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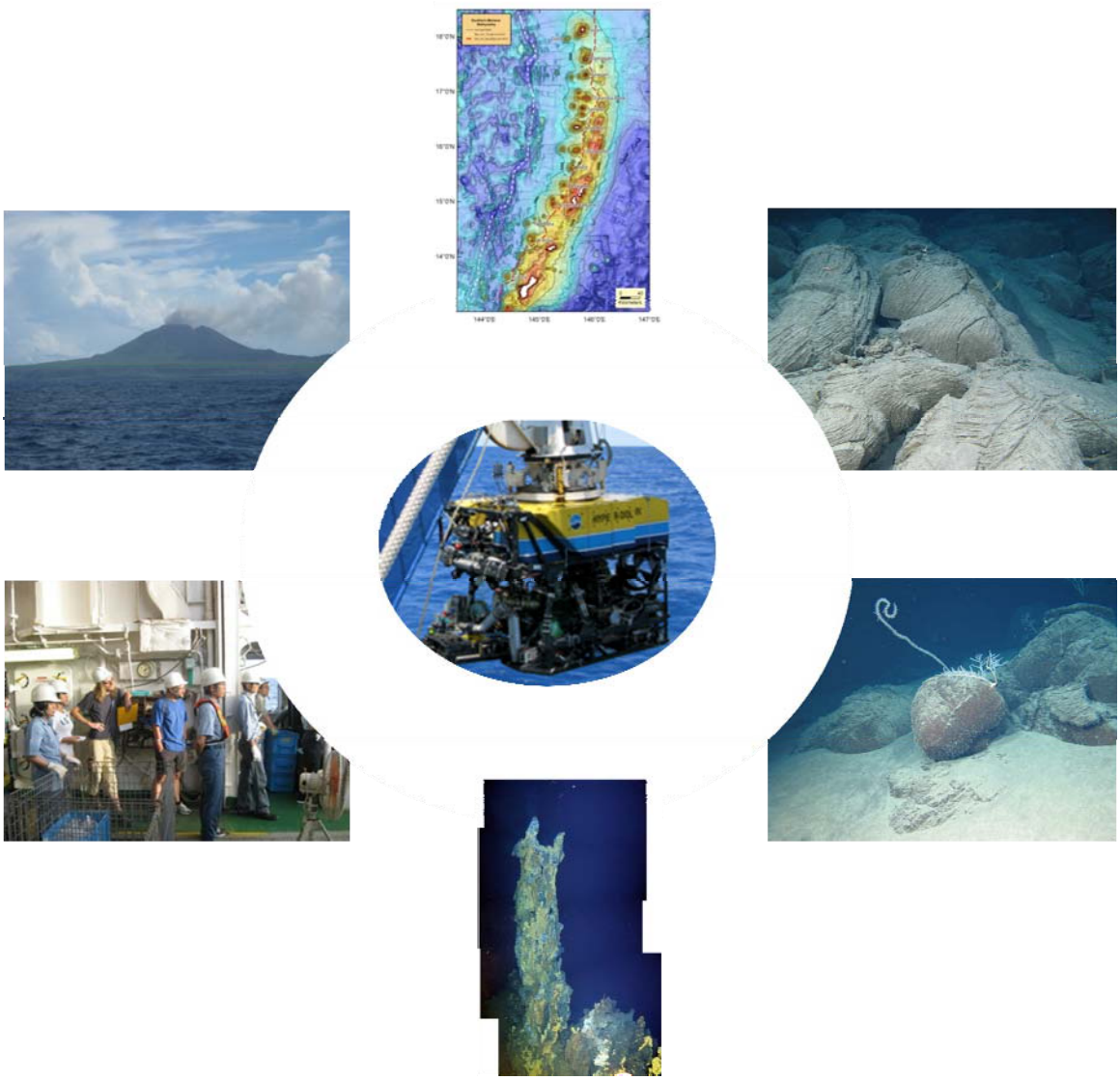
R/V Natsushima CRUISE REPORT
NT10-12

Southern and Central Mariana Arc

July 9 to July 19, 2010

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



LIST OF CRUISE PERSONNEL

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ACKNOWLEDGEMENTS

We are grateful to Captain Hitoshi Tanaka and the excellent crew of the R/V Natsushima, the Hyper Dolphin operation team manager Kazuya Mitsufuji and the Hyper Dolphin 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.

NT10-12 Shipboard Log

July 8 (Thu), 2010

Weather: fine but cloudy/ Wind direction: NE/ Wind force: 4/ Wave: 1m/ Swell: 1 m/
Visibility: 8nautical miles (12:00 JST + 1h)

22:00	Onboard

July 9 (Fri), 2010

Weather: fine but cloudy/ Wind direction: East/ Wind force: 4/ Wave: 4m/ Swell: 3 m/
Visibility: 8nautical miles (12:00 JST + 1h)

09:00	Departure from Guam
10:30-11:30	Briefing about ship's life and safety
15:00-15:30	Scientific Meeting
19:00-20:00	Scientific Seminar

July 10 (Sat), 2010

Weather: fine but cloudy/ Wind direction: East/ Wind force: 4/ Wave: 3m/ Swell: 3 m/
Visibility: 8nautical miles (12:00 JST + 1h)

08:30	Arrived at survey area
08:33	XBT
09:20	Start of MBES mapping survey (Alamagan, Pagan)
19:00-20:00	Scientific Seminar

July 11 (Sun), 2010

Weather: fine but cloudy/ Wind direction: East/ Wind force: 4/ Wave: 3m/ Swell: 2 m/
Visibility: 7nautical miles (12:00 JST + 1h)

03:03	End of MBES mapping survey
06:25	XBT
08:13	Launch HPD (HPD#1147dive: small cones on NE slope of Pagan)
09:13	HPD lands (1,992m)
16:08	HPD leaves the bottom (1,505m)
17:06	HPD on deck
18:23	Start of MBES mapping survey (Alamagan)
20:20-21:00	scientific meeting

July 12 (Mon), 2010

Weather: fine but cloudy/ Wind direction: ENE/ Wind force: 5/ Wave: 3m/ Swell: 3 m/
Visibility: 7nautical miles (12:00 JST + 1h)

04:18	End of MBES mapping survey
08:14	Launch HPD (HPD#1148dive: lower slope of SW of Pagan)
09:26	HPD lands (2,353m)
16:59	HPD leaves the bottom (2,016m)
17:51	HPD on deck

21:00-21:20	Scientific meeting
20:20	Start of MBES mapping survey (Pagan)

July 13 (Tue), 2010

Weather: fine but cloudy/ Wind direction: East/ Wind force: 5/ Wave: 3m/ Swell: 2 m/ Visibility: 8nautical miles (12:00 JST + 1h)

01:45	End of MBES mapping survey
08:14	Launch HPD (HPD#1149dive: Daon SE ridge)
09:30	HPD lands (2,579m)
16:20	HPD leaves the bottom (2,323m)
17:36	HPD on deck
20:30-21:00	Scientific meeting

July 14 (Wed), 2010

Weather: fine but cloudy/ Wind direction: East/ Wind force: 5/ Wave: 4m/ Swell: 3 m/ Visibility: 6nautical miles (12:00 JST + 1h)

05:48	XBT
08:10	Launch HPD (HPD#1150dive: East Diamante caldera)
08:39	HPD lands (363m)
11:18	HPD leaves the bottom (377m)
11:54	HPD on deck
13:34	Launch HPD (HPD#1151dive: East Diamante caldera)
14:05	HPD lands (360m)
16:31	HPD leaves the bottom (351m)
16:57	HPD on deck
19:30-20:00	Scientific meeting
19:52	Start of MBES mapping survey (East Diamante caldera)
22:53	End of MBES mapping survey

July 15 (Thu), 2010

Weather: fine but cloudy/ Wind direction: East/ Wind force: 4/ Wave: 3m/ Swell: 2 m/ Visibility: 8nautical miles (12:00 JST + 1h)

08:13	Launch HPD (HPD#1152dive: East Diamante small cones)
08:55	HPD lands (1,189m)
10:56	HPD leaves the bottom (1,112m)
11:40	HPD on deck
13:15	Launch HPD (HPD#1153dive: East Diamante caldera)
13:34	HPD lands (406m)
16:21	HPD leaves the bottom (362m)
16:49	HPD on deck
19:30-20:00	Scientific meeting

July 16 (Fri), 2010

Weather: fine but cloudy/ Wind direction: ESE/ Wind force: 2/ Wave: 2m/ Swell: 2 m/ Visibility: 8nautical miles (12:00 JST + 1h)

05:52	XBT
08:14	Launch HPD (HPD#1154dive: West Rota caldera)
09:05	HPD lands (1,327m)
16:14	HPD leaves the bottom (1,135m)
16:56	HPD on deck
19:00-19:45	Scientific meeting
18:40	Start of MBES mapping survey (NW Rota-1)
20:56	End of MBES mapping survey

July 17 (Sat), 2010

Weather: fine but cloudy/ Wind direction: East/ Wind force: 4/ Wave: 3m/ Swell: 2 m/ Visibility: 8nautical miles (12:00 JST + 1h)

08:13	Launch HPD (HPD#1155dive: NW Rota-1 knolls)
09:30	HPD lands (2,570m)
11:23	HPD leaves the bottom (2,470m)
12:40	HPD on deck
13:54	Launch HPD (HPD#1156dive: NW Rota-1 summit)
14:18	HPD lands (575m)
16:39	HPD leaves the bottom (549m)
17:11	HPD on deck
19:00-19:30	Scientific meeting

July 18 (Sun), 2010

Weather: fine but cloudy/ Wind direction: East/ Wind force: 4/ Wave: 3m/ Swell: 2 m/ Visibility: 8nautical miles (12:00 JST + 1h)

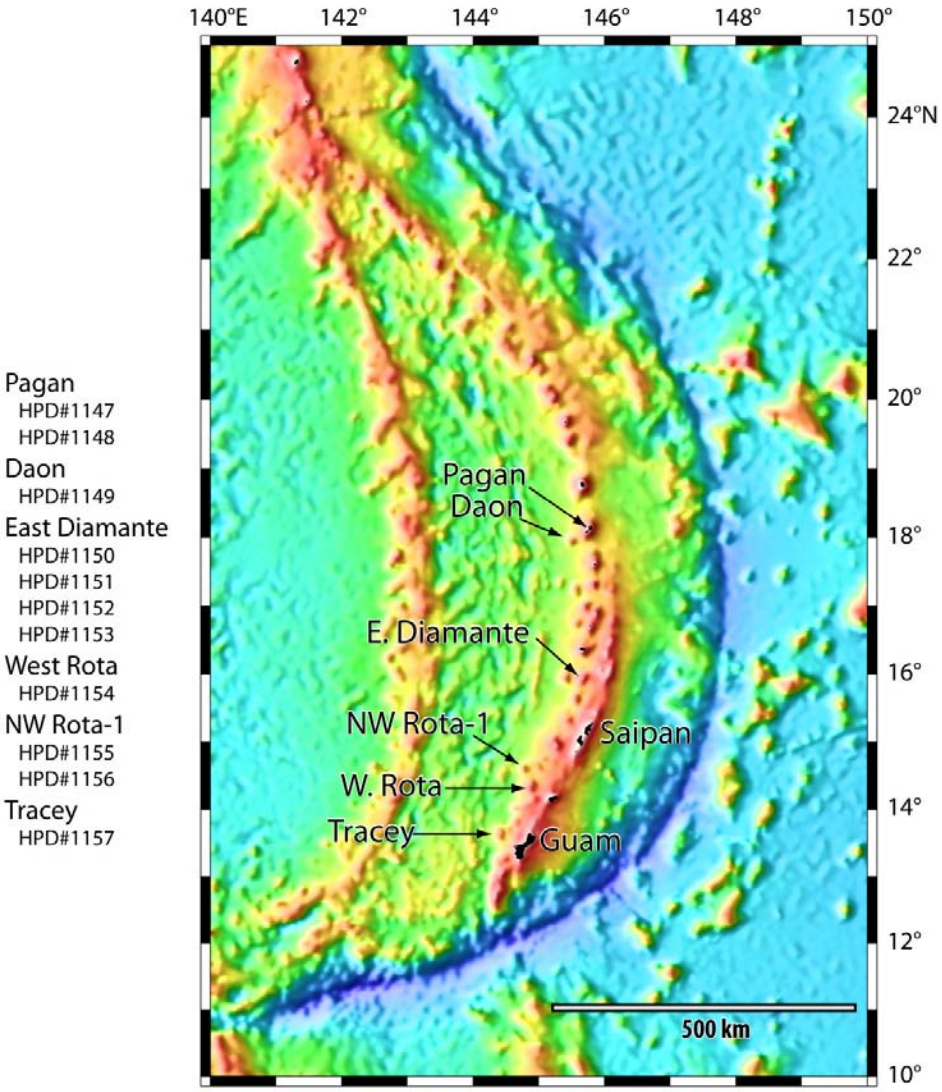
06:30	XBT
08:12	Launch HPD (HPD#1157dive: Tracey)
09:39	HPD lands (2,783m)
15:32	HPD leaves the bottom (2,453m)
16:53	HPD on deck
20:00-20:30	Scientific meeting

July 19 (Mon), 2010

09:00 Arrival at Guam, NT10-12 finish and disembarkation

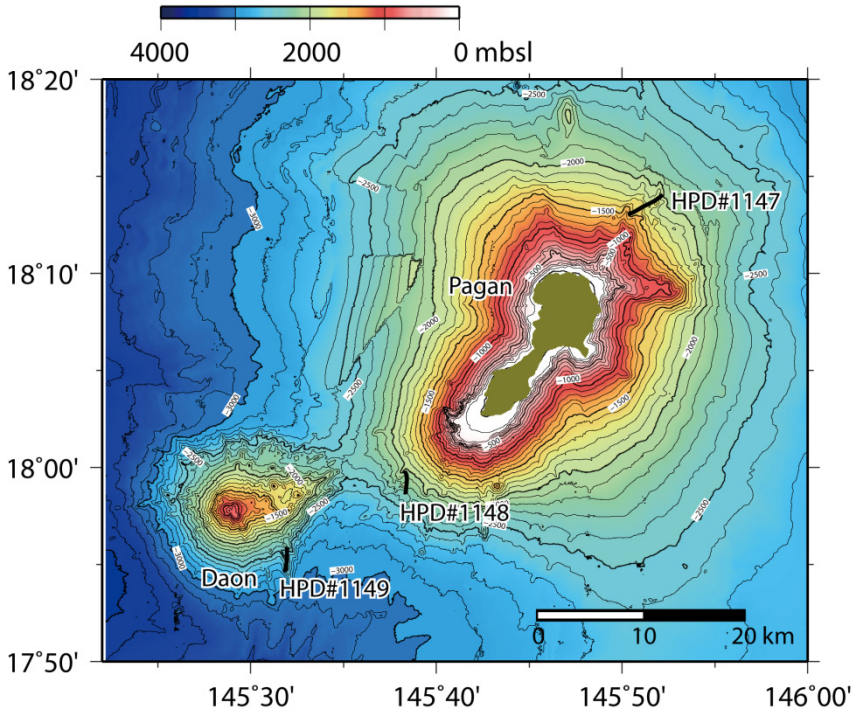
NT10-12 Cruise Summary

ROV Hyper-Dolphin dives and bathymetric surveys in the Southern Mariana region were carried out during NT10-12 cruise (R/V Natsushima) between July 8 and July 19, 2010. A total of 11 dives (HPD#1147~HPD#1157) were focused on the submarine volcanoes within the Pagan-Daon cross-arc chain, and at East Diamante, NW Rota-1, West Rota and Tracey. Previous work in the Izu-Bonin-Mariana arc has shown that small parasitic cones on the flanks of larger volcanoes often yield more mafic lavas than the main edifice. That is certainly true of Pagan, Daon and Tracey, where mostly undifferentiated olivine-bearing basalts were recovered from their lower flanks. These samples will be compared with primitive lavas from NW Rota-1, where two primary magma types have been found. NW Rota-1 is known to have two main types of primitive basalt, COB and POB, which represent clinopyroxene-olivine basalt and plagioclase-olivine basalt, respectively.



Cruise Summary

Pagan Island is one of the active volcanoes in the Central Island Province of the Mariana magmatic arc. Pagan is elongate roughly NE-SW and the southern end of the island is inactive, steep, and eroded. The northern end is active and was producing small clouds of steam and ash during operations for HPD#1147. The northeastern slopes of Pagan show a NNE trending rift zone with several small parasitic cones. This rift and the associated cones were the targets for HPD#1147, in water depths of 2000-1500 m, which were found to mainly consist of basaltic pillow lavas. For example, Hyper-dolphin came into outcrops with spectacular pillows and pillow tubes (see Fig. 4, Fig. 5A, B of HPD#1147). There were large pillows, with strongly striated outer surfaces and concentric cooling cracks, and long pillow tubes with similar outer surfaces. Some of the pillow tubes were clearly elongate down-slope. Sediment cover was very light in most of the section.



The south end of the Pagan Island is inactive, with steep eroded slopes. As with dive HPD#1147, HPD#1148 was planned to investigate small parasitic cones and a ridge to the southwest of Pagan, east of the cross-chain Daon Seamount. The principal goal was to characterize and sample the eruptive products on the southwest slopes of Pagan and determine how these compared with those to the northeast. The traverses produced quite different results: the lava flows are less obviously pillowed, considerably older, and the sediment cover was considerably more extensive. The rocks recovered generally displayed greater alteration, no glass, and many were considerably more porphyritic and less vesicular than the younger rocks recovered from the northeast of Pagan.

Daon seamount is a “behind-the-magmatic-front” (cross-chain or rear-arc) volcano associated with Pagan. No volcanic or hydrothermal activity is known. Daon’s summit rises

from a base ~3000-3200 m to a summit that lies less than 900 m b.s.l. In map view, the edifice is elongated E-W, 20 km E-W and ~15 km N-S. Bloomer *et al.* (1989) calculate a volume of 150 km^3, ~10% of the size of the largest Mariana volcanoes such as Pagan and Agrigan. Daon merges across a ~2500 m deep saddle with the SW extension of S. Pagan. Daon has an unusual morphology, with many ridges radiating from it, which may reflect the presence of radiating dikes. No studies are reported for Daon, although Bloomer *et al.* (1989) dredged the SW part of the edifice, recovering dacites with phenocrysts of plagioclase, hornblende, clinopyroxene, and orthopyroxene. Some of these samples contained disseminated sulfides. Our principal goal in the dive HPD#1149 was to characterize and sample the eruptive products on the lower eastern slopes of Daon. The dive was planned in a series of three traverses, the first two on the longest southward trending ridge on the south side of the volcano at depths of 2580 to 2470 m. b.s.l., and the third on the south-facing slope of a short but steep ridge to the north, at depths of 2520-2320 m.b.s.l. Samples recovered were fairly homogeneous, all 18 rock samples are basalts; 11 are described as olivine basalts, 2 are olivine-clinopyroxene basalts, the remainder are aphyric basalts. All samples had some Mn coating, ranging from almost nothing to 10 mm thickness.

East Diamante seamount lies about 80 km north of Saipan and is the northernmost volcano of the Southern Seamount Province of the Mariana magmatic arc. Moreover, East Diamante is located on the volcanic front side of the Diamante cross-arc chain and has a complex volcanic history. East Diamante is an irregular caldera about 10 km x 4 km that is breached on the north and south sides. The caldera floor has a maximum water depth of about 700 m. After caldera collapse, dacitic domes intruded into the center of the caldera providing the heat source for production and circulation of hydrothermal fluids that generated the large mounds field and two nearby chimney fields, one active and one inactive, found in 2004 during a NOAA Ring-of-Fire cruise. An elongate field of hydrothermal mounds was discovered along the NE flank of a cluster of resurgent dacite domes in East Diamante Caldera using the ROV Hyper-Dolphin aboard the R.V. Natsushima in June 2009 and July 2010. The mounds field is more than 100 m long and about 25-30 m wide and occurs along a NE-SW rift valley at water depths of about 365-400 m b.s.l. Individual hydrothermal mounds and ridges along this trend vary in size and the bases of the mounds are buried beneath hydrothermal sediment so that only minimum dimensions can be determined. Mounds are typically 1-3 m tall and 0.5-2 m wide, with lengths of about 3 to more than 5 m. The sulfide/sulfate mounds are layered and an iron- and manganese-oxide subsidiary mound venting low-temperature fluids caps some of them. Some mounds also support inactive sulfide/sulfate chimneys and spires; chimneys rarely occur as independent structures within the mounds field. The mounds are composed primarily of barite layers and sphalerite (high cadmium, low iron) plus galena layers with up to 470 ppm silver and 3 ppm gold. Several age

dates for one mound show the layered section to have formed about 4,000 years ago while the subsidiary oxides formed during the past 4 years.

West Rota volcano is the largest submarine caldera in the Mariana arc. The eastern caldera wall preserves much of the stratigraphic and intrusive relationships. West Rota consists of a lower, predominantly andesite, section overlain by a bimodal rhyolite-basalt layered sequence. In our ROV studies of HDP#1154, intensely hydrothermally altered and mineralized rocks have been observed and collected in the lower caldera wall.

Tracey Seamount lies about 30 km due west of Guam and is the southernmost substantial volcano of the Mariana magmatic arc. With an estimated volume of 45 km^3, Tracey is one of the smaller volcanoes along the Mariana magmatic arc (compare with Pagan with a volume of 2200 km^3, Bloomer et al, 1989). Tracey forms a perfect cone that rises over 2 km, to a water depth of 750 mbsl, and has a diameter of approximately 7 km at the 3000 m water depth contour. At the present day Tracey is believed to be extinct, with no eruptive or hydrothermal activity having been recorded. The western side of the summit is dissected by a sector collapse crater, within which a resurgent dome formed. Tracey Seamount was first visited by ROV in dive HPD#949, cruise NT09-02, which traversed up the resurgent dome and west-facing, eastern wall of the crater. The dome was found to consist of dacite and one of the samples collected has been dated at 500 ka. The dome is believed to be the youngest magmatic event at Tracey. The crater wall is made up of basaltic andesites to andesites, volcaniclastics and pumiceous sandstone that becomes increasingly prevalent towards the top, and a cap of pumice. This suggests that Tracey erupted increasingly evolved material. Unusually for the Mariana Arc, where most rocks are medium-K, Tracey appears to erupt low-K material. The trace element signatures of the felsic and mafic magmas of Tracey make it impossible to relate them by fractional crystallization. HPD#1157 dive aims to recover material from the lower slopes of the edifice and thus from earlier in the evolutionary history of Tracey than the samples recovered to date, allowing the geochemical characteristics of Tracey volcano to be investigated further. The lower slopes of this part (2790-2450 m water depths) of Tracey Seamount appear to be constructed of basalt, with some pumice that may be in situ, suggesting bimodal volcanism, although an exotic origin cannot be ruled out. The cone sampled in the first traverse appears to consist of basalts with a phenocryst assemblage of olivine + plagioclase + clinopyroxene. In the higher slopes the clinopyroxene is absent from the basalts' phenocryst population, and the rocks are more olivine-rich, almost picritic. In the highest part of the slope sampled in this dive the basaltic rocks are less porphyritic and more vesicular. Together with the observations made and samples collected during dive HPD#949, the samples collected in this dive suggest that Tracey Seamount is largely a basaltic edifice, although there may have been minor amounts of more explosive felsic volcanism that produced pumice. Towards the end of Tracey's eruptive history felsic volcanism became more dominant.

BATHYMETRIC SURVEYS

R/V Natsushima completed additional Seabat surveys (Figs. 1 through 6) in several areas around the dive sites. These data will be merged with existing multibeam data to produce final maps of each study area.

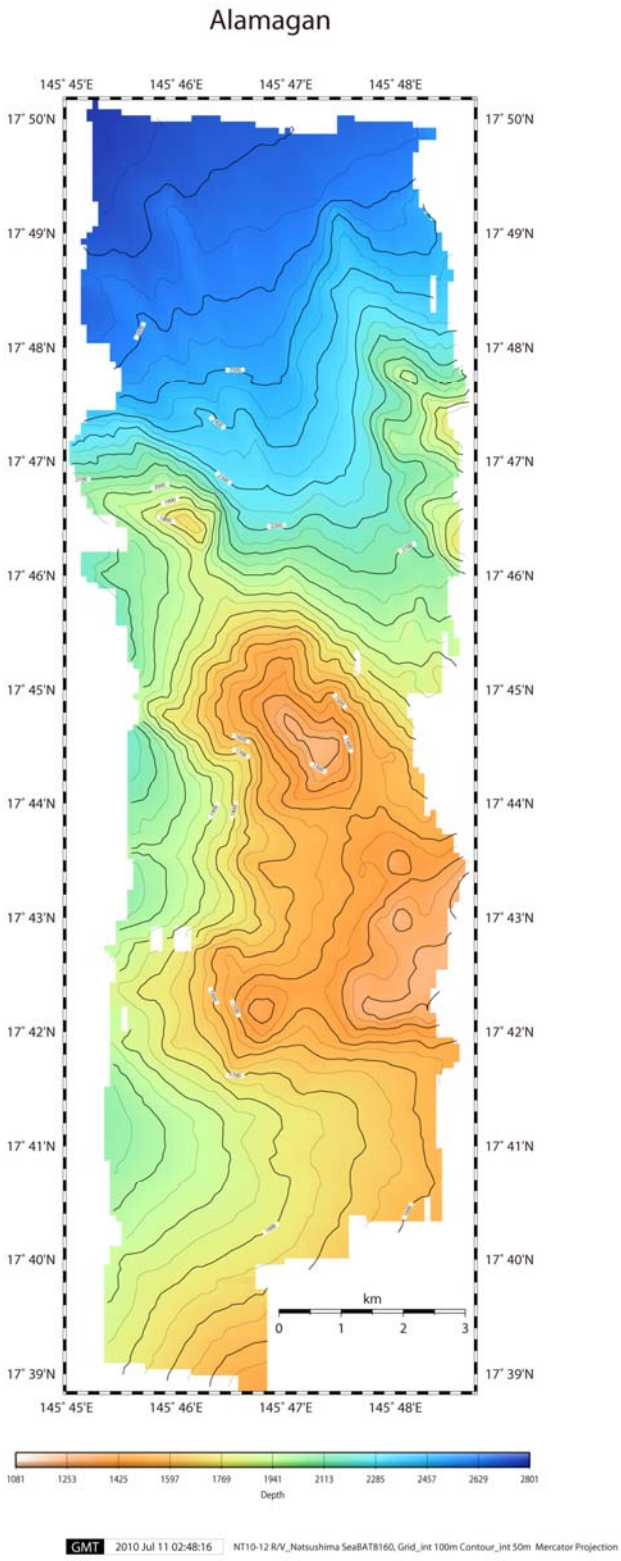


Figure 1. Seabat surveys in the vicinity of the northern flanks of Alamagan

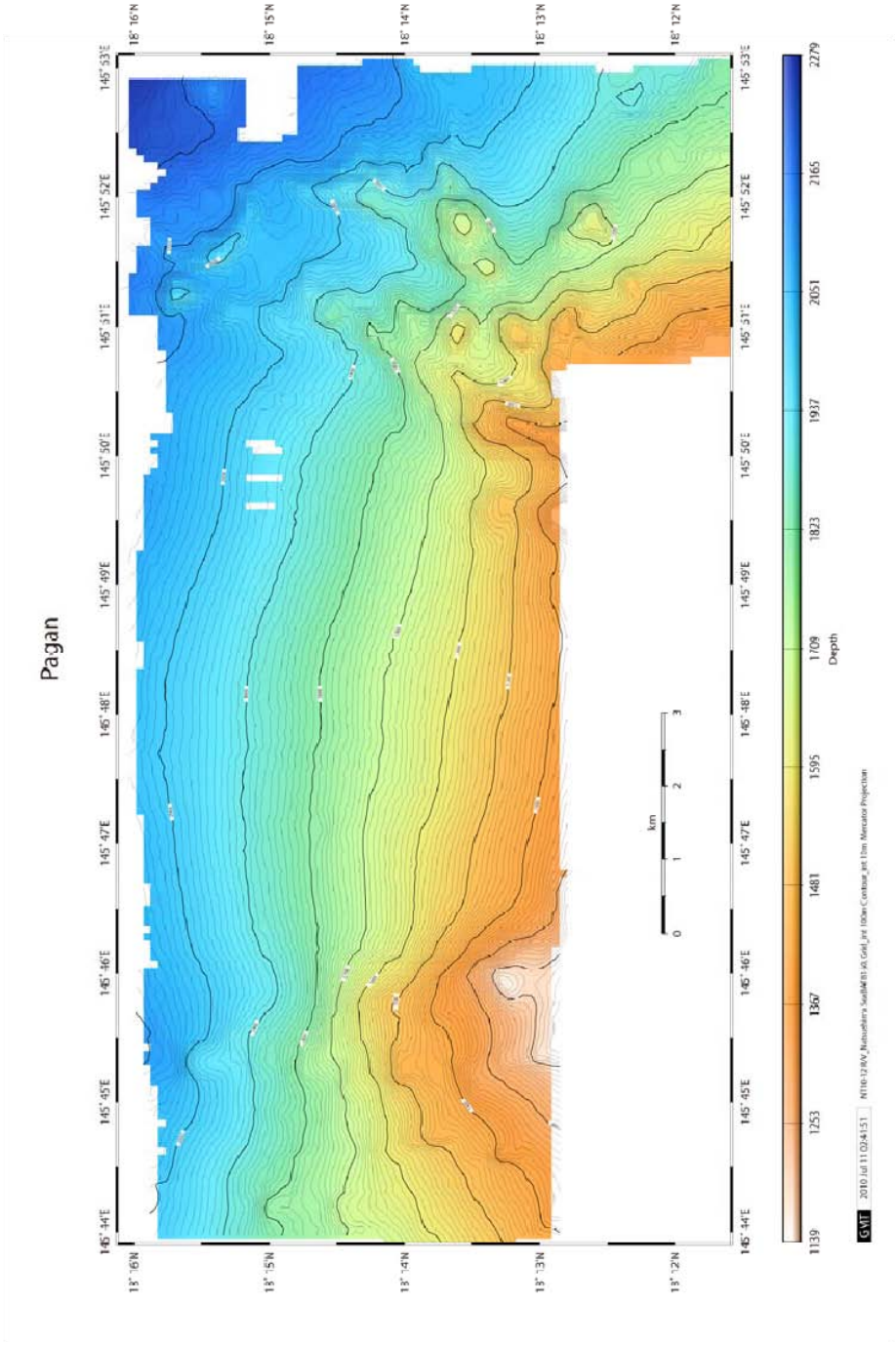


Figure.2. Seabat surveys on the northern flanks of Pagan

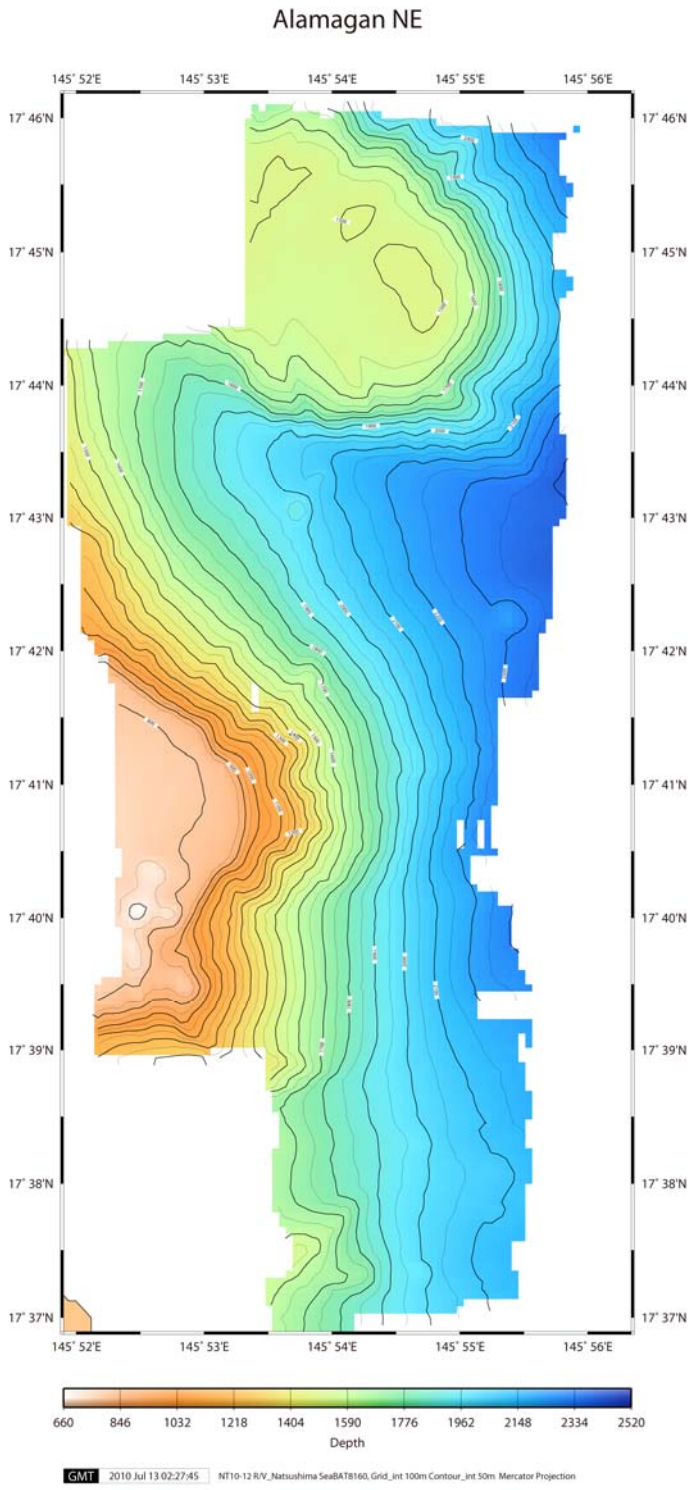


Figure 3. Seabat surveys in the vicinity of the northeastern flanks of Alamagan

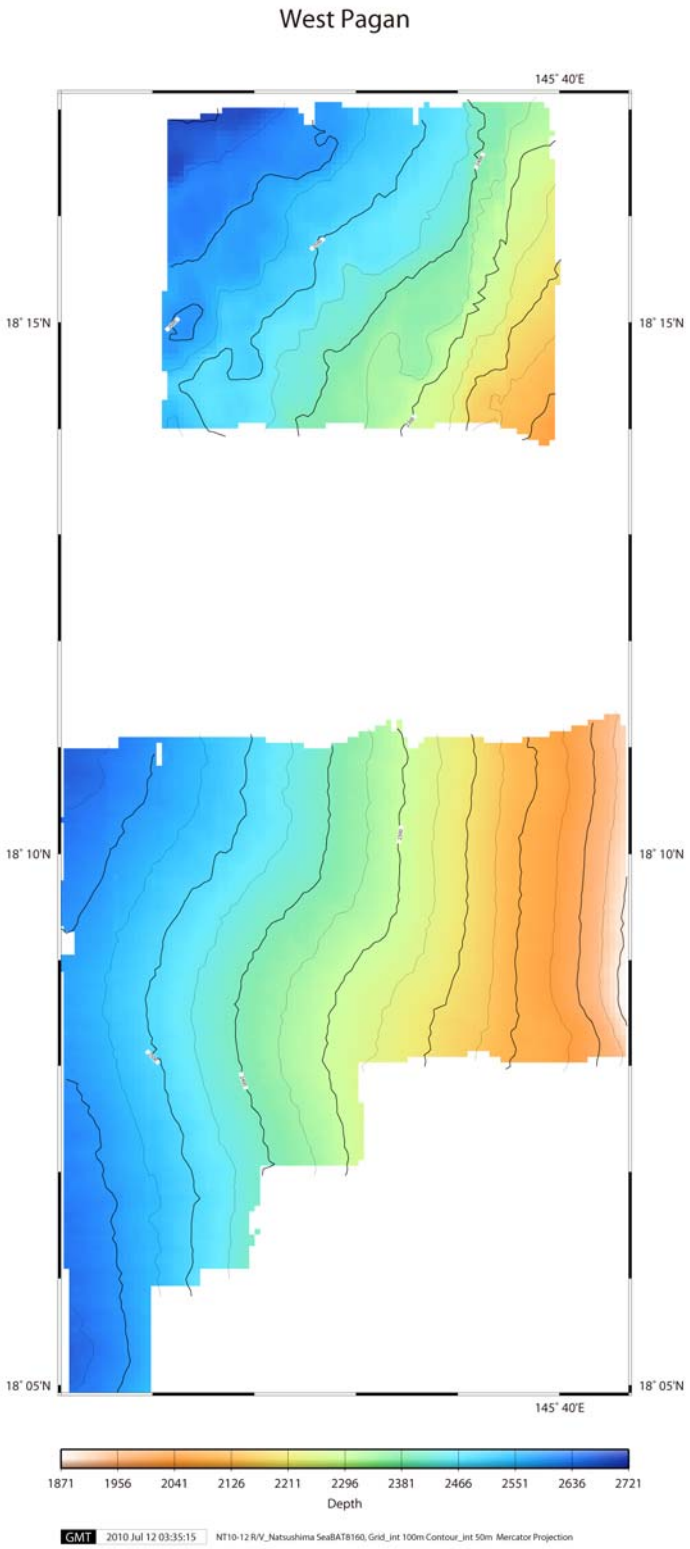


Figure 4. Seabat surveys around the western flanks of Pagan.

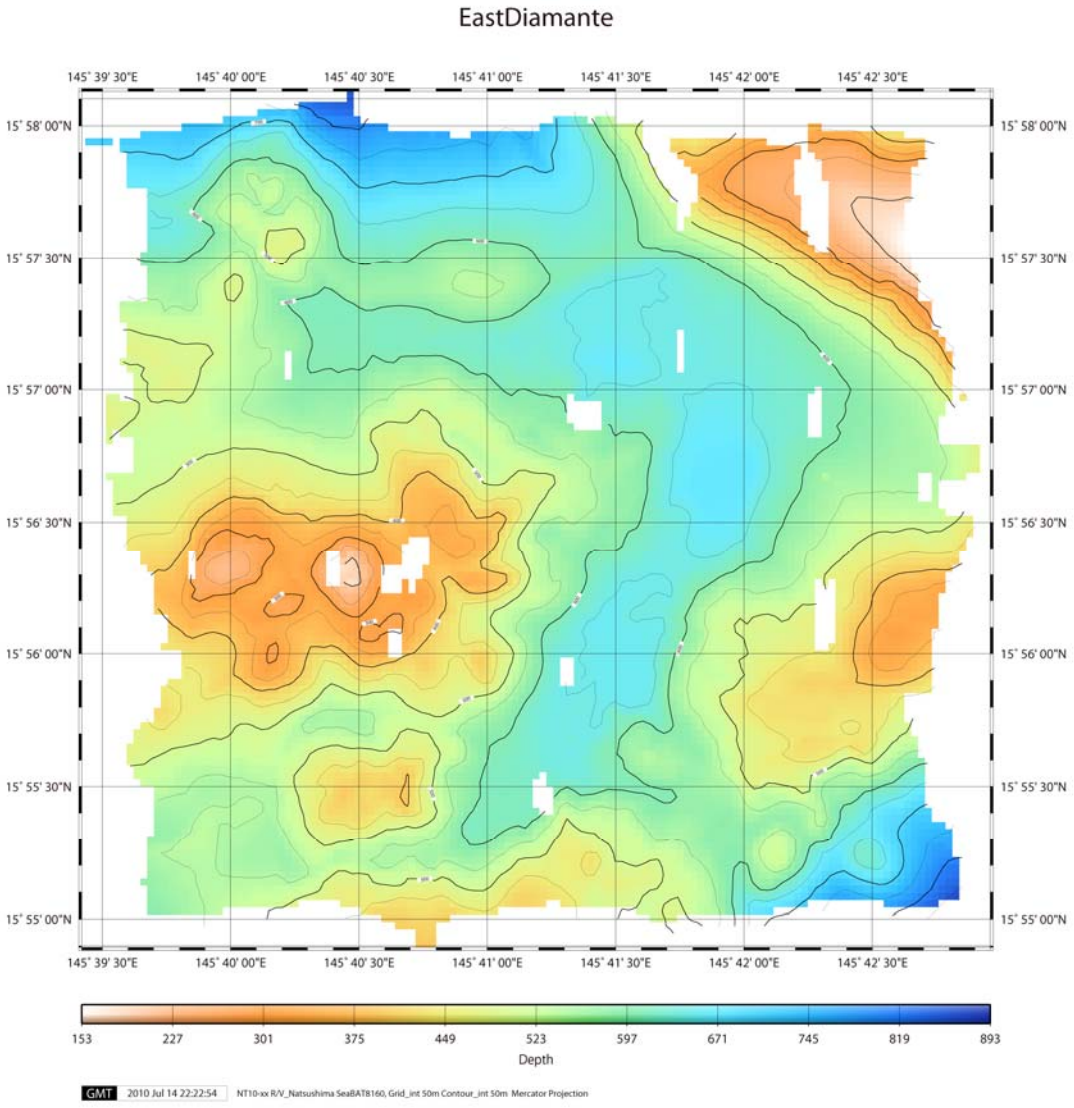


Figure 5. Seabat surveys of the resurgent dome and eastern caldera at East Diamante Seamount

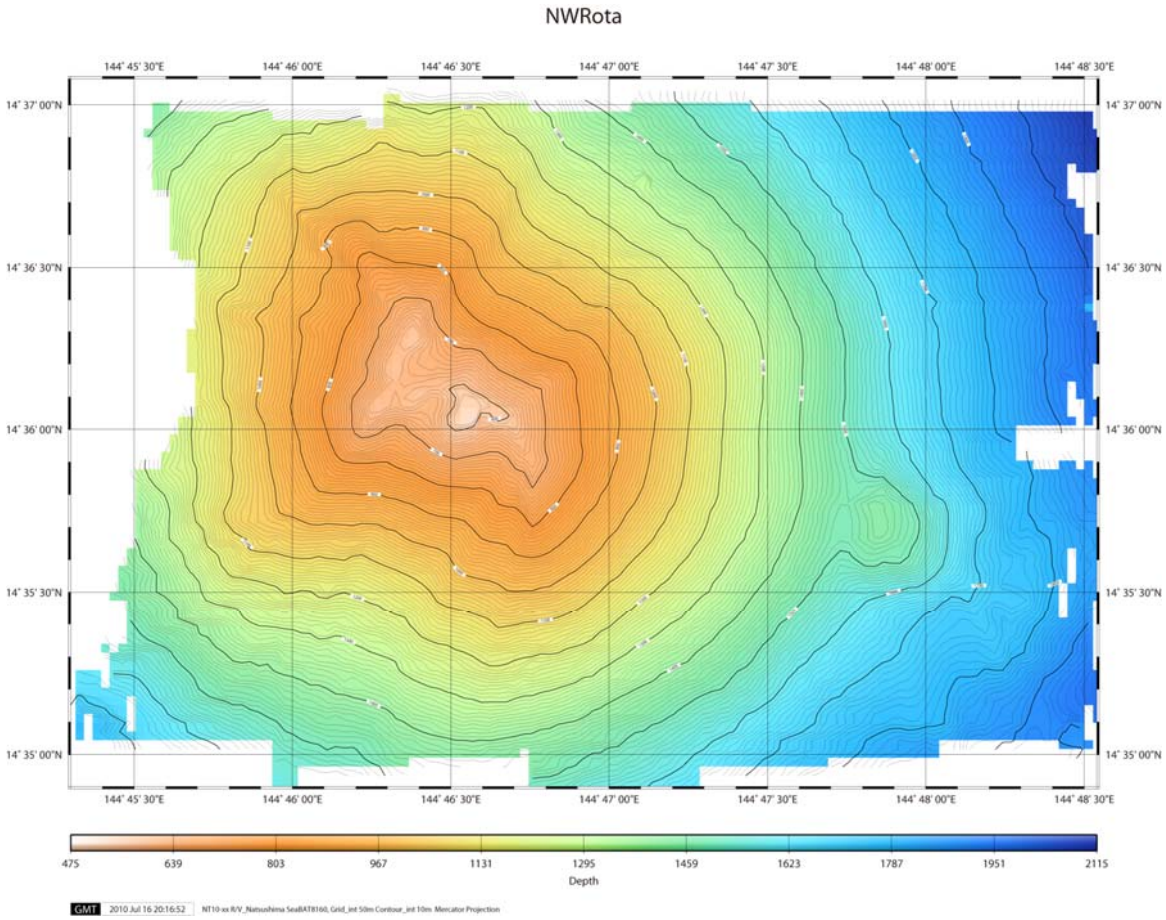


Figure 6. Seabat surveys of NW Rota-1 Seamount

Hyper-DOLPHIN STUDIES AND SAMPLE DESCRIPTIONS

Summaries of the results of each dive with representative pictures start and finish locations, track maps, and dive logs are included in the sections below. All samples were cut and described aboard ship. A comprehensive list of samples with brief descriptions is included in Appendix A.

HYPER-DOLPHIN DIVE #1147

TECHNICAL INFORMATION

Location: Lower slopes northeast of Pagan
Objective: Survey and sample small volcanic cones on the deeper flanks of North Pagan

DIVE 1147	**On bottom:**	**Off bottom:**
Transect #1:		
Time (local): July 11, 2009	09:13	11:54
Latitude:	18°13.925'N	18°13.678'N
Longitude:	145 °52.200'E	145 °51.858'E
Depth (m):	1992	1697
Transect #2:		
Time (local): July 11, 2009	12:36	13:17
Latitude:	18°13.487'N	18°13.447'N
Longitude:	145 °51.599'E	145 °51.493'E
Depth (m):	1765	1658
Transect #3:		
Time (local): July 11, 2009	14:02	15:02
Latitude:	18°13.295'N	18°13.234'N
Longitude:	145 °51.202'E	145 °51.022'E
Depth (m):	1715	1508
Transect #4:		
Time (local): July 11, 2009	15:51	16:06
Latitude:	18°13.015'N	18°13.004'N
Longitude:	145 °50.460'E	145 °50.367'E
Depth (m):	1536	1505

Samples returned: 23 rocks sampled (R08 lost before recovery on deck)

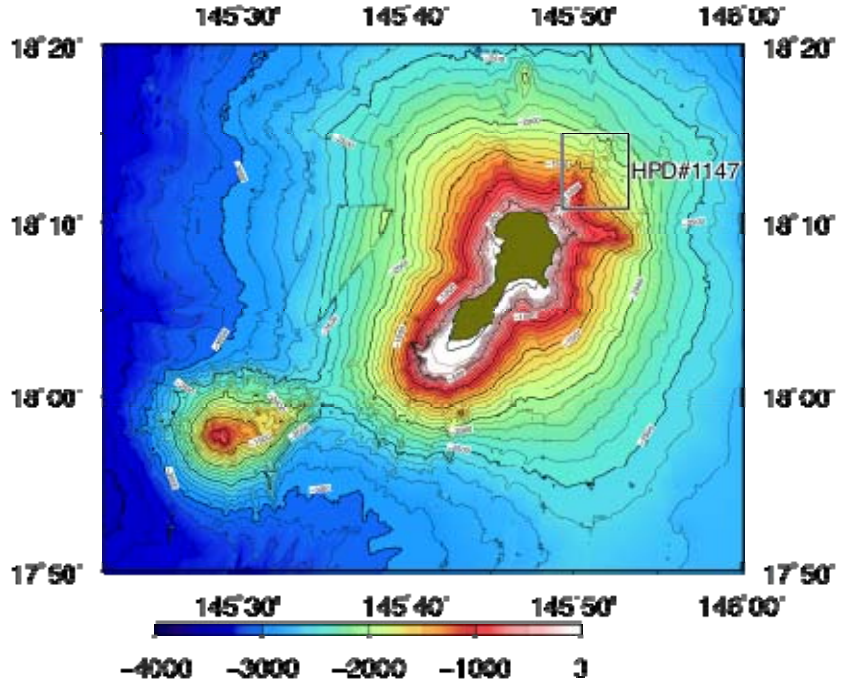


Figure 1: Location of dive operations for HPD#1147 near the island of Pagan from Mariana Bathymetric Compilation (Susan Merle, PMEL/NOAA, compiler). Area of Figure 3 shown in box.

SCIENTIFIC SUMMARY:

Pagan Island is one of the active volcanoes in the Central Island Province of the Mariana magmatic arc. Pagan is elongate roughly NE-SW and the southern end of the island is inactive, steep, and eroded (Figure 1). The northern end is active and was producing small clouds of steam and ash during operations for HPD#1147 (Figure 2).

There is one cross-chain seamount WSW of the southern end of Pagan, Daon Seamount. The northeastern slopes of Pagan show a NNE trending rift zone with several small parasitic cones. This rift and the associated cones were the targets for HPD#1147. Previous work in the Marianas has shown that these small parasitic cones on the flanks of larger volcanoes often yield more mafic lavas than the main edifice. Our principal goal in this dive was to characterize and sample the eruptive products on the northeast slopes of Pagan. The dive was planned in a series of four traverses, the first three on small cones at depths of 1500 to 1900 meters, and the fourth on the eastern flank of a small NNE-trending ridge on the western boundary of the "rift" zone. The actual dive tracks are shown in Figure 3.

Figure 2: View of North Pagan steam and ash eruption from the area of operations of HPD#1147, July 11, 2010 (local time)

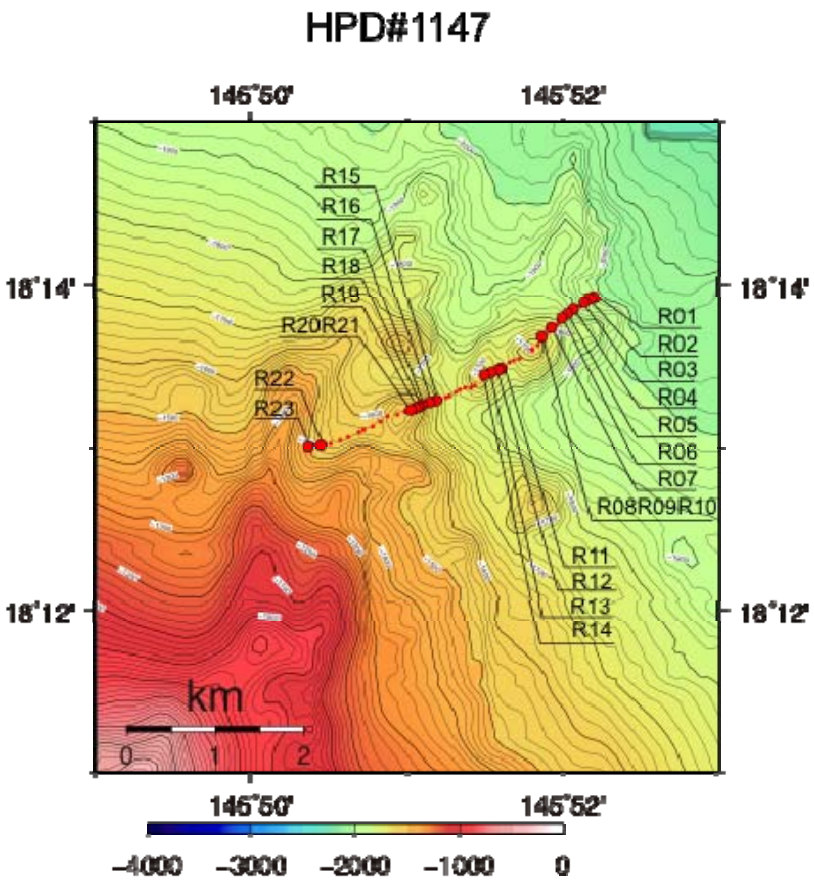


Figure 3:Bathymetry of northeastern slopes of Pagan (bathymetry by S. Merle, NOAA) showing tracks for Dive#1147. Samples R01-R10 were from Traverse#1, R11-R14 from Traverse#2, R15-R21 from Traverse#3, and R22 and R23 from Traverse#4

Traverse #1: This traverse was up the northeastern-most small cone on the NE flanks of Pagan from 1992 m to 1679 m depth. The vehicle reached bottom at 1992 m in a field of talus blocks, many with forms that showed they originated from pillows. R01, a vesicular basalt, was sampled here. Hyperdolphin moved upslope and quickly (09:22) came into outcrops with spectacular pillows and pillow tubes (Fig. 4, Fig. 5A, B). This morphology persisted for most of the first 75% of the traverse. There were large pillows, with strongly striated outer surfaces and concentric cooling cracks, and long pillow tubes with similar outer surfaces. Some of the pillow tubes were clearly elongate down-slope. Sediment cover was very light in most of the section. The pillows in places seem to have formed tall piles with at least a couple meters of relief. The piles were, in places, cut by fissures or small scarps trending roughly parallel to the vehicle track (SW-NE). Samples R02, 03, 04, 05, and 06 all came from or near pillow outcrops. All are vesicular olivine-plagioclase basalts.

The section at about 1800 m showed more sediment, though still with occasional large pillows and pillow fragments. Large tubes were less common and there were frequently stalked corals, sponges, and brittle stars on many of the outcrops. Sample R08 came from a blocky pillow fragment and was a vesicular, olivine-plagioclase-clinopyroxene phyric basalt.

The upper portion of the traverse (from about 1730 m to 1679 m) had fewer large pillows and tubes, (though they were still seen) and more slabby and irregular outcrops (Fig. 5C). The surfaces of some outcrops had ropey, pahoehoe like textures. Sediment was more abundant in chutes and flatter areas, as were expanses of basalt talus. The outcrops in places appeared to have reddish staining or deposits. Samples R08, R09, and R10 came from such a spot near the end of the traverse. All three came from the same outcrop; R08 was lost somewhere on the way to the surface. R09 and R10 were vesicular olivine-plagioclase basalts. This traverse ended at 1697 m at 11:54 and Hyperdolphin was moved to the next cone to the southwest.

Figure 4: Pillow basalt outcrop in the lower half of Traverse #1, HPD #1147; Seamax 2010_0711_103800AA

Traverse #2: This section of the dive traversed a second small cone from 1765 m to its summit at 1568 m. Exposures included pillow outcrops interspersed with areas covered with cobble and gravel sized talus (Fig. 5 D and E). Sediment was common in chutes between outcrops and in flatter spots between outcrops. There are places with

distinct reddish alternation in the basalt blocks. The section appears somewhat older than that seen in traverse #1. Sample R12 came from the base of a pillow outcrop and is an olivine-plagioclase-clinopyroxene basalt. Samples R11, R13, and R14 were talus or float pieces and are vesicular olivine-plagioclase basalts; R13 may contain a small amount of clinopyroxene. At 11:57 Hyperdolphin was pulled off the bottom and moved to the beginning of Traverse #3.

Traverse #3: This part of the dive examined a third small cone to the WSW of the first two, from 1715 m to its summit at 1508 m (Fig. 3). The outcrops here still included pillowed forms, but those were more often fractured and broken than in the earlier transects, and there were more slabby and irregular outcrops than previously. The bottom in much of the traverse was covered with gravel, cobbles, and boulders of various sizes with sediment in chutes, on flatter areas, and between outcrops (Fig. 5F, 5G). Samples R15, R18, R19, R20, and R21 appear to have come from outcrops; R16 and 17 were from talus. All are vesicular, sparsely porphyritic basalts. R15 and R16 are olivine, plagioclase, and clinopyroxene phyric; R17 and R19 are plagioclase-clinopyroxene phyric; R18 has olivine and plagioclase phenocrysts; and R20 and R21 are plagioclase basalts. This transect concluded at 1508m at the summit of the cone and Hyperdolphin was moved to the beginning of Traverse #4.

Traverse #4: This section examined a steep east-facing slope on a narrow NNE-trending ridge that marks the western side of what may be a rift or extension zone extending NE from Pagan (Fig. 3). The transect went from 1536 m to 1505 m, about a quarter of the way to the summit of the ridge, before the dive ended. The bottom was covered with black to light colored sands, with occasional blocks sticking up through the sands (Fig. 5H). Samples R22 and R23, were such blocks. R22 was a vesicular clinopyroxene-bearing olivine and plagioclase phyric basalt and R23 was a vesicular olivine- plagioclase phyric basalt. The darker sands may be basaltic fragments, the lighter material ash or mixtures with pelagic sediments. The sandy material was not sampled. The sandy bottom showed streaks roughly parallel to the HPD track; these could be tracks downslope motion of small blocks or cobbles. Dive #1147 left the bottom at 16:06 local time.

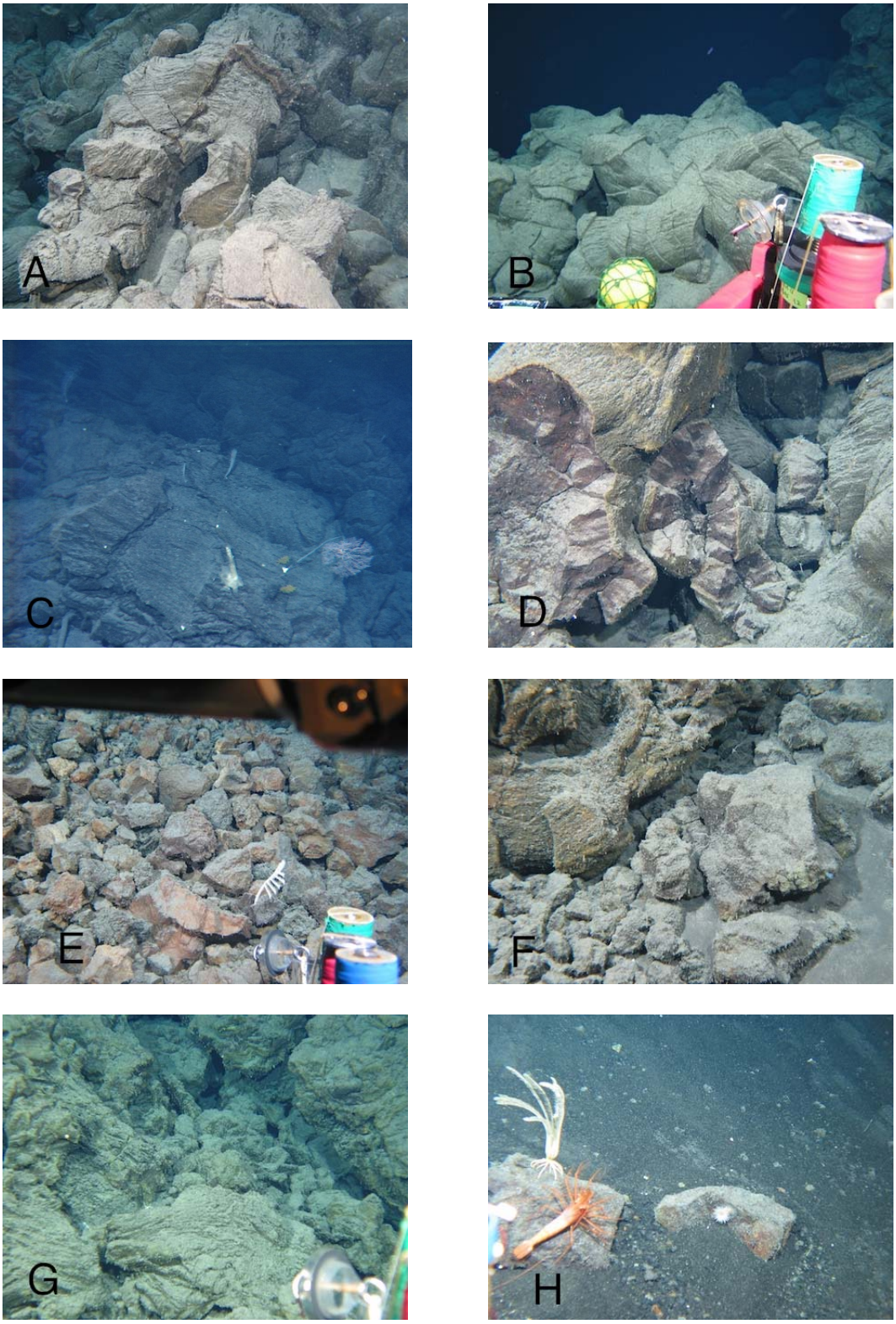


Figure 5: Representative pictures from HPD #1147.
A. Pillow basalt tube in lower part of Transect #1, Seamax 2010_0711_092325AA.
B. Pillow basalts in Transect #1, Seamax 2010_0711_095044AA
C. Outcrop more typical of upper section of Traverse #1, hdc20100711113953
D. Fractured pillow basalts in lower part of Traverse #2, Seamax 2010_0711_124414AA
E. Basalt rubble and talus typical of much of Traverse #2, Seamax 2010_0711_131838AA
F. Pillow basalts and basalt talus with sediment in Traverse #3, Seamax 2010_0711_141836AA
G. More massive outcrop in upper part of Traverse #3, Seamax 2010_0711_150255AA
H. Dark sediment with occasional light blocks , Traverse #4, Seamax 2010_0711_160646AA

DIVE LOG HPD#1147

Dive #:	**NT10-12 HPD#1147**
Date:	July, 10, 2010 (local)
Location:	Small cones on NE slope of Pagan
Objectives:	Study and sample four small cones for primitive basalts

Logger: Bloomer

samples are no HPD#xxx-RYY

where xxx is dive number, X is S for scoop, R for rock, C for push core, W for water, YY is number

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
8:02	0		In water		
9:13	1992	224	Bottom in sight, covered with talus, small to large blocks, Waypoint #1		
9:14	1996	264	lot of rubble, pillow like fragments; settled on bottom sampling; looks like smooth topped pillow piece; into circular basket	R01	vesicular basalt
9:17	1996	251	View of pillow talus; underway up slope; steep slopes in places, all covered in rubble		
9:18	1992	252	large pillow boulders; rat tail fish; very light dusting of sediment		
9:20	1984	251	looks like some orange/yellow coatings on some of the blocks on the right side of the field of view		
9:21	1979	252	moving along scarp, steep down to port, nice lava tube on side of edifice		
9:23	1979	288	sampling, near pillow tube; very light sediment dusting; piece was loose with curved and striated outer surface; into Box 2; dropped chain weight out of Box 4 here	R02	pillow basalt
9:29	1978	278	underway upslope; still pillow flows and tubes; tubes running roughly down slope		
9:30	1973	270	over top of a scarp or pillow pile and into somewhat gentler slope with tubes and pillow rubble. Clear tubes running downslope with large pillows and pillow rubble; light sediment dusting		
9:32	1967	260	fewer tubes here; more pillows and pillow rubble		
9:33	1964	261	beautiful pillow outcrop with truncated pillow ends and tubes		
9:35	1960	251	sampling; in pillowed outcrop, steeper to port….small constructional pile?....change of heart, no sample taken here		
9:38	1958	246	sailed off pillows over steep fault scarp, dropped off below vehicle; no bottom in sight		
9:40	1961	240	bottom in sight again, covered in pillow talus again, some tubes		
9:40	1960	240	pillow outcrop, tubes and pillows, outsides striated, brittle stars; moving upsloe and appears to slope steeply to starboard		
9:42	1952	235	brittle stars, beautiful pillows with stretched and broken outer rinds; entire slope covered in pillows; 09:43 a great shot		
9:43	1946	234	over small ridge or scarp; whip coral in image; pillows		
9:44	1944	235	settle on bottom for sampling; pillow pile; smaller piece out of outcrop; angular piece, some orange staining; cylindrical outside with fractured ends; into Box 2	R03	pillow basalt
9:48	1943	234	underway upslope; pillows, 9:49 over top of a constructional pile or scarp, bottom falls away a bit		
9:50	1942	235	near bottom again, tubes and pillows, light sedimnet dusting, cracked outer surfaces;		
9:51	1940	235	over top of another pile or scarp; bottom drops away again (6 m off bottom from 2 m off)		
9:52	1939	235	close to bottom again; pillow talus and blocks here; light sediment here;		
9:53	1928	240	into pillow outcrop, steep scarp on port side running about 245 (parallel to vehicle track); cut pillow sections, probably a fault feature		
9:56	1921	245	moving along scarp, down to port		
9:57	1912	272	working up and along scarp,		
9:58	1909	270	came up pretty quickly, looks like trying to clear scrap; flew over top of pile or edge of scarp, about 9 meters off bottom		
9:59	1895	258	bottom in sight barely…about 7 m off		
10:01	1895	259	nearer bottom, came up pretty quickly; looks like pillows still		
10:03	1892	245	tall pillow pile, land and sample. Slight sediment but very fresh looking; sample a pillow fragment; kind of two pieces with an elbow bend, some orange stain on rinds; into Basket 5	R04	pillow basalt
10:07	1889	246	underway, flew off little pillow stack bottom not visible yet		
10:09	1894	239	bottom in sight again, pillow rubble and boulders		
10:12	1888	044	change course and head for another point…moving in a circle…east, then north, then back to 240		
10:13	1897	241	back on bottom, again large pillows and pillow debris, slight sediment		
10:15	1892	241	moving along and up a large pillow flow		
10:16	1888	241	over edge of scarp or constructional igh; bottom drops off a bit again		
10:19	1880	241	corals, sponge, on a pillow pile		
10:23	1864	241	pillow rubble now, sponges and stalked corals common		
10:25	1855	240	back into pillow outcrop it looks like; couple large sponges, crinoids, sea fan		
10:26	1851	232	on bottom sampling; pillow piece perhaps broken from flow, large irregular piece; some orange staining, white sediment; into Basket 1;	R05	pillow basalt
10:30	1849	225	underway, pillow fragments and outcrop; small crab? Vase sponge; light sediment dusting		
10:34	1834	226	looks like top of a flow or a flatter, smoother morphology…not broken ends of pillows, lots of stalked corals and sponges; looks like behnch or flow top		

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
10:34	1838	225	pillow fragments and pillows in outcrop; nice coolking cracks in outer rinds		
10:37	1830	222	back into more bulbous pillows, highly striated outside surfaces; some sediment pockets between pillows		
10:40	1828	225	distinctly more sediment here….coats smaller pillows and fills spaces between them…pillows not quite as perfectly formed…some more blocky forms, some areas with smooth sediment fill		
10:42	1822	225	sedimented slope leading up to another pillow pile		
10:46	1816	225	pillows and tubes, sediment filling chutes and flats		
10:48	1809	225	pillowed flow with large pillows, somewhat less sediment now?		
10:50	1808	239	sampling; pillow fragments….pillow fragment about size of claw, angular; Basket 1	R06	pillow basalt
10:56	1807	240	underway, pillowed terrain		
10:58	1805	232	rough crinkly surface; flow top area?		
11:02	1800	233	larger more bulous pillows it seems…less small ones and tubes; fair bit of sediment in flats		
11:04	1796	231	quite sedimented pillows, more weathered….all surfaces covered with sediment and lots of accumulation in flat spots and chutes		
11:07	1790	231	blocky terrain, large pillow talus		
11:10	1782	231	looks like steeper scarp off to left side, still pillows, older with more sediment than early in dive		
11:15	1762	231	large pillows again, sedimented, frequent sponges, some crinoids		
11:19	1749	230	down to bottom for a sample; blocky pillow fragments; triangular-ish long keystone shaped piece; small white organic attachments; basket 4	R07	vesicular ol-pl-px phyric basalt
11:23	1748	228	underway upslope, pillows, somewhat sedimented, frequent sponges, stars; some very large bulbous pillows, not really any good tubes		
11:28	1738	252	some very large pillows; some look like they may be parts of very large tubes in places		
11:33	1738	259	across a somewhat flatter area; lots of stalked fans, sponges, corals		
11:37	1730	251	over a flatter area, slabbier outcrop, ropey surfaces in places, almost a pahoehoe look; pink coral on corkscrew stalk		
11:39	1724	247	can see some tube like forms running down slope to starboard ; back into good pillow forms in places		
11:43	1715	240	over top of high into a somewhat more rubbly flattish area, then to a scarp where it drops down a couple meters		
11:44	1712	259	bottom covered with smaller rubble blocks and talus now		
11:46	1708	220	iron stained in places it looks like…sedimented in flatter spots and chutes		
11:47	1702	215	some outcrops sticking out of rubble; some pillowed, some look fractured; bright oragne alteration on one outcrop surface	R08, R09, R10	R8 lost on ascent; 9 & 10 vesicular basalt
11:48	1699	210	sampling reddish coated rock; small piece picked off outcrop into box 3; then a larger piece fell into box 3 (R09), also another smaller piece fell in (R10)		
11:53	1697	211	just upslope a bit to stop and look at samples in box 3--3 pieces; End Transect #1 at Waypoint #2; Traverse to Waypoint #3		
11:57	1679	203	pull up into water column and transit to next point, point 3		
12:37	1765	275	Begin Tranverse #2 at Waypoint #3; bottom in sight; fine to large rubble and talus with sediment in chutes on between blocks;		
12:37	1765	278	sampling; piece from talus pile; red on fracture small brittle star on one surface; into box 4	R11	olivine basalt
12:41	1759	256	over rubbly surface, lots of pillows, seem lighter colored than previous transect, lots of fine gravel and sediment between pillows and in chutes		
12:43	1752	250	across chute into nice pillow pile, less altered perhaps…		
12:44	1752	250	sampling; base of pillow pile across sediment chute; first attempt missed, stirred up some sediment; got a small pillow piece out of the outcrop; angular, into basket 3	R12	sparsely phyric basalt
12:50	1744	269	underway; large blocky pillow outcrops then up onto slope covered in smaller rubble		
12:52	1741	261	slope a little smoother and coveredwith fine angular gravel to cobble sized materials; some fractured outcrop; could be volcanoclastic? Or just an altered zone? With some sediment dusting?		
12:58	1717	251	still in smooth lighter colored area covered in smaller rubble and gravel		
13:00	1710	258	sampling an area here with slighter larger block sticking out; settling on bottom threw up a large cloud of sediment; pieces very weak and friable…move up then back in….grabbed an irregular piece, looks a bit vuggy an orange patch on one side ; sitting on top of Basket 1; may have broken when put on Basket?	R13	vesicular basalt
13:06	1708	260	underway, crossing light colored rubbly terrane		
13:09	1694	261	larger rubble now; cobble and boulder size, angular blocks not really pillows; some reddish blocks;		
13:12	1667	251	still rubble covered slopes; some quite reddish blocks		
13:15	1658	241	sampling; rubble pile with some very red blocks; took a block that was quite red; Box 3	R14	vesicular basalt
13:18	1651	241	End Traverse #2 at Waypoint #4; pull up off bottom, transit to point 5; a pretty steep block and massive outcrop at 1648 m		
13:22	1640	242	transit to Waypoint # 5 through water column		

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
14:03	1716	262	Begin Traverse #3 at Waypoint #5; bottom in sight; covered in angular rubble, looks like some sediment in pockets and on blocks.		v
14:05	1708	262	occasional large piece, some like pillow fragments, other cover from sediment through cobbles, boulders, gravel in some places		
14:07	1703	261	looks like slabby outcrop, sampling; trying to break piece off…got one from outcrop; kind of a short stubby columnar piece? In Basket 3	R15	vesicular ol-px-plag porphyritic basalt
14:09	1702	261	underway, mixed large pillows sticking out of gravel, sediment covered slope		
14:14	1682	256	still rubbly, gravelly slope, fair bit of sediment; some of outcrop blocks look fractured; marked absence of the stalked sponges, etc, probably indicates an unstable slope; occasional places with piles of coarse rubble and some large boulders		
14:19	1655	255	down to bottom to sample a piece from coarser talus; talus piece, angular and irregular; Basket 3	R16	cpx-bearing ol basalt
14:21	1653	251	underway; some of pieces look a bit lighter colored and striated like more silicic blocks		
14:25	1632	252	mixed boulders, gravel, cobbles, sediment, altered and fractured larger blocks of rocks		
14:30	1599	229	same; more frequent large blocks, still rubbly and fractured		
14:31	1598	230	sampling; trying for piece from sediment covered talus pile; irregular prism, vesicular; into box with cover	R17	vesicular basalt
14:32	1597	233	underway; large blocky pieces, gravelly, fractured surface mostly		
14:38	1577	250	looks like following a small rock ridge , outcoprs here and there, fractured, significant sediment and talus		
14:39	1576	253	sampling base of an outcrop just off the small ridge; small piece loose as base of ourcrop; smallest sample yet; into box with cover	R18	vesicular basalt
14:41	1575	250	underway upslope still same, occational large blocks or outcrops, irregular, gravvelly, altered surface with sediment		
14:43	1567	253	mostly outcrop, fractured, irregular, no evidence of pillows; then back into zone with rubble and talus and sediment in chures		
14:48	1544	233	highly fractured and irregular outcrop		
14:50	1538	231	sampling the highly fractured, irregular outcrop; small piece, a bit oval with some orange, into box with a lid	R19	vesicular plag porphyritic basalt
14:53	1532	234	steep ridge, outcrop with steep ridge, drops off to both sides, irregular and fractured blocky appearance; at 14:54 a section that looks like it might be part of a pillow		
14:55	1524	232	off end of ridge into flatter area covered with rubble and talus; some larger blocks in places, near summit of cone		
14:58	1513	238	blocky talus, large and small pieces, sediment between, a ten-armed brittle star		
15:00	1508	238	outcrop, must be near top of little cone, sampling, took a piece, likely out of outcrop, very small piece; in Box with lid, took a second piece as wellalso in box with lid (fell apart as it went into the box); End Traverse #3 at Waypoint #6	R20, R21	R20, PL phyric basalt; R21, PL bearing basalt
15:03	1500	242	pull off bottom and head to Waypoint #7 at base of small steep N-S ridge		
15:52	1537	251	Begin Traverse #4 at Waypoint #7; bottom in sight, white blocks and sandy material, pale and black coloured		
15:53	1537	251	sample, small gray colored subrounded piece, placed in box with a lid	R22	cpx-bearing ol porphyritic basalt
15:55	1534	271	kind of a sandy bottom , mottled grey, white; small white blocks sitting here and there		
16:03	1512	270	same sandy black-white bottom, actually streaked parallel to HPD track (downslope motion?) with occasional white blocks or clasts on surface		
16:06	1505	270	sampling loose block from surface, reddish basalt piece kind of columnar, into box with lid, or on top of box with lid really; piece was next to a block sticking out of sediment	R23	vesicular porphyritic basalt
16:08	1505	271	preparing to leave bottom; end Traverse #4		
16:09	1505	271	off bottom		
16:49	3		Hyperdolphin at surface		
17:06			Hyperdolphin on deck		

HPD#1147 NE Pagan

HPD#1147	July 11 2010		NE Pagan										
sample No.	latitude(N)		longitude(E)		depth (m)	rock type	shape	X (cm)	Y (cm)	Z (cm)	(kg)	colour	alteration	Mn coating
HPD#1147-R01	18	13.93	145	52.200	1992	vesicular basalt	subangular	25	22	14	8	dark gray	weak	
HPD#1147-R02	18	13.92	145	52.171	1978	pillow basalt	rounded	31	16	18	14	dark gray	weak	
HPD#1147-R03	18	13.89	145	52.133	1944	pillow basalt	subrounded	17	13	12	3.3	dark gray	weak	
HPD#1147-R04	18	13.85	145	52.063	1893	pillow basalt	rounded	30	25	15	11	dark gray	weak	
HPD#1147-R05	18	13.82	145	52.025	1851	pillow basalt	subrounded	22	21	19	11.5	dark gray	weak	
HPD#1147-R06	18	13.79	145	51.990	1812	pillow basalt	subangular	20	14	10	3.2	dark gray	weak	
HPD#1147-R07	18	13.74	145	51.919	1749	vuggy ol-plag-px porphyritic basalt	angular	40	17	13	8.5	dark gray	weak	
HPD#1147-R08(Missing)														
HPD#1147-R09	18	13.68	145	51.858	1697	vesicular basalt	subangular	18	13	10	2.2	black	weak	
HPD#1147-R10	18	13.68	145	51.858	1697	vesicular basalt	subangular	7	5	4	0.2	dark gray	weak	
HPD#1147-R11	18	13.49	145	51.599	1765	ol-basalt	subangular	27	16	15	9.5	black	fresh	
HPD#1147-R12	18	13.48	145	51.583	1752	sparsely phyric basalt	subangular	19	12	10	2.4	dark gray	fresh	
HPD#1147-R13	18	13.46	145	51.537	1711	vesicular basalt	angular fragments	30	20	18	12	dark gray	weak	
HPD#1147-R14	18	13.45	145	51.493	1658	vesicular basalt	subangular	12	10	9	1.8	dark gray	weak	
HPD#1147-R15	18	13.29	145	51.183	1702	vesicular ol-px-plag porphyritic basalt	subangular	10	8	7	0.7	dark gray	weak	
HPD#1147-R16	18	13.28	145	51.143	1654	cpx-bearing ol basalt	subangular	42	16	12	4.7	black	fresh	
HPD#1147-R17	18	13.26	145	51.092	1597	vesicular basalt	subangular	15	12	8	2	dark gray	fresh	
HPD#1147-R18	18	13.25	145	51.075	1575	vesicular basalt	angular	10	10	6	0.6	black	weak	
HPD#1147-R19	18	13.25	145	51.053	1538	vesicular plag porphyritic basalt	subangular	10	9	6	0.5	black	weak	
HPD#1147-R20	18	13.23	145	51.022	1508	plag porphyritic basalt	subrounded	6	4	3	0.2	black	weak	
HPD#1147-R21	18	13.23	145	51.022	1508	plag-bearing basalt	angular	15	10	5	0.7	black	weak	
HPD#1147-R22	18	13.02	145	50.446	1536	cpx-bearing ol porphyritic basalt	subangular	12	9	7	0.8	black	fresh	
HPD#1147-R23	18	13	145	50.367	1505	vesicular porphyritic basalt	subangular	24	10	19	3.5	dark gray	fresh	
HPD#1147-unknown(incl.R08)											4			

HPD#1147 NE Pagan

Glass rim	phenocrysts	vesiculation	Memo	
5 mm	ol 5; pl 10	moderate 15%	green alteration rim below glass; vuggy, vesicles <1-2 mm; Fe-staining on outside; xstallinity increases towards interior	HPD#1147-R01
2-3 mm	ol 5; pl 10	moderate 15%	striated surface; alteration below glassy rim; veiscles <4 mm; ol <4 mm	HPD#1147-R02
3 mm	ol 5; pl 10	moderate 20%	vesicles in bands parallel to pillow exterior; vescles <2 mm; xstallinity increases towards interior	HPD#1147-R03
2-3 mm	ol ±; pl 10	moderate 15%	striated surface; vesicles <5 mm, mostly <2 mm	HPD#1147-R04
2-3 mm	ol <5; pl 10	moderate 25%	rounded surface, pillowy; alteration beneath glass; vesicles <3 mm	HPD#1147-R05
3 mm	ol 5; pl 5	moderate 20-25%	banded vesicles, vesicles <5 mm; alteration rim below glass	HPD#1147-R06
	ol 5; px 5; pl 5	moderate 15%	vuggy, 1 cm long, aligned (deformed or way up indicator?); glomerocrysts of ol+px	HPD#1147-R07
			Missing	HPD#1147-R08(Missing)
altered	ol 5; pl 5	moderate 20%	altered glass; alteration rim; Fe-staining on surfaces; vesicles <1 mm	HPD#1147-R09
altered	ol 5; px ±; pl 5	moderate 20-25%	Fe staining; alteration rim beneath altered glass	HPD#1147-R10
3 mm	ol 2; pl 5	strong 35%		HPD#1147-R11
2 mm	ol <5; px <5; pl 10	moderate 20%	vesicles in bands, vesicles <5 mm in diameter, phenocrysts <5 mm	HPD#1147-R12
2-3 mm	ol 5; pl 10	moderate 25%	fragments; alteration rim underneath glass; Fe-staining; vugs >1 cm; vesicles	HPD#1147-R13
	px ±; pl 10	moderate 20%	flow banded and deformed vesicles; outer part not vesicular; Fe-staining on exterior	HPD#1147-R14
4 mm	ol 5; px 2; pl 10	moderate 25%	alteration band underneath glass; ol <5 mm; vesicles <2 mm	HPD#1147-R15
2 mm	ol 6~8; px 1~2; pl 4~6	strong 30%		HPD#1147-R16
	px 5; pl 5	strong 35%	vesicles <6 mm	HPD#1147-R17
1 mm	ol 2; pl <5	strong 30%	green/gray alteration rim; small vesicles mostly <1 mm, few 1-5 mm	HPD#1147-R18
1-2 mm	px ±; pl 10	strong 30%	green/gray alteration rim; small vesicles mostly <1 mm, larger vesicles in interior <2 mm	HPD#1147-R19
2 mm	pl 15	moderate 20%	vug in core; green/gray alteration rim	HPD#1147-R20
1 mm	pl	moderate 25%	in fragments; green alteration rim	HPD#1147-R21
2 mm	ol 8; px 2~3; pl 4~6	strong 30%		HPD#1147-R22
	ol 2; pl 10	moderate 25%	vesicles <4 mm	HPD#1147-R23
				HPD#1147-unknown(incl.R08)

HYPER-DOLPHIN DIVE #1148

TECHNICAL INFORMATION

Location: Lower slopes southwest of Pagan
Objective: Survey and sample small volcanic cone and ridge on the deeper flanks of South Pagan

DIVE 1148	**On bottom:**	**Off bottom:**
Transect #1:		
Time (local): July 12, 2010	09:26	11:04
Latitude:	17° 58.487'N	17° 58.667'N
Longitude:	145° 38.318'E	145° 38.280'E
Depth (m):	2352	2258
Transect #2:		
Time (local): July 12, 2010	11:41	13:50
Latitude:	17° 58.930'N	17° 59.102'N
Longitude:	145° 38.317'E	145° 38.291'E
Depth (m):	2215	2013
Transect #3:		
Time (local): July 12, 2010	14:34	17:00
Latitude:	17° 59.286'N	17° 59.514'N
Longitude:	145° 38.008'E	145° 37.992'E
Depth (m):	2202	2013

Samples returned: 22 rocks sampled (R-20 lost before recovery on deck) and one sediment core.

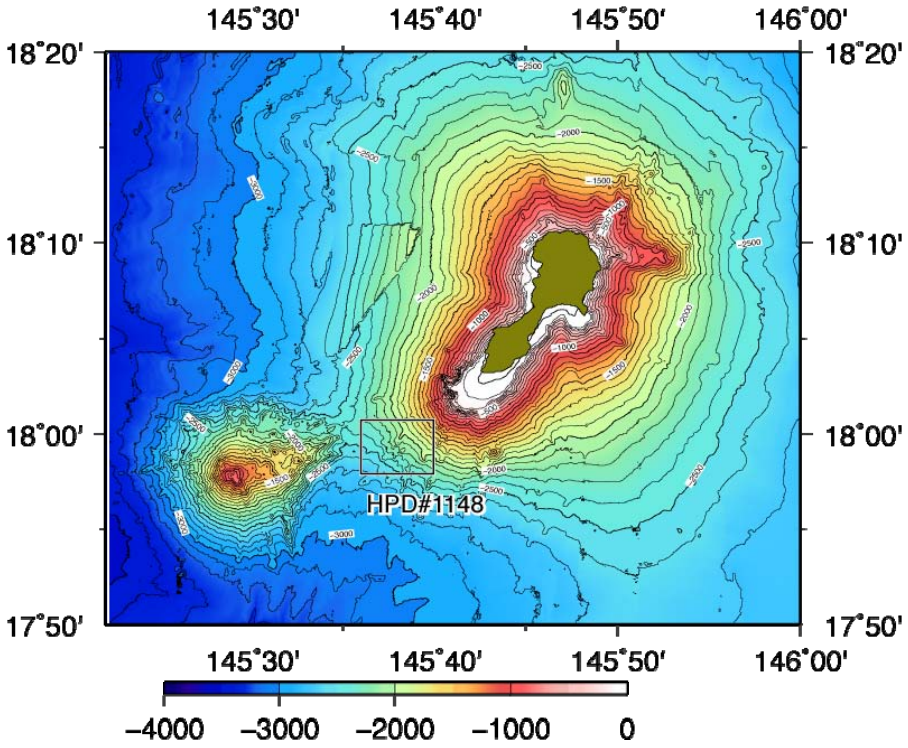


Figure 1: Location of dive operations for HPD#1148 to the southwest of the island of Pagan, from Mariana Bathymetric Compilation (Susan Merle, PMEL/NOAA, compiler). Daon Seamount is to the west of the survey area. Area of Figure 3 shown in box.

SCIENTIFIC SUMMARY:

The north end of Pagan Island is currently active, as evidenced by the clouds of steam and ash. In contrast, the south end of the island is inactive, with steep eroded slopes (Figures 1 and 2). As with dive HPD#1147, dive HPD#1148 was planned to investigate small parasitic cones and a ridge to the southwest of Pagan, east of the cross-chain Daon Seamount (Figure 1). The parasitic cones to the northeast of Pagan are young with relatively fresh pillow lavas. Our principal goal in this dive was to characterize and sample the eruptive products on the southwest slopes of Pagan and determine how these compared with those to the northeast. The dive was planned in a series of three traverses; the first two climbed a small cone at depths of 2,400 to 2,000 meters, and the third on the southeastern flank of a small SSW-trending ridge. The actual dive tracks and the sample locations are shown in Figure 3. The traverses produced quite different results: the lava flows are less obviously pillowed, considerably older, and the sediment cover was considerably more extensive. The rocks recovered generally displayed greater alteration, no glass, and many were considerably more porphyritic and less vesicular than the younger rocks recovered from the northeast of Pagan. There is a change in the sediment and the rock types along the three transects, with the rocks becoming more porphyritic and the sediments more rippled and ultimately more altered and partially indurated/cemented. Where not covered by sediment, rocks and outcrops during today's dive were generally black in outcrop color, probably a function of thin Mn coating.

Figure 2: View of Pagan from the south near the area of operations of HPD#1148, July 12, 2010 (local time).

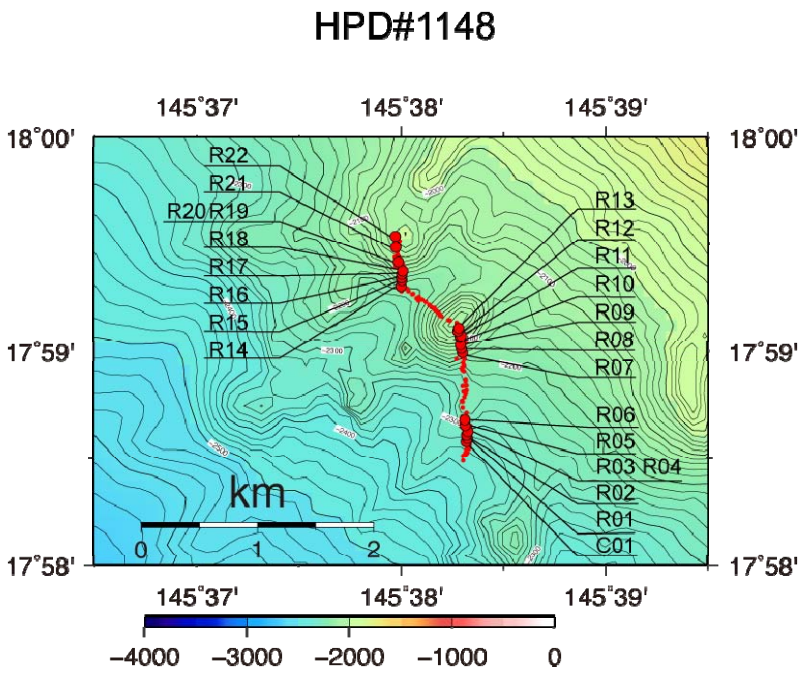


Figure 3:Bathymetry of southwestern slopes of Pagan (bathymetry by S. Merle, NOAA) showing track for Dive #1148. Samples C-01 and R-01 to R-06 are from Traverse #1, R-07 to R-13 are from Traverse #2, and R-14 to R-22 are from Traverse #3.

Traverse #1: This traverse climbed up the southeastern wall of a small ridge on the SW flank of Pagan from 2,352 to 2,258 m depth, below the small seamount, which was the focus of Traverse #2. The vehicle reached bottom at 2,352 m in relatively featureless sediment. The surface of the sediments in this area was generally unrippled, the main feature consisting of tracks and traces. The first sampling attempt looked like an isolated rock, but turned out to be a coconut. A core sample was taken of the sediment, which appears to be quite thick. C-01 is a sandy-silt, generally fine-grained, but with sand-sized basaltic rock fragments and shell fragment. As Hyperdolphin continued upslope over the sediment cover, an isolated rock clast was sampled (R-01; vesicular basalt). A few meters further upslope, the first outcrop was encountered; a massive looking ledge, with Fe-staining at the base of the outcrop. Sample R-02 was collected here and is volcaniclastic. Further on, more flattish outcrops were crossed, and sample R-03 is from one of these at 2,306 m depth. The outcrop is also covered with volcaniclastics, indurated, poorly sorted and generally fine-grained. In the outcrop below the volcaniclastics, cooling joints were evident, and sample R-04 was collected here, a vesicular olivine basalt. Similarly, sample R-05 was collected from a more massive outcrop near bedded outcrops (volcaniclastics?). Sample R-05 is vesicular basalt. Toward the end of the traverse, some outcrops had pillow forms, and sample R-06, vesicular basalt, was collected from one of these. In summary, the first traverse was dominated by sediment, with layered to massive outcrop ridges/ledges, and minor examples of pillow flows. The rocks collected represent volcaniclastic rocks and sparsely phyric vesicular basalts. Phenocrysts are < 10% by volume and dominated by olivine, lesser clinopyroxene, and rare plagioclase. At 11:04, Hyperdolphin was pulled off the bottom and moved to the start of the next traverse.

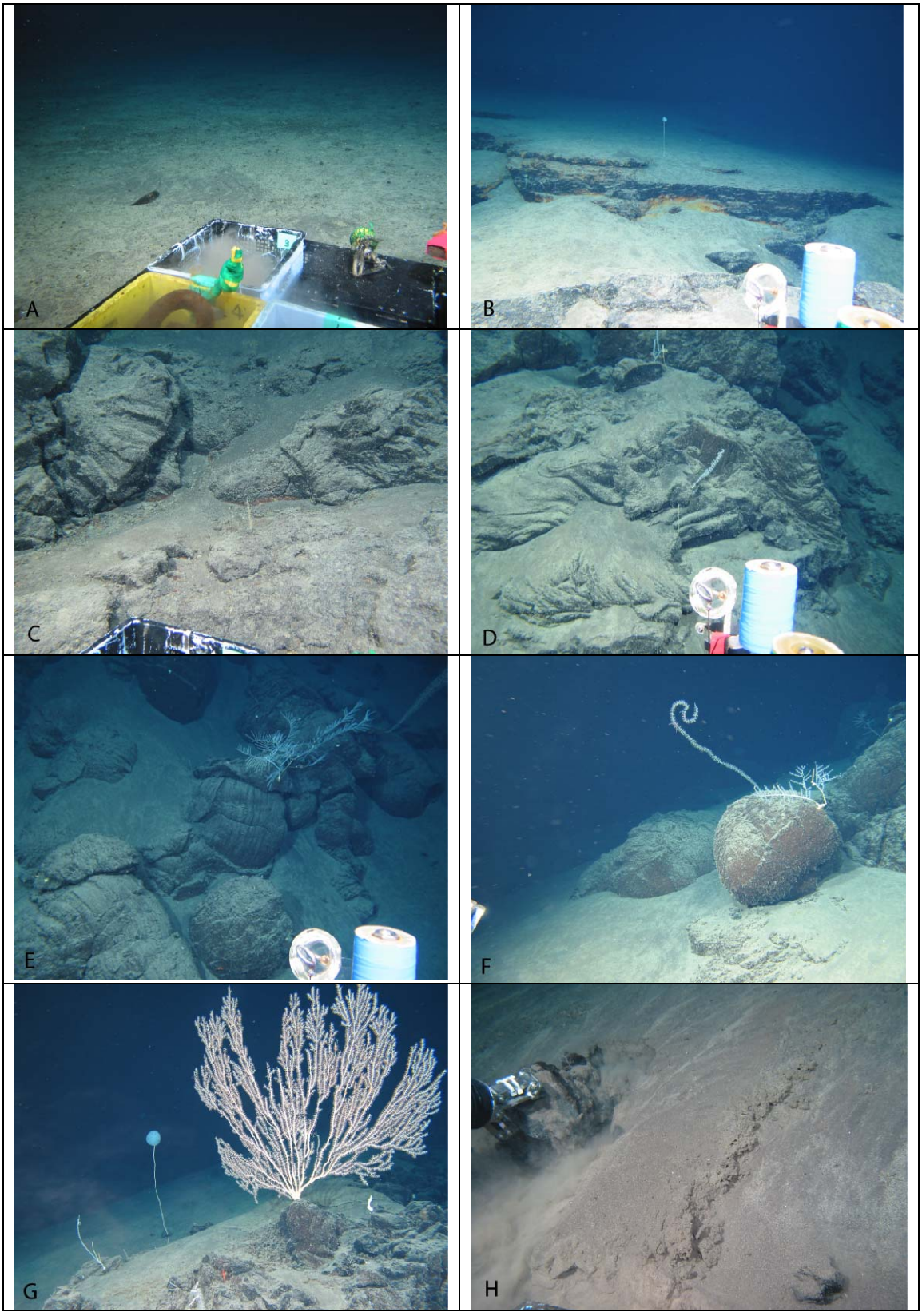
Figure 4: Typical view of Traverse 2, with outcrops of basalt partially covered by variably thick sediment, HPD #1148; Seamax 2010_0712_122202AA.

Traverse #2: This section of the dive traversed a small cone from 2,215 m to its summit at 2,020 m. This traverse was dominated by sediment, with numerous outcrops of massive to pillowed flows. As with Traverse #1, the sediments are generally featureless, with the exception of tracks and traces. Outcrop much more common on this traverse. In total, seven outcrops were sampled. Samples collected are all basalt, variably porphyritic with up to 15-20% phenocrysts, composed of varying amounts of olivine, clinopyroxene, and plagioclase. The rocks are variably vesicular, 10-30%, but less vesicular than the outcrops NE of Pagan. Outcrops are surrounded and topped by sediment. At 13:50 Hyperdolphin was pulled off the bottom and moved to the beginning of Traverse #3.

Traverse #3: Traverse #3 climbed NNW up the side of a ridge extension to the SW of Pagan (Fig. 3). Generally, the traverse was similar to Traverse #2, although pillow forms were less common. The seafloor was dominated by sediments with common isolated to extensive blocky outcrops with sediment dusting and sediment filling chutes and hollows between outcrops. The sediments differed in that they displayed less common traces and tracks and were more commonly rippled. The latter part of the transect showed that the sediments in places developed a crust and had a mauve to slightly greenish hue. Corals were common, with rare sponges. In total eight samples were collected on this traverse, although R-20 was subsequently lost (note, there was some degree of confusion as to whether R-13 or R-20 was lost, but the consensus was that R-20 was the sample lost), and most of R-21 fell off the sample basket (although three fragments or this sample were retained). Rocks collected on this traverse are moderately vesicular (5-15%) and porphyritic, with up to 30% phenocrysts. Phenocrysts are dominated by plagioclase, and include some large plagioclase glomerocrysts in some samples. Olivine is also common, but clinopyroxene was only observed in two samples. This transect concluded at 2,016 m at the top of the ridge and Hyperdolphin left the bottom at 17:00 local time.

Figure 5: Representative pictures from HPD #1148. A. Flat sediments with tracks, first part of Transect #1, Seamax 2010_0712_093351AA; B. Outcrop of volcaniclastic sediments, Transect #1, Seamax 2010_0712_100753AA; C. Outcrop of pillow basalts, note radial cooling joints, upper left. Traverse #1, Seamax 2010_0712_105623AA; D. Flow structures in basalt outcrop, Traverse #2, Seamax 2010_0712_124648AA; E. Striations on pillow basalt surfaces, Traverse #2, Seamax 2010_0712_125507AA; F. Pillow basalt bud with coral, Traverse #2, Seamax

2010_0712_125635AA; G. More massive outcrop of basalt with coral, Traverse #3, Seamax 2010_0712_134829AA; H. Example of crust formed in sediment, Traverse #3, Seamax 2010_0712_153453AA.



DIVE LOG HPD#1148

Dive #:	**NT10-12 HPD#1148**
Date:	July, 12, 2010 (local)
Location:	Small cones on SW slope of Pagan
Objectives:	Study and sample small cones for primitive basalats

Logger: Leybourne
samples are HPD#xxx-RYY
where xxx is dive number, X is S for scoop, R for rock, C for push core, W for water, YY is number

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
8:00			In water		
9:26	2352	001	Bottom in sight; sedimented bottom, light colored with some darker pebbles, cobbles		
9:28	2352	001	Muddy bottom continues; pebbles are possibly pumice.		
9:29	2349	001	Critter trace in the seds		
9:30	2347	000	More critter traces in sediment		
9:32	2346	000	Sedimented bottom continues, rare rocks/coconuts		
9:32	2347	001	Sampling an isolated rock on sedimented bottom - actually it's a coconut		
9:34	2346	003	Moving on, still sedimented bottom		
9:36	2343	000	Lots of traces in the sediment surface, rather curvilinear		
9:39	2340	000	More traced sediment, coconut, shrimp		
9:41	2341	354	Light colored sediment continues, with scattered darker pebbles.		
9:42	2342	355	Stopped to sample, nothing as it transpires		
9:43	2340	355	Moving on, excellent traces on sediment		
9:44	2339	353	Stopping to sample isolated rock; no ts a dead sponge		
9:46	2337	353	Sedimented bottom continues. Degraded ripples evident to left side.		
9:50	2334	352	Sediment continues, abundant traces, some linear, others very contorted		
9:51	2334	353	Stopping for a pushcore sample; red sampler; five penetrations, partially extracted then put down in a different location. Successfully put back in holder. Sediment clearly reasonably thick in this area. Sediment darker below the surface.	C-01	sandy-silt sediment
9:55	2334	353	Back in motion, heading north over sedimented surface		
9:57	2332	355	Stopping to sample isolated rock; and it is a rock!! Float, covered with critters. Sample is in yellow circle basket.	R-01	vesicular basalt
9:59	2331	354	Heading off; sedimented surface continues.		
10:01	2328	322	Very cool traces, highly contorted.		
10:02	2324	321	Outcrop in sight, massive lava flow, flat upper surface sediment covered, so just seeing a small part in a small cliff/ledge		
10:04	2324	338	Approaching section of outcrop, looks like a lava flow or volcaniclastic; stopping to sample.		
10:05	2326	356	Sampling part of the flow; difficult to collect		
10:08	2324	353	Outcrop behind looks massive, with some layering - sheet flows from effusive eruption? At base of flow, some Fe-staining. More likely its mainly volcaniclastic.		
10:08	2324	353	Moving to find a more accessible sample		
10:09	2325	334	Attempting to sample ledge of lava flow. No, too massive		
10:10	2325	350	Another attempt, near section with lots of Fe staining/leaching. Sampling from top ledge, very crumbly, possiby just a crust on top of flow?		
10:13	2324	348	Moving to another spot to sample, using the suction sampler to collect the sample of ledge, but dropped, and on second attempt as well; poorly consolidated volcaniclastics?		
10:18	2325	346	Finally, a fragment collected with the suction device, into basket 5	R-02	volcaniclastic
10:20	2322	350	Moving off again, on top of slope with outcrop, mostly sediment again		
10:21	2320	350	Another ledge/outcrop, similar to before, but with less Fe staining evident, beyond the ledge, sediment with isloted ledge areas		
10:22	2314	350	Back to generally monotonous sediment		
10:23	2308	350	Another ledge/outcrop, less massive, stopping to sample; looks much more like a lava flow, possible pillows, but mostly blocky; ripples in the sediments at the base of the outcrop. Probably dominantly volcanicastic.		
10:27	2307	007	Sampling the outcrop; first attempt was very friable although it looked black and massive. Second attampt is float, but also friable, layered. This second sample collected with the suction device, lots of Fe, layered sample. R-03 in basket 5.	R-03	volcaniclastic
10:31	2306	008	Repositioning to sample the outcrop; Cooling joints evident in the outcrop		
10:35	2306	359	Sample taken, abundant critters on the sample, Fe staining on interior surfaces, R-04 into yelow circle basket	R-04	vesicular ol-basalt
10:36	2305	350	Heading off above the outcrop, sediment with more outcrops, some flow banding in one outcropm		
10:38	2300	350	Continuing up along the spine of an outcrop, sediment common		
10:38	2298	350	Large scarp of outcrop - lava flows, sediment on top of scarp, with isloated outcrops		
10:40	2293	350	Layered outcrop; volcaniclastics?		
10:40	2288	001	Layered outcrop with some more massive flows interspersed/overlying the bedded rocks.		
10:41	2287	030	Stopping to sample, more massive lava near the bedded outcrops		
10:44:30	2287	037	Sample taken of outcrop - brittle star swam out of the way just in time. Large sample, abundant critters on it, Fe staining and Mn crust. Vesicular. R-05 into basket 2.	R-05	vesicular basalt
10:46	2285	014	Moving off again. Sediment, bedded outcrop and massive flow outcrop.		
10:48	2280	359	On top of the outcrops, more sediment cover, with ripples on slope. Jim indicates tidal oscillation ripples.		
10:49	2276	360	More outcrop, pillows and blocky flow stack/scarp. Massive looking outcrop.		
10:53	2275	001	The outcrop has some pillow flows, and more columnar jointed looking parts; a mix of lava forms, clearly relatively old.		
10:53	2271	000	Crossed an area of sediment, then another scarp of outcrop, similar to the previous		
10:54	2268	005	Climbing up the scarp wall of pillowed/pillow tubes and massive outcrop		
10:55	2264	010	Good shot of old pillow form/pillow tube		
10:56	2262	010	Stopping to sample from the scarp wall; having trouble extracting a sample from the outcrop; Moving slightly for better position;		

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
11:01	2262	353	Sample taken from outcrop of pillow form, altered sample, Fe staining, Mn crust, and altered interior. Vesicular. R-06 into basket 2. Near the sample location the outcrop has classic jointing of a pillow form.	R-06	vesicular basalt
11:03	2262	356	End Transect 1, ~ 15-20 minute flight time to next transect.		
11:04	2258	358	Off bottom.		
11:41	2215	357	Back on bottom; Begin Transect 2; mainly sediment		
11:42	2213	001	Still crossig generally featureless sediment, light colored with darker pebbles		
11:44	2202	000	Sediment with a lone sponge; some tracks in sediment but no ripples evident		
11:45	2195	000	Excellent example of critter trail in the sediment. Bioturbation may be too pervasive to preserve ripples?		
11:48	2186	359	Sediment continues, tracks from critters reveals that the underlying sediment is darker, as also seen with the push core.		
11:49	2177	000	Sediment with isolated cobbles/boulders of rock.		
11:50	2172	360	Stopping to sample from the sediment covered outcrop. Probable pillow forms are evident.		
11:54	2174	002	Proving difficult to get a sample, three different locations failed.		
12:04	2174	000	Finally, large piece extracted from outcrop. R07 in basket 2 at 12:08	R-07	ol-basalt
12:09	2175	001	Continuing with sediment and outcrops penetrating through, massive blocks and thin-bedded outcrops		
12:11	2169	351	Pillow basalts, orange seastar, shrimp, sediment		
12:13	2163	351	Mostly sediment with abundant traces and nearly buried lava boulders		
12:15	2158	350	Larger pillow and massive flow outcrops, amount of sediment versus outcrop changes commonly up slope.		
12:17	2150	350	Stop for sampling outcrop mostly buried in sediment; R08 in basket 1 at 12:20	R-08	porphyritic basalt
12:21	2151	346	Ditching chain balast		
12:22	2151	350	Moving off, up the outcrop of pillows and massive blocks with lots of sediment around outcrops.		
12:24	2149	350	Larger, more massive outcrop/scarp wall. Lovely sponge.		
12:25	2145	350	Large blocks in sediment, probably outcrop, but sed covered.		
12:27	2137	350	Large block with nice sponge; sediment with basalt blocky isolated outcrops continues.		
12:29	2130	350	Continuing to climb the slope, lots of sediment, but still with rock outcrops.		
12:30	2128	350	More sediment and less boulders for a section.		
12:30	2126	350	Back to more massive outcrop with sediment filling lower spaces between outcrops.		
12:31	2124	350	Coral and sea whip at base of outcrop boulder.		
12:33	2122	350	Stopping for a sample; blocky outcrop, lots of sediment.		
12:38	2122	350	Long attempt to extract what looked like float, but was probably outcrop. Finally a small piece removed.		
12:40	2122	348	Sample of the outcrop extracted; R-09 into basket 1	R-09	px porphyritic basalt
12:43	2122	350	Heading on up the slope; continues with sediment and isolated outcrop.		
12:44	2118	350	Red jumbo shrimp		
12:44	2115	350	Climbing slope, crossing large scarp outcrop with coral		
12:46	2111	345	Outcrop with ropey texture to surface		
12:47	2108	347	Still climbing steepish slope, sediment with lots of isolated to linear rock outcrop		
12:49	2106	345	Nice pillow in outcrop, then large sponge.		
12:50	2103	345	Pretty coral isolated outcrops in sea of sediment		
12:51	2098	345	Same, outcrops are blocky to subangular; only rarely is a pillow form evident		
12:54	2089	345	Nice pillow forms, large coral, pillows have striations, flow tubes. Pillows are relatively large; lots of large corals in background. Pillows surrounded by sediment. Crossed larger expanse of sediment before the pillow outcrop.		
12:58	2091	329	Taking a sample of the pillow outcrop. Mn crust; R-10 in basket 1	R-10	vesicular porphyritic basalt
13:01	2087	345	Crossing very long pillow tube forms, then into more massive pillow outcrop. Large dendritic corals common.		
13:03	2083	345	Climbing a sediment ridge, outcrop to the right side.		
13:05	2079	345	More outcrop, pillow forms common, as are corals. Still lots of sediment to the left of the outcrops and filling low points between outcrops.		
13:07	2077	349	Stopping for a sample.		
13:12	2077	347	Sample taken. Large piece. R-11 in basket 4	R-11	porphyritic basalt
13:15	2076	350	Heading off, up pillowed and contorted/blocky outcrop.		
13:19	2066	340	Continuing to climb sedimented slope with rock outcrop.		
13:21	2060	338	Similar, blocky outcrop on sedimnted slope.		
13:21	2059	330	Lovely dandelion crinoid		
13:22	2058	330	Red shrimp at rock outcrop		
13:23	2056	330	More continuous outcrop, sediment in hollows and coating surfaces		
13:25	2052	330	Sedimented slope with isolated outcrops, some ripples to the sediment, oriented with axes downslope.		
13:25	2050	330	Large outcrop of rock with large coral.		
13:27	2046	331	Stopping to take a sample.		
13:28	2047	324	Mn crust on the sample. R-12 in basket 4. Brown sponge nearby.	R-12	ol-basalt
12:31	2046	324	Underway again, crossing rock outcrops, sedimented, with corals.		
13:34	2040	320	More extensive sediment as we move away from the rock outcrop, into a gulley, with darker sediment debris		
13:35	2039	321	Back to more outcrop, large corals. Some pillow forms, but mostly blocky outcrop.		
13:36	2037	330	Stopping to sample. Sample surrounded by sediment. Still proves difficult to dislodge.		
13:40	2037	330	Sample finally extracted, Mn crust. Large sample, vesicular. R-13 basket 3	R-13	basalt
13:42	2037	333	In motion again, climbing sedimented slope with rock outcrops. Some pillow forms evident. Some tube structures.		
13:45	2028	321	More of the same, sedimented slope with large rock outcrops, and smaller more isolated outcrops.		
13:46	2019	315	Large coral, sediment seems to be more extensive here.		
13:49	2020	312	Stopped for close up of coral and sponge.		
13:49	2020	315	End of transect 2, moving to next site.		
13:50	2015	316	Off bottom.		

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
14:34	2202	000	Back on bottom for transect 3; sediment with isloated boulders.		
14:36	2200	258	Larger rock outcrops in sedimented substrate.		
14:37	2199	000	Large outcrop, blocky with large sponge at base. Stopping to sample.		
14:39	2199	300	Moving slightly to get a better sampling opportunity.		
14:40	2199	304	Sample collected, loose on top of outcrop. R-14, Mn coated, some Fe staining as well. In basket 3.	R-14	ol porphyritic basalt
14:42	2199	302	Heading off again; sediment with rock outcrops, minor rippling of sediment, defined by darker color.		
14:43	2194	001	Sediment more continuous, but outcrop in distance. Ripples to the right on a slope.		
14:44	2192	003	Rattail fish on sediment.		
14:46	2190	000	Ripples in sediment in front of rock outcrop.		
14:48	2188	350	Outcrops, but sediment cover is dominant, some ripples.		
14:48	2186	351	More extensive rock outcrop, sediment in hollows and chutes. Grain size variations in the sediments indicates flow of sediment over ledges.		
14:52	2181	351	Same, dark, generally blocky rock outcrops in sediment. Some alignment of the outcrops at right angles to direction of sub, ledges/steps in flows?		
14:53	2178	352	Stopping for a sample - blocky outcrop, sediment cover extensive.		
14:55	2178	350	Sample collected, relatively easy to recover. R-15 in basket 3.	R-15	porphyritic basalt
14:56	2178	351	Moving off again, climbing more rock outcrop, but sediment dominant.		
14:58	2175	352	Blocky outcrop, sediment common.		
14:59	2172	353	Stopping for a sample. Blocky to subangular outcrop with good dusting of sediment and surrounded by sediment.		
15:02	2172	028	Small piece of rock collected. R-16 in basket 3. Mn-coated.	R-16	plag basaltic andesite
15:03	2172	025	Underway again, mainly sediment and rock outcrop.		
15:05	2168	002	Sediment cover more extensive again, some ripples, oriented parallel to slope.		
15:06	2164	002	Larger, more extensive rock outcrop, massive to blocky.		
15:07	2161	360	Beyond the rock outcrops, more extensive sediment, well rippled, with ripples oriented downslope.		
15:08	2158	000	More isolated rock outcrops in rippled sediments, sediments in chutes between outcrops as well.		
15:10	2154	002	More extensive rippled sediment		
15:10	2152	002	More rock outcrop, with rippled sediment between blocks/outcrops.		
15:12	2148	002	Stopping to take a sample, from more massive blocky outcrop.		
15:15	2149	360	Sample broken from outcrop. R-17 in basket 3. Dropped lots of sand also into basket 3.	R-17	ol-basalt
15:20	2149	001	Heading off again. Large massive to blocky rock outcrops. Sediment in hollows.		
15:22:30	2144	351	Greenish tint to a crust in the sediment. Sediment in general is slightly darker and rippled than earlier in the day.		
15:24	2140	348	More crust-looking aspect to some of the sediment at base of outcrop.		
15:25	2137	345	Sediment on top of outcrops in places appears to have red tint - Fe staining?		
15:26	2134	345	More massive rock outcrop. Nature of the sediment cover appears to have changed in the last 15 minutes or so.		
15:27	2131	346	Again, some crust-looking aspects to some of the sediments. Indicates partial consolidation by Fe?		
15:28	2130	320	Stopping for a sample from rock outcrop. Mauve-greenish sediments nearby.		
15:47	2132	317	Finally, large sample. R-18 into basket 1 (sort of).	R-18	px-bearing porphyritic basalt
15:51	2131	321	Underway again, mainly sediment and rock outcrop.		
15:51	2127	351	More greenish crusty sediment, appears to have flowed down from rock outcrop.		
15:53	2123	343	Well-rippled sediment surface, large area then more outcrop. Sediment at base of outcrop has a reddish hue.		
15:54	2120	340	More greenish crusty sediment.		
15:55	2114	335	More extensive rock outcrop, blocky, with greenish crusty sediment in hollows.		
15:57	2105	336	Sediment crusts getting ticker and more extensive. But generally, rock outcrops in dominant sediment.		
16:00	2092	338	Very nice, greenish crusts.		
16:02	2087	340	Large blocky outcrops in sediment		
16:04	2078	336	Rock outcrop and some blocky talus. Larger outcrop behind.		
16:05	2073	329	Large outcrop with clear ledges. Stopping at base of outcrop for a sample.		
16:06	2074	331	Sample taken from outcrop - broken off. R-19 into basket 3	R-19	ol porphyritic basalt
16:08	2073	331	Moving off again, up the face of the ledged scarp outcrop.		
16:09	2067	331	This outcrop is the most extensive of the day. Some apparent layering - but it is a flow. Sediment dusting but otherwise rock only. Could be a dike.		
16:10	2065	330	Taking a sample. R-20 in basket 3	R-20	sample lost
16:15	2060	207	Off bottom for a short while.		
16:16	2060	334	Massive outcrop, with some large blocky talus. Dusting of sediment, but no more sedimented slope. Lots of coral.		
16:17	2056	344	On top of outcrop, lots of corals.		
16:18	2055	000	Some elongate structures to some of the outcrop - flow features?, some deep crevaces as well.		
16:20	2052	003	Massive jointed outcrop, possibly a large dike system?		
16:21	2050	350	On top, back to rippled sediment, with more outcrop in the distance.		
16:21	2047	340	Large upstanding outcrops surrounded by sediments, with abundant corals on top. Sediments are commonly rippled.		
16:22	2045	341	Mainly sediment now, sparse outcrop, with corals on isloated blocks		
16:24	2039	010	Dominantly sediment plain, rippled where there is a slope to the side.		
16:26	2038	020	Generally flat sediment, ripples, and only rare outcrop to the side.		
16:27	2036	019	Minor isolated blocky outcrops with corals in sediment plain.		
16:28	2035	020	Larger outcrop, blocky, rising high above sediment plain. Stopping to take a sample.		
16:35	2033	108	Moved to get better aspect at a large block. R-21 held between the two arms, with a fragment in the port claw.	R-21	porphyritic basalt
16:40	2032	100	Back in motion. Heading on up to the summit.		
16:41	2022	011	Lots of corals on outcrops, hard to see past the arms holding the two large samples in place.		
16:42	2022	031	Rippled sediments, rock outcrops with abundant branching corals. One large sponge as well.		
16:44	2020	042	Large abundant corals on upstanding outcrops.		

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
16:45	2017	041	Large scarp face to the left of the track, losing contact with the bottom as we head that way, so scarp wall to the right.		
16:46	2015	001	Lost contact with bottom, looking for the bottom		
16:48	2021	360	Bottom back in sight, outcrop with some sediment cover. Corals, relatively steep slope.		
16:49	2015	359	Approaching top of the outcrops, sediment at top. Stopping to view the last of the outcrop. Sample 21 in claw into basket 5. Rest of sample 21 broke into a couple of pieces, still on top of basket 4. Trying to take another sample.		
16:52	2016	359	Sample taken. R-22 into basket 5. The largest piece of sample 21 fell out. Some of R-21 still in basket 4.	R-22	porphyritic basalt
17:00	2016	002	Heading off again.		
17:00	2013	360	End of dive, off bottom.		
17:51	3		Hyperdolphin at surface		
18:08			Hyperdolphin on deck		

HPD#1148 Pagan SW

HPD#1148 July 12 2010 S Pagan

sample No.	latitude(N)		longitude(E)		depth (m)	rock type	shape	size X (cm)	size Y (cm)	size Z (cm)	weight (kg)	colour	alteration	Mn coating
HPD#1148-R01	17	58.59	145	38.33	2331	vesicular basalt	angular	13	9	8	1.2	dark gray	fresh	
HPD#1148-R02	17	58.61	145	38.32	2334	volcaniclastic	angular	9, 5, 4	6, 3, 3	3, 2, 2	0.4	brown	altered	
HPD#1148-R03	17	58.62	145	38.33	2307	volcaniclastic	subangular	22	18	8	3	brown	altered	
HPD#1148-R04	17	58.62	145	38.33	2307	vesicular ol-basalt	angular	13	10	9	1.5	dark gray	fresh	
HPD#1148-R05	17	58.65	145	38.31	2287	vesicular basalt	angular	20	14	9	4.1	dark gray	weak	
HPD#1148-R06	17	58.68	145	38.31	2262	vesicular basalt	angular	20	13	12	2.9	dark gray	fresh	2 mm
HPD#1148-R07	17	58.99	145	38.30	2175	ol-basalt	subangular	33	30	23	28	black	moderat	
HPD#1148-R08	17	59.01	145	38.30	2151	porphyritic basalt	subangular	30	22	15	8	black	weak	
HPD#1148-R09	17	59.03	145	38.29	2121	px porphyritic basalt	angular	15	9	8	1.1	dark gray	fresh	1 mm
HPD#1148-R10	17	59.07	145	38.29	2090	vesicular porphyritic basalt	angular	14	8	4	0.8	black	fresh	
HPD#1148-R11	17	59.07	145	38.29	2077	porphyritic basalt	angular	30	23	19	9.5	black	fresh	
HPD#1148-R12	17	59.09	145	38.28	2047	ol-basalt	angular	19, 16	12, 8	12, 9	3.5	dark gray	weak	1-2 mm
HPD#1148-R13	17	59.11	145	38.28	2037	basalt	subangular	26	23	16	7.5	dark gray	fresh	
HPD#1148-R14	17	59.30	145	38.00	2200	ol porphyritic basalt	subrounded	11	11	6	1.5	gray	fresh	
HPD#1148-R15	17	59.33	145	38.01	2178	porphyritic basalt	subrounded	12	7	7	1	black	fresh	
HPD#1148-R16	17	59.34	145	38.00	2172	plag basaltic andesite	subangular	12	11	8	1	dark gray	weak	film
HPD#1148-R17	17	59.36	145	38.01	2148	ol-basalt	angular	22	18	17	8	black	fresh	
HPD#1148-R18	17	59.37	145	38.01	2132	px-bearing porphyritic basalt	angular	38	30	26	36	black	moderat e	
HPD#1148-R19	17	59.41	145	37.99	2073	ol porphyritic basalt	subangular	16	10	11	1.7	dark gray	fresh	
HPD#1148-														
HPD#1148-R21	17	59.48	145	37.98	2033	porphyritic basalt	angular	16, 16, 8	13, 10, 7	11, 10,	4	black	weak	
HPD#1148-R22	17	59.54	145	37.97	2016	porphyritic basalt	angular	30	20	16	11.5	dark gray	fresh	
HPD#1147-unknown							rounded	many pieces			0.8			
HPD#1148-C01	17	58.578	145	38.32	2334	sediment					1.6	brown-black		

HPD#1148 Pagan SW

Glass rim	phenocrysts	vesiculation	Memo	
	ol 2; px 3	moderate 15%	vugs <5 mm	HPD#1148-R01
			muddy-sandy matrix; basaltic clast ~5 cm	HPD#1148-R02
			vesicular (basaltic) clast (vesicularity ~30%); clay-sandy matrix	HPD#1148-R03
	ol <5	moderate 20%	ol <2 mm; possible banding of vesicles	HPD#1148-R04
	ol 2; px ±	moderate 15%	veiscles <4 mm	HPD#1148-R05
	ol <5; px <5; pl 1	moderate 15%	vugs up to 8 mm, some flattened	HPD#1148-R06
	ol 5; pl 5	moderate 15%	ol <1 mm; pl <2 mm	HPD#1148-R07
	ol 6-8; px 2-3; pl 2-3	moderate 30%		HPD#1148-R08
	ol ±; px 15; pl 2	moderate 20%	vugs <5 mm; large 1 cm pl megacryst/glomerocryst with some cpx	HPD#1148-R09
2 mm	ol 5; pl 5	moderate 15%	Fe-crust; ol altered; vesicles 1-2 mm	HPD#1148-R10
3 mm	ol 5; px 3; pl 8	moderate 30%		HPD#1148-R11
1 mm	ol 5-10; pl 10	moderate 10%	vugs <1 cm, flattened	HPD#1148-R12
	ol 5; px 2-4; pl 10	moderate 10%		HPD#1148-R13
	ol 5-10; pl 15	moderate 10%	ol <1 mm; pl <2 mm; ol glomerocryst	HPD#1148-R14
	ol <1; px <1; pl 20	weak <10%		HPD#1148-R15
	px 5; pl 20	weak 5%	vugs <1 cm	HPD#1148-R16
	ol 5; pl <10	moderate 10%	ol <1 mm; pl <2 mm; vesicles up to 1 cm	HPD#1148-R17
	ol 5; px 10; pl 15	weak 5-10%	glomerocrysts	HPD#1148-R18
	ol 5-10; pl 15	moderate 15%	ol <2 mm; pl glomerocrystic 4-5 mm; vuggy	HPD#1148-R19
			Missing	HPD#1148-R20(Missing)
	ol 5; pl 20	moderate 10%	ol <1 mm; pl <2 mm	HPD#1148-R21
	ol 5; pl 25	moderate 10%	ol <1 mm; pl <2 mm	HPD#1148-R22
				HPD#1147-unknown
			20% sand-sized, 80% salt-sized	HPD#1148-C01

HYPER-DOLPHIN DIVE #1149

TECHNICAL INFORMATION

Location: Lower slopes east of Daon seamount

Objective: Survey and sample ridges and outcrops on the flanks of Daon seamount

DIVE 1149	**On bottom:**	**Off bottom:**
Transect #1:		
Time (local): July 13, 2010	09:30	10:59
Latitude:	17°54.819'N	17°54.824'N
Longitude:	145°31.823'E	145°31.913'E
Depth (m):	2579	2460
Transect #2:		
Time (local): July 13, 2009	11:34	12:49
Latitude:	17°55.125'N	17°55.239'N
Longitude:	145°31.893'E	145°31.877'E
Depth (m):	2512	2473
Transect #3:		
Time (local): July 13, 2009	13:56	16:21
Latitude:	17°55.701'N	17°55.901'N
Longitude:	145°31.900'E	145°31.922'E
Depth (m):	2522	2323

Samples returned: 18 rocks and one core

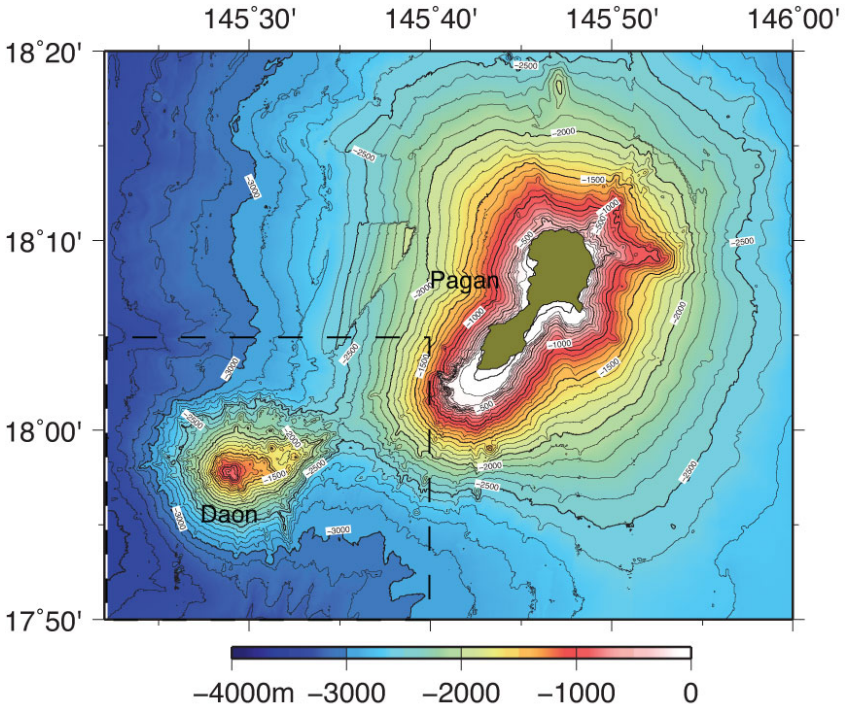


Figure 1: Location of dive operations for HPD#1149 on Daon seamount SW of the island of Pagan, from Mariana Bathymetric Compilation (Susan Merle, PMEL/NOAA, compiler). Area of Figure 2 shown in dashed box.

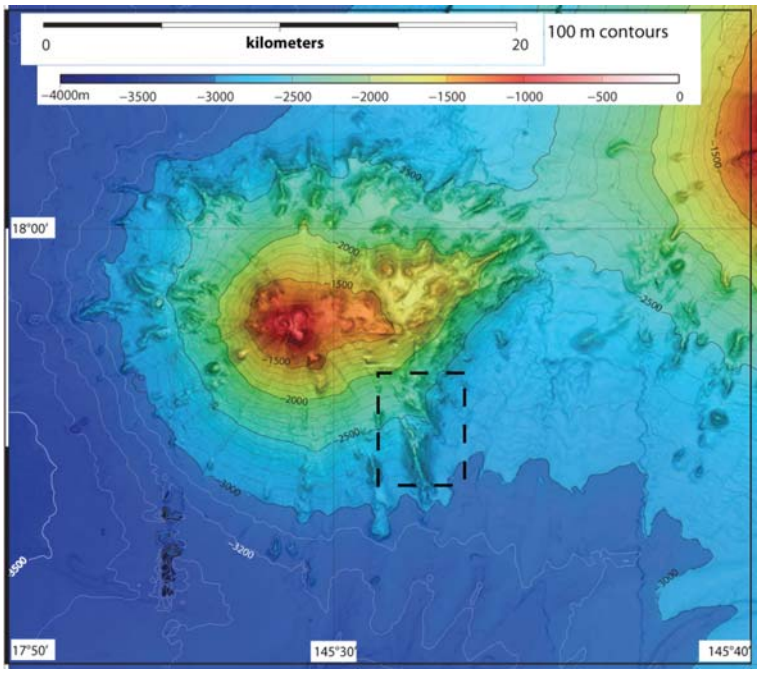


Figure 2: Close-up of bathymetry around Daon seamount, showing the location of dive operations for HPD#1149 shown in Fig. 3 (dashed box). From Mariana Bathymetric Compilation (Susan Merle, PMEL/NOAA, compiler).

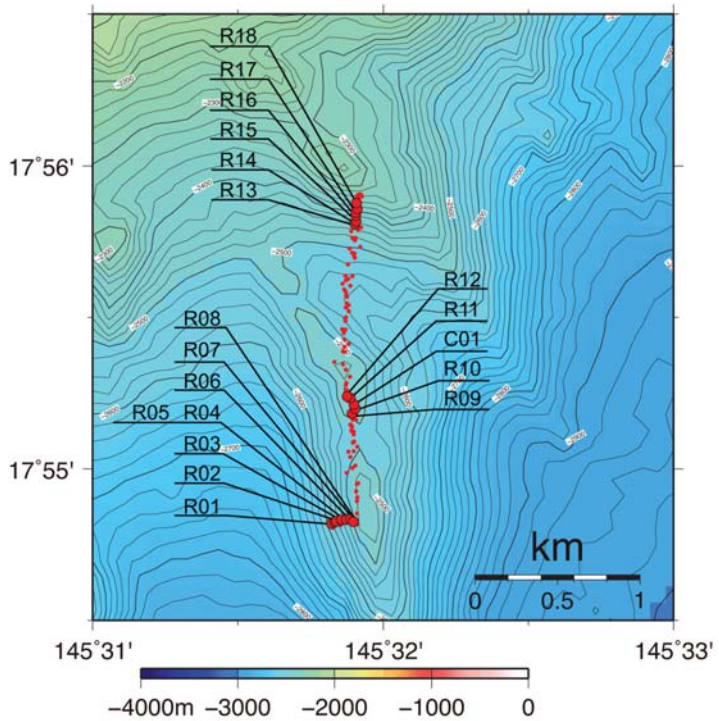


Figure 3: Bathymetry of southern ridge projecting from Daon showing three traverses carried out during Dive #1149. Samples R01-R08 were from Traverse #1, R09-R12 and C01 from Traverse #2, R13-R18 from Traverse #3.

SCIENTIFIC SUMMARY:

Daon seamount is a "behind-the-magmatic-front" (cross-chain or rear-arc) volcano associated with Pagan (Figure 1). No volcanic or hydrothermal activity is known. Daon's summit rises from a base ~3000-3200 m to a summit that lies less than 900 m b.s.l. In map view, the edifice is elongated E-W, 20 km E-W and ~15 km N-S. Bloomer *et al.* (1989) calculate a volume of 150 km^3, ~10% of the size of the largest Mariana volcanoes such as Pagan and Agrigan. Daon merges across a ~2500 m deep saddle with the SW extension of S. Pagan. Daon has an unusual morphology, with many ridges radiating from it, which may reflect the presence of radiating dikes. No studies are reported for Daon, although Bloomer *et al.* (1989) dredged the SW part of the edifice, recovering dacites with phenocrysts of plagioclase, hornblende, clinopyroxene, and orthopyroxene. Some of these samples contained disseminated sulfides.

Our principal goal in this dive was to characterize and sample the eruptive products on the lower eastern slopes of Daon. The dive was planned in a series of three traverses, the first two on the longest southward trending ridge on the south side of the volcano at depths of 2580 to 2470 m. b.s.l., and the third on the south-facing slope of a short but steep ridge to the north, at depths of 2520-2320 m.b.s.l. The actual dive tracks are shown in Figure 3. Samples recovered were fairly homogeneous, all 18 rock samples are basalts; 11 are described as olivine basalts, 2 are olivine-clinopyroxene basalts, the remainder are aphyric basalts. The principal lithologic variation is seen in degree of vesicularity, brecciation, and whether or not samples were pillows. All samples had some Mn coating, ranging from almost nothing to 10 mm thickness.

Traverse #1: This traverse was up the western slope of the longest southward trending ridge on the south side of the volcano major from 2579 m to 2460 m depth. The vehicle reached bottom at 2579 m amongst outcropping volcaniclastics and rubbly lava. Hyperdolphin moved upslope and quickly (10:01) came into outcrops with spectacular pillow lavas (Fig. 4A). Pillows alternated with rubbly lava flows and layered volcaniclastics (Fig. 4B). Rocky outcrops had abundant branching corals and some sponges (Fig. 4C).

Traverse #2: This section of the dive touched down in a field of loose sediment, with well-defined ripples. Such sediments were traversed for 18 minutes, from 2512 to 2495m b.s.l. (Fig. 4D) before outcropping pillow basalt was encountered. This outcrop was small (3m total elevation change) and loose rippled sediment was traversed again for 10 minutes. The core sample C01 was taken during this traverse, which consisted of sand and mud. The traverse reached outcrop, where it ended and Hyperdolphin flew to begin the third traverse.

Traverse #3: This part of the dive examined the south-facing slope of a short but steep ridge (Fig. 3). Hyperdolphin touched down in a field of loose, rippled sediment and traversed this for almost 20 minutes and 29 m elevation change. Outcrops at this point were massive lavas overlain by well-indurated, layered volcaniclastics (Fig. 4E). Fine volcaniclastics, coarse volcaniclastics, rubbly flows, and small pillows (Fig. 4F) were traversed from this point until an outcrop with distinctive horizontal columnar jointing was encountered; we think this may be a dike (Fig. 4G). The traverse continued over a variety of outcrops: volcaniclastics, blocky lava, and small pillows. The dive ended with 13 minutes spent traversing loose, rippled sediments.

References

Bloomer, S. H., Stern, R. J., and Smoot, N. C. "Physical Volcanology of the Submarine Mariana and Volcano Arcs." *Bull. Volcanology*, 51, 210-224, 1989.

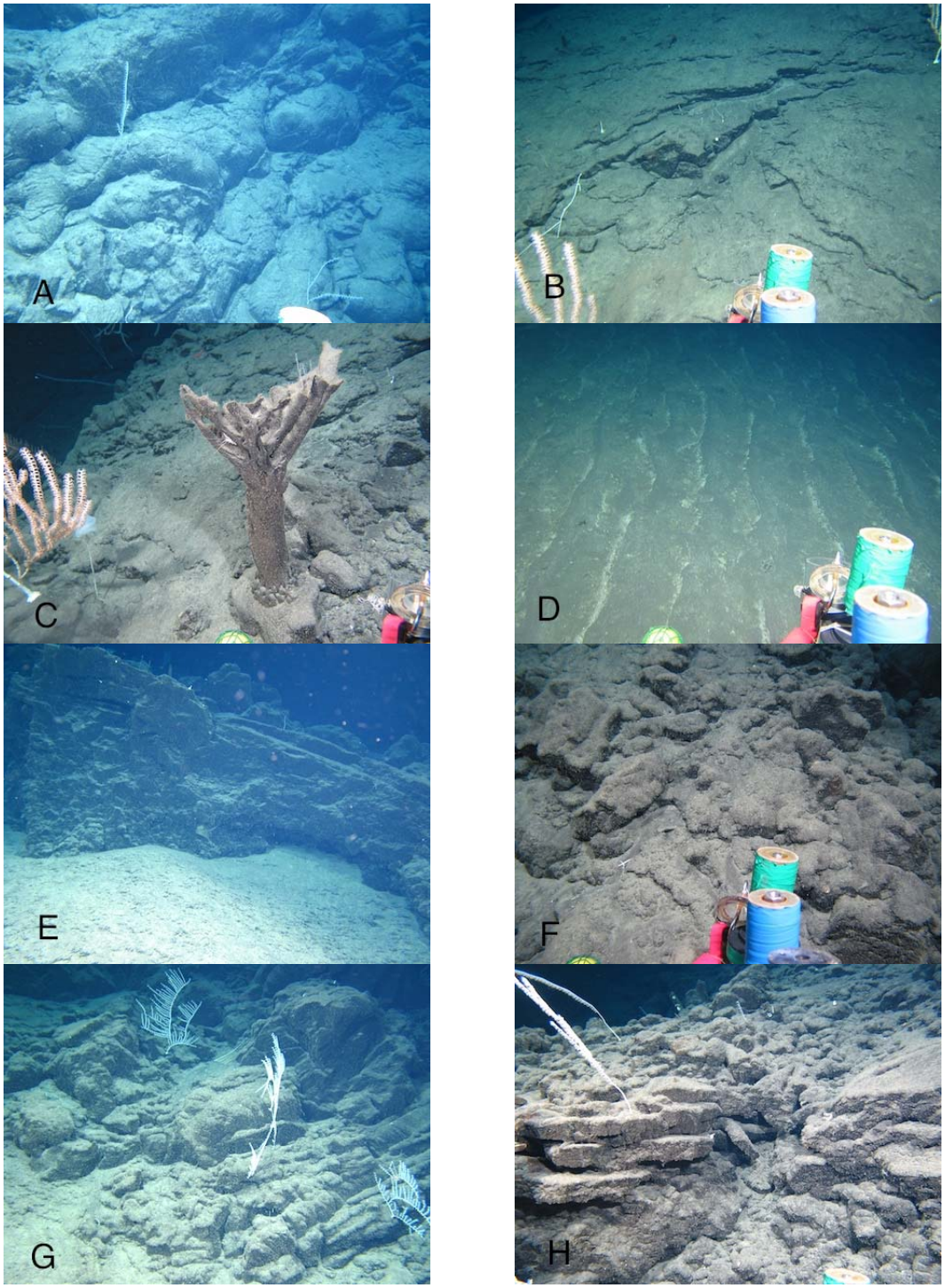


Figure 4: Representative pictures from HPD #1149.
A. Pillow lavas from transect 1 (Seamax 2010_0713_100050AA). R04 is from near here;
B. Layered volcaniclastics from transect 1 (Seamax 2010_0713_104204);
C. Black coral on lava outcrop, transect 1 (Seamax 2010_0713_104454);
D. Ripples on loose sediments, transect 2 (Seamax 2010_0713_114753AA);
E. Outcrop of lava overlain by layered volcaniclastics, transect 3 (Seamax 2010_0713_142523AA);
F. Outcrop with small pillows, transect 3; R15 is from near here (Seamax 2010_0713_144907AA);
G. Outcrop with subhorizontal columnar jointing, possibly a dike, transect 3 (Seamax 2010_0713_145426AA);
H. Close-up of outcrop with thin flow layers, transect 3; R16 is from projecting outcrop on the left. (Seamax 2010_0713_152809AA)

Dive #:	**NT10-12 HPD#1149**
Date:	July, 13, 2010 (local)
Location:	E. Lower Slope of Daon seamount
Objectives:	Study and sample lavas and other rocks

Logger: Stern
samples are HPD#xxx-RYY
where xxx is dive number, X is S for scoop, R for rock, C for push core, W for water, YY is number

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck descriptio
08:14			In water		
09:30	2579	084	On bottom, outcropping volcaniclastics and rubbly lava; some coral		
09:34	2580		Collecting sample from angular rubble; in circular basket	R01	Ol-basalt
09:37	2578	034	Moving over rubbly seafloor		
09:44	2560	039	Sampling tall cliff of outcropping lava; in basket 3	R02	Glassy rimmed Ol-basalt (pillow?)
09:50		040	Traversing blocky outcrops		
09:54			Sampling rubbly outcrop; Mn coating; Basket 1	R03	vesicular Ol-basalt (pillow?)
10:01		041	Traversing slope of beautiful elongate pillows; lots of pink coral		
10:07	2542		Sampling outcropping pillow lavas; in basket 1	R04	basalt
10:10	2537	057	Traversing outcrop with pink coral		
10:15	2530		Sampling outcrop of pillow breccia/volcaniclastics; in basket 1	R05	vesicular Ol-basalt (pillow?)
10:18	2530		Stopping to admire sponge and coral		
10:23	2517	066	Continuing over rubbly outcrop with abundant pink coral		
10:26	2510	084	Stopping to sample outcrop of coarse volcaniclastics; in basket 1	R06	basaltic breccia
10:30	2507	078	Continuing over outcropping coarse volcaniclastics with lots of coral		
10:32	2499	071	Continuing over outcroppig fine-grained volcaniclastic sediments; seem to lie on top of coarse volcaniclastics		
10:34	2494		Stopping to sample outcrop of pillow lavas; in the aft of basket 2	R07	vesicular basalt
10:41	2490	057	Continuing over rubbly outcrops of slabby volcaniclastics with lots of coral		
10:44	2482		Stopping to admire black coral		
10:46	2480	081	Continuing over outcroping lava with lots ofcoral		
10:52	2470		Stopping to sample rubble; in basket 2	R08	vesicular Ol-basalt
10:56	2470		Chain weight removed		
10:57	2466	080	Continue over rubbly outcrop, lots of coral		
10:59	2460		Fly to Waypoint 3		
11:34	2512	010	On the bottom; sandy/granuley bottom with ripples		
11:42	2505	010	Continue over sandy/granuley bottom with ripples; no outcrop seen;some "chutes" of coarse material		
11:52	2495	330	Outcrops of pillow lava are reached		
11:55	2496		Sampling pilowed outcrop; in basket 2	R09	Ol-basalt
11:59	2494	010	Continue over rippled sediments		
12:01	2491	010	Continue to cross rippled sediments, with rare coral, ripples less well defined compared to earlier		
12:02	2490	011	Outcrop of pillow tube, starfish, stopping to collect a sample		
12:06	2491	007	Sample broken from outcrop with some difficulty; R10 in Basket 2; Mn-stained	R10	vesicular basalt
12:09	2491	012	Continuing over massive outcrop, sediment dusting, scarp to the right, down to rippled sediment.		
12:11	2488	002	Off the edge of the small rock scarp and back over rippled sediment		
12:14	2485	351	Climbing a gentle slope, dominated by rippled sediment		
12:16	2485	352	Stopping to take a core sample; green core sampler used; C01; sediment light brown below darker surface; core inserted a total of 3 times to collect sufficient material to fill the core barrel; Successfully returned to holder with a full core	C01	
12:20	2485	352	Continuing over rippled sediment		

12:24	2481	310	Outcrop in sight, ripples less well defined; stopping to collect R11 at this outcrop.		
12:36	2480	292	After much struggle, sample finally removed from outcrop; in box 2	R11	Cpx-Ol basalt
12:41	2472		Stopping to sample outcrop with strong vertical fracture; maybe a dike? Sample has some Mn stain; goes into box 2	R12	Ol-basalt
12:55	2465	335	Move to wayoint 5		
13:56	2522	000	On bottom; sedimented with pebble-sized material		
14:02	2504	005	Sedimented; mottled appearance		
14:15	2451		Outcrop of well-indurated, layered volcaniclastics; in basket 3	R13	Ol-basalt
14:25	2455		Stop to photograph outcrop		
14:30	2444		Traveling over volcaniclastic outcrops with coral		
14:31	2443		Stopping to sample coarse volcaniclastics or underlying basalt flow; in basket 5	R14	Ol-basalt
14:40	2437	005	Travelling over dipping, layered, fine-grained volcaniclastics, some low outcrops of lava and/or coarse volcaniclastics		
14:45	2420	004	Stopping to sample outcrop of lava or coarse volcaniclastics; in basket 5	R15	Ol-basalt
14:50	2418	003	Travelling over outcrops of blocky lava (maybe pillows), with coral		
14:54	2408		Stopping to sample outcrops of blocky lava; horizontal columnar structure suggests dike; give up after 22 minutes; move over a few meters and try again		
15:19	2406		Sample from tabular outcrop; Mn-stain; in basket 5	R16	Ol-cpx basalt
15:30	2404		Moving over outcrop of blocky flow/coarse volcaniclastics		
15:31	2399		Pillows seen; some are quite small		
15:38	2384		Blocky outcrops with columnar jointing		
15:41	2383		Stopping to sample fractured outcrop; give up after 6 minutes and move a bit to resample; in basket 5	R17	Ol-basalt
15:50	2371	000	Move over outcrops		
15:55	2365	012	Move over sediments and massive outcrops		
15:58	2362		Stopping to collect sample from blocky outcrop; basket 5	R18	Ol-basalt
16:02	2358	011	Continue over blocky to craggy outcrops with coral		
16:05	2346	011	Travel over sedimented area		
16:18	2323		End dive in sedimented area		
16:21			Off bottom		

HPD#1149 SE Daon

HPD#1149 July 13 2010 SE slopes of Danon

sample No.	latitude(N)		longitude(E)		depth (m)	rock type	shape	size X (cm)	size Y (cm	size Z (cn	weight(kg)	colour
HPD#1149-R01	17	54.82	145	31.82	2579	ol-basalt	subangular	17	22	13	6	black
HPD#1149-R02	17	54.82	145	31.83	2560	glassy rimmed ol-basalt (pillow?)	angular	18, 6	21, 4	11, 5	4.7	dark gray
HPD#1149-R03	17	54.83	145	31.84	2554	vesicular ol-basalt (pillow?)	subangular	23	29	15	8.75	black
HPD#1149-R04	17	54.83	145	31.86	2542	basalt	subangular	8	10	8	0.5	black
HPD#1149-R05	17	54.83	145	31.86	2530	vesicular ol-basalt (pillow?)	angular	11	11	13	2.5	black
HPD#1149-R06	17	54.83	145	31.87	2510	basaltic breccia	subrounded	12	14	12	2	dark gray
HPD#1149-R07	17	54.83	145	31.89	2494	vesicular basalt	angular	31	21	18	15	dark gray
HPD#1149-R08	17	54.83	145	31.90	2470	vesicular ol-basalt	rounded	18	16	17	6	dark gray
HPD#1149-R09	17	55.18	145	31.89	2496	ol-basalt	subrounded	10	9	4	0.5	dark gray
HPD#1149-R10	17	55.2	145	31.90	2491	vesicular basalt	subrounded	12	18	11	2.5	black
HPD#1149-R11	17	55.23	145	31.89	2480	cpx-ol basalt	angular	4	10	7	0.25	black
HPD#1149-R12	17	55.24	145	31.88	2473	ol-basalt	angular	34	10	12	5.25	black
HPD#1149-R13	17	55.81	145	31.90	2459	ol-basalt	angular	31, 22	17, 13	14, 4	10	black
HPD#1149-R14	17	55.82	145	31.91	2443	ol-basalt	angular	10	16	11	2.7	black
HPD#1149-R15	17	55.83	145	31.91	2420	ol-basalt	subrounded	16	17	12	2.5	black
HPD#1149-R16	17	55.85	145	31.91	2404	ol-cpx basalt	angular	7	13	8	0.5	black
HPD#1149-R17	17	55.86	145	31.91	2381	ol-basalt	rounded	12	9	8	1	black
HPD#1149-R18	17	55.88	145	31.91	2362	ol-basalt	subangular	24	15	19	9	black
HPD#1149-unknown							angular	many pieces			0.6	
HPD#1149-C01	17	55.21	145	31.90	2485	sand to mud					2	brown

HPD#1149 SE Daon

alteration	Mn coating	Glass rim	phenocrysts	vesiculation	Memo	
weak	film		ol 5; px 2; pl 5-10	moderate 20%	ol 1-2 mm; pl 2 mm	HPD#1149-R01
weak	film	10 mm	ol 5-10; px 5; pl 5	moderate 20%	ol 2 mm; px 2 mm; pl 2 mm; vesicles <2 mm; alteration rim below glassy area, greenish-gray	HPD#1149-R02
weak	film	4 mm	ol 5; pl 5-10	moderate 20%	pl 1-2 mm; vesicles increase in size towards interior - vuggy in interior	HPD#1149-R03
weak	<5 mm		ol 2; pl 5	moderate 15%	ol <1 mm; pl 2 mm; vesicles <3 mm; various alteration rims under Mn-coating	HPD#1149-R04
weak	<2 mm	5 mm	ol 5-10; px ±; pl 5	moderate 20%	alteration below glassy rim; vesicles increase in size and become vuggy towards interior (from <2 mm to 20 mm)	HPD#1149-R05
weak (clasts)	botryoidal 2-5 mm				angular vesicular basaltic clasts set in a clay matrix with Mn; monomictic breccia? botryoidal Mn coating; basaltic clasts - ol 5%; pl 5-10%; ±px	HPD#1149-R06
weak			ol 2; pl 10	moderate 30%	ol 1 mm; pl 2 mm; vesicles <5 mm, some vuggy	HPD#1149-R07
weak	<3 mm		ol 5-10; pl 5-10	moderate 20%	ol 2-3 mm; pl 2 mm	HPD#1149-R08
moderate	5-10 mm		ol 5-10; pl 5	moderate 20%	ol <2 mm; pl <2 mm; flattened vesicles towards outside, some vuggy; alteration banding	HPD#1149-R09
weak	2 mm		ol 2; px ±; pl 2	moderate 30%	vesicle zoning, more massive zone without vesicles; Fe alteration rim under Mn-coating	HPD#1149-R10
fresh	2 mm		ol 5-7; px 2-3; pl 3-4	moderate 20%		HPD#1149-R11
fresh	4 mm		ol 2-3	weak < 10%		HPD#1149-R12
weak	5 mm		ol 8; pl 1-2	moderate 25%		HPD#1149-R13
fresh	8 mm	7-8 mm	ol 6-8; px ±; pl 1-2	moderate 20%		HPD#1149-R14
fresh	7 mm		ol 6; pl 2	strong 35%		HPD#1149-R15
weak	<5 mm		ol 2; px 2; pl 2	moderate 20%	vesicles <3 mm	HPD#1149-R16
fresh	6 mm	7 mm	ol 6; pl 2	moderate	8 mm pl glomerocryst	HPD#1149-R17
fresh	5 mm	5 mm	ol 8; pl 1	moderate 25%		HPD#1149-R18
						HPD#1149-unknown
						HPD#1149-C01

HYPER-DOLPHIN DIVE #1150

TECHNICAL INFORMATION

Location: Eastern resurgent domes in E. Diamante caldera
Objective: Survey and sample hydrothermal mounds field found in 6/2009

DIVE 1150	**On bottom:**	**Off bottom:**
Time (local): July 14, 2010	09:30	10:59
Latitude:	15°56.523'N	15°56.528'N
Longitude:	145°40.909'E	145°40.922'E
Depth (m):	364	377

Samples returned: 6 rocks

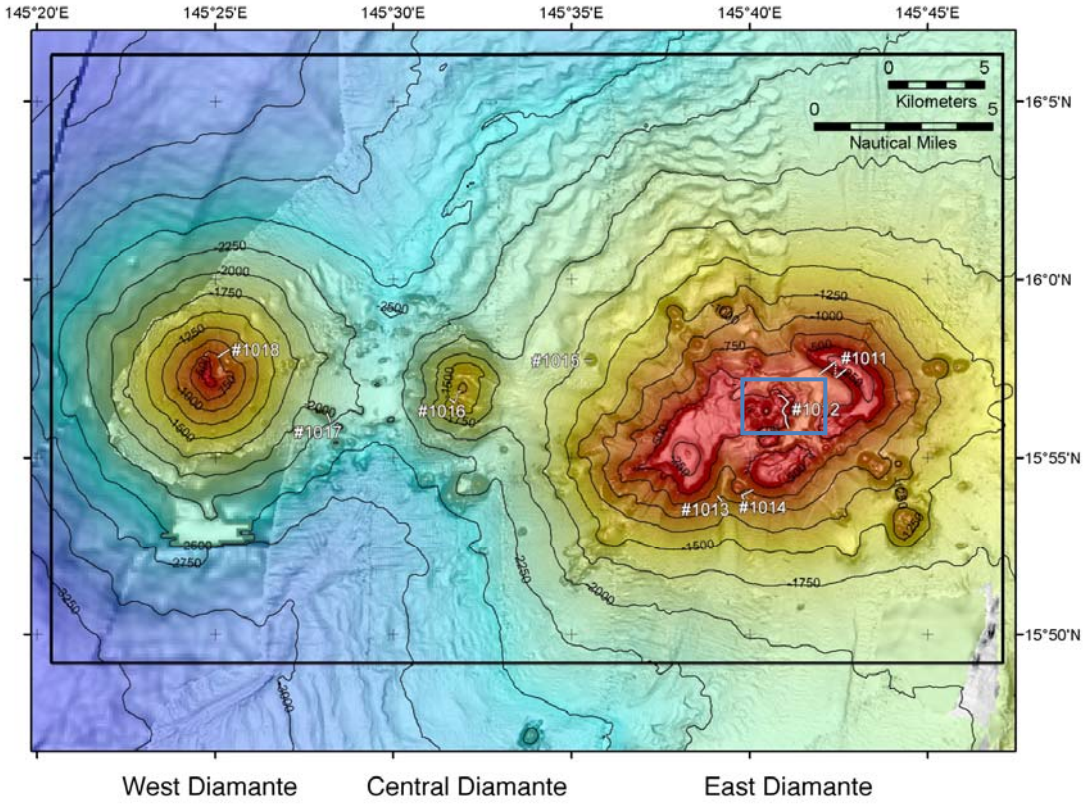


Figure 1: Location of dive operations for HPD#1150 E. Diamante caldera. Area of Figure 2 shown in blue box.

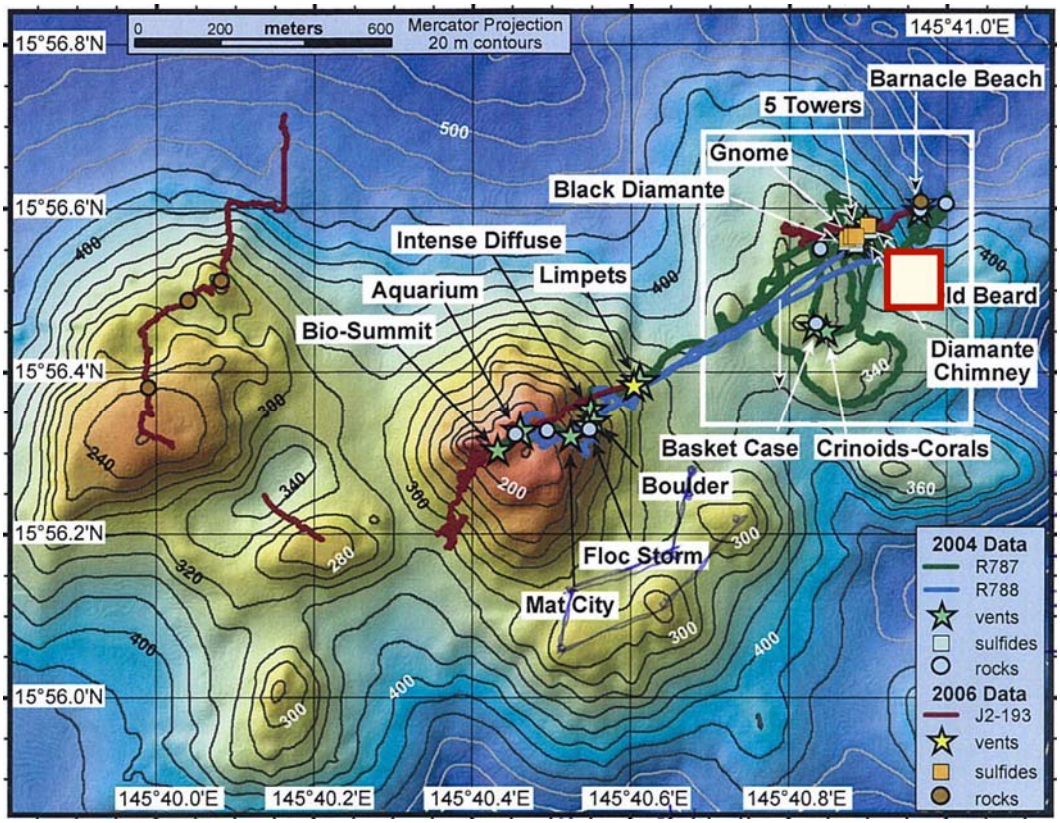


Figure 2: Close-up of bathymetry within E. Diamante caldera, showing the location of dive operations for HPD#1150 shown in Fig. 3 (red box).

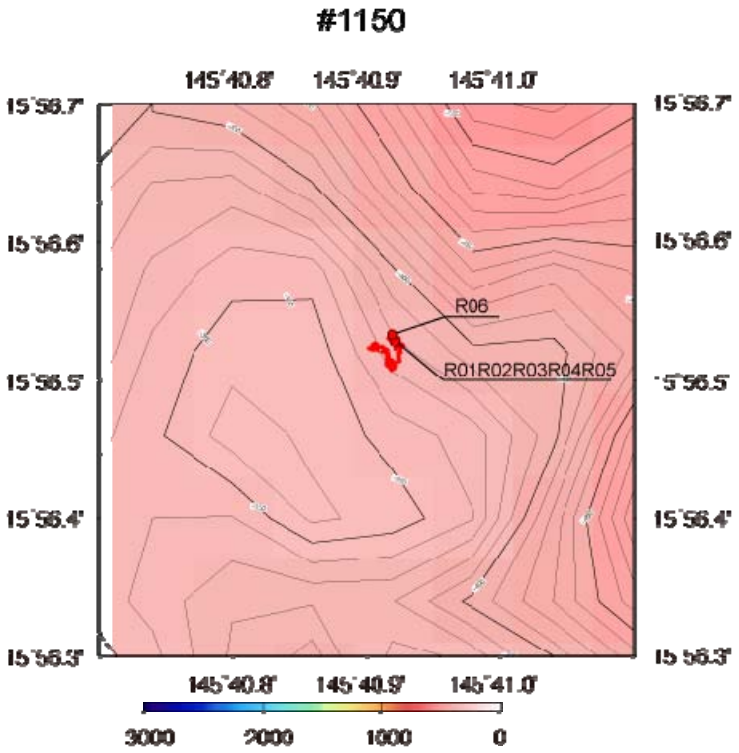


Figure 3: Bathymetry of Resurgent dome in E Diamante caldera carried out during Dive #1150. Samples R01-R06

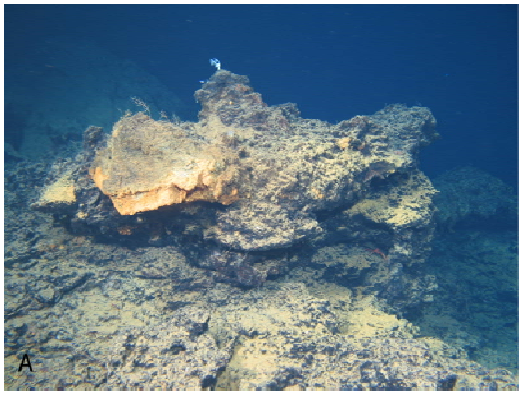
SCIENTIFIC SUMMARY:

The objectives of Dive 1150 were to survey and sample a large field of hydrothermal mounds located along the east flank of a complex of resurgent domes in E. Diamante caldera and to sample known dead and active hydrothermal chimney fields located to the NW of the mounds field (Figures 1-3). Because a very large rock sample (R06) was collected a short way into the dive, the Hyper-Dolphin had to be returned to the ship to offload the sample. The objective of sampling the chimneys was completed in the afternoon on Dive 1151, during which the mounds area was revisited, but time ran out after just an hour survey. The mounds field was revisited again on Dive 1153 to survey the size of the field.

Dive 1150 landed at 364 m water depth after descending through a plume of particulate matter. The seabed at the landing site consisted of dacite cobbles and blocks and sediment. That combination continued until the mounds field was reached at waypoint 1 at 377 m water depth. A large group of mounds were seen (Fig. 5). The first mound encountered was venting clear fluid through a subsidiary mound located on top of the main mound edifice. The subsidiary mound is composed of iron and manganese oxides. Many of the large mounds have this subsidiary oxide mound at one end of their elongate summit. A layer of encrusting Fe and Mn oxides was draped over the sides of the large mound. The mound was measured by placing a 31 cm marker at its base, which was later moved to its top so the area could be easily relocated. The base of the mound is buried in sediment, so these are minimum dimensions: main mound height 1.3+ m, width 0.5 m; length continues outside field of view as an elongate ridge >3 m; subsidiary oxide mound height varies from 0.4-1.0 m, width about 0.6 m and length about 0.5 m. The Fe and Mn oxides draping the sides of the mound were collected (R01) and those near the subsidiary mound vent (R02), but most of R02 crumbled. A barite, sphalerite, galena layer in the lower part of the main mound was collected (R05). A dacite sample (R04) was taken from an outcrop on which the main mound abuts. Sample R06 (Fig. 4) was collected from a slope adjacent to another mound. Hydrothermal Fe and Mn oxides covered most of the slope so geological relationships could not be established. Sample R06 is a meter long barite, sphalerite, galena dead chimney with a central conduit lined with tentatively identified yellow barite and sulfur. The fallen chimney was buried in oxides and it was not clear until it was broken open what it was when collected because of a rather large width to length ratio. Collection of that sample ended the dive because of its weight, about 125 kg.

Figure 4. Cross section of R06 chimney composed of barite, sphalerite, and galena, with outer rind of Fe and Mn oxides; barite and sulfur line the conduit.

***Figure 5 (next page)**: Representative pictures from HPD #1150.*
***A**. Upper subsidiary mound composed of Fe and Mn oxides and venting clear fluid; Seamax 2010_0714_091034AA;*
***B**. Main and subsidiary mounds with 31 cm marker (rope plus ball); lower flank of mound covered with sediment; dacite outcrop at left margin; Seamax 2010_0714_091708AA;*
***C**. Sampling (R01) the Fe and Mn oxide draped over the flank of the mound; Seamax 2010_0714_092800AA;*
***D**. looking at the width of the upper part of the mound with a marker, note other mounds in the background; Seamax 2010_0714_095609AA;*
***E**. Looking at the opposite side of the mound with marker; dacite outcrop in upper right corner; Seamax 2010_0714_102248AA;*
***F**. Another cluster of mounds, each with an oxide subsidiary mound on the top; Seamax 2010_0714_103455AA;*
***G**. Sample R06 taken from the slope in the background, adjacent to the mound on the right; Seamax 2010_0714_110446aa;*
***H**. Dacite outcrop from which sample R03 was taken; Seamax 2010_0714_084802AA.*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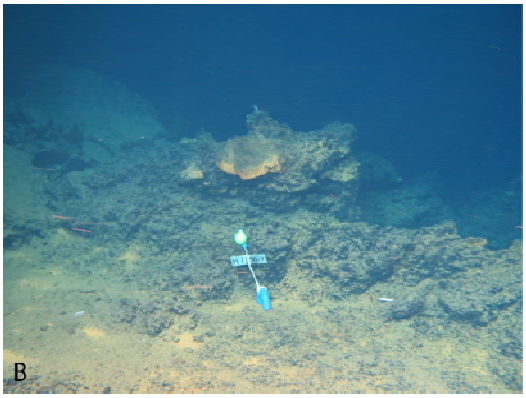
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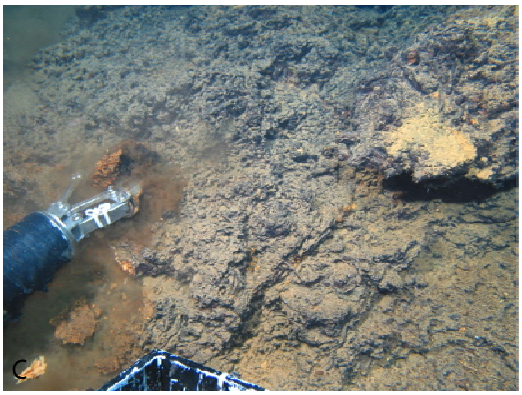
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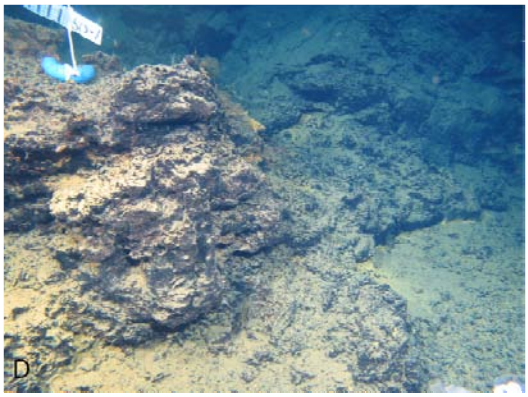
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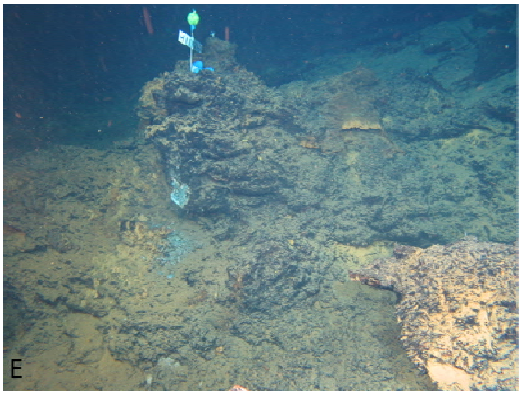
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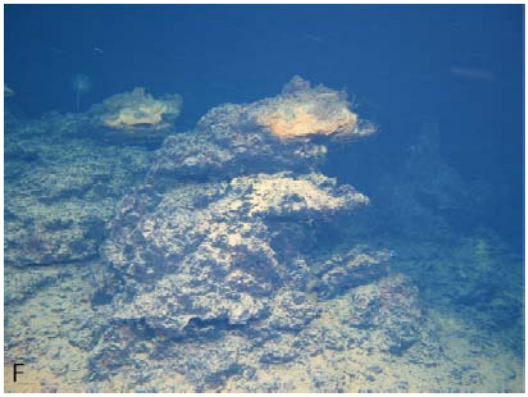
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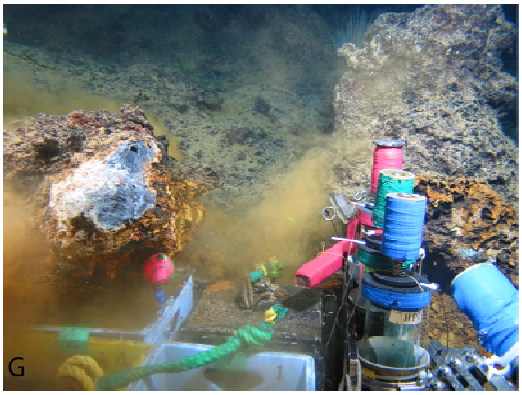
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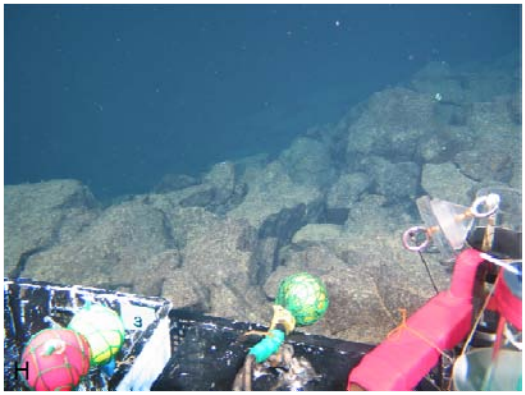
H

Dive #:	NT10-12 HPD#1150
Date:	July 14, 2010 (local)
Location:	Hydrothermal mound field of East Diamante caldera
Objectives:	Map, measure, and sample hydrothermal mounds and smokers

Logger: Erika Jordan

samples ar HPD#xxx-RYY

where xxx is dive number, X is S for scoop, R for rock, C for push core, W for water, YY is number

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #
08:10			In the water.	
08:28	315	269.0	Smoke/particles in water during descent.	
08:35	315.2	275.0	Will move downslope before reaching bottom to move out of plume.	
08:39	364.4	275.2	At bottom. Lots of rubble, boulders, fragments. Blocky and angular. Water is still quite cloudy.	
08:46	363	88.3	Moving to way point 1.	
08:48	365.4	89.6	On bottom again.	
08:50	365.4	91.4	More sharp rubbly boulders and fragments. Foggy water with small pelagic biota. Strong turbidity.	
08:58	366.3	141.7	Strong increase in smoke/particles in water. Very foggy.	
09:00	374.2	1.1	Smaller rubble on bottom, still angular clasts. High volume of sediment on tallus.	
09:02	377.6	310.6	At way point 1. Most surface covered in fairly thick sediment layers. Rocks appear to have dark Mn crust.	
09:06	377.2	320.0	Searching for hydrothermal mounds. Moving over thickly crusted coarse blocks (dacite).	
09:10	376.9	328.2	Found mound field. Shimmering water coming out of thick orange/brown oxide (sulfide) mounds attached to volcanic outcrop. One small anemone on top of mound. Drop yellow marker (H1150-1) to photograph. (Rope & ball = 31 cm.)	
09:22	377	328.2	Attempted to sample base of mound. Very soft oxide. Oxide formed on outer part of mound as well as top. Moved over.	
			Low temperature fluids venting from entire side of mound. Sample base of mound. (Basket 3)	R-01
			Tried to sample small vent near major vent and whole structure collapsed. Put some crumbles in basket 1.	R-02
09:45	376.1	377.5	Collected sample from what looks like dacite mound. Highly altered. (Basket 1)	R-03
09:49	376.4	311.2	Collected sample appears to be barite, sphalerite, galena layer just under bulbous oxide we knocked over (Circle Basket)	R-04
09:53			Collected yellow marker and moved it to the top of the mound.	
09:59	376.3	247.8	Attempt to collect sample of top layer. Crumbled apart.	
10:16	377.1	217.8	White dust coming from sample location (different composition? Barite & zinc sulfide?) Broke into 2 pieces (Basket 1)	R-05
10:29	377	218.4	Attempt to sample near last sample, soft red oxide crumbles apart.	
10:39	377.3	300.8	Attempt to sample second mound, but soft orange oxide crumpled.	
10:47	377.1	280.3	Attempt to sample outcrop on slope adjacent to a third mound, but soft orangish-tan crumbled, but can see white underneath. Attempt to sample white/grey/blue banded part of outcrop - only exterior has orange oxide. Pulled off enormous sample from the slope (On top of baskets)	R-06
11:17	377.4	277.6	End dive	

HPD#1150 East Diamante

HPD#1150	July 14 2010				Hydrothermal mound field, East Diamante						
sample No.	latitude(N)		longitude(E)		(m)	rock type	shape	cm	cm	cm	kg	colour
HPD#1150-R01	15	56.53	145	40.922	377	Fe-oxides with coating on Mn-oxides	subangular	6	3	5	0.1	
HPD#1150-R02 (Missing)	15	56.53	145	40.922	376							
HPD#1150-R03	15	56.53	145	40.922	376	Fe(+Mn)-oxides - goethite	angular	13	6	10	0.4	
HPD#1150-R04	15	56.53	145	40.922	377	dacite	angular	25	12	18	6	gray
HPD#1150-R05A	15	56.53	145	40.922	377	dacite	angular	10	5	6	1 (A+B)	gray
HPD#1150-R05B	15	56.53	145	40.922	377	barite + Pb, Zn sulfides	angular	10, 7, 10	3, 4, 5	10, 5, 3		
HPD#1150-R06	15	56.53	145	40.920	377	massive sulfide chimney(?)	subrounded	95	40	35	150	dark gray
HPD#1150-unknown						Fe-Mn-oxides	subangular				2	

HPD#1150 East Diamante

alteration	Mn coating	phenocrysts	Memo
weak	film	px ~1; pl 15; qz <5	several fragments; contains fine-grained felsic (probably pl+qz) enclave, ~2 cm in size; partly hydrothermally altered
moderate	1 mm	pl 5; hbl 1-2; qz 5-10	R05A (1 piece): fp <2 mm; hbl <2 mm; qz <3 mm
			R05B (several pieces): massive barite + Pb, Zn sulfides; thin barite crust; barite in vugs/channels tentatively interpreted as a fallen chimney with central conduit, blocked at one end, open in center; conduit runs through length of chimney; central conduit is yellow/orange - barite + sulfur coating or sulfur crystals? barite rim surrounded by Fe-Mn oxide rim which partially penetrates the barite rim; 2 mm thick coarser grained layers rims conduit, dominantly galena; most of chimney is massive barite, sphalerite and galena; lots of vugs that may be old conduits for hydrothermal fluids; Fe-Mn coating can be up to 4 cm (or more)
			several fragments; perhaps older

HYPER-DOLPHIN DIVE #1151

TECHNICAL INFORMATION

Location: Eastern Resurgent domes in E. Diamante caldera

Objective: Survey and sample both dead and active massive sulfide chimneys; continue survey of mound area

DIVE 1151	**On bottom:**	**Off bottom:**
Time (local): July 14, 2010	14:05	16:30
Latitude:	15° 56.492'N	15° 56.489'N
Longitude:	145° 40.985'E	145° 40.936'E
Depth (m):	365	351

Samples returned: 8 rocks (four massive sulfide chimneys, one sulfide, two dacite, one Fe-Mn crust)

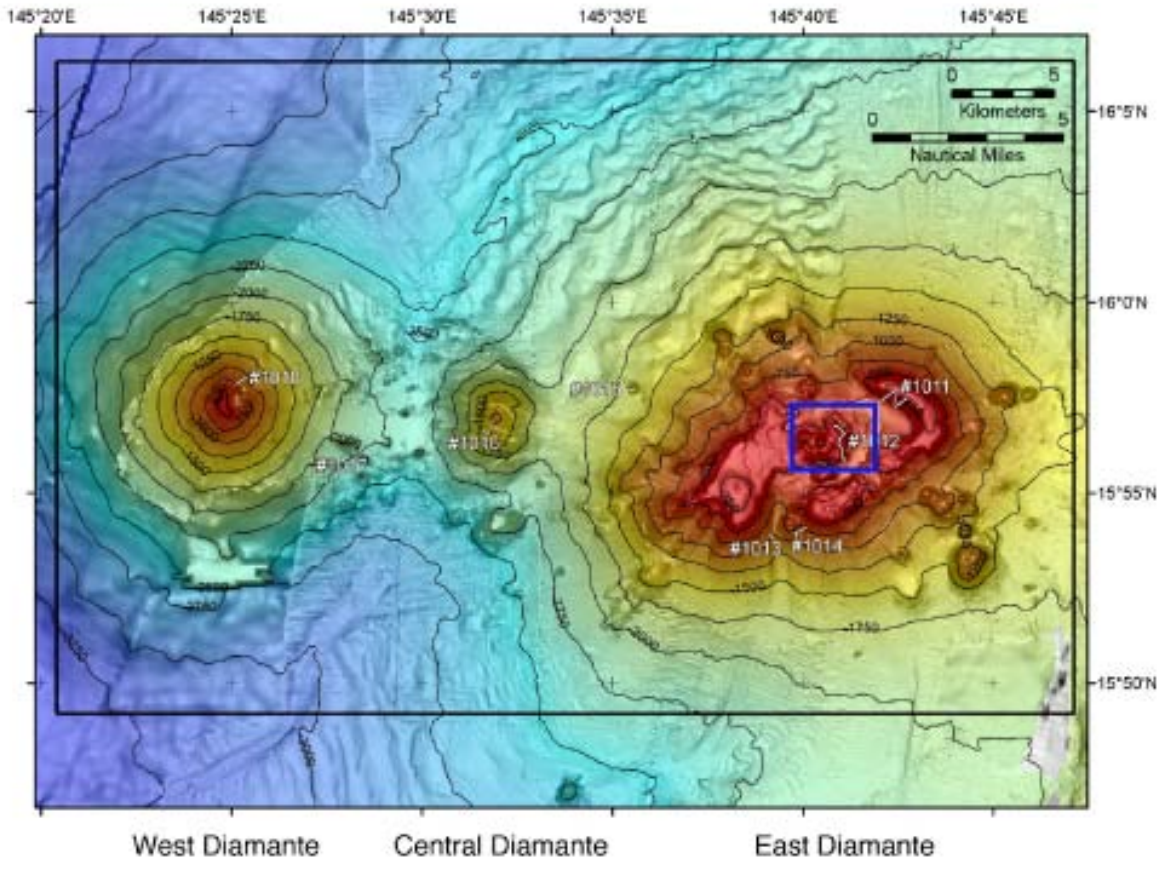

Figure 1: Location of dive operations for HPD#1151, E. Diamante caldera. Area of Figure 2 shown in blue box.

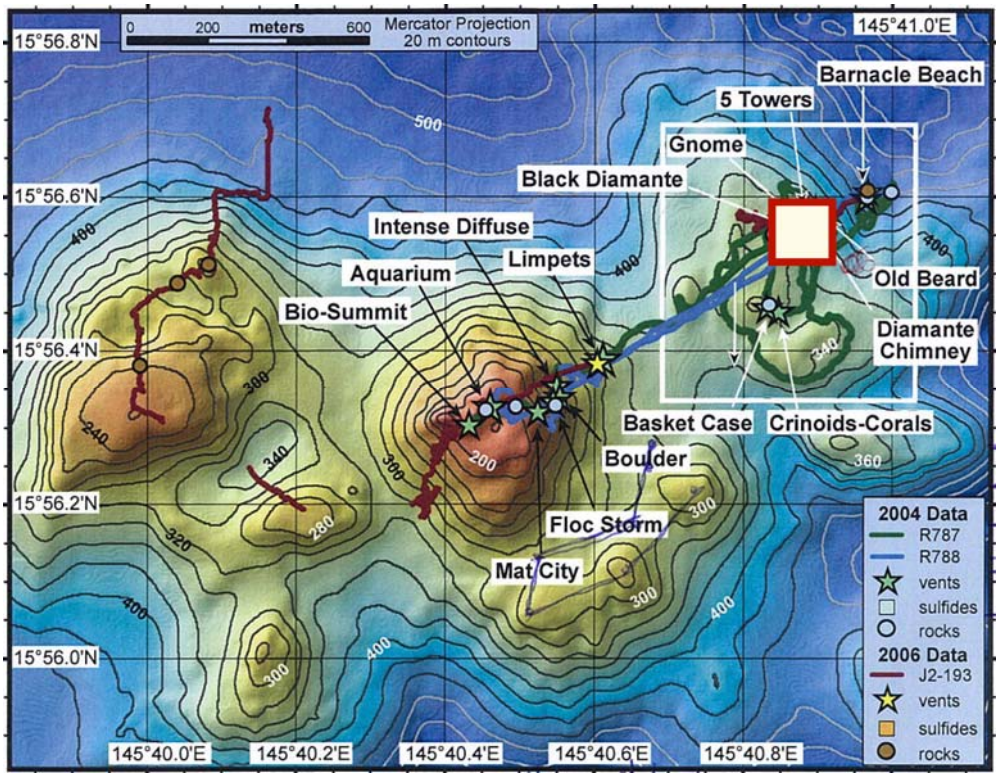

Figure 2: Close-up of bathymetry around E. Diamante caldera, showing the location of dive operations for HPD#1151 shown in Fig. 3 (red box).

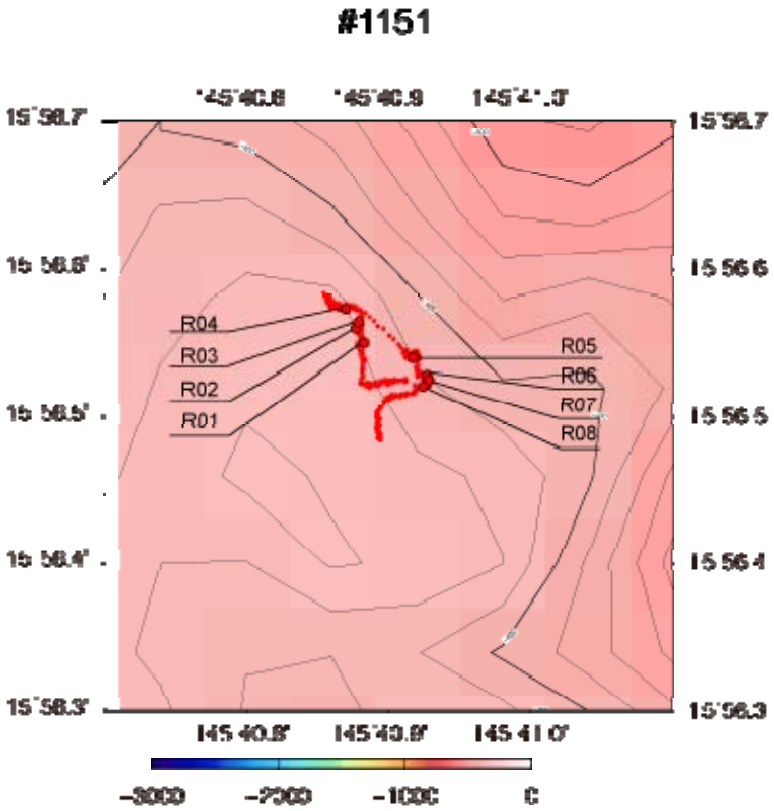

Figure 3: Bathymetry of Resurgent domes in E Diamante caldera carried out during Dive #1151. Samples R01-R08.

SCIENTIFIC SUMMARY:

Dive 1151 was designed to survey and sample known hydrothermal vent areas and collect old and young chimney material for chemical and age analysis to understand the temporal and spatial evolution of the East Diamante hydrothermal system. If there was time, the dive plan included a return to the mound area to complete the survey there. A subsidiary goal of the dive was to investigate the region between the mound and the known chimney areas (i.e., a period of exploration) to see if there were any additional chimney fields. In 2004, black smoker chimneys at the active site were venting fluids of 220°C, around 20°C below the boiling curve for the water depth (Figure 4).

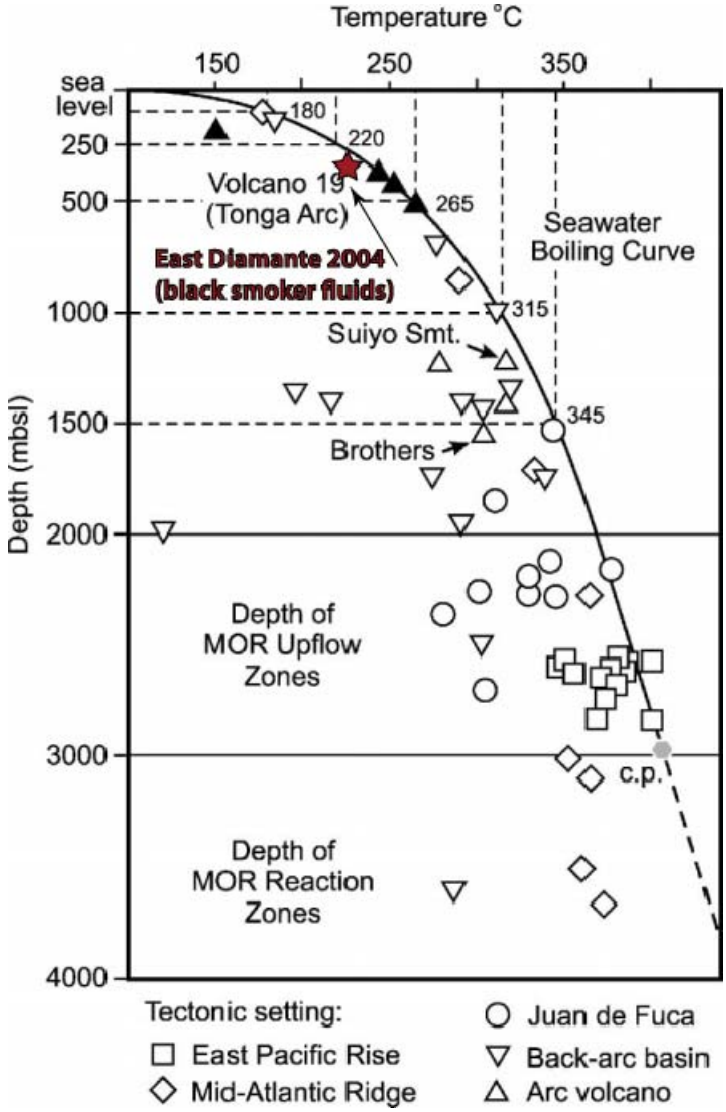

Figure 4. Depth-temperature relationship showing the boiling curve for seawater. Also shown are several vent sites from arc, backarc and mid-ocean ridge settings. Fluids from East Diamante had recorded temperatures of 220° C in 2004, slightly below boiling. Modified from Stoffers et al. (2006).

Dive 1151 landed at 365 m water depth half way between the mound area and the first exploration waypoint. Dacite blocks and boulders dominated the seabed at the start of the dive (Figure 5A). Near the second exploration waypoint, and south of the known active chimney field, we encountered a large field of extinct chimneys. These chimneys were variably sized, but up to several meters tall, and typically several chimneys were in close proximity. At the first sampling location, the Hyperdolphin crew was able to sample an essentially complete chimney (R-01; Figure 5B). A little further to the north, we sampled another extinct chimney

(R-02; Figure 5C), although not as close to the base. A close up of the exposed chimney interior (Figure 5D) shows an outer rim of Fe and Mn oxides surrounding the main chimney mass, composed primarily of barite, sphalerite and galena. Further to the north, the dive reached the known active vent field. Here, several actively venting chimneys were observed including one with 4-5 small chimneys atop a larger older structure. All of these small chimneys were venting high temperature fluids. We were able to sample two of these small chimneys that were connected (R-03; Figure 5E). One of these chimneys has a central conduit rimmed by sphalerite, the other is rimmed by chalcopyrite. We also observed a large chimney that we tentatively assessed at some 8 meters in height (Figure 5F, Figure 6). This portion of the dive ended with a traverse to the northwest of the active field to the known inactive chimney field. Here, a final chimney sample was collected (R-04; Figure 5G). All of these chimneys were left intact on retrieval and will be sent to GNS Science for cutting and sample distribution. At the completion of the chimney-sampling portion of the dive, Hyperdolphin was moved to the mound area. A portion of the pedestal of an old chimney on a larger mound was sampled (R-06; Figure 5H). Two dacite samples were also collected (R-06, R-08). The final sample collected was a piece of Fe-Mn mineralization that covers much of the sulphide mound/chimney material.

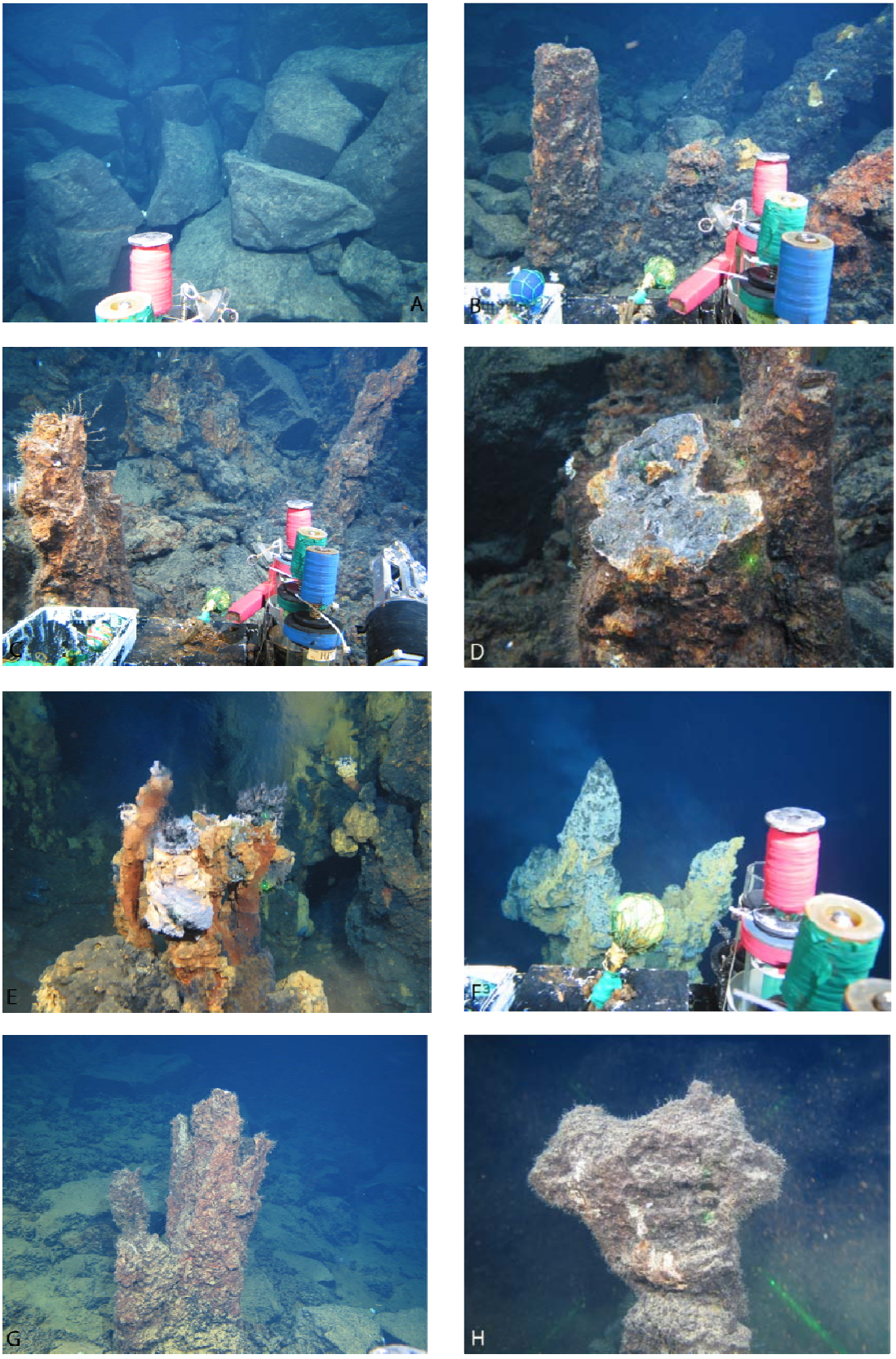

Figure 5: Representative pictures from HPD #1151. **A**. Dacite blocks, on which chimney fields have formed, first part of Transect #1, Seamax 2010_0714_141216AA; **B**. Dead chimney, south of known chemney fields. This chimney was sampled as HPD# 1151, R-01, Transect #1, Seamax 2010_0714_142246AA; **C**. Dead chimney just to the north of R-01. This chimney was sampled as HPD #1151, R-02. Traverse #1, Seamax 2010_0714_143631AA; **D**. View of the

section where R-02 was removed. The interior of the chimney is dominated by barite, sphalerite and galena. Traverse #1, Seamax 2010_0714_143722AA; **E**. Active chimneys from the active field. Here there are four small chimneys on a larger, older chimney. Two of the small chimneys were recovered as sample HPD #1151, R-03. Traverse #1, Seamax 2010_0714_144649AA**; F**. Venting fluids from the top of the largest chimney observed, probably around 8 meters in height, Traverse #2, Seamax 2010_0714_145736AA; **G**. Dead chimney, west of the active field. Sampled as HPD #1151, R-04, Traverse #1, Seamax 2010_0714_150447AA; **H**. Dead chimney in the mound area, which was also the focus of HPD #1150, Traverse #1, Seamax 2010_0714_153057AA.

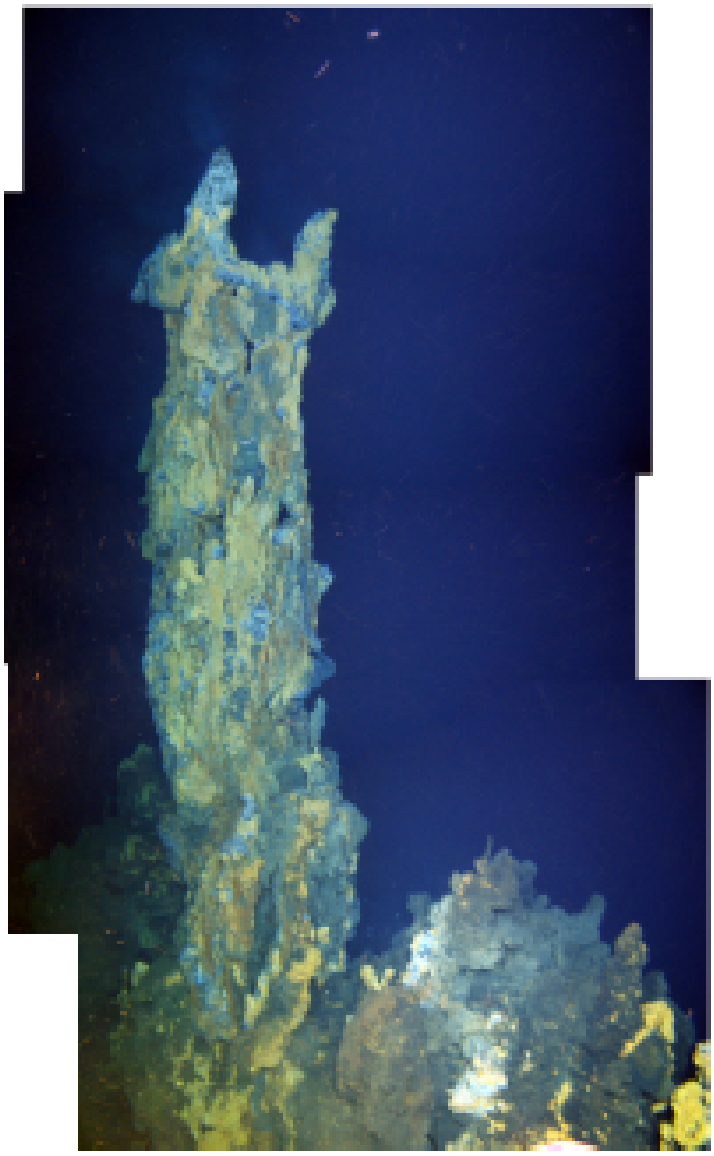

Figure 6. Composite image of large chimney from the active hydrothermal vent field at East Diamante. Both small chimney structures at the top of the main chimney were venting high temperature fluids.

Stoffers, P., Worthington, T.J., Schwarz-Schampera, U., Hannington, M.D., Massoth, G.J., Hekinian, R., Schmidt, M., Lundsten, L.J., Evans, L.J., Vaiomo'unga, R., and Kerby, T., 2006, Submarine volcanoes and high-temperature hydrothermal venting on the Tonga Arc, southwest Pacific: Geology, v. 34, p. 453-456.

Dive #:	**NT10-12 HPD#1151**
Date:	July 13, 2010 (local)
Location:	Hydrothermal mound field of East Diamante caldera
Objectives:	Map, measure, and sample hydrothermal mounds and smokers

Logger: Erika Jordan

samples are HPD#xxx-RYY

where xxx is dive number, X is S for scoop, R for rock, C for push core, W for water, YY is number

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #
14:05	365.4	269.9	On bottom. 2 sharks swimming around ROV.	
			Large angular blocks and boulders everywhere. Random orientation.	
14:12	347	349.9	Turned facing down slope. Still large angular blocks, but some smaller ones.	
14:16	350.4	338.9	Large massive bedded and fragmented outcrop.	
14:17	348	341.0	Heading to Way Point 5. More blocky rubble.	
14:18	350	359.3	Several chimneys (5-6 standing + a few fallen; inactive) surrounded by large angular boulders. Sulfide chimney sample broke off very near the base. Baskets 1 and 2.	R-01
14:29	352.3	336.4	Dropped blue marker on base of chimney R-01 (H1151-1)	
14:31	349.8	348.1	Alignment along ridge of additional inactive chimneys. Surrounded by large angular boulders. Can see numerous chimneys in the distance.	
14:36	349.2	330.8	Collected top half of composite chimney (Basket 3)	R-02
14:39	347.6	343.2	Chimney "forest" surrounded by more subangular, smaller rubble covered in a moderate layer of sediment. Some chimneys are extremely large and very tall.	
14:41	351.2	344.6	At base of extremely tall chimney.	
14:46	354	343.7	Four smaller active chimneys on top of larger chimney. Sample two small rigorously active chimneys. (Covered basket)	R-03
15:01	341.7	302.9	Heading away from chimney field. Some massive subangular blocks, smaller rubble, and lots of sediment.	
15:03	354.3	254.9	A smaller set of chimneys (inactive) set in degraded material, rubble, and a lot of sediment.	
15:06	345.8	122.7	Collected small chimney with coral on it (Basket 1)	R-04
15:16	339.8	237.1	Fly to mounds area to finish work not completed in HPD#1150	
15:30	370.5	147.3	Back at mound site from HPD#1150. Several mounds surrounded by altered rubble and sediment.	
15:34	371.2	319.2	Collected sample from pedestal of chimney (very small sample) (Basket 5). Mound appears to have some sulfide and barite.	R-05
15:38	367.3	138.4	Traveling but cannot see bottom.	
15:42	374.1	139.3	Rubbly bottom, subangular to subrounded in appearance, with some moderate sediment cover.	
15:45	375.8	149.6	Back to yellow marker on top of active hydrothermal mound.	
15:47	375.1	148.8	Moving over sediment covered rubble.	
15:51	381.3	163.0	Picked up large boulder that had something white, maybe barite? Too large to sample. Collected smaller sample. (Basket 5)	R-06
15:57	376.3	183.0	Moving over more rubble. Some plank-like slabs appear to be crusted and altered. Covered with a moderate amount of sediment. Collect sample (Basket 4)	R-07
			Large area of mineralization. Lots of sulfides.	
16:06	375	214.8	Broke piece off large angular slab/block. White inside (barite/zinc sulfide?). Too large to sample. Collected large angular sample. (On top of boxes)	R-08
16:15	372.7	224.2	Moving over very sharp angular clasts of various sizes. Less sediment.	
16:20	361.7	219.6	Moving over larger angular boulders.	
06:14	352.1	182.2	Massive angular blocky boulders.	

16:30	350.9	180.2	End of dive.	

HPD#1151 East Diamante

HPD#1151 July 14 2010 Chimney field and Hydrothermal mound field, East Diamante

sample No.	latitude(N)	longitude(E)	depth (m)	rock type	shape	cm	cm	cm	kg	colour	alteration	Mn coating	phenocrysts	Memo
HPD#1151-R01	15 56.55	145 40.88	352	massive sulfide chimney	angular	64	26	18	37	metallic gray interior, orange exterior				Fe oxide coating; barite, sphalerite, galena metallic gray interior
HPD#1151-R02	15 56.56	145 40.89	349	massive sulfide chimney	angular	30	22	20	11.3	metallic gray interior, orange exterior				Fe oxide coating; barite, sphalerite, galena metallic gray interior
HPD#1151-R03	15 56.56	145 40.88	344	massive sulfide chimney	subrounded	18	10	8	1	gray				chimneys were actually venting; main piece represents two high-T fluid pathways - one is lined with sphalerite, the other with chalcopyrite; mainly barite, sphalerite, galena; another small conduit has chalcopyrite as well
HPD#1151-R04	15 56.57	145 40.87	346	massive sulfide chimney		57	18	17	24	gray interior				Fe oxide coating; barite, sphalerite, galena metallic gray interior
HPD#1151-R05	15 56.54	145 40.92	371	sulfide	subrounded	10	10	4	0.5	dark gray to gray		1-2 mm		barite, sphalerite, galena; more porous interior, massive exterior
HPD#1151-R06	15 56.53	145 40.93	381	dacite (altered)	subrounded	20	13	5	1.5	gray to greeny gray	moderate	1 mm	pl 10; hbl 5; qz 10	alteration rim; hbl 2 mm; qz 5 mm
HPD#1151-R07	15 56.53	145 40.98	377	Fe-Mn oxides	angular	17	11	11	1.3					
HPD#1151-R08	15 56.52	145 40.92	375	dacite	subrounded	63	40	24	60	gray	weak	1 mm	pl 10; hbl 5; qz 10	lithic fragments; hbl 2 mm; qz 5 mm

HYPER-DOLPHIN DIVE #1152

TECHNICAL INFORMATION

Location: Small cones on flanks of East Diamante Caldera
Objective: Survey and sample small volcanic cones on the deeper flanks to find more mafic lavas

DIVE 1152	On bottom:	Off bottom:
Transect #1:		
Time (local): July 15, 2010	08:55	09:47
Latitude:	15°59.186'N	15°59.150'N
Longitude:	145 °37.740'E	145 °37.813'E
Depth (m):	1189	1104
Transect #2:		
Time (local): July 15, 2010	10:30	10:54
Latitude:	15°58.815'N	15°58.777'N
Longitude:	145 °37.964'E	145 °37.969'E
Depth (m):	1139	1112

Samples returned: 10 rocks sampled

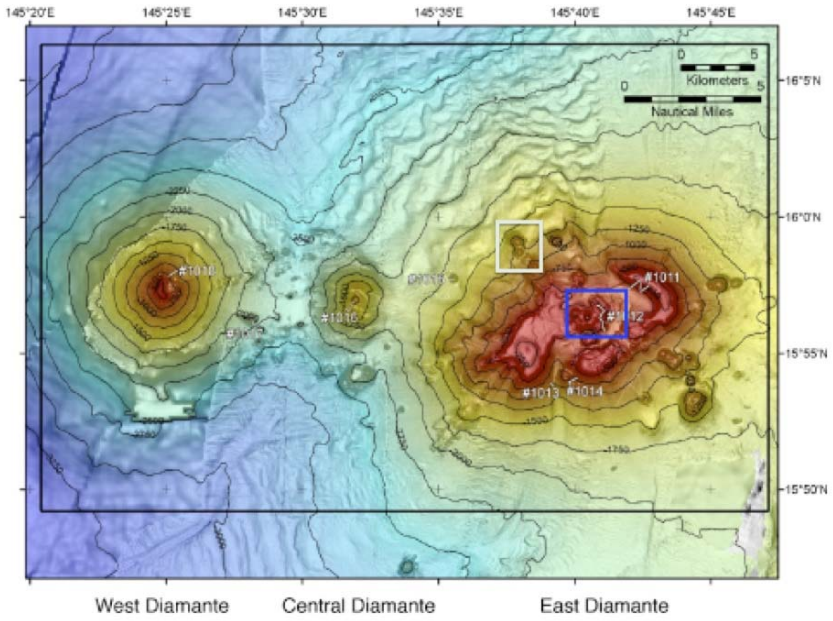

Figure 1: Location of dive operations for HPD#1152, E. Diamante caldera from Mariana Bathymetric Compilation (Susan Merle, PMEL/NOAA, compiler). Area of Figure 2 shown in white box.

SCIENTIFIC SUMMARY:

East Diamante Seamount lies about 80 km due north of Saipan and is the northernmost volcano of the Southern Seamount Province of the Mariana magmatic arc. East Diamante is also the easternmost of a 30 km long, E-W cross-chain comprising 3 volcanoes: East, Central, and West Diamante volcanoes. East Diamante has the appearance of an irregular caldera that is ~10 km x 4 km and that is breached on the north and south. The caldera floor has a maximum depth of ~700m. E. Diamante is unusually complex, both volcanologically and petrologically, and includes basalts, andesites, and dacites. Figure 1 depicts the region of E. Diamante volcano, which has the form of a complex caldera, elongated ENE-WSW and breached on its northern and southwest sectors. The NE caldera wall is simplest, with a steep inner wall, gentler outer slope, and a boomerang-shaped outline. Two transects of the inner wall during NT09-08 HPD#1011 demonstrated that it is entirely composed of biogenic carbonate rocks and shelly detritus. We strongly suspect that this carbonate buildup developed on the remnants of an older caldera wall.

Previous work on submarine arc volcanoes in the Marianas has shown that small, parasitic cones on the flanks of the larger seamounts commonly comprise more mafic lavas than the main edifice. There are a number of such

small cones around East Diamante (Fig. 1) and the principal goal of Dive 1152 was to examine and sample two small cones northwest of the caldera to try to find such mafic lavas. The Dive was planned in two short transects along the two cones (Fig. 2).

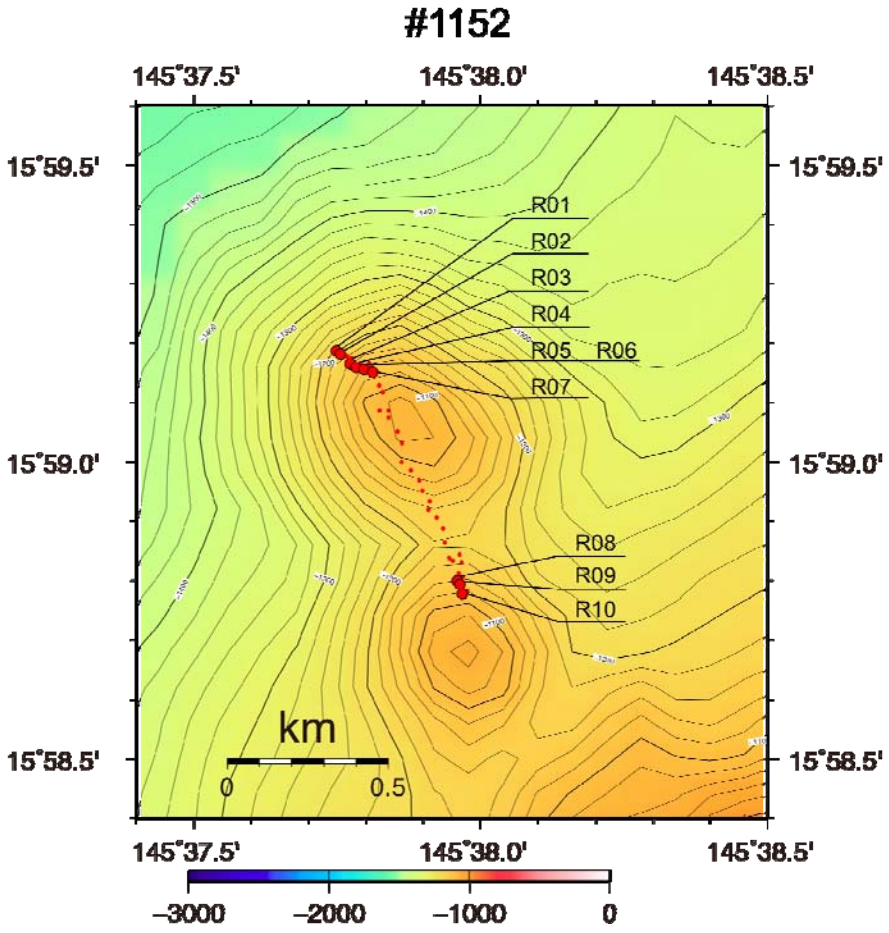

Figure 2: Bathymetry of northwestern slopes of East Diamante Caldera showing tracks for Dive#1152. Samples R01-R07 were from Traverse #1 and R08-R10 from Traverse #2.

Traverse #1: This traverse was up a small cone on the NW flanks of East Diamante from 1189 m to 1104 m depth. The vehicle reached bottom at an outcrop; sample R01 was from here. R01 and all other samples from this transect proved to be rhyodacites. The bottom varied from massive outcrops to slopes covered with car-sized boulders and cobbles (Fig. 3A) with interspersed sediment. Some outcrops appeared to be fractured (Fig. 3B), others are massive with some jointing (Fig. 3C), and others strongly jointed (Fig. 3D). Samples R05 and R06 were from outcrop; R01 and R03 may be close to in place. Samples R02, R04, and R07 were pieces from talus. At the end of Traverse #1 there was a sea cucumber on one of the talus blocks (Fig.3E). It is a type that seems similar to specimens belonging to genus *Oneirophanta* (communication from L. Lundsten at MBARI).

In the transit between the two transects the bottom was seen briefly at 10:01 (local) when the vehicle was at a depth of 1046 m. This was probably near the summit of the first small cone.

Traverse #2: This section of the dive traversed a second small cone from 1139 m to its summit at 1112 m. The bottom alternated from boulder and cobble-sized talus with patches of sediment in between blocks (Fig. 3F) to massive outcrops that appear irregular and fractured or somewhat jointed (Fig. 3G). Some of the talus blocks are extremely large (Fig. 3H). Both samples in this traverse were rhyodacite. R08 was a piece of talus, R09 was from a large block that was probably outcrop.

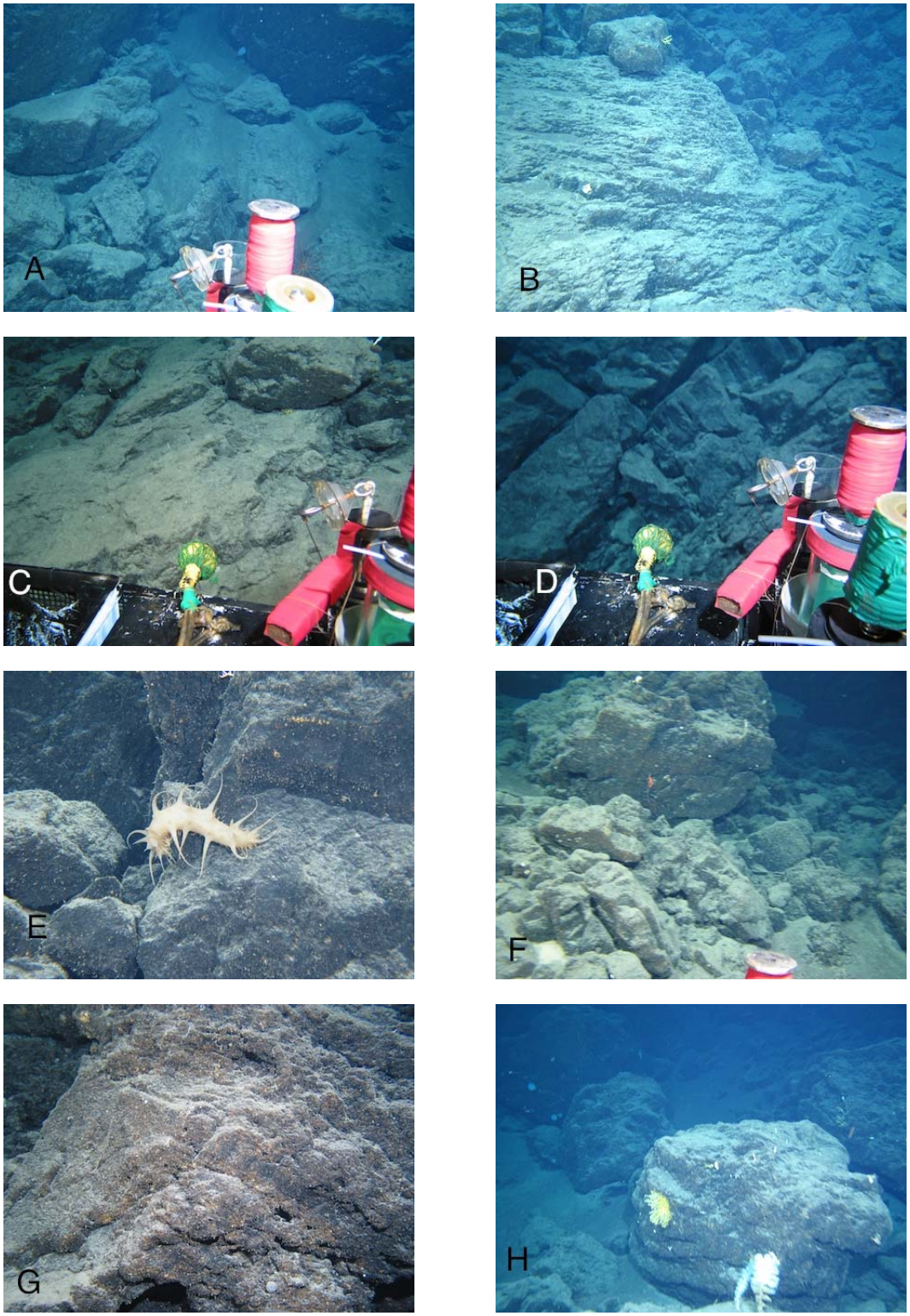

Figure 3: Representative pictures from HPD #1152. **A**. Rhyodacite blocks in lower part of Transect #1, Seamax 2010_0715_090254AA; **B**. Rhyodacite outcrop that appears somewhat fractured in Transect #1, Seamax 2010_0715_092108AA; **C**. Somewhat jointed rhyodacite outcrop in Traverse #1 near sample R04, Seamax 2010_0715_092517AA; **D**. Massive, jointed outcrops of rhyodacite in Traverse #1, Sample R05 from here, Seamax 2010_0715_093142AA; **E**. Sea cucumber on outcrop near R07, top of Traverse #1, Seamax 2010_0715_094847AA**;** **F**. Rhyodacite boulders and talus, near beginning of Traverse #2, Seamax 2010_0715_103446AA; **G**. More massive rhyodacite outcrop in Traverse #2, Seamax 2010_0715_104531AA; **H**. Large rhyodacite talus blocks, upper part of Traverse #2, Seamax 2010_0715_104701AA

HPD#1152

Dive #:	**NT10-12 HPD#1152**
Date:	July, 15, 2010 (local)
Location:	Small cones on the flank NW of East Diamante summit
Objectives:	Study and sample two small cones seeking primitive basalts

Logger: Bloomer

samples are noted HPD#xxx-RYY
where xxx is dive number, X is S for scoop, R for rock, C for push core, W for water, YY is number

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
8:00			In water		
8:55	1190	142	on bottom, rocky , massive outcrop, sponge in field of view		
8:57	1190	142	very large blocky outcrops, slope appears steep, sediment draped on slope between outcrops		
8:58	1191	136	sampling piece on top of large outcrop; loose pieces on top; rock 1 in circle basket	R01	rhyodacite
9:01	1191	140	underway towards WP#2; sediment between outcrops is rippled; outcrop is massive and jointed to irregular		
9:02	1188	137	into steep outcrop wall, massive and fractured/jointed, about 4 meters up then into blocky talus with sediment in between blocks (car size boulder to cobbles); significant sediment on and between blocks		
9:04	1178	137	one block looks like it might have some layers; could also be sediment resting on sub parallel joints		
9:07	1172	135	still scattered boulder to cobble sized blocks on steep slope, sediment in between, no obvious ripples here		
9:08	1172	136	go down to pick up a sample; loose block from talus; angular piece into Basket #2	R02	rhyodacite
9:10	1173	131	underway upslope, similar terrain, talus blocks with sediment; no pillow forms at all		
9:11	1170	135	area of particularly large blocks (boulder to car size?); blocks angular and massive		
9:12	1163	135	into area of smaller blocks (cobbles to boulders, with sediment patches in between		
9:14	1157	135	larger boulders again, some of these are jointed and some look quite fractured (highly irregular surfaces)		
9:16	1151	133	a very large block with highly irregular, fractured appearing surface	R03	rhyodacite
9:17	1152	135	land on very large fractured block to take a piece; tried to break a piece off very large block….didn't work. Move down on block a bit and try again; clearly some Mn since where block gets scraped it exposes light colored brown interior….volcaniclastic? sample broken from large block, but unclear that the large block itself is outcrop. into Basket #1		
9:21	1152	130	underway, coming into low somewhat layered area, looks like outcrop; fractured irregular surface, may have some layering, could be what R03 came from		
9:22	1146	129	back into boulder covered slope, dense field of boulders with sediment in between, not much life, occasional sponge or brittle star		

9:24	1138	128	large outcrop? To left surrounded by boulders…definitely looks like outcrops of the somewhat layered, fractured materials; boulders around it include more massive material		
9:24	1131	126	sampling, down onto what looks like one of the jointed outcrop areas; maneuvering for spot; moved around, settled at 09:26		
9:27	1133	165	taking sample; loose piece on top of large block or slab; thin slabby piece; into basket 1	R04	rhyodacite
9:29	1134	129	underway upslope; talus strewn slope, cobble to small boulder size, significant sediment;		
9:30	1124	129	definitely some outcrop; layered and slabby, dipping steeply to port;		
9:31	1120	129	very steeply dipping ridges, almost look like dikes; they are dipping steeply (60-70 degrees maybe) to the northeast		
9:32	1118	131	sampling this dipping ridge; small columnar like structures in places perpendicular to the dip-slope; piece looks like its close to in place, it's fairly loose but likely in place; clearly jointed or fractured, lighter colored interior? Into basket #2..actually really sitting on top of Basket #2	R05	rhyodacite
9:36	1118	130	taking a second sample from this outcrop; breaking a piece off of one of the layers; a little columnar joint; breaks fairly easily, light colored on the interior (small piece came off may have fallen in somewhere); into Basket #5; drop chain weights here	R06	rhyodacite
9:39	1116	131	underway, talus covered slope, cobbles to boulders, almost complete talus cover here;		
9:42	1103	179	rubble covered, may be occasional outcrop; take sample of talus pile; grabbed a piece of talus; large somewhat elongate angular piece Basket #1; again, actually sitting on top of Basket #1 rather than in it	R07	rhyodacite
9:48	1104	180	fly to WP #3 from here, see small worm/polycheate of some kind…09:49:08 a good picture of it…soft bodied, spined		
9:50	1104	179	secure R07 with starboard manipulator; pull up into water and proceed to WP#3		
9:52	1076	177	underway to WP#3; end Traverse #1		
10:01	1046	160	glimpsed bottom, probably passing over summit area of the small seamount; looked like outcrop or rock talus		
10:30	1139	182	Begin Traverse #2; Bottom in sight again, WP #3; lot of talus, big boulders down to cobbles, some sediment patches in between; no obvious outcrop		
10:31	1141	182	sampling, loose piece of talus; first one picked up broke in manipulator, tan inside, volcaniclastic? Try another one…somewhat slabby, Mn coating clearly, into Basket #4	R08	rhyodacite
10:35	1140	182	underway, talus covered, large boulders to cobbles, 60% rubble with sediment patches, no obvious outcrop		
10:37	1131	175	some very large blocks here…maybe into outcrop, blocks large enough may not have gone far; irregular and fractured surface appearance		
10:39	1129	167	sampling at the base of one of these very large blocks or outcrops; tried a piece that is broken off but still wedged in…probably close to in place from the associated large block; got it on second try; seems to be light colored where claw scrapes it. clearly has Mn; underside tan; into Basket#4	R09	rhyodacite

10:46	1131	179	underway; rocky bottom, large blocks and cobbles, sediment on benches and between large blocks		
10:47	1124	170	blocks from cobbles to car size then into area with smaller average size, cobbles to small bouldes with occasional very large blocks		
10:49	1116	170	rocky bottom, mixed cobbles and boulders with sediment on flat areas		
10:50	1112	171	sampling talus piece; tried for a quite large rectangular piece, couldn't break it off its larger block; took another talus piece; also light colored on broken/unexposed surface; in Basket #3	R10	rhyodacite
10:55	1112	162	End Transect #2; Conclude dive; secure samples with arms		
10:57	112	168	Leave bottom		

HPD#1152 East Diamante NW knolls

HPD#1152 July 15 2010 Cones on NW slopes of East Diamante

sample No.	latitude(N)	longitude(E)	depth (m)	rock type	shape	size X (cm)	size Y (cm)	size Z (cm)	weight(kg)	colour	alteration	Mn coating
HPD#1152-R01	15 59.18	145 37.750	1192	rhyo-dacite	angular	28	15	9	5	gray	fresh	film
HPD#1152-R02	15 59.18	145 37.757	1173	rhyo-dacite	angular	37	15	21	8	dark gray	fresh	film
HPD#1152-R03	15 59.16	145 37.774	1152	rhyo-dacite	subangular	25	22	12	7	pale gray	moderate	1 mm
HPD#1152-R04	15 59.16	145 37.784	1133	rhyo-dacite	angular	22	8	13	2	gray	fresh	film
HPD#1152-R05	15 59.16	145 37.798	1118	rhyo-dacite	angular	45	23	30	26.6	gray	weak	film
HPD#1152-R06	15 59.16	145 37.798	1118	rhyo-dacite	angular	37	20	20	10.5	dark gray to gray	fresh	film
HPD#1152-R07	15 58.82	145 37.813	1104	rhyo-dacite	angular	45	32	27	29	gray	weak	film
HPD#1152-R08	15 58.8	145 37.960	1141	rhyo-dacite	subangular	25	21	13	4.7	gray	weak	film
HPD#1152-R09	15 58.79	145 37.965	1141	rhyo-dacite	angular	35	22	31	21.5	pale gray	weak	1 mm
HPD#1152-R10	15 58.78	145 37.969	114	rhyo-dacite	angular	31	21	13	9.7	pale gray	weak	1 mm
HPD#1152-unknown					subangular				0.2			

HPD#1152 East Diamante NW knolls

Glass rim	phenocrysts	vesiculation	Memo	
	pl 7-9; hb 1-2; qz 2-3	moderate 15%	pl <2 mm; hb <1 mm; qz <2 mm; enclave? fine-grained <1 cm	HPD#1152-R01
	pl 8-10; hb 1; qz 1-2	moderate 15%	pl <3 mm; qz <2 mm; hb <1 mm	HPD#1152-R02
	pl 5; hb 2; qz 5	weak 5%	pl <2 mm; hb <1 mm; qz <2 mm; altered along fractures	HPD#1152-R03
	pl 6-8; hb <1; qz 2~3	moderate 20%	pl <2 mm; hb <2 mm; qz <2 mm	HPD#1152-R04
	pl 6-8; hb 1-2; qz 2-4	moderate 20%	pl <2 mm; hb <3 mm; qz <2 mm	HPD#1152-R05
	pl 8-10; hb 1-2; qz 1-2	moderate 20%	pl <3 mm; qz <2 mm; hb <5 mm	HPD#1152-R06
	px <1; pl 6-8; qz 3-5	moderate 20%	pl <3 mm; qz <2 mm	HPD#1152-R07
	px <1; pl 4-6; hb 2; qz 2	moderate 25%	px <1 mm; pl <2 mm; hb <2 mm; qz <2 mm	HPD#1152-R08
	pl 5-10; hb 2; qz 5-10	weak 5%	pl 1-2 mm; hb <2 mm (long axis); qz 1-2 mm	HPD#1152-R09
	pl 5; hb 2; qz 10	weak 5%	pl <5 mm; hb <2 mm; hb <2 mm	HPD#1152-R10
				HPD#1152-unkno

HYPER-DOLPHIN DIVE #1153

TECHNICAL INFORMATION

Location: Eastern resurgent domes in E. Diamante caldera
Objective: Survey and sample mound hydrothermal area near resurgent domes

DIVE 1153	**On bottom:**	**Off bottom:**
Transect #1:		
Time (local): July 15, 2010	13:34	14:54
Latitude:	15°56.546'N	15°56.550'N
Longitude:	145 °40.959'E	145 °40.904'E
Depth (m):	406	360
Transect #2:		
Time (local): July 15, 2010	15:01	16:21
Latitude:	15°56.537'N	15°56.541'N
Longitude:	145 °40.958'E	145 °40.899'E
Depth (m):	406	362

Samples returned: 7 rocks sampled

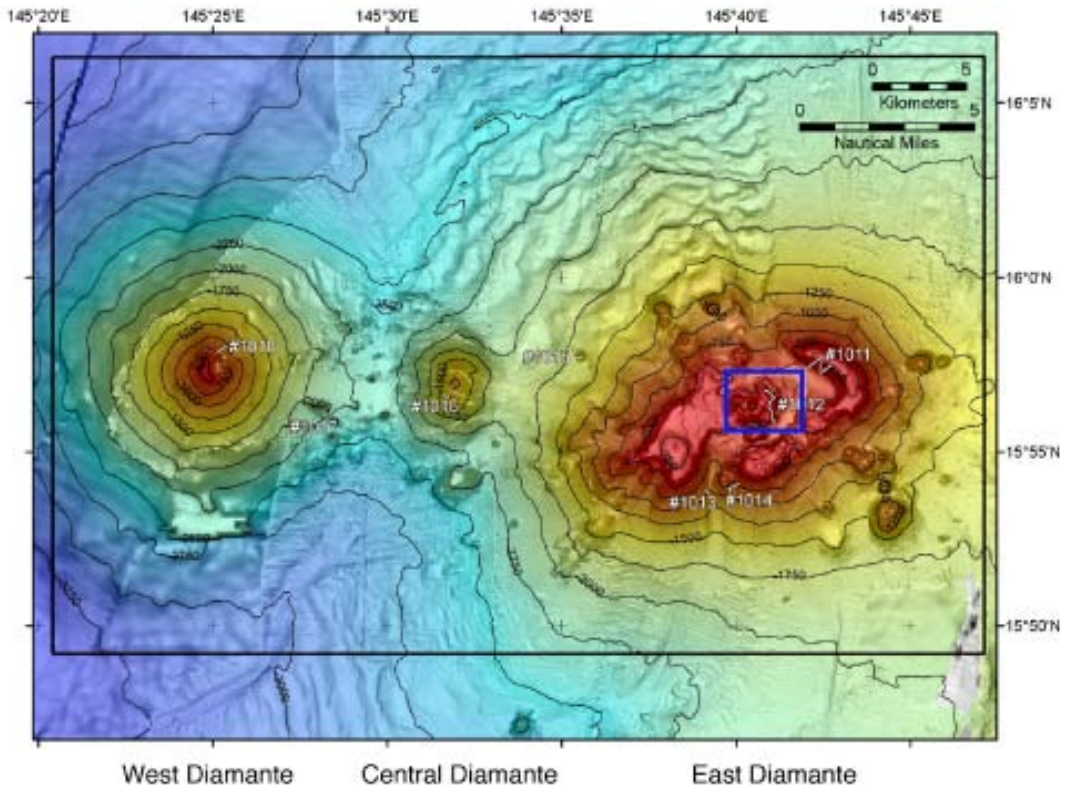

Figure 1: Location of dive operations for HPD#1153, E. Diamante caldera. Area of Figure 2 shown in blue box.

SCIENTIFIC SUMMARY:

East Diamante Seamount lies about 80 km due north of Saipan and is the northernmost volcano of the Southern Seamount Province of the Mariana magmatic arc. East Diamante is also the easternmost of a 30 km long, E-W cross-chain comprising 3 volcanoes: East, Central, and West Diamante volcanoes. East Diamante has the appearance of an irregular caldera that is ~10 km x 4 km and that is breached on the north and south. The caldera floor has a maximum depth of ~700m. E. Diamante is unusually complex, both volcanologically and petrologically, and includes basalts, andesites, and dacites. Figure 1 depicts the region of E. Diamante volcano, which has the form of a complex caldera, elongated ENE-WSW and breached on its northern and southwest sectors. The NE caldera wall is simplest, with a steep inner wall, gentler outer slope, and a boomerang-shaped outline. Two transects of the inner wall during NT09-08 HPD#1011 demonstrated that it is entirely composed of biogenic carbonate rocks and shelly detritus, and we now think that the entire NE sector of the volcano as far south as the morphological change near 15°56'N (from high, steep, and smooth to low, gentle, and rough) is composed of carbonate rocks. We strongly suspect that this carbonate buildup developed on the remnants of an older caldera wall.

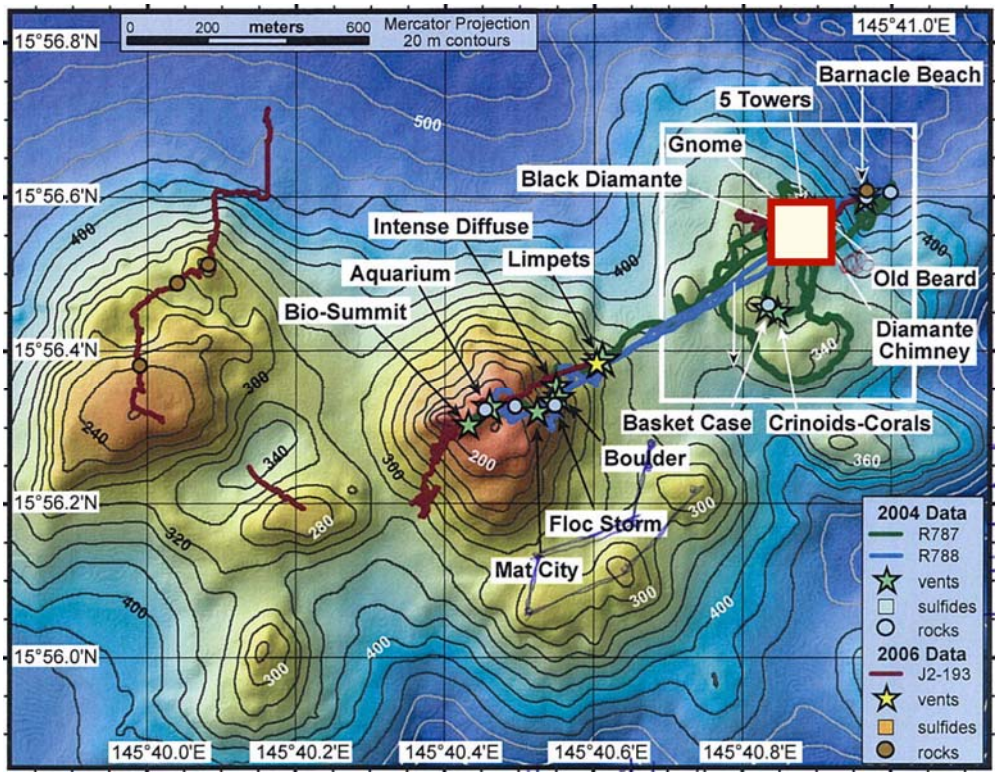

Figure 2: Close-up of bathymetry around E. Diamante caldera, showing the location of dive operations for HPD#1153 shown in Fig. 3 (red box).

East Diamante is the only volcano within the Mariana arc known to have black (and gray) smoker sulfide chimneys, which occur in the northeast sector of the central caldera resurgent domes (Fig. 2). After caldera collapse, the dacitic domes intruded into the center of the caldera thereby providing a heat source for the production and circulation of the hydrothermal fluids that generated the large chimney and mound fields. East Diamante volcano supports one of the shallowest water black smoker systems known and thereby has the unique characteristic of the interaction of chemosynthetic and photosynthetic communities. The E. Diamante hydrothermal field was visited in 2004 during ROPOS dive R788 aboard R.V. T. Thompson on a NOAA cruise. Active chimneys were found at 344 m water depth with a measured fluid temperature of 220° C. Inactive chimneys were found in somewhat deeper water than the active ones. All the chimneys collected in 2004 and those collected during NT09-08 dive #1012 are predominantly zinc sulfides, with minor Cu sulfides lining the main chimney conduit. One chimney in 2004 was seen to be venting gas from one orifice and fluid from another indicating that boiling and phase separation were taking place at shallow water depths and near the seabed. The input of magmatic gases to the E. Diamante field may be less than at other hydrothermal fields along the Mariana arc because elemental sulfur is not found, but it does occur at all the other Mariana hydrothermal sites. Inactive chimneys were found during NT09-08 dive 1012 at water depths of 375 m to 344 m. The group of chimneys found at 344 m looks much like a group found at the same water depth in 2004, which at that time was actively venting. If these were the same chimney field, then that knowledge would provide important constraints on the longevity of arc hydrothermal systems.

A new type of hydrothermal deposit was discovered during NT09-08 at water depths of 387 to 348 m; the deposits are mounds, the larger of which measure about 4 m high, 3 m wide, and 8 m long. The mounds are made up of two parts, a lower pedestal that may be composed of sulfides and an upper spire or bulbous construction that is made up of relatively low-temperature (<110° C) Fe and Mn oxides. Shimmering water emanating from the summit of two of the mounds indicate active fluid flow at temperatures higher than ambient bottom waters. The mounds have delicate networks of anastamosing fluid-transport channels. The active field showed both diffuse and focused flow through spires and bulbous constructions built on top of mounds. The mineralogy of the mounds indicates that the mineralizing fluids varied greatly in temperature and oxygen fugacity, but the present stage is low temperature. The mound fields cover large areas containing numerous mounds as well as chimneys. The mounds are located along a NE-SW trending rift valley and all mounds in a single field are elongate parallel to the fracture system. The full extent of the hydrothermal fields is not known, but they are at a minimum 40 m by 50 m. This field may be in a waning stage of activity and higher temperature fluids may have been involved in constructing the pedestals of the mounds.

The principal goal of HPD #1153 was to follow up the work of HPD #1154 and map the distribution and structure of the mound-type hydrothermal deposits. The dive was planned in a series of five east to west transects across the suspected mound area. Two of those transects were completed in the available time (Fig. 3) and provided significant information on the distribution and structure of the mounds.

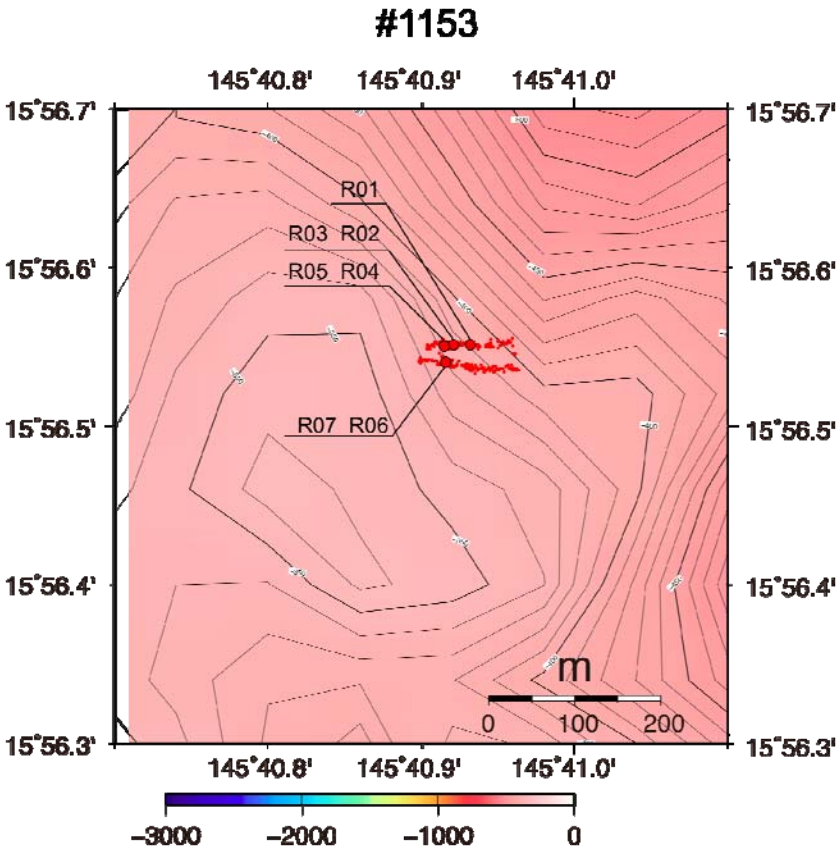

Figure 3:
Bathymetry of the eastern end of the resurgent domes in East Diamante Caldera showing tracks for Dive#1153. Samples R01 to R05 were from Traverse #1 and R06 and R07 from Traverse #2.

Traverse #1: This traverse was from east to west, near what is estimated to be the northern boundary of the mound deposit. Hyperdolphin reached bottom at 13:34 (413 m) in dacite talus blocks. Shortly after beginning Traverse#1 friable, irregular material was observed on some of the dacite blocks (Fig. 4A). A poke with the manipulator confirmed these as hydrothermal oxide deposits. The oxide/dacite mix continued to 13:45 (403.6 m) after which the bottom was dacite blocks with sediment pockets between them but no hydrothermal coatings (Fig. 4B). No extinct chimney structures were identified in this first hydrothermal area.

At about 13:49 (391.9 m) some yellow-brown sediments appeared and by 13:50 (390.4 m) there were significant hydrothermal deposits on some of the dacite (Fig. 4C). The manipulator found this to be stronger than some of the oxides; R01 was a piece from this block and was identified on deck as rhyolite. A mix of silicic volcanic blocks with and without hydrothermal deposits, with interspersed sediment (some of which was distinctly yellow-brown) continued to 14:01 (378 m) where a large hydrothermal construct was encountered (Fig. 4D). The hydrothermal construct at 378 m appeared to be a small elongate ridge on a flatter layered deposit. The "ridge" was something like a knobbly book on end and had an extinct chimney on one end (Fig. 4D). R02 came from the chimney, and where it was broken off the grey barite/sulfide interior of the chimney could be clearly seen (Fig. 4E). Small conduits can be seen in the grey interior and there is an orange oxide core around portions of the chimney. R03 came from as close to the base of this construct as Hyperdolphin could reach. R02 came back as many fragments, mostly of oxide. R03 was a piece of massive sulfide.

From here to the end of transect #1 the outcrop was predominately hydrothermal, with the underlying silicic volcanic blocks visible in a few places. Another very large hydrothermal structure was found at 14:25 (370.6 m). Where scraped with the manipulator the rocks appeared white to very light gray on fresh surfaces. Most of the exposure here appears to be hydrothermal. R04 and R05 are from the large hydrothermal deposit; both are massive sulfides and sulfates. R05 was from somewhat lower in the structure than R04. When Hyperdolphin pulled back a bit, a white layer could be seen at the base of the deposit (Fig. 3F). This may be a part of a layered barite-sulfide deposit that the mounds or chimneys sampled here are built on.

Moving upslope towards the end of Traverse #1 it looked on the CCD view that the oxides might die out to starboard at about 14:50 (371.7 m) although Hyperdolphin was still in oxides. In fact, the dive transect ended at 14:51 (368.5 m) as the vehicle arrived at another large hydrothermal deposit. Hyperdolphin was pulled up off the bottom a few tens of meters and flown back SSE to start traverse #2.

Traverse #2: Traverse #2 ran east to west parallel to and about 20-30 meters south of Traverse #1. Hyperdolphin was on the bottom at 15:03 (406.5 m) in dacite blocks with interspersed sediment. The initial traverse looked like it was slope parallel with a slope dipping off to starboard. Irregular, slabby outcrops appeared at 15:08 (396.4 m). A poke with the manipulator confirms this as hydrothermal oxide. These hydrothermal deposits continued to 15:41 (386.3 m), characterized by slabby irregular blocks. At 15:12 (391 m) it looked like the boundary with the dacite talus terrain could be seen to starboard. Hyperdolphin stopped at 15:14 (385.4 m) to sample one of the slabby areas. A small piece broken off outcrop showed a grey interior (likely barite-sulfide) with an orange oxide rim. Repeated attempts to recover the small broken fragment or to secure another piece failed.

This first hydrothermal area ended at 15:14 and the bottom was covered by dacite talus with interspersed sediment. The first hydrothermal deposit here may be contiguous with the first deposit on Tranverse #1, but the deposit on this traverse covered a wider area and appeared more substantial.

At 15:44 (376.4 m) oxide-sulfide deposits were again seen on dacite blocks and at 15:45 (372.1 m) a large, complex hydrothermal deposit was encountered. This included several extinct chimneys that are clearly built on a layered basal mound (Fig. 4G). Sample R06 from the base mound was massive sulfide. An extended attempt was made to sample the bulbous head on an extinct chimney that, when scraped by the manipulator, was bright white and likely made principally of barite. However, the chimney proved too difficult to sample. Hyperdolphin moved on to another extinct chimney with multiple openings and a somewhat botryoidal outside surface. Sample R07 was from this chimney and was also massive sulfide.

Hyperdolphin moved upslope and back into bottom covered with very large silicic volcanic blocks and interspersed sediment but no obvious hydrothermal material at 16:14 (367.6 m). The dacite continued to the end of the dive at 16:19 (362.5 m). If this second hydrothermal area on Traverse#2 is contiguous with the second area on Traverse #1, it is narrower here, but with some quite complex structures.

Figure 4: Representative pictures from HPD #1153. **A**. Oxide/sulfide deposits on dacite block in first of two hydrothermal deposits in Transect #1, Seamax 2010_0715_134157AA; **B**. Dacite blocks without hydrothermal coatings between two deposits on Transect #1, Seamax 2010_0715_134750AA; **C**. Oxide/ sulfide deposits on dacite blocks at beginning of second hydrothermal deposit on Traverse #1, Seamax 2010_0715_140147AA; **D**. Old chimney deposit in second hydrothermal area, Traverse #1, Seamax 2010_0715_140420AA; **E**. Section of old chimney in D, where broken in sampling, Seamax 2010_0715_141022AA**;** **F**. White layer in second hydrothermal complex near end of Traverse #1, the layer maybe barite and is near the top of a layered sulfide/oxide deposit on top of which is an extinct chimney structures. Samples R04 and R05 came from this deposit. Seamax 2010_0715_144534AA; **G**. Old chimneys in the second hydrothermal area in Traverse #2. Note one chimney in foreground and one in background., Seamax 2010_0715_154634AA; **H**. Bulbous head on the background chimney seen in G. When scraped with the manipulator the exposure was bright white, probably barite. However we were unable to collect a sample. Seamax 2010_0715_155527AA.

HPD#1153

Dive #:	**NT10-12 HPD#1153**
Date:	July, 15, 2010 (local)
Location:	Hydrothermal mounds area near resurgent dome in E. Diamante caldera
Objectives:	Estimate dimensions and distribution of mounds; additional sampling

Logger: Bloomer

samples are noted HPD#xxx-RYY

where xxx is dive number, X is S for scoop, R for rock, C for push core, W for water, YY is number

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
13:03			in water; descend to WP#1; plan a series of E to W transects across layered mound area		
13:34	411	268	bottom in sight		
13:35	413	268	on bottom, large angular dacite blocks with some sediment between them, traverse towards mound field		
13:40	407	270	starting to see some friable, irregular material, some red…friable Fe-Mn oxides		
13:41	405.2	270	clearly in Fe-Mn oxide material…feathery irregular surfaces, black and orange colors; pan port and starboard with CCD, can see blocky dacite to starboard at +30 (30 degrees starboard), at +20 start to see oxides; pan to port with HD all oxides		
13:43	406	270	poke block with manipulator…clearly oxides, bright orange interior		
13:44	405	269	underway on traverse, still oxides; on and around dacite blocks		
13:45	403.6	269	out of oxides, back into dacite blocks;		
13:46	401.7	270	dacite blocks and sediment in between		
13:47	398.2	270	Jim reports some oxide between dacite blocks, but almost all dacite blocks and sediment		
13:49	391.9	270	sediment between blocks a little lighter brown to yellow in places it seems here, still mostly big blocks		
13:50	390.4	269	some irregular, friable looking coating on one big block, stop and check it; poke with manipulator….harder than oxide it seems, light colored underneath when scraped, but not orange; took piece of it (when big piece broke off it did look orange inside)…stronger than oxides but has some oxide...took one piece that broke off; could just be dacite with oxide on it, in Basket #2	R01	rhyolite
13:55	390.8	265	Underway on transect; mostly blocks of dacite; with sediment in between		
13:57	386	269	bits of yellowish, brownish sediment (usual is grayish, grey brown) then back to usual		
14:00	380	269	piles of very large dacite blocks, some oxide coatings on joints, small sedimented areas		
14:01	378	269	as we got closer to a particularly big dacite block, can see some irregular oxide deposits on joint surfaces; this actually may not be dacite but a large hydrothermal deposit?		
14:02	378.2	271	stop for a close look; CCD pans right, looks like oxide out to +74 degrees (at least shows irregular surfaces on blocks)		
14:04	377.5	270	underway; still some oxide		

14:04	377.4	273	looks like a substantial oxide on a block, tall and narrow but long spine…like a knobbly book on end		
14:05	377.4	293	stop, looks like old chimney system; when grabbed bright orange underneath, pretty friable; can see grey inside the orange likely barite-sulfide mix; trying for piece but very tough; manipulator managed to break off a small piece of the grey stuff; in circle basket; HD can see oxide like texture at -28 to port;	R02	oxides (many fragments)
14:12	377.2	270	underway again; things still look hydrothermal;		
14:13	375.1	270	hydrothermal deposits; can see in places what look like the outline of dacite blocks under them, but also see larger hydrothermal constructs; stop and try sample from an old hydrothermal construct; trying to grab a loose piece at base of old construct; friable and quite white inside; nice piece into Basket #1; drop chain weight here	R03	massive sulfide
14:21	375.2	282	poking outcrop with manipulator to check material; pretty strong it seems….mostly hydrothermal to starboard, though seems a bit less out at 2 o'clock from our heading		
14:23	374.1	269	underway; large dacite blocks with irregular hydrothermal coatings and deposits on them; sediment in between blocks; can see outline of blocks in places, in others it is quite obscured; orange in places (although Jim notes that he thinks some of these blocks are hydrothermal constructs)		
14:25	370.6	253	stop and check a large hydrothermal construct; scrape with manipulator; good picture from CCD here of what looks like a hydrothermal construct on a dacite block (14:27:45) (or base is a hydrothermal mound deposit itself); orange white on inside; could all be hydrothermal		
14:29	370.4	256	still working on the large construct; manipulator broke off a big piece; very orange cloud of dust…broken surface looks like barite-sulfide material; pieces broke off and seem to have fallen into Basket 4; one perched on edge of baskets 4 and 1----pushed down between lidded basket and basket #1	R04	massive sulfide/ sulfate
14:36	370.8	259	as CCD panned around, the whole construct does look hydrothermal…seems twice the height of vehicle or so?		
14:37	370.8	262	pulled back and looked at deposit; CCD shows where larger block broke off deposit; can see base and Jim thinks it is sitting on top of the layered barite and sulfide; trying to sample again; broke a much more substantial piece out this time; from lower part of mound; in Basket #4	R05	massive sulfide/ sulfate
14:41	371		pulled back to get a view of the deposit		
14:43	371	227	can see white layer near base of the chimney deposits; here it looks like many of the blocks may be broken apart hydrothermal deposits, and not hydrothermally coated dacite blocks; an excellent photo of a white layer near base of construct; shot from CCD suggests it is subhorizontal, maybe dipping gently to the east??		
14:48	372.2	227	working on taking photos to map structure		
14:49	372.2	227	get underway to continue transect; Jim notes the structure is very complex; everything in view is judged hydrothermal		
14:50	371.7	266	moving up slope; looks like hydrothermal deposits may die out to starboard;		
14:51	369.7	259	over another large, complex hydrothermal construct		

14:51	368.5	249	hydrothermal material, red patches visible in places; here and there can see dacite blocks underneath		
14:52	366.7	249	now can see dacite blocks to port with less hydrothermal material; CCD look ahead definitely looks less hydrothermal		
14:53	364.3	254	about at WP#2; move on to WP #3; now clearly in dacite; rectangular, blocky pieces		
14:54	359	259	pull up in water go back to WP #3; end Transect #1		
15:02	406.7	270	on bottom WP #3; begin Transect #2		
15:03	406.5	268	moving slope parallel for a while; dacite blocks, a lot of sediment here; slope quite steep, 30-40 degrees to starboard?		
15:04	404.9	270	some of large blocks have somewhat irregular surfaces, maybe a bit of oxide coating?		
15:05	403.9	269	large angular blocks, assumed to be mostly dacite;		
15:06	400.2	270	still mostly dacite, sediment in between; flatter now, moving upslope, still a bit steeper to starboard		
15:08	396.4	269	bottom character changes, irregular, small slabby pieces sticking out along with larger angular cobbles; reddish brown sediment at the small ledge that marks the change; hover to take some pictures and poke with manipulator; bright red when broken; a thin, sheet like deposit		
15:11	395	270	irregular surface, yellow-brown sediment in places; looks like blocks of dacite to starboard?		
15:12	391	270	still irregular, oxide-covered bottom, some large slabby pieces; CCD to starboard seems to show some large blocks much like dacite; boundary may be close there		
15:14	385.4	270	stop to look at a lighter colored sediment area, yellowish-brown sediment by a layered, slabby outcrop; poke with manipulator---a lot of red dust when broken and it took a couple minutes for cloud to disperse; reddish on broken surface, probably an oxide layer; try to take a sample--pretty tough stuff, manipulator having a hard time breaking it. try closer to end--		
15:22	386.7	270	still working on sampling same spot; did break a small corner piece off and it's grey inside;		
15:35	386.5	265	still trying to nab the small little broken off piece; keeps getting lost in the fine red oxide sediment; went back to trying to break a piece off the slab; couldn't get one		
15:41	386.3	271	moving up slope again; immediately into large blocky dacite pieces it seems with sediment in between; here and there might be a little oxide/sulfide coating but hard to tell		
15:43	381.5	270	dacite talus blocks, highly angular, with grey-brown to grey-green sediment in between		
15:44	376.4	270	starting to see oxides on the dacite blocks; oxides beginning to get denser and coming up on a mound-like structure		
15:45	374.5	268	into a mound-like structure with an irregular surface; dacite gone, mounds and chimneys covering it; very complex structure		
15:47	372.1	264	can see large chimney structure (good view on CCD too) sitting on top of mounds		
15:48	371.9	227	sample--try to sample base mound chimney is on and the chimney itself; nice picture on CCD looking sideways		

15:51	371.7	236	claw working on base sample; barite vein just below where it is; grabbed a projecting piece off base area; small grey piece, triangular cross section from pedestal area, in lidded box; broke into pieces as dropped	R06	massive sulfide
15:54	371.9	242	pan HD over chimney; try to find a place to take a sample; can see other chimneys in the background; move off and around, good view on camera		
15:56	371.5	241	move up under bulbous head and try to sample using starboard arm; very tough; where scraped off quite bright white…mostly barite? As the arm works quite a few pieces seem to be falling into basket 3; no good, try port claw; more tiny pieces fell into basket 3 (in emptying baskets no obvious pieces of this material were found)		
16:03	371.3	239	still trying to sample chimney; just too tough; going to move on		
16:06	371.5	241	move on, perhaps look for another chimney to sample		
16:07	371.3	243	a shorter almost botryoidal surfaced chimney; move up and try to sample that; trying to push over a piece;		
16:11	371.4	243	still trying to break a piece off; no success; orange, white, grey inside; move up under a projecting knob to try to knock it off; can see open channels in the chimney; got a piece, into lidded box; larger than last one (but probably broke when it went in)	R07	massive sulfide
16:13	371	247	moving on up slope; still hydrothermal		
16:14	369.8	270	back into large dacite blocks; very large, angular blocks		
16:16	367.6	270	huge dacite blocks, 100% talus, very little sediment (no flat spots)		
16:19	362.5	269	all dacite up to here; end dive here		
16:22	361.9	272	off bottom		

HPD#1153 East Diamante

HPD#1153	July 15 2010				Hydrothermal mound field, East Diamante						
sample No.	latitude(N)		longitude(E)		depth (m)	rock type	shape	size X (cm)	size Y (cm)	size Z (cm)	weight(kg)	colour
HPD#1153-R01	15	56.55	145	40.932	391	rhyolite	subangular	28	24	26	13	gray
HPD#1153-R02	15	56.55	145	40.921	378	oxides (many fragments)	angular	5 (largest)	3	2	0.1	dark gray
HPD#1153-R03	15	56.55	145	40.921	375	massive sulfide	angular	30	20	28	16.5	dark gray to gray
HPD#1153-R04	15	56.55	145	40.915	370	massive sulfide/sulfate	angular	9, 8, 4	6, 2, 1	3, 5, 3	0.2	dark gray to gray
HPD#1153-R05	15	56.55	145	40.915	370	massive sulfide/sulfate	angular	17	12	9	2.3	gray to pale gray
HPD#1153-R06	15	56.54	145	40.916	371	massive sulfide	angular	7, 6	4, 3	5, 5	0.6	dark gray
HPD#1153-R07	15	56.54	145	40.916	371	massive sulfide	angular	11	10	7	1.2	dark gray to gray
HPD#1153-unknown						chminey fragments					0.5	

HPD#1153 East Diamante

alteration	Mn coating	Glass rim	phenocrysts	vesiculation	Memo	
fresh	film		px <1; pl 5-7; hb 2~3; qz 5-7	weak <10%	pl <2 mm; hb <2 mm; qz <3 mm	HPD#1153-R01
					many fragments (at least 6) of Fe+Mn oxides + hydrothermal Mn (steel-gray color)	HPD#1153-R02
	1-3 mm (Fe+Mn)				barite lines vugs; Mn in some interior vugs; barite coating outer surface; finer-grained dark gray mineral (sphalerite?) in some vugs	HPD#1153-R03
					3 fragments; largest fragment massive dark gray barite+galena; probably also sphalerite; vug with brown crystals of barite	HPD#1153-R04
	1-4 mm (Fe+Mn)				coarse-crystalline massive, dense sulfate/sulfide; yellow-orange stain, possibly orpiment; barite veins; barite >50%?	HPD#1153-R05
					many fragments; massive sphalerite>barite; botryoidal surface on one fragment lined by barite - part of conduit	HPD#1153-R06
	1-2 mm				several fragments; several closed conduits; coarse crystalline barite in vugs; barite lining of vugs; pyrite in small fragments	HPD#1153-R07
					many chimney fragments; barite+sphalerite, some barite veins; one piece with chalcopyrite	HPD#1153-unknown

HYPER-DOLPHIN DIVE #1154

TECHNICAL INFORMATION

Location: Lower slopes of eastern caldera wall, W. Rota
Objective: Survey and sample altered and mineralized rocks

DIVE 1154	**On bottom:**	**Off bottom:**
Transect #1:		
Time (local): July 16, 2010	09:06	12:38
Latitude:	14°20.258'N	14°20.367'N
Longitude:	144°50.733'E	144°50.809'E
Depth (m):	1327	1174
Transect #2:		
Time (local): July 16, 2010	14:29	16:15
Latitude:	14°19.41'N	14°19.358'N
Longitude:	144°50.820'E	144°50.976'E
Depth (m):	1296	1135

Samples returned: 18 rocks and one sediment core.

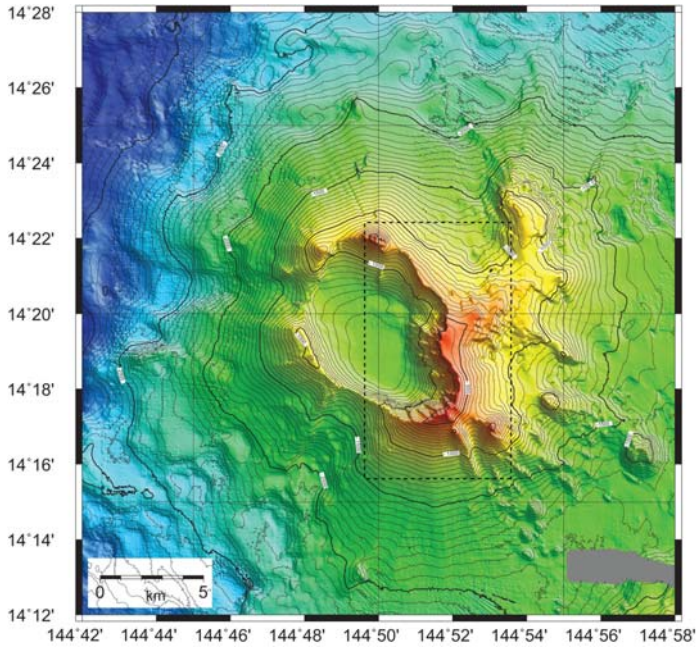

Figure 1: Bathymetry of West Rota Volcano (bathymetry by S. Merle, NOAA). Location of Fig. 2 is shown by dashed rectangle.

SCIENTIFIC SUMMARY:

West Rota Volcano (WRV) is an extinct submarine volcano in the southern Mariana Arc. It lies just south of the E-W trending 14°20'N cross-chain (which includes actively erupting

NW Rota-1 volcano studied during HPD 1155). WRV is large (25 km diameter base), shallow (as little as 300 m below sea level), and contains the largest caldera in the Mariana arc (6 x 10 km, with up to 1 km relief). The steep eastern caldera wall preserves much of the history of the volcano in the stratigraphy and intrusive relationships exposed there. Stern et al. (2008) summarize this history. WRV consists of a lower, predominantly andesite section overlain by a bimodal rhyolite-basalt layered sequence. $^{40}Ar–^{39}Ar$ dating indicates that andesitic volcanism comprising the lower volcanic section occurred 0.55-0.33 Ma, whereas eruption of the upper rhyolites and basalts occurred 51-37 thousand years ago. The andesitic rocks are locally intensely altered and mineralized along the lower caldera wall, and it is this alteration and mineralization that was the focus of HPD 1154.

WRV was first sampled by Dixon and Stern (1983) but it was not understood to contain a large caldera until bathymetric and sonar backscatter swath mapping took place during cruise Cook 7 in 2001. West Rota volcano has been the focus of several ROV diving campaigns, beginning with R785 during TT-167 in 2004, continuing with HPD 482-484 and HPD 489 during NT0517 and HPD 950 during NT0902. The locations of these dives and HPD 1154 are shown on Fig. 2.

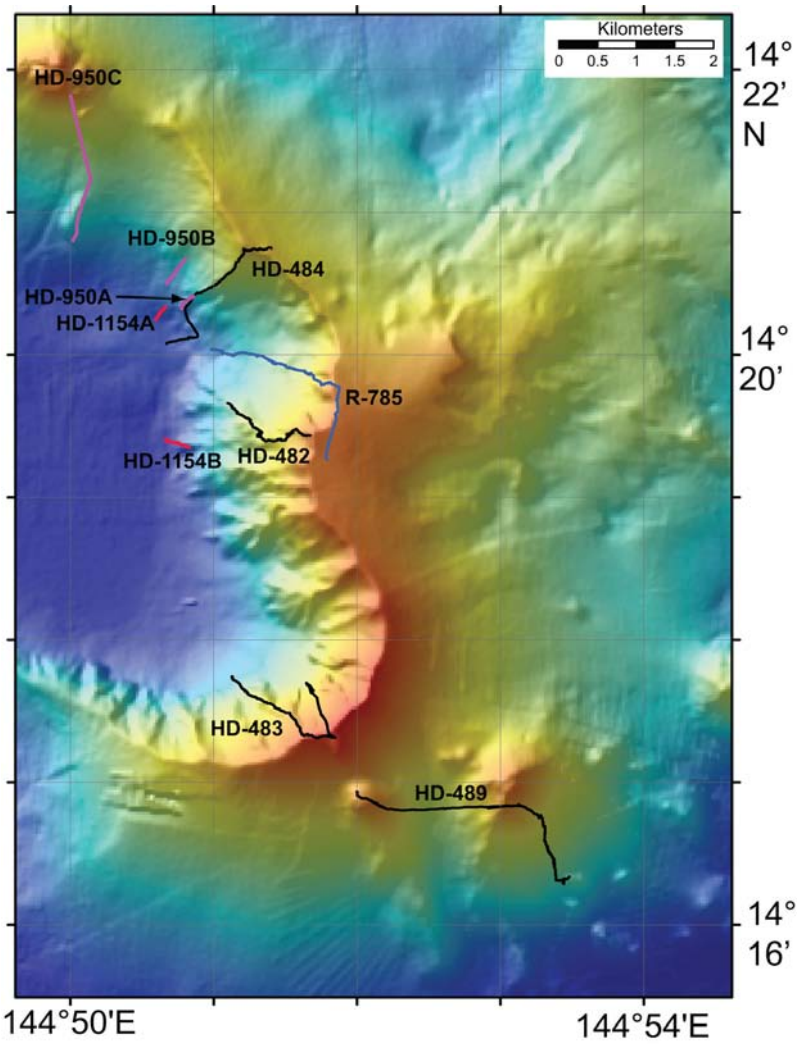

Figure 2: Bathymetry of the eastern half of West Rota Volcano (bathymetry by S. Merle, NOAA). Locations of all ROV dives, including HPD 1154, are shown.

Our principal goal for HPD 1154 was to observe and sample the altered and mineralized

andesitic sequence, exposed on the lower slopes of the eastern caldera wall. We originally planned for 5 traverses but were only able to complete two. The actual dive tracks and sample locations are shown in Figure 3.

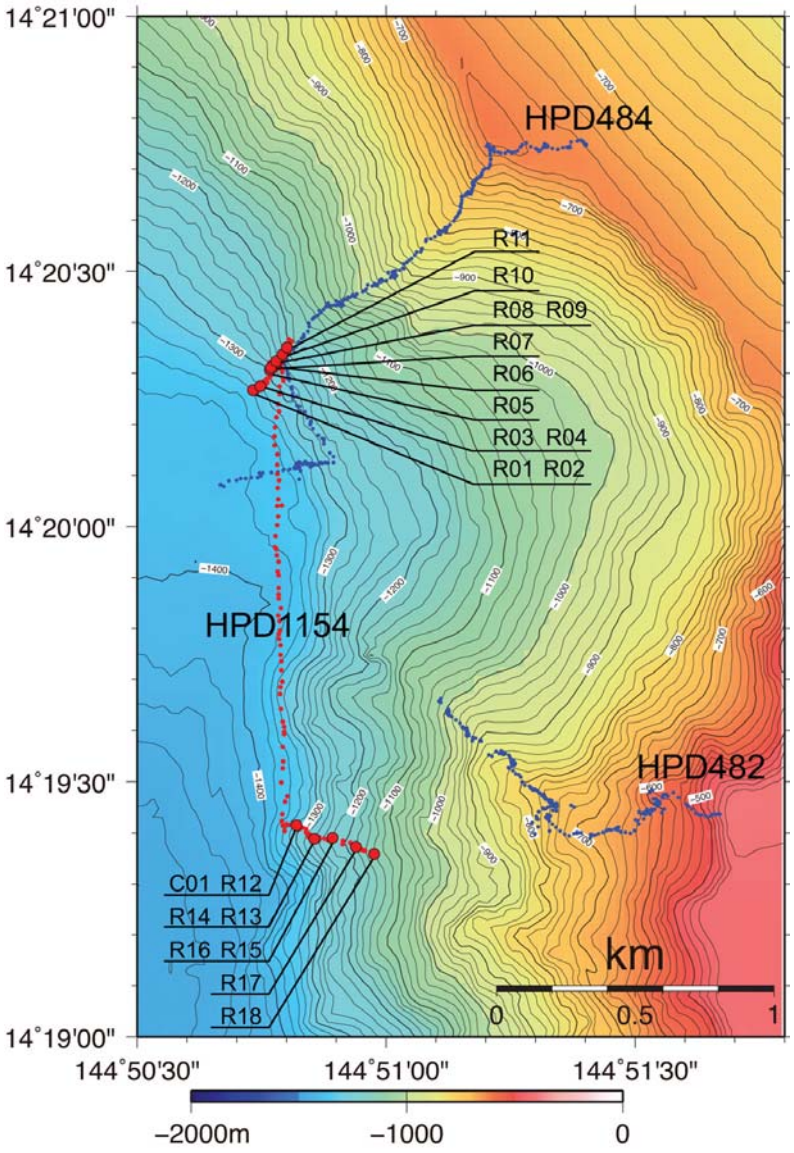

Figure 3: Bathymetry, dive tracks of HPD 1154, HPD 482, and HPD 484, and locations of samples collected during HPD 1154.

The two lines traversed showed mostly altered, mineralized andesites but these were quite different along each traverse. The first, northern traverse encountered mostly bleached outcrops that were intensely fractured and hard due to silicification, thought to be hydrothermally altered andesites. The second traverse also encountered altered andesites but these were altered to clay and were very weak and difficult to collect with the ROV claws. These traverses are described in greater detail below.

Traverse #1: The first traverse on dive HPD#1154 was designed to investigate the deeper parts of the hydrothermal upflow zone previously discovered and to collect more material from the high-grade copper zone (up to 14% copper in HPD #484 R06). Hyperdolphin made

contact with the seafloor at 1327 meters water depth and immediately traversed a zone of sediment and leached, hydrothermally altered rocks. This traverse was dominated by this landscape, with rocks dominated by intensely hydrothermally altered andesites, silicified and mineralized with sulfides, which in some cases may be chalcopyrite. Sulfides form veins with quartz, clots and disseminations. A total of 11 samples were collected along the traverse. Most of the samples are highly altered and were most likely originally porphyritic andesites. Phenocryst forms are preserved in some samples, but have been completely altered. Several samples represent hydrofractured breccias, with altered andesite clasts and a matrix of silica, sulfides, and in some samples chlorite. The traverse ended at 1174 m water depth.

Traverse #2: Hyperdolphin flew to the start of the second traverse, which began at 1296 m water depth. This traverse was quite different from the first traverse. Whereas, on the first traverse, we were able to sample (with effort) competent, silicified samples, the second traverse was dominated by intensely altered rocks characterized by clay alteration minerals. Thus, sampling was difficult owing to the lack of coherence of the outcrops. This traverse also contained a number of large dikes, with clay alteration "veins" along dike margins. Commonly, talus and outcrops looked dark and competent, but readily crumbled to fine particles where touched with Hyperdolphin's claws. On this traverse we collected 6 rock samples of highly altered andesite; the andesite has largely been replaced by clays and in some samples, chlorite. Some of the samples also contained disseminated and vein sulfide. An additional rock sample was largely clay with altered andesite clasts, and one core sample of alteration sticky clays was also collected at the start of the traverse. The dive ended at 1135 m water depth.

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Stern, R.J., Tamura, Y., Embley, R.W., Ishizuku, O., Merle, S., Basu, N.K., Kawabata, H., and Bloomer, S.H., 2008. Evolution of West Rota Volcano, an extinct submarine volcano in the Southern Mariana Arc: Evidence from sea floor morphology, remotely operated vehicle observations and $^{40}Ar/^{39}Ar$ Geochronology. The Island Arc 17, 70-89

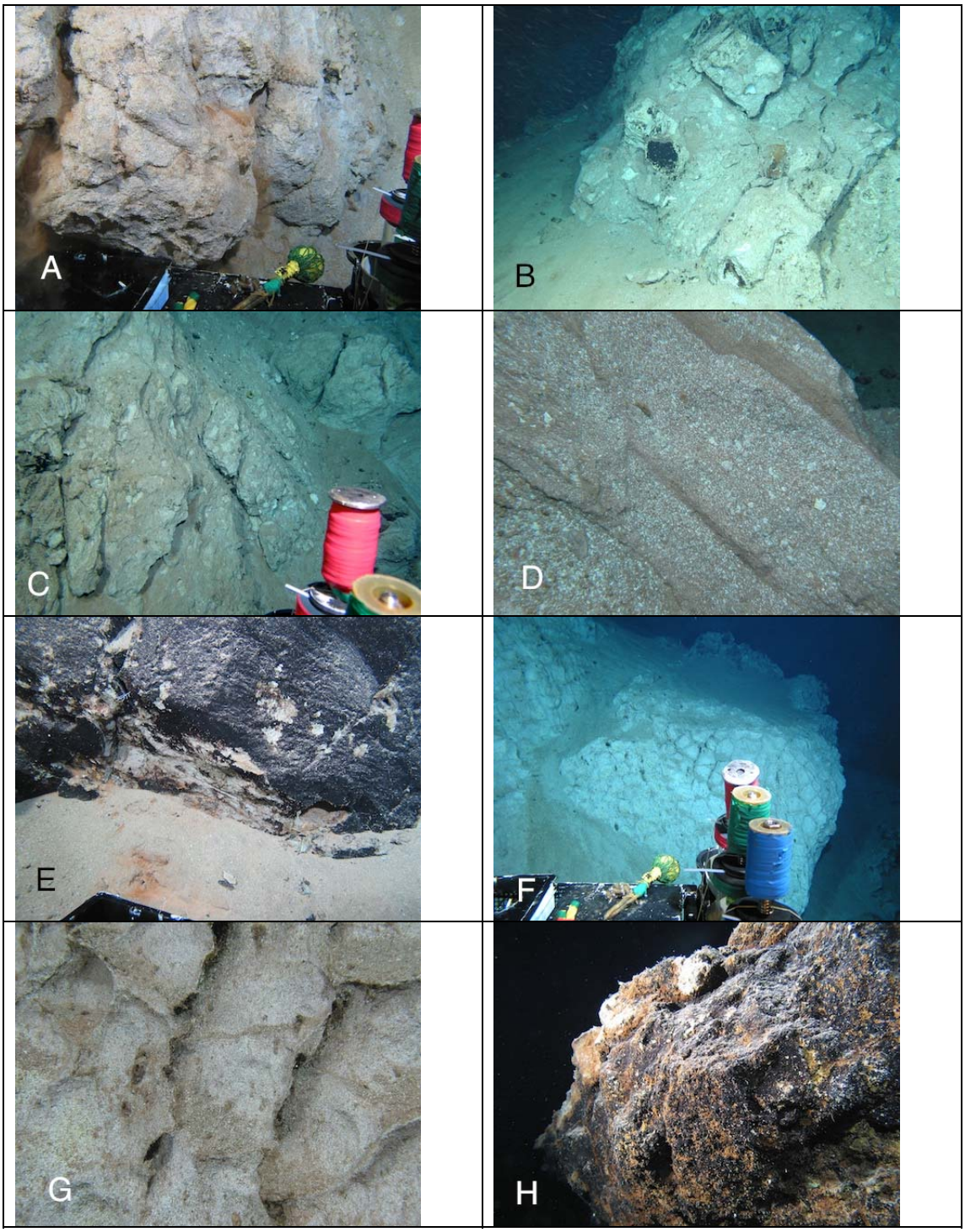


Figure 4: Representative pictures from HPD #1154, all taken during first (northern) traverse. **A**. SEAMAX 2010_0716_090906AA Outcrop of fractured and veined altered andesite (R01 altered andesite with sulfide mineralization is from here); **B**. SEAMAX 2010_0716_100407AA Fractured altered andesite outcrop. R04 (altered andesite) is float from near here. C shows a close-up of this outcrop; **C**. SEAMAX 2010_0716_100619AA steep outcrop of bleached layered breccias. This is a close-up of outcrop seen in B; **D**. SEAMAX 2010_0716_101024AA outcrop of layered breccias. Beds or layers dip to right (SE); **E**. SEAMAX 2010_0716_104314AA Dark outcrop of silicified and mineralized andesite. R06 is from here; **F**. SEAMAX 2010_0716_112145AA intensely altered and close-up of fractured outcrops of bleached rock; **H**. SEAMAX 2010_0716_112941AA Dark outcrop of sulfide breccia. R08 (altered andesite clast) is from this unit.

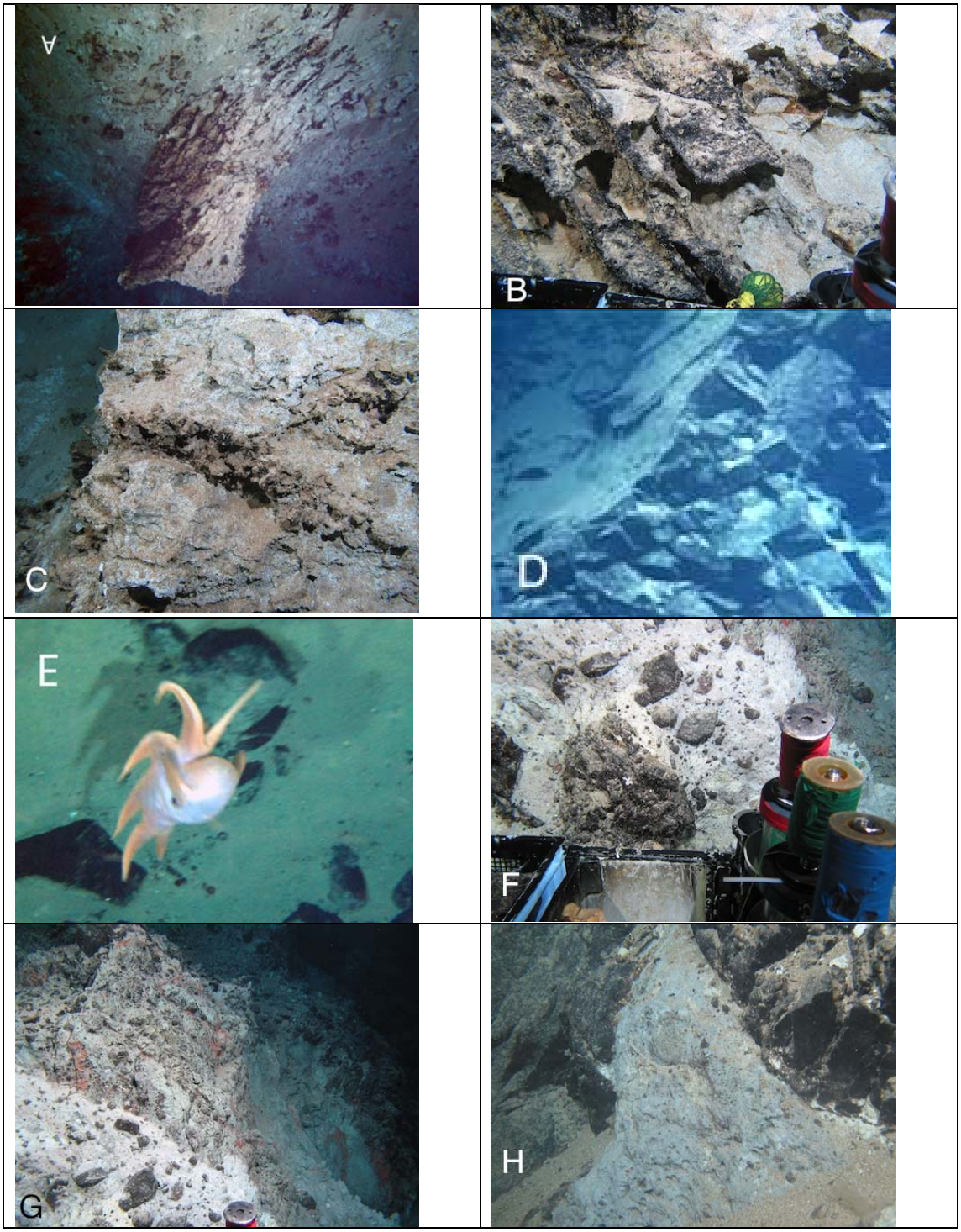


Figure 5: Representative photographs from HPD #1154. A-C are from first (northern) traverse, D-H are from second (southern) traverse. **A**. SEAMAX 2010_0716_120214AA white outcrop with dark staining on one side, standing up from sea floor like a broken column; looks like some banding or vertical planar veins in it. **B**. SEAMAX 2010_0716_120407AA Outcrop of hydrothermally fractured silicified rock. R09 is from this outcrop; **C**. SEAMAX 2010_0716_122108AA Outcrop of bleached rock with thick darker layer. R10 (hydrothermal breccia) is from the dark layer; **D**. HDC20100716143235: mafic dike showing beautiful curved surface, probably chilled dike margin; **E**. SEAMAX 2010_0716_150126AA octopus with two swimming fins; **F**. SEAMAX 2010_0716_152851AA Dipping layer of breccia, whitish matrix and dark clasts. Close-up of outcrop shown in G; **G**. SEAMAX 2010_0716_152654AA Outcrop of whitish rock, probably highly altered andesitic? breccia. R15 is from this outcrop; **H**. SEAMAX _0716_154302AA weak, bleached, altered material next to dike; R18 (hydrothermally altered rock) is from here.

Dive #:	NT10-12 HPD#1154
Date:	July, 16, 2010 (local)
Location:	East wall of W. Rota caldera
Objectives:	Study and sample mineralized zone

Logger: Stern

samples a HPD#xxx-RYY

where xxx is dive number, X is S for scoop, R for rock, C for push core, W for water, YY is number

Time	Depth	Vehicle	Notes	Sample #	On deck
8:00			In water		
9:06			On bottom. Sediment and loose talus covering bleached rocks		
9:08			Stopping to take sample from veined bleached outcrop. In circular basket.	R01	altered andesite (with sulfide mineralization)
9:18	1325		Stopping to collect from steep outcrop of friable, bleached rock. In basket 3	R02	highly altered andesite (to clay and sulfides)
9:29	1325	046	moving again, upslope		
9:32	1317	045	Travel over knobs of bleached rocks, highly fractured, with lots of intervening loose sediment		
9:39	1310	075	Stop at heterogeneous bleached outcrop to sample and photograph. Sample is to hard to extract so try another spot. Go a m or so down the cliff		
9:47	1311	076	Sampling piece of float, in circular basket	R03	altered microdiorite
9:50	1309	055	continue over slope of bleached rock with lots of blocks and loose sediment (whitish and reddish).		
9:53	1306	055	stopping at bleached, brecciated outcrop for sampling. Work on knobby, fractured outcrop for a while.		
9:58	1306		give up, move a little to left		
9:59	1305		Photograph outcrop		
10:02	1307		collecting sample from float on sandy sediment; circular basket	R04	altered andesite
10:04	1307	068	photographing large layered outcrop		
10:06	1304	057	coming up steep outcrop of bleached layered breccias		
10:08	1300	048	traversing bleached outcrops with intermittent cover of loose sediment		
10:09	1299	051	outcrop of layered breccias, could be slump block of pyroclastic material from higher up. Steeply dipping to right (SE)		
10:12	1295	040	traverse more angular blocks, some are layered and steeply dipping to right (SE)		
10:15	1294	043	stopping to sample outcrop or block, well layered and dipping right (SE). Reddish, very friable and easily crushed, probably pyroclastic slump block		
10:20	1292	040	Pass one block with layering steeply dipping to left (NW)		
10:23	1284	041	slopes are mostly covered with loose sediment		
10:25	1278	025	outcrops of bleached rocks with some loose sediment. Bleacbed outcrops show vertical dark veins = mineralized zones?		
10:29	1271	024	stopping to sample bleached outcrop with vertical dark veins. It falls out of claw but we retrieve it. Box 2	R05	altered silicified andesite (with sulfide veining and disseminated sulfides)
10:36	1270		continue up steep outcrops of bleached rocks		
10:39	1265	025	vertical mafic dike; now we get into steep outcrop of dark rocks		
10:40	1262	024	outcrops are mixed dark and light. Mn stain? Stop to sample. Collect small sample of light vein material. In rear of basket 2.	R06	silicified and mineralized andesite
10:50	1266	025	descend back to 1266 to look for sulfide veins. This is the depth that massive sulfide veins were found on HPD 484. Lots of dark veins or layers in bleached rocks.		
10:55	1265	357	stop at outcrop with orthogonal veins in bleached rocks. Try to sample dark veins. Try to sample at a couple of places but rocks are too hard to grab.		
11:10	1265		Grab a vein fragment; in rear of box 2. Second fragment appears to be in basket #1 rear.	R07	qz and sulfide vein in silicified andesite
11:17	1264	016	continue over steep landscape of layered, bleached rocks. Lots of angular jagged outcrops		

11:20	1262	052	go up loose sedimented slope to steep fractured outcrops of bleached, well-layered rocks. Stop for Seamax photo		
11:23	1258	051	continue up steep, partially sedimented slope, exposing bleached rocks.		
11:27	1246	049	very dark, rouded blocks, maybe Mn-coated rhyolites from above?		
11:38	1245	049	2 small pieces; seems to have lots of sulfides, in Basket 1	R08	sulfide breccia (altered andesite clasts)
11:42	1245		Try for bigger sample of sulfide-rich black body. Several places are attempted. A few pieces break off and we try to retrieve these. Black coated but white on the inside. Broke off several pieces; three pieces into basket 1, all parts of R08; broken surfaces are bright white	R08	sulfide breccia (altered andesite clasts)
11:59	1244	041	underway again, low relief white outcrops, darker blocks sticking up from sediments		
12:01	1241	034	dark block with thin dark veins standing up in relief		
12:01	1238	036	white outcrop with dark staining on one side, standing up from sea floor like a broken column; looks like some banding or vertical planar veins in it; hover and take pictures		
12:03	1236	034	heading in to sample it; quite fractured and full of veins; try to sample some of the vein material. Took piece off outcrop that looked like it had one of the thin platy black veins in it. Into Basket #1	R09	hydrothermally fractured silicified rock
12:07	1238	032	underway from outcrop; slope covered in bleached rock with darker knobs standing out from it. Good picture 12:08		
12:09	1233	034	coming up another massive outcrop, looks white-tan, finely layered or laminated, black orange at top; again a broken column kind of form standing up over seafloor; 1231 meters when passed over it		
12:10	1230	034	over column back to slope with white bleached rubble; covered in places with a sediment blanket in a chute of some kind; more abundant white bleached blocks to starboard		
12:13	1225	034	into low outcrop of bleached white rock;		
12:14	1219	034	still bleached white outcrop; odd fattish rat tail fish		
12:16	1217	034	large outcrop white and pale brown layered irregularly; outcrop a little higher here		
12:17	1213	033	stop and look at the upper part of the pale brown/white outcrop. It stands up in an elongate ridge here; this stop is near its NE end		
12:18	1212	040	position for sampling; try for piece of pale brown material; got a small piece and a big section broke and fell to port; R10 in Basket #1; take some pictures of outcrop; can see contact with white bleached outcrop to port	R10	hydrothermal breccia
12:22	1213	044	underway; off ridge and into low outcrop of white, bleached rock, then into a flatter bench covered in rilled sediments with "islands" of the bleached white rock sticking up in it		
12:24	1207	031	mostly sediment here, interspersed with low outcrops of the white rock		
12:28	1194	010	stop and look at float rocks with apparent iron stain; in circular basket; thought to be local	R11	altered andesite (with sulfides)
12:34	1184	020	sediment and low outcrops of bleached rocks		
12:38	1174		End of traverse 1; go to waypoint 3		
14:29		099	Begin traverse #2 (waypoint 3). Seafloor is massive fractured igneous rocks.		
14:31		110	seafloor is massive dark igneous rocks, not bleached.		
14:32		110	beautiful surface, probably chilled surface of dike		
14:34	1291	162	stop to inspect white veins in dark rocks. Also to sample. Very weak. Try push core. Mixture of white vein and reddish sediment (blue).	C01	clay and altered rock
14:45	1290		grab sample from just above white vein. In Box #2	R12	altered dacite (altered hb)
14:51	1290		discarding chain		
14:53	1286	120	Ascending steep blocky outcrops with strong vertical fracture - could be dikes.		
14:56	1269	110	Whitish zone is adjacent to dike, could be fluid conduit or bake zone.		
14:58	1263	110	Angular dark blocks, talus, and loose sediments		

15:00	1260		blue winged octopus		
15:04	1255	100	dark blocky fractured outcrops, maybe dikes		
15:06	1249	088	stopping to sample talus; some interesting rocks with Mn coated outsides and white-grey insides. Mn coated sample in basket 3	R13	breccia (altered)
15:17	1248		get sample with grey brecciated interior; dark coated exterior; in box with lid	R14	hydrothermal fractured breccia
15:18	1245	073	ascend steep outcrops of dark, fractured rocks - dikes?		
15:22	1218	098	ascend steep outcrops of dark, fractured rocks. Some white zones of alteration		
15:25	1202	080	more bleached rock here than lower down		
15:26	1200	077	Dipping layer of breccia, whitish matrix and dark clasts. Stop to sample rock whitish inside, dark coated outside; goes in box with lid; breaks into at least two pieces. Overlain by layer that is reddish, altered.	R15	(andesitic?) breccia (highly altered)
15:30	1200	078	Collect sample from reddish breccia overlying whitish breccia. Very crumbly and weak. Lots of material slumps into box with lid and Box 3. Maybe base of pyroclastic section.	R16	hydrothermally altered rock
15:33	1199	079	Continue up pervasively altered knife-ridge		
15:38	1185	090	Still in altered white material but some bigger blocks		
15:41	1179	090	massive dark outcrops with two white veins filling fractures. Stop to sample vein material. This is very weak, like grey breccia just below here. Get a sample and put in basket 4, but it probably fell apart. Try to sample dark material on side of grey vein but it is very friable. Looks like a felsic dike.	R17	clay and sulfides
15:56	1179	100	continue up steep outcrops with fractured massive rocks, look like dikes, maybe mafic and felsic.		
16:01	1151	105	continue to ascend steep outcrops with dikes.		
16:05	1136	091	steep outcrop of breccia and white rock		
16:07	1135	045	stop to sample bleached rock or tuff, very friable; in box 5	R18	hydrothermally altered rock
16:15	1135		End of Dive		
16:56			On deck		

HPD#1154 West Rota caldera

HPD#1154	July 16 2010		E caldera wall of W. Rota							
sample No.	latitude(N)		longitude(E)		depth (m)	rock type	shape	size X (cm)	size Y (cm)	size Z (cm)	weight (kg)
HPD#1154-R01	14	20.27	144	50.733	1330	altered andesite (with sulfide veins, disseminated sulfide and clots of sulfide)	subrounded	17	12	9	3
HPD#1154-R02	14	20.27	144	50.733	1330	highly altered andesite (to clay and sulfides)	subangular	25, 16, 18	18, 14, 8	14, 14, 7	14
HPD#1154-R03	14	20.27	144	50.748	1311	altered microdiorite	subrounded	10	9	6	0.5
HPD#1154-R04	14	20.27	144	50.748	1311	altered andesite	subangular	15	12	10	2.5
HPD#1154-R05	14	20.31	144	50.767	1270	altered silicified andesite (with sulfide veining and disseminated sulfides)	angular	33	21	15	11
HPD#1154-R06	14	20.32	144	50.778	1262	silicified and mineralized andesite	angular	10	7	3	0.5
HPD#1154-R07	14	20.31	144	50.769	1265	qz and sulfide vein in silicified andesite	angular	7	5	3	0.2
HPD#1154-R08	14	20.32	144	50.780	1237	sulfide breccia (altered andesite clasts)	subangular	20, 13, 14	12, 10, 7	7, 7, 5	3.5
HPD#1154-R09	14	20.32	144	50.780	1237	hydrothermally fractured silicified rock	angular	21	10	5	0.5
HPD#1154-R10	14	20.34	144	50.793	1213	hydrothermal breccia	angular	14	13	10	2
HPD#1154-R11	14	20.35	144	50.801	1193	altered andesite (with sulfides)	subangular	18	11	14	3
HPD#1154-R12	14	19.41	144	50.820	1290	altered dacite (altered hb)	angular	41	24	20	19
HPD#1154-R13	14	19.39	144	50.856	1248	breccia	angular	24	12	8	3
HPD#1154-R14	14	19.39	144	50.856	1248	hydrothermal fractured breccia	angular	18	14	12	2.3
HPD#1154-R15	14	19.39	144	50.893	1198	(andesitic?) breccia (highly altered)	angular	10	10	7	1.5
HPD#1154-R16	14	19.39	144	50.893	1198	hydrothermally altered rock	angular	17, 10, 9, 6	8, 10, 8, 5	6, 6, 2, 3	2.5
HPD#1154-R17	14	19.37	144	50.939	1183	clay and sulfides	rounded	7	4	5	1.5
HPD#1154-R18	14	19.36	144	50.976	1135	hydrothermally altered rock	subangular	11	9	9	0.5
HPD#1154-unkown											3
HPD#1154-C01	14	19.41	144	50.820	1290	clay and altered rock					1.7

HPD#1154 West Rota caldera

colour	alteration	Mn coating	Memo	
gray	altered		Fe-staining; disseminated and veins of sulfide; sulfide clots (<5 mm); fp altered, replaced by white mica/clays	HPD#1154-R01
gray	altered		Fe-staining (Fe-oxide on surfaces); sulfide clots (<10 mm); disseminated sulfides; fp altered to clay	HPD#1154-R02
gray	altered	film (Mn+Fe sulfides)	sparse disseminated sulfides	HPD#1154-R03
gray	altered	1 mm	disseminated sulfides (chalcopyrite/pyrite) 10-15%; phenocrysts replaced by clays/chlorite	HPD#1154-R04
gray	altered	2 mm	disseminated sulfides (pyrite); sulfide veins (<3 mm) of chalcopyrite + pyrite; original rock plag phyric, plag all altered; vugs with qz infilling	HPD#1154-R05
green-gray	altered	film	altered phenocrysts (maybe plag); disseminated sulfides	HPD#1154-R06
mottled black-white			cross-cuts a qz vein	HPD#1154-R07
mottled gray-white	altered	oxide film	breccia includes chalcopyrite; soft white mineral (talc, kaolinite, magnesite?); sulfides oxidising in the interior; Cu on outer surface	HPD#1154-R08
gray	altered		silicified, silica and sulfide veins; alteration rim	HPD#1154-R09
gray-green	altered		chlorite, qz and sulfide veins; clasts of clay and chlorite; matrix of sulfides	HPD#1154-R10
gray	altered		several fragments, largest measured; disseminated and clots of sulfides; phenocrysts of fp completely altered	HPD#1154-R11
gray	moderate		calcite veins; former hb phenocrysts (<5 mm) heavily altered, replaced by chlorite	HPD#1154-R12
green-gray-red	altered	2 mm	polymictic, angular to subangular clasts, chlorite altered clasts; calcite cement	HPD#1154-R13
gray-white	altered	1 mm	matrix supported; monomictic (clasts from same rock); clasts contain replaced hb phenocrysts	HPD#1154-R14
pale gray-white-green	altered	film	3 fragments, largest measured; clasts altered to chlorite; subrounded to subangular clasts	HPD#1154-R15
gray-white-green	altered	patchy film	several fragments, 4 largest measured; sulfide veins; clasts silicified in veins; altered to clay away from veins	HPD#1154-R16
gray	altered		several fragments, largest measured; 2 colors of clay, gray and green	HPD#1154-R17
gray-pale gray-white	altered		sulfide veins; original rock largely replaced by clays and silica	HPD#1154-R18
			several fragments, largest was identified as a fragment of R13	HPD#1154-unkown
pale gray-green				HPD#1154-C01

HYPER-DOLPHIN DIVE #1155

TECHNICAL INFORMATION

Location: Small volcanic ridge on North flank of NW Rota volcano

Objective: Survey and sample small parasitic volcanic ridge for primitive basalts (POBs and COBs)

DIVE 1155	**On bottom:**	**Off bottom:**
Time (local): July 17, 2010	9:30	11:24
Latitude:	15° 56.492'N	15° 56.489'N
Longitude:	145° 40.985'E	145° 40.936'E
Depth (m):	2568	2470

Samples returned: 10 rocks

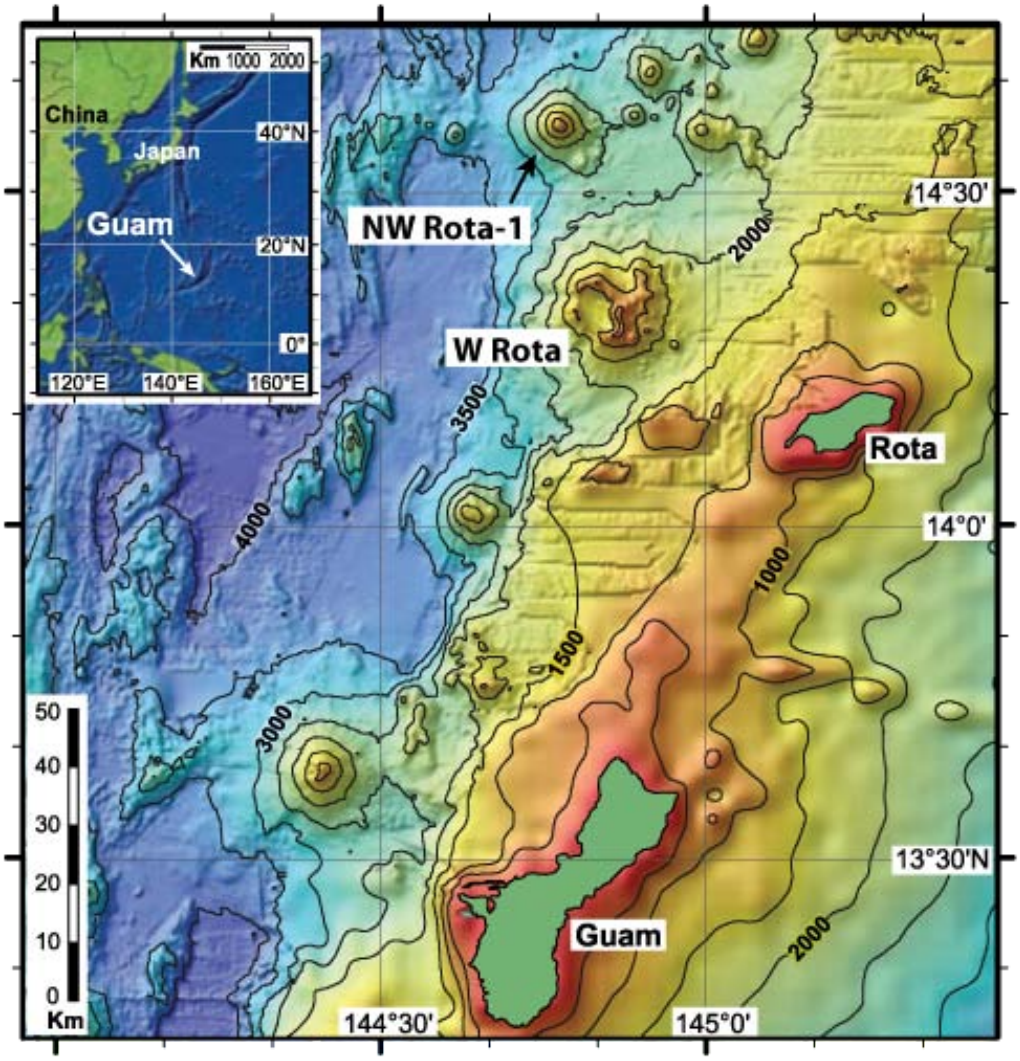


Figure 1: Location of NW Rota-1, approximately 60 km NW of the island of Rota and 20 km from W Rota caldera. Modified from Chadwick et al. (2008).

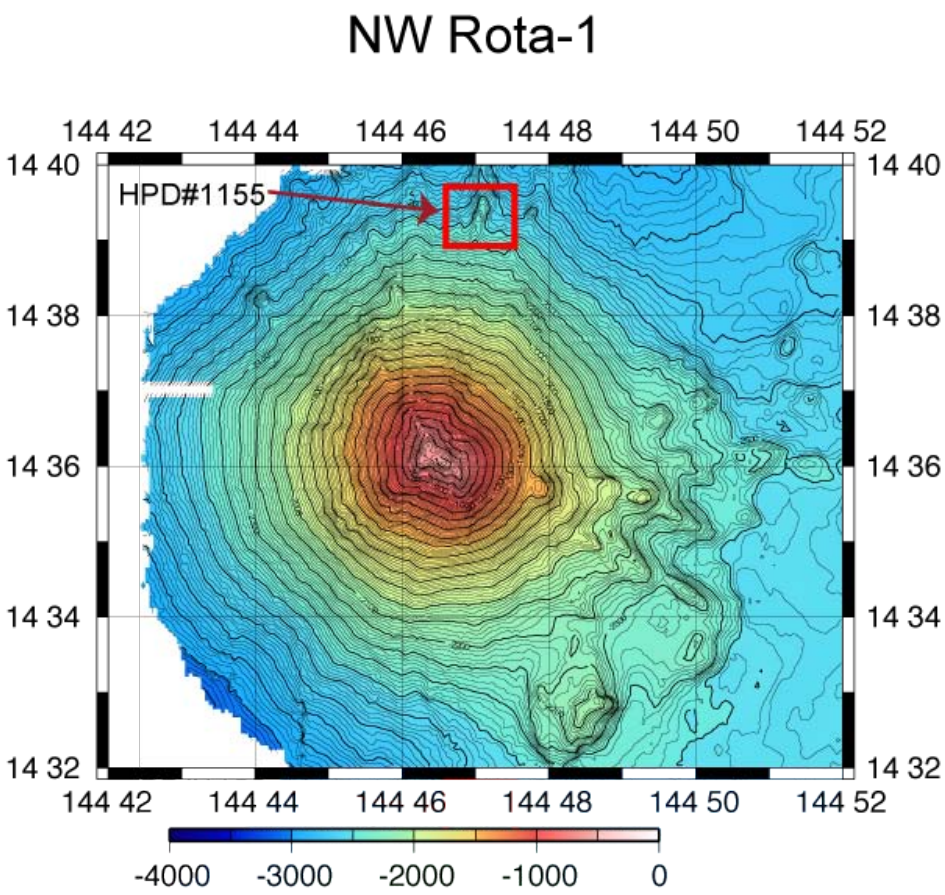


Figure 2: Close-up of bathymetry NW Rota-1 volcano, showing the location of dive operations for HPD#1155 shown in Fig. 3 (red box).

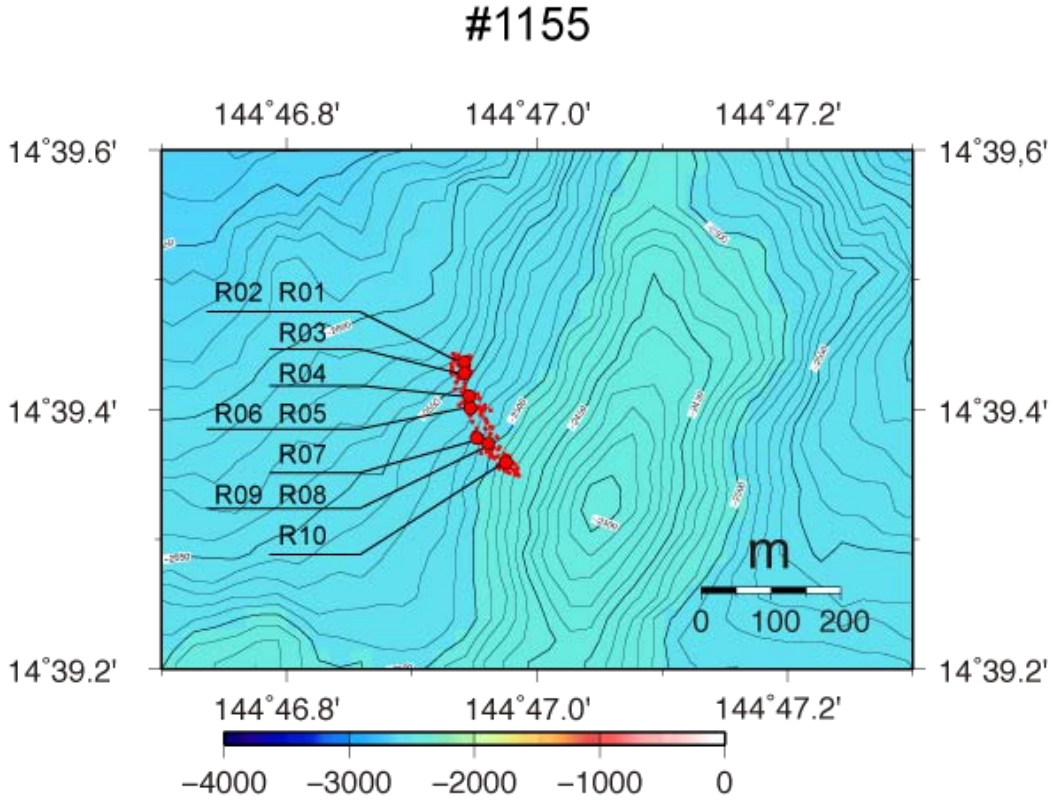


Figure 3: Bathymetry of ridge on northern flank of NW Rota-1 carried out during Dive #1155. Samples R01-R10.

SCIENTIFIC SUMMARY:

NW Rota-1 volcano is situated to the northwest of West Rota caldera, which was investigated during dive HPD#1154 (Figure 1). NW Rota-1 has steep slopes and forms a relatively symmetrical cone (Figure 2). Compositionally, the lavas are basaltic to basaltic-andesite, and include some of the more primitive rocks recovered from an arc-front volcano. The cone summit is at 517 m water depth, and the base is at 2800 m where it has a diameter of 16 km (Figure 2) (Chadwick Jr. et al., 2008). The first direct observations of explosive eruptions at the summit of NW Rota-1 were made in 2004, with continuing observations made during a number of different ROV cruises in 2004, 2005, 2006, 2009 and 2010. NW Rota-1 has been known to be hydrothermally active, with hydrothermal plumes evident from the 2003 NOAA Mariana Submarine Ring of Fire expedition in 2003 (Walker et al., 2008). Walker et al (2008) noted that the upper flanks of the volcano are characterized by unstable deposits of volcaniclastic debris, sand, and talus, with common mass wasting.

Dive 1155 was designed to survey and sample a volcanic ridge on the north flank of NW Rota-1 in order to collect primitive basalts. NW Rota-1 is known to have two main types of primitive basalt, COB and POB, which represent clinopyroxene-olivine phyric and plagioclase-olivine phyric rocks, respectively.

Dive 1155 landed at 2568 m water depth on the north flank of NW Rota-1. The dive involved a traverse up the flank of a ridge. The seafloor throughout the dive was dominated by sediment and talus blocks of plagioclase-olivine basalt (POB). In the lower part of the traverse, the blocks ranged in size from less then 50 cm to larger slabs of several cubic meters that were most likely slump blocks. In the upper part of the section, outcrops of basalt formed short ridges with sediment cover in the swales between ridges. The sediments are commonly rippled, with ripples elongated down slope. Compared to other volcanoes observed in previous dives, here the sediments are generally darker, as a result of the more mafic composition of this volcano (i.e. basaltic ash and fragmentation of flows). About halfway up the slope a ledge with Fe staining and lighter color was encountered. This was likely an ash layer, and was the source of some of the Fe-stained and cemented blocks observed down slope. Immediately below the ash layer was a layer of ash-cemented blocks of basalt (breccia). These two layers formed a ledge, which was undercut by mass wasting of non-cemented talus. As noted by Walker et al (2008), mass wasting is common; where the Hyperdolphin knocked the ledge material, mass wasting occurred. In total, ten samples were collected. All had some Mn coating, generally 1-2 mm in thickness over 3-5 mm of glass. All of the samples are plagioclase-olivine basalts (POB).

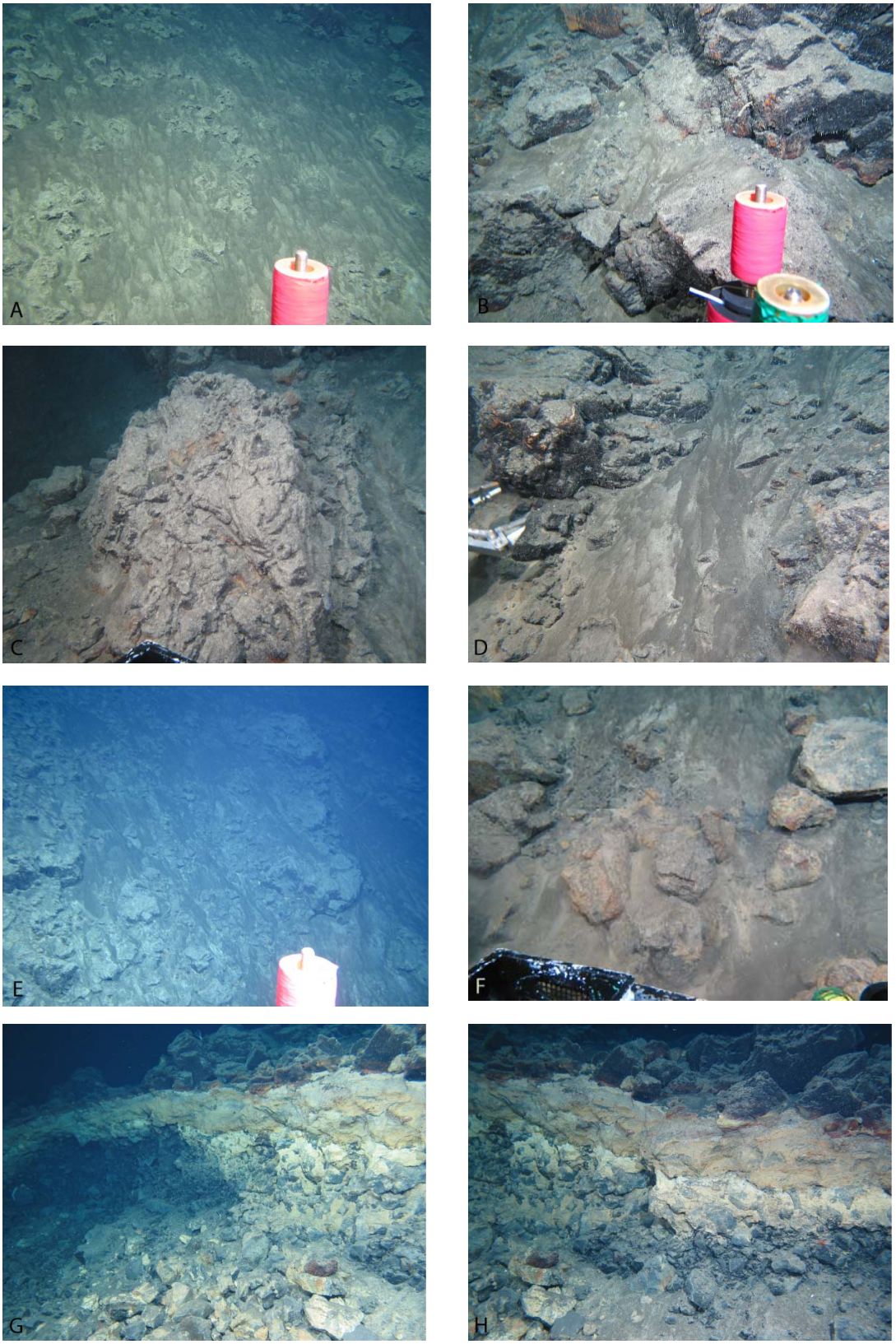


Figure 4: Representative pictures from HPD #1155.
A. Typical view of lower part of dive HPD#1155, showing sediment cover with basalt talus, Seamax 2010_0717_093354AA;

B. larger slump block of basalt, lower part of ridge on north flank of NW Rota-1, Seamax 2010_0717_093527AA;
C. Large block of basalt, Seamax 2010_0717_100343AA;
D. Outcrop of basalt about to be sampled, R-05, Seamax 2010_0717_101716AA;
E. Slope of sediment and isolated talus and outcrop of basalt, Seamax 2010_0717_102628AA**;**
F. Talus of basalt showing ash and Fe-oxide from ledge further upslope, Seamax 2010_0717_103519AA;
G. View of ash and ash-indurated breccia Seamax 2010_0717_104126AA;
H. Close up of the ledge, showing less consolidated basalt blocks and cobbles below the ledge, Seamax 2010_0717_104138AA.

References

Chadwick Jr., W.W., Cashman, K.V., Embley, R.W., Matsumoto, H., Dziak, R.P., de Ronde, C.E.J., Lau, T.K., Deardorff, N.D., and Merle, S.G., 2008, Direct video and hydrophone observations of submarine explosive eruptions at NW Rota-1 volcano, Mariana arc: Journal of Geophysical Research-Solid Earth, v. 113, p. B08S10.

Walker, S.L., Baker, E.T., Resing, J.A., Chadwick, W.W., Lebon, G.T., Lupton, J.E., and Merle, S.G., 2008, Eruption-fed particle plumes and volcaniclastic deposits at a submarine volcano: NW Rota-1, Mariana Arc: Journal of Geophysical Research-Solid Earth, v. 113, p. -.

Dive #:	NT10-12 HPD#1155
Date:	July, 17, 2010 (local)
Location:	Small ridge on N flank of NW Rota-1 volcano
Objectives:	Study and sample small ridge for primitive basalats

Logger: Leybourne
samples ar HPD#xxx-RYY
where xxx is dive number, X is S for scoop, R for rock, C for push core, W for water, YY is number

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #
08:00			In water	
09:30	2568	132	On bottom	
09:30	2571	132	Blocky basalt with rippled sediments between talus blocks, sediment quite dark (mafic pyroclastics?)	
09:31	2572	132	Some Fe alteration at base of some of the talus blocks	
09:32	2572	136	Taking sample of one of the talus blocks. R-01 into circular basket. Some Mn crust and Fe alteration on the sample. Probably relatively old.	R-01
09:33	2572	135	Moving off, continuing over sedimented slopes with blocky talus. Blocks of variable size up to perhaps a meter in long axis.	
09:34	2570	125	Much larger slump block of same material.	
09:35	2569	126	Stopping to take a sample from near a ~ 1 meter sized slump block; Fe staining evident in places.	
09:41	2568	150	Sample taken from piece of talus near the bigger block. Mn crust and Fe-staining, medium grey interior. R-02 into basket 1.	R-02
09:42	2567	154	Heading off, over much the same material, talus more common and generally smaller in size. Dark sediment in interstices. Fe staining evident. Most of the talus blocks are angular to subangular, commonly with a knobby appearance.	
09:44	2561	131	In larger sediment areas, ripples common, but irregular in geometry.	
09:48	2558	121	Stopping to sample a many meter size slump block (I assume, although could be outcrop?)	
09:50	2558	121	Sample taken, Mn crust, subangular. R-03 into basket 2	R-03
09:51	2558	121	Moving off.	
09:53	2554	131	Ripples in sediment a little more elongate, oriented downslope.	
09:54	2550	131	Still crossing talus slope with significant volume of sediment, and most talus is < 1 m in size, rare larger slump blocks.	
09:55	2547	126	Sediment cover predominant over talus. Sediment grain size variable.	
09:56	2540	126	Crossed large expanse of sediment, then into large slump block, fractured, knobby apperance, talus at base of block, stopping for sample	
10:02	2538	135	Sample taken, Mn coat. R-04 into basket 2.	R-04
10:05	2538	134	Moving off.	
10:06	2536	120	Back into talus, lots of sediment cover, alhough sediment may not be all that thick, as in places seems to be rock just beneath.	
10:07	2528	121	More masive rocks - probably into outcrop now, small ridges, with sediment in swales.	
10:08	2425	140	Stopping for sample R-05 from what looks like outcrop. Still subangular with knobby appearance. Mn coating evident	
10:18	2525	135	Sample R-05 into basket 2. Mn coated, largish sample.	R-05
10:19	2525	134	Moving off to the right to sample another ridge-spine outcrop.	
10:24	2424	144	Sample R-06 from outcrop, Mn coated, going into basket 2. Fe staining evident in the outcrop.	R-06
10:26	2523	133	Moving off up the slope.	
10:28	2521	132	Slope with lots of darkish sediment and talus, generally small blocks.	
10:31	2510	122	Still in sample material, rare outcrop spines, otherwise rippled darkish sediment with talus.	
10:33	2504	121	Stopping for a sample of outcrop. Some blocks around this outcrop look highly Fe altered? Or at least Fe-cemented. Lots of mottled sediment around, but lack of life. Large boulder of clasts cemented by Fe-oxides.	

10:35	2504	121	Sample R-07, large, with Mn coat on upper surface, some Fe-staining. R-07 into basket 2.	R-07
10:37	2503	121	Moving off. Up the talus slope, blocks here seem a little darker, generally small (< 50 cm) blocky talus.	
10:40	2492	113	Ledge with Fe staining and lighter colored ash layer - source of the Fe-rich material. Stopping for a sample near here. A lot more blocks with Fe staining/cement/alteration, but fresher blocks darker than downslope. Ash layer perhaps? With clasts in it? Also partially cemented blocks below the layer - debris flow? Ash in the matrix, most likely. As blocks are subrounded in that layer. The ledge is partially undercut, attesting to it being more indurated/cemented.	
10:46	2494	153	R-08 in two pieces, likely clast from the breccia layer below the ash layer. In basket 1. Where Hyoerdolphin touched the breccia layer or underlying material, mass wasting ensued.	R-08
10:47	2492	150	Sampling darker blocks overlying the ash ledge.	
10:53	2494	076	Sample R-09 collected. Mn coat, alteration rim as well. In basket 5	R-09

HPD#1155 NW Rota-1 northern flank

HPD#1155	July 17 2010				lower N slopes NW Rota						
sample No.	latitude(N)		longitude(E)		depth (m)	rock type	shape	size X (cm)	size Y (cm)	size Z (cm)	weight(kg)	colour
HPD#1155-R01	14	39.44	144	46.94	2570	ol-basalt	subrounded	13	17	13	4.5	black
HPD#1155-R02	14	39.44	144	46.94	2570	ol-basalt	angular	29	19	12	7	dark gray
HPD#1155-R03	14	39.43	144	46.94	2558	vesicular basalt	angular	15	15	10	1.5	black
HPD#1155-R04	14	39.41	144	46.95	2537	ol-basalt	subrounded	10	10	4	0.5	black
HPD#1155-R05	14	39.4	144	46.95	2525	basalt	subangular	17	10	12	2.5	black
HPD#1155-R06	14	39.4	144	46.95	2525	basalt	angular	13	22	13	4.5	black-dark gray
HPD#1155-R07	14	39.38	144	46.95	2502	ol-basalt	angular	37	22	17	16	black
HPD#1155-R08	14	39.37	144	46.96	2495	ol-basalt	angular	8, 7	5, 3	7, 6	0.5	black
HPD#1155-R09	14	39.37	144	46.96	2495	ol-basalt	angular	20	13	20	5	black
HPD#1155-R10	14	39.36	144	46.98	2470	ol-basalt	subangular	10, 6, 5	5, 7, 8	13, 7, 8	2	black
HPD#1155-unkown											0.2	

HPD#1155 NW Rota-1 northern flank

alteration	Mn coating	Glass rim	phenocrysts	vesiculation	Memo	
weak	1 mm	5 mm	ol 15; pl 5	moderate 15%	ol 2-3 mm; pl < 1mm; glassy rim and chilled margin = 5 mm; green/gray alteration rim below glassy rim	HPD#1155-R01
weak			ol 10; pl 10	weak 5-10%	vug 2 cm, generally vesicles <4 mm; flattened vesicles; Fe-staining	HPD#1155-R02
weak			ol 5; pl 10	moderate 25%	ol <1 mm; pl <1 mm; ol glomerocrysts 5 mm; vesicles <3 mm	HPD#1155-R03
weak		5 mm	ol 5; pl 2	moderate 20%	glassy rim and chilled margin = 5 mm; vesicles increase in size away from chilled (glassy) margin; green/gray alteration below chilled margin	HPD#1155-R04
weak	Mn+Fe film	5 mm	ol 5; px ±; pl 5	moderate 20%	ol <2 mm; pl 1 mm; vugs 20 mm	HPD#1155-R05
weak	1 mm	3-4 mm	ol 5; pl 10-15	moderate 20%	ol <1 mm; pl 2 mm; vugs 12 mm; pipe vesicles 30 mm; green/gray alteration rim below glass	HPD#1155-R06
weak	2 mm	5 mm	ol 10; pl 10	moderate 20%	ol 2 mm; pl 1-2 mm; banded vesicles; vug 10 mm, other vesicles <5 mm, increase in szie away from glassy margin	HPD#1155-R07
weak		5 mm	ol 10; pl 10	moderate 20%	ol <2 mm; pl <2 mm; glassy rim and chilled margin = 5 mm; green/gray alteration rim below chilled margin; vesicles < 2mm, vesicles heterogeneously distributed, slight increase in size away from chilled margin	HPD#1155-R08
weak	1 mm	5 mm	ol 10; pl 5	moderate 25%	ol 2-3 mm; pl <2 mm; vug 20 mm, veiscles increase in size away from glassy margin	HPD#1155-R09
weak	film	5 mm	ol 10; pl 5	moderate 15%	ol 2-3 mm; pl <1 mm; banded vesicles	HPD#1155-R10
					several fragments	HPD#1155-unkown

HYPER-DOLPHIN DIVE #1156

TECHNICAL INFORMATION

Location: Summit of the NW Rota-1 submarine volcano

Objective: Surveying and sampling of the summit outcrops and volcanic ejecta, examining volcanic activity

DIVE 1156	**On bottom:**	**Off bottom:**
Transect #1:		
Time (local): July 17, 2010	14:18	15:08
Latitude:	14°36.036'N	14°36.063'N
Longitude:	144°46.567'E	144°46.548'E
Depth (m):	575	526
Transect #2:		
Time (local): June 17, 2009	15:21	15:42
Latitude:	14°36.048'N	14°36.055'N
Longitude:	144°46.493'E	144°46.529'E
Depth (m):	567	542
Transect #3:		
Time (local): June 17, 2009	15:49	16:06
Latitude:	14°36.051'N	14°36.040'N
Longitude:	144°46.508'E	144°46.534'E
Depth (m):	552	555
Transect #4:		
Time (local): June 17, 2009	16:11	16:20
Latitude:	14°36.049'N	14°36.041'N
Longitude:	144°46.513'E	144°46.527'E
Depth (m):	549	554
Transect #5:		
Time (local): June 17, 2009	16:26	16:39
Latitude:	14°36.032'N	14°36.050'N
Longitude:	144°46.487'E	144°46.519'E
Depth (m):	579	549

Samples returned: 4 rocks

NW Rota-1 is an active submarine volcano (Figure 1), which was first reported to be active in 2004 (Embley et al., 2006). Several scientific cruises had been made to this volcano since then, reporting high level of venting activity (e.g. Chadwick et al., 2010). Previous studies also reported landslide events that have caused a significant change in the bathymetry of the area (Figure 2). Rock samples that were collected previously were basalts to basaltic andesites, including two types of primitive basalts, clinopyroxene-olivine basalts (COBs) and plagioclase-olivine basalts (POBs) (Tamura et al. in prep.). The objectives of this dive were to collect rock samples for the study of the magmatic evolution at this volcano, and to assess the level of volcanic activity. We made 5 traverses and collected 4 rock samples during this dive. The dive tracks are shown in Figure 3, and the brief descriptions of each traverse are provided below, followed by the summary of the dive.

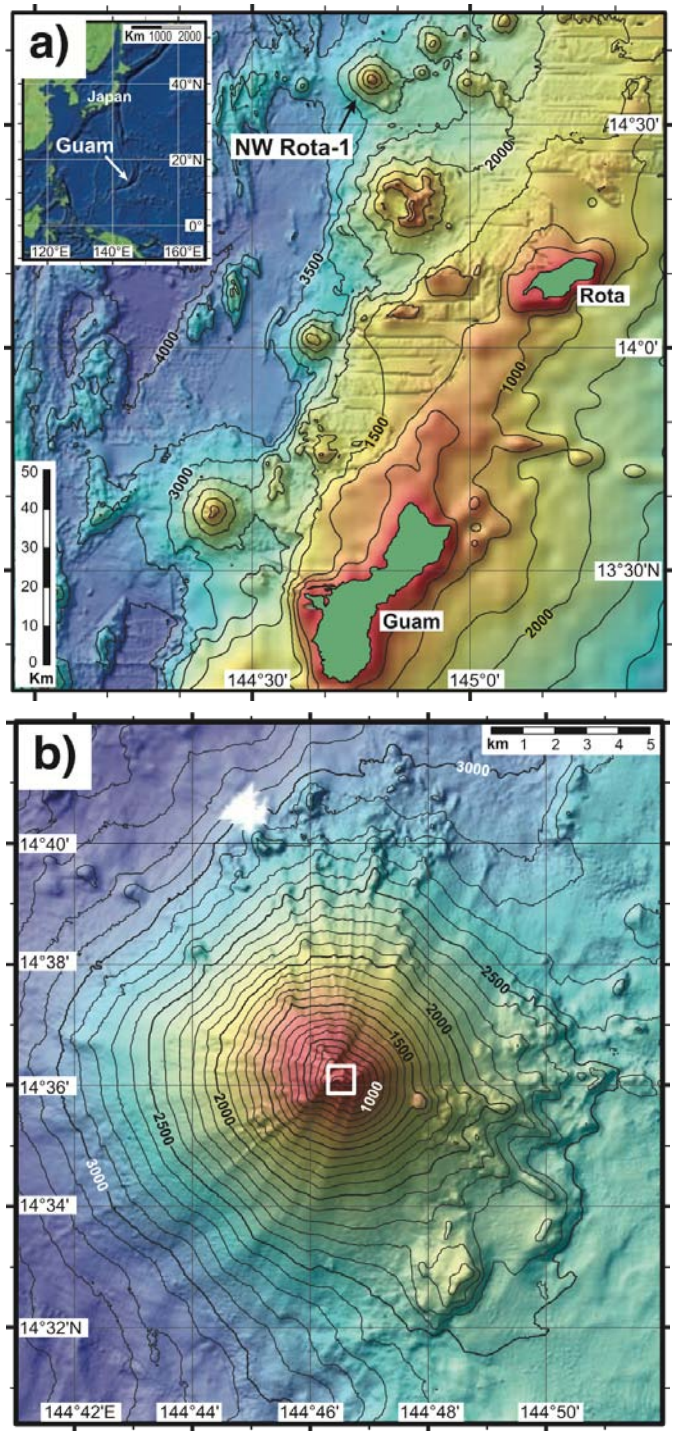


Figure 1. Maps showing the locations of (a) NW Rota-1 and (b) dive operations for HPD#1155 on the NW Rota-1 summit indicated by a white box (Chadwick et al. 2008).

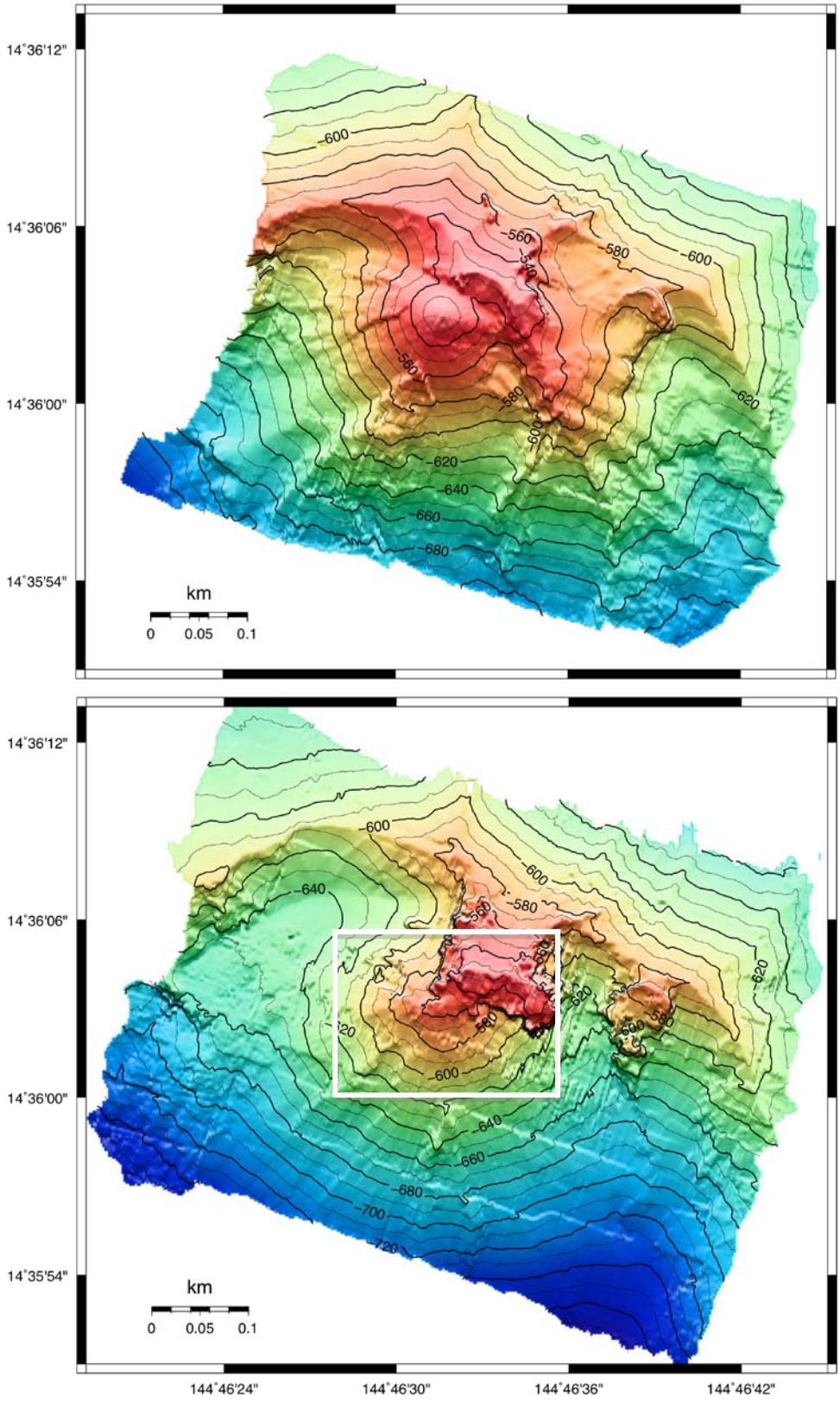


Figure 2: Bathymetry on the NW Rota-1 summit area based on the data collected (Top) in 2009 and (Bottom) in 2010 after a landslide event (Chadwick et al., 2010). White box in the bottom panel indicates the area of dive operations for HPD#1155 shown in Figure 3.

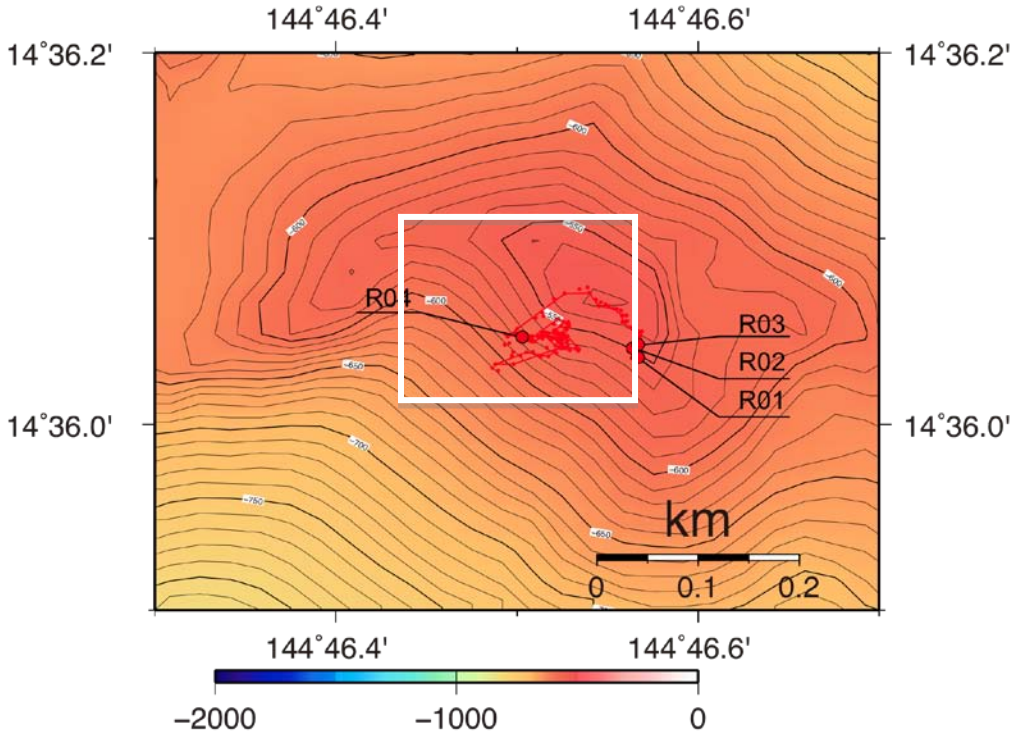


Figure 3: Bathymetry of the NW Rota-1 summit (10-m contours) showing three traverses carried out during Dive #1156. Samples R01-R03 were from Traverse #1, R04 from Traverse #2. White box approximately corresponds to that in Figure 2 Bottom.

Traverse #1: The vehicle landed on the southeast of the summit at 575 m depth. It immediately faced a nearly vertical south-facing scarp (Figure 4A) covered with bits of yellow sulfur deposit (Figure 4B). After collecting a sample of the scarp rock, the vehicle moved up northward, encountering taluses covered with sediments and volcaniclastic rocks. Two samples were collected from these taluses. The vehicle's orientation changed to NW, and it continued to move up the scarp. At ~530 m depth, the vehicle entered into a plume and lost visibility. To continue searching for an active venting site, the vehicle was moved to SWW of the summit for the second traverse.

Traverse #2: The vehicle landed SWW of the summit at 567 m depth. The seafloor was covered with volcanic rocks, some of which were light in color and appeared to be highly altered. The vehicle moved upslope eastward for a few minutes encountering sulfur degassing from the seafloor (Figure 4C). After collecting a sample from the seafloor in this area, the vehicle continued to move upslope, entering into a more sediment-dominated area (Figure 4D) and onto a sediment-covered steep-sided ridge (Fig. 4E), and the visibility grew poorer at 542 m depth. The vehicle was moved back to the west for the third traverse.

Traverse #3: The vehicle landed at 552 m depth and moved eastward without much change in its depth, searching for a venting site. The visibility was very poor. The area was mostly covered with angular boulders, rocks, and sediments. On this traverse, we spent about 18 minutes and found no vents.

Traverse #4: On this traverse, we spent 19 minutes moving in the SWW direction from 555 to 549 m depth SSW of the summit. The area was covered with sediments and angular

volcaniclastic rocks of various sizes (Figure 4F). Some rocks were covered with sulfur. We found no vents.

Traverse #5: The vehicle landed about 40 m south of the starting point of Traverse #2, at 579 m depth. The seafloor was covered with volcaniclastic rocks of various sizes, with occasional outcrops (Figure 4F). It moved upslope westward and found a dead vent (Figure 4H) but no active one. After 13 minutes the vehicle reached 549 m depth and was pulled out of the water.

SCIENTIFIC SUMMARY:

The steep scarp that we observed on the first traverse mostly likely resulted from the 2009 landslide, which removed a large volume of material from the summit area (Figures 2 and 5). The depths of the traverses during the dive are comparable to the bathymetry that was mapped in March 2010, and provided no evidence of another major landslide.

We observed sulfur degassing from the seafloor and plumes of thick white to yellowish particulates, both of which indicate that the volcano is still active. However, due to poor visibility, we were forced to move out of the plumes without obtaining any visual observations of eruptive activity.

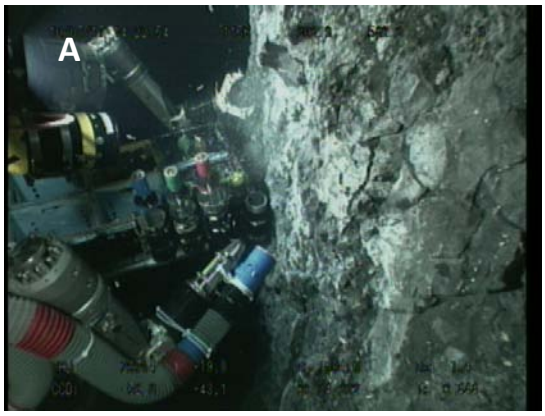
Two of the rock samples we collected from this dive were identified as plagioclase-clinopyroxene basalts, and the other two plagioclase-clinopyroxene-olivine basalts. Further analyses are required to determine whether they are COBS or POBS.

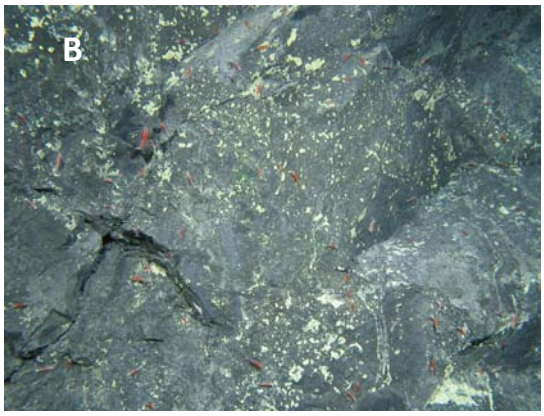
References

Chadwick Jr., W.W., Cashman, K.V., Embley, R.W., Matsumoto, H., Dziak, R.P., de Ronde, C.E.J., Lau, T.K., Deardorff, N.D., and Merle, S.G. (2008), Direct video and hydrophone observations of submarine explosive eruptions at NW Rota-1 volcano, Mariana arc, Journal of Geophysical Research-Solid Earth, v. 113, p. B08S10.

Chadwick Jr., W.W. and others (2010), NW Rota-1 2010 Cruise Report, R/V Kilo Moana Cruise KM-1005, March 16-30, 2010, Guam – Guam, JASON Dives J2-486 to J2-495.

Embley, R. W., et al. (2006), Long-term eruptive activity at a submarine arc volcano, Nature, 441, 494–497, doi:10.1038/nature04762.





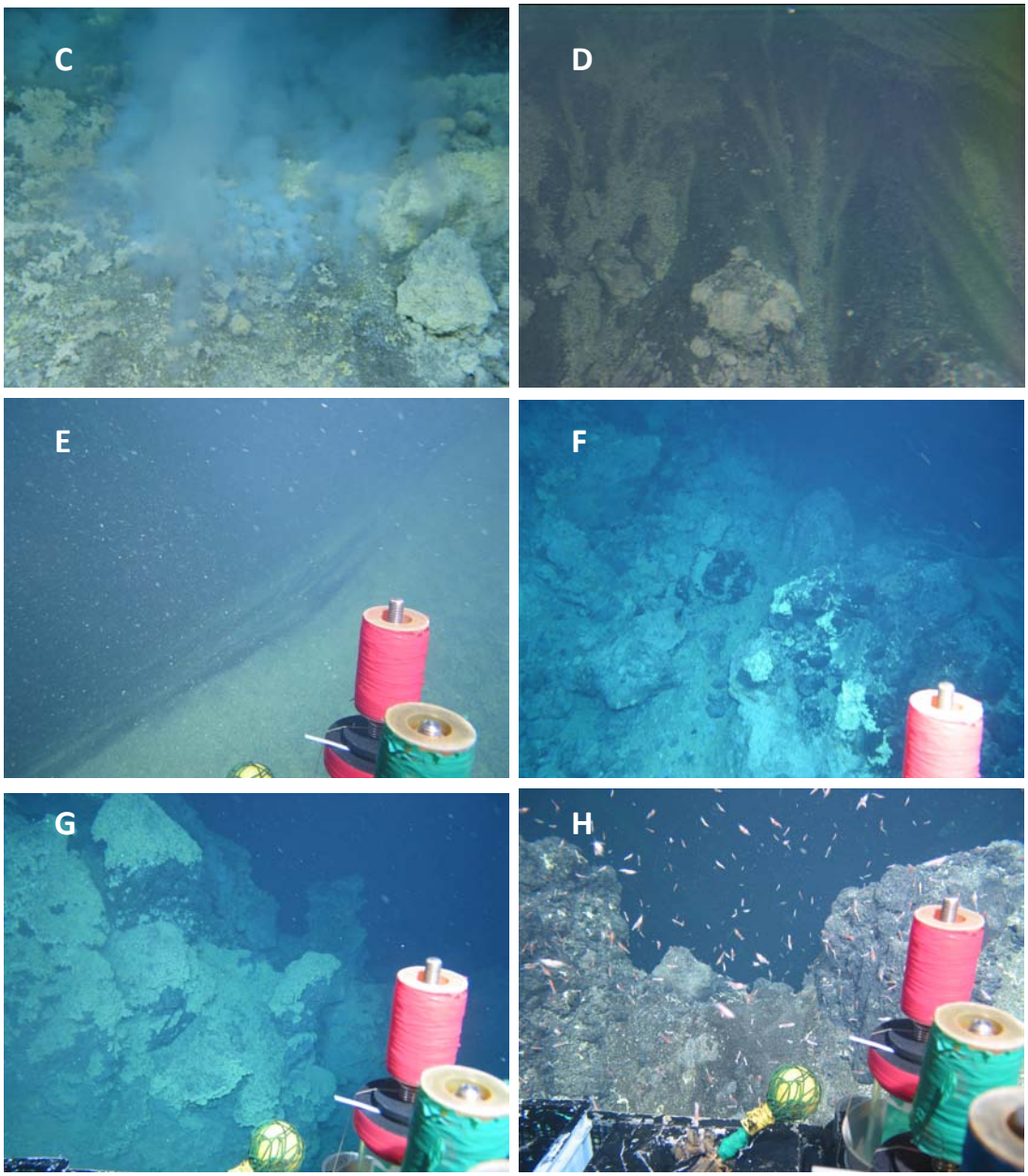


Figure 4: Representative pictures from HPD #1156. **A**. Hyperdolphin collecting a sample from steep scarp, traverse 1 (CCD DSC00007); **B**. Scarp with sulfur deposits and shrimp, traverse 1 (Seamax 2010_0717_142824AA); **C**. Sulfur degassing, traverse 2 (Seamax 2010_0717_152631AA); **D**. Sediments and volcaniclastic rocks, traverse 2 (HDTV hdc20100717153533); **E**. Sediment-covered steep-sided ridge, traverse 2 (Seamax 2010_0717_155729AA)**; F**. Sediments and rocks, transverse 4 (Seamax 2010_0717_163240AA); **G**. Outcrop covered with thick white sulfur coating, transverse 5 (Seamax 2010_0717_163759AA); **H**. Outcrop surrounded by shrimp, at the end of transverse 5 (Seamax 2010_0717_163943AA)

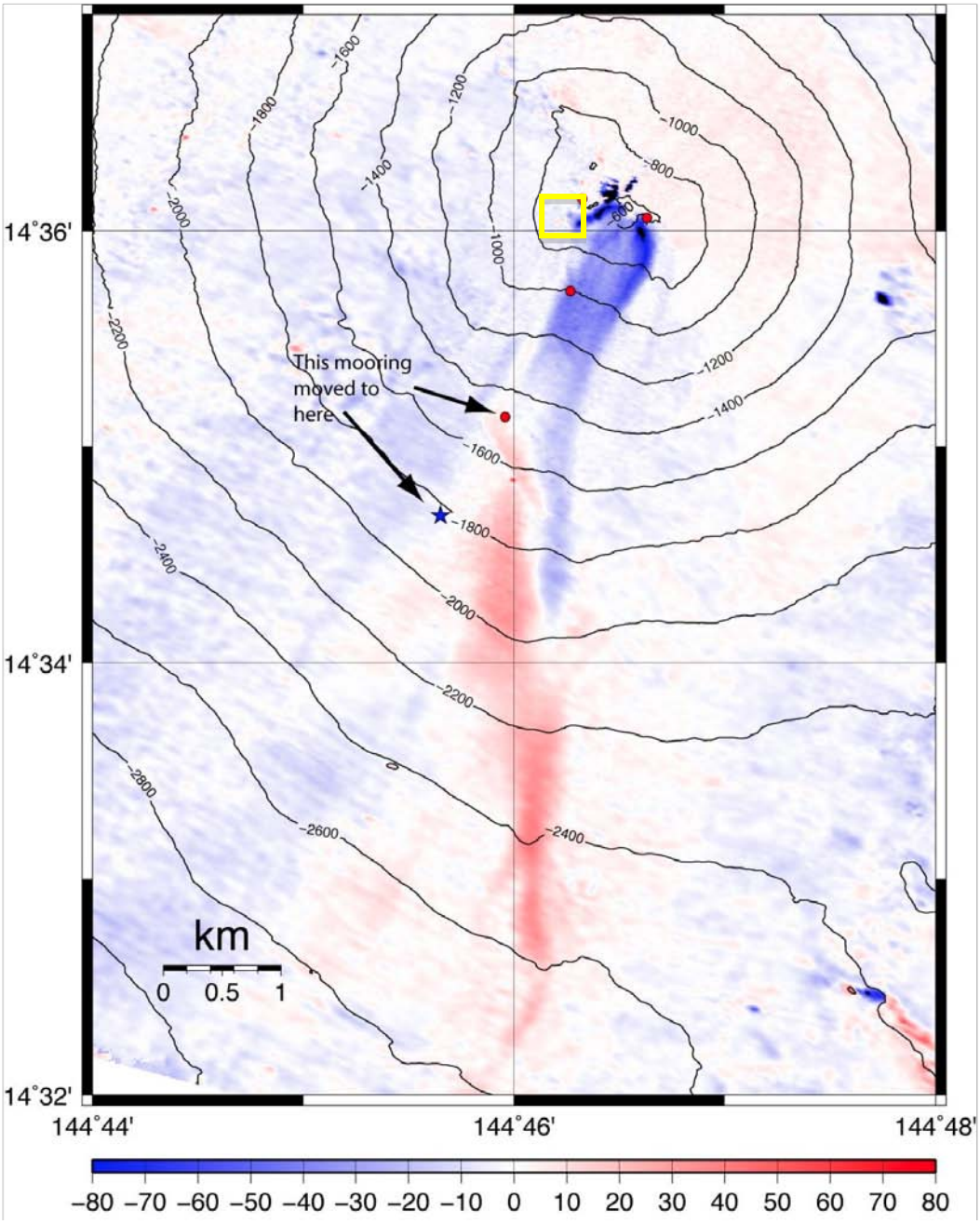


Figure 5. Map showing differences in bathymetry (m) mapped between 2009 and March 2010 (Chadwick et al., 2010). Yellow box indicates the approximate area covered by Dive #1156.

Dive #:	**NT10-12 HPD#1156**
Date:	July, 17, 2010 (local)
Location:	NW Rota-1 summit
Objectives:	Surveying and sampling of the summit outcrops and volcanic ejecta, examining volcanic activity

Logger: Ikuko Wada
samples are HPD#xxx-RYY
where xxx is dive number, X is S for scoop, R for rock, C for push core, W for water, YY is number

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
13:43			In water		
14:06	257		Water temperature of 17 deg C. Continuing descent.		
14:17	547		Cloudy water, white particulates (possibly pumice mixed with bubbles)		
14:19	579		On bottom, Waypoint 1, covered with volcanic rocks		
14:20	581	304	Bacteria mats, lots of shrimp. Facing a sharp rock wall, possibly a scarp that resulted from last year's landslide. 5 m off the floor, lots of little shrimp, little yellow sulfur dots on the wall.		
14:22	582	302	Collecting a sample from the rock wall, 5 m off the floor. Small dark grey sample in the circle basket.	R01	Vesicular pl-ol-cpx basalt
14:27	582		Observing the wall. Lots of white particulates in the water, lots of shrimp. Yellow sulfur dots covering the outcrop wall, moving up the scarp.		
14:29	581	332	Still moving up the steep wall, which is fractured and covered with yellow sulfur.		
14:31	577	347	Talus with sediments and blocky rocks. Collecting a sample that lies on the talus. Dark grey sample with bit of reddish Fe(?) stain, covered partly with some white coating, placed in the circle basket.	R02	Vesicular pl-cpx basalt
14:35	572	347	Moving up the wall, outcrop now less fractured, covered more with sulfur. Approximately at Waypoint 2.		
14:37	566	020	Vehicle orientation changed. Moving up the wall, less sulfur, temperature of about 6.5 deg C, lots of shrimp		
14:42	560	036	Collecting a sample from a sediment/rock talus at the foot of a smoother looking outcrop; grey sample in the circle basket	R03	Vesicular pl-cpx basalt
14:47	557	036	Moving up the wall, facing sulfur coated tubelike structures, likely dead vents. Water is cloudy, low visibility.		
14:50	553	030	Continue up the nearly vertical wall. Less shimp, cloudy water. Increasing amout of sulfur cover on the wall. Temperature of 7 deg C		
14:53	546	002	Moving up a massive fractured outcrop. Some sulfur coverred breccia.		
14:56	539	356	Passed a zone of outcrop completely covered with sulfur, continue moving up		
14:58	535	326	Reached the top of the scarp(?). Lots of shrimp, temperature of 7 deg C.		
15:00	538	355	Hit another wall, some reddish and yellowish white coating on the outcrop, continue moving up		
			Covered with sediments and reddish Fe-stained breccia		
15:04	531	270	Covered with finer sediments and altered rocks		
15:05	530	271	Cloudy water, zero visibility, in a plume? near the vent? Temperature of 7 deg C, continue moving up.		
15:08	527	300	See a break in the cloudy water, entering another plume		
15:09	524	334	Flying to Waypoint 5		
15:10	508	333	Improved visibility, in between plumes		
15:12	507	230	Cloudy water with slightly yellow color to it		
15:16	501	210	Out of a plume/cloudy water		
15:19	529	086	Descending. Enters cloudy water. Continuing descent.		
15:21	565	080	On bottom, at Waypoint 5. Floor covered with volcanic rocks/rubbles, some highly altered rocks with whitish coating. No shrimp, clear visibility.		
15:24	566	080	Some sulfur degassing from the seafloor, very diffuse, moving NEE.		
15:27	567	063	Increased degassing, whitish/greyish smoke seeping out of the seafloor. One shrimp, temperature of 6.5 deg C.		
15:29	567	062	Collecting a smaple from a talus. Appears to be an altered volcanic rock, placed in Basket 2	R04	Vesicular pl-ol-cpx basalt

15:30	567	062	Leaving a marker H1156-1 with a red ball, continue moving up the slope		
15:33	560	070	Moving up a slope covered with sediments between two ridges		
15:34			Encountered a large dead chimney?		
15:35			Some ripples on sediment covered part of the floor. Large/angular volcanic rocks		
15:36			Completely covered by sediments with ripple marks		
15:37			Passing a few large outcrop, half covered with sulfur, sediments are sulfur sand?		
15:39	545	070	Moving over the outcrop		
			No visibility		
15:40	544	060	Sand/sediment covered steep-sided ridge, poor visibility, moving up the ridge		
15:43	540	059	Zero visibility		
15:44	540		Turn to Waypoint 6		
15:48	540		Descending, poor-zero visibility		
15:49	553	085	On bottom, covered with dark and light sediments surrounded by lots of outcrops		
15:53	551	058	Moving up slope, ragged with outcrops, large angular boulders/rocks		
15:55	548		Poor visibility, seafloor covered with angular boulders with some sediment cover		
15:56	548	010	Facing the edge of layered basalt? Moving over the basalt unit. Top is flat and covered with sulfur sand.		
15:57	547	005	Moved over the "layered basalt?" unit. Steep slope, completely covered with sediments. Moving up slope, reaches the end of the ridge.		
15:58	545		Moving up the ridge, poor visibility, lots of white particulates in cloudy water, couple of shrimp.		
16:00	550	167	Arrives at Waypoint 4, moving towards Waypoint 12		
			Moving up. Some parts covered with both dark sediments and others with light colored sediments.		
16:01	548	140	Outcrop on the flank of the ridge		
16:04	552	080	Moving up, poor visibility, rubbles on the seafloor? Sediment covered seafloor with rocks/outcrops here and there, the side of the ridge exposing outcrops		
16:05	555	028	Appears to be moving down the side of the ridge, searching for vents, outcrop covered with sulfur		
16:06			Turn towards Waypoint 6		

16:11	552	110	Arrives at Waypoint 6 and moving towards Waypoint 12. Floor mostly covered with sediments, occasional outcrops. Poor visibility, lots of particulates in water, one shrimp passing by		
16:14	552	098	Searching for an active vent. Volcaniclastic rocks, sulfur, pyroclasts, angular rocks		
16:16	552	098	Lots of angular boulders/rocks on the floor, some partly covered with sediments, cloudy water		
16:16	554		We are at Waypoint 12		
16:20			Traveling to slightly south of Waypoint 5, planning to travel to Waypoint 4		

16:27	577	071	On bottom, covered with sediments, volcaniclastics, boulders, ripples on the floor, moving up slope		
16:30	571	081	Tall outcrop, going around the outcrop, moving up sediment covered slope with outcrops on the sides, lots of volcaniclatic. Both light colored and black rocks are present.		
16:33	554	037	Altered volcanic rocks, mostly light colored		
16:35	548	027	Increasing particulate matters in the water, decreasing visibility, reaches sediment talus, at Waypoint 12, still no vent		
16:39	549	028	Large/tall body of outcrop, an old vent? Lots and lots of shrimp		
16:40			Began ascent		

HPD#1156 NW Rota-1 summit

HPD#1156	July 17 2010		summit area of NW Rota -1									
sample No.	latitude(N)		longitude(E)		depth (m)	rock type	shape	size X (cm)	size Y (cm)	size Z (cm)	weight(kg)	colour	alteration
HPD#1156-R01	14	36.04	144	46.57	582	vesicular pl-ol-cpx basalt	angular	8	6	6	0.5	black	fresh
HPD#1156-R02	14	36.04	144	46.56	576	vesicular pl-cpx basalt	subangular	18	15	14	4.4	black	fresh
HPD#1156-R03	14	36.04	144	46.57	559	vesicular pl-cpx basalt	subangular	12	11	10	1.2	dark gray	fresh
HPD#1156-R04	14	36.05	144	46.50	566	vesicular pl-cpx-ol basalt	subangular	12	7	6	0.6	black	fresh
HPD#1156-unknown											0.05		

HPD#1156 NW Rota-1 summit

Mn coating	Glass rim	phenocrysts	vesiculation	Memo	
		ol 2; px 1; pl 10	moderate 8-10%	ol <2 mm; px <2 mm; pl <3 mm; glassy matrix; some sulfur odour	HPD#1156-R01
	<1 mm	px 10; pl 10	moderate 10%	px <3 mm; px <3 mm; glassy matrix; sulfur odour	HPD#1156-R02
		ol ?; px 5; pl 5~10	moderate 15%	px 2~4 mm; pl 2~3 mm	HPD#1156-R03
	1-2 mm	ol 1; px 3; pl 10	moderate 8-10%	ol <3 mm; px <2 mm; pl <4 mm	HPD#1156-R04
					HPD#1156-unknown

HYPER-DOLPHIN DIVE #1157

TECHNICAL INFORMATION

Location: NW lower slopes and cones on NW lower slopes of Tracey Seamount.
Objective: Observe and sample material that makes up the lower NW slopes and cones on the NW slopes of Tracey Seamount.

DIVE 1157	**On bottom:**	**Off bottom:**
Transect #1:		
Time (local): July 18, 2010	09:39	11:24
Latitude:	13° 41.059’ N	13° 41.157’ N
Longitude:	144° 20.381’ N	144° 20.430’ E
Depth (m):	2783	2701
Transect #2:		
Time (local): July 18, 2010	12:11	13:16
Latitude:	13° 41.030’ N	13° 41.001’ N
Longitude:	144° 20.667’ E	144° 20.780’ E
Depth (m):	2610	2553
Transect #3:		
Time (local): July 18, 2010	13:29	14:04
Latitude:	13° 40.956’ N	13° 40.924’ N
Longitude:	144° 20.900’ E	144° 20.949’ E
Depth (m):	2523	2483
Transect #4:		
Time (local): July 18, 2010	14:45	15:33
Latitude:	13° 40.750’ N	13° 40.753’ N
Longitude:	144° 21.187’ E	144° 21.240’ E
Depth (m):	2497	2454

Samples returned: 17 rocks recovered and accounted for.

SCIENTIFIC SUMMARY:

Tracey Seamount lies about 30 km due west of Guam and is the southernmost substantial volcano of the Mariana magmatic arc. South of Tracey the volcanism is more diffuse and does not form such large edifices (Martínez et al, 2000), which is believed to be a result of a combination of back-arc spreading, rapid slab rollback, and tearing of the subducting slab (Gvirtzman and Stern, 2004). Even so, with an estimated volume of 45 km^3, Tracey is one of the smaller volcanoes along the Mariana magmatic arc (compare with Pagan with a volume of 2200 km^3, Bloomer et al, 1989). Tracey forms a perfect cone that rises over 2 km, to a water depth of 750 mbsl, and has a diameter of approximately 7 km at the 3000 m water depth contour. At the present day Tracey is believed to be extinct, with no eruptive or hydrothermal activity having been recorded. The western side of the summit is dissected by a sector-collapse crater, within which a resurgent dome formed.

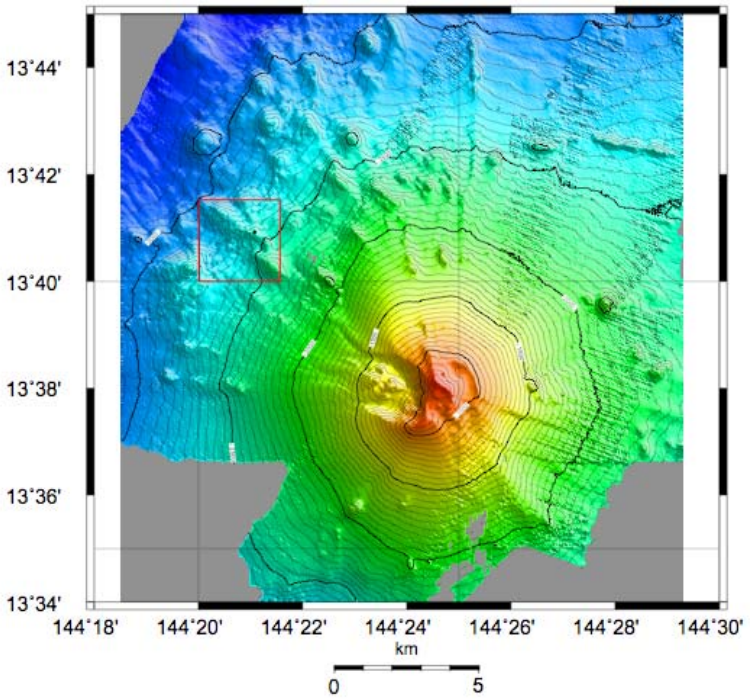


Figure 1: Bathymetry of Tracey Seamount. Red box defines area of dive operations for HPD#1157 and Figure 2.

Tracey Seamount was first visited by ROV in dive HPD#949, cruise NT09-02, which traversed up the resurgent dome and west-facing, eastern wall of the crater. The dome was found to consist of dacite and one of the samples collected has been dated at 500 ka. The dome is believed to be the youngest magmatic event at Tracey. The crater wall is made up of basaltic andesites to andesites, volcaniclastics and pumiceous sandstone that becomes increasingly prevalent towards the top, and a cap of pumice. This suggests that Tracey erupted increasingly evolved material. Unusually for the Mariana Arc, where most rocks are medium-K, Tracey appears to erupt low-K material. The trace element signatures of the felsic and mafic magmas of Tracey make it impossible to relate them by fractional crystallization. Today's dive aims to recover material from the lower slopes of the edifice and thus from earlier in the evolutionary history of Tracey than the samples recovered to date, allowing the geochemical characteristics of Tracey volcano to be investigated further.

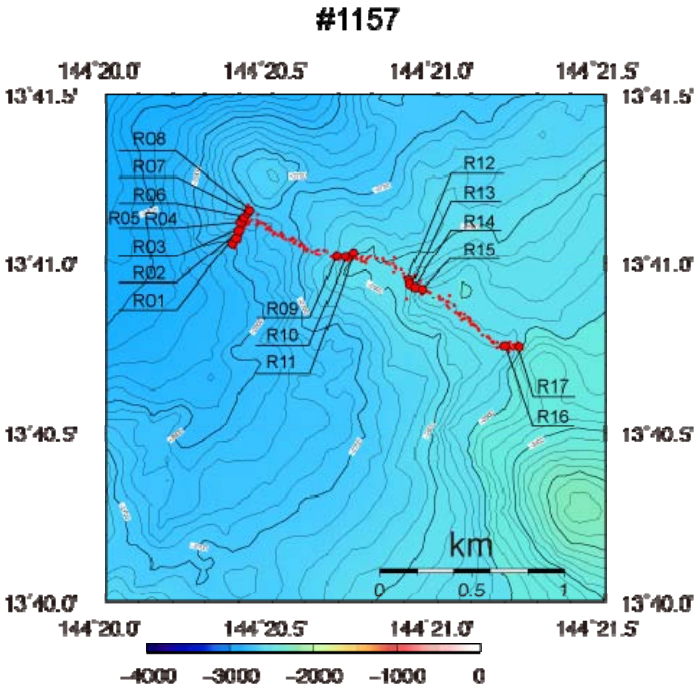


Figure 2: Close-up of bathymetry and track followed during HPD#1157.

Traverse #1: The first traverse of this dive climbed part of the southern slope of a cone on the lower northwestern slopes of Tracey Seamount from 2789 to 2701 mbsl; the cone rises about another 40 m. The slope consisted of some talus, but mostly outcrops of Mn-coated lava flows. Sediment cover was light. Several large, m-scale, subrounded structures, sometimes exhibiting radial columnar jointing (Fig. 3A, B and C), were observed, which were tentatively interpreted as giant pillow structures. R02, a cpx-ol basalt, was clearly taken from such a structure (Fig. 3A). Other rocks sampled during this traverse, except for the last two, are also cpx-ol basalts. They were taken from outcrop and loose rocks, which were likely to have been proximally derived. The last two sample from this traverse, R07 and R08, are pumice. R07 appeared to be taken directly from an outcrop, R08 may have been float.

Traverse #2: The second traverse climbed the upper 50 m, from 2610 to 2554 mbsl, of a NW facing knoll on the slopes of Tracey Seamount. Once more most of the seafloor was covered in sparse sediment, and outcrop was extensive although Mn-coated. Some of the outcrop appeared to be brecciated lava, possibly pillow breccia, particularly early in the traverse, and possible pillow morphologies were observed (similar to Fig. 3B and C). All three samples collected during this traverse, R09 to R11, are olivine-rich porphyritic basalts. Olivines are particularly abundant in R09.

Traverse #3: This climbed up the steepest part of the next knoll from 2523 to 2483 mbsl. Four samples were collected from this traverse, the first two, R12 and R13, are pumice and appeared to be broken off outcrop. R14 was taken from outcrop, while R15 was a loose block but had a similar appearance to the adjacent outcrop, and thus was assumed to be derived from it. Both are porphyritic olivine basalts, R15 is notable for containing an enclave of less porphyritic basalt, suggesting mixing of different batches of magma. Between R14 and R15 the outcrop had a slabby appearance, with blocks having planar upper surfaces or crust (Fig. 3F).

Traverse #4: The final traverse that we were able to complete during dive HPD#1157 climbed part of a spur, from 2491 to 2453 m, on the lower part of one of the largest cones on northwest slopes of Tracey. The outcrop on the lower part of the traverse was rugged before giving way to tube structures. R16 was taken from one of the loose block amongst the rugged outcrop, while R17 was a loose block taken from close to one of the tube structures. Both samples were basalt, but were less porphyritic and more vesicular than the other basaltic samples collected in this dive.

Summary

The lower slopes of this part of Tracey Seamount appear to be constructed of basalt, with some pumice that may be in situ, suggesting bimodal volcanism, although an exotic origin cannot be ruled out. The cone sampled in the first traverse appears to consist of basalts with a phenocryst assemblage of olivine + plagioclase + clinopyroxene. In the higher slopes the clinopyroxene is absent from the basalts' phenocryst population, and the rocks are more olivine-rich, almost picritic. In the highest part of the slope sampled in this dive the basaltic rocks are less porphyritic and more vesicular. Together with the observations made and samples collected during dive HPD#949, the samples collected in this dive suggest that Tracey Seamount is largely a basaltic edifice, although there may have been minor amounts of more explosive felsic volcanism that produced pumice. Towards the end of Tracey's eruptive history felsic volcanism became more dominant.

It should be noted that samples from traverse #1 were described by Osamu Ishizuka and Yuka Hirahara, while the samples from the other traverses were described by Matthew Leybourne and Alex Nichols.

References:

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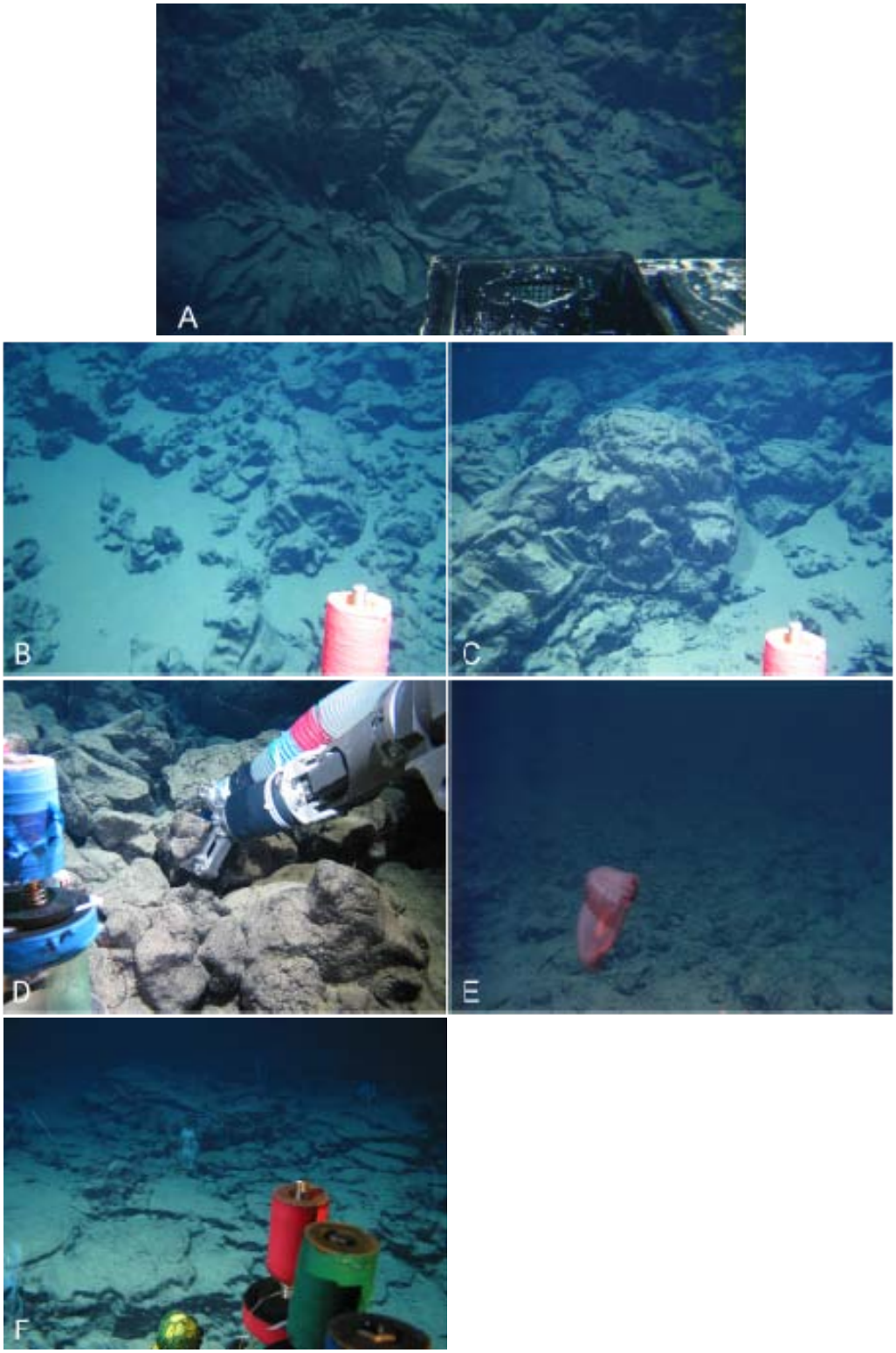

Figure 3: Representative pictures from HPD #1157. **A**. Tube/dike/pillow body exhibiting radial jointing, from which R02, a cpx-ol basalt was taken, during traverse #1, HD camera capture hdc20100718100146_1; **B**. Pillow tube structures, observed during traverse #1, Seamax 2010_0718_103434AA; **C**. An example of the large subrounded morphologies from traverse #1, possibly pillow structures, often seen on the seafloor during HPD#1157, Seamax 2010_0718_104925AA; **D**. Sampling R10 from jointed outcrop during traverse #2, Seamax 2010_0718_123139AA; **E**. Jelly fish passing ROV during traverse #2, HD camera capture hdc20100718131229_1**; F**. Slabby crust on outcrop, observed during traverse #3, Seamax 2010_0718_135603AA.

Dive #:	**NT10-12 HPD#1157**
Date:	July, 18, 2010 (local)
Location:	lower slope and cones on lower slopes of NW Tracey
Objectives:	Observe and sample

Logger: Nichols

samples are HPD#xxx-RYY

where xxx is dive number, X is S for scoop, R for rock, C for push core, W for water, YY is number

Time (Local)	Depth (m)	Vehicle	Notes	Sample #	On deck
8:00			In water		
9:40	2788.2	020	Bottom in site. Plan 5 traverses today.		
9:40	2789.0	030	Begin the first traverse.		
9:40	2789.3	030	Sediment dusted talus and outcrop. Lava flow outcrop. Pillow tube? Attempt to sample outcrop.		
9:47	2790.2	032	Outcrop looks Mn coated.		
9:49	2790.9	039	Managed to sample from outcrop. Mn-coated. Goes into circular basket.	R-01	cpx-ol basalt
9:55	2783.0	041	Crossing partially sediment covered rubble strewn seafloor.		
9:59	2767.2	020	Crossing basaltic outcrop.		
10:00	2761.0	010	Reach what looks like a dike, nice view of radiating columnar jointing on HDTV. Giant pillow? Moved in for closer look and to sample.		
10:06	2763.3	016	Sample angular block, bounded by jointing. Mn coating. Rectangular prism, ~50 cm long. Goes into basket 2.	R-02	cpx-ol basalt
10:10	2758.5	026	Large subrounded structures on seafloor. Large pillows?		
10:14	2757.0	042	Large subrounded structure with radial columnar jointing. Move in to sample. Difficult - Mn. Nice view of jointing on CCDTV.		
10:25	2756.7	064	Still trying...		
10:27	2757.2	064	Pick piece below outcrop. Fallen from outcrop? Seems likely. Goes into basket 1.	R-03	ol-cpx basalt
10:29	2756.0	056	Patch of sediment.		
10:35	2735.5	051	Outcrop. Partially sediment covered, Mn-coated. Break off large piece with convex outer surface. Falls down slope. Go for smaller piece that was loose, partially buried in the sediment. Fairly irregularly shaped piece. Goes into basket 1.	R-04	cpx-ol basalt
10:41	2736.2	052	Move for large piece from outcrop. Outcrop crumbly. Mn-coated, Fe-stained in places and patches of sediment. Joins other samples in basket 1. Broken into two pieces, large piece stays in basket 1. Smaller piece falls in basket 2.	R-05	cpx-ol basalt
10:47	2735.8	055	Problem with manipulator. Left-hand broken.		
10:52	2725.5	052	A little less sediment cover. More outcrop - lava flows. Pillowy structures.		
10:55	2717.2	353	Look to sample outcrop with vacuum encumbered right manipulator.		
11:05	2717.4	003	Small sample broken from the outcrop. Mn-coated, Fe-stained. Basket 5.	R06	ol-cpx basalt
11:09	2713.1	030	More irregular, knobbly outcrop on seafloor.		
11:12	2705.1	028	Attempt to sample. Mn coated. Knobbly outcrop. Break off small piece. Pale white to orange color. Broke up a little in manipulators. Goes into basket 5.	R07	pumice
11:17	2703.0	041	More sediment cover. Weakly rippled.		
11:19	2701.0	039	Move in to sample. Use vacuum. Looks altered, float? Placed into basket 5.	R08	pumice
11:25			End the first traverse and fly to way point 4.		
12:11	2605.2	094	Seafloor looms into view. Begin the second transect. Scarp of fractured outcrop, could be brecciated lava or breccia. Covered with thin sediment. Fairly friable.		
12:14	2609.0	081	Trying to sample. Very easily broken apart.		
12:19	2596.0	101	Continue to climb up steep scarp of breccia.		
12:20	2595.0	051	Pillow breccia? Try to sample.		
12:24	2595.0	051	Manipulator breaks up outcrop a little. At first unable to pick up a sample, but swiftly grab a block. Mn-coated. Angular. Placed in basket 5.	R09	ol-basalt
12:29	2584.0	088	More continuous outcrop. Some benthic life. Less fractured than in first traverse. Some subrounded morphologies - pillow forms?		

12:31	2577.0	087	Look to sample. Pick up slabby piece, loose. Black exterior - Mn. Left manipulator comes back to life and helps in long-winded maneouvre to secure sample. Finally topples off baskets..... But hang on!!.. all is not lost... At 12:59 notice that it is lying between left manipulator and baskets.	R10	ol-basalt
12:40	2577.0	092	Start again.		
12:49	2578.0	092	Trouble to break a piece off.		
12:53	2574.0	102	Give up and move on.		
12:54	2572.0	123	Outcrop of lava flow; tube structures?		
12:59	2572.0	121	Tear a piece from outcrop. Falls in front of ROV and rolls underneath baskets. Maneouvre to try and pick up. Finally pick it up. Subangular, Mn and sediment coated. Possible layering/banding, although maybe Mn. Basket 5. Notice we still have R10 between the left manipulator and the baskets. Drop the weight chain.	R11	ol-basalt
13:12	2564.4	108	Pinky purple creature floats past. Jelly fish?		
13:16	2552.8	095	Reach way point 5 and will now fly to way point 6.		
13:26	2533.0	143	Seafloor visible.		
13:29	2522.2	140	Reach way point 6. Similar seafloor morphologies to transect 2. Rubbly, some outcrop, sparse sediment cover. Begin transect 3.		
13:30	2518.0	139	Move in to sample. Benthic lifeforms on outcrop. Outcrop easily breaks up and thus easy to sample. Take angular piece, orange surfaces, angular. Goes into basket 4. Breaks up into several pieces.	R12	pumice
13:38	2503.0	163	Move in to look at one of the larger blocks on the seafloor. Mn coated. Nice sponge. Decide against sampling.		
13:44	2501.1	139	Attempt to sample from outcrop with knobbly surface. Break a piece off outcrop. Orange color. Falls into basket 3	R13	pumice
13:50	2488.7	117	Move in to sample from outcrop. Break a piece off. Black with some sediment cover. Mn-coat. Small sample, subrounded. Basket 4.	R14	porphyritic ol-basalt
13:54	2483.6	119	Rocks have slabby appearance. Flat upper surfaces. Light sediment cover.		
13:57	2482.7	117	Try to sample. Take a loose subangular block. Mn-coated. Dropped into basket 3 and then moved to 4. Once sample is secure leave way point 8 and fly on to way point 9.	R15	porphyritic ol-basalt
14:45	2496.8	121	Bottom in view. Head to bottom and start transect four from somewhere around way point 9.		
14:46	2493.0	101	Rugged seafloor, rough Mn-coated outcrop. Attempt to sample. There are loose blocks. Able to lift one up with manipulator, disturbs sediment and HPD enveloped in cloud. Wait for it to clear. Large block. Partially covered in pale orange sediment. Drops in to basket 3.	R16	vesicular basalt
15:01	2453.1	102	Flying over lava flow outcrops. Look like tubes, with ribbed exterior surface. Mn coating or primary? Move down to sample this area - looks like we will try and sample tube structure.		
15:13	2453.1	020	Shrimp wonders what the fuss is about. Swims around investigating... Still working on tube structure, trying to break a piece off. Mn coat - annoying. Scarring and scratching the Mn, but beyond that not having any success...		
15:26	2453.5	015	Pick up block from the vicinity of the tube structure - think it was loose, but likely to proximally derived. Basket 4.	R17	vesicular basalt
15:28	2453.5	015	Thinking about R10 - still resting against the elbow of the left manipulator. Secure the samples with the right manipulator.		
15:33	2453.7		Leave the seafloor.		
16:53			On deck		

HPD#1157 Tracey NW lower slope

HPD#1157 July 18 2010 NW lower slopes and cones on NW lower slopes of Tracey Seamount

sample No.	latitude(N)		longitude(E)		depth (m)	rock type	shape	size X (cm)	size Y (cm)	size Z (cm)	weight(kg)	colour	alteration
HPD#1157-R01	13	41.059	144	20.381	2783	cpx-ol basalt	angular	18	20	9	5.5	black	fresh
HPD#1157-R02	13	41.075	144	20.392	2763	cpx-ol basalt	angular	32	12	18	16.5	black	fresh
HPD#1157-R03	13	41.097	144	20.399	2757	ol-cpx basalt	subangular	10	7	6	0.5	black	fresh
HPD#1157-R04	13	41.122	144	20.404	2736	cpx-ol basalt	subangular	23	21	18	4.5	black	fresh
HPD#1157-R05	13	41.122	144	20.404	2736	cpx-ol basalt	subangular	28	25	20	13	black	fresh
HPD#1157-R06	13	41.136	144	20.412	2717	ol-cpx basalt	angular	7	10	7	0.5	black	fresh
HPD#1157-R07	13	41.15	144	20.423	2705	pumice	subangular	10	7	7	0.5	brown	altered
HPD#1157-R08	13	41.157	144	20.430	2701	pumice	subangular	7	6	5	0.1	brownish white	altered
HPD#1157-R09	13	41.021	144	20.693	2597	ol-basalt	subangular	15	15	17	4.5	black	fresh
HPD#1157-R10	13	41.02	144	20.719	2577	ol-basalt	subangular	45	34	30	38	black	weak
HPD#1157-R11	13	41.031	144	20.743	2572	ol-basalt	subangular	35	22	17	15	dark gray	weak
HPD#1157-R12	13	40.95	144	20.911	2518	pumice	subangular	8, 9, 10	6, 7, 3	8, 11, 5	0.5	pale gray	altered
HPD#1157-R13	13	40.939	144	20.913	2500	pumice	subangular	12, 5, 13	11, 10, 15	8, 14, 14	3.5	orange-white	altered
HPD#1157-R14	13	40.929	144	20.930	2488	porphyritic ol-basalt	subrounded	12	10	8	1	dark gray	weak
HPD#1157-R15	13	40.924	144	20.949	2483	porphyritic ol-basalt	angular	30	14	18	10	black	weak
HPD#1157-R16	13	40.756	144	21.198	2494	vesicular basalt	subrounded	35	22	23	13	dark gray	weak
HPD#1157-R17	13	40.753	144	21.240	2453	vesicular basalt	subrounded	28	22	19	7	dark gray	altered
HPD#1157-Unknown											0.5		

HPD#1157 Tracey NW lower slope

Mn coating	Glass rim	phenocrysts	vesiculation	Memo	
1 mm		ol 6; px 3; pl 4	moderate 15%	ol <2 mm; px <3 mm; pl <2 mm	HPD#1157-R01
2 mm		ol 6~8; px 2~3; pl 3~5	weak 5-10%	ol <1 mm; px <2 mm; pl <4 mm	HPD#1157-R02
10 mm	8 mm	ol 1~3; px 3~5; pl 4~5	moderate 15%	vesicles filled by sediment	HPD#1157-R03
1 mm		ol 6-8; px 2-3; pl 2-4	moderate 20%		HPD#1157-R04
5 mm	3 mm	ol 8-10; px 1-2; pl 1-3	moderate 20%	ol, px <2 mm; pl <3 mm	HPD#1157-R05
8 mm	4 mm	ol 4-6; px 4-6; pl 3	moderate 15%	ol <1 mm; px <3 mm; pl <2 mm	HPD#1157-R06
film		px <1; pl 1-2; hb <1; qz <1	strong 40%		HPD#1157-R07
1 mm		px <1; pl 1-2; hb <1; qz <1	strong 40%	includes mafic enclave, <3 mm x 2 mm	HPD#1157-R08
film	5 mm	ol 25; pl 5	moderate 20%	vitreous ol ~3 mm; pl glomerocrysts 3 mm	HPD#1157-R09
1~2 mm	3~4 mm	ol 15; px ±; pl <1	moderate 20%	ol <2 mm; rare glomerocrysts of fp, 3 mm; zeolite amygdales	HPD#1157-R10
2-3 mm	3-4 mm	ol 15; pl 10	moderate 20%	ol <2 mm; pl <5 mm; vesicles <5 mm	HPD#1157-R11
		hb 5	strong 50%	hb 3 mm	HPD#1157-R12
patchy		hb 5; qz 5	strong 50%	hb 3 mm; qz <2 mm	HPD#1157-R13
3-4 mm		ol 15; pl 10	moderate 15%	vesicles <5 mm, filled with sediment; 10 mm pl glomerocryst	HPD#1157-R14
2-3 mm		ol 20; pl 5	weak 5-10%	ol <5 mm; pl <2 mm, pl glomerocrystic; enclave of less porphyritic basalt, irregular morphology, 20 mm long axis; vugs <20 mm; rock massive other than vugs	HPD#1157-R15
	2 mm	pl 2-5	moderate 25%	pl <1 mm; vesicles 15 mm; vesicles infilled with sediment	HPD#1157-R16
10 mm	3-4 mm	ol 1-2; pl 1-2	strong 30%	green/gray alteration rim below glass; vesicles <10 mm; vesicles infilled with sediment and oxides	HPD#1157-R17
				several fragments, include pumice	HPD#1157-Unknown