

# **CRUISE REPORT**

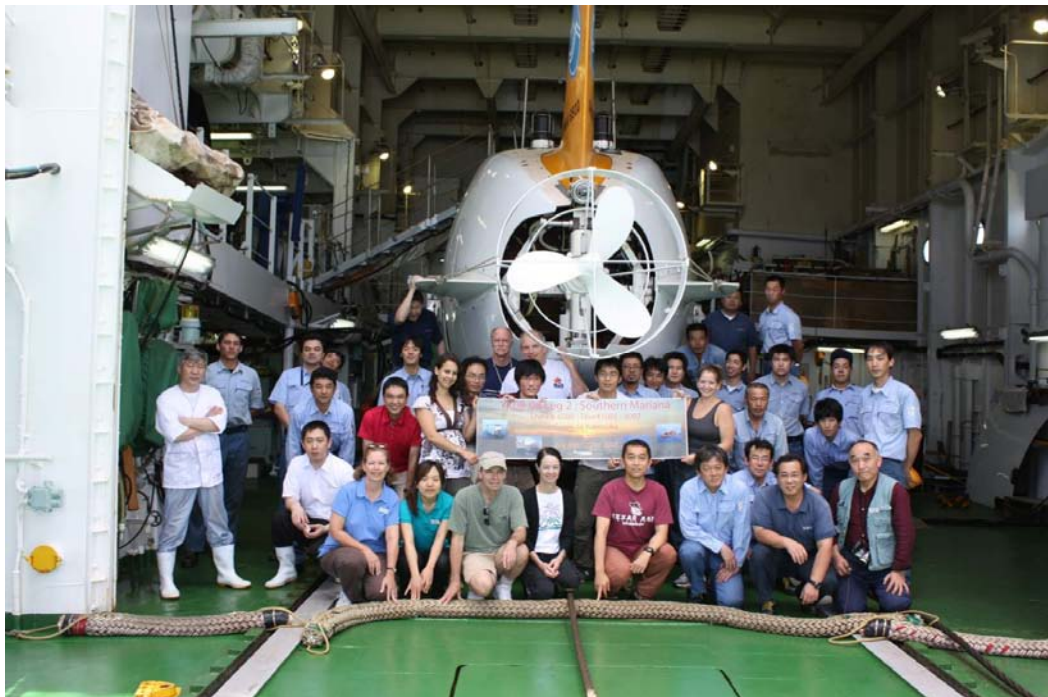
**JAPAN AGENCY FOR MARINE-EARTH SCIENCE AND  
TECHNOLOGY**

## **R/V YOKOSUKA YK08-08 LEG 2 CRUISE**

**STRUCTURE AND ORIGIN OF THE MARIANA FOREARC AND  
IMPLICATIONS FOR THE ORIGIN OF CONTINENTAL CRUST: A  
SHINKAI 6500 STUDY OF THE SOUTHERN MARIANA FOREARC**

**JULY 8<sup>TH</sup>, 2008 TO JULY 22<sup>ND</sup>, 2008**

**(GUAM, USA TO YOKOSUKA, JAPAN)**



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**Notice on using**

This cruise report is a preliminary documentation as of the end of the cruise. It may not be corrected even if changes on content are found after publication. It may also be changed without notice. Data on the cruise report may be raw or not processed. Please ask the Co-Chief Scientists for the latest information before using the report/data.

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 Shinya Ryono, 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 Texas at Dallas. Most of the expendable supplies used in the cruise were provided from the Hydrographic and Oceanographic Department of Japan.

## 1. General cruise information

Cruise number / ship name: YK08-08-Leg2 / R/V Yokosuka

Title of the cruise:

“Structure and origin of the Mariana Forearc and implications for the origin of continental crust: a Shinkai 6500 study of the Southern Mariana Forearc”

Proposal number and scientific title:

S08-55 “Composition and structure of the early Mariana Arc: submersible study at the southern tip of the Mariana Ridge (Part 2)”

Period of the cruise: July 8 to July 22, 2008

Port calls:

Departure: Guam (July 8, 2008)

Arrival: Yokosuka (July 22, 2008)

Investigation area:

Southern part of the Mariana Trench within the region enclosed by the following coordinates:

11°05.0'N, 143°05.0'E

12°10.0'N, 142°05.0'E

14°00.0'N, 142°05.0'E

14°00.0'N, 147°00.0'E

11°40.0'N, 147°00.0'E

11°05.0'N, 143°30.0'E

Shinkai 6500 dive list:

#1091: Rosemary Hickey-Vargas (with Tetsuya Komuku and Hirofumi Ueki)

#1092: Mark Regan (with Keita Matsumoto and Kazuhiro Chiba)

#1093: Osamu Ishizuka (with Yoshitaka Sasaki and Fumitaka Saito)

#1094: Katsuyoshi Michibayashi (with Tetsuya Komuku and Hirofumi Ueki)

#1095: Yasuhiko Ohara (with Keita Matsumoto and Fumitaka Saito)

#1096: Sherman Bloomer (with Yoshitaka Sasaki and Kazuhiro Chiba)

#1097: Patricia Fryer (with Tetsuya Komuku and Fumitaka Saito)

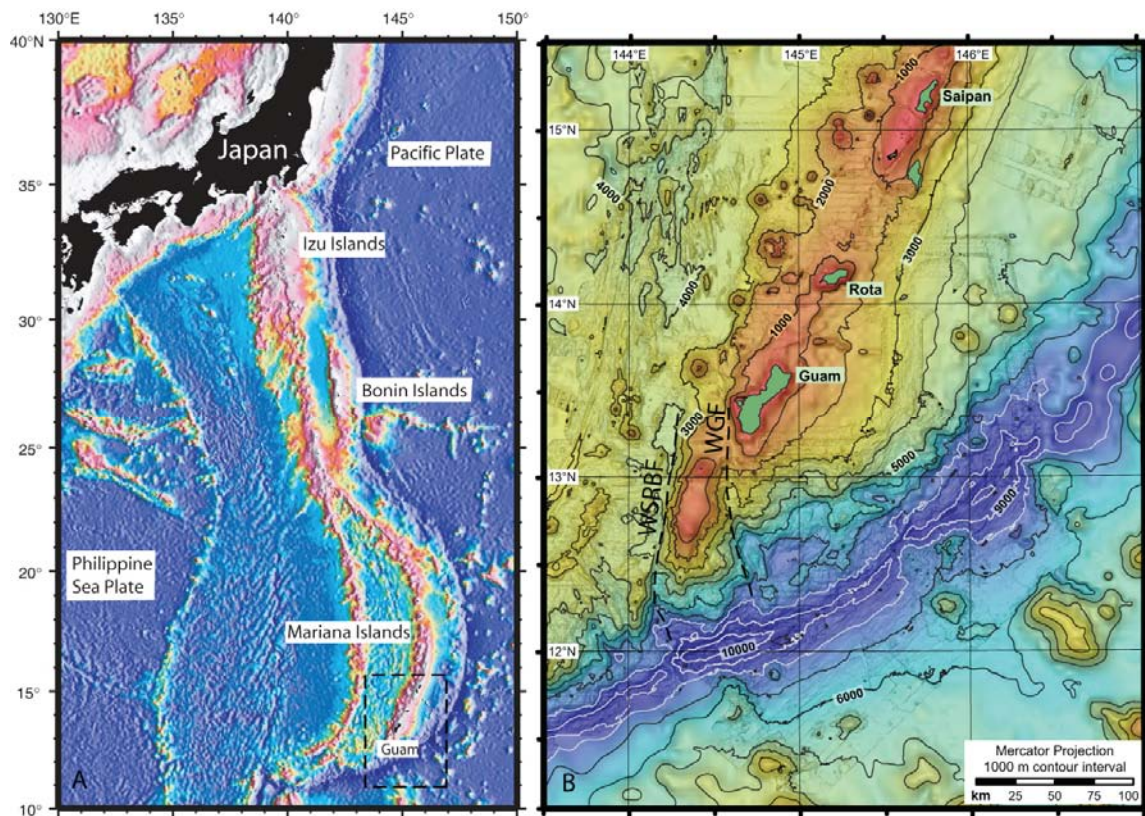
## 2. Introduction

Understanding how subduction starts, how magmatic arcs develop with time after subduction begins, mass cycling through subduction zones, and the role that arc crust plays in the formation of continental crust are all important questions that broadly impact the geoscientific community. A lot of progress has been made in understanding especially the volcanic outputs at arcs, but our understanding of how arcs form and the nature of the structure and composition of deep arc crust and upper mantle is not as far advanced.

The importance of understanding the composition and structure of the deep parts of juvenile arcs has been recognized by most international geoscientific research programs concerned with crust formation and evolution (e.g., IODP, ICDP, MARGINS). It also is widely acknowledged that

research into these topics is best carried out on juvenile “intra-oceanic” arcs, such as the Izu-Bonin-Mariana (=IBM) arc system, because their historical record is not complicated by the presence of preexisting continental crust (Leat and Larter, 2003).

Research results presented here is a continued research program begun in 2004 with diving west of the Bonin Ridge and furthered with diving southeast of Guam in 2006. YK04-05, dives 823-826 were intended to study lower crust and upper mantle exposed on the eastern escarpment of the Ogasawara Ridge north and west of the Ogasawara Islands. We found that these scarps were mantled with 41.8-43.9 Ma andesitic lavas (Ishizuka et al., 2006). YK06-12, dives 973-977 SE of Guam sampled many of the igneous rocks associated with subduction initiation in the IBM system, including relatively fresh mantle peridotites at Dive Site 973. YK08-08 (this cruise) continued this effort with 7 Shinkai 6500 dives near Guam, in the southernmost IBM arc system (Fig. 1). The goal was to sample the remaining early arc crust and upper mantle exposed in the forearc, and to use this to gain a clearer understanding of the structure and evolution of Mariana fore-arc crust and upper mantle. We hope these efforts will stimulate geophysical experiments designed to better resolve crustal and upper mantle structure in three dimensions.



**Fig. 1.** A: Locality map for the IBM arc system. Bathymetry (red = shallow and blue = deep seafloor) is from ETOPO2. B: Locality map of the southern Mariana arc, depth in m. The map is a compilation of swath bathymetry from several US and Japanese research cruises over the past decade. Dashed lines represent two faults: West Santa Rosa Bank fault (WSRBF) and West Guam fault (WGF).

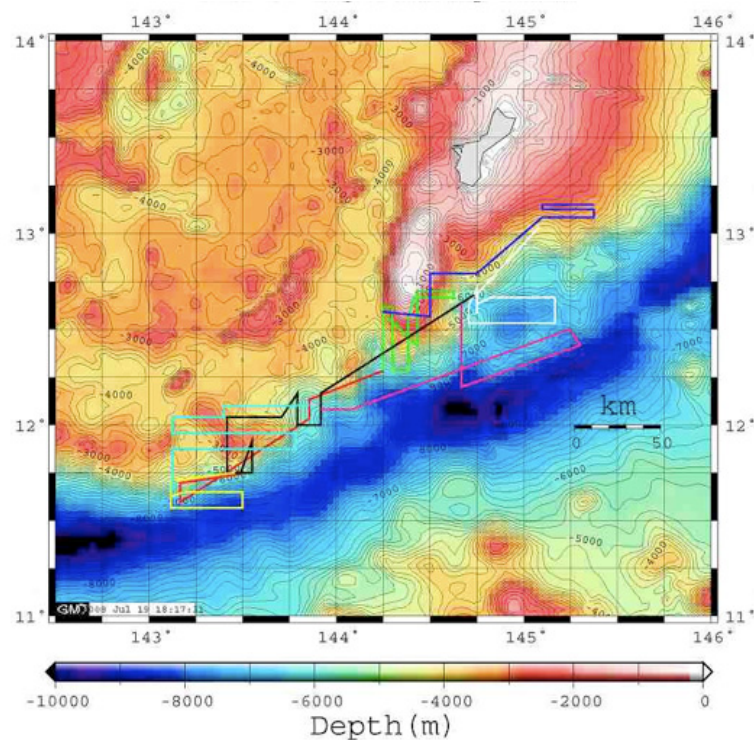
### 3. Objectives of the cruise

Observations and sample analyses from YK08-08 Leg 2 will test the following related three major hypotheses:

- (1) The Mariana forearc is floored dominantly crust produced early in the evolution of the convergent margin and is formed at rate much higher than that of "normal" arc volcanism. Older MORB crust is a minor component of forearc basement, having been removed by forearc spreading.
- (2) The composition of Mariana arc crust could be a progenitor of continental crust if modern arc and early arc crustal compositions are balanced and crust thickens to the point that refractory lower arc crust can delaminate.
- (3) Forearc environment of juvenile arcs is a better analog for most ophiolitic complexes than are mid-ocean ridges or back-arc basins (Stern 2004).

### 4. Survey items

In addition to Shinkai 6500 dives, bathymetric surveys with SeaBeam 2112 were conducted to map the southern Mariana region during night during the YK08-08-Leg 2 cruise (Fig. 2). Gravity and three-component magnetic vector data were simultaneously obtained; however total magnetic intensity data by a surface-towed proton magnetometer were not obtained during this cruise.



**Fig. 2.** Survey lines and way points employed during YK08-08-Leg 2 cruise. Colored lines indicate different days or evenings of surveying.

## 5. Running cruise narrative

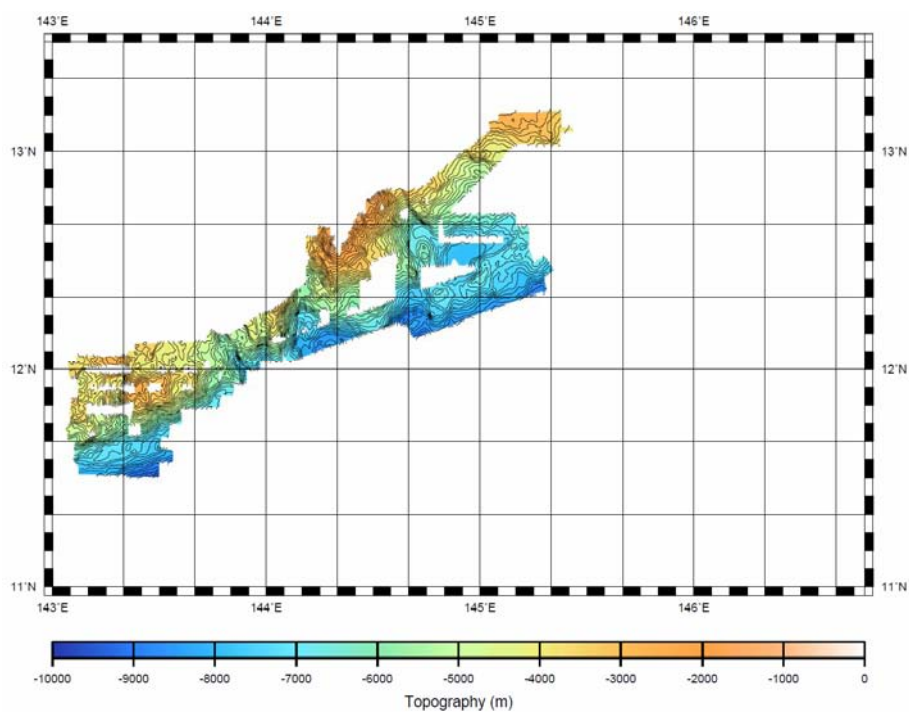
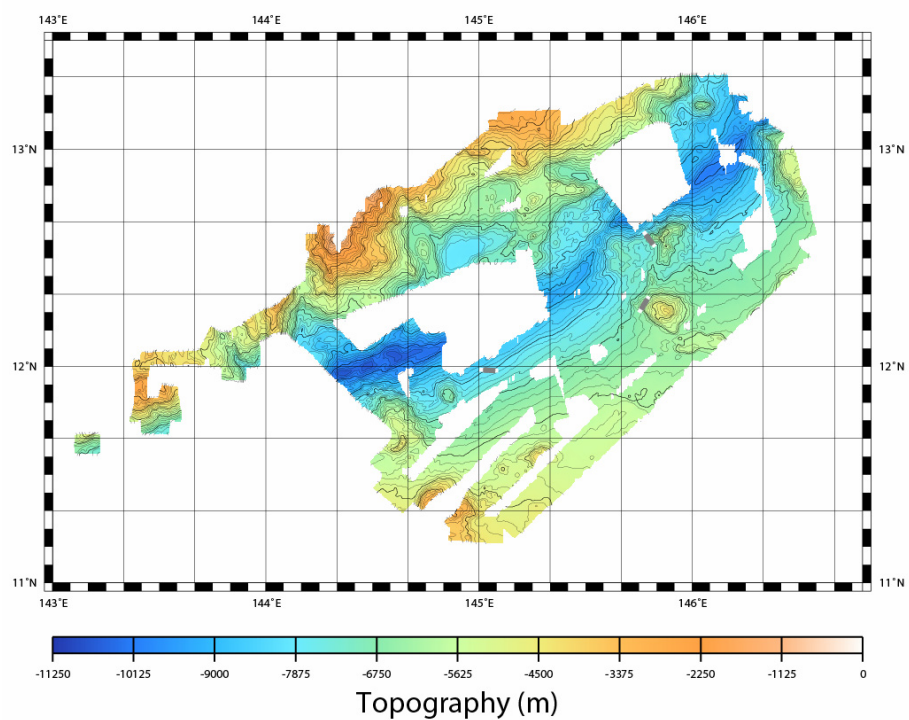
| Local time<br>(Approximate) | Notes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|-----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>08-Jul-08</b>            | <b>The Yokosuka YK08-08-Leg 2 cruise began. It was rainy (sometimes heavy rain) in Guam. The Yokosuka was underway to the western part of the proposed survey area to target the mantle section of the landward slope of the southern Mariana Trench. Bathymetric mapping during the night.</b>                                                                                                                                                                                        |
| 10:00                       | Scientists arrived at the Yokosuka. Ship's clock used Guam local time (UTC + 10 h).                                                                                                                                                                                                                                                                                                                                                                                                    |
| 14:10                       | YK08-08-Leg 2 cruise began. Ship's clocks used Guam local time (UTC + 10 h) during this cruise.                                                                                                                                                                                                                                                                                                                                                                                        |
| 18:00-19:00                 | Science meeting was held at the No. 1 laboratory. Yasuhiko Ohara summarized the objectives and logistics of the cruise. Katsuyoshi Michibayashi, who was designated as the 1st observer, presented the strategy for the tomorrow's dive (Dive #1091).                                                                                                                                                                                                                                  |
| <b>09-Jul-08</b>            | <b>The first dive, Dive #1091, targeted the mantle section of the landward slope of the southern Mariana Trench, was canceled due to an expected worsening weather condition. The Yokosuka headed to the east to map the Santa Rosa Bank area, preparing the tomorrow's dive.</b>                                                                                                                                                                                                      |
| 8:30                        | Dive #1091 was canceled.                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 18:00-19:00                 | Science meeting was held at the No. 1 laboratory. Yasuhiko Ohara summarized the reason for the today's canceling of the dive, and then introduced JAMSTEC's new policy for sample handling. Mark Reagan presented what we know about the shallow crustal section of the southern Mariana forearc, and summarized the reason for the choice of the tomorrow's dive site, which is the western slope of the Santa Rosa Bank. Rosemary Hickey-Vargas summarized tomorrow dive's strategy. |
| <b>10-Jul-08</b>            | <b>Dive #1091 was conducted along the western slope of the Santa Rosa Bank. Rosemary Hickey-Vargas as the observer. Bathymetric mapping during the night.</b>                                                                                                                                                                                                                                                                                                                          |
| 10:06                       | Dive #1091 started (the Shinkai opened vent).                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 11:19                       | The Shinkai on bottom (2969 m).                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 16:11                       | The Shinkai off bottom (1958 m); total 29 rocks were sampled.                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 17:23                       | The Shinkai on deck.                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 19:00-20:00                 | Science meeting was held at the No. 1 laboratory. Yasuhiko Ohara summarized the reason for the choice of the tomorrow's dive site, which is a shallow dive located off the southeast of Guam. Rosemary Hickey-Vargas summarized the results of the today's dive, and Mark Reagan summarized tomorrow dive's strategy.                                                                                                                                                                  |
| 20:00-21:40                 | Scientists worked on curating the Dive #1091's samples.                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>11-Jul-08</b>            | <b>Dive #1092 was conducted off the southeast of Guam, upslope of the YK06-12 dive sites (#974, #975, #976). Mark Reagan as the observer. Bathymetric mapping during the night.</b>                                                                                                                                                                                                                                                                                                    |
| 10:09                       | Dive #1092 started (the Shinkai opened vent).                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 11:29                       | The Shinkai on bottom (3000 m).                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 15:59                       | The Shinkai off bottom (2599 m); total 25 rocks were sampled.                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 17:24                       | The Shinkai on deck.                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 19:00-19:40                 | Science meeting was held at the No. 1 laboratory. Yasuhiko Ohara and Mark Reagan summarized the reason for the choice of the tomorrow's dive site, which is expected to cross the Moho, near the Jason 2 dive site by Patricia Fryer. Mark Reagan summarized the results of the today's dive, and Osamu Ishizuka summarized tomorrow dive's strategy.                                                                                                                                  |
| 19:40-22:00                 | Scientists worked on curating the Dive #1092 samples.                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>12-Jul-08</b>            | <b>Dive #1093 was conducted off the south of Guam, near the Jason-2 dive site by</b>                                                                                                                                                                                                                                                                                                                                                                                                   |

|                                                                                              |                                                                                                                                                                                                                                                                                                                                                                   |
|----------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Patricia Fryer. Osamu Ishizuka as the observer. Bathymetric mapping during the night.</b> |                                                                                                                                                                                                                                                                                                                                                                   |
| 9:03                                                                                         | Dive #1093 started (the Shinkai opened vent).                                                                                                                                                                                                                                                                                                                     |
| 11:46                                                                                        | The Shinkai on bottom (6441 m).                                                                                                                                                                                                                                                                                                                                   |
| 14:53                                                                                        | The Shinkai off bottom (5798 m); total 18 rocks were sampled.                                                                                                                                                                                                                                                                                                     |
| 17:24                                                                                        | The Shinkai on deck.                                                                                                                                                                                                                                                                                                                                              |
| 19:00-19:55                                                                                  | Science meeting was held at the No. 1 laboratory. Yasuhiko Ohara summarized the reason for the choice of the tomorrow's dive site, which is expected to explore the mantle exposure along the previous dredge hauls by Teruaki Ishii. Osamu Ishizuka summarized the results of the today's dive, and Katsuyoshi Michibayashi summarized tomorrow dive's strategy. |
| 20:00-22:00                                                                                  | Scientists worked on curating the Dive #1093 samples.                                                                                                                                                                                                                                                                                                             |
| <b>13-Jul-08</b>                                                                             | <b>Dive #1094 was conducted along the slope previously dredged by Teruaki Ishii. Katsuyoshi Michibayashi as the observer. Bathymetric mapping during the night.</b>                                                                                                                                                                                               |
| 9:01                                                                                         | Dive #1094 started (the Shinkai opened vent).                                                                                                                                                                                                                                                                                                                     |
| 11:34                                                                                        | The Shinkai on bottom (6469 m).                                                                                                                                                                                                                                                                                                                                   |
| 14:46                                                                                        | The Shinkai off bottom (5964 m); total 17 rocks were sampled.                                                                                                                                                                                                                                                                                                     |
| 17:22                                                                                        | The Shinkai on deck.                                                                                                                                                                                                                                                                                                                                              |
| 19:00-20:00                                                                                  | Science meeting was held at the No. 1 laboratory. Yasuhiko Ohara summarized the reason for the choice of the tomorrow's dive site, which is expected to explore the mantle exposure to the west of today's dive site. Katsuyoshi Michibayashi summarized the results of the today's dive, and Yasuhiko Ohara summarized tomorrow dive's strategy.                 |
| 20:00-22:00                                                                                  | Scientists worked on curating the Dive #1094 samples.                                                                                                                                                                                                                                                                                                             |
| <b>14-Jul-08</b>                                                                             | <b>Dive #1095 was conducted along the slope to the west of Dive #1095. Yasuhiko Ohara as the observer. Bathymetric mapping during the night.</b>                                                                                                                                                                                                                  |
| 9:02                                                                                         | Dive #1095 started (the Shinkai opened vent).                                                                                                                                                                                                                                                                                                                     |
| 11:36                                                                                        | The Shinkai on bottom (6405 m).                                                                                                                                                                                                                                                                                                                                   |
| 14:56                                                                                        | The Shinkai off bottom (5356 m); total 21 rocks were sampled.                                                                                                                                                                                                                                                                                                     |
| 17:20                                                                                        | The Shinkai on deck.                                                                                                                                                                                                                                                                                                                                              |
| 19:00-20:00                                                                                  | Science meeting was held at the No. 1 laboratory. Yasuhiko Ohara summarized the reason for the choice of the tomorrow's dive site, which is expected to explore the mantle exposure of the Mariana Trough backarc affinities. Yasuhiko Ohara summarized the results of the today's dive, and Sherman Bloomer summarized tomorrow dive's strategy.                 |
| 20:00-22:00                                                                                  | Scientists worked on curating the Dive #1095 samples.                                                                                                                                                                                                                                                                                                             |
| <b>15-Jul-08</b>                                                                             | <b>Dive #1096 was conducted along the slope to the east of Dive #1095. Sherman Bloomer as the observer. Bathymetric mapping during the night.</b>                                                                                                                                                                                                                 |
| 9:01                                                                                         | Dive #1096 started (the Shinkai opened vent).                                                                                                                                                                                                                                                                                                                     |
| 11:30                                                                                        | The Shinkai on bottom (6077 m).                                                                                                                                                                                                                                                                                                                                   |
| 15:05                                                                                        | The Shinkai off bottom (5414 m); total 28 rocks were sampled.                                                                                                                                                                                                                                                                                                     |
| 17:31                                                                                        | The Shinkai on deck.                                                                                                                                                                                                                                                                                                                                              |
| 19:00-20:00                                                                                  | Science meeting was held at the No. 1 laboratory. Mark Reagan summarized the reason for the choice of the tomorrow's dive site, which is expected to cross the Moho at the eastern slope of the Santa Rosa Bank. Sherman Bloomer summarized the results of the today's dive, and Patricia Fryer summarized tomorrow dive's strategy.                              |
| 20:00-22:00                                                                                  | Scientists worked on curating the Dive #1096 samples.                                                                                                                                                                                                                                                                                                             |
| <b>16-Jul-08</b>                                                                             | <b>Dive #1097 was conducted along the eastern slope of the Santa Rosa Bank. Patricia Fryer as the observer. The Yokosuka was underway to JAMSTEC right after recovery of the Shinkai.</b>                                                                                                                                                                         |
| 9:01                                                                                         | Dive #1097 started (the Shinkai opened vent).                                                                                                                                                                                                                                                                                                                     |

|                  |                                                                                                                                                                                                                                                                                                                                                       |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 11:43            | The Shinkai on bottom (6494 m).                                                                                                                                                                                                                                                                                                                       |
| 14:56            | The Shinkai off bottom (5978 m); total 14 rocks were sampled.                                                                                                                                                                                                                                                                                         |
| 17:31            | The Shinkai on deck.                                                                                                                                                                                                                                                                                                                                  |
| 19:00-20:00      | Science meeting was held at the No. 1 laboratory. Yasuhiko Ohara summarized the schedule of the rest of the cruise. Since deteriorating sea condition is expected due to the typhoon near Taiwan, the Yokosuka steamed at full speed to JAMSTEC; no chance to conduct bathymetric mapping. Patricia Fryer summarized the results of the today's dive. |
| 20:00-22:00      | Scientists worked on curating the Dive #1097 samples.                                                                                                                                                                                                                                                                                                 |
| <b>17-Jul-08</b> | <b>The Yokosuka was underway to JAMSTEC. Scientists worked on curating the samples.</b>                                                                                                                                                                                                                                                               |
| Day time         | Scientists worked on curating the samples and writing cruise report. A map compiling the dive results and previous studies are produced, to be included for the synthesis chapter of the cruise report.                                                                                                                                               |
| 18:00-18:30      | Science meeting was held at the No. 1 laboratory. Yasuhiko Ohara summarized the schedule of the rest of the cruise. Scientists discussed the compiled map.                                                                                                                                                                                            |
| 0:00             | Ship's clocks were changed from Guam local time (UTC + 10 h) to Japan local time.                                                                                                                                                                                                                                                                     |
| <b>18-Jul-08</b> | <b>The Yokosuka was underway to JAMSTEC. Scientists worked on curating the samples.</b>                                                                                                                                                                                                                                                               |
| Day time         | Scientists worked on curating the samples and writing cruise report. The compiled map was revised.                                                                                                                                                                                                                                                    |
| 9:00-10:00       | A seminar was held. Yasuhiko Ohara gave two talks. One was the summary of the cruise, and the other was on Japan's Law of the Sea project. Keita Matsumoto (the Shinkai Team) gave a talk about his recent visiting to IFREMER and the French DSV Nautille.                                                                                           |
| 18:00-18:30      | Science meeting was held at the No. 1 laboratory. Yasuhiko Ohara summarized the schedule of the rest of the cruise. Scientists discussed and revised the compiled map.                                                                                                                                                                                |
| <b>19-Jul-08</b> | <b>The Yokosuka was underway to JAMSTEC.</b>                                                                                                                                                                                                                                                                                                          |
| Day time         | Scientists worked on writing cruise report. The compiled map was further revised.                                                                                                                                                                                                                                                                     |
| 18:00-18:30      | Science meeting was held at the No. 1 laboratory. Yasuhiko Ohara summarized the schedule of the rest of the cruise. Cruise report assignment was confirmed.                                                                                                                                                                                           |
| <b>20-Jul-08</b> | <b>The Yokosuka was underway to JAMSTEC.</b>                                                                                                                                                                                                                                                                                                          |
| Day time         | Scientists worked on writing cruise report.                                                                                                                                                                                                                                                                                                           |
| Afternoon        | The Yokosuka anchored off JAMSTEC.                                                                                                                                                                                                                                                                                                                    |
| 18:00-18:30      | Science meeting was held at the No. 1 laboratory.                                                                                                                                                                                                                                                                                                     |
| <b>21-Jul-08</b> | <b>The Yokosuka anchored off JAMSTEC.</b>                                                                                                                                                                                                                                                                                                             |
| Day time         | Scientists worked on writing cruise report.                                                                                                                                                                                                                                                                                                           |
| 18:00-18:30      | Science meeting was held at the No. 1 laboratory.                                                                                                                                                                                                                                                                                                     |
| <b>22-Jul-08</b> | <b>End of the cruise.</b>                                                                                                                                                                                                                                                                                                                             |
| 9:00             | Arrived at the JAMSTEC's pier. End of the YK09-08-Leg 2 cruise.                                                                                                                                                                                                                                                                                       |

## 6. Bathymetric results

The areas surveyed during our 2008 operations concentrated on the inner trench slope from 143°E to 145°30'E and on the eastern side of the Santa Rosa Bank, as well as over portions of the HMR-1 surveys where track-parallel artifacts existed. The map showing both the 2006 and this year's data is given in Figure 3a. A chart showing bathymetric data collected only during YK08-08 Leg 2 is included as Figure 3b.

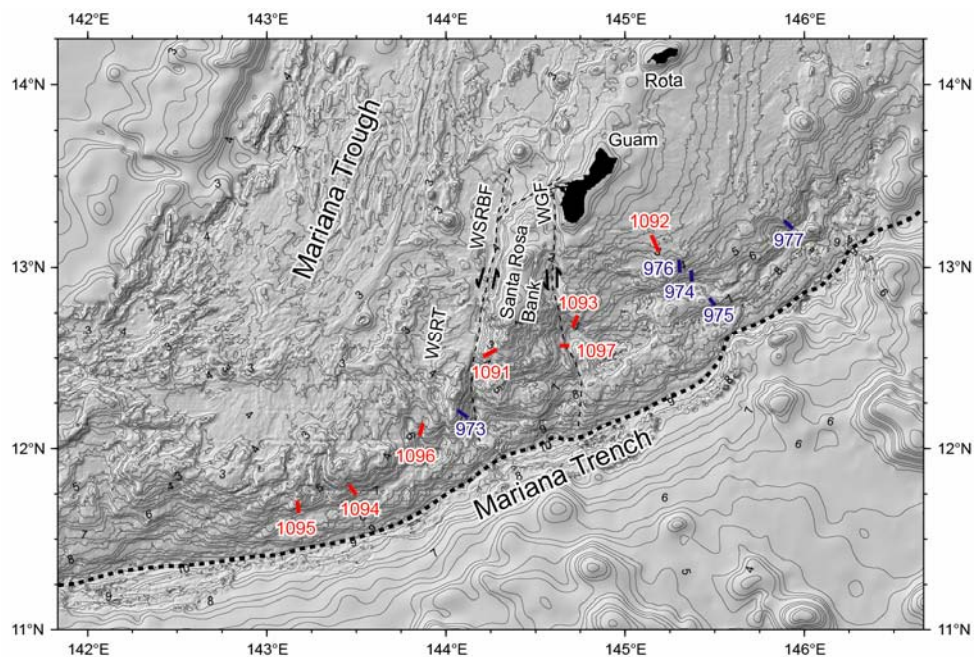


**Fig. 3.** A (upper) Bathymetry data collected during YK06-12 and YK08-08-Leg 2 cruises. B (lower) Bathymetry data collected during YK08-08-Leg 2 cruise.

Previous cruises in the area of our dive operations collected survey data used to construct the bathymetry basemap of the southern Mariana area. This includes surveys collected with the Hawaii Mapping Research Group (HMRG) shallow-towed swath mapping system (HMR-1) collected in 1997 and 2001, Seabeam data collected from the R/V Yokosuka in 1993, 2006 and 2008, EM300 hull-mounted swath mapping system collected with the R/V Thomas G. Thompson in 2001, and is augmented by ETOPO2 satellite derived bathymetry data.

The bathymetry to the southeast of Guam (Fig. 4) shows a series of down-faulted blocks of forearc along roughly E-W trending normal faults, antithetic to the main subduction thrust. Furthermore, there are several narrow terraces on the east wall of the canyon formed along the left-lateral, dip-slip fault to the east of Santa Rosa Bank, suggesting these are fragments of the forearc to the south of Guam that have also been down-faulted toward the fault trace. This degree of faulting surrounding Guam probably accounts for the degree of uplift (footwall uplift?) necessary to expose dike complexes on the western coast of the island and raise the boninitic pillow basalts of the Facpi Formation and associated volcanoclastics.

Deformation to the west of Santa Rosa Bank, in the highly deformed (and possibly intruded) forearc region, is probably related to the N-S extensional regime in this part of the arc-trench gap (Fryer et al., 2003). N-S trending faults along the inner trench slope (e.g., Dive#1096) may be related to disruption of blocks of the West Mariana Ridge and forearc that was called for by Karig (1971a, b; 1972) to accommodate the 25% E-W extension of the southern Mariana region that he required to explain opening of the southern Mariana Trough.



**Fig. 4.** Contoured, shaded bathymetry data compiled from academic sources augmented with ETOPO2 data. Contour interval is 250 m. Red lines indicate Shinkai 6500 dive locations during YK08-08-Leg 2 cruise, whereas blue lines indicate dive locations during YK06-12 cruise. WSRT = West Santa Rosa Trench; WSRBF = West Santa Rosa Bank Fault; WGF = West Guam Fault.

## 7. Summary of the Shinkai 6500 dive results

The YK06-12 Shinkai 6500 dives and dredge hauls along the forearc south and east of Guam collected the entire suite of rocks associated with what could be termed a “supra-subduction zone ophiolite” that formed during subduction initiation, and four dive sites for YK08-08-Leg 2 (1091, 1092, 1093, 1097) were chosen to further sample and observe the geology and geomorphology of this region. Dredges in the region bordering the southeastern termination of the Mariana Trough showed this area exposes depleted Mariana forearc related peridotites, less-depleted back-arc related peridotites as well as arc-related crustal rocks. Three dive sites for this cruise (1094, 1095, and 1096) were targeted to collect both types of peridotites. SeaBeam mapping, sidescan imagery and gravity data were collected around all of the dive sites, spanning a region from 11°35'N, 143°5'E to 13°20'N, 145°10'E (Fig. 4).

**Dive 1091** was from 2696 to 1954 m depth along a steep escarpment created by a N-S strike slip or normal fault on the west side of Santa Rosa Bank. Overall, the rocks encountered in this section are broadly consistent with the volcanic section exposed on Guam. The presence of diabase together with highly-altered pillow lavas at several sites early in the dive demonstrates that dikes are present in the sequence, at least up to 2250 meters. Siltstone, sandstone and volcanic breccia join the sequence at 2050 meters. This lower part of the section may correlate with the Oligocene Alutom Formation or both the Alutom and part of the middle to late Eocene Facpi Formation. The upper portion of the dive collected basaltic andesite with unusually large (up to 0.5 cm) augite phenocrysts reminiscent of Miocene lavas in the Umatac Formation on Guam.

**Dive 1092** was from 3000-2600 m depth on an escarpment upslope from YK06-12 dive number 976. The dive was mostly on dip-slopes of volcanoclastic breccias and related sandstones and shales. These breccias are typically heterolithic, with andesitic clasts containing phenocrysts of plagioclase and pyroxenes less than 1 mm in length. These lithologies are reminiscent of the late Eocene to Oligocene volcanic rocks from the Alutom Formation on Guam and similar units on Rota and Saipan. The volcanoclastic sedimentary rocks formed dip-slopes in most locations. Exceptions to this are where sub-sea landslides removed the surface rocks, or where faulting produced scarps that cut through the sediments. In some of these areas, the faulting and landsliding exposed the igneous basement on the sea floor. Igneous basement pokes through the dip-slope sediments in other areas suggesting that it was incompletely covered during sedimentation. This igneous basement was diabase with crystals of fine-grained plagioclase, augite and magnetite and minor basalt. Thin-section examination indicated that the diabase is similar in texture and composition to those associated with the fore-arc basalts discussed in more detail below. The sedimentary rocks that coat most of the surface are significantly faulted and folded in the upper half of the dive, showing that significant tectonic activity occurred after their deposition.

**Dive 1093** examined a southward-facing steep slope south of Guam and east of Santa Rosa Bank from 6441 to 5798 m depth. Good exposures of basalt lava flows and diabases were encountered along the entire length of the dive. Based on petrographic similarities, we correlate these basaltic rocks to the “fore-arc basalts” that were recovered at dive sites 974, 975, and 977 during YK06-12. Field relations imply that the diabase intruded into the pillow basalt lava flow sequence in an extensional tectonic environment. The pillow lavas are aphyric. Pillow interiors have a micro-diabasic texture composed of finely intergrown plagioclase and augite. Rims are nearly pure altered glass. The diabases have classic subophitic textures and generally lack olivine.

**Dive 1094** examined a southward facing slope along the southern margin of the Mariana Trough from 6469 to 5964 m depth. The dive track was mostly on boulder-scale talus covered by whitish sediments. Small outcrops a few meters wide and striking 320° suggest that a fault system with this orientation cuts the area. The color of the outcrops and talus clasts change from dark to lighter at around 6000 m. Samples collected from this dive show that those from the deeper levels were similar to those identified as back-arc type peridotites at YK06-12 dive 973, whereas those from the light colored peridotites obtained from shallower levels were low-pyroxene harzburgite or dunite that are similar to fore-arc type peridotites found in many dredge hauls from the region.

**Dive 1095** was further west along the southern margin of the Mariana Trough from 6405 to 5456 m depth. The lithology of the seafloor along the dive course was mostly debris made of angular peridotite clasts of various sizes, ranging from fist-size gravel to large-sized boulders. Two possible outcrops were encountered during the dive, each exposed at the very steep slope ~5800-5400 m deep. Hand specimen observations suggest that dive samples are serpentinized peridotites. Many of these serpentinized peridotites preserve fresh portions, and look petrographically very similar to the highly-depleted serpentinized “forearc” peridotites dredged during KH92-1-D2 (Ohara and Ishii, 1998) along the slope below dive 1094 and in the upper portion of dive 1094.

**Dive 1096** was from 6069-5414 m depth along a west-southwest-facing escarpment formed by faulting on the west side of a comparatively low-elevation crustal block that is bounded on the east by the West Santa Rosa Bank Fault. Nearly all of the rocks collected in this dive were fresh or nearly fresh pillow lavas with phenocrysts of plagioclase and olivine. The most important conclusion of the dive was that the crust here comprises volcanic rocks that appear to be of back-arc affinity, based upon mineralogy, texture, and freshness of the rock. This suggests that the crustal block bounded by the north-south valley here and fault west of Santa Rosa Bank is a previously-unknown rift that has been accompanied by basaltic volcanism of unknown but relatively recent age. This result is somewhat surprising, given the proximity of this site to the Mariana Trench, only 30 km distant, in part of the forearc that elsewhere have no igneous activity.

**Dive 1097** was from 6494 to 5978 m depth along an east-facing slope west of the major N-S left-lateral strike-slip fault separating the Santa Rosa Banks from Guam (West Guam Fault). Despite significant sediment cover over most of the gentler slopes, the dive traversed a sequence of dike rock and pillow lavas, apparently of boninitic parentage. The rocks have abundant large olivine phenocrysts, tiny euhedral augite, and sporadic plagioclase, and are reminiscent of the high-Ca boninites of the Facpi Formation on southwestern Guam (Reagan and Meijer, 1984). This is not surprising considering that Santa Rosa Bank was separated from the Guam block by faulting. This requires, however, that the whole of the Santa Rosa Bank block is tilted to the east/southeast in order to place these equivalent rocks at depths of greater than 6000m. This is consistent with dips found in sedimentary rocks on Guam and is consistent with our 2006 results. Most of the samples appear reasonably fresh and should, we hope, provide age constraints for this eruptive phase of the arc.

## 8. Synthesis

The YK06-12 Shinkai 6500 dives and dredge hauls along the forearc south and east of Guam collected the entire suite of rocks associated with what could be termed a “supra-subduction zone ophiolite” that formed during subduction initiation, and four dive sites for YK08-08 (1091, 1092, 1093, 1097) were chosen to further sample and observe the geology and geomorphology of this

region.

Dredges in the region bordering the southeastern termination of the Mariana Trough showed this area exposes depleted Mariana forearc related peridotites, less-depleted back-arc related peridotites as well as arc-related crustal rocks. Three dive sites for this cruise (1094, 1095, and 1096) were targeted to collect both types of peridotites. SeaBeam mapping, sidescan imagery and gravity data were collected around all of the dive sites, spanning a region from 11°35'N, 143°5'E to 13°20'N, 145°10'E.

Taken together, the dives to the east of Santa Rosa Bank document a sequential but disjointed crustal section. Based on dredge hauls in waters deeper than our dive sites, the lowermost unit appears to consist of a relatively thin gabbroic layer with rare tonalite, underlain by harzburgite and dunite. Overlying the gabbroic layer is a comparatively thick zone of diabasic-textured rocks and pillow basalts. These basaltic rocks are olivine-poor with abundant intergrown acicular plagioclase and augite. The pillow lavas might have erupted superheated based on the lack of the phenocrysts and the unusual microdiabasic texture exhibited by the pillow lavas. Based on geochemical results from the last dive cruise, these lavas have compositions similar to those of mid-ocean ridge or back-arc basin lavas, except for greater concentrations of V and Cu, suggesting that they were unusually oxidized (M. Reagan and K. Kelley unpublished data). We postulate that these were the first magmas to erupt after subduction initiation. Overlying these lavas are low-Ca and high-Ca boninites, with compositions that suggest generation from a depleted mantle source at shallow levels in the presence of a water-rich slab fluid. Above these lavas are normal arc basalts and andesites similar to those found in the Alutom Formation on Guam, which have ages of 38-32 Ma (Reagan et al., 2008).

An unusual site of hornblende andesites with light-enriched REE patterns was found in dives 974, 976, and 1092. These have tentative  $^{40}\text{Ar}/^{39}\text{Ar}$  ages of 30-32 Ma (O. Ishizuka, unpublished data), suggesting that these could be the youngest lavas in this region and that they erupted at about the same time as the Kyushu-Palau Ridge rifted. The entire section has been broken up by a series of normal faults that generally down-drop lithologies toward the trench. Folding seen in dive 1092 could be related to the normal faulting if it was listric, but it also could document a compressional event that occurred after normal arc volcanism began in this region.

Peridotites exposed at the southern end of the Mariana Trough at dives 1094 and 1095 are mostly pyroxene-poor peridotites with porphyroclastic to granular textures. These are interpreted to be “forearc type” peridotites comprising structural blocks of the original Mariana forearc left along the transpressional boundary between Santa Rosa Bank and Yap. Dredge hauls have shown that forearc crustal rocks overlay these pieces of the mantle in some locations. Interspersed with the forearc peridotites are “backarc” type peridotites with that are less depleted in pyroxene and have spinels that are enriched in Al because of less melting. One location with backarc-type peridotites is dive site 973 on the east side of a small block of crust located within a trough that lies between faults to the west of the Santa Rosa Bank. Dive 1096 on the other side of this small block recovered fresh basalts with petrographic characteristics like backarc basin lavas. This opens the possibility this trough is a site of recent basaltic volcanism, despite its proximity to the trench. Age determinations for these basalts and their compositions will be crucial for determining whether young hot asthenosphere has recently circulated close to the trench here, or whether these are remnants of early Mariana Trough back-arc basalts that were once further from the trench. Because it is structurally bounded, has potentially recent volcanism, and may have a separate geological history

from adjacent crust, we have given this feature a tentative name of the West Santa Rosa Terrane.

## 9. References

- Fryer, P., Becker, N., Appelgate, B., et al., 2003, Why is the Challenger Deep so Deep?, *Earth Planet. Sci. Lett.*, 211, 259-269.
- Ishizuka, O., Kimura, J.-I., Li, Y.B., et al., 2006, Early stages in the Evolution of Izu-Bonin Arc volcanism: new age, chemical, and isotopic constraints, *Earth Planet. Sci. Lett.*, 250, 385-401.
- Karig, D.E., 1971a, Origin and development of marginal basins in the western Pacific, *J. Geophys. Res.*, 76, 2542-2561.
- Karig, D.E., 1971b, Structural history of the Mariana island arc system, *Geol. Soc. Am. Bull.*, 82, 323-344.
- Karig, D.E., 1972, Remnant arcs, *Geol. Soc. Am. Bull.*, 83, 1057-1068.
- Leat, P.T., and Larter, R.D., 2003, Intra-oceanic subduction systems: Introduction, In Larter, R.D., and Leat, P.T. (Eds.), *Intra-Oceanic Subduction Systems: Tectonic and Magmatic Processes*, *Geol. Soc. London Spec. Paper*, 219, 1-17.
- Ohara, Y. and Ishii, T., 1998, Peridotites from the southern Mariana forearc: Heterogeneous fluid supply in mantle wedge, *The Island Arc* 7, 541-558.
- Reagan, M.K. and Meijer, A., 1984, Geology and geochemistry of early arc-volcanic rocks from Guam, *Geol. Soc. Am. Bull.*, 95, 701-713.
- Reagan, M. K., Hanan, B. B., Heizler, M. T., et al., 2008, Petrogenesis of Volcanic Rocks from Saipan and Rota, Mariana Islands, and Implications for the Evolution of Nascent Island Arcs. *Jour. Petrol.*, 49, 441-464.
- Stern, R.J., 2004, Subduction Initiation: Spontaneous and Induced, *Earth Planet. Sci. Lett.*, 226, 275-292.

## **10. Appendix A. Sample descriptions**

| YK08-08-Leg2 Dive1091 |                                      | Ave. grain size | Igneous texture                               | Glass (mm) | Plag. (%) | Oliv. (%) | Cpx. (%) | Opx. (%) | Alteration |         | Sample characteristics |        |        |        |                 |            |         | Comments |                                                                                       |
|-----------------------|--------------------------------------|-----------------|-----------------------------------------------|------------|-----------|-----------|----------|----------|------------|---------|------------------------|--------|--------|--------|-----------------|------------|---------|----------|---------------------------------------------------------------------------------------|
| Sample #              | Lithology                            |                 |                                               |            |           |           |          |          | %          | Sulfide | Wt (kg)                | X (cm) | Y (cm) | Z (cm) | Weathering      | Angularity | Surface |          | Mn (mm)                                                                               |
| 1                     | altered ol basalt                    |                 | partially variolitic, sparsely ol-phyric      | -          |           | <5        |          |          | 90?        |         | 15.9                   | 25.0   | 19.0   | 19.0   | extensive       | SA         |         | 3        | qz veinlet network pervasive                                                          |
| 2                     | altered andesite lava                |                 | porphyritic                                   | -          | ?         |           | ?        |          | 100        |         | 0.85                   | 13.0   | 9.0    | 6.0    | hydrothermal    | SR         |         | 1        | pervasive qz veinlet network. Extensive hydrothermal alteration                       |
| 3                     | altered andesite lava                |                 | aphyric? Difficult to identify                | -          |           |           |          |          | 100        |         | 3.5                    | 16.5   | 16.0   | 10.0   | hydrothermal    | SA         |         | 1        | pervasive qz veinlet network. Extensive hydrothermal alteration                       |
| 4                     | altered basaltic glass               |                 | glass                                         | 2-3%       |           |           |          |          | 98         |         | 0.2                    | 8.0    | 6.0    | 5.0    | extensive       | A          |         | 4        | altered hyaloclastic breccia (basaltic glass partially remained)                      |
| 5a                    | diabase                              |                 |                                               |            | 60        | <10       | 25-30    |          | ~30        |         | 3.1                    | 16.0   | 13.0   | 11.5   | weak            | SR         |         | 2        | moderately altered ol?-px diabase                                                     |
| 5b                    | altered aphyric lava                 |                 | variolitic texture                            |            |           |           |          |          | 100        |         | 0.7                    | 10.5   | 8.5    | 8.2    | extensive       | A          |         |          | extensively altered aphyric lava with variolitic texture                              |
| 6                     | altered volcanic rock                |                 | variolitic texture                            | -          | ~40       |           |          |          | 100        |         | 7.4                    | 18.0   | 18.0   | 17.0   | extensive       | SR         |         | 5        | original composition unknown                                                          |
| 7                     | altered pillow basalt                |                 | aphyric (abundant pl microphenocryst)         | 2-3mm      |           |           |          |          | ~100       |         | 5.9                    | 22.0   | 18.3   | 11.0   | extensive       | A          |         | 6        | pillow lava with glassy rind                                                          |
| 8                     | altered porphyritic lava             |                 | porphyritic (no original phenocryst remained) |            |           | ?         | ?        |          | ~100       |         | 2.0                    | 17.5   | 11.0   | 10.0   | extensive       | A          |         | 10       | 1mm thick quartz veinlet                                                              |
| 9                     | altered aphyric lava                 |                 | variolitic texture                            |            |           |           |          |          | ~100       |         | 7.6                    | 31.0   | 19.0   | 14.0   | extensive       | A          |         | 2        |                                                                                       |
| 10                    | altered brecciated pillow            |                 | fragmented glass &altered lava                |            |           |           |          |          | ~100       |         | 2.0                    | 17.0   | 11.0   | 10.0   | extensive       | A          |         | 1        | completely altered pillow breccia? Hard to recognize original texture                 |
| 11                    | silicified lava                      |                 | no original texture remained                  |            |           |           |          |          | ~100       |         | 1.3                    | 16.0   | 10.0   | 9.0    | extensive       | A          |         | film     |                                                                                       |
| 12                    | altered diabase                      |                 | doleritic texture                             |            | ~60       |           | 20-30    |          | 80-90      |         | 2.9                    | 21.0   | 18.0   | 7.0    | extensive       | A          |         | film     | some qz veinlet                                                                       |
| 13                    | altered lava                         |                 | px-(pl)-phyric?                               |            | ?         |           | ?        |          | ~100       |         | 1.1                    | 18.0   | 8.2    | 5.2    | extensive       | A          |         | film     | no original phenocryst remained. Qz veinlet                                           |
| 14                    | altered basaltic andesite lava?      |                 | sparsely px-phyric                            |            |           |           |          |          | ~100       |         | 1.5                    | 16.0   | 9.5    | 5.5    | extensive       | A          |         | film     |                                                                                       |
| 15                    | altered massive andesitic? lava      |                 | sparsely px-phyric                            |            |           |           | ~5       |          | 70-80      |         | 3.9                    | 15.0   | 15.0   | 15.0   | weaker          | A          |         | 2        | non vesiculated cpx-pl andesite lava block. Alteration is weaker than other samples.  |
| 16                    | altered pillow basalt lava           |                 | px-phyric & variolitic                        |            |           |           | 6-8      |          | ~90        |         | 1.9                    | 13.5   | 10.5   | 8.5    | extensive       | A          |         | film     | altered non-vesiculated px-phyric basalt                                              |
| 17                    | hyaloclastic breccia(pillow breccia) |                 | hyaloclastite                                 |            |           |           |          |          | ~100       |         | 1.1                    | 18.5   | 7.5    | 9.0    | extensive       | A          |         | ~10      | completely altered hyaloclatsite. Some hydrotherma Mn and qz veinlet network present. |
| 18                    | altered basaltic lava                |                 | px-phyric                                     |            |           |           | 4-5      |          | 100        |         | 1.5                    | 14.0   | 9.5    | 6.5    | extensive       | A          |         | film     | altered non-vesiculated moderately px-phyric basalt lava                              |
| 19                    | pillow breccia                       |                 | sparsely px-phyric & variolitic               |            |           |           | 2-3      |          | 90-95      |         | 2.4                    | 15.0   | 11.5   | 11.0   | slightly weaker | A          |         | 1        | altered non-vesiculated pillow breccia (basaltic or andesitic)                        |
| 20                    | hyaloclastite                        |                 | hyaloclastic                                  |            |           |           |          |          | 100        |         | 2.2                    | 18.0   | 10.0   | 7.5    | extensive       | A          |         | 1        | completely altered hyaloclastite composed of fragmented glass                         |
| 21                    | pillow breccia                       |                 | hyaloclastic                                  |            |           |           | 2-3      |          | ~100       |         | 3.7                    | 17.0   | 12.0   | 11.0   | extensive       | A          |         | 1        | sparsely px-phyric basaltic pillow breccia                                            |

| YK08-08-Leg2 Dive1091 |                                     | Ave. grain size | Igneous texture                   | Glass (mm) | Plag. (%) | Oliv. (%) | Cpx. (%) | Opx. (%) | Alteration |         | Sample characteristics |        |        |        |            |            |         |         | Comments                                                                                                     |
|-----------------------|-------------------------------------|-----------------|-----------------------------------|------------|-----------|-----------|----------|----------|------------|---------|------------------------|--------|--------|--------|------------|------------|---------|---------|--------------------------------------------------------------------------------------------------------------|
| Sample #              | Lithology                           |                 |                                   |            |           |           |          |          | %          | Sulfide | Wt (kg)                | X (cm) | Y (cm) | Z (cm) | Weathering | Angularity | Surface | Mn (mm) |                                                                                                              |
| 22                    | basaltic lava~diabase               |                 | sparsely px-phyric and doleritic? |            |           |           | 2-3      |          | ~70        |         | 1.5                    | 15.5   | 8.0    | 9.0    | weaker     | A          |         | 1       | dense sparsely px-phyric basalt lava or diabase                                                              |
| 23                    | altered basaltic lava?              |                 | no original texture remained      |            |           |           |          |          | 100        |         | 5.5                    | 30.5   | 18.0   | 9.5    | extensive  | A          |         | 1       | pervasive alteration & qz-epidote vein network                                                               |
| 24                    | altered basaltic lava?              |                 | no original texture remained      |            |           |           |          |          | 100        |         | 2.2                    | 17.0   | 9.5    | 8.9    | extensive  | A          |         | 2       | reddish colored completely altered lava with qz-epidote veins                                                |
| 25                    | hyaloclastite                       |                 | hyaloclastite                     |            |           |           |          |          | 100        |         | 0.7                    | 17.0   | 10.0   | 5.5    | extensive  | A          |         | 2       | hyaloclastite disseminated with hydrothermal Mn-oxides                                                       |
| 26                    | sandstone~siltstone                 |                 |                                   |            |           |           |          |          |            |         | 4.0                    | 23.0   | 17.0   | 9.0    |            | A          |         | film    | weakly stratified and cross laminated                                                                        |
| 27                    | sandstone                           |                 |                                   |            |           |           |          |          |            |         | 2.3                    | 25.0   | 18.5   | 3.5    |            | platy      |         | film    | weakly stratified volcanic sanstone                                                                          |
| 28                    | volcanic breccia                    |                 | heterolithic                      |            |           |           |          |          |            |         | 6.1                    | 22.0   | 20.0   | 14.0   | moderate   | A          |         | film    | clast-supported, some breccias are relatively fresh.Hb or cpx crystals are fresh. Some breccias are dacitic. |
| 29                    | px-pl phyric basaltic andesite lava |                 | porphyritic                       |            | 10-15     | ?         | 15-20    |          | 60         |         | 3.4                    | 19.0   | 15.0   | 10.5   | moderate   | A          |         | 10      | phenocryst are relatively fresh, dense non-vesiculated px-pl phyric basaltic andesite lava                   |

| YK08-08-Leg2 Dive1092 |                                             | Ave. grain size | Igneous texture            | Glass (mm) | Plag. (%) | Oliv. (%) | Cpx. (%) | Opx. (%) | Alteration |         | Sample characteristics |        |        |        |             |            |         |         | Comments                                                                                                       |
|-----------------------|---------------------------------------------|-----------------|----------------------------|------------|-----------|-----------|----------|----------|------------|---------|------------------------|--------|--------|--------|-------------|------------|---------|---------|----------------------------------------------------------------------------------------------------------------|
| Sample #              | Lithology                                   |                 |                            |            |           |           |          |          | %          | Sulfide | Wt (kg)                | X (cm) | Y (cm) | Z (cm) | Weathering  | Angularity | Surface | Mn (mm) |                                                                                                                |
| 1                     | diabase                                     |                 | partly variolitic          |            | 60-70     |           |          |          | 50-100     |         | 7.8                    | 21.0   | 20.0   | 13.0   | extensive   | SR         |         | film    |                                                                                                                |
| 2                     | mudstone, siltstone                         |                 |                            |            |           |           |          |          |            |         | 0.80                   | 17.0   | 11.0   | 9.0    |             | SR         |         | -       | forma-rich, tuffaceous                                                                                         |
| 3                     | sandstone                                   |                 |                            |            |           |           |          |          | 100        |         | 0.6                    | 11.0   | 8.0    | 6.5    | extensive   | SA         |         | film    | stratified altered volcaniclastic sandstone, parallel lamination                                               |
| 4                     | mudstone, siltstone                         |                 |                            |            |           |           |          |          |            |         | 6.2                    | 28.0   | 24.0   | 12.0   |             | SA         |         | film    | foram-rich, tuffaceous                                                                                         |
| 5                     | scoriaceous, tuff breccia                   |                 |                            |            |           |           |          |          | 90         |         | 3.8                    | 28.0   | 21.0   | 7.0    | extensive   | platy      |         | 1       | similar to 7                                                                                                   |
| 6                     | diabase                                     |                 | variolitic texture         |            | 60-70     | ?         | ?        |          | 70         |         | 10.8                   | 31.0   | 22.0   | 13.5   | moderate    | SR         |         | 1       | brown-colored weathered diabase                                                                                |
| 7                     | volcanic sandstone, breccia                 |                 | heterolithic               |            |           |           |          |          | 60         |         | 5.0                    | 23.0   | 34.0   | 9.5    | moderate    | SR         |         | 1       | dominantly composed of altered lithic fragments; there is a 4-5 cm thick socria-rich layer ?, grain size 1-3mm |
| 8                     | andesitic breccia                           |                 | pl-phyric                  |            | 20-30     | ?         | ?        |          | 20         |         | 1.2                    | 11.0   | 9.0    | 7.0    | fresh       | SR         |         | film    | large breccia of moderately vesicular hornblende-bearing CPX-PL phyric andesitic lava                          |
| 9                     | diabse                                      |                 | fine-grained equigranular? |            | ~60       | ?         | ~10      |          | 30         |         | 3.5                    | 17.0   | 13.0   | 10.0   | fresh       | SR         |         | film    | dense relatively fresh dark-colored diabase                                                                    |
| 10                    | altered diabase?                            |                 | partly variolitic          |            | 60-70     |           | 20-30    |          | 60         |         | 2.0                    | 16.0   | 13.0   | 9.8    | moderate    | SR         |         | 3       | weathered diabase with variolitic PL texture                                                                   |
| 11                    | diabase                                     |                 |                            |            | 60-70     | ?         | ?        |          | 60         |         | 5.0                    | 28.0   | 14.0   | 10.5   | moderate    | A          |         | 1       | PL are fresh                                                                                                   |
| 12                    | diabse                                      |                 |                            |            | 70-80     |           |          |          | 40         |         | 9.7                    | 25.0   | 24.0   | 13.0   | moderate    | SR         |         | 1       | more PL-rich than others                                                                                       |
| 13                    | tuff; pumice breccia                        |                 |                            |            |           |           |          |          | 40         |         | 5.1                    | 25.0   | 18.0   | 14.5   | moderate    | A          |         | film    | matrix is pumiceous, matrix supported; relatively fresh. PL-PYX are fresh. There are some fresh felsic blot    |
| 14                    | pumiceous tuff breccia                      |                 | matrix supported           |            |           |           |          |          | 50         |         | 0.9                    | 14.0   | 9.0    | 8.0    | moderate    | A          |         | 11      | pumiceous matrix; some dacitic clasts are fresh                                                                |
| 15                    | volcanic sandstone, breccia                 |                 |                            |            |           |           |          |          | ~10        |         | 8.7                    | 28.0   | 14.0   | 17.5   | fresh       |            |         | 3       | non-structured; dark colored moderately sorted; there are convolutions of the silty stuff???                   |
| 16                    | andesitic dacitic lava                      |                 |                            |            |           |           |          |          |            |         | 2.5                    | 15.0   | 8.5    | 9.0    | fresh       | SR         |         | 5-6     | non-vesiculated light gray-colored PX-PL phyric andesitic-dacitic lava                                         |
| 17                    | volcanic sandstone                          |                 |                            |            |           |           |          |          |            |         | 5.6                    | 25.0   | 16.0   | 12.0   | extensive   | platy      |         | 1       | finely bedded volcanic sandstone                                                                               |
| 18                    | sandstone                                   |                 |                            |            |           |           |          |          |            |         | 1.0                    | 21.0   | 10.0   | 4.5    |             | platy      |         | 1       | well-stratified brownish colored volcanic sandstone                                                            |
| 19                    | tuffaceous siltstone and volcanic sandstone |                 |                            |            |           |           |          |          |            |         | 1.6                    | 13.5   | 9.2    | 9.0    | extensive   | A          |         | 20      | lower 3/4 a brownish tuffaceous siltstone; upper 1/4 is moderately sorted volcanic sandstone                   |
| 20                    | aphyric basalt                              |                 |                            |            |           |           |          |          |            |         | 0.7                    | 10.0   | 6.0    | 5.5    | weak        | SA         |         | <1      | dark grey colored non-vesiculated aphyric basalt                                                               |
| 21                    | volcanic breccia                            |                 |                            |            |           |           |          |          |            |         | 0.9                    | 13.0   | 11.0   | 8.0    | breccia are | SR         |         | 10      | breccia clasts are diabase                                                                                     |
| 22                    | siltstone                                   |                 |                            |            |           |           |          |          |            |         | 3.4                    | 17.5   | 9.0    | 23.0   |             | platy      |         | 2       | non structured siltstone with abundant burrows                                                                 |
| 23                    | siltstone                                   |                 |                            |            |           |           |          |          |            |         | 2.2                    | 24.0   | 7.0    | 5.0    |             | platy      |         | 10      | dark brown colored siltstone with many burrows                                                                 |

| YK08-08-Leg2 Dive1092 |                      | Ave. grain size | Igneous texture | Glass (mm) | Plag. (%) | Oliv. (%) | Cpx. (%) | Opx. (%) | Alteration |         | Sample characteristics |        |        |        |            |            |         |         | Comments                                          |
|-----------------------|----------------------|-----------------|-----------------|------------|-----------|-----------|----------|----------|------------|---------|------------------------|--------|--------|--------|------------|------------|---------|---------|---------------------------------------------------|
| Sample #              | Lithology            |                 |                 |            |           |           |          |          | %          | Sulfide | Wt (kg)                | X (cm) | Y (cm) | Z (cm) | Weathering | Angularity | Surface | Mn (mm) |                                                   |
| 24                    | dacitic lava         |                 |                 |            |           |           |          |          |            |         | 7.5                    | 21.0   | 22.0   | 8.5    | weak       | SR         |         | 2       | non-vesiculated HB-bearing dacite lava            |
| 25                    | altered tuff breccia |                 |                 |            |           |           |          |          |            |         | 3.4                    | 18.0   | 17.0   | 7.0    | extensive  | A          |         | 1       | clast supported, but matrix is completely altered |

| YK08-08-Leg2 Dive1093 |                    | Ave. grain size | Igneous texture                     | Glass (mm) | Plag. (%) | Oliv. (%) | Cpx. (%) | Opx. (%) | Alteration |         | Sample characteristics |        |        |        |                            |            |         |         | Comments                                                                             |
|-----------------------|--------------------|-----------------|-------------------------------------|------------|-----------|-----------|----------|----------|------------|---------|------------------------|--------|--------|--------|----------------------------|------------|---------|---------|--------------------------------------------------------------------------------------|
| Sample #              | Lithology          |                 |                                     |            |           |           |          |          | %          | Sulfide | Wt (kg)                | X (cm) | Y (cm) | Z (cm) | Weathering                 | Angularity | Surface | Mn (mm) |                                                                                      |
| 1                     | diabase            | 0.2mm           | medium-grained                      |            | 60        | 10        | 30       |          |            |         | 6.5                    | 29.0   | 12.0   | 10.0   | light to strong            |            |         |         | weathered rind otherwise relatively fresh                                            |
| 2                     | microdiabse        | <0.1mm          | very fine grained basalt            |            |           |           |          |          |            |         | 2.7                    | 17.0   | 12.0   | 9.0    | light to moderate          | A          |         | coating | 100% fine-grained matrix, mostly pl, ol, px; glassy rind (FAB)                       |
| 3                     | microdiabse        | <0.1mm          | very fine grained basalt            |            |           |           |          |          |            |         | 0.2                    | X      | X      | X      | strong                     | A          |         |         | several small pieces                                                                 |
| 4                     | diabase            | <0.1mm          | fine-grained diabase                |            | 60        | 40        |          |          |            |         | 2.1                    | 14.0   | 8.5    | 8.0    | moderate                   | A          |         | coating | difficult to identify: olivine or cpx                                                |
| 5                     | microdiabse        | <0.1mm          | very fine grained basalt            |            |           | 1         |          |          |            |         | 1.2                    | 8.0    | 12.5   | 7.0    | strongly                   | A          |         | coating | like R2, but more altered                                                            |
| 6                     | microdiabse        | <0.1mm          | very fine grained basalt            |            |           |           |          |          |            |         | 11.5                   | 29.0   | 20.0   | 10.0   | light to strong            | A          |         | coating | veins of alteration, like R2 otherwise                                               |
| 7                     | microdiabse        | <0.1mm          | very fine grained basalt            |            |           |           |          |          |            |         | 19.5                   | 27.0   | 24.5   | 20.0   | light to moderate          | A          |         | coating | veins of alteration, like R2 otherwise                                               |
| 8                     | hyaloclastite      |                 | holohyaline                         |            |           |           |          |          |            |         | 0.7                    | 9.0    | 8.0    | 5.0    | slight                     | A          |         | hydroth | glass&palagonite rind, glass has layered texture                                     |
| 9                     | microdiabase       | <0.1mm          | very fine grained basalt            |            |           | 1         |          |          |            |         | 0.4                    | 7.0    | 7.0    | 4.0    | moderate                   | A          |         | 2mm     | glassy rind                                                                          |
| 10                    | diabase            | 0.5-1mm         | coarse diabasic                     |            | 60        | 10        | 30       |          |            |         | 1.5                    | 17.0   | 10.0   | 6.0    | slight - moderate          | A          |         | coating | good geochronology (buddelyite?)                                                     |
| 11                    | diabase            | 0.5-1mm         | coarse diabasic                     |            | 60        | 10        | 30       |          |            |         | 4.0                    | 19.0   | 10.0   | 8.0    | moderate                   | A          |         | coating | alteration along veins like R10, but more altered generally                          |
| 12                    | diabase            | 0.5-1mm         | coarse diabasic                     |            | 60        | 10        | 30       |          |            |         | 8.5                    | 17.0   | 13.0   | 28.0   | moderate                   | A          |         | coating |                                                                                      |
| 13                    | microdiabase       | <0.1mm          | very fine grained basalt            |            |           | 1         |          |          |            |         | 0.6                    | 12.0   | 7.0    | 4.0    | slight                     | A          |         | coating |                                                                                      |
| 14                    | diabase            | 0.2mm           | fine diabasic                       |            | 60        | 40        |          |          |            |         | 0.5                    | 14.0   | 6.5    | 6.0    | light-strong               | A          |         | coating | oOtherwise light to moderate weathering; difficult to identify: olivine or cpx       |
| 15                    | microdiabase       | <0.1mm          | very fined grained basalt           |            |           |           |          |          |            |         | 2.8                    | 21.0   | 14.0   | 9.5    | slight(except along veins) | A          |         | coating | like R2                                                                              |
| 16                    | diabase            |                 | porphyritic medium-grained diabasic |            | 60        | 40        |          |          |            |         | 5.5                    | 14.5   | 14.0   | 15.0   | light-moderate             | A          |         | coating | ol phenocrysts 1-3mm alteration to iddingsite; difficult to identify: olivine or cpx |
| 17                    | mudstone-siltstone |                 |                                     |            |           |           |          |          |            |         | 1.5                    | 21.0   | 10.0   | 10.0   | light - heavy              | A          |         | coating | core is fairly fresh, disrupted bedding                                              |
| 18                    | mudstone-siltstone |                 |                                     |            |           |           |          |          |            |         | 2.5                    | 12.0   | 10.0   | 17.0   | light - heavy              | A          |         | coating | core is fairly fresh, disrupted bedding                                              |

| YK08-08-Leg2 Dive1094 |                                               |                 |                                    |             |            |           |            |          |            |         |                        |        |        |        |                 |            |         |         |                    |  |                                                                                                                                                                                                                                                     |
|-----------------------|-----------------------------------------------|-----------------|------------------------------------|-------------|------------|-----------|------------|----------|------------|---------|------------------------|--------|--------|--------|-----------------|------------|---------|---------|--------------------|--|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sample #              | Lithology                                     | Ave. grain size | Igneous texture                    | Glass (mm)  | Plag. (%)  | Oliv. (%) | Cpx. (%)   | Opx. (%) | Alteration |         | Sample characteristics |        |        |        |                 |            |         |         | Samples            |  | Comments                                                                                                                                                                                                                                            |
|                       |                                               |                 |                                    |             |            |           |            |          | %          | Sulfide | Wt (kg)                | X (cm) | Y (cm) | Z (cm) | Weathering      | Angularity | Surface | Mn (mm) | Sectioned on-board |  |                                                                                                                                                                                                                                                     |
| 1                     | Gabbro with pyroxenite vein                   | 2-3 mm          | equigranular                       | gabbro-vein | 40-50 none | none none | 40-60? >90 | none ??  | 30? >50?   |         | 0.3                    | 8.0    | 7.0    | 4.0    | moderate        | A          |         | film    |                    |  | PYX-gabbro cut by pyroxenite vein (vein contains fragments or clots of the gabbro); pyroxenite cut by a couple <1-1 mm white-green veins; thin veins of pyroxenite invade the gabbro; also thin (~1 mm) veins or crushed zones in one end of gabbro |
| 2                     | Serpentinized harzburgite                     | <1-4 mm         | granular, slightly porphyroclastic | -           | -          | 15-25     | <1         | 2-8?     | ~75        |         | 0.35                   | 11.0   | 7.0    | 3.5    | high            | A          |         | <1      |                    |  | Orange-brown extensively serpentinized with black serpentine veins; Cr-spinel present                                                                                                                                                               |
| 3                     | Fine-grained pyroxenitic gabbro or pyroxenite | <1-2 mm         | equigranular                       | -           | 10-20      | 5-15      | 65-90?     | ?        | 10-15      |         | 4.3                    | 22.0   | 10.0   | 10.0   | moderate        | A          |         | <1      |                    |  | texture to diabasic in places; seems to be pyroxene -rich in parts; dark, irregular 1-2 mm clots appear to be altered olivine (?) pseudomorphs; PLAG is largely interstitial; hard to tell PYX proportions                                          |
| 4                     | Serpentinized harzburgite                     | <1-3mm          | slightly porphyroclastic           | -           | -          | <5        | -          | 5-15     | 80-90      |         | 1.7                    | 11.0   | 12.0   | 9.0    | very high       | SA         |         | <1      |                    |  | highly weathered, orange-brown, OPX largely pseudomorphed                                                                                                                                                                                           |
| 5                     | Serpentinized harzburgite                     | <1-10 mm        | little original texture left       | -           | -          | <5        | 10.0       | ?        | 80-90      |         | 10.7                   | 31.0   | 17.0   | 16.0   | high            | A          |         | <1      |                    |  | orange-brown serpentinite; abundant grey, translucent veins, 1 very large OPX clot; some remnant PYX but much is replaced; only minor to rare spinel?                                                                                               |
| 6                     | Pyroxenite                                    | <1-3 mm         | equigranular                       | -           | 1-3?       | 3-8?      | 70-90      | 70-90    | 10-30      |         | 6.5                    | 16.5   | 15.0   | 13.0   | moderate        | A          |         | <1      |                    |  | proportions of PYX (OPX-CPX) hard to determine; some interstitial OL now largely altered to serpentinite; may be minor interstitial PLAG; some grain size variations <1 to 3 mm                                                                     |
| 7                     | Very coarse sandstone                         | <1-5 mm         | grain supported                    | -           | -          | -         | -          | -        | -          |         | 0.5                    | --     | --     | --     | high            | A          |         | film    |                    |  | 6 pieces, each ~5cm length; largely serpentinized harzburgite (orange brown) fragments, some serpentine mud, minor other lithics                                                                                                                    |
| 8                     | Serpentinized harzburgite                     | <1-2 mm         | slightly porphyroclastic           | -           | -          | <10?      | <2?        | 3-10?    | 70-80      |         | 0.5                    | 12.0   | 6.0    | 7.0    | high            | A          |         | film    |                    |  | orange-brown, some spinel, some OPX (now bastite?); slight fabric                                                                                                                                                                                   |
| 9                     | Serpentinized harzburgite                     | <1-10 mm        | porphyroclastic                    | -           | -          | <5-30     | <2??       | 15-25    | 60-90      |         | 2.7                    | 16.0   | 10.0   | 10.0   | moderate - high | A          |         | <1      |                    |  | orange-brown serpentinite; distinct elongation in OPX pseudomorphs; some gray-green less altered (?) sections with more olivine remnants perhaps                                                                                                    |
| 10                    | Serpentinized harzburgite                     | <1-4 mm         | weakly porphyroclastic             | -           | -          | <5-10     | <1?        | 5-15     | 70-90      |         | 2.2                    | 17.0   | 13.0   | 9.0    | high            | A          |         | <1      |                    |  | orange-brown serpentinized harzburgite; highly weathered, a few grains of spinel                                                                                                                                                                    |
| 11                    | Serpentinized harzburgite                     | <1-3mm          | strongly foliated                  | -           | -          | <5-10?    | <1         | 5-15     | 65-90      |         | 0.4                    | 7.0    | 7.0    | 7.0    | very high       | A          |         | film    |                    |  | highly weathered orange-brown serpentinite; some OPX mostly gone to bastite; some spinel; appear to be some less altered clots in a foliated matrix                                                                                                 |

| YK08-08-Leg2 Dive1094 |                                                       |                 |                            |            |               |           |                 |                     |            |         |                        |        |        |        |            |            |              |         |                   |  |                                                                                                                                                                                                                                                                              |
|-----------------------|-------------------------------------------------------|-----------------|----------------------------|------------|---------------|-----------|-----------------|---------------------|------------|---------|------------------------|--------|--------|--------|------------|------------|--------------|---------|-------------------|--|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sample #              | Lithology                                             | Ave. grain size | Igneous texture            | Glass (mm) | Plag. (%)     | Oliv. (%) | Cpx. (%)        | Opx. (%)            | Alteration |         | Sample characteristics |        |        |        |            |            |              |         | Samples           |  | Comments                                                                                                                                                                                                                                                                     |
|                       |                                                       |                 |                            |            |               |           |                 |                     | %          | Sulfide | Wt (kg)                | X (cm) | Y (cm) | Z (cm) | Weathering | Angularity | Surface      | Mn (mm) | Sectioned onboard |  |                                                                                                                                                                                                                                                                              |
| 12                    | Serpentinized harzburgite                             | <1-10 mm        | slight fabric              | -          | -             | 10-15?    | <3?             | 10-20               | 50-60      |         | 12.0                   | 31.0   | 22.0   | 13.0   | high       | SA         | <1 in places |         |                   |  | fairly abundant OPX; many to bastite and serpentinite pseudomorphs; probably some spinel                                                                                                                                                                                     |
| 13                    | Serpentinized harzburgite with gabbroic impregnation? | <1-4 mm         | porphyroclastic            | -          | some in veins | <5        | 1-3? > in veins | 5-10 some in veins? | 60-90      |         | 1.5                    | 16.0   | 10.0   | 9.0    | high       | SR         | film         |         |                   |  | orange-brown porphyroclastic harzburgite cut by irregular veins and clots of white-grey gabbroic-pyroxenitic (?) material; veins distributed and diffuse but clearly cut porphyroclastic fabric; suggested that the white could also be diallage structure/alteration in PYX |
| 14                    | Serpentinized harzburgite                             | <1-2 mm         | granular                   | -          | -             | <5        | <1?             | 5                   | 80-90      |         | 0.3                    | 12.0   | 6.0    | 5.0    | very high  | A          | film         |         |                   |  | orange-brown, highly weathered                                                                                                                                                                                                                                               |
| 15                    | Serpentinized harzburgite                             | <1-3 mm         | granular, no strong fabric | -          | -             | <5        | -               | <5                  | 85-95      |         | 4.5                    | 28.0   | 22.0   | 9.0    | very high  | A          | film         |         |                   |  | highly weathered orange-brown serpentinite, some spinel, little evidence of bastite pseudomorphs; may have been dunite                                                                                                                                                       |
| 16                    | Serpentinized harzburgite                             | <1-3 mm         | weak fabric                | -          | -             | <5        | <2?             | 5-10                | 85-95      |         | 16.2                   | 32.0   | 20.0   | 18.0   | very high  | A          | film         |         |                   |  | highly weathered orange-brown serpentinite, some spinel, most of OPX to bastite pseudomorphs                                                                                                                                                                                 |
| 17                    | Serpentinized harzburgite                             | <1-4 mm         | porphyroclastic            | -          | -             | 30-40     | <5?             | 5-15                | 30-60      |         | 7.5                    | 19.0   | 17.0   | 13.0   | moderate   | A          | <1           |         |                   |  | grey-green serpentinized harzburgite; blocky, black serpentine veins, some fractures                                                                                                                                                                                         |

Note: Observer = Bloomer; olivine proportions in pyroxenites are estimates of original amounts; most now altered; OPX/CPX proportions hard to establish.

| YK08-08-Leg2 Dive1095 |                                              | Ave. grain size | Igneous texture         | Glass (mm) | Plag. (%) | Oliv. (%) | Cpx. (%) | Opx. (%) | Alteration |         | Sample characteristics |        |        |        |                  |            |         |         | Comments                                                                                                                                                                                                                                                                                                                                                             |
|-----------------------|----------------------------------------------|-----------------|-------------------------|------------|-----------|-----------|----------|----------|------------|---------|------------------------|--------|--------|--------|------------------|------------|---------|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sample #              | Lithology                                    |                 |                         |            |           |           |          |          | %          | Sulfide | Wt (kg)                | X (cm) | Y (cm) | Z (cm) | Weathering       | Angularity | Surface | Mn (mm) |                                                                                                                                                                                                                                                                                                                                                                      |
| 1                     | Serpentinized harzburgite                    | <1 to 3 mm      | porphyroclastic         |            |           | 5-15      | <3?      | 10-15    | 60-75      |         | 6.3                    | 20     | 24     | 12     | moderate to high | A          |         | <1      | orange-brown; little CPX? But spinel is common some fabric                                                                                                                                                                                                                                                                                                           |
| 2                     | Serpentinized harzburgite                    | <1 to 3 mm      | porphyroclastic         | -          | -         | 5-15      | <3?      | 10-15    | 60-75      |         | 2.5                    | 12     | 12     | 10     | moderate to high | A          |         | <1      | orange-brown; abundant deformed OPX pseudomorphs; also some greyish clots; veins could be secondary or deformed OPX; original OPX % hard to estimate                                                                                                                                                                                                                 |
| 3                     | Serpentinized harzburgite with veins         | <1 to 2 mm      | porphyroclastic         | -          | -         | 5-10      | <2?      | 10-15?   | 60-75      |         | 4                      | 14     | 18     | 13     | high             | A          |         | <1      | 2 cm vein of pyroxenite or OL-PYXenite cuts sample; also a 1 cm vein of gabbroic material with significantly altered PLAG; spinel common, abundant secondary magnetite                                                                                                                                                                                               |
| 4                     | Serpentinized dunite with vein               | <1 to 6 mm      | granular                | -          | -         | 20-30     | <1?      | <3?      | 35-60      |         | 1.3                    | 11     | 16     | 8      | moderate         | A          |         | <1      | seppentinized dunite with grey-green core; 0.5-3 cm rim of orange oxidized weathering; spinel common but not much OPX; cut by 1 cm pyroxenitic vein; PYX quite altered                                                                                                                                                                                               |
| 5                     | Serpentinized dunite                         | <1 to 4 mm      | granular                | -          | -         | 25-50     | <1?      | <3?      | 45-50      |         | 1.9                    | 22     | 10     | 8      | low to moderate  | A          |         | <1      | 0.5-3 cm orange-brown rim on a fresher grey core; OL in places quite granular, might have interstitial PYX though most of what is around remnant OL likes like black serpentine; some spinel                                                                                                                                                                         |
| 6                     | Serpentinized dunite                         | ~2 to 4 mm      | granular                | -          | -         | 45-50     | <1?      | <3?      | 45-50      |         | 4.3                    | 30     | 16     | 10     | low to moderate  | A          |         | <1      | serpentinized dunite; grey core quite fresh, common spinel, little PYX; spinel common; oragne brown rim 2-6 cm thick; cut by 2-3 mm black serpentine vein; OL in places equigranular texture seems not very deformed                                                                                                                                                 |
| 7                     | Serpentinized dunite                         | <1 to 5 mm      | granular                | -          | -         | 5-40      | <1?      | <3?      | 50-90      |         | 2.7                    | 16     | 15     | 10     | low to high      | A          |         | <1      | grey fairly fresh core, 1-4 cm oragne brown rim; one <1 mm irregular felsic vein; OL granular, doesn't seem very deformed                                                                                                                                                                                                                                            |
| 8                     | Serpentinized harzburgite                    | <1 to 4 mm      | granular                | -          | -         | 5-25      | <1?      | 5-10     | 60-90      |         | 7.4                    | 31     | 28     | 12     | moderate to high | A          |         | <1      | grey-green fresher core, 2-4 cm orange-brown rim; some OPX pseudomorphs, spinel common                                                                                                                                                                                                                                                                               |
| 9                     | Serp. Pyroxenite/ Serpentinized harzburgite? | <1 to 5 mm      | strong foliation        | -          | -         | ?         | ?        | ?        | 70-90      |         | 2                      | 20     | 14     | 8      | high             | A          |         | <1      | very odd; strong porphyroclastic texture; serpentine has a pronounced fibrous structure; makes one think it could be pyroxenite; grey-green lenses in more weathered orange-brown could also be stretched and then serpentinized OL ("cleavable OL") giving rise to this domino-like serpentine fabric; original mineral proportions impossible to tell; some spinel |
| 10                    | Serpentinized harzburgite                    | <1 to 4 mm      | porphyroclastic         | -          | -         | 5-10      | <1?      | 10-15    | 75-90      |         | 1.4                    | 16     | 13     | 7      | moderate to high | A          |         | <1      | orange brown, distinct fabric, OPX pseudomorphs; common spinel                                                                                                                                                                                                                                                                                                       |
| 11                    | Serpentinized harzburgite                    | <1 to 3 mm      | granular? Little fabric | -          | -         | 2-5       | <1?      | 10-15    | 80-95      |         | 2.8                    | 17     | 13     | 8      | high             | A          |         | <1      | orange brown; some spinel; OPX largely replaced; little primary OL                                                                                                                                                                                                                                                                                                   |
| 12                    | Serpentinized dunite                         | <1 to 4 mm      | granular                | -          | -         | 50-60     | <1?      | <5       | 30-50      |         | 12                     | 18     | 24     | 18     | low to moderate  | SA         |         | <1      | very fresh grey dunitic core; orange weathered on rim and along crosscutting fracture                                                                                                                                                                                                                                                                                |

| YK08-08-Leg2 Dive1095 |                                                   | Ave. grain size | Igneous texture               | Glass (mm) | Plag. (%) | Oliv. (%)  | Cpx. (%) | Opx. (%)        | Alteration |         | Sample characteristics |        |        |        |                       |            |         |         | Comments                                                                                                                                                     |
|-----------------------|---------------------------------------------------|-----------------|-------------------------------|------------|-----------|------------|----------|-----------------|------------|---------|------------------------|--------|--------|--------|-----------------------|------------|---------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sample #              | Lithology                                         |                 |                               |            |           |            |          |                 | %          | Sulfide | Wt (kg)                | X (cm) | Y (cm) | Z (cm) | Weathering            | Angularity | Surface | Mn (mm) |                                                                                                                                                              |
| 13                    | Serpentinized dunite                              | <1 to 4 mm      | granular to fibrous           | -          | -         | <5-10      | <1?      | <5?             | 75-85?     |         | 3.1                    | 19     | 18     | 9      | high                  | A          |         | <1      | grey to orange; mostly dunitic; beginning of fabric like R9; suggests fabric in R9 does derive from OL deformation and alteration, not pyroxenite alteration |
| 14                    | Serpentinized dunite                              | <1 to 4 mm      | pronounced foliation          | -          | -         | 5-40       | <1?      | <3              | 50-90      |         | 0.9                    | 16     | 11     | 6      | moderate to high      | A          |         | <1      | gray dunitic core; thick orange-brown rim; spinel present                                                                                                    |
| 15                    | Serpentinized dunite to serpentinized harzburgite | <1 to 6 mm      | granular to somewhat deformed | -          | -         | 35-40      | <3?      | 5-10?           | 40-70      |         | 8.7                    | 35     | 15     | 11     | moderate              | A          |         | <1      | grey, relatively fresh core, though still extensive alteration of OL and PYX; not as fresh as R12                                                            |
| 16                    | Serpentinized dunite                              |                 |                               | -          | -         | 5-40       | <1?      | <3?             | 50-95      |         | 6.4                    | 25     | 20     | 12     | moderate to high      | A          |         | <1      | very sheared, strong fabric; elongate fresher grey clots in orange-brown matrix; little PYX                                                                  |
| 17                    | Serpentinized dunite to serpentinized harzburgite |                 |                               | -          | -         | 40-60      | <2?      | to 5% in places | 30-50      |         | 2.8                    | 18     | 13     | 11     | moderate              | A          |         | <1      | fresh grey core, clots of small OPX in places, cleavage is clear; some spinel; orange-brown weathered rind                                                   |
| 18                    | Serpentinized dunite                              |                 |                               | -          | -         | 50 in core | <2?      | <3?             | 50-95      |         | 4.5                    | 25     | 20     | 13     | moderate to very high | A          |         | <1      | grey fresher core; 1 cm green rim on that, 1-2 cm orange brown rim on outermost rind; some spinel                                                            |
| 19                    | Serpentinized dunite                              |                 |                               | -          | -         | 50 in core | <2?      | <3?             | 50-95      |         | 4.8                    | 31     | 14     | 11     | moderate to very high | A          |         | <1      | very much like R18; cut by thin black serpentine vein                                                                                                        |
| 20                    | siltstone, fine to medium sandstone               |                 |                               | -          | -         |            |          |                 |            |         | 5.5                    | 29     | 25     | 15     |                       |            |         |         | very much like R21 with fewer black lithic (?) grains                                                                                                        |
| 21a                   | siltstone, fine to medium sandstone               |                 |                               | -          | -         |            |          |                 |            |         | 7                      | 31     | 20     | 15     |                       |            |         |         | brown fine sandstone-siltstone with scattered coarser black grains (volcanic lithic fragments? Mn pieces?)                                                   |
| 21b                   | Serpentinized dunite                              |                 |                               | -          | -         | <5         | <1       | <5              | 90-100     |         | 0.5                    | 14     | 7      | 5      | high                  | A          |         | <1      | orange-brown, highly altered, little PYX                                                                                                                     |

| YK08-08-Leg2 Dive1096 |                | Ave. grain size | Igneous texture                     | Glass (mm) | Plag. (%) | Oliv. (%) | Cpx. (%) | Opx. (%) | Alteration |         | Sample characteristics |        |        |        |            |            |         |         | Comments                                                                |
|-----------------------|----------------|-----------------|-------------------------------------|------------|-----------|-----------|----------|----------|------------|---------|------------------------|--------|--------|--------|------------|------------|---------|---------|-------------------------------------------------------------------------|
| Sample #              | Lithology      |                 |                                     |            |           |           |          |          | %          | Sulfide | Wt (kg)                | X (cm) | Y (cm) | Z (cm) | Weathering | Angularity | Surface | Mn (mm) |                                                                         |
| 1                     | aphyric basalt |                 | aphyric, vesicularity 30%           | -          |           |           |          |          | 0          |         | 6.2                    | 30.0   | 16.0   | 17.0   | fresh      | SA         |         | film    | fresh highly-vesiculated aphyric basalt with pl and ol microphenocrysts |
| 2                     | aphyric basalt |                 | aphyric, vesicularity 40-50%        | -          |           |           |          |          | 0          |         | 8.50                   | 30.0   | 20.0   | 15.0   | fresh      | SA         |         | film    | fresh highly-vesiculated aphyric basalt with pl and ol microphenocrysts |
| 3                     | aphyric basalt |                 | aphyric, vesicularity 40-50%        | 8 mm       |           |           |          |          | 0          |         | 9.5                    | 23.0   | 16.0   | 26.0   | fresh      | SA         |         | film    | pillow lava with glass rind                                             |
| 4                     | aphyric basalt |                 | aphyric, vesicularity 50%           | -          |           |           |          |          | 5          |         | 13.0                   | 27.0   | 23.0   | 18.0   | fresh      | A          |         | film    | same as above,slightly weathered rim, vesiculated fillings              |
| 5                     | aphyric basalt |                 | aphyric, vesicularity 50%           | 10 nn      |           |           |          |          | 10         |         | 3.0                    | 19.0   | 13.0   | 12.0   | weak       | A          |         | film    | pillow lava fragment                                                    |
| 6                     | aphyric basalt |                 | aphyric, vesicularity 50%           | -          |           |           |          |          | 5          |         | 1.4                    | 15.0   | 11.0   | 11.0   | fresh      | A          |         | film    | similar to above                                                        |
| 7                     | aphyric basalt |                 | aphyric, vesicularity 40-50%        | 6 mm       |           |           |          |          | 0          |         | 6.5                    | 24.0   | 19.0   | 15.0   | fresh      | SA         |         | film    | pillow lava with glassy rind                                            |
| 8                     | aphyric basalt |                 | aphyric, vesicularity 30-40%        | 10 mm      |           |           |          |          | 0          |         | 7.0                    | 15.0   | 18.0   | 18.0   | fresh      | SA         |         | film    | pillow lava with glassy rind                                            |
| 9                     | aphyric basalt |                 | aphyric, vesicularity 40-50%        | 2 mm       |           |           |          |          | 0          |         | 2.5                    | 23.0   | 12.0   | 11.0   | fresh      | A          |         | film    | pillow lava with glassy rind                                            |
| 10                    | aphyric basalt |                 | aphyric, vesicularity 30-40%        | -          |           |           |          |          | 0          |         | 6.2                    | 26.0   | 20.0   | 13.0   | fresh      | A          |         | film    | vesiculated aphyric basalt                                              |
| 11                    | aphyric basalt |                 | aphyric, vesicularity 40%           | -          |           |           |          |          | 5          |         | 3.2                    | 15.0   | 18.0   | 12.0   | weak       | A          |         | film    | vesiculated aphyric basalt                                              |
| 12                    | aphyric basalt |                 | aphyric, vesicularity 40-50%        | -          |           |           |          |          | 5          |         | 1.8                    | 17.0   | 10.0   | 9.0    | weak       | A          |         | film    | some vesicular fillings                                                 |
| 13                    | siltstone      |                 | semiconsolidated                    | -          |           |           |          |          |            |         | 1.0                    | 15.0   | 10.0   | 8.0    |            | R          |         | -       | tuffaceous non-structured siltstone                                     |
| 14                    | ol basalt      |                 | (ol)-pl-phyric                      | -          | 30        | 4-5       |          |          | 0          |         | 9.2                    | 37.0   | 20.0   | 13.0   | fresh      | A          |         | film    | fresh ol basalt with ol and abundant pl                                 |
| 15                    | ol basalt      |                 | (ol)-pl-phyric                      | 2 mm       | 30        | 3-4       |          |          | 0          |         | 2.0                    | 14.0   | 14.0   | 9.0    | fresh      | A          |         | film    | pillow lava of ol basalt                                                |
| 16                    | ol basalt      |                 | sparsely ol-phyric,vesicularity 50% | -          | 20-30     | 2-3       |          |          | 0          |         | 3.7                    | 18.0   | 15.0   | 12.0   | weak       | A          |         | film    | some vesicular fillings                                                 |
| 17                    | ol basalt      |                 | sparsely ol-phyric,vesicularity 50% | -          | 20-30     | 1-2       |          |          | 0          |         | 8.30                   | 15.0   | 12.0   | 11.0   | fresh      | A          |         | film    | highly vesiculated sparsely ol phyric basalt                            |

| YK08-08-Leg2 Dive1096 |                       | Ave. grain size | Igneous texture                     | Glass (mm) | Plag. (%) | Oliv. (%) | Cpx. (%) | Opx. (%) | Alteration |         | Sample characteristics |        |        |        |            |            |         |         | Comments                                           |
|-----------------------|-----------------------|-----------------|-------------------------------------|------------|-----------|-----------|----------|----------|------------|---------|------------------------|--------|--------|--------|------------|------------|---------|---------|----------------------------------------------------|
| Sample #              | Lithology             |                 |                                     |            |           |           |          |          | %          | Sulfide | Wt (kg)                | X (cm) | Y (cm) | Z (cm) | Weathering | Angularity | Surface | Mn (mm) |                                                    |
| 18                    | ol basalt             |                 | sparsely ol-phyric,vesicularity 50% | 6 mm       | 20-30     | 2-3       |          |          | 0          |         | 7.0                    | 23.0   | 20.0   | 17.0   | fresh      | A          |         | film    | pillow basalt                                      |
| 19                    | ol basalt             |                 | sparsely ol-phyric,vesicularity 50% | -          | 20-30     | 1-2       |          |          | 0          |         | 0.9                    | 13.0   | 9.0    | 9.0    | fresh      | A          |         | film    | some aphyric segregation vein                      |
| 20                    | nearly aphyric basalt |                 | vesicularity 50%                    | -          | 20-30     | <1        |          |          | 0          |         | 5.4                    | 18.0   | 19.0   | 15.0   | fresh      | A          |         | film    | nearly aphyric basalt lava                         |
| 21                    | ol basalt             |                 | vesicularity 40-50%                 | 3 mm       | 20-30     | 3-4       |          |          | 0          |         | 7.0                    | 32.0   | 18.0   | 12.0   | fresh      | A          |         | film    | pillow lava                                        |
| 22                    | ol basalt             |                 | vesicularity 40-50%                 | -          | 20-30     | 2-3       |          |          | 0          |         | 4.0                    | 20.0   | 15.0   | 16.0   | fresh      | A          |         | film    | fresh ol basalt                                    |
| 23                    | aphyric basalt        |                 | vesicularity 40-50%                 | -          | -         | -         |          |          | 0          |         | 7.5                    | 28.0   | 25.0   | 15.0   | weak       | A          |         | film    | slightly weathered along margin                    |
| 24                    | mudstone              |                 | semiconsolidated                    | -          | -         | -         |          |          | 0          |         | 5.5                    | 27.0   | 17.0   | 10.0   |            | R          |         |         | brown colored semiconsolidated tuffaceous mudstone |
| 25                    | aphyric basalt        |                 | vesicularity 40-50%                 | 3 mm       | -         | -         |          |          | 0          |         | 2.5                    | 17.0   | 14.0   | 11.0   | strong     | A          |         | film    | altered pillow lava                                |
| 26                    | siltstone             |                 | unconsolidated                      | -          | -         | -         |          |          |            |         | 6.8                    | 33.0   | 20.0   | 19.0   |            | R          |         |         | tuffaceous mudstone                                |
| 27                    | pl-phyric basalt      |                 | vesicularity 40%,pl-phyric          | -          | 40        | <1        |          |          | 0          |         | 14.0                   | 38.0   | 23.0   | 18.0   | weak       | A          |         | film    | blocky pl-phyric lava                              |
| 28                    | pl-phyric basalt      |                 | vesicularity 40%,pl                 | -          | 30-40     | <1        |          |          | 5          |         | 7.0                    | 34.0   | 19.0   | 13.0   | weak       | A          |         | film    | blocky pl-phyric lava                              |

| YK08-08-Leg2 Dive1097 |                                                          | Ave. grain size | Igneous texture                                | Glass (mm) | Plag. (%) | Oliv. (%) | Cpx. (%) | Opx. (%) | Alteration |         | Sample characteristics |        |        |        |            |            |         |         | Comments                                                                                                        |
|-----------------------|----------------------------------------------------------|-----------------|------------------------------------------------|------------|-----------|-----------|----------|----------|------------|---------|------------------------|--------|--------|--------|------------|------------|---------|---------|-----------------------------------------------------------------------------------------------------------------|
| Sample #              | Lithology                                                |                 |                                                |            |           |           |          |          | %          | Sulfide | Wt (kg)                | X (cm) | Y (cm) | Z (cm) | Weathering | Angularity | Surface | Mn (mm) |                                                                                                                 |
| 1                     | ol basalt (boninitic)                                    |                 | highly ol-phyric (groundmass rapid quenched)   | -          |           | ~30       |          |          | 60         |         | 3.5                    | 22.0   | 14.0   | 12.0   | 80         | A          |         | film    | non vesiculated weathered "picritic" basaltic lava, probably boninitic, but pl is abundant in glassy groundmass |
| 2                     | diabase                                                  | 0.5-1           | diabasic                                       | -          |           |           |          |          | -          |         | 1.10                   | 13.0   | 9.0    | 7.0    | 50         | A          |         | film    | weathered pl-ol?? Diabase                                                                                       |
| 3                     | diabase                                                  | ~1              | diabasic?aphyric?                              | -          | 60-70     |           |          |          | 30         |         | 28.5                   | 34.0   | 28.0   | 24.0   | 70         | A          |         | film    | Only core part seems to be fresher, very fine grained ol-pl diabasic rock                                       |
| 4                     | pl-phyric basalt                                         | <1              | non vesiculated, pl-phyric (very fine grained) | -          | 20-30     |           |          |          | 30         |         | 0.9                    | 11.0   | 10.0   | 9.0    | 30         | A          |         | -       | finely pl-phyric weathered basaltic lava                                                                        |
| 5                     | ol basalt (boninitic)                                    | <1              |                                                | -          | 20-30     | 20-30     |          |          | 80         |         | 1.0                    | 15.0   | 9.0    | 8.0    | 80         | A          |         | -       | Groundmass is vvery glassy (boninitic?)                                                                         |
| 6                     | non vesiculated pl-phyric basalt ot andesite (boninitic) | 1-2             | finely pl-phyric                               | -          | 40        | ?         |          |          | 70         |         | 7.4                    | 20.0   | 19.0   | 18.0   | 30         | A          |         | -       | glassy pl-phyric basaltic lava                                                                                  |
| 7                     | ol-rich basalt (boninite)                                | 1-2             | ol-pl-phyric                                   | -          | 20-30     | 30-40     |          |          | 60         |         | 2.8                    | 18.0   | 16.0   | 10.0   | 70         | A          |         | film    | ol-rich basalt or boninite with glass-rich groundmass                                                           |
| 8                     | ol-rich basalt (boninite)                                | 1-2             | ol-pl-phyric                                   | -          | 20-30     | 30-40     |          |          | 90         |         | 3.6                    | 23.0   | 20.0   | 14.0   | 90         | A          |         | film    | highly altered boninitic? basalt, only iddingsitized ol can be recognized.                                      |
| 9                     | ol-phyirc basalt? (boninitic)                            | 1-2             | ol phyric                                      | -          |           | 20        |          |          | 40         |         | 3.2                    | 17.0   | 16.0   | 12.0   | 40         | A          |         | 1       | weakly weathered ol-rich boninitic? Basalt                                                                      |
| 10                    | ol-rich basalt (boninite)                                | 1-2             | ol phyric                                      | -          | 20-30     | 30        |          |          | 90         |         | 12.0                   | 37.0   | 29.0   | 12.0   | 90         | A          |         | -       | similar to R08                                                                                                  |
| 11                    | aphyric basalt? (boninitic)                              | <1              | aphyric (could be diabasic)                    | -          | -         | -         |          |          | 50         |         | 1.9                    | 13.0   | 10.0   | 9.0    | 50         | A          |         | -       | non vesiculated aphyric lava with microphenocrysts of ol,pl, pervasive chloritization?                          |
| 12                    | aphyric basalt? (boninitic)                              | <1              | aphyric (could be diabasic)                    | -          | 60        | 20        |          |          | 80         |         | 0.2                    | 7.0    | 5.0    | 3.0    | 80         | A          |         | -       | non vesiculated aphyric lava with microphenocrysts of ol,pl, pervasive chloritization?                          |
| 13                    | aphyric basalt? (boninitic)                              | <1              | aphyric (could be diabasic)                    | -          | 60        | 20        |          |          | 90         |         | 1.4                    | 14.0   | 12.0   | 7.0    | 90         | A          |         | 1       | non vesiculated aphyric lava with microphenocrysts of ol,pl, pervasive chloritization?                          |
| 14                    | diabase                                                  | ~1              | diabasic (could be aphyric basalt)             | -          | 60        | ?         |          |          | 70         |         | 0.4                    | 4.0    | 2.0    | 4.0    | 70         | A          |         | -       | diabasic, but very fine-grained                                                                                 |