doi : 10.17596/0003220

CRUISE REPORT

JAPAN AGENCY FOR MARINE-EARTH SCIENCE AND TECHNOLOGY

R/V YOKOSUKA YK09-05 CRUISE

COMPOSITION AND STRUCTURE OF AN OCEANIC CORE COMPLEX: A DIVE STUDY OF GODZILLA MULLION

MAY 3, 2009 TO MAY 22, 2009

(YOKOSUKA TO CHICHI-JIMA ISLAND, JAPAN)

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Users of the data and/or results of this cruise are requested to submit their results to Data Integration and Analysis Group, JAMSTEC (diag-dmg@jamstec.go.jp).

Acknowledgements

We are grateful to captain Eiko Ukekura, the Shinkai operation team manager Toshiaki Sakurai, the crew of R/V Yokosuka , and the Shinkai team for their outstanding efforts to make this scientific program successful. We also thank JAMSTEC for their support of this project. The U.S. science group acknowledges the support of a National Science Foundation grant to the University of Houston.

1. General cruise information

Cruise number / ship name: YK09-05 / R/V Yokosuka

Title of the cruise:
"Composition and structure of an oceanic core complex: a dive study of Godzilla Mullion"

Proposal number and scientific title:
S09-23 "Composition and structure of an oceanic core complex: a dive study of Godzilla Mullion"

Period of the cruise: May 3-May 22, 2009

Port calls:
Departure: Yokosuka (May 3, 2009)
Arrival: Chichi-jima Island May 22, 2009)

Investigation area:
Godzilla Mullion in the Parece Vela Basin by the following coordinates:
15°00.0'N, 138°30'E
15°00.0'N, 140°00'E
17°00.0'N, 138°30'E
17°00.0'N, 140°00'E

Shinaki 6500 and deep-towed camera dive list:
6K-#1140: Yasuhiko Ohara
6K-#1141: Henry J.B. Dick
6K-#1142: Jonathan E. Snow
6K-#1143: Yumiko Harigane
6K-#1144: Katsuyoshi Michibayashi
6K-#1145: Hiroyuki Yamashita
6K-#1146: Teruaki Ishii
6K-#1147: Dorene Nakata
6K-#1148: Yasuhiko Ohara
YKDT-#62
YKDT-#63
YKDT-#64

2. Introduction

Oceanic core complexes (OCCs) are domal bathymetric highs interpreted as portions of the lower crust and/or upper mantle exposed via low-angle detachment faulting. OCCs have been recognized in many places along intermediate, slow and ultra-slow spreading ridges.

Godzilla Mullion occurs along the Parece Vela Rift, extinct spreading center of the Parece Vela Basin (Fig. 1). Godzilla Mullion is a uniquely interesting geologic structure for a number of important reasons including (Ohara et al., 2001; 2003a):

- Godzilla Mullion is the largest known OCC so far, with approximate dimension ~ 125 km × ~ 55 km, being about the size of the US state of Delaware, which is almost three times as large as the metropolis of Tokyo.
- It formed in a backarc setting, allowing the only access to the lower crust and upper mantle of a young oceanic backarc.

In order to distinguish different processes of OCC formation, the composition of the backarc mantle, and to provide a comparison of present day backarc mantle useful for the study of ophiolitic lower crustal and mantle sequences, we have conducted a series of cruises to the area during the past few years. As the IODP Expeditions 304/305 at Atlantis Massif in the Mid-Atlantic Ridge have shown (Ildefonse et al., 2007), however, there is significant geological variability in the footwalls of mullion structures that cannot necessarily be identified by seismic site survey complemented by dredging. For this reason, we conducted dive operations on Godzilla Mullion.

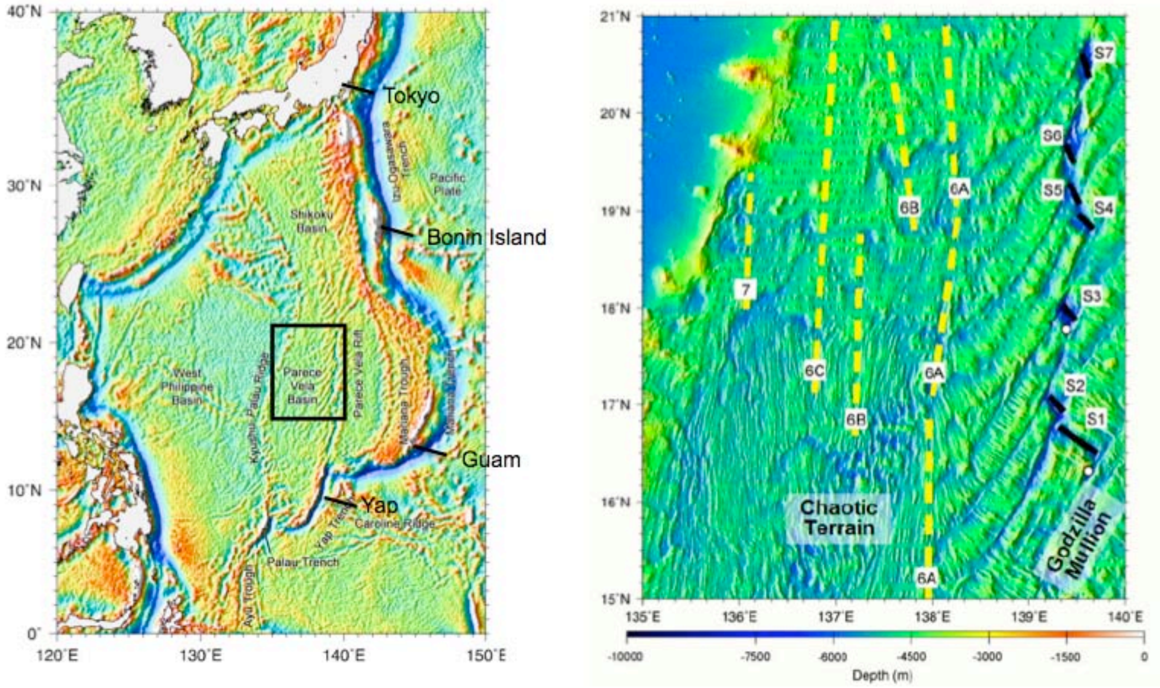

Fig. 1. Locality map of the Parece Vela Basin and Godzilla Mullion (Ohara et al. 2001).

3. Objectives of the cruise

The primary objective of the cruise is to map and sample Godzilla Mullion using the Shinkai 6500 and deep-towed camera, thereby to test the hypothesis that Godzilla Mullion represents a large and long-live detachment surface, and to construct an evolutionary model of Godzilla Mullion. In particular, we wished to test the hypothesis that Godzilla Mullion is a gabbro massif with an onlying peridotite sheath, or whether it exposes mixed rooted mantle and gabbroic components, or perhaps a combination of both. In detail, we considered that the following items are particularly important:

3-1. Lithological mapping of the Godzilla Mullion

Understanding the detailed outcrop pattern within the mullion structure remains a major goal of the overall research effort. Despite the extensive survey conducted so far, the massive size of the mullion structure spreads the ~24 sampling stations to date over a huge area. Dive sampling and observations allow us to far better constrain the geologic framework of the mullion structure.

3-2. Spatial relationships of fault rocks in the outcrop

The temporal and P-T history of deformation within the detachment surface are critical to understand the core complex as a whole. In situ sampled tectonites from the detachment surface help to constrain different models of the emplacement of the mullion structure.

3-3. Sampling of lithologies beneath the detachment surface

Geologic survey of other OCC structures (Atlantis Massif (IODP Expedition 304/305) and Atlantis Bank (ODP Legs 118, 176 and 179)) has shown that lithologies on the detachment surface may not correspond to those immediately below it. Thus, a gabbroic massif may be sheathed by deformed mantle peridotite along the detachment (Ildefonse et al., 2007). By sampling deeply incised landslide scarps we are able to sample to a limited extent below the detachment. This gives a preliminary indication of the relationship between seismic and petrologic structure of core complexes suggested by Canales et al. (2008).

4. Previous studies

More than 15 expeditions were conducted for the study of Godzilla Mullion and the Parece Vela Basin as of fall 2008. These expeditions included the recent dredging cruises KH07-2 (Ohara et al., 2007a), KH05-1 (Okino et al., 2009) and KR03-01 (Ohara et al., 2003b; Harigane et al., 2008), the Shinkai 6500 dive cruise YK04-05-Leg 4, and the seismic study cruises by the Japanese government for the Law of the Sea (Ohara et al., 2007a; b).

5. Survey items

We conducted nine Shinkai 6500 dives as the primary survey item, although three deep-towed camera dives were also conducted during the cruise. We did not conduct extensive surface geophysical survey (bathymetry mapping, magnetics, and gravity) during the cruise, since the Godzilla Mullion area is almost completely mapped.

6. Running cruise narrative

Local time (Approximate)	Notes
03-May-09	**The Yokosuka YK09-05 cruise began. Since the typhoon #1 has just born near the Godzilla Mullion area, the captain decided to heave-to in the Sagami Bay for approximately 1 day.**
13:00	Scientists arrived at the Yokosuka moored in the Yokosuka Shinko Harbor.
14:00	YK09-05 cruise began. Ship's clocks used Japan local time (UTC + 9 h) during this cruise.
18:15	The Yokosuka anchored off Ito City in the Sagami Bay.
04-May-09	**The Yokosuka anchored off Ito City in the Sagami Bay. In the afternoon, the Yokosuka way underway to the Godzilla Mullion area, making a big detour to escape from the typhoon #1.**
15:30	The Yokosuka weighed anchor and started to steam to the Godzilla Mullion area, making a big detour. The estimated arrival time at the first dive site was afternoon, May 8.
05-May-09	**The Yokosuka was underway to the Godzilla Mullion area. A rough sea condition was encountered during all the day.**
06-May-09	**The Yokosuka was underway to the Godzilla Mullion area. The sea condition became better than the day before.**
07-May-09	**The Yokosuka was underway to the Godzilla Mullion area. The sea became almost calm. The estimated arrival time was 15:00, May 8.**
08-May-09	**The Yokosuka arrived at the Godzilla Mullion area. Bathymetric survey for dives #1140, #1141 and #1148, together with the deep-towed camera DT-2, was conducted in the afternoon.**
13:30-13:45	The Yokosuka arrived at the first dive site on the Godzilla Mullion. XBT was deployed.

14:24-20:18	Bathymetric survey for dives #1140, #1141, and #1148, together with the deep-towed camera DT-2, was conducted.
09-May-09	**Dive #1140 was conducted along the lower western slope of the northern portion of the West Arm Rise. Yasuhiko Ohara as the observer. Bathymetric survey for dives #1142, #1143 and #1144, together with the deep-towed camera DT-1, was conducted during the night.**
9:05	Dive #1140 started (the Shinkai opened vent).
11:18	The Shinkai on bottom (5166 m).
15:33	The Shinkai off bottom (4651 m).
17:57	The Shinkai on deck.
19:09-23:06	Bathymetric survey for dives #1142, #1143 and #1144, together with the deep-towed camera DT-1, was conducted.
10-May-09	**Dive #1141 was conducted along the upper western slope of the northern portion of the West Arm Rise. Henry J.B. Dick as the observer. Heaving-to during the night.**
10:02	Dive #1141 started (the Shinkai opened vent).
11:42	The Shinkai on bottom (3991 m).
15:44	The Shinkai off bottom (3501 m).
17:25	The Shinkai on deck.
11-May-09	**Dive #1142 was conducted along the lower western slope of the southern portion of the West Arm Rise. Jonathan E. Snow as the observer. Bathymetric survey for dive #1145 and #1146 was conducted during the night.**
9:52	Dive #1142 started (the Shinkai opened vent).
12:02	The Shinkai on bottom (4576 m).
15:31	The Shinkai off bottom (4205 m).
17:33	The Shinkai on deck.
18:51-19:45	Bathymetric survey for dives #1145 and #1146 was conducted.
12-May-09	**Dive #1143 was conducted along the upper western slope of the southern portion of the West Arm Rise. Yumiko Harigane as the observer. Heaving-to during night.**
9:51	Dive #1143 started (the Shinkai opened vent).
11:56	The Shinkai on bottom (4162 m).
15:55	The Shinkai off bottom (3638 m).
17:45	The Shinkai on deck.
13-May-09	**Dive #1144 was conducted along the southern slope of the southern toe of the West Arm Rise. Katsuyoshi Michibayashi as the observer. Heaving-to during the night.**
9:57	Dive #1144 started (the Shinkai opened vent).
11:58	The Shinkai on bottom (4403 m).
15:41	The Shinkai off bottom (4038 m).
17:33	The Shinkai on deck.

14-May-09	**Dive #1145 was conducted along the eastern slope of the West Hipbone Rise. Hiroyuki Yamashita as the observer. Bathymetric survey for dive #1147 was conducted during the night.**
9:59	Dive #1145 started (the Shinkai opened vent).
11:56	The Shinkai on bottom (4667 m).
15:30	The Shinkai off bottom (4159 m).
17:28	The Shinkai on deck.
20:17-21:14	Bathymetric survey for dive #1147 was conducted.
15-May-09	**Dive #1146 was conducted along the south slope of a possible back fault, located south of the West Hipbone Rise. Teruaki Ishii as the observer. Heaving-to during the night.**
9:02	Dive #1146 started (the Shinkai opened vent).
11:06	The Shinkai on bottom (4991 m).
14:50	The Shinkai off bottom (4570 m).
16:55	The Shinkai on deck.
16-May-09	**Dive #1147 was conducted along the south slope of the southernmost West Leg Ridge. Dorene Nakata as the observer. Heaving-to during the night.**
9:56	Dive #1147 started (the Shinkai opened vent).
11:55	The Shinkai on bottom (4301 m).
15:45	The Shinkai off bottom (3624 m).
17:36	The Shinkai on deck.
17-May-09	**Dive #1148 was conducted along the southwest steep slope of East Shoulder Ridge. Yasuhiko Ohara as the observer. Heaving-to during the night.**
10:00	Dive #1148 started (the Shinkai opened vent).
11:28	The Shinkai on bottom (3407 m).
16:00	The Shinkai off bottom (2622 m); total 26 rocks and 1 scoop were sampled.
17:57	The Shinkai on deck.
18-May-09	**YKDT-#62 was conducted on the eastern side of the Backbone Rise. Bathymetric survey for YKDT-#63 and #64 was conducted during the late afternoon. Heaving-to during the night.**
8:07	YKDT-#62 started (the deep-tow camera was put in the water).
9:37	The deep-tow camera towing started (4043 m).
11:23	The dredge was released (3679 m).
11:40	The deep-tow camera towing was halted (3684 m).
12:49	YKDT-#62 ended (the deep-tow camera was on deck).
19-May-09	**YKDT-#63 and #64 were conducted along the north slope of the Neck Peak. The Yokosuka started steaming to Chichi-jima Island in the late afternoon.**
6:17	YKDT-#63 started (the deep-tow camera was put in the water).
7:51	The deep-tow camera towing started (4541 m).
9:09	The dredge was released (3717 m).
9:43	The deep-tow camera towing was halted (3556 m).

10:50	YKDT-#63 ended (the deep-tow camera was on deck).
11:16	YKDT-#64 started (the deep-tow camera was put in the water).
12:31	The deep-tow camera towing started (3484 m).
13:20	The dredge was released (3439 m).
13:32	The deep-tow camera towing was halted (3369 m).
14:37	YKDT-#64 ended (the deep-tow camera was on deck). The Yokosuka started steaming to Chichi-jima Island.
20-May-09	**The Yokosuka was underway to Chichi-jima Island.**
21-May-09	**The Yokosuka arrived in Chichi-jima Island in the afternoon.**
14:40	The Yokosuka arrived at the Futami Harbor, Chichi-jima Island.
22-May-08	**End of the cruise.**
9:00	Scientists disemberked.

7. Names of the individual topographic parts of Godzilla Mullion

As noted above, before YK09-05 cruise, more than 15 expeditions were conducted for the study of Godzilla Mullion and the Parece Vela Basin as of fall 2008. These cruise resulted in 24 different sample locations on the Godzilla Mullion surface. During YK09-05 cruise, we completed successful 9 dives of Shinkai 6500 and 3 dives of deep-towed camera, resulting in additional 12 sample locations (= total 36 sample locations on the Godzilla Mullion surface).

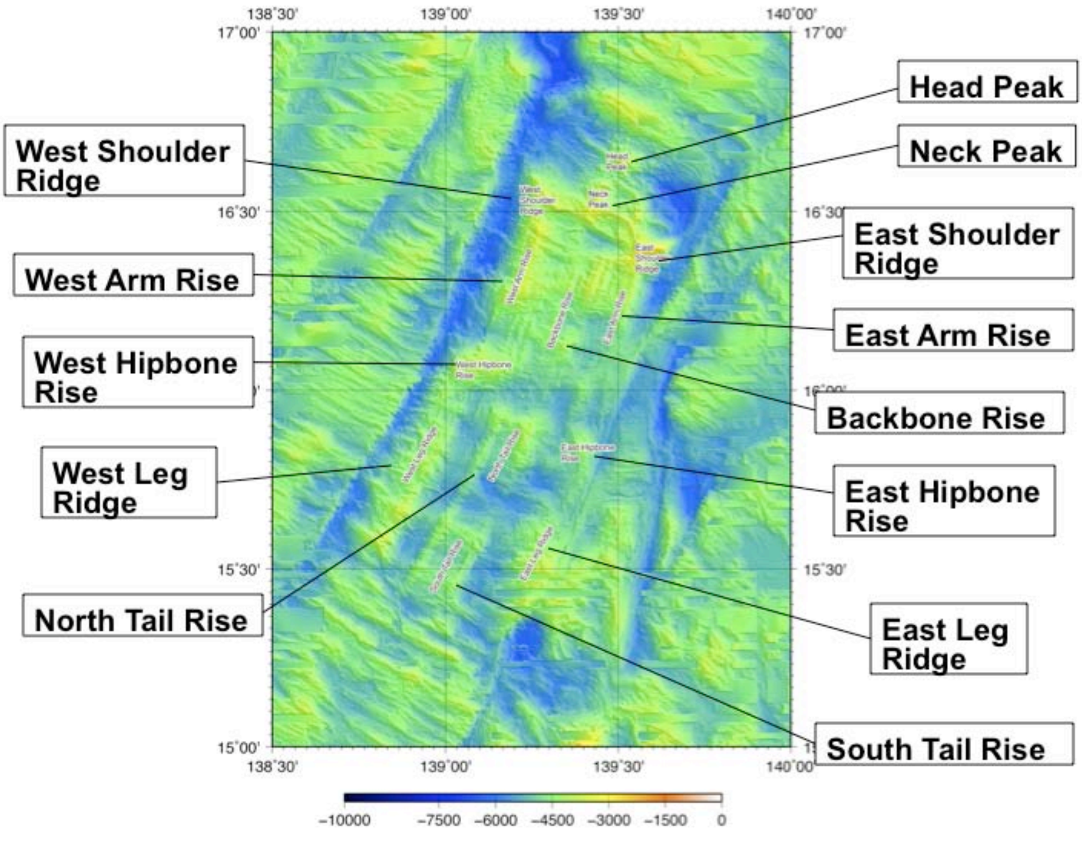

Fig. 2. Names of the individual topographic parts of Godzilla Mullion.

Before YK09-05 cruise, we used a single name of "Godzilla Mullion" for its description. However, now that we have 36 sample locations, it became difficult to describe the very enormous mullion with only the single name. We therefore decided 13 names for individual topographic parts of Godzilla Mullion (Fig. 2).

8. Summary of the dive results

Using the new individual names, the dive sites during YK09-05 cruise can be described as follows (Fig 3):

- 6K-#1140 and 6K-#1141: Western slope of the northern West Arm Rise
- 6K-#1142 and 6K-#1143: Western slope of the southern West Arm Rise
- 6K-#1144: Southern slope of the southern West Arm Rise
- 6K-#1145 and 6K-#1146: Eastern slope of the southeastern West Hipbone Rise
- 6K-#1147: Southwestern slope of the southern West Leg Ridge
- 6K-#1148: Southeastern slope of the East Shoulder Ridge
- YKDT-#62: Eastern slope of the middle Backbone Rise
- YKDT-#63: Northern slope of the foot of the Neck Peak
- YKDT-#64: Northern slope of the top of the Neck Peak

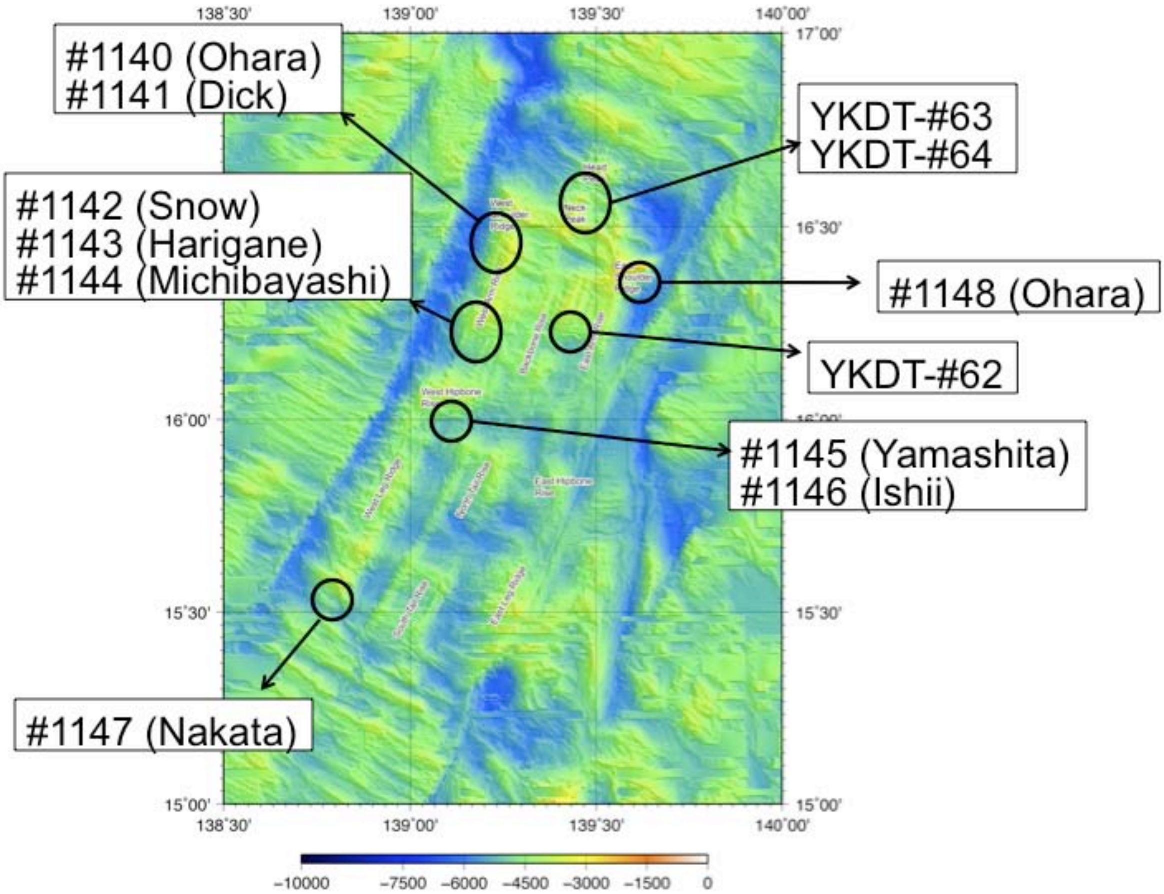

Fig. 3. Approximate location of the dive sites on Godzilla Mullion during YK09-05 cruise.

The main results of these dive operations are:

- Lithologies below and above a detachment fault (i.e., peridotite mylonite, talc schist and basalt) were discovered in the West Arm Rise (6K-#1140 to 6K-#1144) (Fig. 4).
- Outcrop of pillow lava was discovered in the West Hipbone Rise (6K-#1146) (Fig. 5).
- Troctolite, which we interpret represent a primitive magma, were discovered in the West Leg Ridge for the first time in Godzilla Mullion (6K-#1147) (Fig. 6).
- Although the East Shoulder Ridge is located very close to the spreading axis, we confirm that it is a peridotite massif (6K-#1148).
- Hydrothermal Mn-nodule relevant to detachment faulting was discovered in the Backbone Rise (YKDT-#62) (Fig. 7).
- Although the Neck Peak is located north of the presumed termination of the Godzilla Mullion detachment, we recovered peridotite and glassy basalt (YKDT-#63 and YKDT-#64). This observation indicates that detachment faulting was even occurred in this location, but later magma eruption at spreading axis covered the detachment surface.

Fig. 4. Peridotite mylonite collected from the West Arm Rise during 6K-#1140.

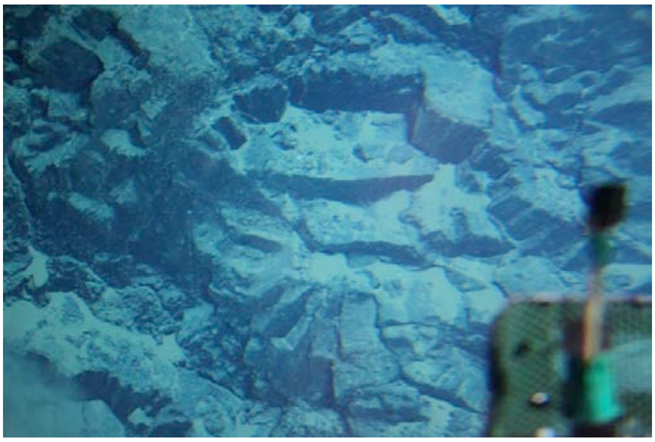

Fig. 5. An outcrop of pillow lava observed in the West Hipbone Rise during 6K-#1146.

Fig. 6. Troctolite collected from the West Leg Ridge during 6K-#1147.

Fig. 7. Hydrothermal Mn-nodule relevant to detachment faulting collected in the Backbone Rise during YKDT-#62.

9. References

Canales, J.P., B.E. Tucholke, M. Xu, J.A. Collins and D.L. DuBois, Seismic evidence for large-scale compositional heterogeneity of oceanic core complex, Geochemistry, Geophysics, Geosystems, 9, Q08002, doi:10.1029/2008GC002009, 2008.

Harigane, Y., K. Michibayashi, and Y. Ohara, Shearing within lower crust during progressive retrogression: Structural analysis of gabbroic rocks from the Godzilla Mullion, an oceanic core complex in the Parece Vela backarc basin, Tectonophysics, 457, 183-196, 2008.

Ildefonse, B., D.K. Blackman, B.E. John, Y. Ohara, D.J. Miller, C.J. MacLeod, and Integrated Ocean Drilling Program Expeditions 304/305 Science Party, Oceanic core complexes and crustal accretion at slow-spreading ridges, Geology, 35, 623-626, 2007.

Ohara Y., T. Yoshida, Y. Kato et al., Giant megamullion in the Parece Vela backarc basin, Marine Geophysical Researches, 22, 47-61, 2001.

Ohara Y., K. Fujioka, T. Ishii et al., Peridotites and gabbros from the Parece Vela backarc basin: unique tectonic window in an extinct backarc spreading ridge. Geochemistry, Geophysics, Geosystems, 4 (7), 8611, doi: 10.1029/2002GC000469, 2003a.
Ohara Y., K. Okino, J.E. Snow et al., Preliminary report of Kairei KR03-01 cruise: amagmatic tectonics and lithospheric composition of the Parece Vela Basin. InterRidge News, 12 (1), 27-29, 2003b.
Ohara, Y, K. Okino, and J. Kasahara, Seismic study on oceanic core complexes in the Parece Vela backarc basin, Island Arc, 16, 348-360, 2007.
Ohara, Y., K. Okino, J. E. Snow, and KH07-2 Science Party, IODP site survey for drilling Godzilla Mullion: preliminary report of R/V Hakuho KH07-2 Leg 2 & 4 cruise, EOS Trans. AGU 88(52) Fall Meeting supplement, T53B-1314, Poster presentation, San Francisco, USA, 2007.
Okino K., Y. Ohara, T. Fujiwara, S.-M. Lee, K. Koizumi, Y. Nakamura, and S. Wu, Tectonics of the southern tip of the Parece Vela Basin, Philippine Sea Plate, Tectonophysics, 466, 213-228, 2009.