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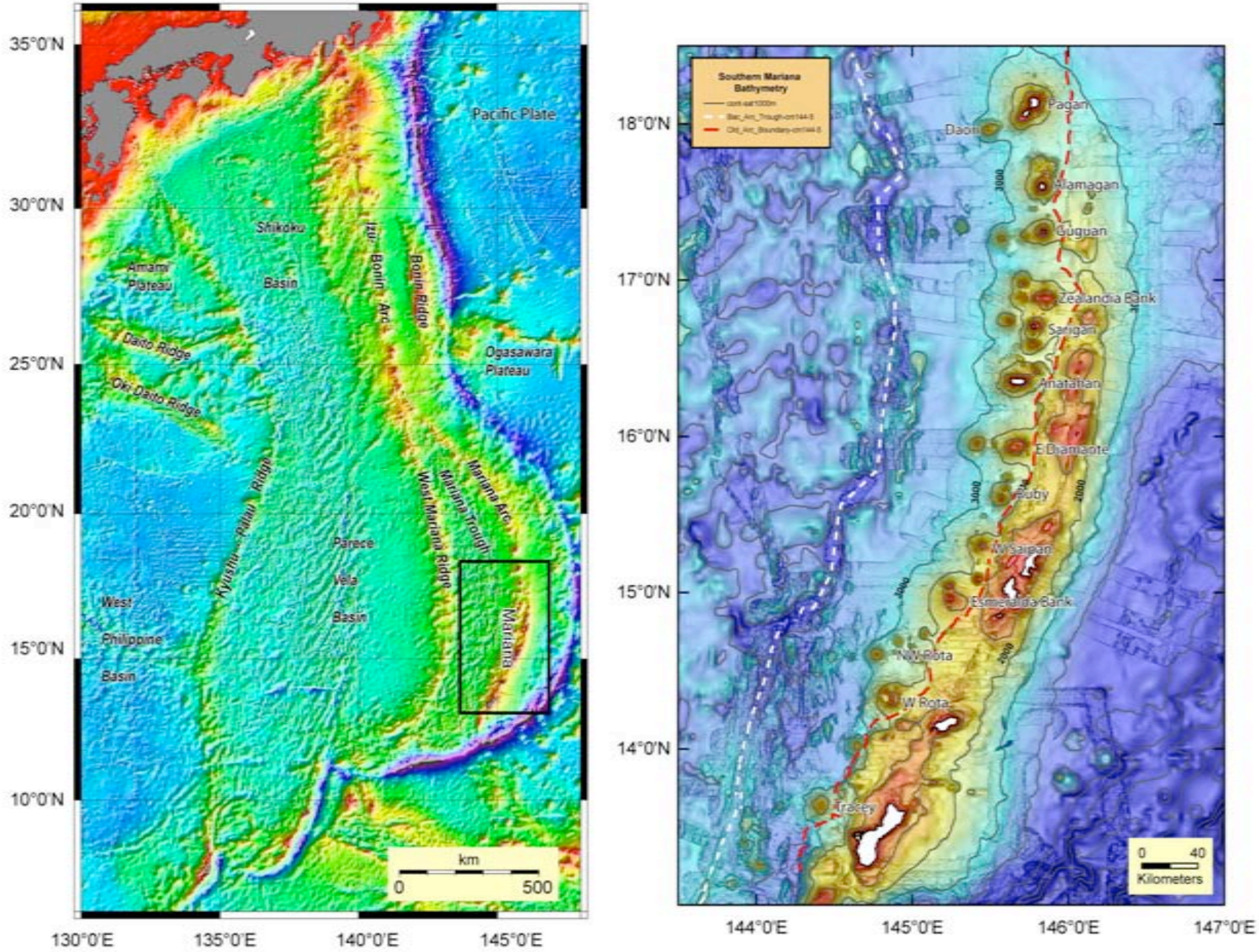
R/V NATSUSHIMA CRUISE REPORT
NT09-08
SOUTHERN MARIANA ARC, JUNE 9 TO JUNE 23, 2009

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

Anatahan, Mariana



Volcanoes in the Mariana arc (upper figure) and the Izu-Bonin-Mariana arc (lower figure)

LIST OF CRUISE PERSONNEL

Scientific Personnel

Yoshihiko TAMURA
Institute for Research on Earth Evolution (IFREE),
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

Robert J. STERN
Geosciences Dept. University of Texas at Dallas

Robert W. EMBLEY
NOAA. Pacific Marine Environmental Laboratory,

James HEIN
U.S. Geological Survey, MS 999

Erika JORDAN
Geosciences Dept. University of Texas at Dallas

Julia RIBERIO
Geosciences Dept. University of Texas at Dallas

Nicole SICA
Geosciences Dept. University of Texas at Dallas

Edward John KOHUT
University of Delaware , Dept. of Geological Sciences

Scott Andrew WHATTAM
Rutgers University

Alexander NICHOLS
Institute for Research on Earth Evolution (IFREE),
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

Yuka HIRAHARA
Institute for Research on Earth Evolution (IFREE),
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

Ryoko SENDA
Institute for Research on Earth Evolution (IFREE),
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

Akiko NUNOKAWA
Institute for Research on Earth Evolution (IFREE),
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

Misumi AOKI
Marine Technician
Nippon Marine Enterprises, LTD.

Displays in the room controlling the Hyper-dolphin

ROV Hyper-Dolphin Operation Team

Operation Manager	Kazuya MITSUFUJI
1st Submersible Staff	Yoshio ONO
1st Submersible Staff	Kazuki IIJIMA
2nd Submersible Staff	Katsushi CHIBA
2st Submersible Staff	Hideki SEZOKO
3rd Submersible Staff	Shigeru KIKUYA
3nd Submersible Staff	Atsushi TAKENOUCHI

R/V Natsushima Crew

Captain	Sadao ISHIDA
Chief Officer	Rikita YOSHIDA
2nd Officer	Kazunori KAMIYA
3rd Officer	Motoi KATSUMATA
Chief Engineer	Hiromi KIKKAWA
1st Engineer	Masahiro KAJIHARA
2nd Engineer	Yoshinobu HIRATSUKA
3rd Engineer	Yoshiaki HIRATSUKA
Chief Electronic Operator	Masamoto TAKAHASHI
2nd Electronic Operator	Hidehiro ITO
3rd Electronic Operator	Ken YAMAGUCHI
Boat Swain	Kazuo ABE
Able Seaman	Masanori IWASAKI
Able Seaman	Takuya MIYASHITA
Able Seaman	Hatsuo ODA
Able Seaman	Jiro HANAZAWA
Able Seaman	Kozo YATOUGO
Able Seaman	Takao KUBOTA
No.1 Oiler	Seiichi MATSUDA
Oiler	Yuji HIGASHIKAWA
Oiler	Sota MISAGO
Oiler	Yuki NAKAHARA
Oiler	Tsuneo HARIMOTO
Chief Steward	Teruyuki YOSHIKAWA
Steward	Hideki KUBOTA
Steward	Yukio TACHIKI
Steward	Shinsuke TANAKA
Steward	Norito IZUMI

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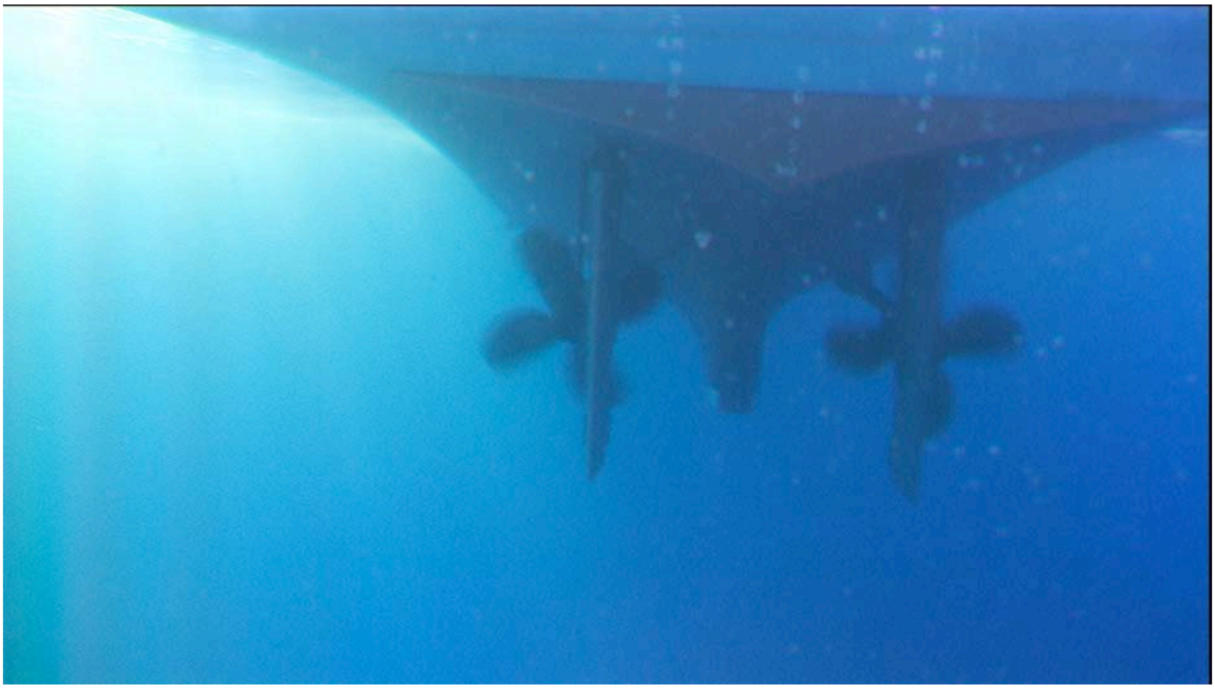

Propellers and rudders of Natsushima viewed from Hyer-Dolphin.

Rainbow in Mariana

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1. INTRODUCTION AND BACKGROUND

The Izu-Bonin-Mariana arc system (IBM) extends over 2800 km south from near Tokyo, Japan, to beyond Guam, U.S.A. (Fig. 1), and is an excellent example of an intra-oceanic convergent margin (IOCM). IOCMs are built on oceanic crust and contrast fundamentally with arcs built on continental crust, such as Japan or the Andes. Because IOCM crust is thinner, denser, and more refractory than that beneath Andean- or Japan-type margins, study of IOCM melts and fluids allows more confident assessment of mantle-to-crust fluxes and processes than is possible for continental arcs. Because IOCMs are far removed from continents they are not affected by the subduction of large volume of fluvial and glacial sediments. The consequent thin sedimentary cover makes it much easier to study arc infrastructure and determine the composition of mantle-derived melts. Active hydrothermal systems found on the submarine parts of IOCMs give us a chance to study how ore deposits form, and IOCM vents often have a uniquely diverse biota that we are only starting to study.

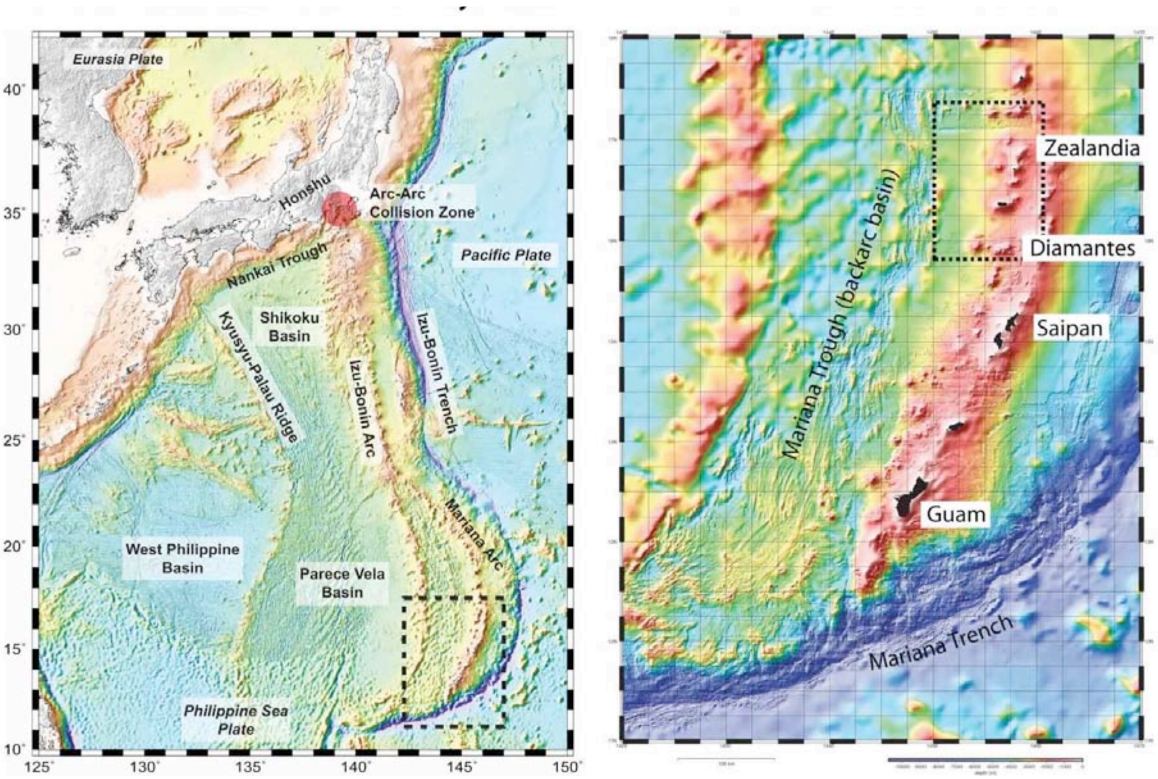

Figure 1. (left): The Izu-Bonin-Mariana arc system in the western Pacific; (right) The southern Mariana arc system, showing the area of Fig. 2 in dashed box.

The IBM arc presents an outstanding opportunity to study the operation of the Subduction Factory at an IOCM, for several reasons: 1) the history of IBM evolution is one of the best known of any convergent margin; 2) there are four opportunities across the arc to sample products being produced by the Subduction Factory – the forearc, the active magmatic arc, arc cross-chains, and back-arc basins - more than any other convergent margin; 3) subducted sediments are simple, diagnostic, and completely subducted; 4) IBM is a type example of convergent margins undergoing extension; and 5) IBM is large and diverse. Furthermore, a collision zone in the north provides an unparalleled opportunity to study the composition of middle IBM crust and so better infer products and processes leading to the formation of this crust. Because the islands and EEZ's of IBM are governed by the US in the south and Japan in the north, IBM provides special opportunities for teambuilding between US and Japanese scientists to collaborate and learn from each other, to involve young scientists in this process, and to work together to develop research proposals. The suitability of IBM for studies that promise to lead to fundamental understanding of Earth processes has made it a focus of international research efforts, including the US NSF-MARGINS 'Subduction Factory' experiment. It is likely to be an important focus of IODP drilling. In spite of its importance, we have much to learn about it in order to allow the best proposals to be written. An up-to-date overview of the IBM arc system can be found in (Stern *et al.*. 2003). This overview notes that the arc system shows important variations in tectonic and magmatic expression along its strike.

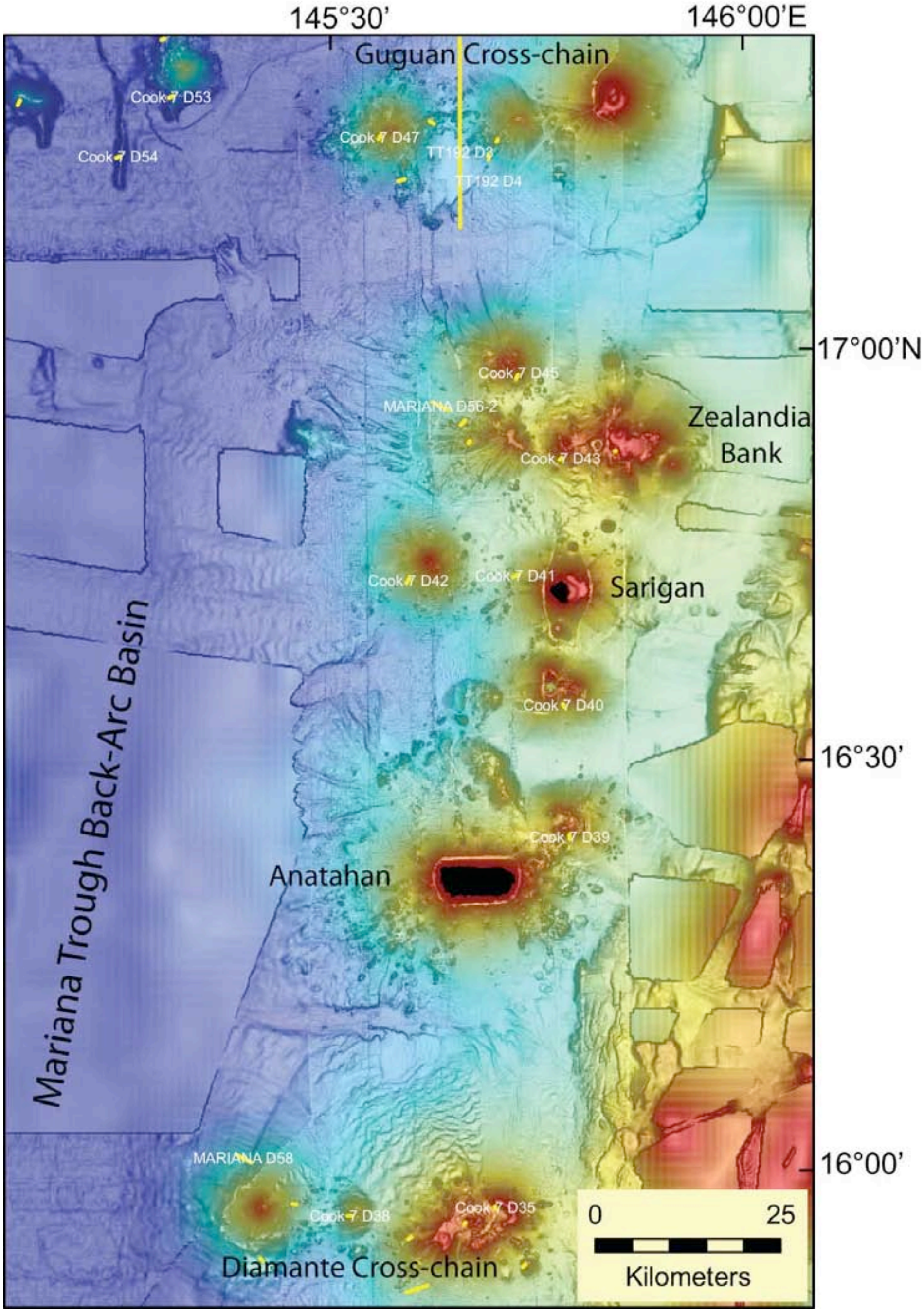

Figure 2. Region of the Mariana arc studied with Hyper-Dolphin during NT09-08. Five days of diving (HD1011-1018; June 11-15) were spent studying the Diamante Cross-chain. Five days of diving (HD 1019-1027; June 17-21) were spent studying the Zealandia/Sarigan region.

The southern Mariana arc is logistically favorable for marine geoscientific studies. It is situated close to populated islands of Guam, Rota, Tinian, and Saipan and these volcanoes mostly lie within the US EEZ. There are good international airports and ports on Saipan and Guam, so a minimum of time is spent transiting to and from ports and the study area. In spite of this, there have been relatively few studies of southern Mariana arc volcanoes, although this is rapidly changing. In 2001 this region was surveyed with HAWAII MR-1 and extensively dredge-sampled during the COOK 7 cruise (R/V Melville; Bloomer and Stern, co-chief scientists). In 2003 a NOAA cruise (R/V Thompson, Bob Embley, chief scientist) surveyed the region and identified likely sites of hydrothermal activity with CTD casts. In 2004 the NOAA team returned for interdisciplinary studies of vent geology, biology, and chemistry using ROV ROPOS. The NOAA effort has discovered numerous sites of volcanic and vigorous hydrothermal activity (Baker *et al.*, 2008). In 2006, the NOAA team returned with ROV JASON2 to continue their studies of hydrothermal vents.

Our team of Japanese and US scientists began studying the submarine volcanoes of the southern Mariana arc in 2005. During NT05-17, we made 10 dives with ROV Hyper-Dolphin on several geologic targets, including the 14°40'N cross chain, the active NW Rota-1 volcano (Embley *et al.*, 2006) and extinct W. Rota volcano and caldera (Stern *et al.* 2008). During NT09-02, we studied Tracey seamount, just west of Guam, for the first time; we also revisited West Rota caldera and NW Rota-1 volcano. West Rota and NW-Rota-1 provide important insights for understanding magmatic degassing (NW Rota-1) and formation of felsic magmas and associated massive sulfide mineralization (W. Rota). Bathymetric surveys of Tracey show a sector collapse with what appeared to be a small dome; if silicic, this area could also provide information on the formation of felsic magmas.

During the present cruise (NT09-08), we began to study two volcanic cross-chains that have not been previously studied in detail: the Diamante cross-chain (~16°N) and the volcanic plexus around Zealandia Bank and Sarigan island (~16°45'N). These two volcanic complexes represent volcanic cross-chains. Arc volcanic cross-chains provide excellent perspectives on how the subduction factory operates, because the volcanoes and their associated magmaic systems are built above the descending slab at different distances; the rear-arc volcano always over the subducted slab at greater depth than the volcano along the magmatic front. The magmatic systems at the magmatic front and the rear arc volcanoes sample fluids and melts released from the subducted slab at different depths and thus different P-T environments.

The IBM arc system has several cross-chains that have been studied, from the Izu cross-chain in the north (~32°N; Hochstaedter *et al.*, 2000, 2001; Machida & Ishii, 2003; Ishizuka *et al.*, 2003, 2006; Honda *et al.*, 2007; Tamura *et al.*, 2007), to the Kasuga cross-chain in the northern Marianas ~22°N (Stern *et al.*, 1993), to the Guguan cross-chain ~17°N (Stern *et al.*, 2006). The Zealandia/Sarigan and Diamante volcanoes studied during NT09-08 provide another outstanding perspective

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2. SUMMARY OF PRINCIPAL CRUISE RESULTS

2.1 The Diamante Cross-chain and East Diamante Geologic Evolution

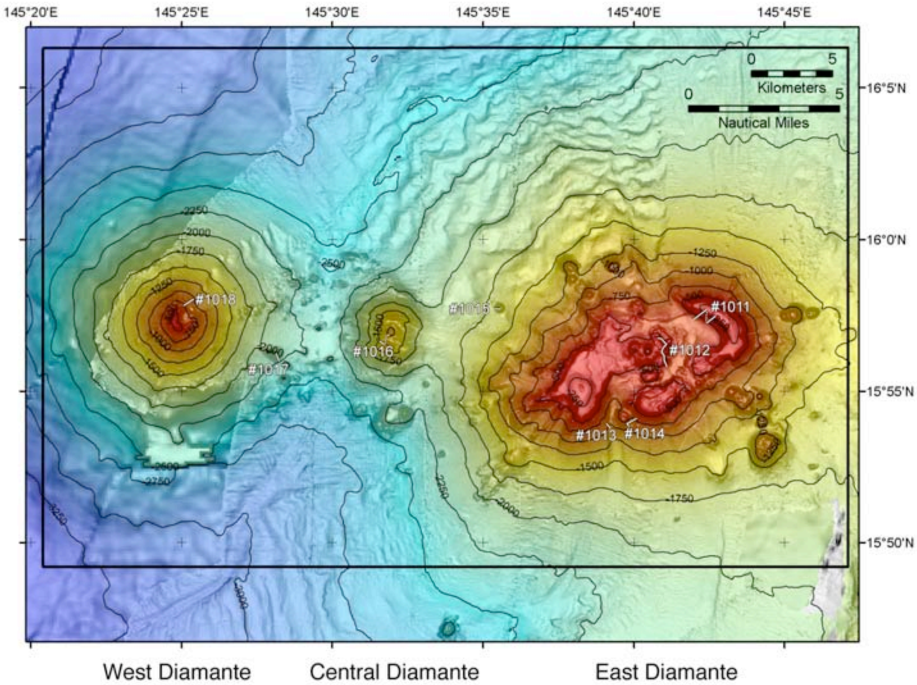

Figure 3. Bathymetric map of the Diamante cross-chain, showing locations of 8 dives.

The observations and samples carried out during HPD#1011-1014 represent a major improvement in our understanding of the Diamante cross-chain (Fig. 3) and especially how East Diamante volcano evolved. The Diamante cross-chain also provides another useful perspective about magmatic evolution varies with depth to the subduction zone, complementing studies in the Izu cross chains ~32°N (Hochstaedter et al., 2000, 2001; Machida & Ishii, 20086; Ishizuka et al., 2003, 2006; Honda et al., 2007; Tamura et al., 2007), the Kasuga cross-chain in the northern Marianas ~22°N (Stern et al., 1993), and the Guguan cross-chain ~17°N (Stern et al., 2006).

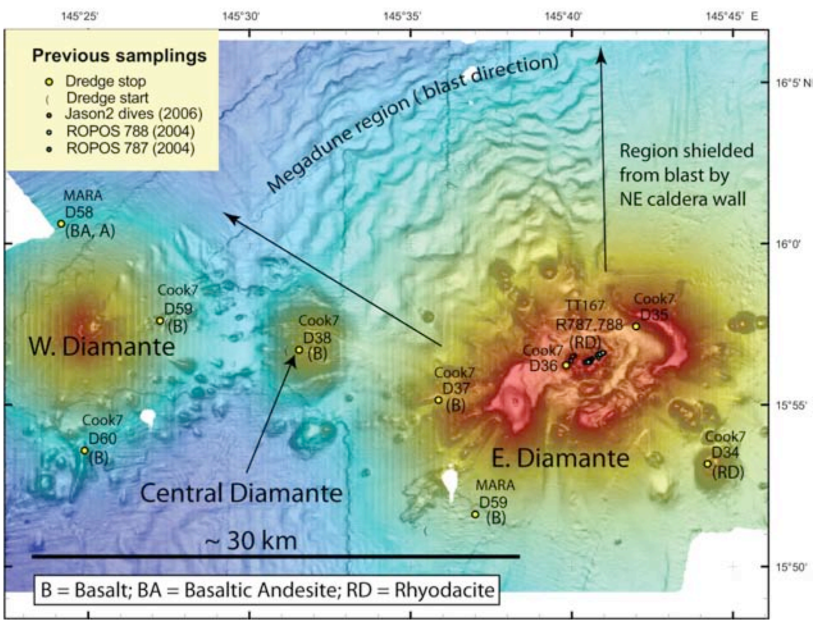

Figure 4. Bathymetric map of the Diamante cross-chain, showing locations of 4 of previous dredge samplings (1979 MARA and 2001 Cook7 expeditions). Also note location of megadune field, reaching >20km from caldera. These megadunes are thought to have formed as a result of NW-directed blast from E. Diamante caldera region, presumably during the latest episode of caldera collapse (schematically shown in Fig. 7).

West and Central Diamante are relatively simple basaltic volcanoes. Our dive results on these volcanoes (HPD#1016 and HPD#1018, respectively) and parasitic cones on their eastern slopes (HPD #1015 and HPD#1017, respectively are consistent with previous dive results indicating that these edifices are basaltic. Central Diamante is volcanologically interesting because it encapsulates the fact that the cross-chain is built on a site of N-S crustal extension, one of several E-W volcanic systems between 14°40’ and 17°N that are so controlled. The Diamantes are the site of a 2003 earthquake swarm (Heeszel et al., 2008). The Diamante swarm occurred between June and August 2003 and consisted of 111 crustal and shallow mantle earthquakes, concentrated beneath Central Diamante. Heeszel et al. (2008) concluded that these earthquakes reflected motion along a generally E–W striking, steeply dipping normal fault plane, with a dominantly N–S oriented tensional axis. This extension is also seen morphologically in Central Diamante, where E-W trending normal faults with scarps facing the summit region indicate that this volcano forms over a zone of strong N-S extension. The overall orientation of the cross-chain and the E-W elongation of E. Diamante volcano are also consistent with formation of the cross-chain in a stress regime dominated by N-S extension.

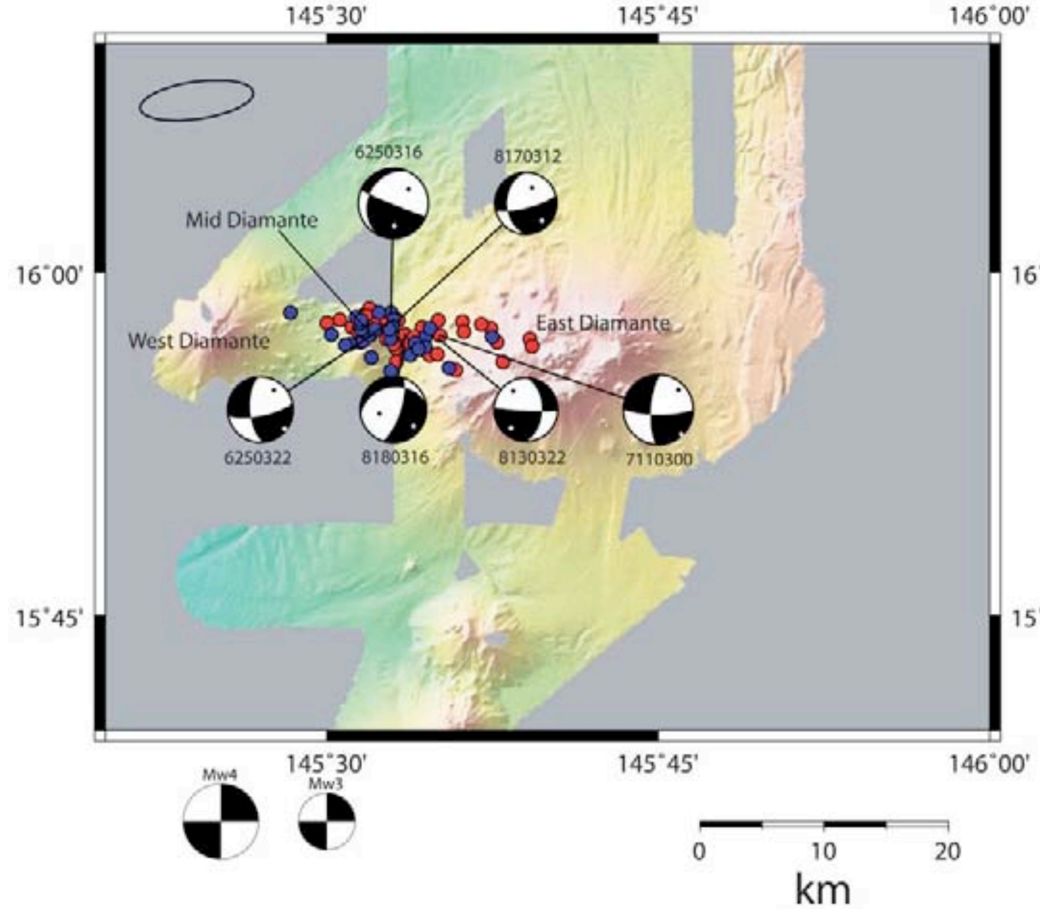

Figure 5. Detail of Diamante cross-chain area with focal mechanisms and earthquakes that were <20 km (red dots) and >20 km (blue dots) deep. East Diamante, Middle Diamante, and West Diamante seamounts are labeled. There is an E–W trending line of events centered over middle Diamante seamount. The focal mechanisms are largely consistent with an N–S extensional axis. Most share a steeply dipping E–W fault plane. Black and white diamonds on focal mechanisms represent compression and tension axes, respectively. Average 95% confidence ellipse plotted in upper left-hand corner (Heeszel et al. 2008)

E. Diamante is unusually complex, both volcanologically and petrologically. It is also the only known Mariana arc volcano with a vigorous “smoker” hydrothermal system, so understanding its geologic and petrologic evolution is of special interest. A 1-mile radius around the hydrothermal field is part of the US Mariana Marine Monument, established in late 2008. Furthermore, although E Diamante is a dormant volcano, it has erupted violently and thus poses some hazard to residents of the CNMI, Guam, and perhaps Japan. It is quite puzzling that nothing has been written about this volcano, except for the first report by Dixon & Stern (1983). This volcano is sufficiently important from a number of perspectives, warranting detailed geologic study, including geochronology, geochemistry, and a summary of hydrothermal activity and Zn-dominated mineralization. Nevertheless, our observations, coupled with dredge samplings and ROV studies of the hydrothermal fields by NOAA teams in 2003, 2004, and 2006 allow us to sketch the geology of the volcano, at least in broad strokes.

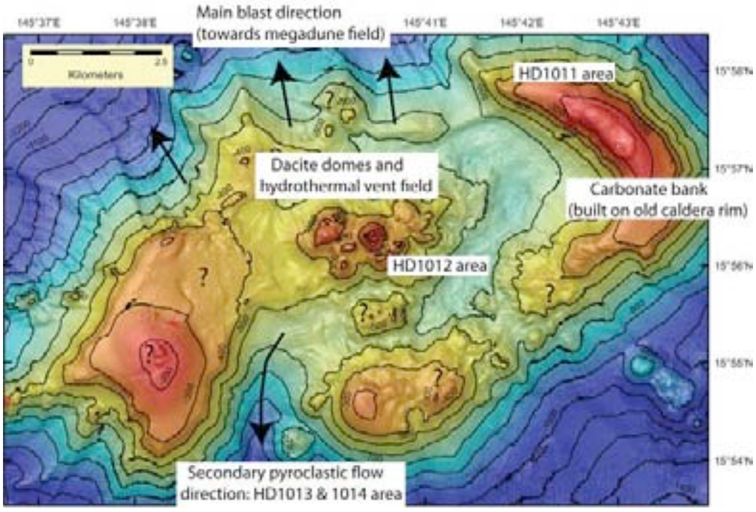

Figure 6. Bathymetric map of E. Diamante volcano, showing general location of 4 HPD dives and major geologic units. Six question marks '?' indicate regions where further dives are needed to better understand the evolution of the volcano.

Figure 6 depicts the summit 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. This is the only sector of the volcano that is so regular, and before diving on it, we were sure that it would expose pre-caldera collapse volcanic stratigraphy. Two transects of the inner wall during 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, as summarized in Fig. 7A-C.

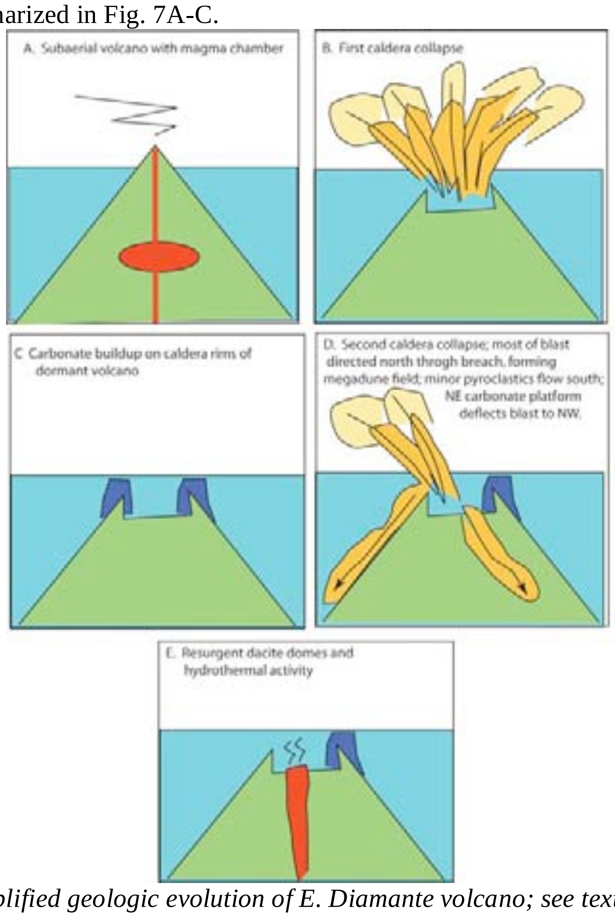

Figure 7. Simplified geologic evolution of E. Diamante volcano; see text for discussion

The igneous rocks that we collected during this and previous cruises allow us to paint the volcanologic and magmatic history of E. Diamante volcano, at least with broad strokes. Dixon & Stern (1983) described 4 samples of fractionated pyroxene basalt and basaltic andesites from ~1900m deep on the SW slope of E. Diamante. Cook7 Dredge 37 recovered fractionated basaltic andesite from the western flank of E. Diamante at 1766-1477 m. Such fractionated mafic and intermediate lavas may represent the early stage of the volcano (Fig. 7A). Two samples of basaltic andesite recovered as float during HPD#1013, 7 samples of andesitic float from HPD#1014, and two samples of pyroxene andesite float were collected during HPD#1012. None of these 11 basaltic andesitic/andesitic samples were collected from outcropping lava flows or dikes and we suspect that these are blocks ripped off of the older, buried volcano when younger felsic magmas ascended through this. These blocks were then distributed around the volcano during explosive felsic eruptions.

In support of the idea that E. Diamante basaltic andesites and andesites are petrogenetically liked to younger felsic magmas, a K_2O-SiO_2 diagram plots available analyses for the Diamante cross-chain (Fig. 8). This diagram shows that all analyses plot in the field for intermediate-K lavas, that E. Diamante has erupted significantly more fractionated lavas and pyroclastics than Central and Western Diamante, and that there is a significant “silica gap” for E. Diamante igneous rocks. These are “garden variety” Mariana arc lavas for the most part, which are typically a medium-K suite (Stern *et al*.., 2003). Diamante cross-chain lavas are distinguished only the abundance of felsic igneous rocks.

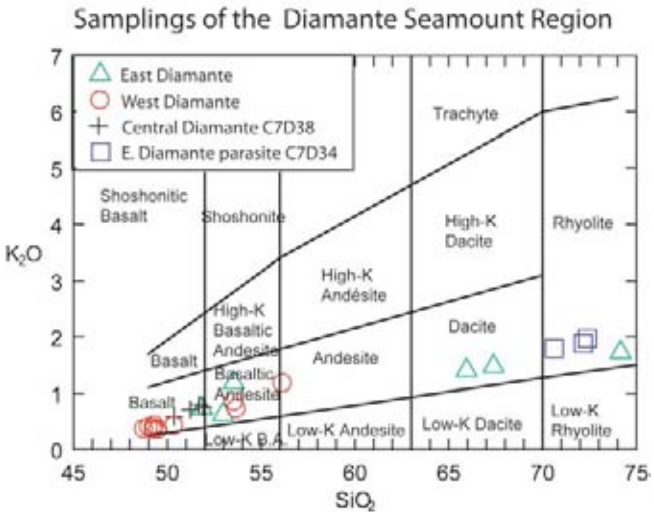

Figure 8. Potassium-silica diagram for samples previously collected and analyzed from the Diamante cross-chain. Note that the 3 samples of felsic igneous rocks from E. Diamante are from resurgent domes in the caldera.

This petrologic information provides context for the hydrothermal field in E. Diamante caldera. 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. 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 construction of the mounds pedestal.

NT09-08 HPD#1013 traversed a ~100m thick section of submarine felsic pyroclastics that coarsen upwards. These pyroclastics probably erupted from vents in what is today the caldera. This section is the only site observed during NT09-08 where evidence for explosive felsic eruptions, presumably related to caldera formation, were observed.

Observations from HPD#1011-#1015 and previous samplings allow for a simple, five stage history of E. Diamante seamount to be envisioned, which is presented in Fig. 7. It should be noted that, at present, we have no age constraints on any of the events depicted in Fig. 7, except that all Mariana arc volcanoes (including East Diamante) formed after the Mariana Trough back-arc basin began to open ~7Ma, and the hydrothermal system is still active. In the first stage, a large, basaltic to andesitic volcano was constructed, probably rising above sea level (A). Some time after this, the volcano “blew its top”, forming a large caldera (B). We have no direct evidence for this caldera, it is inferred from the presence of the NE caldera rim and the fact that the second caldera-forming eruption that formed the remarkable megadune field on the N flank of the volcano (Fig. 4) was diverted by the carbonate bulwark. Volcanic activity diminished and carbonate organisms, especially corals, grew on the remaining volcanic rim. These carbonate platforms thrived long enough to build up a several hundred meter thickness of shallow water carbonates, interrupted only rarely by minor volcanic eruptions (C). Pleistocene changes in sea level and tectonic uplift periodically exposed the carbonate platform to erosion and karstification. Finally, the volcano reawakened, and another explosive eruption created new caldera and a field of megadunes, up to 20 km distant from the caldera. A subordinate but still impressive, 100m-thick pyroclastic flow was directed south. Sometime after the second caldera-forming event, rhyodacitic domes were intruded into the caldera and minor dacitic lava flows issued from these domes. These felsic magmatic system provided sufficient heat to allow the development of a vigorous hydrothermal system, the activity of which continues today.

In contrast to the complex evolution of E. Diamante volcano, there is little that we can say about the evolution of Central and West Diamante volcanoes, other than that they formed above regions of mantle melting. In contrast to E. Diamante they had no discernible episodes of caldera formation. The relatively unfractionated lavas that we collected and that have been previously studied from these volcanoes indicate that no significant magmatic reservoirs exist beneath either volcano, perhaps because N-S extensional stresses allow direct routes to the surface for mantle-derived melts.

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2.2 Zealandia Bank-Sarigan Multi-Volcanic Complex Geologic Evolution

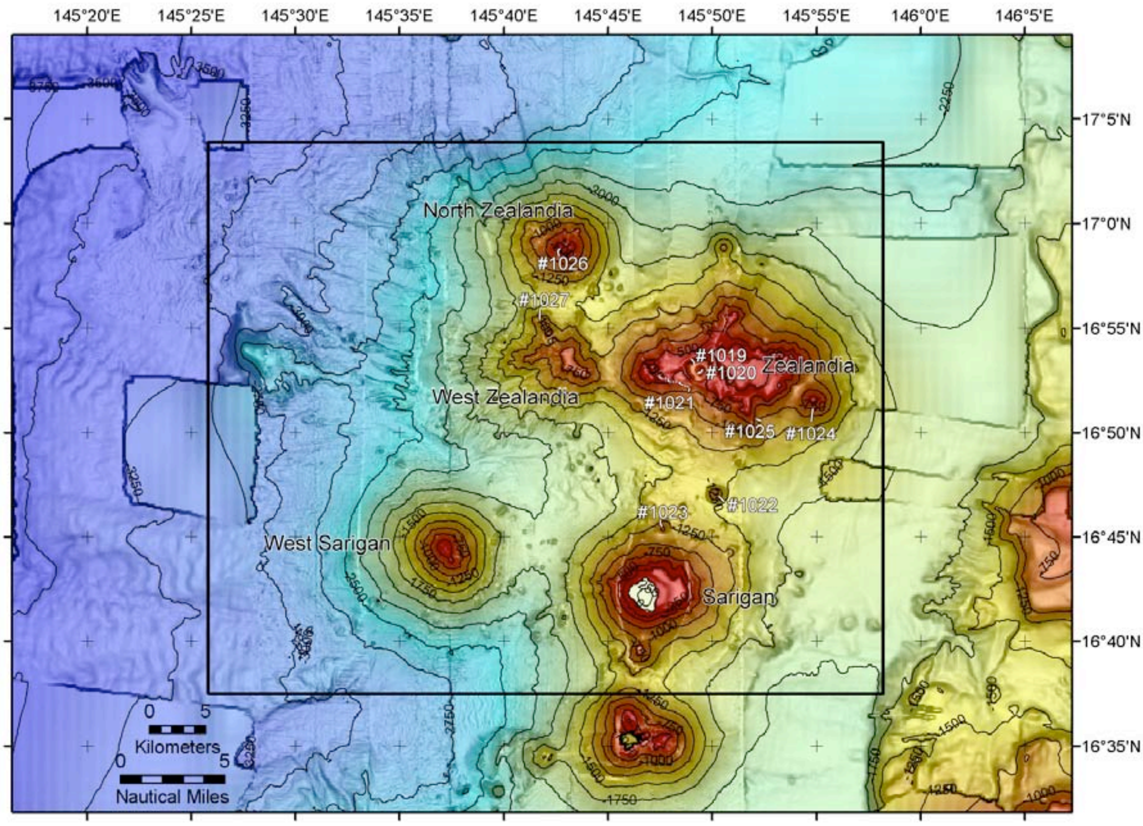

Figure 9. Dive tracks in the Zealandia and Sarigan.

The second area studied by NT09-08 is a group of 6 volcanoes around Sarigan island and Zealandia Bank, which lies about 100 km north of the Diamante cross-chain (Fig. 9). The tectonomagmatic history of the Mariana arc is dominated by formation ~50 Ma and reorganization of the magmatic arc following rifting to form the Mariana Trough back arc basin ~ 7Ma. The magmatic arc in this part of the Marianas is associated with a well-defined, west-facing scarp that separates the shallower, structurally uplifted frontal arc (and its associated islands) from the magmatic arc, which is built on significantly deeper backarc basin crust to the west (Bloomer *et al.*., 1989). This scarp is actually a broad fault zone, which can be seen to comprise several anastamosing splays where it is exposed, some of which we mapped during evening surveys with SeaBat. This fault system formed during Late Miocene rifting, and it may have been reactivated more recently in association with uplift of the southern Mariana forearc. The magmatic arc is built on seafloor ~2500m deep whereas the forearc ridge is mostly <1000m deep, so there is at least 1.5 km of throw along the several strands of this fault system, and probably significantly more. We suspect that similar normal faults are buried beneath the arc volcanic pile north of ~17°N and that these faults exert important controls on the location of the magmatic arc. This fault system is not discernible north of ~17°N. Very little is known about this fault system, and it should be examined more closely in the future.

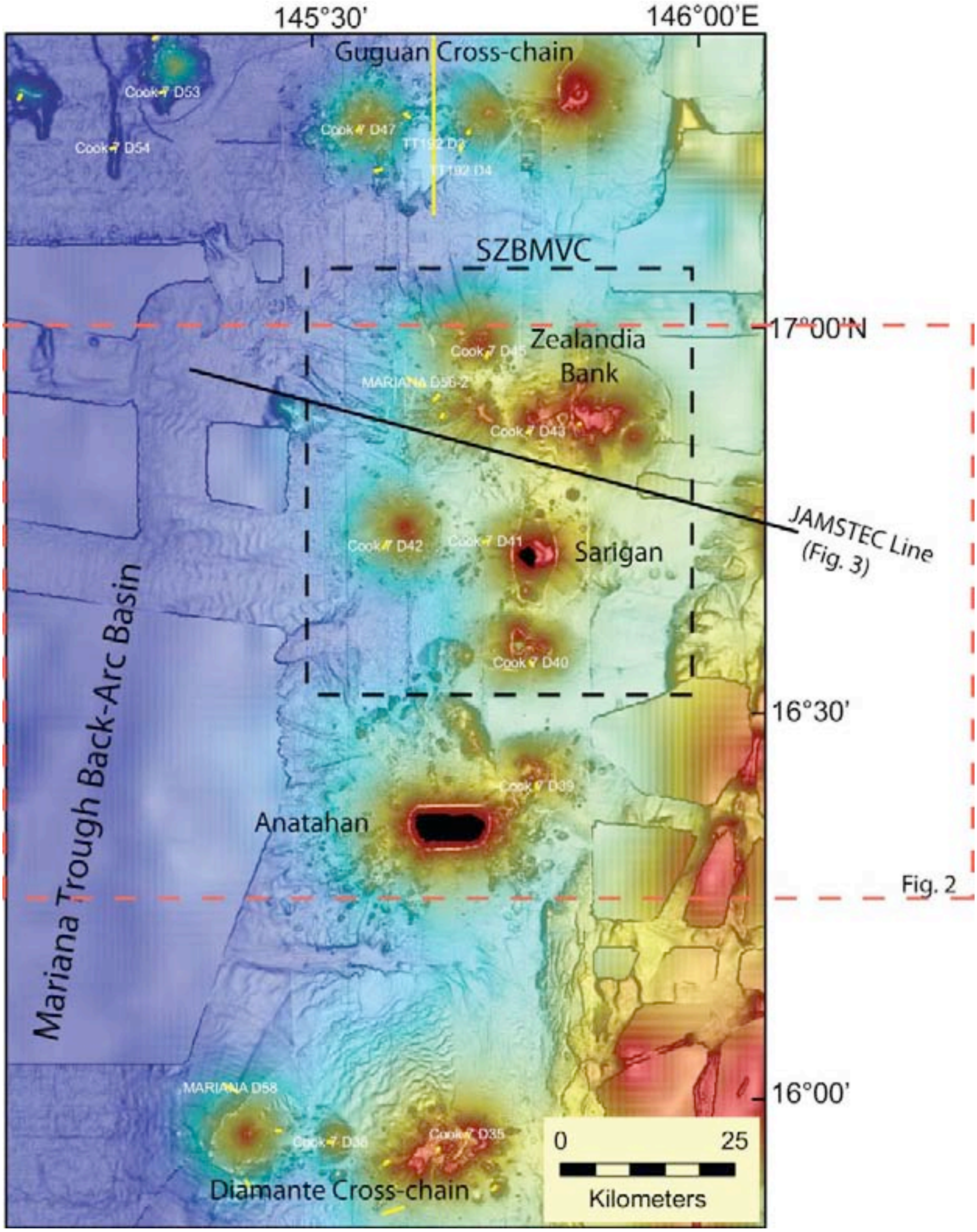

Figure 10. Bathymetric map of the greater Diamante-Zealandia Bank/Sarigan area, showing locations of previous dredge samplings (1979 MARA and 2001 Cook7 expeditions). Dashed red box shows the region covered in Fig.11. Dashed black box shows the area encompassed by the Sarigan-Zealandia Bank Multi-Volcanic Complex.

The study area is around Zealandia Bank and Sarigan island, between ~16°30' and 17° N, in the southern part of the Mariana Central Island Province (Bloomer *et al.*, 1989). Volcanic rocks from this region have been studied somewhat, including petrologic and volcanologic studies of Sarigan (Dixon & Batiza 1979; Meijer & Reagan, 1981), reconnaissance studies of Zealandia Bank and West Zealandia (Dixon & Stern,1983), and unpublished analyses of rocks recovered from W. Sarigan and NW Zealandia during Cook 7. Because of the several volcanoes in the region and their petrologic diversity, we informally refer to the region outlined in the dashed black box in Fig. 8 as the Sarigan-Zealandia Bank Multi-Volcanic Complex (SZBMVC).

There are some unusual aspects of SZBMVC volcanism. First, igneous activity along this part of the magmatic front is distributed among 6 closely-spaced major edifices, rather than being concentrated in a single volcano (such as Anatahan to the south) or in a single cross-chain (such as Guguan to the north and Diamante to the south). The volcanoes are not organized into a well-defined cross-chain, either. Instead the volcanoes define two parallel magmatic loci, one along the magmatic front (Zealandia Bank, Sarigan, and S. Sarigan) and the second, rear-arc locus ~15 km west (NW Zealandia, W. Zealandia, and W. Sarigan). It seems that either there is a broad zone of melt generation beneath this region or melt conduits to the surface are poorly organized.

The seismicity study of Heeszel *et al.* (2008) revealed shallow seismicity in the Sarigan-Zealandia region, but no stress field that would tend to favor cross-chain alignments. Four focal mechanisms were calculated, showing different orientations of extension. Forearc extension is directed WNW-ESE, probably related to continued movements along the arc-forearc normal fault system, whereas extension just NE of Zealandia is NW-SE, and extension seamounts of West Zealandia and West Sarigan is oriented N-S. It may be that coexisting NW-SE-directed extension along the magmatic front and N-S directed extension beneath the rear-arc volcanoes allows melts to be distributed between E-W and NNE-trending conduits, the intersection of which defines where volcanoes grow. Such an interpretation is attractive because of the line of small basaltic volcanoes, trending NNE-SSW between Sarigan and Zealandia, studied during HPD#1022, #1023, and #1024.

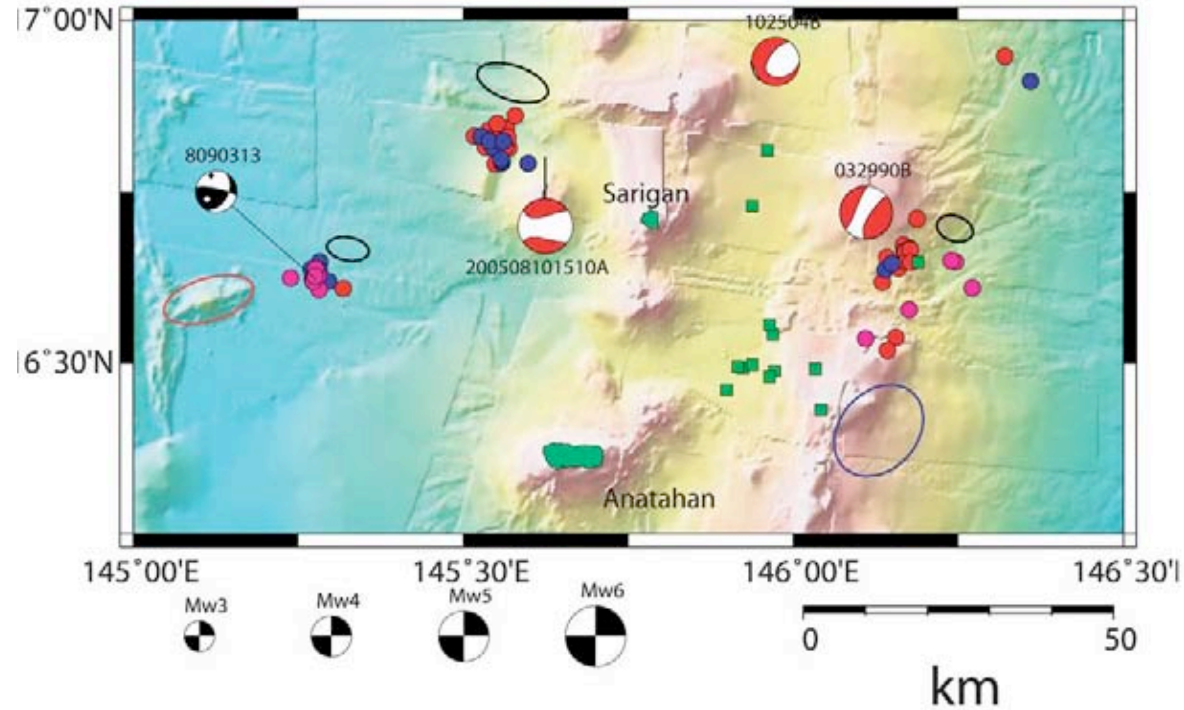

Figure 11. Figure from Heeszel et al. (2008) showing four earthquake swarms in 2003 around Anatahan and Sarigan Islands. Epicenters detected with a local seismic network are shown as red (0–20 km), blue (20–30 km) and magenta (30–40 km) circles with average 95% confidence ellipses plotted in black near each swarm. Teleseismically detected earthquakes that predate (1990) their deployment are plotted as green squares with an average 95% confidence ellipse plotted in blue. The swarm at 16_40N is the only one, besides that at Diamante, for which a focal mechanism was determined. Its proximity to a small anomalous seafloor structure (red circled region) indicates potential contraction of the region between the arc and back-arc spreading center. The swarm near northwest Sarigan along with a CMT solution for the same region suggests possible volcanic activity. The two swarms in the fore arc, of which the 1990 swarm is the most spread out, are likely the result of arc-perpendicular stresses in the fore arc. Focal mechanism from Heeszel et al. (2008) study is in black and those in red are from CMT catalog. Location of this study area is shown in Figure 10.

Takahashi *et al.* (2007) investigated crustal and mantle structure along a WNW-oriented line sited between Zealandia Bank and Sarigan, using active-source seismic profiling. They interpreted velocity variations to indicate a middle crust with velocity of ~6 km/s (which may be tonalitic in composition), laterally heterogeneous lower crust with velocities of ~7 km/s, and unusually low mantle velocities. Fig. 12 summarizes the results and interpretations of Takahashi *et al.*. (2007) near the Mariana arc. This is essentially the structure beneath the SZBMVC. Of special significance to the results of NT09-08 is the inferred presence of middle crust with Vp corresponding to felsic or intermediate igneous rocks. The abundant felsic igneous rocks that we recovered, especially from the western part of Zealandia Bank may reflect melts derived from this layer; this may also be the source of abundant felsic material found on E. Diamante farther south. The inferred presence of mafic and ultramafic cumulates at the base of the arc crust is also important, in light of the ultramafic xenoliths recovered in HPD#1027 samples, which may be the first recovery of such material from an intra-oceanic magmatic arc.

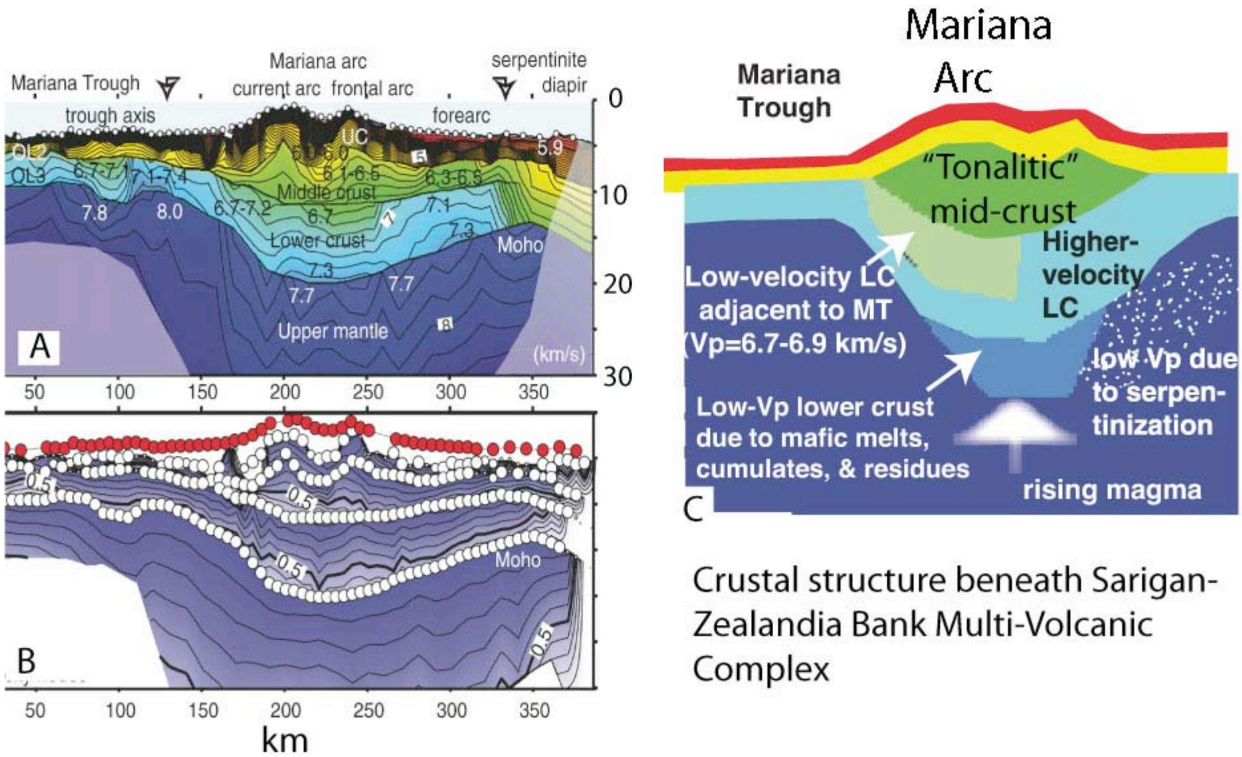

Figure 12. Crustal structure beneath the Sarigan-Zealandia Bank Multi-Volcanic Complex, modified after Takahashi et al. (2007). A. Final velocity model. Solid circles indicate ocean-bottom seismograph (OBS) locations. Numerals denote P-wave velocity (Vp) (km/s). Open arrows indicate boundaries between arc and backarc areas. UC, OL2, and OL3 are upper crust and oceanic layers 2 and 3, respectively. Dark shading shows region of seismic-ray penetration; bsl—below sea level. B: Resolution of final model. Resolutions of velocity nodes are indicated by color scale with contour spacing of 0.1, and those of interface nodes are shown by size of open circles. Red circles indicate OBS locations. C: Schematic interpretation of crustal growth of Mariana arc-backarc system: Mariana Trough (MT) and Mariana Trench; LC—lower crust.

A complementary geophysical perspective on crustal structure was presented by Calvert *et al.* (2008), who used active source crustal profiling and multiple crossing lines to produce a 3-dimensional map of crustal structure for much of the southern Mariana magmatic arc and frontal arc. This is shown in Fig. 13, which emphasizes the variable thickness of crust along as well as across strike of the arc. The thickest part of the arc in the sector between Zealandia Bank and Diamante is beneath the forearc, where it is 20-25 km thick. In contrast, the crust beneath this sector of the active arc is 15-20 km thick.

These geophysical perspectives provide useful context for the great petrologic diversity of SZBMVC shown in Fig. 12. The presence of a mid-crustal tonalitic layer is particularly important, because this may serve as the source of abundant felsic and intermediate lavas in the region. SZBMVC lavas show similarities and differences with other Mariana arc lavas. On one hand, SZBMVC lavas share the overall medium-K nature of Mariana arc volcanoes (Fig. 14), contrasting markedly with the Izu arc, which also contains abundant felsic lavas which contain less potassium (and other LIL elements).

There are significant and interesting differences between existing data for SZBMVC igneous rocks overall and those of larger volcanoes to the north and from Guguan and Diamante cross-chains. On one hand SZBMVC lavas define a medium-K suite similar to most Mariana arc volcanoes south of 20°N. On the other hand, magmatic front volcanoes to the north are dominated by fractionated basalts and basaltic andesites, whereas SZBMVC frontal arc lavas include abundant andesites and rhyodacite in addition to mafic lavas. This was first recognized on the larger, subaerial volcanoes of Sarigan and Anatahan. Meijer & Reagan (1981) first commented on the abundance of andesites on Sarigan, and Wade *et al.*. (2005) commented that "The large proportion of lavas with silicic compositions at Anatahan (>59 wt.% SiO_2) is unique within the active Mariana Islands…", including May 2003 tephra, with 59-63% SiO_2. In fact, Stern & Hargrove (2003) identified the Anatahan felsic province as a 115 km-long arc segment extending from East Diamante seamount (15° 55'N) to NW Zealandia Bank (17° N). The West Rota felsic volcanics (Stern *et al.*., 2008) could also be related to this well-developed factory for generating andesite and rhyodacite, although the mafic submarine volcanoes of Ruby and Esmeralda separate West Rota volcano from the Anatahan felsic province. Studies and sampling carried out during NT09-08 confirm the conclusions of Stern & Hargrove (2008) that felsic volcanism is common in the region between Zealandia Bank and E. Diamante seamount.

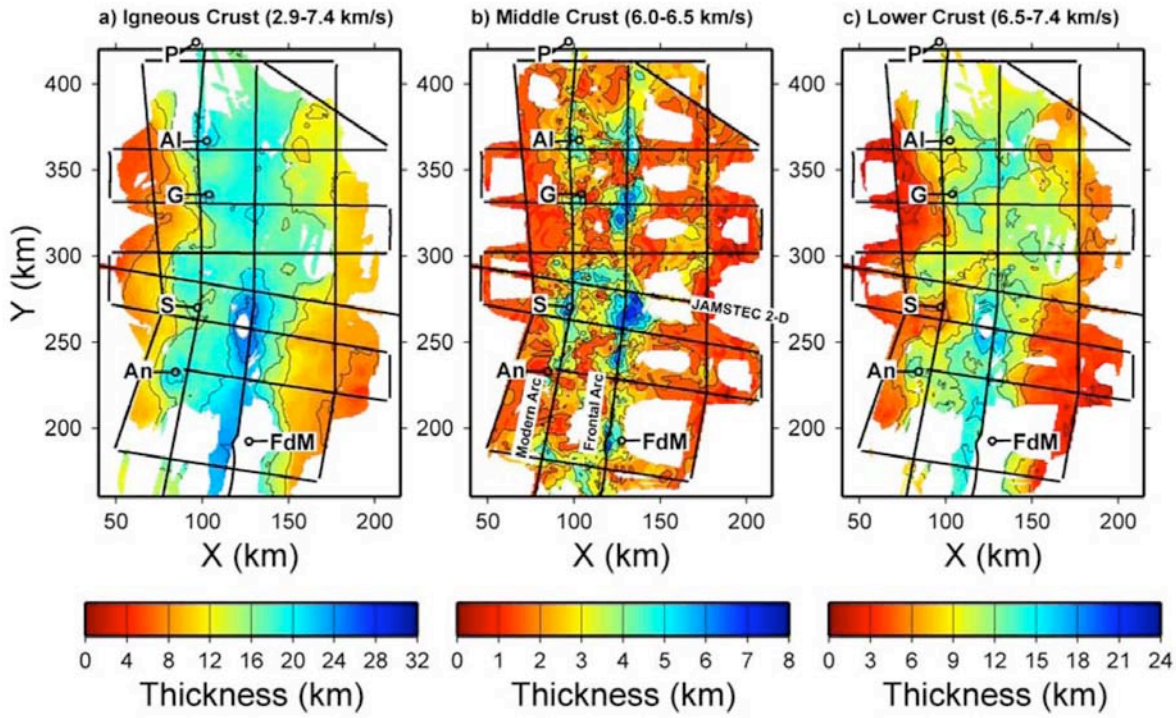

Figure 13. Crustal structure of the central Mariana arc, from active source seismic studies of Calvert et al. (2008). P, Al, G, S, and An are the active volcanic islands of Pagan, Alamagan, Guguan, Sarigan, and Anatahan, respectively. FdM is Ferdinand de Medinilla on the frontal arc. Location of the seismic line reported by Takahashi et al. (2007) and shown in Fig. 12 is also plotted. Isopachs are calculated from 3-D velocity model for: (a) igneous crust (2.9–7.4 km s^{-1}), (b) middle crust (6.0–6.5 km s^{-1}), and (c) lower crust (6.5–7.4 km s^{-1}).

NT09-08 explored Zealandia Bank volcano itself during four dives. The edifice is irregular in shape, a rhombohedra that is elongated E-W with spurs that strike due north and south of the main edifice. The faceted outline of the volcano does not appear to reflect sector collapse, there are no obvious slide or slump blocks around Zealandia Bank Volcano's flanks; instead the angular outline may be constructional. The overall elongated E-W shape of Zealandia Bank may reflect how N-S and E-W extensional stresses control volcanoes and cross-chains from Guguan in the north to the 14°40'N cross-chain in the south.

Dixon & Stern (1983) reported andesite from near the summit region (Fig. 10) and Cook 7 D43 from its western slope (Fig. 10) recovered voluminous felsic tuffs and pumice. This is all that was known about Zealandia Bank prior to NT09-08. Dives HPD#1019 explored the northern wall of the 1.5 km diameter caldera, Dive 1020 explored the cone in the caldera, and Dive 1021 explored the ridge to the west of the caldera (Fig. 9). These dives revealed that the western half of Zealandia bank is dominated by felsic tuffs and chaotic, pyroclastic flows. The presence of carbonates, both defining shoal surfaces and as xenoliths in the pyroclastics, suggests that the volcano has a protracted history of volcanism and quiescence, when reefs develop. Breccias and conglomerates dominated by mafic clasts found during HPD#1021 (traverse 6) and HPD#1024 suggest that the bulk of the volcano may be dominated by more mafic lavas and that felsic activity may have begun relatively recently.

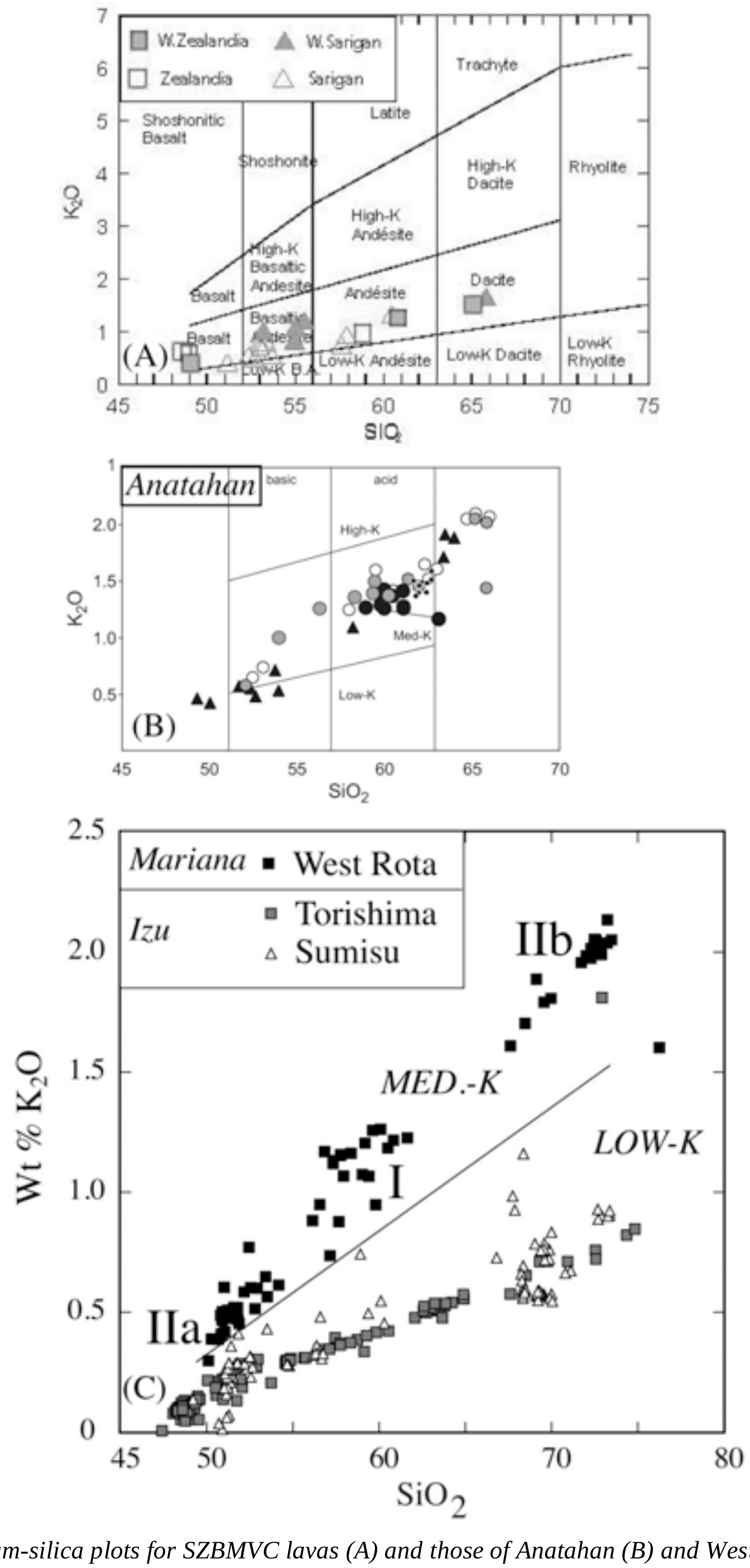

Figure 14. Potasium-silica plots for SZBMVC lavas (A) and those of Anatahan (B) and West Rota Caldera (C). Note the abundance of andesitic and rhyodacitic lavas, which is uncommon in other Mariana arc volcanoes to the north. SZBMVC data is from Dixon & Stern (1983) and Stern & Bloomer (unpublished Cook 7 data). Anatahan data is from Wade et al. (2005) and West Rota data is from Stern et al. (2008). Note that the Mariana data define a medium-K suite, in contrast data for the Izu arc define a low-K suite. Compare with K-Si plot for Diamante cross-chain in Diamante summary chapter.

Igneous banding was seen in rhyodacitic lavas recovered during dives 1020 (on the caldera cone) and dive 1021. This indicates magma mixing or mingling was important in the evolution of Zealandia rhyodacites. It could be that the unusual abundance of intermediate and felsic lavas reflects a well-developed magmatic reservoir associated with larger, older volcanoes. This argument is attractive for West Rota and E. Diamante volcanoes, where large calderas mark where extensive shallow magma chambers collapsed. Nevertheless, abundant intermediate and felsic lavas in the SZBMVC are not associated with large calderas (there is a small caldera on Zealandia Bank) and are not restricted to the subaerial volcanoes. Such lavas are even more abundant on three of the smaller, submarine volcanoes (Zealandia Bank, NW Zealandia, and West Sarigan; Fig. 15). In fact, volcano size does not control the abundance of felsic lavas within the Anatahan Volcanic Province; felsic lavas are not reported from Sarigan, whereas small parasitic cones NE of Anatahan and SW of E. Diamante erupt lavas with 65% and 72% SiO_2, respectively. The abundance of intermediate and felsic lavas in the Anatahan Felsic Province (including the SZBMVC) is a property of the region, not the volcano, suggesting that it reflects processes going on at depth.

Wade *et al.* (2005) specifically addressed the question of whether Anatahan felsic lavas formed via crystal fractionation or crustal assimilation. They concluded that the lack of $^{87}Sr/^{86}Sr$ variation with silica content, the MORB-like $d^{18}O$, and the incompatible behavior of Zr precluded assimilation of old or altered crust, or zircon-saturated crustal melts. They concluded that the constancy of isotopic and trace element ratios, and the systematic variations in REE patterns were most consistent with evolution by crystal fractionation of similar parental magmas. They did not specify where this fractionation occurred, and it seems likely that the felsic magmas are ultimately extracted from the middle crust shown in Fig. 12.

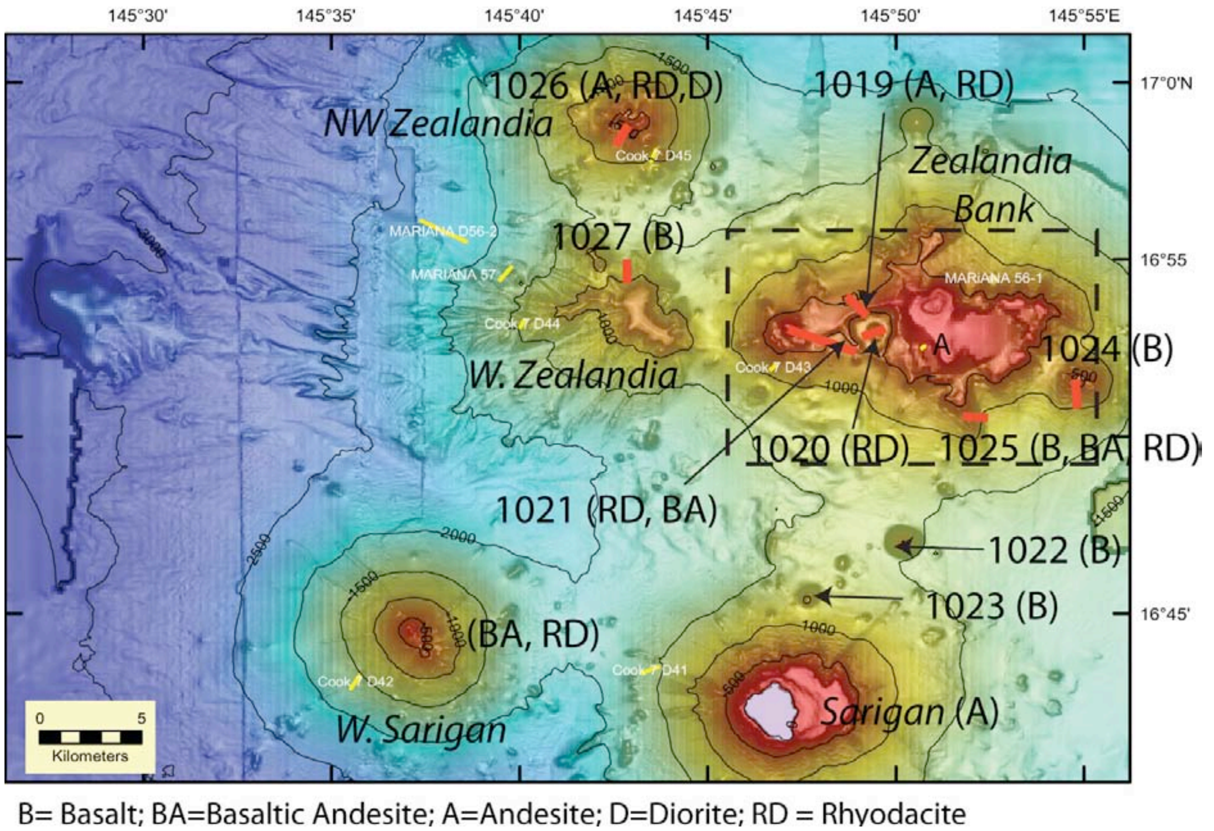

Figure 15. Region around Sarigan and Zealandia Bank studied during NT09–08. NT09-08 dives shown with red line, other samplings are shown with a thin yellow line: Mariana 56-1 = andesite; Mariana 56-2 = no sample; Mariana 57 = Ol basalt; Cook D41 = gabbro, basalt, pumice; Cook D42 = basaltic andesite, andesite, and dacite; Cook D43 = rhyodacite tuff; Cook D44= pumice; Cook D45 = basalt, andesite, and rhyodacite. Dashed box shows the area of detail shown in Fig.16.

Abundant rhyolite has erupted from the Izu-Bonin-Mariana volcanic arc (IBM arc) from its earliest stage (Eocene) to the present. Tamura *et al.* (2009) showed that, geochemically, three types of Quaternary rhyolites exist in the Izu-Bonin arc front, and they are closely related to volcano type and crustal structure. The dominantly basaltic islands of the volcanic front produce small volumes of rhyolites that we will call R1. The submarine calderas of the volcanic front erupt mostly rhyolite that we will call R2. Seamounts, knolls, and pillow ridges in the backarc extensional zone are mostly basaltic but also contain rhyolites that we will call R3.

The thickest total crust, and the thickest intermediate composition middle crust, occurs below the dominantly basaltic volcanoes, while the intermediate composition middle crust tends to be thinner beneath the submarine calderas. R1 rhyolites may be derived from Quaternary andesitic sources whereas R2 and R3 rhyolites may be derived from Oligocene ones. Remelting of middle crust to form rhyolite magmas takes place beneath both basaltic and rhyolitic volcanoes in the Izu-Bonin arc (R1 and R2 rhyolite, respectively). However, basalt volcanoes consume new middle crust to produce rhyolite magma whereas rhyolite volcanoes consume old Oligocene middle crust. Moreover, rhyolite volcanoes have no mantle roots beneath the crust. Instead, dikes from basalt volcanoes provide the heat source to partially melt the crust (Tamura *et al.,* 2009). The origin of felsic magmas in the Mariana arc will be informed by our current interpretations of those in the Izu-Bonin arc and will lead to fuller understanding of intra-oceanic arc genesis.

Another interesting result from NT09-08 was the recovery of olivine basalts from West Zealandia during HPD#1027. This volcano has an unusual morphology, with a summit region that has an arcuate summit and long flow-like features that may be lava reaching far to the west (Fig. 15). Dixon & Stern (1983) reported primitive basalts from this volcano and HPD#1027 also recovered abundant, fresh olivine basalts. Some HPD #1027 samples contain ultramafic xenoliths, quite unusual in the Mariana or any other intra-oceanic arc. Definitely, West Zealandia volcano warrants additional investigation.

Dives HPD#1022, #1023 and #1024 explored three small volcanoes, which we originally suspected were rhyodacitic. In fact, all three volcanoes are basaltic.

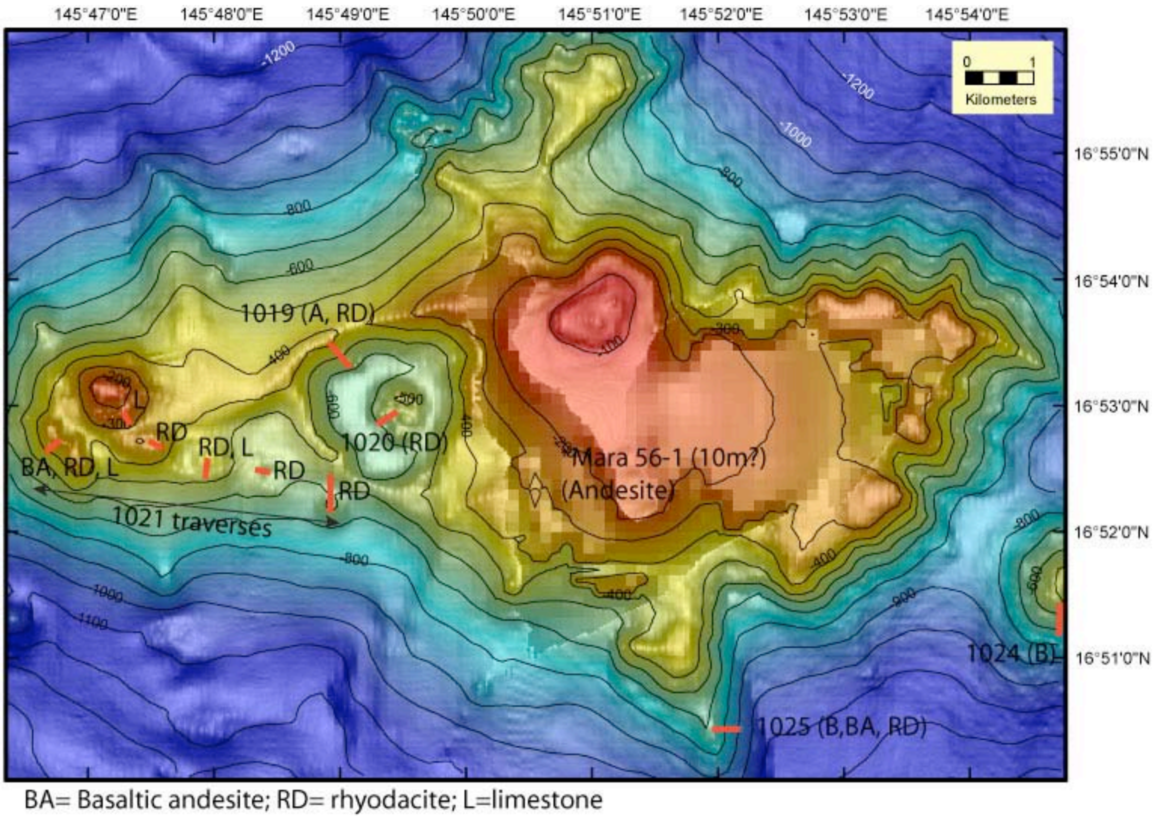

Figure 16. Bathymetric map of Zealandia Bank volcano (location shown in Fig. 15), showing general location of 5 HPD dives and major rock types recovered. Position of 10m SCUBA dive recovery of andesite (Dixon & Stern, 1983) also shown but must be mislocated. Shallow region around summit is unsurveyed (bathymetry estimated using satellite gravity).

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Sarigan

3. CRUISE NARRATIVE AND SCHEDULE OF OPERATIONS

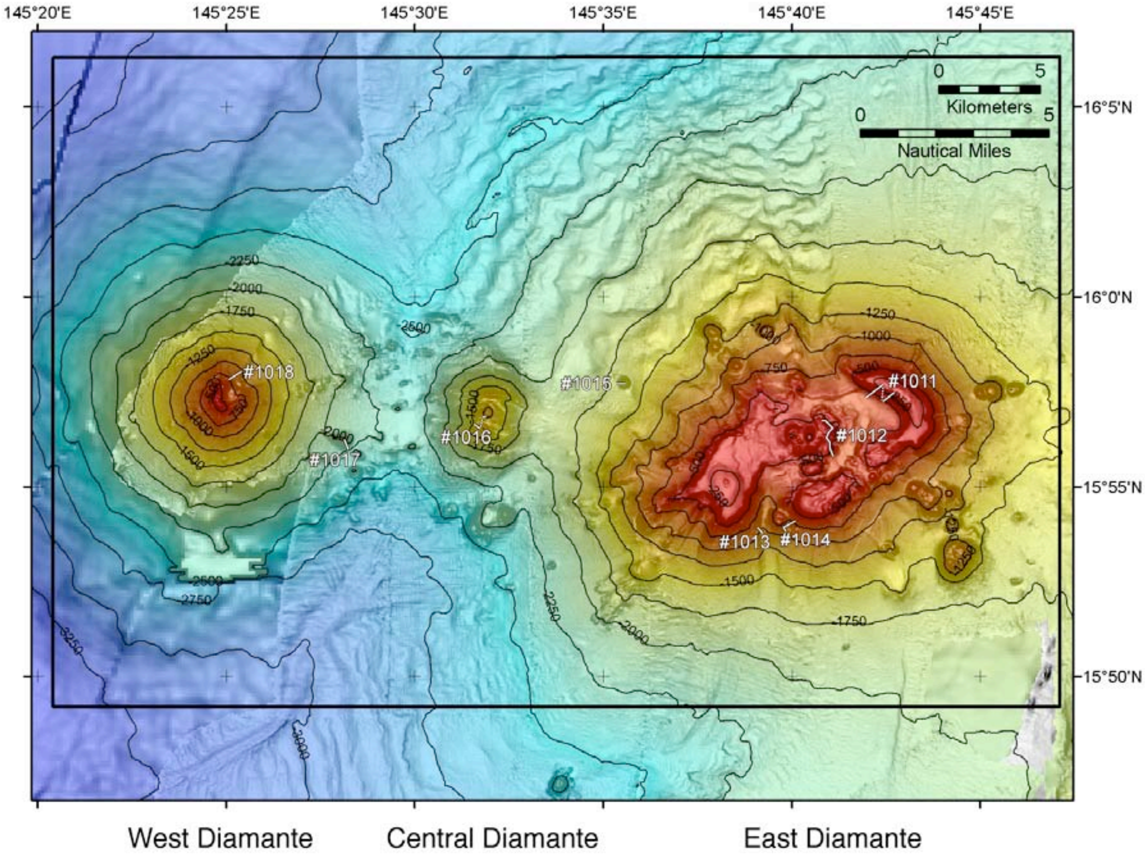


Figure 17. Bathymetric map of the Diamante cross-chain, showing locations of 8 dives.

R/V Natsushima departed Apra Harbor, Guam at 9:00 on June 10th, 2009. The ship arrived at East Diamante on June 11th and commenced dive operations for HPD#1011 at 8:00 (all times are local). Five days of diving (HPD#1011-#1018; June 11-15) were spent studying the Diamante Cross-chain (Table 3.1). R/V Natsushima completed additional Seabat surveys in southeast of East Diamante (145°28'E-145°58'E, 15°28'N-15°53'N) in the night-time from June 11 to June 14.

Dive #	Date	On Bottom		Off Bottom	
HPD#1011	June 11, 2009	08:43	560 m	14:45	145 m
HPD#1012	June 12, 2009	08:38	547 m	17:10	348 m
HPD#1013	June 13, 2009	08:54	1,076 m	10:47	861 m
HPD#1014	June 13, 2009	13:44	895 m	16:10	731 m
HPD#1015	June 14, 2009	09:11	1,591 m	10:33	1,496 m
HPD#1016	June 14, 2009	14:02	1,411 m	16:28	1,258 m
HPD#1017	June 15, 2009	09:22	2,211 m	10:48	2,078 m
HPD#1018	June 15, 2009	13:50	988 m	16:09	748 m

Table 3.1. Date, on bottom- and off bottom- time and depth of eight dives in the Diamante cross-chain.

R/V Natsushima completed additional Seabat surveys in east of Anatahan (145°50'E-145°59'E, 16°10'N-16°33'N) on June 16. Natsushima then moved to the Zealandia Bank-Sarigan Multi-Volcanic Complex on June 16th and commenced dive operations from June 17th.

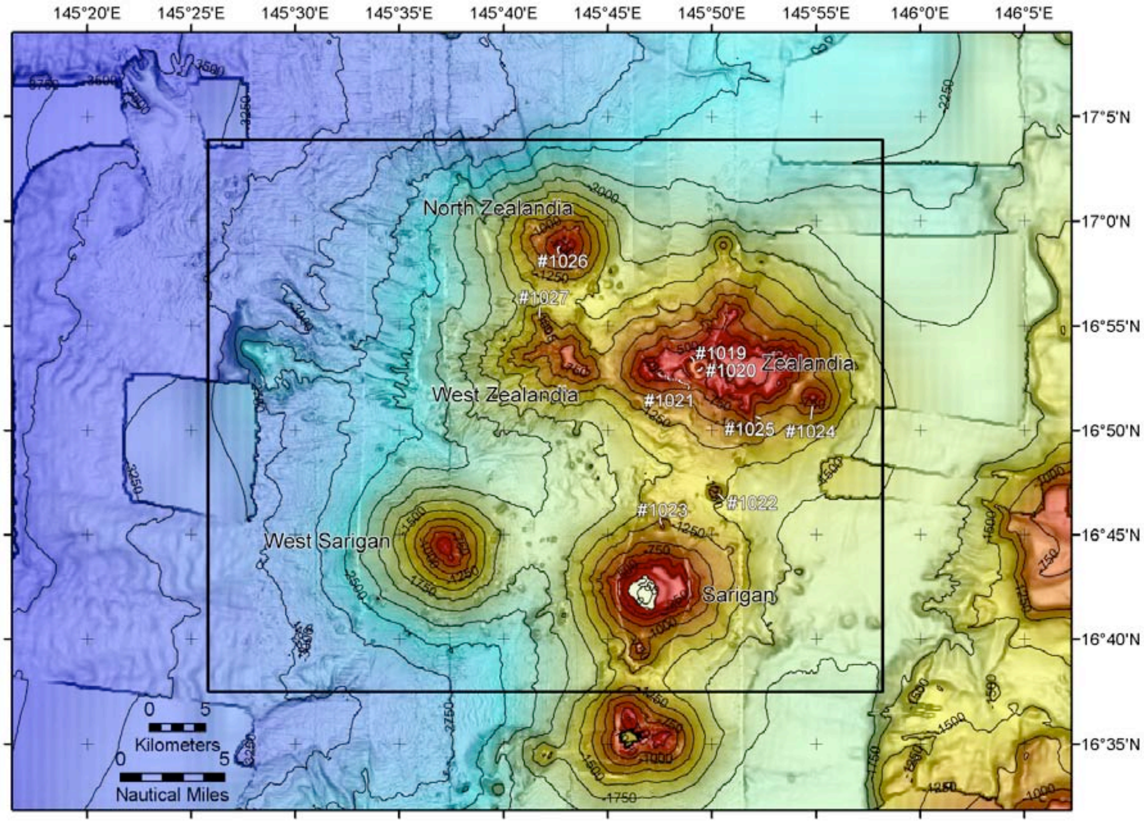


Figure 18. Bathymetric map of the Zealandia Bank-Sarigan Multi-Volcanic Complex, showing locations of 9 dives.

Dive #	Date	On Bottom		Off Bottom	
HPD#1019	June 17, 2009	08:37	637 m	11:09	368 m
HPD#1020	June 17, 2009	13:34	616 m	16:11	479 m
HPD#1021	June 18, 2009	08:41	716 m	15:44	288 m
HPD#1022	June 19, 2009	09:07	1,496 m	11:02	1,175 m
HPD#1023	June 19, 2009	13:50	1,286 m	16:01	1,059 m
HPD#1024	June 20, 2009	08:49	1,096 m	11:02	778 m
HPD#1025	June 20, 2009	13:44	1,023 m	16:06	838 m
HPD#1026	June 21, 2009	08:36	662 m	11:00	475 m
HPD#1027	June 21, 2009	13:50	1,390 m	16:13	1,135 m

Table 3.2. Date, on bottom- and off bottom- time and depth of nine dives in the Zealandia Bank-Sarigan Multi-Volcanic Complex.

Five days of diving (HPD#1019-#1027; June 17-21) were spent studying the Zealandia/Sarigan region (Table 3.2). Seabat surveying was completed in east of Zealandia Bank (145°52’E-146°06’E, 16°45’N-17°01’N) in the night-time from June 17 to June 20. Natsushima entered port at Saipan early on June 23rd where the scientific party disembarked.

4. BATHYMETRIC SURVEYS

R/V Natsushima completed additional Seabat (Figs. 19, 20 and 21) surveys in several areas around the dive sites. These data will be merged with existing multibeam data to produce final maps of each study area.

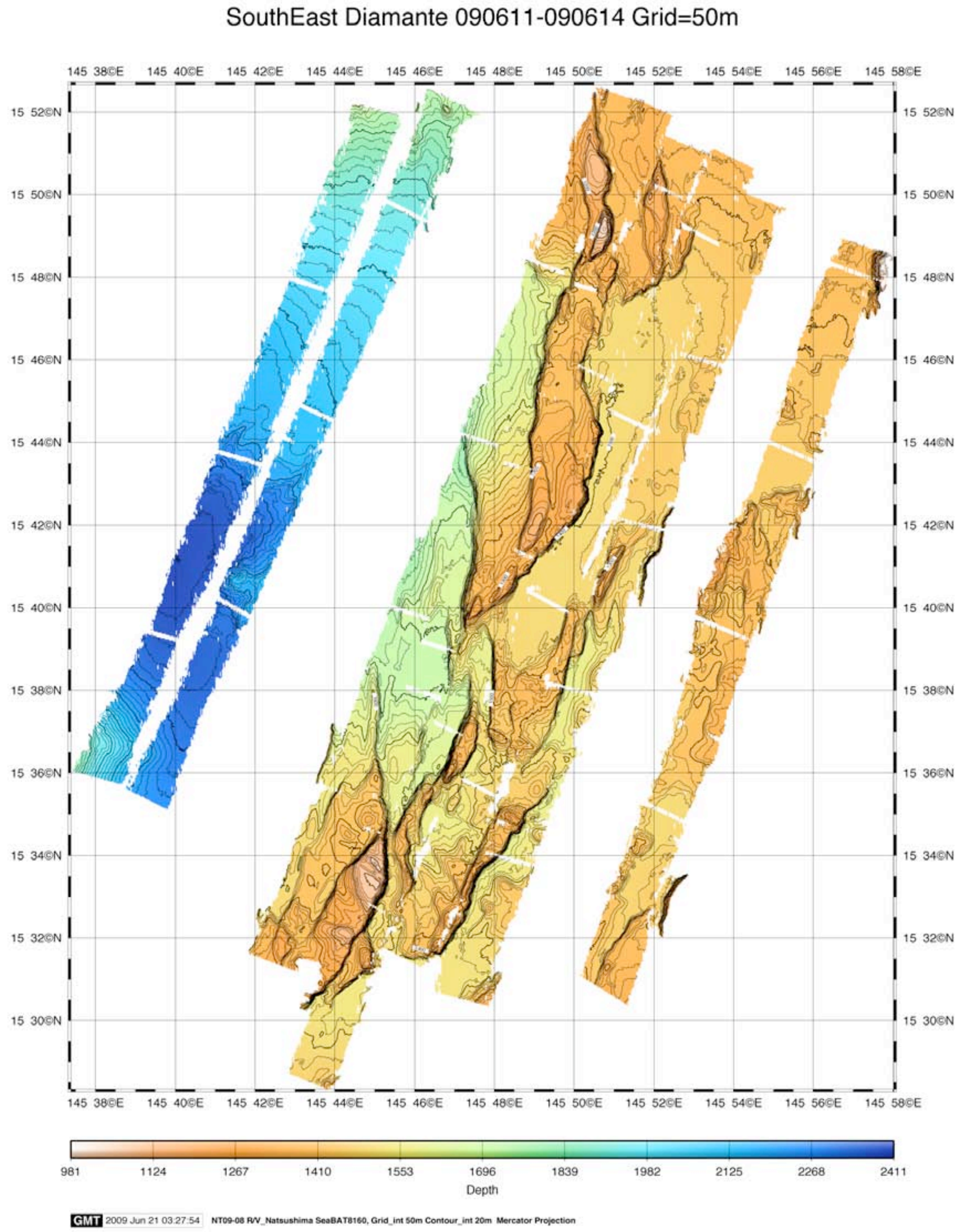


Figure 19. Seabat surveys in the vicinity of Diamante volcano.

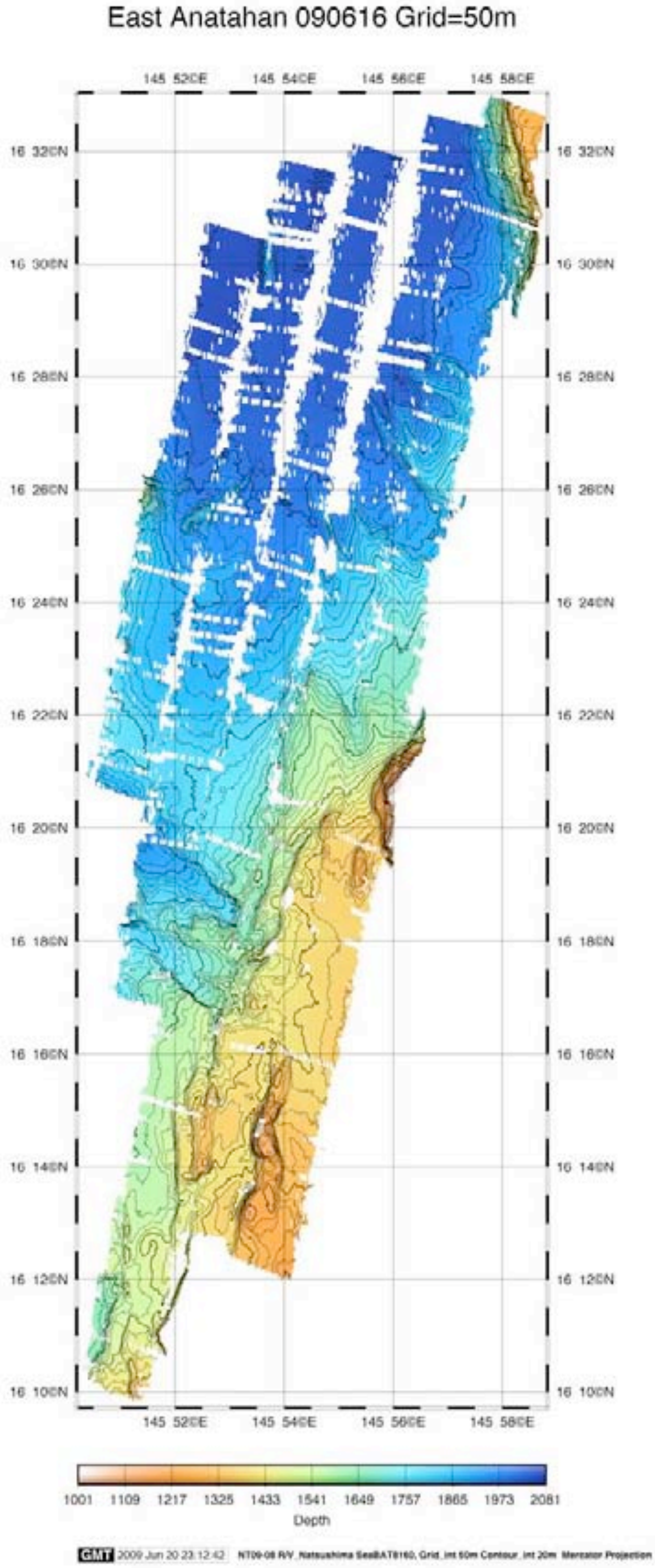


Figure 20. Seabat surveys in the vicinity of Anatahan volcano.

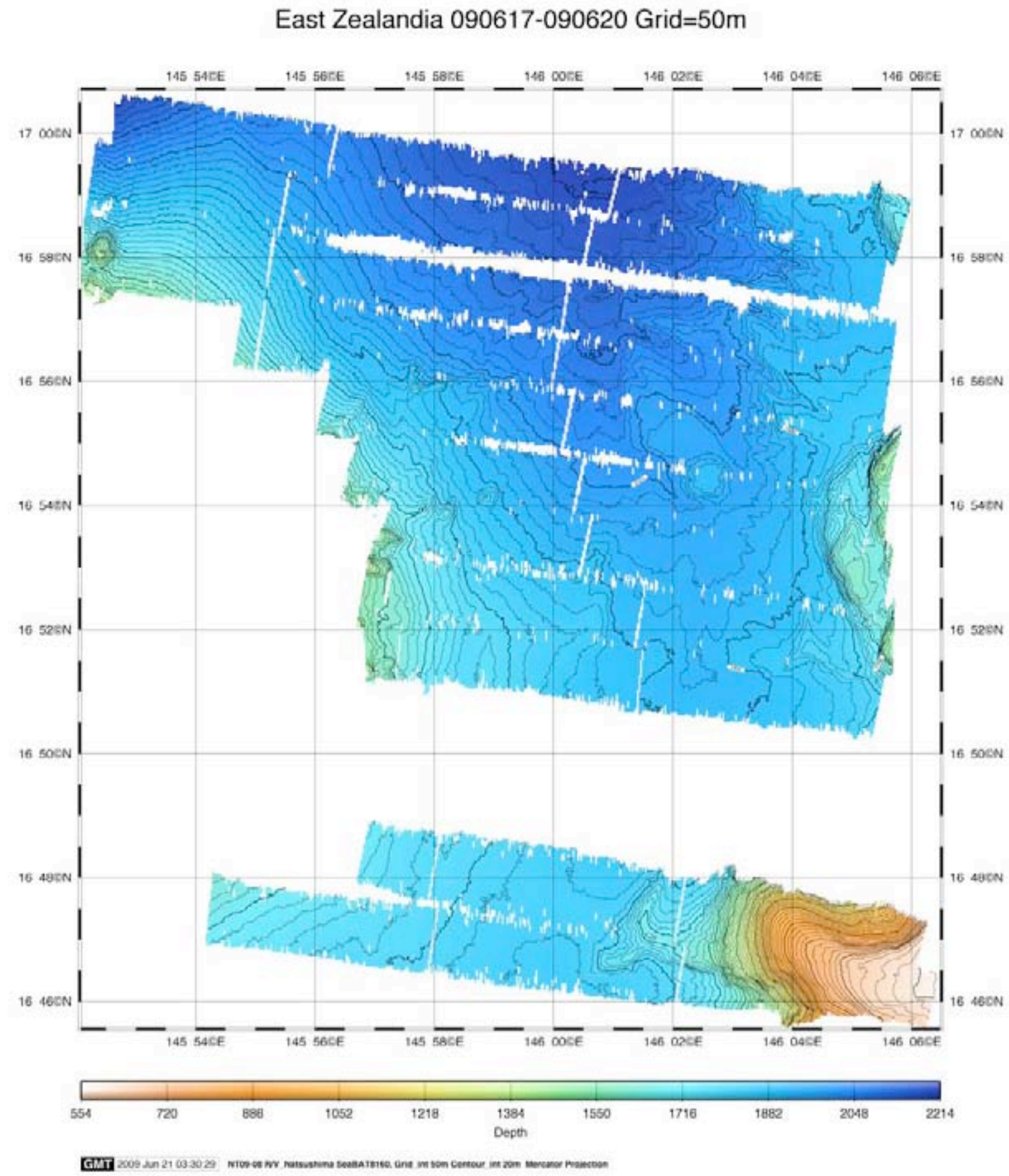


Figure 21. Seabat surveys in the vicinity of Zealandia Bank volcano.

5. 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 #1011

Technical information

Location: East Diamante Seamount, inner NE scarp of inferred caldera wall.
Objective: Survey and sample volcanic stratigraphy exposed in inferred caldera wall

DIVE 1011	On bottom:	Off bottom:
Time (local): June 11, 2009	08:43	14:45
Latitude:	15°57.225'N	15°57.293'N
Longitude:	145 °42.281'E	145° 42.899''E
Depth (m):	574	145

Samples returned: 20 rocks, 2 cores

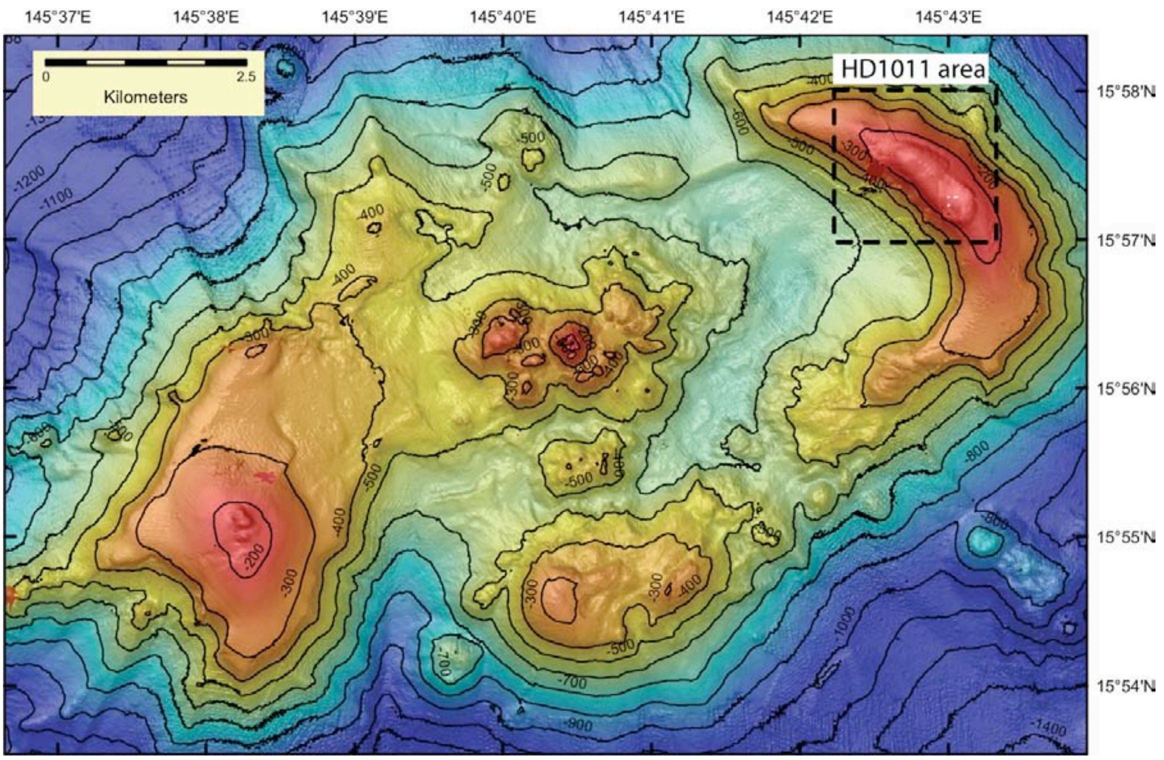


Figure 22. Bathymetric map of East Diamante Seamount, from Mariana Bathymetric Compilation (Susan Merle, PMEL/NOAA, compiler. Dashed box shows location of Fig 23.

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. In fact our dive results indicate that much of the morphology of E. Diamante is constructional as a result of carbonate reef and platform sedimentation, so that it could also be regarded as a submerged atoll. Nevertheless, three features indicate that it does represent an ancient volcano with a caldera: 1) It lies along the magmatic front of the Mariana arc; 2) It has an active hydrothermal field in resurgent dacitic domes in its center (A significant hydrothermal signal was observed when it was surveyed with CTD casts in 2003 by NOAA (Baker et al., 2008); and 3) An extensive field of megadunes –similar to those associated with major eruptions on other submarine volcanoes – are found north of the volcano. Nevertheless, the rim of the volcano is built up of shallow-water carbonate sediments and none of the precaldera volcanic sequence was found. We did not know this when we planned our dives.

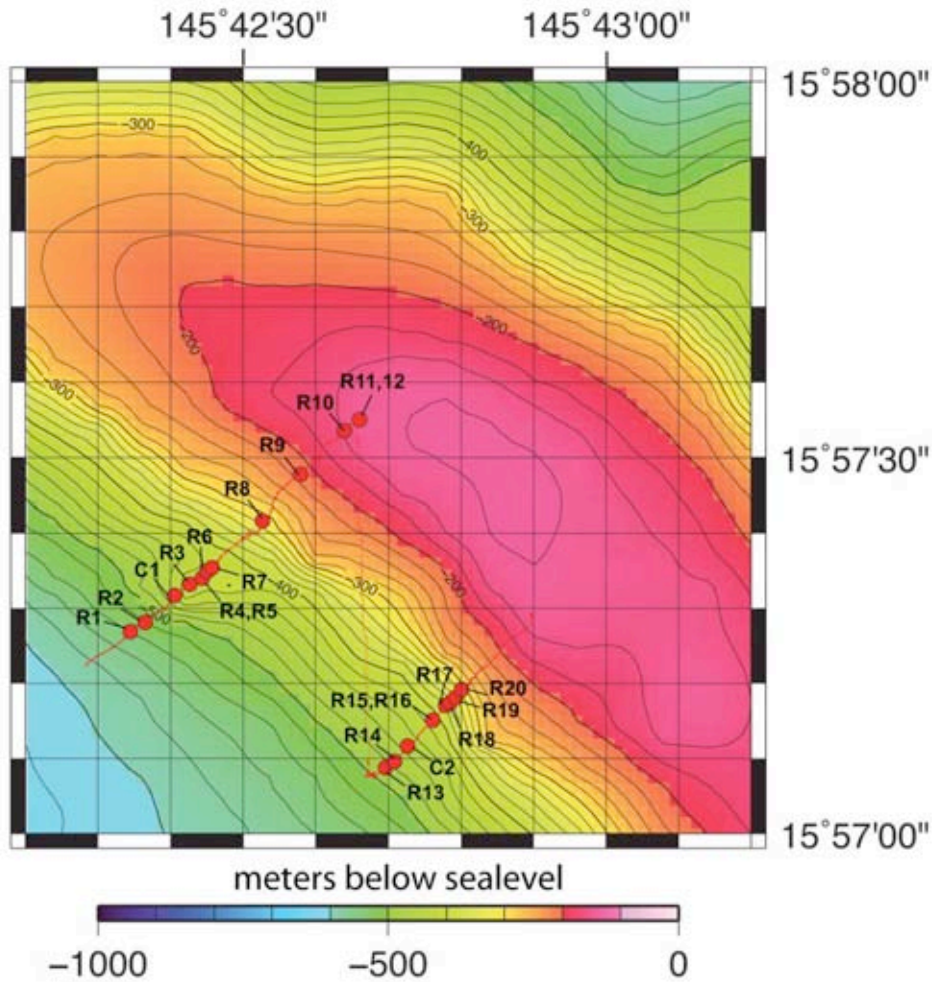


Figure 23. Bathymetric map of the NE wall of E. Diamante Seamount, surveyed during NT0908. Track of HD 1011 is also shown. Note that samples R01 to R12 were collected from the northern traverse whereas samples R13 to R20 were collected from the southern traverse.

Dive 1011 consisted of two parallel, NE-oriented traverses up the steep inner slope of the NE caldera/atoll wall. The two traverses were ~500m apart. The northern traverse was ~800m long and the southern traverse was ~500m long. The ROV landed near the base of the slope, at a depth of 574m, and started the northern traverse. Samples R01-R12 and C01 were collected from this traverse, which ended on top of the NE rim at a water depth of 143m. Following this, the ROV flew to begin the second traverse, touching down near the base of the caldera/atoll wall, at a depth of 497m, and began the southern traverse. Samples R13-R20 and C02 were collected from this southern traverse, which ended at the top of the NE rim at a water depth of 145m.

Observations from the two traverses were quite similar. Once we traversed a sandy-gravelly debris slope at the base of the wall, we reached the wall itself. Exposures along the wall were of vaguely layered material with large cavities (Fig. 24 A & B). The rocks were well indurated and strong, so sampling was quite difficult. As a result, most samples were collected as float. Several of the outcrops showed large clasts (Fig. 24 C&D); these outcrops are best interpreted as breccias but, surprisingly, they are not volcanic in origin. Subsequent examination of samples on deck showed that these are overwhelmingly carbonate rocks. A well-developed shallow cavernous feature was observed near the summit (Fig. 24 C); this may be incipient karst, requiring exposure above sealevel. The nearly flat summit of the NE wall (Fig. 24 G&H) also argues for subaerial exposure or at least erosion near wave base.

In spite of our strong expectation that HPD1011 would traverse a caldera wall, we saw no evidence in the rocks we collected that the innards of a volcano were exposed, either as a result of caldera collapse or for any other reason. All of the rocks collected on the first traverse were carbonate sediments, including coquina, coral bioclastic rock, and vuggy carbonate. Three samples from the southern traverse appear to be highly altered volcanics of mafic to intermediate composition, but the overall proportion of volcanic rocks seems small. We did not see any evidence for a major, caldera-forming eruption itself, which is often observed as an uppermost unit of thick, felsic, pyroclastic deposits; no pumice was observed at all.

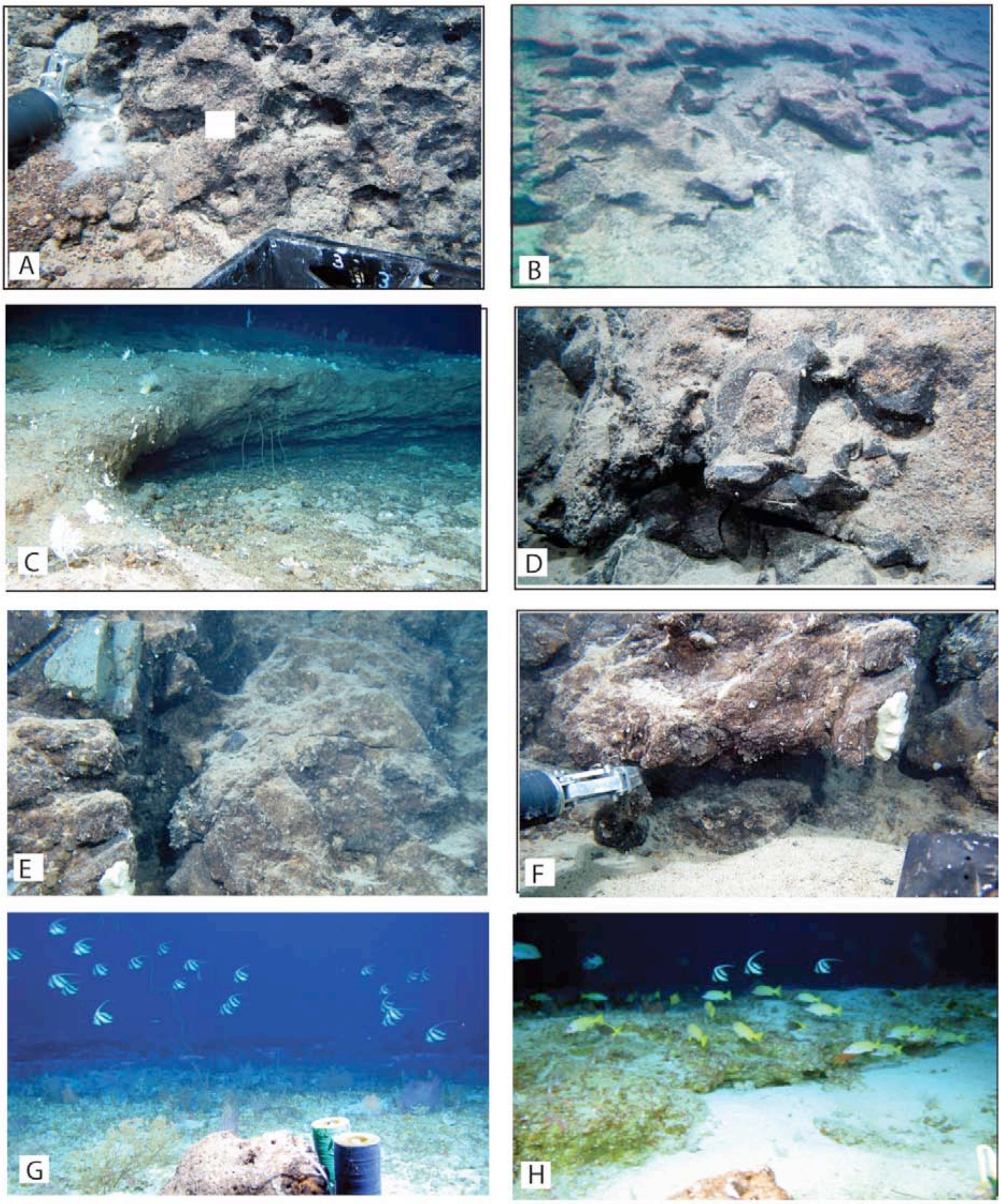


Figure 24. Representative bottom photos from HD949. A: SeaMax 2009_0611_094922AA vuggy carbonate scarp; B: HDC20090611102851 vuggy outcrop of carbonates; C: SeaMax 2009_0611_105822A cavernous feature; D: SeaMax 2009_0611_134340AA close up of carbonate outcrop; E: SeaMax 2009_0611_140648AA close up of carbonate outcrop; F: 2009_0611_140731AA close up of carbonate outcrop;G: 2009_0611_121124AA view of summit region; H: 2009_0611_143711AA view of summit region.

DIVE LOG

Dive #:	NT09-08 HPD#1011
Date:	June 11, 2009 (local)
Location:	E. Diamanate, NE Caldera Wall
Objectives:	survey and sample pre-caldera volcanics
Logger:	Stern & Jordan
samples are noted	HPD#xxx-XYY
	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
8:15			In water		
8:43	560	51	On bottom.		
8:48			sandy bottom, several fish		
8:54	533	45	sandy bottom, some rocks		
8:56	531		Stopping for sampling; friable probably pumice. We collect big wedge-shaped piece that breaks when placed in basket. One piece in basket 5, second piece behind the basket.	R01	shelly bioclastic limestone sandy sized clasts - coquina
9:04	525	46	moving over sandy-gravelly bottom, just an angle-of-repose slope at base of slope		
9:06	515	47	Slabby rocks appear. Not clear if it is in place or not		
9:08	516	44	Sampling slabby rock, it fights back. Collect small piece that breaks off. Lots of fine particulate matter is thrown up during sampling. Placed in round basket	R02	coquina
9:22	511	45	moving over gravelly (pumice) slope		
9:28	481	40	stopping to sample with M-type scoop. Looks like pumice	SC1	polymictic sandy gravel
9:33	480	40	Moving over gravelly pumice slope. Much darker here than below		
9:39	461	39	Sampling slabby rock (float). Well indurated, with what look like abundant clasts. Placed in box 2	R03	bioclastic - coral
9:45	452	40	Moving over pumice-covered slope		
9:47	443	40	Big blocks suggesting base of caldera wall is near.		
9:49	445	70	Sampling very vuggy outcrop (probably). Is it volcanic or karstified limestone? Finally we give up and sample float (2 pieces). R04 and R05 placed in Box 1	R04, R05	R4: shelly bioclastic with sandy sized clasts-coquina; R5: calcareous nodule
10:00	430	41	Travelling over blocky lava flows, probably in place.		

10:01	424	41	Sampling in place horseshoe-shaped rock. Too strong and give up. Move off the get another piece that is stuck in the outcrop,also too hard. Try another two pieces, both are too attached to the outcrop. Try another rock, too hard. Finally grab a piece of dark float, which breaks into two pieces. Both are in box 1	R06	vuggy carbonate
10:13	418	42	Moving over outcrop		
10:15	416		Sampling outcrop, too tough. Move a bit further and try again. Collect large brown piece of float. In box #1.	R07	bioclastic limestone - corals
10:22	411	41	Continue climbing caldera wall, lots of massive outcrops, some with clear brecciated or agglomeratic surface.		
10:41	268	37	Stop to sample light-colored outcrop on top of dark material with possibly rounded cobbles. Large piece comes off but it is not taken. Rock with bizarre big holes is taken in Box #5	R08	carbonate
10:55	261	34	Cave in tuffaceous outcrop		
11:00	255	34	Kinder, gentler outcrop. Covered with pumice		
11:09	204	40	Sampling solitary (float) in box 4	R09	shelly limestone - coquina
11:12	193	40	Continue over ground with mixed outcrop and gravelly pumice		
11:16	186	41	Sampling low, pumice-covered outcrops with lots of coral. Give up		
11:26	180	40	Moving over low, pumice-covered outcrops with lots of coral.		
11:34	157	62	Trying to sample but fail. Move a little bit and try again. Outcrop is very red and not so many corals. Small piece is ripped off of outcrop. Nice fresh surface. Placed in box 4	R10	carbonate
11:42	152	56	Continue over ground with mixed outcrop and gravelly pumice		
11:47	145	55	Try sampling but give up		
11:52	144	56	Sample very small piece in box 4	R11	carbonate
12:01	144	81	Continue sampling. Break off several pieces of encrusted grey rock, appears like tuff that may be welded.		
12:03	143	79	Try push core, doesn't work		
12:07	143	82	Move a bit for more sampling try. Collect a piece of float in box 4	R12	shelly limestone - coquina
12:12	143	180	Heading to begin second transect		
12:40	497	40	On bottom; sediment and rock slabs; lots of gravel		
12:45	490	40	Collecting large piece of float	R13	shelly bioclast sandy-siized clasts -coquina
12:46	485	41	Travelling over black gravel (coated pumice)		

12:52	480	35	Collecting dark rock, placing in box with lid	R14	shelly bioclast sandy-sized clasts - coquina
13:02	456	40	Collecting with blue push core; multiple penetrations	C02	poorly sorted carbonate sediment
13:09	448	40	Continuing over light-colored sandy slope		
13:18	409	42	Sampled light colored material from big rock. Very crumbly. In basket 3. R16 much larger than R15	R15, R16	R15: mud-supported shelly carbonate; R16: moderately altered basalt
13:26	402	44	continue over surface with lots of slabs and		
13:28	399	46	continue over big blocks		
13:31	377	38	sampling float; black coated sample in box 3	R17	shelly bioclast sandy-siized clasts -coquina
13:33	371	41	travelling over massive outcrop of breccia/agglomerate		
13:35	359	41	sampling massive agglomrate/breccia. 2 pieces come, the larger piece was from the outcrop, broke into two pieces. Placed in Box 4	R18	calcareous sandstone
13:41	352	41	continue over steep (nearly vertical) outcrop of breccia/agglomerate		
13:44	339	41	trying to sample outcrop		
13:54	330	52	sample piece of breccia/agglomerate flow; box4	R19	weakly altered basaltic andesite
14:09	303	67	trying to sample near contact between two flows, lower one is darker and more massive, upper is lighter and more brecciated. Collect piece of lower flow from outcrop. In box 3.	R20	altered basalt
14:20	243	53	continue over layered sequence		
14:22	231	46	sandy covered slope		
14:28	186	41	moving over low sandy-pumice covered outcrop		
14:44	145	32	finished traverse		

Tropical fish

HYPER-DOLPHIN DIVE #1012

TECHNICAL INFORMATION

Location: East Diamante Seamount, south & east part of resurgent domes
Objective: Survey and sample volcanic stratigraphy & hydrothermal sulfides

DIVE 1012	On bottom:	Off bottom:
Time (local): June 12, 2009	08:38	16:31
Latitude:	15°55.795'N	15° 56.571'N
Longitude:	145° 41.040'E	145° 40.869'E
Depth (m):	547	347

Samples returned: R1-R27 rocks but R5 lost during operations, 1 core

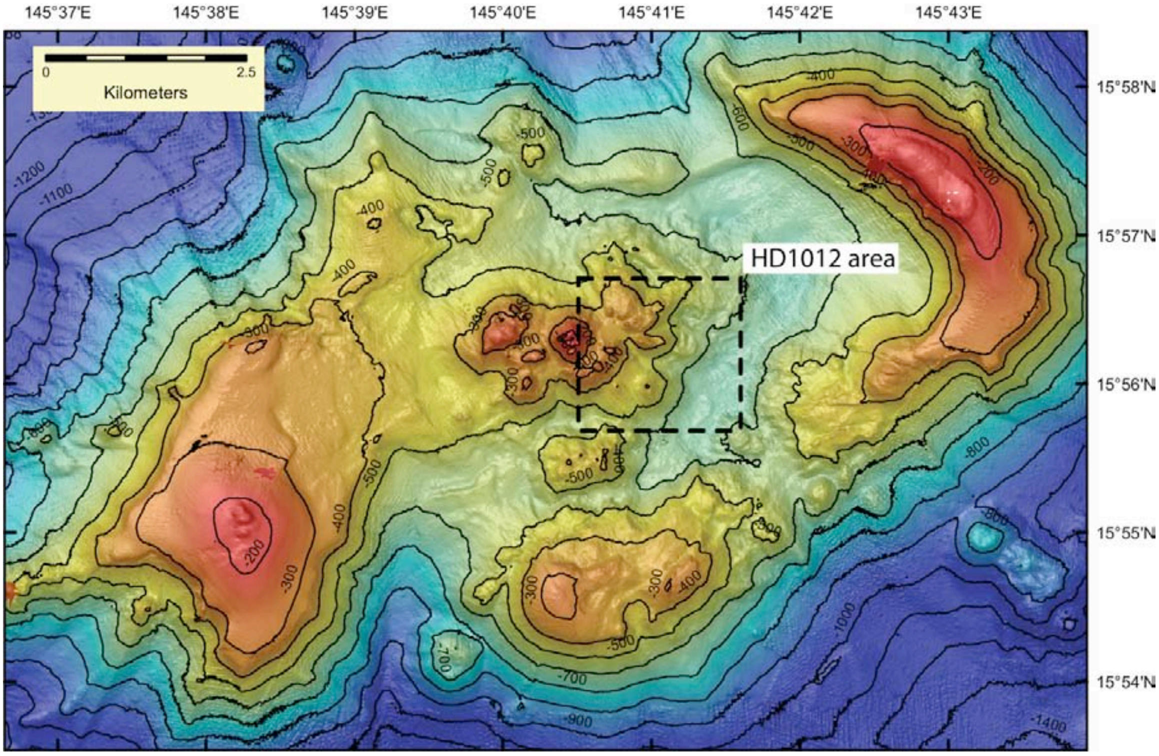


Figure 25. Bathymetric map of East Diamante Seamount, from Mariana Bathymetric Compilation (Susan Merle, PMEL/NOAA, compiler. Dashed box shows location of Fig. 26.

SCIENTIFIC SUMMARY

The objectives of Hyper-Dolphin dive HPD-1012 were to investigate and age date the volcanic units that make up the central caldera resurgent domes and build on the data set and samples collected in 2004 by NOAA for active and inactive hydrothermal sulfide chimney fields. Dive 1012 consisted of an approximately NS-oriented traverse across the eastern most three resurgent domes (Figs. 25 and 26), and included a search for the active hydrothermal field at the northern end of the transect discovered in 2004. However, the 2004 active chimney field was not found. The ROV landed near the base of the slope at a depth of 547 m (Fig. 26) on a sediment surface strewn with boulders and cobbles. Samples R01-R10 were collected on the south flank of the SE seamount, whereas the north flank of that edifice was not sampled. Samples R11 and R12 were collected at the bottom of a rift valley separating two seamounts and samples R13-R16 were collected up the south flank of the middle seamount. Sample R17 was collected at the bottom of another rift valley and samples R18-R27 were collected on the NE flank of the northeast seamount (Fig. 26). The ROV was flown over the northern flanks of the middle and southern seamounts.

Outcrops along the south flank of the southeast seamount consist of bedded volcaniclastic/pyroclastic rocks intercalated with volcanic rocks (Fig. 27A) with a range of compositions including dacite, andesite, and rhyolite (see dive log below). Typically, the seamount flank is covered with sediment with large areas covered with pebble fields that look like pavement, and talus blocks. Other places show huge talus piles of boulders and cobbles (Fig. 27C,D). Most of the talus blocks were eroded from thick breccia sequences (Fig. 27B). The lava outcrops are strongly jointed and fractured. White bacterial mat was noted in only one place. Only one sample (R4) was mineralization, consisting of Mn oxide-cemented sandstone. Samples R11 and R12 were collected from a rift valley and consist of dacite talus. The valley is covered predominantly by rippled sediment with lava cobbles and boulders scattered over the surface and cobble piles in places.

The south flank of the middle seamount (Fig. 26) starts at the base (~480 m) with sediment supporting scattered boulder and cobble talus with gravel patches. Boulder and cobble talus piles increase up slope (Fig. 27C). Most samples from this flank were collected from talus piles. The first outcrop was crossed at 393 m water depth. Three of the four rocks collected along this flank are dacite and the other rock is a basaltic andesite. Columnar lava boulders occurred in some of the talus piles.

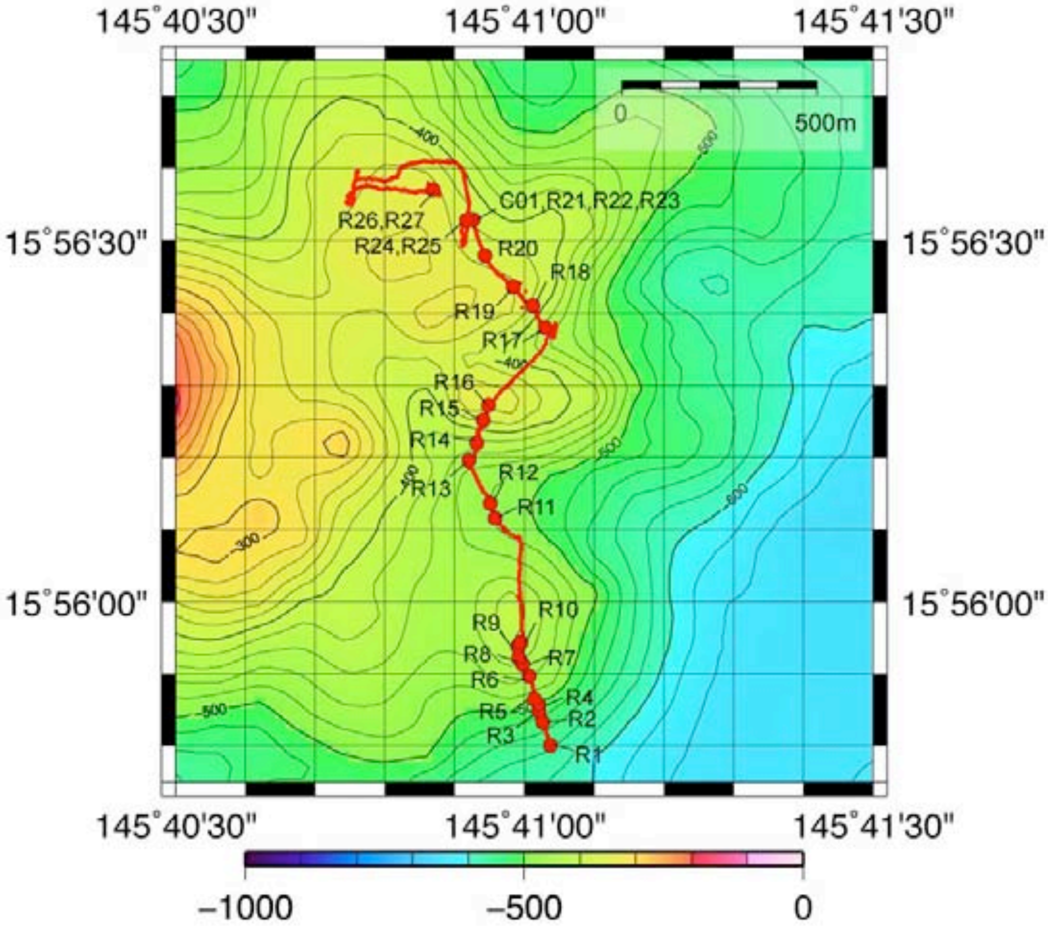


Figure 26. Bathymetric map of western part of the central caldera resurgent domes of E. Diamante Seamount, surveyed during NT09-08. Track line and sample locations of the HD-1012 dive are shown.

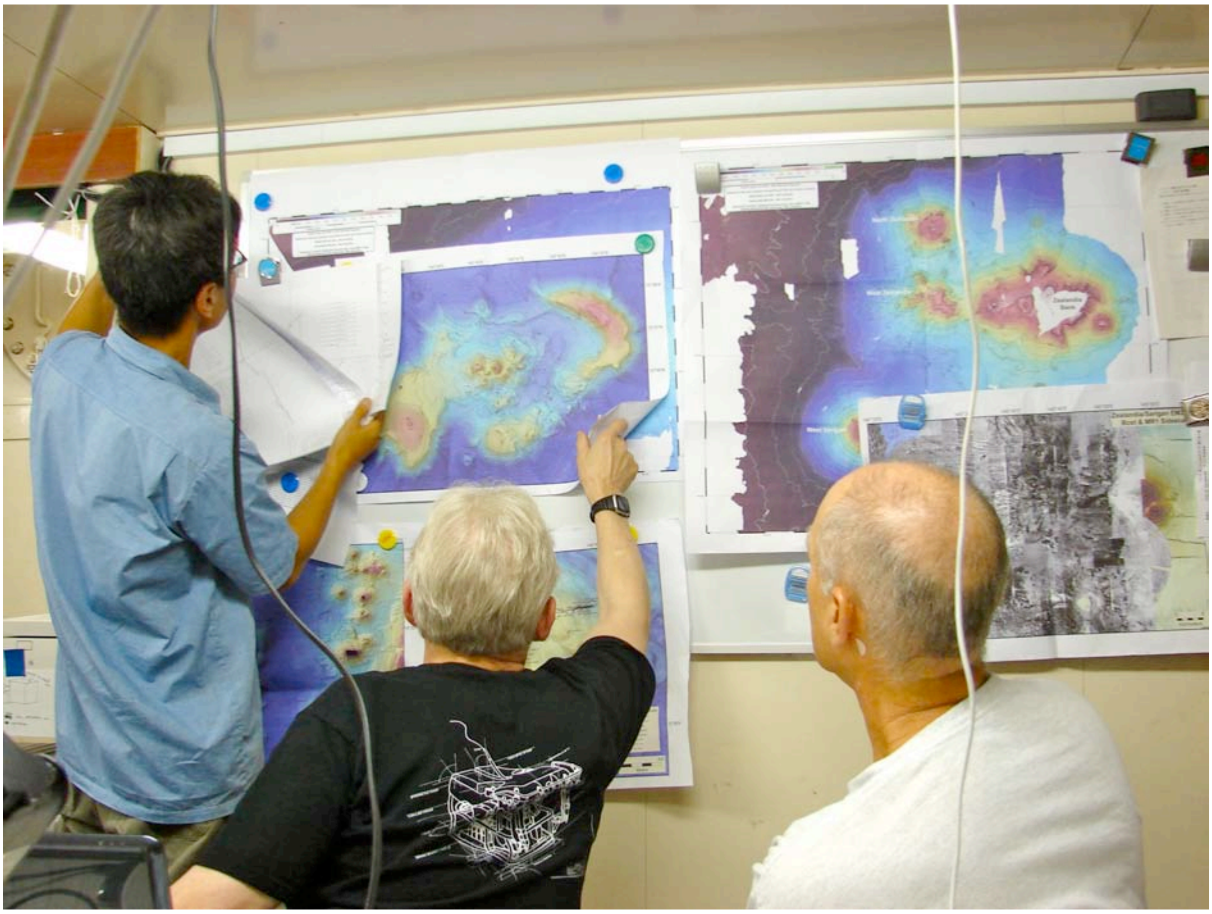
Samples R17 and R18 were collected from talus piles within the northern rift valley and both are dacite. The rift valley is covered by sediment with scattered boulders and cobbles and in places boulder/cobble piles (Fig. 27D). The first outcrop was encountered at 390 m and consists of strongly jointed and fractured lava. Rocks crop out at the base of the SE flank of the northern seamount and are composed of columnar jointed basalt overlain by massive lavas, which in turn are overlain by breccia.

Samples R19 through R27 were collected on the northern seamount, which encompasses an area known to include active and inactive hydrothermal sulfide chimneys. The SE flank is covered with sediment and talus as noted for the other seamounts. All the volcanic rocks collected are from talus and of dacite composition. Moving up slope, the ROV encountered reddish sediment, shimmering fluids, and turbid bottom water. The first active vent site along the 1012 transect is located at 377 m water depth, and consists of a large area containing many hydrothermal mounds and chimneys (two of which are described below), the larger ones measuring about 4 m high, 3 m wide, and 8 m long. Many of the mounds are topped by a spire or bulbous construction (Fig. 27E). Inactive mounds and chimneys also occur in this area (Fig. 26, sample locations CO1, R21, R22). These hydrothermal edifices are located along a NE-SW trending rift valley. The full extent of the hydrothermal field is not known, but it is at a minimum 40 m by 50 m. The top of a large elongate mound was sampled where shimmering fluids were diffusely venting. The upper mound was friable, but a push core (C01) collected iron oxides from the site of venting. The ROV moved about 10-15 m to another mound with a reddish bulbous top from which fluids were venting, and a black pedestal (mound), composed possibly of sulfides (Fig. 27E). Part of the bulbous top was knocked into the sample box (R21) and is composed of hydrothermal Mn and Fe oxides that make up a delicate network of anastomosing channels. The channels are 2-10 mm in diameter and are not blocked, which allows for the unimpeded flow of hydrothermal fluids throughout the mound. A white rock (R22) protruding from near the top of the pedestal may be a lens of massive sulfide. Similar whitish rocks were noted at the base of the mound and as veins. The white is an alteration rind on a black rock. The mineralogy indicates that the mineralizing fluids varied greatly in temperature and oxygen fugacity, but the present stage in low temperature, less than 110 ° C. No probe was available to directly measure temperature.

Another field of small chimneys (Fig. 27F) and large mounds with spires was found after 30 minutes of ROV operations. Venting fluids were not seen on any of the edifices. The size of the mounds is about the same as in the previous field described above. A small dead chimney (R24) was collected from near the base of a large reddish mound (Fig 27G) and another small dead chimney (R25) was collected from this field. During the transect from this field to the next large field, small chimneys or chimney groups (Fig. 27H) with small mounds were crossed.

About two hours after traveling a circuitous route, another large field was found, again without venting. This field is only about 100 m from the second large vent field. The field consists of mounds and chimneys all resting on a sandy seabed. A 50+ cm tall chimney was collected (41 cm recovered) from this field and, like the other chimneys collected, is composed predominantly of zinc sulfide. Sampling of another chimney resulted in recovering only the topmost 16 cm.

Mineralization appears to be controlled by proximity to a large fracture zone, where active chimneys were collected in 2004. Two of the three large fields discovered during dive 1012 are inactive and perhaps dead (no chance of rejuvenation), however, fallen chimneys were only rarely encountered and inactivity may be fairly recent. The one active field showed diffuse and focused flow through spires and bulbous constructions built on top of mounds. This field may be in a waning stage of activity and higher temperature fluids may have been involved in construction of the mounds pedestal. After caldera collapse, dacitic domes intruded into the center of the caldera providing a heat source for production and circulation of hydrothermal fluids that generated the large chimney/mound fields found on dive 1012 and that was found during the 2004 NOAA cruise.



Discussion

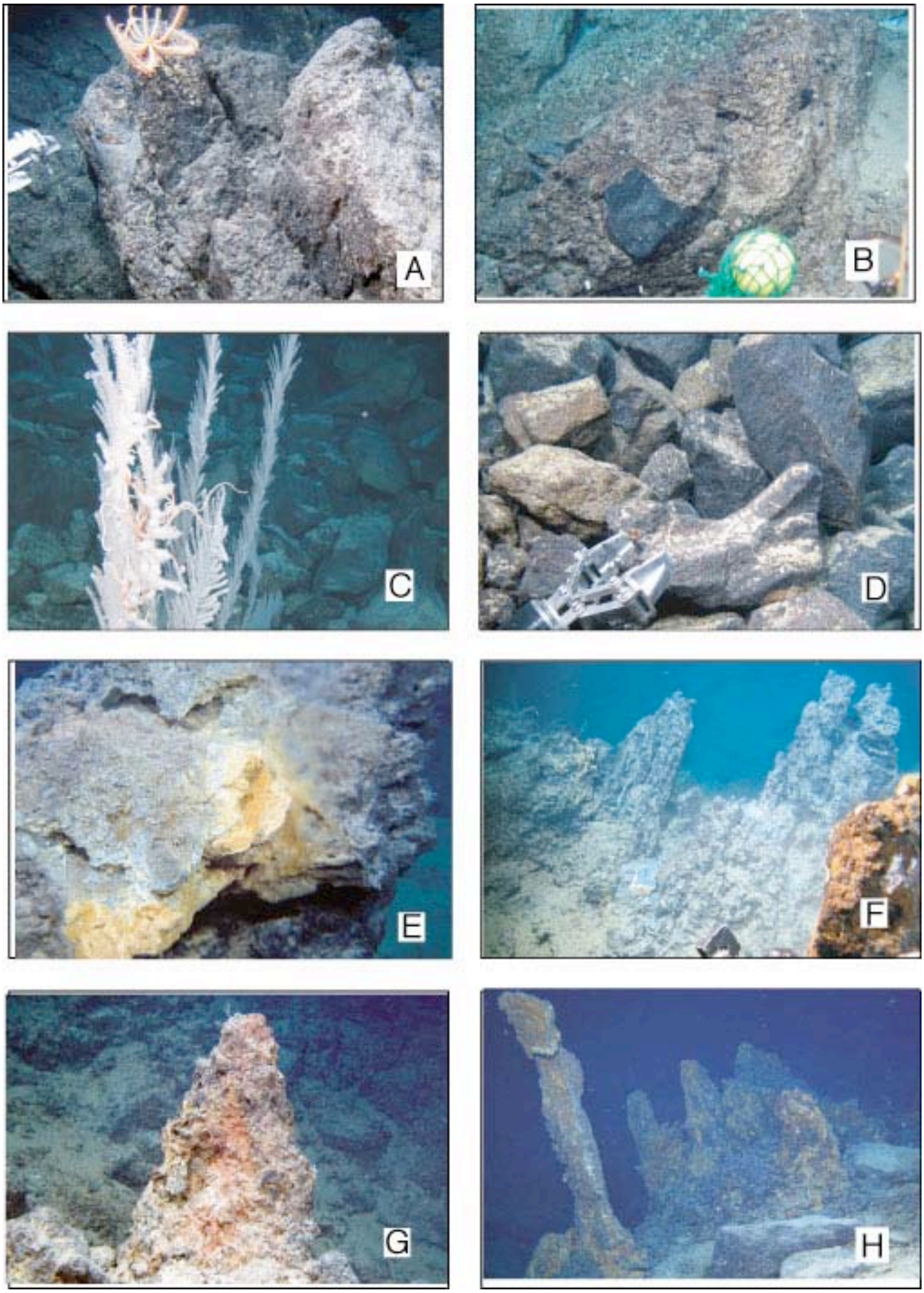


Figure 27. Representative bottom photos from HPD#1012. A: SeaMax 2009_0612_091217AA, Bedded volcaniclastic rocks from about 495 m water depth; B: SeaMax 2009_0612_093702AA, outcrop of breccia showing large black clasts of black basalt; C: SeaMax 2009_0612_115031AA, large coral stock living on cobble talus pile at 381 m water depth; D: SeaMax 2009_0612_1238212AA, dacite boulder talus pile; E: SeaMax 2009_0612_133047AA, bulbous construction venting fluids sitting atop a hydrothermal mound, 377 m water depth; F: SeaMax 2009_0612_150005AA, set of three spires sitting atop a hydrothermal mound, no venting noted, about 375 m water depth; G: SeaMax 2009_0612_11407AA; large reddish spire sitting atop a hydrothermal mound, water depth 387 m; H: SeaMax 2009_0612_161707AA, tall thin sulfide chimney and four spires sitting atop a small hydrothermal mound at about 345 m water depth.

DIVE LOG

Dive #:	NT09-06 HPD#1012
Date:	June 12, 2009 (local)
Location:	E. Diamante caldera, central resurgent dome
Objectives:	Volcanic history and hydrothermal sulfide sampling

Logger: Hein

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
8:04		274	In water		
8:38	548	345	On bottom. Mix of sediment & rock, lg. Boulders		
8:40	547	348	Sampling, thin bedded outcrop on slope, sparse corals	R01	Altered pyroclastic
8:46	546	344	Boulder to gravel field; looks like pavement in places		
8:48	534	345	Sediment w/ ripples; cobbles on surface in places; gravel patches		
8:53	520	343	Sampling, large boulders, flat slabs; part of friable slab collected; boulders & cobbles sitting on rippled sediment	R02	Altered pyroclastic
8:59	502	345	Large field of boulders, blocky to slabs, sampling aborted		
9:02	502	345	Sampling,	R03	
9:04	502	345	Sampling, whitish rock on fresh surface; reddish sediment	R03	Volcaniclastic
9:11	498	345	Sampling, large outcrop bedded lava flows, aborted		
9:15	490	344	Sampling, same outcrop as above; reddish, friable, broke into many pieces in box; some pieces in box 4	R04	Mn-cemented sediment
9:23	480	343	Continuing up steep rock face, coral, anemone, crinoid, all sparse, highly fractured/jointed; all reddish brown		
9:27	465	289	Sampling, reddish-brown slab; friable, broke into pieces, but 2 larger ones; highly altered volcaniclastic or breccia; filled box 3	R05	Lost sample
9:34	452	340	Topography flattened and boulder/cobble surface		
9:37	439	341	Sampling, same appearance as R05; breccia, large black lava clast in breccia, collected both large basalt clast and matrix; 3+ pieces; 1 piece in box 4, one in box 2	R06	Px andesite
9:45	428	345	Approaching summit, lots of patchy white bacterial mat, sediment shouts, and rock outcrop; breccia		
9:47	425	346	Sampling, breccia, or altered lava, friable, aborted; trying again, aborted;		
9:51	424	349	Sampling, lava/pumice clast from breccia, reddish	R07	Dacite
9:56	419	349	Sampling, lava clast from breccia, black surface, reddish elsewhere; attached coral	R08	Rhyolite/welded tuff

10:03	411	9	Strongly jointed and fractured breccia outcrop		
10:05	407	3	Sampling, breccia, lava clast, black exposed surface, took half of a large cobble, reddish inside, rounded	R09	Pumiceous andesite
10:17	405	31	Sampling, same as R09	R10	Rhyolite/welded tuff
10:19	400	1	Flying to bottom of rift valley between two cones		
10:37	480	315	On bottom, rippled sediment, w/ scattered cobbles		
10:39	480	342	Sampling talus cobble, black exposed surface, lava?	R11	Qtz dacite
10:43	478	320	Rippled sediment, w/scattered cobbles becoming more abundant		
10:46	476	320	Sampling, talus, elongate block, lava, reddish & black stain	R12	Px-pl dacite
10:53	471	320	Sediment dominated, degraded ripples, sparse cobbles and gravel patches; gravel dominated at 470 m, then back to sediment		
11:00	450	20	Change course to go up second cone/dome; many cobbles		
11:01	453	19	Sampling, talus, black stain, attached coral, tabular, reddish	R13	Qtz-pl dacite
11:04	451	20	Boulder field on sediment, tabular and blocky; 432 m, columnar blocks; dominantly subangular blocks; sediment becomes less abundant upslope and nearly gone at 417 m		
11:10	417	11	Sampling, blocky lava from boulder pile; black & reddish stained, aborted, try again at 416 m; 30 minute sampling effort; most stain removed from rock during sampling	R14	Qtz dacite
11:45	398	14	Cobble talus replaces boulder talus, first outcrop at 393 m, the source of all the talus; large coral stock at 381 m w/brittle stars		
11:52	370	10	Sampling from talus pile, large tabular block (columnar), stained black/reddish	R15	Qtz-hb dacite
12:01	353	9	Alternating cobble fields and blocky outcrops, strongly fractured; outcrop just below summit at 341 m;		
12:05	332	0	Sampling from cobble pile; black/reddish stains	R16	Basaltic andesite
12:07	324	3	Flying down N flank of cone to center of rift valley		
12:23	424	325	At point 6, moving to point 7: Large angular blocks		
12:26	421	327	Sampling, cobble talus, black/reddish stain Mn patina on all rocks	R17	Qtz dacite
12:30	412	326	Poorly sorted boulder-cobble field, boulder piles		
12:34	390	327	First outcrop at 390 m, massive, jointed & fractured; talus away from outcrop		

12:38	378	327	Sampling from talus pile, black/reddish stain	R18	hb-qtz dacite
12:42	360	322	Contact between massive flow and overlying breccia; outcrop with columnar jointing just blow that		
12:47	343	320	Flying across flat area just SE of chimney		
12:49	352	320	Back on bottom, boulder/cobble field		
12:50	353	319	Sampling from talus pile, black/reddish stains, slab, thin bed	R19	Qtz dacite
13:00	352	320	Moving across talus/boulder field		
13:06	357	332	Moving across sediment covered cobble field		
13:20	360	335	Sampling cobble field, angular dark rocks, fragile. Sampling took 10 minutes.	R20	Hb dacite
13:22	361	327	Resume track across cobble field		
13:24	368	330	Moving across blocky talus field, pebble to boulder size blocks		
13:26	372	330	Crossing jagged terrain, blocks and possible blocky outcrop.		
13:28	376	330	Orange/yellow sediment appears, shimmering water noted		
13:33	377	326	In turbid water on bottom, red to yellow particles in water column		
13:35	377	323	Still sitting on bottom, turbid plume from seafloor noted, no chimney		
13:37	377	330	Moving again, more vents observed		
13:41	377	328	Stopped near vent, awaiting sediment to settle. Turbidity is reddish-orange with clots of bacterial floc floating in water column.		
13:55	377	328	Sampling deposit through active vent with MBARI-green	C01	Fe oxides
14:02	378	280	Moving towards another vent, about 10 m away		
14:04	377	280	Sampled top of upper part of mound, at venting summit	R21	Mn/Fe oxides
14:27	377	279	Sampling more of the same vent deposit, red & brown coated whitish rock embedded at top of the pedestal	R22	Massive sulfide
14:32	376	274	Moving away from vents		
14:34	374	269	Sampling cobble, on blocky black flow outcrop	R23	Qtz-hb dacite
14:37	370	273	Crossing blocky, black outcrop (flow) and loose blocks		
14:38	368	179	Change course, crossing cobble field, starfish noted		
14:41	367	180	Crossing variable size boulders & cobbles, variable amount of sediment		
14:44	359	0	Change course and depth, crossing field of pebbles & cobbles		
14:46	370	2	Angular blocks in outcrop, turbidity increasing		
14:47	374	346	Approaching inactive chimneys		
14:55	375	342	Sampling chimney, nearly whole chimney collected	R24	Sulfide chimney

14:57	375	349	Picking up broken chimney, nearly complete chimney	R25	Sulfide chimney
15:01	374	350	Moving away from last vent, across slopes with blocky outcrop		
15:03	372	348	Passed inactive chimney, turbidity high		
15:05	390	340	Crossing sediment covered slope, some white patches and boulders, turbidity decreasing		
15:07	389	340	Steep slope with talus and blocky outcrop		
15:11	390	272	Change course, crossing outcrop, mot likely breccia with spots of red/orange sediment		
15:12	387	270	Approaching inactive spire w/ red oxide/sulfide surface		
15:21	384	250	Continuing traverse, traveling over boulder and cobble covered slopes		
15:30	355	219	Turbidity and sediment cover increasing, fish and soft coral noted		
15:36	342	200	White basket stars on blocky flows (columnar joints?)		
15:49	361	170	Orange-red oxide coated sediment on gentle slope		
15:54	361	varying	Changing course, attempting to locate active black smokers from 2004 cruise		
15:55	361	90	Passed through heavy turbidity		
16:00	357	100	Traversing red-orange sediment covered slope and turbid water		
16:04	343	89	Basket stars again		
16:17	344	164	Tall thin, extinct chimneys; excellent photos, no sampling		
16:46	347	242	Attempting to sample chimney		
17:04	348	280	Sampling chimney; collected about 75%, missing lowermost and uppermost parts.	R26	Sulfide chimney
	348		Sampling, time, depth, etc. not recorded, chimney fragment; depth assumed, same general location as R26	R27	Fragment of sulfide chimney
17:11	348		Off bottom		

Hyper-Dolphin

HYPER-DOLPHIN DIVE #1013

TECHNICAL INFORMATION

Location: East Diamante Seamount, E-facing scarp and channel of SW caldera wall.
Objective: Survey and sample volcanic stratigraphy exposed in inferred caldera wall

DIVE 1013	On bottom:	Off bottom:
Time (local): June 13, 2009	08:54	10:54
Latitude:	15° 53.699'N	15°53.740'N
Longitude:	145 ° 39.196'E	145° 39.014''E
Depth (m):	1076	861

Samples returned: 11 rocks

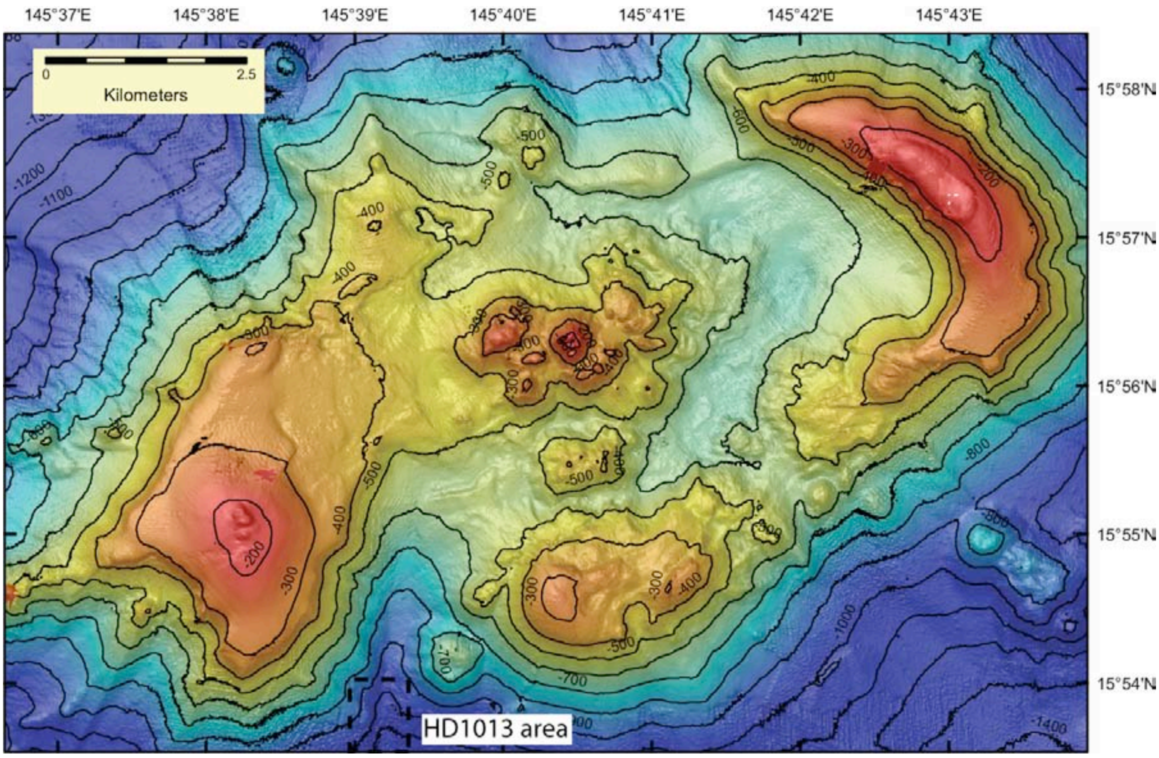


Figure 28. Bathymetric map of East Diamante Seamount, from Mariana Bathymetric Compilation (Susan Merle, PMEL/NOAA, compiler. Dashed box shows location of Fig. 29.

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, all of which were studied during the first 5 days of this cruise. 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; we studied the southern breach during dives 1013 and 1014. The caldera floor has a maximum depth of ~700 m and this is dominated by a complex set of fractured dacite domes with hydrothermal fields that were studied during dive 1012. HD1011 dive results indicated that the horseshoe-shaped NE caldera wall is a submerged carbonate reef and associated platform sediments, so we were very interested to see what the SW caldera wall is composed of, which was the principal objective of dives 1013 and 1014. The southern caldera breach is also the site of a well-defined N-S channel that funnels to the south volcaniclastics produced by eruption of the domes. Dive 1013 revealed that this channel has cut through and exhumed a sequence of layered volcaniclastic rocks that is more than 200 m thick (Fig. 30).

Figure 29 shows the region studied during this dive. The dive occurred during the morning of June 14 and traversed about 700 m horizontally and 185 m vertically. The dive began near a well-developed submarine channel issuing from the south side of the E. Diamante caldera. The vehicle first traversed a gentle slope covered with sand and gravel, where three samples of float were collected (R01-R03, two basaltic andesites and a pumiceous rhyolite). This gentle slope is probably part of the N-S channel. A layered felsic volcaniclastic outcrop is exposed in the channel wall; most of the rest of the traverse studied outcrops on the steep lower flank of the caldera wall and included felsic volcaniclastic units ranging in thickness from ~3 m to 30 m. Figure 30 is a simplified stratigraphic column for this dive, showing where samples were recovered. The lowermost nine units define a 100 m-thick coarsening-upward volcaniclastic succession. Figure 31 shows photographs of the section, including layered fine-grained pyroclastic flows at the base of the section (A-C), coarse breccias higher up in the section (D-G), and well-layered tuff at the top (H). Clasts in the upper, coarse volcaniclastic breccias are angular, and except for the relatively thin tuffs at the base of the section, are poorly bedded. The uppermost felsic volcaniclastic unit is ~30 m thick and contains blocks that are comparable in size to the Hyperdolphin ROV.

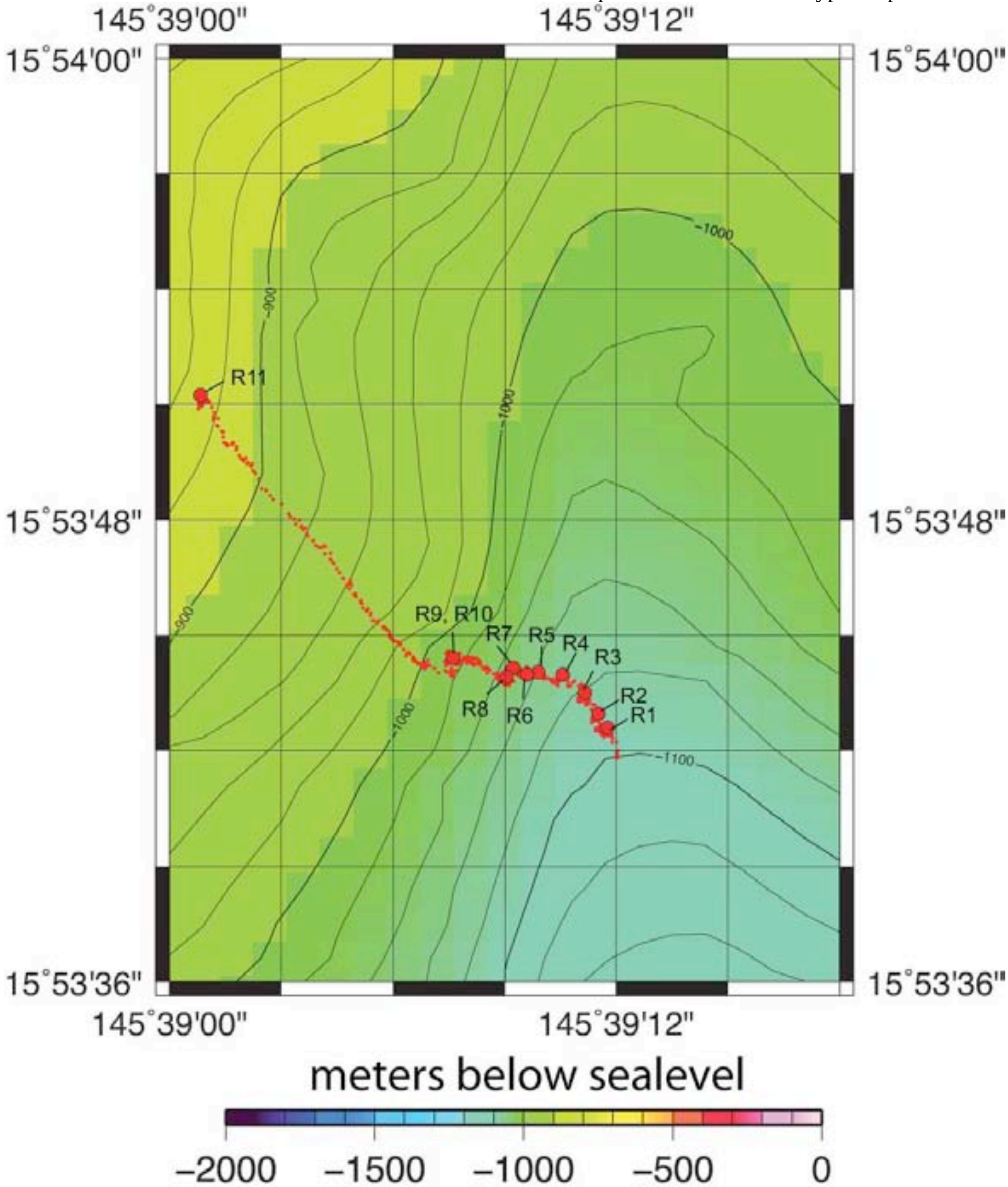


Figure 29. Bathymetric map of the southern breached caldera wall region of E. Diamante Seamount, surveyed during NT09-08. Track of HPD 1013 is also shown, along with sample locations

Other than the two samples of basaltic andesite collected as float near the start of the dive, all samples collected during this dive were felsic and quite pumiceous, with 20-25% vesicles. The felsic samples contain phenocrysts of quartz and/or pyroxene near the base of the section and become aphyric upsection. R02, R04-06 contain 5-10% quartz phenocrysts, R05, R06, and R08 contain 5% pyroxene phenocrysts.

The sequence of felsic pyroclastics observed during HPD1013 probably was deposited as a result of chaotic outflow from the caldera as a result of rapid series of major felsic eruptions, perhaps leading up to caldera formation itself. Similar sorts of felsic volcaniclastic successions have been observed as the youngest units exposed in West Rota volcano (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. Island Arc 17, 70-89). It seems unlikely that these pyroclastics erupted from the presently exposed dacitic domes, because coarse pyroclastics would be expected to have buried these domes if the eruption produced 100 m thick deposits at the site of HPD 1013.

It is noteworthy that no carbonate units or clasts were observed or recovered during this dive, indicating that either the carbonate platform observed during HPD 1011 does not exist in this sector of E. Diamante volcano or it is not exposed. The implications of this are considered in the summary section: East Diamante Summary.

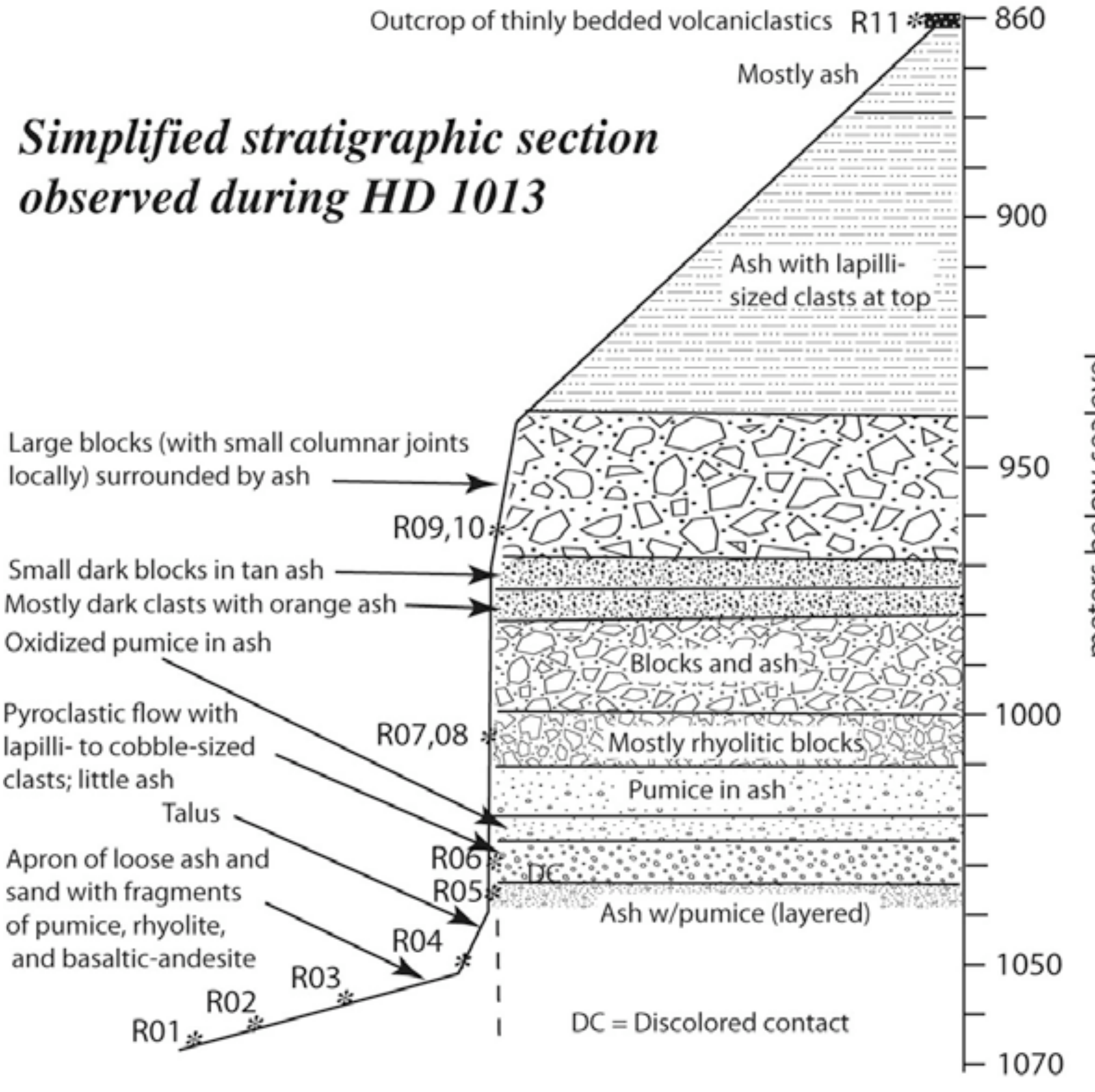


Figure 30. Simplified stratigraphic column traversed during HPD#1013, showing approximate slopes, location of rock samplings, (R01-R11), lithostratigraphy, and relative thickness of beds. After sketch by E. Kohut.

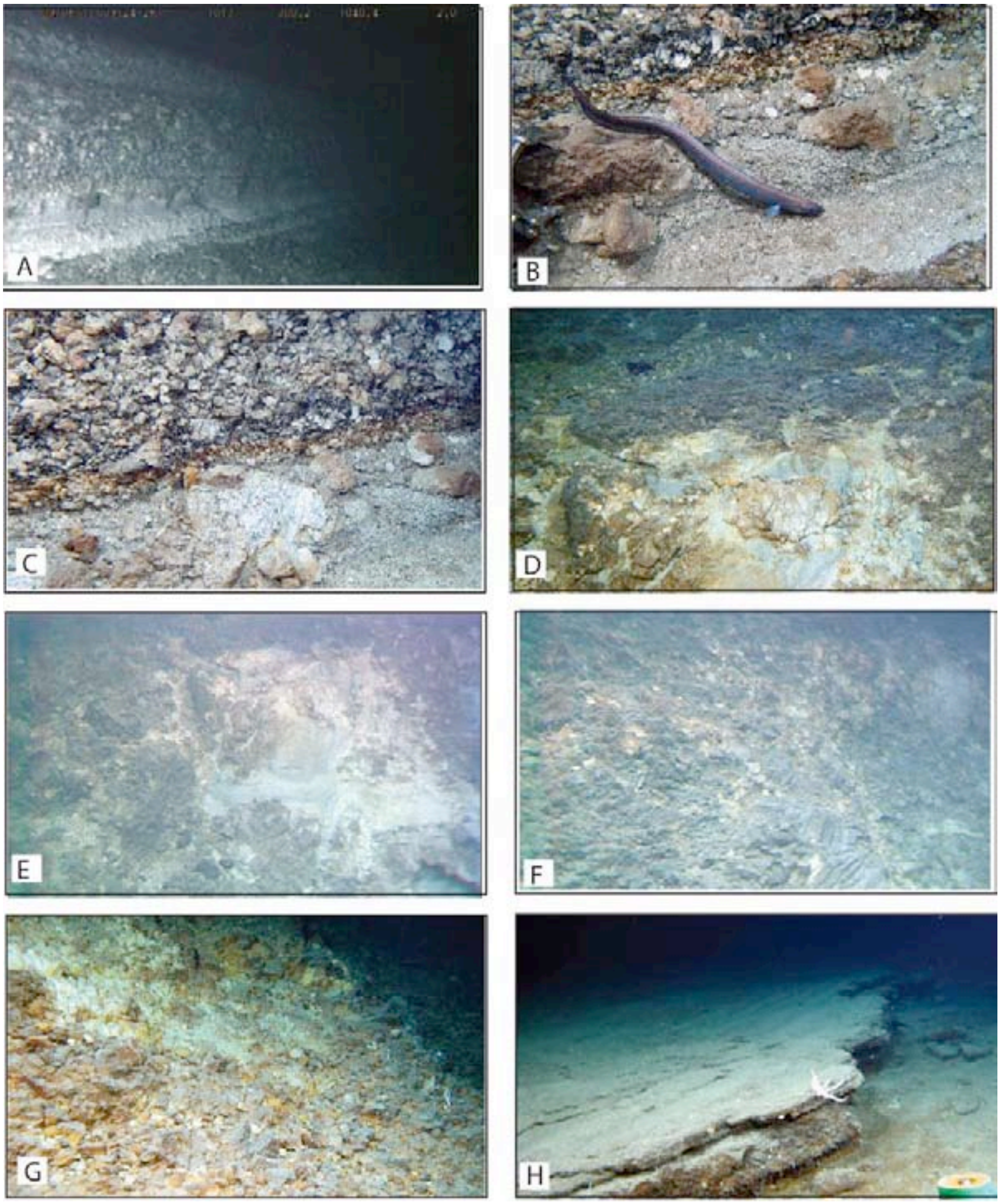


Figure 31. Representative bottom photos of outcrops observed and sampled during HD1013. A) CCD capture DSC00013 (09:24:26) photo of 1-2m high wall exposing ash and layered pyroclastics near start of dive; B) SeaMax 2009_0613_092749A showing details of lower graded felsic volcaniclastics overlain by coarse, ungraded felsic volcaniclastics; C) SeaMax 2009_0613_0933477A showing discolored (bake?) zone at base of coarse, ungraded felsic volcaniclastics (note photos A-C are of units sampled by R05 & R06; D) SeaBat 2009_0613_094156AA; E) HDTV capture HDC20090613094208_1 near coarse felsic breccia sampled by R07; F) HDTV capture HDC20090613095743_1 near coarse felsic breccia sampled by R08; G) SeaMax 2009_0613_100312AA coarse felsic volcaniclastic breccia; H) SeaMax 2009_0613_103931AA; photo of dipping, well indurated, diping slab sampled by R11.

DIVE LOG

Dive #:	NT09-08 HPD#1013
Date:	June 15, 2009 (local)
Location:	East Diamante, southwest caldera wall
Objectives:	Examine SW caldera wall
Logger:	Erika Jordan

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
8:10			In water		
8:54	1076	315	On the bottom, rocky bottom		
8:54	1076		Stopped to examine dark loose rocks		
9:01	1073		Sampling	R01	Basaltic andesite
			Moving over poorly graded seafloor		
9:06	1070		Sampling pumice with well defined layering	R02	Pumiceous rhyolite
			Moving over poorly sorted seafloor		
9:11	1063		Sampling	R03	Basaltic andesite
			Moving over poorly sorted seafloor		
9:20	1053		Sampling	R04	Pumiceous banded rhyolite
		303	Moving over rocky bottom		
			Stopped at wall		
			Examining contact at wall		
9:32	1040		Sampling pumice layer in wall	R05	Pumiceous rhyolite
			Examine wall: poorly sorted volcaniclastic eruption (?)		
9:38	1038		Sampled pumice wall	R06	Pumice
			Examine large blocky wall		
			Examine multiple boundaries in wall		
9:47	1015.5	274.5	Sample wall	R07	Fine-grained pumice
			Moving over poorly sorted seafloor		
			Examine small columns (?)		
9:54	1011.3	274	Sample pumice with columnar jointing	R08	Fine-grained pumiceous rhyolite
			Moving over dark coarse ground		
			Moving up slope		
	983.5	290.5	Moving up gradient, coarse ground		
	977.4	290.4	Stopped to examine flow (?)		
		290.8	Moving laterally along wall		
		300	Moving up gradient, coarse rocks in situ		
	967.2	300.8	Dark horizon		

10:14	966.8	300.4	Sampling	R09	Volcaniclastics with pumice banding
10:14	967.3		Sampling	R10	Fine-grained Pumice
		300.3	Moving over smooth ground with large outcrops		
	953.5	309	Moving over more large outcrops of rhyolite (?)		
	950		Moving over smooth ground, no observable outcrops		
	906.5	319.7	Moving over smooth ground		
	885		Moving over smooth ground		
	863.8		Moving over small outcrop		
10:44	861.5	297.3	Sampling, extremely soft angled slab - semi-indurated volcaniclastic (?)	R11	Volcaniclastics
10:54	861.3		secure manipulators; end of dive		
10:47	861		off bottom		
11:15			at surface		
11:25			HPD on deck		

Identifying rocks.

HYPER-DOLPHIN DIVE #1014

TECHNICAL INFORMATION

Location: East Diamante, western part of the southern caldera remnant
Objective: Examine the western part of the southern caldera wall

DIVE 1014	On bottom	Off bottom
Time (local): June 13, 2009	13:44	16:11
Latitude:	15°53.867’N	15°54.056’N
Longitude:	145°39.821’E	145°40.042’E
Depth (m):	895	731

Samples returned : 14 rocks

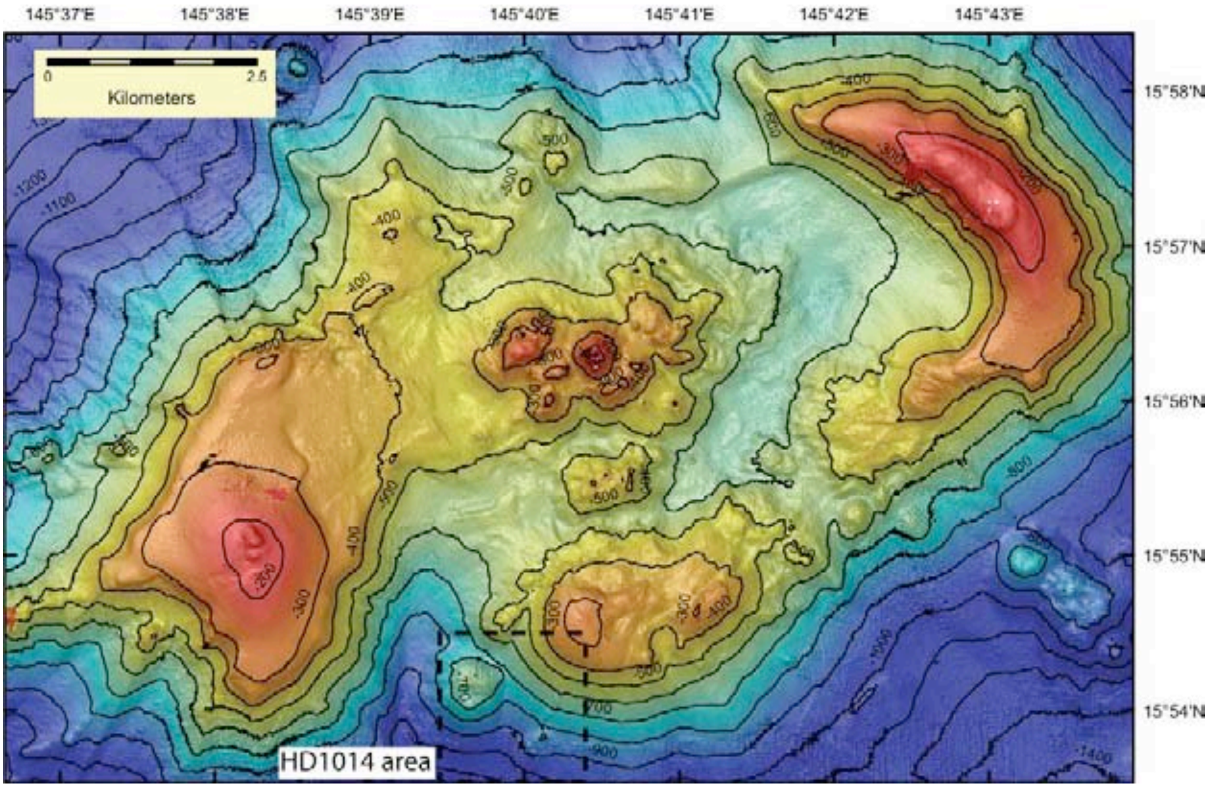


Figure 32. Bathymetric map of East Diamante Seamount, from Mariana Bathymetric Compilation (Susan Merle, PMEL/NOAA, compiler). Dashed box shows the studied area.

SCIENTIFIC SUMMARY

East Diamante is composed of an outer irregular caldera that is breached on the north and south, with resurgent felsic domes at its center, some of which are hydrothermally active. The northeast wall has been investigated during HD-1011, and the western caldera wall has been investigated during HD-1013. This dive (HD-1014) examined the western part of the southern caldera wall. The objective of Hyper-Dolphin dive 1014 was to continue investigating the East Diamante caldera by sampling volcanic units exposed along the western part of the southern caldera wall. Dive 1014 landed near the base of the southwest slope of the southern caldera wall at the depth of 895 m. The dive was composed of two traverses: the first traverse was oriented NW and ~200 m long, the second traverse was oriented NE and was ~ 175 m long. Samples R01-R09 were collected from the first traverse from scattered brownish subangular volcanic rocks lying on a fine-grained volcanic sand showing some ripple marks. The first traverse ended at 805m. The ROV flew to begin the second traverse where samples R10-R14 were collected. The ROV touched down at 802 m on seafloor that was similar to that observed on the first traverse. Samples were collected from dark subangular volcanic rocks lying on coarse-grained volcanic sand. Ripple marks were also observed. The second traverse ended at 731 m depth. No outcrops were observed during this dive. All sized rocks have been observed and sampled.

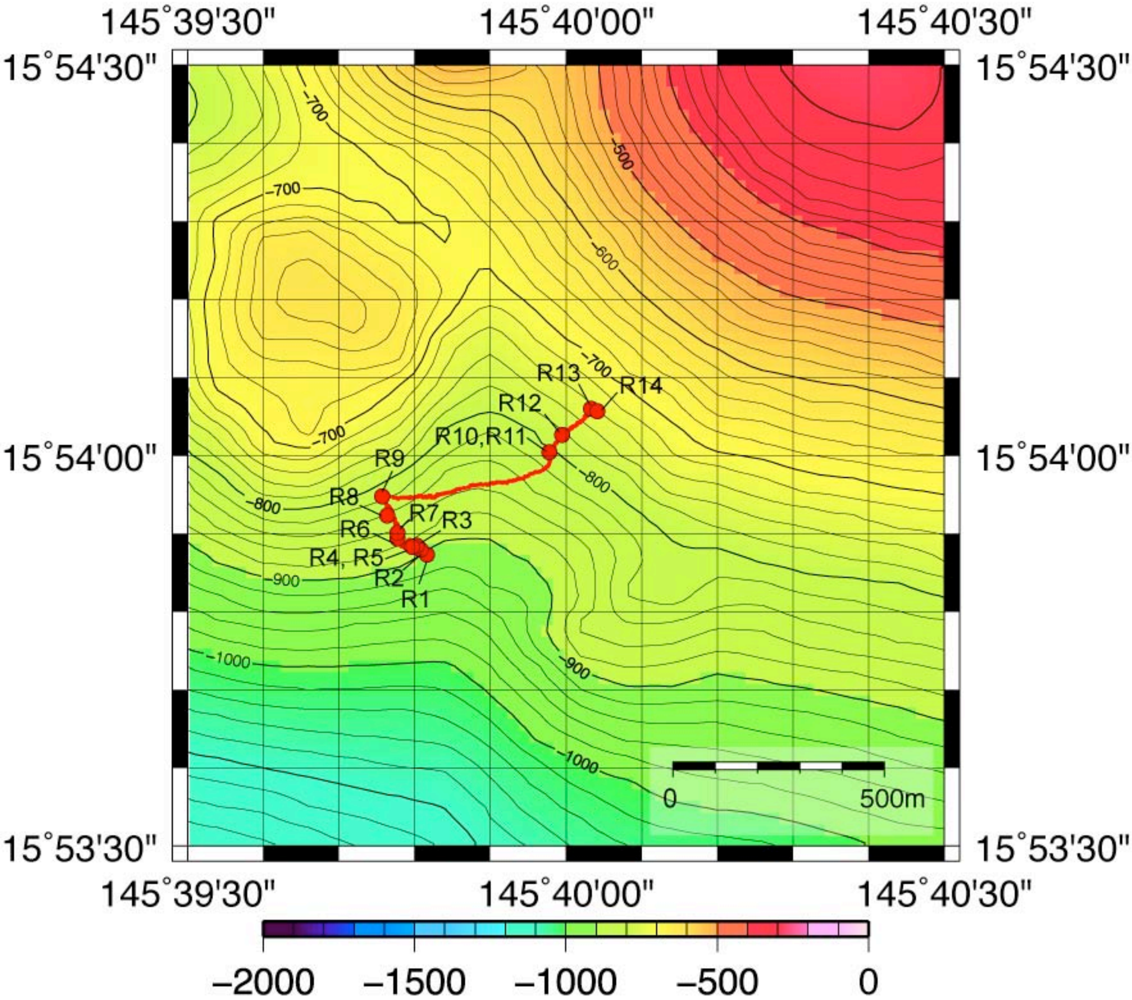


Figure 33. Bathymetric map of the western part of the southern caldera wall with HPD#1014 track.

The rocks sampled are all volcanic but diverse; no systematic variations in size or petrography were observed. They are alternatively composed of moderately vesicular hornblende dacite (R01, R09, R06) with glassy matrix (R03), pyroxene andesite (R02, R04, R08, R10, R13), basaltic andesites (R11, R12) and volcaniclastics (R06, R07). One crystal-rich pumice (R14) was collected during the final part of the second traverse at 731 m. Samples R08 and R13 show a pumiceous rim with an irregular boundary. Sample R13 has a rim showing columnar jointing which suggests rapid crystallization. All show a thin manganese coating. Samples are weakly to moderately altered and most have an alteration rim that is a few millimeters thick. The degree of vesiculation varies from 5 to 30%. Rocks can be porphyritic (R06, R11) to aphyric (R10).

Our observations suggest that the rocks we collected were deposited during an explosive event. The similarities between the volcaniclastic sequence observed during HD 1013 and the felsic rocks collected during this dive suggest that all the samples might be volcaniclastic clasts. The different kinds of rocks may indicate that different lavas were expelled together during the explosive event. An alternative hypothesis is the andesite / dacite started crystallizing in the vent and were expelled along with pumice during the explosive event.

A sparse biota was observed during this dive, including algae, sponges, coral, and anemone living on the volcanic rocks. Star fish were also present. A grey nurse shark was observed at 871 m and a red fish at 735 m.

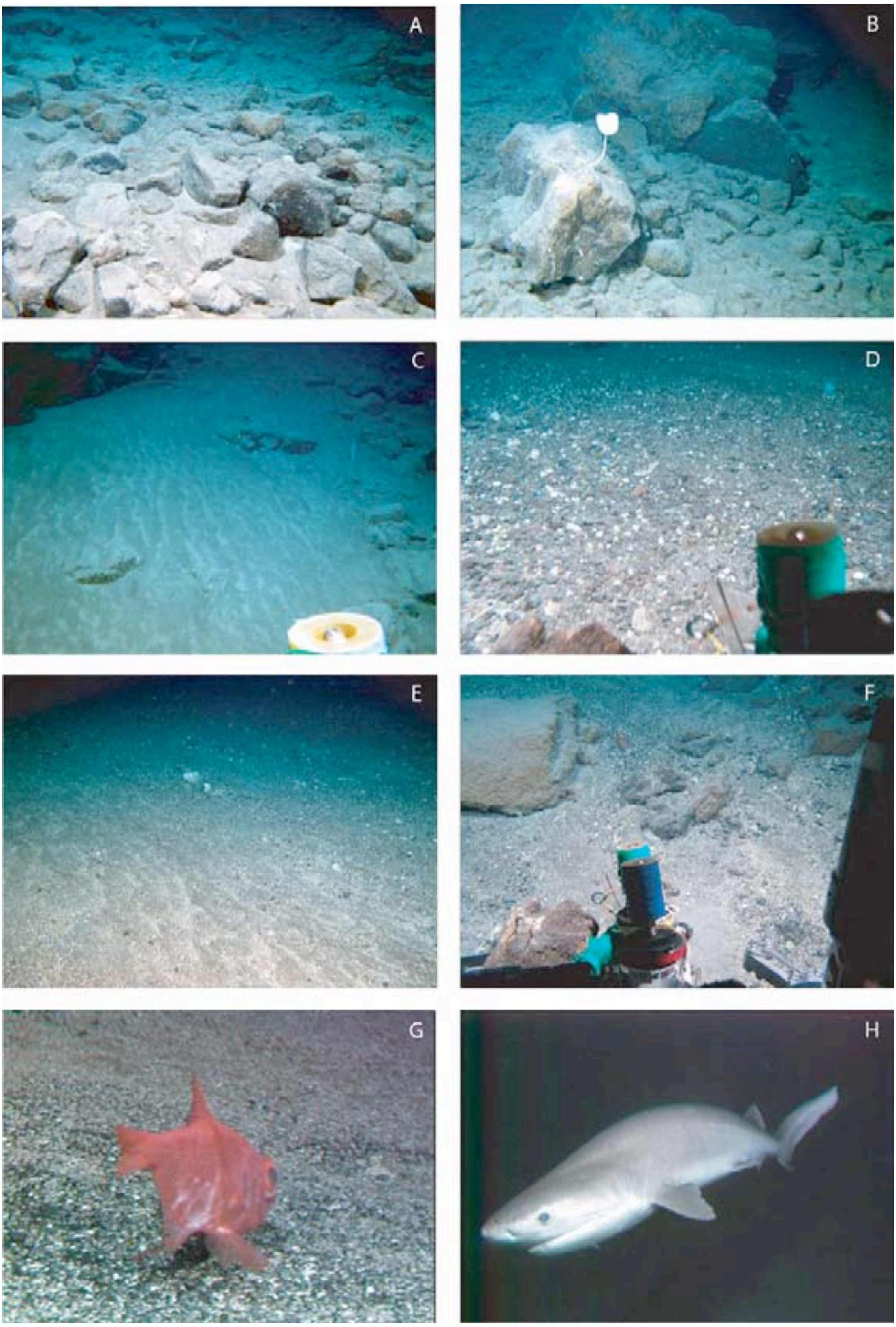


Figure 34. Photos from the bottom during HD-1014 dive. A: SeaMax 2009_0613_145316AA scattered subangular volcanic rocks lying on fine volcanic sand; B: SeaMax 2009_0613_145433AA sponge living on volcanic rock; C: SeaMax 2009_0613_144330AA ripple marks on volcanic sand; D: SeaMax 2009_0613_153758AA coarse volcanic sand; E: SeaMax 2009_0613_154005AA ripple marks on coarse volcanic sand; F: SeaMax 2009_0613_160552AA scattered brownish subangular volcanic rocks lying on coarse volcanic sand; G: HDTV hdc20090613160315 Red fish observed at 735 m. H: HDTV hdc20090613141821 nurse shark observed at 871 m.

DIVE LOG

Dive #:	NT09-08 HPD#1014
Date:	June 13, 2009 (local)
Location:	East Diamante, Western part of the southern caldera remnant
Objectives:	Examine the western part of the southern caldera wall

Logger: J. Ribeiro, R.J. Stern, N. Sica

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
13:07			In water		
13:44	895.7		Bottom		
			Not well-sorted dark volcanic rocks lying on finely layered grey volcanic sediment (sandy surface, possible volcanic sand). All size of volcanic rocks.		
13:48	895.8		Sampling from the dark volcanic rocks. Manganese rim on the sample with some red covering (possible bacteria or iron covering). Rounded sample. Sample in box 2.	R01	dacite
			Sedimentary layer with less block of dark volcanic rocks		
13:54	886.7		Prismatic piece of light brown volcanic rocks with manganese covering. Rocks show a white part beneath the Mn rim. Possible pumice. Fish		
13:59	886.7		Sampling R02 from the prismatic / subangular brownish volcanic rocks. Red covering at the base of the rocks possibly related to bacteria or iron. Sample in circle box.	R02	andesite
14:00	885.1		Long blue / white fish. Few shrimps.		
14:04	881.2		Sampling from a piece of volcanic rocks lying on finely layered sediment layer (sandy surface). Box 1	R03	glassy dacite
14:06	880.3		Sampling in the same area. Subangular sample with possible manganese rim. Sample with dark rim. Rubble slope. Box 2	R04	andesite
14:10	880		Algae and corals living on the volcanic rocks		
14:15	879		Red anemone living on layered volcanic rock. Sampling a small piece of volcanic layered rocks. Lightly brownish sample. Box 1	R05	volcanicastic
14:17	871		Blocks of all-sized volcanic rocks lying on finely layered volcanic sediment. Big grey nurse shark.		
14:20	866.9		finely layered volcanic sediment with smaller blocks of volcanic rock. Rubble slope.		
14:21	864.5		Sampling from small volcanic rocks. Dark and reddish. Possible manganese rim. Box 1	R06	porphyritic dacite
14:26	855.7		Bigger angular brownish volcanic rocks reappear. Rocks with possible layering. Sponge living on the volcanic rock.		

14:27	854		Sampling a piece of the bigger subangular layered volcanic rocks. Possible manganese rim. Dark sample. Box 3	R07	volcanicastic
14:44	823.7		Sandy surface with ripple marks. Big blocks of brownish volcanic rock.		
14:46	824.3		Sampling angular dark volcanic rocks with incrusting sponge around it. Possible pumice. Dark rim (manganese rim?) and white core. Reddish covering. Box 5	R08	andesite with glassy dacite pumiceous rim
14:54	813		White sponge living on volcanic rocks		
14:58	805		Sampling subangular volcanic rocks lying on sediment layer. Dark (manganese rim). In black box.	R09	dacite
15:00			Flying from point 2 to point 3		
15:23	801.9		Bottom. Dark volcanic sand (coarse grained) with ripple marks. Small dark volcanic rock are lying on the sediment layer.		
15:25	797.7		Sampling dark volcanic layer with possible manganese rim. Partial reddish covering at the base of the sample.Box 2.	R10	andesite
15:30	795.5		Sampling from steep outcrop a piece of dark volcanic rock surrounded by dark volcanic sand. Rocks broke in to 2 pieces in box 4.	R11	porphyritic basaltic andesite
15:32	785.3		Volcanic sand. Coarse grained. Very few angular volcanic rocks. Flat area. Ripple marks.		
15:35	744.8		Sampling angular dark volcanic rocks lying on volcanic sand. Reddish at the base of the sample. Box 4.	R12	basaltic andesite/andesite
15:46	732.7		Anemone living on big subangular volcanic rock lying on volcanic sand. Star fish. Sampling a rounded piece of this big dark volcanic rock. Manganese rim. White core, possible pumice. Big rock on top of box 5.	R13	andesite with pumiceous rim
			The big volcanic rock shows a possible contact between dark volcanic rocks and lightly colored volcanic rocks.		
16:00	735.7		red fish		
16:05	731.9		reddish anemone living on volcanic rock.		
16:07	731.4		Sampling subangular dark volcanic rock lying on volcanic sand. Manganese rim. Brownish / reddish in color. In box 3.	R14	crystal-rich pumice
16:11			Dive is over		
			We did not reach points 4 and 5.		

HYPER-DOLPHIN DIVE #1015

TECHNICAL INFORMATION

Location:	Small cone on the northwestern flank of East Diamante Volcano
Objective:	Survey and sample volcanic sequences

DIVE 1015	On bottom:	Off bottom:
Time (local): June 14, 2009	09:11	10:33
Latitude:	15 °57.702' N	15° 57.689 'N
Longitude:	145° 35.463'E	145° 35.558' E
Depth (m):	1591	1496

Samples returned: 7 rock samples

SCIENTIFIC SUMMARY

Dive HPD-1015 landed at 09:11 1591 m depth near the western base of an isolated small (100 m diameter) cone on the northwestern flank of East Diamante volcano (Figs. 35, 36). The dive consisted of a short traverse of ~150 m from the base of the cone to near the summit at 1495 m. The seafloor was mostly talus and some outcrops with large sediment pockets (Fig. 37A). Sessile organisms were colonizing the rocks and outcrops on the cone's slope. During the first part of the dive, most of the slope consisted of loose lava pieces with some outcrop. Sample R01 is a loose piece taken from the slope at 09:17. At 09:22, an outcrop at 1575 m exposed a narrow dike (Fig. 37B). Sample R02 was taken from this outcrop and R03 was taken on the slope above at 1551 m. Right after leaving the R03 site, jointed outcrops were observed followed by layered outcrops (Fig 37C). R04 was a piece of this layered material, possibly a flow top of the more massive jointed rocks. After sampling a loose rock at R05, the HPD moved upslope to encounter an area of jointed flow pieces lying loose on the slope (Fig. 37D) where the final samples (R06 and R07) were taken at 1495 m. The dive ended at 10:34 (1495 m) slightly below the summit of the cone. All the rocks collected on HPD-1015 were basalts with devitrified rims with small phenocrysts and microphenocryst. One sample (R03) had a dacitic xenolith.

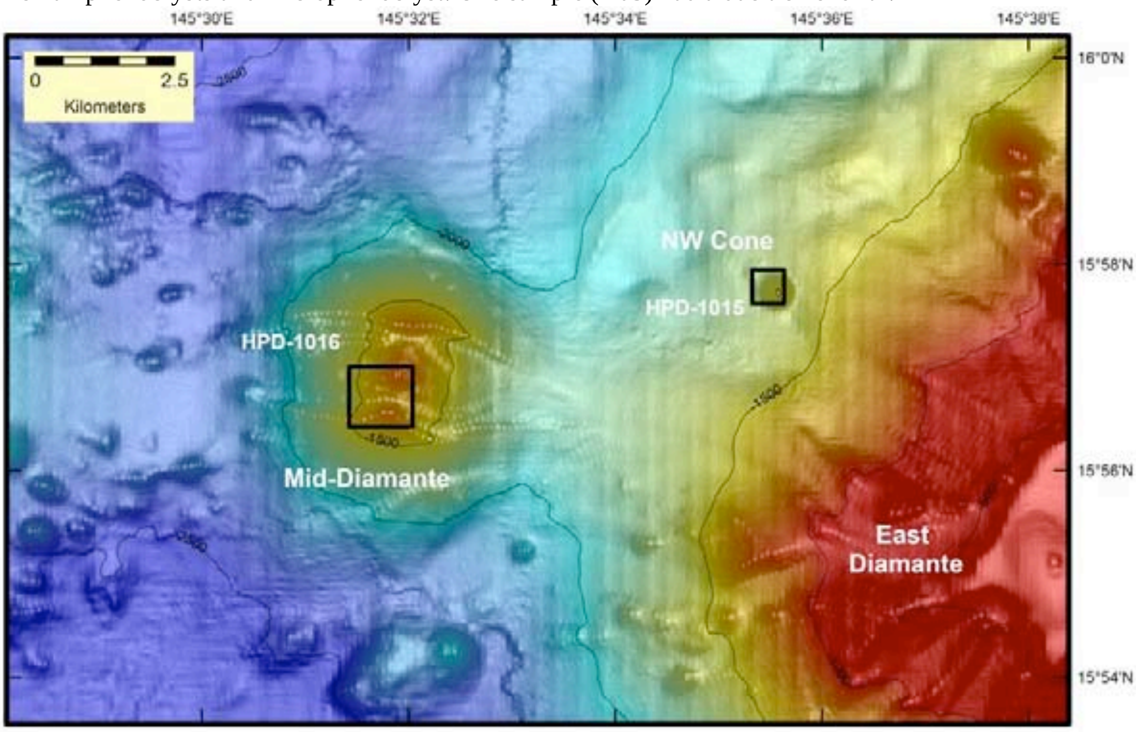


Figure 35. Bathymetry map showing locations of dives HPD-1015 & 1016 (boxes) and features referred to in text. Bathymetry from NOAA.

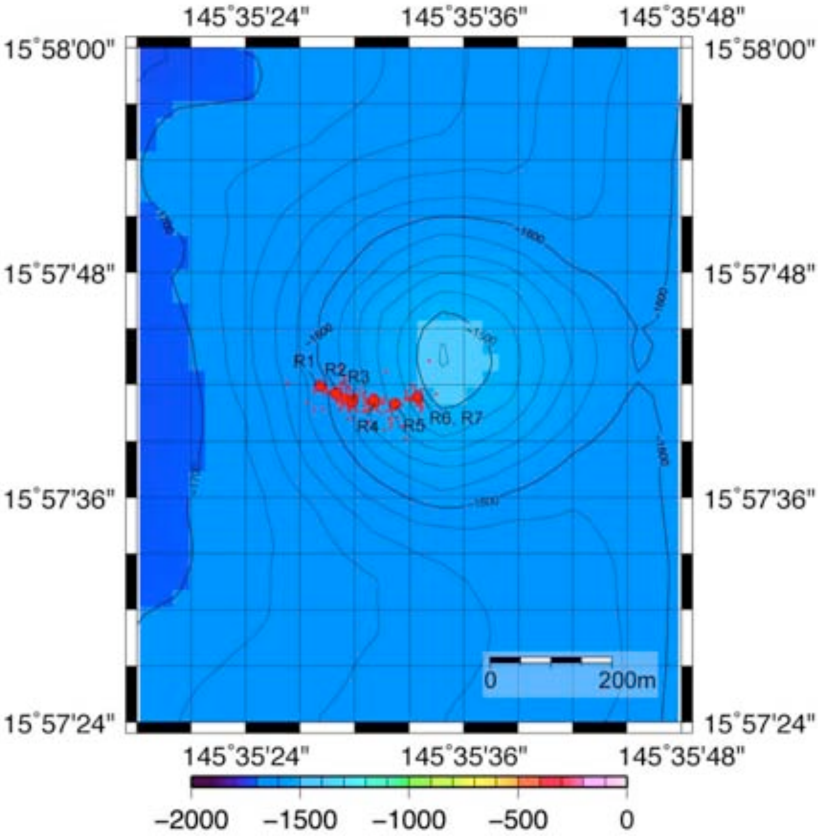


Figure 36. Bathymetry of dive HPD-1015 and locations of samples.

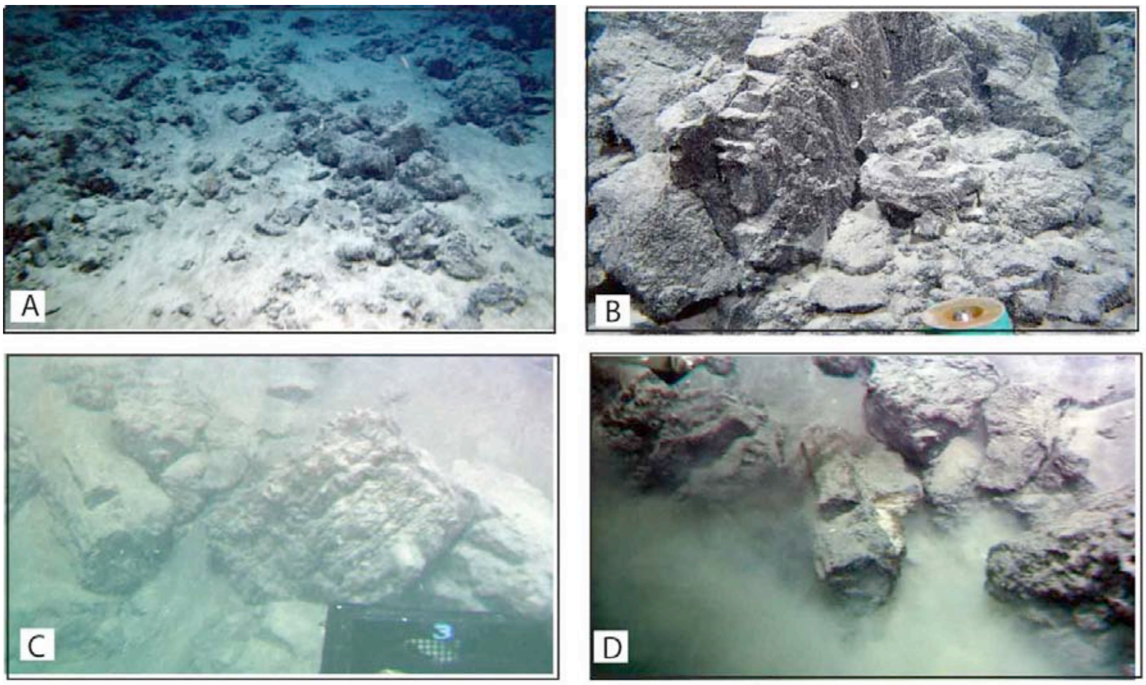


Figure 37. Representative photos from Dive HPD-1015: A: Slope of basaltic rocks near beginning of HPD-1015. SeaMax photo 2009_0614_091951AA. B: Exposure of thindike on slope of cone. SeaMax photo 2009_0614_092822AA). C: Layered rock on slope near end of dive HPD-1015. Frame grab hdc20090614101942_1. D: Columnar jointed flow sampled on station R06. Note fresh surface from sampling on right side of column. Frame grab hdc20090614102528_1.

DIVE LOG

Dive #:	NT09-08 HPD#1015
Date:	June 14, 2009 (local)
Location:	Cone on NW Flank of East Diamante Volcano
Objectives:	Sample rocks
Logger:	

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #
8:07			In water	
9:11	1590	87	On bottom. Sedimented slope with some talus	
9:14	1589	89	Stopped to sample on rubbly slope. Could be broken up blocky flow	
9:17			Rock placed in Box looks basaltic.	R01
9:18			Leave sample site, proceeding upslope.	
9:20	1582	84	More of same. Rubbly basaltic rocks with large sediment pockets. Some sessiles, e.g. sea whips.	
9:22	1575	83	Stopping at outcrop (probably in place). Possible small dike.	
9:23	1577	83	Taking massive rock from outcrop	R02
9:28			Leaving sample station	
9:31	1566		Probable pillows in place	
9:32	1561	83	Some outcropping of rock mixed with talus and sediment pockets	
9:35			Getting closer to slope, still lots of talus of angular rocks, some outcrop. See some pieces that could be rounded pillow fragments.	
9:36	1561		Looking for sample spot, moving slowly over bottom.	
9:38	1557	83	Slope of talus.	
9:40	1551		Stopped to sample outcrop(?). Not clear if sample was in place or not. Large angular piece with rounded top.	R03
9:44			Start up again.	
9:45	1543	75	Jointed outcrops, mixed with rubble and sediment pockets.	
9:47	1536		Distinct layered outcrops, sub-horizontal. Appears to be some fine-grained layered material between rubbly horizons.	
9:51	1536		Stopped for sample.	
9:56	1537	30	Stopped on slope waiting for suspended matter to clear out to sample.	
10:06			Sample 04 in Box 3 from outcrop of layered outcrop. Dipping steeply off to north.	R04
10:08			Leaving sample station	
10:10	1525	70	Rubble slope with large sediment pockets.	
10:12	1519	66	Stopped to sample. Looks like rocks are not in place.	R05
10:15			Leave station to continue upslope.	
10:17	1505	60	Rubble slope with large sediment pockets.	
10:19	1496	60	Rubble, some with fine layering and jointing.	
10:20	1496	65	Looking at slope, moving in to sample again.	
10:21	1495		Tried to sample in mostly rubble slope. Piece of columnar jointed section broke off, so pretty friable (heavily altered/oxidized?)	
10:29	1495		Broke off small jointed piece from side of larger one.	R06
10:31	1495		Another broken piece of column	R07
10:34	1495		Leave bottom; End Dive HPD #1015	

HYPER-DOLPHIN DIVE #1016

TECHNICAL INFORMATION

Location: Mid-Diamante Seamount, graben with constructional cone
Objective: Map geology and sample rocks from base to top of graben and constructional cone

DIVE 1016	On bottom:	Off bottom:
Time (local): June 14, 2009	14:02	16:28
Latitude:	15°56.646'N	15°56.835'N
Longitude:	145°31.693E	145°31.828'E
Depth (m):	1411	1258

Samples returned: 10 rocks, 1 core

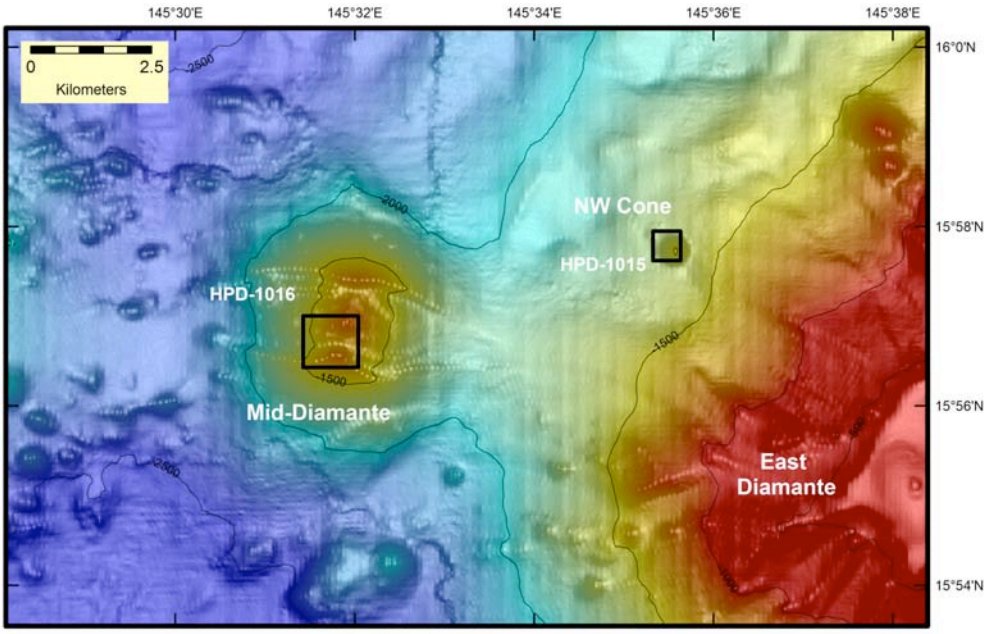


Figure 38. Bathymetric map of East and Mid-Diamante Seamount, from Mariana Bathymetric Compilation (Susan Merle, PMEL/NOAA, compiler).

SCIENTIFIC SUMMARY

The Diamante Seamount chain comprises three volcanoes aligned along an east-west transect at the northernmost margin of the Southern Seamount Province of the Mariana arc some 80 km north of Saipan. Compared to the East and West Diamante Seamounts that flank it, the Mid- (or Central) Diamante Seamount is relatively small (~4 km diameter) (see Fig. 5.6.1). Its diminutive size discriminates Mid-Diamante from East and West Diamante as well as two other features: (a) its constructional cone is fully enclosed within an E-W trending graben (see Fig. 5.6.1); and (b) there is no caldera associated with the cone. The localized significance of the graben is uncertain but it is likely a result of N-S movement along the arc front manifest as E-W extension and may be related to earthquake swarms recorded in the region (Heeszel *et al.*, 2008). Furthermore, unlike East and West Diamante, Mid-Diamante does not have a caldera. Our dive revealed that although the graben wall comprises volcanic rocks (tuff, breccia, basaltic andesite through to dacite), the southern wall of the cone, surveyed during the second traverse sampled only hydrothermal manganese.

Dive 1016 consisted of two traverses. The first one was oriented SE along and up the steep graben wall from base to top, and the second one was oriented E/SE along a track from the base of the constructional cone to approximately one third up the cone. The graben wall traverse was ~ 170 m long while the cone wall traverse was less than ~ 50 m. HD touched down at the base of the western margin of the southern wall of the graben some 300 m to the south of Mid-Diamante proper (graben base-cone edifice base) at a water depth of 1411m and commenced the steeply upwards graben wall traverse. Samples R01-R05 were collected during this traverse that terminated near the top of the graben wall at a depth of 1223m. Subsequently, HD flew about 400 m in a NE direction at a water depth of about 1200m to commence the second traverse. Touching down at the base of the Mid-Diamante cone at a water depth of 1274m, HD began its short E/SE traverse. Samples R06 to R10 were subsequently collected during this traverse that ended some 200m from the summit of the cone at a water depth of 1257m.

On the approach to the base of the graben wall, the floor was typically sandy and strewn with infrequent cobbles (Fig. 40A). As HD approached the base of the graben wall however, the floor became littered with large, angular (Fig. 40B) and apparently brecciated, blocky lava flow blocks (talus?) and /or joints. This loose material presumably originated from the top of the graben wall or the wall itself. Sample R01 was collected as float from this region and is a typical piece of this presumed blocky lava flow. R01 fragmented into two dominant pieces and subsequent to rock cutting was described as an (a) tuff/breccia and (b) volcanic breccia comprising mafic/basaltic clasts set in a matrix of ash +/- pumice and the latter comprising vesiculated clasts of basalt supported within a clastic matrix. Such 'fist-sized' basaltic-andesitic clasts were recovered elsewhere (e.g., Fig. 40C) independent of their brecciated host. The base of the graben wall is also demarcated by striations of uncertain affinity (e.g., Fig. 40B & D). Further up the wall however, such 'striations' appear to delineate fault planes (Fig. 40E). R02 is a small, dense sample collected in-situ (at 1366 m) at the base of what appears to be a set of near-vertical fault planes at the graben edge. The sample is a weakly altered, strongly vesiculated (~40%) basaltic andesite comprising ~ 10% plagioclase (other phases are not recognizable in hand specimen). R03 is a large (~50-60 cm), slabby segment of apparent in situ flow at edge of graben wall. R03 is a weakly altered, moderately vesiculated auto-brecciated basaltic andesite comprising less than 5% pyroxenes and <10% plagioclase feldspar and a thin (<1 mm) devitrified rim; a sharp contact exists between the inner crystalline body and the outer clastic margin. R04 is similar to R03 but is a basaltic andesite clast within breccia. R05 is a weakly altered, moderately vesiculated aphyric dacite-ryhodacite.

Due to time restrictions, the second traverse was modest in scope. HD was able only to survey a very short tract of the lower third of the cone over a distance of ~ 50m from 1274 - 1257m depth (Fig. 39). Samples R06-R10 were recovered from this short traverse and all comprised hydrothermal manganese (deposits/rocks?) As a result it is impossible to characterize the geology of the constructional cone at this point. Nonetheless, the lack of felsic pyroclastics and pumice is consistent with the bathymetric data that indicate a lack of caldera formation in the Mid-Diamante volcano.

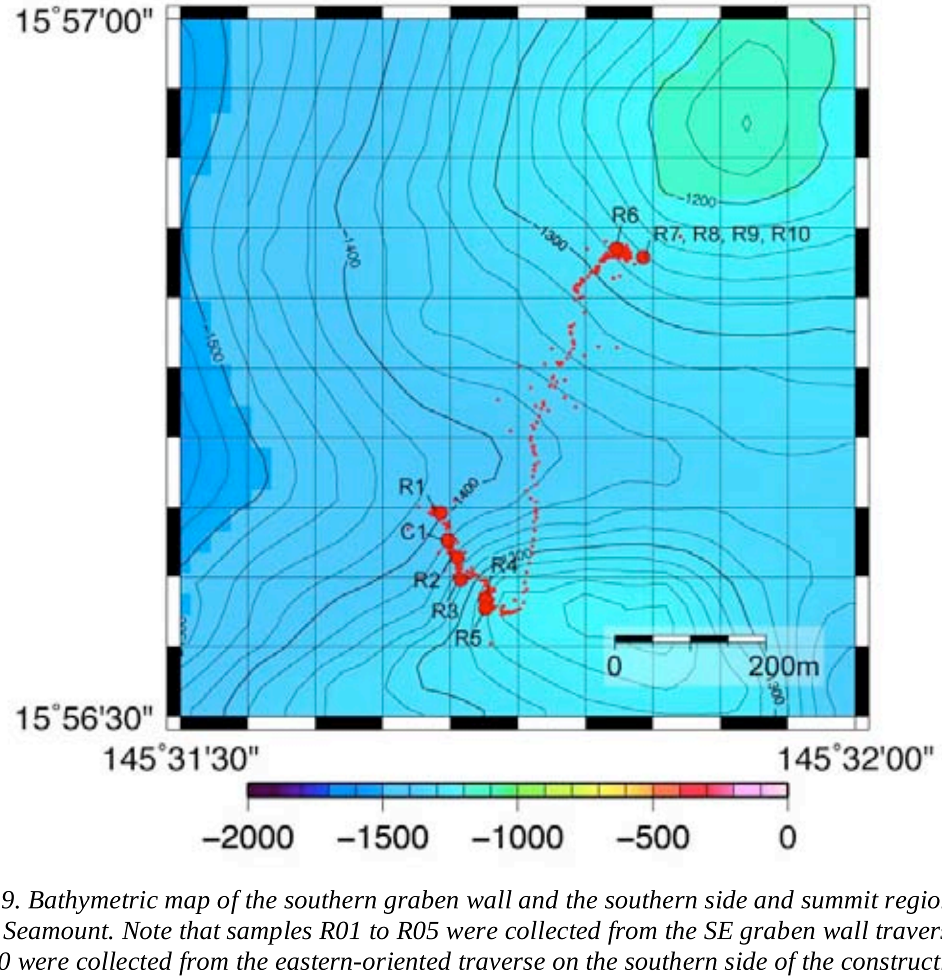


Figure 39. Bathymetric map of the southern graben wall and the southern side and summit region of Mid-Diamante Seamount. Note that samples R01 to R05 were collected from the SE graben wall traverse whereas R06 to R10 were collected from the eastern-oriented traverse on the southern side of the constructional cone.

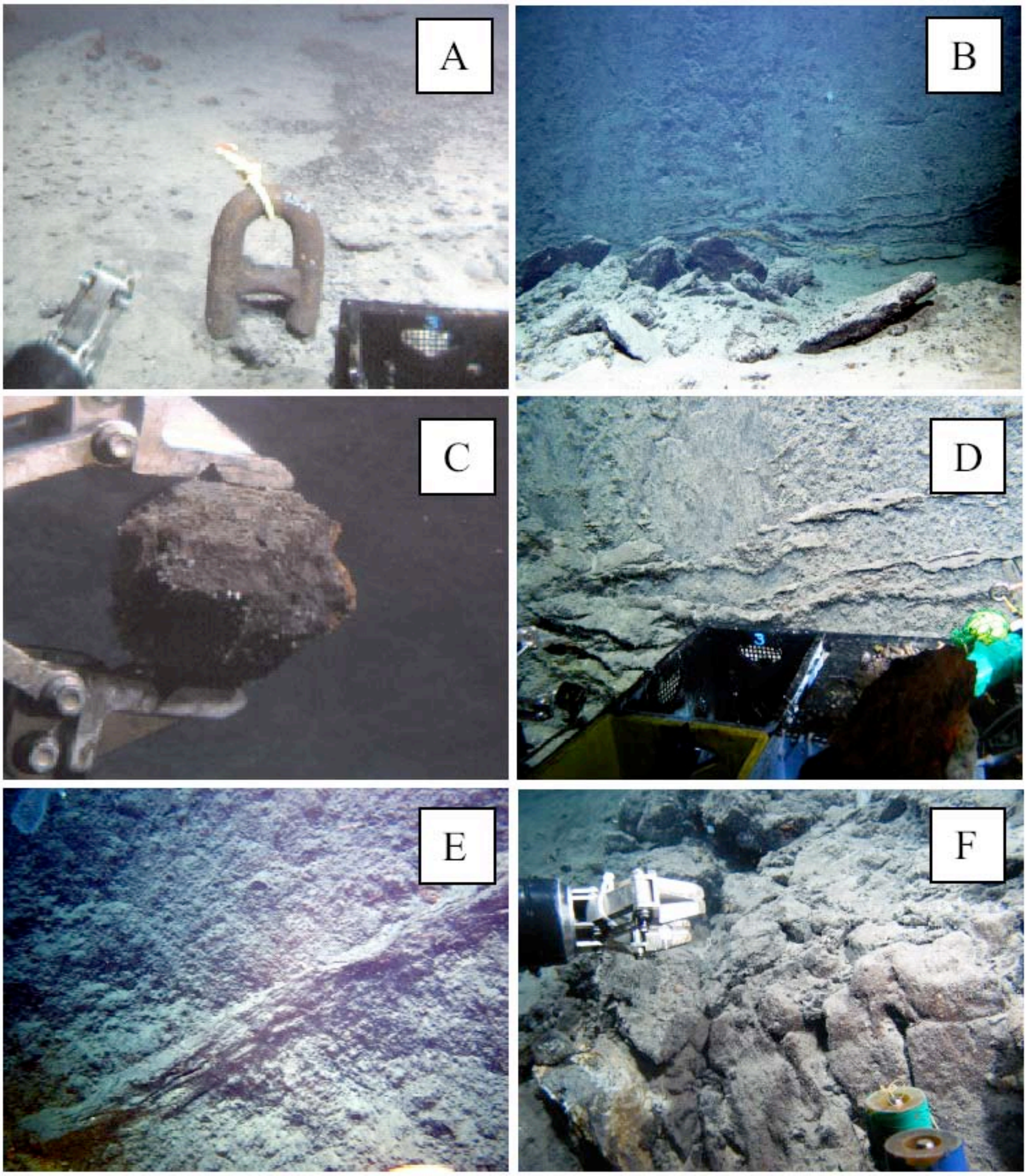


Figure 40. (A) Sandy seafloor bottom near beginning of traverse 1. Frame grab hdc20090614141727. (B) Angular blocks of lava flow/breccia at base of southern graben wall SeaMax photo 2009_0614_142345AA. (C) Basaltic andesite clast (Sample R04). Frame grab hdc20090614145442. (D) Striations of uncertain affinity near base of southern graben wall. SeaMax photo2009_0614_142605AA (E) Fault plane on graben wall near wall summit. SeaMax photo 2009_0614_145322AA. (F) Outcrop of hydrothermal manganese on second traverse on constructional cone wall (southern wall, ~ 100m from the base at ~1270m water depth). SeaMax photo 2009_0614_161636AA.

Dive Log

Dive #:	NT09-08 HPD#1016
Date:	June 14, 2009 (local)
Location:	Mid-Diamante Volcano; Graben with constructional cone
Objectives:	Map geology and sample rocks
Logger:	Whittam

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
13:05			In water		
13:28	280	286.6	Still descending.		
14:02	1411	119	On bottom. Blocky flows/joints? + pillows with deep sediment pockets		
14:04	1414	119	Stopped; collecting very large slabby sample (R1). Sample brownish/black, probably not in-situ (loose). Brownish sandy bottom. Grey on interior and red-orange exterior. Very angular sample. Dike? Flow top? Put into basket: behind basket and one in basket 1. Orange coloration: oxidation? Hydrothermal percolation? Note: sample fragmented into smaller chunks (but still relatively very large). Appears very light grey in interior and brown weathering crust? on exterior.	R1	(a) tuff/breccia; (b) volcanic breccia
14:17	1414	120	Common patchy, black (Mn-coated?) regions in otherwise brownish, sandy floor bottom. Placed 'A' anchor on floor bottom.		
14:18	1407	120	Traversing slowly. Moving over large (meter-scaled) angular boulders.		
14:20	1404	126	Traversing slowly. More large angular apparently variably weathered/altered blocks (sheet flow fragments?)		
14:22	1400	125	On bottom (sandy, reddish brown floor).		
14:23	1401		On bottom at edge of scarp/wall. Basaltic flows? (very thin apparent flows of ~ 5-10 cm). Red-domed jellyfish. Reddish-orange crust or paleo-water level indicator. Angular blocks of flows? Dike prominent on scarp wall. Lava shelves? Layered flows (very thin 4-5 cm rind).		

14:26	1400	162	Collecting grey flow rock associated with the orange discoloration (pervasive alteration). Probably not flow but simply an alteration crust. Reason being is that this rock is very friable and disintegrates upon arm contact (i.e. upon claw clenching). As a result, a core sample was obtained (instead of a rock sample). Core sample taken from orange alteration region of lava flow "wall". Taken with green-handled push core sampler. Multiple attempts to obtain orange alteration product. Put core sample into URHS container (but uncertain if any sample survived).	C1 (BUST)	
14:35	1400	162	Second push core sampled exact same material/outcrop as C1. Whole section possibly volcaniclastics instead (of flows). Blue-handled push core sampler tube used. Blue-handled core sampler, C2 placed directly behind C1.	C1	
14:42	1399	163	Panning up and towards "wall". Light grey-colored wall rock appears to comprise lava flows.		
14:45	1377	123	Traversing slowly. Light grey sea bottom. Moving over huge angular boulders.		
14:47	1366	121	Grey-brown blocky bottom. Eel swam by. Region appears to be built up of near-vertical fault planes. Collecting from grey bottom (boulders and cobbles). Took R2 in-situ--> light brown/pink. Hard material (no crumbling like previous orange samples). Still wrestling with sample (R2). Sample is very small, subrounded, with disctinctive orange (alteration) around exterior. Sample into basket 2.	R2	vesicular basaltic andesite
14:54	1362	121	Climbing slowly and traversing floor.		
14:57	1320	121	Still climbing/traversing slowly.		
14:59	1293	111	Lava flows on sea bottom. Rare sponges. Floor strewn with what appears to be exotic blocks, some in-situ.		
15:00	1293	111	Collecting large slabby segment of flow that is in-situ along wall. Grey interior, looks fresh for most part. Much trouble liberating jointed sample. Finally liberated a large, elongated sample. Sample placed behind basket (along two blue ones at back).	R3	auto-brecciated basaltic andesite
15:09	1288	99	Traversing slowly along floor. Uneven floor with many cobble-boulder-sized (presumably) lava flow-derived segments.		
15:13	1260	111	Traversing slowly. Floor here is not completely littered with boulders and there is ample smooth, sandy floor between boulders/cobbles. Copious red bacterial streams.		

15:16	1240	168	Traversing slowly over jointed flows.		
15:17	1238	167	Collecting slabby sample from jointed flows. Appears to be a contact with light grey rock at bottom and reddish ones on top. Sample is from reddish section. Reddish section disintegrates upon claw contact. Very tiny samples. Actually last attempt grabbed relatively large subangular, reddish-brown sample. Into box: 5.	R4	basaltic andesite (clast in breccia)
15:23			Left station, at wall of truncated lavas, possibly some pillows.		
15:24	1226	139	Slope is flattening out.		
15:25	1226		Stopping to sample again. Near top of cone, a large orangish-red slab was collected and put into basket 5. Sample broke into pieces.	R5	aphyric daciate/rhyodacite
15:29	1221	107	Traversing and climbing slowly to top of cone and/or scarp.		
15:30	1201	39	Moving to Target 3. Flying quickly (horizontally at 1200m depth).		
15:36	1200	19	Moving quickly at 1200m to large cone almost exactly due north.		
15:40	1199	29	Still traversing due north at 1200m.		
15:44	1199	10	Still traversing due north at 1200m.		
15:46	1230	38	Climbing now to 1300m at Site/Target 3 at base of cone.		
15:49	1300	40	Cobbly flow with angular boulders. Floor itself appears to be comprised of flows. The exposed boulders appear to be in-situ.		
15:52	1274	68	Collecting small angular sample from floor. Appears very oxidized/altered. Into basket 4.	R6	hydrothermal manganese
15:55			Irregular (angular flow-derived segments) litter floor along with subordinate large (0.5 diam.) boulders. Blocky/jointed flows/dikes.		
15:57	1256	53	Collecting from columnar joint on wall. Variably altered (red/orange) as seen previously. But it appears rather fresh grey on sample interior. Very small subangular powdery-red sample. Disintegrated upon deposit into basket X. (However, it appears that some did survive to comprise R7). Claw still wrestling with outcrop for sample R7.Claw wrestled with outcrop (for sample R7) for ~ 11 mins.) Sample placed into basket 3?	R7	hydrothermal manganese
16:08	1256	55	Claw attempting to obtain another similar piece to R7. Obtained another 'red' sample' (i.e. R8) which appears to be part of the oxidized carapace that caps the greyer, fresher rocks below. (Stratigraphy appears to be red on top of grey). Sample placed into basket 4.	R8	hydrothermal manganese

16:12	1257	54	Attempting to collect rounded black 'clast' from red section. Into basket? Claw still struggling with R9. As well, this whole section appears to comprise a set of columnar joints. Still at apparent contact between f-g grey flows (it appears) and redder, more oxidized joints. R9 another red sample?	R9	hydrothermal manganese
16:25	1257	56	Attempting to collect from more f-g grey region. Collected very tiny triangular piece (in basket 3) but appears to be the altered/powdery red material again.	R10	hydrothermal manganese
16:28	1258	53	Ascending; dive finished.		
NOTE: orange colour may be result of fluid circulation through (fractured) flows etc.					

Squall

HYPER-DOLPHIN DIVE #1017

TECHNICAL INFORMATION:

Location: East slope of parasitic cone on lower east slope of West Diamante Seamount.
Objective: Survey and sample basalts

DIVE 1017	On bottom:	Off bottom:
Time (local): June 15, 2009	09:22	10:48
Latitude:	15°56.060'N	15°56.173'N
Longitude:	145°28.272'E	145°28.191'E
Depth (m):	2211 m	2078 m

Samples returned: 9 rocks

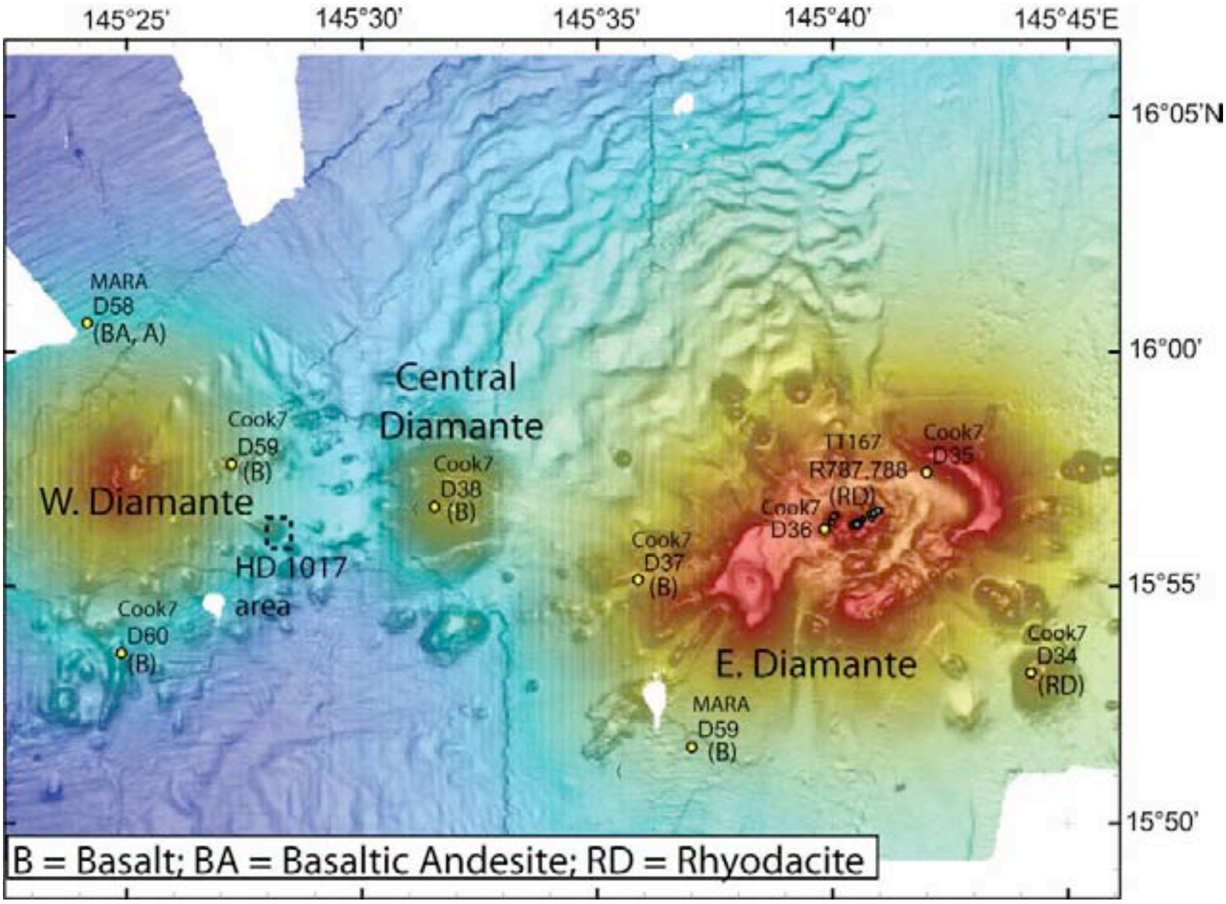


Figure 41. Bathymetric map of Diamante Seamount Chain, from Mariana Bathymetric Compilation (Susan Merle, PMEL/NOAA, compiler. Dots indicate previous dredges (Mara, Cook7 cruises) and ROV dives (TT167). Dashed box shows location of Fig. 42.

SCIENTIFIC SUMMARY

West Diamante seamount has a number of small parasitic cones. Similar cones erupt mafic magmas that are sometimes primitive. Primitive arc lavas provide very useful insights about the composition of the mantle wedge and the subduction-related fluids that modify it, and about the conditions of melt generation in the mantle wedge. This dive was intended to recover such samples.

The targeted parasitic cone is about 200m tall and about 1 km in diameter. It could be a monogenetic volcano, built from a single protracted eruption. This dive traversed about 300m horizontally and ascended 133m up the lower SE slope of the unnamed parasitic cone. The traverse was monotonous, dominated by rubbly basalt flows that were covered by thin brownish sediment. All 9 samples collected were dark, mafic lavas that are weakly to moderately altered, with Mn coating that ranges from thin films to 5 mm thick. Phenocryst assemblages for all samples are similar; these are olivine basalts with subequal proportions of olivine, pyroxene and plagioclase. The lack of compositional diversity is consistent with this being a monogenetic volcano, with little time for magmatic fractionation.

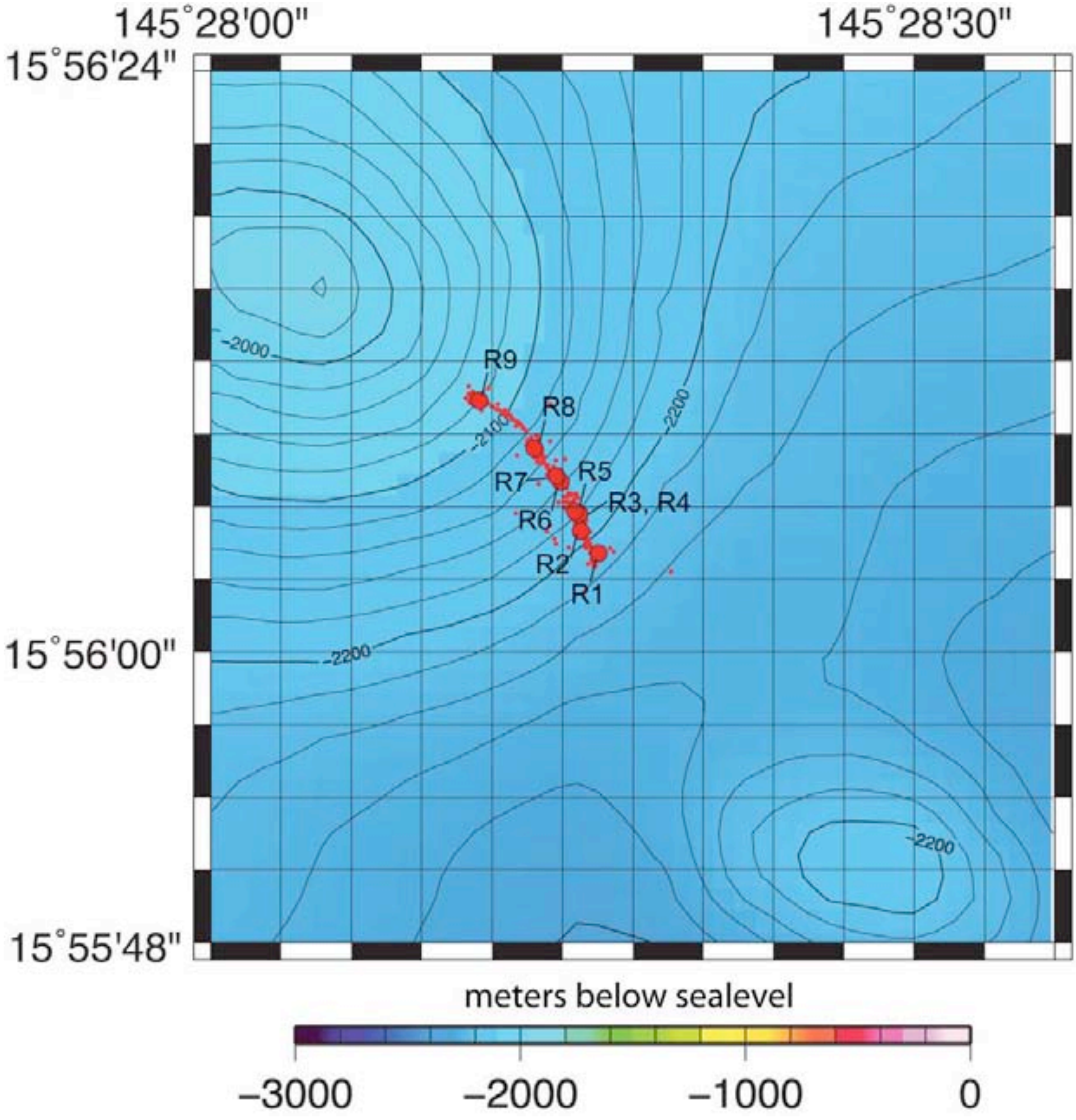


Figure 42. Bathymetric map of part of a parasitic cone on the eastern slope of W. Diamante Seamount, surveyed during NT09-08. Track of HD 1017 is also shown, along with sample locations.

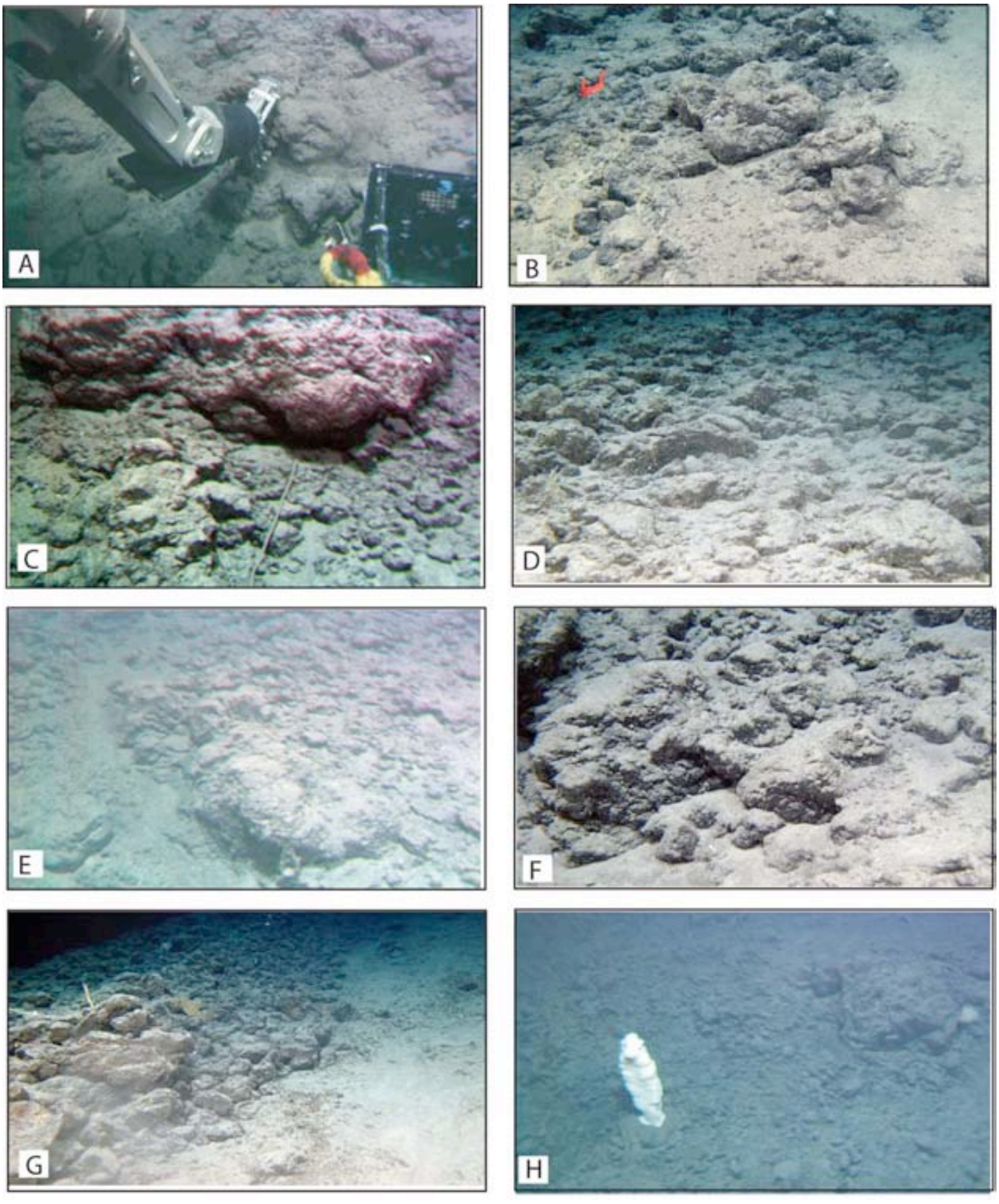


Figure 43. Photos of basaltic lava flows covered by thin sediments, observed and sampled during HD1017. Sequence of photos is from start A) to end H) of dive. A) HDTV capture HDC20090615092516 collecting R01 from rubbly basaltic lava flows; B) SeaMax 2009_0615_093209AA photograph of rubbly basaltic lava flow sampled by R01; C) HDTV HDC20090615095346_1 lava flow with larger blocks, near where R05 was collected; D) SeaMax 2009_0615095708AA rubbly basaltic lava outcrop sampled by R05;E) HDTV capture HDC20090615100133_1 rubbly basaltic lava flow sampled by R06; F) SeaMax 2009_0615_100409AA rubbly basaltic lava flow sampled by R06; G) SeaMax 2009_0615_100930AA rubbly basaltic lava flow sampled by R07; H) HDTV HDC20090615102928 silica sponge and rubbly outcrop near where R09 was collected.

DIVE LOG

Dive #:	NT09-08 HPD#1017
Date:	June 15, 2009
Location:	Parasitic cone, W. Diamante
Objectives:	Sample basalts
Logger:	Nicole Sica

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
8:02			In the water		
9:23	2211	322	See bottom, sediment with scattered cobbles		
9:24	2209	319	See outcrop, rubbly/pillow outcrop		
9:25	2209	317	Taking first sample		
9:28	2209	318	Sampling rubbly outcrop, big rock from outcrop, sample placed in box 2	R01	Olivine basalt
9:32	2210	318	Leaving sampling site 1		
9:34	2199	314	Moving away from outcrop and moving into sediment with scattered cobbles		
9:37	2193	316	Taking second sample, sample is one of the cobbles within the sediment area, sample is float, small sample, sample placed in circle basket	R02	Olivine basalt
9:41	2191	315	Leaving sampling site 2		
9:43	2186	310	Surface change and now moving through rubbly outcrop		
9:45	2182	310	Taking third sample, sample is float but is within the outcrop area, sample broke, rocks are very friable and dusty		
9:48	2182	309	Moving over slightly to take a new sample, having trouble doing so due to the very friable aspect		
9:49	2183	309	Small rock taken and placed in box 1, sample is outcrop	R03	vesicular basaltic rind
9:51	2183	309	Taking another sample, sample 4 from the same area of 3, sample placed in box 1, sample is outcrop	R04	Olivine basalt
9:52	2181	310	Leaving sampling site 3, we are still in rubbly outcrop		
9:54	2176	310	Surface is changing, rubbly outcrop is getting bigger rocks and boulders, and you see more rubble and barely see sediment		
9:55	2176	309	Taking fifth sample, sample is small but bigger than 3 and 4, sample was taken was outcrop and placed in box 1	R05	Olivine basalt
9:57	2175	309	Leaving sampling site 4, we are still in rubbly outcrop		
10:01	2156	300	Taking sixth sample, sample is rubble not outcrop, sample placed in box 1	R06	Olivine basalt
10:04	2155	300	Leaving sampling site 5, we are still in rubbly outcrop		
10:07	2150	300	collected sample of talus; in box 1	R07	Olivine basalt

10:08	2150	300	Leaving sampling site 6, we are still in rubbly outcrop		
10:13	2126	315	Taking seventh sample, sample is outcrop and is a large sample, rock is rounded, sample is placed ontop of box one, too large to fit inside	R08	Basalt
10:23	2122	317	Leaving sampling site 7, we are still in rubbly outcrop		
10:27	2105	300	Outrop is still rubbly but rubbles are smaller and still dominate over sediment		
10:30	2080	300	Outcrop is becoming more rubble with sediment and gravel		
10:31	2077	280	Taking eigth sample, sample is rubble and float, shape is elongated and edges a fairly smooth, rock is placed in box 3	R09	Olivine basalt
10:36	2078	278	Taking a core in same area as R09, core taken in green core, core taken of sediment and gravel, core couldn't penetrate deep enough, so no core taken and not trying again		
10:49	2078	277	Leaving sampling site 8, we are still in rubbly outcrop		
10:49			Coming up		

LUNCH OF ONE DAY

HYPER-DOLPHIN DIVE #1018

TECHNICAL INFORMATION:

Location: West Diamante Seamount, northeastern side
Objective: survey and sample seamount SW of Anatahan Island.

DIVE 1018	On bottom:	Off bottom:
Time (local): June 15, 2009	13:02	16:09
Latitude:	15°58.032'N	15°57.8'N
Longitude:	145°25.412'E	145°25.052'E
Depth (m):	988	748

Samples returned: 12 rocks, 3 cores

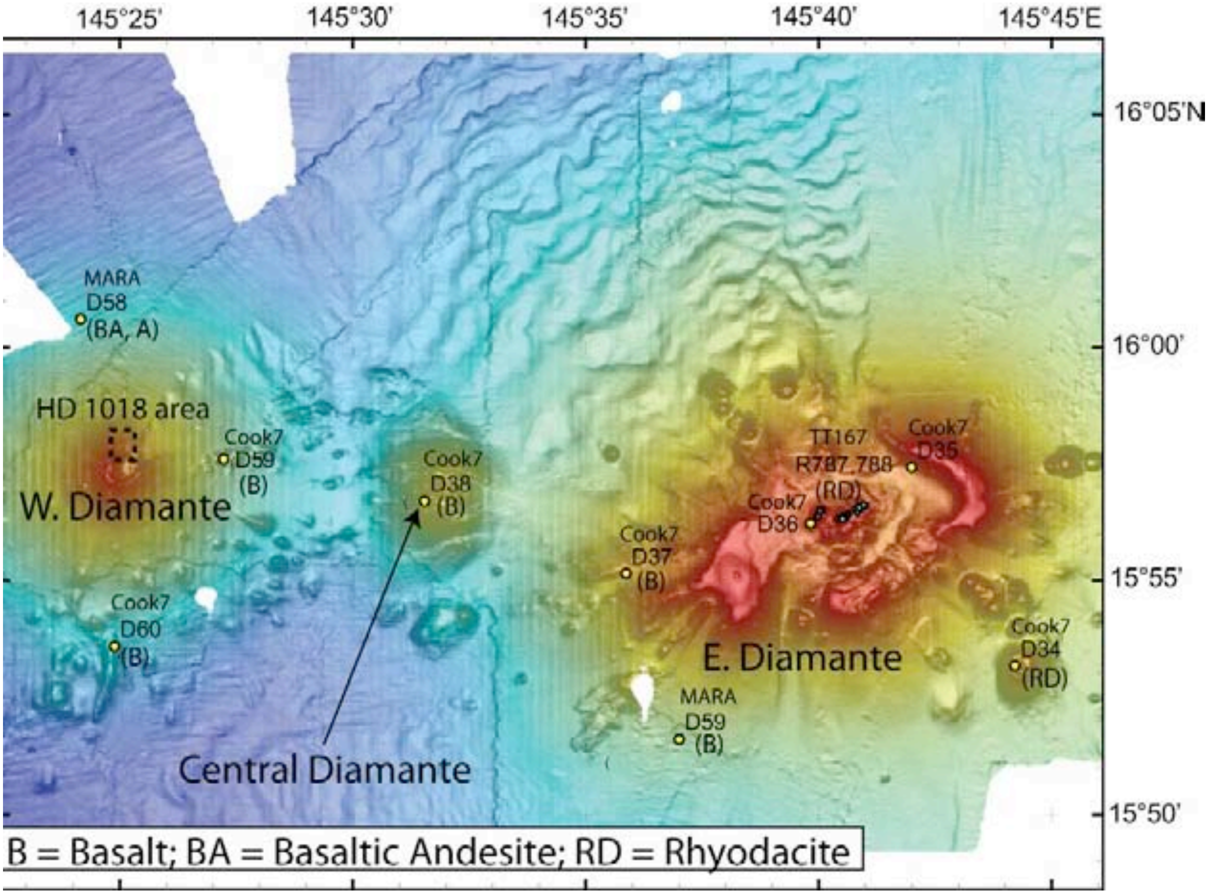


Figure 44. Location of study area shown in Fig. 5.8.2 for HPD 1018 (dashed box)

SCIENTIFIC SUMMARY

West Diamante is the rear-arc member of the Diamante pair of large submarine volcanoes in the Southern Seamount province. The overall morphology of West Diamante is fairly symmetrical with relatively smooth slopes. This is strikingly different than East Diamante, which has collapsed caldera morphology, resurgent domes and a hydrothermal field. Such obvious differences indicate a contrast in magma type and eruption styles between the two main Diamante volcanoes. Previous sampling on the lowermost slopes by Cook 7 D59 and D60 recovered basalt, indicating that W. Diamante was likely composed of mafic material. ROV sampling would provide the means to more accurately observe and sample this member of the Diamante pair and complete the current in-depth investigation of the Diamante system.

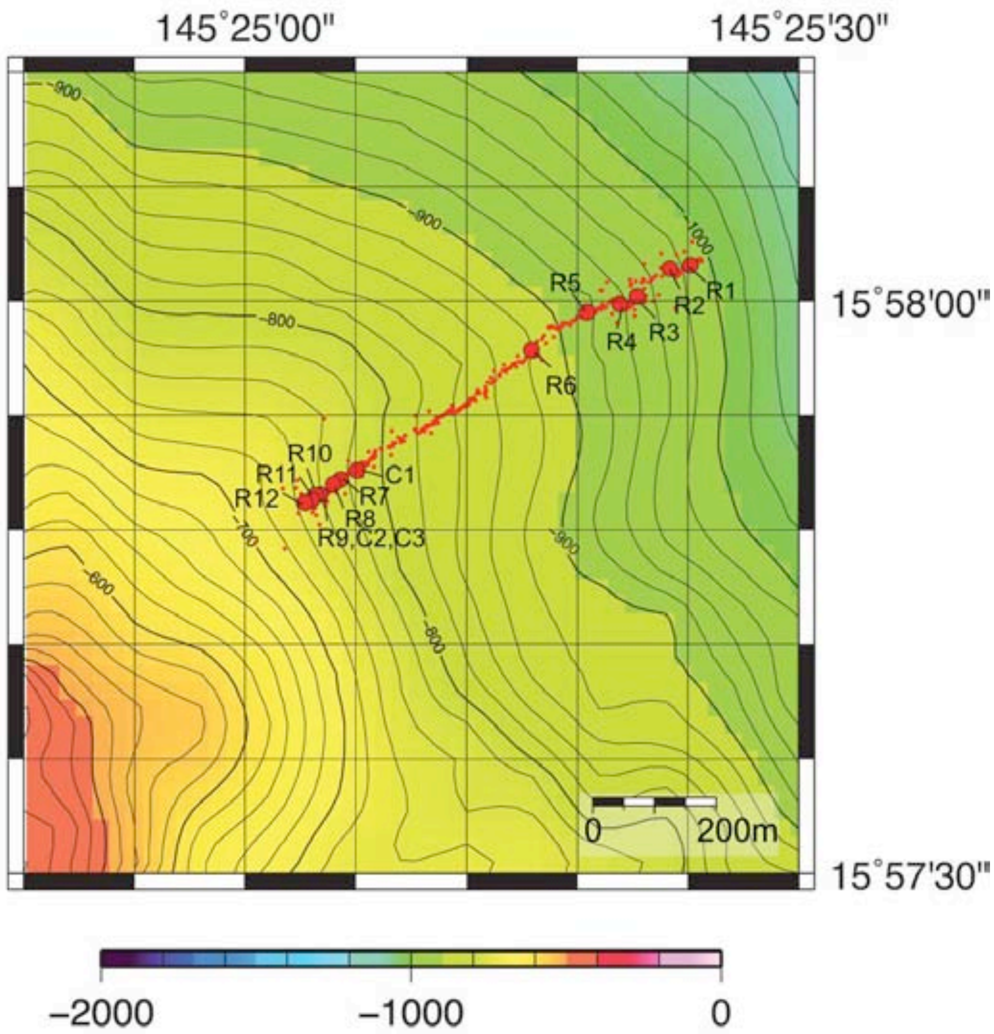


Figure 45. Bathymetry and station locations for HD 1018

Dive 1018 reached bottom at a depth of 988 meters on the NE flank of the volcano. Although good samples of basaltic lava and sediment were recovered, the morphology of this seamount is unremarkable. The immediate landing location was a shallowly dipping slope covered with mottled gray-white sediment. This sediment appeared to cover a crust with rifted ridges, exposing the edges. The crust was logged as Fe-Mn but on-deck examination of recovered samples revealed it to be sheet flows of lava. Hyper Dolphin then sampled a rougher portion, recovering a cobble-size fragment. The morphology of the slope varied between regions of sediment, sediment strewn with small rounded lumps and areas of blocky cobble to boulder size clasts that may have included outcrop. The sediment covered slopes had sinuous and elongate patches of coarser reddish and black colored material, possibly due to winnowing during down- slope movement. Ridges, some rifted, also appeared, these may have been inflated flows. At 864 meters Hyper Dolphin crossed what appeared to be a collapsed part of the underlying flows. From this point to 772 meters, Hyper Dolphin transited a monotonous sediment covered slope. Loose clasts of rock again appeared above 772 meters and larger rocks, either blocks half-buried in sediment or outcrop were observed. Several sampling attempts were made in this area, five of which were successful. Hyper Dolphin came off the bottom at 748 meters, below the mapped summit at 500 meters.

The first rocks sampled were loose parts of the crust or sheet flow (R01 and R02) and separated rounded clasts in the sediment (R03-R06) on the lowest slopes. Later samples were collected from the areas of loose blocks/blocky outcrop on the upper slope. Samples were uniformly dark, probably due to Mn coating. No consistent changes in outcrop or sample morphology with position on the slope were observed. Twelve rock samples and three cores were recovered. All the samples are black, porphyritic plagioclase, plagioclase-pyroxene or olivine-pyroxene phyric basalt. The degree of vesiculation differed between samples, the most highly vesiculated samples had a few oblong vesicles measuring ~3-5 mm along the long axis. The cores were taken in the areas of coarser sediment. Scattered sponges and whip corals were present on the slope, nekton included shrimp, blue eels and an unidentified, large red eye and silver fish.

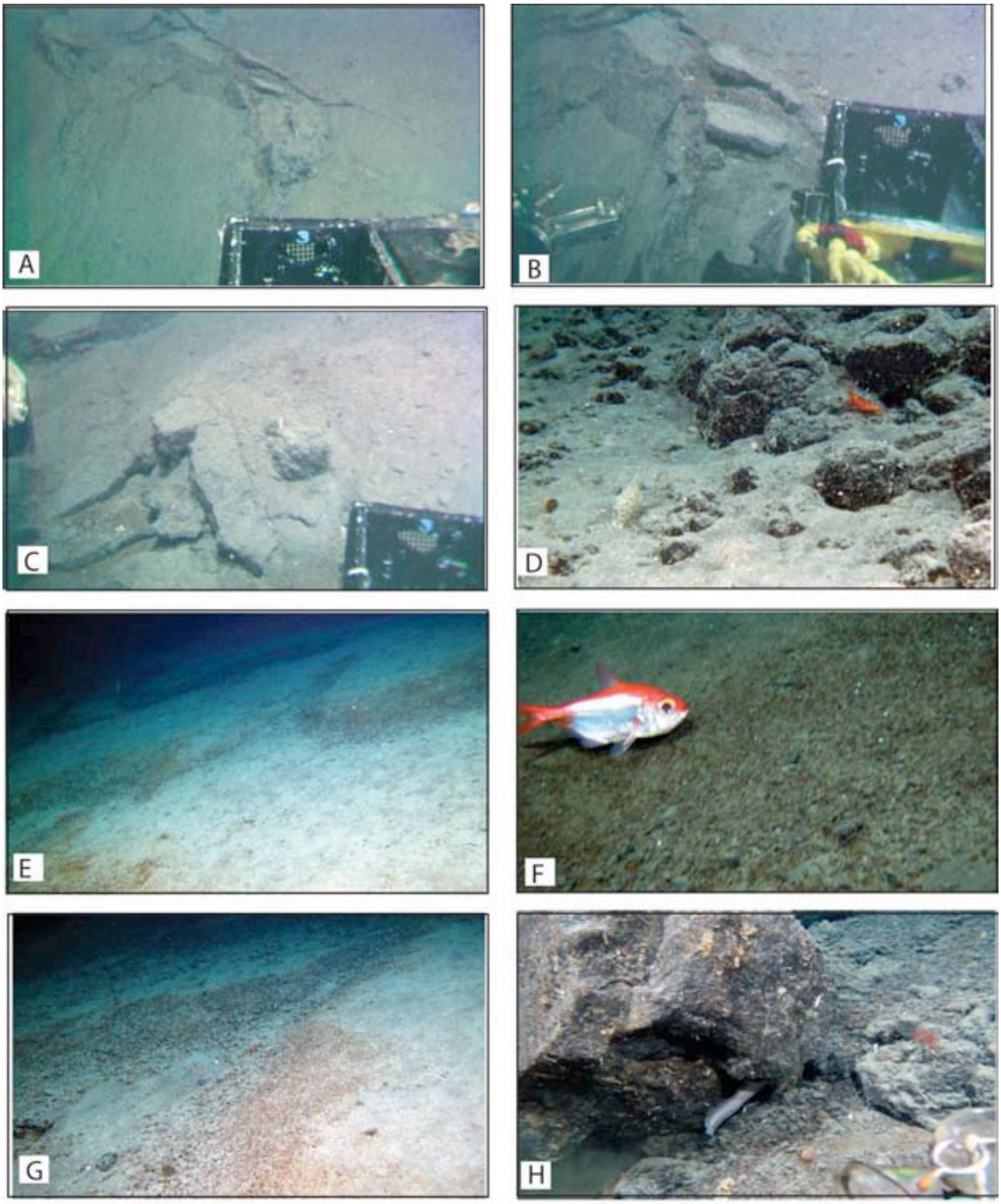


Figure 46. Representative images from dive HPD1018. A: Blocky boulder clasts or outcrop SeaMAX2009_0615_144238AA. B: Sinous ridges of coarse, dark sediment SeaMAX2009_0615_145146AA. C: Large eye red-silver fish, SeaMAX2009_0615_151639AA D: Irregular patches of coarse sediment with scattered cobbles SeaMAX2009_0615_151835AA E: Angular basalt block or outcrop w/eel, SeaMAX2009_0615_153133AA. F: Rifted lava crust exposure HDTV capture 20090615135214_1. G: Possible inflated flow w/ rifted flow top HDTV capture 20090615135305_1. H: Possible inflated flow w/large rounded boulder clast HDTV capture 20090615135351_1

DIVE LOG

Dive #:	NT09-08 HPD#1018
Date:	June 15, 2009 (local)
Location:	West Diamante
Objectives:	Sampling NE flank of W. Diamante
Logger:	Kohut

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	Description
13:02			In water		
13:50	988	229	On bottom. mottled colored sediment w/ cobbles and platy crust		
13:52	977	227	Crust is rifted and edges exposed in places.		
13:54	977	230	Sampling crust, lumpy, Fe-Mn crust (circular)	R01	Plag-px basalt
14:03	966	228	Sampling another lumpy part of crust or clasts in crust (circular)	R02	Plag basalt
14:08	942	219	Still crossing sediment covered crust, sinuous (pressure?) ridges noted		
14:11	941	219	Sampling blocky clast (basket 2)	R03	Plag basaltic andesite
14:13	929	220	Transiting rubbly slope with subangular and sub-rounded blocks		
14:17	928	225	Sampling either a clast or lumpy part of crust (basket 2)	R04	Olivine-plag basalt
14:22	916	234	Transiting rubbly slope with glass sponges and whip coral		
14:27	912	232	Sampling rounded clast (basket 5)	R05	Plag-px basalt
14:32	888	220	Larger, rounded blocks have begun to appear		
14:37	880	230	Sampling subangular block, unsuccessful		
14:40	880	248	Same location, sampled small rounded clast (basket 6)	R06	Plag-px basalt
14:45	864	230	Passed over collapse hole, blue eels and red shrimp noted.		
14:47	853	229	Mottled, sediment covered slope, no clasts.		
14:52	840	229	Still crossing sediment covered slope, darker sinuous and elongated patches of coarser sediment noted.		
15:00	801	230	Continuing to cross sed. covered slope, no major changes.		
15:07	787	220	Continuing to cross sed covered slope, no major changes.		
15:09	784	220	Stopped to sample sediment in red, coarser grained patch. (green)	C01	Brown polymictic mud-sand
15:14	781	220	resume transit, bottom unchanged		
15:16	778	222	Red-silver large-eyed fish		
15:19	772	220	Sampling clast out of coarse grained sed patch. (basket 1)	R07	Ol-px basalt
15:23	769	221	Sampling rounded clast out of coarse grained sed patch (basket 1)	R08	Plag basalt
15:27	760	209	Sampling large pile of boulders and cobbles (outcrop?) (basket 1)	R09	Ol-px basalt
15:37	759	248	Sampling pebble size clasts w/ core, same location as 15:27 (blue)	C02	Brown polymictic mud-sand
15:43	759	248	Now sampling with M-type (scoop)	C03	polymictic

					sand-pebbles
15:45	758	217	resume transit, large boulders now visible, possible outcrop		
15:46	756	219	Sampling cobble near layered, friable appearing boulder or outcrop with orange layer and thick sed. coated crust on top (basket 4)	R10	Crystal-rich plag basalt
15:53	752	219	Approaching more boulders and cobbles		
15:55	753	240	Sampling jagged block, broke apart, sampling fragment of block (basket 3)	R11	Ol-px basalt
15:58	749	229	Transiting sediment covered slope strewn with boulders and cobbles, many partially buried.		
15:59	748	241	Attempting to sample partially buried cobble, unsuccessful		
16:01	747	240	Another attempt on different cobble, also unsuccessful		
16:04	748	259	Third attempt on a rough cobble, breaks apart in (basket 3)	R12	Plag-px basalt
16:09	748	259	Off bottom		

Saw rocks

HYPER-DOLPHIN DIVE #1019

TECHNICAL INFORMATION

Location: Zealandia Bank, NW wall of crater in west-central part of the topographic high.
Objective: Examine stratigraphy and sample crater wall.

DIVE 1019	On bottom:	Off bottom:
Time (local): June 17, 2009	08:37	11:09
Latitude:	16°53.255'N	16° 53.497'N
Longitude:	145 °49.087'E	145° 48.904'E
Depth (m):	637	368

Samples returned: 12 rocks, 1 core

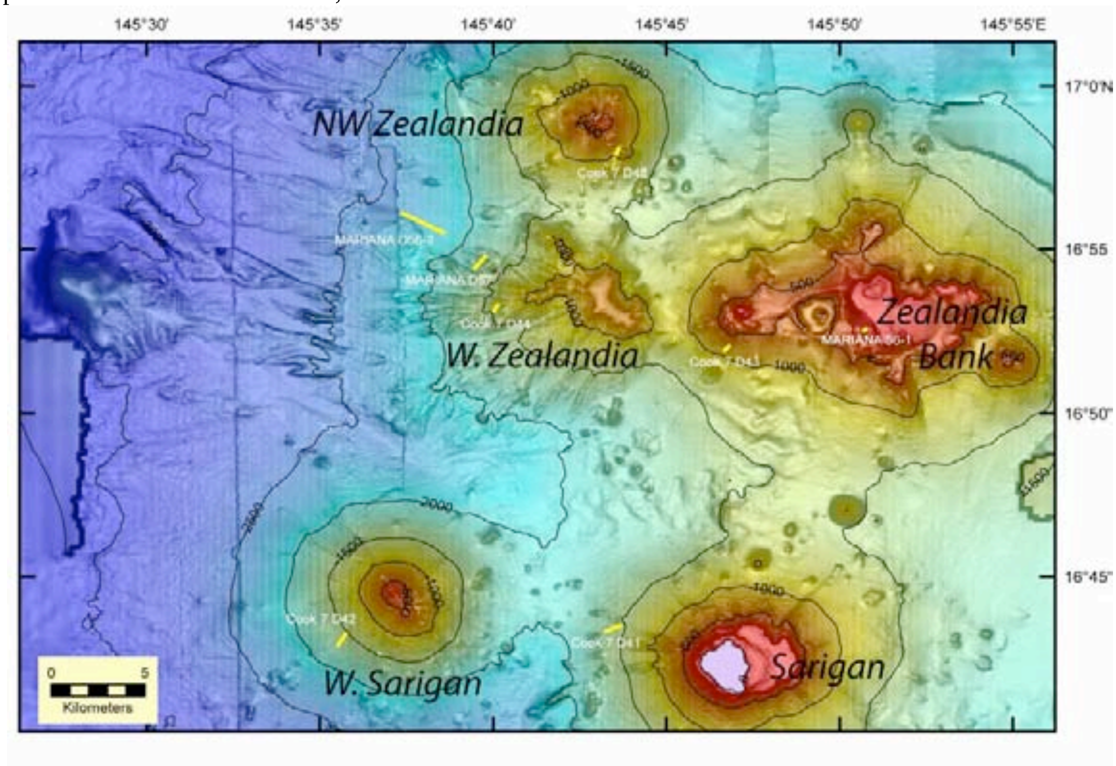


Figure 47. Bathymetric map of the Zealandia and Sarigan, from Mariana Bathymetric Compilation (Susan Merle, PMEL/NOAA, compiler), showing the locations of previous dredges in the area and scuba sampling (Mariana 56-1) of the summit of Zealandia Bank by Stern & Dixon (1983).

SCIENTIFIC SUMMARY

The Zealandias lie approximately 160 km north of Saipan, between the volcanic islands of Guguan and Sarigan in the Central Island Province of the Mariana Arc. It is an entirely submarine topographic high, which at its shallowest point comes within a few meters of the surface, and forms the northern end of a ridge that extends 30 km south to Sarigan. The Zealandias are three volcanic edifices. Zealandia Bank, the eastern-most, which includes the shallowest point; West Zealandia, 10 km due west, whose summit reaches water depths of 620 m; and North-West Zealandia, about 15 km due north of West Zealandia, within 315 m of the surface.

Zealandia Bank is elongated in an E-W direction, having dimensions approximately 17 km x 11 km. Much of the eastern side of the summit area is too shallow for bathymetry to be measured and drops away steeply with a parasitic cone to the south-east (dived on in HPD 1024). In the north of this area is a dome-like structure, which rises 200 m. The western side of the summit is complex. Two features dominate; towards the centre is a crater 300 m deep, with a resurgent dome rising 150 m at the centre, while at the western end there is a dome-like structure 200 m high. The crater and its resurgent dome are the subject of dives HPD 1019 and 1020. In addition, extending west-north-westward from the southern end of the crater, there is a lineament of topographic highs and lows that will be investigated during dive HPD 1021. Previous sampling of Zealandia Bank has been limited to sampling by scuba of the summit area (Dixon & Stern, 1983) and a dredge from 887 to

801 m on the south-western flank, Cook 7 D43 in 2001. Andesites were recovered from the summit area. The dredge has not been fully characterized but on-deck inspections revealed it to contain pumice and weakly welded tuff. It is thus clear that further investigations and sampling of Zealandia Bank are required to provide a fuller picture of the rocks erupted from this centre and the relationships between them.

The objective of HPD 1019 was to investigate the central crater in Zealandia Bank for the first time. The dive will climb up the NW wall and accompanies dive HPD 1020, which will climb the resurgent dome and the E wall.

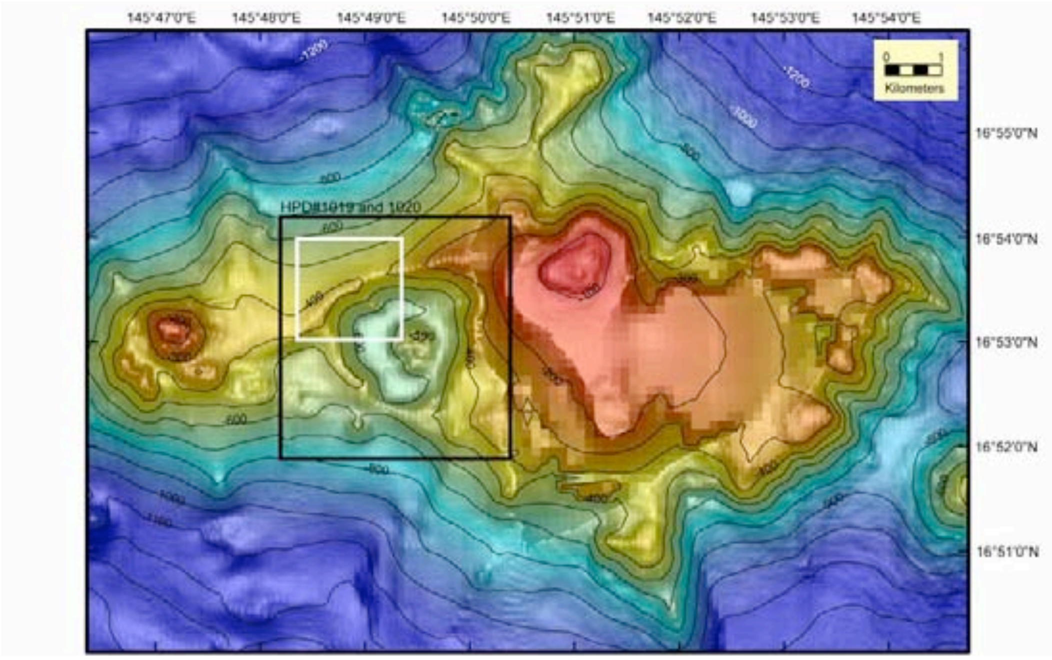


Figure 48. Bathymetric map of Zealandia Bank from Mariana Bathymetric Compilation (Susan Merle, PMEL/NOAA, compiler), showing the crater targeted in dives HPD 1019 and HPD 1020. The white box encloses the area covered by Figure 49.

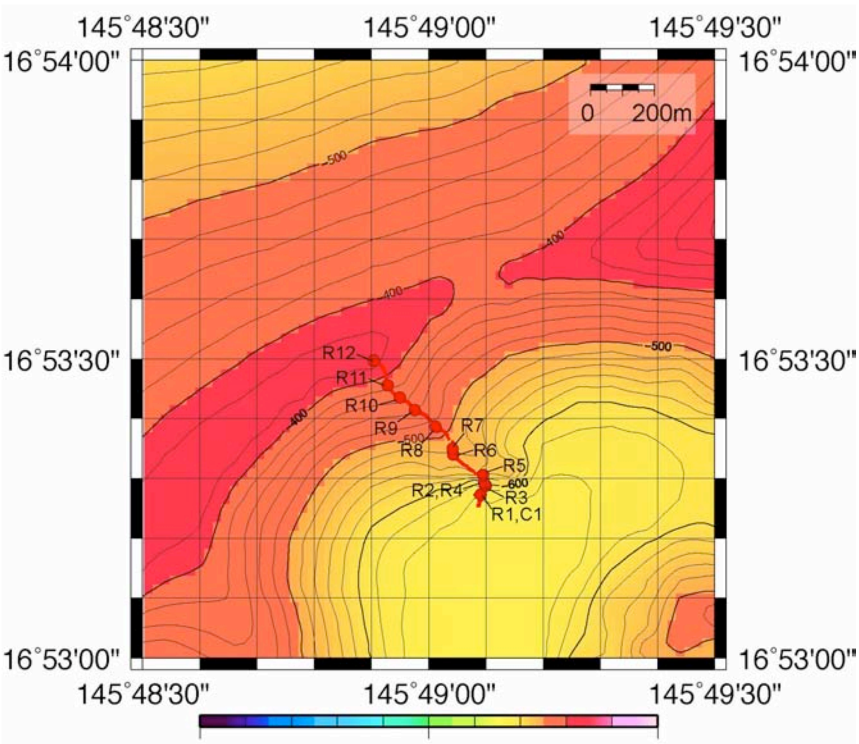


Figure 49. Bathymetric map of the NW wall of the crater in Zealandia Bank, showing track and sampling points of HPD 1019.

Dive HPD 1019 covered a horizontal distance of approximately 660 m and an elevation of 269 m. The ROV landed on the crater floor at 637 m. The floor was covered in muddy to sandy looking sediments, which exhibited ripple marks (Fig. 5.9.4A). Quickly loose blocks partially covered with sediment came into view. These appeared to be broken columns forming a talus slope (Fig. 5.9.4B). R01, a sparsely porphyritic andesite, was taken from these. The crater floor sediment was also sampled (C01).

After heading about 75 m north from the landing site the ROV encountered the base of the steep spur in the crater wall (620 m) that was targeted in the planning of this dive. The spur consists of an approximately 90 m high near-vertical cliff of dark columnar jointed lava. R02 was taken from talus at the foot of the cliff, while R03-R05 were taken directly from the cliff face. All the samples were similar, sparsely porphyritic andesites to dacites. The rocks in most of the cliff-face were columnar jointed (Fig. 5.9.4D and E). Towards the base pillowy morphologies were observed and also dyke-like structures. Near the top the jointing became less organized (hackly jointed) with possible flow structures (Fig. 5.9.4F). The base of the spur was home to a colony of red crinoids (Fig. 5.9.4C).

At the top of the spur (534 m) the morphology of the rocks in the crater wall changed, with outcrop replaced by sand to boulder sized sediment/talus cover. From this area R06- R08 were taken. R06, a basaltic andesite, was more porphyritic than any of the other samples in this dive. R07 and R08 were more similar to the rocks from the spur. The rubbly deposit continued beyond 474 m with pale brown, black stained, pitted boulders becoming more prevalent and then dominating (Fig. 5.9.4H). These also began to form outcrop, surrounded by rock debris that appeared to be derived from them. These were sampled as R09-R12. Handling with the manipulator showed these samples to be much less dense and much more fragile than any previous sample collected in this dive, and to avoid break up the suction gun was used for R10 and R11. R09, R10 and R12 appeared to be volcaniclastics or pyroclastics, some of which appeared to be pumiceous and weakly welded. R10 also contained darker mafic clasts. Additionally, these volcanic rocks were covered in a buff colored carbonate carapace up to 10s of cm thick, which gave the rocks a very irregular pitted appearance (Fig. 5.9.4H). In some cases there appeared to be space between the carapace and the pumiceous material. R11 entirely consists of this carbonate material. After the collection of the very large boulder that formed R12 the dive ended at 368 m.

bonito

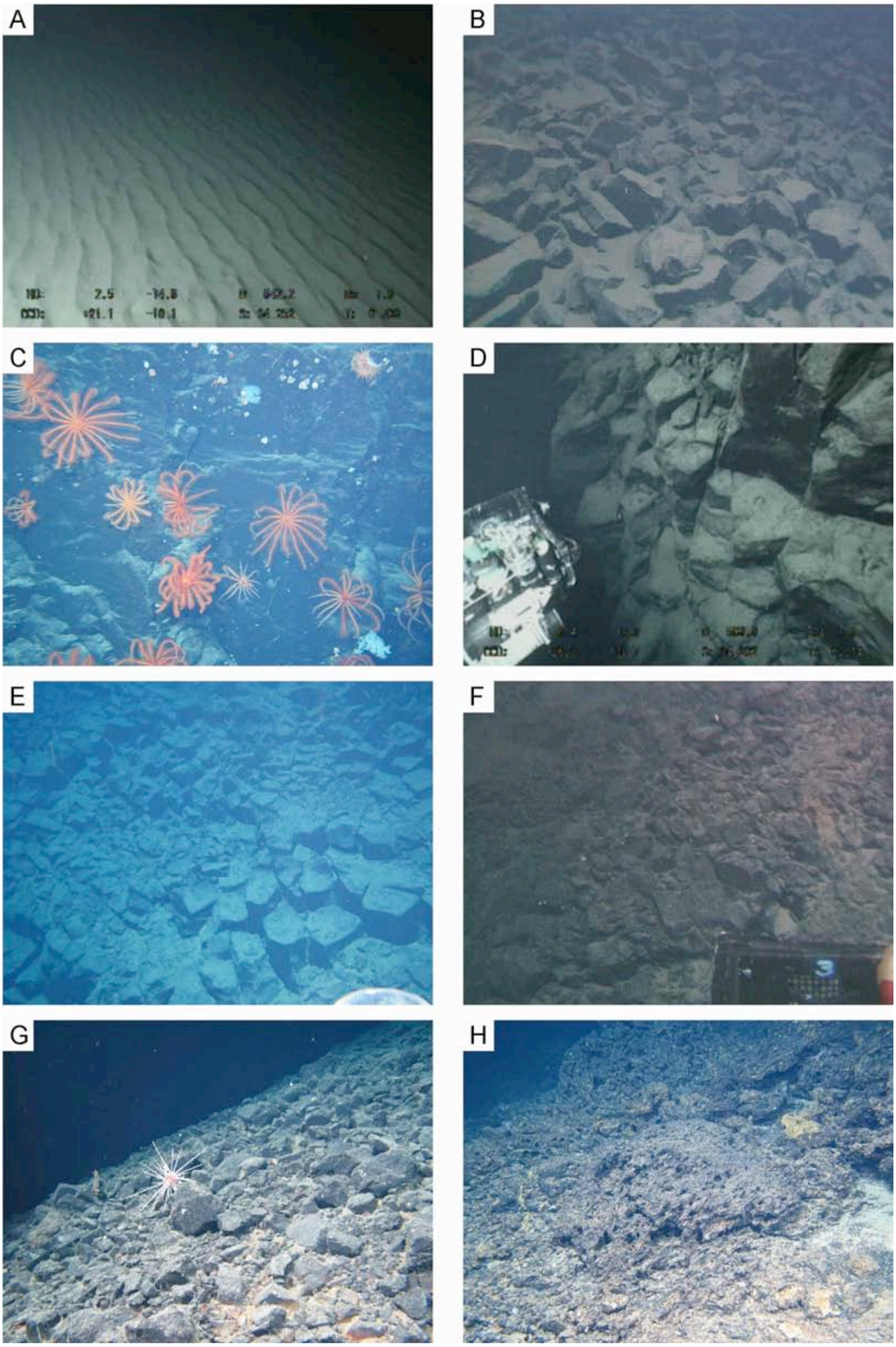


Figure 50. Representative bottom photos from HD1019. A: CCD DSC00005, ripple marks in sediment on crater floor; B: HDC20090617084919_1, column fragments making up talus on crater floor; C: SeaMax 2009_0617_090856AA, colony of red crinoids living at base of spur; D: CCD DSC00037, columnar jointing and steep cliff of spur; E: SeaMax 2009_0617_092412AA columnar jointed lava; F: HDC20090617095008_1 hackly jointed lava, and perhaps a curved flow structure to the upper left; G: SeaMax 2009_0617_100809AA, spikey sea urchin lying in talus at top of cliff; H: SeaMax 2009_0617_104520AA, highly irregular carbonate carapace covering pumiceous volcaniclastics towards the end of dive.

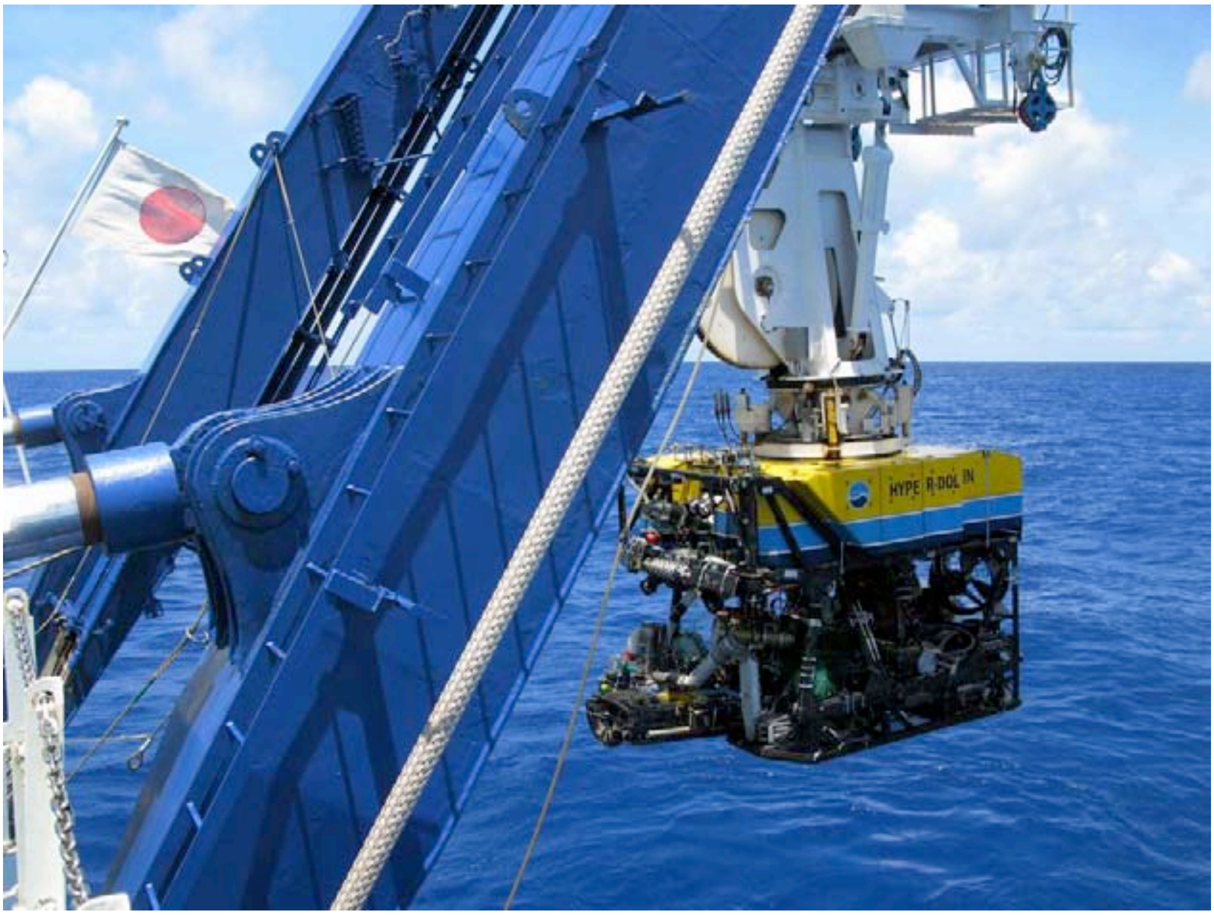
DIVE LOG

Dive #:	NT09-08 HPD#1019
Date:	June 17, 2009 (local)
Location:	NW wall of crater in Zealandia Bank
Objectives:	survey and sample the previously unexplored crater towards the western end of Zealandia Bank
Logger:	Nichols

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
8:00			In water		
8:37	640	003	Sandy bottom looms into view		
8:39	640	003	Ripple marks. Fish swims by along the bottom.		
8:40	638	003	Two fish.		
8:41	636	003	Loose rocks partially covered in sediment. Looks columnar. Basaltic? Move in to sample.		
8:44	637	003	Sample what looks like a fragment of columnar basalt. Goes into circular basket.	R01	andesite
8:46	637	002	Take out green handled push core. Easily pushed into sediment. Green MBARI core sample	S01	mud
8:48	636	003	Look around and survey the sampling area. Move on.		
8:50	621	349	Move across what appears to be talus.		
8:51	620	038	Vertical cliff of similar material as the talus. Red crinoid colony on cliff face. Pillowy and dyke-like morphologies in crater wall. Fractured.		
8:57	621	041	Break off piece. Exposing orange-coloured surface. Difficult to sample piece off cliff directly.		
9:04	621	048	Take rock from right at the foot of the cliff. Black sample. Goes into basket 2.	R02	andesite
9:07	621	050	Take a look at the red crinoids.		
9:10	612	046	The colony continues.		
9:12	604	038	Sub-vertical columnar jointing. Nice view on CCD camera.		
9:15	593	011	Still climbing vertical cliff of what looks like columnar lava flows.		
9:17	593	007	Sample loose slabby block. Initially went for smaller piece, but larger piece moved when brushed by manipulator. Changed targets and grabbed larger piece. Shrimps flitter across CCD camera. Sample coated in black. Into basket 3.	R03	andesitic dacite
9:21	589	351	Move over the top of the vertical cliff. Shallower slope of talus debris, looks like broken up columns.		
9:22	584	340	Columnar flow outcrop. Pink anemone		
9:23	579	351	Perfect view looking down on cross-section of hexagonal columns on HDTV.		
9:29	581	008	Shrimp close up on HDTV.		

9:33	581	009	Attempting to sample block directly from outcrop. It's loose, but is it loose enough to liberate?		
9:37	581	009	Block falls out of cliff. Lots of reddish particulate matter released into the water column. Boulder falls on sampling basket. Wait several minutes for sediment to clear before moving sample into basket 1.	R04	andesite
9:44	573	001	Columnar jointed outcrop.		
9:45	568	005	Come over rim into a little depression in the outcrop.		
9:47	559	000	Columns parallel with slope		
9:49	544	001	More hackly jointed - flow top? Curved feature on HDTV - channel structure?		
9:52	536	000	Loose, unfussily sampled. Black with some orange staining. Placed in basket 1.	R05	andesite
9:56	534	320	Move over top of steep cliff. Outcrop out of view for a while. Different morphology comes back into view, finer grained sandy-pebbly-rubbly sediment/talus cover.		
10:01	511	328	Take large boulder lying loose. Moved into basket 2, dislodging sample R02 towards basket 1. Use R02 to lever R06 to area behind basket 2, R02 back in basket 2.	R06	basaltic andesite
10:07	508	345	Paler material in sediment.		
10:08	507	342	Spikey sea urchin.		
10:11	499	331	Remove ballast from basket 4 and dump on sea floor.		
10:12	499	331	Pick up another loose boulder from talus. Triangular shape - angular. Coated in black - Mn? Placed into basket 5	R07	dacite
10:21	478	317	Move in to sample. Take loose piece. Coated in Mn. Orange on scratched surfaces. Goes into basket 5.	R08	andesite - dacite
10:25	474	316	Pale brown rocks in amongst darker material. Darker material sampled as R05.		
10:30	447	309	Take friable yellow-pale brown rock. Breaks up. Pale brown in colour, irregular shape. Placed on basket 4. Many pieces broke off. One piece fell into basket 5, one in front of basket 6.	R09	felsic pumiceous pyroclastics
10:38	442	319	Yellow-pale brown material forms mound-like features.		
10:41	428	320	Black material coats yellowy-pale brown material. Black rocks have knobbly textured surface. Red fish.		
10:45	425	320	Black coated rock friable and brittle. Suction gun comes in to use. Picks up black coated material, with paler surfaces. Irregular shape into basket 3.	R10	volcaniclastic with pumice and mafic clasts
10:46	418	320	Flow surface. Pillowy/ropey texture.		
10:47	412	320	Move over large paler block with black coat. Appears to be hollow behind coat.		

10:53	401	320	Sample equidimensional boulder with suction gun. Placed into basket 3. Black and yellowy-pale brown exterior. Brittle and low density. Scoraceous, pumiceous?	R11	pumiceous volcaniclastic (includes rhyolite)
10:57	371	309	Clown fish-like fish hiding in crack in rock.		
11:05	368	343	Looking to sample large pitted boulder as a final hurrah? Successful. Large, but low density. Covers all basket 4 and basket 1.	R12	volcaniclastic possibly welded
11:07	368	343	End of dive. Secure samples.		
11:10			Leave the floor.		
11:23			at surface		
11:34			HPD on deck		



Hyper-Dolphin

HYPER-DOLPHIN DIVE #1020

TECHNICAL INFORMATION

Location: Zealandia Caldera resurgent dome
Objective: Survey and sample volcanic stratigraphy & potential hydrothermal sites

DIVE 1020	On bottom:	Off bottom:
Time (local): June 17, 2009	13:34	16:11
Latitude:	16°52.797'N	16° 53.010'N
Longitude:	145° 49.316'E	145° 49.551'E
Depth (m):	616	479

Samples returned: 12 rocks, 1 core

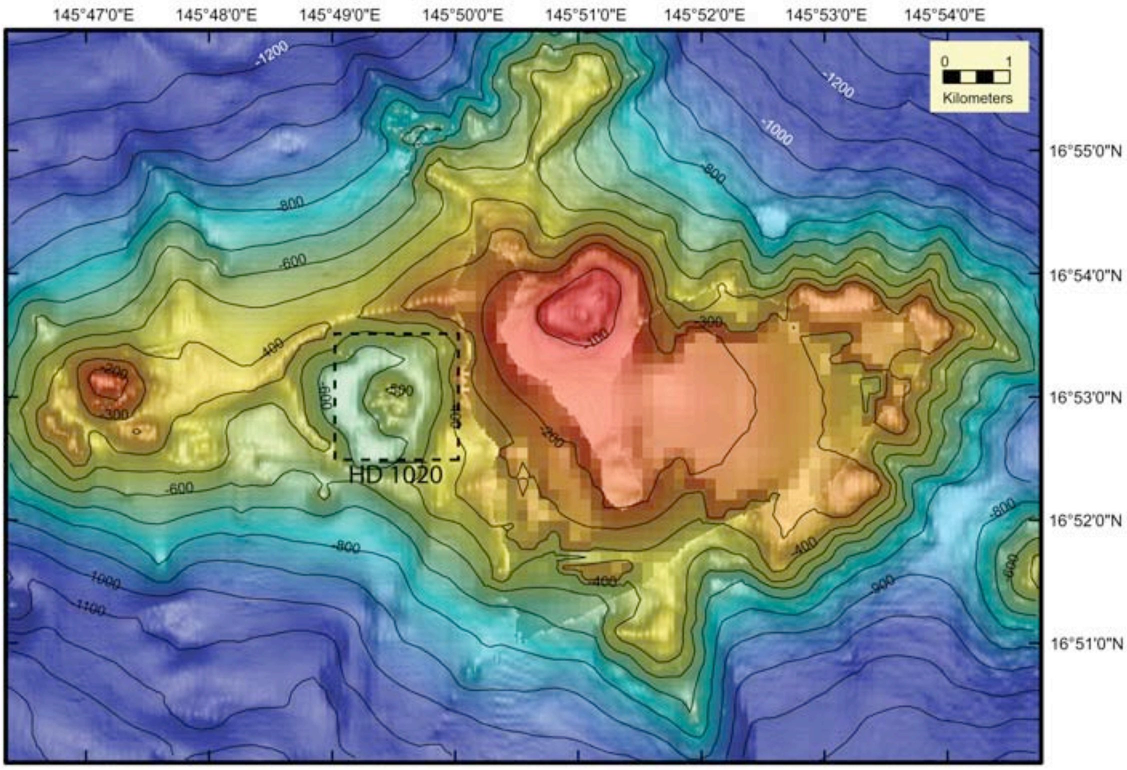


Figure 51. Bathymetric map of Zealandia Bank Volcano, from Mariana Bathymetric Compilation (Susan Merle, PMEL/NOAA, compiler and ETOPO data for the shallow part of Zealandia Bank volcano. Dashed box shows location of Fig. 52.

SCIENTIFIC SUMMARY

Zealandia Bank volcano lies about 18 km NNE of Sarigan Island, about 140 km north of Saipan, and is in the Central Island Province of the Mariana magmatic arc. Zealandia Bank volcano is a complex edifice that consists of a barely submerged summit (Zealandia Bank), which is part of a ~15 km elongated E-W volcanic edifice. The volcano complex is divided into a steep, dissected, older eastern half and a smoother, younger western half. To the south and east of the Bank is a broad region that has not been bathymetrically mapped except by satellite gravity. A well-preserved caldera lies just southwest of the Bank and is ~1 km in diameter and is as deep as 640 m. The caldera hosts a central resurgent dome, which is the target for dive 1020. At the western limit of the volcanic complex is a cone or dome that rises to within 80 m of sea level. A CTD cast in the caldera in 2003 showed a distinct particle plume below the sill depth of about 550 m, but weak 3He and Eh anomalies (Baker *et al.*, 2008). Other than this, the caldera/cone complex has not been previously studied or sampled. Zealandia Bank was sampled during a SCUBA dive by T.H. Dixon in 1979. The bank is composed of high magnesium basalt enriched in Ni and containing forsteritic olivine; hypabyssal andesite was also collected (Dixon & Stern, 1983). Cook 7 dredge D43 (887-801 m) from the western flank of Zealandia Bank volcano recovered welded tuffs and pumice. Zealandia volcano basalts are among the most primitive collected along the arc (Dixon & Stern, 1983). The objectives of Hyper-Dolphin dive 1020 were to investigate and date the volcanic units that make up the central caldera resurgent dome and investigate areas that may have active and inactive hydrothermal sulfide chimney fields.

Dive 1020 was an approximately NE-SW-oriented traverse across the central resurgent dome at the center of the small Zealandia caldera (Figs. 51, 52). The ROV landed near the base of slope at a depth of 620 m (Fig. 52) on a sediment surface peppered with black pebbles (Fig. 53A). Samples R01 is a small cobble collected from that sediment surface. The lower flank of the dome is sediment covered on which rests gravel fields and extensive angular cobble/boulder talus piles, which was sampled as R02 (Fig. 53B). This rock/sediment distribution continued until about 600 m water depth, where rock outcrops started. The first outcrop encountered is composed of breccia at 592 m with a pale-colored matrix and dark lava clasts. The matrix was sampled by push core (C01) in which some small black clasts were also collected. Continuing upslope, areas of talus alternate with breccia/lava flow outcrops to a water depth of about 560 m. Much of the remainder of transect 1020 showed steep slopes and vertical walls of lava flows with flow banding and dikes, where samples R05 and R06 were collected (Fig. 53C, D). At about 510 m water depth, the topography flattened and areas of talus lie adjacent of low-lying outcrops. Much of the sediment is reddish-orange and may have a hydrothermal component. Another steep wall occurs at 488 m, and then flattens out again. The ROV flew across a small valley and was back on bottom at 502 m. Another steep wall occurs on the east side of the valley at the same water depth of 488 m (Fig. 53E, F). The section between 500 m and 480 consists predominantly of moderate to gentle slopes with talus debris on sediment adjacent to rubbly lava flow outcrops. Some of the outcrops showed flow banding (Figs. 53G, H).

Hydrothermal chimneys or mounds were not found along transect 1020. Some basalt and breccia samples collected from 583 m to 483 m water depths contain fine-grained pyrite on fracture surfaces and lining vugs, but generally pyrite is not disseminated in the rocks. Pyrite is disseminated in the sediment collected in cores CO1 and CO2. Reddish-orange sediments are common throughout the transect across the resurgent dome and may reflect low-temperature, diffuse-flow hydrothermal circulation at some point in the history of the dome.

References cited

Baker, E., et al., 2008. Hydrothermal activity and volcano distribution along the Mariana arc. Journal Geophysical Research, v. 113, p. 1-16, B08S09.

Dixon, T.H. and Stern, R.J., 1983. Petrology, chemistry, and isotopic composition of submarine volcanoes in the southern Mariana arc. Geol. Soc. Amer. Bulletin, v. 94, p.
1159-1172.

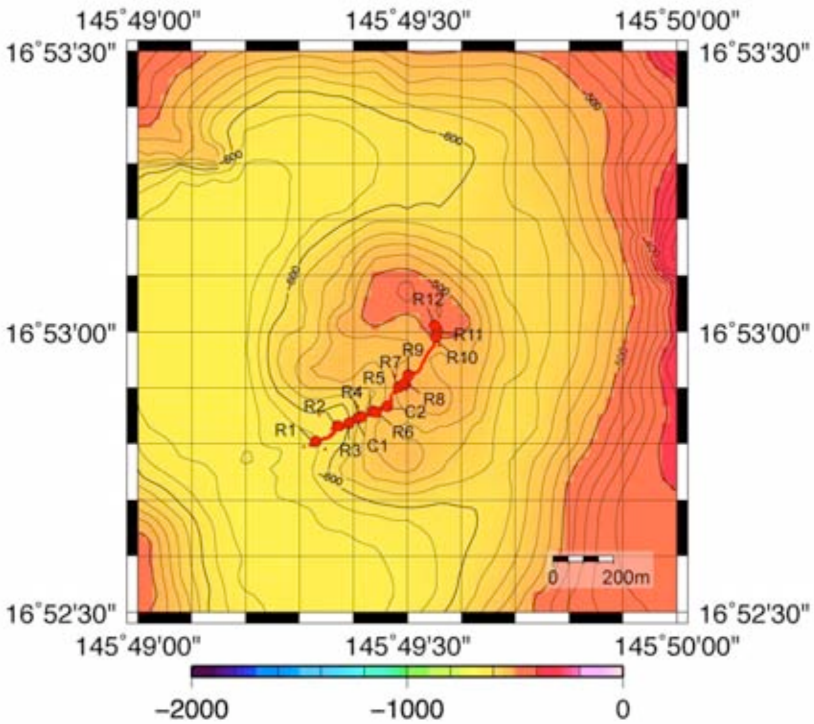


Figure 52. Bathymetric map of central caldera resurgent dome of Zealandia Seamount surveyed during NT0908. Track line and sample locations of the HD-1020 dive are shown.

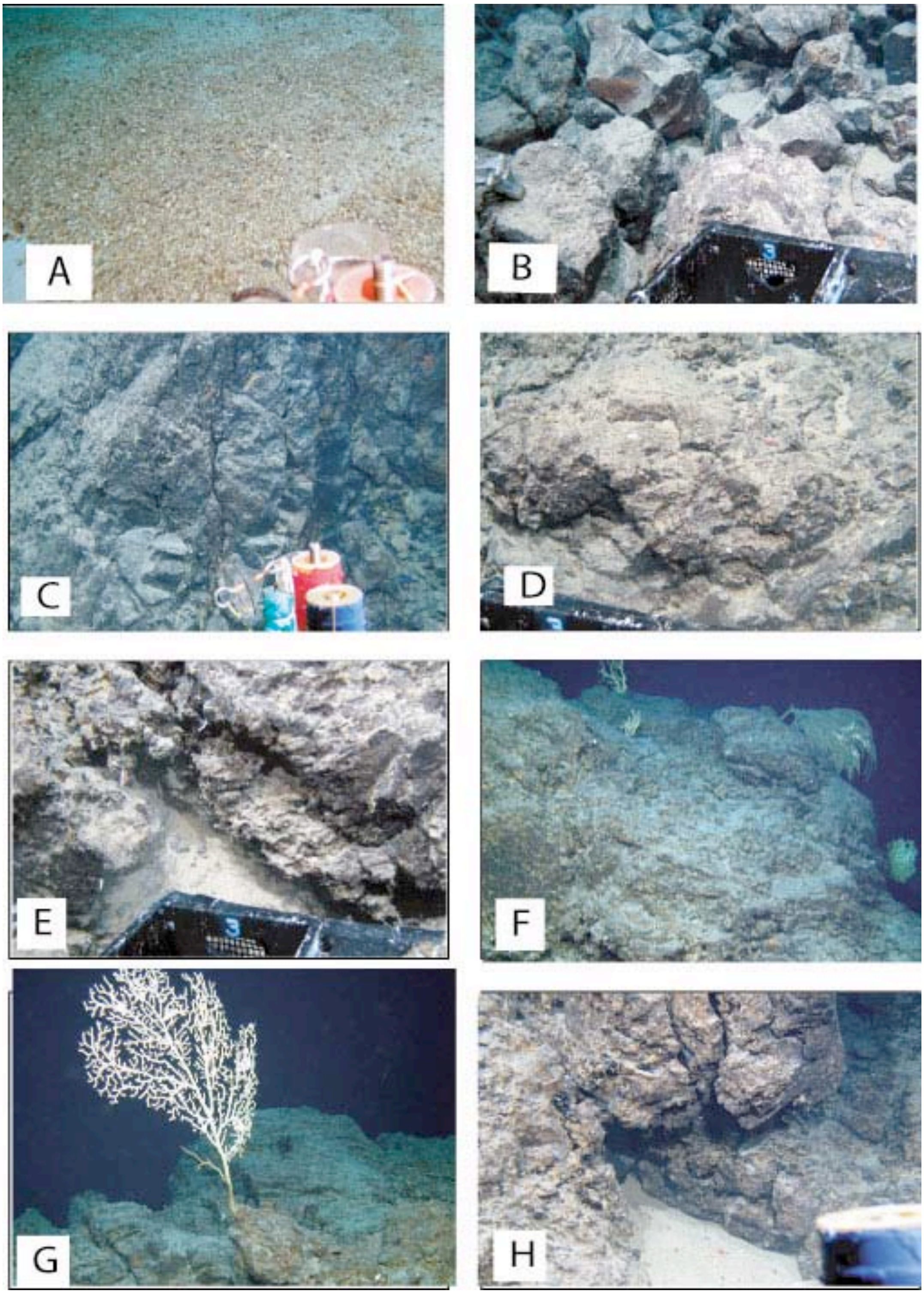


Figure 53. Representative bottom photos from HD-1020. A: SeaMax 2009_0617_1348287AA, rippled sediment and large gravel field near base of resurgent dome slope from about 607 m water depth; B: SeaMax 2009_0617_135627AA, extensive pile of angular cobbles and boulders from which sample R2 was collected at 616 m water depth; C: SeaMax 2009_0617_144210AA, steep wall showing contact of dike and dacite lave flow, 543 m water depth; D: SeaMax 2009_0617_154500AA, prominent flow banding in dacite outcrop at about 500 m water depth; E: SeaMax 2009_0617_154703AA, thin, banded dacite flows from which sample R10 was collected, 494 m water depth; F: SeaMax 2009_0617_155340AA, thick, massive, banded dacite flows and several types of branching coral, about 491 m water depth; G: SeaMax 2009_0617_155512AA; dacite flow with well displayed flow banding and branching coral, water depth about 488 m; H: SeaMax 2009_0617_160159AA, thick dacite flow with flow banding from which sample R11 was collected at about 488 m water depth.

DIVE LOG

Dive #:	NT09-08 HPD#1020
Date:	June 17, 2009 (local)
Location:	Zealandia caldera resurgent dome
Objectives:	Survey and sample volcanic stratigraphy and hydrothermal sites
Logger:	Hein

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
13:02			In water		
13:34	620	50	On bottom; sandy, peppered with pebbles, no ripples		
13:40	618	50	Degraded ripples with pebbles lining troughs		
13:41	618	50	Sampling small cobble talus (side basket)	R01	Dacite
13:46	611	51	First large rock talus, boulders, cobbles, gravel patches		
13:48	607	46	Large gravel fields, rippled sediment		
13:55	616	73	Sampling extensive pile of angular cobble and boulder talus (box 2)	R02	Flow banded rhyolite
14:08	616	70	End sampling		
14:12	608	55	Talus field continuing, but outcrop may be just beneath		
14:14	605	65	Sampling talus cobble, not many boulders here (box 2)	R03	Banded dacite
14:17	602	51	Mixture of gravel, cobbles, and boulders on sand; talus shouts		
14:19	592	55	Jointed outcrops, some light colored rock, breccia,		
14:21	584	81	Sampling outcrop of pale rock (matrix) with embedded black lava (clasts), breccia; taking a core sample of matrix and pebble clasts	C01	Weathered dacite
14:29	572	72	Massive lava flows		
14:30	571	77	Sampling talus from lava flow, pale gray, broke in 2 pieces (one in box 4) (behind boxes)	R04	Dacite
14:37	563	61	Large cobble-boulder field again		
14:38	556	50	Outcrops on steep slope, breccia; 545 m lava flows, dikes		
14:42	543	75	Dikes; steep wall of dikes and lava flows; crinoid,		
14:44	534	76	Sampling dike; 533 m back into breccia, flows, and dikes (box 1)	R05	Banded rhyo-dacite
14:28	526	76	Sampling steep wall dike or flow; rubbly (box 1)	R06	Dacite

14:52	521	61	Top of steep wall and flows and dikes; another one further up with large open fractures		
14:54	511	61	Massive rubbly flows on steep face		
14:55	506	65	Sampling, flattening out with pebble-cobble talus field and orange staining. Low outcrops of thin flows; cobbles in red-orange matrix in places (box 2)	R07	Dacite
15:00	504	55	Sediment and pebble fields in odd patterns, maybe following old ripples		
15:04	508	51	Outcrops on steep face and sand shouts, rubbly surface;		
15:05	510	52	Cobble talus, orange sediment kicked up on landing; sand/gravel/cobble talus slopes		
15:08	504	51	Sampling core, white to black gravel on sediment; ash colored (blue)	C02	Gravel/sand/mud
15:13	498	51	Sediment-covered slope, white to reddish, w/pebbles to boulders and outcrops of breccia(?) or rubbly flows		
15:16	495	40	Sampling rubbly flow; red sediment around cobbles (box 1)	R08	Dacite
15:21	488	42	Steep wall with dike, sediment and talus; giant fish attacked		
15:23	483	40	Sampling altered light flow; couldn't get, so sampling darker talus next to it; steep outcrops of flows and dikes; reddish sediment and alteration (box 5)	R09	Banded dacite
15:34	483	60	Flying over small valley on dome		
15:42	502	34	Back on bottom on dome; outcrop of rubbly flows, w/talus and sediment at foot of vertical outcrops; massive fractured flows		
15:47	494	30	Sampling vertical cliff, thin flow unit; aborted, try another, crumbled; try a third, got it; finished 15:52 (box 5)	R10	Banded dacite
15:54	491	21	Large massive flows, red and white corals; flow banding		
15:56	488	22	Sediment and outcrops, gravel, massive flows		
15:58	488	17	Sampling massive flow; sand at foot of steep wall, starfish; broken from outcrop; finished 16:02; moving up cliff face (box 4)	R11	Banded dacite
16:04	480	8	Talus on sediment, moderate slope, pebbles to boulders		
16:05	480	9	Sampling talus, boulder size (box 1)	R12	Banded dacite
16:12	480	8	Off bottom		
16:30			On surface		

HYPER-DOLPHIN DIVE #1021

TECHNICAL INFORMATION

Location:	Western section of Zealandia Bank Volcano
Objective:	Survey and sample volcanic sequences on 6 traverses

DIVE 1021	On bottom:	Off bottom:
Time (local): June 18, 2009	08:42	15:44
Latitude:	16 °51.999' N	145° 48.895 'E
Longitude:	16° 52.769' N	145° 46.739' E
Depth (m):	716	288
Samples returned:	25 rock samples (one lost)	

SCIENTIFIC SUMMARY

The objectives of HPD-1021 were to explore and sample the top of the Zealandia Bank volcano west of the young caldera. Targets included several small knolls, a lava flow and a large cone on the western edge of Zealandia Bank volcano. The dive was organized in six traverses separated by short transits above the bottom to maximize sampling on the targeted features. With the exception of traverse 5, which encountered a limestone cap on the main cone, the seafloor observed on HPD-1021 was covered with a blocky rhyolite flow or flows (Figs. 54; 55). The flow surface was characterized by large blocks of contorted pumiceous acidic rocks with flow banding and large gas expansion/release cavities.

Dive 1021 landed at 08:42 at 716 m depth and began its first traverse up a small knoll SW of the young caldera (Figs. 54; 55). There was almost continuous rock cover, with large blocks predominating with only small sediment pockets between the boulders (Fig. 55; 56A). Many of the boulders contain gas escape/expansion structures and flow banding. Their surfaces are a variegated black (manganese veneer) to orange color, and broken surfaces are lighter in color. Figures 55 and 56B-E shows the surfaces of the siliceous flows taken during the dive transects. Traverse 1 ended at 9:50 at 589 m.

The second traverse began at a depth of 568 m (10:27) on the southern flank of Zealandia Bank volcano and went northwest upslope to sample a lava flow that appears to have flowed downslope to this site from the west and thence further downslope to the south. All samples taken on this traverse (R-06-08) are banded rhyolite/pumice. Sample R-06 had a mafic clast in it. The traverse ended at 10:48 at 634 m depth.

The third traverse began at 11:13 at 459 m depth and climbed the flank of a small volcanic feature that is the likely source of the lava flow on the second traverse. The terrain resembled the first two traverses. Two of the rocks collected on this traverse are recrystallized limestones (R-09 and R-12) and the other two are brown pumiceous tuff with flow bands (R-12) and grey rhyolite (R-10). It should be noted that R-09 sampled a slabby layer beneath the large blocks, which is consistent with it being a limestone. On the other hand, R-12 sampled one of the large blocks, so there is an apparent inconsistency, although the limestone could have different origins (e.g., capstone on rhyolite). The traverse ended at 12:05 at 427 m.

The fourth traverse (began 12:21 at 411 m) climbed the flank of a small cone on the SW corner of the main volcanic platform of the western half of Zealandia Bank volcano. The terrain was much the same as Traverses 2 and 3. Two samples were recovered during this traverse, a grey rhyolite (R-13) and a brown pumiceous volcaniclastic (R-14). The sample recovered from the R-16 site was not identified during the post-dive processing so it was declared "Lost". The traverse ended at 13:01 at 312 m.

Traverse five began at 13:29 at 299 m and sampled southwest flank of the main cone of the western part of Zealandia Bank volcano. The seafloor basement surface here consists of crusts and slabs of a carbonate cap (Figs. 55; 56F and G). Samples R17 and R-18 are both recrystallized limestone. Reddish coralline encrusting algae (photosynthetic) were seen here to at least 223 m depth. The traverse ended at 14:00 at 223 m depth.

The sixth and final traverse began at 14:30 at a depth of 364 m and sampled several blocky areas and a wall of breccia (old caldera wall?) on the SW edge of the western platform (Fig. 55; 56H). The samples from the blocky area were a mixture of limestones (R-19 and R-22 - taken at the same location) and a tuff sample (R-22). Sample R-19 was taken off one of the large boulders. Sample R-22 was a slabby piece taken at the base of the boulders. Clast samples from the wall were all porphyritic basaltic andesites (R-23 to R-26). The dive ended at 15:44 at 288 m.

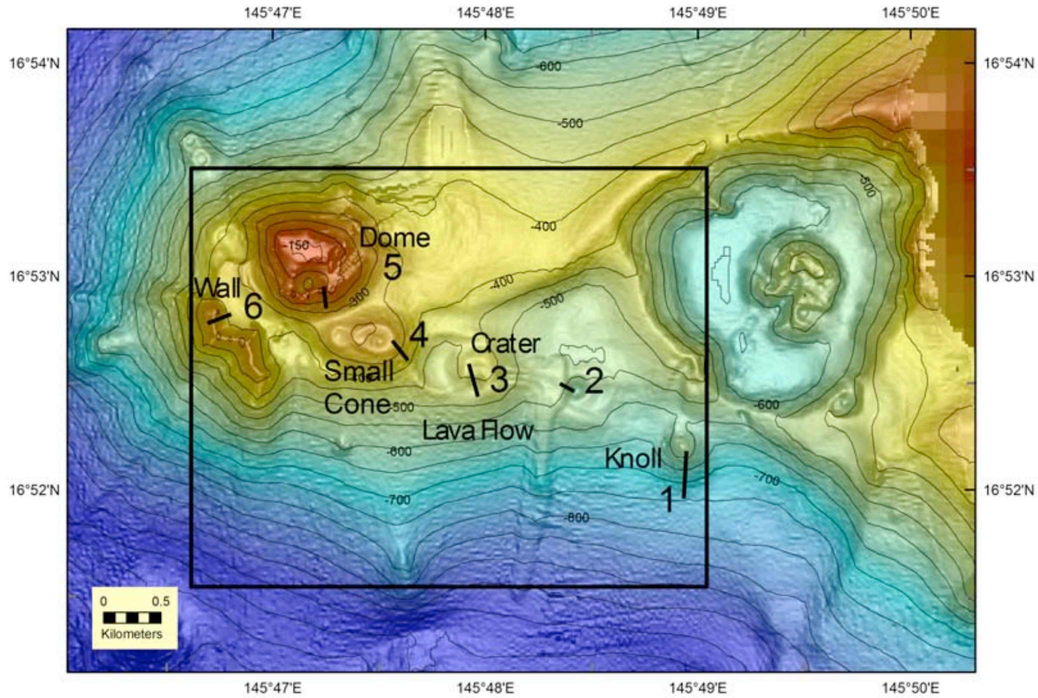


Figure 54. Bathymetric map showing area (Box) of Dive HPD-1021 on western Zealandia Bank volcano in area west of young caldera. Numbers and place names are those referred to in narrative. Bathymetry from NOAA. Contour interval is 50 m.

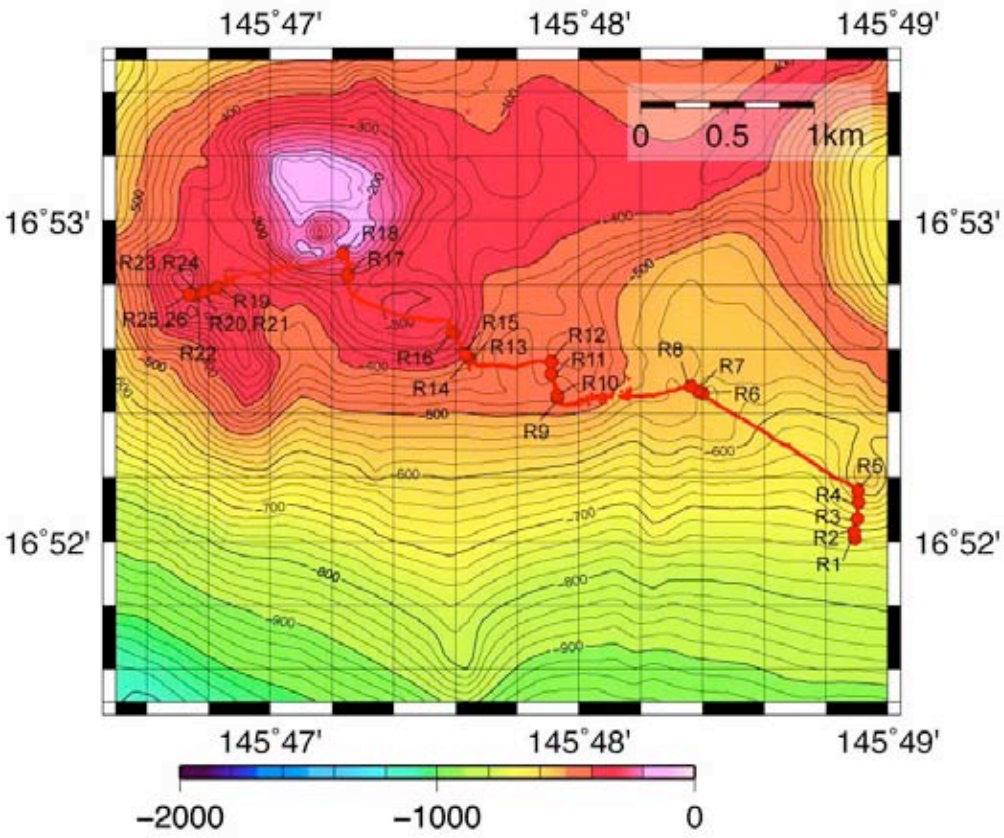


Figure 55. Bathymetric map showing track of Dive HPD-1021 western Zealandia Bank Volcano.

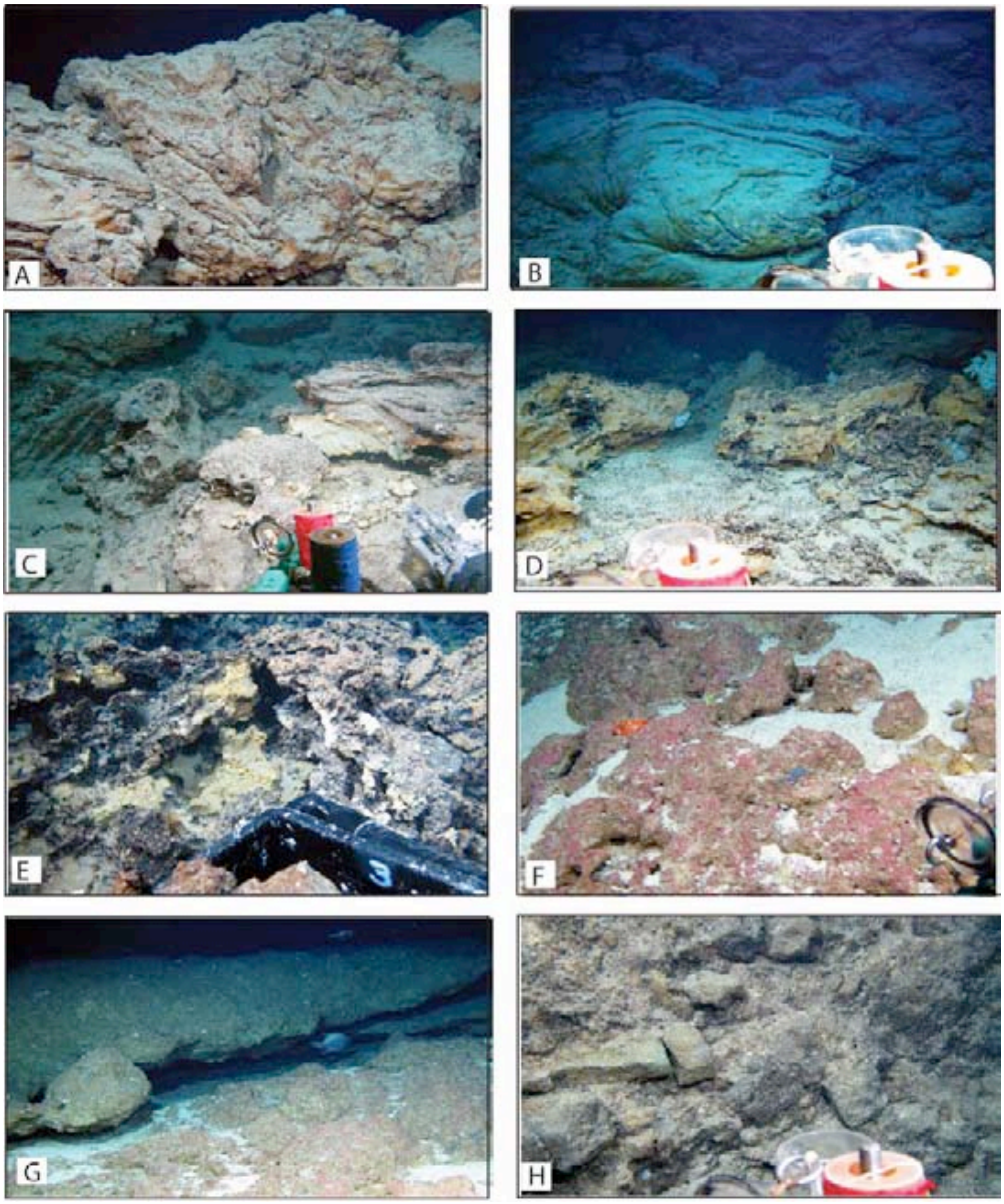


Figure 56. Photos of outcrops observed and sampled during HD1021. (A) 2009_0618_085023AA SeaMax photo of coarse felsic block observed near landing spot during Traverse 1.1021-R01 (orange pumice) was collected here; (B) 2009_0618_090947AA SeaMax photo of large, rounded felsic pyroclastic block observed during Traverse 1; Note unusually smooth nature of this block, defined by wrap-around structure that is probably compositional layering; 1021-R05 (dark grey banded rhyolite) was collected near here. (C) SeaMax 2009_0618_103150AA photo of chaos of large felsic blocks in submarine pyroclastic flow, taken during Traverse 2. Note that many blocks show cavernous porosity (gas pockets) and some also showing layering (left). 1021-R06 (grey banded tuff with mafic clast) was collected at this site. (D) SeaMax 2009_0618_113031AA photo of ragged black and orange outcrops, taken during Traverse 3. 1021-R09 (recrystallized coralline limestone) was taken from this site. (E) SeaMax photo 2009_0618_120433AA of vuggy recrystallized limestone collected at end of Traverse 4. 1021-R12 (recrystallized reefal limestone) was collected here. (F) SeaMax photo 2009_0618_134505AA of carbonate surface with encrusting algae, taken during Traverse 5. 1021 R16 (pale brown carbonate) taken near here. (G) SeaMax photo 2009_0618_135835AA cavernous carbonate ledge observed at 350 m during Traverse 6. Surface shown in F) is visible below and to the right of 16 (pale brown carbonate) taken near here. (H) SeaMax 2009_0618_152803AA coarse breccia at base of vertical wall observed near end of Traverse 6. Four clasts of porphyritic basaltic andesite were collected as clasts (1021-R23 to R26).

DIVE LOG

Dive #:	NT09-08 HPD#1021
Date:	June 18, 2009 (local)
Location:	Upper flank of Zealandia Bank volcano, SW and west of young caldera
Objectives:	Sample rocks, map geology
Logger:	Embley

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
8:05			In water		
8:42	716	0	On bottom for Traverse #1 at Target #1 up small cone SW of caldera; Talus lying over outcrop? Orange coloration on surfaces		
			exposed surfaces. Very friable and low density pieces.		
			Sample taken at landing spot. Basket 5	R01	orange pumice
8:51			Starting traverse upslope on small knob		
8:53	702		Large rounded blocks (probably pumice)		
8:54	700		Stopping in area of large blocks to sample. Large block appears to be breccia of some sort. Could be in place?		
			Arm is able to break out pieces from this breccia. Orange matrix in this piece. Some subtle layering.		
9:07			Small sample taken from same place. Basket 6	R02	grey banded pumice
9:19		0	Start up traverse again		
9:10	693		still more or less the same,, large blocks of varying shapes, but mostly with some layering and subangular edges.		
9:14	655		Some larger blocks with some corals on them. Some of these are slabby shaped but most are large subangular blocks. Not any deep sediment pockets but flatter blocks are covered with a coating of sediment.		
9:16	666		Have settled sown to sample again.		
			Took loose piece from base of large block. Some of it broke up when putting in circular basket. Very friable. Pieces in circular basket	R03	grey pumice
9:20		0	Starting up on traverse after sampling.		
9:22	655		Large striated angular blocks lying strewn over slope.		
9:23	650		Saw what appeared to be piece with flat top… intact part of flow?		
9:25	635		More subangular blocks. Some flat surfaces but mostly chaotic		
9:29	620		More of same. Stopping to sample again. Probably intact piece. Distinct layering in it. Broke off piece near base- it's yellow inside. Had to take with suction sampler because it breaks up when claw is used. Basket 2	R04	grey banded pumice
9:38			Start up traverse again		
9:40	612	5	These blocks seem to have more layering in them.		
			Large mound-like feature could be part of intact flow		

9:41	603		Smaller pieces for a while.		
9:42	594	19	Larger blocks with organisms.		
9:45	589		Stopping at more massive-looking flow, large vesicles and black in color (probably manganese). Sample taken from base. When it broke off the inside was yellow. It was put in Basket 2 in pieces.	R05	dark grey banded rhyolite
9:50			End of Traverse # 1 at Target #1. Transit to Target #3 on Traverse #2 in above bottom		
10:27	568	310	On bottom to start Traverse # 2 at Target 3. NW traverse up slope towards lava flow SW of young caldera and W-NW of Traverse # 1		
			Settling down to sample		
10:30	567	286	Broke off piece of block. Light color inside. Basket 5	R06	grey banded tuff with mafic clast
10:30	563	299	Appear to be seeing primary flow surface. Large rounded and subangular flows. Large holes in some of the flow top.		
10:34	555	290	More broken up now. Some flow banding.		
10:35	552		Stopped for another sample from this flow. Broken surface is orange and yellow. Basket 2.	R07	grey banded pumice
10:39		300	Start moving again. Area has rounded to subangular flows.		
10:40	541	300	Saw block with contorted flow banding.		
10:42	537	299	Looks more like the seafloor on Traverse #1; large blocks sticking up.		
10:43	632		Settling down to sample. Could be intact flow surface but some large blocks lying about. Only small amount of sediment. Basket 1.	R08	brown/grey banded rhyolite
10:48	634		Sample R08 taken of flow.		
			End Traverse #2 at Station R08 at Target 4		
11:13	459		Start Traverse # 3 at Target 5. This is S-N traverse on cone midway between caldera and Large edifice on western end of Zealandia Bank volcano.		
11:14			Off bottom again, so must not have been on right spot		
11:21	470		On Bottom to start Traverse # 3. Looks similar to Traverse # 2.		
11:23	471		Stopping to sample from flow. Seafloor has a lot of flattish		
			pieces…not clear if part of flow surface or are float. More whitish sediment between protuberances here.		
			There appears to be groundmass of dark colored rocks with larger blocks having orange surfaces, but could because outcrop pieces have been weathered out as much.		
			Sample R09 is rugose piece with black and orange coloration. Basket 1	R09	recrystallized coralline limestone

11:30	469	4	Begin traverse #3 at Target 5. Large blocks sticking up from flow top.		
11:32	467		Stop to sample at large angular outcrop (?).		
			Sample R10 is from this orange colored outcrop. Has small sponge on it. Basket 3 and a piece fell into Basket 4	R10	grey rhyolite
11:37	467		Leaving sample station on Traverse #3		
11:39		350	Came off bottom after leaving R10, now back on bottom.		
			Seafloor appears to be flow of rugose light-colored rocks coated with manganese on many surfaces, many of which may be loose.		
11:40	463	344	Very rugose, ornamented flow surface, lots of yellow-orange coloration; chaotic.		
11:42	463		now on locally flatter area, but rugose flow surface all around.		
11:43	457	339	Large flow-banded (?) blocks sticking up. Sponges common.		
11:44	451	349	Same, more white sandy material between blocks.		
			Impression is that this is large silicic flow. Lots of degassing structures, viscous taffy like stuff in places.		
11:46	440	0	More of same, but large blocks are more angular.		
11:48	437	0	Stopping to sample again. Basket 1.	R11	brown pumiceous tuff with flow bands
11:53	435	0	Starting up traverse again		
11:54	435	0	Surface is broken into smaller pieces. Mostly black and more slabby now.		
11:56	432	0	Large Coral. Very interesting looking. More corals now on rocks.		
11:57	428		Lots of chaotic blocks of various sizes, lot of corals, crinoids, etc.		
11:58	427	9	Similar to last entry, but blocks smaller.		
12:00	426	10	Still same basic surface		
12:02	427		Sampling again on side of large block. Basket 4	R12	recrystallized reefal limestone
12:05			End Traverse #3 at Target # 6 after Sample R12		
12:21	411	320	At target #7 moving to target #8 on Traverse #4		
			Large banded boulders, probable flows, some biota. Appear to be large pillow structures.		
12:25	406		Taking sample from large block jutting from seafloor		
			Very crumbly. Box with Lid	R13	grey rhyolite
12:31	403		Large holes in blocks		
12:33	401	320	Large upturned block with banding. Lots of sessile organisms on these blocks. Can't see any distinct sediment pockets.		
12:34	398	302	Settling down in area of jumbled blocks to sample again. Box with Lid	R14	brown pumiceous volcaniclastic
12:03	395	324	Moving off again, amongst large blocky flow surface(?)		

12:38	392	335	See some large rounded blocks that are probably parts of intact flow. Stopping to sample again. Box with lid.	R15	
12:40			Lift off from station to continue traverse		
12:41	385	325	See what appears to be very vesicular intact flow surface		
12:43	382	324	More of same variegated orange and black surfaces, angular to rounded large blocks.		
12:45	372	326	More of same. Lots of small corals and other sessile organisms on these rocks		
12:47	355	320	More of same; large blocks often with many corals.		
12:48	344	319	In place blocks. Lots of corals on these blocks.		
12:50	334		Stopping in large flow forms to sample again.		
			This is harder to break off blocks than earlier samples. Broken surface is very orange		
			Sample taken. Box with the lid	R16	Lost=Never Identified in basket
12:56	331	325	Start up traverse again.		
12:58	325	309	Similar to before last sample; blocks with corals.		
13:01	312	287	Similar terrain. End Traverse # 4 at Target #8.		
13:29	299	349	Begin Traverse #5 at Target #9. This traverse goes up SE flank of large cone west of caldera. Different than last traverse, finer textured bottom without the larger blocks.		
13:30	330		Sampling flattish piece; perhaps intact. In Box 4	R17	buff bioclastic (beach deposit?)
13:34	290		Start again, going over rubbly flow, but without the large blocks. More sediment cover because of lower relief. See lots of what appear small lobate forms with rugose surface.		
13:39	265		Still going over lava flow surface (?). Rugose at smaller scale than previous traverses and no big blocks. It's uniformly black to dark gray. White sediment pockets. Large holes in surface.		
13:42	242	350	Much the same. Saw area where there was a lot of white patches down in the holes in the lava.		
13:43	246	330	Large white sediment patch.		
13:44	234	320	Settling down to sample rock from within sediment patch.		
			Rocks are dark brownish red in close-up. Difficult to sample, perhaps more crystalline rock and in place. In Basket.	R18	pale brown
13:59	223	356	Appears to be encrusting coralline algae on this so we may have some ambient light here.		
14:00			Moving off bottom after R18. End Traverse #5 at Target 10.		
			Some discussion of whether this was carbonate or lava.		
14:30	364	249	Start Traverse # 6, at Target 11. Big blocks again.		
14:31	364	249	Stopped, taking piece off of large block with well-defined banding. Box Basket 3.	R19	pale brown carbonate

14:45	364		Moving off Sample station R19		
14:48	348		At next sample site. More sedimented here.		
			As before, rock has variegated brownish orange and dark gray color. Crumbly and hard to get an intact piece, although sometimes hard to actually break off from block. Yellow color on broken surface. In Box 3.	R20 & 21	brown & grey tuff
14:56			Leaving Sample Station 20/21.		
14:57	343	250	Fewer large blocks, mostly partly sedimented low relief surface with vugs in them.		
14:59	332	270	Once in a while get to larger blocks, perhaps flow fronts?		
15:00	324	280	Going over larger blocks with corals and sponges on them, then into flatter area.		
15:01	314	280	Saw large block with distinct banding.		
15:02	313	280	Stopping to sample again. R22 very large sample. Behind the basket area.	R22	buff bioclastic limestone
15:08	307	279	Same again.		
15:09	300	279	Against breccia flow. Sampling again.		
			Trying to sample on breccia zone outcropping on side of old caldera. From in Round Basket	R23	porphyritic basaltic andesite clast
			Took another sample; loose rock from base of wall. On ledge top of basket 1	R24	porphyritic basaltic andesite clast
15:29	295		Ascending scarp in volcanic breccia.		
15:32	289		Sampling again on wall. Took oblong piece (R25) from rubble on wall. On top of Box 4.	R25	porphyritic basaltic andesite clast
15:26			Taking another piece from rubble. Behind Sample R25 on top of Box 5.	R26	porphyritic basaltic andesite clast
15:44	288		End Traverse 6 at Target 12; End Dive 1021, Traversed up wall as ascending; 35 m relief on wall.		

HYPER-DOLPHIN DIVE #1022

TECHNICAL INFORMATION:

Location:	Seamount between Zealandia Bank and Sarigan	
Objective:	Sample small arc volcano NNE of Sarigan Island.	
DIVE 1022	On bottom:	Off bottom:
Time (local): June 19, 2009	9:08	11:02
Latitude:	16°46.592'N	16°46.827'N
Longitude:	145°50.551'E	145°50.332'E
Depth (m):	1496	1175
Samples returned: 14 rocks		

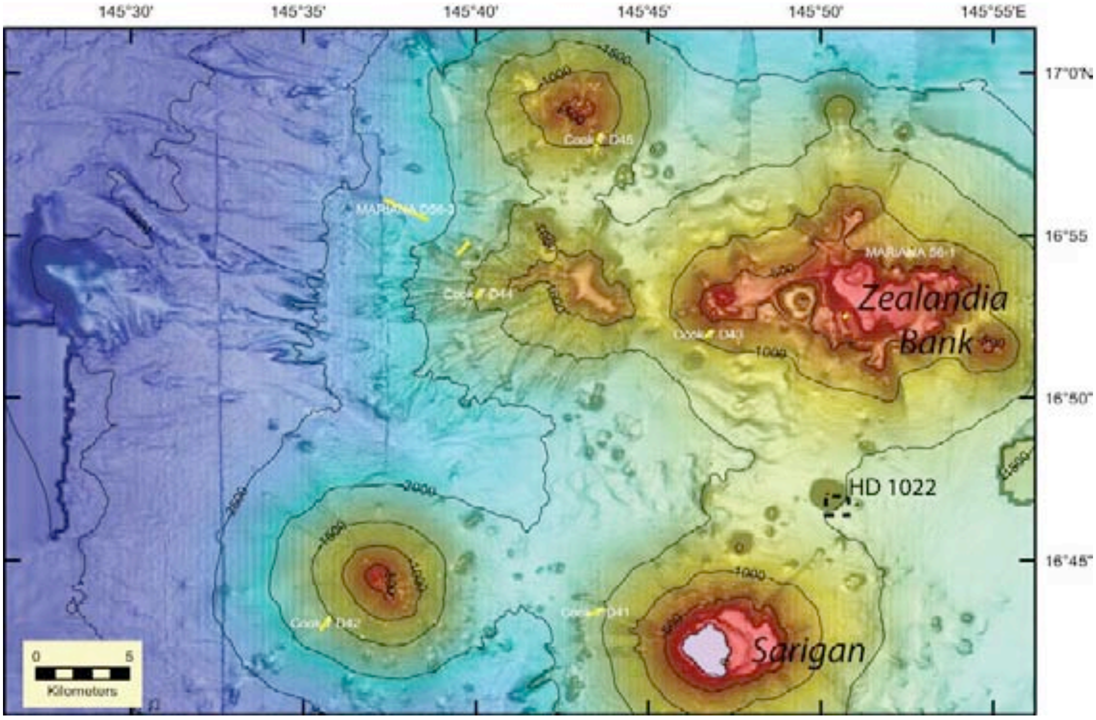


Figure 57. Location of study area for HPD 1022. Dashed box shows location of Fig. 58.

SCIENTIFIC SUMMARY

The target of Dive HD-1022 was a small seamount roughly equidistant between the flanks of Zealandia Bank to the NNE and Sarigan Island to the SSW. For the purposes of this report the volcano will be referred to as South Zealandia Seamount (SZS) due to its location. The base of SZS is at approximately 1500 meters and its summit is 985 meters below the surface.

SZS has not been sampled before and its petrological characteristics were unknown. Its location is at the magmatic front and thus the possibility that it had erupted felsic and/or intermediate lavas was considered possible. However, most small submarine volcanoes in the Marianas Arc have been found to have erupted mafic lavas. Hyper-Dolphin reached bottom at a depth of 1496 meters on the SE flank of SZS.

The surface encountered at the lowermost slope consisted of mottled sand/mud sediment strewn with pebble and cobble size blocks and rounded clasts. As Hyper-Dolphin ascended SZS's flank, the amount of larger clasts covering the slope varied. Most clasts were cobble-size, but occasional boulder size blocks were encountered. A larger boulder resting on mud at 1415 meters was angular and appeared to contain planar joints. The amount of surface covered by blocks increased as Hyper-Dolphin continued its transit and by 1380 m most of the slope was block-covered and the proportion of boulder-size blocks increased. Above 1380m, the block-covered portions of the slope were locally separated by lower-lying "chutes" with a higher proportion of sand/mud and dark pebble-size clasts. The block-covered areas at 1350 meters and higher were coated with fine sediment, indicating these blocks had been in place longer than those on the lower slopes. These may have been flows of blocks erupted from the summit, the blocks at greater depth were float derived from the block-flows from later non-volcanic down-slope movement. The slope surface encountered by Hyper-Dolphin above 1350 meters appeared gullied and projections of outcrop appeared. Prior to this point, all samples (R01-R06) were collected from float. R07 was pulled off the outcrop. This uneven terrain of higher relief block-flows with outcrop projections was encountered by Hyper-Dolphin until it came off the bottom at 1175 meters.

Fourteen rock samples were recovered, most float or loose in block-flows. The samples were all porphyritic Ol-Pl-PX basalts. Most had no Mn coating and two had altered remains of glassy rims. All were moderately vesiculated. Thus, we conclude that SZS is a basaltic volcano. Organisms were scarce and biological diversity very low – a few sponges and whip corals were observed. This stands in contrast to the next seamount to the south, studied during HD-1023.

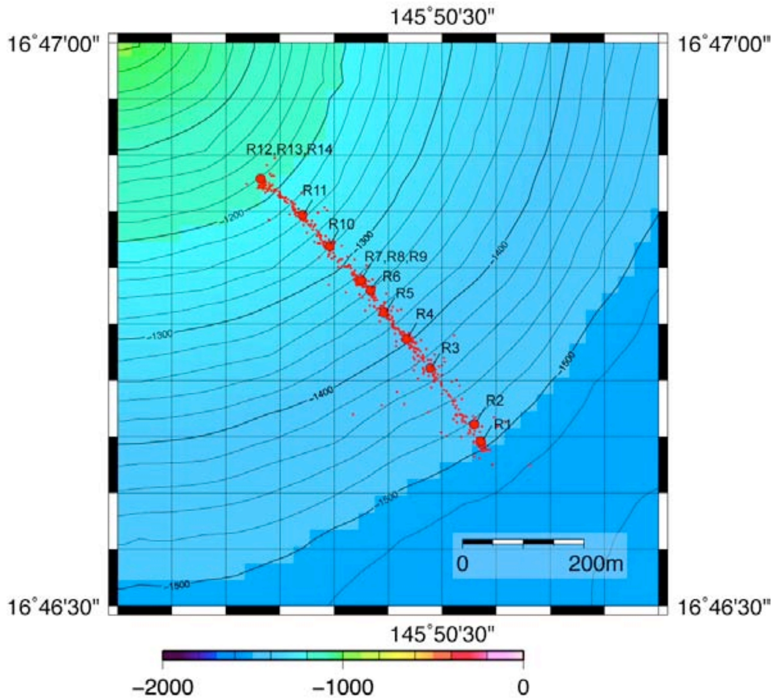


Figure 58. Bathymetry and station locations for HD 1022

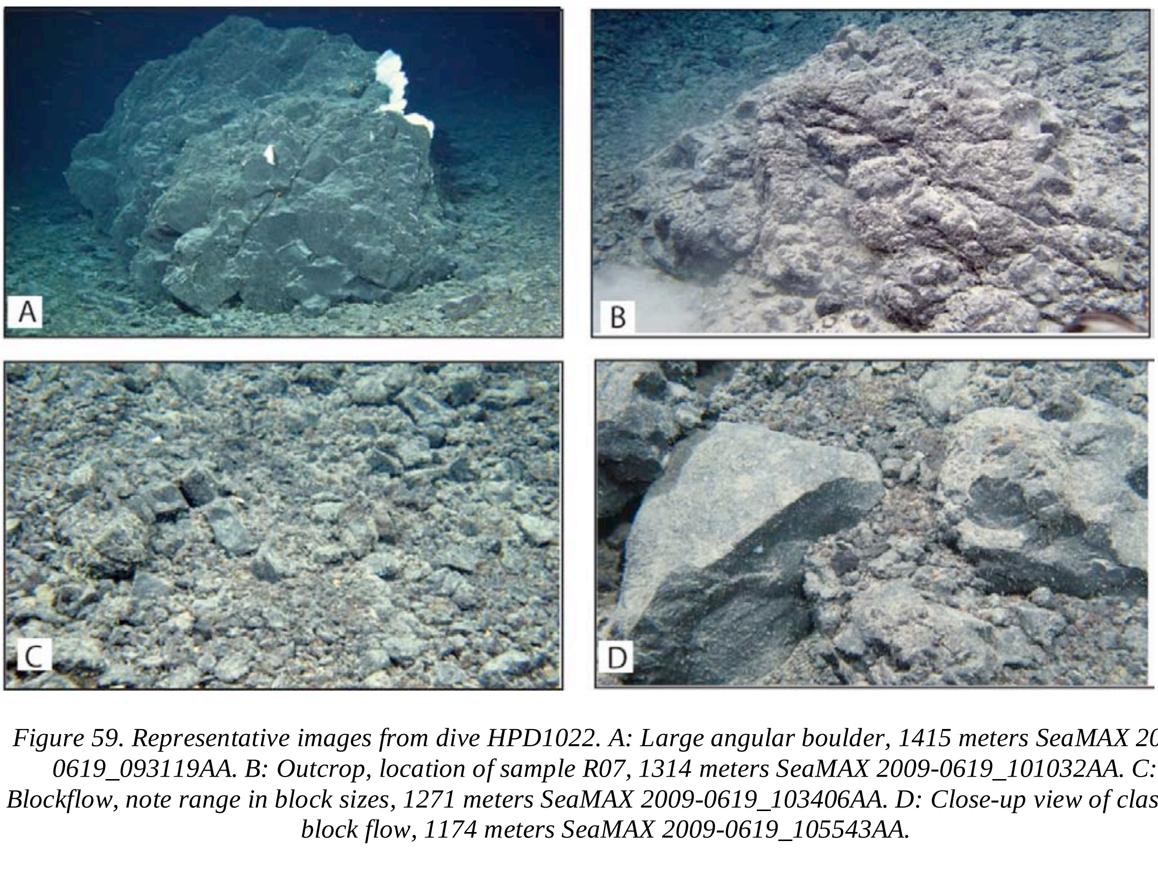


Figure 59. Representative images from dive HPD1022. A: Large angular boulder, 1415 meters SeaMAX 2009-0619_093119AA. B: Outcrop, location of sample R07, 1314 meters SeaMAX 2009-0619_101032AA. C: Blockflow, note range in block sizes, 1271 meters SeaMAX 2009-0619_103406AA. D: Close-up view of clasts in block flow, 1174 meters SeaMAX 2009-0619_105543AA.

DIVE LOG

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
8:04			In water		
9:08	1496	320	On bottom. Mottled dark sediment with cobbles and blocks		
9:09	1496	319	Sample from cobbles, angular clasts	R01	Porphyritic basalt
9:11	1490	320	Transiting cobble and boulder covered slope. Appear to be basalt blocks.		
9:16	1479	320	Sampling clasts	R02	Porphyrtitic basalt
9:19	1472	321	Larger blocks, some may be in place. Glass sponges present.		
9:24	1441	321	Traversing cobble covered slope, occasional boulders		
9:29	1417	321	Cobble covered slope, sample larger clast (small boulder)	R03	Porphyritic basalt
9:31	1415	320	Passing over large, angular boulder. Appears jointed.		
9:35	1405	320	Stop on slope, small clasts (10-50 cm) appear to be touching, surface could be eroded flow top as well as float.		
9:37	1398	320	Continuing ascent of seamount.		
9:39	1392	321	Irregular patches of sand/mud with no cobbles.		
9:42	1381	320	Slope now has higher proportion of boulders, some possible radial jointing.		
9:44	1379	321	Sampling clast.	R04	Porphyritic basalt
9:51	1358	320	Slope remains fairly constant, some sinuous sand mud/chutes at this depth.		
9:54	1350	320	Sampling cobbles, these appear to have a rougher surface and are coated with fine sediment at this location.	R05	Porphyritic basalt
10:04	1326	320	Blocky boulder and cobble talus slope, some may be columnar blocks. No fine sand or mud. Sampling	R06	Porphyritic basalt
10:08	1319	320	Slope becomes more uneven and mildy gullied. Prominent meter-scale boulders (outcrop?).		
10:09	1314	320	Flow outcrop, may have eroded pillows. Attempting to sample.	R07	Porphyritic basalt
10:15	1314	320	Did get small outcrop sample. Another sample attempt, failed. Sampled loose clasts.	R08/ R09	Porphyritic basalt
10:28	1290	320	Traversing loose blocks and outcrop.		
10:32	1271	314	Sampling small cobble from block flow.	R10	Porphyritic basalt
10:38	1249	314	Whip coral on outcrop		
10:41	1232	318	Sampling loose clast near outcrop.	R11	Porphyritic basalt
10:47	1213	313	Layered flow outcrop.		
10:55	1174	314	Continuing ascent, alternating blocky slope and projecting outcrop. Sampling clasts in float and loose clast on flow surface.	R12/ R13	Porphyritic basalt
11:02	1175		off bottom		
11:35	0		at surface		

HYPER-DOLPHIN DIVE #1023

TECHNICAL INFORMATION

Location: Cone off north flank of Sarigan Island
Objective: Sample basalts

DIVE 1023	On bottom:	Off bottom:
Time (local): June 19, 2009	13:50	16:02
Latitude:	16°45.776'N	16°45.620'N
Longitude:	145°47.487'E	145°47.585'E
Depth (m):	1286 m	1059 m
Samples returned: 11 rocks		

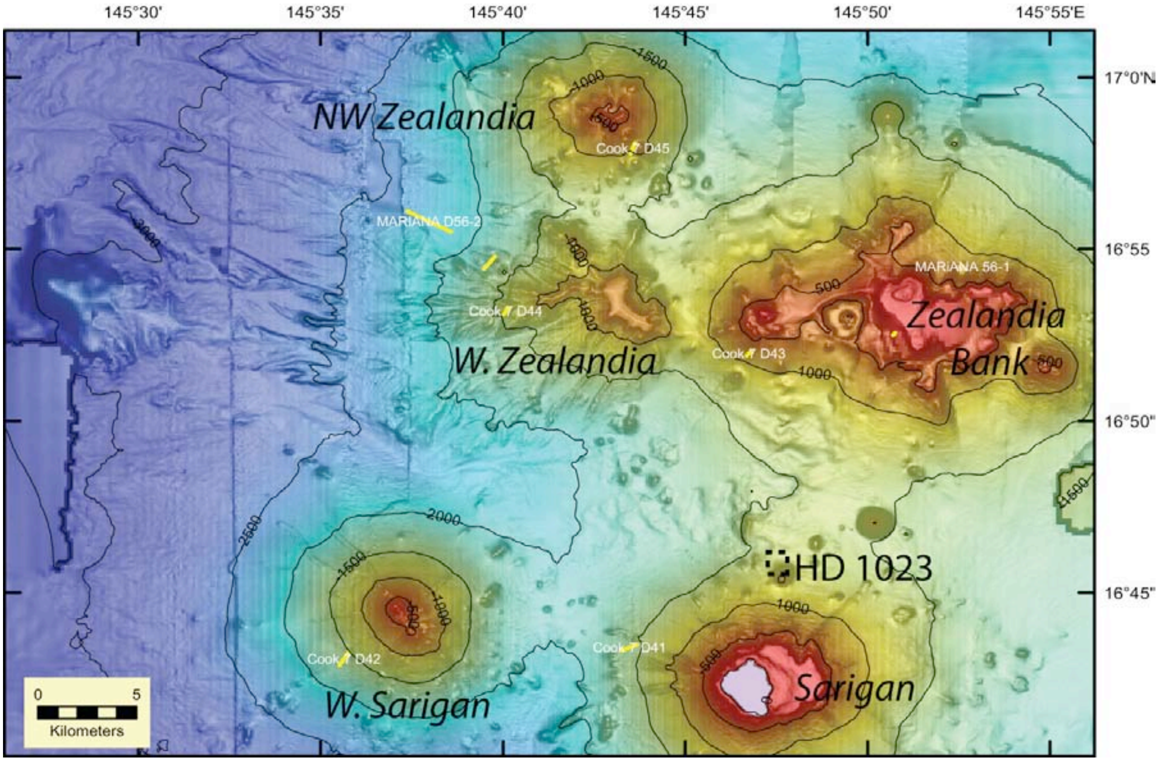


Figure 60. Bathymetric map of region around Sarigan Island, W. Sarigan, Zealandia Bank volcano, and NW and W. Zealandia, from Mariana Bathymetric Compilation (Susan Merle, PMEL/NOAA, compiler. Dots indicate previous dredges (Mara, Cook 7 cruises) and ROV dives (TT167). Dashed box shows location of Fig. 61.

SCIENTIFIC SUMMARY

The target cone is located approximately three kilometers from the base of the northern flank of Sarigan Island. The geologic history and composition of this cone was unknown prior to the subject dive. This dive was intended to recover samples that could help evaluate the origin and composition of the cone. The targeted cone is approximately 380 m tall and 1 km in diameter. This cone may be a monogenetic volcano, constructed from a single protracted eruption of basalt. This dive traversed about 450m horizontally and ascended approximately 220 m up the NNW slope of the unnamed cone. The seafloor was fairly uniform throughout the traverse, characterized by abundant talus with occasional protruding basaltic outcrops. A rich benthic biota dominated by sponges, corals, and crinoids was observed during the traverse, which became increasingly dense and diverse on the steeper and shallower outcrops.

All eleven samples collected were basaltic, and many were collected from what appeared to be flows, pillows, or dikes. Seven of the eleven samples are fresh, dark basalts with little or no Mn coating. The remaining four samples are dark pyroxene basalts, also fresh, with no Mn coating. The phenocryst assemblages for all of the samples are similar. Ten samples contain 1-15% olivine phenocrysts, whereas no olivine was seen in one sample (R09). Nine samples contain 1-5% plagioclase phenocrysts, while two of the samples (R01 and R03) do not. Eight samples contain weakly altered or oxidized glass ranging from less than one millimeter to two millimeters, and all of the samples were weakly to moderately vesiculated. The lack of compositional diversity is consistent with this being a monogenetic volcano, with little opportunity for magmatic fractionation.

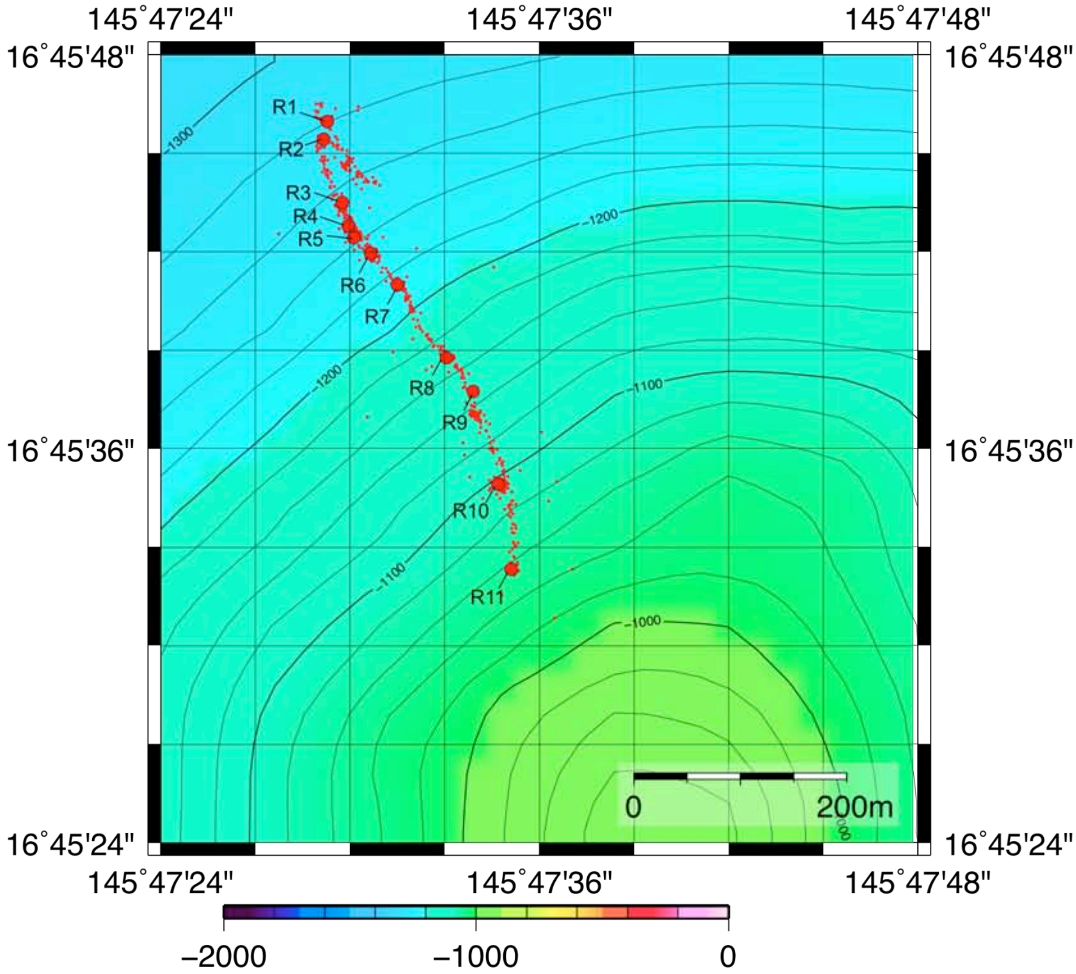


Figure 61. Bathymetric map of part of an unnamed cone off the northern flank of Sarigan Island. Track of HD 1023 is also shown, along with sample locations.

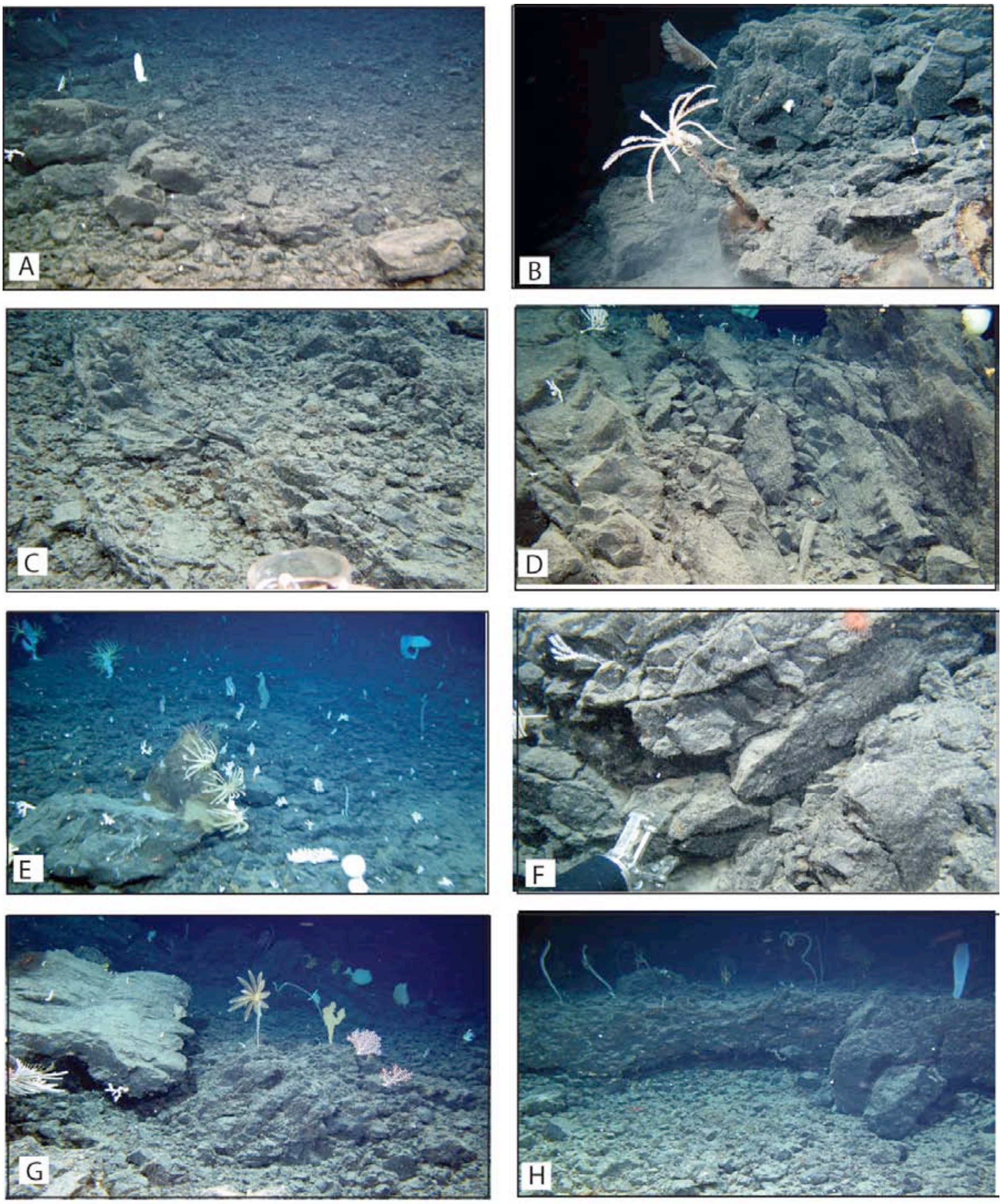


Figure 62. Photos of talus, basaltic outcrops, and benthic biota, observed and sampled during HD1023. Sequence of photos is from start A) to end H) of dive. A) SeaMax 2009_0619_141621AA rubbly talus with some large blocks; B) SeaMax 2009_06191142033AA photograph of pyroxene basalt outcrop at location of sample R03; C) SeaMax 2009_0619_142421AA lava flow with observable lineation and possible pillows; D) SeaMax 2009_0619_143144AA jointed basalt outcrop appears to be a dike near location of sample RO5; E) SeaMax 2009_0619_145411AA talus slope with few large angular blocks and large variety of biota; F) SeaMax 2009_0619_150332AA collection of sample R08 from basalt outcrop; G) talus slope with large boulders, possible outcrops, and benthic biota (sponges, crinoids, and coral); H) SeaMax 2009_0619_152659AA sample R10, pyroxene basalt, collected from large slab on which sponges, crinoids, and gorgonian corals grow.

DIVE LGO

Dive #:	NT09-08 HPD#1023
Date:	19-Jun-09
Location:	Cone off northern flank of Sarigan Island
Objectives:	Sample basalts
Logger:	Erika Jordan

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
12:59			In the water		
13:50	1286	153	On bottom		
			Rubbly ground, mostly small with few larger blocks. Sponges present.		
13:52	1286	152	Stopped for sample of medium size rock on smaller rubbly surface. Small red crab and crinoid.		
13:55	1286	152	Sample with crinoid.	R01	basalt
13:56	1286	142	Continue over rubbly ground.		
13:58	1281	143	Continue upslope over rubbly ground with greater abundance of larger pieces. Sea whip present.		
14:02	1277	148	Stopped for sample on rubbly ground with larger few larger angular rock fragments.		
14:06	1278	144	Collected sample with blackened surface with some red underneath. (behind basket)	R02	pyroxene basalt
14:10	1276	152	Continue over rubbly ground with angular fragment. Corals present.		
14:13	1268	159	Rubbly ground with fewer large angular fragments. Shrimp and corals present.		
14:15	1263	160	Large angular rock fragments and boulders on rubbly bottom.		
14:18	1257	160	Stopped on steep slope to collect sample from large rocks. Did not appear to be from outcrop.	R03	pyroxene basalt
14:21	1254	160	Continue upslope away from what appeared to be an outcrop. Moving over more rubbly ground with some moderately sized rock fragments.		
14:23	1247	148	Stopped at base of steep slope. Appears to be outcrop with possible pillows or flow lineation. Continued upslope.		
14:26	1240	149	Continued upslope. Poorly sorted rubble. Anemone and coral present. Apparent outcrop.		
14:28	1240	148	Sampled. Not in situ, possible fragment of outcrop.	R04	basalt
14:30	1236	148	Continue up steep outcrop slope. Many corals present.		
14:33	1234	149	Sampled jointed outcrop, possibly a dike. Sample collected in situ.	R05	basalt
14:35	1233	149	Continue up steep outcrop cliff with giant sponges, crinoids, coral, anemones, sea fans and jellyfish. Very dense biota.		

14:39	1222	140	Stopped for sample on slope. Large reddish angular block sample.	R06	basalt
14:44	1221	138	Continue up rubbly talus slope. Not as steep with smaller fragments. Corals present.		
14:48	1210	139	Outcrop, possible breccia.		
14:50	1210	139	Sample possible outcrop, very loose. Brittle star on sample.	R07	basalt
14:52	1207	150	Continue up rubbly talus slope. Corals and anemones present.		
14:56	1193	149	Continue up rubbly talus slope. Corals, shrimp, scallops, anemones, sea whips, giant sponges present.		
14:58	1189	149	Still going up talus slope. Large variety of corals and sponges present.		
15:00	1173	149	Continuing up talus slope with slightly larger blocks and into outcrop. Many colors of coral.		
15:03	1170	149	Stopped to sample outcrop cliff. Sample in situ.	R08	basalt
15:06	1167	149	Continue up talus slope with some large boulders. Some boulders appear to be banded.		
15:09	1156	166	Talus slope with small to medium size fragments.		
15:11	1147	165	Going up steeper talus slope with larger boulders. Large amount of biota, colored corals, sponges (trumpet sponge), and eel.		
15:14	1142	155	Stopped to sample possible outcrop. Broke off large fragment with many corals and crinoids. Small piece broke off of larger block	R09	pyroxene basalt
15:19	1138	153	Continue up talus slope with large boulders, possible outcrops and biota.		
15:21	1128	153	More rubbly talus, less biota.		
15:22	1118	153	Continue up talus slope, very few larger fragments, few larger boulders.		
15:25	1106	154	Talus slope with some small to medium size fragments. Some biota.		
15:27	1104	153	Stopped to view large slab, possibly outcrop. Covered in biota over the top. A large portion of the slab broke off and fell into pieces.		
15:47	1104	153	Picked up what appeared to be a very large sample that fell from the slab.	R10	pyroxene basalt
15:50	1098	153	Continue up talus slope with corals, sea whips.		
15:52	1093	153	Small outcrop		
15:53	1084	160	Talus slope with corals, no boulders.		
15:55	1072	160	Talus slope with medium to large boulders.		
15:57	1059	159	Possible outcrop		
15:58	1059	160	Sampled talus. End traverse.	R11	basalt
16:02	1059	160	Off bottom		
16:45			At surface		

HYPER-DOLPHIN DIVE #1024

TECHNICAL INFORMATION

Location: Parasitic cone on SE flank of Zealandia Bank
Objective: Survey and sample volcanic stratigraphy & potential hydrothermal sites

DIVE 1024	On bottom:	Off bottom:
Time (local): June 20, 2009	08:49	11:02
Latitude:	16°50.609'N	16° 51.110'N
Longitude:	145°54.907'E	145° 54.941'E
Depth (m):	1096	778
Samples returned:	9 rocks, 2 cores	

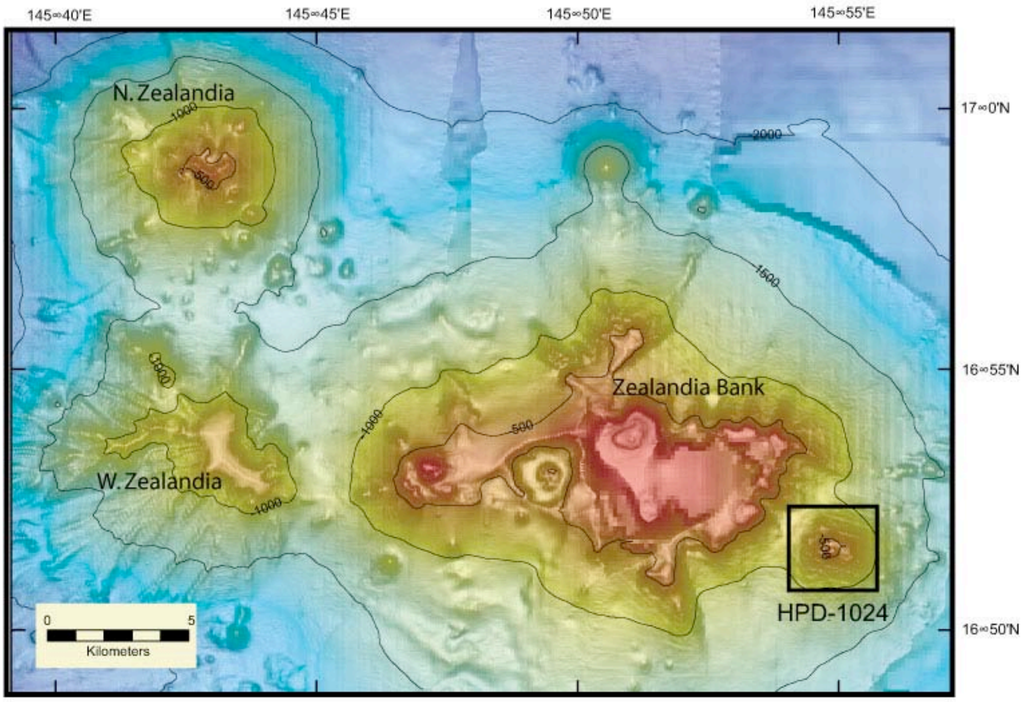


Figure 63. Bathymetric map of Zealandia Bank and surrounding volcanic edifices, from Mariana Bathymetric Compilation (Susan Merle, PMEL/NOAA, compiler and ETOPO data for the shallow part of Zealandia Bank. Box area is the location of dive 1024 and the location of Fig. 64.

SCIENTIFIC SUMMARY:

Zealandia Bank volcano lies about 18 km NNE of Sarigan Island, about 140 km north of Saipan, and is in the Central Island Province of the Mariana magmatic arc. Zealandia Bank volcano is a complex edifice that consists of a barely submerged summit (Zealandia Bank), which is part of a ~15 km elongated E-W volcanic edifice. The volcano complex is divided into a steep, dissected, older eastern half and a smoother, younger western half. Dive 1024 transect was on the south flank of a parasitic volcanic edifice located on the lower part of the western dissected flank of Zealandia Bank. Additional background information can be found in the 5.9 HPD Dive 1019. The objectives of Hyper-Dolphin dive 1024 were to investigate and date the volcanic units that make up parasitic volcanic edifice on the flank of Zealandia Bank and investigate areas that may have active and inactive hydrothermal sulfide chimney fields.

Dive 1024 consisted of an approximately N-S-oriented traverse up the southern flank of a parasitic volcanic edifice located on the lower southeast flank of Zealandia Bank (Figs. 63, 64). The ROV touched bottom at 1097 m and traversed to 778 m water depth, covering 319 meters of section. Generally, the dive showed outcrops of basalt flows interspersed with areas of white sediment that was devoid of coarser-grained detritus on its surface in the lower half of section and gravel on its surface in the upper half of the section. The last significant outcrop was at about 925 m and the rest of the traverse showed predominantly sediment with extensive pebble fields and cobbles in places. This sediment-dominated section extends from 925 m to 778 m, which most likely continues to the top of the edifice, which was not surveyed.

In detail, the ROV landed at the base of a basalt outcrop at 1097 m (Fig. 65A). The basalts occur as thin-to-medium-thick flows exposing an approximately 6 m-thick section; some flows are channel-fill units. Sample R01 was collected from this outcrop. White sediment with rare cobbles scattered on the surface covered the surface until the next outcrop. The next outcrop of basalt flows started at 1089 m and sample R02 was collected there (Fig. 65B); then sediment cover again and a third outcrop of basalt flows started at 1085 m and ended at 1073 m, exposing 12 m of section. That section shows thin-to-medium-thick flows, lobate flows, and pillow lavas. The next outcrop of basalt exposes 9 m of section (1067 m to 1058 m) composed of thin to thick flows (Fig. 65C); R03 sampled a thin flow from this outcrop. Two more outcrops of basalt expose 6 m (1051-1045 m) and 8 m (1044-1036 m) of section, the first consisting of thick flows and the second of blocky flows. White sediment occurs over the intervals between the basalt flow outcrops and at about 1030 m shows N-S oriented long-crested asymmetric ripples indicating the predominant current direction is west to east. Sample R04 was collected from a 13-m thick (1023-1010 m) section of blocky flows with some pillow lavas (Fig. 65D). Sample R05 was collected from the next outcrop that exposes 7 m of blocky lava outcrop with radial jointing in places; thick massive flows are predominant and thin flows are minor. Sample R05 was collected at this outcrop from talus at the base of a nearly vertical cliff. Sample R06 was collected from an elongate, narrow outcrop with steep sides that exposes 9 m of section (Fig. 65E); the morphology of these flows suggest that they may have filled a channel. Several more basalt sections were encountered, but they are becoming more subdued, low-lying outcrops that are mostly buried in sediment. The first one exposes 8 m (979-971 m) of blocky basalt and the next one shows 4 m of blocky lava outcrop (961-957 m). At about 970 m, gravel on the sediment becomes extensive and commonly fills networks of channels; cobbles are abundant in some of the gravelly areas. Core C01 sampled a gravel patch at 953 m and recovered white sediment below the basalt gravel (Fig. 65F). A 14 m-thick section (938-924 m) of low-lying blocky to massive flows was sampled at 938 m (RO7) (Fig. 65G). Benthic biota is very scarce from the beginning of the traverse to about 905 m, and then an increase was noted, but still the population density was very small. Sediment and gravel continued up slope and was sampled with a push core (C02) at 886 m. Cobbles mixed with gravel are more common above 835 m. The last two outcrops encountered are low-lying exposures of flows at 827 m depth, where sample R08 was collected, and a 20 cm-thick layer of conglomerate or small pillows at 778 m, where R09 was collected (Fig. 65H). The dive ended at this outcrop, but sediment with gravel is predominant for the uppermost 150 m of slope. Hydrothermal chimneys or mounds were not found along transect 1024.

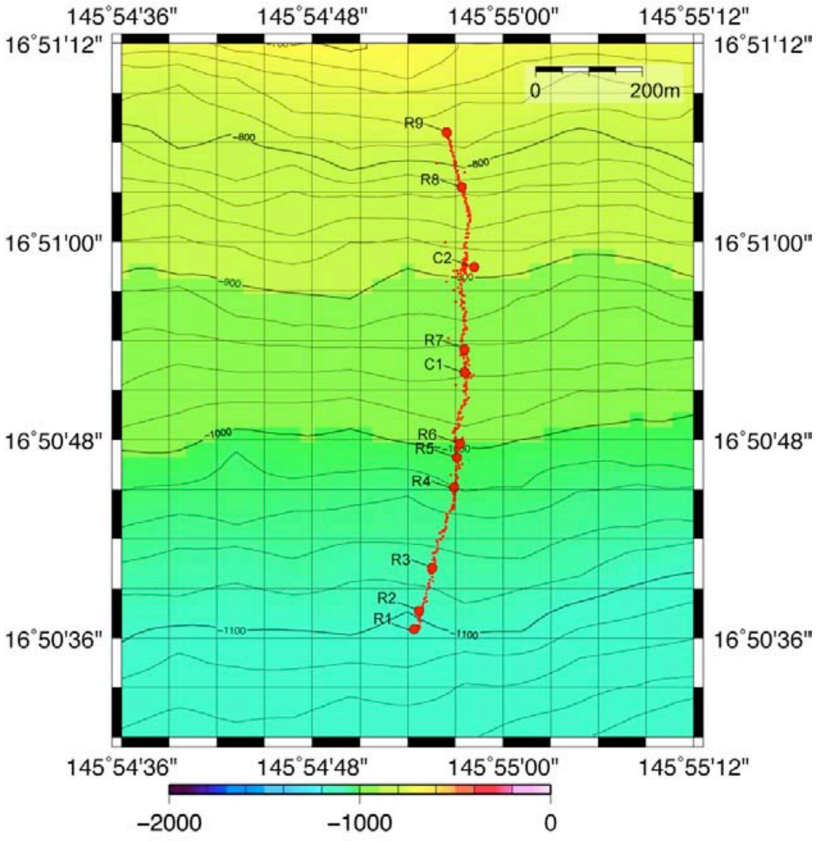


Figure 64. Bathymetric map of parasitic volcanic edifice located on the SE flank of Zealandia Bank surveyed during NT09-08. Track line and sample locations of the HD-1024 dive are shown.

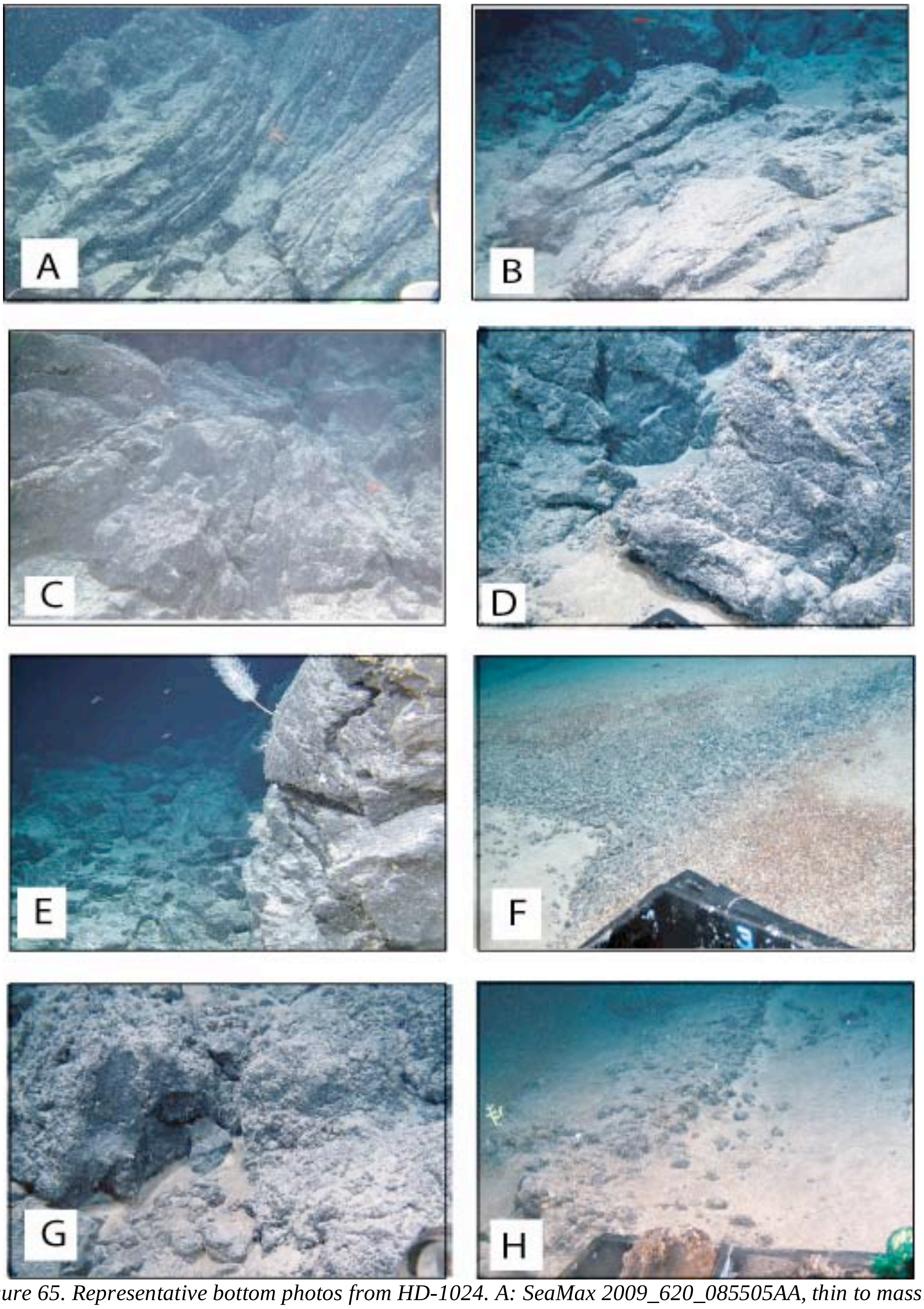


Figure 65. Representative bottom photos from HD-1024. A: SeaMax 2009_620_085505AA, thin to massive basalt flows from which sample R01 was collected at about 1097 m water depth; B: SeaMax 2009_0620_090156AA, thin to thick bedded basalt flow from which sample R02 was collected at 1089 m water depth; C: SeaMax 2009_0620_091724AA, massive basalt flows from which sample R03 was collected at 1067 m water depth; D: SeaMax 2009_0620_092943AA, steep face of massive basalt flows outcrop from which sample R04 was collected at about 1019 m water depth; E: SeaMax 2009_0620_094216AA, steep wall of massive basalt flows from which sample R06 was collected at 991 m water depth; F: SeaMax 2009_0620_100633AA, sediment-covered seabed with gravel filling shallow channels, core C01 was collected from the gravel patch in the foreground, about 953 m water depth; G: SeaMax 2009_0620_101033AA; blocky basalt flows from which sample R07 was collected from a water depth about 938 m; H: SeaMax 2009_0620_110202AA, thin beds of low-lying outcrop of basalt flow from which sample R09 was collected at about 778 m water depth.

DIVE LOG

Dive #:	NT09-08 HPD#1024
Date:	June 20, 2009 (local)
Location:	Parasitic flat-topped edifice on SE flank of Zealandia Bank
Objectives:	Survey and sample volcanic stratigraphy and hydrothermal sites
Logger:	Hein

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
8:05			In water.		
8:50	1097	41	On bottom; thin-bedded to medium-bedded basalt flows crop out, surrounded by sediment; 5-6 m cliff face; small channel-fill flow units.		
8:55	1097	41	Sample from outcrop.	R01	px basalt
9:00	1093	359	Sediment covered seabed with boulders and cobbles scattered about, some maybe outcrops of the same thin-bedded rock; degraded ripples.		
9:02	1089	344	Sample from outcrop, similar outcrop to R01 location.	R02	px basalt
9:05	1085	359	Another large outcrop, this time basalt flows, some pillows, lobate flows; outcrop ends at 1073 m; minimum thickness of 12 m		
9:08	1072	350	Sediment devoid of pebbles, gravel, and other rock debris, which is the same as between the outcrops.		
9:09	1067	350	Another outcrop of lava flows, some massive flows, sample thin-bedded part from outcrop; large sample collected; sampling ended at 09:17; outcrop ends at 1058 m, minimum 9 m thick.	R03	px basalt
9:19	1052	355	Another outcrop of thick flows; and another at 1051 m until 1045 (6 m thick), thin flows, all with clean sediment between them; another at 1044 m to 1036 m (8 m thick), blocky flows, then sediment again.		
9:24	1029	0	Another outcrop, blocky (off to left of field of view); sediment still clean, long straight-crested ripples, degraded in places, oriented up slope, small outcrops through sediment.		
9:28	1023	349	Blocky outcrop of flows, pillows, sampling 1019 m from outcrop, outcrop ends at 1010 m plus, minimum 13 m thick.	R04	px basalt
9:36	1010	349	Sediment, some debris on surface, very weird fish, gravel areas.		
9:38	1002	351	Another rubbly outcrop, some radial jointing, vertical wall in places, massive flows mostly, some thin bedded, sampling cobbles below the vertical face, outcrop ends at 995 m, minimum 7 m thick.	R05	px basalt
9:44	991	350	Sediment then another massive flow, steep wall, may be channel fill, sample from outcrop, 09:51 finished sampling; outcrop ends at 982 m, min. 9 m thick.	R06	px basalt

9:55	979	0	Blocky outcrop, much buried in sediment and gravel; 976 m mostly gravel and sediment with sparse cobbles to 971 m, about 8 m of section exposed.		
9:58	969	349	Small outcrop, then sediment and gravel again, rippled areas and gravel fills network of channels; outcrop at 961 m to 957 m, minimum 4 m thick.		
10:02	956	342	Sediment with ripples oriented with crests upslope, gravel-filled channels, sparse cobbles.		
10:03	953	344	Sampling gravel patch with blue push core, White sediment below gravel, two penetrations; rippled sediment.	C01	Pebbles, sand, mud
10:08	946	345	Lots more gravel on sediment and ripples degraded, low outcrop at 941 m, looks like flow rock, sampling at 938 m, 10:10, from outcrop, finished sampling at 10:19.	R07	px basalt
10:20	937	346	Outcrop continuing, blocky to massive flows; ends at 924 m, minimum 14 m thick.		
10:22	923	343	Again sediment with lots of gravel, degraded ripples, sparse cobbles and pebbles, ripples crests oriented upslope, crinoid, fish, very scarce life until 905 m, then more common, but still sparse, channels filled with gravel; asymmetric ripples, current from west to east, shrimp, sponge.		
10:30	890	349	Continuing sediment and gravel.		
10:31	886	348	Sampling gravel and white sediment below, red push core, 3 penetrations, moving upslope, same stuff, sponges on gravel, 835 m, cobbles mixed in with the gravel.	C02	Pebbles, sand, mud
10:46	827	340	Sampling, cobble outcrop, conglomerate or pillow flow, thin layered, low-lying outcrop, red coral stocks.	R08	px basalt
10:50	823	339	Back to rippled sediment and gravel; continuing low-lying outcrops, platy surface in places--thin beds of probably poorly consolidated material.		
10:54	793	344	Some large cobbles on sediment, but mostly pebbles on sediment and gravel/cobble in channels and lows.		
10:56	778	344	Platy/rubbly outcrop with cobbles along its 20 cm face, sampling large cobble from outcrop, finished at 11:02; sediment dominated for minimum of 85 m depth range.	R09	Basalt, glass rind
11:03	778	347	Off bottom		
11:25			At surface		

HYPER-DOLPHIN DIVE #1025

TECHNICAL INFORMATION:

Location:	East flank of ridge south of Zealandia Bank
Objective:	Sample deep stratigraphy of Zealandia Bank Volcano

DIVE 1025	On bottom:	Off bottom:
Time (local): June 20, 2009	13:44	15:58
Latitude:	16°50.508'N	16°46.827'N
Longitude:	145°52.295'E	145°52.125'E
Depth (m):	1023	838

Samples returned: 17 rocks

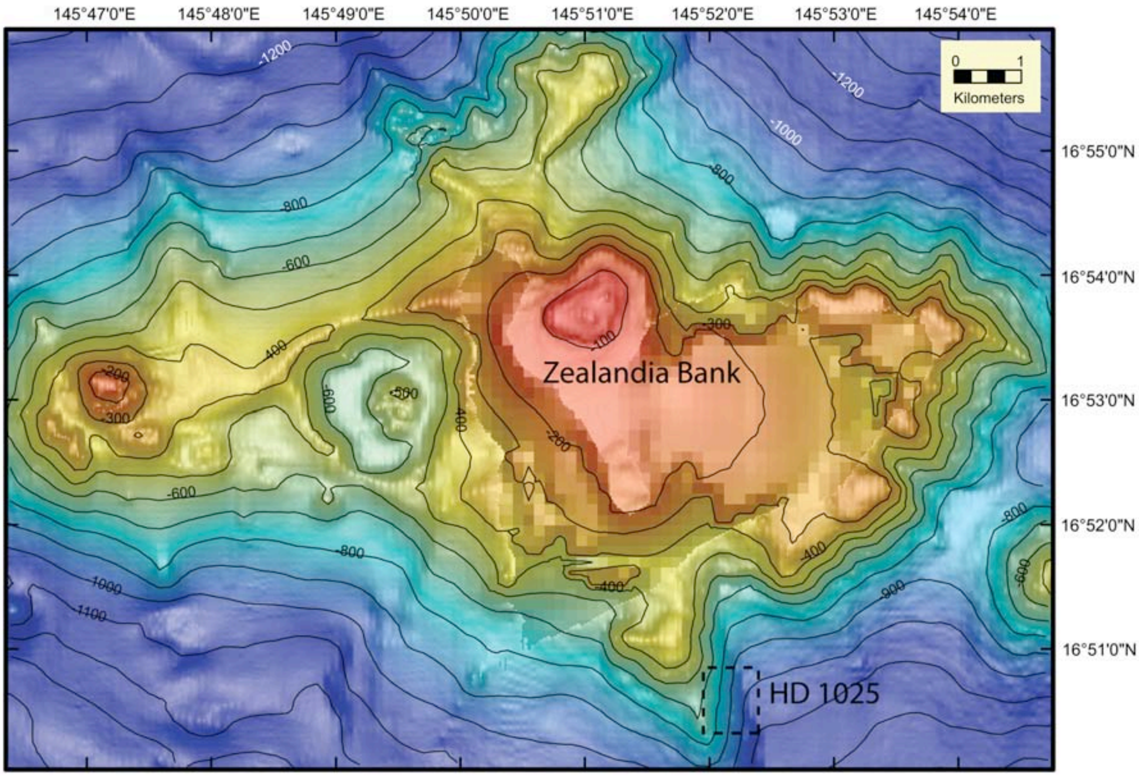


Figure 66. Zealandia Bank and location of study area for HD 1025. Dashed box shows location of Fig. 67.

SCIENTIFIC SUMMARY

Zealandia Bank volcano is a large (elongated ~14 km E-W) volcano, about which very little was known prior to this cruise, other than a few basalt and andesite samples described by Dixon & Stern (1983). Bathymetric mapping shows that the western and eastern halves of the volcano are morphologically distinct, with a western half that has a smoother, gentler slope and a well-preserved caldera, which contrasts with the much steeper and more incised eastern half. Three dives (#1019-#1021) were devoted to exploring the western half and revealed that the caldera walls, central cone, and summit region farther west have surfaces that are dominated by abundant felsic pyroclastic deposits. Cook 7 D43 on the SW flank of Zealandia Bank (887-801m) recovered pumice and welded tuff from the western part of the volcano as well. Dive HD-1025 was targeted to examine the southeastern flanks of Zealandia Bank volcano. Hyper-Dolphin reached bottom at a depth of 1023 m at the base of the steep, east-facing scarp associated with a prominent ridge that extends south of Zealandia Bank. The dive proceeded due west, directly up this slope. The surface encountered upon landing (13:45, 1024 m) was light colored, sandy sediment, often rippled. The sediment surface has a thin crust that weakly binds grains (Figure 68A). Larger blocks were encountered as the ROV proceeded west and up the slope, and R01 through R04 are samples of these blocks. Steep outcrops were encountered at 977 m, composed of well-indurated volcanic breccia, dominated by equant mafic clasts (Figure 68B). The slope from this point in the dive onward was mostly very steep, and exposures are dominated by coarse volcaniclastic rocks (Figure 68C). Some intervals dominated by finer volcaniclastic rocks were also observed (Figure 68D, G), as well as a unit dominated by bowling-ball-like clasts or pillows (Fig. 68E). A coarse volcanic breccia with a smooth and very large clast of altered volcaniclastic rock was observed (Figure 68F), further indicating that these sedimentary rocks were deposited very rapidly, close to a volcanic vent or over steepened slope. A massive dike (Figure 68H) was observed near the end of the dive, supporting the suggestion that these volcaniclastic rocks were deposited near a volcanic center.

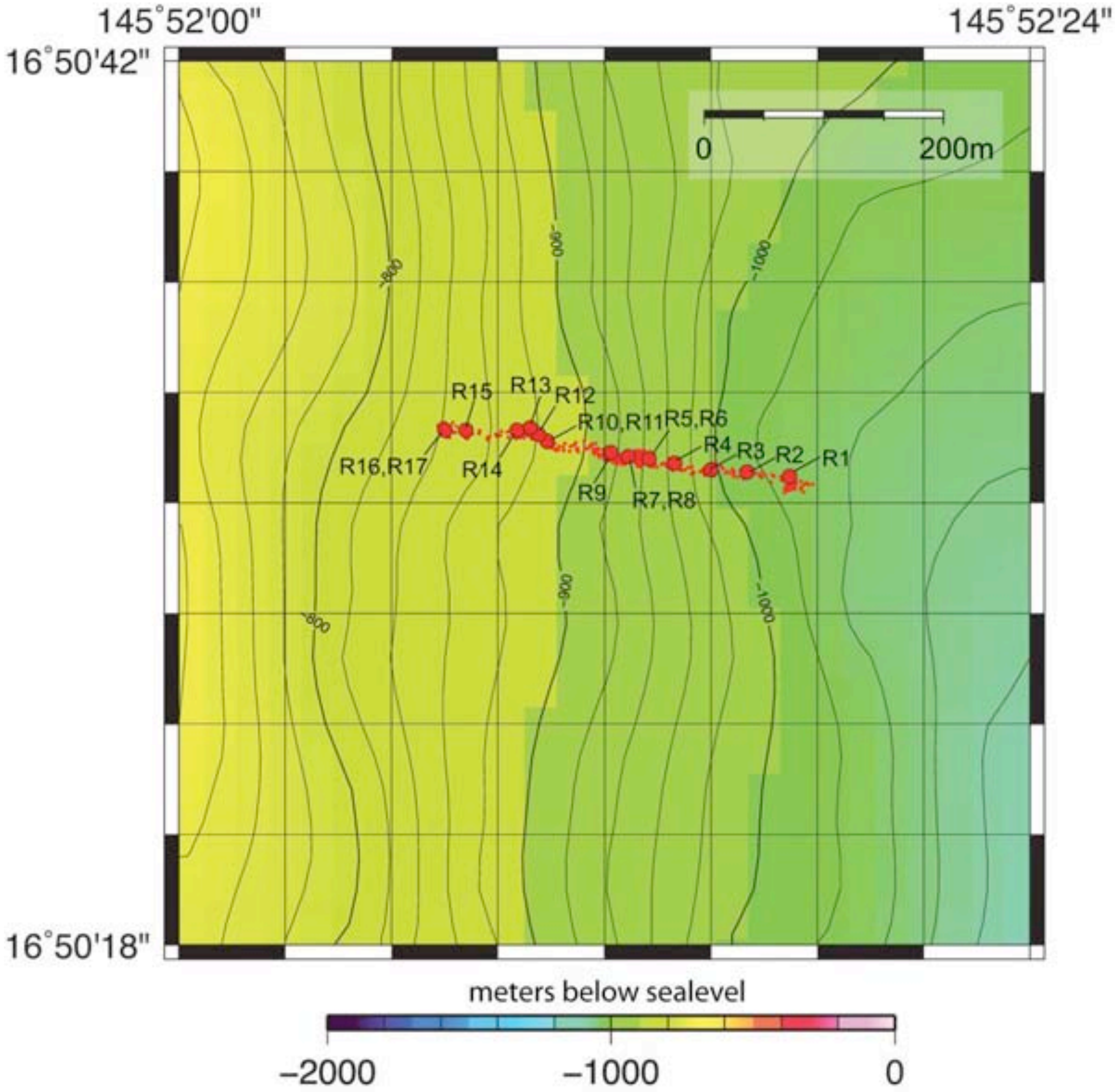


Figure 67. Bathymetry and station locations for HD 1025.

One of the things that we were looking for is rounded cobbles, which could have formed in a beach environment and thus indicate that a significant island existed at one time. Although some rounded cobbles were observed, there were not enough to provide compelling evidence that these were originally beach cobbles. Of the samples collected, nine were identified as basalts, three as basaltic andesites, and one as dacite. No rhyodacites similar to those collected on dives 1019-1021 were observed. Overall, the mafic, volcaniclastic nature of the HD 1025 section is most similar to the volcaniclastics observed and sampled at the end of HD 1021. These two sections may have formed at similar stages in the life of Zealandia Bank volcano, when this was a predominantly mafic volcano that rose above sea level. Organisms were scarce and biological diversity very low, a few sponges and whip corals were observed.

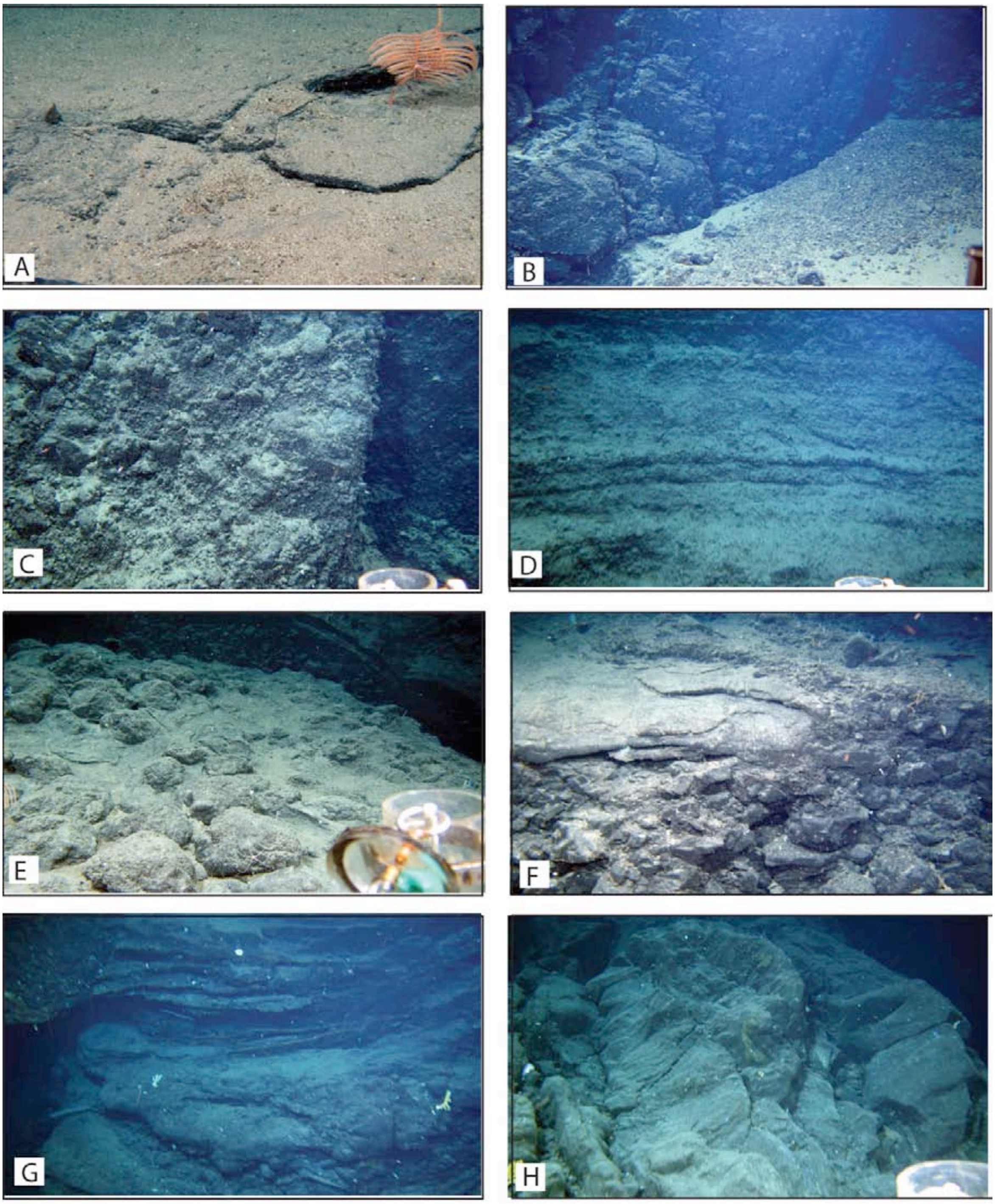


Figure 68. Photos of outcrops observed and sampled during HD1025. A) SeaMax 2009_0620_140008 AA photo of sandy, weakly indurated bottom near start of dive. B) SeaMax 2009_0620_142302AA photo of wall of volcaniclastics; first outcrop encountered in dive. R06 (vesicular basalt) was taken from this outcrop. C) SeaMax 2009_0620_143015AA close-up of well-indurated volcaniclastic breccia in outcrop wall seen in B). D) SeaMax 2009_0620_144325AA outcrop of layered volcaniclastics; R07 & R08 (basalts) are taken near here. E) SeaMax 2009_0620_150242AA photos of rounded blocks or small pillows, no samples taken here. F) SeaMax 2009_0620_1526238AA photo of large, rounded, elongate block in coarse volcaniclastic rock. R12 (altered volcaniclastic rock) is a sample of this elongate block. G) SeaMax 2009_0620_153947AA photo of outcrop of layered fine-grained sediments. H) SeaMax 2009_0620_154417AA photo of massive dike. R14 (basaltic andesite) was collected here.

DIVE LOG

Dive #:	NT09-08 HPD#1025
Date:	June 20, 2009 (local)
Location:	SE flank of Zealandia Bank
Logger:	Kohut &, Stern

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
12:59			In water		
13:45	1024	280	On bottom. Light colored sandy sediment, featureless.		
13:46	1020	280	Ridge in sediment. Scattered small cobbles, cemented or part of outcrop, difficult to sample. Seapen. Sampled slabby material.	R01	Welded scoria with pumice clast
14:03	1020	279	Continued transit upslope.		
14:04	1013	273	Subtle ripples in sediment and patch of gravel.		
14:05	1011	274	Large, rough boulder and cobbles resting on sediment, sample loose clast.	R02	Pillow basaltic lobe with chilled margin
14:10	999	270	Still crossing sandy sediment with scattered cobbles, boulders and gravel patches.		
14:11	998	270	Sample block on sediment.	R03	Porphyritic vesicular basalt
14:14	996	270	Passing large boulder of breccia.		
14:16	985	271	Sampling slabby block on sandy bottom.	R04	volcanic breccia
14:20	977	270	Area of blocks projecting from sandy sediment. Possible outcrop.		
14:21	973	269	Sampling slabby block.	R05	volcanic breccia
14:27	972	266	sampling outcrop	R06	vesicular basalt
14:30	970	270	Ascending vertical outcrop of dark volcanic breccia. Steep layering dips south. Fractures dip north.		
14:35	952	267	Sampling outcrop, well indurated. Give up, too tough.		
14:42	949	270	Rise through nicely layered breccia and sandy sediments, could be volcanic ash, thinly layered.		
14:44	935	272	Rise through coarse volcaniclastics		
14:45	928	270	Well-lithified layered material on top of breccia. Stop to sample breccia just below slabby stuff. Some clasts are very well rounded.	R07,08	R07: porphyritic Ol-Pl-Pyx basalt; R08: Basaltic pillow lobe
14:49	926	270	Ascend covered interval.		
14:50	924	270	Large outcrop of massive, fractured lava above covered interval covered interval. Stop to sample. Crumbles during sampling, maybe medium-gained volcaniclastic breccia.		
14:54	921	270	Covered interval with ripple marks.		

14:56	918	270	Top of outcrop just visited, cobble conglomerate/breccia; rounded cobble. Stop to sample cobbles. Try 2 clasts but they are too well-cemented to extract. Finally got loose clast.	R09	Weathered basaltic andesite
15:02	916	270	Continue up spire of cobbles, maybe pillows		
15:04	912	270	Traverse small covered area and reach outcrop of brecciated lava. Try to sample but first clast crumbles. Continue ascent.		
15:07	908	270	Covered interval with ripple marks.		
15:09	889	270	Dips of sloping surface that is slightly dissected, exposing lithified layers of sand or ash.		
15:11	889	270	Outcropping breccia, poorly sorted and angular; trying to sample steep wall that is overhanging in some places. One piece shows beautiful layering, maybe clast of welded tuff? Tried to get a sample but it crushed.		
15:20	887	314	Rise up vertical wall through very angular breccia. Try to sample. Finally rip off 2 samples from outcrop.	R10, R11	R10: basalts; R11: Porphyritic Ol-Cpx-Plag basalt
15:26	886	285	Continue up outcrop of coarse breccia.		
15:28	881	284	Sampling breccia outcrop. Going after large elongate block that breaks easily into orange pieces (tuff?)	R12	Layered volcaniclastic (altered)
15:36	879	286	Continue up breccia outcrop		
15:37	879	266	Sampling another large block in breccia. Light color on broken surface.	R13	Porphyritic Cpx-Plag basalt
15:39	874	272	Nice layering seen in vertical wall, succeeded by massive flows or dikes; faint horizontal columnar jointing suggests dike. Sampling dike.	R14	Basaltic andesite (weakly altered)
15:44	862	270	Continue up steep slope of dikes or flows with vertical fracture.		
15:47	845	280	Coarse outcrop of breccia. Stop to sample clasts	R15	Pale grey dacite
15:55	842	280	Continue up breccia slope.		
15:57	838	290	Sample slabby rock (R16) and rounded cobble (R17).	R16; R17	R16: basaltic andesite; R17: porphyritic Ol-Cpx-Pl basalt
16:05	838		END OF DIVE		

HYPER-DOLPHIN DIVE #1026

TECHNICAL INFORMATION

Location:	North Zealandia seamount, southern part/wall of the caldera
Objective:	Examine the geology and stratigraphy of segment of caldera

DIVE 1016	On bottom:	Off bottom:
Time (local): June 21, 2009	8:38	10:59
Latitude:	16°58.400' N	16°58.469' N
Longitude:	145°42.643' E	145°42.637' E
Depth (m):	662	475

Samples returned: 20 rocks, 1 core

SCIENTIFIC SUMMARY

The North Zealandia Seamount lies seven km due north of West Zealandia and 10 km NW of Zealandia Bank. These three magmatic arc volcanoes and numerous parasitic cones comprise the Zealandia group (Fig. 63) situated within the Central Island Province of the Mariana arc some 140 km north of Saipan. Compared with West Zealandia and the Zealandia Bank to the south, the North Zealandia volcanic edifice is broadly symmetrical; its base measures ~ 8 km in diameter. Dive 1026 transected the southern segment of North Zealandia (Fig. 69). The dive was rather unspectacular and revealed that the geology consisted largely of poorly sorted debris flow with infrequent small outcrops and only one sizeable outcrop. The objective of the dive was to investigate the volcanic units comprising the southern wall of the volcanic edifice.

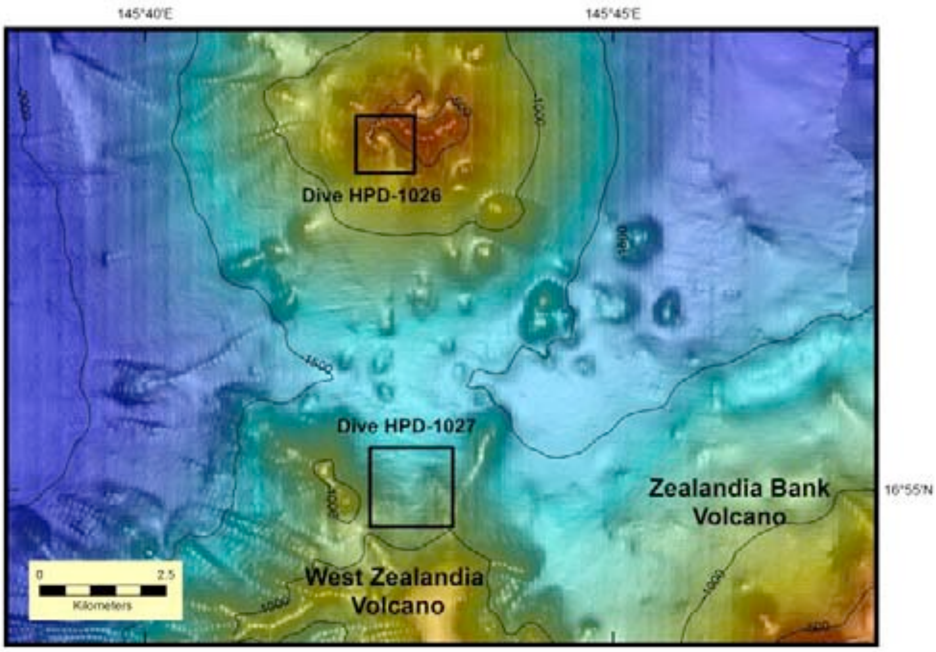


Figure 69. Bathymetric map of the southern graben wall and the southern side and summit region of North Zealandia Seamount.

Dive 1026 comprised only one traverse along and up the wall of the volcanic edifice from base to the southern lip of the inferred caldera/crater at ~475 m water depth. The first half of the traverse was oriented due north and the second half NE (Fig. 70). The entire traverse covered about ~ 600 m, the distance of which was roughly split between the N and the NE oriented tracks of the traverse. HD touched down at a water depth of 662 m on the southwestern segment of the volcanic edifice and began its northerly traverse. Samples R01-R06 and the lone core sample (C1) were collected on this northerly traverse that terminated at a water depth of 629 m. Subsequently, HD began its NE-oriented traverse and the collection of samples R07-R20 before terminating the dive at a water depth of 475 m. The first 200 m of the N-oriented transect surveyed floor/edifice wall that was monotonously sandy and strewn with infrequent cobbles (Fig. 71A) and commonly with “ground”, cm-scale mafic pebbles/sand (Fig. 71B). R1 to R4 are samples of occasional angular cobbles and C1 is a sample of the mafic sand. At approximately 632 m water depth near the end of the northerly traverse, the floor topography changed as the sand-only floor gave way to infrequent, small (meter-scale) rubbly “outcrop”. R5-R11 are samples of these outcrops. At ~623 m water depth, the floor was approximately 50% covered by cobbles and infrequent meter-sized boulders and at ~613 m depth the floor was 90-100% masked by talus (Fig. 71C). This feature is interpreted to represent the products of a debris flow. Small infrequent outcrops continued until near the end of the traverse and the floor fluctuated from ~50% (e.g., 5.2.16-3D) to 100% talus-covered. Samples R12-R16 are dominantly loose slabs/blocks of talus removed from these outcrops. Not until 517 m water depth was the first “true” outcrop (Fig. 71E, F) observed. The outcrop was very steep and comprised what appeared to be tilted sheeted dikes. The remaining samples (R18-R20) were taken at various stratigraphic levels of this outcrop. Time constraints did not allow HD to characterize and sample the crater/caldera summit.

Although the majority of samples appeared mafic during the log, the on-desk description illustrates that most are dacite, although a large range of rock types were described (see Appendix). That the majority of samples collected were float, and only a relatively modest small segment of the caldera/crater wall was examined, a thorough description of Northern Zealandia requires further mapping and stratigraphic analysis.

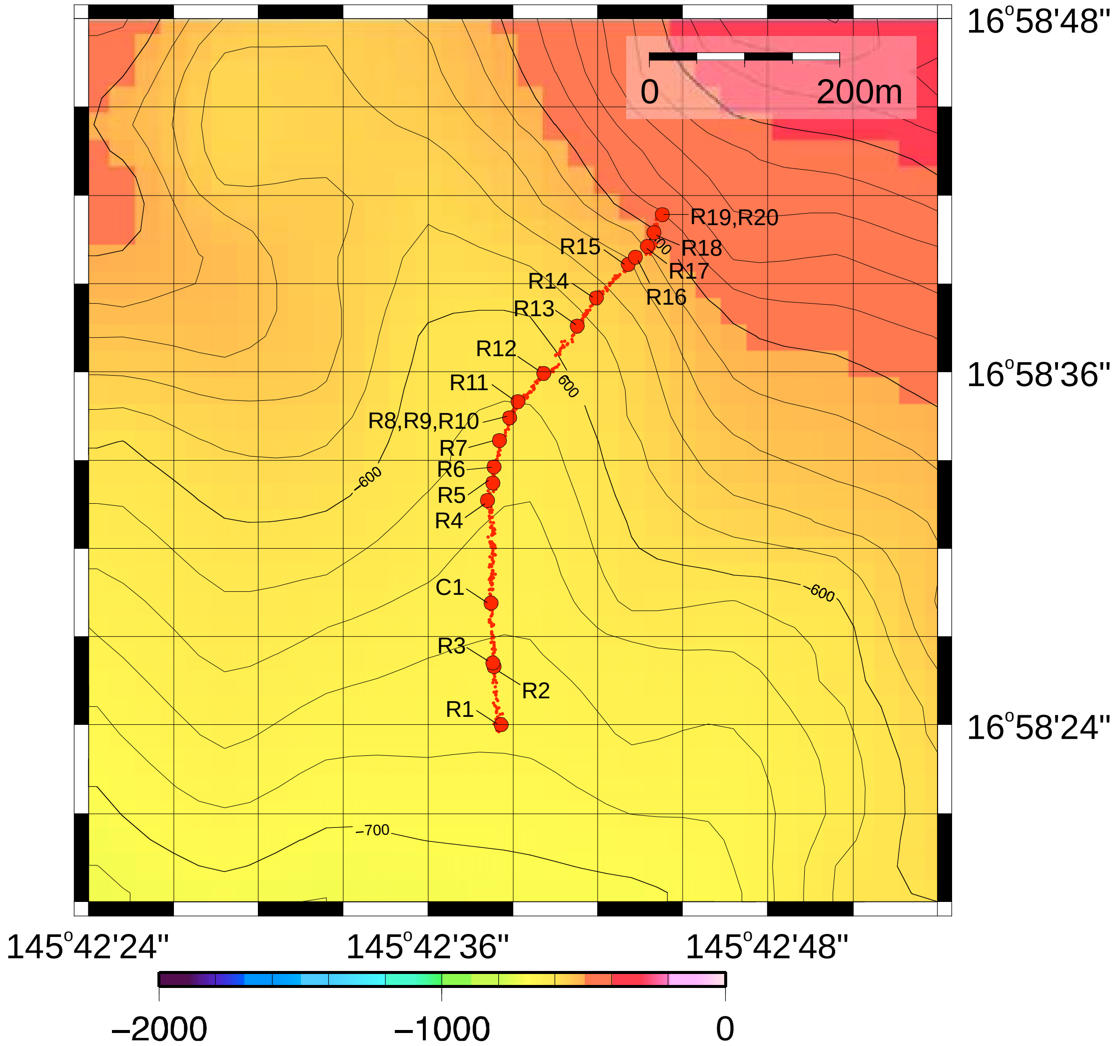


Figure 70. Bathymetric map and superimposed survey/sampling traverse of the southern side and summit region of North Zealandia seamount.

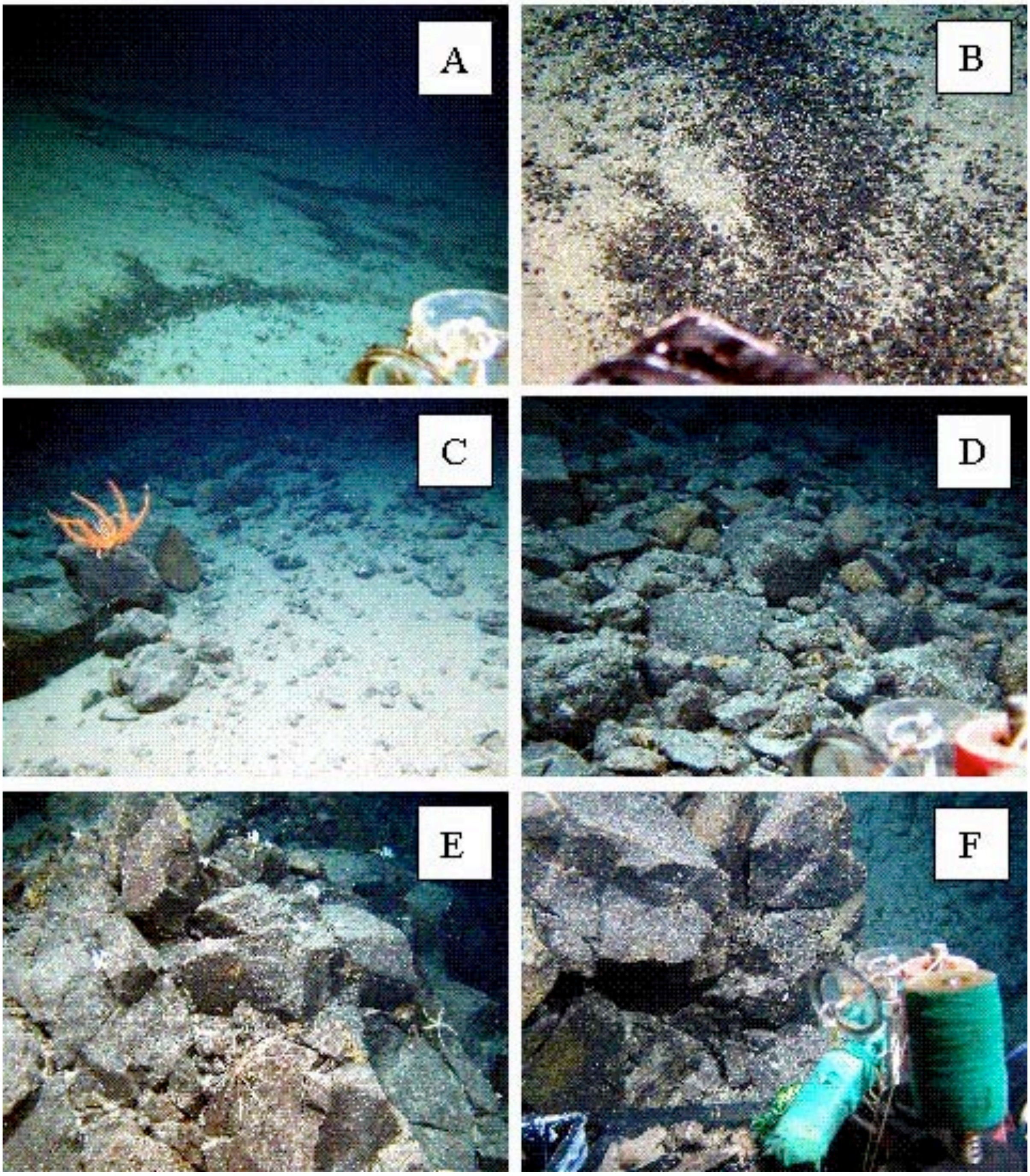


Figure 71. Representative bottom photos of Dive 1026. (A) Inclined sandy seafloor bottom near beginning of traverse and typical of water depths of ~660-630 m. SeaMax photo 2009_0621_091615AA. (B) Cm-sized ground mafic rock (similar as to shown in A but at higher magnification). C1 collected here and comprises this mafic sand. SeaMax photo 2009_0621_085755AA. (C) Floor comprised of unsorted mostly subangular components of debris flow. Sample R12 collected from near here. SeaMax photo2009_0621_102809AA. (D) Angular talus and bright orange crinoid at about 560 m depth. Sample R14 collected near here. SeaMax photo 2009_0621_101347AA. (E) Angular blocks near base of first 'true' outcrop observed. Samples R17-R20 collected from here. R17 collected some 10 m below here and R18 above 15 m above. SeaMax 2009_0621_103913AA. (F) Fresh jointed blocks displaying probable radial joints near top of outcrop. Sample R19 obtained here (loose). SeaMax photo 2009_0621_104636AA.

DIVE LOG

Dive #:	NT09-08 HPD#1026
Date:	June,21, 2009 (local)
Location:	North Zealandia volcano ,southern slope
Objectives:	survey and sample pre-Miocene basement and Kanbun Seamount volcanics
Logger:	Whittam

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample #	On deck description
08:00		312	In water. Planned trek is northwards transverse over southern crater/caldera wall.		
08:38	662	358	On bottom.		
08:38	662	3.2	Sampling. Loose angular (talus?) slabby, relatively small (20-30 cm across) samples. Otherwise sandy bottom.	R1	basaltic andesite
08:40	662	3.9	Faint ripple marks apparent on floor bottom. Strewn cobbles.		
08:42	660	0.1	Traversing slowly, monotonous sand with ripple marks.		
			Plentiful "snow".		
08:44	653	0	Still sand only, no blocks (talus), no outcrop.		
08:46	652	1.3	Sampling. Loose, shiny blue-black angular sample (brown once dust clears)	R2	dacite
08:49	652	2	Sampling. Black, angular, small, loose.	R3	diorite (intrusive)
08:51	652	0.8	Blue eel spotted. Lots of "snow".		
			Ripple marks trending NW-SE.		
08:55	648	0.7	Traversing and moving upwards very slowly; very gentle slope.		
08:58	647	0.8	Still sandy floor with ground up black rocks (pebbles/sand).		
09:00	647	2	As above but sampling with push core (green-handled).	C1	muddy sand
09:02	645	0.1	Slope steepening moderately.		
09:04	644	1.7	Another flat, blue eel. Stopped on cobble, sand-sized broken up basalt (or at least mafic rock) flow.		
09:06	642	1	Moving alongside (i.e. perpendicular to) slope as opposed to climbing; mainitaining constant elevation (water depth).		
09:09	640	0.2	"Sea-spider" and lone crinoid spotted. Still traversing perpendicular to slope. Sampling --> black broken up flow sand.		
09:11	640	359	Heading due north (i.e. 359) but slope appears as tilted NE/SW.		
			Still monotonous sand. Strange, small silvery fish spotted. Moved away very quickly.		

			Note that up until this point the floor has been sand only.		
09:14	637	0.3	Climbing but still relatively gently.		
09:17	634	359	Sampling. Lone, loose, small (claw-sized) angular brownish-black sample.	R4	dacite with dacitic enclaves (xenoliths)
09:19	632	359	Same monotonous sandy bottom, still same trending ripples, lack of outcrop, lack of talus etc.		
09:22	633	359	Sampling lone apparently in-situ angular basalt?		
			Trouble liberating sample; obviously in-situ. Unsuccessful; moving on.		
09:26	632	0	Attempting to sample another very tiny outcrop. Very tiny subrounded sample. Black/grey with orange oxidation.	R5	hornblende pumice
09:30	629	2.8	Another small, cobbly outcrop. Samples small, subrounded claw-sized, probably pumiceous sample, obviously in-situ.	R6	hornblende pumice
			Powdery, brown subangular. Strange creature on underside.		
			Rare biota here; lone sponges, etc.		
09:33	628	0.3	Floor bottom geomorphology changes slightly to more common occurrence of small boulders (as opposed to monotonous sand with infrequent small, angular outcrop).		
09:35	626	7.4	Sampling small outcrop with large boulder nearby. Sample is black, small, subrounded with orange oxidation (basaltic clast; actually is elongated and subangular). Sample came from floor (not boulder) and appeared to be in-situ.	R7	hornblende andesite
09:37	623	15	Floor topography changing again; now, cobbles occupy about 50% of floor and large (meter-scale) boulders are not uncommon. Cobbles are subangular, appear to be talus. A few sponges (lone).		
09:38:00	621	14	Sampling talus. Small, claw-sized subangular sample; flattened	R8	andesite with dark band
			(R8); R9 very similar and from same location.	R9	pumiceous hornblende rhyolite
			R10: slightly larger angular sample.	R10	hornblende dacite with mafic enclaves
			Lone bluish sponge (fern-like) as well as other unidentified biota.		
09:45	618	20	Heading slightly more NE now. Floor becoming more littered with cobble-sized blocks.		
09:47	616	48	Sampling more talus. Some talus blocks with rounded faces. Sample is elongated and black with obvious oxidation.	R11	dacite with mafic enclaves

09:51	613	35	Floor bottom now 90-100% cobble/boulder-covered. Many cobbles are sub-rounded. Sponges more common and present in groups of 4-6 as opposed to alone.		
09:53	608	34	Larger boulders becoming more common.		
09:55	604	34	Rather strange as appears to be an ~ meter-wide "path" in otherwise cobble/boulder-strewn floor.		
09:56	602	34	Sampling from talus. Relatively large angular pieces; appears coarse but might just be agglutinated sediment from floor.	R12	andesite
10:00	593	34	Blocks very angular and generally larger. Topography appears as a large debris flow.		
10:03	582	35	More sandy floor exposed; perhaps site of rock/talus slides.		
10:05	579	34	Sampling loose angular, relatively small, black, probably loose block. Actually rather large, subangular slab.	R13	dacite
10:08	575	34	A little more floor exposed, but still essentially looks like a debris flow.		
10:12	560	34	Sampling. More relatively small (decimeter-scale) angular, black, loose talus. Relatively large, thick slabby sample with some oxidation. Beautiful flourescent red/orange crinoid seen here.	R14	dacite
10:15	550	34	Larger boulders more common.		
10:15	548	35	Then back to predominantly just sandy floor again with infrequent cobbles. Elongated jellyfish?		
10:18	534	34	Rare felsic boulder spotted (pumice?).		
10:20	536	36	Sampling relatively large, angular black talus.	R15	hornblende dacite
10:24	527	26	Poorly sorted talus (again). A few felsic talus blocks in otherwise dominantly dark, black blocks. Sampling here a relatively large, tabular lightish-brown slab via vacuum. Couldn't liberate large slab, so took a smaller claw-sized angular sample (brownish).	R16	andesite
10:31			Floor bottom now completely talus-covered again. Mainly angular small-large cobbles (poorly-sorted).		
10:32	517	42	Finally hit (first definitive and sizeable) outcrop. Very steep & comprised of joints or dikes? Sampled this and was able to dislodge a loose piece (otherwise in-situ). Very large (largest yet) slabby, tabular block. This outcrop looks like tilted (~45 NE/SW-trending) sheeted dikes.	R17	banded hornblende dacite

10:40	506	30	Moving up and over large outcrop. Many brittle-stars (star-fish, bright orange).		
10:43	504	2	Still hovering in front of steep outcrop. Some distinctively light regions in otherwise black rock. Some beautiful fluorescent red-orange crinoids here.		
10:45	496	3	Still climbing steep (~45 degree) rubbly-outcrop. Appears as brecciated.		
10:47	490	350	Sampling. Large angular brownish sample take from wall. Probably largest sample yet.	R18	dacite with mafic enclaves
10:54	475	12	Sampling blocky talus. Some loose samples appear to display radial fractures. Sample grabbed is relatively large, black, brick-like. 0.5 cm Mn-coat.	R19	plagioclase-pyroxene basalt
			Took another sample fom here. Medium-sized, subangular, appears not fresh.	R20	vesicular dacite
10:59	475	12	Ascending. Dive finished.		

Sunset

HYPER-DOLPHIN DIVE #1027

TECHNICAL INFORMATION

Location: Northern flank of West Zealandia Seamount
Objectives: Survey and sample the northern flank and the top of West Zealandia Seamount

DIVE 1027	On bottom:	Off bottom:
Time (local): June 21, 2009	13:50	16:14
Latitude:	16°55.690N	16°55.413N
Longitude:	145°41.638E	145°41.677E
Depth (m):	1390	1135
Samples returned: 15 rocks		

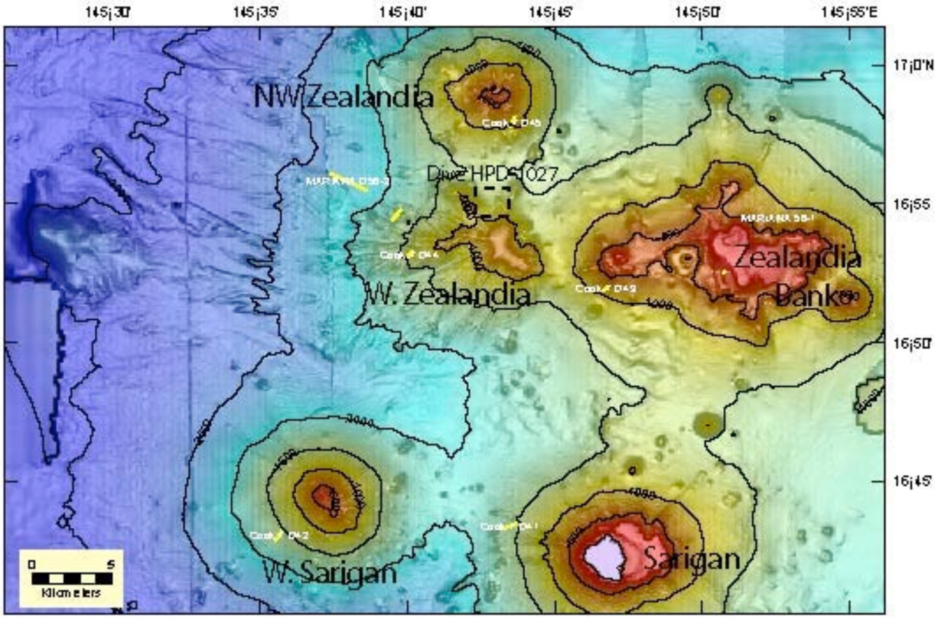


Figure 72. Bathymetric map of West Zealandia Seamount, from Mariana Compilation (Susan Merle, PMEL/NOAA, compiler). W. Zealandia volcano is on the western side of Zealandia Bank Seamount, north of Sarigan. Dashed box shows the studied area. A more precise map of the studied area is shown Figure 5.17.12.

SCIENTIFIC SUMMARY:

West Zealandia Seamount is located in the Central Island Province (16°N – 20.5°N). It is an old volcano situated to the west of Zealandia Bank Seamount and between Sarigan and Guguan island arc volcanoes. W. Zealandia Seamount belongs to the modern Mariana arc (Calvert et al., 2008). West Zealandia Seamount is about 13 km x 18 km and its summit is at ~ 950 m water depth. Its volcanic units were first dredged by Dixon & Stern (1983) on its western flank. Rocks are composed of primitive arc lavas rich in olivine, indicating they could be derived from direct melting from peridotite mantle beneath the Central part of the Mariana island arc (Dixon & Stern, 1983). The objective of Hyper-Dolphin dive 1027 was to investigate the volcanic units exposed from the northern flank to the summit of the West Zealandia Seamount.

Dive 1027 landed near the base of the northern flank of West Zealandia Seamount at the depth of 1390 m. The ROV sampled 15 rocks from a N-S traverse of ~550 m long. Dive 1027 ended at a water depth of 1135 m and did not reach the top of the seamount.

Observations from the seafloor shows that the northern flank of W. Zealandia Seamount is composed of several volcanic units, which are alternatively volcanic breccias, with a range of clast sizes, and more recent dark grey lava flow. The first unit is composed of volcanic breccia with a light brown matrix and dark subrounded to subangular volcanic clasts. Samples R01- R03 have been sampled in the volcanic clasts. This lower volcanic breccia unit ends at ~ 1359 m depth. The second unit is composed of lava flows showing layering, fractures and collapse. Deep channels exposing volcaniclastics were also been observed in the lava flow possibly due to submarine erosion. Tectonics and erosion seem to have occured in this middle unit, which ends at ~1327 m depth. Samples R04 – R06 have been collected in that unit. The following unit is a fine-grained volcanic breccia with grey to brown and angular to subrounded volcanic clasts surrounded by a darker matrix. This upper volcanic breccia unit shows thin layers and erosion channels. It ends at ~ 1135 m depth. Samples R07 – R09, R11 – R13 and R15 were recovered volcanic clasts. The third unit is cross-cut by two dykes (at 1268 m and 1195 m) from which samples R10 and R14 were recovered. The first dyke displayed columnar jointing features. The second dyke might also be a lava flow. The outcrop slope varied from quite flat to very steep, through a quite gentle slope.

On deck examination showed that most of the samples are olivine-rich vesicular basalt and are more or less porphyritic (R01, R04, R05, R07 – R10, R12 – R14). Sample R08 is a pillow basalt with concentric cracks and possible hyaloclastite on its outside rim. These basalts have been collected through the three different units. They contain phenocrysts of olivine, pyroxene and zoned plagioclase. Some samples also contained ultramafic xenoliths (R04, R07) which could possibly be pieces of peridotite mantle. This is a significant finding, as no mantle xenoliths have previously been sampled in the Mariana island arc. Some pumice, with pyroxene and quartz, (R02, R03) have been collected in the lower volcanic unit and volcaniclastic breccia with mafic clasts (R06, R11, R15) have also been sampled. All the samples have a manganese crust. They are weakly to strongly altered (up to 55% alteration).

West Zealandia Seamount erupted very primitive lavas, in contrast with the felsic lavas observed in NW Zealandia and Zealandia Bank Seamounts. Sparse marine biota have been observed throughout dive 1027, such as sponge, corals, orange crinoids and seapens living on the volcanic outcrop, as well as oursins, starfish and shrimps.

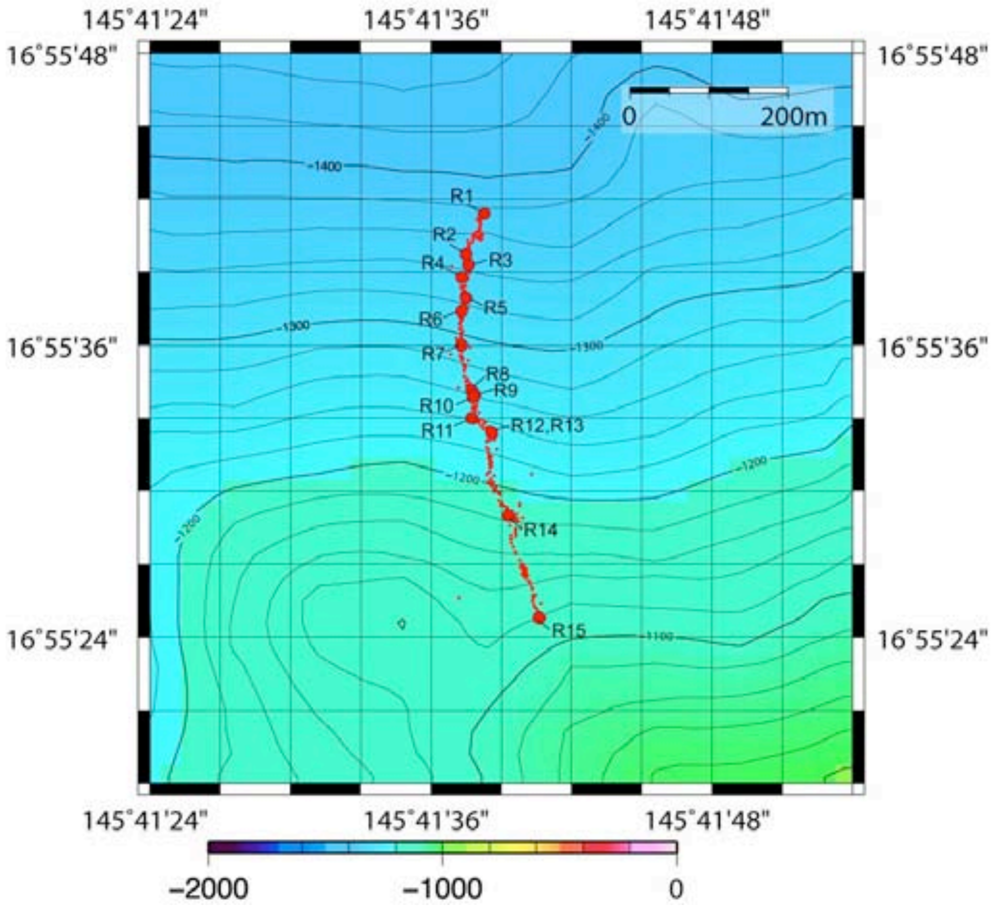


Figure 73. Bathymetric map of the northern flank of W. Zealandia seamount, surveyed during NT09-08. HD track is also shown.

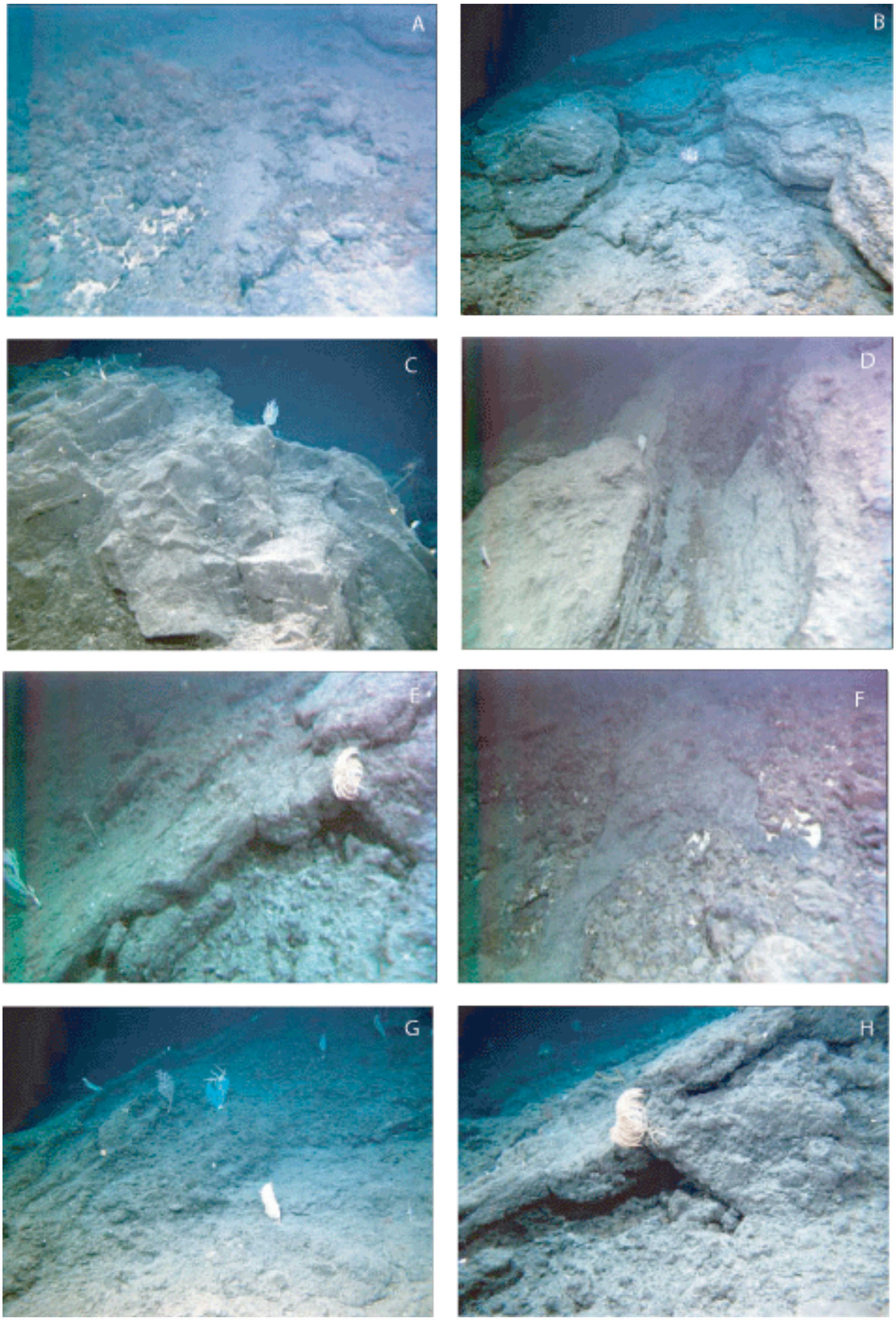


Figure 74. Photos from the bottom during HD-1027 dive (on the next page). A: hdc20090621135611_1contact between the volcaniclastics of the lower volcanic breccia unit (left) and the middle lava flow unit (right). B: SeaMax 2009_0621_135642AA Collapse and layering in the magma flow unit with oursin is in the middle of the picture. C: SeaMax 2009_0621_145600AA dyke with columnar jointing cross-cutting the volcanic breccia. D: hdc20090621143000_1Erosion channel in the lava flow unit. E: hdc20090621151418_1thin layers observed in the upper volcanic breccia unit F: hdc20090621135528_1 lava flow surrounded by volcanic breccia. G: SeaMax 2009_0621_150745AA diverse marines organisms are observed living on the outcrop (sponge, corals, seapen) H: SeaMax 2009_0621_151427AA Orange crinoid living on layered magma flow.

DIVE LOG

Dive #:	NT09-08 HPD#1027
Date:	June 20, 2009 (local)
Location:	Northern flank of West Zealandia volcano (old volcano)
Objectives:	Survey and sample the northern flank of the west Zealandia volcano
Logger:	J. Ribeiro, R.J. Stern

Time (Local)	Depth (m)	Vehicle Heading	Notes	Sample	On deck description
12:59			in the water		
13:50	1390	149	Bottom. Outcrop composed of volcanic breccia. Subrounded brown rock with dark grey clast.		
13:52	1393	148.1	Sampling rocks from the outcrop. In circle basket.	R01	porphyritic olivine basalt
13:55	1387	161.1	sponge and coral. Dark magma flow, possibly recent lava flow with pillow lavas. Lot of cracks in the magma flow. Layering in the outcrop.		
14:02	1372	165	Coral and sponges living on the outcrop		
14:03			Dark volcanic outcrop with layering. Surface with more massive material.		
14:04	1362	165	Volcanic breccia (brown) composed of angular brown and dark grey clasts. Light brown matrix		
14:05	1362	165	Sampling rock from the volcanic breccia. Possible rhyolite. Dark outside and light brown inside. In basket 6. The breccia seems to be superposed to the darker volcanic flow.	R02	altered pumice
14:11	1359	159.2	Sampling from the volcanic breccia. Dark grey angular rock with a lot of cracks. Rock white inside, possible pumice.	R03	pumice
14:12	1354		Seapen and crinoid living on the outcrop. Shrimps.		
14:14	1351	159	Dark volcanic outcrop with lava flow features, layering, cracks and more massive rocks. Sampling from the massive brown rock (outcrop). In basket 2.	R04	basalt with olivine clots
14:17	1343		Coral, sponge and seapen living on the outcrop		
14:19	1338	159.8	Sampling from outcrop. Trying to sample elsewhere because of massive rock.		
14:21	1337	159.5	Sampling from outcrop (dark magma flow). In basket 2	R05	porphyritic olivine basalt
14:23	1333		sponge and corals, maybe crinoids.		
14:25	1327	157	Gentle slope with volcanic lava flow with layering (outcrop). Sampling from the outcrop. Difficulties to sample from this outcrop (massive rock). Dark grey sample in basket 2.	R06	volcaniclastic breccia
			Collapse in dark volcanic rock. A piece of the volcanic flow broke off. Multiple cracks. Volcaniclasts in the lava flow. Layering. Corals land sponge living on the outcrop.		
14:30	1313	160	Possible channel in the outcrop related to submarine erosion		
14:31	1308	159	Red crinoids on the outcrop		
			Deeper channels related to erosion with angular rocks. Steep slope on the outcrop		

13:33	1305	198.7	Layering in the outcrop with thin beds. Volcanic breccia with subrounded rock of small size (dark grey). Shrimps. Steep slope.		
14:35	1306	233	Sampling from the volcanic breccia. Volcaniclastics. In basket 2.	R07	porphyritic olivine basalt
14:38	1297	158	Gentle slope with channels in the outcrop. Layered outcrop. Subrounded volcaniclastics. Corals living on the outcrop, orange crinoids, sponge. Subrounded to subangular rocks. Volcanic breccia.		
14:40	1290	158	Giant crinoid. Steep slope. Seapen, sponge and corals living on the outcrop. Shrimps.		
14:41	1284		Flat outcrop		
14:42	1281	158	Volcanic fine-grained breccia with angular dark grey clasts. Layering. Gentle slope. Sampling from the outcrop (volcanilcalstic). In basket 5. More massive rocks are lying on the oucrop.	R08	basaltic pillowy lobe
14:48	1279	152	dark grey breccia with light brown subangular clasts. Pumice breccia? Sampling from the steep outcrop. Sample broke off and a piece of it falls down in Basket 3?		
14:51	1276	151	Top of the breccia is composed of small angular to rounded dark grey rocks lying on the volcanic breccia (outcrop). Sampling from the volcanic dark rocks (not outcrop). Moderately steep slope. In basket 5	R09	basalt
14:55	1270	152	Steep outcrop. Dyke with sponges and corals living on it. Columnar jointing.		
14:58	1268	146	Sampling from the outcrop. Difficulties to sample rocks because massive rock. Try to sample elsewhere.		
15:00	1268	152	Starfish, corals, sponges. Samping from the outcrop. Layering in the dyke. Reddish sample on the edge. In basket 5.	R10	altered basalt
15:06	1266		Coral, sponge, crinoids, seapen		
			Steep outctcrop on the left. More gentle on the right. Fined-grained volcanic breccia with sponge, corals.		
15:08	1260	151	Channels and layering in the outcrop. Crinoids. Angular rocks lying on the outcrop (volcanic breccia). Gentle slope. Sampling from volcanic rocks lying on outcrop. In basket 5	R11	basaltic breccia
15:15	1252		Flat outcrop with corals, sponge and crinoids. Volcanic breccia with angular clasts. Cracks in the outcrop.		
15:17	1248	159	Sampling from the outcrop (volcanic breccia). Steep slope. Difficulties to sample from the outcrop (massive rock). Manganese crust. Reddish sample on the edge. In basket 1.	R12	basalt
15:25	1248	157.2	Sampling from the outcrop (volcanic breccia). Subrounded volcaniclastic. Too difficult. Sampling a smaller angular fragment in the same area. Black and reddish sample outside. In basket 1.	R13	porphyritic basalt
15:29	1244	167	Steep slope on the right, more gentle on the left. Corals, sponge, crinoids living on the outcrop. Lot of cracks.		
15:30	1235	170	Seapens. Collapse in outcrop. Angular rocks of all size. Layered outcrop.		
15:36	1204	160	Flat volcanic outcrop with seapens, crinoids, sponge on it.		

15:37	1195	157	Dyke or lava flow? Gentle slope. Layering. Sampling from the outcrop. Difficulties to sample, massive outcop. Thick dark crust on the sample. Orange inside. Cracks in the outcrop. In basket 1.	R14	porphyritic basalt
15:47	1185	159	Outcrop with gentle slope, cracks, crinoids. Volcanic breccia. Channel flow. Layering in the outcrop. Corals, sponge		
15:49	1171	160	Very gentle slope. Volcanic outcrop with sponge, coral.		
15:51	1167	187	steep outcrop with starfish. Volcaniclastic. Sampling from the outcrop (dark matrix with light brown clasts). Volcanic breccia? Too difficult to sample here.		
15:58	1156	159.5	Top of the breccia is flat with crinoids, sponge and corals. Fractures in the outcrop.		
16:02	1134	159	Possible pillow lavas above layered outcrop with crinoids. Sampling from the outcrop.Sample in basket 1. Broke in 2 pieces. Shrimp.	R15	volcaniclastic breccia
16:14	1135		Dive is over.		

Alamagan (left) and Guguan (right)

HPD#1011 Jun. 11 2009 NE crater wall of E. Diamante

sample No.	latitude(N)		longitude(E)		depth (m)	rock type	shape	size X (cm)	size Y (cm)	size Z (cm)	weight(kg)
HPD#1011-R01	15	57.269	145	42.345	531	shelly bioclastic limestone sandy sized clasts - coquina	subangular	51	27	38	35.30
HPD#1011-R02	15	57.281	145	42.365	516	coquina	subrounded	12	7	6	0.60
HPD#1011-R03	15	57.332	145	42.427	461	bioclastic - corals	subrounded	54	41	18	30.00
HPD#1011-R04	15	57.340	145	42.444	444	shelly bioclast sandy sized clasts - coquina	subangular	21	16	7	1.60
HPD#1011-R05	15	57.340	145	42.444	444	calcareous nodule	rounded	8	6	5	0.30
HPD#1011-R06	15	57.349	145	42.451	424	vuggy carbonate	subangular	12	10	10	1.50
HPD#1011-R07	15	57.354	145	42.457	416	bioclastic limestone - corals	subrounded	50	39	10	29.00
HPD#1011-R08	15	57.416	145	42.527	266	carbonate	subangular	32	28	20	14.00
HPD#1011-R09	15	57.477	145	42.579	205	shelly limestone - coquina	subangular	22	13	7	1.70
HPD#1011-R10	15	57.535	145	42.639	155	carbonate	subangular	11	7	2.5	0.18
HPD#1011-R11	15	57.550	145	42.661	144	carbonate	subangular	6.5	6	4	0.14
HPD#1011-R12	15	57.550	145	42.661	144	shelly limestone - coquina	subangular	6	6.6	1	0.04
HPD#1011-R13	15	57.088	145	42.696	492	shelly bioclast sandy sized clasts - coquina	subrounded	23	27	9	4.80
HPD#1011-R14	15	57.096	145	42.709	479	shelly bioclast sandy sized clasts - coquina	subangular	38	21	10	10.00
HPD#1011-R15	15	57.151	145	42.761	410	mud supported shelly carbonate	subangular	8	5.5	5	0.40
HPD#1011-R16	15	57.151	145	42.761	410	basalt	subangular	22	19	13	6.50
HPD#1011-R17	15	57.170	145	42.779	377	shelly bioclast sand-sized clasts - coquina	subangular	18	8	13	2.60
HPD#1011-R18	15	57.174	145	42.785	359	calcareous sandstone	subangular	15/8	9/10	12/4	1.32
HPD#1011-R19	15	57.181	145	42.793	336	basaltic andesite	subangular	26	15	11	5.00
HPD#1011-R20	15	57.192	145	42.801	304	altered basalt	subangular	15	16	5	1.90
HPD#1011-unknowns from box 1						calcareous nodules	rounded				1.60
HPD#1011-unknowns from box 3						shelly bioclast sandy sized clasts - coquina	subangular				0.40
HPD#1011-unknowns from box 4						shelly bioclast sandy sized clasts - coquina	subangular				0.56
HPD#1011-unknowns from box 5						shelly bioclast sandy sized clasts - coquina	subrounded				0.08
HPD#1011-C01	15	57.317	145	42.365	483	polymictic sandy gravel	subrounded				
HPD#1011-C02	15	57.116	145	42.727	456	poorly sorted carbonate sediiment	subangular				

colour	alteration	Mn coating	phenocrysts	vesiculation	Memo
pale gray	weakly altered	film			
pale brown	weakly altered	film			
pale brown	weakly altered	film			
pale gray	weakly altered	1 mm			
white	weakly altered	film			
white	weakly altered	film			
pale brown	weakly altered	film			beautiful coral structures form clasts
pale brown	weakly altered	film			oolites
pale brown	fresh				
creamy white	fresh				coral clasts, coated in algae
white	fresh				
creamy white	fresh				
pale brown	weakly altered	film			
pale brown	weakly altered	film			
pale gray	weakly altered	film			
dark gray	moderately altered	1 mm	px 5%; pl 20%	0%	cpx 1-2 mm in size; alteration rim persisting 20 mm from rim
pale brown	weakly altered				
pale brown	weakly altered	film			2 pieces
gray	weakly altered		pl < 2%; hb 5%	0%	10 mm thick layer on sample -> interbedded calcareuos material
brownish black	altered	film	px <5%	0%	alteration rim throughout sample
pale brown	weakly altered	film			lots of nodules, 2 to 6 cm in diameter
pale brown	weakly altered				
pale brown	moderately altered	film			
pale brown	weakly altered				
brown					clasts up to 10 mm, include shell and Mn fragments
pale brown	weakly altered	film			Mn fragments, carbonate clasts, 1 - 20 mm

HPD#1012 Jun. 12 2009 S and E part of resurgent domes on crater floor of E. 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	phenocrysts
HPD#1012-R01	15	55.801	145	41.000	548	altered pyroclastic	subrounded	44	25	30	9.40	brown	altered	< 1mm	qz 15%; px 5%; fp
HPD#1012-R02	15	55.833	145	41.027	520	altered pyroclastic	subrounded	17	15	13	2.80	brown	altered	< 1mm	qz 5%
HPD#1012-R03	15	55.848	145	41.021	502	volcaniclastic	subrounded	9	11	12	0.50	brown	altered	< 1mm	
HPD#1012-R04	15	55.857	145	41.021	490	Mn cemented sediment		10	6	2.5	0.14				
HPD#1012-R05	15	55.865	145	41.015	465										
HPD#1012-R06	15	55.897	145	41.007	439	pyroxene andesite	rounded	25	33	27	25.00	pale gray	altered	< 1mm	px 20%; pl 10%
HPD#1012-R07	15	55.913	145	40.998	424	feldspar hornblende dacite	subrounded	17	12	6	2.60	dark gray	weakly altered	< 1mm	qz 10%; hb 10%; fp
HPD#1012-R08	15	55.922	145	40.992	420	rhyolite/welded tuff	subangular	18	10	11	4.00	pale gray	altered	< 1mm	qz 30%
HPD#1012-R09	15	55.937	145	40.991	407	pumiceous rhyolite	subangular	23/19	18/8	17/20	6.50	pale gray	altered	< 1mm	qz 5%
HPD#1012-R10	15	55.943	145	40.995	405	welded tuff or rhyolite with flow banding	angular	15	24	22	11.70	gray banded	altered	< 1mm	qz 10%; fp 10%
HPD#1012-R11	15	56.115	145	40.958	480	quartz dacite	subangular	20	20	15	8.10	gray	weakly altered	< 1 mm	qz 20%; fp 20%
HPD#1012-R12	15	56.136	145	40.951	476	pyroxene-plagioclase dacite	angular	20	15	9	3.20	gray	weakly altered	< 1 mm	px 10%; pl 10%
HPD#1012-R13	15	56.196	145	40.921	453	quartz-feldspar dacite	subangular	25	18	8	6.00	dark gray	moderately altered	< 1 mm	fp 20%; hb 5%; qz
HPD#1012-R14	15	56.219	145	40.932	416	quartz dacite	angular	28	23	13	17.20	gray	weakly altered	< 1 mm	qz 25%; hb 10%; fp
HPD#1012-R15	15	56.251	145	40.941	370	quartz-hornblende dacite	angular	66	25	20	33.50	gray	fresh	none	qz 20%; hb 20%
HPD#1012-R16	15	56.272	145	40.949	332	plagioclase-pyroxene basaltic andesite	angular	22	17	13	6.50	dark gray	fresh	< 1 mm	px 15%; pl 20%
HPD#1012-R17	15	56.379	145	41.040	421	quartz dacite	subangular	20	9	12	5.50	gray	fresh	< 1 mm	qz 20%; fp 10%
HPD#1012-R18	15	56.410	145	41.030	378	hornblende-quartz dacite	subangular	18	11	6	1.80	gray	fresh	< 1 mm	qz 15%; hb 10%
HPD#1012-R19	15	56.436	145	41.012	353	quartz dacite	subangular	50	25	9	16.50	gray	moderately altered	< 1 mm	qz 20%; hb 5%; fp
HPD#1012-R20	15	56.479	145	40.984	360	hornblende dacite	subrounded	30	25	14	14.00	gray	weakly altered	< 1 mm	qz 15%; hb 5%; fp
HPD#1012-R21	15	56.529	145	40.927	377	hydrothermal Mn oxide and Fe oxide		25	25	18	6.00	black-yellow-brown		none	
HPD#1012-R22	15	56.529	145	40.927	377	massive sulfide		15	11	4	1.50	outer rind black to reddish and gray; interior dark, submetallic gray		film	
HPD#1012-R23	15	56.529	145	40.927	377	quartz-hornblende dacite	subrounded	29	10	13	4.90	dark gray	weakly altered	< 1 mm	qz 10%; hb 10%; fp 15%
HPD#1012-R24	15	56.528	145	40.917	374	dead sulfide chimney		20	7	5	1.20	dark gray		film	
HPD#1012-R25	15	56.528	145	40.917	374	dead chimney		15	9	10	1.40	dark gray		patina	
HPD#1012-R26	15	56.571	145	40.869	348	sulfide chimney		41	20	10	8.10	black and reddish exterior		film to ~ 3 mm	
HPD#1012-R27	15	56.571	145	40.869	348	fragment of sulfide chimney		16	8	13	1.00	black surface, dark gray interior		film	
HPD#1012-C01	15	56.529	145	40.927	377	Fe-oxides		5	5	5	0.20	orangey black	altered		

vesiculation	Memo
none	heavily oxidized, matrix is non described, qz & fp phenoscrypt noted. Possible crystal rich pumice or pyroclastic
none	same as R01
none	lithic & qz clasts, clasts are sandsize. Clasts are also Fe and Mn stained. Either pyriclastic or epiclastic.
none	~1 cm alteration rind
very weakly	
very weakly	very small mafic minerals could be hornblende or biotite
moderately	half sample altered, large inclusions, lithic or encloves
weakly	thin, lighter gray layers alternating with thicker dark gray; aphonitic matrix could be glassy; vesicles elongated
none	enclaves of dacite or andesite present
	8 mm alteration rind; possible magmatic enclaves
weak	~0.5 - 2 cm enclaves of dacite or andesite
none	several 0.5 cm enclaves
moderately	
weak < 5 %	
moderately	vesiculated
weakly	crystal-rich
weakly	enclaves of dacite or andesite
	friable black Mn oxide matrix with Fe oxide lining; anastomizing series of channels 3 - 10 mm in diameter; areas rich with Fe oxide; rocks from venting hydrothermal mound - maybe also contains nontronite
	massive dark gray zinc sulfide, vuggy in places and variable texture; swirly in places - rind of Fe oxides and light colored minerals (zeolites?)
weakly	
	zinc sulfide chimney with filled anastomizing channels; mostly porous with some massive layers disseminated pyrite and Cu-sulfides (?)
	zinc sulfide chimney with filled anastomosing conduits (channels); mostly porous, one massive area, pyrite-rich area; white biota on outer surface.
	large uncut chminey; a dead chminey; attached end shows large 2 cm channel which is blackened (filled) at the chminey top; mostly massive dark gray Zn sulfide at margins and more porous towards central channel
	sample not cut, but appears to be massive Zn sulfide along margins and porous around central channel, which is mostly filled in with sulfides
	1 large fragment, other smaller fragments

HPD#1013 Jun. 13 2009 E facing scarp on SW wall of E. 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#1013-R01	15	53.710	145	39.196	1073	basaltic andesite	subangular	45	34	19	22.00	black
HPD#1013-R02	15	53.716	145	39.192	1070	pumiceous rhyolite	subrounded	11	8	6	0.30	black, gray, white
HPD#1013-R03	15	53.725	145	39.186	1063	basaltic andesite	subrounded	18	13	6	2.40	black
HPD#1013-R04	15	53.733	145	39.176	1053	pumiceous banded rhyolite	subangular	21	13	13	1.72	dark gray, pale gray; banded
HPD#1013-R05	15	53.733	145	39.160	1042	pumiceous rhyolite	subrounded	4	8	7	0.40	pale gray
HPD#1013-R06	15	53.733	145	39.160	1040	pumice	subangular	30	17	8	3.40	pale gray
HPD#1013-R07	15	53.736	145	39.154	1015	fine-grained pumice	subrounded	12	7	4	0.30	gray
HPD#1013-R08	15	53.732	145	39.151	1011	pumiceous rhyolite	subangular	9	4	5	0.20	pale gray
HPD#1013-R09	15	53.740	145	39.127	967	fine-grained volcaniclastics with pumice banding	subangular	23	10	7	1.90	orange brown
HPD#1013-R10	15	53.740	145	39.127	967	fine-grained pumice	subrounded	11	9	8	0.34	pale gray
HPD#1013-R11	15	53.854	145	39.014	861	volcaniclastics	rounded	14	11	6	1.20	orangey black

alteration	Mn coating	phenocrysts	vesiculation	Memo	
weakly altered	-	ol <1%; fp 10%	moderately (10%)	heterogeneous vesicle distribution; patches of high vesicularity; olivine altered	HPD#1013-R01
weakly altered	none	qz 10%	25%		HPD#1013-R02
fresh	none	fp 20%	none	pillowy morphology; radial fractures; fps up to 5 mm	HPD#1013-R03
weakly altered		qz 5%	moderately 15%	orange staining on some surfaces; banded darker and lighter layers; braided layering	HPD#1013-R04
moderately altered	none	qz 10%; px 5%	20%	banded/swirly layering; orange surface	HPD#1013-R05
weakly altered		qz 10%; px 5%	25%	patches of pumice; high vesicularity, patches of reticulite, tube vesicles; qz grains up to 2mm; px mostly < 1 mm, a few 1 mm	HPD#1013-R06
moderately altered	film		25%	orange film on some surfaces	HPD#1013-R07
weakly altered	film	px 5%	20%		HPD#1013-R08
altered	film		none	bits of pumice on outside	HPD#1013-R09
moderately altered	film		25%	orange film on surface	HPD#1013-R10
moderately altered	film		none	black mafic clasts 10 mm; clasts medium-coarse > 1 mm	HPD#1013-R11

HPD#1014 Jun. 14 2009 W part of S caldera wall remnant of E. 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#1014-R01	15	53.873	145	39.817	896	dacite	subrounded	22	30	20	13.00	gray	moderately altered	film
HPD#1014-R02	15	53.879	145	39.808	887	andesite	subangular	30	20	10	5.30	pale gray	weakly altered	film
HPD#1014-R03	15	53.884	145	39.803	881	glassy dacite	subrounded	38	20	11	13.00	gray	moderately altered	film
HPD#1014-R04	15	53.884	145	39.803	881	andesite	subrounded	35	16	15	14.00	mottled pale gray	weakly altered	film
HPD#1014-R05	15	53.883	145	39.797	878	volcaniclastic	subrounded	10	9	4	0.40	mottled gray, dark gray	moderately altered	film
HPD#1014-R06	15	53.893	145	39.778	865	porphyritic dacite	subangular	22	13	8	4.40	gray	weakly altered	film
HPD#1014-R07	15	53.901	145	39.764	855	volcaniclastic	subangular	26	24	20	15.60	gray	moderately altered	film
HPD#1014-R08	15	53.932	145	39.757	824	andesite with glassy dacite pumiceous rim	subrounded	28	23	18	25.30	gray	weakly altered	film
HPD#1014-R09	15	53.947	145	39.978	805	dacite	subangular	50	20	15	14.00	gray	moderately altered	film
HPD#1014-R10	15	54.004	145	39.978	797	andesite	subrounded	50	40	8	36.00	gray	weakly altered	film
HPD#1014-R11	15	54.004	145	39.995	796	porphyritic basaltic andesite	subrounded	16	10	4	0.70	dark gray	weakly altered	film
HPD#1014-R12	15	54.026	145	39.995	775	basaltic andesite/andesite	subrounded	45	20	23	16.10	gray	moderately altered	film
HPD#1014-R13	15	54.060	145	40.033	732	andesite with pumiceous rim	subrounded	43	37	29	52.00	gray to pale gray	weakly altered	film
HPD#1014-R14	15	54.056	145	40.042	732	(crystal-rich) pumice	subrounded	17	17	10	3.90	pale gray	weakly altered	film

phenocrysts	glass	vesiculation	Memo	
qz 10%; hbl 5%; fp 10%		moderately	2 mm altered rind	HPD#1014-R01
fp: 15%; px 5%; hb 5%		weakly 10%	orange alteration rind < 2 mm	HPD#1014-R02
qz; hbl	glassy matrix	weakly 5%		HPD#1014-R03
px <5%; fp 10%		weakly 5%		HPD#1014-R04
fp 5%; qz <1%; hb 5%		weakly 5%	fp up to 1 mm; dark clasts; friable	HPD#1014-R05
qz 5%; fp 10%; hb 5%		weakly 5%	orange alteration rind < 25 mm; qz infilling vesicles	HPD#1014-R06
x 5%; hb 5%; qz+fp 10%		moderately 20%	1 mm alteration rim; large (lithic) clasts in outer rind; Mn + Fe oxides crust	HPD#1014-R07
px <5%; pl <5%		moderately 30%	inner region aphanitic; rim pumiceous, light gray, qz+amph, glassy dacite ?, variably sized vesicles up to 2	HPD#1014-R08
qz 10%; fp 5%; hb 5%		moderately 25%	~5 mm alteration rind along fractures	HPD#1014-R09
aphyric		weakly 10%	aphyric, but no glass	HPD#1014-R10
fp 10%			alteration rim 2 mm; fp up to 10 mm -> white phenocrysts	HPD#1014-R11
x 15%; pl 10%; hb < 5%				HPD#1014-R12
microphenocrysts		interior vuggy 5%; pumiceous rim up to 25%	vugs in interior rimmed by alteration products, Fe oxides; organised fractures around interior body, arranged radially, from rim towards interior, mini-columns; pumiceous cap ~5 cm thick, mottled gray, highy vesiculated, small vesicles; crystal rich -> fp + qz + mafic phase (amph?); fracturing in interior body appears to be absent from where cap exists. Andesite clast erupted in pumice?	HPD#1014-R13
hb 15%; qz 15%	glassy matrix	moderately 15%	dense	HPD#1014-R14

HPD#1015 Jun. 14 2009 seamount on NW slopes of E. 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#1015-R01	15	57.699	145	35.468	1590	basalt	subrounded	37	22	15	14.70	black	weakly altered	film
HPD#1015-R02	15	57.692	145	35.483	1577	basalt	subrounded	45	32	20	24.00	black	weakly altered	film
HPD#1015-R03	15	57.685	145	35.498	1552	basalt	subrounded	40	30	22	23.50	black	fresh	film
HPD#1015-R04	15	57.686	145	35.518	1537	basalt	subangular	28	20	15	16.20	black	weakly altered	film
HPD#1015-R05	15	57.683	145	35.537	1519	basalt	subrounded	37	20	25	22.00	black	weakly altered	film
HPD#1015-R06	15	57.689	145	35.558	1495	basalt	subangular	12	10	6	1.30	black	fresh	none
HPD#1015-R07	15	57.689	145	35.558	1495	basalt	subangular	10	9	6	1.10	black	weakly altered	film

phenocrysts	glass	vesiculation	Memo	
ol 5%; px 5%; fp 15%	devitrified/altered glassy rim	weakly	alteration rim <2 mm; fp phenocrysts 5 mm	HPD#1015-R01
pl 10-15%	devitrified altered glassy rim, 5 mm	weakly 5%	including dacitic xenolith (< 12 mm); size of pl < 5 mm	HPD#1015-R02
px 10%; pl 20%	<5 mm devitrified glass	weakly 5-10%	range of sizes for pl, between phenocrysts to microphenocrysts; larger vesicles up to 5 mm	HPD#1015-R03
px 5%; pl 10-15%	devitified/altered glassy rim <2 mm	wealy <5%	knobbly textured rim	HPD#1015-R04
px 10%; pl 15%	devitrified glass rim up to 10 mm	weakly 5-10%	ropey texture on outside, Mn-crust or glass (?)	HPD#1015-R05
px <5%; fp 10%	devitified/altered glassy rim	wealy <5%		HPD#1015-R06
px <5%; pl 10%	devitrified glass rim up to 10 mm	weakly		HPD#1015-R07

HPD#1016 Jun. 14 2009 Mid-Diamante, fault scarp and central cone

sample No.	latitude(N)		longitude(E)		depth (m)	rock type	shape	size X (cm)	size Y (cm)	size Z (cm)	weight(kg)	colour
HPD#1016-R01a	15	56.646	145	31.693	1414	tuff/breccia	angular	83	55	16	64.30	gray
HPD#1016-R01b	15	56.646	145	31.693	1414	volcanic breccia	angular	20/30/14	16/20/11	10/6/9	15.70	black
HPD#1016-R02	15	56.626	145	31.705	1367	vesicular basaltic andesite	subrounded	10	10	7	1.70	black
HPD#1016-R03	15	56.598	145	31.708	1293	auto-brecciated basaltic andesite	subrounded	73	28	22	15.00	black
HPD#1016-R04	15	56.583	145	31.726	1238	basaltic andesite (clast in breccia)	subangular	28	21	15	6.40	black
HPD#1016-R05	15	56.577	145	31.726	1226	aphyric dacite/rhyo-dacite	angular	13	13	9	1.00	gray
HPD#1016-R06	15	56.829	145	31.813	1274	hydrothermal manganese	subrounded	17	22	8	8.50	black
HPD#1016-R07	15	56.835	145	31.828	1256	hydrothermal manganese	subangular	13	10	6	0.60	black with brown swirls
HPD#1016-R08	15	56.835	145	31.828	1256	hydrothermal manganese	subangular	13	11	5.5	0.80	black with brown swirls
HPD#1016-R09	15	56.835	145	31.828	1256	hydrothermal manganese	angular	14.5	12	6.5	0.74	black with brown swirls
HPD#1016-R10	15	56.835	145	31.828	1256	hydrothermal manganese	subrounded	12	10	7	0.60	black
HPD#1016-unknown from box 3						pumiceous dacite	subrounded	29	14	15.5	4.50	dark gray
HPD#1016-C01	15	56.614	145	31.698	1399	volcanic clasts (-> volcanic breccia)	subangular					brown and black

alteration	Mn coating	phenocrysts	glass	vesiculation	Memo	sample request
fresh	film		perhaps in matrix		fines > 50%; mafic/basaltic clasts; matrix of ash, perhaps includes pumice	HPD#1016-R01a
moderately altered	film	pl 10% in basalt clasts		weakly 10% in basalt clasts	0.5 to 2 cm vesiculated basalt clasts, supported by clastic matrix; m to oxides within 50 mm of exterior surface	HPD#1016-R01b
weakly altered	film	pl 10%		strong 40%		HPD#1016-R02
weakly altered		px < 5%; pl 15%	devitrified 1 mm	moderate 15%	sharp contact between crystalline body and clastic 'margin'	HPD#1016-R03
moderately altered		px 5-10%; pl 20%		moderate 10-15%	volcanic clast with auto-brecciated rim/margin	HPD#1016-R04
weakly altered	film	aphyric	in devitrified spots	moderate 25%	pumiceous in places	HPD#1016-R05
					Mn cement supported; micro-columnar Mn structure	HPD#1016-R06
					Mn cement supported	HPD#1016-R07
						HPD#1016-R08
						HPD#1016-R09
					Mn cement supported	HPD#1016-R10
weakly altered	film	pl 10%; px 5%		strong 50%	rounded dark (mafic) xenolith 15 mm; light discontinuous bands, ve layering	HPD#1016-unknown fro box 3
						HPD#1016-C01

HPD#1017 Jun. 15 2009 parisitic cone on W. 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	phenocrysts
HPD#1017-R01	15	56.068	145	28.276	2210	(olivine) basalt	subrounded	35	30	28	20.00	black	weakly altered	5 mm	ol 10%; px 5%; pl 10-15%
HPD#1017-R02	15	56.083	145	28.263	2193	(olivine) basalt	subrounded	15	13	6.5	1.50	black	weakly altered	2 mm	ol 10%: px 5%: pl 15%
HPD#1017-R03	15	56.095	145	28.262	2183	vesicular basaltic rind	subangular	9	7.5	5.5	0.40	black	moderately altered	2 mm	ol 5%; px 5%; pl 10%
HPD#1017-R04	15	56.095	145	28.262	2183	(olivine) basalt	subrounded	8.5	8	5.5	0.50	black	weakly altered	film	ol 10%; px 5%; pl 15-20%
HPD#1017-R05	15	56.097	145	28.259	2176	(olivine) basalt	subrounded	11.5	10	6.5	1.30	black	weakly altered	crust 2 mm	ol 10%; px 10%; pl 15%
HPD#1017-R06	15	56.117	145	28.249	2156	(olivine) basalt	subrounded	21	16	7.5	3.50	black	altered	2-5 mm	ol 10%; px 5%; pl 20%
HPD#1017-R07	15	56.121	145	28.246	2150	(olivine) basalt	subangular	21	18	6	1.90	black	weakly altered	film	ol 10%; px 10%; pl 20%
HPD#1017-R08	15	56.140	145	28.230	2127	basalt	rounded	46	38	26	31.00	black	weakly altered	5-10 mm	ol 5-10%; px 5%; pl 10%
HPD#1017-R09	15	56.173	145	28.191	2028	(olivine) basalt	rounded	33.5	19	16	9.20	black	weakly altered	2 mm	ol 10%; px 10%; pl 15%

	glass	vesiculation	Memo	
%		moderately 30%	pl phenocrysts up to 5mm:; ol glomerocrysts; px 5% porphyritic	HPD#1017-R01
		moderately 20%	porphyritic	HPD#1017-R02
		strongly 40-50%	highly vesicular, porphyritic	HPD#1017-R03
%		moderately 20%	glomerocryst of pl and ol; ol < 5mm, pl < 3mm; porphyritic	HPD#1017-R04
,		moderately 20%	porphyritic; glomerocrysts of ol and pl; phenocrysts < 5mm	HPD#1017-R05
		moderately 25-30%	altered rim < 5 mm; radial fractures; vuggy; light layer around alteration rim; porphyritic	HPD#1017-R06
	glassy rim?	moderately 25%	shape flat-slabby; porphyritic; phenocrysts < 10mm - glomerocrysts; vesicles < 15mm - vuggy; lighter layer, 10mm thick - 5mm below the exterior (weathered) surface, contains phenocrysts, possibly glassy rim	HPD#1017-R07
%		moderately 25%	small vesicles < 10mm; ol < 4-5mm, glomerocrysts; pl phenocrysts< 5mm; porphyritic	HPD#1017-R08
,		moderately 20%	porphyritic; radial fracturing; fine grained rim, 10 - 20 mm thick, defined by radial fractures	HPD#1017-R09

HPD#1018 Jun. 15 2009 NE slope of W. 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#1018-R01	15	58.031	145	25.402	978	basalt	rounded	20	15	14	4.70	black	weakly altered	film
HPD#1018-R02	15	58.028	145	25.384	966	basalt	subangular	13	12	7	1.20	black with orange rim	weakly altered	1-2 mm
HPD#1018-R03	15	58.004	145	25.354	941	basaltic andesite	rounded	22	21	15	15.80	gray	weakly altered	film
HPD#1018-R04	15	57.997	145	25.339	929	basalt	subrounded	20/13	14/12	13/9	4.75	black with orange rim	weakly altered	film
HPD#1018-R05	15	57.990	145	25.309	913	basalt	rounded	30	20	24	14.40	black	weakly altered	film
HPD#1018-R06	15	57.957	145	25.259	880	basalt	subangular	12	11	7	1.05	black with orange rim	fresh interior	film
HPD#1018-R07	15	57.844	145	25.086	773	basalt	subrounded	27	11	10	2.75	black with orange rim	weakly altered interior, heavily altered rim	film
HPD#1018-R08	15	57.840	145	25.080	769	basalt	rounded	7	6	6	0.30	black	weakly altered	film
HPD#1018-R09	15	57.831	145	25.068	759	basalt	rounded	13	12	6	1.13	black with orange rim	weakly altered	film
HPD#1018-R10	15	57.830	145	25.064	756	crystal-rich basalt	subangular	32	24	18	12.60	gray	weakly altered	film
HPD#1018-R11	15	57.826	145	25.060	753	basalt	subangular	22	16	15	5.80	black	weakly altered	film
HPD#1018-R12	15	57.824	145	25.054	748	basalt	subangular	22	16	15	1.70	black with orange rim	moderately altered	film
HPD#1018-C01	15	57.852	145	25.101	784	polymictic mud-sand	rounded carbonates; subangular rest				1.82	brown		
HPD#1018-C02	15	57.831	145	25.068	759	polymictic mud-sand	rounded carbonates; subangular rest				2.60	brown		
HPD#1018-C03	15	57.831	145	25.068	759	polymictic sand-gravel-pebbles	subrounded to angular				0.94	variable		

phenocrysts	glass	vesiculation	Memo	
px 10%; pl 15%		moderately 25%	altered glass present on outer surfaces; porphyritic	HPD#1018-R01
pl 10%		moderately 20%	bright orange oxidation rim 3- 5 mm -> altered glassy rim; porphyritic plag < 5 mm	HPD#1018-R02
px < 5%; pl 15%		weakly < 5%		HPD#1018-R03
ol 2%; pl 15%		moderately 30%	oxidation rim 5 mm -> altered glassy margin; porphyritic plag < 5 mm; radial jointing; vesicle distribution radially distributed; lobey sample morphology	HPD#1018-R04
px 10%; pl 20%		moderately 20%	porphyritic	HPD#1018-R05
px 10%; pl 15%		moderately 25%	orange alteration rim < 3 mm -> altered glassy interior; vesicles up to 1 cm; porphyritic	HPD#1018-R06
ol 5%; px 10%		moderately 20%	orange alteration rim < 5 mm -> altered glass; porphyritic	HPD#1018-R07
pl 15%		moderately 25%	porphyritic, plag < 3 mm	HPD#1018-R08
l 1%; px 10%; pl 3%		weakly 10%	orange alteration rim < 4 mm, Fe-Mn oxides -> altered glassy rim; porphyritic	HPD#1018-R09
pl 20%		weakly < 5%	1 - 2 mm oxidation/alteration rim -> altered glass; porphyritic	HPD#1018-R10
ol 10%; px 10%		weakly 15%	altered outer margin -> altered glass?; porphyritic	HPD#1018-R11
px 10%; pl 5%		weakly 15%	altered outer margin, Fe-Mn crust 5 mm -> altered glass?	HPD#1018-R12
			grain size from mud to sand; clasts include: carbonate/shell fragments, basalt fragments; ol, px xstals, Fe-Mn oxides	HPD#1018-C01
			grain size from mud to sand; clasts include: carbonate material, black fragments (basalt, Fe-Mn oxides), olivine	HPD#1018-C02
			poorly sorted from 2 mm to > 5 mm; clasts include: shelly fragments, basaltic frgaments, Fe-Mn oxides	HPD#1018-C03

HPD#1019 Jun. 17 2009 NW wall of crater in west-central part of Zealandia Bank

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#1019-R01	16	53.273	145	49.087	637	andesite	angular	32	27	10	10.00	gray	weakly altered	film
HPD#1019-R02	16	53.291	145	49.098	621	andesite	angular	22	23	19	10.00	gray	weakly altered	film
HPD#1019-R03	16	53.288	145	49.100	593	andesitic dacite	angular	36	19	8	9.60	gray	weakly altered	film
HPD#1019-R04	16	53.291	145	49.098	581	andesite	angular	26	22	23	21.00	dark gray	weakly altered	film
HPD#1019-R05	16	53.306	145	49.095	536	andesite	angular	14	9	9	2.00	dark gray	fresh	film
HPD#1019-R06	16	53.340	145	49.043	511	basaltic andesite	angular	33	35	12	26.40	dark gray	fresh	film
HPD#1019-R07	16	53.350	145	49.042	500	dacite	subangular	20	12	14	7.50	gray	fresh	film
HPD#1019-R08	16	53.386	145	49.012	478	andesite - dacite	subangular	22	16	8	4.50	dark gray	weakly altered	film
HPD#1019-R09	16	53.414	145	48.976	448	felsic pumiceous pyroclastics with bioclastic carbonate carapace	angular	17/28	12/31	13/22	9.70	pale brown	altered	film
HPD#1019-R10	16	53.435	145	48.950	425	volcaniclastic with pumice and mafic clasts coated with carbonate carapace	angular	22	11	8	1.00	pale brown	moderately altered	film
HPD#1019-R11	16	53.456	145	48.928	401	bioclastic carbonate	subangular	17	15	12	1.50	buff	altered	film
HPD#1019-R12	16	53.497	145	48.928	368	volcaniclastic possibly welded coasted in carbonate	angular	71	46	58	34.00	mottled pale brown	altered	film
HPD#1019-C01	16	53.273	145	49.091	637	mud					1.00	black, brown, gray		

phenocrysts	glass	vesiculation	Memo	
px 2%; pl 5%		weakly < 5%	orange rim 1-2 mm thick; sparsely porphyritic	HPD#1019-R01
pl 10%		none	orange rim 2-3 mm; sparsely porphyritic	HPD#1019-R02
px 5%; pl 5%		none	sparsely porphyritic, phenocrysts < 2 mm; may also be qz or ol, small so difficult to positively identify	HPD#1019-R03
pl 5%		none	orange rim 5 mm thick; fine-grained, very sparesly porphyritic	HPD#1019-R04
pl 10%		none	sparsely porphyritic	HPD#1019-R05
px 5-10%; pl 15%		none	more phenocryst rich that other samples from this dive	HPD#1019-R06
px 5%; pl 10%; hb 5%		weakly < 5%	microcrystalline, hb possibly present, sugary texture, qz in the matrix? phenocrysts fp	HPD#1019-R07
pl 5%		none	orange rim 2-3 mm; sparsely porphyritic; fine-grained; some flow structures	HPD#1019-R08
		strongly 50%	fine-grained	HPD#1019-R09
		strongly	mafic clast with px +/- ol - dark clast (andesitic); also pale clasts; veins of vesiculated material, not many vesicles in matrix; buff coloured rim 2 mm across -> carbonate; forms highly irregular pitted surface	HPD#1019-R10
		strongly 45%		HPD#1019-R11
		moderately 30%	pumiceous clasts; dense clasts; lighter pale area, also dark areas creating mottled appearance; carbonate material, 10s of cms thick, mottled buff color, spongey, forms irregular pitted surface with cavities and arches.	HPD#1019-R12
				HPD#1019-C01

HPD#1020 Jun. 17 2009 resurgent dome in crater and E wall of crater in west-central Zealandia Bank

sample No.	latitude(N)		longitude(E)		depth (m)	rock type	shape	size X (cm)	size Y (cm)	size Z (cm)	weight(kg)	colour
HPD#1020-R01	16	52.804	145	49.33	618	dacite	subangular	10	7	6	0.30	dark gray
HPD#1020-R02	16	52.832	145	49.371	616	flow banded rhyolite	subangular	30	25	15	12.00	gray
HPD#1020-R03	16	52.837	145	49.392	605	banded dacite	angular	20	12	10	2.50	gray
HPD#1020-R04	16	52.848	145	49.415	572	dacite	angular	54	24	23	24.00	dark gray
HPD#1020-R05	16	52.858	145	49.436	534	banded rhyo-dacite	subangular	29	18	17	6.50	gray
HPD#1020-R06	16	52.856	145	49.442	528	dacite	subangular	16	18	15	5.00	dark gray
HPD#1020-R07	16	52.867	145	49.463	506	dacite	subangular	17	12	9	2.00	gray
HPD#1020-R08	16	52.908	145	49.495	495	dacite	angular	12	12	3	0.50	black
HPD#1020-R09	16	52.933	145	49.502	483	banded dacite	subangular	25	17	15	8.00	gray
HPD#1020-R10	16	52.990	145	49.554	495	banded dacite	subangular	16	14	12	1.90	gray
HPD#1020-R11	16	53.002	145	49.555	488	banded dacite	angular	18	12	12	3.60	gray
HPD#1020-R12	16	53.010	145	49.551	480	banded dacite	angular	45	40	20	27.00	dark gray
HPD#1020-C01	16	52.846	145	49.409	584	weathered dacite					0.98	pale gray
HPD#1020-C02	16	52.901	145	49.484	505	gravelly sand/mud					0.90	pale gray, orange clasts

alteration	Mn coating	phenocrysts	glass	vesiculation	Memo	
weakly altered	film	px 25%; fp 10%		weakly < 5%	swirly banding	HPD#1020-R01
weakly altered	film	px 5%; fp 25%; qz 5%		none	banded; qz up to 10mm; intensely banded; swirly in places; oxidation rim 20mm	HPD#1020-R02
moderately altered	film	fp 10%		weakly 10 %	oxidation rim 10 mm; mafic enclaves, include crystal-like spaces, minerals (px?) being replaced; banded	HPD#1020-R03
moderately altered	1 mm	fp 5%		weakly 5%	sulphides in vesicles; sulphide (pyrite) on broken surface; 2 mm gray rim; 3 mm orange rim; fp up to 2	HPD#1020-R04
weakly altered	film	fp 10%		moderately 15%	wavy banding, vesicle rich (30%) layers, denser layers (<5%)	HPD#1020-R05
weakly altered	film	px 5%; fp 5%		weakly 5%	subtle banding	HPD#1020-R06
moderately altered	film	px 5%; hb 5%; fp<5%		weakly 10%	px and/or hb	HPD#1020-R07
moderately altered	film	fp 10%		weakly < 5%	a mineral type (mafic) appears to be being altered; subtle banding	HPD#1020-R08
weakly altered	film	px 5%; fp 5%; qz 5%		weakly < 5%	oxidation rim to 10mm (5 mm pale colored, 5 mm orange colored); qz up to 10 mm; sheen on broken	HPD#1020-R09
moderately altered	film	fp 5%		weakly <5%	swirly flow banding	HPD#1020-R10
moderately altered	film	px 5%; fp 5%		weakly <5%	banded, well defined (dark layers -> denser; light layers -> vesiculated); oxidation on some surface;	HPD#1020-R11
weakly altered	film	px 5%; fp 10%; qz 5%		weakly <5%	px being replaced; banded darker and slightly lighter layers	HPD#1020-R12
altered					pyrite (FeS); weathered alasts derived from lava	HPD#1020-C01
					pyrite (FeS); fp; clay; poorly sorted	HPD#1020-C02

HPD#1021 Jun. 18 2009 several transects up features between crater and dome-structure on western side of Zealandia Bank

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
transect 1														
HPD#1021-R01	16	52.007	145	48.894	716	pumice	subangular	23	16	19	4.50	orangey pinky gray	altered	none
HPD#1021-R02	16	52.028	145	48.892	701	banded tuff	subangular	7	5	6	0.44	drak gray/pale gray banded	weakly altered	film
HPD#1021-R03	16	52.069	145	48.903	668	pumice	subangular	19	11	9	0.80	gray	moderately altered	film
HPD#1021-R04	16	52.121	145	48.906	621	banded rhyolite with polycrystalline aggregate	subangular	16	11	9	1.20	drak gray/pale gray banded	weakly altered	film
HPD#1021-R05	16	52.158	145	48.904	590	banded rhyolite	angular	22	12	15	3.00	dark gray	weakly altered	film
transect 2														
HPD#1021-R06	16	52.462	145	48.402	567	banded tuff with mafic clast	subangular	23	23	13	6.70	dark gray	weakly altered	film
HPD#1021-R07	16	52.468	145	48.385	552	puimiceous tuff	subangular	35	25	17	9.50	banded gray	moderately altered	patchy film
HPD#1021-R08	16	52.483	145	48.362	534	banded rhyolite	subangular	27	12	10	2.50	brown/gray banded	moderately altered	film
transect 3														
HPD#1021-R09	16	52.447	145	47.930	471	recrystallised coraline limestone	subangular	24	14	14	2.60	buff	moderately altered	film
HPD#1021-R10	16	52.454	145	47.931	467	rhyolite	subangular	37	26	16	10.30	gray	weakly altered	film
HPD#1021-R11	16	52.520	145	47.911	437	pumiceous tuff with flow bands	subangular	14	17	10	1.30	brown	moderately altered	film
HPD#1021-R12	16	52.560	145	47.666	428	recrystallised reefal limestone	subangular	18	18	10	1.20	pale brown	weakly altered	film
transect 4														
HPD#1021-R13	16	52.568	145	47.647	407	rhyolite	subangular	25	10	16	0.60	gray	moderately altered	film
HPD#1021-R14	16	52.579	145	47.638	398	pumiceous volcaniclastic	subangular	14	11	5	0.55	pale brown	moderately altered	film
HPD#1021-R15	16	52.584	145	47.632	392	tuff coated in carbonate	subrounded	26	17	14	5.70	gray to pale gray	altered	film
HPD#1021-R16	16	52.648	145	47.592	335									
transect 5														
HPD#1021-R17	16	52.829	145	47.252	295	bioclastic (beach deposit?)	subangular	32	31	20	6.50	buff	weakly altered	film
HPD#1021-R18	16	52.897	145	47.236	234	carbonate	subangular	11	7.5	3.5	0.30	pale brown	fresh	
transect 6														
HPD#1021-R19	16	52.790	145	46.828	364	carbonate	subrounded	6.5	6	5	0.20	pale brown	moderately altered	film
HPD#1021-R20	16	52.779	145	46.790	348	tuff	angular	10	6	6	0.40	pale brown	moderately altered	film
HPD#1021-R21	16	52.779	145	46.790	348	pumiceous tuff	angular	7.5	5.5	4.5	0.30	gray	moderately altered	film
HPD#1021-R22	16	52.769	145	46.752	314	bioclastic limestone	subrounded	39	30	25	22.00	buff	moderately altered	film
HPD#1021-R23	16	52.770	145	46.742	300	porphyritic basaltic andesite	angular	22	13	13	5.20	dark gray	weakly altered	film
HPD#1021-R24	16	52.770	145	46.742	300	porphyritic basaltic andesite	subrounded	31	15	13	7.60	dark gray	weakly altered	film
HPD#1021-R25	16	52.769	145	46.739	289	porphyritic basaltic andesite	subangular	46	24	23	27.00	dark gray	weakly altered	
HPD#1021-R26	16	52.769	145	46.739	289	porphyritic basaltic andesite	subangular	23	20	13	5.50	black	weakly altered	none

phenocrysts	glass	vesiculation	Memo	
		strong 50%	oxidised throughout; dark lithic fragments; polycrystalline aggregates	HPD#1021-R01
qz < 5%		moderately 15%; varies between layers	strongly banded; denser layers, vesicular layers usually lighter in colour, pumiceous in places; lithic clasts	HPD#1021-R02
fp 1%		moderately 20%	lithic fragments; fine grained matrix - glass?	HPD#1021-R03
		moderately 15%	fine-grained; swirly banding; dark gray and lighter gray bands; lithic fragments polycrystalline aggregates (fp, px)	HPD#1021-R04
fp 5%; +/- bt		weakly 10%	oxidation rim 1-2mm; banded darker and lighter layers; clusters of fp < 2mm; +/- bt	HPD#1021-R05
dark layers: px 5% large mafic (basaltic) clast: ol+px+plag		weakly 5%	Layer 1: pale colored material, smaller vesicles; oxidation rim 2 mm on outer surface, overall thickness 5 mm. Layer 2: banded dark gray layer containing small (<2 mm) lithic fragments, 50 mm thick. Layer 3: discontinuous wavy pale layer, smaller vesicles; up to 10 mm thick; pinched out in places (boudinage?); mostly within it is a large mafic (basaltic) clast 20 mm in size; no reaction rim. Layer 4: dark gray banded layer (similar to layer 2), contains darker lithic fragments, disaggregated olivines in vesicles.	HPD#1021-R06
qz <5%		moderately 20%	lithic fragments, contain fp +/-hbl	HPD#1021-R07
px 5%		moderately 10%	lithic fragments, mostly plag (phenocryst and surrounding matrix preserved during break up of mafic rock?); calcite vein	HPD#1021-R08
			shell coated in Mn attached	HPD#1021-R09
qz 10%		weakly 10%	+/- bt	HPD#1021-R10
		moderately 25%	3-5 mm wavy, interrupted bands of mottled gray and black; black areas are lithic clasts; low density	HPD#1021-R11
				HPD#1021-R12
fp 5%; qz 5%; px ?		moderately 15%	coated in buff colored carbonate, forms fragile looking carapace	HPD#1021-R13
qz 1 grain		moderately 15-20%	lithic clasts	HPD#1021-R14
fp 5%		weakly 10%	lithic clasts 10% -> some lenticular; coated in carbonate, carbonate appears baked; carbonate veining lost	HPD#1021-R15
				HPD#1021-R16
			with active biology	HPD#1021-R17
			red color on exterior surface - algae? corals growing in rock	HPD#1021-R18
			spongey appearance	HPD#1021-R19
fp 5%; hb <5%		weakly 5%	thin banding 1-2 mm; lithic clasts 0.5 - 5 mm, some may be amphibole; thin qz or calcite veins (1-2 mm wide	HPD#1021-R20
fp <1; hb 5%; qz <1%		weakly 10%	dark and light banding; lithic clasts; orange oxidation coating; small vesicles	HPD#1021-R21
				HPD#1021-R22
px 10%; pl 15%		weakly 5%	oxidation rim up to 10 mm thick	HPD#1021-R23
px 10%; pl 15%		weakly 5%	ol and pl in glomerocryst; oxidation rim 5 mm thick; cracks filled with calcite	HPD#1021-R24
pl 25%; px 5%		weakly <2%	oxidation rim < 10 mm thick	HPD#1021-R25
px 10%;pl 15%		weakly <5%	oxidation rim up to 10mm; pl < 2 mm; px 1 mm	HPD#1021-R26

HPD#1022 Jun. 19 2009 500 m high steep seamount/spire between Sarigan and Zealandia

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#1022-R01	16 46.646	145 50.536	1496	porphyritic basalt	subangular	17	15	12	3.12	black	fresh	none
HPD#1022-R02	16 46.661	145 50.530	1479	basalt	angular	20	20	10	5.50	black	fresh	film
HPD#1022-R03	16 46.711	145 50.489	1418	porphyritic basalt	angular	40	30	9	18.80	black	fresh	film
HPD#1022-R04	16 46.737	145 50.467	1380	porphyritic basalt	angular	16	10	9	2.70	black	fresh	none
HPD#1022-R05	16 46.760	145 50.446	1350	porphyritic basalt	subangular	16	10	9	1.10	black	fresh	none
HPD#1022-R06	16 46.780	145 50.434	1326	porphyritic basalt	subangular	16	14	14	3.20	black	fresh	none
HPD#1022-R07	16 46.789	145 50.425	1315	porphyritic basalt	subangular	7	5	2	0.10	black	fresh	none
HPD#1022-R08	16 46.789	145 50.425	1315	porphyritic basalt	subangular	6	5	3	0.13	black	fresh	none
HPD#1022-R09	16 46.789	145 50.425	1315	porphyritic basalt	subangular	7	5	4	0.20	black	fresh	none
HPD#1022-R10	16 46.819	145 50.396	1272	porphyritic basalt	subangular	10	7	6	0.70	black	fresh	none
HPD#1022-R11	16 46.846	145 50.371	1232	porphyritic basalt	angular	27	19	17	9.70	black	fresh	none
HPD#1022-R12	16 46.879	145 50.332	1175	porphyritic basalt	subangular	33	22	8	8.30	black	fresh	none
HPD#1022-R13	16 46.879	145 50.332	1175	porphyritic basalt	angular	20	19	7	3.60	black	fresh	none
HPD#1022-R14	16 46.879	145 50.332	1175	porphyritic basalt	subangular	40	30	10	20.00	black	fresh	film

phenocrysts	glass	vesiculation	Memo	
ol 10%; pl 15%; px 5	none	moderately 15%	pl < 3mm; ol/px < 1mm	HPD#1022-R01
ol 10%; pl 10%; px 5	none	moderately 15%	pl < 1mm; ol/px < 1mm	HPD#1022-R02
ol 10%; pl 10%; px 10	none	moderately 15%	pl < 2mm; ol/px < 1mm	HPD#1022-R03
ol 5%; pl 10%; px 5	none	moderately 10%	pl < 2mm; ol/px < 1mm	HPD#1022-R04
ol 5%; pl 10%; px 5	none	moderately 20%	pl < 2mm; ol/px < 1mm; vesicles up to 5mm	HPD#1022-R05
ol 5%; pl 10%; px 5%	glassy crust 2mm; altered to orange in places	moderately 15%	pl < 2mm; ol/px < 1mm	HPD#1022-R06
ol 5%; pl 10%; px 5%	none	moderately 15%	pl < 2mm; ol/px < 1mm	HPD#1022-R07
ol 5%; pl 10%; px 5%	none	moderately 20%	pl < 2mm; ol/px < 1mm	HPD#1022-R08
ol 5%; pl 10%; px 5%	none	moderately 15%	pl < 2mm, laths; ol/px < 1mm	HPD#1022-R09
ol 2%; pl 10%; px 2%	none	moderately 10%	pl < 2mm, laths, albite twinning visible; ol/px < 1mm	HPD#1022-R10
ol 5%; pl 15%; px 5%	glassy rim 1mm; altering to orange	moderately 15%	pl < 5mm; ol/px < 1mm	HPD#1022-R11
ol 5%; pl 10%; px 5%	glassy margins 2mm	moderately 15%	pl < 3mm; ol/px < 1mm; glass fresher than in other samples from this dive	HPD#1022-R12
ol 5%; pl 15%; px 5%	none	moderately 20%	pl < 5mm; ol/px < 1mm	HPD#1022-R13
ol 10%; pl 10%; px 5%	none	moderately 15%	pl < 3mm; ol/px < 1mm	HPD#1022-R14

HPD#1023 Jun. 19 2009 seamount on lower slopes of Sarigan

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#1023-R01	16	45.766	145	47.488	1287	basalt	angular	20	17	11	3.00	black	fresh	none
HPD#1023-R02	16	45.757	145	47.486	1278	pyroxene basalt	angular	40	33	22	31.00	black	fresh	none
HPD#1023-R03	16	45.725	145	47.496	1257	pyroxene basalt	angular	32	28	14	12.00	black	fresh	none
HPD#1023-R04	16	45.713	145	47.499	1240	basalt	angular	31	31	24	16.50	black	fresh	film or none
HPD#1023-R05	16	45.707	145	47.502	1235	basalt	subangular	28	17	13	7.00	black	fresh	film?
HPD#1023-R06	16	45.699	145	47.511	1222	basalt	subangular	40	23	17	28.00	black	fresh	none
HPD#1023-R07	16	45.683	145	47.525	1211	basalt	subangular	20	20	12	7.00	black	fresh	none
HPD#1023-R08	16	45.646	145	47.551	1170	basalt	angular	37	27	23	21.00	black	fresh	none
HPD#1023-R09	16	45.620	145	47.565	1142	pyroxene basalt	angular	11	10	8	1.00	black	fresh	none
HPD#1023-R10	16	45.582	145	47.578	1103	pyroxene basalt	angular	60	40	20	60.00	black	fresh	none
HPD#1023-R11	16	45.539	145	47.585	1059	basalt	subangular	30	23	20	17.00	black	fresh	none

phenocrysts	glass	vesiculation	Memo	
ol 5%; cpx 15%	weakly altered glassy rim	weakly 5%	phenocrysts < 1mm	HPD#1023-R01
ol 5%; cpx 10%; pl 5%	< 1mm	moderately 15%	phenocrysts < 1mm; red oxidation spots on surface, could be altered glass	HPD#1023-R02
pl 5%; cpx 15%	altered < 1mm	weakly 10%	small phenocrysts of px and pl; large sample with radial fractures; brownish crust onj outer surface could be altered glass	HPD#1023-R03
ol 5%; cpx 10%; pl 1%	oxidized 1-2mm	weakly 5%	subparallell fractures; surface 'coated' with black/brown crust -> possible Mn film and/or altered glass	HPD#1023-R04
ol 5%; cpx 15%; pl 1%		weakly 10%		HPD#1023-R05
ol 10%; cpx 10%; pl 5%		weakly 10%	pl < 4mm; ol < 2mm; cpx 1-3mm; many olivine have rims; subparallel fractures	HPD#1023-R06
ol 5%; cpx 10%; pl 5%	oxidized 1mm	moderately 15%	pl 2-4mm; fractured	HPD#1023-R07
ol 5%; cpx 10%; pl 1%	oxidized in spots < 1mm	moderately 15%	phenocrysts 1-2mm; some olivine may be rimmed	HPD#1023-R08
cpx 10%; pl 5%	altered < 1mm	moderately 15%	small phenocrysts 1-2mm; possible thin altered glass rind; coraline growths 2-3cm on surface	HPD#1023-R09
ol 1%; cpx 15%; pl 1%	oxidized 1mm	moderately 20%	minor pyrite	HPD#1023-R10
ol 5%; cpx 10%; pl 1%	none	moderately 20%	possible 1-2mm rimmed olivine	HPD#1023-R11

HPD#1024 Jun. 20 2009 Seamount on SE slopes of Zealandia Bank

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#1024-R01	16	50.609	145	54.907	1096	porphyritic pyroxene basalt	subangular	26	12	12	6.20	black	fresh	
HPD#1024-R02	16	50.627	145	54.912	1089	porphyritic pyroxene basalt	angular	30	11	7	3.00	black	fresh	
HPD#1024-R03	16	50.671	145	54.926	1066	porphyritic pyroxene basalt	subrounded	51	32	30	31.00	black	fresh	
HPD#1024-R04	16	50.752	145	54.949	1019	porphyritic pyroxene basalt	subangular	32	23	23	13.70	black	fresh	
HPD#1024-R05	16	50.782	145	54.952	1003	porphyritic pyroxene basalt	subangular	27	16	14	7.40	black	fresh	
HPD#1024-R06	16	50.796	145	54.955	991	porphyritic pyroxene basalt	subangular	17	20	13	5.86	black	fresh	
HPD#1024-R07	16	50.891	145	54.960	938	porphyritic pyroxene basalt	angular	28	23	20	14.00	black	fresh	
HPD#1024-R08	16	51.055	145	54.957	827	porphyritic pyroxene basalt	subrounded	16	11	8	1.98	black	fresh	
HPD#1024-R09	16	51.110	145	54.941	778	basaltic pillow lobes with glassy margins	subrounded	30	30	20	13.00	black	fresh	
HPD#1024-C01	16	50.868	145	54.960	952	mud-sand-pebble					1.68	muddy brown		
HPD#1024-C02	16	50.974	145	54.960	885	pebbly mud and sand					1.40	muddy brown		

phenocrysts	glass	vesiculation	Memo	
ol 5%; cpx 15%; pl 5%	oxidizing altered glassy rim or Mn	moderately 15%	px < 2mm; ol < 1mm; sub-parallel fracturing	HPD#1024-R01
ol 10%; cpx 15%; pl 15%		moderately 10%	oxidation rim 1mm; ol < 1mm; cpx < 5mm; pl < 2mm; phenocryst-rich	HPD#1024-R02
ol 10%; cpx 20%; pl 15%	altered glassy margin 2 mm	weakly 10%	cpx < 10mm; pl < 5mm; ol < 1mm -> glomerocrysts < 5mm	HPD#1024-R03
ol 5%; cpx 15%; pl 15%	altered 1-2mm	moderately 20%	glassy rim -> oxidized; pl < 2mm -> some laths; cpx-ol intergrowths; vesicles infilled with oxidation products	HPD#1024-R04
ol 10%; cpx 15%; pl 10%	oxidized glassy rim 1mm	moderately 10%	ol < 1 mm; ol+cpx clusters < 2mm; pl < 1mm; discontinuous sub-parallel fracturing; ropey exterior surface	HPD#1024-R05
ol 5%; cpx 10%; pl 15%	oxidized glassy rim 2mm	moderately 10%	crystals near outer margin altered	HPD#1024-R06
ol 5%; cpx 15%; pl 10%	altered glassy margin 2 mm	moderately 20%	ol < 1mm; cpx < 2mm; pl < 2mm; vesicles up to 15mm	HPD#1024-R07
ol 10%; cpx 15%; pl 10%		moderately 15%	ol < 1mm; cpx < 2mm; pl < 5mm	HPD#1024-R08
ol 5%; cpx 10%; pl 15%	10 mm (altered)	moderately 30%	ol < 1mm; cpx < 3mm; pl < 5mm; pillow lobe, concentric fractures, glass to fine-grained rim (outer surface altered), vesicle-rich interior	HPD#1024-R09
			subrounded grains; dark clasts -> glass?; fp, ol clasts	HPD#1024-C01
			subrounded grains; dark clasts -> glass?; fp clasts	HPD#1024-C02

HPD#1025 Jun. 20 2009 up steep valley slope on SE slope of Zealandia Bank

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	phenocrysts
HPD#1025-R01	16	50.512	145	52.287	1022	welded scoria with pumice clast	angular	33	13	4	1.50	black	weakly altered		
HPD#1025-R02	16	50.514	145	52.267	1011	basaltic pillow lobe with chilled margin	rounded	10	8	8	0.80	black	fresh interior; altered exterior		ol <1%; cpx 5%; pl 15%
HPD#1025-R03	16	50.515	145	52.250	999	porphyritic vesicular basalt	subrounded	32	19	20	17.00	black	fresh		ol 5%; cpx 15%; pl 15%
HPD#1025-R04	16	50.518	145	52.233	985	volcanic breccia	subangular	27	20	12	5.20	black	moderately altered	film	
HPD#1025-R05	16	50.520	145	52.221	974	volcanic breccia	angular	50	24	10	14.70	black	moderately altered	film	
HPD#1025-R06	16	50.520	145	52.221	973	vesicular basalt	angular	10	6	3	0.20	black	altered		ol 1%; cpx 10%; pl 15%
HPD#1025-R07	16	50.521	145	52.211	929	porphyritic basalt	subangular	12	9	10	1.00	black	fresh		ol 10%; cpx 5%; pl 15%
HPD#1025-R08	16	50.521	145	52.211	929	basaltic pillow lobe	subrounded	13	12	9	1.40	black	weakly altered		ol <5%; cpx 10%; pl 15%
HPD#1025-R09	16	50.523	145	52.203	918	weathered basaltic andesite	subangular	8	7	6	0.50	orange gray	altered	film	px 20%; fp 10%; +/- hbl
HPD#1025-R10	16	50.528	145	52.173	889	basalt	subangular	10	8	5	0.20	black	weakly altered	film	ol <5%; cpx 10%; pl 25%
HPD#1025-R11	16	50.528	145	52.173	889	porphyritic basalt	subrounded	12	9	8	1.00	black	fresh		ol 10%; cpx 10%; pl 20%
HPD#1025-R12	16	50.531	145	52.169	881	layered altered volcaniclastic	subangular	33	16	5	2.30	orange	altered		
HPD#1025-R13	16	50.534	145	52.165	877	porphyritic basalt	subangular	25	22	18	10.70	black	fresh	film	cpx 10%; pl 20%
HPD#1025-R14	16	50.533	145	52.159	864	basaltic andesite	subrounded	15	15	10	3.80	gray	weakly altered	film	px <5%; pl 10%
HPD#1025-R15	16	50.533	145	52.135	845	dacite	subangular	13	10	8	1.40	mottled pale gray	moderately altered	film	
HPD#1025-R16	16	50.533	145	52.125	838	basaltic andesite	subangular	23	18	14	6.00	dark gray	fresh	film	pl 5%; hb +/-
HPD#1025-R17	16	50.533	145	52.125	838	porphyritic basalt	subangular	20	11	12	2.98	black	fresh	film	ol 5%; cpx 10%; pl 15%

glass	vesiculation	Memo	
	pale clasts weakly 15%; black clasts weakly	rounded pale clasts (px; fp); dark matrix	HPD#1025-R01
altered 10 mm	strongly 45%	ol < 1mm; cpx < 3mm; pl < 8mm, most < 3mm; vesiculated interior; concentric fractures	HPD#1025-R02
altered glassy rim 1mm	strongly 50%		HPD#1025-R03
		basalt clast (-> pl, px, vesiculated strongly)	HPD#1025-R04
		basaltic clasts (-> pl, px, strongly vesiculated < 50%), Mn clasts, matrix up to a few mm in size	HPD#1025-R05
oxidized 1mm	strongly 40%		HPD#1025-R06
possible rim	moderately 25%	ol < 1mm; cpx < 3mm; pl <5 mm; variably vesiculated	HPD#1025-R07
outer altered, inner fresh looking 5mm	strongly 45%	ol < 1mm; cpx < 3mm; pl < 5mm	HPD#1025-R08
		mafic minerals replaced by oxides, including haematite	HPD#1025-R09
	weakly <5%	2mm oxidation rim	HPD#1025-R10
		ol < 1-2mm; cpx < 2-3mm; pl < 5mm	HPD#1025-R11
		completely oxidized, rusted	HPD#1025-R12
altered glass 2mm	weakly 10%	cpx < 5mm, mostly < 2mm; fp < 3mm; concentric fractures	HPD#1025-R13
		oxidation rim 2-3mm; phenocrysts < 1mm	HPD#1025-R14
	weakly <5%	sub-parallel interrupted fracturing - vugs along planes - dendritic mineral growing onto rock along fracture planes -> MnO	HPD#1025-R15
			HPD#1025-R16
	moderaltely 20%	oxidation rim; px < 5 mm, most < 1mm; ol < 1mm; pl < 3mm	HPD#1025-R17

HPD#1026 Jun. 21 2009 NW Zealandia

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#1026-R01	16	58.400	145	42.643	662	basaltic andesite	subangular	27	15	12	8.20	black	weakly altered	
HPD#1026-R02	16	58.433	145	42.639	652	dacite	subangular	15	14	10	3.40	gray	fresh	film
HPD#1026-R03	16	58.435	145	42.638	652	diorite (intrusive)	subrounded	20	17	12	4.00	mottled gray	fresh	film
HPD#1026-R04	16	58.527	145	42.635	634	dacite with dacitic enclaves (xenoliths)	subangular	30	17	15	7.40	gray	weakly altered	film
HPD#1026-R05	16	58.537	145	42.638	632	hornblende pumice	subrounded	15	13	9	1.00	white (dark area)	moderately altered	film
HPD#1026-R06	16	58.546	145	42.639	630	hornblende pumice	subrounded	18	14	12	1.10	white (gray stained interior)	moderately altered	up to 2mm
HPD#1026-R07	16	58.561	145	42.642	627	hornblende andesite	angular	21	14	10	3.40	gray	weakly altered	< 2mm
HPD#1026-R08	16	58.574	145	42.648	621	andesite with dark band	subangular	20	12	5	1.60	dark gray with black layer (~ 30 mm thick)	weakly altered	film
HPD#1026-R09	16	58.574	145	42.648	621	pumiceous hornblende rhyolite	subrounded	15	9	8	0.60	white	weakly altered	film
HPD#1026-R10	16	58.574	145	42.648	621	hornblende dacite with mafic enclaves	subrounded	34	23	18	12.50	gray	moderately altered	film
HPD#1026-R11	16	58.583	145	42.653	616	dacite with mafic enclaves	subangular	22	13	12	3.60	gray	fresh	film
HPD#1026-R12	16	58.599	145	42.668	602	andesite	subrounded	29	21	18	10.50	gray	fresh	film
HPD#1026-R13	16	58.626	145	42.688	578	dacite	subangular	30	23	17	9.60	gray	weakly altered	film
HPD#1026-R14	16	58.642	145	42.699	559	dacite	subangular	31	22	17	15.50	gray	fresh	film
HPD#1026-R15	16	58.661	145	42.718	536	hornblende dacite	angular	25	17	15	4.50	gray	weakly altered	film
HPD#1026-R16	16	58.665	145	42.722	527	andesite	subrounded	21	18	15	4.80	gray	weakly altered	film
HPD#1026-R17	16	58.671	145	42.729	517	banded hornblende dacite	angular	38	25	18	13.00	gray with darker	moderately altered	film
HPD#1026-R18	16	58.679	145	42.733	489	dacite with mafic enclaves	subangular	32	23	31	35.00	gray	weakly altered	film
HPD#1026-R19	16	58.689	145	42.738	473	plagioclase-pyroxene basalt	subangular	34	17	15	17.00	black	fresh	
HPD#1026-R20	16	58.689	145	42.738	473	vesicular dacite	subangular	34	20	19	10.50	gray	moderately altered	film
HPD#1020-C01	16	58.469	145	42.637	647	muddy sand					1.40	brown		

phenocrysts	glass	vesiculation	Memo	
pl 25%		weakly 10%	fp < 10mm	HPD#1026-R01
px 5%; fp 15%; hb 5%		weakly <5%	fp < 5mm; px < 10mm; hb < 2mm	HPD#1026-R02
px 10%; fp 10%			qz veining	HPD#1026-R03
px 5%; fp 10%; hb 5%		weakly; enclaves strongly 40-50%	fp < 10mm, most 1-2mm; enclaves -> chilled margin in host rock surrounds them; highly vesiculated 40-50%; 10% hb, fp 5% (one fp 5mm, mostly < 1mm); other than vesiculation looks similar to host rock	HPD#1026-R04
fp 5%; hb 10%; qz 5%	glassy matrix	strongly 50%	black patch -> Mn coating; hb -> fresh; rock fresh away from interior	HPD#1026-R05
fp 10%; hb 10%; qz 10%	glassy matrix	strongly 45%	white rim; gray stained interior (most of boulder volume), Mn getting into boulder; hb < 2mm; fp 2-3mm; qz 1 mm	HPD#1026-R06
fp 15%; hb 10%		weakly <5%	concentric banding	HPD#1026-R07
fp 15%; px < 1%		weakly 10%	dark layer: just fp 15%, px <1%; color change caused by change in composition/grain size of matrix? don't think its alteration	HPD#1026-R08
fp 10%; hb 15%; qz 10%	matrix	moderately 20%		HPD#1026-R09
fp 10%; hb 10%		moderately 15%	fp < 4mm; hb < 3mm; orange staining; fine-grained mafic enclaves, dark gray, vesiculated, < 10mm	HPD#1026-R10
fp 10%; px 10%		moderately 15%	fp < 2mm; px clots < 3mm; mafic enclaves < 5mm	HPD#1026-R11
fp 20%; px 5%		moderately 25%	fp < 5mm, most 2-3mm; px < 1mm; patchy vesiculation; vesiculated outer rim	HPD#1026-R12
fp 15%; px 5%		moderately 20%	fp < 2mm; px < 1mm; textural banding, due to vesiculation; enclaves, denser area	HPD#1026-R13
fp 10%; hb 10%		weakly 10%	fp < 4mm; hbl < 3mm	HPD#1026-R14
fp 10%; px 10%; hb		weakly 10%	fp < 2mm; px < 5mm; hb < 1mm	HPD#1026-R15
fp 10%; px 5%		moderately 20%	fp < 5mm; px < 1mm	HPD#1026-R16
fp 10%; px 5%; hb		weakly <5%	swirly banding; alignment amongst hb; fp < 5mm; hb < 4mm; px < 2mm; oxidation coloration throughout	HPD#1026-R17
fp 10%; hb 10%; qz 5%		weakly 10%	fp < 3mm; hb < 2mm; qz < 1mm; indistinct flow layering; mafic enclaves, 3-10mm, black (contain pl), vesiculated; oxidation rim 2mm	HPD#1026-R18
px 10%; pl 10%	1mm	moderately 15%	px < 2mm; pl < 2mm	HPD#1026-R19
px 5%; fp 10%		moderately 35%	becomes more vesiculated (pumiceous) to outer rim	HPD#1026-R20
			some pebbles -> black; subrounded to subangular; clasts: spherical carbonate, fp, black	HPD#1020-C01

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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#1027-R01	16	55.690	145	41.638	1392	porphyritic olivine basalt	subangular	23	14	5	3.50	black	fresh	film
HPD#1027-R02	16	55.662	145	41.625	1363	altered pumice	subrounded	13	11	10	0.80	orangey gray	altered	film
HPD#1027-R03	16	55.655	145	41.627	1359	pumice	subangular	19	16	8	1.90	gray	weakly altered	
HPD#1027-R04	16	55.646	145	41.622	1350	basalt with olivine clots	subangular	45	19	12	13.00	black	weakly altered	film
HPD#1027-R05	16	55.632	145	41.625	1337	porphyritic olivine basalt	subangular	17	16	10	2.72	black	moderately altered	none
HPD#1027-R06	16	55.623	145	41.622	1327	volcaniclastic breccia	subangular	13	7	4	0.35	black	moderately altered	film
HPD#1027-R07	16	55.600	145	41.622	1307	porphyritic olivine basalt	subangular	25	17	8	4.00	black	weakly altered	none
HPD#1027-R08	16	55.569	145	41.629	1282	basaltic pillowy lobe	subrounded	27	9	8	2.94	black	moderately altered	film
HPD#1027-R09	16	55.566	145	41.631	1277	basalt	subangular	14	11	7	1.10	black	moderately altered	film
HPD#1027-R10	16	55.564	145	41.630	1268	altered basalt	subrounded	8	6	5	0.26	black	altered	2 mm
HPD#1027-R11	16	55.550	145	41.629	1256	basaltic breccia	subangular	32	21	10	8.00	black	moderately altered	1mm
HPD#1027-R12	16	55.540	145	41.643	1247	basalt	subangular	12	6	6	0.80	black	fresh	2mm
HPD#1027-R13	16	55.540	145	41.643	1248	basalt	subrounded	13	10	10	2.00	black	fresh	<5mm
HPD#1027-R14	16	55.483	145	41.655	1196	porphyritic basalt	subrounded	10	10	8	1.00	black	moderately altered	<2mm
HPD#1027-R15	16	55.413	145	41.677	1135	volcaniclastic breccia	subangular	7	9	3	0.10	black	moderately altered	3mm

phenocrysts	glass	vesiculation	Memo	
ol 10%; cpx 10%; pl 15%		moderately 25%	pl < 10mm; ol < 3mm clusters; cpx < 5mm clusters	HPD#1027-R01
px 5%; fp 5%; qz 5%	matrix	strongly 55%	phenocrysts < 1mm	HPD#1027-R02
px 5%; fp 5%; qz 5%	matrix	strongly 45%	px < 2mm; fp < 2mm; qz < 1mm; oxidized surface	HPD#1027-R03
ol 20%; cpx 10%; pl 10%		moderately 25%	ol 1mm, occurs in clots up to 25mm in length, with 1mm ol, also scattered in remaining matrix; pl < 5mm; cpx < 3mm	HPD#1027-R04
	< 1mm	moderately 20%	ol clusters up to 3mm; cpx < 5mm; pl < 5mm; alteration along cracks, chilled margin appears altered	HPD#1027-R05
		none	oxidized in places; ol in matrix; sand size matrix cementing larger clasts together; cm-sized basaltic clasts (ol, cpx, pl), vesiculated; polymictic	HPD#1027-R06
ol 10%; cpx 10%; pl 15%	< 1mm	moderately 20%	chilled margin ~5mm, altered to orange within 2mm of outer surface; concentric fracturing parallel to cooling surface; ol < 5mm; cpx < 5mm; pl < 5mm	HPD#1027-R07
ol 5%; cpx 10%; pl 10%	possibly altered hyaloclastite	moderately 15%	ol altered < 2mm; cpx < 4mm; 1 fp 10 mm, most < 4mm; chiiled margin; concentric fracture; altered hyaloclastite on exterior surface	HPD#1027-R08
ol 2%; px 2%; pl 10%		moderately 30%	pl <5mm; ol <1mm; px clustered; chilled margin appears to be altered	HPD#1027-R09
ol 5%; px 5%; pl 10:		moderately 20%	pl <3mm; ol <,= 1mm; px few 5mm, most <2	HPD#1027-R10
			clast supported, up to 50mm, basaltic. Clasts: pl 15% <5mm; px 10% <5mm	HPD#1027-R11
px 5%; pl 10%		weakly 10%	pl <3mm; px <1mm; chilled margin looks altered	HPD#1027-R12
px 5%; pl 5%		moderately 30%	pl <2mm; px <2mm; fresh interior, altered exterior; chilled margin	HPD#1027-R13
ol 10%; px 10%; pl 20%		weakly 5%	pl <5mm; ol clusters <3mm, ol grains <,=1mm	HPD#1027-R14
			grains <1mm, including Mn	HPD#1027-R15