under review). These geochemical differences may indicate differences of geochemistry and/or lithology of source materials contributing heterogeneity of the Pacific upper mantle. Then, our new data should be compared to these criterions for classification, and will provide us basic geochemical features of basaltic magma addressing detail investigation of magma genesis. Another important problem for magma genesis is that detailed melting condition for petit-spot magma is still unclear. In order to solve this problem, I will conduct (2) melting experiments to define near liquidus phase relations for the petit-spot primary magmas. These experiments constraint the final temperature and pressure conditions and residual solid lithology for melting of petit-spot magma source. Finally, I will examine (3) origin of recycled material by quantitative numerical melting model for bulk rock trace element compositions. Modeling will be conducted assuming solid lithology determined by melting experiments. Then, all of these investigations are expected to contribute to define the source material reproducing trace element composition of primary magma, and magma processes from source to eruption.

5-5. Yuki Sato

The aim of this cruise is to shed light on the relationship between the eruption ages of the petit-spot volcanoes and plate deformation using the rock samples from the study area. Therefore, it goes without saying that most important samples in this study is the lavas of petit-spot volcanoes. Xenoliths and xenocrysts in lavas, and rare earth element concentrations in pelagic mud could provide important information to know the geochemical structure of lithosphere. However, there are something ignored despite being sampled in large doses such as pumice. These pumice are allochthonous because large ones are generally traveled along an ocean current. On the deep seafloor, pumice are coated by manganese, and it is hard to differentiate between them and lavas apparently. Therefore it was often seen that researchers was disappointed when they found out that the content of the sample was just a pumice. Thus pumice became to be regarded as obstacles in this cruse, but are pumice really worthless except for heel rubbing?

In the first place, where are pumice come from? The study area is a meeting point of two ocean currents; Oyashio Current and Kuroshio Current. Oyashio Current is a cold current that flows south from the Bering Sea. In contrast, Kuroshio is a warm current that flows north from the East China Sea. The point is called “Shiome” in Japanese. “Shiome” makes fertile fishing ground because many fish gather from both currents, and pumice also get together in this area. Density of pumice is so low that they can float and drift on the sea until their vesicles are filled with water. Therefore, much pumice are corrected in this area, and they annoyed researchers.

Pumice vary their chemical composition and mineral assemblages depending on volcanoes, even on the eruption age of one volcano. Therefore, it is possible to seek the source volcano of pumice according to their characteristic. Some studies determine the source of drift pumice that has been washed up ashore on the beach (e.g. Jokiel and Cox, 2003), however there are not much research which cover the “sunken” pumice. Kato (1987) used to study the “woody pumice” sampled from seafloor of Okinawa Trough by “Shinkai 2000”, but the woody pumice are considered autochthonous boulders.

If we succeed to determine the source of pumice and their eruption age, clarification of the paleocurrent of East Asian seas which carried the pumice this area and history of the paleocean circulation would be expected. These days, it has been pointed out that ocean current would change the ocean circulation due to climate change. Therefore it is important to know how it has changed, and to estimate how it will change.

In this cruise, the number of pumice which sampled from deep sea exceeds 30. Pumice, which traveled long miles and kept much information, may see the light of day some other time.

References

Jokiel P.L. & Cox E.F. (2003) Drift pumice at Christmas Island and Hawaii: evidence of oceanic dispersal patterns. Marine Geology, 202, 121–133.

Yuzo K. (1987) Woody pumice generated with submarine eruption. J. Geol. Soc. Japan, 93, 11-20.

5-6. Takaomi Kawano

The purpose of the cruse was the salvage samples from petit-spot by Shinkai6500 ———her name is 6K. I participated in this cruse as a member of geologist.

Our targets are Mantle Xenolith and paragonites. Chemical analysis of those lavas revealed chemical composition of upper mantle at outerrise.

On the first day, it was very rough; in diving, sometimes the layers of Mn were too thick, 6K not to strip off the lavas. We, however, finally obtained a number of mantle xenoliths and paragonites. I think these studies must be splendid.

Well, look back on my exciting cruse.
It was hard for me to find something to do for this project because it was the first time to cut rocks and to descript them. I, however, enjoyed observation as I was getting used. Significant experience for me was finding of the mantle xenoliths from the petit-spot lavas. And, these are some of my favorite memories ——————manganese juice and Pumice Pumice.

I would like to express my great appreciation to everyone.

5-7. Yoichi Suzuki

We surveyed petit-spot volcanoes at the northwestern Pacific Ocean in this investigation and we discovered and sampled many rocks come from volcanic activities at the sea bottom. The sampled rocks are alkali-basalts bearing olivine xenocryst from petit-spot volcanoes. It will be useful evidences to resolve the question where the lavas from petit-spot volcanos come from.

And, we also sampled many rocks not to come from petit-spot volcanoes. For example, manganese nodules, the rocks carried by glaciers or icebergs (dropstones) and so on.

It is interesting what the core of manganese nodule is and how the nodules grow into their size. If these manganese nodules accrete to the island arc after plate-subduction, these nodules will be metamorphosed by pressure and heat and will be manganese minerals. It would be interesting to compare the manganese minerals on the ground with manganese nodules. Dropped stones are igneous rocks, and particularly rounded in shape, but they are not generally occurred on oceanic plate. Their features are quite different from each other. It is interesting where these rocks come from and when they occurred.

They would provide much information in this exploration.

5-8. Arashi Taki

It is very significant of the investigation in “Shinkai 6500”. The purpose of this cruise is a research into “petit-spot”, so we picked various samples. For example, lava and hyaloclastite that are the evidence of petit-spot, but manganese nodule, manganese crust and pumice are sampled. In particular, the lava include xenolith and xenocryst originated from mantle. They are very valuable as investigate, because information on temperature and the pressure of the mantle is included.

Researched petit-spot were variously sampled from old to young lavas, and the older one was covered with thick manganese. The structure of some manganeses stratify looks like sedimentary rock, and dentate form. What does the difference in occurrence of them? I imagined two reasons. First is the difference in velocity of growth. Second is the intensity of water current.

I’m more interested in xenolith and xenocryst as well. So I would like to study them and their geology.

5-9. Nana Ukyo

The "petit-spot" magma was penetrated through fracture of the subducting plate (Hirano et al., 2006). However it has not been clarified how melt is derived from asthenosphere. The elementary composition and age of petit-spot rocks have been investigated to comprehend the depth provenance and the eruption age and places. Besides, petit-spot rock provides constitutive material of subducting old oceanic plate. Xenoliths entrained within petit-spot rocks have important information because the P-T information of them should reflect nature of the lithosphere. Thus, petit-spot is related to various researches on the deformation of the plate, the asthenosphere and the chemical composition of lithosphere. In addition, petit-spot could have a potential to upset geological interpretation for the origin of alkali basalt existing in the accretionary prism. Hirano et al. (2010) said that an alkali basalt in Mineoka belt erupted in the place where an oceanic plate approached the trench. Also, picrite basalts, whose chemical composition resemble OIB, are distributed over Setogawa belt, suggesting that they have erupted before emplacement to Honshu. In this way, we need carefully consider characteristic of petit-spot magmatism to interpret the origin of alkali basalt existing in accretionary prism.

We obtained a variety of lavas in this project. Lavas of 6K#1385 are nearly fresh olivine basalts including tiny vesicules, which were not recognized by macroscopic observation. The lavas have is 10–20% vesicularity with altered glass rims, and ferromanganess oxide with 1–2mm thick. On the other hand, the vesicularity of basalt of 6K#1390 is higher than that of #1385. Vesicules were macroscopically visible. The basalts sometimes include olivine grains as phenocrysts. We found the mantle xenolith with 1 cm×2 cm as well. Only a few lavas were confirmed during dives of #1386, #1388, and #1389. Basaltic lava fragments were observed in pelagic mud flow and hyaloclastite. For petit-spot of #1386, alternation of lava flow and pelagic mud was observed, and summit was covered with sedimentary rocks. In addition, we could get basalts including pelagic mud with broken basalt of fragments and their vesicules basalts filled by pelagic mud.

We would consider some things from samples as follows. (1) We would get eruption age of petit-spot from thickness of paragonite or 39Ar-40Ar dating. (2)We would know estimate depth provenance of xenoliths from internal pressure of fluid inclusions. (3)We would understand magma source of petit-spots from their chemical composition. Comparing chemical composition and depth of magma from previous studies, I would identify difference and similar point for petit-spots in this area. It provides us new information of petit-spot, which is universally but locally distributed on the oceanic plates.

Here I consider the eruption mechanism of petit-spot is investigated from relationship between lava flow and pelagic mud. If we get a basalt, which include pelagic mud and basalt whose eruption ages are different each other, the petit-spot magma erupted twice or several times. As the other method, information of sediment and pelagic mud in lavas may have a possibility to reveal the origin of alkali basalt magma such as Mineoka belt alkali basalt having sedimentary rocks.

Understanding of characteristic of petit-spot volcanoes provides new light on studies related to chemical composition and rheological properties of asthenosphere and lithosphere. Consequently, reconsideration of the origin of alkali basalts in accretionary prism would be a clue to reconstruct the plate tectonics.

References:

Hirano, N., Takahashi, E., Yamamoto, J., Abe, N., Ingle, S.P., Kaneoka, K., Kimura, J., Hirata, T., Ishii, T., Ogawa, Y., Machida, S. & Suyehiro, K. (2006) Volcanism in response to plate & flexure. Science 313, 1426‑1428.

Hirano, N., Abe, N., Machida, S., &Yamamoto, J. (2010) New insight into the oceanic lithosphere from petit-spot volcanoes and "Super-Mohole" project. Jour. Geol. Soc. Japan 116, 1–12.

5-10. Taku Yutani

During the submersible Shinkai 6500, sedimentary rocks were found, and not so much lava flow was observed on the summit of petit-spot volcanoes. I got to know that the lava flows of petit-spot volcano were found at halfway up the knoll.

The submersible found pillow lavas at younger volcanoes, and we could find the samples clearly showing ropy lava's structures on their surfaces.

I described the obtained rocks onboard, but I would like to observe it with a polarizing microscope because there were unidentified structures and the mineral (in particular, phenocryst minerals of the basalt) only by the observation using loupes and stereoscopes. It is peculiar to be obtained sandstones including olivine grains and hypabyssal felsic rocks, because such rocks are generally found on the submarine environment. So, I would like to find out their origins.

The rocks sampled around a petit-spot volcanoes were mainly essential lavas and pumices. The thick coating of manganese indicates that the generation of volcano was old. Pebbles as a few sedimentary rocks were found as well.

Some lavas include xenolith and/or xenocryst. I am interested in where they have come and how condition there were.

I got to be able to configure more detail image of submarine volcanic activities through this investigation. The experience would be an important instrumental for me to make decision when I observe an outcrop indicating the trace of a subaqueous volcano on land.

Unfortunately, I was not licensed to get on Shinkai 6500 in this time, so I would like to go into the deep sea and to see outcrops in the future.

6. Bibliography

Amante, C. and Eakins, B. W. (2009) ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis. NOAA Technical Memorandum NESDIS NGDC-24, 19 pp.

Aramaki, S. and Hamuro, K. (1977) Geology of the Higashi-Izu monogenetic volcano group. Bull. Earthquake Res. Inst. 52, 235-366. (in Japanese)

Awaji, S., Nakamura, K., Moriguchi, E., Kato, Y. and Ishii, T. (2004) Chemical compositions of altered volcanic rocks in the western Pacific seamount, Uyeda Ridge. Resource Geol., Soc.4 Resource Geol., Japan 54, 125-138. (in Japanese with English abstract)

Beghein, C., Yuan, K., Schmerr, N., Xing, Z. (2014) Changes in Seismic Anisotropy Shed Light on the Nature of the Gutenberg Discontinuity. Science 343, 1237-1240.

Buchs, D. M., Pilet, S., Baumgartner, P., Cosca, M., Flores, K. E. and Bandini, A. N. (2013) Low-volume intraplate volcanism in the Early/Middle Jurassic Pacific basin documented by accreted sequences in Costa Rica. Geochem. Geophys. Geosyst. 1, doi: 10.1002/ggge.20084

Cadet, J. P., Kobayashi, K., Aubouin, J., Boulegue, J., Deplus, C., Von Huene, R., Jolivet, L., Kanazawa, T., Kasahara, J., Koizumi, K., Lallemand, S., Nakamura, Y., Pautoto, G., Suyehiro, K., Tani, S., Tokuyama, H. and Yamazaki, T. (1987) The Japan Trench and its juncture with the Kuril Trench: cruise results of the Kaiko project, Leg 3, Earth Planet. Sci. Lett., 83, 267-284.

Caldwell, J. G., Haxby, W. F., Karig, D. E. and Turcotte, D. L. (1976) On the applicability of a universal elastic trench profile. Earth Planet. Sci. Lett. 31, 239–246.

Carlson, R. L. and Johnson, H. P. (1994) On modeling the thermal evolution of the oceanic upper mantle: An assessmento f the cooling plate model. J. Geophys. Res. 99, B2, 3201-3214.

Caress, D. W. and Chayes, D. N. (1996) Improved processing of Hydrosweep DS multibeam data on the R/V Maurice Ewing: Marine Geophysical Research, v. 18, p. 631-650.

Chang, Q., Mishima, T., Yabuki, S., Takahashi, Y. and Shimizu, H. (2000) Sr and Nd isotope ratios and REE abundances of moraines in the mountain areas surrounding the Taklimakan Desert, NW China, Geochem. J., 34, 407-427.

Clague, D. A. and Dalrymple, G. B. (1989) Tectonics, geochronology, and origin of the

Hawaiian-Emperor volcanic chain. The Geology of North America, The eastern Pacific and Hawaii (Winterer, E. L., et al., eds.), Decade of North American Geology, vol. N, Geol. Soc. Amer., Boulder, CO., 188-217.

Clague, D. A., Holcomb, R. T., Sinton, J. M., Detrick, R. S., and Torresan, M. E., 1990, Pliocene and Pleistocene alkalic flood basalts on the seafloor north of the Hawaiian islands: Earth Planetary Science Letters, v. 98, p. 175-191.

Clague, D. A., Uto, K., Satake, K. and Davis, A. S. (2002) Eruption style and flow emplacement in the submarine North Arch Volcanic Field, Hawaii: in Hawaiian volcanoes, deep underwater perspectives, Geophysical Monograph, American Geophysical Union, v. 128, p. 65-84.

Clouard, V., Bonneville, A. (2001) How many Pacific hotspots are fed by deep mantle plumes? Geology 29, 695–698.

Crisp, J. A. (1984) Rates of magma emplacement and volcanic output. J. Volcanol. Geotherm. Res. 20, 177–211.

Curewitz, D. and Karson, J. A. (1997) Structural settings of hydrothermal outflow: Fracture permeability maintained by fault propagation and interaction. Journal of Volcanology and Geothermal Research, 79, 149-168.

Dasgupta, R. & Hirschmann, M. M. (2010). The deep carbon cycle and melting in Earth's interior. Earth and Planetary Science Letters 298, 1-13

DeMets, C. (1992) Oblique convergence and deformation along the Kuril and Japan trenches, J. Geophys. Res., vol. 97, no. B12, 17615-17625.

Devey, C.W., Lackschewitz, K.S., Mertz, D.F., Bourdon, B., Cheminée, J.-L., Dubois, J., Guivel, C., Hékinian, R., Stoffers, P. (2003) Giving birth to hotspot volcanoes: Distribution and composition of young seamounts from the seafloor near Tahiti and Pitcairn islands. Geology 31, 395–398.

Dixon, J. E. (1997) Degassing of alkalic basalts: American Mineralogist, v. 82, p. 368-378.

Dupré B. and Allègre C. J. (1983) Pb-Sr isotope variation in Indian Ocean basalts and mixing phenomena. Nature 303, 142-146.

Ebisawa, N., Sumino, H., Okazaki, R., Takigami, Y., Hirano, N., Nagao, K. and Kaneoka, I. (2004) Construction of I-Xe and 40Ar-39Ar dating system using a modified VG3600 noble gas mass spectrometer", Journal of Mass Spectrometry Society of Japan, vol.52, no.4, p.219-229.

Evensen, N. M., Hamilton, P. J. and O'Nions, R. K. (1978) Rare-earth abundances in chondritic meteorites, Geochim. Cosmochim. Acta, 42, 1199-1212.

Faul, U. H. and Jackson, I. (2005) The seismological signature of temperature and grain

size variations in the upper mantle. Earth Planet. Sci. Lett. 234, 119-134.
Fisher, R. V. and Schmincke, H.-U. (1984) Pyroclastic Rocks. Springer Verlag, 472 pp.
Fornari, D. J., Batiza, R. and Luckman, M. A. (1987) Seamount abundances and distribution near the East Pacific Rise 0-24 deg N based on Seabeam data: In Keating, B. H., Fryer, P., Batiza, R. and Boehlert, G. (eds.), Seamounts, Islands and Atolls, AGU Geophysical Monograph, v. 43, p. 13-21.
Frey, F. A., Clague, D., Mahoney, J. J. and Sinton, J. M. (2000) Volcanism at the edge of the Hawaiian plume: petrogenesis of submarine alkalic lavas from the North Arch Volcanic Field. J. Petrol. 41, 667-691.
Fujimaki, H., Tatsumoto, M. and Aoki, K. (1984) Partition coefficients of Hr, Zr and REE between phenocrysts and groundmasses. Proceedings of the fourteenth lunar and planetary science conference, Part 2. J. Geophys. Res. 89, Suppl. B662-B672.
Fujiwara, T., Hirano, N., Abe, N. and Takizawa, K. (2007) Subsurface structure of the "petit-spot" volcanoes on the northwestern Pacific Plate. Geophys. Res. Lett. 34, L13305, doi: 10.1029/2007GL030439.
Gaillard, F., Malki, M., Marziano, G. I.-, Pichavant, M. and Scaillet, B. (2008) Carbonatite melts and electrical conductivity in the asthenosphere. Science 322, 1363-1365.
Gonnerman, H. M. and Mukhopadhyay, S. (2007) Non-equilibrium degassing and a primordial source for helium in ocean-island volcanism. Nature 449, 1037-1040.
Gradstein, F. M., Agterberg, F. P., Ogg, J. G., Hardenbol, J., Veen, P. V., Thierry J. and Huang, Z. (1994) A Mesozoic time scale, J. Geophys. Res., 99, 24051-24074.
Gripp, A. E. and Gordon, R. G. (1990) Current plate velocities relative to the hotspots incorporating the NUVEL-1 global plate motion model: Geophysical Research Letters, v. 17, p. 1109-1112.
Gripp, A. E. and Gordon, R. G. (2002) Young tracks of hotspots and current plate velocities. Geophys. J. International 150, 321-361.
Hanyu T., Kaneoka I. and Nagao K. (1999) Noble gas study of HIMU and EM ocean island basalts in the Polynesian region - Reading the Isotopic Code. Geochim. Cosmochim. Acta 63, 1181-1201.
Harigane, Y., Mizukami, T., Morishita, T., Michibayashi, K., Abe, N., Hirano, N. (2011) Direct evidence for upper mantle structure in the NW Pacific Plate: microstructural analysis of a petit-spot peridotite xenolith. Earth and Planetary Science Letters, 302, 194–202.
Hart, S. R., Staudigel, H., Koppers, A. A. P., Blusztajn, J., Baker, E. T., Workman, R.,

Jackson, M., Hauri, E., Kurz, M., Sims, K., Fornari, D., Saal, A. and Lyons, S. (2000) Vailulu'u undersea volcano: The new Samoa. Geochem. Geophys. Geosyst. 1, 1056, doi: 10.1029/2000GC000108.

Hasegawa, A., Horiuchi, S. and Umino, N. (1994) Seismic structure of the northwestern Japan convergent margin: A synthesis. J. Geophys. Res. 99, 22295-22311.

Hashimoto, M., and Jackson, D. D. (1993) Plate tectonics and crustal deformation around the Japanese Islands, J. Geophys. Res., vol. 98, no. B9, 16149-16166.

Hekinian, R., Cheminée, J-L., Dubois, J., Stoffers, P., Scott, S., Guivel, C., Garbe-Schönberg, C-D., Devey, C., Bourdon, B., Lackschewitz, K., McMurtry, G. and Le Drezen, E. (2003) The Pitcairn Hotspot in the South Pacific: distribution and composition of submarine volcanic sequences: Journal of Volcanology and Geothermal Research, v. 121, p. 219-245.

Hieronymus, C.F. and Bercovici, D. (2000) Non-hotspot formation of volcanic chains: control of tectonic and flexural stresses on magma transport. Earth Planet. Sci. Lett. 181, 539-554.

Hirano, N. (2011) Petit-spot volcanism: a new type of volcanic zone discovered near a trench. Geochemical Journal, 45, 157–167.

Hirano, N., Kawamura, K., Hattori, M., Saito, K., and Ogawa, Y. (2001) A new type of intra-plate volcanism: young alkali-basalts discovered from the subducting Pacific Plate, northern Japan Trench: Geophysical Research Letters, v. 28, p. 2719-2722.

Hirano, N., Clague, D. A., Hirata, T., Coombs, M. and Takahashi, E. (2003) Controls on eruptive style for North Arch lavas: Geochimica Cosmochimica Acta, v. 67, p. A148.

Hirano, N., Ogawa, Y. and Saito, K. (2002): Long-lived early Cretaceous seamount volcanism in the Mariana Trench, Western Pacific Ocean. Marine Geol., 189, 371-379.

Hirano, N., Yamamoto, J., Kagi, H. and Ishii, T. (2004) Young alkali-basalt in the western Pacific containing xenocryst olivine from the lithospheric mantle: Contributions to Mineralogy and Petrology, v. 147, DOI: 10.1007/s00410-004-0593-z.

Hirano, N., Takahashi, E., Yamamoto, J., Abe, N., Ingle, S. P., Kaneoka, I., Kimura, J., Hirata, T., Ishii, T., Ogawa, Y., Machida, S. and Suyehiro, K. (2006) Volcanism in response to plate flexure. Science 313, 1426–1428.

Hirano, N., Koppers, A. A. P., Takahashi, A., Fujiwara, T. and Nakanishi, M. (2008) Seamounts, knolls and petit spot monogenetic volcanoes on the subducting

Pacific Plate. Basin Res. 20, 543-553.
Hirano, N., Abe, N., Yamamoto, J. and Machida, S. (2010) New insights into the oceanic lithosphere from petit-spot volcanoes and "Super-Mohole" project. J. Geol. Soc. Japan 116, 1-12. (in Japanese with English abstract)
Hirano, N., Machida, S., Abe, N., Morishita, M., Tamura, A. and Arai, S. (2013) Petit-spot lava fields off the central Chile trench induced by plate flexure. Geochemical Journal, 47, 249-257.
Hirschmann, M. M. (2000) Mantle solidus: Experimental constraints and the effects of peridotite composition. Geochem. Geophys. Geosyst. 1, 1042, doi: 10.1029/2000GC000070.
Hirose, K. and Kushiro, I. (1993) Partial melting of dry peridotites at high pressures: determination of compositions of melts segregated from peridotite using aggregates of diamond. Earth Planet. Sci. Lett. 114, 477-489.
Hirth, G., Kohlstedt, D. (1996) Rheology of the upper mantle and the mantle wedge: a view from the experimentalists. in Inside the Subduction Factory (ed J. Eiler), Geophysical Monograph Series, American Geophysical Union, Washington, D. C.. DOI: 10.1029/138GM06
Hoernle, K., Tilton, G., Le Bas, M. J., Duggen, S. and Garbe-Schönberg, D. (2002) Geochemistry of oceanic carbonatites compared with continental carbonatites: mantle recycling of oceanic crustal carbonate. Contrib. Mineral Petrol. 142, 520–542, doi: 10.1007/s004100100308.
Hofmann, A. W. and Hart, S. R. (2007) Another Nail in Which Coffin?. Science 315, 39-40, doi: 10.1126/science.315.5808.39c.
Holcomb, R.T., Holmes, M., Denlinger, R.P., Searle, R.C., Normark, W.R. (1988) Submarine Hawaiian north arch volcanic field. EOS 69, 1445–1445.
Honda, M., McDougall, I., Patterson, D.B., Doulgeris, A. and Clague, D.A. (1991) Possible solar noble gas component in Hawaiian basalts. Nature 349, 149-151.
Iwata, N. and Kaneoka, I. (2000) On the relationships between the 40Ar-39Ar dating results and the conditions of basaltic samples. Geochem. J. 34, 271-281.
Jackson, E. D. and Wright, T. L. (1970) Xenoliths in the Honolulu volcanic series, Hawaii: Journal of Petrology, v. 11, p. 405-430.
Johnson, R. H. (1970) Active submarine volcanism in the Austral Islands. Science 167, 977-979.
Jokiel P.L. and Cox E.F. (2003) Drift pumice at Christmas Island and Hawaii: evidence of oceanic dispersal patterns. Marine Geology, 202, 121–133.
Kamikuri, S., Nishi, H., Motoyama, I. and Saito, S. (2004) Middle Miocene to

Pleistocene radiolarian biostratigraphy in the Northwest Pacific Ocean, ODP Leg 186. The Island Arc 13, 191-226.

Kaneoka, I. (2000) Earth's history trapped in the mantle. Science 288, 988 - 989.

Karato, S. (1990) The role of hydrogen in the electrical conductivity of the upper mantle. Nature 347, 272–273.

Karato, S. (2012) On the origin of the asthenosphere. Earth and Planetary Science Letters 321–322, 95–103.

Karato, S. and Jung, H. (1998) Water, partial melting and the origin of the seismic low velocity and high attenuation zone in the upper mantle. Earth Planet. Sci. Lett. 157, 193-207.

Kawada, Y., Yamano, M., Seama, M. (2014) Hydrothermal heat mining in an incoming oceanic plate due to aquifer thickening: Explaining the high heat flow anomaly observed around the Japan Trench. Geochemistry, Geophysics, Geosystems 15, 1580-1599. DOI: 10.1002/2014GC005285

Kawakatsu, H., Kumar, P., Takei, Y., Shinohara, M., Kanazawa, T., Araki, E. and Suyehiro K. (2009) Seismic evidence for sharp lithosphere-asthenosphere boundaries of oceanic plates. Science 324, 449-502.

Kawamura, K. (2007) Occurrence of young basaltic rocks on the oceanward slope of the Japan Trench, off Miyako, NE Japan: discovery by KAIKO 10K#56 dive. J. Geol. Soc. Japan 113, VII-VIII.

Keller, G. (1980) Benthic foraminifers and paleobathymetry of the Japan Trench area, Deep Sea Drilling Project, in Initial Reports of the Deep Sea Drilling Project, edited by Scientific Party, U. S. Govt. Printing Office, Washington, D. C., Leg. 57, pp. 835-865.

Kimura, G., and Tamaki, K. (1985) The Kuril Arc and Kuril Basin - the relationship between rotation of backarc plate and backarc spreading, J. Geography, vol. 94, no. 2, 69-83.

Kinoshita, O. and Ito, H. (1992) Southward movement and collision of northeast Japan against southwest Japan from the Cretaceous to the Paleogene, J. Geol. Soc. Japan, vol. 98, no. 3, 223-233.

Kirby, S. H. (1983) Rheology of the lithosphere: Reviews of Geophysics and Space Physics, v. 21, p. 1458-1487.

Kobayashi, K., Cadet, J. P., Aubouin, J., Boulegue, J., Dubois, J., Von Huene, R., Jolivet, L., Kanazawa, T., Kasahara, J., Koizumi, K., Lallemand, S., Nakamura, Y., Pautot, G., Suyehiro, K., Tani, S., Tokuyama, H. and Yamazaki, T. (1987) Normal faulting of the Daiichi-Kashima Seamount in the Japan Trench revealed by the Kaiko I cruise, Leg 3., Earth Planet. Sci. Lett., 83, 257-266.

Kobayashi, K., Nakanishi, M., Tamaki, K. and Ogawa, Y. (1998). Outerslope faulting associated with the eastern Kuril and Japan Trenches: Geophysical Journal International, v. 134, p. 356-372.

Kobayashi, T., Yamamoto, J., Hirajima, T., Ishibashi, H., Hirano, N., Lai, Y., Prikhod'ko, V. S., Arai, S. (2012) Conformity and precision of CO2 densimetry in CO2 inclusions: microthermometry versus Raman microspectroscopic densimetry. J. Raman Spectr. 43, 1126–1133.

Koppers, A. A. P., Staudigel, H. and Wijbrans, J. R. (2000) Dating crystalline groundmass separates of altered Cretaceous seamount basalts by the 40Ar/39Ar incremental heating technique. Chemical Geology 166, 139–158.

Koppers, A. A. P., Staudigel, H., Pringle, M. S. and Wijbrans, J. R. (2003) Short-lived and discontinuous intraplate volcanism in the South Pacific: Hot spots or extensional volcanism? Geochem. Geophys. Geosyst. 4, 1089, doi:10.1029/2003GC000533.

Koppers, A. A. P., Staudigel, H. and Duncan, R. A. (2003) High-resolution 40Ar/39Ar dating of the oldest oceanic basement basalts in the western Pacific basin. Geochem. Geophys. Geosyst. 4, doi:10.1029/2003GC000574.

Koyama, M. and Umino, S. (1991) Why does the Higashi-Izu monogenetic volcano group exist in the Izu Peninsula?: relationships between late Quaternary volcanism and tectonics in the northern tip of the Izu-Bonin Arc. J. Phys. Earth 39, 391–420.

Lambert, I. B., and Wyllie, P. J. (1968) Stability of hornblende and a model for the low velocity zone: Nature, v. 219, p. 1240-1241.

Le Bas, M. J. (1962) The role of aluminum in igneous clinopyroxenes with relation to their percentage, Am. J. Sci., 260, 267-288.

Levitt, D. A., and Sandwell, D. T. (1995) Lithospheric bending at subduction zones based on depth soundings and satellite gravity: Journal of Geophysical Research, v. 100, n. B1, p. 379-400.

Liu, C.-Q., Masuda, A., Okada, A., Yabuki, S. and Fan, Z.-L. (1994) Isotope geochemistry of Quaternary deposits from the arid lands in northern China, Earth. Planet. Sci. Lett., 127, 25-38.

Machida, S., Hirano, N. and Kimura, J. (2009) Evidence for recycled plate material in Pacific upper mantle unrelated to plumes. Geochim. Cosmochim. Acta 73, 3028–3037, doi: 10.1016/j.gca.2009.01.026.

Masalu, D. C. P. and Tamaki, K. (1997) Paleomagnetism of the Joban Seamount Chain:

its origin and tectonic implications for the Pacific Plate. J. Geophys. Res., 102, 5145-5155.

Masalu, D.C.P., Ogawa, Y., and Kobayashi, K. (2001) Bathymetry of the Joban seamount chain, northwestern Pacific. Marine Geology, 173, 87-96.

Matsuzaka, S., et al. (1991) Detection of Philippine sea plate motion by very long baseline interferometry, Geophys. Res. Lett., vol. 18, no. 8, 1417-1419.

McAdoo, D. C. and Martin, C. F. (1984) Seasat observation of lithospheric flexure seaward of trenches. J. Geophys. Res. 89, B5, 3201-3210.

McAdoo, D. C., Martin, C. F. and Poulouse, S., 1985, Seasat observations of flexure: Evidence for a strong lithosphere: Tectonophysics, v. 116, p. 209-222.

McDougall I. and Harrison T. (1988) Geochronology and thermochronology by the 40Ar/39Ar method. Oxford University Press, 212 pp.

McKenzie, D. P. and Parker, R. L. (1967) The north Pacific: an example of tectonics on a sphere. Nature 216, 1276–1280.

McNutt, M. K. (2006) Another Nail in the Plume Coffin? Science 313, 1394, doi: 10.1126/science.1131298.

McNutt, M. K., Caress, D. W., Reynolds, J., Jordahl1, K. A. and Duncan, R. A. (1997) Failure of plume theory to explain midplate volcanism in the southern Austral islands. Nature 389, 479-482.

Mierdel, K., Keppler, H., Smyth, J. R. and Langenhorst, F. (2007) Water solubility in aluminous orthopyroxene and the origin of Earth’s Asthenosphere. Science 315, 364-368.

Moore, J. G., Normark, W. R. and Lipman, P. W. (1979) Loihi seamount–a young submarine Hawaiian volcano (abstract). Hawaii Symposium Intraplate Volccanoes & Submarine Volcanoes, 127.

Moore, J. G., Fornari, D. J. and Clague, D. A. (1985) Basalts from the 1877 submarine eruption of Mauna Loa, Hawaii: new data on the variation of palagonitization rate with temperature. US Geol. Surv. Bull. 1663, 1-11.

Morgan, W. J. (1971) Convection plumes in the lower mantle. Nature 230, 42–43.

Motoyama, I. and Maruyama, T. (1998) Neogene diatom and radiolarian biochronology of the middle-to-high latitudes of the Northwest Pacific region: Calibration to the Cande and Kent’s geomagnetic polarity time scales (CK 92 and CK95). Journal of Geological Society of Japan, v. 104, p. 171-183. (in Japanese with English abstract)

Nakanishi, M. (1993) Topographic expression of five fracture zones in the northwestern Pacific Ocean. In The Mesocoic Pacific: Geology, Tectonics, and Volcanism, (edited by M. S. Pringle et al.,) Geophys. Monogr. Ser., AGU, 77, 121-135.

Nakanishi, M. and Winterer, E. L. (1998) Tectonic history of the Pacific-Farallon-Phoenix triple junction from Late Jurassic to Early Cretaceous: An abandoned Mesozoic spreading system in the Central Pacific Basin: Journal of Geophysical Research, v. 103, p. 12453-12468.

Nakanishi, M., Sager, W. W. and Klaus, A. (1999) Magnetic lineations within Shatsky Rise, northwest Pacific Ocean: implications for hotspot-triple junction interaction and oceanic plateau formation. J. Geophys. Res., 104, 7359-7556.

Nakanishi, M., Tamaki, K. and Kobayashi, K. (1989) Mesozoic magnetic anomaly lineations and seafloor spreading history of the Northwestern Pacific. J. Geophys. Res. 94, 15437-15462.

Nakanishi, M., Tamaki, K. and Kobayashi, K. (1992a) Magnetic anomaly lineations from late Jurassic to Early Cretaceous in the west-central Pacific Ocean. Geophys. J. International, 144, 535-545.

Nakanishi, M., Tamaki, K. and Kobayashi, K. (1992b): A new Mesozoic isochron chart of the northwestern Pacific Ocean: paleomagnetic and tectonic implications. Geophys. Res. Lett., 19, 693-696.

Nakanishi, M., and Winterer, E.L. (1996) Tectonic events of the pacific Plate related to formation of Ontong Java Plateau (abstract), EOS Trans, AGU 77 (46), Fall Meeting, Suppl., F713.

Natland, J. H. (1980) The progression of volcanism in the Samoan liner volcanic chain: American Journal of Science, v. 280-A, p. 709-735.

Niitsuma, N. (1989) Neogene tectonic evolution of southwest Japan, Modern Geology, vol. 12, no. 1-4, 497-532.

Ogawa Y., Hirano, H. and the Shipboard Scientific Party (2003) Cruise report of R/V KAIREI, KR03-07. JASTEC.

Ogawa, Y. and Kobayashi, K. (1993) Mud ridge on the crest of the outer swell off Japan Trench. Marine Geology, 111, 1-6.

Ogawa, Y., Kobayashi, K., Hotta, H. and Fujioka, K. (1997) Tension cracks on the oceanward slopes of the northern Japan and Mariana Trenches: Marine Geology, v. 114, p. 111-123.

Ohki, J., Watanabe, N., Shuto, K., and Itaya, T. (1993) Shifting of the volcanic fronts during Early to Late Miocene in the northeast Japan arc, The Island Arcs, 2, 87-93.

Oikawa, M. and Morishita, T. (2009) Submarine topography in the east sea to the Minami−Tori Shima Island, Northwest Pacific Ocean. Rept. Hydrogr., Oceanogr.

Res. 45, 13-22.
Okino, K. and Fujioka, K. (2003) The Central Basin Spreading Center in the Philippine Sea: Structure of an extinct spreading center and implications for marginal basin formation: Journal of Geophysical Research, v. 108, 2040, doi:10.1029/2001JB001095.
Okumura, S. and Hirano, N. (2013) Carbon dioxide emission to Earth's surface by deep-sea volcanism. Geology, 41, 1167-1170, DOI | 10.1130/G34620.1
Owens, W. B. and Warren, B. A. (2001) Deep circulation in the northwest corner of the Pacific Ocean. Deep-Sea Res. I 48, 959-993.
Ozawa, A., Tagami, T. and Garcia, M. (2005) Unspiked K–Ar dating of the Honolulu rejuvenated and Ko‘olau shield volcanism on O‘ahu, Hawai‘i. Earth. Planet. Sci. Lett. 232, 1-11.
Ozima M. and Podosek F. A. (2002) Noble gas geochemistry. Cambridge University Press, Cambridge.
Ozima, M., Honda, M. and Saito, K. (1977) 40Ar/39Ar ages of guyots in the western Pacific and discussion of their evolution, Earth Planet. Sci. Lett., 51, 475-485.
Papale, P. (1999) Modeling of the solubility of a two-component H2O + CO2 fluid in silicate liquids: American Mineralogist, v. 84, p. 477-492.
Parsons, B., and Sclater, J.G. (1977) An analysis of the variation of ocean floor bathymetry and heat flow with age: Journal of Geophysical Research, v. 82, p. 803-827.
Priestley K, McKenzie D (2006) The thermal structure of the lithosphere from shear wave velocities. Earth Planet Sci Lett 244:285–301.
Ranero, C. R., Villaseñor, A., P. J., Morgan and Weinrebe, W. (2005) Relationship between bend-faulting at trenches and intermediate-depth seismicity. Geochem. Geophys. Geosyst. 6, Q12002, doi: 10.1029/2005GC000997.
Sager, W.W., Kim, J., Kalus, A., Nakanishi, M., and Khankishieva, L.M. (1999) Bathymetry of Shatsky Rise, northwestern pacific Ocean: Implications for ocean plateau development at a triple junction. J. Geophys. Res., 104, 7557-7576.
Sakai, T. (1980) Radiolarians from Sites 434, 435, and 436, Northwest Pacific, Leg 56, Deep Sea Drilling Project: In Scientific Party, Initial Reports of the Deep Sea Drilling Project, 56/57, Pt. 2, Washington, D.C., U.S. Government Printing Office, p. 695-733.
Sakai, T. (1980) Radiolarians from Sites 434, 435, and 436, Northwest Pacific, Leg 56, Deep Sea Drilling Project: In Scientific Party, Initial Reports of the Deep Sea Drilling Project, 56/57, Pt. 2, Washington, D.C., U.S. Government Printing

Office, p. 695-733.

Sakamaki, T., Suzuki, A., Ohtani, E., Terasaki, H., Urakawa, S., Katayama, Y., Funakoshi, K., Wang, Y., Hernlund, J. W., Ballmer, M. D. (2013) Ponded melt at the boundary between the lithosphere and asthenosphere. Nature Geoscience 6, 1041-1044.

Sandwell, D. T. and Smith, W. H. F. (1997) Marine gravity anomaly from Geosat and ERS-1 satellite altimetry: Jounal of Geophysical Research, v. 102, p. 10039-10054.

Sandwell, D.T., Smith, W.H.F., 2009. Global marine gravity from retracked Geosat and ERS-1 altimetry: Ridge Segmentation versus spreading rate. Journal of Geophysical Research 114, B01411. doi:10.1029/2008JB006008.

Sarda P., Staudacher T. and Allegre C.J. (1988) Neon isotopes in submarine basalts. Earth Planet. Sci. Lett. 91, 73-88.

Seno, T. (1985) Is northern Honshu a microplate?, Tectonophys., vol. 115, no. 3.4, 177-196.

Seno, T., Ogawa, Y., Tokuyama, H., Nishiyama, E. and Taira, A. (1989) Tectonic evolution of the triple junction off central Honshu for the past 1 million yeara, Tectonophys., vol. 160, 91-116.

Seno, T., and Sakurai, T. (1996) Can the Okhotsk plate be discriminated from the North American Plate, J. Geophys. Res., vol. 101, no. B5, 11305-11315.

Shen-Tu, B., and Holt, W. E. (1996) Interseismic horizontal deformation in northern Honshu and its relationship with the subduction of the Pacific plate in the Japan trench, Geophys. Res. Lett., vol. 23, no. 22, 3103-3106.

Shimamura, H., Asada, T., Suyehiro, K., Yamada, T., and Inatani, H. (1983) Longshot experiments to study velocity anisotropy in the oceanic lithosphere of the northwestern Pacific. Phys. Earth Planet. Interiors 31, 348-362.

Shinohara, M., Fukano, T., Kanazawa, T., Araki, E., Suyehiro, K., Mochizuki, M., Nakahigashi, K., Yamada, T., and Kimihiro, M. (2008) Upper mantle and crustal seismic structure beneath the Northwestern Pacific Basin using a seafloor borehole broadband seismometer and ocean bottom seismometers. Phys. Earth Planet. Interiors 170, 95-106.

Shoberg, T., and Bina, C. R. (1994) Some effect of anisotropy on velocity contrasts between subducting lithosphere and overriding mantle, Geophys. Res. Lett., vol. 21, no. 18, 1951-1954.

Sifré, D., Gardés, E., Massuyeau, M., Hashim, L., Hier-Majumder, S., Gaillard, F. (2014) Electrical conductivity during incipient melting in the oceanic low-velocity zone. Nature 509, 81-85.

Smith, J. R., Satake, K. and Suyehiro, K. (2001) Deepwater multibeam sonar surveys along the southeastern Hawaiian Ridge: Guide to the CD-ROM: Geophysical Monograph, American Geophysical Union, v. 128, p. 3-9.

Staudacher, T. and Allègre, C. J. (1982) Terrestrial xenology. Earth Planet. Sci. Lett. 60, 389-406.

Stein, C.A., and Stein, S. (1992) A model for the global variation in oceanic depth and heat flow with lithospheric age. Nature 359, 123-129.

Stixrude L, Lithgow-Bertelloni C (2005) Mineralogy and elasticity of the oceanic upper mantle: Origin of the low-velocity zone. J Geophys Res 110:B03204.

Takahashi, E and Kushiro, I. (1983) Melting of a dry at high pressures and basalt magma genesis. Am. Mineral. 68, 859-879.

Takahashi, E. (1986) Origin of basaltic magmas –implications from peridotite melting experiments and an olivine fractionation model–. Bull. Volcanol. Soc. Jap. 30, S17-S40.

Takahashi, E., Nakajima, K. and Wright, T. L. (1998) Origin of the Columbia River Basalts: Melting model of a heterogeneous plume head. Earth Planet. Sci. Lett. 162, 63-80.

Takigami, Y., Kaneoka, I., Ishi, T., Nakamura, Y. (1989) 40Ar-39Ar ages of igneous rocks recovered from Daiichi-Kashima and Erimo Seamounts during the KAIKO project, Palaeogeography, Palaeoclimatology, Palaeoecology, 71, 71-81.

Taneja, R., O'Neill, C., Lackie, M., Rushmer, T., Schmidt, P., Jourdan, F. (2014) 40Ar/39Ar geochronology and the paleoposition of Christmas Island (Australia), Northeast Indian Ocean. Gondwana Research, in press.

Taylor, B., Crook, K., and Sinton, J. (1994) Extensional transform zones and oblique spreading centers. J. Geophys. Res., 99 (B10), 19,707-19,718.

Uenzelmann-Neben, G., Schmidt, D. N., Niessen, F., Stein, R. (2012) Intraplate volcanism off South Greenland: caused by glacial rebound? Geophysical Journal International 190, 1-7.

Valentine, G. and Hirano, N. (2010) Mechanisms of low-flux intraplate volcanic fields –Basin and Range (North America) and Northwest Pacific Ocean. Geology 38, 55–58, doi: 10.1130/G30427.1.

von Huene, R., Langseth, M., Nasu, N. and Okada, H. (1980) Summary, Japan Trench transect, in Initial Reports of the Deep Sea Drilling Project, edited by Scientific Party, U.S.Govt. Printing Office, pp. 473-503.

von Huene, and Nasu, N. (1978) Japan Trench transected, on Leg 57, Geotimes, vol. 23,

no. 4, 16-21.
Wang, D., Mookherjee, M., Xu, Y. and Karato, S. (2006) The effect of water on the electrical conductivity of olivine. Nature 443, 977–980.
Watts, A. B. (2001) Isostasy and flexure of the lithosphere. Cambridge University Press, Cambridge.
Watts, A. B. and Talwani, M. (1974) Gravity anomalies seaward of deep-sea trenches and their tectonic implications. Geophys. J. R. Astron. Soc. 36, 57–90.
Watts, A. B. and Zhong, S. (2000) Observations of flexure and the rheology of oceanic lithosphere: Geophysical Journal International, v. 142, p. 855-875.
Wessel, P. and Smith, W. H. F. (1998) New version of the Generic Mapping Tools released: EOS Transactions, AGU, v. 76, p.329.
Wessel, P. (1992) Thermal stresses and the bimodal distribution of elastic thickness estimates of the oceanic lithosphere: Journal of Geophysical Research, v. 97, p. 14177-14193.
Wetherill, (1954) G. W. Variations in the isotopic abundances of neon and argon extracted from radioactive minerals. Phys. Rev. 96, 679-683.
Wyllie, P. J. (1988) Magma genesis, plate tectonics, and chemical differentiation of the Earth. Rev. Geopohys. 26, 370-404.
Wyllie P J (1988) Solidus curves mantle plumes and magma generation beneath Hawaii. J Geophys Res 93:4171–4181.
Wyllie, P. J. (1995) Experimental petrology of upper mantle materials, processes and products. J. Geodynamics 20, 429-468.
Yamamoto, J., Hirano, N., Hanyu, T., Kagi, H., and Kaneoka, I. (2003) Noble gases in mantle- derived xenocrysts in an alkali basalt from Japan Trench oceanward slope: in Plumes and problems of deep structures of alkaline magmatism, Russian Academy of Sciences,
Yamamoto, J., Hirano, N., Abe, N., Hanyu, T. (2009) Noble gas isotopic compositions of mantle xenoliths from northwestern Pacific lithosphere. Chemical Geology, 268, 313–323.
Yamamoto, J., Nishimura, K., Sugimoto, T., Takemura, K., Takahata, N. & Sano, Y. (2009) Diffusive fractionation of noble gases in mantle with magma channels: origin of low He/Ar in mantle-derived rocks. Earth Planet. Sci. Lett. 280, 167-174.
Yamamoto, J., Otsuka, K., Ohfuji, H., Ishibashi, H., Hirano, H., and Kagi, H. (2011) Retentivity of CO_2 in fluid inclusions in mantle minerals. Eur. J. Mineral., 23, 805–815.

Yamamoto, J., Nishimura, K., Ishibashi, H., Kagi, H., Arai, S. & Prikhod'ko, V. S. (2012) Thermal structure beneath Far Eastern Russia inferred from geothermobarometric analyses of mantle xenoliths: direct evidence for high geothermal gradient in backarc lithosphere. Tectonophysics 554–557, 74–82.

Yamamoto, J., Korenaga, J., Hirano, N., Kagi, H. (2014) Melt-rich lithosphere-asthenosphere boundary inferred from petit-spot volcanoes. Geology, in press.

Yoshino, T., Matsuzaki, T., Yamashita, S. and Katsura, T. (2006) Hydrous olivine unable to account for conductivity anomaly at the top of the asthenosphere. Nature 443, 973–976.

Yoshino, T., Matsuzaki, T., Shatskiy, A. and Katsura, T. (2009) The effect of water on the electrical conductivity of olivine aggregates and its implications for the electrical structure of the upper mantle. Earth Planet. Sci. Lett. 288, 291–300.

Yuzo K. (1987) Woody pumice generated with submarine eruption. J. Geol. Soc. Japan, 93, 11-20.

Zhang, J., Takahashi, K., Wushiki, H., Yabuki, S., Xiong, J.-M. and Masuda, A. (1995) Water geochemistry of the rivers around the Taklimakan Desert (NW China): Crustal weathering and evaporation processes in arid land, Chem. Geol., 119, 225-237.

7. Notice on Using

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

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