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Cruise Report SONNE 167
LOUISVILLE

Louisville Ridge: Dynamics and Magmatism of a Mantle Plume and its Influence on the Tonga – Kermadec Subduction System

Louisville Rücken: Dynamik und Magmatismus eines Mantelplumes und sein Einfluß auf die Tonga – Kermadec Subduktionszone

Suva, Fiji – Wellington, New Zealand
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FS *SONNE* in front of 'Ata Island (courtesy of S. Fretzdorff)

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TABLE OF CONTENTS

List of Figures **Page**

List of Tables **Page**

List of Appendices **No. of Pages**

1. SUMMARY

Cruise SO 167 of the FS *SONNE* visited the south Tonga volcanic arc, Valu Fa Ridge, South Fiji Basin, Osbourn Trough and Louisville Ridge (Figs. 1.1, 1.2). Key objectives of this program were to provide the first "ground truth" concerning the south Tonga arc, to locate the geochemical signature of the subducting Louisville Ridge within the arc, to examine the relationship between tectonic, magmatic and hydrothermal processes on Valu Fa Ridge, document any changes in hydrothermal venting at the Vai Lili and Hine Hina sites on Valu Fa Ridge since 1989, establish the origin and age of Osbourn Trough, to determine the age of the bend on the Louisville Ridge, and to provide the first geochemical characteristion of the Louisville Ridge. A total of 176 stations were completed, comprising 130 dredge stations, 9 TV-grab stations, 8 OFOS stations, and 29 plankton net stations. Sea conditions were good, and there were no significant problems with either the ship or shipboard equipment.

Only one long-dormant volcano ('Ata Island) was known to exist in the 650 km segment of the Tonga–Kermadec arc between the subaerial Hunga and submarine Monowai volcanoes before SO 167. It had been proposed that this "volcanic gap" was a consequence of Louisville Ridge subduction. Instead, 27 major arc volcanoes were discovered during SO 167 and define a continuous volcanic front. Most have diameters of 10–25 km and summits that are 1000–2000 m above the seafloor; the majority occur as pairs of closely spaced stratocones. Eight calderas were discovered and are associated with widespread voluminous deposits of aphyric pumice. Resurgent volcanism at these calderas can be basaltic or dacitic. Two key findings of the south Tonga arc program were:

1) A remarkable cluster of 14 major volcanic edifices occurs near 'Ata. The eastern volcanoes are degraded, with flat heavily sedimented summits and have been inactive since ~150 ka. In contrast, the western volcanoes are steep-sided active stratocones from which fresh lavas were dredged. This volcanic complex directly overlies a projection of the subducting Louisville Ridge into the subduction system, suggesting subduction of the relatively buoyant seamount chain caused a westward migration and increase in volcanism.
2) Deep, diatreme-like craters up to 1130 m-deep were discovered on three southern volcanoes. Lack of slumping on the inner crater walls suggests these extremely violent eruptions took place recently (<10 ka). These volcanoes overlie a projection of the Osbourn Trough into the subduction system. Dehydration of serpentinitised mantle lenses along the trough axis may have triggered these extreme eruptions.

A total of 55 dredge stations recovered 416 samples from which 191 were prepared for detailed geochemical work. The analytical results will enable modelling of element re-

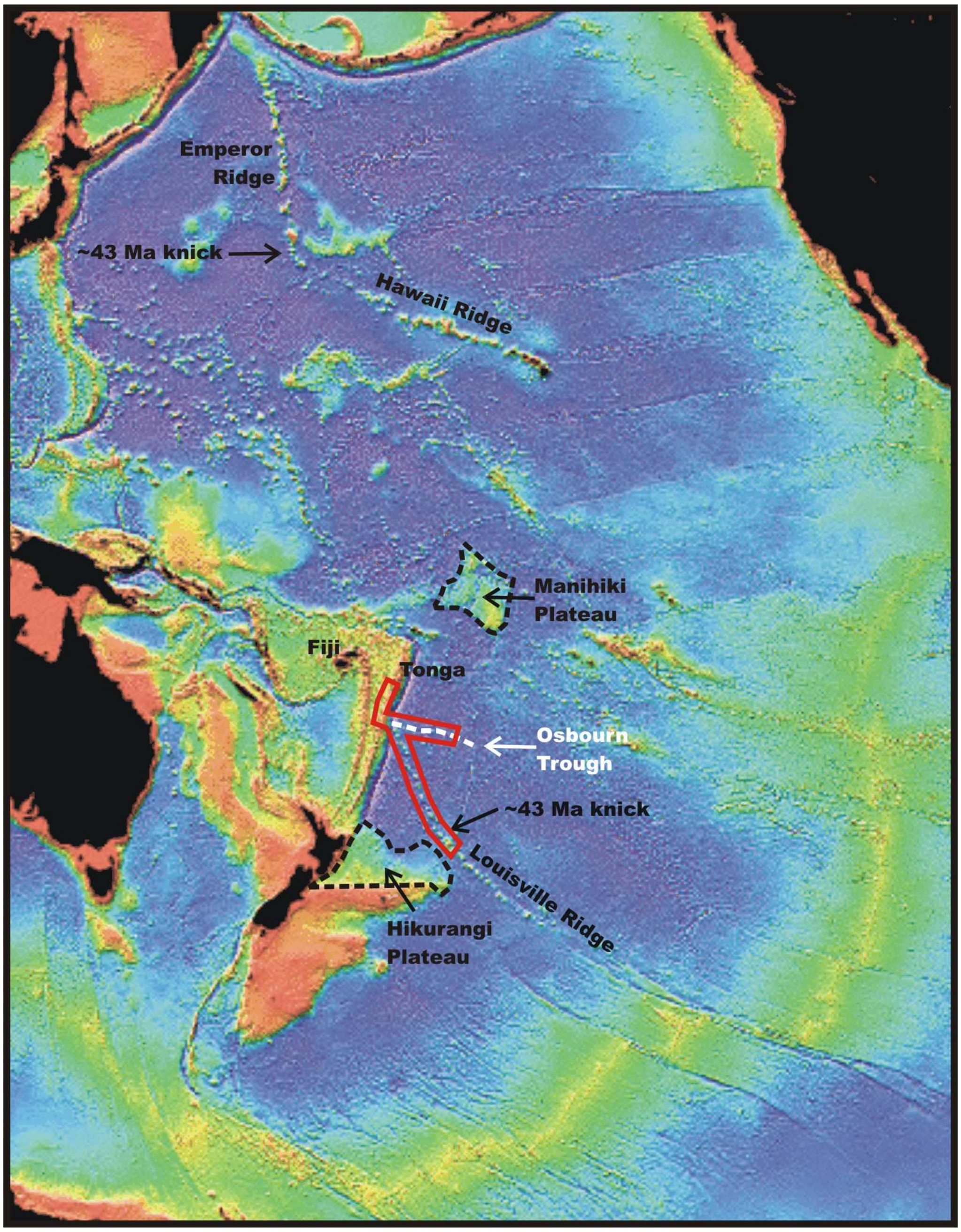

Fig. 1.1: Overview of the SO 167 work area in the SW Pacific.

cycling and mass transfer along this segment of the arc, the genetic relationship between basaltic and dacitic magmas, and the location and character of material derived from the subducting Louisville Ridge and Osbourn Trough within the subduction system.

Hydrothermal investigations during SO 167 concentrated on the southern end of Valu Fa Ridge. Major objectives were to document recent tectonic and magmatic processes in order to assess differences in hydrothermal signatures and mineralisation between the volcanic front and the proximal back-arc, to establish the relationship between hydrothermal activity and rift propagation, to determine changes in the status and extent of hydrothermal venting at the Vai Lili and Hine Hina fields since they were last visited in 1989, and to describe vent communities at the Vai Lili and Hine Hina sites.

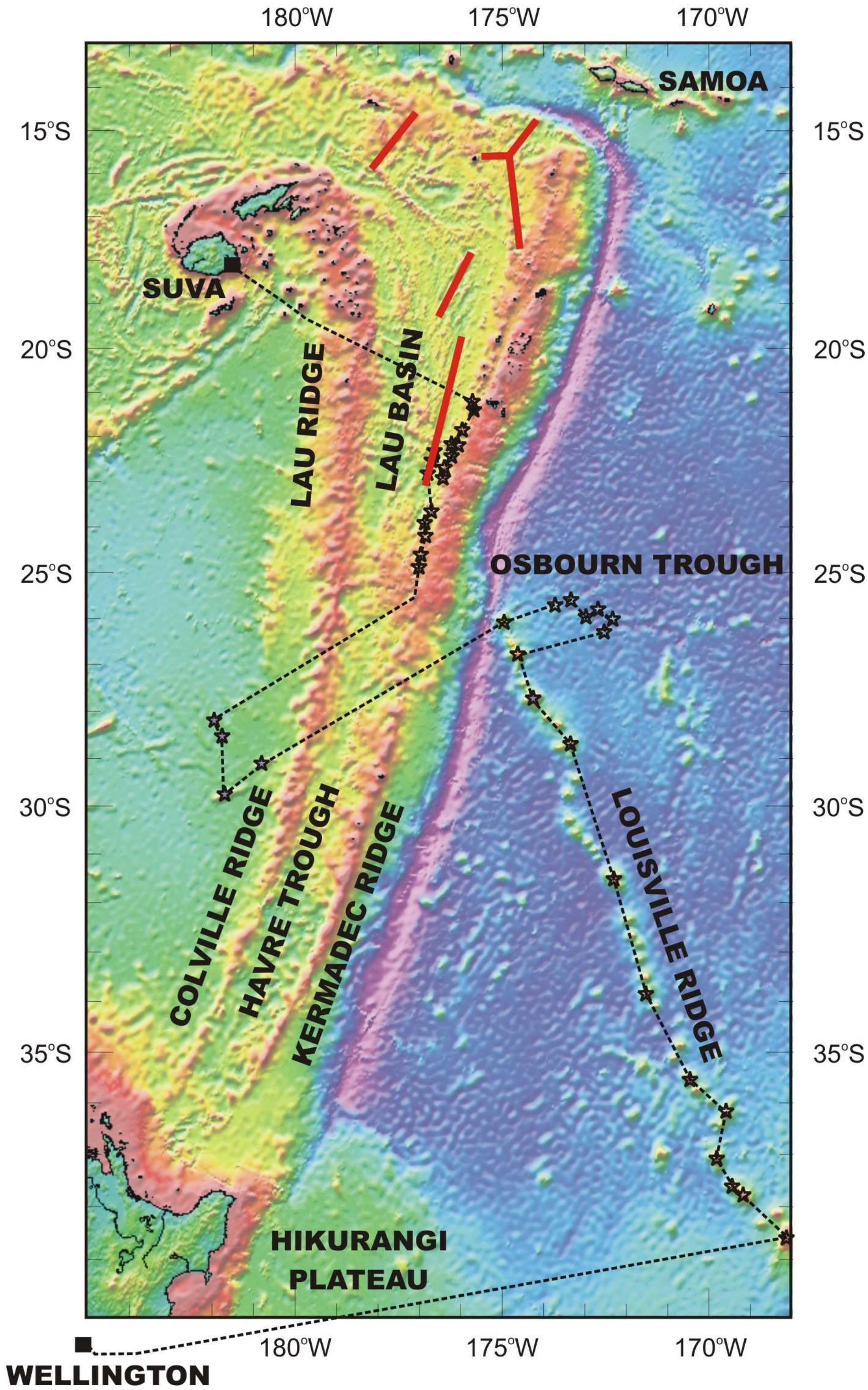

Fig. 1.2: Work stations of the SO 167 cruise. The cruise began in Suva and ended in Wellington. Stations are shown as black stars. Red lines are active spreading centres within the Lau Basin

Mapping revealed that all Valu Fa Ridge segments are left-stepping and that active southward propagation and fast spreading rates have resulted in rapid structural, volcanic and hydrothermal evolution. Hydrothermal activity, and the most recent volcanic activity, is associated with off-axis structures and/or volcanic edifices and concentrated on recent, west-facing structures on the western side of the ridge segments. At Vai Lili, dead colonies of hydrothermal vent fauna, single oxidized chimneys, and the disappearance of vigorously active smokers indicate hydrothermal activity has changed dramatically since 1989 in response to partial burial of the field by andesitic lobate flows. Altered and mineralized volcanic clasts in the “aa-type” lava attest to earlier hydrothermal discharges and suggest the possibility of stratigraphically stacked mineralization. However, continuing low-temperature diffuse hydrothermal activity is indicated by thermal anomalies in the water column. In contrast, the Hine Hina field was found to be larger than in 1989, although with no significant change in the style of low-temperature, diffuse hydrothermal activity. Clasts of altered and mineralized basalt were observed resting on volcanic sand, sulfide chimneys on lobate flows and partly buried by sand, thick Fe-Mn oxyhydroxide crusts on black sand, thermal anomalies in the water column, shimmering water and white-yellow biological mats. In addition, evidence of hydrothermal activity at south Tonga arc volcanoes was discovered. These sites were either associated with calderas or craters, and the style of mineralization coupled with the shallow water depth suggests potential for epithermal-style Au mineralization.

The Osbourn Trough is a 900 km-long linear feature that trends east–west across the Pacific Plate from its intersection with the Tonga–Kermadec Trench near 25°30'S. A key objective of SO 167 was to resolve the origin of this structure. A detailed bathymetric survey was completed across an area 145 km-long by 120 km-wide, and provides compelling evidence that it is a paleo-spreading centre whose morphology is remarkably similar to that of the mid-Atlantic Ridge at 35°N. The trough consists of ~50 km-long parallel segments offset by 15–25 km non-transform discontinuities, and has a 10–15 km-wide axial valley bounded by 300–700 m-high ridges. Corner highs rise up to 1000 m above the axial floor on two segments, and a series of parallel rifted or abandoned ridge segments occur north and south of the trough. Ten dredge stations returned 80 samples, of which 35 were prepared for analytical work to determine the age and composition of oceanic crust generated at the trough. Most samples were subangular boulders of olivine-plagioclase basalt, aphyric basalt and plagioclase basalt set in a clay matrix and thickly encrusted by FeMnOx. Gabbro and small serpentinite pebbles were common in dredges on the flanks of the corner highs. The thick FeMnOx crusts (up to 11 cm) are consistent with a cessation of spreading at >80 Ma.

The Louisville Ridge consists of large seamounts forming NW–SE segments linked by shorter NE–SW segments. The NE–SW segments share the same orientation as the non-transform discontinuities at Osbourn Trough, and represent zones of lithospheric weakness exploited by the Louisville plume. Eleven major seamounts, encompassing the area from Osbourn Seamount (at the Tonga–Kermadec Trench) to the bend, were surveyed and sampled. All were flat-topped guyots, with thick summit deposits of foram-bearing sandstone and drowned coral reefs. Volcano 39, at the bend, comprises two major edifices linked by a long broad flat-topped ridge. This unusual morphology and greater volume of lava suggests temporary slowing of the Pacific Plate accompanied the change in plate motion. A total of 39 dredge stations were completed on the headscarps of slump structures. These returned 226 samples of which 97 were prepared for analytical work. The predominant lithologies were highly vesicular olivine basalt and aphyric basalt, with moderate degrees of marine weathering (all olivine is pseudomorphed by iddingsite). Age determinations by the Ar/Ar technique will establish the age of the bend and Pacific Plate velocity from 70–40 Ma. Geochemical analyses will allow the first characterisation of the Louisville plume, constrain the nature of any Louisville-derived component in the south Tonga arc, and will be examined in detail to look for possible plume–ridge interactions between the Louisville plume and Osbourn Trough.

2. ACKNOWLEDGEMENTS

We thank Captain Martin Kull, his officers and the crew onboard FS *SONNE* for their expert help and advice. The inevitable "wear and tear" problems with the dredges, winches, TV-grab and OFOS were quickly and efficiently repaired, and had no significant effects on our program. It is noteworthy that both the TV-grab and OFOS operated without any significant problems during a 7 day period of intensive use. Sea and weather conditions were generally good throughout the cruise. Nevertheless, maintaining shipboard harmony, safety standards, enthusiasm and high efficiency throughout a 7 week-long cruise is not an easy undertaking. This was particularly important for SO 167, as some of the most important work stations were located near the end of the cruise. At all times potential difficulties were resolved calmly and professionally by the Captain, officers and crew. Onboard harmony is attested to by the high-level of participation (officers, crew and scientists) in the table tennis tournament and social events organised during transit periods.
We would also like to express our gratitude to the Captain, officers and crew for their forbearance and assistance with the official receptions and the highly successful public open day held in Wellington at the end of the cruise. This is no mean feat at the end of such a long cruise, and requires considerable care in planning.

Thanks are also due to the shipping agents in Suva (John Wong; Carpenters Shipping) and Wellington (Morris van Voornveld; Adsteam Agency) for their assistance with our logistic and travel arrangements. We particularly appreciated the efforts and co-operation of Tevita Malolo (Ministry Lands, Survey and Natural Resources; Nuku'alofa), Hua Latu (Yarnton Shipping Agency, Nuku'alofa), and Guido Heymer (German Ambassador, Wellington) in arranging for one of the officers to disembark suddenly and unexpectedly in Nuku'alofa to attend to family difficulties in Germany. We are sure both he and his young family were much comforted by their actions.

We thank the Kingdom of Tonga for permission to work within their territorial waters along the south Tonga arc and Valu Fa Ridge, and to land on 'Ata Island. Aerial photographs provided by the Ministry of Lands, Survey and Natural Resources significantly helped with the landing, mapping and sampling on 'Ata. We also thank the New Zealand Government for permission to work within their territorial waters in the South Fiji Basin.

The LOUISVILLE project is funded by a Bundesministerium für Bildung und Forschung (BMBF) project award to Prof. Peter Stoffers and Prof. Peter Herzig (03G0167A).

3. PARTICIPANTS

LOUISVILLE is a multidisciplinary international project led by the University of Kiel (Institute of Geosciences) and the Technical University of Freiberg (Institute of Mineralogy). Other participating research groups are the Ministry of Lands, Survey and Natural Resources (Kingdom of Tonga), the Senckenberg Research Institute (Germany), the National Institute of Water and Atmospheric Research (New Zealand), Laurentian University (Canada) and the University of Toronto (Canada). The 19 scientists in the Shipboard Scientific Party have diverse interests spanning the fields of petrology, mineralogy, geochemistry, economic geology, biology and tectonics. Full contact details for the shipboard scientists are listed in Appendix 1.

Shipboard Scientific Party:

Stoffers, Prof. Dr. Peter	Chief Scientist, PI	IfG-Kiel	Petrology
Worthington, Dr. Tim	Co-Chief Scientist	IfG-Kiel	Petrology/Geochemistry
Ackermand, Dr. Dietrich		IfG-Kiel	Mineralogy
Beaudoin, Yannick		Uni Toronto	Economic Geology
Bigalke, Nikolaus		IfG-Kiel	Petrology
Fretzdorff, Dr. Susanne		IfG-Kiel	Petrology/Geochemistry
Gibson, Prof. Harold		Laurentian Uni	Economic Geology
Hekinian, Dr. Roger		IfG-Kiel	Petrology/Tectonics
Kindermann, Andreas		IfM-Freiberg	Economic Geology
Kuhn, Dr. Thomas		IfM-Freiberg	Economic Geology
Main, Bill		NIWA	Biology
Schreiber, Kerstin		IfM-Freiberg	Economic Geology
Schwarz-Schampera, Dr. Uli		IfM-Freiberg	Economic Geology
Timm, Christian		IfG-Kiel	Petrology
Tonga'onevai, Sisi		Min Lands Surv	Geology
Türkay, Dr. Michael		Senckenberg	Biology
Unverricht, Daniel		IfG-Kiel	Geomorphology
Vailea, 'Akapei		Min Lands Surv	Geology
Zimmerer, Markus		IfG-Kiel	Petrology

Ship's Officers and Crew:

Kull, Martin	Captain		
Löffler, Jörn	1st Officer	Guzman, Werner	Chief Engin.
Göldner, Frank	1st Officer	Klinder, Klaus	2nd Engineer
Kowitz, Torsten	1st Officer	Lindhorst, Norman	2nd Engineer
Hoffman, Hilmar	Chief Electr. Engineer	Rieper, Uwe	Electrician
Rottkemper, Oliver	Electronic Engineer	Rademacher, Hermann	Motorman
Stammer, Kurt	Systems Manager	Lange, Gerhard	Motorman
Grossman, Mathias	Systems Manager	Zeitz, Holger	Seaman
Beiersdorf, Hans-Hein.	Doctor	Dehnke, Dirk	Seaman
Wieden, Wilhelm	Chief Cook	Gieske, Ralf	Seaman
Braatz, Willy	2nd Cook	Rosemeyer, Rainer	Fitter
Lohmüller, Karl-Heinz	Boatsman	Wege, Andreas	Chief Steward
Ventz, Günther	Matrose	Hoppe, Jan	2nd Steward
Schachel, Dirk	Matrose	Baumgärtel, Anja	2nd Steward
Stängel, Günther	Matrose	v. Berg, Götz	Matrose
Bosselmann, Norbert	Matrose		

4. CRUISE NARRATIVE

The Shipboard Scientific Party boarded the FS *SONNE* in Suva at 09:30 on 12 October. The container and other equipment, which had already been taken aboard on 11 October, were unpacked during the afternoon. A 4 hour tour of Suva for interested members of the scientific party and crew was kindly arranged by the ship's agent (Carpenters Shipping) for the afternoon. An introductory meeting of the Shipboard Scientific Party was held in the Conference Room at 10:20 on 13 October, and the FS *SONNE* left its berth in Suva at 11:00. Sea conditions were moderate, with a gentle 1–2 m swell and mostly blue skies.

The first work station (Volcano 1) on the south Tonga arc was reached during the afternoon of 14 October. The SIMRAD CTD-probe was deployed to calibrate the SIMRAD system, followed by the start of the mapping program. The first dredge took place the following day and recovered a large volume of fresh lava, thereby getting the cruise off to an excellent start. During the next week, the ship worked progressively southwards from Volcano 1 to Volcano 8 along the south Tonga arc and SIMRAD mapping alternated with rock dredging. Many of these previously unsurveyed volcanoes have summits within 100 m of sea level; in consequence, mapping was completed during daylight hours when possible rock pinnacles or reefs could be sighted. Our new surveys confirm that only 'Ata Island and Pelorus Reef (Volcano 8) presently pose any hazard to shipping. Highlights of this interval included two scientists (Tim Worthington, Sisi Tonga'onevai) landing on 'Ata Island during the afternoon of 18 October for 2 hours of mapping and sampling while the ship circled the island at close range, and mapping of Pelorus Reef (Volcano 8) during the late afternoon of 21 October (although the sea was anomalously calm along the trace of the reef, the reef was found to be no shallower than 35 mbsl). Sea conditions remained slight to moderate (swells <2 m) and conditions pleasant (~25 °C, clear skies).

A 3 hour westward transit to Valu Fa Ridge took place early in the morning of 22 October, and was followed by a 24 hour mapping program. The first station of the hydrothermal program on Valu Fa Ridge, a TV-grab at the Vai Lili field (44-GTV), commenced at dawn on 23 October. A combination of TV-grab, OFOS and dredge stations combined with further mapping continued until the Valu Fa program was completed, late on the evening of 28 October.

The scientific program was then interrupted and the ship sailed at top speed for Nuku'alofa, as one of the ship's officers needed to return to Germany urgently to attend to difficulties surrounding the birth of his daughter. FS *SONNE* reached the pilot station at Nuku'alofa during the morning of 29 October and, after disembarking the officer, sailed southwards at noon to resume the scientific program. This unexpected interruption to the program was put to good use, with the southwards transit designed to fill gaps in the bathymetric coverage of Volcanoes 1–8 and to better define their extent. One new volcano and two satellite cones were discovered during this transit.

Work on the south Tonga arc (Volcano 14) re-commenced at dawn on 30 October. As before, mapping and dredge sampling alternated and the ship progressively worked southwards along the volcanic arc. The last and southernmost arc stations (Volcanoes 21–22) proved to be tectonic ridges, in marked contrast to the preceeding stations where many more volcanoes than expected were discovered and sampled. The arc program then terminated and the ship commenced a 30 hour SW transit to the South Fiji Basin during the late morning of 3 November.

The first station in the South Fiji Basin (LINZ area) was reached in the early afternoon of 4 November. Each of the four LINZ stations was mapped, but dredging proved difficult and considerably more time than expected was required in order to achieve sample recovery. An OFOS station at the end of this program confirmed suspicions that the seamounts were covered by thick Fe-Mn oxyhydroxides and sediments. The LINZ program was completed at noon on 7 November, and the ship began a further 30 hour transit heading NE to Osbourn Seamount.

Our arrival at Osbourn Seamount during the evening of 8 November was followed by two deployments of the SIMRAD CTD-probe in order to re-calibrate the SIMRAD system (a malfunction occurred during the first attempt). Partial mapping and dredge sampling of Osbourn Seamount was completed just before midnight on 9 November, and the ship then headed east to Osbourn Trough. The area previously mapped by a US cruise was reached on the morning of 10 November. Thereafter, mapping of Segments 1, 2 and 3 of the trough alternated with dredging in 5 km-deep water at six inner corner highs. Continued calm seas and fine weather assisted these unusually deep dredge stations. However, obtaining fresh lavas again proved difficult due to extremely thick (10 cm) Fe-Mn oxyhydroxide crusts and thick sediment. The Osbourn Trough program was completed late in the morning of 15 November, and the ship then transited SW to rejoin the Louisville Ridge south of Osbourn Seamount.

The final phase of the scientific program involved partial mapping and dredge sampling of selected seamounts along the Louisville Ridge. The ship progressively worked to the SW along the seamount chain from the evening of 15 November until the morning of 26 November. Attempts to deploy the SIMRAD CTD-probe on 20 and 21 November resulted in further malfunctions, and the ship's CTD was successfully substituted for this task. Dredging proved difficult, with the dredge often becoming stuck and sample recovery being poor and often consisting of deeply weathered material. These difficulties were anticipated and overcome by careful targetting of the dredge stations and persistance. Despite the increasing latitude, sea conditions remained moderate and the weather fine, although the temperature slowly decreased. The Louisville Ridge program was completed at 10:00 on 26 November and FS *SONNE* then sailed for Wellington. Three further plankton nets were undertaken during the 3 day transit. All samples and equipment were packed into the container ready for offloading in port, and a series of posters and display specimens were prepared for the forthcoming receptions and open day. Unfortunately weather conditions at Wellington were not so good, with calm seas but dense fog enveloping the harbour approaches and city as the ship approached the pilot station shortly before noon on 29 November. FS *SONNE* docked at the Overseas Passenger Terminal at 13:00, and the scientific party progressively disembarked over the next 3 days.

Wellington turned on two exceptional calm days with blue skies for the weekend engagements. An official reception for ~40 invited guests from various New Zealand science organisations, including NIWA, GNS and LINZ, together with port officials and representatives from the German Embassy was held on the backdeck on Saturday 30 November from 15:00–17:00. A second reception to celebrate ongoing German–New Zealand scientific collaboration was held at the nearby NIWA offices that evening and attended by ~100 guests. The FS *SONNE* was open to the Wellington public as part of the German "Year of Geoscience" on Sunday 1 December from 10:00–15:00. Approximately 400 people boarded the ship for a 40 minute guided tour featuring the scientific equipment, rock samples, videos of the seafloor, posters explaining the key aims and findings of the cruise, and a walk through the labs, cabins and ship's bridge. The German Embassy organised a further onboard function for invited guests that evening. The ship transferred to the commercial part of Wellington Harbour at 08:00 on Monday 2 December for bunkering and offloading of the container, and sailed for Sydney on Tuesday 3 December.

5. STRUCTURE AND PETROLOGY OF THE SOUTH TONGA ARC

Tim Worthington, Peter Stoffers, Roger Hekinian, Dietrich Ackermand, Nikolaus Bigalke, Christian Timm, Sisi Tonga'onevai, Daniel Unverricht, 'Akapei Vailea, Markus Zimmerer

5.1. Objectives of the South Tonga Arc Petrology Program

Recent studies of the Tonga–Kermadec arc suggested that the geochemical signature of volcaniclastic sediments derived from the Louisville Ridge was present in lavas erupted from the northernmost Tonga volcanoes (Turner et al., 1997; Wendt et al., 1997; Turner and Hawkesworth, 1997; Regelous et al., 1997; Turner and Hawkesworth, 1998; Ewart et al., 1998). The Louisville Ridge was subducted at the northern Tonga Trench at ~4 Ma, and at the subduction rate prevailing near the northern Tonga Trench (~20 cm per year) any Louisville Ridge-derived material should have reached the sub-arc magma generation zone beneath northernmost Tonga at ~3 Ma. However, the Louisville signature is claimed to be present in the very young (<10 ka) lavas of these northernmost Tongan volcanoes (Turner et al., 1997; Turner and Hawkesworth, 1998). This interpretation is of profound significance; it suggests that either the sub-arc mantle convection rate is very much slower than the subduction rate or that sediment resides in the non-convecting lithospheric mantle for long periods before sinking further and entering the sub-arc magma generation zone (Turner and Hawkesworth, 1998).

Two independent follow-up studies have visited the northern Tonga volcanoes. Both groups used high-precision geochemical analyses combined with an extensive set of Sr-Nd-Pb-Hf isotope analyses from >50 stratigraphically-controlled lavas to demonstrate that the geochemical signature present in northern Tonga arc lavas is far more consistent with that of the nearby Samoan plume and not, as previously claimed, the subducting Louisville Ridge (Worthington et al., in prep.). A conclusive result is hampered by the paucity of geochemical analyses from both the Louisville Ridge and Samoa. This raises the question, can the Louisville Ridge signature be found elsewhere along the Tonga–Kermadec arc?

The existing geochemical database for central Tonga volcanoes shows no evidence of any Louisville Ridge signature (e.g., Turner et al., 1997; Ewart et al., 1998). Neither have the results of an ongoing detailed stratigraphic and geochemical study of the subaerial central Tonga volcanoes (Tofua, Kao, Late and Fonualei; Worthington et al., in prep.). However, the most logical place to look is the south Tonga arc, which overlies the present location of the Louisville Ridge within the subduction system (Fig. 5.1). Furthermore, the Osbourn Trough is subducting immediately to the south of this area, raising the possibility of locating not only the geochemical signature of the Louisville Ridge in the south Tonga arc but also that of Osbourn Trough.

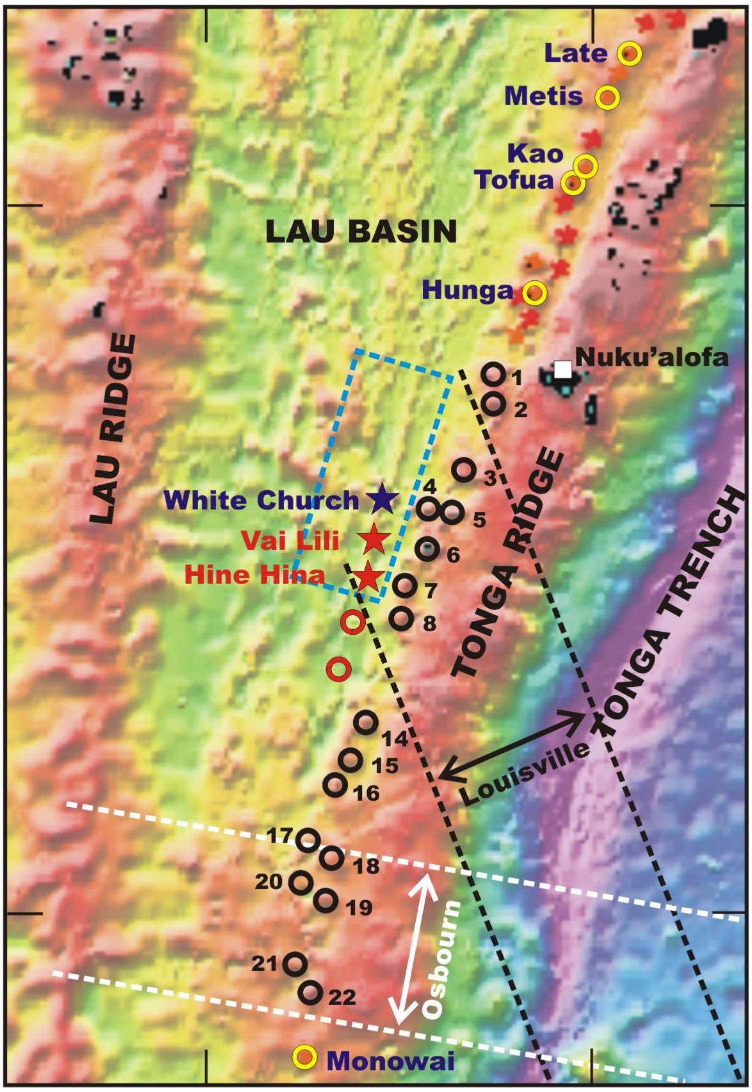

Fig. 5.1: Inferred volcanoes of the south Tonga arc. Volcanoes predicted from the existing bathymetric maps (Chase, 1985; Tagudin and Scholl, 1994) and satellite-derived bathymetry (Smith and Sandwell, 1997) are shown in black together with their designated identification number for the cruise. Black and white dashed lines indicate the projected location of the Louisville Ridge and Osbourn Trough within the subduction system, respectively. Volcanoes sampled or surveyed before SO 167 are shown in yellow (apart from 'Ata, = Volcano 6). Hydrothermal fields and targets are shown in red and blue (refer Chapter 9). The dashed blue box delineates the main work area of previous SONNE cruises (SO 35, 48 and 67).

Factual information concerning the south Tonga arc between the surveyed Hunga and Monowai volcanoes is remarkably scant. Bathymetry compiled by Chase (1985) showed a series of seamounts along the trace of the volcanic front. A few seismic lines and more detailed bathymetry completed in the early 1990s demonstrated that at least some of these were volcanoes, and suggested a general westward migration of volcanism with time (Tagudin and Scholl, 1994).

More recently, satellite-derived bathymetry depicts at least 17 large volcanoes along this section of the arc (Fig. 5.1; Smith and Sandwell, 1997). None of these volcanoes had been sampled or surveyed before SO 167, with the exception of the eroded 'Ata Island (Johnstone, 1978). It was not known whether they were active, or whether the passage of the Louisville Ridge beneath them led to a temporary state of inactivity (e.g., Nur and Ben-Avraham, 1983). Furthermore, a major geochemical boundary between Pacific MORB-source mantle and Indian MORB-source mantle occurs along the nearby (~40 km to the west) backarc Valu Fa Ridge and logically affects the volcanic front as well (Hergt and Hawkesworth, 1994; Turner and Hawkesworth, 1998). The exact location of this boundary along the arc is unresolved because none of the submarine south Tonga arc volcanoes north or south of 'Ata had been sampled.

The principle objectives of the south Tonga arc program were:

1) To find and map the south Tonga arc between 21°S and 25°S. The age, structure and evolution of these volcanoes was expected to be revealed by high-resolution mapping using the SIMRAD EM120 onboard FS *SONNE* and also by collecting the backscatter images. The latter can delineate young rough-surfaced lava flows and volcanic domes from older, more weathered or sedimented, outcrops. Thus, it was anticipated that the mapping program would reveal the number of volcanoes, their evolution and volume. From this dataset, it should then be possible to estimate when the south Tonga arc began to develop and the magma production rate along this section of the Tonga–Kermadec arc.
2) To determine the effects of subducting the Louisville Ridge beneath the south Tonga arc. A simple projection of the Louisville Ridge places it beneath 'Ata Island. However, the ridge is surrounded by a broad volcaniclastic apron, and is segmented rather linear. On this basis, the ridge could presently be anywhere between Volcanoes 3 and 8 in the subduction system (Fig. 5.1). More complex models involving plume–ridge interaction between the Louisville plume and Osbourn Trough are also possible, and the location of the ridge within the subduction system is unpredictable if the plume was ever captured by the Osbourn Trough. Key questions to be addressed include (i) whether the arc switches off while the Louisville Ridge passes beneath it, (ii) whether the location of the volcanic front shifts as the relatively buoyant ridge passes beneath the arc, (iii) whether the geochemical signature of the ridge can be detected in the fluid mobile elements (e.g., Ba, Sr, Pb).
3) To determine whether subduction of the Osbourn Trough affects the volcanic front. The trough is an old paleo-spreading centre with well-developed inner corner highs (refer Chapter 7). These highs reflect extensive hydration (serpentinisation) of the mantle as spreading slowed and eventually ceased. Thus, subducting the Osbourn Trough is equivalent to subducting a water-reservoir, and this might be expected to promote extensive melting in the sub-arc mantle.
4) To establish whether the geochemistry of the volcanic arc varies with either the reduction in subduction rate from 24 cm/year (northernmost Tonga) to 10 cm/year (southern end of the south Tonga arc) or the change in backarc environment from fast spreading (northernmost Tonga) to slow rifting (southern end of the south Tonga arc). To met this objective, the analytical database established from the recent northern and

central Tonga studies will be merged and compared with that arising from SO 167. Samples from the south Tonga volcanoes that are not affected by either the subducting Louisville Ridge or Osbourn Trough are of critical importance to this work.

5) To ascertain whether the widespread felsic volcanism of the Kermadec arc continues into the south Tonga arc. Voluminous, often caldera-forming, eruptions of dacitic pumice have occurred at ~30% of the Kermadec volcanoes. Such eruptions are conspicuously absent from more mature intra-oceanic arcs, such as the Marianas, and comparatively rare at the subaerial volcanoes of the central and northern Tonga arc. The genesis of these dacitic magmas is controversial, with end-member models featuring fractional crystallisation of parental basaltic magma or crustal anatexis. Venting hydrothermal systems enriched in precious metals and supporting extensive ecosystems are commonly associated with the calderas.
6) To use the presence of a Louisville Ridge signature in the arc lavas to constrain the processes, rates and timescales of element re-cycling and magma genesis in the subduction system. Meeting this objective requires knowledge of the Louisville Ridge composition and the tectonic history of the subducting plate. The existing Louisville Ridge dataset is both small and heavily biased by samples from the NW summit of Osbourn Seamount (refer Chapter 8). This situation was rectified by dredging numerous samples from the ridge during the latter part of SO 167; these will be used to establish the compositional range of the ridge, and to constrain the nature and location of the ridge-derived geochemical contribution to the volcanic arc. Mapping, sampling and age determinations of Osbourn Trough (refer Chapter 7) are also necessary to confirm that this is a paleo-spreading centre, to clarify the potential for plume–ridge interactions, and to enable accurate predictions of where the Louisville Ridge is within the subduction system.

5.2. Volcano 1–2 Complex

5.2.1. Bathymetry and Structure

Pre-SO 167 bathymetric maps depicted either a single large inverted "L-shaped" volcanic massif or two adjacent, and possibly intergrown, seamounts ~50 km west to SW of Tongatapu (Chase, 1985; Tagudin and Scholl, 1994). The latter interpretation was more consistent with satellite-derived bathymetry (Fig. 5.1), and on that basis the area was designated Volcano 1 (north) and Volcano 2 (south) during cruise planning. Discoloured water, interpreted as evidence of brief submarine eruptions, was reported from the southern part of this area in both 1907 and 1932 (Richard, 1962). The co-ordinates cited indicate possible activity near the SE margin of Volcano 2.

Mapping during SO 167 revealed a large contiguous volcanic complex at 21°01'–21°31'S, 175°37–175°53'W (Fig. 5.2). The complex features two major stratovolcanoes

(Volcano 1 = 21°09'S, 175°45'W; Volcano 2 = 21°18'S, 175°42'W). Both are capped by summit calderas, and associated with a series of smaller satellite cones and volcanic ridges. Overall, the complex rises from a flat seafloor plain at ~1800 mbsl in the west and north. The southern and eastern flanks of the complex (both >1200 mbsl) were not defined. A marked break in slope occurs near 1400 mbsl on both stratovolcanoes and defines the transition from the steeply sloping lavas of the central facies to the gently sloping volcaniclastic sediment of the distal facies.

Volcano 1 has a basal diameter of ~28 km, reducing to ~18 km at the break in slope, and is broadly symmetrical although elongated NW–SE. The summit is dominated by a large oval caldera, 7 km-long by 4.5 km-wide, whose long axis trends NW–SE. Most of the caldera rim is between 150 mbsl and 250 mbsl, with the highest areas predominating on the SE rim and the lowest to the SW at ~400 mbsl (possibly breached). The caldera floor is at 450 mbsl beneath the north, east and south caldera walls, and the inner caldera walls are generally 200–300 m high. At least two episodes of post-caldera volcanism have occurred. During the first episode, a large post-caldera cone (V1P1) grew in the centre of the caldera and subsequently collapsed, leaving a gently east-sloping plateau bounded by a circular ridge 2.8 km in diameter that ranges from <50 m above the caldera floor in the east to 250 m above the caldera floor in the west. The caldera is interpreted to be largely infilled by the products of this cone and its collapse. Two smaller symmetrical cones have since grown between the western margin of the collapsed V1P1 cone and the western caldera rim. To the NW, the V1P2 cone has a diameter of 1.3 km, a summit at 150 mbsl, and rises 300 m above the caldera floor. To the SW, the V1P3 cone has a diameter of 1.2 km, a summit at 90 mbsl, and rises 350 m above the caldera floor. Tephra +/- lava flows from the V1P3 cone partly bury the SW quadrant of the remnant V1P1 cone, and a crater 100 m-deep and 300 m-wide occurs at its northern base. The V1P3 cone is interpreted as the youngest feature of the summit. The SW flank of Volcano 1 is cut by a series of major faults, with the northernmost trending W–E with a throw of 100–200 m and the more southern ones trending SW–NE with a maximum throw of 100 m. These faults appear to govern both the northern and southern boundaries of the summit caldera, and also the location of the post-caldera V1P2 and V1P3 cones. The northern flank of Volcano 1 (to the north of the W–E fault) exhibits high relief attributed to outcropping lavas, whereas to the south the flanks are smoothed and presumably buried by volcaniclastics or caldera ejecta.

A major satellite cone (V1FA) is located 11 km east of Volcano 1 and forms an 11 km-long by 6 km-wide NNE-trending ridge with a summit at <300 mbsl. Smaller satellite cones occur on the lower NW flanks of Volcano 1 (V1FB = 5 km diameter, 1900–1150 mbsl; V1FC = 2 km diameter, 2100–1850 mbsl; V1FD = 1 km diameter, 1750–1550 mbsl), and along a north-trending lineament that cuts the eastern flank of the volcano (V1FE = 2.5 km diameter, 1500–1050 mbsl; and others that are <100 m in relief). A 3 km-long by 2 km-wide NE-trending ridge (V1FF) rising from 900 mbsl to 500 mbsl at the intersection of

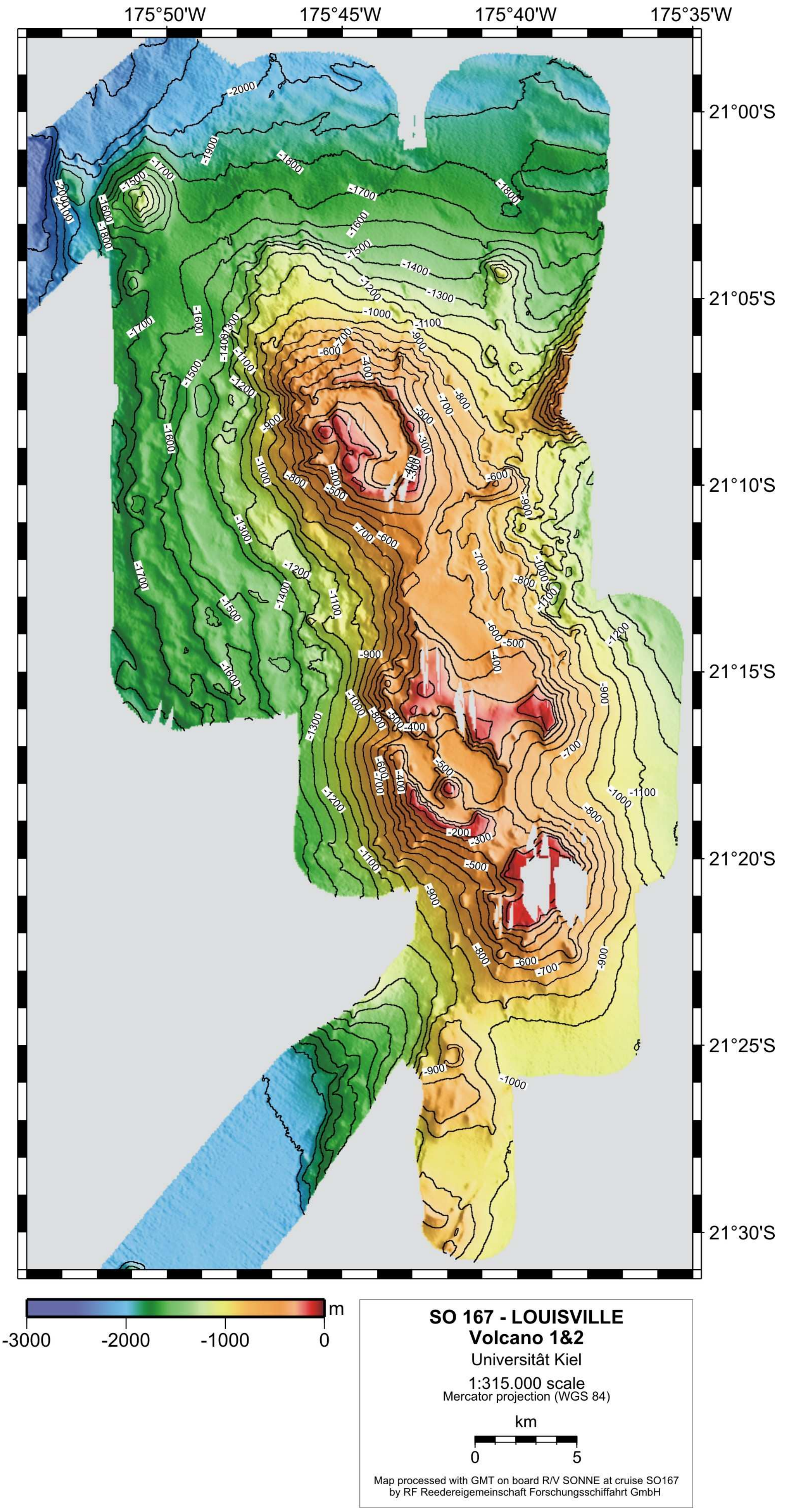

Fig. 5.2: Bathymetry of the Volcano 1–2 Complex. Contour interval is 100 m.

the north-trending lineament and a projection along the long-axis of the V1FA cone may be a flank vent whose NW side has collapsed, or possibly a remnant from an older mostly collapsed volcanic centre; this ridge is onlapped and partly buried by tephra from the caldera.

Volcano 1 is joined to Volcano 2 by a 4 km-long and 3 km-wide flat-topped ridge, with the lowest point on the ridge being 550 mbsl. Hummocky terrain on both flanks of this ridge, but especially on the eastern side, suggests the ridge has a complex history involving multiple sector collapse events. It possibly represents the remnants of a relatively old volcanic centre associated with the V1FF ridge and other structures on Volcano 2 (V2FE, see below).

Volcano 2 is slightly larger (~22 km at the break in slope) than Volcano 1, and has a more complex form. The volcano consists of two large intergrown cones surrounded by two relic ridges (NNW, ENE) and two major valleys (E, SW) that testify to sector collapse of earlier cones. The NW cone is the larger and designated Volcano 2 *sensu stricto*. This cone is elongated NW–SE, with its long-axis parallel to (but offset SW from) that of Volcano 1. Its summit is dominated by a large oval caldera, 6.5 km-long by 4.5 km-wide whose long axis trends NW–SE, with a flat-floor at 550 mbsl. The caldera rim is well preserved in the SW (150–200 mbsl) and NE (200–300 mbsl) quadrants, where the inner caldera walls rise ~200 m above the caldera floor. The SE rim of the caldera is lower (450 mbsl), whereas the caldera is breached to the NW by a narrow chute at 600 mbsl. The caldera floor is subdivided into two halves by a NW–SE trending volcanic lineament bounded by a large post-caldera cone 1.7 km in diameter that rises to 180 mbsl (V2P1) from near the centre of the caldera and a smaller 100 m-high cone on the northern caldera rim (V2P2). Several small cones (<50 m-high) have also erupted along this lineament. A parallel series of discontinuous small (<50 m-high) post-caldera cones, possibly older and partly buried, is located 1.5 km to the west of this lineament. Prominent faults cut the SW flank of Volcano 2 and trend SW–NE, with a maximum throw of 50 m. The other flanks are relatively smooth and appear deeply buried by volcaniclastics or caldera ejecta. Morphologically, both the Volcano 2 caldera and post-caldera volcanism are older than their equivalents on Volcano 1.

The SE satellite cone (V2FA) is located 7 km SE of Volcano 2 and has dimensions of 9 by 6 km at 800 mbsl, below which it merges into the overall Volcano 2 massif. Unlike the main cones, but as with V1FA, this cone is elongated NE–SW. The V2FA cone consists of two intergrown and quite distinct cones separated by a prominent WNW–ESE trending fault associated with a small sector collapse to the WNW. The southern half of the edifice has a flat-topped summit at 150 mbsl and its smooth flanks are disrupted by at least 7 smaller vents, three of which rise more than 100 m above the surrounding slopes (V2FB- 1.1 km-long by 0.7 km-wide and 150 m-high, associated with a series of NW–SE trending faults on the mid-SE flank; V2FC- 0.5 km in diameter and 150 m-high on the mid-SW flank; V2FD- 0.4 km in diameter and 100 m-high on the upper south flank). In contrast, the northern half of the edifice is flat-topped at ~50 mbsl and its outer flanks are smooth, although three small partly buried volcanic cones(?) occur in the moat between this cone and the SE flank of Volcano 2. The V2FA cone is the inferred source of the historical eruptions in 1907 and 1932. The <50 m-deep summit is too shallow to be a wave-cut platform from the last sea-level low-stand, implying significant eruptive activity since 17 ka. Nevertheless, our incomplete bathymetric coverage of this summit plateau found no obvious craters.

An irregular volcanic construct is located 7 km NE of Volcano 2 and joined to it by a low ridge. This construct (V2FE) is 3.2 km-long by 2.8 km-wide at 600 mbsl, somewhat elongated north–south, and below this depth merges into the overall Volcano 2 massif. It is flat-topped at 150 mbsl, suggesting no volcanic activity since the last sea-level low-stand ended at 17 ka. Both the NW and SW upper flanks of this construct are semi-circular in form, suggesting it may be a relict volcanic cone that has undergone sector collapses to both the NW and SE.

Another volcanic cone (V2FF) is located 10 km SW of Volcano 2, but only the lower SE flank of this feature was mapped. It is probably a small cone 1.5–2.5 km in diameter. To the south of Volcano 2 is a 2 km-wide, >11 km-long, volcanic ridge at ~950 mbsl. This ridge hosts a horseshoe crater 1.1 km in diameter whose rim rises 120 m above the ridge (V2FG). Further south on the ridge are two small high-standing but irregularly shaped constructs, each about 2 x 3 km across and 200 m-high. The origin of these constructs is unclear (relics from sector collapse of an old cone in this area or dome complexes?).

5.2.2. Sampling

The first dredge station of the cruise was located on the upper SW flank of the V1FB satellite cone to the NW of Volcano 1. Station 01-DR recovered a conglomerate with clasts of weathered olivine-plagioclase +/- pyroxene basalt and olivine-pyroxene basalt. Although the olivine was green and fresh, the lavas were discolored by marine weathering to a depth of several cm and are clearly old.

Four dredge stations were completed on Volcano 1. Station 03-DR targetted the mid-flanks of the north ridge, and was expected to obtain old lavas. Instead, fresh porphyritic non-vesicular plagioclase basalt and less porphyritic vesicular varieties were recovered, together with an aphyric dacite and an older weathered plagioclase andesite. The youthful plagioclase basalts evidently represent at least two recent (few hundred years?) flank eruptions on the north ridge. Station 04-DR was located on the mid-western flank downslope of the young post-caldera V1P2 cone. Both aphyric basalt and essentially fresh plagioclase basalt were recovered, with the latter tending scoriaceous and appearing to represent bombs. Weak Fe-Si staining typical of very young (<100 year old) lavas was locally found on the plagioclase basalt, which is inferred to represent the V1P2 cone. An older aphyric dacite, interpreted as a scree block from the caldera rim, was also recovered. Station 05-DR was located on the mid-flank of the SW ridge, a site that can be reached by scree from both the caldera rim and the post-caldera V1P3 cone. Many different flow units composed of aphyric to plagioclase-phyric basalt and andesite, vesicular to non-vesicular variants of these, and ranging from fresh to weakly weathered were recovered. An altered dolerite (with mobilised Cu) and chloritised gabbro were also retrieved; these units possibly outcrop in fault scarps higher on the caldera rim. Station 09-DR was an attempt to dredge the inner NE caldera wall and obtain more pre-caldera lavas. The dredge track specifically avoided material derived from the V1P1 post-caldera cone, which is potentially present at both stations 04-DR and 05-DR. Weakly weathered porphyritic plagioclase-pyroxene basalt, aphyric basalt and plagioclase basalt were recovered, together with a claystone of compacted volcanic ash and a fine-grained conglomerate of weathered basaltic lavas. The weakly weathered nature of these lavas suggests the caldera-forming eruption at Volcano 1 took place a few–tens of ka, rather than tens–hundreds of ka, ago.

Five dredge stations were completed on Volcano 2. Stations 06-DR and 07-DR were on the western flank of the large V2P1 cone located in the summit caldera. The first recovered some very deeply weathered small pebbles for which there is no hope of an analysis, deeply weathered pumice (probably float), and large blocks of coralline debris. The second recovered more coralline debris. The absence of any significant lava fragments suggests the V2P1 cone is old and deeply buried by coralline material. Station 08-DR was situated on the lower SW ridge and targetted old lavas. A large block of deeply weathered plagioclase basalt was recovered, together with small fragments of aphyric pumice. The latter were interpreted as float, possibly from the nearby V2FA cone. Station 11-DR was located on the NE flank of the V2FE satellite cone, and confirmed this as a very old centre. A few fragments of deeply weathered basalt, a coral-encrusted conglomerate with deeply weathered clasts, and some aphyric float pumice were retrieved. Station 12-DR was located on the west ridge of the V2FA satellite cone. This station also recovered deeply weathered basalt fragments, coralline debris and pumice float. It is interpreted that the southern part of the V2FA cone is old. Unfortunately, the dredge program provides no confirmation that the northern part of the V2FA cone is active and the source of the relatively fresh aphyric pumice, although both are strongly suspected.

5.3. Volcano 3

5.3.1. Bathymetry and Structure

Pre-SO 167 bathymetric maps consistently suggested either one or two closely-spaced seamounts were located south of the Volcano 1–2 Complex near 21°46'S (Chase, 1985; Tagudin and Scholl, 1994; Smith and Sandwell, 1997). Mapping during SO 167 revealed two large intergrown stratovolcanoes at 21°39'–21°53'S, 175°52'–176°00'W (Fig. 5.3). These volcanoes rise from the surrounding seafloor plain at >1700 mbsl. The break in

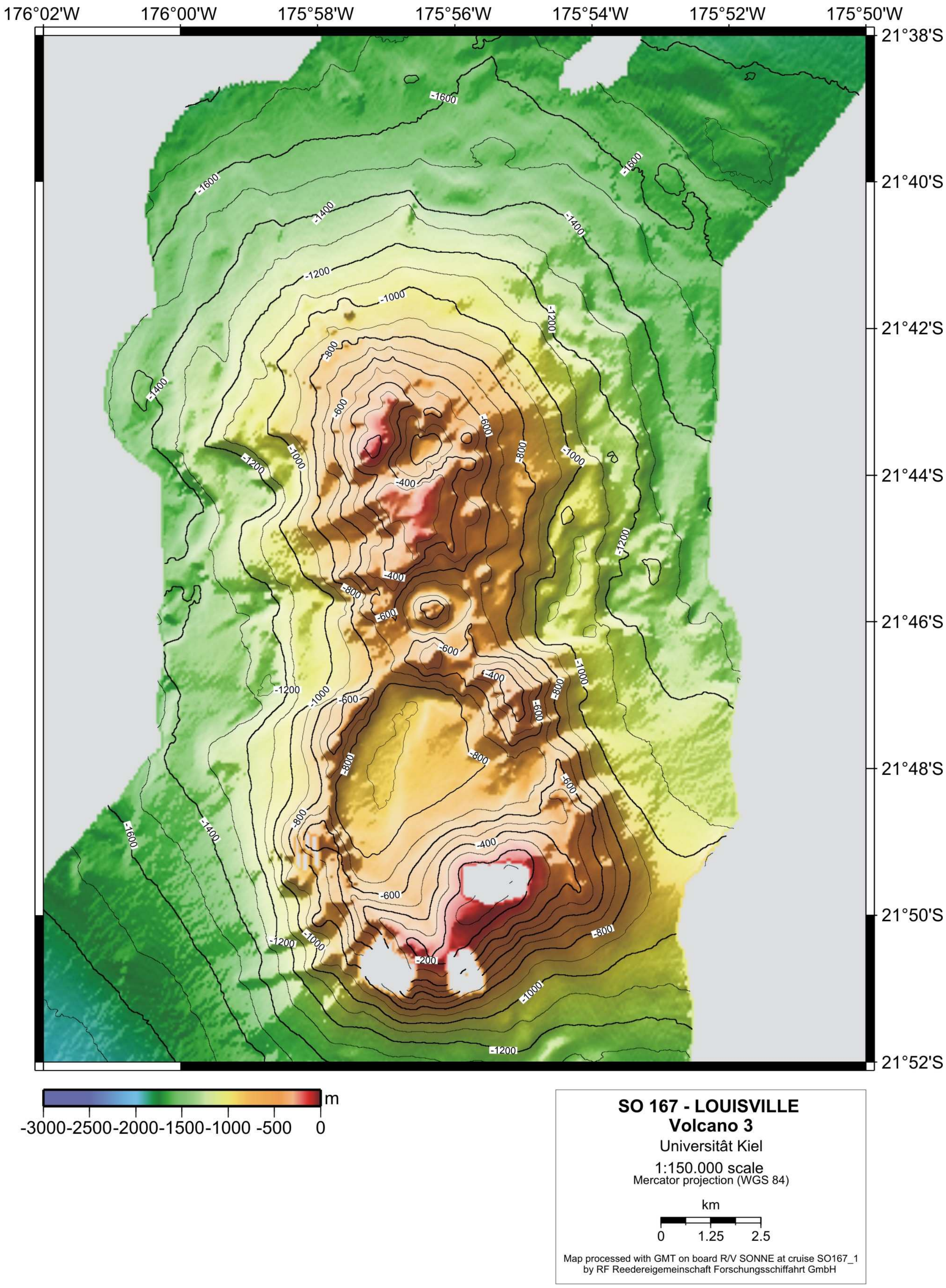

Fig. 5.3: Bathymetry of Volcano 3. Contour interval is 100 m.

slope marking the transition from steeply dipping lavas to surrounding volcaniclastic sediment occurs between 1100 mbsl and 1400 mbsl, and is generally at greater depth on the southern cone.

The northern volcano is a simple but morphologically old cone rising to 150 mbsl from >1700 mbsl on a basal diameter in excess of 15 km. It is capped by a poorly preserved summit crater 2.5 km in diameter and 500 m-deep. Much of the southern crater rim is at 250–300 mbsl, the highest point is on the west, and three low valleys cut the crater wall at 450 mbsl to the north–NE with another at 350 mbsl to the SW. Multiple sector collapses have significantly changed the form of the southern flanks, where at least 5 collapses have left valleys up to 2.5 km-across and 100 m-deep. One of these valleys on the SE flank hosts a 150 m-high, 700 m-diameter, gently sloping volcanic dome (V3FA), suggesting sector collapse may have been triggered by dome intrusion. Others are controlled by a series of prominent WSW–ENE trending faults that cross-cut the southern half of the volcano. The sector collapses and dome emplacement are the most recent events affecting this volcano.

The southern volcano is slightly larger and more complex in form. It is capped by a nearly circular caldera 6.2 km-long by 5.9 km-wide. The caldera rim can be subdivided into three segments; the NW sector ranges in elevation from 550–750 mbsl, the NE sector is less regular and ranges from 350–650 mbsl, whereas the southern sector is significantly higher and rises to the summit at <50 mbsl. Much of the caldera floor, whose deepest point is 920 mbsl, is buried by young volcaniclastic sediments derived from resurgent volcanism on the SE caldera rim. Localised slumping of the inner NE caldera walls is also evident. Sector collapses have generated valleys up to 1 km-wide and 100 m-deep along a series of SW–NE trending faults that cross-cut the outer flanks of the volcano, but in general this cone is better preserved than that of the northern volcano. The <50 mbsl summit on the SE caldera rim is too shallow to be a relic from the last sea-level. Sediment coverage within the caldera and the morphology of both the inner and outer southern caldera walls indicates that three young post-caldera cones (V3P1, V3P2, V3P3) are present and arranged in a triangle with east, central and south apices. Each has a diameter of 500–600 m at 200 mbsl, with the easternmost cone (V3P1) being the largest. Coverage of these post-caldera cones was incomplete due to the shallow water depth, and no craters were identified.

The short ridge segment joining the northern and southern volcanoes hosts a crater 2 km in diameter that is partly filled by a 200 m-high volcanic dome(?) with a diameter of 1 km (V3FB). A smaller volcanic dome <100 m-high occurs immediately NE of this crater. Both of these domes are in close proximity to V3FA and the sector collapses affecting the southern flank of the northern volcano.

5.3.2. Sampling

Two dredge stations were completed on the northern volcano. Station 17-DR targetted the upper northern side of a 100 m-deep sector collapse on the mid-western flank of the northern volcano. The aim was to obtain old lavas from the early stages of cone-building. Several different variants of aphyric dacite were recovered, including pumice, devitrification banded pumice, and dense jointed dacite blocks. The jointed dacite is interpreted as scree blocks spalled from a dome near the present day summit. The pumice may have originated during the same eruptive episode, but more likely represents recent float from the post-caldera cones on the southern cone (see below). Several small pieces of considerably older deeply weathered lava were also recovered. Although representing the target material, these are probably too old and weathered for analysis. Station 18-DR dredged the inner south crater wall with the intention being to obtain the youngest lavas from the northern volcano. Most recovered material consisted of a conglomerate composed of plagioclase dacite variants, some with devitrification banding, and this may be correlative with the dacite from Station 18-DR. One clast each of plagioclase basalt and plagioclase andesite was also retrieved. None of this material was fresh, suggesting a repose period of several ka or more at the volcano and consistent with slumping within the crater to generate the conglomerate.

Station 15-DR was situated on the SW flanks of the large V3FB volcanic dome between the northern and southern volcanoes. Recovered lithologies included porphyritic pyroxene-plagioclase andesite, a variety of aphyric to plagioclase-bearing dacites, aphyric pumice and a conglomerate with small altered and weathered lava fragments. The dacites most probably represent material spalled off the adjacent north wall of the southern cone, as they were also dredged from that locality. Thus, the andesite is interpreted as the dominant material of the dome and source of the conglomerate. The pumice is most probably float from recent eruptions at the young post-caldera cones on the southern caldera rim of the southern cone (see below).

Three dredges were completed on the southern volcano. Station 13-DR was located on the scarp of a fault-controlled valley on the mid-SW flanks, with the aim of obtaining old lavas. Fresh aphyric pumice, locally with devitrification banding, was recovered and interpreted as recent float from the young post-caldera cones along the southern caldera rim. Station 14-DR was targetted at the inner north caldera wall, and recovered a series of weakly weathered aphyric dacite variants grading to pumice with devitrification banding. The dredge avoided the sedimented caldera floor, and the dacite is therefore considered representative of the caldera walls. Station 19-DR was on the mid-flanks of the inner SE caldera wall beneath the central post-caldera cone (V3P2). Large blocks of essentially fresh aphyric pumice were retrieved, locally with devitrification banding and quite dense. They are interpreted as the carapace of a pumiceous dacite dome or flow.

5.4. Volcano 4–5–6: 'Ata Volcanic Complex

5.4.1. Bathymetry and Structure

'Ata Island is the only subaerial volcano of the south Tonga arc, and was briefly described by Johnstone (1978) as an eroded remnant of a formerly much larger island. Both pre-SO 167 bathymetry and satellite-derived bathymetry show the island to be part of a large seamount, and depict at least two nearby and similarly-sized west–east paired seamounts to the north (Chase, 1985; Tagudin and Scholl, 1994; Smith and Sandwell, 1997). Seismic lines provided by Tagudin and Scholl (1994) further suggest the western seamount of the northern pair is the younger. The northern seamounts were designated Volcano 4 (west) and Volcano 5 (east) during planning for SO 167, with 'Ata designated as Volcano 6.

Mapping during SO 167 revealed 14 large volcanic constructs forming the 'Ata Volcanic Complex, bounded by 21°56'–22°27'S, 175°55'–176°21'W (Fig. 5.4). They rise from the seafloor plain at 1900 mbsl to the north and 2100 mbsl to the west; the southern and eastern seafloor plain was not mapped. The pre-SO 167 bathymetry was confirmed in a general sense, as the three largest cones are located at the anticipated sites of Volcanoes 4, 5 and 6. However, many of the other 11 volcanoes are similar in size and occur between or around these larger seamounts. In detail, much of the pre-SO 167 bathymetry bears only passing resemblance to the ground reality (e.g., compare Fig. 6 of Tagudin and Scholl (1994) with Fig. 5.4 of this report), probably reflecting the sparse data points in the earlier bathymetry.

Four volcanoes occur in the NW of the complex at the designated Volcano 4 site:

- The largest of these (Volcano 4A) is a simple cone with a basal diameter of 16 km and summit at 350 mbsl. It has a circular summit crater 2.4 km in diameter that is largely infilled by a younger cone 1.2 km in diameter and 200 m-high. Prominent SW–NE and WSW–ENE trending fault sets cut the southern and eastern flanks of the volcano. These faults are associated with minor sector collapses from the summit crater, and they also cut the cone within the crater. An ESE-trending ridge near the SW summit, and several small protruberances on the lower NW flank, probably represent small cones formed during flank eruptions. Although not deeply eroded, it is evident that Volcano 4A has been inactive for some time (tens of ka?).
- Volcano 4B is located SSW of Volcano 4A, and is a morphologically younger cone with a basal diameter of 9 km that rises to a summit at 180 mbsl. This cone is also cut by a SW–NE trending fault set that passes through the summit region, again triggering small sector collapses predominantly directed to the SE. It does not have a crater.
- Volcano 4C is located NW of Volcano 4A, and is a volcanic ridge 11 km-long by 3.5 km-wide trending SSW–NNE. The southern end of this ridge has irregular topography and is probably affected by sector collapses, a prominent crater 2.9 km in diameter and 200 m-deep occurs in the middle of the ridge, and four small cones including the highest point (850 mbsl) are located at the northern end of the ridge.
- Volcano 4D is located off the NE base of Volcano 4A and is a small 5 km-long by 3 km-wide SSW–NNE trending ridge dominated by two small cones; its highest point is 1580 mbsl at the summit of the south cone.

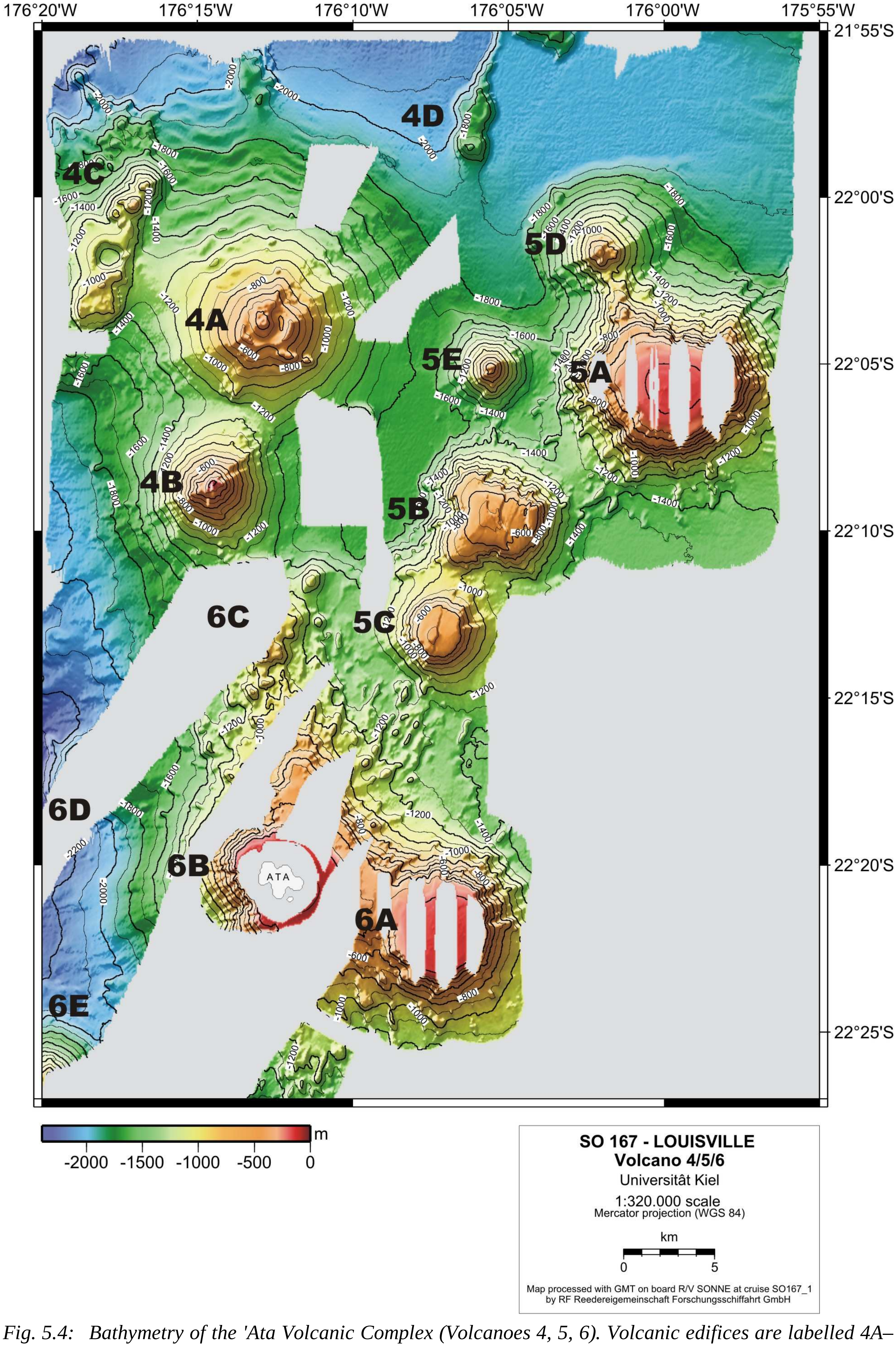

Fig. 5.4: Bathymetry of the 'Ata Volcanic Complex (Volcanoes 4, 5, 6). Volcanic edifices are labelled 4A–4D, 5A–5E, 6A–6E and described in the text. Contour interval is 100 m.

Five volcanoes occur in the NE to central part of the complex at the designated Volcano 5 site:

- The largest of these (Volcano 5A) is a flat-topped cone with basal dimensions of 13 km by 12 km, and is slightly elongated W–E. A pronounced break in slope occurs at 300 mbsl, whereafter the 7 km by 5 km summit plateau slopes gently upwards to peak at 150 mbsl in its centre. The featureless summit plateau is buried by thick sediment and may have been cut during the last sea-level low-stand at 17–20 ka, when the sea-level was ~120 m below its current level and the plateau summit would have been near the wave base. However, given the large dimensions of the plateau and its thick sediment blanket, it seems more probable that much of the plateau was cut during the preceding longer period of sea-level low-stand at 130–160 ka. This would indicate minimal eruptive activity at the volcano summit for >150 ka. The lower flanks of Volcano 5A are extensively dissected by small sector collapses, commonly associated with the dominant SW–NE trending fault set that crosses the edifice.
- Volcano 5B is located SW of Volcano 5A, and is a smaller cone with a basal diameter of 8 km by 7 km and is somewhat elongated WNW–ESE. A break in slope occurs at 600 mbsl, whereafter the summit plateau slopes gently upwards to peak at 480 mbsl. Again the featureless summit plateau is buried by thick sediment. Sector collapses extensively dissect the lower flanks, and are often associated with the dominant SW–NE fault set. The NE quadrant of the volcano is downfaulted by ~50 m along a curvilinear scarp that crosses the summit. This edifice is probably comparable in age to Volcano 5A.
- Volcano 5C is located further to the SW of Volcano 5B, and is another cone with a basal diameter of 6 km. It also has a break in slope at 600 mbsl, whereafter the featureless summit plateau slopes gently upwards to peak at 480 mbsl. Sector collapses have occurred along the SW and NE flanks, mostly associated with the dominant SW–NE fault set. A prominent NNE–SSW fault scarp with a throw of 50 m cuts the centre of summit. Overall, this cone is better preserved than either Volcano 5A or 5B, and it may be slightly younger.
- Volcano 5D is located to the NW of Volcano 5A, and is joined to it by a narrow ridge. Its basal dimensions are 9 km-long by 6 km-wide, and the volcano is presently elongated WSW–ENE. The southern half of this cone is extensively dissected by the dominant SW–NE trending fault set, and may have collapsed to the SE; the ridge from Volcano 5A appears to be younger than this collapse and onlaps Volcano 5D. The cone rises steeply to a summit at 650 mbsl without any break in slope. Two protruberances 900 m in diameter on the lower west and NW flank are probably flank cones. Volcano 5D is morphologically much younger than Volcanoes 5A, 5B and 5C, however the extensive faulting again indicates a significant period of inactivity (tens of ka?). There is an apparent contradiction between this volcano being younger than Volcano 5A but onlapped by the NW ridge from Volcano 5A. The resolution of this issue is unclear, but

possibly the NW ridge is a relatively recent flank eruption from Volcano 5A (and the only activity from that volcano since 150 ka).

- Volcano 5E is located west of Volcano 5A. It is a small well-preserved cone, with a basal diameter of 5 km, that rises steeply to a summit peak at 550 mbsl. The dominant SW–NE fault set crosses the volcano, and has triggered small sector collapses on the SW and NE flanks. This cone has the youngest morphology of the Volcano 5 group.

Five volcanoes occur in the southern to central part of the complex at the designated Volcano 6 site:

- The largest of these (Volcano 6A) is a flat-topped cone with a basal diameter of 10 km. A break in slope occurs at 250 mbsl, whereafter the featureless summit plateau (5 km in diameter) rises gradually to a summit at 150 mbsl. The lower flanks are extensively dissected by small sector collapses, commonly associated with the dominant SW–NE trending fault set that crosses the edifice. Overall, this volcano has very similar morphology to that of Volcano 5A and is probably of comparable age.
- Volcano 6B includes 'Ata Island, and is located WNW of Volcano 6A. The 'Ata cone has a basal diameter of 7 km, with a break in slope at 200 mbsl. Thereafter the summit plateau (5 km in diameter) rises gradually to the margins of 'Ata Island, and thence steeply to the island summit at 309 m above sea-level. It is evident that 'Ata Island represents an erosional remnant of the former cone, whose long-term fate is to be eroded away to generate another featureless summit plateau as at Volcanoes 5A and 6A. The geology of the island is described in Appendix 3. The lower flanks of the 'Ata cone are extensively dissected by small sector collapses, commonly associated with the dominant SW–NE trending fault set that crosses the edifice. It appears to be of comparable age to Volcano 6A, and is joined to it by a 4 km-wide flat-topped ridge at 300–400 mbsl. Both Volcanoes 6A and 6B are built on a large volcanic pedestal 24 km-long by 18 km-wide trending WNW–ESE.
- Volcano 6C is located NW of Volcanoes 6A and 6B, and rises from the NW end of the volcanic pedestal. Little is known of this poorly mapped volcano, which appears to be deeply dissected and have a basal diameter of ~4 km.
- Volcano 6D is located WNW of Volcano 6B. Little is known of this poorly mapped volcano, which appears to be a well-preserved (young?) cone with a basal diameter of ~4 km and elongated SW–NE.
- Volcano 6E is located SW of Volcano 6B. Only the NE flank of this volcano was mapped. It appears to be a well-preserved (young?) cone with a basal diameter of 7 km and summit near 850 mbsl.

In summary, the 'Ata Volcanic Complex includes at least 14 large volcanic edifices. Such a concentration of large volcanoes is rare in subduction-related volcanic arcs, but comparable to that in northern Kamchatka where the Hawaii–Emperor Ridge is being subducted. There is an apparent general westward migration in volcanism with time. Pre-150 ka activity took place at Volcanoes 5A, 5B, 5C, 6A, 6B and 6C. With the possible exception of the NW ridge on Volcano 5A, these eastern volcanoes have been inactive since that time. The remaining volcanoes lack featureless summit plateaus and have either sharp summits or preserved craters. Their faulted lower flanks testify to a long period of intermittent activity. Volcanoes 5E, 4B, the northern part of 4C, and the poorly mapped 6D and 6E appear to have erupted within the last few ka.

5.4.2. Sampling

One dredge station was completed on Volcano 4A. Station 23-DR was located on the upper western flank near the summit and designed to obtain lavas from the cone filling the summit crater. Recovered lavas included aphyric basalt, plagioclase basalt, plagioclase andesite, and aphyric pumice exhibiting a variety of devitrification textures. The basalt-andesite sequence is inferred to represent the summit cone, whereas the pumice is interpreted as float from elsewhere. All lavas were moderately weathered, indicating Volcano 4A has probably been inactive for several tens of ka.

Two dredge stations were completed on Volcano 4B. Station 20-DR was located on the mid-SW flank on a series of fault scarps and recovered weakly weathered plagioclase andesite, together with several small pieces of older deeply weathered lava and weathered aphyric pumice. Station 21-DR was located on the lower NE flank and returned essentially fresh to very weakly weathered plagioclase basalt, aphyric andesite, and a more weathered plagioclase basalt. The very fresh nature of lavas at both these stations indicates Volcano 4B has been active within the last few hundred to thousand years, with lava flows either erupting from the fault scarps on the SW and NE flanks or flowing down these features from the summit. Older lavas outcrop intermittently along the scarps.

One dredge station was completed on Volcano 4C. Station 22-DR was trawled across the inner eastern crater wall of the large crater. Numerous lithologies were recovered, including weakly weathered plagioclase basalt, moderately weathered plagioclase andesite, deeply weathered pyroxene-plagiclase andesite and plagioclase dacite, deeply weathered gabbro and diorite, and weakly weathered aphyric pumice with a variety of devitrification textures. The volcanic ridge clearly has a long and complex history. Equally, the fresh nature of the plagioclase basalt suggests eruptions have occurred within the last few ka.

Two dredge stations were completed on Volcano 5A. Stations 26-DR and 27-DR were both located on the lower SW flank, and designed to return old lavas outcropping along fault scarps and in the headwalls of slump structures. The first recovered a small piece of weathered pyroxene basalt, and the second several small pieces of scoriaceous basalt together with weathered aphyric pumice exhibiting a variety of devitrification textures. The small size of the recovered lava fragments and their unexpectedly weak weathering raises suspicions that they represent contamination by similar lithologies recovered from stations 24-DR and 25-DR on Volcanoes 5D and 5E. The pumice is interpreted as float.

One dredge station was completed on Volcano 5B. Station 29-DR was located on a scarp at the western base of the cone, and recovered a small amount of very deeply weathered conglomerate. Clasts in the conglomerate are too small and weathered for geochemical analyses. The deep weathering confirms the expected old age of this volcano.

One dredge station was completed on Volcano 5C. Station 30-DR was located on the lower SW flank on a prominent fault scarp. The dredge recovered one piece of weathered aphyric pumice that most likely represents float.

One dredge station was completed on Volcano 5D. Station 25-DR was located on a prominent fault scarp on the mid-SW flank of the volcano, and recovered both weakly weathered and moderately weathered pyroxene-plagioclase andesite together with a moderately weathered plagioclase andesite. It is inferred that this volcano has been active within the last few ka, but that the main phase of eruptive activity took place tens of ka ago.

One dredge station was completed on Volcano 5E. Station 24-DR was located on the upper NE flank immediately below the summit, and recovered weakly weathered pyroxene basalt together with aphyric pumice exhibiting a variety of devitrification textures. The weakly weathered character of the lava suggests the volcano has been active within the last few ka, whereas the pumice is interpreted as float.

Three dredge stations were completed on Volcano 6A. Stations 31-DR, 32-DR and 33-DR were all targetted at scarps on the mid-northern flank with the objective of recovering old lavas from the cone. Station 31-DR recovered a deeply weathered plagioclase andesite, aphyric pumice, and a small piece of fresh aphyric basalt. The latter raises suspicions of contamination on account of its youthful character and small size, however the dredge was carefully cleaned before this station and it may be that one or more flank eruptions have recently occurred on the volcano. Station 32-DR recovered a fine grained conglomerate with deeply weathered clasts of various basaltic and andesitic lavas, including one diorite. Station 33-DR recovered weathered aphyric basalt and aphyric pumice. Overall, it is clear that Volcano 6A has had little (if any) recent eruptive activity.

No dredges were completed on the submarine flanks of 'Ata. A description of the island, and samples collected from it, is given in Appendix 3.

The sampling program on Volcanoes 4–5–6 largely confirmed the observations made from the bathymetry. Few lavas were recovered from the eastern volcanoes (5A, 5B, 5C, 6A), suggesting thick sediments on their flanks. Those lavas that were recovered were almost invariably deeply weathered, or occurred as deeply weathered clasts in conglomerates formed by mass wasting on the lower flanks. 'Ata (Volcano 6B) also belongs to this group. In contrast, fresh or weakly weathered lavas erupted within the last few ka were recovered from Volcanoes 4B, 4C and 5E. Somewhat older lavas with estimated ages of tens of ka were recovered from Volcanoes 4A and 5D. Overall, the pattern suggests a westward jump in volcanism took place at ~150 ka.

5.5. Volcano 7

5.5.1. Bathymetry and Structure

A seamount is apparent on all three pre-SO 167 bathymetric datasets near 22°40'S, but the dimensions and form of this seamount vary markedly between the datasets (Chase, 1985; Tagudin and Scholl, 1994; Smith and Sandwell, 1997). Mapping during SO 167 revealed two large adjacent stratovolcanoes at 22°31'–22°46'S, 176°18'–176°28'W (Fig. 5.5). These volcanoes rise from the surrounding seafloor plain at 1950 mbsl. The break in slope marking the transition from steeply dipping lavas to surrounding volcaniclastic sediment occurs between 1100 mbsl and 1300 mbsl on the northern volcano, but appears to be consistent at 1100 mbsl on the more symmetrical southern volcano.

The northern volcano is much the larger of the two, with a basal diameter of approximately 20 km. Its morphology is irregular and dominated by three high-standing regions in the north (summit at 400 mbsl), east (summit at 350 mbsl) and SW (summit at 250 mbsl) that are joined by a sunken plateau at 450–700 mbsl. The three highs and sunken plateau probably represent an eroded caldera 6.3 km in diameter whose western side has collapsed. Alternatively, the plateau could represent an old stratocone surrounded by three younger but now also partly collapsed stratocones. Major sector collapses have occurred to the WNW, ENE and SSE, leaving valleys 2–3.5 km wide and up to 200 m-deep. A large construct 3.5 km in diameter (with an estimated volume of 5 km^3) on the lower NW flank of the volcano lies 7.6 km downslope of the WNW valley headscarp and arguably represents the largely intact slumped section of the western caldera rim. Numerous small ridges occur on the mid to lower flanks of the volcano, but none have the morphology of satellite cones or flank vents. Instead, they appear to be slump blocks from smaller sector collapses. Similarly, irregularly-shaped 100–200 m-high regions on the summit plateau appear to be slumps and collapses from the three high-standing regions and do not have the form of intra-caldera cones. The flanks of the volcano are extensively dissected by prominent WNW–ESE, WSW–ENE, and SW–NE trending fault sets together with a less prominent NW–SE set.

In contrast, the southern volcano is a simple stratocone with a basal diameter of 12 km. It rises to a summit at 480 mbsl on the south side of a large crater, 200 m-deep and 1.2 km in diameter. Both the WSW–ENE and SW–NE trending fault sets are evident on the volcano flanks, and are associated with throws of up to 20 m. Small sector collapses controlled by these fault sets have developed on the SW and NE–east flanks of the cone. A few small protruberances up to 100 m-high on the western flank, within the crater, and a group of these in the valley between the northern and southern volcanoes are interpreted as small sector collapse deposits rather than satellite cones. Overall, the southern volcano is clearly younger than the northern volcano. However, the lack of well-preserved craters or vent structures, extensive faulting, and sector collapses from both volcanoes suggest a long period of dormancy (tens–hundreds of ka).

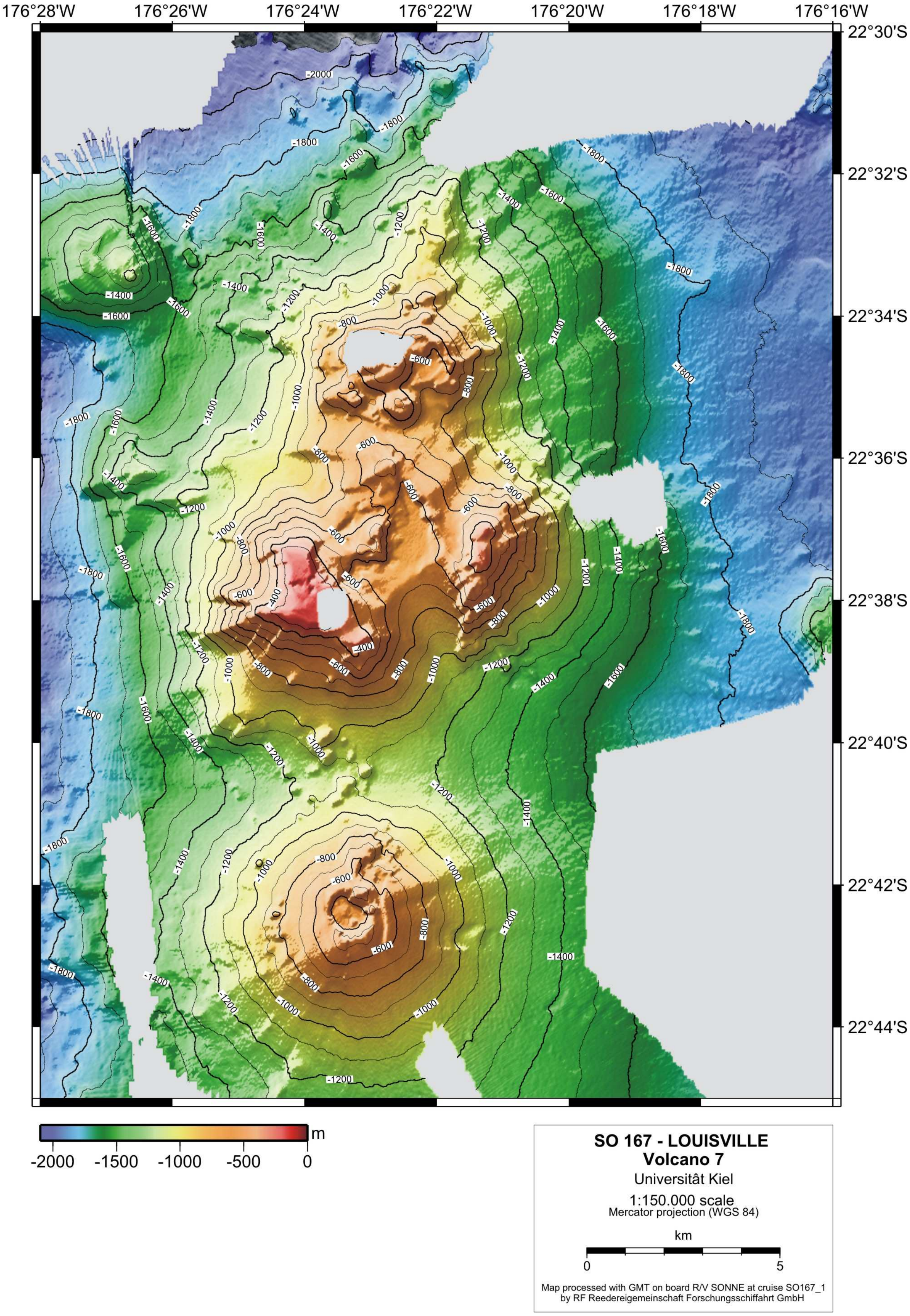

Fig. 5.5: Bathymetry of Volcano 7. Contour interval is 100 m.

5.5.2. Sampling

Two dredge stations were completed on the northern volcano. Station 35-DR was situated on the steep northern wall of a major sector collapse scarp on the mid-SW flank of the SW high-standing region. The objective was to get through any young sediments or pumice float and obtain old lavas from the cone. Several small pieces of deeply weathered conglomerate containing small (<5 mm across) clasts of lava were recovered, together with a large quantity of variably weathered aphyric pumice. The pumice was interpreted as float from a nearby source. Station 36-DR had similar objectives and was located on the mid-eastern flank of the eastern high-standing region. Variably weathered aphyric pumice, locally with devitrification banding, was recovered again. An intense examination of the dredge led to the extraction of some small fragments of aphyric basalt, but suspicions linger that these represent contamination from station 33-DR (which had the same lithology).

Two dredge stations were also completed on the southern volcano. Stations 37-DR and 38-DR were situated on the eastern wall of the SW sector collapse on the mid-flank and lower flank of the cone, respectively. Both recovered weakly weathered aphyric pumice exhibiting a wide range of devitrification textures. The apparent freshness of this pumice, and that recovered from the northern volcano, stand in contrast to the morphological evidence for a long period of inactivity at both volcanoes. Most probably, the pumice is float pumice and was erupted by one of the volcanoes further south.

5.6. Volcano 8: Pelorus

5.6.1. Bathymetry and Structure

Pelorus Reef is marked on the Admiralty Charts as shoaling to 25 mbsl. Both the Chase (1985) and Smith and Sandwell (1997) maps suggest the reef is the summit of a major arc volcano. Pelorus Volcano was duly located at the site of the reef, with the centre of the volcano at 22°51'S, 176°25'W. It is a large and comparatively simple stratocone (Fig. 5.6). The surrounding seafloor is at >1800 mbsl to the SW, but the lower flanks were not mapped out in other directions. A pronounced break in slope at 1200 mbsl on the south, east and north flanks delineates the change from the distal to central volcanic facies. This boundary is obscured on the western flank by at least one major sector collapse. At the break in slope, the cone has a diameter of 14 km.

The south, east and north flanks of Pelorus are smooth, suggesting burial by volcaniclastics or caldera-derived ejecta. No sector collapse scars are evident in these quadrants, further suggesting much of Pelorus is younger than the more eroded volcanoes to the north. The smooth slopes of the south, east and north flanks are broken only by the low SE ridge (50 m-high) and a series of SW–NE faults cutting the NE flank. These faults

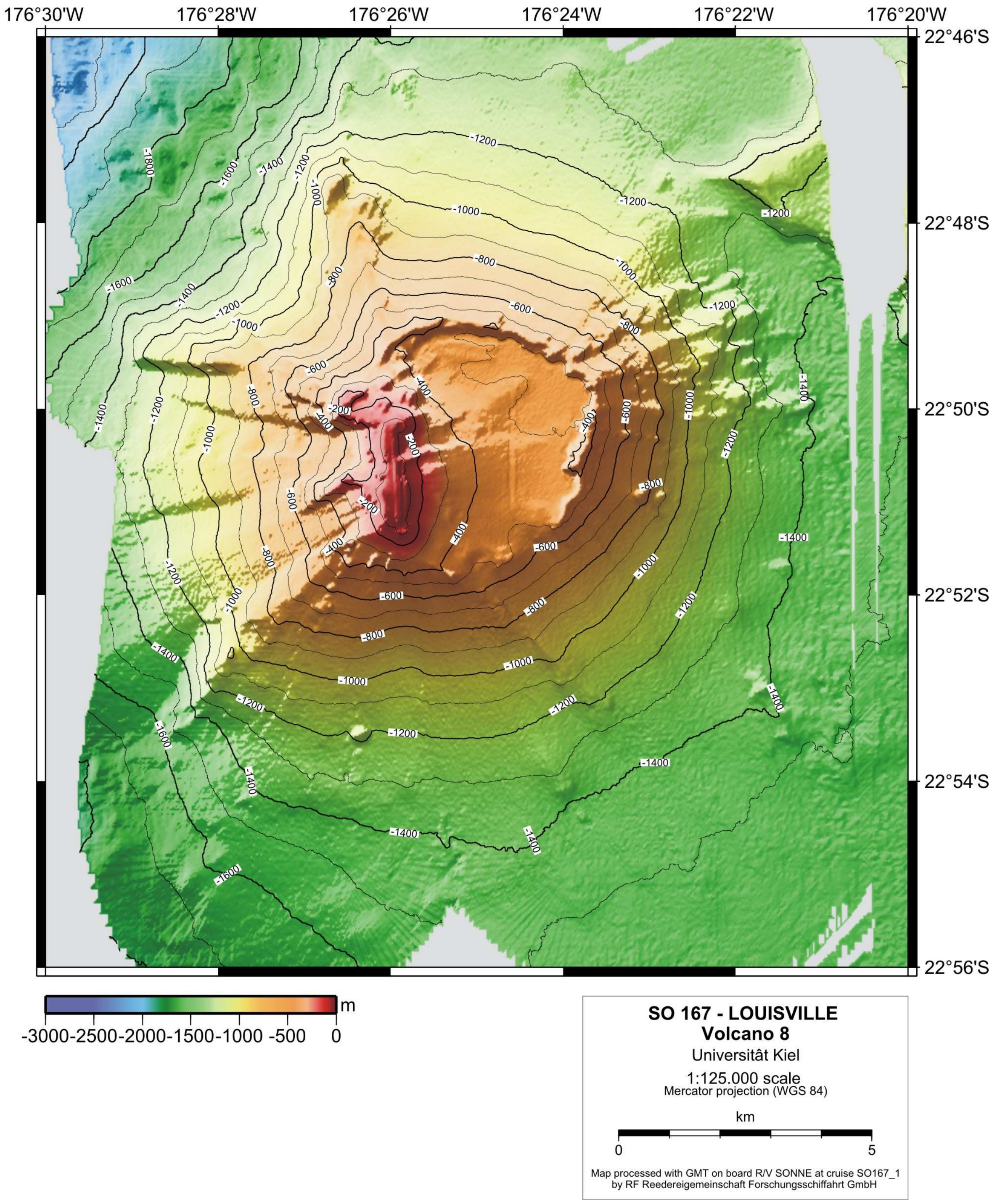

Fig. 5.6: Bathymetry of Volcano 8. Contour interval is 100 m.

protrude as ridges, suggesting possible fissure eruptions. The west flank is more complex and is cut by the NW, west and SW ridges. The west and SW ridges appear to be relics from a former stratocone somewhat smaller (~7 km-diameter at the break in slope) than the present Pelorus cone and located along its western side. The bulk of this cone has collapsed to the west, leaving the deep west valley bounded by the west and SW ridges. The sector collapse left 100 m-high scarps on the southern side of the west ridge and the northern side of the SW ridge; the latter coincides with the southern extension of the SW–NE fault series. A further large WSW–ENE fault bisects the west valley, has a throw of 30 m, and also offsets young sediment infilling the summit caldera. Further north, the origin of the NW valley between the NW and west ridges is unclear. The NW ridge is probably a volcanic construct, as at least two 500 m-diameter and 50 m-high cones have formed near 900 mbsl.

Pelorus is capped by a circular caldera with a diameter of 5 km. The caldera rim is at 500 mbsl except in the west, where it is buried by post-caldera volcanism. The caldera is totally infilled to the south and SE, but the caldera rim is 100 m above the floor along the northern margin. Sediment within the caldera slopes NE away from the young post-caldera cones. Post-caldera volcanism has occurred along the western caldera rim. At least two cones have been constructed with the northern (V8P1) being ~1 km in diameter and rising to 50 mbsl, and the southern (V8P2) ~1.5 km in diameter and rising to the shallowest point on the reef at 35 mbsl. However, the exact form and dimensions of these cones is unclear, as both appear to have suffered major collapses into the west valley (figures cited above are minimum size estimates). These collapses may have been triggered by recent movements on the WSW–ENE or SW–NE faults, both of which offset recent sediments on the caldera floor. At the present time, Pelorus Reef is a north–south lineament formed by the adjoining eastern rims of the northern and southern cones.

5.6.2. Sampling

A large recently formed caldera was predicted at Pelorus from the widespread distribution of weakly weathered aphyric pumice at Volcano 7 and around 'Ata, as no calderas of appropriate age were identified at those complexes. After Pelorus caldera was discovered, it was then anticipated that the smooth outer flanks of the cone would be deeply buried in pumice. Thus, the dredging program specifically targeted steep scarps and the post-caldera cones. Four dredge stations were completed but, contrary to expectations, no pumice was recovered.

Station 39-DR was situated on the northern inner caldera wall from the caldera floor to rim. The aim was to sample pre-caldera lavas, with some possibility of alteration or mineralisation if the caldera ever hosted a hydrothermal field. Recovered lavas ranged from strongly porphyritic plagioclase andesite to pyroxene-plagioclase andesite. Deep weathering and a slight MnOx dusting on the lavas suggests an age of tens to hundreds of ka. There was no evidence of alteration or mineralisation. Station 40-DR was located on the 100 m-high southern scarp of the west ridge. The aim was to sample old pre-caldera lavas exposed along the fault scarp (rather than being buried by pumice elsewhere). Recovered lavas consisted of pyroxene-plagioclase andesite and a series of small subrounded pebbles of varied lithologies including aphyric andesite, plagioclase basalt and plagioclase dacite. These lavas were only weakly weathered, clearly young, and interpreted as part of the post-caldera sequence. They are probably talus detached from the upper NW summit area (V8P1 cone), or possibly were recently erupted on the lower volcano flank.

Station 42-DR was located on the upper west ridge near the base of the V8P1 cone. The aim was to obtain young flows and talus from this cone. Recovered lavas included plagioclase basalts of various ages together with aphyric andesite, pyroxene-plagioclase basalt. All have thin weathering rinds and appear younger than those from 39-DR, but older than those from 40-DR. In addition, two weakly weathered dolerites (representing dykes) and a deeply weathered volcaniclastic conglomerate were recovered. The best interpretation is that the V8P1 cone has a history of intermittent volcanism (few tens of ka) and has collapsed one or more times down the west valley, thus covering the dredge track with lavas and intrusives of various ages. However, the oldest lavas could represent the pre-caldera sequence from the western caldera rim underlying the northern cone. Station 43-DR was located on the upper southern flank of the southern V8P2 cone. The aim was to sample the youngest lavas from Pelorus. Recovered lavas were scoriaceous aphyric basalt and denser plagioclase basalt. These were fresh to only weakly weathered, covered in biota, and have estimated ages of a few hundred years.

5.7. Volcano 14

5.7.1. Bathymetry and Structure

Satellite-derived bathymetry suggests a gap of 80 km between Volcano 8 and Volcano 14, the next significant seamount to the south. The western edge of Volcano 14 was first mapped during the LAUHAVRE cruise (unpublished Cruise Report, 1997), but that cruise had other priorities. Volcano 14 was re-located during SO 167 at 23°34'S, 176°41'W (Fig. 5.7). It rises from the flat seafloor at 1900 mbsl to a summit at 480 mbsl. A subtle break in slope at 1300 mbsl probably marks the transition from the distal to central volcanic facies. The volcano is somewhat elongated in form, being 21 km-long by 17 km-wide at its base with the long-axis orientated NE–SW.

Volcano 14 consists of a main eastern cone capped by a small caldera, a somewhat smaller western cone capped by a deep crater, and an area of irregular topography at its SW base. The main eastern cone has smooth symmetrical flanks rising to an oval summit caldera 4.2 km-long by 3.2 km-wide and elongated WNW–ESE. Almost all of the caldera rim is at ~550 mbsl, with local highs rising to 480 mbsl on the SE and eastern rim and a low point at 620 mbsl to the NW. The caldera floor is at 780–820 mbsl. The smooth flanks of the cone suggest deep burial by pumice or material ejected during the caldera-forming eruption (and/or that of the crater-forming eruption on the adjacent western cone). Five small low-relief volcanic domes(?) are aligned WNW–ESE across the central floor of the caldera, with the largest being 700 m in diameter and 100 m-high. These probably represent the most recent eruptive phase. The smooth flanks of the cone are broken by >30 small volcanic domes up to 500 m in diameter and 100 m-high. The largest of these are

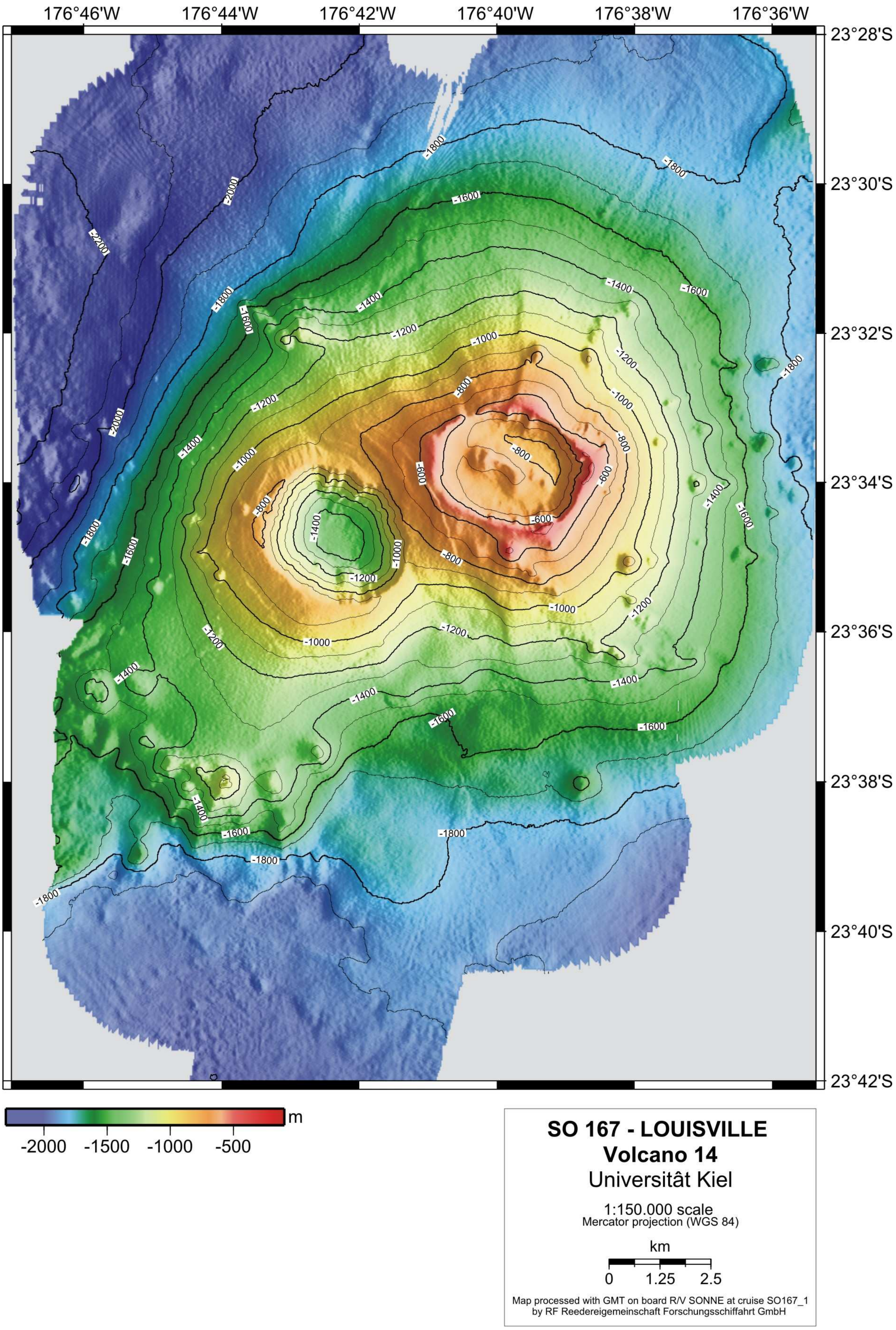

Fig. 5.7: Bathymetry of Volcano 14. Contour interval is 100 m.

located on the lower south flank, mid SW flank, and near the summit immediately south of the caldera rim. Their subdued relief suggests most pre-date the caldera-forming eruption and were partly buried by it. Prominent curvilinear fractures disrupt the SW flank of the cone and are concentric with the crater of the western cone; they indicate the western cone is younger than the eastern cone.

The western cone abuts the eastern cone and is somewhat smaller, with a basal diameter of 11 km. Its flanks are particularly smooth and featureless, rising to a large crater 3.9 km-long by 3.6 km-wide and elongated NW–SE. The crater rim is shallowest in the west (780 mbsl) and decreases gradually to a low at 920 mbsl on the SW rim. The crater floor is flat, with dimensions of 1.4 km-long by 1.0 km-wide at 1420 mbsl, giving a maximum crater depth of 640 m. Irregular topography on the inner north and SW crater walls probably reflects outcropping resistant lavas, as there are no slump deposits beneath these regions. The crater is patently young (no more than a few thousand years), as the steepest section of the northern wall dips at 45–50° and the area is subject to regular strong earthquakes (>6 on the Richter scale) originating at the Tonga–Kermadec Trench. Five small volcanic domes (largest 400 m in diameter, 50 m-high) with subdued relief outcrop on the western flank of the cone, and a series of fractures concentric with the crater outline penetrate the adjacent eastern cone.

At the SW base of Volcano 14 is an area of irregular topography that includes at least 6 constructs up to 700 m in diameter that rise 100–300 m above the surrounding plain. These contructs are aligned WNW–ESE and are both parallel and adjacent to a prominent fault with a 150 m throw. They may represent a series of volcanic domes or the remnants of an old disrupted volcanic edifice.

5.7.2. Sampling

Four dredge stations were completed on the eastern volcano. Station 80-DR was located on the upper western flank and was expected to sample ejecta from either the caldera-forming or crater-forming eruption. Weakly weathered pumice, commonly with devitrification banding and characterised by pyroxene microphenocrysts, was recovered, along with one clast of aphyric dacite. Four deeply weathered xenoliths of aphyric basalt were found in the pumice. Stations 81-DR and 83-DR were located on the upper inner southern caldera wall, with the objective being to obtain pre-caldera lavas. Both recovered the distinctive pyroxene microphenocryst-bearing pumice, with xenoliths of aphyric basalt in the pumice at station 81-DR. More significantly, the former also retrieved weathered aphyric andesite and plagioclase andesite with adhering biota that clearly represent outcropping lavas within the caldera wall. Station 85-DR dredged the southern flank of the dome complex within the caldera. Only the distinctive pyroxene microphenocryst-bearing pumice was recovered. The occurrence of pyroxene microphenocryst-bearing pumice on top of the post-caldera dome indicates that the pumice represents the crater-forming eruption from the western cone, and confirms the morphological interpretation that the western crater is younger than the eastern caldera.

One dredge station was completed on the western cone. Station 82-DR was located on the inner western crater wall, with the objective being to test whether this cone consisted entirely of pumice or really was a crater that blasted through a stacked series of older lavas. The dredge recovered a wide variety of lithologies, including the pyroxene microphenocryst-bearing pumice and weakly weathered plagioclase basalt, aphyric basalt, aphyric andesite and aphyric dacite, together with an old deeply weathered plagioclase andesite and three blocks of olivine gabbro. It is evident that the western cone is a stratocone with a long volcanic history, and whose core has been exposed and partly removed by the highly explosive eruption that formed the 700 m-deep crater.

5.8. Volcano 15

5.8.1. Bathymetry and Structure

Satellite-based bathymetry suggested the next seamount to the south was at 23°50'S. Mapping during the LAUHAVRE cruise (unpublished Cruise Report, 1997) located a large complex topographic high near these co-ordinates. However, mapping during SO 167 revealed this feature was a strongly tectonised broad ridge with no evidence of recent volcanism or recognisable volcanic constructs (Fig. 5.8). The survey area was then extended to the SE, on the basis that the LAUHAVRE data precluded an active volcano in any other direction. Volcano 15 was subsequently discovered 14 km SE of the tectonised ridge at 23°54'S, 176°45'W.

Volcano 15 is one of the smaller volcanoes discovered during SO 167, being a relatively simple cone capped by a caldera. It rises from the flat seafloor plain at 1800 mbsl to a summit on the northern caldera rim at 1080 mbsl, and has a basal diameter of 12 km. No break in slope is apparent on the smooth seamount flanks, which are interpreted to be deeply buried by ejecta from the caldera-forming eruption. The summit caldera is 4.7 km-long by 3.9 km-wide, elongated NW–SE, and breached to the SW. Elevations around the caldera rim decrease from 1080 mbsl on the northern caldera wall to 1500 mbsl in the SE breach. Much of the SW caldera floor is at 1420 mbsl, whereas the NE half is partly filled by a low relief post-caldera cone 2 km in diameter and 120 m-high together with a smaller high relief volcanic dome(?) 900 m in diameter and 200 m-high. The low relief cone itself hosts a 150 m-deep crater 1.3 km across. Two smaller volcanic dones are located along strike of the NW–SE lineament formed by the intra-caldera cone and dome; one on the mid-NW flank, and the other in the SW caldera breach. These four contructs probably represent the most recent eruptive episode at the volcano. A large block measuring 2.5 km-across by 2.5 km-wide is located 2.2 km downslope of the caldera breach and appears to

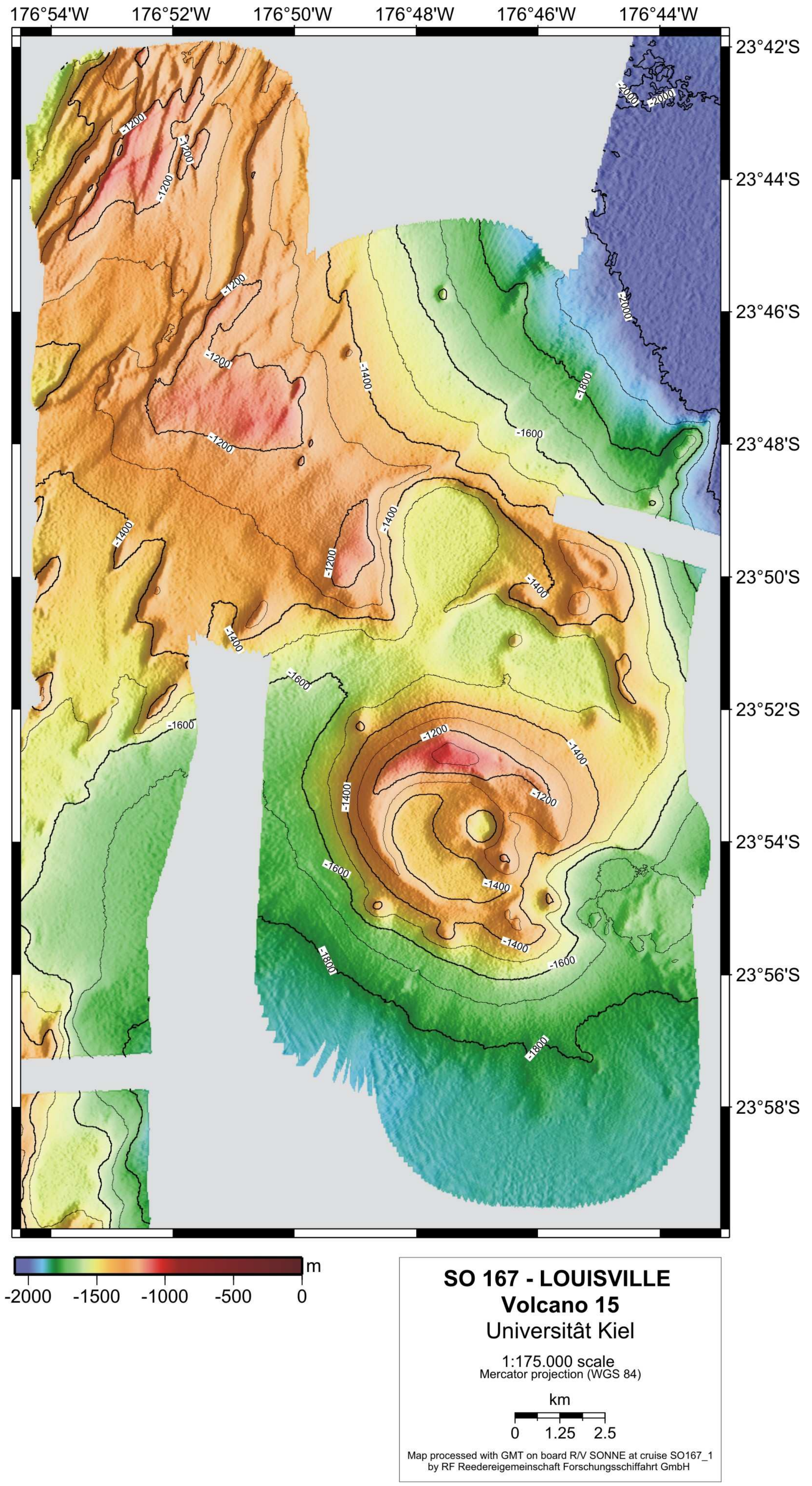

Fig. 5.8: Bathymetry of Volcano 15. Contour interval is 100 m.

represent the still largely intact caldera wall segment that has slumped outwards. This sector collapse may have been triggered by the intrusion of the small dome in the SW caldera breach. A further three small volcanic domes up to 600 m in diameter and 150 m-high are located around the mid-southern flank of the main cone, and three more are located at the northern base of the cone.

A semi-circular 8 km-wide embayment into the tectonised ridge 8 km north of Volcano 15 possibly represents either a much degraded second caldera or, more speculatively, may be the true northern half of a much larger ancestral Volcano 15. In the latter model, the present main cone is simply the younger southern cone built within a much older and larger caldera.

5.8.2. Sampling

Three dredge stations were completed on the main cone of Volcano 15. Station 86-DR was located on the northern side of the SW caldera breach in the hope of obtaining pre-caldera lavas from the scarp. Weathered aphyric pumice, locally with devitrification banding, was recovered together with a distinctive quartz-bearing hard pumiceous unit. Station 87-DR was targetted on the high relief dome within the caldera and recovered the same lithologies. Xenoliths of olivine-plagioclase basalt and andesite were found within some blocks of the quartz-bearing pumice. Station 88-DR was located on the inner north caldera wall directly below the summit and again retrieved the same lithologies. Based on these results, the most probable interpretation has the quartz-bearing pumice representing the post-caldera dome, with the aphyric pumice representing the crater-forming eruption of the adjacent low relief intra-caldera cone and being somewhat younger. The weathered nature of the recovered blocks suggests this volcano has been inactive for a longtime (tens of ka or more).

Station 89-DR was located on the inner east-facing scarp of the semi-circular embayment north of Volcano 15. The objective was to test whether this structure is volcanic and part of a greater, ancestral, Volcano 15. Deeply weathered aphyric pumice was recovered, along with small fragments of the less weathered pumice and its variants as recovered from Volcano 15 *sensu stricto*. The dredge results fail to resolve the origin of the semi-circular embayment, but do demonstrate that it pre-dates the post-caldera activity at Volcano 15.

5.9. Volcano 16

5.9.1. Bathymetry and Structure

Satellite-based bathymetry depicts the next seamount at 24°10'S. The lower western flank of this seamount was partly mapped during the LAUHAVRE cruise (unpublished Cruise Report, 1997). Volcano 16 was duly discovered at 24°11'S, 176°52'W during SO

167. The lower flanks of this volcano were mapped only to the NE and SW of the edifice, where the seafloor plain is at 1800 mbsl.

Volcano 16 is large edifice >19 km-long by 19 km-wide and elongated WNW–ESE (Fig. 5.9). It is irregular in form, with three high-standing peaks in the SW (550 mbsl), NW (750 mbsl) and NE (580 mbsl) joined by a broad summit plateau. The summit plateau is interpreted as a large oval caldera, 12 km-long by 6.3 km-wide, elongated WNW–ESE, and now completely infilled by younger ejecta. The caldera rim is best preserved in the west, and originally linked all three high-standing peaks. The absence of a SE peak may indicate the caldera was breached to the SE. Within this caldera is a second younger caldera, 8.0 km-long by 5.6 km-wide, also elongated WNW–ESE. The rim of this caldera remains well-defined, but it too has been almost completely infilled by subsequent eruptions. Within the second caldera are three circular craters, the largest of which is 3.6 km in diameter and 450 m-deep. At the base of this crater is a low relief cone 900 m in diameter and 50 m-high. The flanks of Volcano 16 are exceptionally smooth and gently sloping (especially to the SE), reflecting deep burial by the repeated voluminous caldera-forming eruptions. Several SW–NE trending fault sets cross the SW and NE summit peaks, and are inferred to control the caldera boundaries. Two small collapses from the original SW caldera rim have occurred where it is cut by these faults, and the slump blocks have come to rest on the lower southern flank against another sub-parallel fault set. Volcano 16 adjoins a strongly tectonised ridge to the NW.

5.9.2. Sampling

Three dredge stations were completed at Volcano 16. Station 91-DR dredged the inner NE wall of the young 450 m-deep crater. A distinctive weakly weathered hornblende-quartz pumice was recovered, together with more weathered hornblende-quartz dacite, quartz-plagioclase dacite, and several diorite blocks. The dacites are interpreted as the remnants of post-caldera volcanic domes, whereas the pumice probably represents more recent eruptions (estimated age of a few ka) that largely infilled the smaller caldera. Station 92-DR dredged the outer NW rim of the smaller caldera and recovered more hornblende-quartz pumice with a variety of devitrification textures, together with a series of small deeply weathered mafic lavas occurring as xenoliths in the pumice. Station 93-DR targetted the upper southern flank of the SW peak in an attempt to recover older pre-caldera lavas. Hornblende-quartz pumice with a variety of devitrification textures was again retrieved, but the haul also included one small block of weathered andesite. Volcano 16 is the only volcano in the Tonga arc known to have erupted either hornblende or quartz.

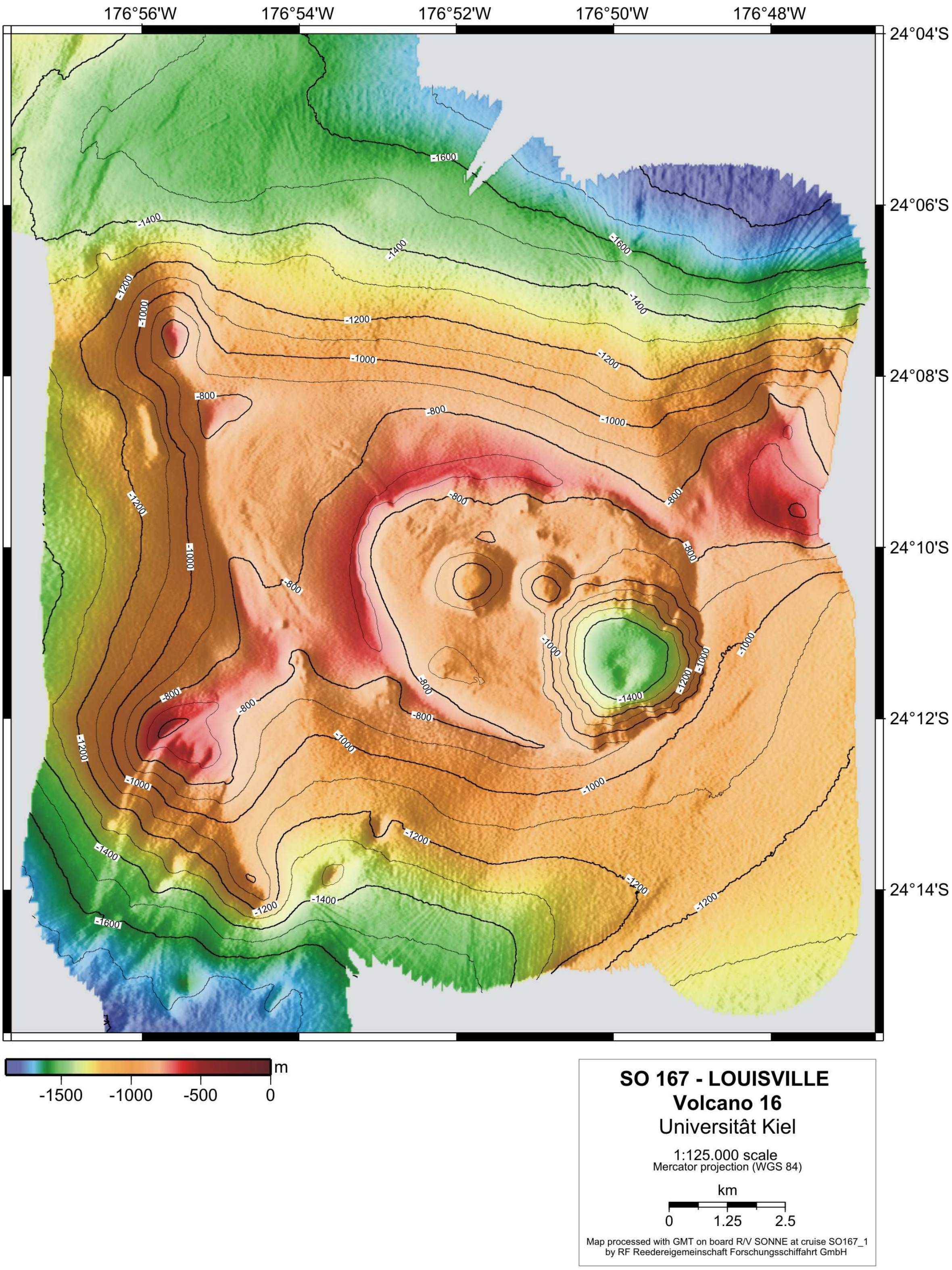

Fig. 5.9: Bathymetry of Volcano 16. Contour interval is 100 m.

5.10. Volcano 18

5.10.1. Bathymetry and Structure

A west–east pair of volcanoes near 24°30'S was predicted from satellite-based bathymetry, and designated Volcano 17 (west) and Volcano 18 (east). Part of the larger eastern volcano was mapped by the LAUHAVRE cruise (unpublished Cruise Report, 1997). Mapping during SO 167 located two large volcanoes at the Volcano 18 site (Fig. 5.10). In light of this result and time constraints, no attempt was made to search for what was expected to be a much smaller edifice to the west. The two discovered volcanoes are adjacent northern (24°29'S, 176°55'W) and southern (24°35'S, 176°54'W) stratocones. Their lower flanks were incompletely mapped, but both rise from the flat seafloor plain at ~1500 mbsl and have basal diameters of 15–20 km. Both volcanoes have smooth flanks that indicate deep burial by material probably ejected from the large crater on the southern volcano.

The northern volcano is a relatively simple stratocone with a diameter of 10 km at 1200 mbsl (the lowest closed isobath during the mapping) rising to a summit at 190 mbsl. A striking feature of this volcano is the presence of >40 small pyroclastic cones crossing the volcano along a SW–NE lineament and giving it the appearance of a stegosaurus. Most of these cones have basal diameters of 300 m, are up to 100 m-high, and have completely modified the summit morphology of the volcano. The largest cone is 800 m in diameter, 150 m-high, occurs at the summit of the volcano, and is breached to the NNE. In detail, several sub-parallel cone lineaments are present and associated with sub-parallel SW–NE and SSW–NNE fault sets. The lower SW flank of the volcano is cut by a NW–SE fault set, and another prominent SW–NE fault set cuts the lower NW flank of the volcano but is not associated with any of the cones. Small sector collapses on the upper NE flank were probably contemporaneous with the cone-building eruptions. The SE flank of the volcano is exceptionally smooth, whereas the NW flank shows very subdued relief. This suggests deep burial by material erupted from the nearby southern volcano. A large satellite cone 500 m-high and 2.8 km in diameter occurs on the lower NW flank and is extensively disrupted by SW–NE faults. Overall, the northern volcano is interpreted as an old faulted stratocone whose recent activity is restricted to small pyroclastic cone-forming eruptions along the dominant SW–NE fault set. The relief of these cones and their occasional small craters suggests at least some are younger than the blanketing eruption from the southern volcano.

The southern volcano is the larger, with a diameter of 14 km at the 1200 mbsl isobath (the lowest closed isobath during the mapping). It is dominated by a large funnel-shaped crater 6.9 km-long by 6.3 km-wide. Although the crater rim is weakly elongated E–W, the crater floor is elongated SW–NE and follows the more prevalent trend. The eastern crater rim includes the summit at 390 mbsl, and progressively decreases in height to 950 mbsl in

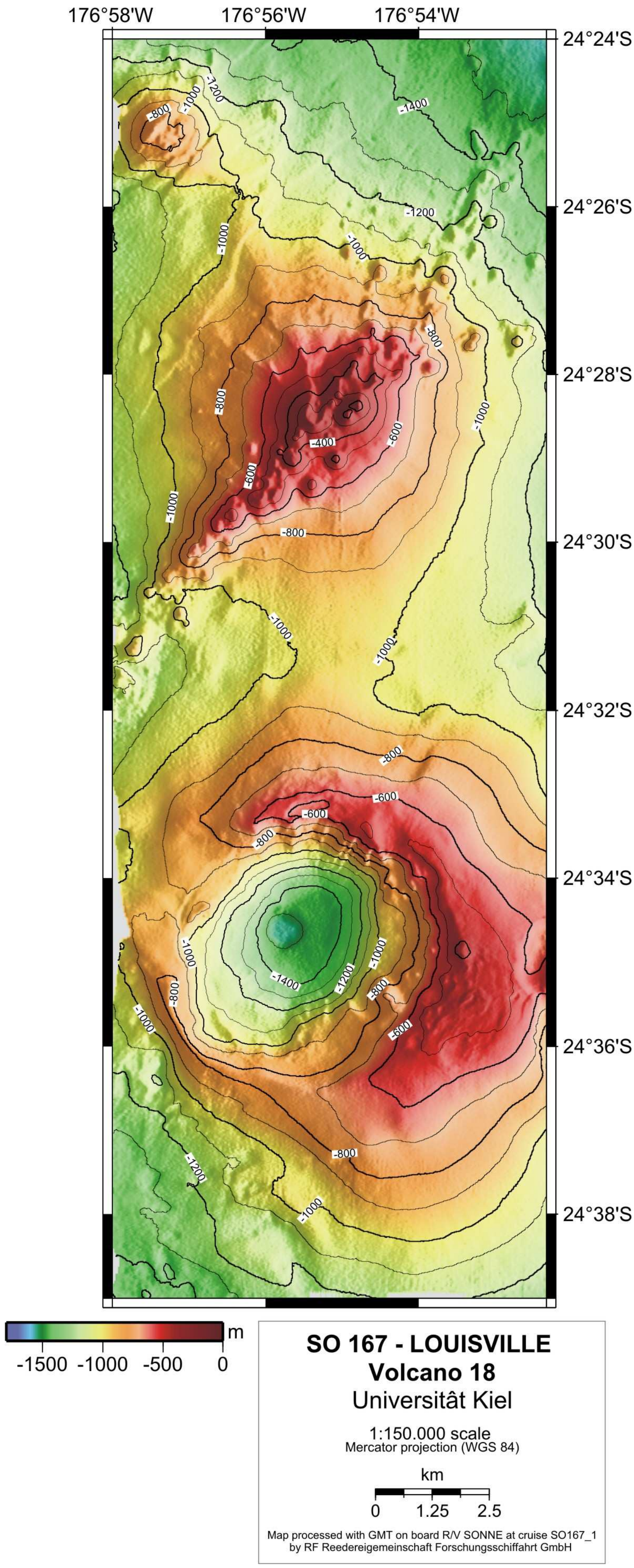

Fig. 5.10: Bathymetry of Volcano 18. Contour interval is 100 m.

the west. The base of the crater is at 1520 mbsl, approximately the same altitude as the surrounding seafloor plain, making it 1130 m-deep as measured from the summit. Irregular topography on the inner north and SE crater walls probably reflects outcropping resistant lavas, as there are no slump deposits beneath these regions. As with the deep crater on Volcano 14, this crater is patently young (no more than a few thousand years) as the steepest part of the crater wall (a 600 m-high section below the northern crater rim) has a slope of 45–50° and the area is subject to regular strong earthquakes (>6 on the Richter scale) originating at the Tonga–Kermadec Trench. The eastern crater rim has a pronounced bench at 900 mbsl that may reflect the original height of the volcano; if this interpretation is correct, then the shallower part of the crater rim to the east is an ejecta blanket from the crater-forming eruption and is up to 500 m-thick. Further east on the mid-flank of the volcano is a SSE-directed sector collapse scar whose headscarp is filled by large cone 1.7 km in diameter and 300 m-high. This sector collapse is almost completely buried by the crater ejecta blanket, and therefore pre-dates the crater-forming eruption. The northern flank of the volcano has a few subdued SW–NE trending lineaments that probably represent buried faults. In summary, the southern volcano is interpreted as an old stratocone cut by several fault sets and suffering at least minor sector collapse before the catastrophic crater-forming eruption occurred. Evidence that this was a single event includes the thick summit ejecta blanket to the east, the widespread burial of both this stratocone and the nearby northern volcano, and the simple funnel-shaped crater morphology.

5.10.2. Sampling

One dredge station was completed on the northern volcano. Station 95-DR was located on the upper NE flank near the summit and expected to return material from both the summit cone and an adjacent slightly lower cone. The dredge recovered essentially fresh scoriaceous aphyric basalt (with an estimated age of a few hundred years), a weakly weathered series of plagioclase basalts, and weathered quartz-hornblende pumice. The basalts are interpreted to represent the cones and to confirm their youthfulness. The pumice is identical to that recovered from Volcano 16 to the north, and distinct from that erupted during the crater-forming eruption from the southern volcano (see below).

Two dredge stations were completed on the southern volcano. Stations 96-DR and 97-DR were located on the inner northern crater wall, with 96-DR at mid-elevation and 97-DR near the crater rim. The objective was to sample stacked lava flows from the pre-crater stratocone followed by the crater-forming event. The mid-level dredge returned numerous lithologies including variably weathered aphyric andesite, plagioclase andesite, aphyric dacite, plagioclase dacite, aphyric pumice locally with devitrification textures, and strongly chloritised and sheared fault gouge material. With the exception of the pumice, these are interpreted to represent lavas emplaced before the crater-forming event. The summit dredge was dominated by weathered aphyric pumice locally exhibiting a wide variety of devitrification textures. Also recovered were some small fragments of weathered olivine-plagioclase basalt and aphyric basalt, and a weathered conglomerate. The pumice is interpreted to represent the crater-forming event, and its moderate weathering suggests an age of several ka.

5.11. Volcano 19–20

5.11.1. Bathymetry and Structure

A west–east pair of volcanoes near 24°45'S was predicted from satellite-based bathymetry and the semi-regular volcano spacing along the south Tonga arc, and designated Volcano 19 (east) and Volcano 20 (west). No other evidence for either volcano existed. Mapping during SO 167 located a large volcano at the Volcano 19 site (Fig. 5.11). In light of this result and time constraints, no attempt was made to search for what was expected to be a much smaller edifice to the west.

Volcano 19 rises from the seafloor plain at 1400 mbsl, has basal dimensions of 14 km by 12 km, and is somewhat elongated NW–SE. The volcano has smooth flanks that rise to a complex summit peaking at 450 mbsl. The summit is dominated by an old crater, an infilling cone, and a younger western crater. The old crater is poorly preserved, 3.2 km-long by 2.2 km-wide, and elongated NW–SE. Only its eastern wall remains, together with a few sections of the northern wall. This crater is now largely filled by a younger cone 1.7 km in diameter, whose highest point is the volcano summit at 450 mbsl. More recently, a crater 1.8 km in diameter and 250 m-deep has blasted away much of the western wall of the old crater. The cone has partly collapsed into this young crater, and also down the outer southern flank of the volcano. Two small constructs 250 m in diameter and <100 m-high occur on the floor of the young west crater, but it isn't clear whether these represent post-crater cones or slump blocks from the older cone to the east. At least 15 small cones, each <200 m across and <100 m-high, have broken through the smooth SW and NE flanks of the volcano. They form a SW–NE volcanic lineament that passes through the summit of Volcano 19 and a satellite cone 500 m-high with a basal diameter of 2.5 km further to the SW. Only the northern flank of the satellite cone was mapped. Volcano 19 adjoins a strongly tectonised ridge to the NW.

5.11.2. Sampling

Two dredges were completed on Volcano 19. Station 19-DR was located on the inner NE wall of the young western crater. Samples from numerous lava flows were recovered, including both vesicular and non-vesicular variants of olivine-plagioclase basalt, plagioclase basalt and plagioclase andesite. Most were weakly weathered. Station 100-DR targetted the western flank of the cone filling the old crater and recovered a similar

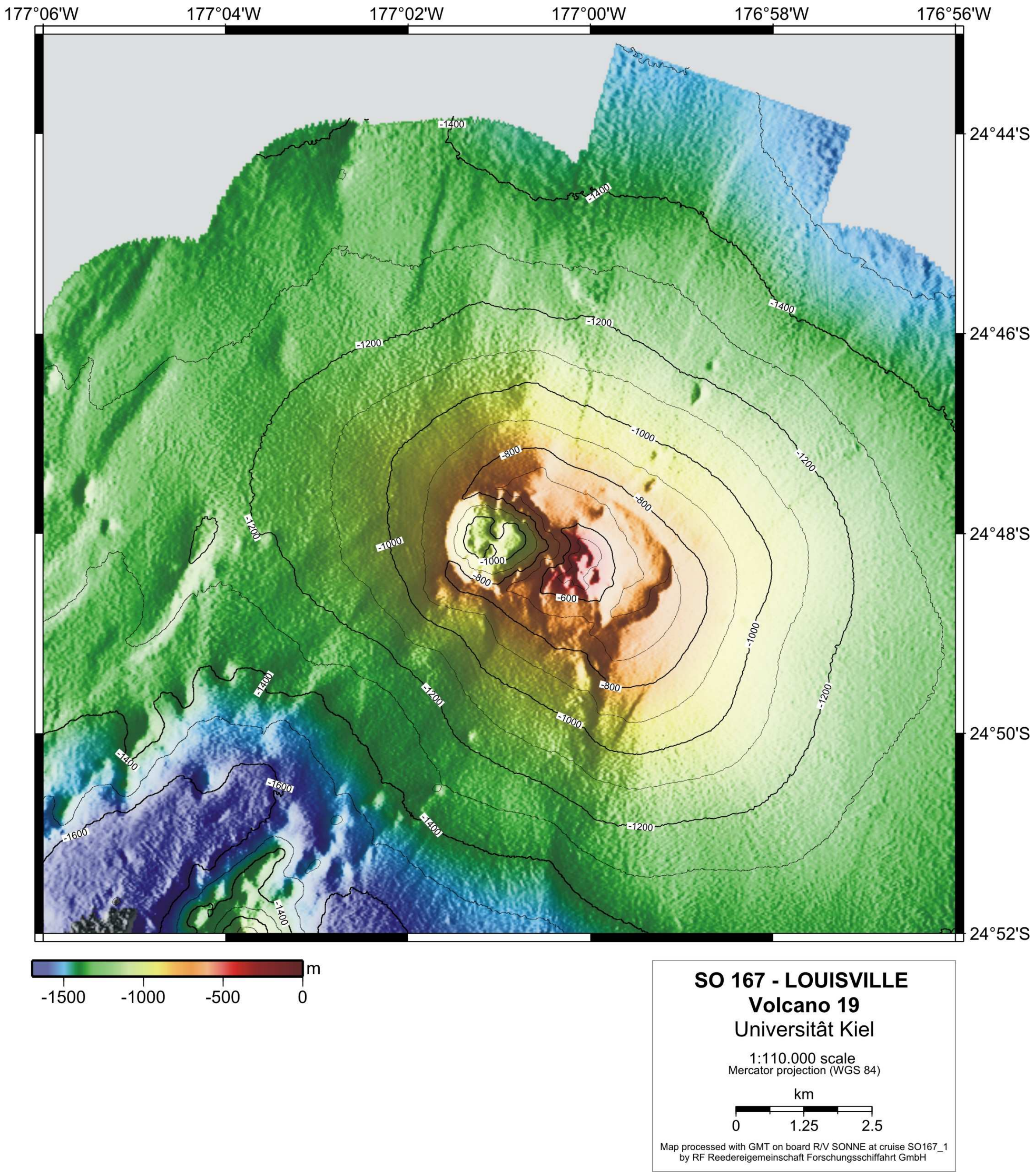

Fig. 5.11: Bathymetry of Volcano 19. Contour interval is 100 m.

sequence of equal variety. These dredge stations indicate that numerous small eruptions ranging from olivine basalt to plagioclase andesite have taken place within the old summit crater over the last few ka.

One dredge was completed on the satellite cone SW of Volcano 19. Station 102-DR dredged the SW summit of this cone, and recovered weathered aphyric andesite. The satellite cone probably pre-dates the recent activity at the summit of Volcano 19.

5.12. Volcano 21–22

A further pair of volcanoes near 25°10'S were described by Tagudin and Scholl (1994), who presented a seismic line purporting to show volcaniclastic sediment from the western volcano onlapping older volcaniclastic sediment from the eastern of the pair. On this basis, these volcanoes were designated Volcano 21 and 22 during planning for SO 167. However, no volcanic structures were found near the cited co-ordinates for either volcano during SO 167. The survey area was extended to the south and east, but again failed to detect any significant edifices rising from the seafloor. Satellite-derived bathymetry for this area is not conclusive, as the relatively shallow seafloor is a complex tectonic mosaic (generating a high background noise level) and even large volcanic edifices could lurk unseen in the database (Fig. 5.1).

The SO 167 bathymetry precludes any significant volcanoes from the mapped area. However, our coverage to the north and south of the target area is insufficient to support an argument that there is a volcanic gap in this part of the arc. Arc volcanism may change from focussed (stratocones) to diffuse (fissure venting), be offset to either the east or west relative to the Volcano 14–19 sector of the arc and Monowai area, or continue unchanged with large volcanoes immediately north and south of our mapped area. It is evident that the co-ordinates of the seismic line given by Tagudin and Scholl (1994) are incorrect, and that the true location and identity of those two volcanoes is presently unknown.

5.13. Conclusions

Prior to SO 167, only one long-dormant volcano ('Ata Island) was known to exist in the 650 km segment of the Tonga–Kermadec arc between the subaerial Hunga and submarine Monowai volcanoes. It had been proposed that a volcanic gap existed in this segment, as a consequence of subducting the Louisville Ridge (Nur and Ben-Avraham, 1983). Furthermore, the geochemical signature of the Louisville Ridge was thought by some to have been found in the northermost Tonga arc volcanoes (Turner et al., 1997; Wendt et al., 1997; Turner and Hawkesworth, 1997; Regelous et al., 1997; Turner and Hawkesworth, 1998; Ewart et al., 1998). However, satellite-derived bathymetry provided confidence that the volcanic front did continue throughout this arc segment, and that 17 major volcanoes waited to be ground-truthed and sampled (Fig. 5.1).

The results of the south Tonga arc work far exceeded expectations. Mapping led to the discovery of 27 major volcanoes together with a large number of smaller flank vents and satellite cones. Sampling of these volcanoes was highly successful. In total, 55 dredge stations were completed and 416 samples logged (Tables 5.1 and 5.2; refer also Appendix 2). Of these, 119 samples were selected and prepared for analytical work back in Kiel. The

Table 5.1: Petrology Samples and Lithologies, South Tonga Arc Phase 1 (Volcanoes 1–8)

Station No.	Samples logged	Selected analysis		Aph Bas	Ol-Pl Bas	Ol-Px Bas	Ol-Px-Pl Bas	Px Bas	Px-Pl Bas	Pl Bas	Aph And	Px-Pl And	Pl And	Aph Dac	Pl Dac	Pum	Doler	Gabb	Dior	Con
01 DR	12	5			X	X	X													X
03 DR	15	4								X			X	X						
04 DR	8	4		X						X				X						
05 DR	20	10		X						X	X		X				X	X		
06 DR	2	-														X				
07 DR	-	-																		
08 DR	2	1		X												X				
09 DR	14	5		X						X		X								X
11 DR	3	-														X				X
12 DR	3	-														X				X
13 DR	7	3														X				
14 DR	12	5												X		X				X
15 DR	13	4										X		X	X	X				X
17 DR	11	4												X		X	X			
18 DR	13	5								X			X		X					X
19 DR	7	3														X				
20 DR	6	2											X			X				
21 DR	7	3								X	X									
22 DR	16	7								X		X	X		X	X		X	X	
23 DR	9	6		X						X			X			X				
24 DR	7	4						X								X				
25 DR	6	3										X	X							
26 DR	1	-						X												
27 DR	9	2		X												X				
29 DR	1	-																		X
30 DR	1	-														X				
31 DR	3	-		X									X			X				
32 DR	1	-																		X
33 DR	5	3		X												X				
35 DR	6	2														X				X
36 DR	9	4		X												X				
37 DR	7	4														X				
38 DR	4	2														X				
39 DR	6	3										X	X							
40 DR	2	1										X								

Station No.	Samples logged	Selected analysis		Aph Bas	Ol-Pl Bas	Ol-Px Bas	Ol-Px-Pl Bas	Px Bas	Px-Pl Bas	Pl Bas	Aph And	Px-Pl And	Pl And	Aph Dac	Pl Dac	Pum	Doler	Gabb	Dior	Con
42 DR	9	8						X	X		X						X			X
43 DR	5	2		X						X										
'Ata Is.	10	10										X	X							
37 Stns	**272**	**119**		**10**	**1**	**1**	**1**	**3**	**1**	**9**	**3**	**7**	**10**	**5**	**3**	**21**	**3**	**2**	**1**	**11**

Table 5.2: Petrology Samples and Lithologies, South Tonga Arc Phase 2 (Volcanoes 14–19)

Station Number	Samples logged	Selected analysis		Aph Bas	Ol Bas	Ol-Pl Bas	Pl Bas	Aph And	Pl And	Aph Dac	Hb-Qz Dac	Pl-Qz Dac	Pl Dac	Pum	Gabb	Dior	Ch-Ze Clay	Congl
80 DR	6	3											X	X				
81 DR	8	4						X	X					X				
82 DR	17	8		X			X	X	X	X				X	X			
83 DR	2	2												X				
85 DR	4	2												X				
86 DR	4	3												X				
87 DR	6	3				X								X				
88 DR	4	3												X				
89 DR	2	1												X				
91 DR	10	4									X	X		X		X		
92 DR	6	3												X				
93 DR	7	3						X						X				
95 DR	8	5		X			X							X				
96 DR	12	6						X	X	X			X	X			X	
97 DR	17	6		X		X				X				X				X
99 DR	12	6				X	X		X									
100 DR	15	8		X	X		X	X	X									
102 DR	4	2						X										
18 Stns	**144**	**72**		**4**	**1**	**3**	**4**	**6**	**5**	**3**	**1**	**1**	**2**	**15**	**1**	**1**	**1**	**1**

dominant lithologies were aphyric basalt, plagioclase basalt and plagioclase andesite. Fine-grained volcaniclastic conglomerate, generated by mass wasting on the slopes of the older volcanoes, was also common. Pumice was recovered at most dredge stations, reflecting both *in situ* outcrops and the widespread distribution of voluminous tephra deposits from caldera-forming eruptions.

The key provisional results of the SO 167 south Tonga arc program are:

1) 27 major arc volcanoes were discovered and mapped on the 650 km-long arc segment between the previously known Hunga and Monowai volcanoes. Most have basal diameters of 10–25 km and summits that are 1000–2000 m above the seafloor. The majority of the summits in the northern region (Volcanoes 1–8) are within 200 m of sea-level. In the south (Volcanoes 14–19), they are deeper and generally at 500–700 mbsl.
2) These volcanoes are spaced at semi-regular intervals throughout the segment. There is no evidence of a volcanic gap associated with subduction of the Louisville Ridge. However, two anticipated volcanoes south of Volcano 19 and north of Monowai were not located. Our results leave open the possibility that a small gap of up to 120 km exists in the volcanic front in this region.
3) Most volcanoes occur as closely-spaced pairs of major stratocones (Volcanoes 1–2, 3, 7, 14, 16). In general, these consist of a northern and southern massif. At some, one stratocone is clearly younger than the other, but at others both stratocones are either active or inactive. There is no evidence of a consistent migration in active centres with time at these volcanoes. Only three volcanoes occur as discrete single stratocones (Volcanoes 8, 16, 19).
4) A remarkable cluster of 14 major volcanic edifices occurs near 'Ata (Volcanoes 4, 5, 6). Here, the eastern volcanoes are flat-topped and heavily sedimented with summit plateaux at 150 mbsl. This indicates no summit eruptions since the sea-level low-stand at 17 ka (and probably that at 130–160 ka). Their lower flanks are extensively faulted, also indicating a long period of inactivity. Conversely, the western volcanoes are steep-sided stratocones with sharp summits. Dredging obtained fresh lavas from many of the latter cones. Thus, there is clear evidence of a westward migration of volcanism at the 'Ata Volcanic Complex since ~150 ka.
5) The 'Ata Volcanic Complex directly overlies the most probably location of the subducting Louisville Ridge within the subduction system. The Louisville Ridge consists of large (>1000 km^3) seamounts composed of marine weathered (hydrated) lavas. Subduction of these relatively less dense seamounts may cause the slab to dip at a shallower angle, the effect of which would be an apparent westward migration in volcanism. Furthermore, dehydration of these seamounts within the subduction system may release more water than usual, resulting in increased mantle melting and volcanism. These ideas will be confirmed (or rejected) by high-precision trace element and isotopic analyses of the arc lavas.

6) 8 calderas were discovered (Volcanoes 1, 2, 3, 7, 8, 14, 15, 16). Typically, these are oval-shaped and ~6 km-long. Most are partly infilled by resurgent volcanism that may develop at the caldera centre (e.g., Volcano 2, 14) or, more commonly, on the caldera rim (e.g., Volcanoes 1, 3, 8). Resurgent volcanism may be basaltic (Volcanoes 1, 8) or dacitic (Volcano 3). A remarkable series of nested calderas occurs on Volcano 16. In all cases, pumice erupted during the voluminous caldera-forming events has blanketed and smoothed the surrounding flanks of the stratocone.
7) Deep, funnel-shaped craters occur on Volcanoes 14, 16 and 18. The diatreme-like crater on Volcano 14 is 640 m-deep, and that on Volcano 18 is 1130 m-deep. Stacked successions of older lavas flows and intrusive rocks (Volcano 14 = gabbro; Volcano 18 = chloritic gouge from a plug carapace) were recovered from the steep (locally 45–50° dip) inner crater walls of both volcanoes, indicating that the structures are explosive craters and not a build-up of fragmental material around a simple vent. Lack of slumping on the inner crater walls suggests these extremely violent eruptions took place recently (<10 ka).
8) Osbourn Trough, a paleo-spreading centre, is subducting beneath the Volcano 14–19 area. The trough features several inner corner highs, which reflect diapiric uprise of serpentinised mantle. Most probably, this extensive mantle serpentinisation took place when spreading ceased but hydrothermal convection cells persisted through the hot rock near fracture zones. Dehydration of the serpentinite during subduction may release excessive amounts of water compared to that elsewhere, and this release may be episodic (as the inner corner highs only occur near the fracture zones of the trough). Speculatively, the released water may have generated volatile-rich mantle melts that either erupted explosively at Volcanoes 14–18 or triggered crustal anatexis.
9) 191 representative samples from the south Tonga arc volcanoes have been prepared for detailed geochemical work. Lavas ranging in composition from basalt to dacite were recovered at many of the 27 volcanoes. The analytical results will enable modelling of element re-cycling and mass transfer along this segment of the arc, together with the definition of a possible Pacific-type vs Indian-type mantle boundary. They will also enable the genetic relationship between basaltic and dacitic magmas to be unravelled (i.e., are the dacites generated by fractional crystallisation, crustal anatexis, or some other process). Finally, in combination with our successful sampling of Louisville Ridge and Osbourn Trough, we will be able to recognise any contribution from these subducting features in the arc lavas. That will, in turn, place new constraints on the rates and processes of mass transfer in subduction systems.

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6. SOUTH FIJI BASIN: LINZ AREA

Tim Worthington, Peter Stoffers

6.1. South Fiji Basin Overview

Four targets were designated by LINZ (Land Information New Zealand) for dredging in the South Fiji Basin during cruise SO 167 of the *SONNE*, pursuant to the signed contract between LINZ and Universität Kiel (Fig. 1.2). The South Fiji Basin is a large oceanic basin bounded by the Three Kings Rise to the SW, the Norfolk Ridge to the NW, the Lau–Colville Ridge to the east, the Hunter Fracture Zone to the north, and the Vening Meinesz Fracture Zone to the south (the latter marking the transition from oceanic crust to the continental margin of New Zealand). Seafloor magnetic anomalies suggest the basin developed as a backarc basin behind an active volcanic arc on the Lau–Colville Ridge and a remnant arc on the Norfolk Ridge (Weissel and Watts, 1975; Davey, 1982; Malahoff et al., 1982). A ridge–ridge–ridge triple junction near the centre of the South Fiji Basin was envisaged in these models, and the magnetic anomalies require that most of the spreading occurred during the Oligocene (26–33 Ma).

The South Fiji Basin has two distinct sub-basins separated by the Cook Fracture Zone (Fig. 1.2). To the north is the structurally simple and comparatively well-understood Minerva abyssal plain, for which the above model appears well-established. To the south is the Kupe abyssal plain. There, the magnetic anomalies are fewer and less well-defined, and require subduction of the SW arm of the inferred South Fiji Basin spreading system beneath the Three Kings Rise. Such models are supported by the recovery of subduction-related Miocene lavas from the Three Kings Rise. However, recently completed geophysical surveys near the New Zealand margin provide strong evidence that much of the Kupe abyssal plain must be of Miocene or younger age, in apparent contradiction with the earlier magnetic studies (Herzer et al., 2000). Consequently, the age and evolution of the South Fiji Basin to the south of the Cook Fracture Zone remains controversial.

The four targets designated by LINZ are close to the Cook Fracture Zone (Fig. 1.2). Two of these (LINZ #3 and #4) form obvious anomalies on satellite-derived bathymetric maps and have long aroused the curiosity of New Zealand geologists. They have the appearance of large intraplate seamounts located along an eastward extension of the Cook Fracture Zone, and thus may have potential both to yield a minimum age for this feature and to constrain the magmatic evolution of the basin. Alternatively, they could be related to subduction-related volcanism along the Lau–Colville Ridge or associated with opening of the backarc basin. The smaller LINZ #1 and #2 are somewhat to the north of the Cook Fracture Zone. Seismic lines across all four targets were provided by the GNS (Institute of Geological and Nuclear Sciences, New Zealand) geologists contracted to LINZ in order to help facilitate the dredging program.

6.2. LINZ #1 and #2

These targets were depicted as the western and eastern bounding faults of a 9 km-wide graben in oceanic crust on the seismic section provided by GNS. Hydroacoustic soundings during the approach revealed this interpretation was incorrect (Fig. 6.1). In reality, the suggested faults are the SE and NW lower flanks of two small seamounts (respectively).

LINZ #1 is the larger of the two seamounts, with a basal diameter of nearly 8 km at 4000 mbsl. The seamount rises to a summit rim at 2950 mbsl that hosts a circular depression (relic crater?) breached to the NE, 1.5 km in diameter and approximately 100 m deep. A low and gently sloping ridge extends from the lower NW flank of the seamount for a further 9 km. All other flanks of the seamount, including the suggested dredge track on the seismic section, are relatively steep and smooth. The SE flank of the seamount was dredged (103-DR) at the specified co-ordinates between 3945 mbsl and 3621 mbsl. One

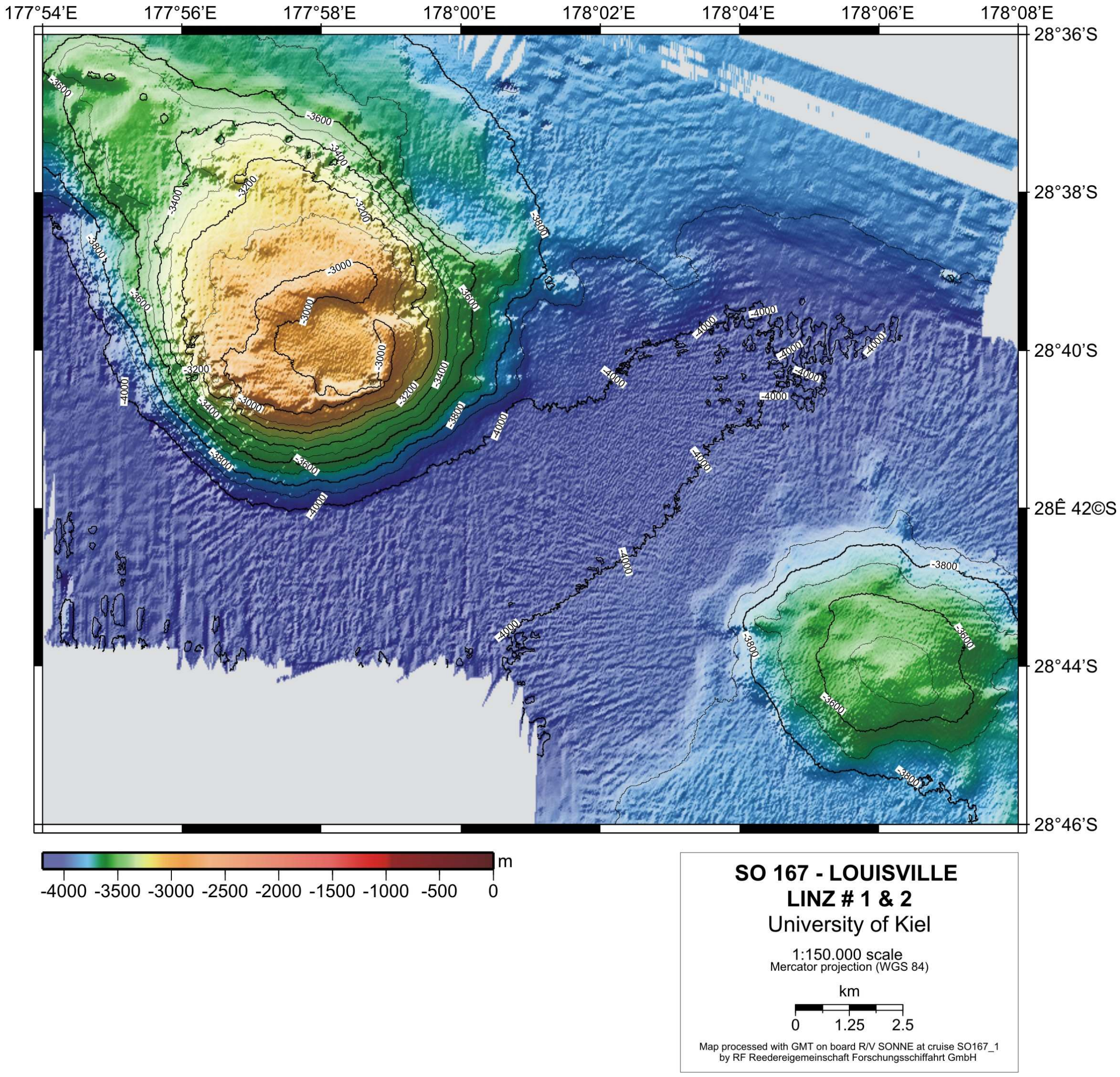

Fig. 6.1: Bathymetry of LINZ #1 and #2. Contour interval is 100 m.

significant bite of 7.1 tonnes was recorded shortly after heaving began. Thereafter the cable tension was low with regular elastic rebounds, consistent with the dredge dragging through soft sediment. Approximately 10 kg of material was recovered, being light brown clay encrusted by Fe-Mn oxyhydroxides (FeMnOx). The clay probably represents deeply weathered basaltic lava. The FeMnOx formed a smooth concentric crust over the clay up to 4 cm thick. The dredge was repeated at higher elevation (104-DR) between 3528 mbsl and 3229 mbsl along a closely parallel track in an attempt to recover fresher material. This dredge was recovered empty. No significant bites were recorded, and elastic variations in the cable tension were consistent with dragging through thick soft sediment.

LINZ #2 is the smaller of the two seamounts, with basal dimensions of 5.4 x 6.3 km at 4000 mbsl. It is somewhat elongated NW–SE and lies along strike of the long axis of LINZ #1. The seamount rises gently to a flat summit at 3550 mbsl, with the steepest slopes being between 3900 mbsl and 3600 mbsl. The NW flank of the seamount was dredged (106-DR) at the specified co-ordinates between 3940 mbsl and 3608 mbsl. The cable tension remained low with regular elastic rebounds (biggest bite of 5.6 tonnes), suggesting the dredge was going through thick soft sediments. Problems with the winch resulted in a 1.5 hour delay before the dredge could be brought onboard, but this would not have affected the dredge results. The dredge was recovered empty apart from one piece of drift pumice.

6.3. LINZ #3

This is a large and complex seamount (Fig. 6.2). The western half trends east–west and has basal dimensions of 20 x 9 km at 3000 mbsl. The eastern half trends NE–SW and has basal dimensions of 25 x 7 km. Several summit peaks with irregular shapes occur near the junction of the two segments, and most of these are at 1000 mbsl to 1200 mbsl. The seismic section provided by GNS closely matched the SW Ridge of the western segment, except that the latitude provided in the faxed co-ordinates was 1' to the south of the ridge. At the specified locality there was a very flat rise, which clearly did not match the seismic profile and was not a sensible dredge target. In light of the difficulties at LINZ #1 and #2, the dredge was changed to one with a rectangular cross-section that has given better results on similar seamounts in the past.

The SW Ridge of the seamount was dredged at co-ordinates exactly 1' north of those specified. The first attempt (107-DR; 2363 mbsl to 2198 mbsl) resulted in several hard bites (to 8.9 tonnes), but the dredge was recovered empty. The high cable tension and nature of the bites suggested lavas with thick FeMnOx crusts. A second attempt was made at higher elevation along the same track (108-DR; 2099 mbsl to 1957 mbsl). This dredge became stuck as soon as it reached the seafloor, with cable tensions as high as 8.8 tonnes during heaving. After leaving the seafloor, the dredge was towed to a slightly higher

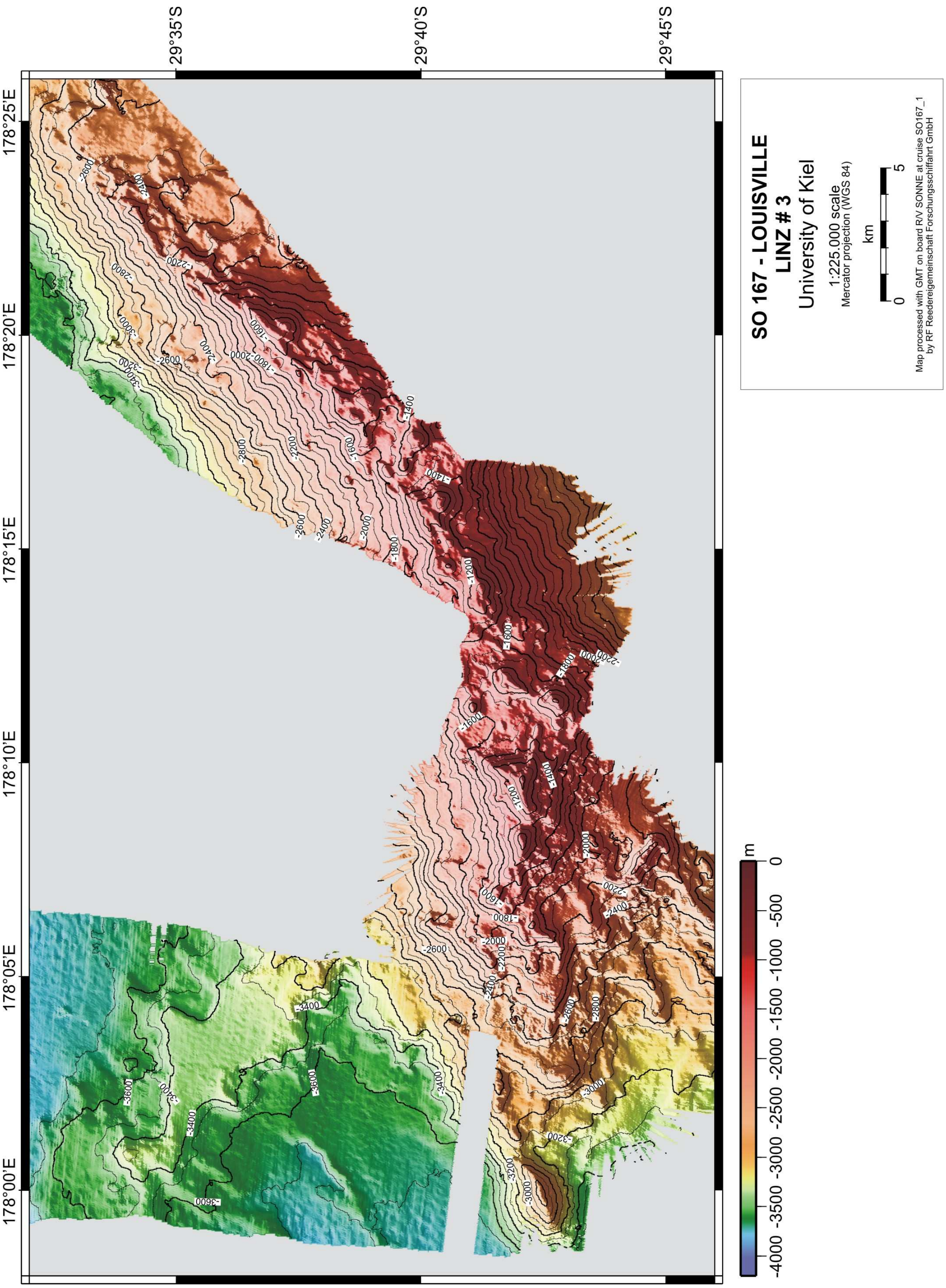

Fig. 6.2: Bathymetry of LINZ #3. Contour interval is 100 m.

elevation and put down, where it again became stuck and yielded further bites to 8.0 tonnes. The dredge was recovered empty apart from the upper jaw bone of a dolphin. A third dredge was then targeted for the nearby upper south summit (110-DR; 1460 mbsl to 1298 mbsl), as steep slopes beneath this peak suggested outcropping lavas. In light of the continued difficulties in recovering rocks, the dredge was changed back to that used at LINZ #1 and #2. After reaching the seafloor the dredge quickly became stuck, with cable tensions up to 7.3 tonnes during heaving. The dredge was recovered empty. In view of the time spent, the *SONNE* then proceeded to LINZ #4.

After success at LINZ #4 (refer Section 6.4 below), the *SONNE* returned to LINZ #3. The fourth attempt at this site involved dredging on the SW Ridge at a higher elevation than the first two attempts (112-DR; 2042 mbsl to 1795 mbsl). Again the dredge became stuck, with cable tensions up to 7.9 tonnes. Nevertheless, numerous pieces of weathered vesicular olivine basalt were recovered in which the olivine was completely pseudomorphed by iddingsite and the lava encrusted with smooth FeMnOx up to 3 cm thick. Also recovered were several small pieces of drift pumice and two biology fragments.
To clarify the reason for difficult dredging at the LINZ sites, the video-sled was lowered onto the SW Ridge (113-OFOS). The upper ridge slopes consisted of smooth low-relief FeMnOx-encrusted boulders separated by thin drifts of pelagic sediment to 5 cm thick. The mid-slopes and adjacent valley were thickly sedimented with no outcropping rock.

6.4. LINZ #4

This is a large and complex seamount trending NE–SW, with basal dimensions greater than 22 x 7 km at 3000 mbsl (Fig. 6.3). Only the area near the specified dredge track was mapped. The specified dredge location on the seismic section provided by GNS correlated well with the NW flank of the narrow 5 km-long SW Ridge.

The SW Ridge of this seamount was dredged at the specified co-ordinates (111-DR; 2490 mbsl to 2231 mbsl). Numerous large bites were recorded, with cable tensions up to 6.5 tonnes. Numerous pieces of weathered vesicular basalt were recovered, encrusted with smooth FeMnOx up to 6 cm thick. The extreme thickness of FeMnOx and the lack of steeper slopes or scarps in the target area indicated negligible chances for the recovery of fresher material. Although the time allocated to the LINZ work had long since expired, the *SONNE* then returned to LINZ #3 for a last dredge (refer Section 6.3 above).

6.5. Summary

Work in the South Fiji Basin at the designated LINZ sites was additional to the SO 167 LOUISVILLE project, and was undertaken on a contract basis. Stations LINZ #1–2 proved to be small conical seamounts, whereas LINZ #3–4 were large complex seamounts. All were entirely of oceanic character, and no evidence that any of them ever formed islands was found. Dredging was extremely difficult with limited sample recovery. Stations LINZ

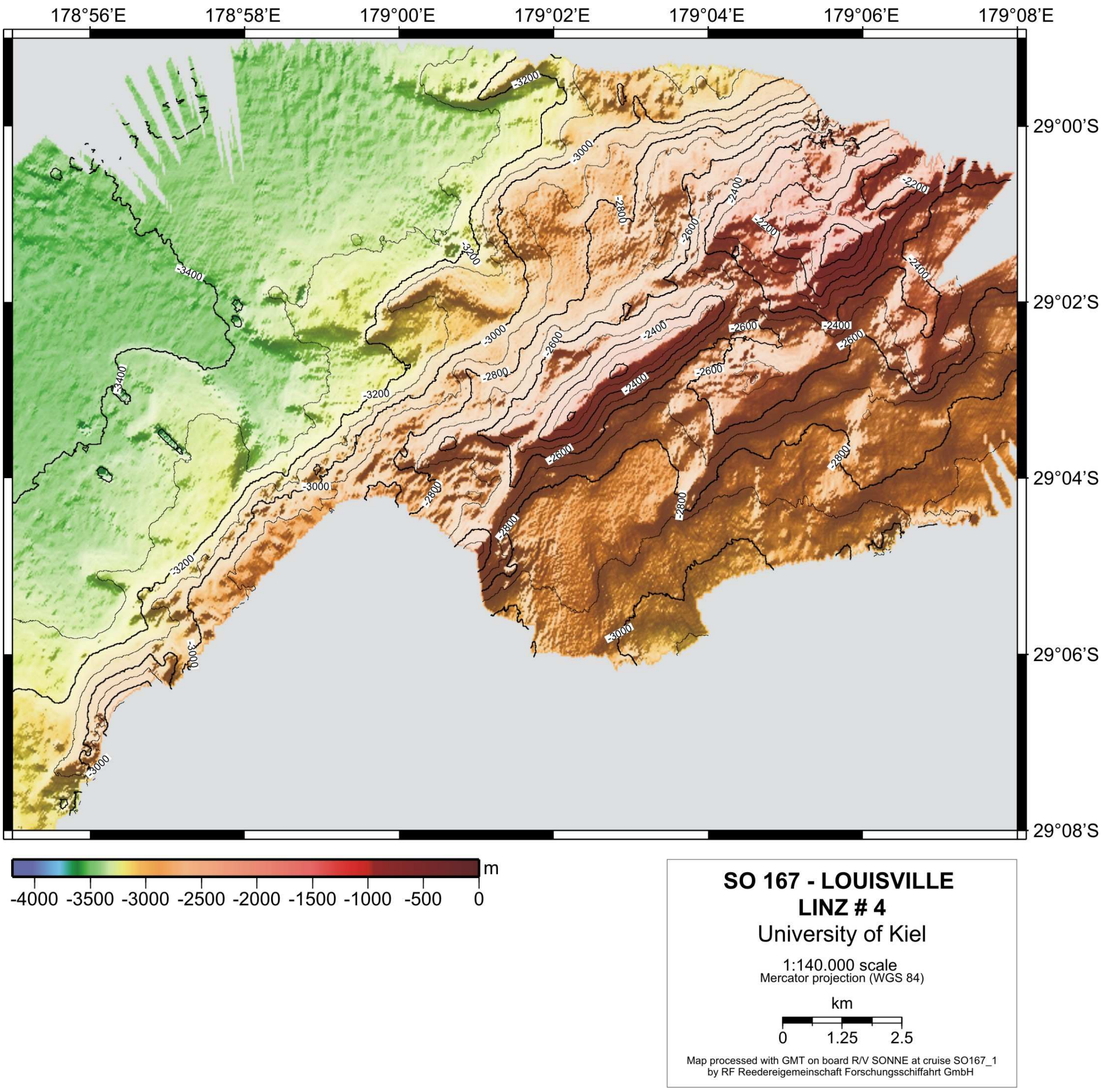

Fig. 6.3: Bathymetry of LINZ #4. Contour interval is 100 m.

#1–2 were blanketed by thick sediments, and a small amount of clay (deeply weathered basalt or sediment) thickly encrusted by black FeMnOx (4 cm thick) was recovered from LINZ #1. Weathered vesicular basalt encrusted by FeMnOx (3–6 cm thick) was recovered from both LINZ #3–4. Video-sled observations at LINZ #3 confirmed the dredge results; these seamounts are blanketed by thick sediments with rare outcrops of smooth FeMnOx-encrusted lava.

A total of 31 hours was spent in 8 dredges and 1 video-sled at the LINZ stations (*versus* 24 hours specified in the contract). All recovered material was placed in bags for collection by LINZ representatives in Wellington. The weathered basalt from LINZ #3–4 was not cut or broken (pursuant to email correspondence from the GNS geologists contracted by LINZ in September explicitly forbiding this), and it was therefore impossible to assess the true sample quality of the relatively fresh sample interiors. However, this material should be sufficiently fresh for geochemical analyses if care is taken.

The deep weathering, thick FeMnOx crusts, and thick blanketing sediments observed at LINZ #1–4 are consistent with an Oligocene (30 Ma) or older age for these seamounts built on and adjacent to the Cook Fracture Zone. LINZ #1–2 appear to be small intraplate seamounts that, together with a further partly mapped seamount to the SE of LINZ #2, define a NW–SE magmatic lineation. Such lineations may occur along "leaky" fracture zones or represent passage of the overlying plate across a mantle plume. LINZ #3–4 are large complex seamounts whose origin remains unclear. However, the recovery of vesicular olivine basalt from these seamounts is more consistent with intraplate volcanism than with alternative models invoking a link to subduction-related volcanism or rifting processes on the nearby Lau–Colville Ridge. Although not conclusive, our observations lend support to models featuring an early (Oligocene) opening of the South Fiji Basin.

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7. STRUCTURE AND PETROLOGY OF THE OSBOURN TROUGH

Tim Worthington, Roger Hekinian, Peter Stoffers, Dietrich Ackermand, Nikolaus Bigalke, Christian Timm, Daniel Unverricht, Markus Zimmerer

7.1. Osbourn Trough

The Osbourn Trough is linear, 900 km-long, bathymetric low that trends east–west across the Pacific Plate from its intersection with the Tonga–Kermadec Trench near 25°30'S to another enigmatic north–south trending curvilinear feature known as the Wishbone Scarp (Fig. 7.1). It was first recognised from the satellite-derived bathymetry (Smith and Sandwell, 1997), and thus might more correctly be termed a gravity anomaly. Near the Tonga Trench, the Osbourn Trough consists of several east–west trending *en echelon* segments about 50 km-long. Three possible interpretations of the Osbourn Trough have been proposed: (i) a paleo-spreading centre, (ii) an old fracture zone, or (iii) a recent tear in the Pacific Plate generated by the stress of the Louisville Ridge–Tonga Trench collision.

A small section of the Osbourn Trough was surveyed in the late 1990s (Billen and Stock, 2000). In their survey area, designated Segment #1 by them, the trough is a 6–8 km-wide flat-floored valley at 5200 mbsl bounded by steep walls 200–500 m-high. They interpreted the trough as the axial valley of a paleo-spreading centre. The presence of a high-standing area interpreted as an inner corner high further suggested a medium to slow spreading rate, analogous to inner corner highs found on the equatorial mid-Atlantic Ridge. Unfortunately, magnetic anomalies across the trough axis were subtle and failed to provide any conclusive supporting evidence. Such a result is consistent with a late Cretaceous age (late Cretaceous magnetic quiet period). Billen and Stock (2000) concluded that spreading at 6–8 cm/year probably ceased at either 71 Ma (preferred) or 82 Ma. Plate tectonic reconstructions by others have suggested a faster spreading rate and earlier cessation (20 cm/year finishing at 105 Ma; Lonsdale, 1997). Basalts from DSDP 595/596, ~250 km north of the trough axis, have a minimum age of 100 Ma (Menard et al., 1987). The nearer DSDP 204, ~50 km from the trough axis, intersected a thick volcaniclastic succession derived from the adjacent Louisville Ridge (Turner et al., 1997).

In a regional context, the Osbourn Trough probably developed at ~120 Ma and appears to have rifted the formerly contiguous Manihiki and Hikurangi Plateaux, both of which are large igneous provinces (Billen and Stock, 2000). Both plateaux are equi-distant from the trough axis (Fig. 7.1). The Hikurangi Plateau was transported southwards by spreading at the trough and eventually collided with, and blocked subduction beneath, the Chatham Rise of New Zealand. Unfortunately, the Chatham Rise is also little surveyed and the only information available before SO 167 was that subduction there ceased by the late Cretaceous.

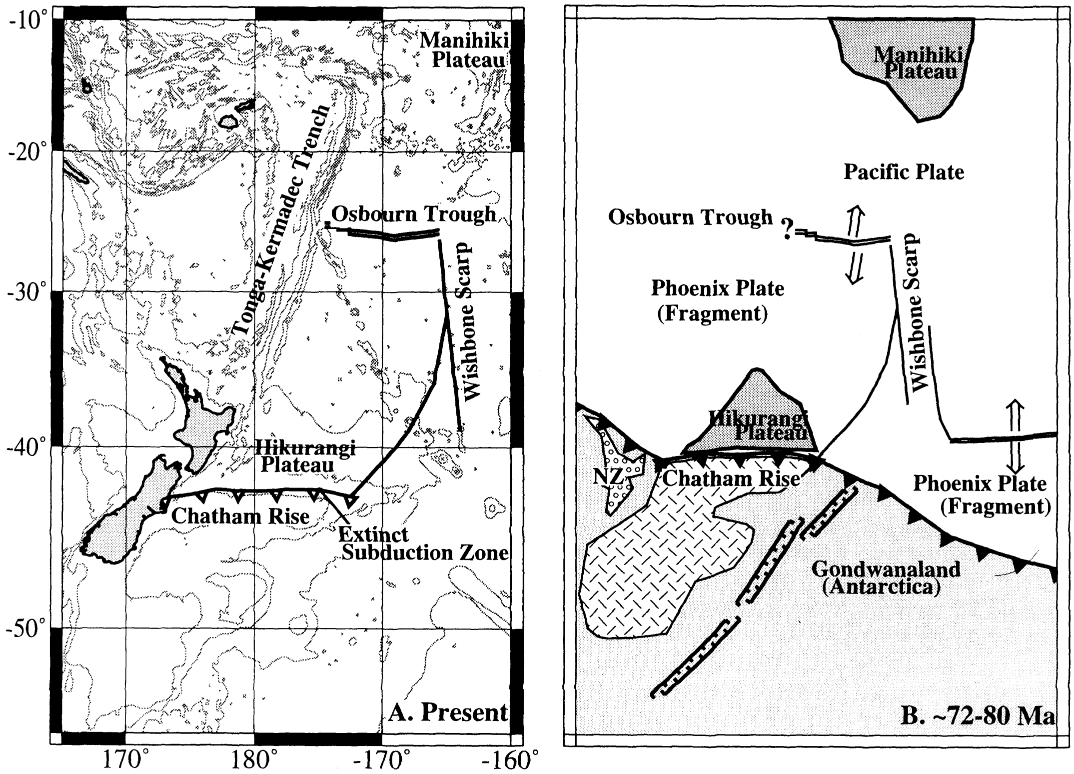

Fig. 7.1: Osbourn Trough as a paleo-spreading centre. The spreading centre split the formerly contiguous Manihiki and Hikurangi Plateaux, with the latter eventually colliding with and blocking a southwards-dipping subduction system at the Chatham Rise. After Billen and Stock (2000).

The key objectives of the Osbourn Trough survey during SO 167 were:

1) To obtain detailed bathymetry across an area 145 km-long by 120 km-wide adjacent to the area surveyed by Billen and Stock (2000). This box covers the termination of Segment #1, all of the next trough segment (Segment #2), and a substantial part of Segment #3. The results should confirm or reject the interpetation of Billen and Stock (2000).
2) To obtain samples for high-precision Ar/Ar dating from the trough. These samples will provide the age at which spreading ceased, if the paleo-spreading centre model is confirmed. Our results would then be interpreted in conjunction with those of SO 168 (ZEALANDIA) cruise, which has the Hikurangi Plateau and Chatham Rise as its prime work areas. Thus, close collaboration between these cruises should establish the age at which spreading commenced (SO 168) and when it ceased (SO 167).
3) To obtain relatively unweathered lavas from the trough walls to confirm that they have MORB geochemistry and to categorise the trace element and isotopic composition of oceanic crust generated at this spreading centre. This information is vitally important to models of element re-cycling and mass transfer in the Tonga–Kermadec subduction system, as it is oceanic crust generated at Osbourn Trough that is being subducted (assuming the Osbourn Trough is shown to be a paleo-spreading centre).

7.2. Segment #1

Only the eastern end of Segment #1 was mapped (Fig. 7.2). This area adjoins the survey by Billen and Stock (2000). Osbourn Trough is a 13 km-wide deeply sedimented and flat-floored plain at 5500 mbsl in this region. A gravity anomaly suggests an inner corner high has developed along the southern wall at the eastern tip of Segment #1 (Billen and Stock, 2000). Our bathymetry revealed a lens-shaped bathymetric high at this site, rising to a summit at 4550 mbsl (950 m above the trough floor). Discontinuous peaks along the summit crest were separated by narrow valleys and testify to mass wasting and flank collapses.

Three dredge stations were located on the NE flank of the inner corner high. Station 121-DR recovered weathered olivine gabbro and variably weathered (fresh to deeply weathered) aphyric to olivine-phyric to plagioclase-phyric basalt (all olivine was pseudomorphed by iddingsite). The basaltic pebbles were typically subrounded and set in a clay matrix covered by a thick coating of FeMnOx, and testify to mass wasting on the slopes of the inner corner high. Stations 122-DR and 123-DR were less successful, and returned claystone with thick FeMnOx encrustations together with deeply weathered float pumice. Some of the FeMnOx encrustations were up to 8 cm thick, implying an age of ~80 Ma (typical FeMnOx growth rates are 1 mm/Ma).

7.3. Segment #2

Segment #2 is offset 22 km to the south of Segment #1 by a north–south section of trough floor interpeted as a non-transform discontinuity (Fig. 7.2). The segment is 60 km-long and varies from 9–13 km-wide. The trough floor is shallower in the west (5400 mbsl) and deepens slowly to the east (5650 mbsl); this probably reflects recent uplift in the west as the Pacific Plate goes over the outer flexural high of the Tonga–Kermadec Trench. The trough has the morphology of an axial valley, with its northern wall rising to 5150 mbsl (350 m above the valley floor) and southern wall rising to 4900 mbsl (500 m above the valley floor). A centrally-located narrow *en echelon* ridge about 6 km-long rises to 5300 mbsl (~200 m above the surrounding floor). Oval-shaped nodal basins bound the western and eastern ends of the segment and are associated with two corner highs. Both corner highs are lens-shaped and decrease in elevation away from the segment boundaries. The NW corner high rises to 4450 mbsl (950 m above the trough floor), and the SE corner high to 4300 mbsl (1300 m above the trough floor). Further from the axial trough are a series of semi-regularly spaced ridges that trend east–west parallel to the trough. These ridges are spaced 15–20 km apart, become progressively deeper with distance from the trough, and appear to represent either rifted or abandoned ridge segments.

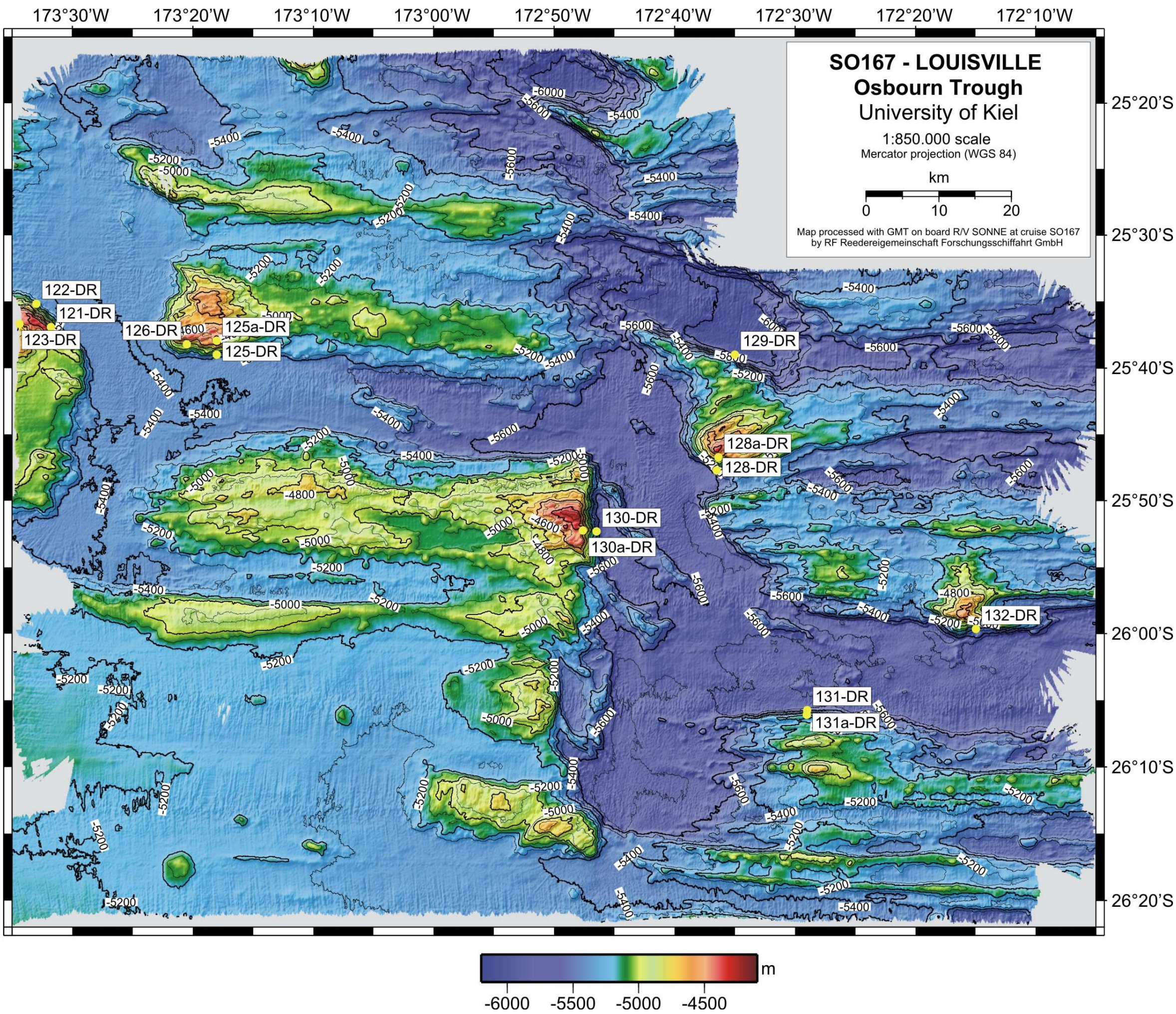

Fig. 7.2: Bathymetry and dredge stations on a 145 km by 120 km section of Osbourn Trough. Segment #1 terminates immediately north of Station 122-DR. Segment #2 is in the centre of the map, with Segment #3 at the lower right. Note the corner highs on Segment #2, orthogonal offsets of the segments, and trough-parallel but progressively deepening ridges to the north and south. Contour interval is 100 m.

Two dredge stations were located on scarps cutting the steep lower flanks of the NW corner high. The aim was to avoid the thick sediment covering the upper flanks of the corner high, while also avoiding the thick sediment blanketing the axial floor. Station 125-DR recovered claystone bearing subangular boulders of strongly porphyritic olivine-plagioclase basalt with relatively fresh cores (olivine still pseudomorphed by iddingsite), smaller pebbles of aphyric basalt, and a fine-grained gabbro. All samples were thickly encrusted by FeMnOx. Station 126-DR was less successful, returning only claystone, FeMnOx and float pumice. The FeMnOx on one sample was 10.5 cm thick.

Station 130-DR was located on the steep lower flank of the SE corner high. This highly successful dredge recovered boulders of weakly weathered olivine-plagioclase basalt, in which some olivines were still green and only slightly discolored, together with more weathered aphyric basalt. Both lithologies occur in a subangular breccia with a clay matrix; the breccia was thickly encrusted with FeMnOx up to 8 cm thick.

7.4. Abandoned Ridge Segment

A series of ridges parallel to the axial valley walls occur along strike of Segment #2 and to the NE of the segment boundary (Fig. 7.2). The western termination of these ridges bend towards the SW. They are associated with several deep basins (6000 mbsl), 10–15 km wide and 20 km-long, bounded by normal faults striking 110–120° (oblique with respect to Osbourn Trough). The ridges possibly represent abandoned ridge segments of the Osbourn Trough. However, the deep basins may have formed in response to much later events. The 110° orientation of these basins and their fault scarps are orthogonal to the NW motion of the Pacific Plate indicated by seamount chains (e.g., the Hawaii–Emperor and Louisville Ridges) and fracture zones on the Farallon Plate. It could be that the basins are pull-apart basins developed along an extension of the Farallon fracture zones in response to changes in plate motion during the early Tertiary.

Station 129-DR was located on the steep southern wall of the abandoned ridge north of Segment #3. A breccia consisting of varied lithologies including porphyritic olivine-plagioclase basalt, sparsely olivine-phyric basalt, plagioclase basalt and aphyric basalt set in a clay matrix and encrusted by FeMnOx up to 4 cm thick was recovered. Clasts varied from weakly to deeply weathered, but all olivine was pseudomorphed by iddingsite or smectite. Serpentinite pebbles in the breccia support the notion that the high-standing area formed by diapiric uprise of serpentinised peridotite. Float pumice was also recovered.

Station 128-DR was located on the lower flank of a lens-shaped high-standing region that possibly represents a relic corner high at the SW margin of an abandoned ridge segment. This high is also along strike of Segment #2. The dredge recovered a breccia of weathered subangular aphyric basalt, plagioclase basalt, olivine-plagioclase basalt, and rare dolerite clasts set in a clay matrix and encrusted by FeMnOx up to 5 cm thick. All olivine was pseudomorphed by iddingsite. Float pumice was also recovered.

7.5. Segment # 3

Segment #3 is offset 30 km to the south of Segment #2 by a north–south trending section of the valley floor interpreted as another non-transform discontinuity (Fig. 7.2). Only the western 50 km of Segment #3 was surveyed. In this area, the axial trough is 12–15 km-wide and its floor is at 5700 mbsl. The northern valley wall typically rises to 5000 mbsl (700 m above the valley floor) and the southern wall to 5200 mbsl (500 m above the valley floor). Corner highs are not well-developed at the margins of this segment, although part of the SW valley wall rises to 4800 mbsl and a lens-shaped high on the northern wall 30 km from the segment boundary rises to 4550 mbsl. A narrow 10 km-long, 200 m-high, *en echelon* central ridge occurs near the western margin of the segment. As with Segment

#2, a series of parallel ridges occur to the north and south of the axial trough at 15–20 km intervals and progressively deepen with distance from the trough.

Station 131-DR was located on the lower flank of the high-standing region near the SW segment boundary. It was recovered empty. In view of the limited time available, the ship moved to the more promising high-standing region on the northern trough wall

Station 132-DR was located on the lower flank of the high-standing region on the northern trough wall 30 km east of the Segment #3 boundary. A breccia containing variably weathered subangular boulders of porphyritic olivine-plagioclase basalt and plagioclase basalt was recovered. Some olivine crystals near clast cores was still green and only weakly discolored. The breccia matrix was clay, and samples were encrusted by FeMnOx up to 6 cm thick. A few small pebbles of serpentinite were found in the breccia. These suggest the high-standing region results from diapiric uprise of serpentinised peridotite.

7.6. Conclusions

Our bathymetry of Osbourn Trough provides compelling evidence that the trough is indeed a paleo-spreading centre. The morphology of the trough, including the elevation of the trough walls relative to the axial valley floor, the short spreading ridge segments terminating at nodal basins, and the associated development of inner corner highs, are all strikingly similar to those of the mid-Atlantic Ridge (MAR) near 35°N (e.g., Bideau et al., 1999). Segmentation at slow spreading ridges, such as the MAR, is characterised by short second-order non-transform discontinuities. Nodal basins develop at the ends of these segments, where extension is either amagmatic or weakly magmatic and the resulting new crust is thin. Tectonism, rather than magmatism, dominates at these segment boundaries. Hydrothermal circulation is enhanced along the fractured and extending lithosphere, leading to hydration of mantle peridotite and serpentinite formation. Isostatic re-adjustments in response to the lower specific gravity of serpentine can generate localised uplifts and the diapiric rise of serpentinite bodies to elevations >1000 m above the axial valley. During uplift, overlying basalt and gabbroic intrusions are displaced and slump off the flanks of the serpentinite diapirs.

Ten dredge stations were completed at Osbourn Trough, principally targetted at scarps on the steep lower flanks of the corner highs (Table 7.1). A total of 80 representative samples were logged, with 35 being prepared for analytical work in Kiel. The dominant lithology was a volcaniclastic breccia consisting of subangular boulders of olivine-plagioclase basalt, aphyric basalt and plagioclase basalt in a clay matrix and thickly encrusted by FeMnOx. Gabbro and small serpentinite pebbles were also common in the breccia. Considering the thick FeMnOx crusts suggest an age of >80 Ma, many of the

Table 7.1: Petrology Samples and Lithologies, Osbourn Trough

Station No.	Sample logged	Selected analysis		Aph Bas	Ol Bas	Ol-Pl Bas	Pl Bas	Pum	Doler	Gabb	Brecc	MnOx Crust	Clayst
121 DR	5	1								X		X	X
122 DR	5	1						X				X	
123 DR	2	-						X					X
125 DR	8	3				X		X			X		
126 DR	4	1						X				X	X
128 DR	15	6		X		X	X	X	X		X		
129 DR	13	7		X	X	X	X	X					X
130 DR	15	7		X		X				X	X	X	
131 DR	-	-											
132 DR	13	9				X	X				X	X	X
10 Stns	**80**	**35**		**3**	**1**	**5**	**3**	**6**	**1**	**2**	**4**	**5**	**5**

samples were remarkably fresh with some green olivine phenocrysts still preserved near the cores of clasts. This, together with occurrence of plagioclase phenocrysts, augurs well for both Ar/Ar age determinations and trace element and isotopic analyses intended to characterise the composition of oceanic crust generated at the Osbourn Trough.

The presence of short linear segments bounded by faulted marginal scarps associated with corner highs and nodal basins supports the interpretation of Osbourn Trough as a paleo-spreading centre (Billen and Stock, 2000). Furthermore, the recovery of MORB-like basalt and gabbro, breccias containing serpentinite clasts, evidence of mass wasting on the steep flanks of the corner highs (such as required for the formation of the breccias), and 10 cm-thick FeMnOx crusts all argue convincingly for Osbourn Trough being a paleo-spreading centre last active in the mid- to late Cretaceous.

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8. STRUCTURE AND PETROLOGY OF THE LOUISVILLE RIDGE

Tim Worthington, Peter Stoffers, Roger Hekinian, Dietrich Ackermand, Nikolaus Bigalke, Christian Timm, Daniel Unverricht, Markus Zimmerer

8.1. Objectives of the Louisville Ridge Program

The 4300 km-long Louisville Ridge is the second most prominent "hotspot" chain in the Pacific Ocean after the Hawaii–Emperor chain (Fig. 1.1). Nevertheless, few sections of the ridge have been surveyed in detail and very few samples have been collected (Hawkins et al., 1987; Lonsdale, 1988). The few available age determinations indicate that seamount ages progressively decrease from 66 Ma at Osbourn Seamount (presently entering the Tonga–Kermadec Trench) to 0.5 Ma near Hollister Ridge and the Pacific–Antarctic Ridge (Hawkins et al., 1987; Watt et al., 1988; Vlastelic et al., 1998). A marked bend occurs near the centre of the ridge. By analogy with the Hawaii–Emperor Ridge, this bend has been inferred to represent a change in Pacific Plate motion at ~43 Ma (Lonsdale, 1988). However, there are no actual ages from the area of the bend to support this contention.

Neither seafloor magnetic anomalies nor reconstructions of Pacific–Farallon Plate motions support the idea of a major change in Pacific Plate motion at ~43 Ma (Atwater, 1989; Hey et al., 1988). Instead, a change in motion at 48–50 Ma is suggested. The evidence can be reconciled if: (i) the real age of the Hawaii–Emperor bend is ~50 Ma and the younger age was obtained on alkalic post-erosional stage lavas that do not represent the passage of the Hawaiian plume beneath the seamount (e.g., Clague and Dalrymple, 1987), or (ii) mantle plumes do not provide a fixed mantle reference frame (Molnar and Stock, 1987; Acton and Gordon, 1994; Cande et al., 1995; Norton, 1995). Determining the age of the bend in the Louisville Ridge provides one method of resolving this controversy. Furthermore, as the Hawaii–Emperor bend is in the northern part of the Pacific Plate whereas the Louisville bend is in the southern part, the potential exists to examine how quickly both sides of the Pacific Plate underwent any change in velocity and to distinguish between models invoking relative plume motion or plastic deformation of the Pacific Plate.

Prior to SO 167, samples were obtained from only 10 of 67 recognised seamounts (Hawkins et al., 1987). The geochemical database consisted of 22 major element analyses (9 from Osbourn Seamount), 15 trace element analyses (9 from Osbourn Seamount), and 15 isotope analyses (5 from Osbourn Seamount) (Hawkins et al., 1987; Cheng et al., 1987). Most of these samples were alkali basalt, raising the possibility that the majority reflect post-erosional stage volcanism at the sampled seamounts and not the main stage of shield-building eruptions that represent the passage of the plume beneath the seamount and the plume geochemistry (Clague and Dalrymple, 1987; Hawkins et al., 1987). In addition, there is a patent bias towards the alkalic lavas from the NW summit of Osbourn Seamount in the database.

The recent recognition of Osbourn Trough as a paleo-spreading centre that ceased spreading in the late Cretaceous has important implications for Louisville Ridge (Billen and Stock, 2000; refer also Chapter 7). As the age of Osbourn Seamount entering the Tonga Trench is 66 Ma, and the most probable time spreading ceased at Osbourn Trough is 71 Ma, there exists the very real possibility of plume–ridge interactions between the Louisville plume and Osbourn Trough. Reconstructions show that the plume would have been located on or very close to the trough axis at 71 Ma (Fig. 1.2), and may even have been captured by it. Thus, the geochemistry of Osbourn Seamount and other nearby Louisville seamounts may not be representative of the Louisville plume. A similar situation involving dilution of the Hawaiian plume by MORB-like magmas from an adjacent spreading centre has recently been recognised at the northern end of the Emperor Ridge (Keller et al., 2000; Regelous et al., 2003). If the plume was captured by the Osbourn Trough spreading centre, then an "Iceland" may have been subducted at the Tonga Trench and the location of the Louisville Ridge within the subduction system north of 25°S is unpredictable.

The principle objectives of the south Tonga arc program were:

1) To obtain samples from the main shield-building phase of volcanism on representative seamounts along the Louisville Ridge between Osbourn Seamount and the bend for Ar/Ar age determinations. These ages will enable the velocity of south Pacific Plate to be calculated for the late Cretaceous and early Tertiary.
2) To use Ar/Ar age determinations to obtain the age of the bend in the Louisville Ridge. This age will be correlated with the results of a similar ongoing study of the Hawaii–Emperor Ridge (SO 141- HULA project). The results will enable a critical re-appraisal of whether Pacific Plate motion changed at ~43 Ma or some other time, whether the Louisville and Hawaiian plumes are fixed in the mantle reference frame with respect to each other, and whether the Pacific Plate has behaved as a rigid or elastic plate.
3) To expand the geochemical database for the Louisville Ridge in order to test whether plume–ridge interactions took place between the Louisville plume and Osbourn Trough spreading centre. If they did, then samples from Osbourn Seamount should show hybrid plume–MORB characteristics that decrease along the ridge to the SE. Only lavas from seamounts near the bend will unequivocally give the true plume composition.
4) To use the new Louisville Ridge geochemical database as an end-member in models of element re-cycling and mass transfer in the Tonga–Kermadec subduction system. In the first instance, knowing the composition of the subducting Louisville Ridge will assist in detecting and discriminating between possible Louisville contributions to the Tonga arc lavas.
5) To look for evidence of plume pulsing or long-term changes in the plume geochemistry that do not reflect possible plume–ridge interactions. Such temporal trends would assist current models of how plumes form and evolve.

8.2. Volcano 23 (Osbourn Seamount)

Osbourn Seamount is the oldest preserved seamount of the Louisville Ridge, and is presently tilted down to the west as it begins to enter the Tonga–Kermadec Trench. This unusual tectonic situation has generated significant attention, and both bathymetric and acoustic surveys have been completed over the seamount (e.g., Lonsdale, 1986). Osbourn Seamount is a guyot, with its summit at 1953 mbsl and a broadly triangular form with the apex pointing SE. Major sector collapses have occurred on both its southern and northern flanks (refer Fig. 11 of Lonsdale, 1986). The acoustic surveys suggest significant areas of rock outcrop along fault scarps that trend N–S across the SE summit plateau and were activated when the seamount recently passed over the outer flexural high of the Tonga–Kermadec Trench. Previous dredging of Osbourn Seamount has recovered a variety of mostly basanitoid lavas and alkali basalt, together with picritic basalt, tephrite and nepheline hawaiite, from the NW flank of the seamount at 2443–3270 mbsl (Hawkins et al., 1987). In light of the existing bathymetric coverage, only the southern flank of Osbourn Seamount was mapped during SO 167. The dramatic 4 km-wide SW-facing sector collapse on the southern flank was located, and sampling concentrated on this previously undredged feature. The sharp character of the escarpments suggests the collapse is relatively recent and probably occurred during the passage of the seamount over the outer flexural high of the trench.

Stations 115-DR, 117-DR, 118-DR and 120-DR were located in the central valley of the SW sector collapse and terminated at or below the headscarp. Dredging at stations 115-DR and 118-DR failed to recover any samples, despite cable tensions up to 8 tonnes. Station 117-DR recovered an oxidised red pyroxene basalt, interpreted as a subaerial lava, together with siltstone and coralline reef debris. Station 120-DR was markedly more successful, and returned a conglomerate composed of subrounded clasts of various lithologies including aphyric basalt and olivine basalt set in a carbonate-cemented matrix. These were the best samples obtained from Osbourn Seamount.

Station 116-DR was located on the inner western escarpment of the SW sector collapse in deeper water. A conglomerate consisting of small subrounded to subangular clasts of various lithologies, including a strongly porphyritic pyroxene basalt, set in a carbonate-cemented matrix was recovered. Also retrieved were claystone and coralline reef debris.

Station 119-DR was targeted to cross a fault scarp near the edge of the SW summit plateau, where acoustic surveys suggested outcropping rocks. A conglomerate composed of small, subrounded to rounded pebbles of various lithologies set in a carbonate-cemented matrix was recovered. The clast-supported conglomerate was interpreted as a paleo-beach deposit.

8.3. Volcano 32

This seamount was first examined by Lonsdale (1988), who described two intergrown guyots with summits at 1660 mbsl and 1220 mbsl respectively. It was unsampled before SO 167. Our mapping revealed a large, complex and elongated seamount that follows the NW–SE alignment of the Louisville Ridge (Fig. 8.1). The complex has basal dimensions of 55 km-long by ~15 km-wide at 4300 mbsl, and consists of two coalesced volcanic centres. Bathymetric coverage of the smaller NW centre was more complete, and revealed a guyot with a break in slope at 2000 mbsl, summit at 1680 mbsl, and a prominent ENE ridge (in addition to the NW and SE ridges). Only the SW flank of the larger SE centre was mapped, but this is also a guyot with the break in slope at 1700 mbsl, summit at <1500 mbsl, and a broad W-trending ridge. A prominent SSW-trending ridge protrudes from the southern flank of the SE centre and is coincident with a 25 km SW offset in the segmented Louisville Ridge. The available bathymetry suggests, but does not prove, that the ridge joining both centres was once emergent (i.e., flat-topped). Our mapping is broadly consistent with the reconnaissance bathymetry of Lonsdale (1988).

Station 134-DR was located on the northern escarpment of a W-facing sector collapse on the upper NW flank of the NW centre. A small piece of weathered olivine-plagioclase basalt with clay-lined vesicles was recovered. The dredge also retrieved a siltstone with small angular clasts of deeply weathered plagioclase basalt, and sediment ranging from brown clay to foram sandstone locally bearing reef-detritus. Most samples had thin FeMnOx crusts (3 mm).

Station 135-DR was located on steep slopes immediately above a 3 km-long slump block thought to have detached from the western face of the SE centre near its break in slope. The dredge terminated at the break in slope. Several pieces of dense aphyric basalt ranging from weakly to deeply weathered were recovered. Significant differences in weathering may indicate several similar lava flows were sampled. Brown clay and foram sandstone, locally with reef detritus and worm burrows, were also recovered. Station 136-DR was located in the valley downslope of this station and the inferred slump block (900 m deeper), partly in an attempt to retrieve samples from greater depth and partly to test the dredging strategy (shallow scarps vs deeper valleys). No samples were recovered, despite high cable tensions.

Station 137-DR was located on steep slopes near the junction of the SE centre and the SSW-trending ridge in an attempt to obtain lava from this ridge. Although the slope was steep, there was no evidence of slumping at this site. The dredge recovered foram sandstone, bits of FeMnOx crust, and drift pumice.

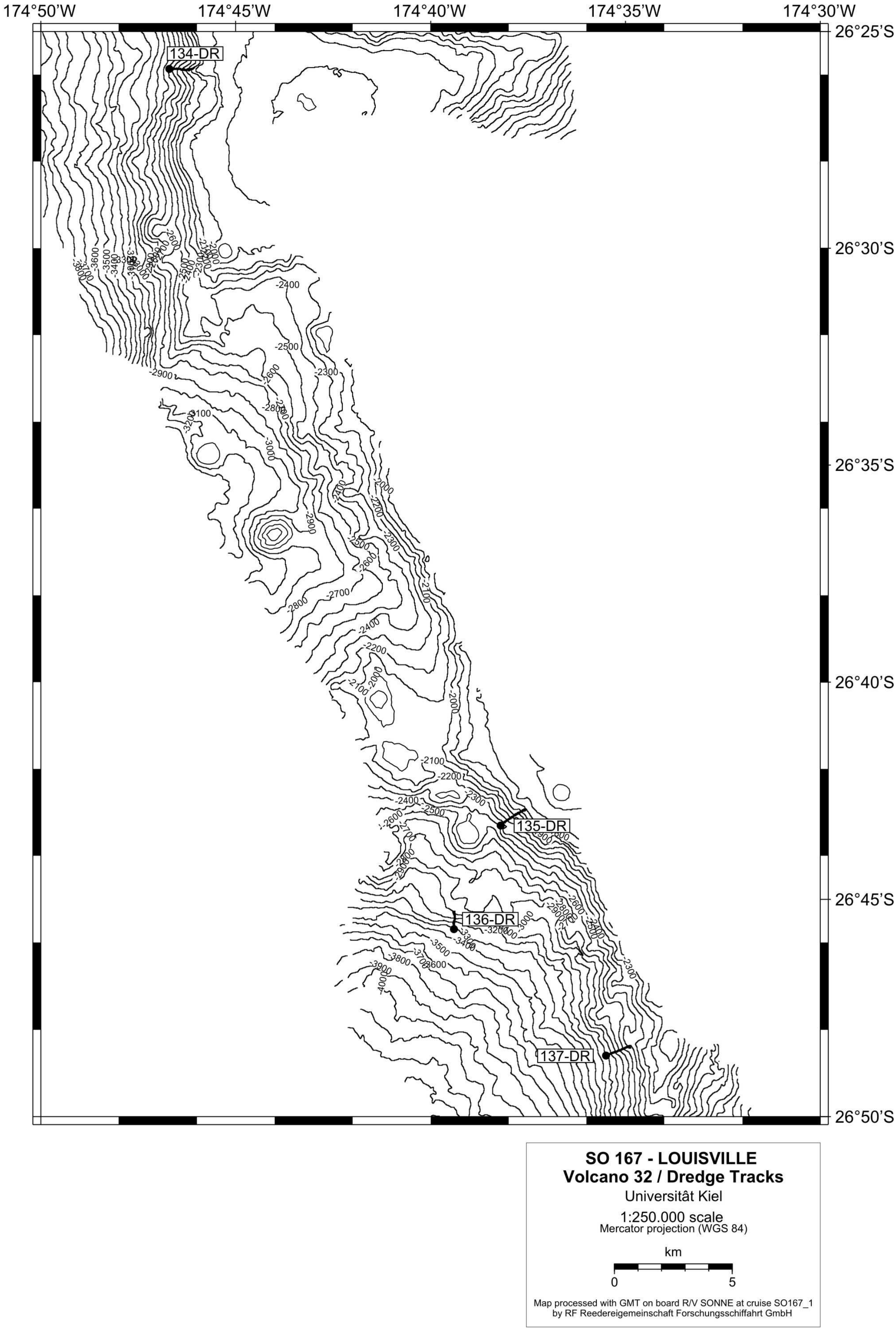

Fig. 8.1: Bathymetry and dredge stations on Volcano 32, Louisville Ridge. Contour interval is 100 m.

8.4. Volcano 33

A series of 6 large seamounts and several smaller ones joined by a low continuous ridge comprise the next NW–SE segment of the Louisville Ridge. These seamounts increase in size from the NW to Volcano 33, which is the third large seamount in the sequence. Lonsdale (1988) described it as a large guyot with a summit at 1085 mbsl. Samples dredged from 3480–3593 mbsl on the western flank were alkali basalt (Hawkins et al., 1987). Our results demonstrate that Volcano 33 is a structurally simple guyot rising from 4300 mbsl to a break in slope at 1700 mbsl, a summit at 1050 mbsl, and with a basal diameter of 40 km (E–W) by 25 km (N–S). A single traverse was made over the seamount, revealing prominent NW and ENE ridges. Thereafter, mapping and sampling were conducted exclusively along the southern side of the ENE ridge and the SE face of the seamount (Fig. 8.2).

Station 139-DR was located on the inner northern escarpment of a sector collapse on the southern face of the ENE ridge near its junction with the main seamount. The dredge terminated at the break in slope. This was a highly successful dredge, recovering a conglomerate consisting of well-rounded pebbles and occasional boulders in a sandy-silt matrix encrusted by up to 8 mm of FeMnOx. The conglomerate is interpreted as a paleo-beach deposit. A wide range of lavas were present in the conglomerate, including several different vesicular olivine-plagioclase phyric basalts and an aphyric basalt. Most clasts were weakly weathered, although olivine phenocrysts are pseudomorphed by iddingsite and smectite and these phases line some vesicles. Foram sandstone and drift pumice were also recovered.

Station 140-DR was located on steep slopes in the central valley of a sector collapse on the SE face of the main seamount behind a small (1 km-long) slump block, ~4 km to the SW of station 139-DR. The dredge terminated at the break in slope. A breccia composed of subangular lava clasts in a matrix of volcaniclastic sand and forams was recovered. Lavas within the breccia ranged from olivine-plagioclase phyric basalts to aphyric basalt, and most were small and deeply weathered. FeMnOx encrusts both clasts within the breccia (to 1 mm thick) and the breccia itself (to 3 cm thick). Foram sandstone was also recovered.

Station 141-DR was located on steep slopes at the northern escarpment of a small sector collapse, ~4 km to the SW of station 140-DR. The dredge terminated at the break in slope. A breccia consisting of variably weathered clasts of aphyric to plagioclase-bearing basalt set in a poorly indurated sandy matrix was recovered. Some well-rounded and flattened clasts within this breccia suggest deposition at, or near, a paleo-beach. Also recovered was a second breccia, consisting exclusively of subangular deeply weathered aphyric basalt clasts in a silica-cemented matrix and interpreted as an autobreccia. Both breccias were encrusted by up to 3 cm of FeMnOx.

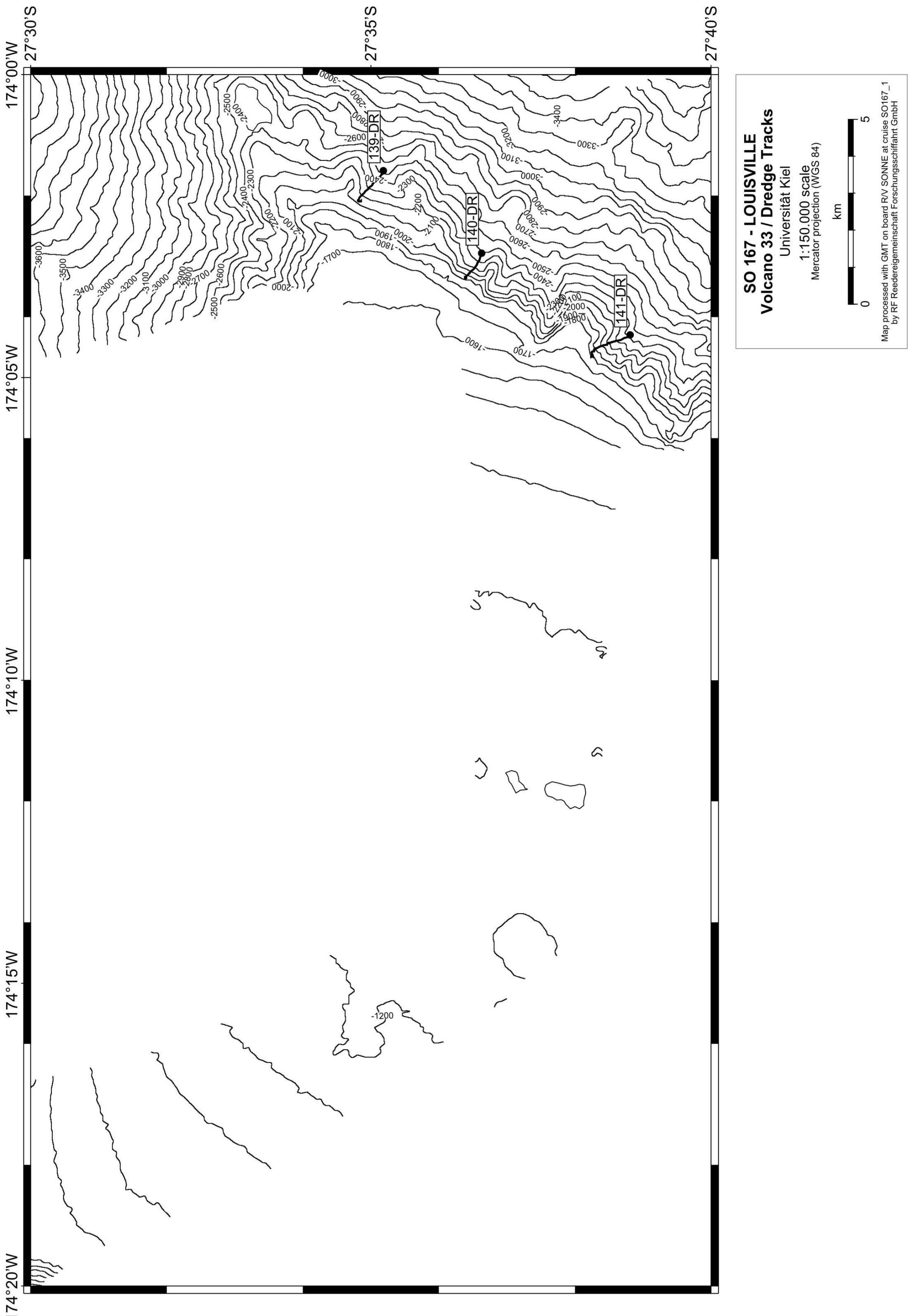

Fig. 8.2: Bathymetry and dredge stations on Volcano 33, Louisville Ridge. Contour interval is 100 m.

8.5. Volcano 34

Volcano 34 is situated at the SE end of the Louisville Ridge segment that includes Volcano 33. Lonsdale (1988) described it as a guyot with a summit at 1375 mbsl, and considered it larger than Volcano 33. It was unsampled before SO 167. Our results demonstrate that Volcano 34 is smaller than Volcano 33, although still the second largest seamount of this segment with basal dimensions of ~28 km by ~22 km at 3800 mbsl. Nearly complete bathymetric coverage of the seamount was achieved, revealing two intergrown volcanic centres of similar size linked by a broad flat-topped 4 km-wide ridge (Fig. 8.3). Both volcanic centres are guyots, with break in slopes near 1700 mbsl and summits at ~1350 mbsl. The northern centre has a 150 m-high, 1 km-diameter, sediment-covered pinnacle to the SW of the true summit and smaller pinnacles with diameters up to 500 m near the western rim of the summit plateau. These may represent very late-stage resurgent volcanism that followed the erosion and submergence of the volcano, and nearby areas on the seamount flanks were specifically omitted from the dredging program to avoid any ambiguity in data interpretation. The northern centre has two prominent ridges extending to the NW and SW, whereas the southern centre has two prominent ridges extending to the NE and SE.

Stations 142-DR and 143-DR were located on the northern escarpment of a large sector collapse from the western flank of the NW ridge of the northern volcanic centre. A 3 km-long block 6 km downslope of the head scarp possibly represents the slumped block. Both dredges terminated 200–300 m below the break in slope. Station 142-DR was recovered empty, despite cable tensions over 9 tonnes. Station 143-DR recovered a breccia of deeply weathered subangular basalt clasts set in a carbonate-zeolite cemented volcaniclastic matrix, with an FeMnOx crust up to 3 cm thick. Both vesicular olivine basalt and aphyric basalt were sub-sampled from this breccia. Foram sandstone was also recovered.

Stations 145-DR and 146-DR were located on the western escarpment of a large (3 km-wide) sector collapse from the southern flank of Volcano 34, adjacent to the junction of the two volcanic centres. Material retrieved from these stations originates on the SE flank of the northern volcanic centre. Both stations dredged along the crest of the escarpment, and recovery was poor. Station 145-DR, terminated 300 m below the break in slope, returned FeMnOx-encrusted sediment containing a few small well-rounded pebbles of vesicular aphyric basalt with carbonate-zeolite infilling the vesicles. Station 146-DR, terminated 600 m below the break in slope, recovered a weathered olivine basalt with zeolite on one side.

Station 147-DR was located on the eastern escarpment of the same sector collapse as stations 145-DR and 146-DR. However, the dredge track was changed to straight up the flank of the steeply sloping escarpment, and terminated at the break in slope. Material from this station originates on the SW flank of the southern volcanic centre. A breccia composed of deeply weathered, well-rounded and flattened basalt clasts set in a matrix of zeolitic clay

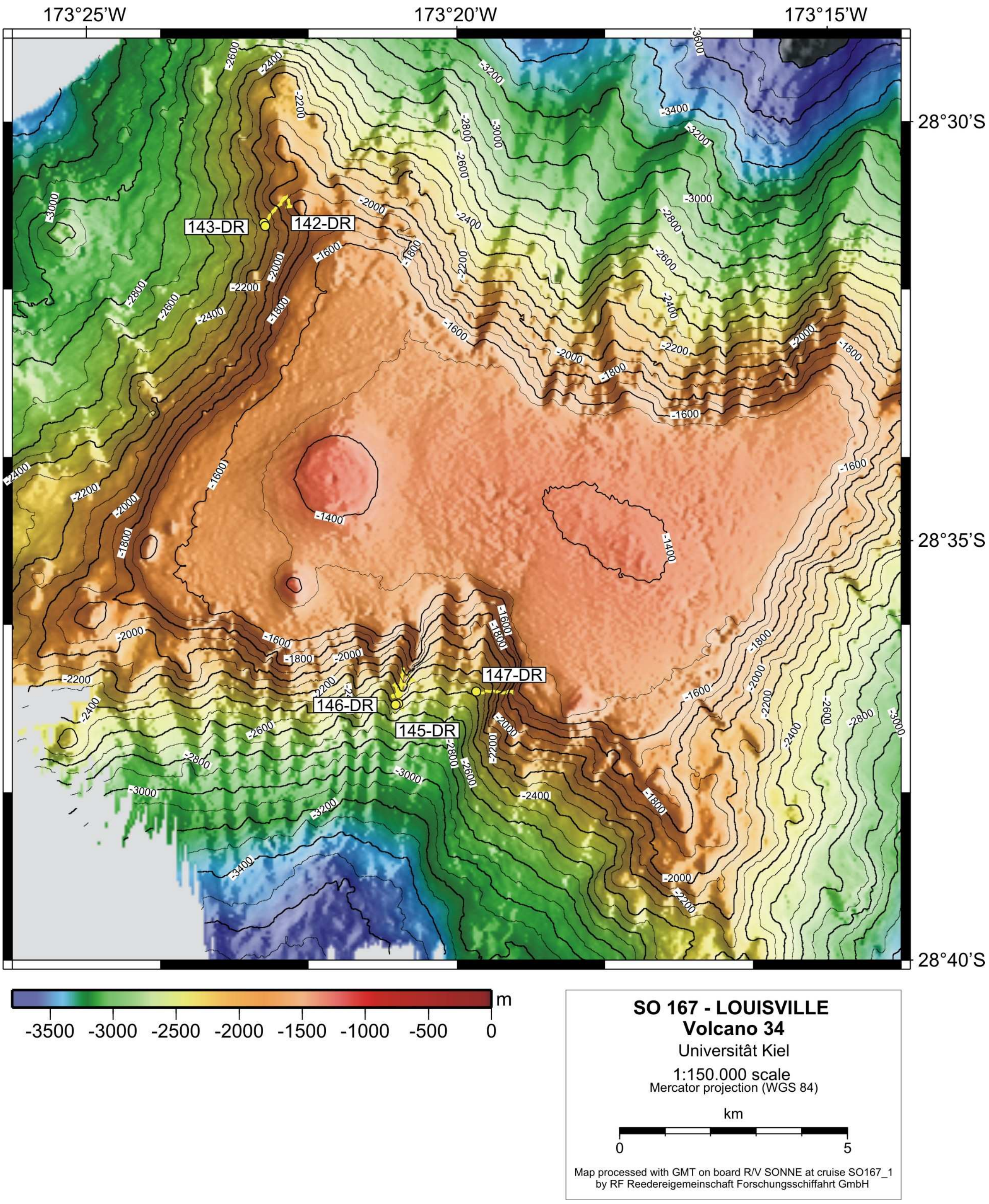

Fig. 8.3: Bathymetry and dredge stations on Volcano 34, Louisville Ridge. Contour interval is 100 m.

and encrusted by up to 2 cm of FeMnOx was recovered. The clasts include vesicular olivine basalt and aphyric basalt, with many of the vesicles infilled by carbonate-zeolite. The breccia is interpreted as a paleo-beach deposit.

8.6. Volcano 35 (Louisville Seamount)

Only one volcano on the next Louisville Ridge segment was sampled. This is the Louisville Seamount itself, described by Lonsdale (1988) as a large guyot with a summit at 1135 mbsl. It was unsampled before SO 167. Volcano 35 is a structurally simple, but very large, NW–SE elongated guyot with a basal diameter of 60 km by 30 km at 5000 mbsl. Part of the NW flank was mapped, followed by a single traverse near the centre of the seamount to the SE flank. Thereafter, mapping and sampling were conducted exclusively along the SE flank and its extension as the SE ridge (Fig. 8.4). The break in slope is at 1350 mbsl, and the shallowest point on our central traverse of the seamount was ~1100 mbsl.

Station 149-DR was located in the central part of a small sector collapse on the SW side of the SE ridge, and terminated 500 m below the break in slope. A 2 km-wide block has slumped 6 km downslope from the head scarp at the break in slope. A weathered non-vesicular aphyric basalt was recovered, together with coralline reef debris, foram sandstone locally with worm burrows, and drift pumice.

Station 150-DR was located on steeper slopes up the western escarpment of an adjacent 3 km-wide sector collapse to the NW of station 149-DR. The dredge terminated 400 m below the break in slope. As with the previous station, a weathered non-vesicular aphyric basalt was recovered together with foram sandstone locally with worm burrows and drift pumice.

Stations 151-DR, 152-DR and 153-DR were located on the eastern escarpment of a 4 km-wide sector collapse on the SE flank of Volcano 35, ~15 km to the NW of the earlier stations. Stations 151-DR and 152-DR terminated 300 m below the break in slope; the first was recovered empty despite cable tensions up to 7 tonnes, whereas the second recovered a non-vesicular olivine basalt. This sample represents the best material obtained from Volcano 35. Station 153-DR was started in deeper water but also terminated 300 m below the break in slope. The dredge was lost.

8.7. Volcano 36

A gap of ~50 km occurs to the next segment of the Louisville Ridge, which features a series of 7 medium-sized seamounts spaced at 15–25 km intervals. Volcano 36 is the sixth in this series, and was described by Lonsdale (1988) as a guyot with its summit at 1250 mbsl. It was unsampled before SO 167. Bathymetric coverage of the seamount was not complete, but it appears to be a structurally simple guyot with a basal diameter of 25 km at ~4000 mbsl, break in slope at 1400 mbsl, and summit at 1250 mbsl (Fig. 8.5). Mapping and dredging concentrated on the SE flank of the seamount, and also detected prominent N and SE ridges.

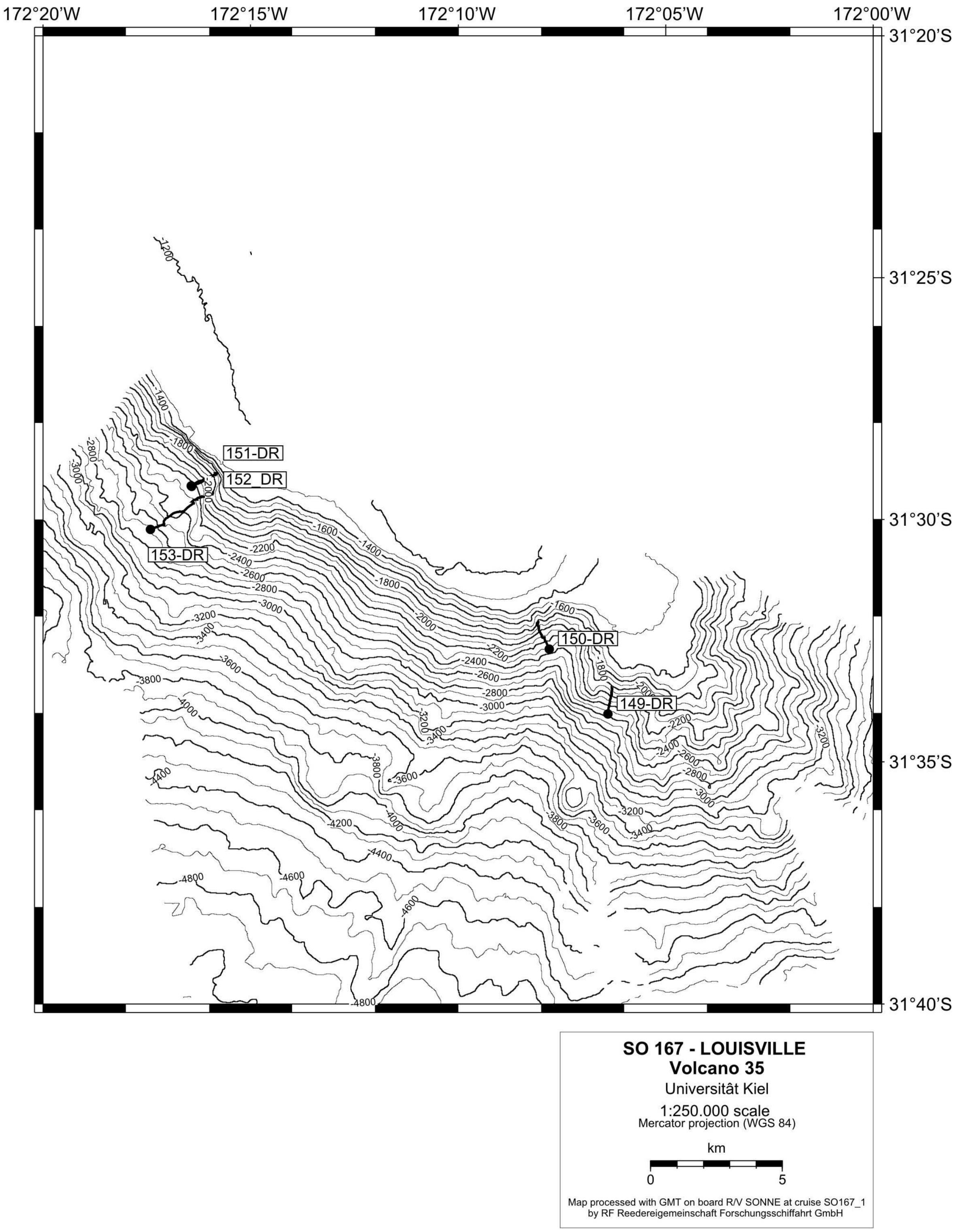

Fig. 8.4: Bathymetry and dredge stations on Volcano 35, Louisville Ridge. Contour interval is 100 m.

Station 154-DR was located on the inner western escarpment of a 4 km-wide sector collapse on the SE flank of the seamount, and terminated 100 m below the break in slope. A slump block has travelled 2 km downslope from the headscarp at the break in slope. A breccia consisting of subangular basalt clasts mostly <1 cm in diameter was recovered, and

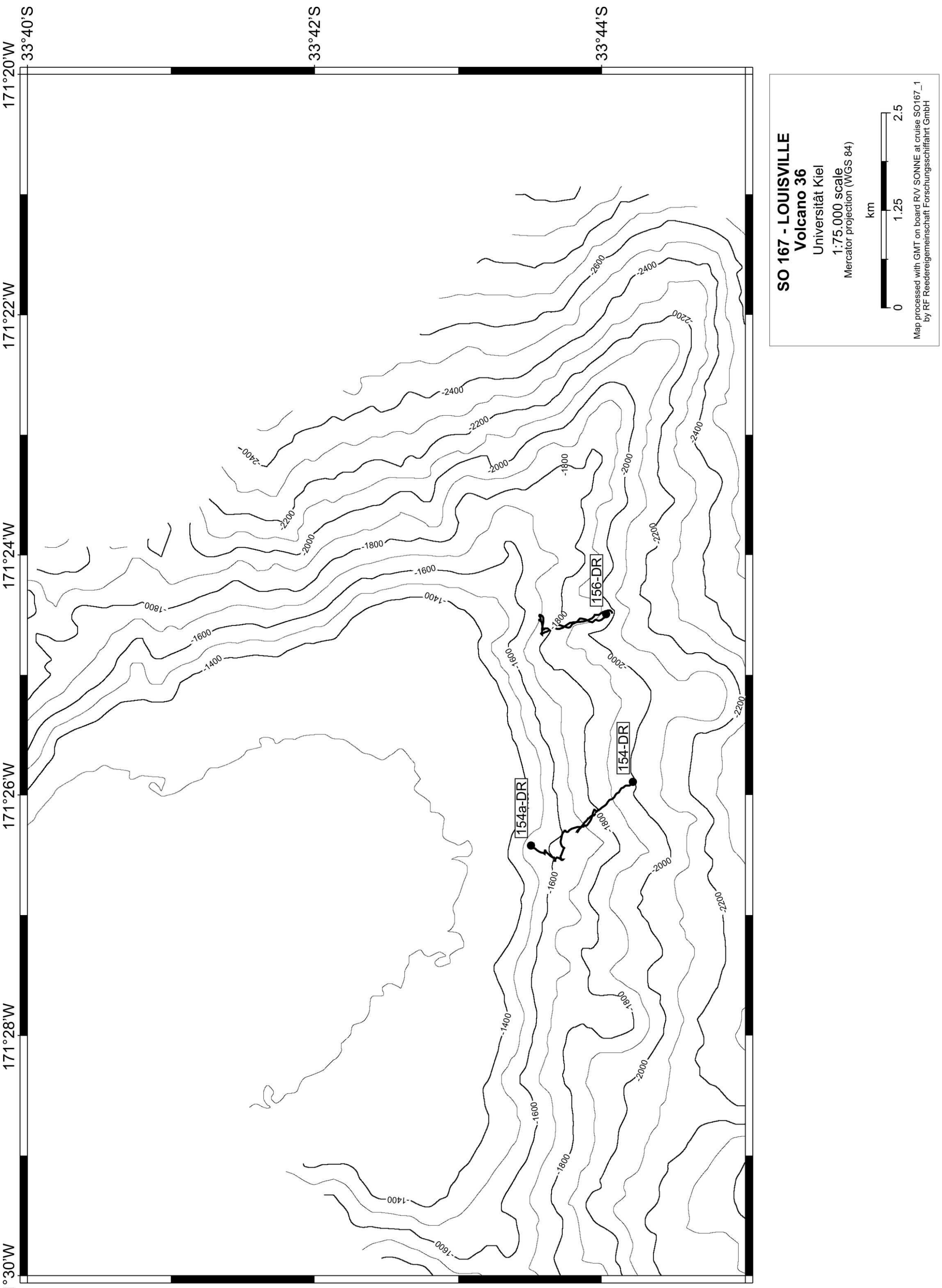

Fig. 8.5: Bathymetry and dredge stations on Volcano 36, Louisville Ridge. Contour interval is 100 m.

included relatively large pieces of vesicular and non-vesicular aphyric basalt. Although both basalts were relatively fresh and unweathered, their vesicles were filled with blue silica(?) and/or zeolite. The breccia has a 3.5 cm-thick FeMnOx crust. Foram sandstone was also retrieved.

Station 156-DR was located on the inner eastern escarpment of the same sector collapse, and terminated 300 m below the break in slope. However, samples at this station would have originated on the SE ridge. The dredge was recovered empty.

8.8. Volcano 37 (Forde Seamount)

Volcano 37 is the largest seamount of the next Louisville Ridge segment, and is located in the centre of that segment. Lonsdale (1988) described this seamount, also known as Forde Seamount, as a guyot with a summit at 980 mbsl. He noted a second guyot immediately to the SE with its summit at 1210 mbsl. Neither guyot had been sampled before SO 167. We found the seamount to be a large complex NW–SE elongated guyot with basal dimensions of 70 km by 25 km at ~4000 mbsl, break in slope at 1200 mbsl, and summit at 1050 mbsl (Fig. 8.6). It consists of a dominant northern volcanic centre and a smaller southern volcanic centre joined at 2500 mbsl by a 7 km-long ridge. Mapping and dredging concentrated on the SW flank of the northern volcanic centre.

Station 157-DR was located on the crest of a small SSW-trending ridge interpreted as the escarpment of a sector collapse on the SW flank, but it isn't clear whether this is the western or eastern escarpment, or if collapses occurred on both sides. The dredge terminated 500 m below the break in slope. A breccia consisting of subangular basalt clasts was recovered, with clasts including both vesicular and non-vesicular aphyric basalt together with olivine basalt. The breccia was encrusted by FeMnOx up to 5 cm thick. Another breccia composed of deeply weathered small subrounded basalt clasts pseudomorphed by apple green clay was also retrieved, together with coralline reef debris.

Station 158-DR was located on the inner eastern escarpment of a 2 km-wide sector collapse on the SW flank, 4 km to the SE of station 157-DR. This collapse scar faces SE, which is unusual and suggests an origin by relatively recent slumping on the flank of S-trending ridge that was itself the escarpment from an earlier sector collapse. The dredge terminated 600 m below the break in slope. Weakly weathered, strongly jointed, dense fine grained aphyric basalt (possibly representing dykes) was recovered, together with a breccia consisting of subangular boulders of this material and older more weathered plagioclase-olivine basalt set in a matrix of foram sandstone. Only thin (<3 mm thick) FeMnOx encrusted these samples, consistent with relatively recent slumping and exposure in this area. A variety of sediments including volcaniclastic sandstone, siltstone and claystone, locally with worm burrows, was also recovered.

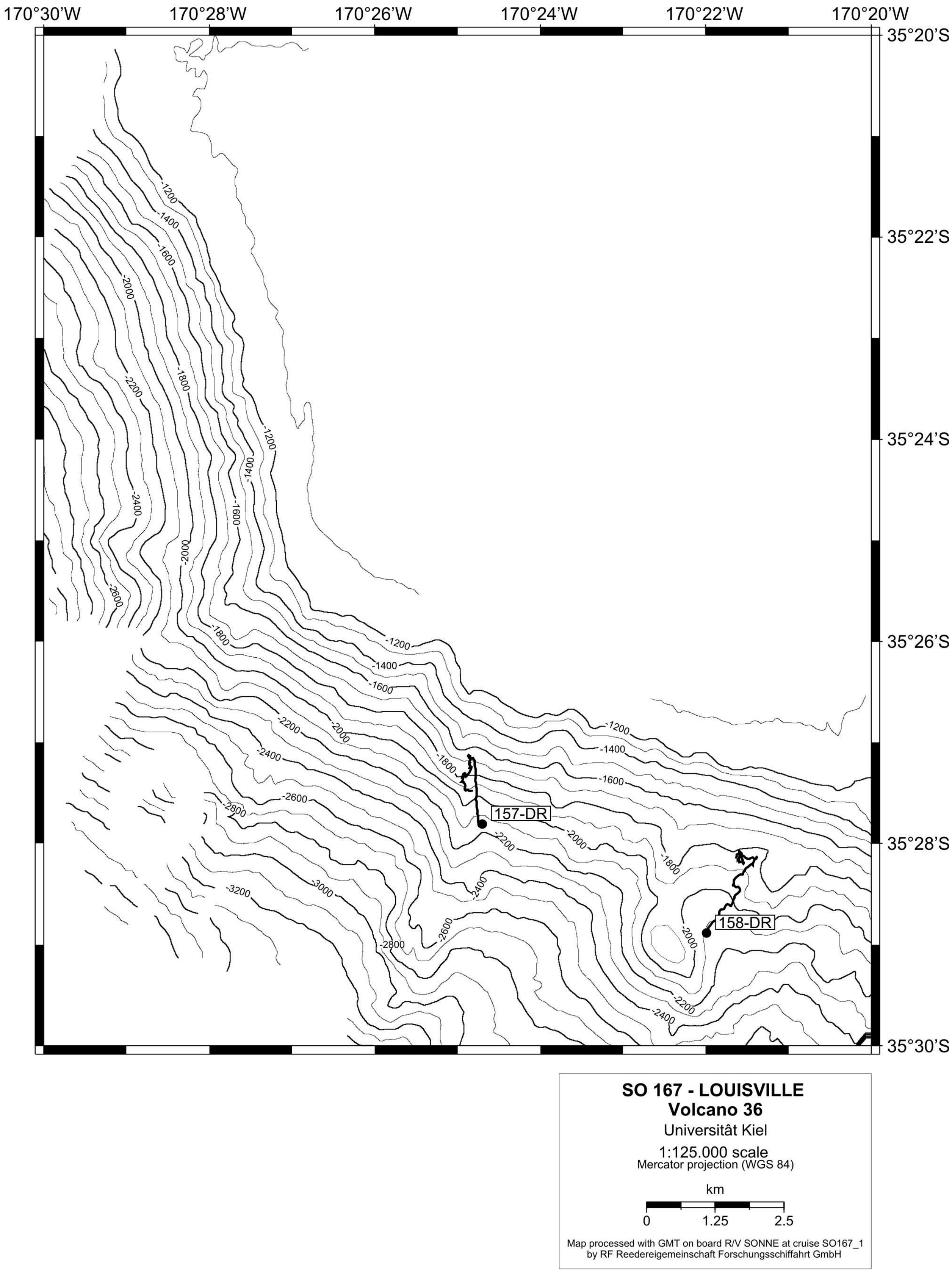

Fig. 8.6: Bathymetry and dredge stations on Volcano 37, Louisville Ridge. Contour interval is 100 m.

8.9. Volcano "x"

A large seamount is located along an extrapolation of the Louisville Ridge segment that includes Volcano 37 to the SE. This seamount was missed by early reconnaissance studies of the Louisville Ridge (Lonsdale, 1988), and was not originally considered a target for SO 167. However, in light of its proximity to the inferred Louisville bend and indications from satellite-derived bathymetry that the seamount may have an unusual NE–SW orientation, the decision was taken to pass over it and attempt one dredge (hence the designation Volcano "x"). It was unsampled before SO 167. The seamount has a medium-sized NE–SW elongated guyot at its northern end, whose diameter is 18 km at ~4000 mbsl, break in slope at 1100 mbsl, and summit at 880 mbsl (Fig. 8.7). The seamount also has a short NW ridge and a prominent, highly unusual, 40 km-long SW ridge; the SW ridge has several secondary volcanic centres that rise 100–400 m above its average height, and the trend of this ridge gradually curves to the SSW with distance from the guyot. The SW ridge occupies approximately half the offset distance between the Volcano 37 segment and the next segment of the Louisville Ridge, and the first seamount of the next Louisville Ridge segment is located along an extrapolation of the SW ridge.

Station 159-DR was located on the northern escarpment of a small, 1.5 km-wide, WNW-facing sector collapse on the SW flank of the guyot. The dredge terminated 500 m below the break in slope. Weathered vesicular strongly porphyritic olivine basalt was recovered, with zeolite-carbonate lined vesicles and FeMnOx crusts up to 3 cm thick. Coralline reef debris, foram sandstone and claystone were also retrieved.

8.10. Volcano 38

The next segment of the Louisville Ridge incorporates the inferred 43–53 Ma bend. Volcano 38 is the second seamount in this segment, and was described by Lonsdale (1988) as a guyot with a summit at 1025 mbsl. Picritic basalt and foidite were previously dredged from this seamount at 1446–2910 mbsl on the SW flank (Hawkins et al., 1987). We found it to be a large complex NW–SE elongated guyot with a basal diameter of 55 km by >20 km at 4400 mbsl, break in slope at 1200 mbsl, and summit at 900 mbsl (Fig. 8.8). Bathymetric coverage was restricted to the NW and SE flanks and a single pass over the summit. This revealed a large guyot with prominent NW and SSE ridges, and a smaller satellite volcanic centre at the end of the 10 km-long SSE ridge. The satellite centre is not a guyot and its flanks rise steeply to a summit at 1300 mbsl; there is no evidence this centre ever formed an island.

Station 161-DR was located on the inner eastern escarpment of a 2 km-wide sector collapse on the southern flank of the main guyot and to the NW of the SSE ridge. A large

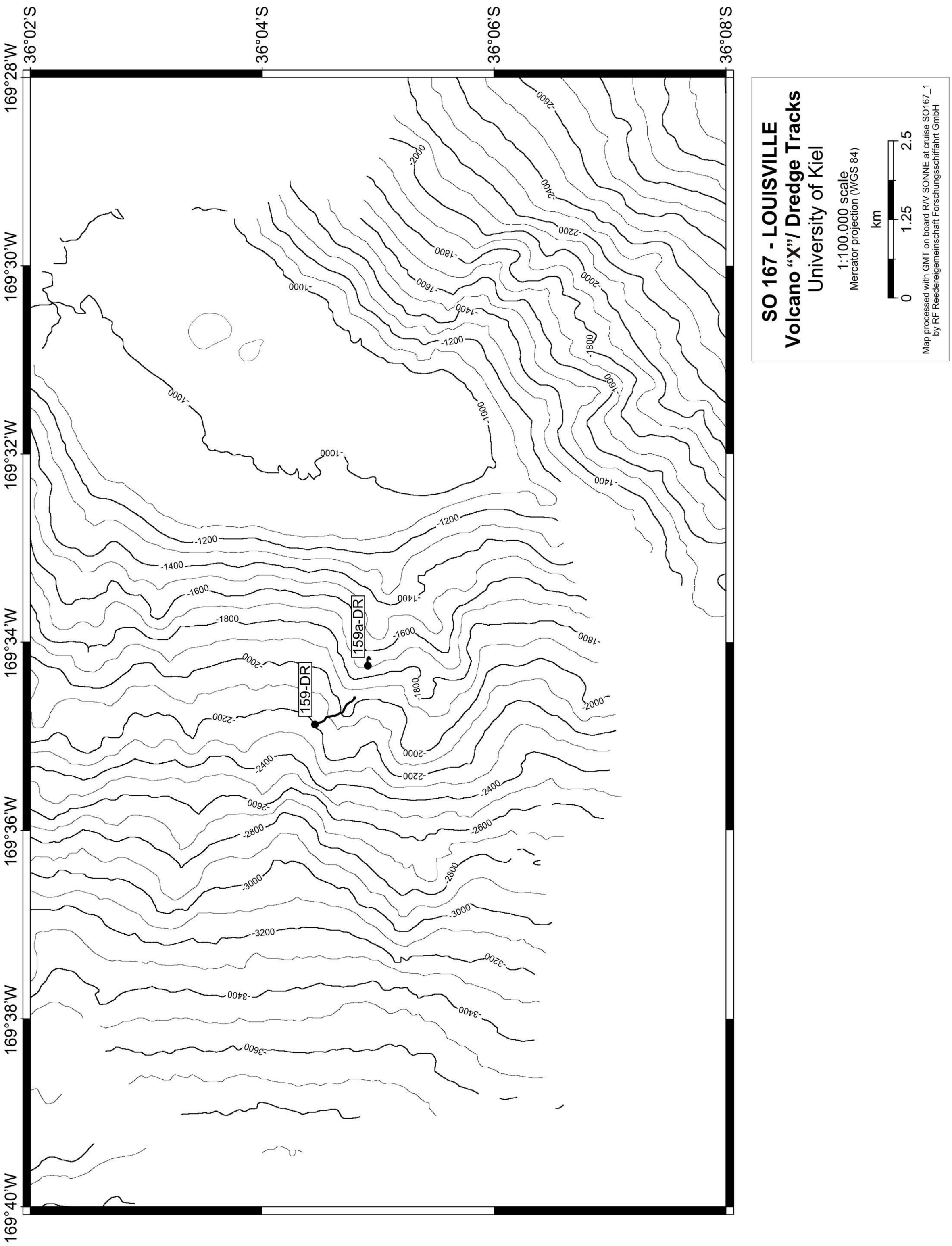

Fig. 8.7: Bathymetry and dredge stations on Volcano "X", Louisville Ridge. Contour interval is 100 m.

block has slumped >5 km downslope from the headscarp of this feature. The dredge terminated 300 m below the break in slope. A breccia composed of subangular clasts of vesicular strongly porphyritic pyroxene-olivine basalt and non-vesicular olivine basalt was recovered. Vesicles in the lava were lined and often filled by zeolite-carbonate, and the breccia was encrusted with up to 3 cm of FeMnOx. Foram sandstone was also retrieved.

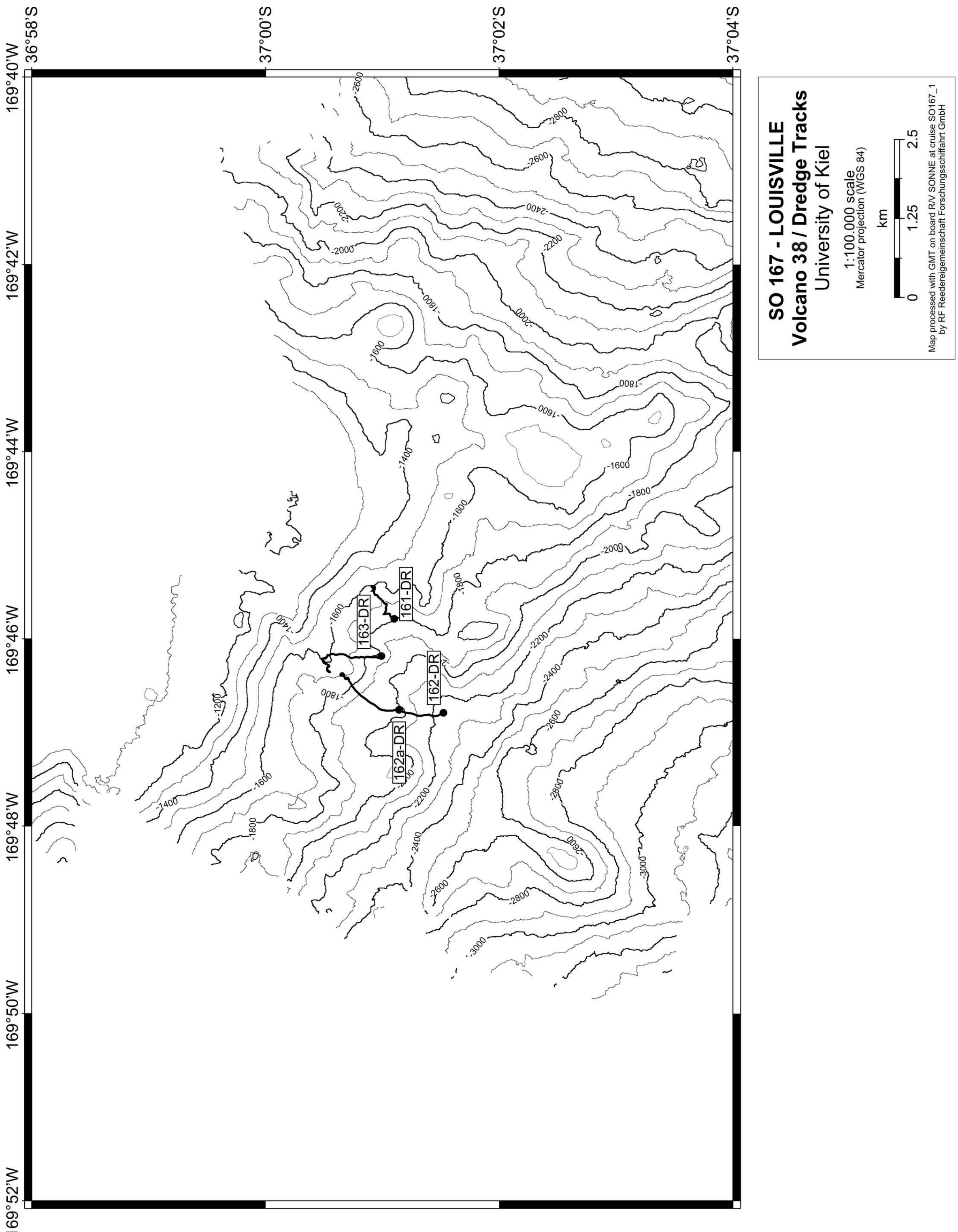

Fig. 8.8: Bathymetry and dredge stations on Volcano 38, Louisville Ridge. Contour interval is 100 m.

Stations 162-DR and 163-DR were in the central part of the same sector collapse, and terminated on a small ridge-like protruberance 300 m below the break in slope. This protruberance is probably a structurally resistant remnant from the original collapse. Station 162-DR recovered a breccia composed of subangular clasts of highly vesicular and strongly porphyritic olivine basalt in a matrix of foram sandstone and zeolite-carbonate.

An unusual characteristic of these lavas is the fragmented nature of the olivine phenocrysts and their poorly sorted size distribution. Most vesicles were filled with zeolite-carbonate, and some by soft clay. Deeply weathered variants of this breccia were also recovered, along with coralline reef debris. Station 163-DR was targeted only at the upper part of the sector collapse, and recovered vesicular olivine basalt whose vesicles were often filled or lined with zeolite-carbonate (different lithology to station 162-DR). A breccia containing deeply weathered clasts of this basalt in a sand-silt matrix was also obtained, together with deeply weathered dolerite.

8.11. Volcano 39

Volcano 39 is located 25 km SE of the small satellite centre belonging to Volcano 38. Lonsdale (1988) described two guyots separated by a ridge at ~2000 mbsl at this location, with summits at 1035 mbsl (NW) and 1085 mbsl (SE) respectively. Neither guyot had been sampled before SO 167. Tectonic reconstructions (Watts et al., 1988; Lonsdale, 1988) and satellite-derived bathymetry indicate these guyots mark the location of the Louisville bend. Consequently, complete bathymetric coverage of both guyots was a high priority for SO 167 and was achieved (Fig. 8.9). Overall, the two expected guyots proved to be part of a single NW–SE elongate seamount with basal dimensions of 70 km by 30 km at 4000 mbsl. However, the seamount has a complex structure and is composed of three distinct sections:

(1) a symmetrical NW guyot with a basal diameter of 30 km, break in slope at 1200 mbsl, and summit at 1050 mbsl
(2) a flat-topped NW–SE trending ridge 20 km-long, whose summit at 1150–1250 mbsl is 6 km in width
(3) a second SE guyot similar in size to the first, with a break in slope at 1300 mbsl, summit at 1080 mbsl, and three prominent ridges extending to the NE, SE and SW.

These three sections cause the seamount to resemble a Klingon "bird of prey" spaceship from the TV series Star Trek. Unique features of this complex seamount, relative to the other mapped seamounts along the Louisville Ridge, include the broad, flat-topped ridge linking the two guyots (with the possible exception of the incompletely mapped Volcano 32) and the three 15–20 km-long ridges extending from the SE guyot. A 150 m-high irregular pinnacle with a basal diameter of 2 km rises from the SW margin of the southern guyot, and possibly represents very late-stage resurgent volcanism that followed the erosion and submergence of the volcano; nearby areas on the seamount flanks were specifically omitted from the dredging program to avoid any ambiguity in data interpretation.

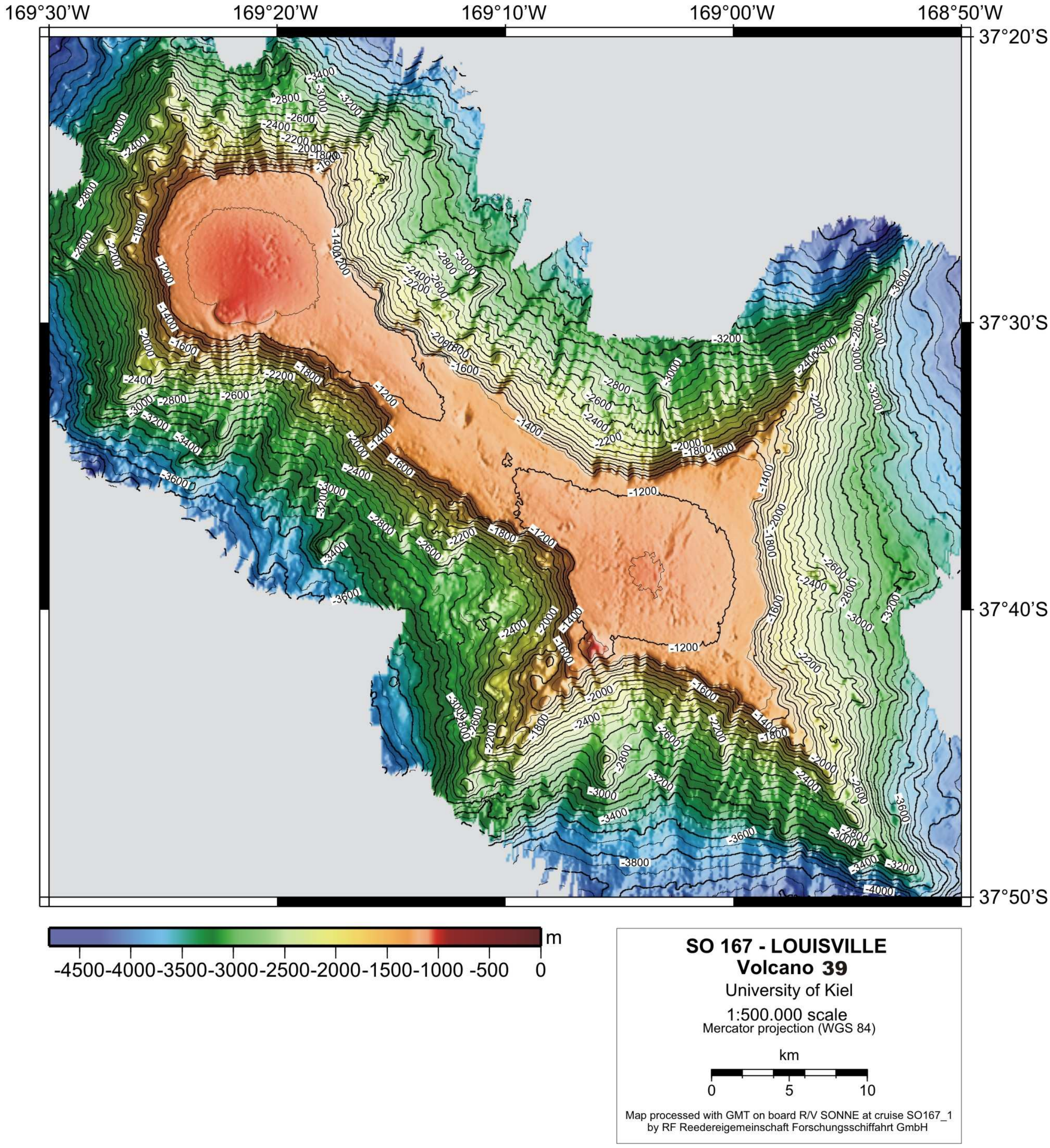

Fig. 8.9: Bathymetry and dredge stations on Volcano 39, Louisville Ridge. Contour interval is 100 m.

Station 164-DR was located on steep slopes at the SW side of a small western ridge extending from the northern guyot. The origin of this western ridge is unclear, and it may be a primary feature rather than a sector collapse scar. The dredge terminated 700 m below the break in slope. A deeply weathered breccia, composed of small pebbles up to 3 cm across and encrusted by up to 1 cm of FeMnOx was recovered. The material may be too small and weathered for analysis.

Station 165-DR was located in a small chute on the SE-facing side of the 10 km-long SW ridge of the northern guyot. The dredge terminated at a small plateau on the SW ridge, 900 m below the break in slope. Recovered lavas included numerous pieces of vesicular pyroxene-olivine basalt and olivine basalt, with most vesicles infilled by zeolite-carbonate. Also retrieved were a breccia composed of these lithologies and coralline reef debris.

Stations 167-DR and 168-DR were located on the inner eastern escarpment of a 5 km-wide sector collapse from the NW end of the flat-topped ridge joining the two guyots. Both dredges terminated 500 m below the break in slope. Station 167-DR recovered a breccia composed of subangular clasts of non-vesicular dense jointed aphyric basalt and weakly vesicular olivine basalt set in a volcaniclastic sand and zeolite-carbonate matrix. The basalt clasts were variably weathered, with most vesicles filled by zeolite-carbonate. Coralline reef debris and drift pumice were also retrieved. Station 168-DR followed the same dredge track, as doubts existed about whether all geochemical and Ar/Ar work could be undertaken on the small clasts from station 167-DR. A similar breccia was recovered, but dominated by strongly porphyritic non-vesicular pyroxene-olivine basalt clasts, as well as further coralline reef debris.

Station 169-DR was located on a 100 m-high scarp on the upper NW flank of the northern guyot. The scarp is interpreted as the southern escarpment of a small (1 km-wide), shallow sector collapse. The dredge terminated 500 m below the break in slope and was recovered empty.

Station 171-DR was located on the eastern escarpment of a 2 km-wide sector collapse from the SE end of the flat-topped ridge joining the two guyots. The dredge terminated 200 m below the break in slope. A wide variety of lavas were recovered, including relatively fresh hard non-vesicular aphyric basalt, an olivine-pyroxene basalt, and a series of mostly non-vesicular olivine basalts (modal olivine ranging from 5 % to 30 %; locally with relict light green cores). Where present, vesicles were usually filled by zeolite-carbonate or dark clay (chlorite?). Deeply weathered breccia and a volcaniclastic sandstone were also retrieved.

Station 172-DR was located in the central valley of a 2.5 km-wide sector collapse from the upper NE-facing side of the SE ridge on the southern guyot. The dredge terminated 700 m below the SE ridge crest. A monolithologic breccia composed of subangular clasts of variably weathered highly vesicular aphyric basalt set in a zeolite-carbonate matrix and encrusted by up to 3 cm of FeMnOx was recovered. Many of the vesicles were infilled by zeolite-carbonate, and some clasts are cut by veinlets of this material.

8.12. Volcano 40

A gap of 35 km separates Volcano 39 from a pair of small seamounts that were not investigated by SO 167. A further 30 km to the SE is the largest seamount on the Louisville Ridge: Volcano 40. Lonsdale (1988) noted that this was by far the largest volcanic edifice along the Louisville Ridge, and described it as a guyot with a summit at 274 mbsl. He also noted that a 300 m-high volcanic peak, interpreted as an erosional remnant, rises from the mid-western summit plateau. Both alkali basalt and picritic basalt have previously been recovered from the eastern flank of the seamount at 1232 mbsl (Hawkins et al., 1987). A brief stop to complete one dredge was made in order to have further age and geochemical control over the Louisville bend. Volcano 40 was approached from the NW, and the limited bathymetric coverage of a small part of the western flank adds little new information apart from identification of the break in slope at 1100 mbsl.

Station 173-DR was located on the inner northern escarpment of a 4 km-wide sector collapse on the western flank of the guyot. The dredge terminated 800 m below the break in slope. A monolithologic breccia composed of variably weathered subangular non-vesicular aphyric basalt clasts set in a zeolite-carbonate-clay matrix was recovered, together with a conglomerate containing well-rounded weakly weathered pebbles of the same lithology set in a volcaniclastic sand-silt matrix. Both were encrusted by up to 2.5 cm of FeMnOx. The conglomerate is interpreted as a paleo-beach deposit.

8.13. Summary

Eleven major seamounts along the Louisville Ridge from its intersection with the Tonga–Kermadec Trench to the area of the bend were surveyed and sampled. All surveyed seamounts were flat-topped guyots. Their wave-cut summit plateaux testify to volcanic islands that were eroded down to sea-level and have subsequently subsided by as much as 2000 m. The amount of subsidence decreases to the SE as the seamounts become younger. Thick deposits of foram-bearing sandstone bury drowned coral reefs on their summits. The dredging program utilised the ability of the SIMRAD EM120 to provide high resolution bathymetric coverage of a wide swath in real-time. Slump blocks 2–6 km downslope of their headscarps were quickly identified. Dredging targetted the steep headscarps behind these slumps on the upper flanks of the seamounts, typically at 2000–2500 mbsl but still 500–1500 m below the wave cut break in slope. Thus, by analogy with the Hawaiian Islands, dredging should have sampled the late main shield-building phase of volcanism and avoided any post-erosional stage lavas (the latter being mostly confined to the central summit region). The majority of the slumps occur on the south-facing flanks of the Louisville seamounts for reasons that are not presently understood.

Our bathymetry confirmed that the Louisville Ridge comprises NW–SE ridge segments that are linked by short NE–SW segments. The largest seamounts are built along the dominant NW–SE segments and are commonly elongated in this direction. However, less voluminous volcanism has occurred along the NE–SW segments (mostly notable the SW ridge of Volcano "x"). Both the NE–SW segments, and some flank ridges extending from the larger seamounts, have the same trend as the non-transform discontinuities recognised at Osbourn Trough. The trend of these ridge segments progressively swings from north–south to NE–SW with increasing distance from the Osbourn Trough. These non-transform discontinuities evidently represent zones of lithospheric weakness that were exploited by the Louisville plume magmas.

Volcano 39 stands out as exceptional. This is the only surveyed seamount that consists of two major edifices linked by a long broad ridge. Both seamounts and the ridge were once subaerial, as they are now wave-cut flat-topped guyots. Volcano 39 is located at the bend in the Louisville Ridge. Changes in Pacific Plate velocity (temporary slowing?) may be responsible for the unusual morphology of the volcano and apparent enhancement of volcanism along the central ridge. Dredging at this important seamount recovered lavas from both seamounts and the central ridge, and should confirm or reject such ideas.

A total of 39 dredge stations were completed, yielding 226 representative samples of which 97 were selected and prepared for analytical work in Kiel (Table 8.1). The predominant lithologies were highly vesicular olivine basalt and aphyric basalt. Marine weathering affects the samples, but apart from all olivine being pseudomorphed by iddingsite the degree of weathering was not severe (and in fact considerably less than that affecting younger lavas recovered from the Hawaii–Emperor seamounts during SO 141). This probably reflects the success of the dredging strategy in targetting relatively young slump scarps, and thus seawater exposure ages that are less than the age of the seamount. Breccias were recovered from many dredge stations and testify to mass wasting on the slopes. Well-rounded beach pebbles were located at some sites, and commonly contained relatively fresh clasts; probably the fine grained clay matrix of these conglomerates prevented water from circulating.

8.14. References

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Table 8.1: Petrology Samples and Lithologies, Louisville Ridge

Station Number	Samples logged	Selected analysis		Aph Bas	Ol Bas	Ol-Pl Bas	Ol-Px Bas	Px Bas	Pl Bas	Pum	Doler	Brecc	Congl	MnOx Crust	Foram Sandst	Siltst	Clayst	Limest
115 DR	-	-																
116 DR	4	1						X					X					
117 DR	3	1						X								X		X
118 DR	-	-																
119 DR	1	-											X					
120 DR	3	2		X	X								X					
134 DR	6	1				X						X		X	X		X	
135 DR	13	5		X											X		X	
136 DR	-	-																
137 DR	3	1								X				X	X			
139 DR	17	9		X		X				X			X		X			
140 DR	9	3		X		X			X			X		X	X			
141 DR	7	3		X					X			X		X				
142 DR	-	-																
143 DR	6	1		X	X									X	X			
145 DR	1	1												X				
146 DR	1	1			X													
147 DR	5	5		X	X							X						
149 DR	7	2		X						X					X		X	X
150 DR	6	2		X						X					X			
151 DR	-	-																
152 DR	1	1			X													
153 DR	-	-																
154 DR	4	2		X								X			X			
156 DR	-	-																
157 DR	10	3		X	X							X						X
158 DR	12	6		X					X			X				X	X	
159 DR	8	4			X												X	X
161 DR	4	3			X		X								X			

Station Number	Samples logged	Selected analysis		Aph Bas	Ol Bas	Ol-Pl Bas	Ol-Px Bas	Px Bas	Pl Bas	Pum	Doler	Brecc	Congl	MnOx Crust	Foram Sandst	Siltst	Clayst	Limest
162 DR	16	7			X							X						X
163 DR	4	2			X						X	X						
164 DR	4	-										X						
165 DR	13	6			X		X					X						X
167 DR	9	2		X	X					X		X						X
168 DR	6	4					X					X						X
169 DR	**-**	**-**																
171 DR	24	12		X	X		X					X			X			
172 DR	13	4		X								X						
173 DR	6	3		X								X	X					
39 Stns	**226**	**97**		**16**	**13**	**3**	**4**	**2**	**3**	**5**	**1**	**16**	**5**	**6**	**11**	**2**	**5**	**8**

9. MAGMATICALLY INDUCED HYDROTHERMAL PROCESSES

Ulrich Schwarz-Schampera, Harold Gibson, Thomas Kuhn, RogerHekinian, Susanne Fretzdorff, Andreas Kindermann, Kerstin Schreiber

The Tonga Trench is a classic example of an immature, intra-oceanic, convergent margin where Pacific Plate lithosphere is subducted beneath a volcanic island arc chain (Fig. 9.1). A fore-arc basin separates the Tonga Trench from the active Tofua volcanic arc. The extensional back-arc and southwards propagating Lau Basin separates the Tofua volcanic arc from the remnant Lau volcanic arc.

The plate margin lacks evidence for remnants of continental crust and is inferred to be entirely oceanic. The back-arc Lau Basin opened by the successive southward propagation of discrete seafloor spreading centers. The site of active rifting is located at its southern end, the southernmost Eastern Lau Spreading Center (ELSC), commonly referred to as the Valu Fa Ridge. The Valu Fa Ridge was identified as a site of intense tectonic, magmatic,

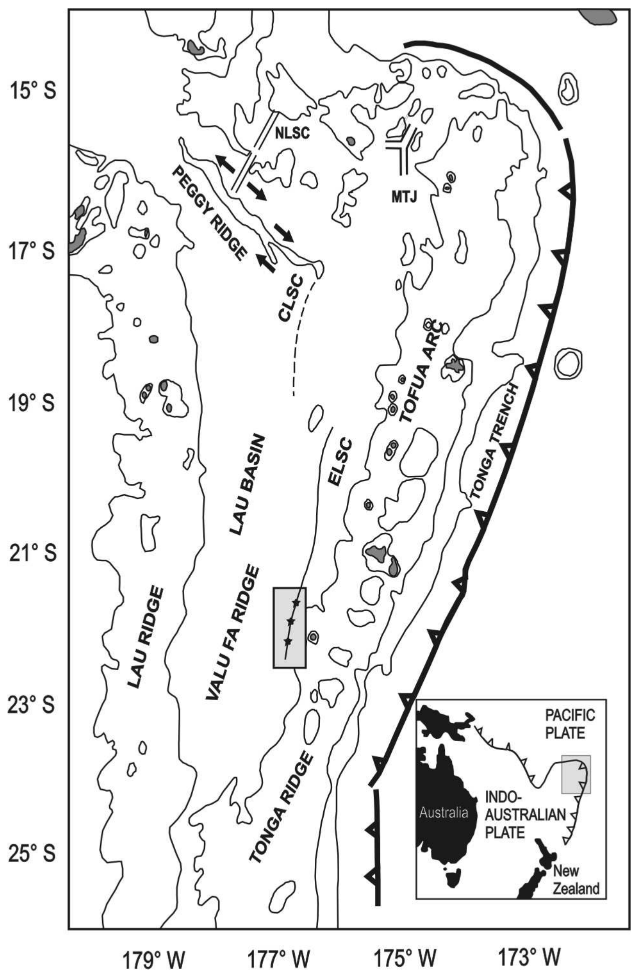

Fig. 9.1: Geological setting of the Lau Basin behind the westward-dipping Tonga–Kermadec subduction zone in the SW Pacific, also showing with locations of known hydrothermal vent fields along the Valu Fa Ridge (shaded area; NLSC, CLSC, ELSC = northern, central, and eastern Lau spreading centers; MTJ = Mangatolu Triple Junction; modified after Hawkins, 1995a).

and hydrothermal activity which also makes it a type example for rift-related volcanism and associated hydrothermal processes. The Lau Basin, and its southern part, represents an environment which is commonly compared to ancient volcanogenic massive sulfide deposit-hosting, back-arc successions that were obducted and embedded in orogenic sequences during the geological past. This integrated study will contribute to the understanding of tectonic, magmatic, and ore-forming processes and their evolution within an immature, rifted arc environment.

9.1. Objectives of the Hydrothermal Program

The main objectives of the hydrothermal program during SO-167 emphasized the detailed mapping of the southern Lau back-arc region in order to study the spatial and temporal relationships between the passage of the propagating tip along the ridge segments and the tectonic and magmatic processes involved in rifting and associated hydrothermal activity. Special emphasis was placed on the evolution of hydrothermal systems and the temporal relationships between initial, rift-related volcanism and the potential onset of coeval magma-induced hydrothermal activity. The program included sampling of the previously documented Vai Lili and Hine Hina hydrothermal fields and associated volcanic rocks along the southern part of the Valu Fa Ridge near its southward propagating tip.

The mapping and sampling of arc volcanoes along the Tonga arc was accompanied by a search for shallow submarine hydrothermal systems related to arc volcanism and magmatic exhalations. There is significant potential for shallow submarine, epithermal-style mineralization within island arc systems, as was shown during previous cruises to the Manus-Kilinailau (Conical Seamount; SO-94, SO-133, SO-166) and the Kermadec (Brothers Volcano, Clark Volcano, Whakatane Graben; SO-135; Stoffers et al., 1999a) island arcs. Exploring the island arc and back-arc systems allows for the comparison of volcanic and hydrothermal processes in these two magmatic-tectonic environments, and to determine the influence of end-member magmatic volatiles versus seawater-driven systems in arc metallogeny.

Specific objectives of the hydrothermal program included:

1) Establishing detailed and high resolution swath bathymetry and back-scattered imaging between 22°S and 23°S using SIMRAD, in order to document recent tectonic and magmatic processes in greater detail and to study promising and potential targets for hydrothermal activity. The data obtained will be integrated with existing bathymetric and geophysical data in order to construct and assess a three-dimensional bathymetric and geological model for the southern Lau Basin and related tectonic, volcanic, and hydrothermal processes. The data will also be integrated with ongoing studies of the southern Kermadec and south Tonga arc volcanoes in order to assess

differences in hydrothermal signatures and mineralisation between the volcanic front, and the proximal Valu Fa Ridge back-arc.

2) The investigation and sampling of recent volcanism. The area is one of continuing seismic activity and may have been modified by renewed volcanism since the last surveys in 1991. The recent increase in opening rates and continuous volcanic and hydrothermal activity confirm that extension beneath the southernmost part of the Lau Basin is continuing. The emphasis during SO-167 was placed on studying volcanism at actively rifting propagators, spreading ridges, and bathymetric highs at the central (22°10'S; 22°25'S) and southern (22°32'S; 22°40'S; and the inferred propagating tip at 22°51'S) Valu Fa Ridge. Recovered samples of intermediate to felsic volcanic rocks will be studied geochemically (including isotopes) and petrographically, and integrated with the existing database for the Valu Fa Ridge obtained from earlier cruises. This will permit a comprehensive petrological assessment of magma evolution and the potential of these magmas to contribute metals to VMS-type deposits.

3) The documentation of the status and extent of hydrothermal venting at the Vai Lili and Hine Hina hydrothermal fields. Previous cruises (NAUTILAU, SO-48) documented vigorous active venting at the Vai Lili hydrothermal field. The number of actively venting chimneys, however, was small when compared to the number of inactive chimneys, and it was unclear whether this field was in a waning stage similar to Hine Hina, possibly as a result of ongoing tectonic and volcanic activities. In 1989, the Hine Hina field was characterized by widespread diffuse discharge with hydrothermal crusts and single occurrences of inactive chimneys. Low temperature sulfide nodules and massive sulfide crusts yielded data indicating contributions of magmatic volatiles during sulfide precipitation during the volcanic stage of this vent field. It is unclear whether this stage is related to the early onset of hydrothermal activity after the passage of the propagating tip, or if it represents low-temperature exhalations preceding or following volcanic eruption. Additional surveys were intended to document changes in the intensity of hydrothermal upflow and related precipitates, and to document the volcanology of the respective footwalls in greater detail.

4) Determining the age and temporal variability of alteration and mineralization at Vai Lili, Hine Hina, and other hydrothermal sites. Samples will be studied in terms of their mineralogical, geochemical, and isotopic composition in order to document their evolution within the last decade, and the present day status of the hydrothermal fields. Special emphasis is placed on the comparison with ancient VMS deposits and settings, which are a product of robust, long-lived hydrothermal systems.

5) Establishing the relationship between hydrothermal activity and rift propagation. The deep rift structure immediately to the south of Valu Fa Ridge was surveyed in detail for the first time in an attempt to identify the Valu Fa tectonic propagator and to establish whether hydrothermal systems develop before or after the development of the propagating tip. Special emphasis is placed on the temporal relationships between

initial rift-related volcanism and the onset of coeval magma-induced hydrothermal activity, as well as the composition of potential volcanic source rocks.

6) Documenting the status of vent communities at the Vai Lili and Hine Hina hydrothermal sites. During NAUTILAU, intense hydrothermal but minor faunal activity was discovered. Limited occurrences of small shrimps, large gastropods, and white crabs were described around white smokers of the Vai Lili field. Considering the large number of inactive chimneys, the limited colonization might have indicated the decrease in hydrothermal activity, a possible collapse of the hydrothermal upflow, and focus to single faults. Dense populations of vent fauna were identified around outlets of diffuse discharge at the Hine Hina site. Since the field was thought to be in a volcanic stage, the colonization of the diffuse vents may have been very rapid. Subtle changes in the nature of the hydrothermal system in the intervening 13-year period are likely to be recorded by the migration, growth/extinction and distribution of the vent fauna (refer Chapter 11 for biological investigations).

9.2. Geological Background

9.2.1. Tectonic Evolution of the Southern Lau Basin

Following initial rifting of the Lau arc crust, close to the formerly active volcanic front, the back-arc Lau Basin opened by the successive southward propagation of discrete seafloor spreading centers over the past 4 million years (Taylor et al., 1996). Lithospheric accretion at discrete spreading centers, the seafloor bathymetry, and magnetization fabric in this back-arc basin are fundamentally similar to that of mid-ocean ridges, as is the pattern of ridge segmentation, which includes propagating rifts, overlapping spreading centers, extensional transform zones and transform faults (Taylor et al., 1996). Present-day rifting occurs along the southern extension of the ELSC (Valu Fa Ridge) south of 23°S, and along the eastern margin north of 18°S. From the comparison of geodetic data (Bevis et al., 1995) and seafloor magnetization, it is inferred that opening rates have recently increased along the CLSC and ELSC (Taylor et al., 1996).

Evidence for active extension in the Lau Basin is provided by the shallow seafloor morphology, general thin sediment cover, active magma chamber(s) with the eruption of young tholeiitic basalts to dacites, geodetic and geophysical surveys, and vigorous hydrothermal systems (e.g., von Stackelberg and von Rad, 1990; Collier and Sinha, 1992; Fouquet et al., 1993; Hawkins, 1995ab; Taylor et al., 1996). For basin opening, a two-stage model was proposed in which rifting processes are replaced progressively southwards by clear evidence for a seafloor-spreading magnetic pattern in the central Lau Basin (Parson and Hawkins, 1994; Hawkins, 1995ab; Taylor et al., 1996). Seafloor-spreading rates between 42 to 99 mm/year have been proposed due to different interpretations of the magnetic lineations (Weissel, 1977; Malahoff et al., 1982; Morton and Pohl, 1990; von Rad et al., 1990; Malahoff et al., 1993; Parson and Hawkins, 1994).

Crustal stretching between the Lau and Tonga Ridges began at ~6 Ma, accompanied by magmatism and the eruption of arc- and MORB-like magmas (Hawkins, 1995ab). Extension and magmatism continued to the south, being progressively replaced from the north by focused accretion (volcanism) on the ELSC which propagated south from 16.5°S to 20°S between ~4 and ~2 Ma. The initial ELSC was oriented north-south and spread at ~100 mm/year. It consisted of two segments; the northeastern segment propagated south faster than the other segment to produce a pseudofault oriented at 170°. When the pseudofault intersected the propagation boundary at ~2 Ma, the ELSC rotated 15–25° clockwise and was subdivided into left-stepping *en echelon* overlapping segments that continued to propagate south. This tectonic pattern of *en echelon* segments can be traced to the actual site of rift propagation. The Peggy Ridge transform fault was initiated, together with the Central Lau Spreading Center (CLSC) and an extensional transform zone (ETZ) linking the two. The CLSC, formed by this propagating rift, penetrated crust originally generated at the ELSC at ~1.5 Ma (Hawkins, 1995).

Paleomagnetic data suggests that the Tonga arc has rotated as a rigid body clockwise relative to the Lau Ridge by 20.8° (± 12.6°; Sager et al., 1994). This, and the approximate 17° angle formed by the azimuths of the inner escarpments of the Lau and Tonga Ridges (Parson and Wright, 1996), are in close agreement with the ELSC rotation and probably define a regional plate re-orientation at ~2 Ma.

9.2.2. Valu Fa Ridge

The southernmost part of the ELSC, south of 21°20'S, is referred to as the Valu Fa Ridge (VFR; Morton and Sleep, 1985; Jenner et al., 1987; Vallier et al., 1991). This well-defined, linear feature is the propagating rift-tip and represents one of the youngest locations of back-arc rifting in the Lau Basin (Hawkins, 1995ab). The ridge extends for at least 165 km, subparallel to the Tonga Ridge. It is 5 to 6 kilometers wide and generally strikes N20°E. The ridge flanks rise about 600 m above the surrounding seafloor and, near the ridge crest, locally exceed a slope angle of 30° (Wiedicke and Collier, 1993). The ridge has a narrow crestal area that is usually only a few hundred meters wide that lacks a central axial graben structure. The VFR approaches to within about 40 km of 'Ata Island in the Tofua island arc. At the southern end of the Lau Basin, the VFR is propagating southward into older crust of uncertain composition, possibly equivalent to the rifted fore-arc terrane that forms the basin-range seafloor of the western Lau Basin (Hawkins, 1995ab), or remnant fragments of old arc material, or single arc edifices (Parson and Wright, 1996). It hosts 'oceanic andesite' (Vallier et al., 1991) having chemical and isotopic signatures which indicate a supra-subduction zone (SSZ) component similar to the nearby Tofua arc.

The Valu Fa Ridge extends to 22°45'S, which is thought to be the southernmost extent of current spreading (Wiedicke and Collier, 1993). Fujiwara et al. (2001) interpreted the southernmost tip of the spreading center to be defined by a deep graben located at 24°00'S, 177°10'W and oriented at the same N20°E orientation. Elongated deeps with water depths greater than 3100 m in this area support the concept of propagation as graben formation, preceding the evolution of a volcanic ridge, is described from other propagating rifts (Kleinrock and Hey, 1989). Additional evidence for VFR propagation is an oblique (i.e., by 30°) or 'V-shaped' bathymetric feature located to the southwest of the VFR (Wiedicke and Collier, 1993); a pattern which is produced as ridges propagate (e.g., Hey, 1977; Hey et al., 1980). Two large seamounts south of the ridge tip were interpreted as rudimentary, or an initial stage of, southward ridge propagation (Wiedicke and Collier, 1993). Von Rad et al. (1990) discussed the ridge propagation based on patterns of crustal magnetization. Unpublished bathymetric data suggest that the ridge tip may extend southward into the eastern flank of a 3000 m deep basin (in: Parson and Wright, 1996). These >3000 m deeps were interpreted to be a product of the rifting process that immediately precedes crustal rupture and subsequent initiation of spreading (cf., Fujiwara et al., 2001). Clusters of normal fault earthquakes south of 23°S are associated with continued back-arc rifting (Pelletier and Louat, 1989).

Brunhes Chron spreading rates for the ELSC increase northwards, from 65 mm/year at 115° at 21°S, to 90 mm/year at 115° at 18°S, to perhaps 100 mm/year along the ETZ (Taylor et al., 1996). Revised magnetic anomaly interpretation indicates a late Pliocene and Quaternary spreading history at a rate of 91 mm/year between 20°S and 22°S (Parson and Hawkins, 1994). GPS network data (Bevis et al., 1995) indicate that the Tonga Ridge is moving on an azimuth of ~115° at rates increasing from ~90 mm/year at 21°S to ~130 mm/year at 18.5°S and ~160 mm/year at 16°S. This contrasts with the Brunhes Chron seafloor spreading rates, and appears to require either a recent increase in opening rates or, in addition to spreading, significant off-axis extension.

9.2.3. The Valu Fa Ridge Magma Chamber

Analysis of seismic data indicate that the whole of the central VFR (CVFR) is underlain by a robust axial magma chamber (Morton and Sleep, 1985; Collier and Sinha, 1990; 1992ab; 1996). The magma chamber reflector is continuous for at least 10 km, and may extend for an additional 20 km on a reflection profile recorded along the entire axis of the CVFR from the northern end of segment no. 9 (*sensu* Wiedicke and Collier, 1993) at 22°10'S south to segment no. 6 of the northern SVFR. Axial discontinuities along the ridge axis (i.e., overlapping ridge segments, deviations from axial linearity) apparently do not mark principle breaks in the magma chamber reflector (Wiedicke and Collier, 1993). There are no significant or systematic variations in the depth to the top of the chamber over the 35 km-long portion of the surveyed ridge system. The axial magma chamber is unusual in that the top is interpreted to be 2–3 km wide, flat, and relatively deep (3.2 km below seafloor), as compared to those identified on mid-ocean ridges (e.g., East Pacific Rise at 9–13°N and 14–18°S; Reykjanes Ridge at 57°N). The magma chamber reflector is widest beneath the NVFR/CVFR overlapping spreading center and also broadens underneath the CVFR/SVFR (no. 6/no. 7 segments) overlap. Well-defined seismic reflectors, and a large reflective coefficient, as well as the flattened top might be related to a low-density, highly viscous siliceous melt.

9.2.4. Magmatism and Volcanism on the Valu Fa Ridge

Magma viscosity and magma supply rate along the VFR most likely influence the style of volcanism in the southern Lau Basin. Intermediate to fast spreading rates and enhanced magma supply, but also the higher viscosity of the siliceous melts, are probably responsible for the relatively narrow shape of the VFR near the ridge axis. Based on our bathymetric data, the VFR gently slopes except in the immediate vicinity of the present ridge axis. Wiedicke and Collier (1993) argued that the VFR magma is so viscous that it tends to solidify and clog potential fissures reaching the seafloor at very localized points. Following this interpretation, short-term fissure-fed small-scale eruptions and well-constrained axial cones of andesitic to dacitic composition should dominate along the ridge crest-axis VFR, while thick and extensive piles of massive sheet flows are expected deeper and lateral to the ridge axis, as well as further to the north of the ELSC. The style of magmatism likely influences the style of hydrothermal activity. There is unequivocal evidence that high-level magma chambers with limited magma supply rates strongly favour the formation of long-lived sustainable hydrothermal convection. The clogging of faults and fissures, which represent potential channelways for the upflow of hydrothermal fluids, by viscous melts may prevent the ridge segment from developing hydrothermal fields at the surface. However, tectonic activity may continuously re-open or re-establish cross-stratal structures.

The Lau Basin crust ranges in element and isotopic chemistry from MORB to arc compositions (Hawkins, 1995b). ELSC magmas were interpreted to have remained fairly constant over at least 3 Ma to the present (Hawkins, 1995b), suggesting a uniform, long-term composition for the magma sources. The main variability in ridge chemistry seems to be expressed near the rift tip(s), or as the rift approaches the Tofua arc (Ernewein et al., 1995). The ELSC and CLSC both consist of similar rock types, however the CLSC rocks have the chemical characteristics of MORB whereas the ELSC rocks show much more variability and are transitional from MORB to arc tholeiite southward towards the Valu Fa Ridge. They trace a supra-subduction zone (SSZ) component having distinctive arc-type chemical and isotopic signatures. This may reflect crustal assimilation, different water contents in the source, or a variable input from a MORB-source mantle. The ELSC propagator encountered much older crust, much of which may represent remnants of the Lau Ridge fore-arc or arc fragments. Assimilation of this older crust, but also the increasing proximity to the Tofua arc, may have been an important factor in developing more arc-like magmas (Hilton et al., 1993; Ernewein et al., 1994). Rocks from the ELSC propagating rift tip include some low-K, high silica andesites that are probably extreme fractionates formed as the rift penetrated older crustal segments. The compositional range for ELSC and CLSC samples may be explained in terms of low-pressure fractional crystallization of the observed phenocryst assemblages (Hawkins, 1995b).

The Valu Fa Ridge contains some of the most arc-like rocks whose composition is probably related to proximity to the Tofua arc. Jenner et al. (1987) proposed that the trace element and isotopic data indicate a minor, but significant, contribution from the subducted slab. Vallier et al. (1991) concluded that VFR lavas are isotopically similar to the volcanic island of 'Ata on the Tofua arc, about 40 km to the east of the VFR. The data, however, are consistent with transitional arc – back-arc signatures.

9.3. Valu Fa Ridge: Topography, Structure and Volcanism

Detailed mapping of the southern Lau Basin seafloor topography between 22°S and 23°S reveals a number of important structural elements of the tectonically and magmatically active VFR and its southern extension (Fig. 9.2). These structural features may account for the location of very recent volcanic and hydrothermal activity and may represent potential sites for future hydrothermal activity.

The Valu Fa Ridge extends for at least 165 km, is 5 to 6 km wide, and generally strikes N20°E. The flanks rise about 600 m above the surrounding seafloor (Wiedicke and Collier, 1993). The ridge crest was formerly documented as steep and narrow ('razor-blade'-like) when compared to the spreading axis of the northern Lau Basin and normal mid-ocean ridges (Wiedicke and Collier, 1993). It also lacks a central axial graben structure. The crestal depths of the VFR range between 1950 m in its southern portion and 1700 m, reaching a minimum of approximately 1600 m in the central area. The general elevation and doming to bathymetric highs along the CVFR is likely a consequence of the underlying magma chamber. In general, the bathymetry deepens southward from the elevated region with the NVFR/CVFR overlapping spreading center at its center. The axes of ridges and depressions subside by several hundreds of meters over a distance of about 50 km. The greatest depths (>3000 m) occur in the strongly faulted southern extension of VFR at 23°00'S (Fig. 9.2).

Previous studies (e.g., von Stackelberg et al., 1988) have recognized three ridge sections including the southern, central and northern Valu Fa Ridge (SVFR, CVFR, NVFR), but Wiedicke and Collier (1993) have interpreted a much more differentiated ridge segmentation. Their axial depth profile along the crest reveals 11 volcanic ridge edifices (nos. 3 to 14) and dozens of small topographic highs, interpreted to be cones, aligned along the entire VFR (Wiedicke and Collier, 1993). Segments no. 3 to no. 6 belong to the SVFR, no. 7 to no. 9 to the CVFR, and no. 10 to no. 14 to the NVFR. The segments are not strictly aligned along axis, but are slightly offset *en echelon* to the southeast following the regional

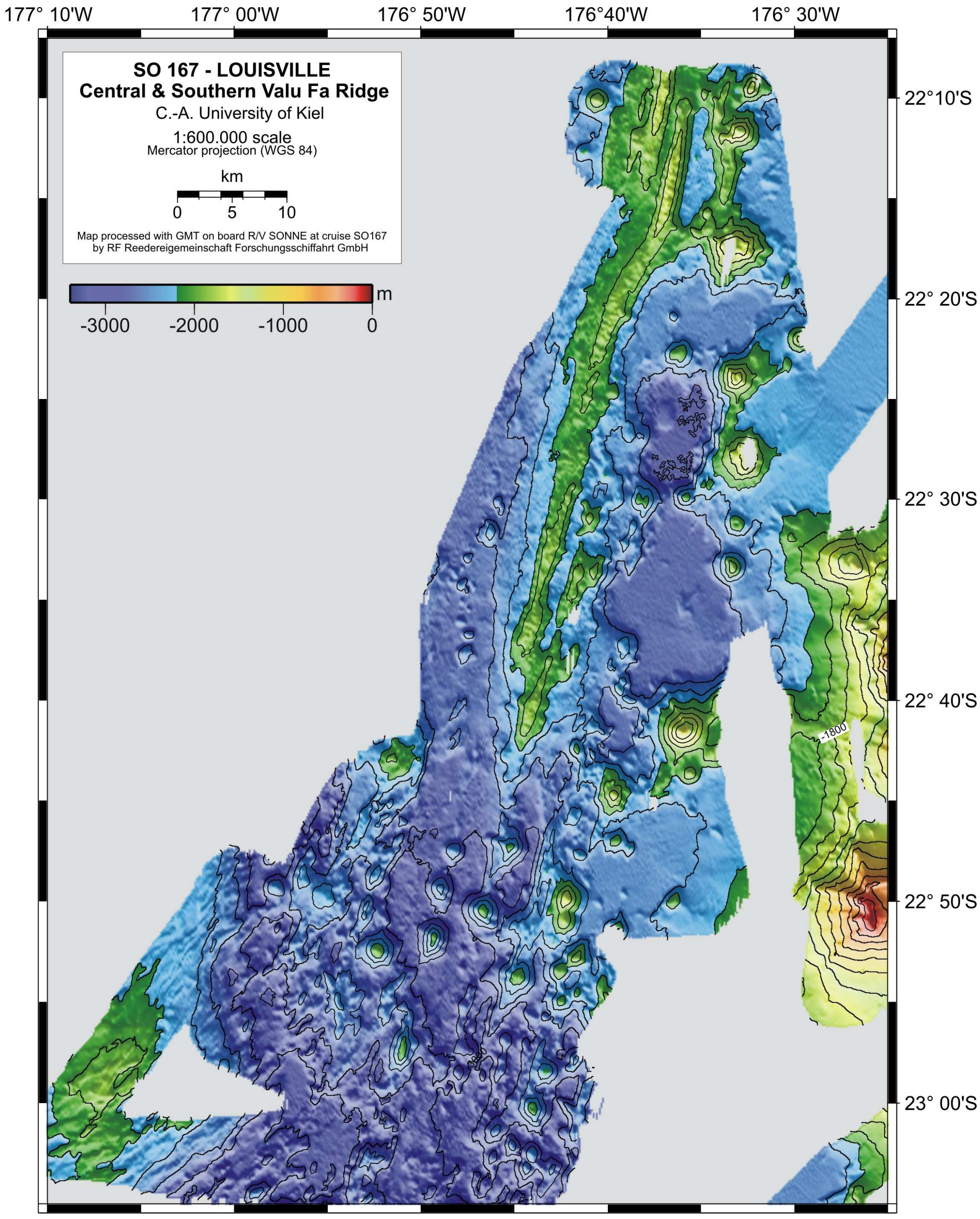

Fig. 9.2: Seafloor bathymetry of the central and southern Valu Fa Ridge, as recorded and processed by the multichannel SIMRAD EM 120 system during SO-167. Mapping encompassed the ~110 km-long segment between the NVFR and CVFR overlapping spreading center at ~22°10'S to 22°15'S and the sites of recent tectonic and volcanic activity along the southward propagating fault zone between 22°45'S and 23°05'S.

pattern of the ELSC after clockwise rotation at about 2 Ma. The offset between individual segments is generally of the order of 0.4–2.3 km and affects only the neovolcanic zone at the crest of the ridge, except for overlapping spreading segments (e.g., NVFR/CVFR;

Wiedicke and Collier, 1993). The base and the surroundings of the VFR are likely to be unaffected by these offsets.

The morphology of the VFR region shows a general structural continuity. It consists of several 3rd and possibly 4th order discontinuities along its entire length with the pronounced NVFR/CVFR overlapping spreading center to the north and an offset spreading segment to the southeast (southern tip segment, 22°40'S). The eleven short (few km) dome-shaped segments show low relief and are elongated along the strike of the ridge. Backscatter imagery (Fig. 9.3) shows light reflectivity with faint lineations associated with these segments. These short lineations follow the N020°E orientation of the VFR and might represent fissures and/or fault scarps. A few small volcanic cones (e.g., at 22°32'S and 22°38'S) are recognized along the margin of the VFR and may represent either recent off-axis construction or are vestiges of arc volcanoes obliterated by recent volcanism.

There are major differences between the southern (i.e., SVFR) and the northern (i.e., CVFR) region of the explored VFR area. The most striking one is the absence of recently formed spreading segments south of latitude 22°43'S. Instead, we conclude that this southern region is at a more tectonic stage of spreading and consists essentially of the remnants of ancient volcanic structures inheritated from arc volcanism. Also, numerous linear and deep seated (>2500 m water depth) small horst and graben structures occur.

Some of the volcanic features encountered have a hummocky appearance, and they may represent slumped and collapsed ancient constructional edifices. Deep troughs (about 3000 m depth) bounded by normal faults are observed on both sides of the VFR as well as in the region south of latitude 22°43'S. Volcanic cones, probably representing the remnants of ancient arc volcanoes, occur on both sides of the VFR suggesting that recent spreading has altered the ancient seafloor in this area.

The vicinity of the VFR, here referred to as old island arc crust, is characterized by a succession of major ridges (mainly to the (south)west), large single seamounts to the south, and seamounts and deep troughs to the east. To the east, the transition to an arc volcano-dominated area of the nearby island arc is obvious. The most pronounced marginal deeps occur approximately 3 km to the east and parallel 2/3rd of the CVFR and almost the entire SVFR. These two deeps represent 18 by 40 km and 19 by 38 km wide and 2400 to 3000 m deep troughs, respectively, which shallow slightly towards the Tonga island arc. The orientation of the troughs follows the overall N20°E trend of the VFR and even displays a northward left-stepping alignment. They clearly represent features of crustal subsidence between regions of distinct crustal elevation. The orientation and horst and graben pattern suggest a structural (i.e., basin-and-range tectonics due to crustal extension) and/or magmatic control (i.e., extensive magma chamber versus crustal mass deficit) which also seems to be typical of the nearby active magmatic regions of the VFR to the west and the island arc to the east. Backscatter data indicate thick sediment coverage and only single volcanic edifices (i.e., seamounts) in these deep troughs. To the north, the deeps are

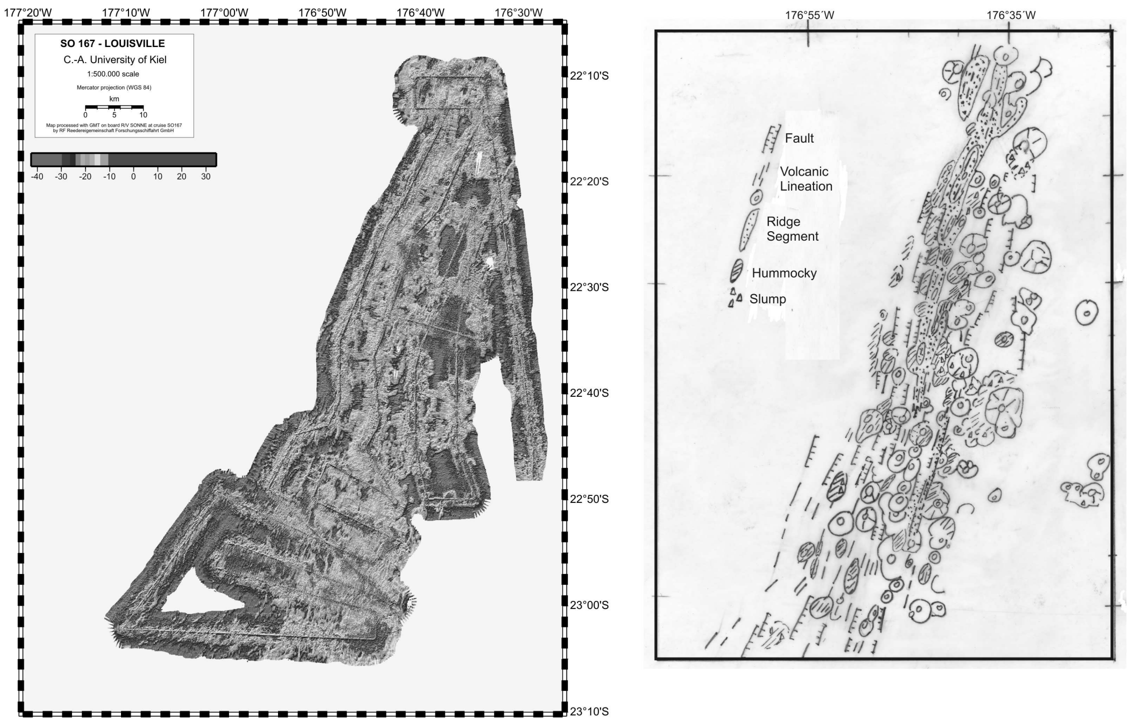

Fig. 9.3: Backscatter imagery (without noise reduction) and morphological interpretation of the central and southern Valu Fa Ridge. The data were obtained from the multichannel SIMRAD EM 120 system during SO-167 LOUISVILLE. Interpretation and sketch based on the reflectivity of the seafloor as a function of the backscattered signal. Light grey (low reflectivity) represents mainly sediments (>50%; mainly volcaniclastic) and a few volcanic outcrops (lobate flows) almost completely buried by volcanic sediment. Mid–light grey (intermediate reflectivity) consists of older lava flows partly buried by sediment (20–40%) or volcanic ejecta and hyaloclastites mixed with sediment and rock debris, whereas the darker grey represents older flows with interstitial sediment (15–20%). Black (high reflectivity) indicates fresh lava flows as well as prominent fissures and fault scarps.

followed by a failed rift segment which parallels the NVFR/CVFR overlapping spreading center.

The overall strike direction of most of the bathymetric features surrounding the VFR largely follows the N20°E orientation of the VFR (NNE–SSW). An 030° angle described for the region to the west of VFR by Wiedicke and Collier (1993) could not be verified by our bathymetric data. However, there is a distinct angle of about 15° to the east that can be identified in the older ridges to the southwest, and in some of the seamounts to the east. Considering that this deviation is confined to the older island arc crust, we conclude that this direction is related to the general regional orientation before the clockwise rotation of the ELSC at 2 Ma and, therefore, is missing in the younger volcanic ridges and edifices.

During SO-167, the northern ridge segment of the CVFR (around 22°13'S; segment no. 9) hosting the Vai Lili hydrothermal vent field, the southward propagating segment no. 7 (around 22°25'S), the segments no. 5 (22°32'S) hosting the Hine Hina hydrothermal field and no. 3 (22°40'S) on the SVFR, as well as the inferred propagating rift in the southward extension of the Valu Fa Ridge (22°51'S) were studied and sampled in detail.

9.3.1. Valu Fa Ridge Profiles

Five profiles across the VFR were constructed to examine the large-scale morphology of the ridge along its length from the northernmost ridge segment of the CVFR (i.e., north of the Vai Lili field) to the southernmost tip of the known ridge, and further south to the location of a fault zone which might represent the possible propagator (Fig. 9.4). The sections are oriented normal to the ridge axis and presented without vertical exaggeration. Section A is located just north of the Vai Lili site, Section B is located at the Vai Lili field, Section C includes the Hine Hina site, Section D the southernmost segment of the Valu Fa Ridge, and Section E is through a narrow graben-like fault zone propagating into older island arc crust and located south of the known ridge. The main features include:

1) From north to south there is a systematic eastward shift in the propagation of the ridge axis.
2) The Vai Lili and Hine Hina hydrothermal fields occur at overlapping ridge segments.
3) The Vai Lili and Hine Hina hydrothermal fields are located on the topographically highest ridge segment.
4) The Valu Fa Ridge can be subdivided into two morphologically distinct components. A broad, basal part which is reminiscent of a low relief plateau- or shield-like edifice with gentle slopes that merge with the surrounding ocean floor. A steeper, more aerially restricted upper part which includes the ridge axis or axes, in the case of overlapping ridge segments. This upward and lateral change in ridge morphology may reflect a change in the viscosity and rate and volume of magma eruption, from initial more voluminous eruptions of basalt which constructed the broad shield-like base to the eruption of more viscous basaltic andesite, andesite and locally dacite flows which constructed the steeper upper parts of the ridge that now define the ridge axis. This inferred change in magma composition may reflect the emplacement of a high level magma chamber which is interpreted to underlie the entire length of the ridge, and where the more “evolved magmas” may be a product of fractional crystallization and assimilation (i.e., FCA) processes within the chamber.
5) The fault discovered during 77-OFOS, located south of the southernmost segment of the Valu Fa Ridge as illustrated in Section E, may in part represent the southern propagator of the VFR as it is: (a) parallel the strike of the VFR, (b) located south and east of the southernmost segment, which is consistent with the eastward shift in the ridge axis during southward propagation, (3) occupied by younger, non-sedimented talus deposits and lobate flows as compared to the highly sedimented character of the ocean floor adjacent to the fault, and (4) located on a portion of the ocean floor that is higher and gently inclined to the west (due to doming?), as compared to the relatively flat ocean floor east and west of the fault.
6) The older arc volcanoes are clearly differentiated from the VFR by their steeper slopes and symmetry. Their morphology is typical of central vent composite volcanoes (as compared to fissure-fed, basalt-dominated volcanoes that comprise spreading ridges).

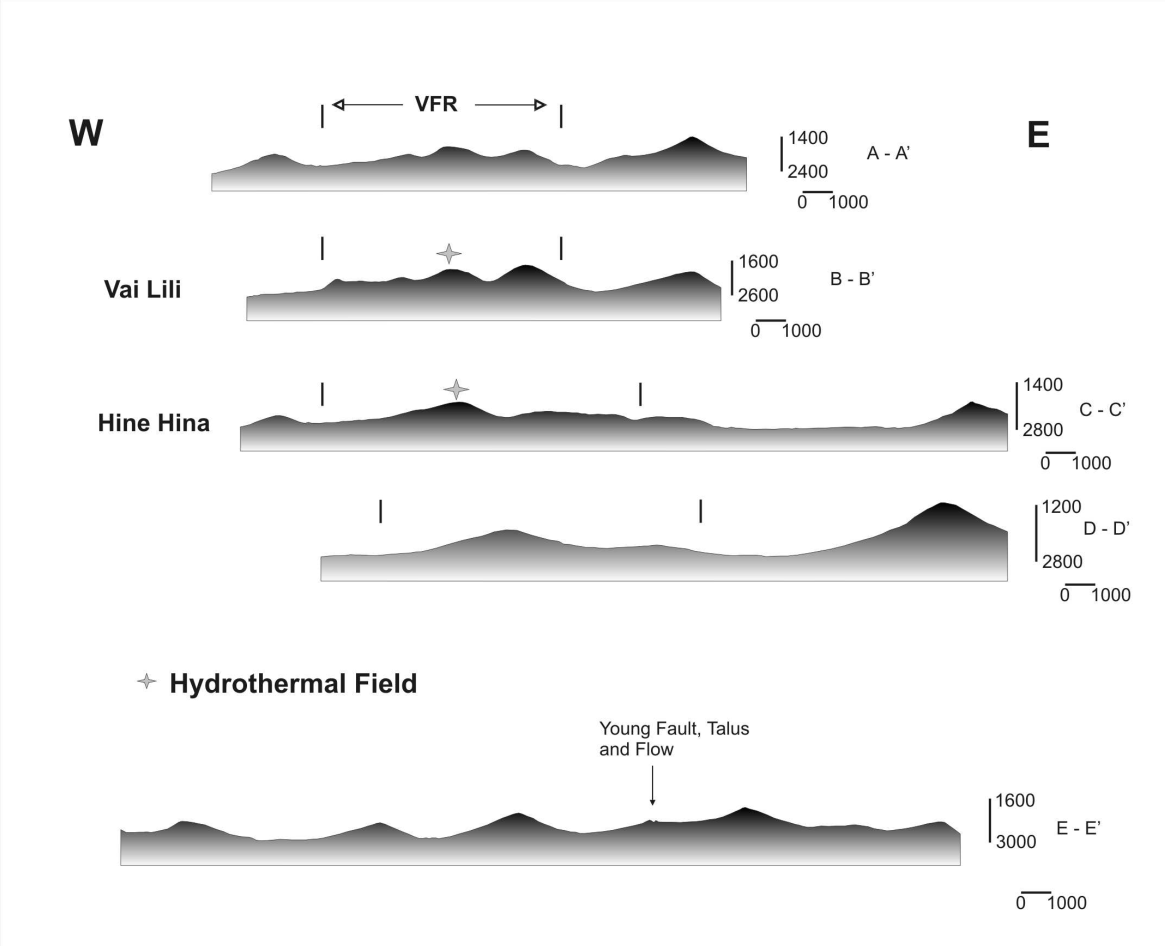

Fig. 9.4: Valu Fa Ridge profiles and large-scale morphology from the northern tip of the CVFR to the southernmost tip of the SVFR and further south to the propagator fault zone. The sections are oriented normal to the ridge axis and without vertical exaggeration. Note the systematic eastward shift in the propagation of the ridge axis from north to south. Section A is located just north of the Vai Lili site, Section B is located at the Vai Lili field, Section C includes the Hine Hina site, Section D the southernmost segment of the Valu Fa Ridge, and Section E is through a narrow graben-like fault zone propagating into older island arc crust south of the VFR.

9.3.2. The Vai Lili Segment (No. 9)

At about 22°12'S, the CVFR (segment no. 9) and the NVFR (segment no. 10) overlap by 10 km, with an offset of 2.3 km (Wiedicke and Collier, 1993). A narrow, 500 to 700 m-wide and 450 m-deep basin separates the ridge segments. Both ridge tips are particularly narrow and steep, locally exceeding a slope of 30°, with a triangular cross-sectional shape that is typical of ridge axes near discontinuities (Macdonald et al., 1988). In the area of the overlapping spreading center, the segments have the highest elevations of the VFR. Subparallel to both the overlapping segments, and within 1–9 km lateral distance, several 5 to 18 km long curved inactive and sedimented ridge segments have been mapped (Wiedicke and Collier, 1993; this study). At its southern end, the inactive ridge east of segment no. 9 is geographically linked to the active ridge, suggesting a temporary northward bifurcation and failed-rift origin. Five evolutionary stages of this overlapping spreading center, including two northward and two southward propagations of the overlap zone, were interpreted by Wiedicke and Collier (1993). Based on this model, the inactive ridges represent temporal reversals in propagation direction with migration rates between 5 and 20 km during the last 220,000 years. A slightly higher spreading rate in this area (Taylor et al., 1996) might decrease the time for propagation and reversals. The bifurcation into several ridge segments and reversals in propagation directions are most likely related to the emplacement of the (high-level?) axial magma chamber beneath the CVFR, associated doming, and subsequent magmatism. The recent situation describes a southward propagation of the NVFR rift tip by 5.2 km at velocities of about 13 cm/year (Brunhes Chron of 6.5 cm/year at 21°S) over the past 40,000 years.

This ridge segment displays several well-constrained volcanic edifices, up to 60 m high, along the crestal area. Ridge axis discontinuities include a small flexural offset (400 m east offset) that is not located at the bathymetric maximum, but at a water depth of approximately 1690 m. This offset occurs at slightly greater water depths and is strongly structurally controlled with ridge-parallel, east- and west-stepping normal faults indicating a tectonic horst structure. The offset coincides with the location of the Vai Lili hydrothermal vent field, where venting is strongly controlled by west-facing normal faults. Continuing southward propagation of the ridge, contemporaneous seafloor spreading, and doming in the overlapping spreading center suggest pull-apart structures associated with regional extension that enable enhanced heat and fluid flow. Around 22°17'S, this segment is characterized by another slight deviation from axial linearity which, however, is not associated with a significant offset. Wiedicke and Kudrass (1990) documented a microrelief of 0.5 to 3 m caused by closely spaced fissures, small faults, and small-scale grabens indicating active tectonic extension. This fabric was reported to be particularly well developed in the northern section, at the Vai Lili hydrothermal vent site (Fouquet et al., 1993). Our observations revealed that the microrelief was dominated by autoclastic ('aa-type') flow breccias that have also influenced the topography of parts of the Vai Lili site (see below).

The entire segment is at a magmatic stage (cf., Fouquet et al., 1993). When compared to the descriptions of the volcanology at the vent site provided by Fouquet et al. (1993), more recent volcanism may have had a significant impact on this ridge segment. Mineralization at Vai Lili occurs along the northestern flank of a horst-like structure forming a larger, structurally controlled volcanic edifice. The edifice is mantled by a widespread, 'aa-type', aphyric and aphanitic, basaltic–andesitic(?) flow that has been mapped over a large, 850 m x 400 m area. The flow appears to be recent, and shows very minor sediment cover and few sessile gorgonians (refer Section 11.2.2). The 'aa-type' lava is characterized by a rubbly, chaotic appearing, autoclastic flow breccia containing slab-like, vesicular to scoriaceous, clinker blocks that range from decimeters to more than 3 m in size. Where exposed at the surface, and not covered or mantled by volcanic sediment, the autoclastic breccia is densely packed and attains thicknesses of up to 4 m. It generally lacks a finer matrix component. Limited observations along fault scarps suggest that the interior of apparently massive sections of the 'aa-type' flows may be lobate. The 'aa-type' flow is often covered by a thin dusting of grey, pelagic sediment that only locally accumulates enough thickness to completely inundate and smooth the irregular, underlying clinker flow breccia. This type of 'aa flow' at the Vai Lili site was not described in the literature before and appears to be unique to the Vai Lili area. In general, it is not a flow-type commonly recognized at mid-ocean or back-arc spreading ridges (R. Hekinian, pers. comm. 2002). Sampling of this unit by dredging and TV-guided grab revealed no alteration attributable to hydrothermal water/rock interaction or a massive sulfide-forming system.

Pillow (tubular) lava, that includes lobate flows, is preferentially restricted to the 250 x 150 m, north–south elongated fault-bounded block of an interpreted horst-like structure. This structure is located along the northern slope of a volcanic edifice (bathymetric high) constructed along the ridge axis. The pillow lava is completely surrounded by 'aa-type' lava, but appears to be younger based on the following observations: (1) pillow lava overlying aa-type lava, and (2) minimal or absent pelagic sediment cover on pillow lava (locally black volcanic sand and possibly hydrothermal plume fall-out represented by black, sooty looking material dusting pillowed flows). The restriction of the pillow lava to fault bounded blocks suggests it was erupted within and largely confined to a morphological graben within the 'aa-type' flows, and provides evidence for fissure-fed emplacement. This vent proximal volcanic environment is also where the hydrothermal activity is concentrated (high heat flow, cross-stratal structural permeability).

Deposits of volcaniclastic sand occur along the slope of this ridge segment as well as in the interstices of both the 'aa-type' and 'pahoehoe-type' lavas. Based on a preliminary examination of a small sample of the coarser size fraction of the sand (311 lapilli-sized clasts that range in size from 0.4 to 1.9 cm, having an estimated median grain size of about 1.1 cm and obtained from 45-GTVA), the sand was found to consist of three clast populations: (A) Population 1 consists of grey rounded clasts that comprise 23 % of the sample, (B) Population 2 consists of dark grey and rusty brown angular clasts that comprise 51 % of the sample, and (C) Population 3 consists of black angular clasts that comprise 27 % of the sample.

The grey to white, rounded clasts of Population 1 are divisible into four types: (i) approximately 2 % are fragments of barite–pyrite veins, (ii) 2 % are fragments of finer breccia characterized by white, clay altered and pyritic, angular clasts 1–4 mm in size in a darker grey, more resistant (siliceous) matrix, (iii) 1 % are subangular clasts of semi-massive, fine-grained, pyrite (trace sphalerite) and crystalline barite (massive sulfide), and (iv) the majority (95 %) of the clasts are subrounded to rounded in form and consist of white to light grey, vesicular to scoriaceous, clay altered basalt containing finely disseminated pyrite and trace sphalerite. The composition of the clasts comprising Population 1 are consistent with their derivation from altered, mineralized basalts and stringer sulfides from the footwall to massive sulfide. The clasts may have been derived through tectonic processes, such as faulting and mass wasting of a sulfide deposit, and/or mild phreatic or hydrothermal explosions. The generally rounded form of the clasts contrasts markedly with the angular clast morphology of Populations 2 and 3 and indicate that the former have undergone more re-working, and are therefore interpreted as an older component.

Clasts of Populations 2 and 3 differ only slightly in their color and, until geochemical data is available, are treated as a single population that constitutes 78 % of the coarse “sand” sample. This large population contains clasts of aphanitic, aphyric and vesicular basalt that are separated into two types based on differences in their morphology. The first clast type, which constitutes 20 % of the population, is characterized by a plate-like, lesser equant morphology where the clasts have distinctive, sculptured, flow lined, smooth ribbed surfaces that are occasionally folded into fluidal forms that are typically broken by smooth or concave surfaces. Vesicles within these clasts are typically elongate parallel to the long axis of the clast and are somewhat flattened parallel to the clast surfaces. Vesicle content ranges from 2 % to 10 %. The second clast type, which constitutes 80 % of the population, is characterized by a blocky, equant morphology where fragment surfaces are irregular and meet in knife-like points. The clasts range from scoriaceous (30–40 % vesicles) to containing only 10 % vesicles; the vesicles are round. The clast morphology of Populations 2 and 3 is consistent with an origin through passive quench fragmentation.

Although chimneys were not observed during the OFOS traverses, the hydrothermal activity appears to be restricted to the fault block containing pillowed and lobate flows as evidenced by the occurrence of sulfide and altered rock debris, hydrothermal alteration, hydrothermal Fe-Mn oxyhydroxide crust, bacterial mats, biological remains and thermal anomalies in the bottom water. A single bottom water thermal anomaly was recorded in the 'aa-type' flow immediately north of the pillow lava. Assuming the pillow lava is younger than the 'aa-type' flow, the occurrence of white, hydrothermally altered basalt xenoliths in unaltered 'aa' lava indicates that the 'aa-type' flow was erupted after or during an earlier mineralization event, raising the possibility for stratigraphically stacked mineralization as observed in many ancient systems (e.g., Noranda camp, Ontario, Canada).

The hydrothermal activity was studied during the 72-OFOS track, which passed over the former sites of vigorously active, high-temperature hydrothermal discharge several times (Fig. 9.5). The active chimneys identified during the NAUTILAU cruise (Fouquet et al., 1989; 1991) were not observed during SO-167. As both our OFOS and GTV positionings were well-constrained during the tracks, we suggest that the present day hydrothermal activity at the Vai Lili field is probably represented by rather diffuse hydrothermal venting.

9.3.3. Valu Fa Ridge, Segment No. 7

This ridge segment represents the southernmost segment and the rift tip of the central Valu Fa Ridge (Wiedicke and Collier, 1993). Those authors reported an offset of about 0.6–1.0 km, with an overlap of about 6 km between SVFR and CVFR respectively. This is

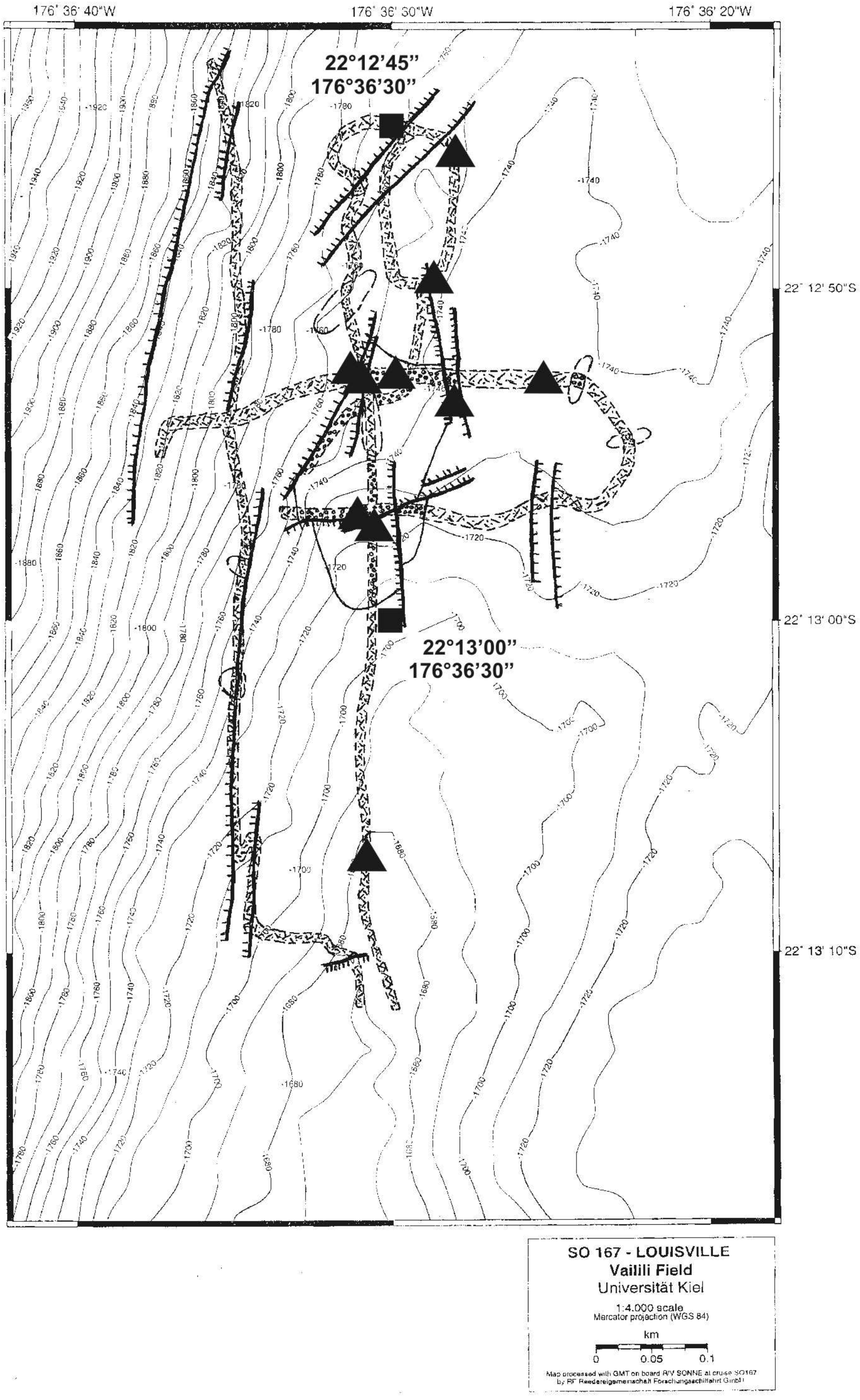

Fig. 9.5: Bathymetry of the Vai Lili hydrothermal vent field. The locations of the chimneys vigorously active in 1989 are given by black squares, with recent diffuse activity shown by black triangles. Activity is closely related to a fault block of unaltered pillowed and lobate flows.

consistent with the results from SO-167. The segment discontinuity is largely characterized by a chain of small volcanic edifices which extend for about 6 km down the eastern flank. These are in alignment with segment no. 6 to the south. Segments no. 7 and no. 6 are underlain by a distinct magma chamber reflector of variable width and offset relative to the ridge axis (Collier and Sinha, 1990; 1992ab). The complexity of this offset, which is generally westward but slightly to the east underneath the segment overlap, and the overlapping structure between segments no. 7 and no. 6, is most likely to be a result of heterogeneous melt emplacement and other previous magmatic events that were, perhaps, triggered by strike-slip or pull-apart structures. Divergence from the actual crest towards the north was interpreted to result from southward progression of this segment, which resembles the situation at the NVFR/CVFR overlapping center. The subparallel trend and the small distance (2–3 km) between the two lines of volcanic edifices, as well as the lack of off-ridge structures, have led to the interpretation of rapid and fairly recent southward extension of this segment (Wiedicke and Collier, 1993). Southward propagation might have been associated with magmatic as well as hydrothermal activity. Indeed, a major temperature anomaly was reported close to the ridge axis at the southern tip (at approximately 22°26.0'S and 176°42.5'W) in water depths between 1800 and 2000 m, based on XBT profiles (Peirce et al., 1996). The temperature anomaly (between about 5 to 15°C) appeared in the bottom 200 m of the water column, although the magnitude of the anomaly seems to be implausibly large even for a major hydrothermal plume.

Based on our SIMRAD mapping, the southern part of the ridge segment is characterized by a strong structural control of the crestal area. The alignment of four volcanic edifices along the crest is very poor and suffers from intense structural displacement to both the eastern and western sides. The crest displays a typical curved outline with prominent, small-scale ridge axis discontinuities up to 250 m in diameter marked by the volcanic edifices that are about 120–200 m high and occur at water depths of between 2000 m and 1940 m. The whole ridge segment has an asymmetric shape, with steeper slopes on the eastern side to water depths of about 2200 m and shallow slopes towards the west (≤ 2100 m). The southernmost volcanic edifice is well constrained in terms of an almost isolated morphological high. This high, however, is characterized by a structured morphology having a larger (~150 x 90 m) top to the west and a smaller (~80 x 80 m) one to the east. The morphology is likely a product of faulting rather than volcanic activity. Strong structural control is also indicated further north, where the other volcanic edifices are slightly offset to the actual crest line and display separation into two bathymetric highs at water depths of about 2000 m to 1940 m.

The OFOS track (56-OFOS; Fig. 9.6) verified that this ridge segment is in a distinctive tectonic stage that lacks any evidence of recent volcanic activity. The top of the ridge is dominated by lobate and minor pillow lava that are partially covered by grey pelagic sediment. In contrast to segments nos. 9 and 5, deposits of black volcaniclastic sand were not observed indicating a different style of volcanism and volcanic activity. Numerous open and partially infilled fractures and fissures were identified in meter-thick basaltic sheet flows. These fissures are large, extending several tens of meters parallel to the inferred ridge axis and form meter-wide and up to several meters-deep open fractures. The open fissures are associated with numerous crosscutting and partially infilled fissures

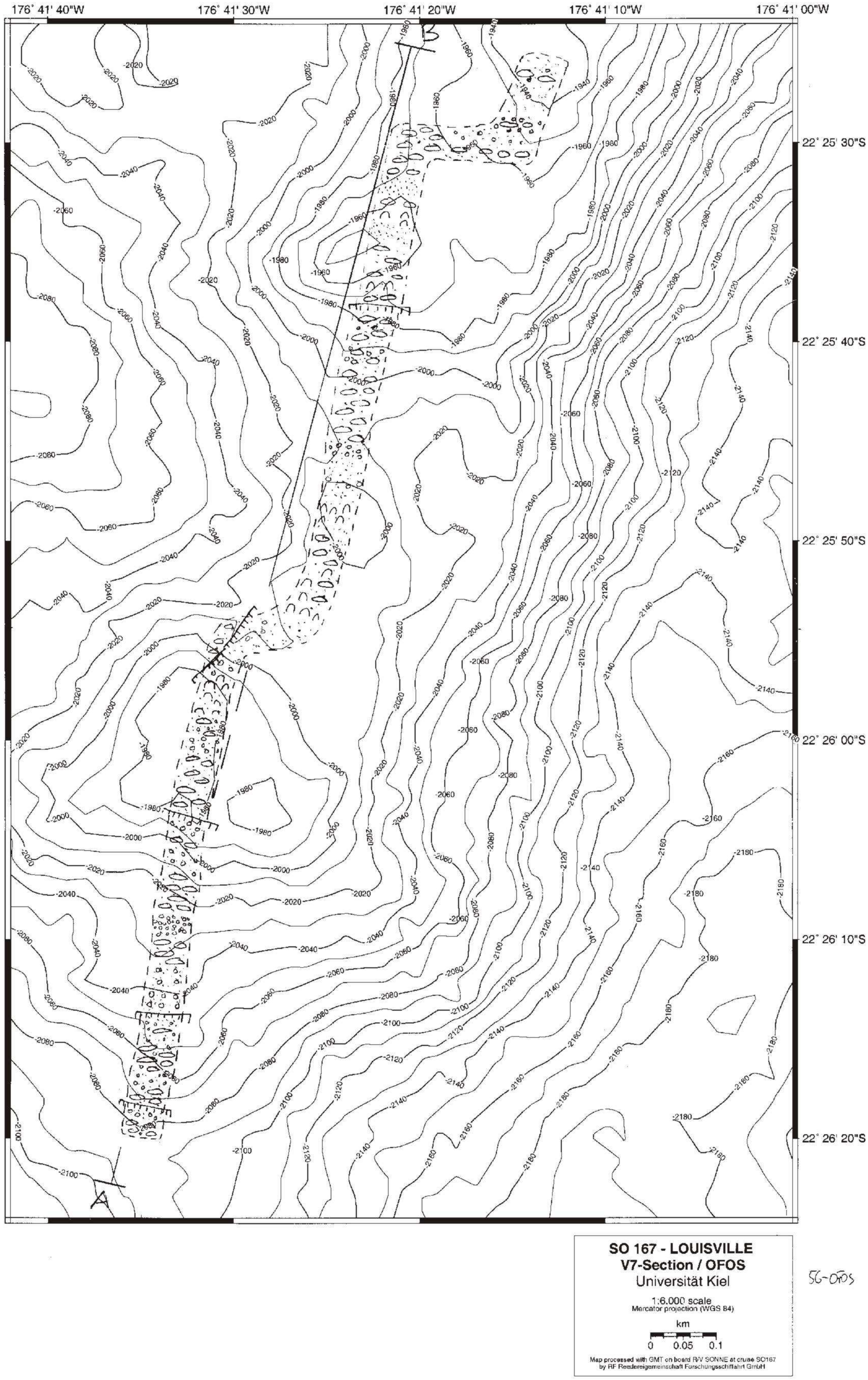

Fig. 9.6: Bathymetry and dredge tracks along the southernmost part of segment no. 7, CVFR.

occurring at a prominent angle of approximately 45° to the ridge axis. The occurrence of numerous fissures and no evidence of recent (i.e., non-sedimented) volcanic rocks or volcaniclastic sediments suggests that this ridge segment has been volcanically inactive for a distinct period of time. However, this segment is still tectonically active as a result of continued extension and associated spreading. During the OFOS track, there was no evidence for hydrothermal activity (i.e., hydrothermal crust or vent fauna associated with hydrothermal activity) nor thermal anomalies in the overlying water column due to diffuse low-temperature discharge. The reported temperature anomaly in the southern part of the segment could not be verified. Single outcrops displayed reddish to yellowish staining which was interpreted as being related to weathering due to cold seawater alteration.

Sampling was carried out during three dredges (53 – 55-DR) on bathymetric highs of single volcanic edifices in water depths between 2120 m and 1900 m.

9.3.4. The Hine Hina Segment (No. 5)

The Hine Hina hydrothermal field is hosted by segment no. 5 (Wiedicke and Collier, 1993), an intermediate segment of the approximately 20 km-long SVFR. The segment displays four major bathymetric highs. The shallowest water depths (up to 1800 m) occur at the two southernmost edifices. This area was surveyed in detail during the NAUTILAU cruise (Fouquet et al., 1989; 1991; 1993), when submersible dives revealed large areas with a smooth surface at the ridge crest. Based on our SIMRAD mapping, this ridge segment is characterized by a well-defined crestal area. The immediate crest shows a remarkable sigmoidal outline along the whole segment, similar to vertically curved axes or vertical listric faults of variable orientation. Structural and/or volcanic control of this orientation is suggested.

The Hine Hina hydrothermal vent is associated with a volcanic edifice (>100 m high, water depth of 1850 m), which is approximately 450 m off-axis to the west of the ridge axis. This edifice, however, is structurally controlled and probably does not represent a single, off-axis volcano. It has a similar geological (i.e., structural) position to the Vai Lili hydrothermal site, which is most likely related to structural control and possibly magma chamber geometry. In contrast to the significant changes at the Vai Lili site, the morphology, tectonic fabric, and volcanological features at this ridge have not changed significantly since the last survey in 1989. This ridge segment has obviously remained at a relatively stable and largely inactive tectonic and magmatic stage when compared to those further to the north. Vast areas of the ridge are covered by volcaniclastic sediments. Only a few fault scarps were observed in the crestal area, and the coverage of small-scale tectonic features by sediments is suggested. Continued tectonic extension can be deduced from the presence of small, ridge-parallel cracks, both open and sealed, and the occurrence of sealed and open cracks within hydrothermal crusts observed during our OFOS tracks (58- and 59-OFOS; Fig. 9.7).

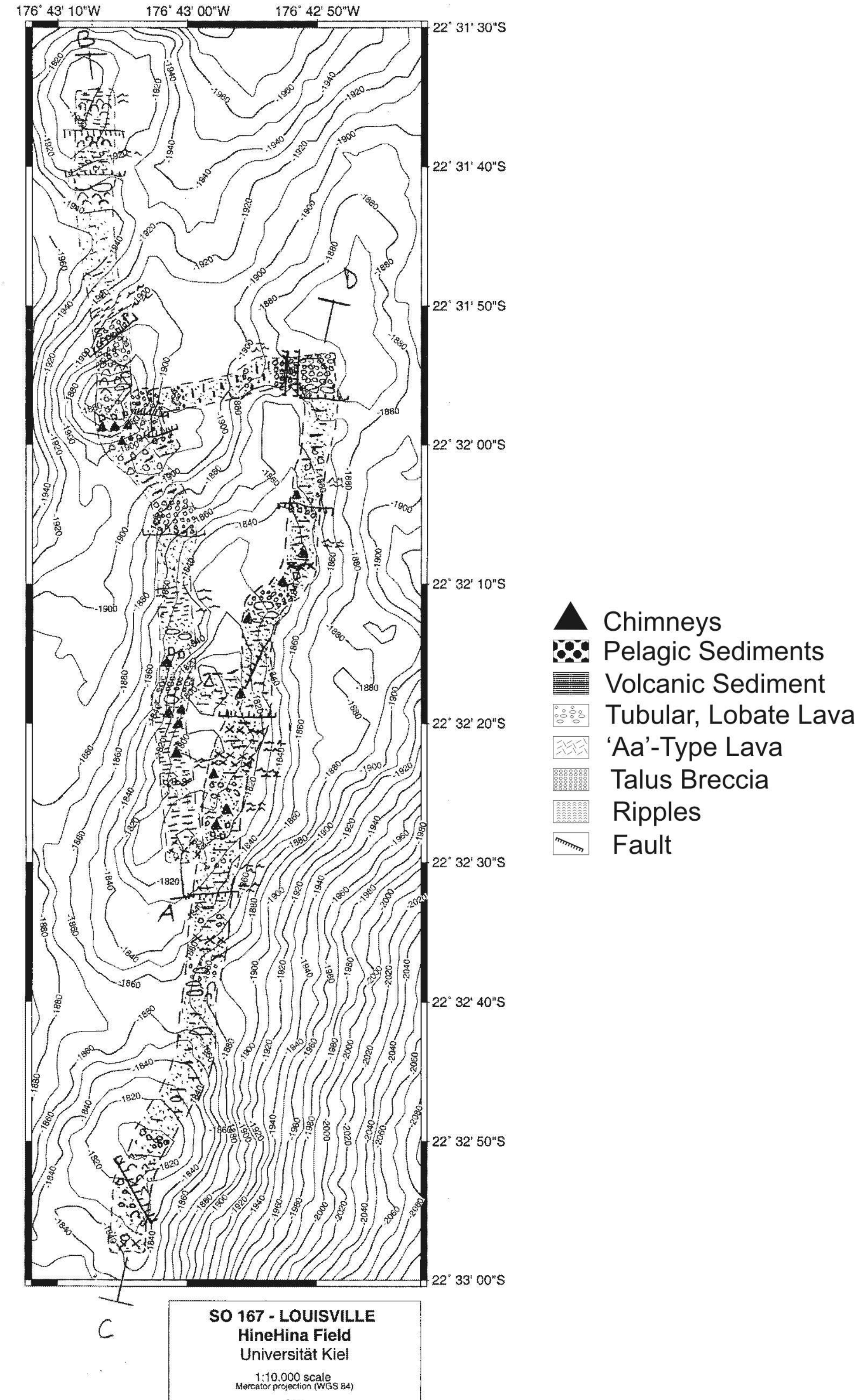

Fig. 9.7: Bathymetry of the Hine Hina hydrothermal vent field, SVFR. Diffuse low-temperature hydrothermal dis charge, first identified in 1989, was re-located. The style of hydrothermal activity has remained stable despite the present wider extent of the Hine Hina field. Activity is closely related to thick deposits of black volcaniclastic sand.

Fouquet et al. (1993) suggested a prominent volcanic stage at the Hine Hina site with sub-recent volcanic activity, whose products are composed of autobrecciated volcanic rocks and volcaniclastic sediments. Outcrops of massive lava beneath the black volcaniclastic sand and breccias on the flank of the ridge suggest an estimated thickness of 50 m for the volcaniclastics. Fouquet et al. (1993) interpreted that the hydrothermal system was divided into two parts; a focused discharge along faults in massive lava, and diffuse discharge through the volcaniclastic pile in the upper part. Indeed, it was found that the extensive low-temperature hydrothermal discharge at the Hine Hina site is a product of a volcanic environment which is markedly different from that of the Vai Lili segment.

Deposits of black volcaniclastic sand are extensive and occur along the length of the mapped ridge segment (for more than 1000 m). The sand ranges from decimeter to meter-thick veneers deposited on a hydrothermal Fe-Mn oxyhydroxide crust, to probably meters-thick deposits along the flanks of the volcanic edifice. Mapping, GTV sampling (60-, 65-, 66-, 68-, 69-GTVA), and exposures along fault scarps indicate that the black–grey volcanic sand also underlies the hydrothermal Fe-Mn oxyhydroxide crust where it may attain thicknesses of several meters, at least enough to subdue the irregular topography of underlying tube-fed 'pahoehoe-type' flows that, based on previous work, comprise the bulk of the volcanic edifice. Significant to the interpretation of the volcanic sand deposits is the local occurrence of fluidal, sculptured volcanic bombs that range up to 35 cm in size. The bombs are characterized by a thick, locally bread-crust textured glassy outer rind or margin and a scoriaceous interior where vesicles are oriented symmetrically about the bomb margin and increase in size toward the interior. The bombs have all the characteristics of subaerial bombs, except for their thick glass margins, and are therefore interpreted to have been ballistically emplaced during mild fire-fountain eruptions. This interpretation is consistent within the significant volume of black volcanic sand that blankets the ridge segment within the map area.

The volcanic 'sand' consists of mm- (sand-sized) to cm-sized (pebble-sized) volcanic clasts and lacks a fine silt- or clay-sized matrix component. The clast morphology is consistent with an origin through passive quench fragmentation, however the large volume of the volcanic sand along this ridge segment is not. The composition, equant to plate-like morphology of the sand grains, occurrence of bombs and the volume of sand are best explained by mildly explosive magmatic and hydrovolcanic eruptions during submarine fire-fountaining. Indeed the fluidal morphology of some clasts is consistent with jetted magma whose form was moulded within an eruption column. The relatively flat upper surface of the ridge segment is therefore attributed to thick deposits of volcanic tephra that blanketed the volcanic edifices and accumulated along the flanks of the volcanoes, in part through sedimentary re-working and re-distribution by currents. The extended distribution (several hundreds of meters to km scales) suggests that the volcanic sand deposits originated from several volcanic vents located along the various edifices that comprise the ridge. The common occurrence of well developed ripples within the volcanic sand is indicative of vigorous bottom currents that are responsible for the re-working and re-sedimentation. The thin (<5–7cm thick) but extensive Fe-Mn oxyhydroxide crust that covers much of the upper part of the edifice may be a product of unfocussed, diffuse low temperature hydrothermal discharge that was, in part, facilitated by the permeability of the porous volcanic sand upon which it developed.

In summary, passive fissure eruptions constructed 'pillow volcanic edifices' along the Hine Hina ridge segment axis. The final stage of this construction was mild fire-fountain eruptions that blanketed the volcanic edifices with deposits of volcanic sand and bombs that were subsequently re-deposited and concentrated by vigorous bottom currents to areas along their tops and flanks. Hydrothermal activity spanned the waning period of basaltic fissure eruptions and continued after fire-fountain eruptions as evidenced by altered and mineralized clasts in the volcanic sand, the occurrence of sulfide chimneys on lobate flows and within and buried by the black sand, and by the development of a Fe-Mn oxyhydroxide crust on the black sand surface. Evidence of present day hydrothermal activity includes a thermal anomaly in the immediately overlying water column, shimmering water and white–yellow biological mats.

9.3.5. The Southernmost Valu Fa Ridge Segment (No. 3)

This segment is south of the ridge which hosts the widespread Hine Hina vent field and represents the southernmost segment of the VFR. The ridge segment extends from 22°38'S to approximately 22°43'S. Thereafter, water depths increase such that at 22°46'S the interpreted rift tip occurs at a water depth of more than 2600 m (e.g., Wiedicke and Collier, 1993; Parson and Hawkins, 1996). The morphology of this ridge segment is very similar to that of segment no. 5, as it is characterized by a well-defined crestal area with steep flanks. The immediate crest shows a very well constrained axis with a relatively broad (300 m to 750 m) central 'plateau'. The crest is defined by five bathymetric highs in water depths between 1880 m and 1770 m. The highest elevation (>300 m) above the surrounding seafloor is associated with the central, cone-shaped volcanic edifice. The axis displays a curved outline suggesting structural and/or volcanic control. The morphology, tectonic fabric, and volcanological features at this ridge segment are very similar to those of segment no. 5, indicating that large sections of the SVFR show similar (and contemporaneous?) styles of volcanic activity whereas evidence for younger structural overprinting due to southward propagation and spreading processes are almost absent. There is clear evidence for a significant difference in ridge propagation and associated tectonic and magmatic processes when compared to the CVFR. It seems obvious that this is most likely related to differences in spreading/rifting rates and the emplacement of a magma chamber beneath the ridge segments.

The situation of this segment is quite similar to the overlapping spreading center between the NVFR and CVFR to the north. A segmented ridge parallels the entire SVFR (segments nos. 4–6) approximately 3 km to the east. In its northern portions, this ridge is interpreted to be inactive due to thick sediment cover (Wiedicke and Collier, 1993). In the south, however, this ridge forms the southernmost active VFR segment and ends in the present ridge tip. The ridge configuration resembles an overlapping spreading center with an offset of approximately 2 km. Both segments overlap for 20 km. Due to the typical *en echelon* offset of the southern part, this segment is interpreted to represent the propagator and is likely the volcanically more active edifice. This portion of the segment overlaps by about 3 km with the western ridge from which it is separated by a wide and shallow (<200 m) basin. The northern ridge shows evidence of an evolved shallow axial graben and ends in a broad, poorly constrained, and deepening tip. In contrast, the southernmost segment forms a particularly narrow and steep axial crest area with steep slope angles consistent with the regional pattern of propagating tips along the VFR. The 20 km-overlap may have resulted from a southward propagation of the spreading axis slightly westward of its previous location (Wiedicke and Collier, 1993). The evolution of two parallel ridges at the SVFR is likely related to temporal, but rapid, changes of the rift propagator and associated magmatic processes. However, it is important to note that despite the temporal changes in propagation orientations and directions, all VFR segments largely follow the regional pattern of east-stepping, *en echelon* orientated ridges and edifices and southwards propagating rift tips (e.g., Figs. 9.2 and 9.4).

Based on SIMRAD mapping, the actual tip of the Valu Fa rift can be constrained at approximately 22°45.6'S. Two seamounts south of this ridge segment (22°47'S and 22°51'S; no. 2 and 1; Wiedicke and Collier, 1993) have the same orientation as the ridge and are found to represent old rifted island arc crust instead of young seamounts associated with southward propagation. The rift tip south of 22°42'S is characterized by slightly westward bifurcation into at least three small and shallow (<100 m) ridge systems whose geometry follows the overall VFR structural pattern in that they show *en echelon* orientation, with the easternmost ridge representing the southernmost propagating ridge. This ridge system may extend south to the older arc seamount at 22°47'S. The deepening of the southern ridge tip occurs over about 7.5 km, from 2100 m water depth at 22°42'S to water depths of more than 2600 m at the southernmost tip area (22°46'S). Based on SIMRAD bathymetry and backscattered data, we conclude that at about 22°44'S the rift propagator, now represented by a V-shaped fault zone, has shifted some 3–4 km to the east. This fault zone is known to extend for at least an additional 40 km to the southern end of the survey area.

A single 3.7 km-long OFOS traverse (73-OFOS) was designed to map the central ridge axis of the southern VFR segment (Fig. 9.8). This ridge segment is similar to segment no. 5 that hosts the Hine Hina hydrothermal field, as both segments share similar features such as; (1) a ridge axis whose volcanic edifices, defined by bathymetric highs, are covered by black volcanic sand identical to that at Hine Hina though possibly not as thick (also interpreted as a product of pyroclastic fire-fountain eruptions), (2) the underlying lavas,

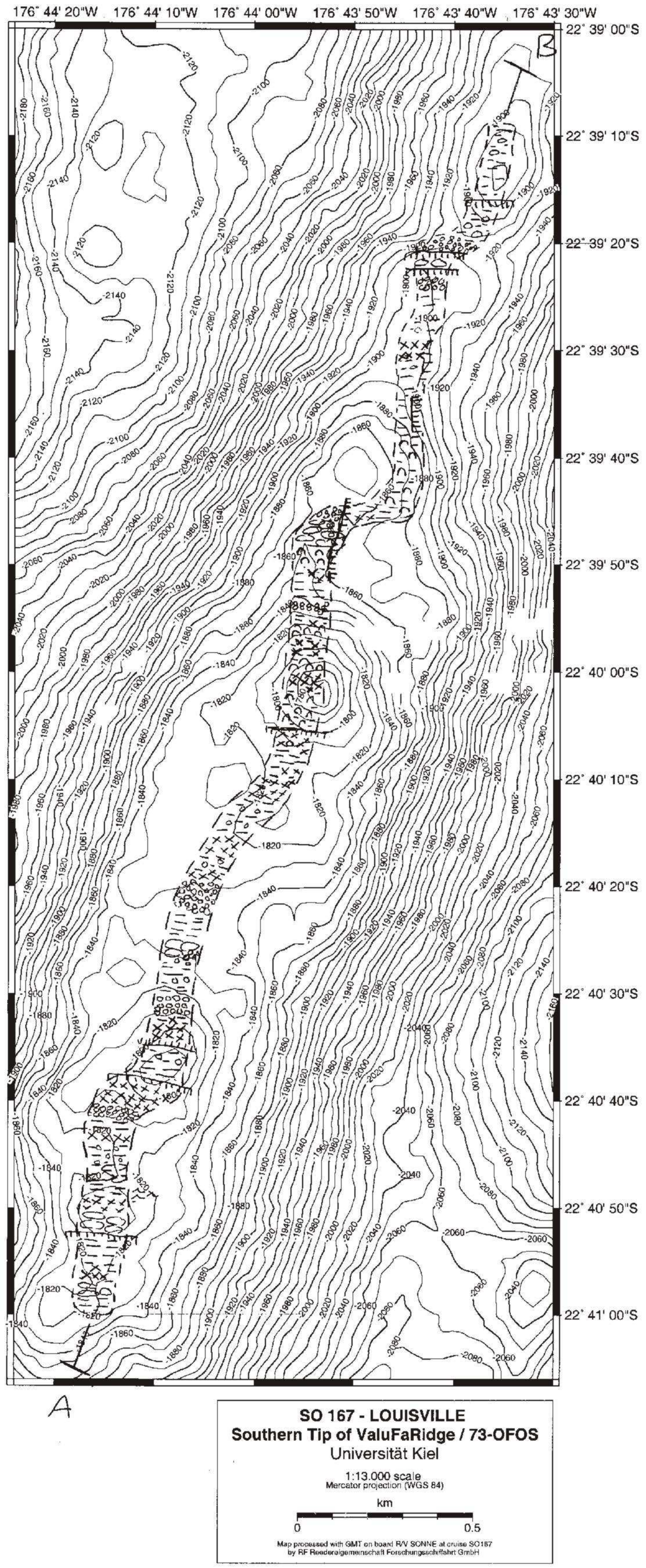

Fig. 9.8: Bathymetry and mapping at the southern tip of the VFR (segment no. 3; 73-OFOS).

although observed infrequently along fault scarps, consist of lobate and tubular lava, and (3) the development of an extensive Fe-Mn oxyhydroxide crust that overlies, and is covered by, deposits of black and grey volcanic sand. The result is a smooth, relatively flat seafloor. The hydrothermal crust is several cm-thick and is interpreted to be a product of unfocussed, diffuse, low-temperature hydrothermal discharge that was facilitated by the permeability and porosity of the volcanic sand upon which it formed. Its frequent brecciation is probably related to minor tectonic activity and/or gravity currents. The lack of any temperature anomaly during the OFOS track suggests that the ridge segment is hydrothermally inactive.

Sampling was carried out during one dredge (74-DR) at a bathymetric high in a water depth between 2013 m and 1775 m. Another attempt (75-DR) did not recover rock samples.

9.3.6. The Southern Rift Fault Zone (22°51'S)

A segment of old island arc crust along the SE extension of the southern VFR tip was surveyed (22°51.40'S, 176°44.40'W) following a preliminary structural interpretation of the bathymetric map. Structures in this area indicate distinct faults that parallel the regional strike of the VFR (N20°E) and its eastward offset. Bathymetric highs of inferred sedimented island arc crust SE of the southernmost VFR segment are bounded by one of the largest fault zones, followed to the west by a single large seamount interpreted by Wiedicke and Collier (1993) to represent the southward extension of the VFR.

The large-scale westward-facing fault-zone represents the eastern limit of a neovolcanic zone and attests to recent tectonic activity. This fault follows the pattern of *en echelon* east stepping ridge segments typical of the VFR, and may represent one of the controlling structures for recent volcanic eruptions at these southward extension sites. At its northern extremity, towards the VFR, the trace of the fault appears to bifurcate at 22°46.5'S, again very similar to the situation at the overlapping spreading centers to the north (Vai Lili segment and southern ridge segment). However, according to the backscattered bathymetry data, it has been buried by recent debris flows and sediments from the nearby VFR, the eastern island arc crust, and pelagic sediments. To the south, this fault zone follows the regional N20°E orientation but shows evidence for subsequent bifurcation that outlines and curves around island arc volcanoes and older volcanic ridges. Along the fault system, single large volcanic ridges and arc volcanoes are characterized by crestal areas that resemble graben-like structures (e.g., at 22°52'S, 22°54'S, 22°58'S) which are likely related to extensional processes. It is suggested that this fault system was recently active.

The objectives of this part of the study were to define and map structures that may represent the southern VFR rift propagator, and to locate any sites of recent rift-related volcanism and/or hydrothermal activity related to these structures. To meet these objectives, an east–west oriented, 1 km-long, OFOS traverse (77-OFOS) was designed to map the ocean floor across the strike of the southern fault-rift zone (Fig. 9.9). Significant results of this traverse and GTV sampling include:

1) Most of the ocean floor in this area is probably represented by older ocean floor or arc volcanics, as it is covered by a relatively thick (centimeters to decimeters) blanket of light grey colored, homogeneous, sediment. The occurrence of star and brittle star fish on this sediment, which feed on organics, indicates that it is pelagic sediment (refer Section 11.2.6). Localized outcrops and ridges of lobate flows and talus are interpreted to define faults within the relatively smooth, flat sediment-covered ocean floor.
2) A prominent, roughly north–south oriented, less than 100 m wide and almost 50 m deep structurally controlled rift graben, encountered at the beginning of the traverse, may represent the volcanically and tectonically active southern propagator as it has: (a) steep near vertical walls with blocky talus at the base, light sediment cover or dusting on some of the talus, and other talus deposits that are presumably young as they have no sediment cover and host no sessile fauna, (b) the floor of the graben is covered by young lobate and tubular flows that have no sediment cover or only a light sediment dusting and lack any sessile fauna, (c) the graben extends subparallel to the strike of the VFR, (d) the graben is located south and east of the southernmost segment, which is consistent with the eastward shift in the ridge axis during southward propagation, and (e) the graben is located on a portion of the ocean floor that is higher and gently inclined to the west, as compared to the relatively flat ocean floor east and west of the fault. This might be related to magmatic doming and high-level magma emplacement.

These results, and the recovery of recent glassy and unsedimented felsic(?) volcanics on the bottom of the graben (78-DR), suggest that this fault may be part of the actively southward propagating Valu Fa rift system. This fault system may develop into the future extension of the VFR. The similar orientation of these southernmost faults, partly associated with recent submarine volcanism, suggests that they are deeply penetrating structures that may have tapped melts at considerable depth in the crust. This also suggests a fairly active seismic zone that is close to the Tonga island arc (≤ 40 km).

The southward transition zone towards the northern Havre Trough and the southernmost extensions of the ELSC and VFR were interpreted to be formed by regional horst-and-graben structures (Matsumoto et al., 1997; Fujiwara et al., 2001). Small, tens of meters wide, horst structures occur further to the west in the southern fault zone and possibly delineate this southward extension. The distance between the southernmost segment of the VFR (segment no. 3 and southward propagator at 22°45'S) and the neovolcanic zone in the rift graben at about 22°51.4'S is approximately 12 km. Considering a spreading (i.e., rifting) rate of 13 cm/year, the development of the southward propagator and the magmatic front towards this neovolcanic zone continued for at least 90,000 years.

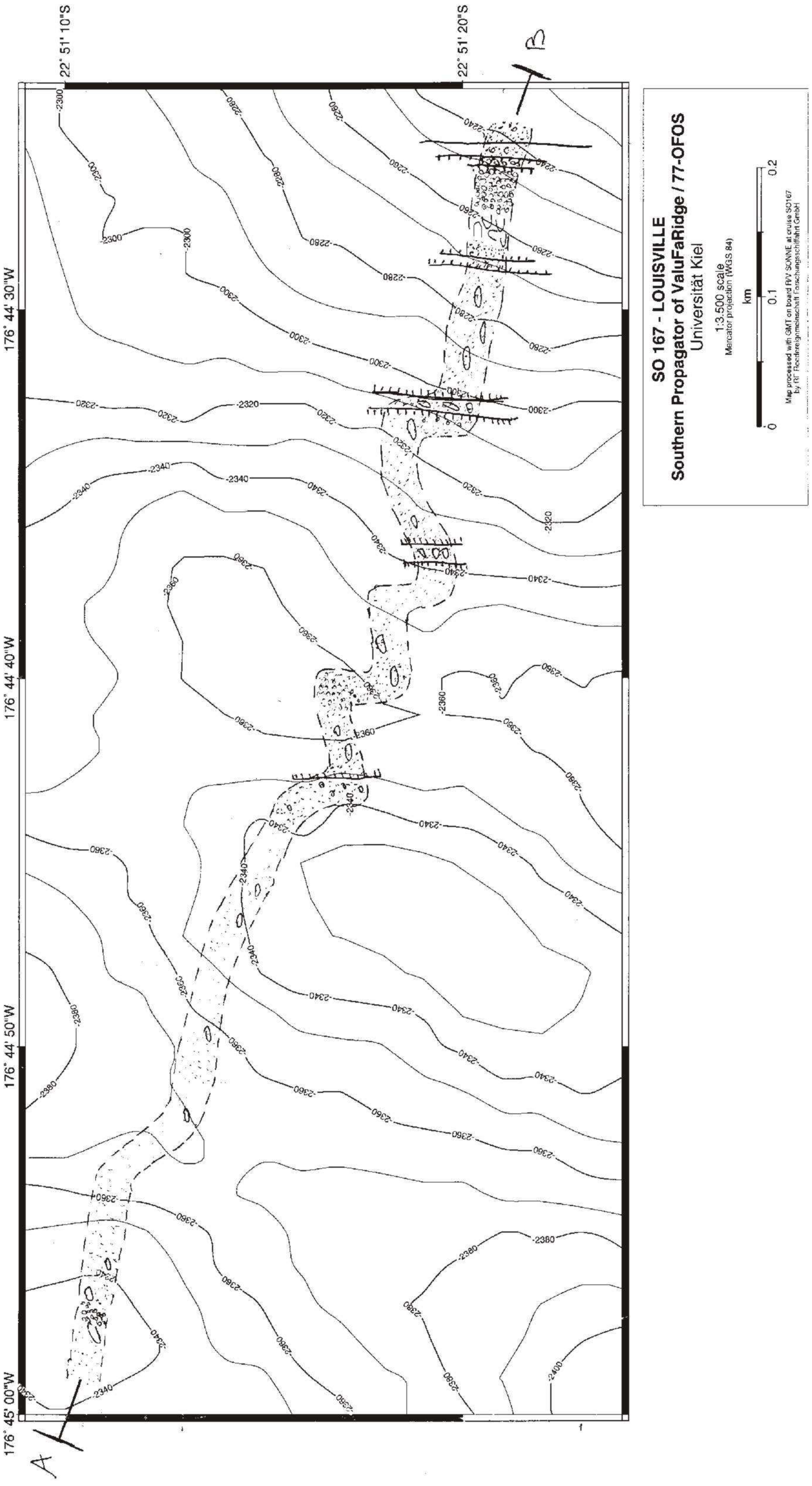

Fig. 9.9: Bathymetry and mapping of the inferred propagator fault zone at the southern tip of the VFR (segment no. 3; 77-OFOS).

Sampling of the seamount at 22°51'S (79-DR) was carried out in order to ascertain its origin as being of island arc affinity. The feldspar-phyric basalt strongly contrasts with the aphyric VFR lavas and indicates its island arc affinity, which is consistent with the interpretation of Mühe (1993) for a similar seamount located at 22°47'S.

9.4. Valu Fa Ridge: Hydrothermal Activity and Sampling

9.4.1. The Vai Lili Hydrothermal Vent Field

The Vai Lili hydrothermal vent field, as surveyed during SO-167, is restricted to a 350 x 200 m structural window comprised of tube-fed lobate flows surrounded by 'aa-type' flows. Fouquet et al. (1989) documented a vigorous, active, high-temperature hydrothermal field and chimneys. However, our well constrained OFOS and GTV positioning tracks (Fig. 9.4) indicate that the former sites of active chimneys are, at least in part, covered by fresh lava. Present hydrothermal activity at Vai Lili is represented by widespread diffuse hydrothermal venting as indicated by temperature anomalies between 0.14 °C and 0.25 °C about 3 m above seafloor (Fig. 9.10). A product of this diffuse low-temperature discharge are the white to yellow precipitates along cracks, small fissures, and the interstices of lobate flows (Fig. 9.11). The white material probably represents abiogenic amorphous silica rather than bacterial mats, whereas the yellow staining locally forms small-scale, cauliflowers-like precipitates most likely representing native sulfur or some mixture between sulfur and silica. A single inactive, oxidized, and about 2 m-high chimney was hit by the GTV, and oxidized sulfide talus at the base of steep fault scarps was observed. However, massive sulfide samples were not retrieved despite several attempts. Dead colonies of *Ifremeria nautilii* (refer Section 11.2.2 below), approximately 5 m long by 5 m wide, occur between large flows of autobrecciated lava. Sampling revealed a substrate of black volcanic sand, hydrothermal Fe- and Mn-crusts and boulders of stockwork-type mineralization, with the latter being similar to that described by Fouquet et al. (1993) at approximately the same position. Unlike the Hine Hina hydrothermal field, passive, fissure controlled eruptions of basalt-andesite flows that constructed the ridge axis edifices at Vai Lili did not end with voluminous fire-fountain eruptions. The absence of a thick blanket of volcanic sand may account for the localized and minimal formation of hydrothermal crusts at Vai Lili, which are interpreted to be a product of diffuse, low temperature hydrothermal discharge facilitated by the permeability of the porous volcanic sand.

Dead colonies of hydrothermal vent fauna, single oxidized chimneys, and the disappearance of vigorously active smokers suggest that the present hydrothermal activity is typical of the waning stage of a hydrothermal vent site that has been modified by recent vent proximal, fissure-fed volcanism. This may have (partially) buried the formerly vigorously active Vai Lili field. There is some uncertainty regarding the number of pillow lava eruptions, as altered pillow lava appears to be locally overlain by unaltered pillow lava. The occurrence of white, hydrothermally altered basalt (andesite) xenoliths in the 'aa-

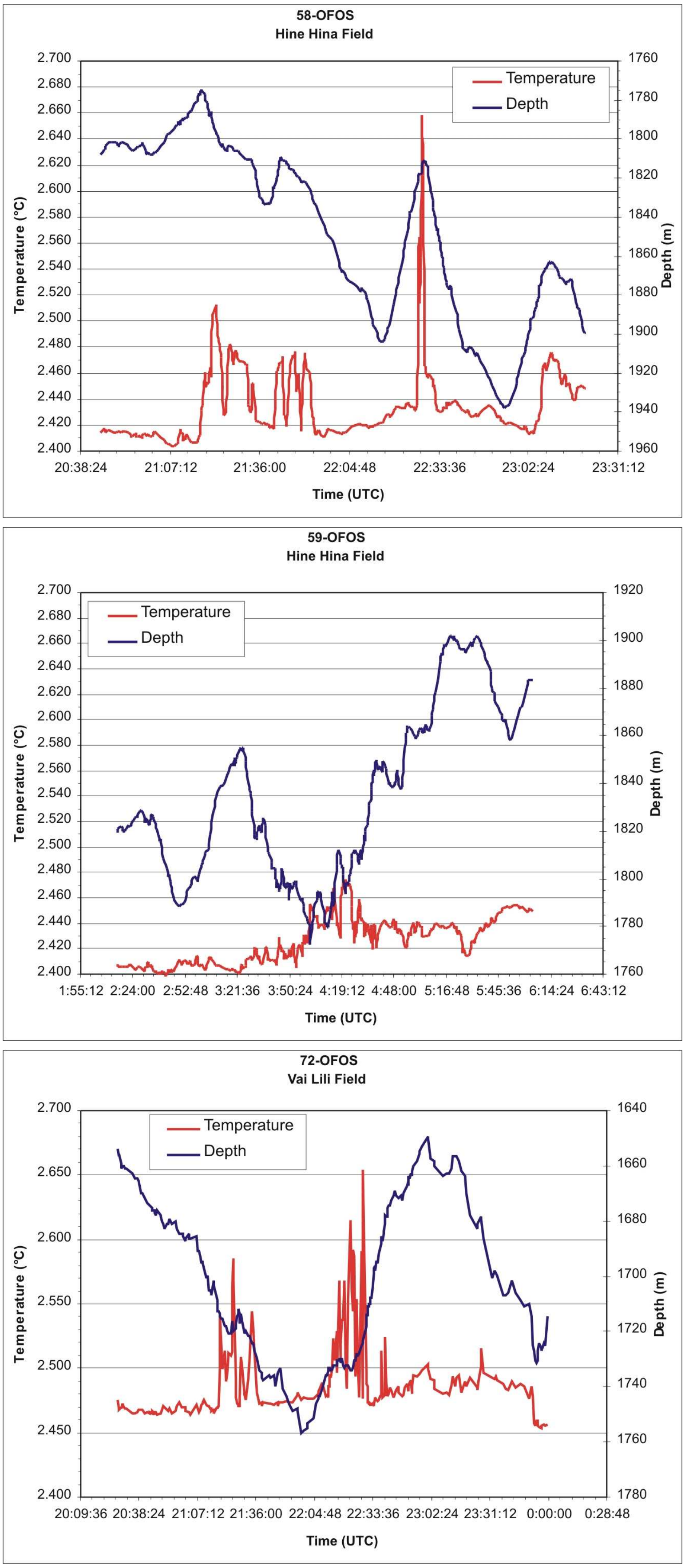

Fig. 9.10: Temperature anomalies related to widespread low-temperature diffuse hydrothermal activity at the Vai Lili and Hine Hina hydrothermal vent fields, Valu Fa Ridge. Anomalies from 0.14°C to 0.25°C (VL) and from 0.05° to 0.22°C (HH), respectively, occur about 3 m above seafloor.

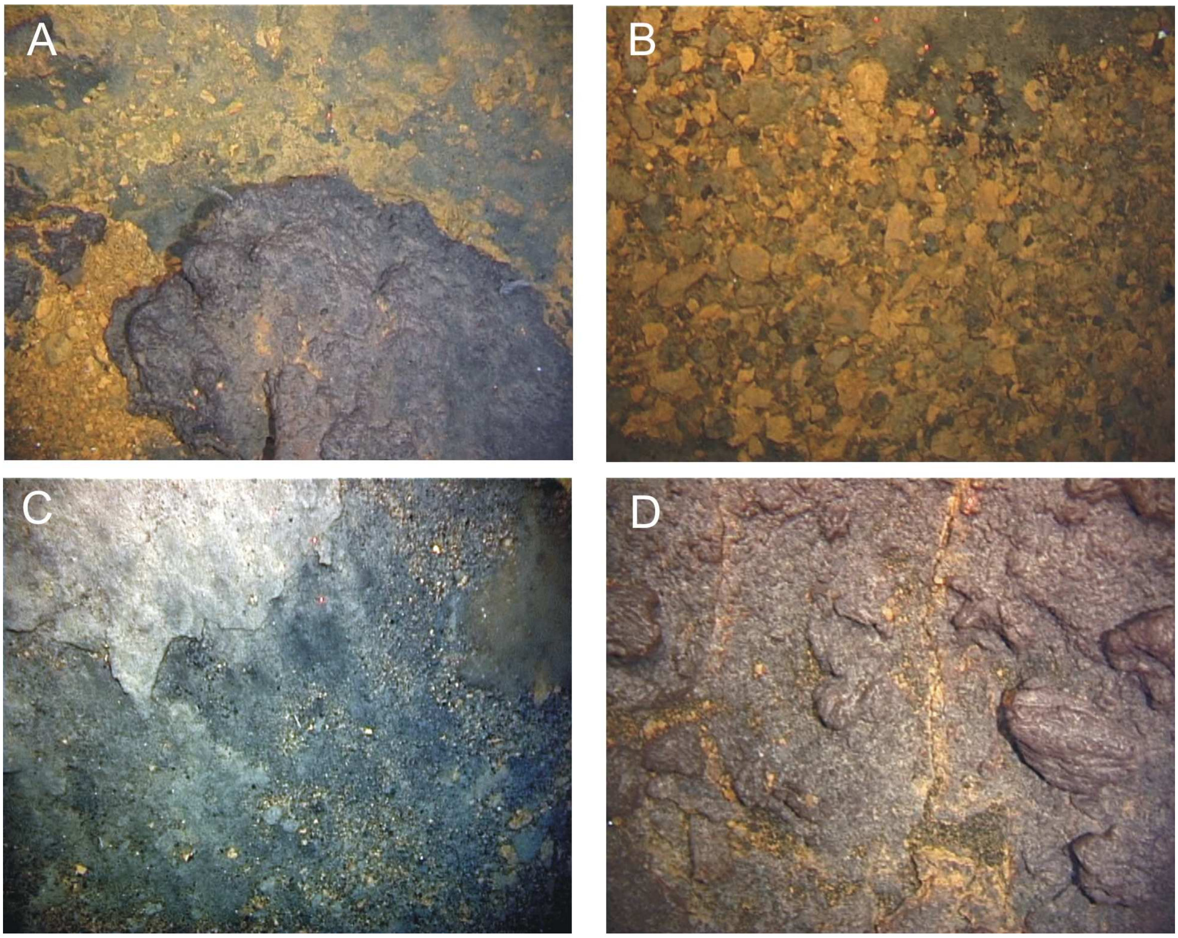

Fig. 9.11: Seafloor photos showing hydrothermal activity, precipitates and volcanic setting of the Vai Lili and Hine Hina hydrothermal vent fields. Plate 1: (A) lobate flow surrounded by hydrothermal crust consisting of Fe-Mn oxides-hydroxides cementing black volcanic sand; (B) plate-like fragments of Fe-Mn crust (as in A); (C) plate-like hydrothermal crust fragments and talus composed of sand; (D) hydrothermal crust with yellow fractures of hydrothermal alteration and precipitates partly burying a lobate flow breccia.

type' lava indicates that this flow was erupted after or during an earlier mineralization event, raising the possibility for stratigraphically stacked mineralization underneath the Vai Lili site.

The Vai Lili hydrothermal field was sampled during four dredge (46-DR, 47-DR, 51-DR, 52-DR) and four TV-guided grab (44-GTVA, 45-GTVA, 48-GTVA, 50-GTVA) stations at water depths between 1783 m and 1650 m. While the dredge program revealed no alteration attributable to hydrothermal water/rock interaction or a massive sulfide-forming system, the TV-grab provided some indications of diffuse low-temperature hydrothermal activity consistent with a waning stage for this vent site. The TV-guided tracks identified large areas of fresh autoclastic ('aa-type') lava and lobate flows, but no evidence for the high-temperature hydrothermal activity and vigorous venting observed in 1989. A single large, inactive and oxidized chimney as well as sulfide talus was observed, but could not be sampled due to the irregular topography and rough flow surface. A total of seven sampling attempts failed because the GTV fell over.

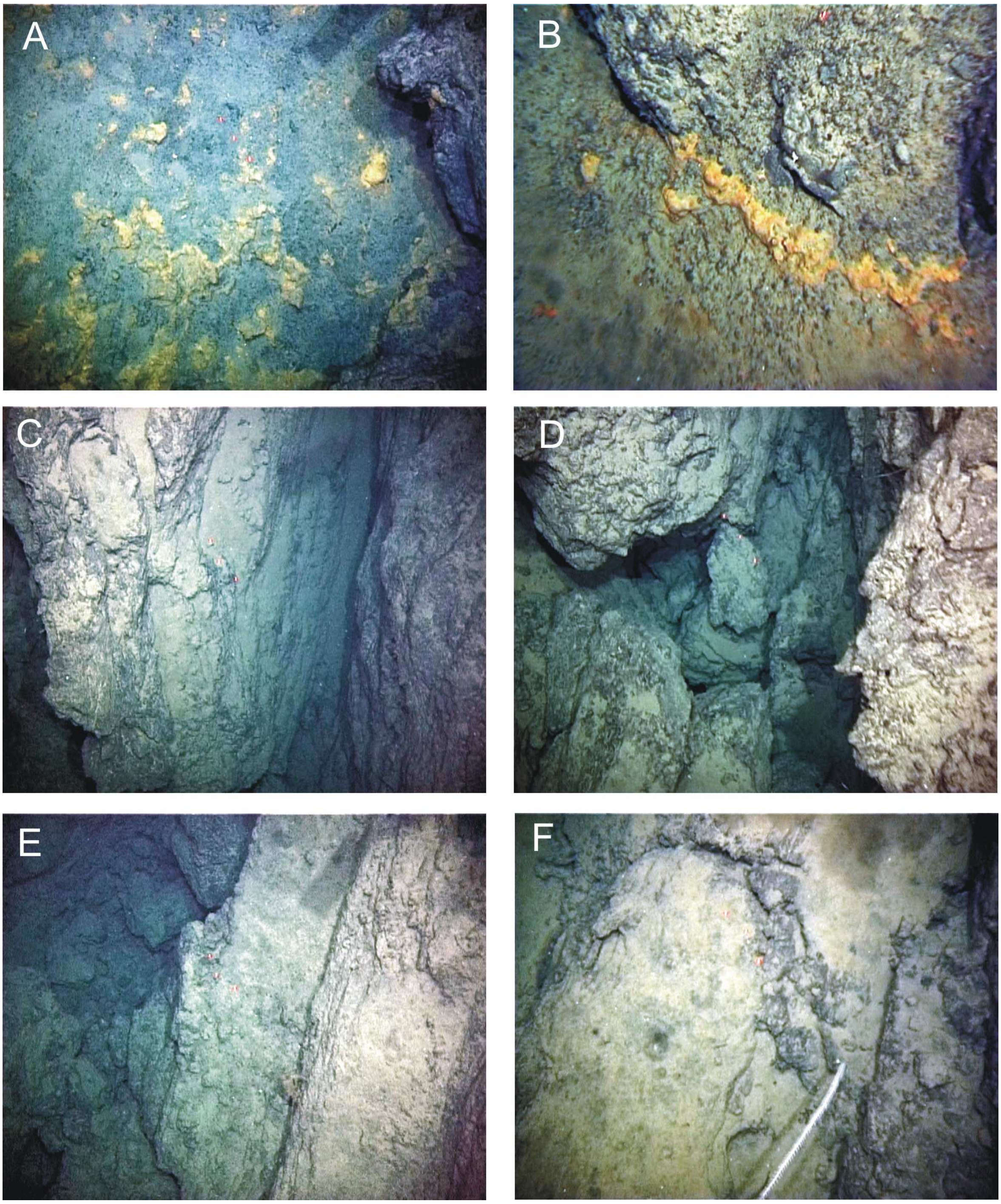

Fig. 9.11: (continued) Plate 2: (A) in situ brecciated and fractured hydrothermal crust with yellow alteration; (B) Fe-oxide-hydroxide hydrothermal vein cross-cutting volcaniclastic debris; (C) fissure in sheet flows; (D) lobate flow blocks partly filling a fissure in sheet flows; (E) step-like structure of a lobate tubular flow; (F) light sediment cover on large tube with small toothpaste-like protrusions.

Samples from the Vai Lili site included a complete suite of fresh, glassy and largely unaltered aphyric volcanic rocks of basaltic to andesitic composition, ranging to bleached and weakly altered varieties and strongly altered rock types. At least two different flow generations could be determined, including a young glassy pillowed flow and an older flow, with the latter mostly represented by boulders of stockwork-type mineralization. The

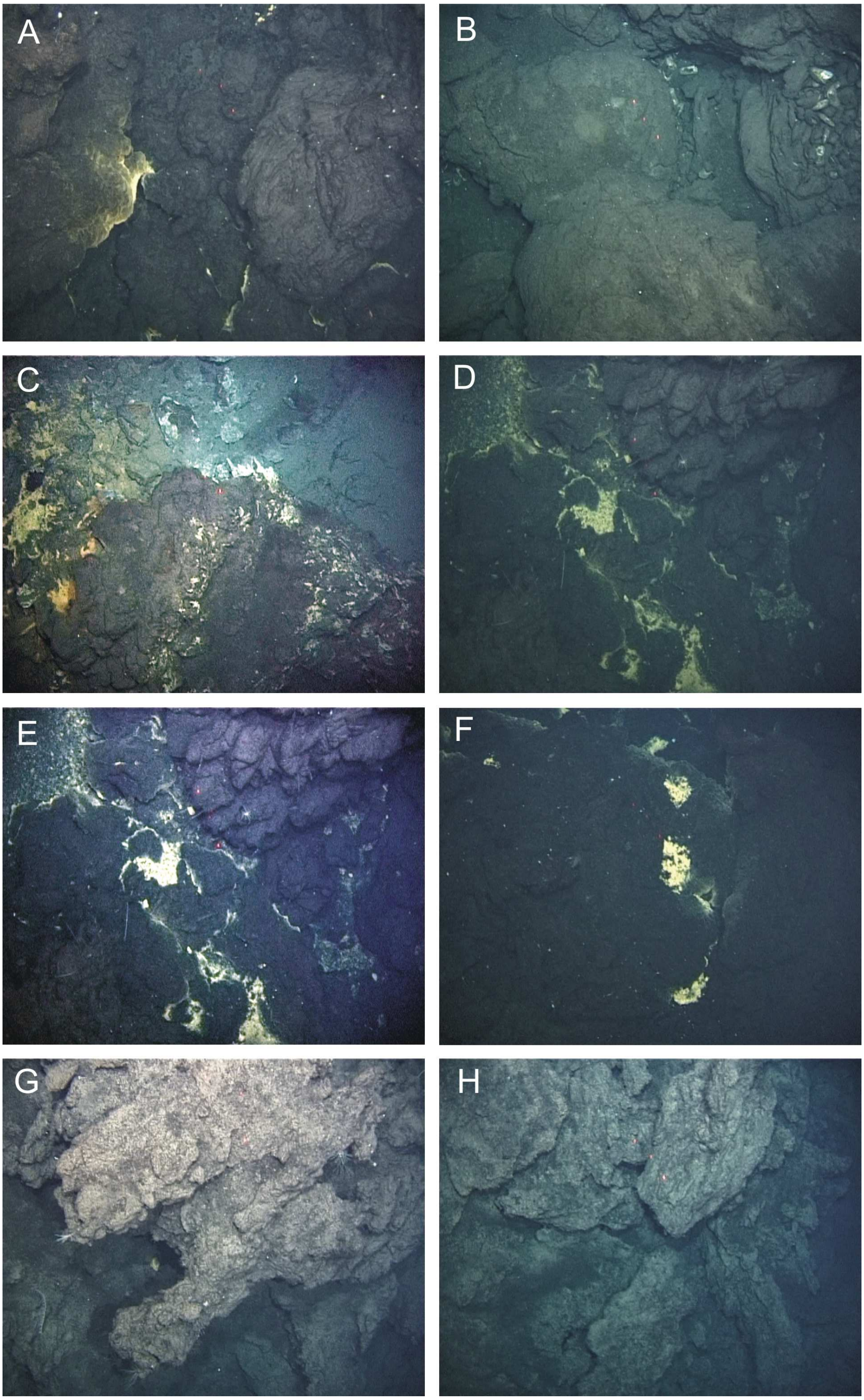

Fig. 9.11: (continued) Plate 3: (A) lobate flow with white hydrothermal staining; (B) lobate tube with a concentration of mussels at right; (C) lobate flow, volcanic sand and mussels; (D) lobate flow protruding through hydrothermal crust with a bacterial mat developed on the crust; (E) lobate scoriaceous flow, black sediment and bacterial mats; (F) white bacterial mats developed along fractures in hydrothermal crust covered by a light dusting of black volcanic sand; (G, H) scoriaceous, clinker-like fragments.

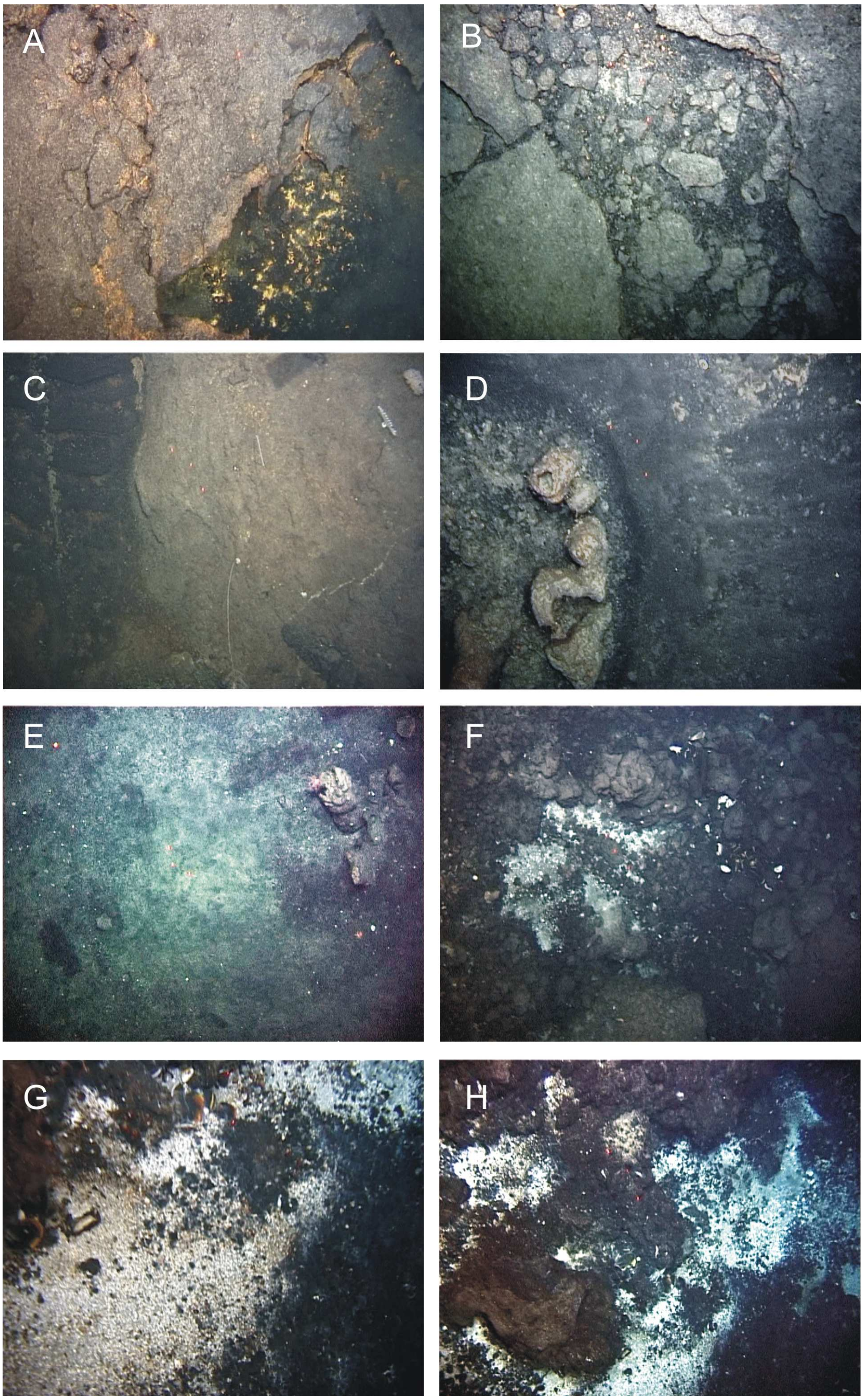

Fig. 9.11: (continued) Plate 4: (A) hydrothermal Fe-Mn oxide-hydroxide hydrothermal crust covering black volcanic sand, note the yellow colored hydrothermal veins in the crust; (B) broken hydrothermal crust showing underlying black volcanic sand, note the plate-like fragments typical of the hydrothermal crust; (C) contact between hydrothermal crust and overlying black sand, note the well-developed current ripples in the sand; (D) hydrothermal mound with extinct sulfide chimneys surrounded by volcanic sand; (E) extinct chimneys partly buried by black volcanic sand; (F, G and H) black volcanic sand and volcanic rubble with white bacterial mats, note the shrimps (red) in (G).

latter occurs as xenoliths in the younger flow and contains minor sulfide mineralization in its vesicles and along cross-cutting fractures, similar to stockwork veining known from ancient massive sulfide deposits on land. Mineralization includes pyrite and minor sphalerite veins, and open space-fillings by pyrite, tennantite, galena, barite, and possibly chalcopyrite. Alteration displays a distinct zonation of pyrite veining to argillic and silica alteration. This is typical of distal, high-temperature hydrothermal activity in the footwall of hydrothermal fields and probably represents remains of the former activity at Vai Lili. According to Fouquet et al. (1993), the outcrop of the stockwork zone at Vai Lili is related to the structural offset associated with the venting. The occurrence of boulders within interstices of lava flows strongly suggests at least partial coverage of Vai Lili by young eruption(s). The recovery of chimney talus at the base of a dead colony of *Ifremeria nautilii* indicates the former site of active high-temperature discharge. The chimney talus includes fragments of several centimeters size including dense intergrowths of barite, silica, pyrite, chalcopyrite, and sphalerite.

9.4.2. Valu Fa Ridge, Segment No. 7

This segment does not show any evidence of hydrothermal activity. No hydrothermal precipitates, crust, alteration or vent fauna associated with hydrothermal activity were seen or recovered during an OFOS track and dredge sampling. Red staining, observed during the OFOS track and sampled from small fractures in the volcanic rocks, probably results from alteration due to seawater–rock interaction. Numerous open fissures offer ideal channel-ways for hydrothermal discharge (or recharge), but thermal anomalies were not detected in the water column. This ridge segment is interpreted as being tectonically active, but volcanically and hydrothermally inactive.

This southernmost segment of the CVFR is characterized by intense structural deformation, including ridge-parallel steep, deep and open fissures, faults and low-angle tension fissures. The segment was sampled during three dredges (53-, 54-, 55-DR) targeted at bathymetric highs that define single volcanic edifices in water depths between 2120 m and 1900 m. Sampling retrieved young glassy aphyric volcanic rocks of andesitic to dacitic composition. There was no evidence for hydrothermal activity or alteration associated with these rocks, and it is concluded that the faults are not associated with low-temperature hydrothermal fluid or volatile (i.e., methane) leakage. The segment may represent a nascent stage of ridge evolution and/or propagation and is volcanically inactive. However, poor sedimentation and the lack of cold seawater alteration and/or weathering suggest a fairly young age of the felsic volcanics.

9.4.3. The Hine Hine Hydrothermal Vent Field

The Hine Hina hydrothermal field is larger than previously outlined by the 1989 Nautile dives. The hydrothermal field extends for approximately 1 km north–south and 350 m east–west along the top and western flank of the ridge segment. The sulfide chimneys are all extinct and they occur in two environments. The most common environment is where the chimneys are partially buried by black to grey colored volcanic sand that accumulated on the Fe-Mn oxyhydroxide crust or on underlying lobate and tubular flows. The second environment is where the chimneys occur directly on the lobate flows that are typically exposed along the top of individual, structurally-controlled edifices which comprise the ridge segment (bathymetric highs). Sulfide talus, hydrothermal sediments, as well as hydrothermal vent fauna and shimmering water were observed along a fault scarp in massive lava. Temperature anomalies between 0.05 °C and 0.22 °C (Fig. 9.10) indicate that these faults are preferential pathways for discharging low-temperature fluids.

The most extensive hydrothermal mineralization occurs as Fe-Mn oxyhydroxide crusts that formed on the black volcanic sand and, like the chimneys, are in turn partially covered by black sand (Fig. 9.11). The hydrothermal crust is exposed sporadically throughout the hydrothermal field area, where it ranges up to several (5–7) cm in thickness. The extent and continuity of the hydrothermal crust is uncertain, but it is interpreted to be extensive and to underlie much of the ridge which is now covered by black volcanic sand. The hydrothermal crust precipitates are a product of unfocussed, diffuse, low temperature hydrothermal discharge that was, in part, facilitated by the permeability of the porous volcanic sand upon which it developed. Chimneys are interpreted to be a product of more focussed hydrothermal discharge localized by cracks and fissures in the underlying lava flows. The extinct chimneys imply that these fissures were only temporary fluid channel ways and that these pathways may exist for only short periods of time, possibly due to local tectonic activity.

The Hine Hina site was found to have remained at the same volcanic and hydrothermal stage since 1989. Sampling during six dredge (62-, 63-, 64-, 67-, 70-, 71-DR) and five TV-guided (60-, 65-, 66-, 68-, 69-GTVA) stations at water depths between 1934 m and 1795 m focussed on the recovery of hydrothermal precipitates and associated host rocks. Two dredge targets retrieved no samples (62-, 63-DR), and a total of four grab attempts failed due to seafloor topography (GTV fell over) and malfunctions. No evidence for high-temperature hydrothermal activity was observed at these sites. However, OFOS tracks and sampling indicate low-temperature diffuse discharge. The dredge program sampled black, vesicular, aphyric, glassy to devitrified andesites and dacites that lack evidence for hydrothermal alteration or significant water/rock interaction. Minor staining is attributed to cold seawater alteration. The sites of inactive chimneys and small hydrothermal mounds, as identified during the OFOS tracks, could not be re-located during the GTV stations. TV-grab sampling retrieved a suite of fresh, glassy to intensely altered andesitic to dacitic lava and large amounts of black volcanic sand. Large areas of the ocean floor at the Hine Hina site are covered by Fe-Mn oxyhydroxides forming hydrothermal crusts several centimeters thick on top of thick layers of the black volcanic sand. While the crusts attest to intense diffuse discharge, the volcanic sand in the footwall shows no evidence of significant alteration, nor bleaching or devitrification. Larger rock fragments that are intensely bleached and mineralized by fine-grained, disseminated sulfides (mostly pyrite) are presumably derived from mineralized footwall rocks. The alteration mineralogy of these samples includes weak silicification by amorphous silica, a few occurrences of native sulfur, and clay alteration.

9.4.4 The Southernmost Valu Fa Ridge Segment (No. 3)

This ridge segment is hydrothermally inactive, but distinct hydrothermal precipitates suggest recent hydrothermal activity. The top of the ridge (22°40.15'S) is characterized by intense red staining of volcanic outcrops (lobate flows?), and large areas of the ridge crest are covered by Fe-Mn oxyhydroxide hydrothermal crusts very similar to those at the Hine Hina field. No sulfide mineralization or chimneys were observed and, unlike Hine Hina, areas covered by the Fe-Mn crust at the southern tip are not associated with bottom water thermal anomalies. The encrustations form smooth, locally brecciated surfaces, underlain by thick deposits of black volcanic sand. A similar style of pyroclastic (fire-fountain) volcanism is suggested for this and the no. 5 (Hine Hina) segment, which may have resulted in a similar style of hydrothermal activity. Thus, as at Hine Hina, the thin hydrothermal crust may be a product of unfocussed, diffuse low-temperature hydrothermal discharge that was, in part, facilitated by the permeability of the porous volcanic sand upon which it developed.

The southernmost segment of the VFR is similar to the Hine Hina segment in that the observed portions are covered by young, black, aphyric volcanic sand. The segment was sampled during three dredges stations (74-, 75-, 76-DR) located at bathymetric highs that define volcanic edifices in water depths between 2322 m and 1756 m. Dredge 75-DR was empty. Sampling retrieved young black plagioclase-phyric (basaltic) andesites with distinct glass crusts and aphyric andesitic lavas of perhaps older age. The rocks do not show any evidence of hydrothermal alteration. However, large areas of the ocean floor are covered by Fe-Mn oxyhydroxide crusts similar to those at Hine Hina, but slightly more oxidized. The crusts formed on thick layers of young volcaniclastic sand and attest to former diffuse discharge, but the underlying volcanic sand lacks any indication of hydrothermal alteration, such as bleaching or devitrification.

9.4.5. The Southern Rift Fault Zone

The recovery of recent glassy and unsedimented felsic(?) volcanics within a young, NE-trending graben suggested that this fault–rift zone is part of the actively southward propagating Valu Fa rift system. The similarity of these fault directions with those controlling recent submarine volcanism suggests deep penetration and tapping of melts, which might act as a potential heat source to drive hydrothermal convection and/or magmatic degassing. However, there is no evidence for recent or former hydrothermal activity associated with this young rift–fault zone. Local yellowish staining along the fault scarp suggests periods of low-temperature hydrothermal activity, possibly during the formation of the old island arc crust or associated with rifting processes.

The southern rift fault zone was sampled mainly for petrologic purposes because an earlier OFOS track did not show any evidence for hydrothermal activity. Sampling at two dredge stations (78-, 79-DR) retrieved glassy aphyric basaltic, andesitic and dacitic rocks. Andesite and dacite lithologies occur as glassy bands or sheets, partly welded together as crusts. The fresh appearance is consistent with the lack of any kind of alteration except for devitrification and incipient, weak weathering due to the interaction with cold seawater. Alteration is also absent in samples recovered from a seamount to the west. Wiedicke and Collier (1993) had interpreted this volcano as representing the southward extension of the VFR, but from the recovery of plagioclase and pyroxene phyric andesite we conclude that it is an older, rifted arc volcano.

9.5. Hydrothermal Activity at the South Tonga Arc

The geological setting, seafloor topography, volcanology, and structure of the south Tonga arc volcanoes are described in Chapter 5. Hydrothermally altered and, in part, strongly mineralized samples retrieved from four arc volcanoes show many characteristics that are typical of epithermal-style, shallow submarine, hydrothermal systems. Active venting in water depths between 600 m and 200 m meet the constraints for shallow submarine (subaerial) hydrothermal systems that are characterized by very low base metal contents (Cu, Zn, Pb) but elevated precious metal contents (Au, Ag). Mineralized and altered samples indicate active, shallow submarine hydrothermal activity for Volcanoes 1 and 19, whereas samples collected from Volcanoes 14 and 18 are strongly hydrothermally altered volcaniclastic breccias indicating older, or perhaps extinct, hydrothermal activity.

Samples from the arc volcanoes were collected by dredging. Due to temporal constraints, direct observations of the ocean floor (OFOS and GTV) were not possible. Thus, the identification and interpretation of hydrothermal processes are strictly restricted to map interpretation (cf., Section 9.4 above) and sample descriptions, including samples of the least-altered and altered rocks, and mineralization.

The locations of hydrothermal alteration and mineralization, taken from the respective dredge track positions, are provided in Table 9.1. Hydrothermal alteration and mineralization is spatially associated with calderas and craters within the upper parts of the arc volcanoes. Within these structures, hydrothermal activity occurs at volcanically active cones or the inner caldera wall. Inactive vent sites, identified from strongly altered and mineralized boulders, are probably derived from caldera and crater walls.

Table 9.1: Shallow submarine mineralization at Volcanoes 1, 14, 18 and 19, Tonga arc

Volcano	Location	Latitude	Longitude	Depth	Mineralization
# 1	W flank of scoria cone A	21°08.88' S 21°08.76' S	175°46.00' W 175°45.80' W	472 m 330 m	py, cp, apy/tn?, rg?, vq, qtz, cl-a, natS, Fe-ox
# 1	outer south caldera wall	21°10.79' S 21°10.56' S	175°45.41' W 175°45.20' W	719 m 612 m	py, vq, qtz, cc, chl, Fe-ox
# 1	inner NW caldera wall	21°07.78' S 21°07.66' S	175°43.68' W 175°43.71' W	474 m 325 m	py, qtz (vq), rg?, cl-a, atc, chl
# 14	inner caldera wall	23°34.40' S 23°34.42' S	176°43.15' W 176°43.46' W	929 m 796 m	py, chl, epd
# 18	NE crater wall	24°33.99' S 24°33.81' S	176°55.01' W 176°54.92' W	1223 m 1011 m	py, chl, epd, anh?, cl-a, Fe-ox
# 18	north crater wall	24°33.79' S 24°33.62' S	176°54.30' W 176°54.15' W	717 m 507 m	py, qtz, chl, cl-a, Fe-ox
# 19	central cone in caldera	24°48.30' S 24°48.29' S	177°00.30' W 177°00.09' W	595 m 469 m	py, vq, ba?, cl-a, Fe-ox

Top line is the "on bottom" co-ordinates and depth, second line is "off bottom".
Abbreviations: py = pyrite; cp = chalcopyrite; tn = tennantite; apy = arsenopyrite; rg = realgar; vq = vuggy quartz; qtz = quartz; cl-a = clay alteration; atc = atacamite; chl = chlorite; epd = epidote; cc = calcite; anh = anhydrite; ba = barite; natS = native sulfur; Fe-ox = Fe-oxyhydroxide.

9.5.1. Arc Volcanoes

Volcano 1 showed the most extensive and strongest mineralization. This volcano is approximately 10 x 6 km in diameter, with a 5 x 3 km central caldera containing two young volcanic cones. Cone A occurs near the western rim of the caldera, and cone B further to the south. Cone A reaches a height of ~90 m below sea level and is localized along a regional, NE–SW trending structure. The top of cone B reaches to within 150 m of the surface. Samples were collected from the western wall of cone A (04-DR), the base of the southern caldera wall (close to cone B; 05-DR), and from the northern inner caldera wall (09-DR) at water depths between 719 m and 325 m, but possibly as shallow as 200 m at cone A. Dredging retrieved samples of hydrothermally altered and mineralized scoriaceous basaltic–andesitic volcanic breccia. The widespread distribution of mineralization at the three different sites, and the occurrence of intensely mineralized boulders at active sites, suggest extensive and widespread hydrothermal activity.

Volcano 14 is a 9 x 6 km edifice with a central caldera that is slightly offset to the west. Dredging (82-DR) occurred at water depths between 929 m and 726 m and retrieved boulders of variably altered and weakly mineralized basaltic to andesitic flows and volcaniclastic rocks.

Volcano 18 is characterized by a distinctive, large (several square kilometers) and deep (~1000 m), cone-shaped central crater (refer Section 5.10). Sampling (96-, 97-DR) occurred at water depths between 1223 m and 507 m. The large amount of fresh, dacitic pumice and basaltic–andesitic scoria collected during dredging is interpreted to be a product of major pyroclastic eruptions which, in part, formed the volcano and the central crater or vent. Dredging at the deeper parts of the NE crater wall at ~1000 m water depth yielded samples of variably altered, basaltic to dacitic volcaniclastic rocks and boulders. Some of the volcaniclastic rocks are presumably altered pumice and variably altered basalt fragments, suggesting low-temperature hydrothermal activity. These samples, however, do not show evidence of sulfide mineralization. Strong hydrothermal alteration and disseminated pyrite were sampled at the very steep northern rim of the crater at a water depth of about 700 m. Samples collected here consist of boulders of basaltic–andesitic volcaniclastic rocks that may be products of initial basaltic–andesitic eruptions that constructed the arc volcano and preceded explosive dacitic eruptions and pumice deposits. However, pumice fragments are also affected by alteration suggesting that the hydrothermal system persisted after dacitic eruptions. Alteration types include silicification, chloritization, sericitization, and disseminated pyrite.

Volcano 19 is a 13 by 15 km edifice with a large NW–SE elongated central caldera. Samples were collected from the western wall of a relatively small cone in the center of the caldera at water depths of 595 m to 469 m (100-DR). The samples consisted of boulders of young but intensely hydrothermally altered andesitic volcaniclastic breccias with angular to subrounded scoriaceous fragments. Interstices between the fragments are strongly mineralized by pyrite, and the fragments are argillically altered. The occurrence of intensely altered and mineralized boulders attests to hydrothermal activity higher up on the cone.

9.5.2. Host Rocks

Hydrothermal mineralization at the four arc volcanoes is closely associated with central to slightly offset (basaltic–) andesitic cinder cones within prominent calderas, or with caldera walls (cf., Section 9.4). Host rocks are scoriaceous or pumiceous volcaniclastic breccia and plagioclase porphyritic andesitic breccias. The occurrence of chilled margins and fractures within and around lithic fragments suggests quench fragmentation.

The arc volcano setting, pumiceous or scoriaceous host rocks, water depths, and the style of mineralization indicate that very shallow submarine pyroclastic eruptions (water depths of <1000 m up to 200 m) played a significant role in the formation of the arc volcanoes, at least in the latter part of their constructional history. The basaltic–andesitic scoria cones were undoubtedly a product of explosive strombolian to surtseyian eruptions. The apparently huge volumes of pumice that mantle the slopes of many of the arc volcanoes, and that constitute most of the upper edifice and funnel-shaped crater (or central vent) of Volcano 18, are likely subaqueous fall deposits produced during catastrophic plinian-style eruptions where the eruption column, depending on water depth, may have broken the sea surface.

9.5.3. Mineralization and Alteration

The altered and mineralized samples are similar to alteration and mineralization described from subaerial epithermal-style high-sulfidation Au deposits, and those reported from shallow submarine hydrothermal vent fields such as the Kermadec and Izu–Bonin arcs (e.g., Hannington et al., 1999; Iizasa et al., 1999; Stoffers et al., 1999b; Glasby et al., 2000; de Ronde et al., 2001; Petersen et al., 2002). Mineralization along fractures and structurally controlled sigmoidal lenses may indicate hydrothermal fracturing due to hydrothermal fluid overpressure (boiling?) and sealing due to the rapid precipitation of pyrite, silica or clay minerals. Localization of mineralization to the caldera walls illustrates the structural control on hydrothermal discharge, the deep penetration of fluid pathways, and/or perhaps magmatic degassing.

Mineralization consists of fine-grained but pervasive disseminated pyrite, variable amounts of more complex sulfides (chalcopyrite, possibly arsenopyrite, tennantite, realgar), magnetite, amorphous and crystalline silica, clay minerals, and subordinate chlorite, calcite, epidote, barite, atacamite and, possibly, native sulfur (Fig. 9.12). Alunite was not determined macroscopically. The high sulfidation stage might be indicated by the occurrence of vuggy silica textures, strong silicification of lithic fragments and matrix, an intense argillic alteration, and disseminated pyrite and chalcopyrite plus additional highly sulfidized phases like arsenopyrite and/or tennantite and realgar.

The mineralized volcaniclastic breccias display distinct blue–green bleaching and pale grey colors attesting to significant sulfide, quartz and clay (argillic) alteration that indurates single fragments as well as the breccia matrix. Samples often show zoning, where pyrite enrichment occurs in outer zones surrounding a siliceous and argillic interior, as well as intense veining and coatings of lithic fragments. Pyrite occurs as fine-grained pervasive disseminated grains, but is best developed where it occurs: (1) coating vesicles within scoriaceous fragments (coatings up to 2 mm thickness), (2) lining fractures and open spaces, and (3) within the matrix between larger fragments. However, a fine pyrite dusting is also associated with smaller, more compact lithic fragments, interstices, and as a coating on larger scoria fragments. More massive aggregates of pyrite are rare and restricted to large vesicles or open spaces related to vuggy silica. Structurally controlled pyrite mineralization along fractures suggest hydrothermal fracturing and healing. Most samples do not visually contain any other sulfide but pyrite. Besides fine-grained disseminated chalcopyrite, no base metal sulfides were observed visually as is characteristic of settings where the mineralizing fluids have undergone phase separation. However, the occurrence of very fine-grained, bluish grey, triangular-shaped arsenopyrite and/or tennantite as well as realgar overgrowths and concentric aggregates with pyrite in highly altered scoriaceous fragments is suggested in samples from Volcanoes 1 and perhaps 19. Close intergrowths of pyrite with magnetite in samples from Volcano 1 are indicative for gold-rich mineralization and constrain conditions of preferential gold transportation.

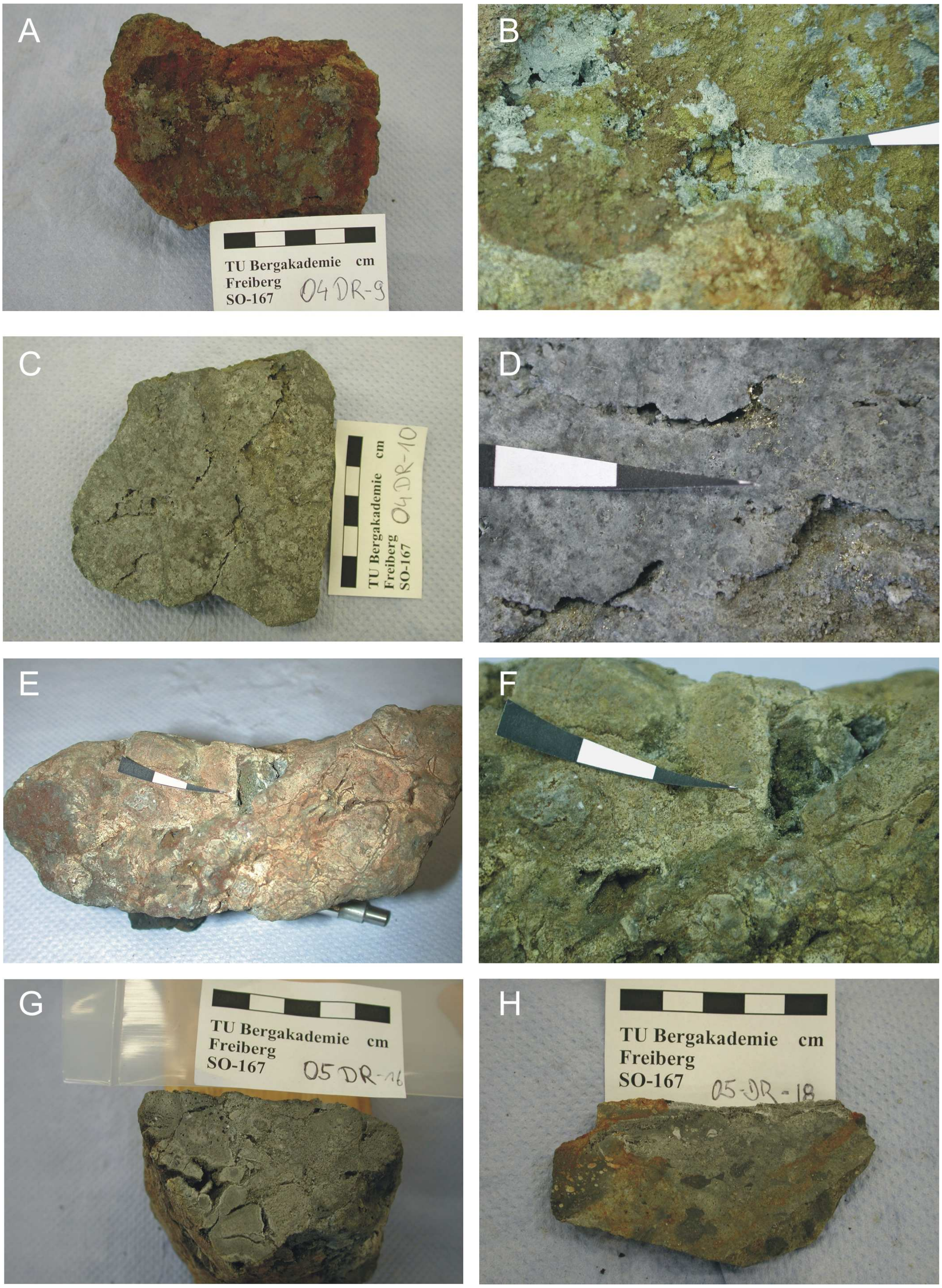

Fig. 9.12: Shallow submarine hydrothermal alteration and mineralization in scoriaceous volcaniclastic andesitic breccias of Volcano 1 in the Tonga island arc: (A, B) intensely pyrite-mineralized volcaniclastic breccia along fractures and within interstices; (C, D) 'vuggy silica'-style alteration texture and pyrite–chalcopyrite mineralization in open spaces; (E, F) pyrite coatings around andesitic clasts and open space fillings in the interstitial matrix; (G, H) scoriaceous breccia showing very fine-grained disseminated ('sooty') pyrite mineralization.

The dominant alteration is inferred to be argillic and silicification. Argillic alteration is characterized by a fibrous clay mineral coating of vesicles and fractures, and replacement of scoriaceous fragments. Whereas clay alteration affects smaller fragments and the matrix, larger and dense lithic fragments lack evidence of intense alteration. The degree of silicification is variable. Single lithic fragments and matrix may be totally silicified, but the most intense disseminated pyrite occurs without amorphous silica. A fine network of silica is often observed to crosscut the matrix of volcaniclastic breccias, again suggesting hydrofracturing and sudden silica precipitation. Single open spaces display aggregates and needles of euhedral quartz crystals.

Chlorite–epidote alteration is restricted to samples collected from sites that are inferred to be inactive. Strong chloritization is associated with disseminated pyrite and occurs in volcaniclastic fragments as well as within the matrix. Epidote is mainly restricted to crosscutting veinlets. Thin, fine-grained, greenish overgrowths along fracture surfaces within lithic fragments are interpreted as atacamite. A few platy barite(?) crystals and collomorphic native sulfur(?) may occur in the open spaces of scoria fragments at Volcanoes 1 and 19. Carbonate veinlets and coatings around clasts were observed in single mineralized boulders. The oxidation of pyrite results in a distinct red staining and forms oxidized crusts up to 2 cm thick on the boulders.

9.6. Conclusions

The Tonga Trench is a classic example of an immature, intra-oceanic, convergent margin setting where Pacific Plate lithosphere is subducted beneath an intra-oceanic volcanic island arc chain. The back-arc Lau Basin opened by the successive southward propagation of discrete seafloor spreading centers. The site of active rifting, the Valu Fa Ridge, was identified as a site of intense tectonic, magmatic, and hydrothermal activity that also makes it a type example of rift-related volcanism and associated hydrothermal processes. The results of cruise SO-167 will lead to a better understanding of the magmatic and structural evolution of the Valu Fa Ridge, of the processes associated with immature back-arc rifting, and the related short-term spatial, temporal, and compositional changes in volcanic and hydrothermal activity. The southern Lau Basin is often compared to ancient back-arc settings and associated volcanogenic massive sulfide deposits. Our results will hopefully provide new insights in the understanding of tectonic, magmatic, and ore-forming processes in this geological environment.

Fresh to weakly weathered lavas were recovered from 27 stations in the survey area, yielding 72 logged samples (Table 9.2). Of these, 56 were prepared for analytical work in Kiel. The predominant lithology was glass-encrusted aphyric andesite. More weathered basaltic lavas were recovered south of the VFR propagator.

Table 9.2: Petrology Samples and Lithologies, Valu Fa Ridge

Station Number	Samples logged	Selected analysis		Aph Bas	Ol Bas	Pl Bas	Aph And	Px And	Pl And	Aph Dac	Pum
44 GTV	-	-									
45 GTV	5	4		X							
46 DR	3	3					X				
47 DR	4	4					X				
48 GTV	5	3					X				X
50 GTV	-	-									
51 DR	3	3					X				
52 DR	2	2					X				
53 DR	3	3								X	
54 DR	3	3					X				
55 DR	3	3								X	
60 GTV	2	2					X				
62 DR	-	-									
63 DR	-	-									
64 DR	3	3					X				
65 GTV	-	-									
66 GTV	3	-					X			X	
67 DR	3	3					X			X	
68 GTV	2	2					X				
69 DR	2	2					X				
70 DR	5	4					X	X			
71 DR	3	3					X				
74 DR	4	3				X	X				
75 DR	-	-									
76 DR	4	-							X		X
78 DR	5	3		X	X		X			X	X
79 DR	5	3							X		X
27 Stns	**72**	**56**		**2**	**1**	**1**	**16**	**1**	**2**	**5**	**4**

The main results of the hydrothermal program during SO-167 LOUISVILLE include:

1) All VFR segments follow the regional pattern of left-stepping, *en echelon* orientated ridges, edifices and southward propagating fault zones.
2) Active southward propagation and fast spreading rates at the VFR have resulted in rapid structural, volcanic and hydrothermal evolution.
3) In contrast to the regional orientation and southward propagation of the VFR, the location of hydrothermal activity, and the most recent volcanic activity, is associated with off-axis structures and/or volcanic edifices where it is concentrated on recent, west-facing structures on the western side of the ridge segments.
4) Hydrothermal activity is controlled by the ridge geometry. The correlation between the hydrothermally active VFR segments and the geometry of the magma chamber reflector, particularly underneath overlapping spreading centers, attests to a strong magmatic control on heat flow and the distribution and development of convection cells.

5) The stable position of the high-level magma chamber, the buoyancy of its low-density, highly viscous siliceous melt, and strong structural overprinting is responsible for recent fissure-fed dike intrusions and continuous eruptions, as shown at the Vai Lili site.
6) The style of magmatism likely influenced the onset and style of hydrothermal activity along the VFR. Elevated magma supply rates at the Vai Lili site undoubtedly arrested hydrothermal activity and discharge during periods of volcanic eruption. For example, hydrothermal discharge at Vai Lili since 1989 may have been affected by the eruption of andesitic lobate flows that may have partly buried the 1989 vent field. Similarly, altered and mineralized volcanic clasts in the "aa-type" lava attest to an earlier hydrothermal event and discharge prior to eruption of that flow. This leads to the distinct possibility of stratigraphically stacked mineralization beneath the present Vai Lili site. In contrast, the Hine Hina ridge segment does not show any volcanic changes since 1989. It is characterized by mild fire-fountain eruptions that blanketed basaltic volcanoes constructed along the ridge with deposits of volcanic sand and bombs that were subsequently re-deposited by strong bottom currents.
7) Dead colonies of hydrothermal vent fauna, single oxidized chimneys, and the disappearance of vigorously active smokers indicate that the present hydrothermal activity at the Vai Lili site has changed dramatically since 1989. However, low-temperature diffuse hydrothermal activity is continuing, as indicated by low-temperature hydrothermal precipitates and thermal anomalies in the immediately overlying water column. Replacement and zone refining of possible lenses of stratigraphically stacked sulfide mineralization may be occurring beneath the present Vai Lili site.
8) The Hine Hina vent field was found to be larger than in 1989. However, there have been no significant changes in the style of low-temperature, diffuse hydrothermal activity since 1989. Hydrothermal activity spanned the waning period of basaltic fissure eruptions and continued after fire-fountain eruptions as evidenced by the clasts of altered and mineralized basalt in the volcanic sand, by the occurrence of sulfide chimneys on lobate flows, and within and buried by the black sand, and by the development of thick Fe-Mn oxyhydroxide crusts on the black sand surface. Evidence of present day hydrothermal activity includes a thermal anomaly in the immediately overlying water column, shimmering water and white-yellow biological mats.
9) At segment no. 7, structural extension and the formation of large fault scarps and fissures is not associated with hydrothermal activity, despite the presence of an underlying magma chamber.
10) Southward propagation of the VFR rift is associated with a fault zone that follows the regional left-stepping, *en echelon* orientation of the ridge. Tectonic and volcanic activity in this fault zone indicate deep penetration and tapping of melts. The combination of tectonic and volcanic activity, however, is not preceded or

immediately associated with hydrothermal activity. It is concluded that fairly fast spreading rates at the propagating rifts of single ridge segments are not associated with significant magmatic degassing or the development of a hydrothermal system. Instead, more stable conditions at intermediate ridge segments, underlain by a high-level magma chamber, favour the onset of hydrothermal activity and the development of sustainable hydrothermal convection cells, allowing for longer lived and higher temperature discharge.

11) The first occurrence of shallow submarine hydrothermal activity has been documented in the Tonga island arc. The mineralization is associated with scoria cones occurring within calderas and craters of large arc volcanoes. The style of mineralization, its mineralogy and attendant alteration, coupled with the shallow water depths (~700 m to 325 m) suggest a real potential for epithermal-style Au mineralization.

9.7. References

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10. FERROMANGANESE PRECIPITATES

Thomas Kuhn

Ferromanganese precipitates were sampled from four different areas during SO-167: Tonga Volcanic Arc, Valu Fa Ridge, Osbourn Trough and Louisville Ridge (Table 10.1).

Table 10.1: Fe-Mn precipitates sampled during SO-167

Station	Coordinates[1] ° S / ° W	Depth (mbsl)	Location[2]	Description
01-DR	-21.0436/-175.8502 -21.0400/-175.8452	1329 1148	TVA Volcano 1	1-3 mm thin layered Mn crust with submetallic lustre (hydrothermal?)
08-DR	-21.3352/-175.7319 -21.3331/-175.7286	985 876	TVA Volcano 1	1 mm thin dull black crust
35-DR	-22.6444/-176.4261 -22.6434/-176.4213	1168 963	TVA Volcano 7	1 mm thin crusts on altered rocks
39-DR	-22.8216/-176.4167 -22.8178/-176.4166	503 408	TVA Volcano 8	1 mm thin crusts on altered rocks
45-GTVA	-22.2171/-176.6078	1625	VFR Vai Lili field	some mm thick hydrothermal Mn crust
48-GTVA	-22.2166/-176.6073	1528	VFR Vai Lili field	some mm thick hydrothermal Mn crust coatings on fresh vesicular basalt; no Mn oxides in vesicles
60-GTVA	-22.5377/-176.7173	1700	VFR Hine Hina field	some mm thick hydrothermal Mn crusts on top of crust-like Fe oxyhydroxides
121-DR	-25.6152/-173.5297 -25.6170/-173.5405	4714 4364	Osbourn Trough	up to 80 mm thick Mn crusts on hyaloclastites, pelagic sediments and conglomerates; built up in layers; clasts in substrate also covered by Mn oxides --> relocation horizon
122-DR	-25.5862/-173.5500 -25.6004/-173.5614	5092 4386	Osbourn Trough	some mm thick Mn crusts on indurated sediments; several thin Mn layers running parallel to surface occur in different depths; 1-2 cm Mn nodules in about 5-6 cm depth; also Mn crusts on hard rocks as in 121-DR but less thick
125a-DR	-25.6326/-173.3001 -25.6326/-173.3002	4361 4360	Osbourn Trough	up to 90 mm thick, layered crusts on indurated sediments; sediments contain Mn oxide veins and Mn nodules
128a-DR	-25.7785/-172.6057 -25.7781/-172.6061	4766 4748	Osbourn Trough	up to 100 mm thick, layered crusts on indurated sediments and volcaniclastics, clasts are also covered by Mn oxides and represent relocation horizons
129-DR	-25.6501/-172.5833 -25.6597/-172.5891	6015 5201	Osbourn Trough	deepest crusts sampled in the Osbourn Trough; they show two growth generations interrupted by phases of sedimentation; indurated sediments also contain Mn oxide veins and slump layers
130a-DR	-25.8704/-172.7933 -25.8707/-172.7931	4425 4434	Osbourn Trough	up to 50 cm large slabs of indurated sediments containing rock clasts which are thinly covered with Mn oxides; slabs are encrusted by two Mn crust generations up to 50 mm; they also contain Mn oxide veins
132-DR	-25.9940/-172.2498 -25.9803/-172.2499	5384 4654	Osbourn Trough	similar to 129-DR with two Mn oxide generations; a lot of small Mn nodules occur around small pieces of rock in indurated sediments
134-DR	-26.4311/-174.7784 -26.4309/-174.7684	2671 2169	Louisville Ridge Volcano 32	up to 2mm thick Mn oxides on volcanic rock fragments and conglomerates; crust was covered by 2-3 mm pelagic sediments
135-DR	-26.7218/-174.6370 -26.7150/-174.6255	2364 1799	Louisville Ridge Volcano 32	as 134-DR but up to 5 mm thick crusts
139-DR	-27.5864/-174.0260 -27.5802/-174.0350	2536 2118	Louisville Ridge Volcano 33	up to 5 mm thick Mn oxide crusts on indurated conglomeratic sediments (clasts are completely oxidized and cemented); the crusts are covered by a thin sediment blanket
141-DR	-27.6469/-174.0720 -27.6373/-174.0771	2331 1803	Louisville Ridge Volcano 33	up to 25 mm thick crusts on rocks and conglomeratic sediment (clasts are completely oxidized and cemented); crusts are rather porous
143-DR	-28.5208/-173.3764 -28.5155/-173.3720	2186 1937	Louisville Ridge Volcano 34	up to 48 mm thick, rather porous crust on conglomeratic sediment; similar to 141-DR, with

Station	Coordinates[1] ° S / ° W	Depth (mbsl)	Location[2]	Description
				nodular-like surface; thin sediment cover
145-DR	-28.6160/-173.3465 -28.6087/-173.3453	2406 1980	Louisville Ridge Volcano 34	up to 20 mm thick crusts with same characteristics as 143-DR
147-DR	-28.6134/-173.3289 -28.6135/-173.3248	2353 2150	Louisville Ridge Volcano 34	up to 37 mm thick, rather porous crusts on brecciated/conglomeratic sediment and on rather fresh volcanic rocks; similar to 143-DR
149-DR	-31.5669/-172.1066 -31.5582/-172.1047	2561 2046	Louisville Ridge Volcano 35	up 5 mm thick Mn oxide coatings on indurated carbonaceous sediment
150-DR	-31.5446/-172.1230 -31.5356/-172.1346	2328 1840	Louisville Ridge Volcano 35	up to 10 mm thick Mn oxide coatings on indurated carbonaceous sediment; same as in 149-DR
154a-DR	-33.7251/-171.4403 -33.7327/-171.4355	1542 1770	Louisville Ridge Volcano 36	up to 30 mm thick crusts; very dense; can be subdivided into two different layers: lowermost layer about 11 mm thick, dense, submetallic lustre; upper
157-DR	-35.4634/-170.4117 -35.4578/-170.4138	2151 1915	Louisville Ridge Volcano 37	Mn crusts on two substrate types: (a) up to 51 mm thick crusts on altered volcanics consisting of 4 different crust layers (see text); (b) up to 35 mm thick crusts on carbonates
158-DR	-35.4814/-170.3666 -35.4692/-170.3606	2114 1842	Louisville Ridge Volcano 37	up to 30 mm thick Mn crusts on carbonates; upper part of crusts consist of dense single laminae, lower part of porous crust with high detrital content; nodular-botryoidal surface
159a-DR	-36.0819/-169.5709 -36.0820/-169.5696	1674 1626	Louisville Ridge Volcano 38	Mn crusts on two types of substrate: (a) directly on altered volcanics (up to 16 mm); (b) on carbonate crusts which are in-between volcanics and crusts (up to 20 mm)
161-DR	-37.0184/-169.7631 -37.0152/-169.7578	1802 1620	Louisville Ridge Volcano 39	up to 32 mm thick layered, Fe-Mn crusts on breccia and conglomerate (clasts consist of altered volcanics)
162a-DR	-37.0190/-169.7793 -37.0111/-169.7729	1986 1683	Louisville Ridge Volcano 39	up to 30 mm thick layered, Fe-Mn crusts on conglomerate (clasts: altered volcanics; matrix: carbonates); large block (450 x 200 x 170 mm); smaller pieces with thinner crusts (up to 8 mm) but same substrate (these crusts do not show layered texture)
163-DR	-37.0165/-169.7670 -37.0091/-169.7723	1864 1659	Louisville Ridge Volcano 39	up to 60 mm thick, massive and compact crusts; very fine laminae at basis consisting of detrital material and ferromanganese oxides; laminae are distinct on dense volcaniclastic substrate but are less distinct on porous volcaniclastics with high amount of carbonate; smooth surface of crusts (less knobby compared to 164-DR)
164-DR	-37.4715/-169.4453 -37.4662/-169.4360	2342 1806	Louisville Ridge Volcano 40	up to 40 mm thick massive crusts; no lamination; partly porous horizons in-between massive crusts; botryoidal surface with thin sediment cover
165a-DR	-37.5228/-169.4170 -37.5228/-169.4157	2106 2081	Louisville Ridge Volcano 40	2 types of Fe-Mn crusts: a) up to 50 mm thick, massive crusts with distinct lamination at basis (up to 10 mm); partly interchange of carbonate horizons with detrital and Fe-Mn oxide laminae at basis; b) up to 20 mm porous crusts; in some samples grown on massive crusts indicating two growth generations; substrate of (a) and (b): volcaniclastics
167-DR	-37.5331/-169.3082 -37.5340/-169.3074	1983 1979	Louisville Ridge Volcano 40	only thin (up to 2 mm) crusts; sometimes only thin Fe-Mn oxide coatings on rocks
168-DR	-37.5327/-169.3072 -37.5309/-169.3039	1932 1756	Louisville Ridge Volcano 40	same as 167-DR
171-DR	-37.6366/-169.1633 -37.6215/-169.1614	2282 1477	Louisville Ridge Volcano 40	up to 20 mm thick crusts, masive, no lamination; no changes in texture
172-DR	-37.7247/-168.9285 -37.7233/-168.9340	2342 2161	Louisville Ridge Volcano 40	2 crust types: (a) up to 20 mm thick massive crusts with smooth surface on weathered volcaniclastics (b) up to 30 mm thick masive crusts with a nodule-like surface on weathered volcaniclastics (partly with carbonaceous matrix, partly with higher amount of detritus)
173-DR	-38.2482/-168.1417 -38.2455/-168.1341	2195 1901	Louisville Ridge Volcano 41	up to 25 mm thick massive crusts on conglomerates

[1] Coordinates are given as –xx.xx° S and –yy.yy° W; for dredge stations the upper line is "on bottom" and lower line is "off bottom".
[2] TVA= Tonga Volcanic Arc; VFA= Valu Fa Ridge.

10.1. Valu Fa Ridge

On the Valu Fa Ridge, Fe-Mn oxides were recovered from the Vai Lili and the Hine Hina hydrothermal fields. Ferromanganese precipitates form mm-thick coatings on fresh vesicular basalts in the Vai Lili field (45-, 48-GTVA; Table 10.1). They do not fill in the vesicles of the basalt. At Hine Hina, Fe-Mn crusts cover Fe oxyhydroxides (60-GTVA; Fig. 10.1) which form exhalites either on fresh andesitic basalts or on coarse-grained sediments. The Fe-Mn oxides form a nodular-like surface, display a submetallic lustre and are only some mm thick. They cover the Fe oxyhydroxide crusts but are not intergrown with them. The macroscopic characteristics of Fe-Mn crusts from the Valu Fa Ridge are typical of hydrothermal low-T precipitates. They are probably enriched in Mn compared to Fe (e.g., Hein et al., 1990).

Fig. 10.1: Hydrothermal Fe-Mn crust from the Hine Hina field, southern Valu Fa Ridge (60 GTV-A).

10.2. Osbourn Trough

The thickest and by far the most ferromanganese crusts sampled during cruise SO-167 came from the Osbourn Trough. The Osbourn Trough is thought to be a fossil spreading axis which could be as old as 110 Ma and was active during the Cretaceous (Billen and Stock, 2000). It is characterized by a number of morpho-structural features which are typical of slow-spreading mid-ocean ridges (refer Chapter 7). Two of these features are corner highs and nodal basins which appear at the intersection of rift segments and non-transform discontinuities (NTD; refer Fig. 7.2). Up to 80 mm thick Mn crusts were recovered from these features from water depths between 6015 m and 4360 m (e.g., Fig. 10.2A and 10.2D). The crusts grew on altered volcanic rocks, volcaniclastics, and indurated sediments (Fig. 10.2A–F). They are composed of an interchange of dense, submetallic-black layers and porous, dull-black layers. Their macroscopic characteristics are typical of hydrogenetic ferromanganese crusts with Fe-Mn ratios of about 1 which precipitated from ambient seawater (e.g., Hein et al., 2000).

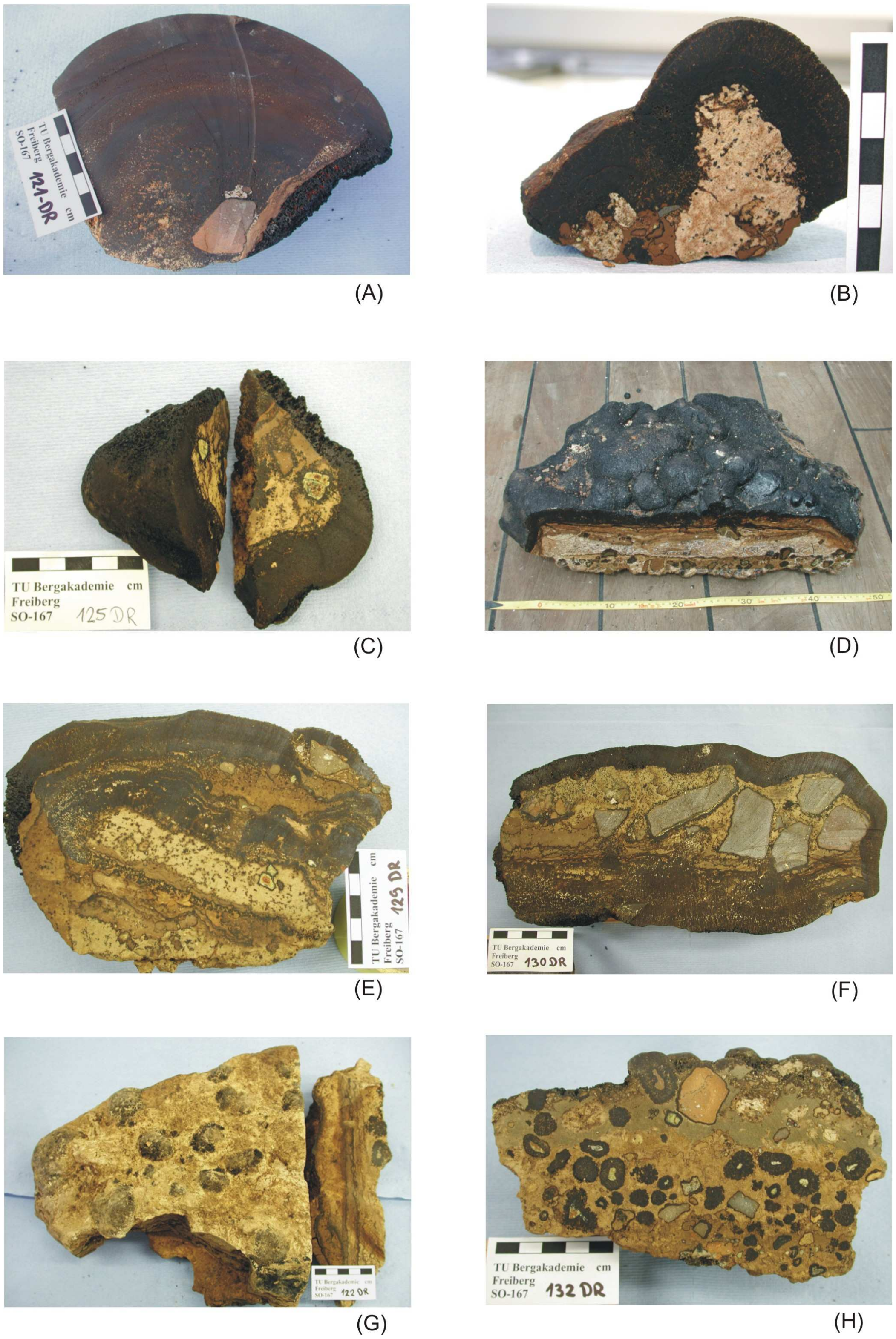

Fig. 10.2: Ferromanganese precipitates from Osbourn Trough: (A) ~80 mm thick layered crust; (B) crust on indurated sediment; (C) crust containing encrusted clasts; (D) Fe-Mn crust on a sediment slab containing layers with slumped material; (E) different crust generations showing that an indurated sediment slab covered by Fe-Mn crusts was transported downhill, re-sedimented and covered by a younger generation of Fe-Mn crust; (F) two Fe-Mn crust generations (older one on base of sample, newer one on top and right side) covering indurated sediments with large angular clasts of volcanic rock; (G) slab of indurated sediment with Mn nodules and veins of Fe-Mn oxides (sample is upside down); (H) small Mn nodules and encrustations around slumped clasts in indurated sediment.

Mn nodules up to 50 mm in diameter occur in indurated sediments down to 150 mm sediment depth (Fig. 10.2G–H). The sediment above the nodules contains parallel-running Fe-Mn oxide veins, which probably represent fossil sediment surfaces. The current surface is also covered by a thin Fe-Mn crust. The Mn nodules show signs of dissolution.

Horizons with an increased number of clasts which are totally encrusted by ferromanganese oxides represent slumped talus material. Most of the clasts are angular indicating transport only over short distances (Fig. 10.2F). Slabs of indurated sediments are covered by Fe-Mn oxides on all sides suggesting downhill transport of these slabs (Fig. 10.2F). Fe-Mn crusts of 10–20 mm thickness occurring in different layers within sediments may represent different growth generations (Fig. 10.2E). Clasts encrusted by Fe-Mn oxides as well as different ferromanganese crust generations in one sample indicate successive periods of downhill transport. Different Fe-Mn crust generations in sediments also suggest periods of sedimentation followed by periods without sedimentation or even erosion, during which the sediments were probably indurated. The last suggestion results from the fact that Fe-Mn crusts only grow on hard ground during periods of virtually no or very reduced sedimentation. Such periods must have persisted for quite awhile since the crusts grow with rates of 1–6 mm/Myr and are 10–20 mm thick (e.g., Hein et al., 2000).

The seamounts and ridges along the slopes of which the Fe-Mn precipitates have been sampled currently have minimal water depths of about 4300 m (Fig. 7.1). According to isostatic subsidence rates and the suggestion that these seamounts and ridges have formed along a spreading axis or as corner highs, they may never have been shallower than 3500 m in their geological history (refer section 7.2). Moreover, most of the crusts have been precipitated after the ridges and seamounts have formed. They should therefore mainly have formed in water depths close to their current position. However, most of the hydrogenetic crusts studied so far formed on seamount slopes between about 1000 m and 2500 m water depth (e.g., Koschinsky and Halbach, 1995; Hein et al., 1997; Hein et al., 2000 and references therein). They are related to the upwelling of O_2-rich deep water along the seamount slopes and mixing with water from the oxygen-minimum zone (OMZ; e.g., Koschinsky and Halbach, 1995). Most of the element enrichments are also related to such mixing processes (e.g., Pt enrichment in hydrogenetic crusts; Halbach et al., 1989). However, the ferromanganese crusts from Osbourn Trough cannot have formed as a result of such mixing processes since there are no edifices which have risen high enough to get close to the OMZ (which is in about 400–1000 m water depth; Chester, 1990). Thus, the ferromanganese crusts from Osbourn Trough offer the possibility to investigate hydrogenetic processes in the deep sea. They may provide new insights in enrichment processes of economically important elements (e.g., PGEs). Furthermore, they provide new possibilities in climate and paleoceanography studies. This is because they may cover a large time range (probably more than 50 Myr) and they may not be phosphatized. The last suggestion results from the hypothesis that phosphatization is also connected to the mixing processes discussed above (Koschinsky et al., 1997). Phosphatization of older crusts, as is typical on shallower seamount slopes, blurs the paleoceanographic signal since it leads to diagenetic readjustment of the chemical and isotopic signals which are used in paleoceanography and climate studies (Hein et al., 2000). If the crusts from Osbourn Trough are not phosphatized, and if they are really that old, they especially offer the possibility to study the onset of the Antarctic Bottom Water (ABW) resulting from the isolation of Antarctica at about 25–30 Ma. Within such a study, new methods of age dating could also be tested (e.g., with ^{54}Mn).

10.3. Louisville Ridge

Louisville Ridge is the trace of the Louisville hotspot, and forms a seamount chain whose summit water depths range from 274 m to 3670 m (Lonsdale, 1988). Eleven of the Louisville seamounts were dredged during SO-167 (26°S to 39°S; Table 10.1).

Ferromanganese oxides from Louisville Ridge differ from the Osbourn Fe-Mn oxides in terms of thickness, macroscopic texture, and substrate on which they have precipitated. They range from 2 mm thin coatings up to about 60 mm thick crusts (e.g., Fig. 10.3A–B; Fig. 10.4E). The thick crusts are either porous with a rather high amount of detrital material (Fig. 10.3B–C) or they consist of different porous and dense layers (Fig. 10.4A–B), or they are made up of dense, massive crusts (Fig. 10.3F–G; Fig. 10.4E–G). The dense ferromanganese crusts from Volcanoes 39 and 40 display fine laminations at their bases (Fig. 10.4E–H). At station 165-DR this lamination occurs together with carbonate layers (Fig. 10.4G–H). Carbonates also occur in samples from station 159-DR as layers or crusts between the volcaniclastic substrate and the Fe-Mn crusts (Fig. 10.4C). A dense layer with metallic lustre makes up the basal part of Fe-Mn crusts from station 154-DR. This layer has macroscopic characteristics which are similar to hydrothermal crusts precipitating from low-T hydrothermal fluids (Fig. 10.3G; e.g., Hein et al., 1990; Kuhn et al., 2002). Some crusts have a very smooth surface, as is typical for hydrogenetic formation under distinct unilateral bottom currents (Fig. 10.3E; Fig. 10.4G), whereas others have a botryoidal or nodular-like surface (Fig. 10.3D, F, H; Fig. 10.4D). The latter may be caused by at least partial coverage of the crusts with sediments, as can be seen at some samples (Fig. 10.3D). The crusts have grown on different substrates including mudstone (Fig. 10.3A), shallow water carbonate (Fig. 10.3E), and conglomerate (Fig. 10.4D), but mainly on weathered volcanic rock or volcaniclastics (Fig. 10.3B–C, G; Fig. 10.4A-C, E–F, H). The water depths within which the crusts were sampled ranged from 2671 m (134-DR) to 1477 m (171-DR), but no water depth dependency with respect to certain textures, crust thickness or other characteristics could be detected.

Crusts from 157-DR are special in that they are very thick (up to 51 mm) and display a distinct layered texture suggesting at least four different growth stages (from top to bottom; Fig. 10.4A–B):

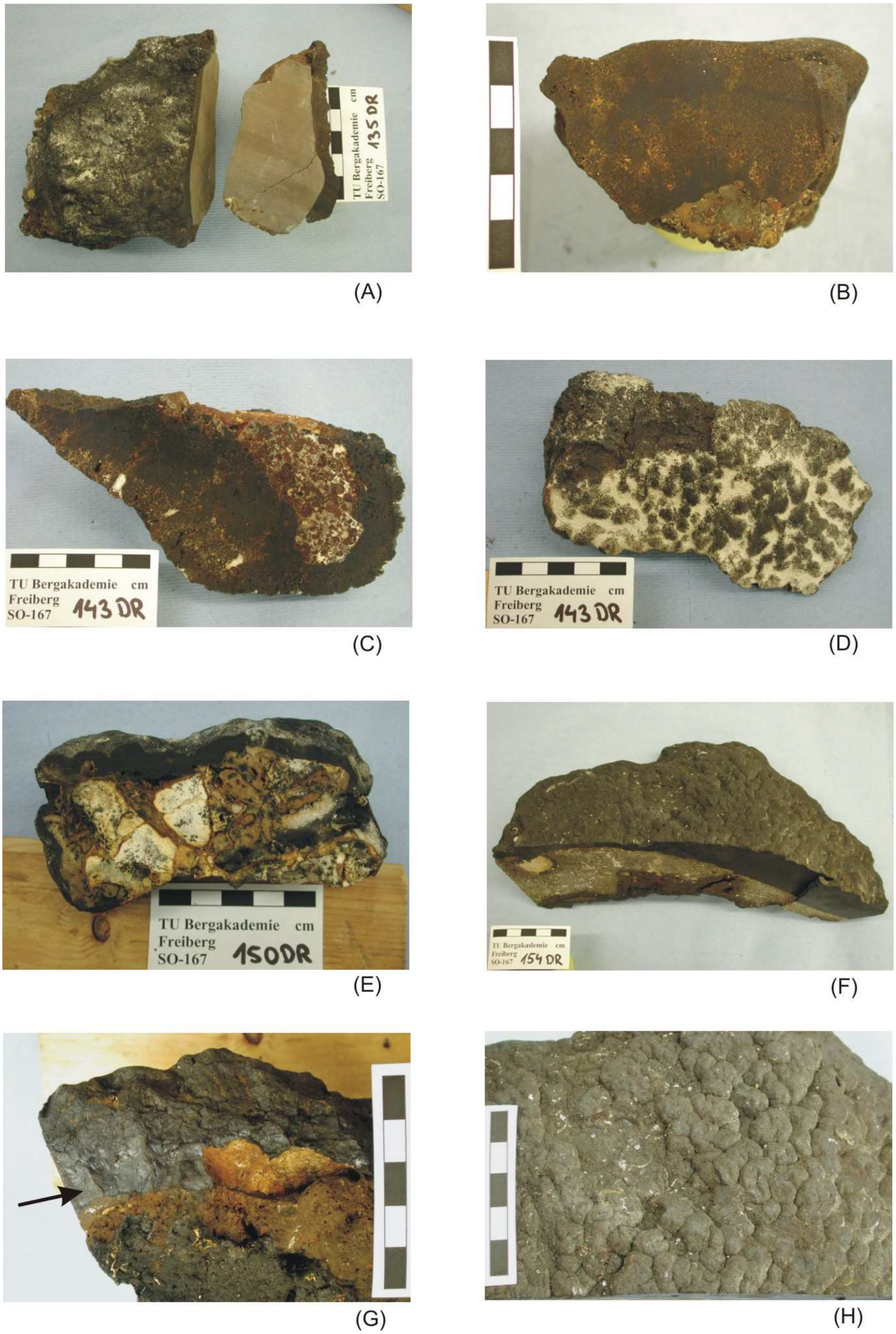

Fig. 10.3: Ferromanganese precipitates from Louisville Ridge (part I): (A) a thin Fe-Mn crust on mudstone; (B, C) thick porous crusts on volcaniclastics containing detritus; (D) botryoidal surface covered by sediment, this crust was buried in sediment and probably grew diagenetically in its last growth stage; (E) thin crust on shallow water carbonate; (F) 25 mm thick crust with a submetallic layer at its base (arrowed in G- hydrothermal formation?) and a botryoidal surface (H).

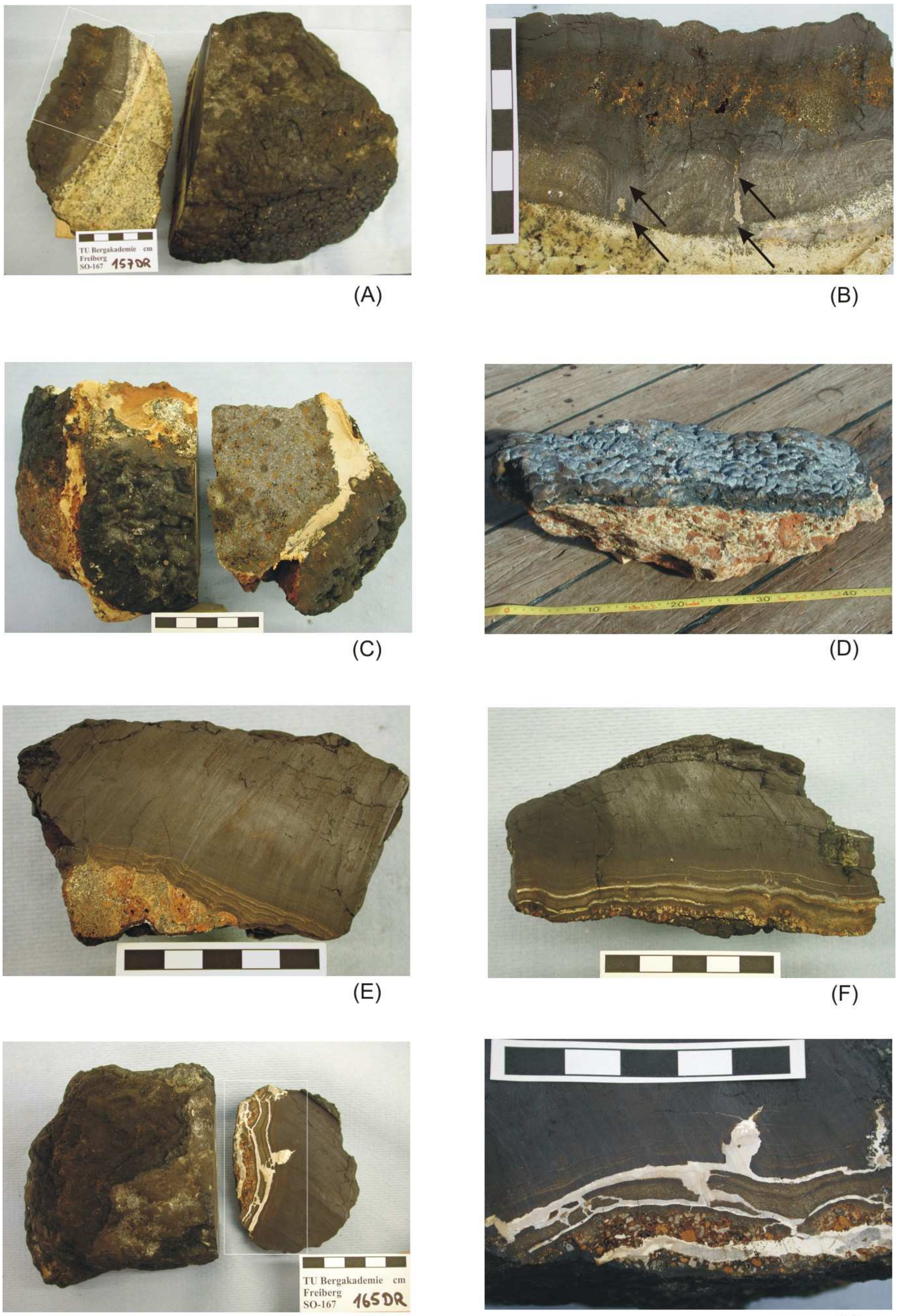

Fig. 10.4: Ferromanganese precipitates from Louisville Ridge (part II): (A) >50 mm thick crust with different layers from Volcano 37; (B) a close-up of A showing the dull layer at the base consists of fine, bent laminae, and the submetallic layer on top of it could represent hydrothermal discharge since it breaks through its substrate (arrows) and is related to fissures in the underlying volcanic rocks; (C) carbonate layers form in between Fe-Mn crusts and volcanic substrate; (D) a large block of conglomerate covered by up to 32 mm thick crusts sampled at 162-DR (Volcano 39); (E–H) thick crusts with fine laminae at their bases partly intergrown with carbonate veins were only recovered from stations 163- and 165-DR (H is a close-up of G), these laminae could result from hydrothermal or diagenetic processes.

1. a dense crust with submetallic lustre, about 10 mm thick forming the surface layer
2. a porous, dull-black crust with a relatively large content of detritus, about 12 mm thick
3. a dense crust similar to surface layer, about 8 mm thick
4. a dense crust but without submetallic lustre, displaying a layered texture of very fine, bent laminae, 16-20 mm thick.

Single “channels” of crust type 3 break through crust type 4 from the substrate (arrows in Fig. 10.4B). They seem to be connected with fissures in the substrate and could represent hydrothermal discharge. Dendritic Fe-Mn oxides also occur within the substrate, which is made up of strongly altered volcanic clasts (change to light greenish material) and carbonate veins.

Some ferromanganese crusts formed on layers of carbonate which are in between the crusts and the altered volcanics (Fig. 10.4C). It is suggested that the carbonates formed when the seamount summits were in shallow water. They may form crust-like layers (as in Fig. 10.4C) by disssolution and re-precipitation processes, or even precipitate such crusts directly from ambient seawater. The Fe-Mn crusts began to precipitate on the carbonates when the seamount sank to depths beneath the oxygen-minimum zone due to isostatic compensation.

Most of the ferromanganese crusts from the Louisville Ridge may be of hydrogenetic formation. Especially the thick crusts which occur from Volcano 34 southwards to Volcano 41, which will therefore represent processes in the South Pacific water column during the last tens of millions of years. This is because the sampled volcanoes of the Louisville Ridge range in age from about 66 Ma (Volcano 32) to about 42 Ma (Volcano 41; Lonsdale, 1988), and the crust formation may have started shortly after the formation of the respective volcano. The investigation of these crusts is important since only a few data for ferromanganese crusts from the South Pacific have been published so far (e.g., Hein et al., 2000), and will give new insights into the paleoceanographic development of this area. Moreover, some of the crusts have an appearance which is similar to hydrothermal crusts (e.g., Hein et al., 1990; Hodkinson et al., 1994; Kuhn et al., 2002). The chemical and mineralogical analysis of the Louisville Fe-Mn precipitates will therefore reveal the hydrothermal potential of the sampled sites.

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11. BIOLOGICAL INVESTIGATIONS

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11.1. Objectives of the Biology Program

Hard bottom biota of the deep sea have long been neglected in biological studies due to the difficulty in obtaining good samples. Trawls and box-corers cannot be used in such areas, as they would be badly damaged and consequently would not yield many animals. Remote picturing and collecting with ROVs and submersibles has been substituted in recent years. However, fauna has been collected as a by-catch in chain-sack dredges used by geologists for obtaining rocks from hard bottoms. Regardless of the great interest shown by biologists, this by-catch has not received due attention. It was therefore fundamental to our biological programme that we participated in the *SONNE* Cruise 167 to study the hard bottom by-catch of dredging along the Tonga arc, Valu Fa Ridge, Osbourn Trough and Louisville Ridge. Our main scientific interest was to visit the known hydrothermal sites on Valu Fa Ridge, as well as to prospect for new hydrothermal areas. The aim there was to describe the status of the known communities after 13 years and sample them.

Besides these objectives, which were already determined during the planning of the cruise, interest was also expressed by the National Institute of Water and Atmospheric Research (NIWA) at Wellington, New Zealand, to gather information on the pelagic communities in the surface waters of the SW Pacific, and to access certain planktonic organisms (e.g., squid). To meet these interests, a small plankton programme was undertaken over a large geographic area to investigate regional variations.

The biological material collected on this cruise will, wherever possible, be jointly studied by scientists at NIWA and the Senckenberg Research Institute. Taxa not covered by specialists at either Institution will be handled by scientists within these fields from other invited establishments. It is hoped that this cruise will be a starting point for long term co-operation on the deep sea environment of the SW Pacific.

11.2. Hydrothermal Fauna at Valu Fa Ridge

11.2.1. Introduction and Methods

Hydrothermalism in the Lau Basin was first investigated in 1989 by French scientists during dives with the submersible *NAUTILE*. A biological description of the area was given by Desbruyères et al. (1994). Before and after that general work, two taxonomic papers have been published that describe major components of the fauna. The inventory, however, is far from being complete. The biological studies on Valu Fa Ridge during the cruise *SONNE*-167 were aimed at gathering more information on the status of the benthic communities after a 13 year absence; (i) to map their distribution, (ii) to complement the faunistic inventory, and (iii) to search for new locations.

The large scale mapping of the communities was performed with the OFOS (Ocean Floor Observation System). This sled has video cameras for direct observation of the sea floor. Also on this sled was a remote operated camera owned by the Technical University of Freiberg, which took videos at higher resolution and could be switched on and off from the ship. Still pictures were taken on slide film whenever interesting structures and fauna appeared. On longer tracks, regular photographing ensured a documentation of the investigated area. These still pictures of high resolution were used for quantitative analysis of the fauna, and medium-sized animals can be recognised from these pictures. The slides contain a time code, which makes a correlation with the real time on the ship possible. By this means, pictures are referred to a latitude–longitude position as recorded by the OFOS sub-positioning system. The slides were projected on a screen, and the animals present were identified and counted. The resulting figures were entered into a database and used for the preliminary analyses presented in this report. The video-tapes served as back-ups and were used to verify the position of species on the sea floor, and for obtaining alternative views of these objects.

Sampling was performed with a video-controlled grab (GTVA) with a sub-positioning system. The grab can be operated from onboard the ship. Its advantage for biological purposes is its capability to gather large samples that contain rarer species. On soft bottoms, the area covered by the jaws and lids of the grab can serve for quantifying the larger benthos sampled. The grab is unstable in rough/steep terrain, where it can fall over and spill the sample before the jaws fully close. Small or no sample results under these conditions. All but a few recovered samples were fixed with formalin-seawater (4 %), with the remainder preserved in alcohol for genetic analyses. The following descriptions of the surveyed sites are based upon the still pictures taken with the OFOS, supplemented by information from the video-tapes and the few samples that were collected during the cruise.

11.2.2. The Vai Lili Field (72-OFOS, 65-GTVA)

The Vai Lili field was examined from one deployment of the OFOS at a position where activity was observed by French *NAUTILE*-dives in May 1989. A sample was taken with the video-controlled grab. Desbruyères et al. (1994) describe the Vai Lili field as very active, with venting in an area 400 m-long by 100 m-wide at 1764–1707 mbsl depth. The communities were dominated by snails belonging to the genera *Alviniconcha* and *Ifremeria*, which were closely associated with smokers. White and black smokers were both active, with the former releasing fluids at 240–309 °C and the latter at 330–400 °C. *Alviniconcha* was closest to the smokers, whereas *Ifremeria* and the barnacle *Eochionelasmus ohtai* preferred lower temperatures of 6–21 °C. Common vent crabs of the species *Austinograea alayseae* (Guinot, 1990) have also been described from this locality.

Neither active smokers nor the associated rich vagile faunas, as described by Desbruyères et al. (1994), were found during *SONNE*-167. Large temperature anomalies of ~0.12 °C and 0.20 °C occurred at two sites. Dense mussel (*Bathymodiolus)* and snail communities, with many living organisms, occupied both sites (Fig. 11.1). This was especially true for the second area, which has the clearly higher temperature anomaly showing that some venting still occurs. All snails had a dark colour, so they must belong to the genus *Ifremeria* rather than the light coloured *Alviniconcha* (see Desbruyères, 1997, for colour pictures). This again demonstrates that there was no high temperature venting at the localities observed by us. The video films showed that these mussel and snail clusters included a fairly large number of stalked barnacles and a few light coloured shrimps (presumably alvinocaridids). Also a lithodid (presumably *Paralomis hirtella*) was present at the sites. Two isolated occurrences of *Munidopsis* sp. were not related to vents or venting.

The remaining non-vent fauna was dominated by gorgonians (~37 % of all sightings). These avoided the areas of active venting, and their presence on pictures was therefore strikingly complementary to the sightings of mussels and snails (Fig. 11.2). This is especially true for the gorgonian frequency peaks. This observation confirms one made at Hine Hina (see below), and is totally in line with our current knowledge. The group "small filter feeders" with sighting numbers are next to the gorgonians. These, as shown above, include numerous polychaetes as well as a variety of animal groups, but the individuals are too small to be readily identifiable from pictures. All the remaining animal groups observed on the still pictures are listed in Table 11.1, together with the number of sightings.

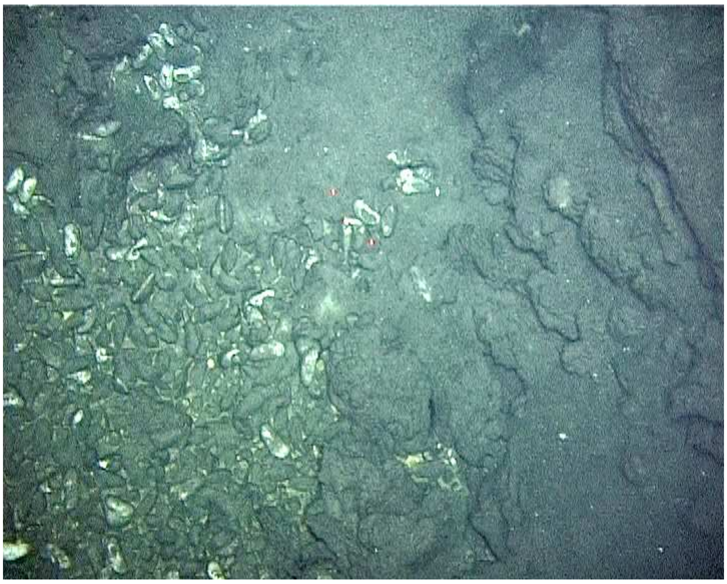

Fig. 11.1: Mussel field in the active part of the Vai Lili hydrothermal field. Mussels are dark in colour and occupy the lower left quadrant of the picture. Picture taken during 72-OFOS.

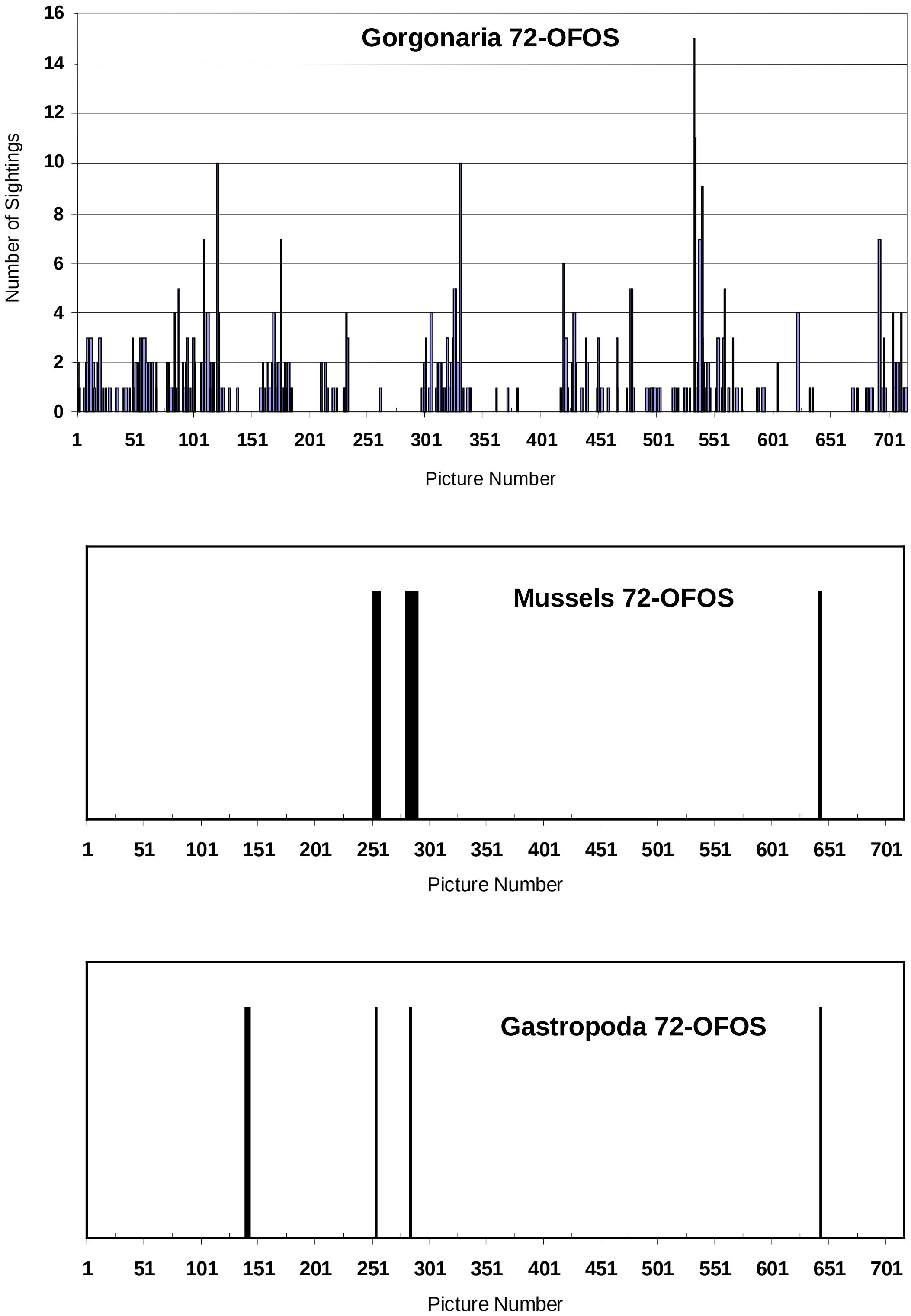

Fig. 11.2: Complementarity in the occurrence of gorgonians (non-hydrothermal), mussels and gastropods (both hydrothermal) on pictures from 72-OFOS.

Table 11.1: Animal group counts for each OFOS track

	Porifera	Gorgonaria	Antipatharia	Actinaria	Ceriantharia	Rhodalid	Small Filter feeders	Polychaeta	Barnacle	Shrimps	Hermit crab	Lithodidae	Munidopsis	Crinoidea	Ophiuroidea	Asteroidea	Holothuroidea	Fish
58 OFOS	3	54	1	30	0	0	334	87	1	5	13	3	8	1	23	2	1	1
59 OFOS	4	91	2	17	1	1	110	20	5	3	15	0	1	2	3	0	4	4
72 OFOS	15	455	3	14	7	10	117	7	174	19	0	0	2	36	6	0	3	1
73 OFOS	125	180	4	4	0	0	1533	1	0	15	0	0	0	8	72	1	2	1

In summary, our observations characterise the area as having very low temperature diffuse venting. The vent fauna was scarce and can only be found in a few places, whereas gorgonians were widely spread and indicate a particle-rich, predominantly hydrothermal, non-active biotope.

Because of the steep escarpments in the venting area, the collection of biological material was not very successful. At station 65-GTVA, the video-controlled grab retained only a small sample containing small snails preliminarily identified as *Desbruyeresia*. All further sampling attempts failed for reasons mentioned above.

11.2.3. Valu Fa Ridge, Segment 7 (56-OFOS)

The fauna of this area was dominated by large sessile filter-feeders, with gorgonians being the most common faunal elements. The gorgonians are seen on 40 % of the pictures taken with the OFOS. This amounts to a gorgonian every 1.4 minutes of the track, if they were evenly distributed. In fact, some clustering is observed so that the distribution is not even within the surveyed area, but the clusters are not very well separated from each other at their borders. Sponges are the next most common, but they are greatly outnumbered by gorgonians. They appear on average about every 10 minutes, but their distribution is also uneven and they tend to be present where there is a cluster of gorgonians. One picture at the beginning of the track shows a barnacle. The group is known from hydrothermal vents, but it is not certain that the depicted species is a vent-associate. The remaining fauna is typical of deep-sea hard bottom communities. The following animal groups have been observed (sorted by number of observations): shrimps- 10 times; ophiurids- 7 times; crinoids- 5 times; holothurians- 5 times; fish- 5 times; actinians- 4 times. This shows that the surveyed area is dominated by filter-feeders which need particle flow. Scavengers are much rarer, so a plentiful food supply is of limited importance. There are no obvious biological traces of the hydrothermal communities.

11.2.4. The Hine Hina Field (58-OFOS, 59-OFOS, 48-GTVA, 60-GTVA)

The Hine Hina Field was examined by two OFOS deployments at and around the locality of the French submersible dives with the *NAUTILE* in May 1989. Desbruyères et al. (1994) described this site as covering a relatively small area at 1832–1887 mbsl depth with moderate hydrothermal activity. Water at 20 °C was discharged from andesitic domes. The mussel later described as a new species, *Bathymodiolus brevior*, by von Cosel et al. (1994) was dominant. The fauna further consisted of barnacles, vestimentiferans (*Alaysia spiralis*), and the clam *Acharax alinae*.

During the OFOS tows we were unable to re-locate this active area, except for one spot containing living mussels associated with a high temperature anomaly (about 0.2 °C at 3 m distance; 22°31.972'S, 176°43.030'W; refer Sections 9.3.4 and 9.4.3 for further site details). Most of the clams and mussels were dead, but on some picture frames larger patches of live *Bathymodiolus* were noted, which were associated with *Munidopsis*, lithodid crabs (presumably *Paralomis hirtella*), and an unidentified species of shrimp. Snails of the genus *Ifremeria*, not reported by Desbruyères et al. (1994), were also seen but only one specimen could be identified from the pictures. Most of these animals, except the shrimp, are known to be typically hydrothermal and their few numbers are indicative of low and diffuse hydrothermal activity. Other lower temperature anomalies (up to 0.12 °C) away from this central spot were sometimes associated with single specimens of *Munidopsis*, but this does not necessarily have any significance. It is impossible to identify *Munidopsis*-species from the pictures as the genus is widespread in the deep sea. Its identity can only be surmised from its association with other hydrothermal species and/or its occurring in large numbers. Neither was the case here.

Only traces of other hydrothermal organisms could be found. *Ifremeria* shells were clustered in areas about 20 m across with normal water temperature, but these were situated among low temperature peaks (<0.1 °C). Within and around these, gastropod clusters including vesicomyid shells were spread. Some of the *Ifremeria*-assemblages looked as if they were composed of live animals. A sample taken with the video-controlled grab (48-GTVA) recovered dead shells in good natural condition. We conclude that these assemblages were still living at the time of the French sampling and died afterwards. The shells have not been transported since that time, and are not decomposed in some areas as seen in the pictures taken at the first OFOS-track (58-OFOS). The second track of the OFOS in the same general area showed more of these assemblages. The shells were mostly rolled over and not in a living position. The same is true for vesicomyid shells that also form distinct patches with fewer specimens. This suggests that they must have been moved or transported from their original beds. That again coincides with the fact that these shells were outside the region showing any temperature anomaly. A slight temperature variation of 0.08 °C was found, but well outside the assemblages of dead shells, and this was the only place in which *Munidopsis* was seen during 58-OFOS.

The remaining fauna was dominated by small filter feeders that were mostly too small to be identified. However, a few larger specimens appear to be tube-dwelling polychaetes. Gorgonians were only more numerous in the peripheral regions which do not overlap largely with active areas. This confirms observations made in other hydrothermal areas, where filter feeding gorgonians and sponges make up the outer zone of the community. They presumably use the particle flow generated by the inner vent community. Animal groups other than the molluscs observed in OFOS deployments are listed in Table 11.1, together with their frequency of observation. Among the animals not mentioned above, the ophiurids were more commonly observed in the first deployment. They live on sedimentary bottoms and eat organic matter from the sediment water interface, and indicate nutrient-rich conditions. They were observed exclusively outside the active areas.

The samples collected with the video-controlled grab complement the results obtained from the OFOS-observations. Though not numerous, a few additional hydrothermal organisms were collected. They include brachylepadid and neoverrucid barnacles, as well as a few limpets. These catches confirm that there is still some hydrothermal activity at the Hine Hina site.

11.2.5. The Southernmost Valu Fa Ridge Segment (73-OFOS)

A long track with the OFOS sled was undertaken on the southern part of the ridge in order to prospect for unknown venting sites. No vent fauna was discovered during the 3.7 km-long track. The subsequent analysis of about 500 pictures taken along this track gave the same result. It was noticeable that here the group "small filter feeders" tended to outnumber the gorgonians and sponges (~79 % of sightings compared to ~16 %, respectively). This suggests that the food availability may be less than at Hine Hina or Vai Lili and restricted, as at station 58-OFOS, to near-bottom particles. This was supported by ophiurids being more numerous in some places (see 58-OFOS above), and the next most common animals after the sponges and gorgonians. Remaining animal groups were seen occasionally. It seems, therefore, that scavengers do not play a major role in the examined area. Details are listed in Table 11.1.

11.2.6. The Southern Rift Fault Zone (77-OFOS)

A short track was completed in this area to the SW of Valu Fa Ridge, and was too short to allow a quantitative discussion. A total of only 96 pictures showed animals, and therefore the following discussion refers only to the presence or absence of features. The two most commonly observed animal groups were ophiurans (present on 40 pictures) and gorgonians (present on 30 pictures), followed by sponges (present on 11 pictures) and holothurians (present on 7 pictures). Polychaets, antipatharians and actinarians were seen on only 2–3 pictures. One shrimp sighting was questionable. Filter feeders and ophiurans rarely occurred on the same picture, but in two instances ophiurans and gorgonians were together. In contrast, holothurians and ophiurans were often in association, and in one instance with a sponge. This is understandable, as both echinoderms feed on sediment or fine particles at the sediment / water interface and are more common in areas where the sediment contains organic matter, whereas the filter feeders depend on particle flow in the water. The transect was too short to detect regional differences. However, gorgonians and antipatharians clustered at the beginning of the transect whereas the sediment feeders prevailed in the second half. A sediment base was present in the first half of the track, so this distribution of animals does not seem to be solely based on the bottom substrate. The sponges were not as specific, but tended to be a bit rarer in the second half. As already mentioned, these rough observations do not allow us to draw definitive conclusions, because a larger area with repeated changes in environmental type is necessary to confirm the observations. The observed benthic fauna did not contain any hydrothermal species.

11.3. Hard Bottom Fauna on the South Tonga Arc Volcanoes, Seamounts and Louisville Ridge

As already pointed out, the by-catch of geological dredgings is a valuable resource for getting pieces of information on the deep-sea hard bottom fauna. Our collection and studies concentrated on analysing the rock samples brought up with a chain-sack dredge. Because of the mesh size (7 cm), small specimens were retained only if the rocks had holes and crevices in which animals could hide. The benthic fauna attached to the rocks was examined. In cases where sediment was retrieved from a large catch, the sediment was sieved to secure the small endobenthic fauna. All sieving for macrofauna was done through screens with a minimum mesh size of 0.5 mm. The smaller material was collected, and a reasonable quantity sieved at 90µ for meiobenthic animals.

The material obtained from the dredges was fixed in formalin-seawater (4 %) and stored for later analysis in the laboratory. Larger animals were photographed in the laboratory to document the real life colours. Samples recovered with dredges are listed in Table 11.2.

11.4. Plankton

Plankton was collected at the sea surface in a simple open net with an 80 cm mouth diameter, 5 m-long, and a mesh-size of 250µ. The net was lowered over the side and towed for at least 10 minutes just below the sea surface at a ship speed of 1.5 knots. Sampling was done at night between 22:00 and 00:00 local time in order to collect organisms migrating to the surface at night. The success of this approach was confirmed by the presence of small myctophid fish in most catches. The sample was concentrated using fine meshed plankton sieves and fixed in a 4 % solution of formalin-seawater. Table 11.3 lists the plankton stations, their general location and environmental parameters of the water.

Table 11.2: Biological material recovered during dredging, *SONNE*-167

Station	Region	Depth	Short Description
1	Tonga Arc, Volcano 1-2	1147-1341 m	Dead shells
3	Tonga Arc, Volcano 1-2	630-787 m	Endolithic sponge
4	Tonga Arc, Volcano 1-2	330-472 m	Serpulids, ophiurid, bivalves
5	Tonga Arc, Volcano 1-2	612-719 m	Porifera
6	Tonga Arc, Volcano 1-2	420-434 m	Volcanic rock, attached animals
7	Tonga Arc, Volcano 1-2	158-314 m	Limestone with holes, attached animals; galatheid, ophiurid
8	Tonga Arc, Volcano 1-2	882-983 m	Hexactinellid sponge
14	Tonga Arc, Volcano 3	577-713 m	Galatheid
15	Tonga Arc, Volcano 3	564-740 m	Sponge/coral
17	Tonga Arc, Volcano 3	924-987 m	Sponge
18	Tonga Arc, Volcano 3	452-461m	Sponge
22	Tonga Arc, Volcano 4-6	1102-1184 m	Alcyonian, ophiuran, part of crionoid
23	Tonga Arc, Volcano 4-6	356-510 m	Diverse benthos incl. Galatheids
24	Tonga Arc, Volcano 4-6	604-798 m	Galatheid and sessile benthos
26	Tonga Arc, Volcano 4-6	925-972 m	Zoanthida, sponge, hydroid
27	Tonga Arc, Volcano 4-6	931-1005 m	Sponges
32	Tonga Arc, Volcano 4-6	485-651 m	Stones with attached fauna; gorgonian
33	Tonga Arc, Volcano 4-6	770-970 m	Various benthos; octopodid
36	Tonga Arc, Volcano 7	686-863 m	Sessile benthos
37	Tonga Arc, Volcano 7	646-808 m	Sessile benthos
38	Tonga Arc, Volcano 7	948-1106 m	Sessile benthos
39	Tonga Arc, Volcano 8	411-504 m	Comatulid crinoid, Scleractinian corals
43	Tonga Arc, Volcano 8	199-292 m	Various benthos
80	Tonga Arc, Volcano 14	809-979 m	Ophiurid, sessile fauna
81	Tonga Arc, Volcano 14	510-763 m	Holothurian
82	Tonga Arc, Volcano 14	796-929 m	Ophiurid, sessile fauna
83	Tonga Arc, Volcano 14	558-638 m	Polychaets
86	Tonga Arc, Volcano 15	1501-1676 m	Sediment, sieve remains
87	Tonga Arc, Volcano 15	1227-1323 m	Stalked crinoid, small benthos, sieve remains
88	Tonga Arc, Volcano 15	1079-1292 m	Unkown eggs?
89	Tonga Arc, Volcano 15	1216-1421 m	Sediment with forams
92	Tonga Arc, Volcano 16	673-752 m	Corals and other hard sessile benthos; gorgonian, ophiurid
93	Tonga Arc, Volcano 17	556-752 m	Shell
95	Tonga Arc, Volcano 17	321-458 m	Crustaceans from rocks
97	Tonga Arc, Volcano 18	507-717 m	Fish, corals, crustaceans, shells etc.
99	Tonga Arc, Volcano 19	914 m	Antipatharian and *Munida*; sediment, sieve remains
100	Tonga Arc, Volcano 19	469-595 m	Brachyura, ophiuroidea,hydroidea
102	Tonga Arc, Volcano 19	1049-1183 m	Coral, shells,sessile fauna; sediment, sieve remains
115	Osbourn seamount	2398-2607 m	Small shark in plastic bag
135	Louisville Ridge, Volcano 32	2345 m	Endolithic sponges?
139	Louisville Ridge, Volcano 33	2116-2541 m	Actinian and sponges
141	Louisville Ridge, Volcano 33	1797-2320 m	Sponges
143	Louisville Ridge, Volcano 34	1920-2203 m	Sponge
147	Louisville Ridge, Volcano 34	2177-2363 m	Sponge
149	Louisville Ridge, Volcano 35	2043-2560 m	Sessile benthos, polychaets
150	Louisville Ridge, Volcano 35	1847-2336 m	Sessile benthos, polychaets
154	Louisville Ridge, Volcano 36	1743-2695 m	Actinian
157	Louisville Ridge, Volcano 37	1921-2165 m	Tube worms, free living polychaet
158	Louisville Ridge, Volcano 37	1814-2107 m	Ophiurid
161/163	Louisville Ridge, Volcano 39	1620-2221 m	Sipunculid
162	Louisville Ridge, Volcano 39	1673-2221 m	Polychaet
163	Louisville Ridge, Volcano 39	1653-1840 m	Sessile benthos
168	Louisville Ridge, Volcano 40	1766-1925 m	Actinan
171	Louisville Ridge, Volcano 40	1481-2283 m	Sessile benthos

Table 11.3: Plankton stations during *SONNE*-167

Station	Date	Time Start	Time End	General Area	Position Start	Position End	Temp. [°C]	Sal. [ppt]
2	15.10.02	22:49:00	23:04:00	Tonga Arc	21°05.45'S 175°44.38'W	21°05.56'S 175°43.99'W	23.15	35.28
10	16.10.02	22:26:00	22:40:00	Tonga Arc	21°14.93'S 175°40.20'W	21°14.83'S 175°39.86'W	23.20	35.29
16	17.10.02	22:17:00	22:27:00	Tonga Arc	21°43.01'S 175°59.72'W	21°42.99'S 175°59.33'W	23.05	35.29
28	19.10.02	22:39:00	22:57:00	Tonga Arc	22°07.43'S 176°02.11'W	22°07.49'S 176°02.49'W	22.83	35.29
34	21.10.02	01:05:00	01:19:00	Tonga Arc	22°39.10'S 176°25.35'W	22°39.04'S 176°24.89'W	22.63	35.30
41	21.10.02	22:51:00	23:06:00	Pelorus Reef	22°49.65'S 176°27.89'W	22°49.45'S 176°27.47'W	22.63	35.30
49	23.10.02	21:28:00	21:41:00	Valu Fa Ridge	22°12.92'S 176°36.48'W	22°12.71'S 176°36.41'W	not noted	not noted
57	24.10.02	22:52:00	23:08:00	Valu Fa Ridge	22°26.28'S 176°41.69'W	22°25.88'S 176°41.86'W	23.75	35.37
61	25.10.02	23:44:00	00:00:00	Valu Fa Ridge	22°32.38'S 176°42.95'W	22°32.46'S 176°43.15'W	24.09	35.27
84	30.10.02	22:56:00	23:09:00	Tonga Arc	23°35.10'S 176°40.00'W	23°35.43'S 176°40.20'W	23.78	35.32
90	31.10.02	22:31:00	22:45:00	Tonga Arc	24°05.11'S 176°58.05'W	24°05.15'S 176°57.98'W	22.78	35.33
94	01.11.02	21:24:00	21:38:00	Tonga Arc	24°28.43'S 176°56.24'W	24°28.23'S 176°55.95'W	22.64	35.35
101	02.11.02	21:49:00	22:03:00	Tonga Arc	24°50.32'S 177°02.68'W	24°50.16'S 177°02.38'W	22.68	35.31
105	04.11.02	23:37:00	23:51:00	South Fiji Basin	28°40.54'S 177°59.35'E	28°40.59'S 177°59.00'E	20.88	35.64
109	06.11.02	00:25:00	00:38:00	South Fiji Basin	29°42.94'S 178°05.90'E	29°42.56'S 178°05.94'E	19.85	35.76
114	08.11.02	22:11:00	22:23:00	Osbourn Seamount	25°58.71'S 174°53.60'W	25°58.72'S 174°53.35'W	22.18	35.48
127	12.11.02	22:10:00	22:25:00	Osbourn Trough	25°47.61'S 172°36.43'W	25°47.26'S 172°36.23'W	22.40	35.55
133	15.11.02	21:43:00	21:55:00	Louisville Ridge	26°25.99'S 174°46.91'W	26°26.13'S 174°46.58'W	21.75	35.50
138	16.11.02	22:05:00	22:18:00	Louisville Ridge	27°32.76'S 173°59.80'W	27°32.85'S 173°59.54'W	21.41	35.58
144	17.11.02	23:03:00	23:21:00	Louisville Ridge	28°32.01'S 173°22.78'W	28°31.93'S 173°23.03'W	21.42	35.49
148	19.11.02	02:00:00	02:15:00	Louisville Ridge	31°18.71'S 172°17.97'W	31°19.05'S 172°17.78'W	19.35	35.64
155	20.11.02	22:15:00	22:27:00	Louisville Ridge	33°44.25'S 171°23.96'W	33°44.22'S 171°24.12'W	17.03	35.35
160	22.11.02	21:55:00	22:08:08	Louisville Ridge	37°01.98'S 169°45.88'W	37°02.16'S 169°46.18'W	15.17	35.15
166	24.11.02	01:43:00	02:00:00	Louisville Ridge	37°31.67'S 169°25.19'W	37°31.96'S 169°25.47'W	15.21	35.17
170	25.11.02	01:44:00	01:57:00	Louisville Ridge	37°43.88'S 168°55.71'W	37°43.70'S 168°55.33'W	15.16	35.19
174	26.11.02	21:34:30	21:49:00	Transit to Wellington	38°54.42'S 171°12.80'W	38°54.14'S 171°12.63'W	15.37	35.12
175	27.11.02	21:33:00	21:43:00	Transit to Wellington	40°04.96'S 176°52.49'W	40°04.82'S 176°52.57'W	15.89	35.36
176	28.11.02	21:37:00	21:51:00	Transit to Wellington	41°09.08'S 177°52.94'E	41°08.79'S 177°52.65'E	15.82	35.42

Notes: Dates and times are UTC; temperature and salinity are averages for the surface values during the tow period

The plankton samples could not be analysed onboard in detail, but this will be done at NIWA. The preliminary results given here summarise the impressions we got by looking at the samples in the jars. Regionally, the composition of the plankton was quite different. Samples recovered along the south Tonga arc were predominantly composed of small holopelagic crustaceans (copepods, amphipods and euphausids). There were relatively few, but small, gelatinous plankton. In one instance, a seawater strider (*Halobates*) was captured. The picture changed in the South Fiji Basin. There, large salps and pyrosomes were floating at the surface and the gelatinous component was markedly increased. Changes also occurred along the Louisville Ridge, with a southwards increase in plankton density. First the number of crustaceans increased dramatically, soon followed by the presence of gelatinous plankton with many hydromedusae within the samples.

11.5. References

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Appendices

APPENDIX 1: SHIPBOARD SCIENTIFIC PARTY CONTACT DETAILS

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APPENDIX 2: STATION AND PETROLOGY SAMPLE DESCRIPTIONS

station	on bottom: day time / lat / long / depth; off bottom: day time / lat / long / depth	sample number: description	sample
DR: dredge PN: plankton net GTV: TV-grab OFOS: video sled also noted: brief site details	**on bottom:** day time lat long depth **off bottom:** day time lat long depth *day time = UTC	NB: each lithology from a station is designated **Unit A**, **Unit B**, etc for classification. NB: **Unit A** at 01 DR is **NOT** the same as **Unit A** at 03 DR or any other station South Tonga Arc Volcanoes: Stations 01–43, 80–102 Valu Fa Ridge: Stations 44–79 South Fiji Basin (LINZ): Stations 103–113 Osbourn Trough: Stations 121–132 Louisville Ridge: Stations 114–120, 133–173 Transit: Stations 174–176 Dredges used: Ship's med. curved + teeth: all DR except below Kiel large rectang. serrated: 107-108, 119-120, 147-152 DR Kiel small rectang. serrated: 153 DR IFREMER circular + teeth: 154-157 DR	TS: thin section TS (gl): TS + glass GC: chemistry block Ar: Ar/Ar block CC: coarse crush & hand pick
01 DR **Volc 1: upper W flank, NW cone**	15.10 07:35 21°02.61' S 175°51.02' W 1341 m 15.10 09:05 21°02.41' S 175°50.71' W 1147 m	1: 13 x 8 x 7 cm black olivine-plagioclase basalt. 15% plagioclase phenocrysts to 3 mm across, 10% greenish-yellow olivine phenocrysts (~iddingsite?) to 1mm across, trace dark green pyroxene phenocrysts to 3 mm across. 10% vesicles to 4 mm across. Weathered, discoloration to 1 cm depth. A clast from a conglomerate. **Unit A**.	TS, GC
		2: 13 x 10 x 4 cm **Unit A**. Most vesicles are circular and large (5 mm across).	
		3: 10 x 8 x 7 cm **Unit A**. Vesicles intermediate between 01DR-01 and 01DR-02.	
		4: 10 x 9 x 6 cm black pyroxene-olivine-plagioclase basalt. 10% plagioclase phenocrysts to 2 mm across, 10% green-yellow olivine phenocrysts to 2 mm across (most are 1 mm), 5% dark green pyroxene phenocrysts to 3 mm across. 15% circular vesicles to 4 mm across. Weakly weathered surface. Clast from a conglomerate. **Unit B**.	TS, GC
		5: 10 x 9 x 6 cm **Unit B**. Surface somewhat more weathered, with discoloration to 1 cm depth.	TS, GC
		6: 17 x 10 x 5 cm **Unit A**.	
		7: 9 x 6 x 5 cm **Unit B**. Surface weathered to 1 mm depth.	
		8: 10 x 10 x 5 cm **Unit B**. Olivine is light green and seems fresher than in the other samples.	
		9: 13 x 13 x 8 cm **Unit B**. Jointed lava block from a flow.	
		10: 7 x 7 x 6 cm black olivine-pyroxene basalt. 10% greenish-yellow olivine phenocrysts to 5 mm across (most are 2 mm), 15% dark green pyroxene phenocrysts to 8 mm across (most are 2 mm), no plagioclase. 10% small vesicles <1 mm across. Weathered surface, with discoloration to 1.5 cm depth. **Unit C**.	TS, GC
		11: 10 x 10 x 10 cm rounded boulder, probably Unit A but contains only 5% olivine. **Unit D**.	TS, GC
		12: 22 x 16 x 15 cm volcaniclastic conglomerate. Weathered boulders and pebbles of Units A-D to 20 cm across, sub-angular to rounded, in a light brown silty clay matrix. Also numerous pebbles up to 3 cm across of fresh to nontronite altered (yellow-green) pumice. **Unit E**. **NB:** All samples clearly came from Unit E conglomerate.	
02 PN	15.10 10:49	Plankton net, trawled at 1.6 knots.	

	21°05.45' S 175°44.38' W 0 m 15.10 11.04 21°05.56' S 175°43.99' W 0 m		
03 DR Volc 1: NE ridge, mid flank	15.10 11:45 21°06.16' S 175°43.30' W 787 m 15.10 12:37 21°06.40' S 175°43.32' W 630 m	1: 13 x 12 x 8 cm black plagioclase basalt. Contains 25% plagioclase phenocrysts up to 3 mm across and traces of dark green pyroxene up to 1 mm across. Non-vesicular. Essentially fresh, with very weak surface weathering. **Unit A**. 2: 13 x 12 x 8 cm **Unit A**. 3: 13 x 9 x 9 cm **Unit A**. 4: 18 x 8 x 7 cm black plagioclase basalt. Contains 10% plagioclase phenocrysts up to 2 mm across. Vesicles (20%) are up to 3 mm across. Essentially fresh, with very weak surface weathering. **Unit B**. 5: 11 x 7 x 6 cm **Unit B**. 6: 11 x 9 x 5 cm **Unit B**, with bands of vesicles in distinct sizes. 7: 16 x 8 x 7 cm **Unit B**. 8: 11 x 8 x 6 cm **Unit B**. 9: 16 x 9 x 9 cm **Unit B**, with bands of vesicles in distinct sizes. Appears to have fewer plagioclase phenocrysts (5%), and may be a separate unit. 10: 8 x 6 x 6 cm dark grey aphyric dacite. Strongly sheared lava with a glassy black rind up to 1 cm thick. **Unit C**. 11: 13 x 13 x 5 cm **Unit C**. 12: 9 x 6 x 6 cm **Unit C**. 13: 11 x 10 x 4 cm **Unit C**, with a particularly well-developed glass crust. 14: 8 x 8 x 8 cm black plagioclase andesite. Contains 10% plagioclase phenocrysts up to 3 mm across. A well-rounded dense boulder with a weathered surface covered by yellow-orange volcaniclastic sand. **Unit D**. 15: Bulk sample of 5 pebbles of glassy plagioclase basalt, each 9 x 5 x 5 cm. They contain 20% plagioclase phenocrysts up to 3 mm across set in a glass-rich matrix. Very weakly weathered surfaces. **Unit E**.	TS, GC TS, GC TS (gl), GC TS, GC
04 DR Volc 1: W post-caldera cone, upper W flank	15.10 13:42 21°08.88' S 175°46.00' W 472 m 15.10 14:26 21°08.76' S 175°45.80' W 330 m	1: 9 x 8 x 7 cm black aphyric basalt. Trace plagioclase phenocrysts up to 2 mm across. Locally up to 10% small vesicles typically 2 mm across. Jointed block with a weathered surface but fresh interior. **Unit A**. 2: 9 x 7 x 7 cm black plagioclase basalt. Contains 10% small plagioclase phenocrysts up to 2 mm across. Tending scoriaceous, with 20% irregularly-shaped small vesicles, and appears to have been a bomb. Weakly weathered surface. **Unit B**. 3: 13 x 8 x 7 cm **Unit B**. 4: 15 x 13 x 10 cm **Unit B**, but grades to denser non-vesicular lava near the boulder core. Also minor Fe-Si staining on the surface. 5: 15 x 11 x 8 cm **Unit B**, but with a woody or ropey texture. Possibly a different unit. 6: 16 x 7 x 7 cm **Unit B**, as for 04DR-5. 7: 10 x 7 x 7 cm dark grey plagioclase basalt. Contains 10% plagioclase phenocrysts up to 2 mm across. Essentially non-vesicular, with only a few small vesicles. Minor Fe-Si staining on the surface. **Unit C** (may be a degassed	TS, GC TS, GC TS, GC

		variant of Unit B).	
		8: 12 x 9 x 4 cm black aphyric dacite. A dense lava with a curved lower surface (pillow?), flow jointed. Moderately weathered surface but fresh interior. Very similar to Unit C at 03DR. **Unit D**.	TS, GC
05 DR Volc 1: SW ridge, mid flank	15.10 15:29 21°10.79' S 175°45.41' W 719 m 15.10 16:18 21°10.56' S 175°45.20' W 612 m	1: 13 x 8 x 7 cm black aphyric basalt. Contains trace plagioclase phenocrysts. Fresh, with flow aligned scoriaceous bands a few cm wide. **Unit A**.	TS, GC
		2: 12 x 10 x 6 cm **Unit A**. Surface weakly weathered.	
		3: 15 x 11 x 9 cm **Unit A**. Surface weakly weathered.	
		4: 11 x 8 x 7 cm black plagioclase basalt. 5% plagioclase phenocrysts to 2 mm across. Highly vesicular (50%) and tending scoriaceous, with vesicles up to 1 cm long. Weakly weathered surface. **Unit B**.	TS, GC
		5: 14 x 12 x 7 cm **Unit B**. Surface is more weathered and yellow in places, may be an older lava.	
		6: 13 x 7 x 5 cm black plagioclase andesite. 5% plagioclase phenocrysts to 2 mm across. Dense. An older lava, with weakly weathered surface on which is yellow volcaniclastic sediment. **Unit C**.	TS, GC
		7: 12 x 7 x 6 cm dark grey plagioclase andesite. 5% plagioclase to 2 mm across, 5% elongated vesicles to 1 cm long. Weakly weathered surface. **Unit D**.	
		8: 7 x 7 x 4 cm dark grey aphyric andesite. As for Unit D apart from being aphyric. **Unit E**.	
		9: 11 x 7 x 4 cm dark grey aphyric andesite. As for Unit E, but with traces of fresh olivine. **Unit F**.	
		10: 15 x 9 x 9 cm dark grey aphyric andesite. Vesicular (30%) with vesicles to 5 cm long. Weakly weathered with local orange-red Fe staining. **Unit G**.	TS, GC
		11: 10 x 8 x 5 cm dark grey aphyric andesite. As for Unit G, but more vesicular (40%) and rimmed by orange-red volcaniclastic sediment. **Unit H**.	
		12: 10 x 7 x 4 cm dark grey plagioclase andesite. 5% plagioclase phenocrysts to 2 mm across. A dense non-vesicular jointed block. Weakly weathered surface. **Unit I**.	TS, GC
		13: 15 x 7 x 7 cm **Unit I**, but more weathered.	
		14: 12 x 8 x 4 cm dark grey plagioclase andesite. 5% plagioclase phenocrysts to 2 mm across. Dense and non-vesicular. A 1 cm thick glassy surface rind. May be a textural variant on Unit I. Weakly weathered. **Unit J**.	TS, GC
		15: 9 x 6 x 5 cm **Unit J**.	
		16: 30 x 18 x 10 cm black plagioclase dolerite. 10% plagioclase phenocrysts to 2 mm across. Very dense, non-vesicular, and jointed. Spheroidal weathering to 3 cm depth, with Cu mobilised and deposited as small blue-green crystals. **Unit K**.	TS, GC
		17: 15 x 10 x 8 cm **Unit K**.	
		18: 18 x 16 x 9 cm black plagioclase basalt. 5% plagioclase phenocrysts to 2 mm across. 10% small vesicles to 2 mm across and often more like pull-aparts. A dense block with a thin quench-jointed rim (hexagonal to 2 mm depth). Weathered surface. **Unit L**.	TS, GC
		19: 15 x 10 x 8 cm black gabbro. Approximately 60% plagioclase and 40% black pyroxene with a grain size of 1 mm. Anisotropic fabric. Deeply weathered with clay alteration to 2-3 cm depth, but a fresh core. **Unit M**.	TS, GC
		20: 15 x 5 x 5 cm speckled gabbro. Approximately 60% albitised plagioclase and 40% chloritised pyroxene, with	TS, GC

		much very fine grained magnetite. Layered, with 2 mm thick beds. Weathered surface. **Unit N**.	
06 DR Volc 2: intra-caldera cone, lower W flank	16.10 00:33 21°18.39' S 175°42.40' W 434 m 16.10 02:06 21°18.37' S 175°42.37' W 420 m	1: Bulk sample of 5 small deeply weathered lava fragments, each 5 x 3 x 2 cm. Protoliths not recognisable, and too small for geochemistry. 2: Bulk sample of 4 deeply weathered yellow aphyric pumice pebbles, each 7 x 4 x 3 cm. Interpreted as drift pumice. **NB:** Dredge recovered several large boulders of coralline debris of interest to the biologists.	
07 DR Volc 2: intra-caldera cone, upper W flank	16.10 02:54 21°18.28' S 175°42.01' W 314 m 16.10 04:00 21°18.15' S 175°42.00' W 158 m	A repeat of 06DR further upslope. Dredge recovered several large boulders of coralline debris, including yellow-brown silty mud with concretions. Much sampled by the biologists. The lack of even deeply weathered lava pebbles suggests inactivity for a long time.	
08 DR Volc 2: SW ridge, mid flank	16.10 05:03 21°20.10' S 175°43.91' W 983 m 16.10 05:58 21°19.97' S 175°43.72' W 882 m	1: 16 x 15 x 10 cm black aphyric basalt. Trace plagioclase phenocrysts to 2 mm across. Several large irregular vuggy voids but otherwise dense. Deeply weathered, with yellow-brown clay to 2 cm depth; fresh core. **Unit A**. 2: 12 fragments of dark grey aphyric pumice, each ~5 x 4 x 2 cm. Glassy but dense. Honeycomb vesicles up to 5 mm and highly vesiculated. Two fragments are somewhat paler (different unit?). **Unit B**.	TS, GC
09 DR Volc 1: inner NE caldera wall	16.10 08:09 21°07.78' S 175°43.68' W 474 m 16.10 09:07 21°07.66' S 175°43.71' W 325 m	1: 10 x 10 x 8 cm black plagioclase-pyroxene basalt. 20% plagioclase phenocrysts to 5 mm across (most 3 mm), 10% dark green pyroxene phenocrysts to 3 mm across. 10% small vesicles <1 mm across and a few large ones to 5 mm in length. A massive flow. Surface weakly weathered with a thin MnOx rind <0.1 mm thick. **Unit A**. 2: 24 x 16 x 7 cm **Unit A**. 3: 13 x 12 x 9 cm **Unit A**.	TS, GC
		4: 9 x 5 x 4 cm, as for Unit A but has a glassy surface crust up to 1.5 cm thick. **Unit B**. 5: 8 x 5 x 2 cm **Unit B**.	TS, GC
		6: 12 x 9 x 5 cm black aphyric basalt. Trace plagioclase phenocrysts to 2 mm across. Highly vesicular with 50% small vesicles to 2 mm across and flow banded. Weakly weathered surface to 1 mm depth and some clay in interior vugs. **Unit C**. 7: 21 x 9 x 7 cm **Unit C**.	TS, GC
		8: 10 x 10 x 5 cm black plagioclase basalt. 10% plagioclase phenocrysts to 2 mm across. 40% small vesicles to 2 mm across and arranged in flow bands. Glassy crust 1.5 cm thick. Yellow-orange stained surface <1 mm thick. **Unit D**. 9: 9 x 7 x 3 cm **Unit D**. 10: 10 x 7 x 5 cm **Unit D**.	TS, GC
		11: 19 x 19 x 19 cm **Unit D**. A rounded boulder with no glassy crust. 12: 18 x 14 x 9 cm brown-grey volcaniclastic conglomerate. Small weathered pebbles of rounded lava, up to 5 mm across, in a silty clay matrix. **Unit E**. 13: 8 x 6 x 2 cm dark grey silty claystone. A rounded boulder of compacted volcanic ash. **Unit F**.	TS, GC

		14: Two 6 x 4 x 3 cm pebbles of glassy plagioclase basalt. Probably **Unit B**.	
10 PN	16.10 10:26 21°14.93' S 175°40.20' W 0 m 16.10 10:40 21°14.83' S 175°39.86' W 0 m	Plankton net, trawled at 1.6 knots.	
11 DR Volc 2: NE ridge, mid flank	16.10 11:16 21°15.58' S 175°38.71' W 500 m 16.10 12:15 21°15.60' S 175°38.71' W 497 m	1: 5 fragments of deeply weathered basaltic lava. Largest is 8 x 7 x 3 cm and may just be usable for geochemistry with care. All are coated with MnOx. **Unit A**. 2: 4 small fragments of pale grey aphyric pumice, each 2 x 1 x 1 cm. Probably drift pumice. **Unit B**. 3: Yellow-orange volcaniclastic conglomerate. Clasts of deeply weathered lava up to 5 mm across in a silty clay matrix. Locally coralline. Encrusted with MnOx. **Unit C**.	
12 DR Volc 2: W Ridge, SE cone	16.10 13:45 21°21.33' S 175°40.91' W 522 m 16.10 14:30 21°21.13' S 175°40.78' W 386 m	1: 3 small fragments of variably weathered lava. The largest is 4 x 4 x 2 cm and less weathered. **Unit A**. 2: About 30 small pumice pebbles, variably yellow to dark grey, fresh to deeply weathered. All aphyric. **Unit B**. 3: Numerous fragments of coralline debris with bryozoans, etc. Minor volcaniclastic conglomerate attached to some. Slight MnOx staining (younger than 11DR). **Unit C**.	
13 DR Volc 3: SW ridge S cone, mid flank	17.10 03:11 21°50.22' S 175°58.42' W 1097 m 17.10 03:48 21°50.10' S 175°58.29' W 996 m	1: 15 x 12 x 9 cm pale grey aphyric pumice. Minor devitrification banding from pale grey to dark grey (dark grey beds <1 mm wide), and locally pinkish. 10% elongated flow aligned vesicles up to 5 mm long. Locally woody textured. Fresh. **Unit A**. 2: 11 x 8 x 6 cm **Unit A**. 3: 14 x 9 x 7 cm **Unit A**. 4: 12 x 9 x 7 cm **Unit A**, with 2 cm wide dark grey vesicular band on one side. 5: 12 x 9 x 5 cm **Unit A**. 6: 11 x 10 x 7 cm **Unit A**, with well-developed woody texture on one side. 7: 15 x 15 x 9 cm **Unit A**.	TS, GC TS, GC TS, GC
14 DR Volc 3: inner NE caldera wall, S cone	17.10 06:06 21°47.02' S 175°55.91' W 713 m 17.10 07:04 21°46.86' S 175°55.82' W 577 m	1: 7 x 6 x 5 cm pale grey aphyric pumice. Trace of black cubic crystals, pyroxene? Dense block with 5% vesicles to 1 mm across, but many fractures. Grades to woody texture. Surface weathered yellow-brown to 0.2 mm depth. **Unit A**. 2: 6 x 5 x 4 cm **Unit A**, mostly woody textured. 3: 8 x 8 x 5 cm **Unit A**, all woody textured. 4: 7 x 5 x 4 cm black aphyric dacite. 10% small fractures to several cm long. Somewhat glassy but mostly crystalline. Weakly weathered surface. **Unit B**. 5: 8 x 6 x 4 cm **Unit B**, grading to woody textured Unit A on one side. Thus these two units appear to be textural (devitrification) variants. 6: 7 x 5 x 5 cm **Unit B**. Flow banded variant of Units A and B, with bands a few mm to 2 cm wide. 7: 7 x 5 x 4 cm black aphyric dacite. Mostly glassy, but a few somewhat devitrified though still black bands. **Unit C**. 8: 6 x 5 x 3 cm **Unit C**. 9: 3 pieces, the largest being 7 x 6 x 5 cm. **Unit C** grading to woody textured Unit A on one surface, ~1.5 cm thick.	TS TS, GC TS, GC

		Almost certainly Units A, B, C are textural variants, but check magma mixing here. 10: 10 x 5 x 4 cm black aphyric dacite. Probably **Unit B** (as for 14DR-04). Has small fragments of Unit A pumice embedded in its surface. Could be a xenolith block of older dacite. 11: 9 x 8 x 4 cm grey aphyric dacite. Largest pebble in a volcaniclastic conglomerate. Flow banded. Surface weathered to yellow-brown clays. **Unit D**. 12: 6 x 4 x 3 cm **Unit D**.	 TS, GC TS, GC
15 DR Volc 3: dome between cones, W flank	17.10 08:04 21°46.02' S 175°56.61' W 740 m 17.10 08:56 21°45.91' S 175°56.41' W 564 m	1: 12 x 9 x 7 cm black pyroxene-plagioclase andesite. 20% plagioclase phenocrysts to 5 mm across (mostly 3 mm), 5% dark green pyroxene phenocrysts to 3 mm across and sometimes in clusters with plagioclase, traces of gabbroic xenoliths. 10% vesicles <2 mm across. Surface weakly weathered yellow-brown to 1 cm depth. **Unit A**. 2: 20 x 13 x 13 cm **Unit A**. 3: 13 x 10 x 8 cm **Unit A**. 4: 13 x 9 x 7 cm **Unit A**. 5: 6 x 6 x 5 cm black aphyric dacite. Contains 5% subangular to rounded altered xenoliths of quartz-plagioclase lava ranging to gabbro (?). One gabbro has large pyroxene phenocrysts. The dacite has few vesicles but many fractures. **Unit B**. 6: 9 x 8 x 5 cm pale grey aphyric pumice. Locally dark grey "blobs" and bands to 2 cm across (devitrified domains). 10% elongated vesicles to 3 mm across. Fresh. Probably the same as 13DR Unit A. **Unit C**. 7: 10 x 7 x 5 cm **Unit C**. 8: 8 x 7 x 5 cm **Unit C**. 9: 7 x 6 x 4 cm **Unit C**, with a rounded xenolith 2 cm across of black plagioclase basalt. 10: 9 x 8 x 5 cm cream yellow aphyric dacite. Strong devitrification banding to dark grey dense vesicular bands 1mm to 3 cm wide. Band contacts are sharp. Possibly a Unit C variant, but seems more weathered. **Unit D**. 11: 10 x 9 x 7 cm grey plagioclase dacite. 5% plagioclase phenocrysts to 2 mm across. Dense block, but with 50% very small (<1 mm) vesicles. Has a wispy texture grading to yellow-brown that may be devitrification or incipient weathering. Weathered surface to 0.1 mm depth. An older unit. **Unit E**. 12: 5 x 4 x 4 cm **Unit E**. 13: 30 x 25 x 7 cm brown volcaniclastic conglomerate. Clast-supported, with pebbles of subrounded variably altered/weathered lavas to 5 cm across (most are 5 mm) set in silty clay. Overall boulder is well-rounded. **Unit F**.	TS, GC TS, GC (also the xenolith) TS, GC TS, GC
16 PN	17.10 10:17 21°43.01' S 175°59.72' W 0 m 17.10 10:27 21°42.99' S 175°59.33' W 0 m	Plankton net, trawled at 1.6 knots.	
17 DR Volc 3: W ridge N cone, mid	17.10 11:06 21°43.40' S 175°58.71' W 987 m	1: 13 x 10 x 9 cm pale grey aphyric pumice. Non-vesicular near the surface, grading to a vuggy core with >50% vesicles. Surface weakly weathered with yellow staining to 0.2 mm depth. **Unit A**.	TS, GC

flank	17.10 11:42 21°43.40' S 175°58.48' W 924 m	2: 8 x 5 x 5 cm **Unit A**. 3: 11 x 6 x 4 cm **Unit A**, devitrification banded with dark grey aphyric dacite. Bands range from a few mm to 3 cm thick and have sharp contacts. 4: 19 x 13 x 11 cm **Unit A**, as for 17DR-03 but dark grey bands up to 5 cm thick. 5: 12 x 6 x 4 cm black aphyric dacite. Dense lava with numerous fractures. Not glassy. Contains several ovoid pale grey pumice patches up to 2 cm across. **Unit B**. 6: 8 x 6 x 3 cm **Unit B**. 7: 17 x 12 x 9 cm **Unit A**, with rare thin (mm - 2 cm thick) dark grey bands. 8: 14 x 14 x 7 cm **Unit A**, as for 17DR-07. 9: 17 x 12 x 8 cm dark grey aphyric dacite. Trace plagioclase phenocrysts to 2 mm across. Strongly jointed in parallel planes 3-4 mm apart (pull-aparts). Surface weathered yellow-brown to 0.2 mm depth and slight MnOx dusting. **Unit C**. 10: 4 pieces, largest 7 x 6 x 3 cm, of weathered and jointed lava (dolerite?). Surface weathered dark grey-brown. Clearly old, and equivalent in age to Unit C. **Unit D**. 11: 5 pieces, largest 6 x 5 x 1 cm, of orange-red hematite-stained lava. Variably weathered, and too small for geochemistry. **Unit E**.	 TS, GC TS, GC TS, GC
18 DR Volc 3: inner SE crater wall, N cone	17.10 12:40 21°43.83' S 175°56.41' W 461 m 17.10 13:08 21°43.89' S 175°56.29' W 452 m	1: 10 x 9 x 9 cm black plagioclase dacite (?). 5% plagioclase phenocrysts to 2 mm across. 10% very small vesicles (<0.5 mm across) in curvilinear bands. Soft and fractured lava. Surface weathered brown to 5 mm depth. An angular clast from the conglomerate. **Unit A**. 2: 12 x 11 x 6 cm **Unit A**. 3: 9 x 8 x 5 cm **Unit A**. 4: 8 x 7 x 6 cm **Unit A**. 5: 10 x 7 x 7 cm **Unit A**, which includes some pumiceous xenoliths to 5 mm across. 6: 8 x 7 x 4 cm **Unit A**. 7: 7 x 5 x 5 cm black plagioclase dacite (?). 5% plagioclase phenocrysts to 2 mm across. Fine scale devitrification banding to grey bands 1-2 mm thick. Much fractured block. Probably a textural variant of Unit A. **Unit B**. 8: 6 x 6 x 5 cm **Unit B**, with devitrified bands tending pale grey-cream. 9: 9 x 9 x 7 cm dark grey plagioclase basalt. 5% plagioclase phenocrysts to 2 mm across. 60% vesicles to 2 mm across, yet overall rock is quite dense. Glassy matrix. A weakly weathered subrounded clast from the conglomerate. **Unit C**. 10: 7 x 7 x 4 cm brown plagioclase andesite. 25% plagioclase phenocrysts to 2 mm across. 5% irregularly shaped vesicles grading to pull-aparts. Surface weathered to 1 mm depth. **Unit D**. 11: 12 x 10 x 8 cm volcaniclastic conglomerate. Weathered subrounded clasts of Units A and B to 5 cm across (most 5 mm), matrix supported. Matrix is yellow-brown silty clay. **Unit E**. 12: 13 x 10 x 5 cm **Unit E**, but finer grained with the largest clasts being only 5 mm across. 13: 8 x 8 x 5 cm dark grey plagioclase dacite. 5% plagioclase phenocrysts to 2 mm across. Also 5% of brown crystals to 3 mm across (possibly iddingsite after olivine?), but with no real crystal shape. A Unit A variant? **Unit F**.	TS, GC TS, GC TS, GC TS, GC TS, GC

		NB: All samples are clasts from the old weathered volcaniclastic conglomerate Unit E.	
19 DR Volc 3: inner SE caldera wall, S cone	17.10 14:20 21°49.09' S 175°56.03' W 410 m 17.10 14:52 21°49.20' S 175°55.94' W 293 m	1: 8 x 8 x 4 cm light grey aphyric pumice. 10% vesicles to 2 mm across. Relatively dense block. Surface weakly weathered and locally stained yellow-brown. **Unit A**. 2: 7 x 4 x 3 cm **Unit A**, but interior of clast has >70% flow aligned very long (many cm) vesicles. 3: 14 x 12 x 9 cm **Unit A**, but with devitrification banding to dark grey 5-15 mm thick bands. All band contacts are sharp and subparallel. 4: 19 x 14 x 10 cm **Unit A**, as for 19DR-03. Thickest bands are 3 cm wide. 5: 13 x 7 x 6 cm dark grey to grey pumice. Darkest part of the devitrification banding in Unit A. Bands are up to 3 cm wide. No light grey bands on these blocks, and may be a separate unit. Surface still only weakly weathered. **Unit B**. 6: 12 x 11 x 7 cm **Unit B**. 7: 10 x 7 x 5 cm **Unit B**. **NB:** Units A and B are interpreted as the source of the widespread young pumice found at other nearby stations. Here they probably occur as a dome or flow carapace.	TS, GC TS, GC TS, GC
20 DR Volc 4: SW ridge S cone, upper flank	18.10 12:17 22°09.01' S 176°15.23' W 584 m 18.10 13:54 22°09.04' S 176°15.26' W 609 m	1: 11 x 8 x 5 cm black plagioclase andesite. 10% plagioclase phenocrysts to 2 mm across. 30% flow aligned elongated vesicles up to 1 cm long and 1 cm across. Grades to light grey devitrified variant within 3 cm of the surface. Surface is weakly weathered. **Unit A**. 2: 11 x 8 x 5 cm **Unit A**. 3: 13 x 9 x 7 cm **Unit A**, but clearly a pillow or tube. 4: 17 x 10 x 6 cm **Unit A**. 5: 3 pieces of older weathered lavas, the largest being 7 x 4 x 1 cm, with one being pumiceous, one dacite, and the last more mafic. Too small to attempt processing onboard. **Unit B**. 6: 4 pieces of weathered pumice, with 3 being aphyric and the last having devitrification banding. **Unit C**.	TS, GC TS, GC
21 DR Volc 4: NE ridge S cone, mid flank	18.10 15:01 22°07.51' S 176°13.20' W 1119 m 18.10 15:35 22°07.62' S 176°13.41' W 1010 m	1: 15 x 11 x 8 cm black plagioclase basalt. 15% plagioclase phenocrysts to 2 mm across. A dense block with small incipient pull-aparts grading to elongated vesicles. Essentially fresh, but weak yellow-orange weathering along fractures to 2 cm depth. Surface only weakly weathered. **Unit A**. 2: 11 x 9 x 5 cm **Unit A**. 3: 14 x 10 x 6 cm black plagioclase basalt. 5% plagioclase phenocrysts to 2 mm across. 20% vesicles to 5 mm across. Locally slightly glassy matrix. A dense subrounded bomb or pillow. Surface weakly weathered with orange-brown stains, but essentially fresh. **Unit B**. 4: 6 x 5 x 3 cm **Unit B**. 5: 14 x 8 x 5 cm black aphyric andesite. 20% vesicles to 4 mm long, often elongated and flow aligned. A dense subrounded block. **Unit C**. 6: 5 x 5 x 3 cm **Unit A**. Somewhat more weathered, and possibly an older lava. 7: 5 x 4 x 2 cm dark grey plagioclase basalt. 10% plagioclase phenocrysts to 2 mm across. A dense non-vesicular pebble. Surface weathered yellow-brown to 0.2	TS, GC TS, GC TS, GC

			mm depth. **Unit D**.	
22 DR Volc 4: inner NE crater wall, NW volc ridge	18.10 18:50 22°01.68' S 176°17.50' W 1184 m 18.10 19:35 22°01.58' S 176°17.27' W 1102 m	1:	12 x 8 x 6 cm pale grey aphyric pumice. 10% vesicles grading to flow aligned vuggy voids >1 cm across. Surface weakly weathered with local yellow-brown staining. **Unit A**.	TS, GC
		2:	15 x 12 x 9 cm **Unit A**.	
		3:	10 x 7 x 7 cm black plagioclase andesite. 5% plagioclase phenocrysts to 2 mm across. 20% very small (<1 mm across) vesicles, although rock feels dense. Surface weathered with mild discoloration (or devitrification banding?) to 1.5 cm depth. Fragmenting near the surface. **Unit B**.	TS, GC
		4:	12 x 9 x 8 cm **Unit B**. A textural variant with a darker black glassy core and more devitrified light grey surface.	TS, GC
		5:	12 x 9 x 7 cm **Unit B**, as for 22DR-04 but mostly light grey.	
		6:	11 x 6 x 4 cm **Unit B**, as for 22DR-05.	
		7:	Two pieces, each 6 x 4 x 3 cm, of dark grey aphyric pumice. 20% vesicles to 2 mm across. **Unit C**.	
		8:	14 x 11 x 8 cm black plagioclase andesite. 20% plagioclase phenocrysts to 2 mm across. A dense massive lava block. Surface weakly weathered with minor orange Fe staining. **Unit D**.	TS, GC
		9:	8 x 6 x 4 cm **Unit D**.	
		10:	10 x 8 x 8 cm black plagioclase basalt. 10% plagioclase phenocrysts to 2 mm across. 15% vesicles to 2 mm across, often elongated and grading to pull-aparts. Locally a glassy matrix. Surface weakly weathered with yellow-brown clays in pull-aparts. **Unit E**.	TS, GC
		11:	19 x 9 x 7 cm grey plagioclase dacite. 5% plagioclase phenocrysts to 2 mm across. 20% small vesicles to 2 mm across. An older and more weathered unit with MnOx dusting on a weathered surface. **Unit F**.	
		12:	10 x 7 x 5 cm **Unit F**.	
		13:	13 x 6 x 5 cm black plagioclase basalt. 10% small plagioclase phenocrysts to 1 mm across. 10% small vesicles <1 mm across. Surface weakly weathered. **Unit G**.	TS, GC
		14:	20 x 18 x 10 cm diorite. 70% white plagioclase crystals to 2 mm across and 30% elongated black hornblende and/or pyroxene crystals to 2 mm across. A smooth rounded boulder. Deeply weathered yellow-brown almost to the core, with only thin bands unweathered. **Unit H**.	TS, GC
		15:	6 x 3 x 3 cm gabbro. 50% grey altered pyroxene crystals and 50% plagioclase crystals, grain size for both is 1-2 mm. Deeply weathered to 1 cm depth. **Unit I**.	
		16:	12 x 5 x 3 cm grey-brown pyroxene-plagioclase andesite. Deeply weathered, with all pyroxene gone to Fe oxides and the matrix to clay. Encrusted by 0.2 mm of MnOx. **Unit J**.	
23 DR Volc 4: W flank of summit dome, NE cone	18.10 20:59 22°03.69' S 176°13.41' W 510 m 18.10 22:03 22°03.70' S 176°12.98' W 356 m	1:	10 x 8 x 3 cm grey pumice. Trace black crystals to 1 mm across (pyroxene?). 30% vesicles grading to vugs 2 cm long. Very lightweight and marginal for geochemistry. Surface deeply weathered yellow-brown and discolored to the core. **Unit A**.	TS
		2:	12 x 12 x 8 cm grey aphyric pumice. 30% vesicles grading to vugs 3 cm long. Devitrification banded to dark grey-black at core, with no sharp contacts. Glassy patches 2 mm across stand out against the lighter matrix	TS, GC

		(some could be plagioclase, but probably not). Surface weathered yellow-brown to 2 cm depth. **Unit B**. 3: 8 x 8 x 5 cm banded pumice. Black bands have 5% plagioclase phenocrysts to 2 mm across and are scoriaceous, yellow weathered bands have lenses of the black material and grade to grey and then black. Surface weathered yellow-brown to 1 cm depth. **Unit C**. 4: 13 x 12 x 3 cm **Unit C**, but mostly weathered yellow bands with dark glassy patches 2 cm across and traces of plagioclase phenocrysts to 2 mm across. Magma mixing. 5: 10 x 9 x 7 cm dark grey plagioclase andesite. 5% plagioclase phenocrysts to 2 mm across. A dense non-vesicular pillow with cooling joints. Surface weathered yellow-brown and discolored to 5 mm depth. **Unit D**. 6: 14 x 10 x 8 cm **Unit D**. 7: 13 x 9 x 6 cm black aphyric basalt. Trace plagioclase phenocrysts to 2 mm across. 10% vesicles to 3 mm across but irregular in shape and grade to vuggy voids, giving a scoriaceous appearance. Surface weathered yellow-brown to 5 mm. **Unit E**. 8: 18 x 10 x 6 cm **Unit E**. A pillow sector. Surface weakly weathered yellow-brown to 2 mm depth and resting on a grey-brown quench crust (not glassy) that persists to 1.5 cm depth. 9: 8 x 6 x 5 cm black plagioclase basalt. 5% plagioclase phenocrysts to 2 mm across, trace dark green pyroxene phenocrysts to 2 mm across. Non-vesicular. Locally finely banded black to dark grey on a sub-mm scale (devitrification). Surface weathered yellow-brown and discolored to 5 mm depth. **Unit F**.	 TS TS, GC TS, GC TS, GC
24 DR Volc 5: NE ridge NW cone, upper flank	19.10 03:05 22°05.01' S 176°05.26' W 798 m 19.10 03:46 22°05.10' S 176°05.41' W 604 m	1: 9 x 7 x 6 cm black pyroxene basalt. 30% dark green pyroxene phenocrysts to 5 mm across. 10% vesicles to 3 mm across. Surface weathered yellow-brown and discolored to 5 mm depth; interior fresh. Locally 0.1 mm MnOx on surface. **Unit A**. 2: 16 x 16 x 8 cm **Unit A**. 3: 18 x 12 x 11 cm black pyroxene basalt. 15% dark green pyroxene phenocrysts to 5 mm across. A dense lava block with flow aligned curvilinear pull-aparts grading to vuggy voids 2 cm long. Surface weathered yellow-brown and discolored to 2 mm depth and along fractures. **Unit B**. 4: 13 x 10 x 10 cm **Unit A**, but 20% vesicles up to 6 mm across. 5: 10 x 9 x 7 cm pale grey aphyric pumice. Generally few vesicles, and locally grading to woody texture. Surface weakly weathered yellow-brown to 5 mm depth. **Unit C**. 6: 7 x 6 x 5 cm **Unit C**, with dark grey devitrification banding. Darker bands to 3 mm thick near core, and minor variations in colour elsewhere. 7: 7 x 5 x 4 cm **Unit C**, as for 24DR-06.	TS, GC TS, GC TS, GC TS, GC
25 DR Volc 5: SW ridge N cone, mid flank	19.10 05:04 22°01.89' S 176°02.69' W 1044 m 19.10 05:51 22°01.80' S 176°02.49' W 878 m	1: 12 x 8 x 6 cm black pyroxene-plagioclase andesite. 10% plagioclase phenocrysts to 2 mm across, 5% dark green pyroxene phenocrysts to 2 mm across (most 1 mm across) with dark specks in it. 15% vesicles to 1 cm across. Surface weakly weathered with pale brown clay in some vesicles. **Unit A**. 2: 12 x 9 x 6 cm as for Unit A, but 10% small vesicles to 3 mm across grading to incipient pull-aparts. Also surface locally dusted with MnOx or with adhering yellow-	TS, GC

		brown volcaniclastic sandstone. Clearly an older lava. **Unit B**. 3: 13 x 9 x 7 cm black pyroxene-plagioclase andesite. 10% plagioclase phenocrysts and 5% pyroxene phenocrysts both to 5 mm across. A dense massive lava block with some flow planes. Surface weathered yellow-brown to 1 cm depth, and MnOx dusting on top of that. **Unit C**. 4: 10 x 9 x 5 cm **Unit C**. 5: 12 x 7 x 6 cm **Unit C**. 6: 15 x 7 x 7 cm black plagioclase andesite. 10% plagioclase phenocrysts to 2 mm across, trace dark green pyroxene phenocrysts to 2 mm across (most 1 mm). A very dense massive lava, with some flow planes. Surface weathered to 5 mm depth, and MnOx up to 0.1 mm thick on top of that. **Unit D**.	 TS, GC TS, GC
26 DR Volc 5: SW ridge NE flat-top, mid flank	19.10 07:31 22°08.10' S 176°00.91' W 972 m 19.10 08:07 22°07.97' S 176°00.77' W 925 m	1: 5 x 4 x 3 cm black pyroxene basalt. 5% dark green pyroxene phenocrysts to 2 mm across. 20% vesicles to 2 mm across, but a dense block. Surface weathered yellow-brown to 1 mm depth with fresh interior. Too small to safely process onboard, and possibly contamination from previous dredge(s) as it was the only fragment found. **Unit A**.	
27 DR Volc 5: WSW ridge NE flat-top, mid flank	19.10 09:20 22°07.51' S 176°01.57' W 1005 m 19.10 09:51 22°07.42' S 176°01.49' W 931 m	1: 13 x 13 x 8 cm pale grey aphyric pumice. A subrounded boulder, with 10% vesicles grading to vuggy voids 5 mm across. Surface weakly weathered yellow-brown to 1 mm depth. **Unit A**. 2: 11 x 7 x 6 cm **Unit A**, but woody textured. 3: 12 x 8 x 6 cm **Unit A**, grading to woody texture. 4: 10 x 8 x 5 cm light to dark grey aphyric pumice. Finely devitrification banded on mm to 5 mm scale. 10% vesicles to 2 mm across. Surface weakly weathered yellow-brown. Probably a textural variant of Unit A. **Unit B**. 5: 8 x 8 x 7 cm **Unit B**. 6: 7 x 4 x 3 cm yellow-brown aphyric pumice. Woody textured. Probably a more weathered clast of **Unit A**. 7: 6 x 3 x 1 cm cream to light grey to dark grey aphyric pumice. Devitrification banded, with grey bands on mm scale but cream >3 cm thick. Woody textured. Probably a **Unit A** textural variant. 8: 3 pieces, each 7 x 5 x 4 cm, of yellow-brown aphyric pumice. Rounded and weathered. Probably drift pumice. **Unit C**. 9: 3 pieces, the largest being 4 x 3 x 3 cm, of black highly vesicular (40% to 2 mm across) scoriaceous basalt. Surface weakly weathered with discoloration to 1 mm depth. **Unit D**.	TS, GC TS, GC
28 PN	19.10 10:39 22°07.43' S 176°02.11' W 0 m 19.10 10:57 22°07.49' S 176°02.49' W 0 m	Plankton net, trawled at 1.6 knots.	
29 DR Volc 5: WSW ridge	19.10 12:08 22°09.93' S 176°07.50' W 1230 m	1: 11 x 11 x 7 cm brown clay. Very deeply weathered volcaniclastic conglomerate with subrounded pebbles to 5 mm across in a yellow silty clay matrix. No chance for geochemistry. **Unit A**.	

central flat-top, mid flank	19.10 12:51 22°09.88' S 176°07.43' W 1183 m		
30 DR Volc 5: SW ridge SW flat-top, mid flank	19.10 14:12 22°13.79' S 176°08.00' W 983 m 19.10 14:37 22°13.71' S 176°07.94' W 903 m	1: 5 x 4 x 3 cm pale grey cream pumice. Contains traces of a black mineral (pyroxene?) and possibly plagioclase (but could be sand stuck in vesicles). A rounded pebble which is vesicular only at its core. Surface weathered yellow-brown and somewhat discoloured to core. Cannot rule out contamination from previous dredges. **Unit A**.	
31 DR Volc 6: N ridge E flat-top, mid flank	19.10 19:38 22°19.71' S 176°07.29' W 817 m 19.10 20:27 22°19.99' S 176°07.34' W 568 m	1: 9 x 7 x 3 cm yellow-brown plagioclase andesite. 5% plagioclase phenocrysts to 2 mm across and traces of dark green pyroxene phenocrysts to 3 mm across. Dense, with traces of vesicles. Deeply weathered with much discoloration to the core and black MnOx coating up to 0.1 mm thick. **Unit A**. 2: 4 x 2 x 1 cm black aphyric basalt. Contains traces of plagioclase phenocrysts up to 2 mm across. A thin piece from a flow top. Fresh, with a weakly weathered surface. Probably contamination from previous dredges. **Unit B**. 3: 3 x 3 x 2 cm light grey to dark grey aphyric pumice. Devitrification banded at mm scale. Weakly weathered. Probably contamination from previous dredges. **Unit C**.	
32 DR Volc 6: ENE ridge E flat-top, upper flank	19.10 21:21 22°21.59' S 176°05.41' W 651 m 19.10 22:07 22°21.58' S 176°05.61' W 485 m	1: Slices from flat and rounded boulders of volcaniclastic conglomerate. Subangular to subrounded clasts of various lavas (red plagioclase basalt, black pyroxene-plagioclase andesite, black plagioclase andesite) and pyroxene-plagioclase diorite set in a silty clay matrix. Beds of this material are interbedded with sandy beds 2 cm thick. The conglomerate boulder is yellow-brown and weathered. Six slices with the largest clasts were taken for Kiel. **Unit A**.	
33 DR Volc 6: NE ridge E flat-top, mid flank	19.10 23:49 22°20.05' S 176°05.66' W 970 m 20.10 01:52 22°20.11' S 176°06.02' W 770 m	1: 10 x 9 x 6 cm black aphyric basalt. Very rare plagioclase and dark green pyroxene phenocrysts both up to 2 mm across- only 1 or 2 of these per block. 20% circular vesicles to 3 mm across. A massive lava flow. Surface weathered yellow-brown, and along fractures. **Unit A**. 2: 12 x 11 x 8 cm **Unit A**. A pillow with yellow-brown weathering to 1 mm depth. Columnar jointing within the pillow. 3: 13 x 10 x 3 cm **Unit A**. A pillow sector with preserved surface lacking any glass. Surface weathered yellow-brown to 1 cm depth, and locally 0.1 mm of MnOx on top of that. 4: 9 x 8 x 7 cm grey aphyric pumice. Weak devitrification banding in shades of grey but not clearly defined bands. 10% vesicles grade to 5 cm long pull-aparts and vugs. A pillow. Surface weakly weathered yellow-brown to a depth of 1 cm. **Unit B**. 5: 8 x 7 x 5 cm **Unit B**.	TS, GC TS, GC TS, GC
34 PN	20.10 13:05 22°39.10' S 176°25.35' W 0 m 20.10 13:19 22°39.04' S 176°24.89' W 0 m	Plankton net, trawled at 1.5 knots.	

35 DR **Volc 7:** **SW ridge** **N cone,** **mid flank**	20.10 14:10 22°38.67' S 176°25.56' W 1161 m 20.10 14:57 22°38.60' S 176°25.28' W 961 m	1: 12 x 10 x 8 cm cream grey pumice. Traces of small black crystals to 1 mm across (pyroxene?). Ranges from few vesicles to 30% vesicles to woody pumice domains. Weak devitrification banding in shades of darker grey, with diffuse boundaries. Surface weakly weathered yellow-brown and discolored to 1 cm depth. **Unit A**. 2: 8 x 5 x 4 cm **Unit A**. 3: 11 x 7 x 6 cm grey aphyric pumice. Devitrification banding in shades of blue-grey to glassy black, often with black ovoids 1 cm across within dark grey bands. 20% vesicles to 5 mm across. Surface weathered yellow-brown to 1.5 cm depth, and with slight MnOx dusting. Older than 35DR-01. **Unit B**. 4: 4 pieces of **Unit B**, each 8 x 4 x 2 cm. 5: 9 x 5 x 4 cm brown aphyric pumice. Vesicles grade to 1 cm across vugs and voids. Deeply weathered and old. **Unit C**. 6: 4 pieces of volcaniclastic conglomerate. Clasts of weathered lavas to 5 mm across. Entire block is coated in MnOx 2 mm thick. Very old, but probably the only sample really from this volcano. **Unit D**.	TS, GC TS, GC
36 DR **Volc 7:** **E flank N** **cone, mid** **flank**	20.10 16:30 22°37.48' S 176°20.41' W 863 m 20.10 17:39 22°37.42' S 176°20.77' W 686 m	1: 11 x 7 x 6 cm pale grey pumice. Traces of black crystals to 1 mm across (pyroxene?). Elongated vesicles up to 1 cm long. Surface and fractures are weathered yellow-brown, with weak discoloration to the core (worst stops at 5 mm depth). Hard (weak silicification). **Unit A**. 2: 14 x 14 x 7 cm **Unit A**. Block is a pillow sector. 3: 8 x 6 x 5 cm **Unit A**. 4: 10 x 8 x 6 cm as for Unit A, but devitrification banded with grey bands up to 1 cm wide with sharp boundaries. **Unit B**. 5: 9 x 7 x 6 cm dark grey aphyric pumice. 20% small elongated vesicles to 1 mm across. Black glassy core grading to a grey surface. Surface weathered brown to 1 mm depth. **Unit C**. 6: 10 x 7 x 4 cm **Unit C**. 7: 12 x 8 x 5 cm as for Unit C, but essentially all black and glassy. Vesicles grade to vugs and voids 1.5 cm across. Relatively fresh, with only weakly weathered brown surfaces. **Unit D**. 8: 10 x 9 x 4 cm **Unit D**. 9: 3 pieces of weathered black aphyric basalt, the largest being 4 x 3 x 2 cm. All are vesicular. Probably contamination from 33DR which had very similar basalts. **Unit E**.	TS, GC (1) TS, GC (4) TS, GC (5) TS, GC (7)
37 DR **Volc 7:** **SW flank** **S cone,** **upper** **flank**	20.10 18:59 22°43.52' S 176°23.61' W 808 m 20.10 20:14 22°43.18' S 176°23.46' W 646 m	1: 16 x 7 x 5 cm cream pumice. Traces of black crystals to 1 mm across (pyroxene?). 50% honeycomb vesicles to 5 mm across. Surface weakly weathered yellow-brown to 3 mm depth. **Unit A**. 2: 7 x 6 x 4 cm **Unit A**. Has irregular devitrification banding in dark grey bands 1 cm thick. 3: 11 x 10 x 7 cm pale grey pumice. Traces of black crystals to 1 mm across (pyroxene?). 20% vesicles grading to 2 cm long vugs. Devitrification banded with 2 cm thick grey bands with sharp contacts. Surface weakly weathered yellow-brown to 3 mm depth. **Unit B**. 4: 8 x 7 x 6 cm **Unit B**. 5: 12 x 8 x 6 cm brown-grey aphyric pumice. 10% vesicles grading to 3 cm long vugs. Dark grey devitrification bands 3 cm wide with very sharp contacts. Surface	TS, GC (1) TS, GC (3) TS, GC (5)

		weathered yellow-brown, but weakly weathered throughout and with slight MnOx dusting. **Unit C**. 6: 10 x 9 x 7 cm yellow-brown aphyric pumice. 20% vesicles grading to irregular vugs 5 mm across. Devitrication banding in yellow-brown and black, with black bands 2 cm thick and glassy. Surface weathered yellow-brown, but weakly weathered throughout and with slight MnOx dusting. **Unit D**. 7: 8 x 6 x 3 cm **Unit D**.	 TS, GC
38 DR Volc 7: SW valley S cone, mid flank	20.10 21:49 22°44.20' S 176°24.12' W 1106 m 20.10 23:01 22°43.75' S 176°23.99' W 948 m	1: 12 x 9 x 7 cm cream pumice. Trace black crystals to 1 mm across (pyroxene?). 10% vesicles to 3 mm long. Surface weathered yellow-brown to 2 mm depth and weakly discolored interior. **Unit A**. 2: 12 x 10 x 9 cm pale grey aphyric pumice. Very rare traces of black crystals to 1 mm across (pyroxene?). Ranges from non-vesicular to 30% vesicles to vugs 5 mm across. Surface weathered yellow-brown to 2 mm depth, with slight discoloration inside of that. **Unit B**. 3: 13 x 11 x 6 cm **Unit B**. 4: Numerous small pieces, each 3 x 2 x 2 cm, of black aphyric pumice. Glassy, with 30% vesicles to 3 mm across. Probably a devitrification variant of Unit B. Surface weakly weathered yellow-brown. **Unit C**.	TS, GC TS, GC
39 DR Volc 8: inner N caldera wall	21.10 07:24 22°49.29' S 176°25.00' W 504 m 21.10 08:00 22°49.07' S 176°24.99' W 411 m	1: 20 x 9 x 8 cm black plagioclase andesite. 10% plagioclase phenocrysts to 2 mm across, trace dark green pyroxene to 2 mm across. A massive jointed lava block. Surface weathered yellow-brown to 5 mm depth, and a thin (<0.1 mm) MnOx dusting. **Unit A**. 2: 21 x 15 x 9 cm **Unit A**, but a pillow sector with a glassy crust up to 5 mm thick below the weathered surface. 3: 16 x 12 x 7 cm **Unit A**. 4: 9 x 6 x 5 cm black plagioclase andesite. 30% rounded plagioclase phenocrysts to 2 mm across, set in a black slightly glassy matrix. A massive non-vesicular block. Surface weathered yellow-brown to 5 mm depth, and a thin 0.1 mm MnOx dusting. **Unit B**. 5: 6 x 5 x 4 cm **Unit B**. 6: 8 x 6 x 5 cm black pyroxene-plagioclase andesite. 25% plagioclase phenocrysts to 3 mm across, 5 % dark green pyroxene phenocrysts to 3 mm across. A dense massive lava block. Surface weathered yellow-brown to 1 mm depth. **Unit C**.	TS, GC TS, GC TS, GC
40 DR Volc 8: WNW ridge, mid flank	21.10 09:21 22°49.69' S 176°28.49' W 1139 m 21.10 10:12 22°49.52' S 176°28.51' W 1075 m	1: 9 x 5 x 4 cm black pyroxene-plagioclase andesite. 10% plagioclase phenocrysts to 2 mm across, 5% dark green pyroxene phenocrysts to 3 mm across. A dense massive jointed lava block. Surface weakly weathered to dark grey. **Unit A**. 2: 16 small pebbles, each about 5 x 3 x 2 cm, of varied lithologies including aphyric andesite, Unit A, 25% plagioclase dacite, 10% plagioclase basalt. Pieces are too small to process onboard. All are subrounded and weakly weathered (as for Unit A). **Unit B**.	TS, GC
41 PN	21.10 10:51 22°49.65' S 176°27.89' W 0 m 21.10 11:06 22°49.45' S 176°27.47' W 0 m	Plankton net, trawled at 1.8 knots.	

42 DR Volc 8: WNW ridge, upper flank	21.10 11:33 22°49.79' S 176°27.00' W 471 m 21.10 12:25 22°49.80' S 176°26.84' W 400 m	1: 15 x 9 x 5 cm black plagioclase basalt. 15% plagioclase phenocrysts to 2 mm across, trace dark green pyroxene phenocrysts to 2 mm across. 15% large irregularly shaped vesicles up to 1 cm across. A pillow sector with no glass crust. Surface weakly weathered yellow-brown, but clearly young. **Unit A**. 2: 13 x 13 x 3 cm as for 42DR-01, but surface weathered to 2 mm depth and along fractures. An older flow. **Unit B**. 3: 17 x 7 x 4 cm as for 42DR-02, but a denser and less vesicular flow of similar age. 5% small vesicles grade to incipient pull-aparts. Surface weathered yellow-brown to 2 mm depth. **Unit C**. 4: 14 x 14 x 5 cm black plagioclase basalt. 10% plagioclase phenocrysts to 2 mm across. 10% vesicles to 4 mm across. A pillow sector. Surface weathered to 5 mm depth and overlain locally by a weathered volcaniclastic conglomerate. An older flow. **Unit D**. 5: 9 x 9 x 6 cm black aphyric andesite. Traces of plagioclase phenocrysts to 2 mm across. 10% small vesicles in zones surrounding incipient pull-aparts, otherwise a dense block. Surface weakly weathered orange-brown, with estimated age similar to Unit B. **Unit E**. 6: 13 x 6 x 5 cm grey pyroxene-plagioclase dolerite. 10% plagioclase phenocrysts to 1 mm across, 5% dark green pyroxene phenocrysts to 2 mm across. Dense and very hard block with columnar jointing. Clearly a dyke. Surface weakly weathered yellow-brown to 1 mm depth. **Unit F**. 7: 8 x 7 x 4 cm black plagioclase dolerite(?). 20% small plagioclase phenocrysts to 1 mm across, traces of dark green pyroxene phenocrysts to 5 mm across (!). Dense and hard block with strong jointing. Surface weakly weathered yellow-brown to 1 mm depth. **Unit G**. 8: 9 x 7 x 4 cm black pyroxene-plagioclase basalt. 15% plagioclase phenocrysts to 2 mm across, 10% dark green pyroxene to 2 mm across. A dense and hard block with few joints. Surface weakly weathered yellow-brown to 1 mm depth. **Unit H**. 9: Two pieces, largest being 9 x 5 x 3 cm, of weathered yellow-brown volcaniclastic conglomerate. Deeply weathered lava pebbles to 5 mm across. **Unit I**.	TS, GC TS, GC TS, GC TS, GC TS, GC TS, GC TS, GC TS, GC
43 DR Volc 8: S post-caldera cone, upper S flank	21.10 13:29 22°51.60' S 176°25.80' W 292 m 21.10 14:00 22°51.45' S 176°25.83' W 199 m	1: 10 x 10 x 7 cm black aphyric basalt. Traces of plagioclase phenocrysts to 2 mm across. Scoriaceous, with 30% small vesicles grading to vugs 1 cm across. Surface is devitrified or quenched equivalent to 2 cm depth, weakly weathered, and covered in biota. Age estimated at a few hundred years. **Unit A**. 2: 10 x 7 x 5 cm black plagioclase basalt. As for Unit 1, but 5% plagioclase phenocrysts and denser in the core (grading to solid lava). Probably still Unit A. **Unit B**. 3: 10 x 9 x 6 cm **Unit B**. 4: 14 x 6 x 6 cm **Unit B**, in which the 1.5 cm thick devitrified or quenched crust is well developed. 5: 16 x 9 x 7 cm **Unit B**, in which solid lava grades to scoria within the 1.5 cm thick devitrified or quenched zone.	TS, GC TS, GC
44 GTV Vai Lili	22.10 18:42 22°12.99' S 176°36.60' W	Empty TV-grab. See Appendix 3 for visual observations.	

	1782 m 22.10 22:49 22°12.97' S 176°36.50' W 1709 m		
45 GTV **Vai Lili**	23.10 00:21 22°13.01' S 176°36.50' W 1701 m 23.10 01:44 22°12.97' S 176°36.50' W 1707 m	1: 12 x 7 x 5 cm black aphyric basalt. 20% vesicles up to 3 mm across grading to incipient pull-aparts. Locally traces of very fine grained pyrite sitting in vesicles or on lava surface. Fresh. **Unit A**. 2: 9 x 7 x 6 cm **Unit A**, but with 40% vesicles and 2 mm thick glass crust on pillow. 3: 8 pieces of black glass from pillow crusts, each typically 6 x 4 x 2 cm. Presumably **Unit A**. 4: 10 x 6 x 6 cm **Unit A**. A pillow with glass crust 2 mm thick. Also local patches of Fe-Si staining on surface. 5: 8 x 8 x 5 cm **Unit A**. **NB:** See Appendix 3 for visual observations.	TS, GC TS (gl), GC GC TS (gl), GC
46 DR **Vai Lili**	23.10 03:51 22°13.12' S 176°36.53' W 1688 m 23.10 04:38 22°12.94' S 176°36.49' W 1650 m	1: 8 x 8 x 7 cm black aphyric andesite (?). 5% vesicles grading to pull-aparts 2 cm long. A pillow with a glass crust 5-6 mm thick (rarely 1 cm) on both sides. Fresh (age ~20 years). Minor Fe-Si orange staining on some surfaces. **Unit A**. 2: 9 x 8 x 8 cm **Unit A**. 3: 13 x 11 x 5 cm **Unit A**.	TS (gl), GC TS (gl), GC TS (gl), GC
47 DR **Vai Lili**	23.10 05:57 22°13.03' S 176°36.62' W 1783 m 23.10 06:47 22°13.02' S 176°36.40' W 1717 m	1: 20 x 15 x 6 cm black aphyric andesite. 10% vesicles grading to incipient pull-aparts up to 5 mm long. A pillow with a 5 cm thick glass crust on both sides. Ropey textured surface. Fresh. **Unit A**. 2: 12 x 12 x 7 cm **Unit A**. Pull-aparts are flow aligned and up to 1 cm long. Slight Fe-Si staining. 3: 13 x 10 x 4 cm **Unit A** (?). Pull-aparts up to 2 cm long. No glass crust. Weak Fe-Si staining in bands within the block. 4: 13 x 8 x 4 cm **Unit A**.	TS (gl), GC TS (gl), GC TS, GC TS (gl), GC
48 GTV **Vai Lili**	23.10 08:17 22°12.94' S 176°36.49' W 1729 m 23.10 08:43 22°12.99' S 176°36.48' W 1733 m	1: 14 x 10 x 8 cm black aphyric andesite. 10% vesicles grading to 3 cm long pull-aparts. A pillow with a glass crust 2-3 mm thick. Fresh. **Unit A**. 2: 14 x 8 x 4 cm **Unit A**. 3: 12 x 7 x 4 cm black aphyric andesite. 30% vesicles to 3 mm across but lava still dense. A pillow but not glassy. Fresh, but probably older than Unit A. **Unit B**. 4: 7 x 5 x 5 cm **Unit B**. 5: 6 x 5 x 1 cm cream aphyric pumice. 60% vesicles forming long tubes up to 3 cm long. MnOx encrusted surface, MnOx 0.1 mm thick. **Unit C**. **NB:** See Appendix 3 for visual observations.	TS (gl), GC TS (gl), GC TS (gl), GC
49 PN	23.10 09:28 22°12.92' S 176°36.48' W 0 m 23.10 09:41 22°12.71' S 176°36.41' W 0 m	Plankton net, trawled at 1.5 knots.	
50 GTV **Vai Lili**	23.10 10:32 22°12.96' S 176°36.49' W	Empty TV-grab. See Appendix 3 for visual observations.	

	1722 m 23.10 13:00 22°13.00' S 176°36.56' W ~1702 m		
51 DR **Vai Lili**	23.10 14:39 22°13.00' S 176°36.60' W 1769 m 23.10 15:18 22°13.00' S 176°36.39' W 1714 m	1: 12 x 10 x 5 cm black aphyric andesite. 10% vesicles grading to flow aligned pull-aparts up to 1 cm long. A pillow with glass crust up to 5 mm thick on both sides. Fresh and dense. **Unit A**. 2: 14 x 9 x 8 cm black aphyric andesite. 20% small vesicles up to 2 mm across and several large pull-aparts up to 2 cm long. Weak development of glass crust on one side. Locally patches of orange-yellow staining. **Unit B**. 3: 13 x 10 x 5 cm **Unit A**.	TS (gl), GC TS, GC TS (gl), GC
52 DR **Vai Lili**	23.10 17:02 22°13.05' S 176°36.60' W 1754 m 23.10 17:46 22°13.05' S 176°36.37' W 1701 m	1: 9 x 8 x 5 cm black aphyric andesite. 10% vesicles grading to flow aligned pull-aparts up to 1 cm long. A pillow with a glass crust up to 1 cm thick on both sides. Fresh and dense. **Unit A**. 2: 10 x 6 x 5 cm **Unit A**.	TS (gl), GC TS (gl), GC
53 DR **Segment 7**	23.10 20:15 22°25.00' S 176°40.50' W 2140 m 23.10 21:08 22°24.87' S 176°40.67' W 2101 m	1: 13 x 8 x 6 cm black aphyric dacite. 5% flow aligned pull-aparts to 2 cm long. Glassy throughout. Fresh and dense. Conchoidal fractures. **Unit A**. 2: 8 x 8 x 7 cm **Unit A**. Slightly less glassy. 3: 8 x 8 x 3 cm **Unit A** (?). Locally discolored to bluish grey and surface weakly weathered. Possibly an older flow.	TS, GC TS, GC TS, GC
54 DR **Segment 7**	23.10 22:44 22°25.34' S 176°41.03' W 2006 m 23.10 23:37 22°41.18' S 176°25.13' W 1977 m	1: 11 x 10 x 5 cm black aphyric andesite. 10% vesicles grading to flow aligned pull-aparts up to 1 cm long. A pillow with a glassy crust (but no true glass rim). Fresh and dense. **Unit A**. 2: 10 x 6 x 5 cm **Unit A**. Slight discoloration or weathering on some surfaces and fractures. Possibly an older flow. 3: 10 x 8 x 4 cm black aphyric andesite. As for 54DR-01, but denser and with semi-conchoidal fractures on some surfaces. A more silicic flow? **Unit B**.	TS, GC TS, GC TS, GC
55 DR **Segment 7**	24.10 01:15 22°26.27' S 176°41.35' W 2113 m 24.10 02:25 22°25.83' S 176°41.31' W 2010 m	1: 10 x 9 x 9 cm black aphyric dacite (?). Numerous flow aligned pull-aparts up to 4 cm long spaced at 1-2 mm intervals. Conchoidal fracture surfaces. Surface 2 mm is glassier, but no true glass. Fresh and dense block with rare patches of orange Fe-Si staining. **Unit A**. 2: 14 x 12 x 5 cm **Unit A**. Weakly weathered surface and orange staining in bands suggest it could be an older flow. 3: 9 x 7 x 7 cm **Unit A**. Has the appearance of a cannon ball.	TS, GC TS, GC TS, GC
56 OFOS **Segment 7**	24.10 04:23 22°25.38' S 176°41.23' W 1917 m 24.10 07:29 22°26.38' S 176°41.58' W 2085 m	See Appendix 3 for visual observations.	
57 PN	24.10 10:52 22°26.28' S 176°41.69' W	Plankton net, trawled at 1.5 knots.	

	0 m 24.10 11:08 22°25.88' S 176°41.86' W 0 m		
58 OFOS **Hine Hina**	24.10 20:44 22°32.46' S 176°42.97' W 1814 m 24.10 23:20 22°31.49' S 176°43.15' W 1945 m	See Appendix 3 for visual observations.	
59 OFOS **Hine Hina**	25.10 02:16 22°32.96' S 176°43.16' W 1854 m 25.10 06:06 22°32.01' S 176°43.06' W 1881 m	See Appendix 3 for visual observations.	
60 GTV **Hine Hina**	25.10 09:50 22°32.48' S 176°43.00' W 1921 m 25.10 10:51 22°32.39' S 176°42.96' W 1803 m	1: 12 x 9 x 4 cm black aphyric andesite. 10% flow aligned pull-aparts to 2 cm long. Glass crust on both sides of pillow up to 2 mm thick. Fresh and dense. **Unit A**. 2: 16 x 12 x 8 cm **Unit A**. **NB:** See Appendix 3 for visual observations.	TS (gl), GC TS (gl), GC
61 PN	25.10 11:44 22°32.38' S 176°42.95' W 0 m 25.10 12:00 22°32.46' S 176°43.15' W 0 m	Plankton net, trawled at 1.0 knots.	
62 DR **Hine Hina**	25.10 13:00 22°31.72' S 176°43.09' W 1950 m 25.10 13:38 22°31.53' S 176°43.06' W 1403 m	Empty dredge.	
63 DR **Hine Hina**	25.10 15:01 22°31.72' S 176°43.00' W 1941 m 25.10 15:55 22°31.56' S 176°43.14' W 1886 m	Empty dredge- cable wrapped around chain sack.	
64 DR **Hine Hina**	25.10 17:06 22°31.49' S 176°43.14' W 1936 m 25.10 18:52 22°32.13' S 176°43.03' W	1: 10 x 8 x 7 cm black aphyric andesite. Numerous flow aligned pull-aparts up to 2 cm long at 2-5 mm intervals. A pillow with a glassy crust (but not true glass). Mostly fresh, but local patches of weak orange Fe staining. **Unit A**. 2: 13 x 13 x 7 cm black aphyric andesite. 20% vesicles to 3 mm across. A pillow sector with irregular development	TS (gl), GC TS, GC

	1874 m	of a glass crust, locally up to 5 mm thick. Weakly weathered (or altered) interior with some blue-yellow bands. **Unit B**. 3: 10 x 9 x 5 cm black aphyric andesite. 20% vesicles to 6 mm across. Probably the core of a pillow. No glass. Weakly weathered surface with orange Fe-Si staining. **Unit C**.	 TS, GC
65 GTV Hine Hina	25.10 20:45 22°32.49' S 176°42.87' W 1896 m 25.10 22:10 22°32.28' S 176°42.98' W 1795 m	Empty TV-grab (small hydrothermal sample?). See Appendix 3 for visual observations.	
66 GTV Hine Hina	25.10 23:53 22°32.46' S 176°42.95' W 1824 m 26.10 01:46 22°32.15' S 176°42.93' W 1831 m	1: Bag of black aphyric andesitic glass, fresh and sand-sized. This material forms large sediment masses throughout the Hine Hina area. **Unit A**. 2: 10 x 7 x 2 cm black aphyric dacite. Thin sheets of lava, often <1 mm thick, locally welded together around large vesicle tubes. Crust from a lava flow. Somewhat woody texture developing on one side of the block. **Unit B**. 3: 7 x 5 x 3 cm **Unit B**. **NB:** See Appendix 3 for visual observations.	
67 DR Hine Hina	26.10 04:13 22°36.41' S 176°43.86' W 1914 m 26.10 04:58 22°36.26' S 176°44.04' W 1809 m	1: 10 x 7 x 3 cm black aphyric andesite. 10% elongated vesicles to 2 mm across. A dense block with a ropey textured surface but no glass. Fresh, but locally orange Fe stained patches. **Unit A**. 2: Two pieces, each about 9 x 4 x 4 cm, of black aphyric dacite. Glass (obsidian) core has 10% elongated vesicles grading to pull-aparts that divide the block into mm or sub-mm thick sheets locally welded together. Upper surface is green-grey woody textured (devitrified) equivalent, ~1 mm thick. Fresh. **Unit B**. 3: 10 x 6 x 3 cm **Unit B**, but consists almost entirely of greenish grey woody textured aphyric dacite with a few relic darker glass cores.	TS, GC TS TS
68 GTV Hine Hina	26.10 07:29 22°31.98' S 176°43.13' W 1880 m 26.10 07:42 22°31.96' S 176°43.08' W ~1880 m	1: 10 x 10 x 5 cm black aphyric andesite. 10% vesicles to 5 mm across, some being flow aligned. Surface weathered light grey with orange stains to 1 cm depth and along fractures. However, the core is fresh. **Unit A**. 2: 6 x 6 x 5 cm **Unit A**. **NB:** See Appendix 3 for visual observations.	TS, GC TS, GC
69 GTV Hine Hina	26.10 09:07 22°32.00' S 176°43.08' W 1891 m 26.10 11:45 22°32.02' S 176°43.04' W 1912 m	1: 11 x 8 x 5 cm black aphyric andesite. 10% vesicles grading to pull-aparts 1 cm long. Local development of a thin glass crust up to 5 mm thick that readily fractures off the block. Ropey surface texture. Fresh. **Unit A**. 2: 18 x 16 x 6 cm black aphyric andesite. 10% vesicles to 5 mm across. The crust consists of glass sheets 5 mm thick locally welded together. Ropey surface texture. Local orange Fe-Si staining to 2 mm depth, but otherwise fresh. **Unit B**. **NB:** See Appendix 3 for visual observations.	TS (gl), GC TS (gl), GC
70 DR Hine Hina	26.10 13:57 22°31.98' S 176°43.17' W	1: 10 x 8 x 4 cm black aphyric andesite. 20% vesicles to 3 mm across grading to flow aligned pull-aparts 1 cm long. Glassy crust up to 2 mm thick on both sides, but not true	TS, GC

	1910 m 26.10 14:38 22°31.98' S 176°42.98' W 1905 m	glass. Surface weakly orange Fe stained on one side, but otherwise fresh. **Unit A**. 2: 16 x 7 x 5 cm as for 70DR-01, but 10% vesicles to 3 mm across and 5% vuggy voids up to 4 cm long. Weakly altered blue-grey along fractures. May be a different flow. **Unit B**. 3: 9 x 6 x 5 cm **Unit A**, but looks slightly more weathered. Probably not a different flow. 4: 11 x 6 x 5 cm black aphyric andesite. 30% vesicles to 2 mm across grading to pull-aparts 5 mm long. No glass. Jointed surface. Surface is weakly weathered brownish, and locally with orange Fe staining in cracks. **Unit C**. 5: 11 x 9 x 7 cm black pyroxene andesite. 5% dark green pyroxene to 2 mm across (most <1 mm). 30% vesicles to 3 mm across. A jointed block. Surface weathered (altered?) to blue-grey shades to 1 mm depth, but interior fresh. **Unit D**.	 TS, GC TS, GC TS, GC
71 DR **Hine Hina**	26.10 16:10 22°31.88' S 176°43.15' W 1906 m 26.10 17:03 22°32.09' S 176°42.98' W 1865 m	1: 15 x 15 x 13 cm black aphyric andesite. 20% small vesicles <1 mm across, and rare pull-aparts to 2 cm long. Glass crust 2-5 mm thick that readily fractures off the block. Block itself is very fractured. Fresh. **Unit A**. 2: 11 x 10 x 5 cm black aphyric andesite. 10% small vesicles <1 mm across. Glassier crust 2-3 mm thick, but no true glass. Crust still fractures off the block readily. A very dense cannon ball. Surface weakly altered to green-yellow-blue shades. **Unit B**. 3: 9 x 8 x 5 cm dark grey aphyric andesite. 20% vesicles to 2 mm across and rarely to 5 mm across. Surface altered to blue-grey shades and locally orange Fe and greenish grey shades. An older flow? **Unit C**.	TS (gl), GC TS, GC TS, GC
72 OFOS **Vai Lili**	26.10 20:28 22°13.22' S 176°36.47' W 1687 m 27.10 04:20 22°12.67' S 176°36.47' W 1761 m	See Appendix 3 for visual observations.	
73 OFOS **S tip, Valu Fa Ridge**	27.10 08:49 22°40.95' S 176°44.26' W 1828 m 27.10 14:36 22°39.11' S 176°43.58' W 1900 m	See Appendix 3 for visual observations.	
74 DR **S tip, Valu Fa Ridge**	27.10 16:19 22°40.07' S 176°43.59' W 2013 m 27.10 17:44 22°39.98' S 176°43.91' W 1775 m	1: 16 x 8 x 4 cm black plagioclase basalt. 5% plagioclase phenocrysts to 2 mm across, trace dark green pyroxene phenocrysts to 2 mm across. 30% small vesicles grading to elongated pull-aparts up to 5 mm long. Glass crust is 2 mm thick on both sides. Fresh. **Unit A**. 2: 9 x 7 x 5 cm as for 74DR-01, but surface weakly weathered greenish-grey to 2 mm depth under the glass crust. Possibly an older flow? **Unit B**. 3: 13 x 7 x 5 cm **Unit B**. 4: 10 x 6 x 6 cm black aphyric andesite. This appears to be an older dense lava block rolled up within the Unit B flow, now having a Unit B crust. **Unit C**.	TS (gl), GC TS (gl), GC TS (gl), GC
75 DR **S tip, Valu**	27.10 18:17 22°41.17' S	Empty dredge.	

Fa Ridge	176°44.01' W 2011 m 27.10 20:48 22°40.93' S 176°44.32' W 1826 m		
76 DR **S tip, Valu Fa Ridge**	27.10 22:35 22°42.44' S 176°45.39' W 2304 m 27.10 23:37 22°42.61' S 176°45.30' W 2217 m	1: 3 x 3 x 3 cm dark grey plagioclase andesite. 5% plagioclase phenocrysts to 2 mm across, trace dark green pyroxene phenocrysts to 2 mm across. 10% small vesicles to 2 mm across. Surface weakly weathered grey with local yellow-brown patches. Too small to process safely onboard. **Unit A**. 2: 3 x 3 x 2 cm black plagioclase andesite. 10% plagioclase phenocrysts to 2 mm across, trace dark green pyroxene to 2 mm across. 20% small vesicles grading to pull-aparts 5 mm long. Surface weakly weathered. Too small to process safely onboard. **Unit B**. 3: 5 small pieces, predominantly of **Unit B**. 4: 6 small pieces of aphyric pumice. Surfaces weakly weathered and locally stained yellow-brown. Probably drift pumice. **Unit C**.	
77 OFOS **S Rift, S of Valu Fa Ridge**	28.10 02:00 22°51.38' S 176°44.39' W 2213 m 28.10 03:40 22°51.18' S 176°45.04' W 2349 m	See Appendix 3 for visual observations.	
78 DR **S Rift, S of Valu Fa Ridge**	28.10 05:48 22°51.47' S 176°44.46' W 2252 m 28.10 06:43 22°51.23' S 176°44.43' W 2290 m	1: Two pieces, each 7 x 6 x 4 cm, of black aphyric andesite(?). Very lightweight. Consists of 5 mm - 1 cm thick glassy bands separated by irregular domains of highly vesicular scoriaceous material. Surface weakly weathered, but overlain by 0.2 mm of MnOx (hydrothermal?). **Unit A**. 2: Seven pieces, largest 5 x 4 x 2 cm, of black aphyric dacite. Consists of 5 mm - 1 cm thick glassy sheets locally welded together as crust. Ropey surface texture. Surface weakly weathered brownish grey. **Unit B**. 3: 10 x 9 x 6 cm black olivine basalt. 15% light green olivine phenocrysts to 3 mm across (most 1 mm). 15% vesicles to 3 mm across (most 1 mm). A jointed block. Surface weathered yellow-brown to 2 mm depth, and much older than either Unit A or B. **Unit C**. 4: 12 x 6 x 6 cm dark grey aphyric basalt. 10% vesicles to 3 mm across. A jointed block. Surface weathered yellow-brown to 2 mm depth and along fractures, often this is a bright yellow-green suggestive of nontronite alteration. Comparable age to 78DR-03. **Unit D**. 5: Five pieces, largest 7 x 5 x 3 cm, of cream grey aphyric pumice. Surfaces weathered brown and often MnOx dusted. Float pumice. **Unit E**.	TS, GC TS, GC TS, GC
79 DR **S Rift, S of Valu Fa Ridge**	28.10 08:38 22°50.21' S 176°47.09' W 2386 m 28.10 09:36 22°50.34' S 176°46.88' W 2173 m	1: 10 x 7 x 4 cm black plagioclase andesite. 10% plagioclase phenocrysts to 3 mm across, trace dark green pyroxene phenocrysts to 2 mm across. 10% small vesicles grading to large vugs up to 3 cm across. Glass crust ranges from 3 mm thick on one side to 8 mm thick on the other, and readily fractures off the block. Fresh. **Unit A**. 2: 10 x 8 x 8 cm black plagioclase andesite. 15%	TS (gl), GC TS, GC

		plagioclase phenocrysts to 3 mm across, trace dark green pyroxene phenocrysts to 3 mm across. 20% vesicles grading to flow aligned pull-aparts up to 1 cm long. No glass. Surface very weakly weathered to shades of yellow-brown. **Unit B**. 3: 11 x 7 x 6 cm **Unit B**, surface locally glassy. 4: 8 x 8 x 8 cm black plagioclase andesite. 5% plagioclase phenocrysts to 2 mm across. 30% large veislces to 6 mm across and most >3 mm across. Surface very weakly weathered to shades of yellow-brown. **Unit C**. 5: 5 x 3 x 3 cm cream grey pumice. Surface weathered brown and locally with an MnOx dusting. Float pumice. **Unit D**.	 TS, GC
80 DR Volc 14: E ridge, upper flank	30.10 01:33 23°33.71' S 176°37.80' W 979 m 30.10 02:32 23°33.70' S 176°38.10' W 809 m	1: 12 x 11 x 7 cm cream pumice. 5% dark green-black pyroxene microphenocrysts to 0.5 mm across. Rare mafic xenoliths to 1 cm across, with a few larger. 20% flow aligned vesicles to 5 mm long. Surface weathered yellow-brown to 1 mm depth and discolored to 5 mm. Minor clay sediment in some crevices. **Unit A**. 2: 13 x 11 x 6 cm **Unit A**, but pale grey in color and with less regular vesicles that grade to 1 cm long vugs. 3: 7 x 7 x 7 cm Unit A as for 80DR-02, but devitrification banded with light grey and dark grey bands up to 5 mm wide, gradational contacts. **Unit B**. 4: 11 x 9 x 6 cm **Unit B**. 5: 5 x 4 x 3 cm black aphyric dacite. 5% plagioclase phenocrysts to 2 mm across in a black glassy matrix. 30% vesicles to 2 mm across, yet the block feels dense. Surface weakly weathered. Probably a xenolith in Unit A pumice. **Unit C**. 6: Four xenoliths, largest 6 x 4 x 2 cm, in Unit A/B pumice. All are deeply weathered and appear to be aphyric basalt or andesite. **Unit D**.	TS, GC TS, GC TS, GC
81 DR Volc 14: inner SE caldera wall (lower)	30.10 04:16 23°34.30' S 176°39.29' W 763 m 30.10 05:14 23°34.53' S 176°39.23' W 510 m	1: 13 x 13 x 8 cm pale grey pumice. 5% dark green-black pyroxene microphenocrysts up to 0.5 mm across. Rare glassy domains to 5 mm across and mafic xenoliths to 1 cm across. 15% irregularly shaped vesicles grading to vugs up to 3 cm long. Weak devitrification banding to dark grey, bands up to 2 cm thick. Surface weakly weathered yellow-brown. **Unit A**. 2: 13 x 8 x 6 cm **Unit A**. 3: 14 x 9 x 6 cm Unit A, but with a 3 cm thick dark grey devitrification band that has sharp contacts. This band was sampled for analytical work. **Unit B**. 4: 5 x 5 x 4 cm Unit A, but with a 2 cm thick black band that is somewhat scoriaceous. Probably a devitrification variant, but should be checked for magma mixing. **Unit C**. 5: Five small xenoliths, largest 5 x 3 x 3 cm, in Unit A pumice. All are black aphyric basalt, tending scoriaceous and possibly equivalent to Unit C. **Unit D**. 6: 10 x 5 x 5 cm dark grey aphyric andesite. Trace plagioclase phenocrysts to 2 mm across. Dense and non-vesicular. A xenolith, with Unit A pumice on one side. Largest clast of **Unit D**. 7: Five pieces, largest 6 x 4 x 4 cm, of dark grey plagioclase andesite. 10% plagioclase phenocrysts to 2 mm across. 5% irregularly shaped vesicles grading to pull-aparts 5 mm long. Surface weakly weathered yellow-brown to 1 mm depth. An older outcropping lava.	TS, GC TS, GC TS, GC TS, GC

		Unit E. 8: Seven pieces, largest 14 x 8 x 3 cm, of greenish grey aphyric andesite. Trace plagioclase phenocrysts to 3 mm across. Has a granular sugary texture. Surface weathered brown to 1 mm depth and has adhering biota. An older outcropping lava. **Unit F**.	
82 DR Volc 14: inner W crater wall (top)	30.10 06:56 23°34.40' S 176°43.15' W 929 m 30.10 07:46 23°34.42' S 176°43.46' W 796 m	1: 12 x 9 x 9 cm cream grey aphyric pumice. Traces of black crystals <0.5 mm across (pyroxene?). 30% flow aligned vesicles to 3 mm across. Relatively compact and dense. Surface weakly weathered yellow-brown. **Unit A**.	TS, GC
		2: 12 x 10 x 8 cm **Unit A**, but grey with 40% vesicles grading to vugs 4 cm long. Also not dense; instead grading to woody texture.	TS, GC
		3: 15 x 13 x 9 cm black plagioclase basalt. 5% plagioclase phenocrysts to 2 mm across and trace dark green pyroxene phenocrysts to 2 mm across. A non-vesicular dense lava flow. Surface weakly weathered yellow-brown. **Unit B**.	TS, GC
		4: 11 x 11 x 7 cm black plagioclase basalt. 10% plagioclase phenocrysts to 2 mm across. Non-vesicular but not dense. Surface weathered yellow-brown to 2 mm depth and locally black. **Unit C**.	TS, GC
		5: 10 x 5 x 5 cm dark grey plagioclase basalt. 5% plagioclase phenocrysts to 2 mm across. 5% very small vesicles <0.5 mm across and often aligned in bands. Weak diffuse flow banding in shades of yellow-grey. Surface weathered yellow-brown to 1 mm depth. **Unit D**.	
		6: 9 x 8 x 7 cm black plagioclase basalt. 5% plagioclase phenocrysts to 2 mm across and traces of bright green mineral (olivine?). Traces of very small vesicles <0.5 mm across. Much fracturing. Surface weakly weathered brown-black to 1 mm depth. **Unit E**.	
		7: 9 x 8 x 5 cm black aphyric basalt. As for 82DR-06, but with only trace plagioclase and green (olivine?) phenocrysts. **Unit F**.	
		8: 9 x 8 x 6 cm black aphyric andesite. Trace plagioclase and dark green pyroxene phenocrysts both to 1 mm across. 20% vesicles grading to pull-aparts 2 cm long. Glassy, with devitrification banded to grey-brown pumice on one side. **Unit G**.	TS, GC
		9: 9 x 8 x 7 cm **Unit G**, but less glassy and no devitrification banding.	
		10: 9 x 8 x 8 cm black aphyric dacite. 10% irregularly shaped vesicles to 3 mm across. Devitrification banded in black and grey-brown shades, with the latter up to 5 mm thick and sometimes occurring as pumiceous lenses within the brown bands. Surface weathered yellow-brown. **Unit H**.	TS, GC
		11: 12 x 9 x 8 cm grey aphyric dacite. 10% vesicles grading to vugs 4 mm across. Weak devitrification banding in shades of dark grey and grey, with diffuse boundaries. Similar but older than Unit H. **Unit I**.	
		12: 12 x 9 x 6 cm black plagioclase andesite. 10% plagioclase phenocrysts to 2 mm across and trace dark green pyroxene phenocrysts. Dense, with only 5% small vesicles <0.5 mm across. Surface weathered brown to 1.5 cm depth and clearly old. **Unit J**.	
		13: 11 x 9 x 7 cm black plagioclase andesite as for 82DR-12, but non-vesicular and denser. Weathered to 3 cm depth. **Unit K**.	

		14: 10 x 6 x 6 cm dark grey aphyric andesite. 30% vesicles to 2 mm across. Surface weakly weathered with local yellow-brown domains, but otherwise fresh. Probably the youngest lava in the haul. **Unit L**. 15: 11 x 9 x 7 cm olivine gabbro. 50% white plagioclase, 35% black pyroxene and 15% green-yellow olivine, all with a grain size of 0.5 mm. A rounded boulder attached to plagioclase basalt on one side indicating it was erupted as a xenolith. Surface weathered black to 1 mm depth, with weak yellow-orange staining persisting to the core along fractures. **Unit M**. 16: 14 x 12 x 10 cm **Unit M**, but with a bimodal size distribution of ~1 mm on one side and <0.5 mm on the other. More weathered, with yellow-orange staining persisting into the core (but not pervasive). Attached to 1 cm of quartz-hornblende pumice on one side. 17: 10 x 8 x 8 cm gabbro. 50% white plagioclase, 45% black pyroxene and 5% green-yellow olivine, all with a grain size of 0.5 mm. Locally yellow-orange stained as for 82DR-16. Attached to 3 cm of quartz pumice cut by quartz veinlets. **Unit N**.	TS, GC TS, GC
83 DR Volc 14: inner S caldera wall (top)	30.10 09:31 23°34.50' S 176°39.82' W 638 m 30.10 10:20 23°34.72' S 176°39.81' W 558 m	1: 17 x 12 x 8 cm pale greyish cream pumice. 5% dark green to black pyroxene phenocrysts <0.5 mm across. Rare glassy ovoids to 5 mm across. 20% flow aligned vesicles to 5 mm long. Surface weathered yellow-brown to 1 mm depth. **Unit A**. 2: 12 x 9 x 6 cm bluish grey pumice as for 83DR-01, but vesicles irregularly shaped and grading to vugs 1 cm across. Also devitrification banded in shades of pale grey with diffuse band contacts. **Unit B**.	TS, GC TS, GC
84 PN	30.10 10:56 23°35.10' S 176°40.00' W 0 m 30.10 11:09 23°35.43' S 176°40.20' W 0 m	Plankton net, trawled at 1.5 knots.	
85 DR Volc 14: intra-caldera cones, S flank	30.10 11:47 23°34.22' S 176°39.98' W 781 m 30.10 13:25 23°33.74' S 176°39.98' W 617 m	1: 15 x 11 x 7 cm pale grey pumice. 5% dark green to black pyroxene phenocrysts <0.5 mm across. 20% weakly flow aligned vesicles grading to vugs 1 cm across. Rare glassy ovoids to 5 mm across. Surface weakly weathered yellow-brown in patches. **Unit A**. 2: 14 x 8 x 4 cm **Unit A**, but dark grey and with vesicles grading to pull-aparts 4 mm long. 3: 7 x 7 x 6 cm as for 85DR-01, but dark grey and with only trace pyroxene phenocrysts. Possibly a devitrification variant. **Unit B**. 4: 16 x 12 x 9 cm as for 85DR-01, but devitrification banded with black glassy aphyric bands and scoriaceous lava. All bands have sharp contacts. The black bands are up to 6 cm thick and sometimes form ovoid domains, suggestive of magma mixing. **Unit C**.	 TS, GC TS, GC
86 DR Volc 15: E ridge, mid flank	30.10 19:37 23°54.22' S 176°44.80' W 1676 m 30.10 20:49 23°53.81' S 176°44.80' W	1: 16 x 9 x 6 cm cream grey pumice. Trace black hornblende phenocrysts (confirmed on one 2 mm long lath) usually <0.5 mm long. Rare glassy ovoid domains to 5 mm across. 30% vesicles to 1 cm across. Surface weathered brown and discolored to 2 cm depth (older than V14). **Unit A**. 2: 17 x 9 x 7 cm as for 86DR-01, but pale grey and with	TS, GC

	1501 m	less regular vesicles that grade to flow aligned vugs 2 cm across. **Unit A**. 3: 12 x 8 x 7 cm as for 86DR-02, but devitrification banded in shades of pale grey and grey arranged subparallel and 1-2 mm thick. Possibly an older unit, with minor MnOx dusting on its surface. **Unit B**. 4: 9 x 6 x 5 cm cream pumice. 5% quartz phenocrysts to 2 mm across. 10% vesicles grading to flow aligned pull-aparts 5 mm long. Woody textured but hard. Surface weathered brown to 2 mm depth, locally with 1 mm thick MnOx crust. Appears older than Units A and B despite thinner crust. **Unit C**.	 TS, GC TS, GC
87 DR Volc 15: E intra-caldera cone, E flank	30.10 22:08 23°54.32' S 176°46.27' W 1323 m 30.10 23:31 23°54.33' S 176°46.55' W 1227 m	1: 14 x 9 x 7 cm pale grey pumice. Trace black crystals <0.5 mm across (hornblende/pyroxene?). 30% flow aligned vesicles 3 mm across grading to vugs 2 cm across. Rare glassy ovoids to 5 mm across. Surface weathered brown and discolored to 2 cm depth. **Unit A**. 2: 14 x 10 x 9 cm **Unit A**, with the core oxidised to pale pink. 3: 7 x 7 x 6 cm cream pumice. 20% rounded quartz phenocrysts to 2 mm across. Also containss 10% black aphyric lava (basalt?) as ovoid patches to 3 mm across. 10% small flow aligned vesicles grading to pull aparts 1 cm long. Surface weathered brown to 2 mm depth but locally with 1 mm of MnOx on this. Definitely older. **Unit B**. 4: 3 pieces of **Unit B**, largest 9 x 6 x 5 cm. 5: 10 x 9 x 6 cm Unit B, with a 5 x 3 x 2 cm rounded xenolith of black olivine-plagioclase basalt bearing 10% olivine phenocrysts and 10% plagioclase phenocrysts both to 5 mm across, although usually the plagioclase is bigger. The basalt has 10% vesicles to 2 mm across and is classified as **Unit C**. 6: 5 pieces, largest 6 x 6 x 2 cm, of xenoliths from Unit B pumice. 3 pieces are a dark grey andesite with trace plagioclase phenocrysts. The other 2 are different but need cutting. **Unit D**.	TS, GC TS, GC TS, GC
88 DR Volc 15: inner N caldera wall	31.10 00:55 23°53.10' S 176°47.31' W 1292 m 31.10 01:45 23°52.80' S 176°47.28' W 1079 m	1: 16 x 13 x 11 cm pale grey pumice. Trace black crystals <0.5 mm across (hornblende/pyroxene?). 10% flow aligned vesicles to 2 mm across grading to pull-aparts 1 cm long. Mud has filled some interior vesicles. Surface weathered brown and discolored to 1 cm depth. **Unit A**. 2: 10 x 6 x 5 cm **Unit A**, but with a 1 cm thick dark grey devitrification band along one side that has a gradational contact. 3: 13 x 8 x 7 cm pale grey pumice. 5% rounded quartz phenocrysts to 2 mm across. 10% vesicles grading to flow aligned pull-aparts 2 cm long. Surface weathered brown with discoloration to 2 cm depth. **Unit B**. 4: 3 pieces, largest 7 x 4 x 3 cm, of cream pumice. 15% rounded quartz phenocrysts to 2 mm across, also bearing 5% rounded black basaltic fragments to 3 mm across. 10% numerous thin pull-aparts to 5 mm long, but hard. Surface weathered brown to 2 mm depth but with a further 1mm of MnOx on top. An older unit. **Unit C**.	TS, GC TS, GC TS, GC
89 DR Volc 15: inner W caldera wall, N	31.10 03:15 23°49.59' S 176°48.40' W 1421 m 31.10 04:07	1: 15 x 7 x 4 cm yellow aphyric pumice. 30% flow aligned vesicles to 5 mm across (most 1 mm). A rounded boulder. Surface weathered brown and discolored to >1 cm depth, locally with an MnOx dusting. **Unit A**. 2: 11 small pieces of pumice, largest 11 x 7 x 2 cm. Various	TS, GC

caldera(?)	23°49.57' S 176°48.67' W 1216 m	types, including aphyric pumice, quartz (15%) pumice, pale to dark grey devitrification banded pumice, and a black glass-rich ball. All are weathered brown. **Unit B**.	
90 PN	31.10 10:31 24°05.11' S 176°58.05' W 0 m 31.10 10:45 24°05.15' S 176°57.98' W 0 m	Plankton net, trawled at 1 knot.	
91 DR Volc 16: inner NE wall, 500 m deep E crater	31.10 16:36 24°11.00' S 176°49.41' W 1357 m 31.10 17:40 24°10.85' S 176°49.26' W 1126 m	1: 16 x 9 x 7 cm cream pumice. 10% rounded quartz phenocrysts to 5 mm across, 5% black hornblende phenocrysts to 3 mm long (most <1 mm). 20% flow aligned vesicles grading to vugs 1 cm across. Surface weakly weathered yellow-brown to 1 mm, but hard and fesh. **Unit A**. 2: 18 x 12 x 10 cm **Unit A**. 3: 11 x 6 x 6 cm **Unit A**, but greyer in color and denser, with glassy ovoid domains to 5 mm across. 4: 24 x 10 x 8 cm diorite. 60% plagioclase and 40% black crystals (hornblende?), grain size of both is <1 mm. Bedded on a sub-mm scale with long axis alignment of hornblende. Loose and almost friable. Surface weathered yellow-brown to 1 mm depth and locally further along some beds. Pieces of Unit A pumice adhere to the block, indicating it was erupted as a xenolith. **Unit B**. 5: 2 pieces, each 6 x 4 x 2 cm, of dark grey diorite. 50% plagioclase and 50% hornblende to 1 mm across. Both pieces have adhering Unit A pumice. **Unit C**. 6: 2 pieces, each 6 x 5 x 2 cm, that appear to be a denser variant of Unit B with only 5% vesicles to 2 mm across. Weakly weathered surfaces. **Unit D**. 7: 5 pebbles, largest being 4 x 4 x 2 cm, of weathered brown lava of assorted compositions. Usable with careful cutting. **Unit E**. 8: 6 x 5 x 4 cm dark grey hornblende-quartz dacite. 10% quartz phenocrysts to 3 mm across and 5% black hornblende phenocrysts to 2 mm long. 10% small vesicles <1 mm across. Dense. Surface weathered brown to 1 mm and locally discolored to 5 mm depth. Probably an old dome. **Unit F**. 9: 8 x 5 x 3 diorite, as for 91DR-05 but deeply weathered brown to 1 cm depth. **Unit G**. 10: 5 x 5 x 2 cm altered dacite. 10% quartz phenocrysts to 2 mm across and 10% plagioclase phenocrysts to 2 mm across set in a light green chloritised matrix. **Unit H**.	TS, GC TS, GC TS, GC TS, GC
92 DR Volc 16: inner NW caldera wall	31.10 20:42 24°09.42' S 176°52.40' W 788 m 31.10 21:48 24°09.21' S 176°52.60' W 673 m	1: 12 x 12 x 9 cm cream pumice. 5% black hornblende phenocrysts to 2 mm long and trace quartz phenocrysts to 3 mm across. 20% flow aligned vesicles grading to vugs 2 cm across. Surface weathered yellow-brown to 1.5 cm depth (older than 91DR pumice). **Unit A**. 2: 22 x 14 x 11 cm **Unit A**. 3: 15 x 11 x 9 cm, as for 92DR-01 but has 5% quartz phenocrysts to 3 mm across. Probably a different unit. **Unit B**. 4: 19 x 15 x 8 cm, as for 92DR-01, but devitrification banded in cream to dark grey shades. Dark grey bands are up to 3 cm thick, subparallel, and have sharp contacts. Weathered yellow-brown to 3 cm depth and	TS, GC TS, GC TS, GC

		older than Unit A. **Unit C**. 5: 10 x 7 x 4 cm **Unit C**, but with 5 cm thick dark grey band along one side. 6: 12 small pieces, largest 6 x 4 x 3 cm, of deeply weathered mafic lavas. Largest might be usable with care. All occur as xenoliths in Units A and C. **Unit D**.	
93 DR Volc 16: S valley SW spur, upper flank	01.11 00:11 24°12.53' S 176°55.61' W 752 m 01.11 01:21 24°12.11' S 176°55.61' W 570 m	1: 10 x 7 x 3 cm cream pumice. 5% black hornblende phenocrysts to 2 mm long and trace quartz phenocrysts to 3 mm across. 20% vesicles grading to vugs 6 mm across. Surface weakly weathered with local yellow-brown staining (most was probably chipped off). **Unit A**. 2: 13 x 7 x 5 cm grey pumice. 5% black hornblende phenocrysts to 3 mm long and 5% rounded quartz phenocrysts to 4 mm across. 10% small vesicles grading to pull-aparts 5 mm long. A dense and hard block with jointed surfaces. Locally the surface is weakly weathered to yellow-brown. **Unit B**. 3: 13 x 9 x 6 cm **Unit B**, but surface weakly weathered yellow-brown to 1.5 cm depth. 4: 12 x 11 x 5 cm as for 93DR-02, but devitrification banded in shades of light to dark grey. Dark grey bands are up to 6 mm thick, have sharp contacts, and 20% vesicles to 5 mm across. The block is also less dense and softer. **Unit C**. 5: 6 x 4 x 3 cm Unit A, but with 4 cm thick black devitrification band on one side. **Unit D**. 6: 2 pieces, largest 3 x 2 x 1 cm, of glassy ovoid domains occurring like xenoliths within Unit A and B pumice. **Unit E**. 7: 6 x 5 x 2 cm dark grey andesite. 20% vesicles to 3 mm across. Surface is weathered brown, and the block is marginal for geochemistry and too small to cut onboard. **Unit F**.	TS, GC TS, GC TS, GC
94 PN	01.11 09:24 24°28.43' S 176°56.24' W 0 m 01.11 09:38 24°28.23' S 176°55.95' W 0 m	Plankton net, trawled at 1.6 knots.	
95 DR Volc 18: NE ridge, N cone, upper flank	01.11 10:17 24°28.18' S 176°54.50' W 458 m 01.11 11:07 24°28.35' S 176°54.62' W 321 m	1: 12 x 7 x 6 cm black aphyric basalt. 20% vesicles to 2 mm across and tending scoriaceous. Ropey textured surface on both sides, not glassy. Surface weakly weathered brown but slightly discolored to 5 mm depth, appearance suggests only a few hundred years old. **Unit A**. 2: 14 x 8 x 6 cm **Unit A**, with minor biota on its surface. 3: 14 x 12 x 7 cm **Unit A**, as for 95DR-02 but with trace plagioclase phenocrysts to 3 mm across. 4: 12 x 7 x 6 cm as for 95DR-01, but surface more weathered to reddish-brown although discolored only to 5 mm depth. Interior matrix is black and glassy. Possibly an older flow. **Unit B**. 5: 11 x 8 x 6 cm black plagioclase basalt. 15% large plagioclase phenocrysts to 5 mm across (most 3 mm). 10% vesicles grading to irregular pull-aparts 1 cm long. Surface weathered reddish-brown to 5 mm depth with biota on the surface. Appears to be the oldest flow. **Unit C**.	TS, GC TS, GC TS, GC TS, GC TS, GC

		6: 14 x 12 x 7 cm **Unit C**, but pull-aparts up to 8 cm long and interior more scoriaceous (20% vesicles to 1 mm across). 7: 12 x 6 x 4 cm, as for 95DR-06 but altered (?) with an orange-red surface persisting to 5 mm depth. Possibly an even older flow. **Unit D**. 8: 4 pieces, largest 5 x 4 x 3 cm, of weathered quartz-hornblende pumice. Three are weathered yellow-brown whereas the other is cream. **Unit E**.	
96 DR Volc 18: inner NE crater wall, S cone (lower)	01.11 14:50 24°33.99' S 176°55.01' W 1223 m 01.11 15:39 24°33.81' S 176°54.92' W 1011 m	1: 15 x 8 x 8 cm black plagioclase andesite. 5% plagioclase phenocrysts to 2 mm across. A non-vesicular dense block with pull-aparts every 6-7 cm separating solid from autobrecciating layers. Surface weakly weathered brown but interior is fresh. **Unit A**. 2: 12 x 8 x 7 cm dark grey aphyric andesite(?). Traces of plagioclase and black hornblende (confirmed by cleavage) phenocrysts both to 1 mm across. A dense, hard and crystalline block, possibly an intrusive.Surface weathered brown and locally orange. **Unit B**. 3: 10 x 5 x 3 cm cream aphyric pumice. 10% flow aligned vesicles to 3 mm long. Surface weathered yellow-brown to 1-2 cm depth. **Unit C**. 4: 6 x 5 x 4 cm **Unit C**. 5: 8 x 5 x 4 cm grey aphyric pumice. 10% vesicles to 4 mm across. Surface weathered brown. **Unit D**. 6: 9 x 6 x 4 cm cream and dark grey aphyric pumice. Devitrification banded, with several grey bands to 2 mm thick with sharp contacts to the predominantly cream pumice. Surface weathered yellow-brown. **Unit E**. 7: 11 x 7 x 5 cm brown plagioclase dacite. 5% plagioclase phenocrysts to 2 mm across. Devitrification banded in shades of dark brown and light grey and cream. These bands are often folded or convolute. The dominant dark band is 3 cm thick. Surface weathered brown. **Unit F**. 8: 8 x 8 x 6 cm **Unit F**, but more weathered. 9: 6 x 5 x 4 cm black aphyric dacite. Glassy matrix with conchoidal fractures grading to dark brown pumiceous layers with woody texture. Surface weakly weathered light brown. **Unit G**. 10: 2 pieces, largest 5 x 3 x 2 cm, of black aphyric dacite. Glassy. **Unit G**. 11: 10 x 10 x 8 cm green chlorite-zeolite claystone. Rock consists of ovoid patches of light green chlorite to 1 cm across and white chalky zeolite(?) up to 6 mm across. Strongly sheared and readily disaggregated. Gouge material from plug-lava contact? **Unit H**. 12: 3 pieces, largest 6 x 3 x 3 cm, of weathered lava. Lithologies are plagioclase dacite, aphyric dacite and plagioclase andesite. Too small to process onboard. **Unit I**.	TS, GC TS, GC TS, GC TS, GC TS, GC TS, GC
97 DR Volc 18: inner NE crater wall, S cone (top)	01.11 16:36 24°33.79' S 176°54.30' W 717 m 01.11 17:26 24°33.62' S 176°54.15' W 507 m	1: 9 x 7 x 6 cm cream aphyric pumice. Trace black crystals(?), but these could be glassy domains or lithics, <1 mm across. 30% flow aligned vesicles grading to pull-aparts 3 cm long. Starting to develop woody texture. Surface weathered brown, with yellow-brown discoloration to 1 cm depth. Age maybe a few ka? **Unit A**. 2: 10 x 6 x 5 cm **Unit A**. 3: 8 x 5 x 4 cm as for 97DR-01, but 30% small elongated vesicles to 2 mm long. Denser, with jointed surfaces.	TS, GC TS, GC

		Almost like a rhyolite. Surface weakly weathered with yellow-brown staining only. **Unit B**. 4: 7 x 5 x 3 cm **Unit B**. 5: 2 pieces, largest 7 x 4 x 3 cm, of devitrification banded cream and dark grey Unit A pumice. Dark grey bands are typically 5 mm thick and have sharp contacts. **Unit C**. 6: 14 x 8 x 6 cm grey aphyric pumice. 10% irregularly shaped vesicles grading to vugs 5 mm across. Surface weakly weathered yellow-brown, but some blocks have discoloration to 1 cm depth. Youngest unit from this volcano in appearance. **Unit D**. 7: 9 x 7 x 5 cm **Unit D**. 8: 9 x 8 x 6 cm Unit D, but devitrification banded with a few cream bands from <1 mm to 5 mm thick and with sharp contacts. **Unit E**. 9: 7 x 6 x 4 cm dark grey aphyric pumice. 20% irregularly shaped vesicles grading to vugs 1 cm across. Surface weathered yellow-brown to 5 mm depth. Maybe a textural variant of Unit D. **Unit F**. 10: 8 x 7 x 5 cm Unit F, but with a "xenolith" 5 cm across of devitrification banded black and cream pumice. Probably all of this is a devitrification variant of the same unit. **Unit G**. 11: 7 x 6 x 4 cm black aphyric dacite(?). Locally glassy domains grading to a devitrified ropey textured surface. Flow aligned pull-aparts every few mm. Surface weathered brown to 2 mm. **Unit H**. 12: 8 x 5 x 4 cm as for 97DR-11, but with 20% vesicles grading to vugs 2 cm long. Markedly more vesicular. Possibly a devitrification variant. **Unit I**. 13: 10 x 7 x 4 cm **Unit H**, but locally a lighter shade of brown (more weathered?). 14: 6 x 5 x 3 cm dark grey olivine-plagioclase basalt. 10% small plagioclase phenocrysts to 2 mm across, 5% light green fresh olivine phenocrysts to 3 mm across (most 1 mm). 10% small vesicles <1 mm across. Surface weathered brown and discolored to 5 mm depth. **Unit J**. 15: 7 x 6 x 4 cm dark grey olivine-plagioclase basalt. 10% plagioclase phenocrysts to 2 mm across, 5% weathered yellow-green olivine phenocrysts to 1 mm across. A dense non-vesicular block. Includes a fine-grained gabbroic xenolith 4 mm across. Surface weathered dark brown. **Unit K**. 16: 4 pieces, largest 7 x 5 x 3 cm, of black aphyric basalt. All have ~10% vesicles to 3 mm across and surfaces weathered brown. **Unit L**. 17: 9 x 8 x 2 cm volcaniclastic conglomerate. Clasts of deeply weathered yellow-brown lavas up to 5 mm across. Conglomerate itself also is very weathered. **Unit M**.	 TS, GC TS, GC TS, GC TS, GC
98 OFOS Volc 18: inner SE crater wall, S cone	01.11 19:22 24°36.00' S 176°54.81' W 798 m 01.11 22:09 24°35.02' S 176°55.26' W 1402 m	Video traverse of the 1100 m deep crater to establish the nature of the seafloor. See Appendix 3 for visual observations.	
99 DR Volc 19: inner NE	02.11 04:52 24°47.90' S 177°00.71' W	1: 16 x 15 x 9 cm black olivine-plagioclase basalt. 10% plagioclase phenocrysts to 2 mm across and 5% green-yellow olivine phenocrysts to 2 mm across. Non-	TS, GC

crater wall	914 m 02.11 05:35 24°47.77' S 177°00.58' W 680 m	vesicular, with irregular pull-aparts to 4 cm long. Surface weathered orange-brown with discoloration to 1 cm. **Unit A**. 2: 8 x 7 x 5 cm black plagioclase basalt. 15% plagioclase phenocrysts to 4 mm across (most 2 mm) and trace yellow-green olivine phenocrysts to 2 mm across. 15% vesicles to 4 mm across. A jointed block. Fracture surfaces are weakly weathered brown. **Unit B**. 3: 17 x 7 x 7 cm **Unit B**, but jointing is stronger. Weathered black on one side with discoloration to 1 cm depth. 4: 9 x 9 x 6 cm black plagioclase basalt. 15% plagioclase phenocrysts to 2 mm across and trace yellow-green olivine phenocrysts to 2 mm across. 10% vesicles grading to vugs 5 cm across. A rounded bomb with a fractured crust. Surface weakly weathered yellow-brown. **Unit C**. 5: 11 x 8 x 6 cm black plagioclase basalt. 20% plagioclase phenocrysts to 3 mm across. Irregular flow aligned pull-aparts to 6 cm long. Massive lava block. Surface weathered brown-black to 5 mm depth. **Unit D**. 6: 13 x 13 x 10 cm black plagioclase basalt. 5% plagioclase phenocrysts to 3 mm across and trace yellow-green olivine phenocrysts to 3 mm across. 20% small vesicles <1 mm across. Scoriaceous rubble top to block underlain by brown discolored lava to 1 cm depth. **Unit E**. 7: 8 x 8 x 7 cm **Unit E**, but developing a glassy crust. Possibly has more plagioclase phenocrysts (~10%). 8: 8 x 7 x 6 cm black plagioclase andesite. 20% plagioclase phenocrysts to 2 mm across and trace dark green pyroxene phenocrysts to 2 mm across. Dense and non-vesicular. A jointed massive flow block. Fracture surfaces are weathered orange-brown to 2 mm depth. **Unit F**. 9: 12 x 9 x 4 cm black plagioclase andesite. 20% plagioclase phenocrysts to 2 mm across. 5% vesicles to 2 mm across. Rectilinear jointing throughout block. Fracture surfaces are weathered black. **Unit G**. 10: 10 x 8 x 6 cm black plagioclase andesite. 10% plagioclase phenocrysts to 2 mm across. Alternating 1 cm thick bands of non-vesicular lava and lava with 20% vesicles to 1 mm across. Surface weathered black. **Unit H**. 11: 16 x 11 x 7 cm black plagioclase andesite. 10% plagioclase phenocrysts to 3 mm across. 10% vesicles to 3 mm across. Jointed on some sides. Surface weathered black to 2 mm depth. **Unit I**. 12: 16 x 10 x 9 cm black plagioclase andesite. A bimodal size distribution in the phenocrysts- 15% plagioclase phenocrysts to 2 mm across and 5% plagioclase phenocrysts to 5 mm across. Numerous parallel pull-aparts to 2 cm long. A fractured block. Surface weathered black to 2 mm depth. **Unit J**.	 TS, GC TS, GC TS, GC TS, GC TS, GC
100 DR Volc 19: summit cone, W flank	02.11 06:48 24°48.30' S 177°00.30' W 595 m 02.11 07:29 24°48.29' S 177°00.09' W 469 m	1: 12 x 10 x 9 cm black aphyric basalt. 10% flow aligned vesicles grading to pull-aparts up to 5 mm long. Surface consists of a scoriaceous autobreccia up to 3 mm thick. Surface is weakly weathered orange-brown, but it is unclear whether this persists to 3 mm or that discoloration is an artifact of the autobreccia. **Unit A**. 2: 10 x 10 x 6 cm **Unit A**. 3: 13 x 9 x 5 cm Unit A, but the surface is more weathered	TS, GC TS, GC

		to orange-brown, the discoloration persists to 5 mm, and there is a slight MnOx dusting. Definitely an older lava. **Unit B**. 4: 10 x 9 x 6 cm black aphyric andesite. Traces of plagioclase phenocrysts to 2 mm across. 10% small flow-aligned vesicles in bands grading to pull-aparts 3 cm long. A semi-jointed block. Surface weakly weathered yellow-brown. **Unit C**. 5: 10 x 8 x 6 cm black aphyric basalt. 30% vesicles up to 5 mm across. Surface weakly weathered with minor yellow-brown clay in some vesicles. **Unit D**. 6: 8 x 8 x 6 cm dark grey aphyric basalt. Traces of yellow-green olivine phenocrysts to 1 mm across. 20% vesicles up to 3 mm across, with rare large elongated vesicles to 2 cm long. A dense block. Surface weathered yellow-green to 1 mm depth. **Unit E**. 7: 11 x 11 x 6 cm black olivine basalt. 5% yellow-green olivine phenocrysts to 1 mm across and traces of plagioclase phenocrysts to 1 mm across. 20% vesicles to 3 mm across. Numerous pull-aparts but only near the surface. Surface weakly weathered yellow-green. **Unit F**. 8: 15 x 12 x 10 cm **Unit F**, but a more massive block. 9: 16 x 9 x 7 cm dark grey olivine basalt. 10% yellow-green olivine phenocrysts to 2 mm across, trace plagioclase phenocrysts to 1 mm across. 15% small vesicles to 2 mm across, which are flow aligned in bands, and 5% large vesicles to 2 cm across. Surface weathered brown-black with yellow-green discoloration on fractures. **Unit G**. 10: 10 x 8 x 6 cm black plagioclase basalt. 5% plagioclase phenocrysts to 2 mm across and trace yellow-green olivine phenocrysts to 1 mm across. 10% small vesicles <1 mm across and 10% large vesicles to 1 cm across. Surface weathered yellow-green. **Unit H**. 11: 9 x 8 x 8 cm as for 100DR-10, but less vesicular with only traces of the larger vesicles. Surface weathered more deeply orange-brown and yellow-green. Autobrecciating on one side. Probably an older flow. **Unit I**. 12: 12 x 8 x 7 cm black plagioclase basalt. 10% plagioclase phenocrysts to 2 mm across and trace olivine phenocrysts to 1 mm across. 20% small vesicles <0.5 mm across. A dense block. Surface weakly weathered yellow-green. **Unit J**. 13: 7 x 4 x 2 cm black plagioclase andesite. 20% plagioclase phenocrysts to 2 mm across and trace yellow-green olivine phenocrysts to 1 mm across. 10% vesicles grading to pull-aparts 1 cm long. Block is a thin slice off a larger block. Surface weathered yellow-green or locally orange-brown. **Unit K**. 14: 8 x 4 x 4 cm dark grey aphyric andesite. 30% vesicles to 4 mm across. Surface deeply weathered yellow-brown to 3 mm depth. A much older flow than all others at this site. **Unit L**. 15: 7 x 4 x 3 cm **Unit L**.	 TS, GC TS, GC TS, GC TS, GC TS, GC TS, GC
101 PN	02.11 09:49 24°50.32' S 177°02.68' W 0 m 02.11 10:03 24°50.16' S	Plankton net, trawled at 1.6 knots.	

	177°02.38' W 0 m		
102 DR Volc 19: SW ridge, SW cone, upper flank	02.11 10:58 24°52.32' S 177°03.88' W 1183 m 02.11 11:43 24°52.17' S 177°03.76' W 1049 m	1: 9 x 8 x 7 cm black aphyric andesite. Dense lava block with 10% flow aligned vesicles grading to pull-aparts up to 4 cm long. Surface and fractures weathered black to orange (Fe), and a thin MnOx dusting (0.1 mm). **Unit A**. 2: 9 x 8 x 7 cm **Unit A**. 3: 12 x 8 x 6 cm black aphyric andesite. Scoriaceous, with 50% vesicles to 1 mm across. Locally oxidised red, especially on the surface. Weakly weathered, with some yellow clay on surfaces. **Unit B**. 4: 13 x 7 x 6 cm **Unit B**, but mostly black in color.	TS, GC TS, GC
103 DR LINZ #1: SE ridge, mid flank	04.11 04:46 28°40.56' S 178°00.77' E 3945 m 04.11 06:42 28°40.47' S 177°59.96' E 3621 m	Several blocks up to 2 m in length of deeply weathered rock, presumably basalt, now completely altered to light brown clay. The clay was encased in MnOx up to 4 cm thick. All samples were bagged for delivery to LINZ in NZ.	
104 DR LINZ #1: SE ridge, lower flank	04.11 09:18 28°40.39' S 177°59.84' E 3528 m 04.11 10:32 28°40.33' S 177°59.49' E 3229 m	Empty dredge. Cable wrapped around and inside dredge, but was plenty of space left to capture rocks.	
105 PN	04.11 11:37 28°40.54' S 177°59.35' E 0 m 04.11 11:51 28°40.59' S 177°59.00' E 0 m	Plankton net, trawled at 1.7 knots.	
106 DR LINZ #2: NW ridge, lower flank	04.11 16:06 28°43.00' S 178°04.20' E 3940 m 04.11 18:31 28°43.34' S 178°05.10' E 3608 m	Dredge empty except for 1 piece of pumice. Cable tension indicates dredge was full of sediment on the seafloor which washed out during heaving. The pumice was bagged for delivery to LINZ in NZ.	
107 DR LINZ #3: WSW ridge, mid flank	05.11 05:05 29°43.04' S 178°05.59' E 2363 m 05.11 07:07 29°42.89' S 178°05.76' E 2198 m	Empty dredge. Nevertheless, dredge was stuck for 2 hours with bites up to 8 tonnes.	
108 DR LINZ #3: WSW ridge, mid flank	05.11 08:21 29°42.82' S 178°05.92' E 2099 m 05.11 10:30 29°42.89' S 178°05.92' E 2189 m	Empty dredge, apart from the upper jaw bone of a dolphin. First attempt was stuck for 30 minutes and interpreted to be empty. The dredge was then lifted to 1800 m and a second attempt made to recover rocks from the upper flank of the ridge. The dredge again became stuck for 30 minutes. The jaw bone was bagged by the biologists.	

	05.11 10:51 29°42.79' S 178°06.02' E 2044 m 05.11 11:39 29°42.85' S 178°06.08' E 2176 m		
109 PN	05.11 12:25 29°42.94' S 178°05.90' E 0 m 05.11 12:38 29°42.56' S 178°05.94' E 0 m	Plankton net, trawled at 1.6 knots.	
110 DR LINZ #3: SW ridge, upper flank	05.11 13:42 29°42.90' S 178°07.99' E 1460 m 05.11 15:04 29°42.29' S 178°08.07' E 1398 m	Empty dredge.	
111 DR LINZ #4: NW ridge, upper flank	05.11 23:48 29°02.87' S 179°02.23' E 2490 m 06.11 00:50 29°03.24' S 179°02.37' E 2231 m	Recovered numerous pieces of MnOx-encrusted deeply weathered vesicular basalt. MnOx crust was up to 6 cm thick, and all surfaces smooth. All samples were bagged for delivery to LINZ in NZ.	
112 DR LINZ #3: WSW ridge, upper flank	06.11 15:25 29°42.60' S 178°06.31' E 2042 m 06.11 18:57 29°42.29' S 178°06.14' E 1791 m	Recovered numerous pieces of MnOx-encrusted deeply weathered vesicular olivine basalt, in which all olivine phenocrysts have been replaced by iddingsite. MnOx crust was up to 3 cm thick, and all surfaces smooth. All samples were bagged for delivery to LINZ in NZ.	
113 OFOS LINZ #3: WSW ridge, upper flank	06.11 20:34 29°42.28' S 178°06.15' E 1769 m 06.11 21:27 29°42.63' S 178°06.33' E 2069 m	Video traverse of LINZ site 3 to clarify the reasons for the difficult dredging. See Appendix 3 for visual observations.	
114 PN	08.11 10:11 25°58.71' S 174°53.60' W 0 m 08.11 10:23 25°58.72' S 174°53.35' W 0 m	Plankton net, trawled at 1.2 knots.	
115 DR Louisville Ridge 23	08.11 13:38 26°02.63' S 174°57.41' W	Empty dredge, despite numerous bites to 8.5 tonnes.	

	2607 m 08.11 14:25 26°02.46' S 174°57.49' W 2398 m		
116 DR Louisville Ridge 23	08.11 16:26 26°03.33' S 174°58.80' W 3021 m 08.11 17:43 26°02.96' S 174°58.69' W 2753 m	1: 21 x 16 x 7 cm conglomerate. Subrounded to subangular pebbles of various lava types up to 4 mm across. Clast-supported with a calcite matrix. MnOx crust <1 mm thick. **Unit A**. 2: 23 x 20 x 5 cm coralline limestone. White carbonate with voids up to 1.5 cm across filled by soft pale brown clay. MnOx crust 5 mm thick. **Unit B**. 3: Two pieces of a 15 x 10 cm block composed of very pale brown clay speckled with MnOx <0.5 mm across. Locally a thin MnOx crust. **Unit C**. 4: Two pieces, each 9 x 8 x 6 cm, of black pyroxene basalt. 30% pyroxene phenocrysts mottled black and white to 3 mm across. Matrix is brown and iron stained. Minor carbonate lining in vuggy voids to 2 cm across. MnOx crust 2 mm thick. **Unit D**.	 TS, GC
117 DR Louisville Ridge 23	08.11 19:44 26°02.73' S 174°57.51' W 2693 m 08.11 21:31 26°02.64' S 174°37.44' W 2599 m	1: 12 x 3 x 2 cm red pyroxene basalt. Trace black pyroxene phenocrysts to 2 mm across. 30% small vesicles filled with calcite and green clay. MnOx crust <0.1 mm thick. **Unit A**. 2: 9 x 5 x 4 cm very pale brown siltstone. **Unit B**. 3: 10 x 8 x 4 cm coralline limestone. Bivalve shells and rock fragments up to 2 cm across (most <5 mm), with calcite filling fractures. MnOx crust <0.1 mm thick. **Unit C**.	TS, GC
118 DR Louisville Ridge 23	09.11 00:23 26°02.60' S 174°57.50' W 2555 m 09.11 01:12 26°02.38' S 174°57.51' W 2159 m	Empty dredge, despite numerous bites to 8.0 tonnes.	
119 DR Louisville Ridge 23	09.11 03:01 26°00.61' S 174°54.59' W 2179 m 09.11 05:11 26°00.64' S 174°54.93' W 1918 m	1: 40 x 25 x 20 cm conglomerate. Subrounded to rounded pebbles of various lithologies to 4 mm across. Calcite-clay cemented. An old beach sand. **Unit A**.	
120 DR Louisville Ridge 23	09.11 07:02 26°02.61' S 174°57.52' W 2594 m 09.11 08:55 26°02.68' S 174°57.55' W 2663 m 09.11 09:36 26°02.48' S 174°57.50' W 2363 m 09.11 10:20 26°02.39' S	1-33: Numerous small pebbles of various lithologies chipped with a hammer from a very large block of conglomerate. Calcite fills fractures in the conglomerate. **Unit A**. 34: 12 x 10 x 9 cm dark grey aphyric basalt. A subrounded clast from the conglomerate. Traces of iddingsite after olivine in the matrix. 5% small vesicles in bands, which are discolored grey with minor chlorite. Weathered surface. **Unit B**. 35: 14 x 10 x 8 cm dark grey olivine basalt. 10% olivine phenocrysts pseudomorphed by iddingsite to 3 mm across. 5% pull-aparts up to 2 cm long, with a few being partly lined by calcite or zeolite or iron-stained. Surface discolored grey near the conglomerate. **Unit C**.	 TS, GC, Ar TS, GC, Ar

	174°57.50' W 2159 m		
121 DR Osbourn Trough: inner corner high, SE Segment 1	09.11 22:28 25°36.91' S 173°31.78' W 4716 m 10.11 00:10 25°37.02' S 173°32.43' W 4376 m	1: 11 x 11 x 10 cm grey olivine gabbro. Thick concentric brown-black MnOx crust over a 7 x 7 x 2 cm gabbro. 30% olivine pseudomorphed by iddingsite (but not dark brown) together with black pyroxene and white plagioclase. Even grain size at ~0.5 mm. **Unit A**. 2: Seven pebbles, largest 3 x 3 x 2 cm, of aphyric basalt, plagioclase basalt, and olivine-plagioclase basalt (olivine pseudomorphed by iddingsite) set in MnOx crust and variably very deeply weathered to only weakly weathered. **Unit B**. 3: Three pieces, largest 13 x 10 x 3 cm, of black-brown MnOx crust up to 8 cm thick. At the lower contact of the crust are deeply weathered lithic fragments in a white clay matrix (breccia?). **Unit C**. 4: Three pieces, largest 10 x 9 x 6 cm, of brown-black MnOx crust up to 3 cm thick. Pale brown clay under the crust with relic clasts, all very deeply weathered. **Unit D**. 5: 10 x 9 x 5 cm **Unit D**, including a black shark's tooth in the pale brown clay that proves the clay is sediment or hyaloclastite.	TS
122 DR Osbourn Trough: inner corner high, SE Segment 1	10.11 03:15 25°45.18' S 173°33.00' W 5100 m 10.11 05:39 25°36.00' S 173°33.69' W 4396 m	1: 21 x 17 x 10 cm black MnOx nodules. The nodules are typically 7 cm in diameter and set in finely bedded and laminated yellow-brown clay, and were evidently buried by the sediment. Uppermost surface is MnOx 2 mm thick. **Unit A**. 2: 10 x 8 x 3 cm black MnOx crust. The 2.5 cm thick crust is underlain by pale brown clay. **Unit B**. 3: 8 x 7 x 4 cm **Unit B**, including a MnOx nodule 4 cm in diameter with a clay core. 4: 9 x 6 x 4 cm cream aphyric pumice. Traces of black hornblende (confirmed by cleavage). Surface weakly weathered yellow-brown (no MnOx). **Unit C**. 5: 8 x 8 x 4 cm **Unit C**.	TS, GC
123 DR Osbourn Trough: inner corner high, SE Segment 1	10.11 08:46 25°36.67' S 173°34.37' W 4715 m 10.11 09:36 25°36.55' S 173°34.12' W 4564 m	1: 8 x 4 x 3 cm yellow-brown clay encrusted with 5 mm of brown-black MnOx. **Unit A**. 2: 4 x 4 x 2 cm cream quartz pumice. 5% quartz phenocrysts. Surface MnOx stained and clearly float pumice. **Unit B**.	
124 PN	10.11 11:04 25°36.61' S 173°34.11' W 0 m 10.11 11:17 25°36.74' S 173°34.03' W 0 m	Plankton net, trawled at 0.9 knots.	
125 DR Osbourn Trough 24: inner corner high, NW Segment 2	11.11 16:26 25°39.00' S 173°18.00' W 5299 m 11.11 19:16 25°37.96' S 173°18.02' W 4361 m	1: 20 x 15 x 12 cm reddish grey olivine-plagioclase basalt. 5% olivine phenocrysts pseudomorphed by iddingsite to 2 mm across and 15% cream to light green smectite or chlorite pseudomorphing olivine phenocrysts to 3 mm across, together with 10% plagioclase phenocrysts to 3 mm across. Highly porphyritic. A few calcite filled fractures to 1 mm wide. Color ranges from grey where freshest in core through reddish grey to brown at the surface. A subangular boulder enclosed in brown clay	TS, GC, Ar

		(sediment) with other pebbles. MnOx crust >5 cm thick. **Unit A**. 2: 13 x 10 x 7 cm **Unit A**, but a different boulder. 3: 23 x 18 x 9 cm **Unit A**. 4: 23 x 16 x 12 cm **Unit A**. Boulder includes a deeply weathered aphyric clast with calcite-filled vesicles, as well as another good basalt clast as for 125DR-01. 5: 11 x 7 x 6 cm **Unit A**, but includes a microgabbro xenolith. 6: 10 x 5 x 5 cm **Unit A**, featuring a small pebble from a large block of crust. 7: 8 x 7 x 3 cm **Unit A**, but more weathered and lava only. 8: 10 x 7 x 6 cm dark grey aphyric pumice. Flow banded. Surface weakly weathered only, but with slight MnOx dusting. **Unit B**.	 TS, GC TS
126 DR Osbourn Trough 24: inner corner high, NW Segment 2	11.11 22:37 25°38.21' S 173°20.50' W 4837 m 12.11 00:12 25°37.60' S 173°20.53' W 4439 m	1: 20 x 17 x 11 cm black MnOx crust. Concentric and 10.5 cm thick, with no base. Includes a 2 cm thick bed with weathered sediment (or hyaloclastite) near the base. **Unit A**. 2: 18 x 15 x 7 cm **Unit A**, but only 5 cm thick and with two 2 cm thick clay bands. 3: 14 x 8 x 8 cm deeply weathered brown clay after sediment. Black MnOx specks in the clay, and an 8 mm thick concentric MnOx crust. **Unit B**. 4: 9 x 8 x 8 cm grey aphyric pumice. Surface weathered brown with slight MnOx dusting. **Unit C**.	 TS
127 PN	12.11 10:10 25°47.61' S 172°36.43' W 0 m 12.11 10:25 25°47.26' S 172°36.23' W 0 m	Plankton net, trawled at 1.8 knots.	
128 DR Osbourn Trough: old inner corner high, N of NW Segment 3	12.11 12:20 25°47.71' S 172°36.50' W 5558 m 12.11 14:41 25°46.69' S 172°36.37' W 4744 m	1: 8 x 6 x 3 cm grey plagioclase basalt. 5% plagioclase phenocrysts to 3 mm across. Groundmass pyroxene appears altered to chlorite(?). Locally patches of green chloritic alteration. A clast in MnOx crust. **Unit A**. 2: 7 x 6 x 5 cm brown-orange aphyric basalt. Deeply weathered with a few relic fresher grey patches. A clast in MnOx crust. **Unit B**. 3: 5 x 3 x 2 cm dark grey plagioclase basalt. 10% plagioclase phenocrysts to 3 mm across. Core is relatively fresh, but surface is discolored brown to 1 cm depth. A clast in MnOx crust. **Unit C**. 4: 14 x 8 x 7 cm orange-brown olivine-plagioclase basalt. 5% plagioclase phenocrysts to 2 mm and 10% olivine phenocrysts pseudomorphed by iddingsite to 3 mm across. Deeply weathered. A second aphyric basalt clast also occurs in the crust. MnOx crust is 5 cm thick. **Unit D**. 5: 6 x 5 x 3 cm deeply weathered brown dolerite. 50% black pyroxene, 30% plagioclase and 20% olivine pseudomorphed by iddingsite, with a grain size of ~0.5 mm. Probably an intrusive, but could be a coarse grained lava. A clast in MnOx crust. **Unit E**. 6: 9 x 7 x 6 cm MnOx crust 1 cm thick, including subangular weathered clasts of various lavas set in pale brown clay. The largest clast is a plagioclase basalt 5 cm in diameter, but most are aphyric basalt. **Unit F**.	TS, GC, Ar TS, GC, Ar TS, GC TS, GC TS

		7: 11 x 10 x 7 cm **Unit F**. 8: 14 x 9 x 7 cm **Unit F**. 9: 12 x 8 x 7 cm **Unit F**. 10: 10 x 9 x 7 cm **Unit F**. MnOx crust is 4 cm thick. 11: 21 x 16 x 10 cm **Unit F**. 12: Three pieces of **Unit F**, the largest being 13 x 11 x 8 cm, with smaller subangular fragments 1.5 cm across set in pale brown clay. MnOx crust is 6 cm thick. 13: 11 x 7 x 6 cm **Unit F**. 14: 7 x 4 x 3 cm cream aphyric pumice. Surface weakly weathered brown. **Unit G**. 15: Nine small pieces of various lithologies, all weathered brown. **Unit H**. **NB:** Overall the haul is MnOx encrusted sediment containing three lithologies (plagioclase basalt, aphyric basalt and olivine-plagioclase basalt) plus the rare dolerite.	 TS
129 DR Osbourn Trough: old inner corner high, N of NW Segment 3	12.11 18:53 25°39.01' S 172°35.00' W 5994 m 12.11 21:01 25°39.59' S 172°35.35' W 5198 m	1: 6 x 6 x 4 cm brown plagioclase-olivine basalt. 10% plagioclase phenocrysts to 2 mm across, 15% olivine phenocrysts pseudomorphed by cream to pale green smectite and rarely iddingsite to 3 mm across. 10% vesicles <1 mm across filled by dark grey chlorite. Locally less weathered with dark grey domains. A large clast in MnOx crust. **Unit A**. 2: 4 x 4 x 3 cm grey olivine-plagioclase basalt. 10% apple green chlorite or smectite pseudomorphing olivine phenocrysts to 2 mm across and 10% plagioclase phenocrysts to 3 mm across. Grades to nearly aphyric on one side (a weathered xenolith?). 5% vesicles <1 mm across filled with dark grey chlorite. A clast in MnOx crust. **Unit B**. 3: 5 x 4 x 3 cm orange-brown olivine basalt. 5% olivine phenocrysts pseudomorphed by iddingsite to 2 mm across. Groundmass is deeply weathered, with orange clay filling the 10% vesicles up to 1 mm across. Black chloritic clay fills thin <0.1 mm wide fractures. A clast in MnOx crust. **Unit C**. 4: 4 x 4 x 3 cm deeply weathered orange-brown lava. Probably a plagioclase basalt, and appears to have 5% plagioclase phenocrysts to 2 mm across. Also possibly with iddingsite after olivine. A clast in MnOx crust. **Unit D**. 5: 4 x 4 x 3 cm deeply weathered orange-brown lava. Probably an aphyric basalt. Locally with orange and black spots to 1 mm across, possibly representing iddingsite after olivine. A clast in MnOx crust. **Unit E**. 6: 4 x 2 x 1 cm green-grey olivine-plagioclase basalt. 5% plagioclase phenocrysts to 2 mm across and 5% olivine phenocrysts pseudomorphed by iddingsite to 1 mm across. A chloritised lava pebble in MnOx crust. **Unit F**. 7: 15 x 14 x 8 cm MnOx crust. Brown clay with deeply weathered clasts of lava up to 1.5 cm across, including one composed of chrysotile serpentine (yellow-green), are overlain by 2 cm thick black MnOx crust. **Unit G**. 8: 13 x 12 x 5 cm **Unit G**, but no MnOx left on the sediment. Several serpentine clasts. 9: 10 x 9 x 8 cm **Unit G**, but no MnOx left on the sediment although a 2 cm thick MnOx band occurs in the centre of the boulder. Includes a 2 cm in diameter clast of	1: TS, GC, Ar 2: TS, GC 3: TS, GC 4: TS 6: TS

		chloritised lava breccia. 10: 12 x 11 x 4 cm **Unit G**. Clasts include a 4 cm diameter deeply weathered plagioclase basalt with plagioclase phenocrysts up to 5 mm long. 11: 6 x 6 x 3 cm grey aphyric pumice. Trace amounts of black specks in groundmass. Devitrification banded in shades of dark grey to cream grey on mm scale. Surface weathered yellow-brown. **Unit H**. 12: 6 x 4 x 4 cm pale grey quartz pumice. Trace quartz phenocrysts to 3 mm across. Surface weathered yellow-brown. **Unit I**. 13: 9 x 8 x 4 cm cream aphyric pumice. Deeply weathered to yellow shades with the surface brown and dusted with MnOx. **Unit J**.	 TS TS
130 DR Osbourn Trough 25: inner corner high, SE Segment 2	13.11 09:56 25°52.30' S 172°46.49' W 5378 m 13.11 13:06 25°52.24' S 172°47.59' W 4435 m	1: 7 x 7 x 4 cm grey olivine-plagioclase basalt. 10% yellow-green olivine phenocrysts partly pseudomorphed by iddingsite to 2 mm across, and 10% plagioclase phenocrysts to 2 mm across and mostly lath-like. Interior is mostly grey, but with some more weathered orange-brown domains. Chloritic clay fills fractures to 1 mm wide. A clast in MnOx crust. **Unit A**. 2: 7 x 5 x 3 cm grey olivine-plagioclase basalt. 10% olivine phenocrysts pseudomorphed by iddingsite to 1 mm across (rarely still green), and 10% plagioclase phenocrysts to 1 mm across and mostly lath-like. Dark grey where least weathered. **Unit B**. 3: 7 x 4 x 4 cm deeply weathered brown aphyric basalt. Groundmass appears to be ~0.5 mm crystals, and this could be a dolerite. Relic plagioclase in the groundmass, and pyroxene in the groundmass is replaced by chlorite. Rare dark crystals could be old relic olivines. **Unit C**. 4: 6 x 6 x 5 cm **Unit C**. 5: 6 x 4 x 3 cm reddish-brown olivine-plagioclase basalt. As for **Unit B**, except for the oxidised color. 6: 4 x 4 x 2 cm **Unit C**. 7: 8 x 8 x 5 cm deeply weathered olivine gabbro. Relic olivine pseudomorphed by iddingsite, plagioclase, and dark grey chlorite after pyroxene. Grain size is ~0.5 mm. Sediment along some margins. MnOx crust is 2 cm thick. **Unit D**. 8: 12 x 11 x 8 cm **Unit C**. A clast in MnOx crust and yellow-brown sediment up to 8 cm thick. 9: 27 x 10 x 6 cm MnOx crust 7 cm thick containing at least 3 subangular pebbles of plagioclase basalt and aphyric basalt. **Unit E**. 10: 12 x 9 x 7 cm MnOx crust 3 cm thick with yellow-brown sediment and numerous small pebbles of deeply weathered lava. **Unit E**. 11: 11 x 5 x 5 cm **Unit E**, MnOx crust 1 cm thick. 12: 8 x 7 x 5 cm **Unit E**, including clasts of breccia. 13: 14 x 8 x 8 cm **Unit E**. 14: 19 small pieces of deeply weathered aphyric basalt and olivine-plagioclase basalt (**Units A, B, C**). Labelled 14a to 14t. 15: 25 x 15 x 10 cm **Unit E**. Contains 5 large basalt pebbles. MnOx crust 2 cm thick. Labelled for the Museum. **NB:** All samples are really Unit E, being clasts in the MnOx encrusted sediment.	TS, GC, Ar TS, GC, Ar TS, GC TS, GC, Ar TS, GC TS, GC TS
131 DR	14.11 12:35	Empty dredge, but had several bites to 8.0 tonnes.	

Osbourn Trough 31: inner corner high, SW Segment 3	26°05.74' S 172°28.98' W 5619 m 14.11 13:54 26°06.18' S 172°28.95' W 5167 m		
132 DR Osbourn Trough 26: inner corner high, NW Segment 3	14.11 18:26 25°59.64' S 172°14.99' W 5419 m 14.11 20:45 25°58.82' S 172°14.99' W 4654 m	1: 8 x 7 x 5 cm brown olivine-plagioclase basalt. 15% plagioclase phenocrysts to 3 mm across, 10% olivine phenocrysts pseudomorphed by cream green smectite or chlorite and rarely iddingsite to 3 mm across. Black chloritic domains occur in the pervasively weathered groundmass. A clast in MnOx crust. **Unit A**. 2: 9 x 7 x 4 cm **Unit A**, possibly slightly less porphyritic. 3: 8 x 8 x 5 cm brown plagioclase basalt. 5% plagioclase phenocrysts to 3 mm across, and trace olivine phenocrysts pseudomorphed by iddingsite to 2 mm across. Groundmass pervasively weathered. Numerous fractures filled with black chlorite to 0.1 mm wide. **Unit B**. 4: 7 x 6 x 4 cm reddish brown plagioclase-olivine basalt. 10% plagioclase phenocrysts to 2 mm across and 15% olivine phenocrysts pseudomorphed by iddingsite to 2 mm across but rarely with discolored yellow-green shades. Locally with fresher dark grey domains. Thin black chloritic fractures <0.1 mm wide. **Unit C**. 5: 6 x 4 x 3 cm **Unit A**. 6: 8 x 3 x 2 cm **Unit A**, but possibly more porphyritic (20% plagioclase phenocrysts). 7: 6 x 4 x 2 cm **Unit A**. 8: 6 x 5 x 4 cm **Unit A**, as for 132DR-06. 9: 5 x 4 x 2 cm **Unit A**. 10: 18 x 10 x 8 cm MnOx crust 5 cm thick over yellow-brown sediment (clay) containing deeply weathered subangular lava pebbles. Largest clast is a plagioclase basalt, and a few are serpentine. **Unit D**. 11: 19 x 9 x 5 cm MnOx crust 1 cm thick over brown sediment (clay) with pebbles to 1 cm across of chlorite, serpentine, and variably to pervasively weathered basalt. **Unit D**. 12: 10 x 8 x 7 cm MnOx crust 6 cm thick over sediment and breccia. **Unit D**. 13: 12 small pieces of deeply weathered basalt, mostly **Unit A** with a few bits of **Unit B**. Labelled 13a to 13l.	TS, GC, Ar TS, GC, Ar TS, GC, Ar TS, GC TS TS TS TS, GC TS
133 PN	15.11 09:43 26°25.99' S 174°46.91' W 0 m 15.11 09:55 26°26.13' S 174°46.58' W 0 m	Plankton net, trawled at 1.6 knots.	
134 DR Louisville Ridge 32	15.11 11:04 26°25.87' S 174°46.70' W 2675 m 15.11 12:37 26°25.86' S 174°46.11' W 2200 m	1: 7 x 4 x 3 cm grey olivine-plagioclase basalt. 10% plagioclase phenocrysts to 3 mm across and 5% olivine phenocrysts pseudomorphed by iddingsite to 2 mm across. 10% vesicles up to 2 mm across lined with dark brown clay. MnOx crust 3 mm thick. **Unit A**. 2: 9 x 5 x 3 cm breccia. Subangular clasts of deeply weathered red-brown plagioclase basalt to 1.5 cm across (most 3 mm) in a dark grey-green silty matrix. **Unit B**.	TS, GC

		3: 11 x 8 x 4 cm brown clay. Finely laminated with cream foram beds <1 mm thick. MnOx dusting on surface. **Unit C**. 4: 16 x 9 x 8 cm pale brown sandstone. Forams and sand-sized reef detritus in clay. Worm burrows on the surface. **Unit D**. 5: 16 x 7 x 7 cm pale brown claystone. Similar to 134DR-04, but much finer grained with the worm burrows filled by coarser brown clay. MnOx crust 1 mm thick. **Unit E**. 6: Several small fragments of black MnOx crust, the largest being 6 x 1 x 1 cm. **Unit F**.	
135 DR Louisville Ridge 32	15.11 17:30 26°43.31' S 174°38.20' W 2345 m 15.11 19:18 26°42.94' S 174°37.56' W 1804 m	1: 8 x 7 x 7 cm dark grey aphyric basalt. Trace plagioclase phenocrysts to 2 mm across. A dense flow jointed block, with the interior locally discolored reddish-brown but mostly quite fresh. MnOx crust <1 mm thick. **Unit A**. 2: 11 x 8 x 4 cm **Unit A**, with yellow-orange staining along one side (hydrothermal?). 3: 11 x 7 x 5 cm **Unit A**, but MnOx crust 1 cm thick. 4: 7 x 6 x 5 cm **Unit A**, but slightly lighter color and more weathered. Possibly a different unit. 5: 6 x 6 x 5 cm **Unit A**. 6: 9 x 5 x 4 cm very pale brown sandstone. Composed of forams, with one apple green nontronite altered pumice clast. **Unit B**. 7: 10 x 6 x 4 cm **Unit B**, but with subangular fragments of dark green sandstone. Maybe volcaniclastic beach sands? 8: 13 x 13 x 6 cm cream foram sandstone with worm burrows to 3 cm long and filled by soft brown clay. MnOx dusting on the surface. **Unit C**. 9: 13 x 9 x 4 cm **Unit C**, heavily MnOx stained. 10: 10 x 9 x 6 cm cream foram sandstone with worm burrows and large shell fragments. Locally brecciated. MnOx crust 2 cm thick. **Unit D**. 11: 7 x 7 x 5 cm **Unit D**. 12: 7 x 6 x 6 cm brown clay with coarser and paler lenses. **Unit E**. 13: 13 pieces, largest 7 x 4 x 3 cm, of more weathered **Unit A**. Some are brecciated. Labelled 13a-13m and put in one bag.	TS, GC, Ar TS, GC, Ar TS, GC, Ar TS, GC TS, GC
136 DR Louisville Ridge 32	15.11 21:32 26°45.68' S 174°39.40' W 3315 m 15.11 22:44 26°45.30' S 174°39.41' W 3010 m	Empty dredge, but one bite to 9.6 tonnes.	
137 DR Louisville Ridge 32	16.11 01:07 26°48.60' S 174°35.50' W 3007 m 16.11 02:49 26°48.40' S 174°34.88' W 2514 m	1: 11 x 9 x 8 cm cream aphyric pumice. 50% large vesicles grading to vugs up to 7 cm long. Slight devitrification banding to pale grey shades. Surface weakly weathered brown with clay in some vesicles. **Unit A**. 2: 13 x 6 x 4 cm very pale brown foram sandstone. Worm burrows to 3 cm long by 0.5 mm wide. Slight MnOx dusting on surface. **Unit B**. 3: 6 x 4 x 2 cm black MnOx crust. **Unit C**.	TS, GC
138 PN	16.11 10:05 27°32.76' S 173°59.80' W 0 m 16.11 10:18	Plankton net, trawled at 1.8 knots.	

	27°32.85' S 173°59.54' W 0 m		
139 DR Louisville Ridge 33	16.11 11:50 27°35.19' S 174°01.58' W 2541 m 16.11 13:09 27°34.79' S 174°02.08' W 2116 m	1: 6 x 6 x 5 cm blue-grey olivine-plagioclase basalt. 5% plagioclase phenocrysts to 2 mm across and 5% olivine phenocrysts pseudomorphed by iddingsite or cream green smectite to 2 mm across. 10% small vesicles <1 mm across occurring in local domains. A well-rounded clast in a beach conglomerate. Surface weakly weathered yellow-brown. **Unit A**.	TS, GC, Ar
		2: 5 x 5 x 4 cm dark grey olivine-plagioclase basalt. 10% plagioclase phenocrysts to 3 mm across and 5% olivine phenocrysts pseudomorphed by iddingsite to 2 mm across. Dense lava with incipient pull-aparts up to 5 mm long. A well-rounded clast in a beach conglomerate. Surface weakly weathered yellow-brown. **Unit B**.	TS, GC, Ar
		3: 8 x 5 x 4 cm as for Unit B, but with 10% vesicles to 3 mm across and pull-aparts filled with white clay. Also olivine phenocrysts grade from cream green to iddingsite pseudomorphs. **Unit C**.	TS, GC, Ar
		4: 8 x 5 x 4 cm **Unit C**, but maybe less porphyritic. Calcite or zeolite lines some vesicles.	TS, GC, Ar
		5: 6 x 5 x 3 cm dark grey plagioclase-olivine basalt. 10% plagioclase phenocrysts to 2 mm across and 10% olivine phenocrysts pseudomorphed by iddingsite to 4 mm across (most 2 mm). Dense lava. **Unit D**.	TS, GC
		6: 7 x 4 x 1 cm grey aphyric basalt. Trace plagioclase phenocrysts to 1 mm across. Dense and non-vesicular. **Unit E**.	TS, GC
		7: 6 x 4 x 3 cm dark grey olivine-plagioclase basalt. 20% plagioclase phenocrysts to 4 mm (most 2 mm) and 10% olivine phenocrysts pseudomorphed by iddingsite to 2 mm across. 5% vesicles to 3 mm across, some with chlorite or zeolite lining. **Unit F**.	TS, GC
		8: 6 x 4 x 3 cm dark grey aphyric basalt. Trace plagioclase phenocrysts to 2 mm across and trace olivine phenocrysts pseudomorphed by iddingsite to 2 mm across. 30% vesicles lined with iddingsite (from groundmass olivine?). Relatively coarse groundmass (~0.2 mm). **Unit G**.	TS
		9: 7 x 4 x 2 cm **Unit D**, but less weathered with olivine phenocrysts mostly creamish green to light brown.	
		10: 5 x 4 x 3 cm **Unit A**.	
		11: 10 x 7 x 5 cm conglomerate of well-rounded basalt pebbles to 1.5 cm long set in a sand to silt volcaniclastic matrix. Stained yellow-brown. All clasts above come from large pieces of this beach conglomerate. **Unit H**.	
		12: 10 x 5 x 3 cm **Unit H**, but with MnOx crust 2 mm thick.	
		13: 16 x 11 x 4 cm **Unit H**, but with clasts up to 6 cm long. MnOx crust 8 mm thick.	
		14: 9 x 6 x 5 cm cream to dark blue aphyric pumice. Devitrification banded in ~0.5 mm thick bands with diffuse margins. 30% vesicles to 5 mm across, which are clay-filled near the surface. **Unit I**.	TS
		15: 10 x 7 x 5 cm cream brown pumice. Probably **Unit I**, but only hints of devitrification banding and more weathered with a yellow-brown surface.	
		16: 13 x 12 x 10 cm light brown foram sands with brown clay, also some well-rounded basalt pebbles. **Unit J**.	
		17: Numerous (21) well-rounded basalt pebbles, typically 4-	

		6 cm in diameter. Clasts extracted from large blocks of the **Unit H** beach conglomerate.	
140 DR Louisville Ridge 33	16.11 15:16 27°36.63' S 174°02.95' W 2388 m 16.11 16:51 27°36.39' S 174°03.35' W 1933 m	1: 5 x 4 x 2 cm grey aphyric basalt. Trace plagioclase phenocrysts to 1 mm across. Olivine in the groundmass is pseudomorphed by iddingsite, but the groundmass is still quite fresh. Dense. MnOx crust 0.5 mm thick. **Unit A**. 2: 8 x 6 x 4 cm brown-grey olivine-plagioclase basalt. 15% plagioclase phenocrysts to 4 mm across and 5% olivine phenocrysts pseudomorphed by iddingsite to 2 mm across. A small pebble in foram-volcaniclastic ooze. Pervasively weathered brown to 5 mm depth. MnOx crust 1 mm thick. **Unit B**. 3: 6 x 4 x 3 cm blue-grey plagioclase basalt. 10% plagioclase phenocrysts to 2 mm across and trace olivine phenocrysts pseudomorphed by iddingsite to 2 mm across. 20% vesicles to 3 mm across lined by zeolite or calcite. A clast from the breccia. MnOx crust 0.5 mm thick. **Unit C**. 4: 5 x 3 x 3 cm **Unit B**, deeply weathered brown. 5: 6 x 3 x 2 cm brown breccia. Subangular clasts of Units A and B, deeply weathered, in sandstone composed of forams and volcaniclastic sand. **Unit D**. 6: 4 x 3 x 2 cm **Unit D**. 7: Several pieces, largest 4 x 3 x 2 cm, of dark grey sandstone composed of forams and sand-sized volcaniclastics. Matrix is Unit D. MnOx crust 2 mm thick. **Unit E**. 8: 3 x 3 x 2 cm cream foram sandstone. MnOx stained surface. **Unit F**. 9: 6 x 5 x 2 cm MnOx crust, 3 cm thick, that covers the Unit D breccia. **Unit G**. **NB**: All samples from this dredge except 140DR-08 were clasts in the Unit D breccia.	TS, GC TS, GC TS
141 DR Louisville Ridge 33	16.11 18:41 27°38.81' S 174°04.30' W 2320 m 16.11 20:21 27°38.24' S 174°04.63' W 1797 m	1: 7 x 6 x 2 cm blue-grey aphyric basalt. Dense and nearly fresh. A flat beach pebble in breccia. MnOx crust 3 cm thick. **Unit A**. 2: 6 x 3 x 2 cm blue-grey plagioclase basalt. 10% plagioclase phenocrysts to 3 mm across and trace olivine phenocrysts pseudomorphed by iddingsite to 2 mm across. 5% small vesicles <1 mm across. A clast in the breccia. MnOx crust 1 mm thick. **Unit B**. 3: 15 x 12 x 4 cm breccia. Subangular to subrounded deeply weathered clasts of brown aphyric basalt in a silica-cemented hard matrix of sand-silt sized volcaniclastics (a different breccia from the loose sands of Units A and B). MnOx crust 2 mm thick. **Unit C**. 4: 9 x 6 x 2 cm **Unit C**. 5: 14 x 11 x 6 cm **Unit C**, MnOx crust 2 cm thick. 6: 6 x 6 x 3 cm MnOx crust, with a deeply weathered pebble of brown aphyric basalt. **Unit D**. 7: 8 x 8 x 8 cm brown aphyric basalt. Trace plagioclase phenocrysts to 2 mm across. Dense but deeply weathered, with the core locally grey. A subrounded clast from the Unit C breccia. **Unit E**.	TS, GC TS TS, GC, Ar
142 DR Louisville Ridge 34	17.11 05:36 28°31.21' S 173°22.61' W 2210 m	Empty dredge- the safety cable broke. Several bites to 9.1 tonnes.	

	17.11 07:21 28°31.03' S 176°22.34' W 1950 m		
143 DR Louisville Ridge 34	17.11 08:51 28°31.25' S 173°22.59' W 2203 m 17.11 10:04 28°30.93' S 173°22.32' W 1920 m	1: 11 x 6 x 3 cm brown-grey olivine basalt. 5% olivine phenocrysts pseudomorphed by iddingsite to 2 mm across. 30% vesicles to 2 mm across lined with white zeolite. Matrix is pervasively weathered. A clast from the breccia. MnOx crust 2 cm thick. **Unit A**. 2: 21 x 18 x 11 cm breccia. Deeply weathered aphyric basalt (Unit A) in a cream zeolite or calcite matrix with numerous smaller sand-sized grains. The basalt is highly vesicular (30%) with the vesicles typically 5 mm long. MnOx crust 2 cm thick. **Unit B**. 3: 12 x 11 x 7 cm **Unit B**, but lacks the MnOx crust. 4: 15 x 8 x 5 cm **Unit B**, but the MnOx crust is 3 cm thick. 5: 15 x 10 x 3 cm MnOx crust with a botryoidal surface. These nodules are ~7 mm in diameter. **Unit C**. 6: 19 x 12 x 7 cm pale brown foram sandstone. Locally MnOx dusting on the surface. **Unit D**.	TS
144 PN	17.11 11:03 28°32.01' S 173°22.78' W 0 m 17.11 11:21 28°31.93' S 173°23.03' W 0 m	Plankton net, trawled at 1.4 knots.	
145 DR Louisville Ridge 34	17.11 13:13 28°36.95' S 173°20.80' W 2321 m 17.11 14:19 28°36.52' S 173°20.72' W 1971 m	1: 18 x 9 x 2 cm black MnOx crust 2 cm thick with underlying yellow-brown clays. Includes small 3 x 1 cm well-rounded aphyric basalt pebbles with groundmass olivine pseudomorphed by iddingsite and 10% vesicles filled with white zeolite. **Unit A**.	TS
146 DR Louisville Ridge 34	17.11 16:11 28°36.96' S 173°20.83' W 2387 m 17.11 19:03 28°36.95' S 173°20.77' W 2420 m	1: 7 x 4 x 3 cm dark grey olivine basalt. 5% olivine phenocrysts pseudomorphed by iddingsite to 2 mm across. Groundmass is weathered brown with minor cream yellow zeolite veins on one side. MnOx crust 1 mm thick. **Unit A**.	TS, GC
147 DR Louisville Ridge 34	17.11 22:10 28°36.80' S 173°19.73' W 2363 m 17.11 23:29 28°36.81' S 173°19.50' W 2177 m	1: 15 x 14 x 12 cm dark grey olivine basalt. 5% olivine phenocrysts pseudomorphed by iddingsite to 1 mm across. Dense, but with 10% large vesicles to 8 mm across totally filled by white zeolite or quartz. Groundmass is relatively fresh. Discolored pale brown to 1 cm depth. MnOx crust 2 cm thick. **Unit A**. 2: 14 x 10 x 4 cm grey-brown aphyric basalt. 30% vesicles to 2 mm across but most much smaller. Most vesicles are empty but some are filled by yellow or cream zeolite. Zeolite also veins one side of the block. MnOx crust 4 mm thick. **Unit B**. 3: 5 x 4 x 3 cm **Unit B**. 4: 10 x 9 x 6 cm breccia. Deeply weathered lava fragments in a matrix of cream yellow zeolite clay. Some clasts are well-rounded and flattened beach pebbles. A 4 x 3 cm clast of dense aphyric basalt was sub-sampled for the	TS, CC TS, CC TS, GC TS, GC

		geochemistry. MnOx crust 2 cm thick. **Unit C**. 5: 12 x 8 x 5 cm **Unit B**. **NB**: Probably all samples at this site are clasts from the Unit C breccia.	 TS, GC
148 PN	18.11 14:00 31°18.71' S 172°17.97' W 0 m 18.11 14:15 31°19.05' S 172°17.78' W 0 m	Plankton net, trawled at 1.6 knots.	
149 DR Louisville Ridge 35	18.11 18:11 31°34.02' S 172°06.39' W 2560 m 18.11 19:41 31°33.50' S 172°06.27' W 2043 m	1: 5 x 3 x 3 cm brown-grey aphyric basalt. A dense block with groundmass olivine pseudomorphed by iddingsite. Surface is deeply weathered orange-brown but the block core is dark grey. Cream zeolite fills some fractures on one side. **Unit A**. 2: 8 x 4 x 4 cm cream grey aphyric pumice. 20% vesicles grading to vugs up to 1 cm across, with some vugs filled by soft pale brown clay. Weakly weathered, with only minor yellow-brown surface staining. **Unit B**. 3: 13 x 10 x 9 cm pale yellow-brown-cream coralline limestone. Shell (bivalve) fragments in a matrix of forams, clay and calcite. Finely bedded at 2-5 mm scale. MnOx crust 1 mm thick. **Unit C**. 4: 13 x 11 x 4 cm **Unit C**, but coarser grained with voids 1 cm across and worm burrows. 5: 13 x 7 x 5 cm yellow-brown calcareous sediment. Pale yellow clay and cream foram ooze speckled with MnOx <0.5 mm across. Large voids 3 cm long are rimmed by calcite. MnOx crust 1 cm thick. **Unit D**. 6: 7 x 5 x 5 cm **Unit D**, mostly cream foram ooze speckled with MnOx. 7: 9 x 6 x 5 cm **Unit D**, mostly pale yellow clay with 1.5 cm long worm burrows.	TS, GC TS
150 DR Louisville Ridge 35	18.11 21:29 31°32.68' S 172°07.80' W 2336 m 18.11 22:59 31°32.14' S 172°08.08' W 1847 m	1: 6 x 3 x 3 cm dark grey aphyric basalt. Trace plagioclase and olivine phenocrysts (the latter pseudomorphed by iddingsite or serpentine) to 1 mm across. A dense block. Surface weathered brown to 1 mm depth, with cream zeolite filling fractures on one side. **Unit A**. 2: 7 x 4 x 4 cm pale grey aphyric pumice. 20% vesicles to 4 mm across locally infilled with pale brown soft clay. Glassy matrix. Surface weakly weathered to grey shades, but otherwise fresh. **Unit B**. 3: 10 x 10 x 6 cm **Unit B**. 4: 13 x 10 x 8 cm cream foram ooze. Calcite cemented foram ooze with minor clay. Worm burrows or feeding tracks on the surface are up to 6 cm long by 1.5 cm wide. MnOx crust <1 mm thick. **Unit C**. 5: 14 x 10 x 9 cm **Unit C**, but more pale yellow clay and fewer forams in matrix. Speckled with MnOx <0.5 mm across. 6: 17 x 7 x 6 cm **Unit C**, as for 150DR-05 but with MnOx crust up to 7 mm thick.	TS, GC TS
151 DR Louisville Ridge 35	19.11 01:07 31°29.32' S 172°16.42' W 2242 m 19.11 02:24	Empty dredge, despite bites up to 6.6 tonnes.	

	31°29.05' S 172°15.78' W 1646 m		
152 DR Louisville Ridge 35	19.11 03:57 31°29.30' S 172°16.43' W 2239 m 19.11 05:12 31°29.05' S 172°15.84' W 1713 m	1: 7 x 5 x 4 cm grey olivine basalt. 30% small olivine phenocrysts pseudomorphed by iddingsite and up to 1 mm across (most 0.5 mm across). Traces of small vesicles to 0.5 mm across and filled with white zeolite on one side. Fractures <0.5 mm wide are filled with black clay. MnOx crust 0.1 mm thick. **Unit A**.	TS, GC, Ar
153 DR Louisville Ridge 35	19.11 07:15 31°30.20' S 172°17.41' W 2695 m 19.11 10:21 31°29.49' S 172°15.90' W 1743 m	Lost the dredge (Kiel small rectangular dredge). Entire dredge and net was gone, but weight remained. Evidently the safety cable gave way, and then the weight ripped through the chain sack and released the dredge.	
154 DR Louisville Ridge 36	20.11 05:25 33°44.21' S 171°25.90' W 1984 m 20.11 09:09 33°43.97' S 171°26.13' W 1798 m	1: 22 x 9 x 7 cm dark grey aphyric basalt. 25% vesicles to 5 mm across (most 1 mm) filled with blue-white zeolite/quartz, or rarely lined with orange-brown iddingsite. Matrix is fresh. Surface discolored brown to 3 mm, and white silicified clay fills rare vuggy voids to 2 cm across. MnOx crust 3.5 cm thick. **Unit A**. 2: 7 x 7 x 6 cm dark grey aphyric basalt. Dense and non-vesicular, with trace vesicles only to <1 mm across but filled with white zeolite. Matrix is fresh. An angular block in a breccia. MnOx crust is 3.5 cm thick. **Unit B**. 3: 17 x 10 x 6 cm breccia. Clasts of Units A and B to 4 cm long, but most <1 cm long (included 154DR-02). MnOx crust 3.5 cm thick. **Unit C**. 4: 12 x 8 x 5 cm yellow clay and white foram sand. Probably grades to Unit C. MnOx crust 2 cm thick. **Unit D**.	TS, CC TS, GC, Ar
155 PN	20.11 10:15 33°44.25' S 171°23.96' W 0 m 20.11 10:27 33°44.22' S 171°24.12' W 0 m	Plankton net, trawled at 0.8 knots.	
156 DR Louisville Ridge 36	20.11 11:22 33°44.03' S 171°24.49' W 1939 m 20.11 13:52 35°44.07' S 171°24.50' W 2001 m	Empty dredge, despite bites up to 8.0 tonnes.	
157 DR Louisville Ridge 37	21.11 04:34 35°27.82' S 170°24.72' W 2165 m 21.11 07:01 35°27.47' S 170°24.83' W 1921 m	1: 15 x 10 x 9 cm dark grey aphyric basalt. A dense and non-vesicular block, with groundmass olivine pseudomorphed by iddingsite. The few fractures and microvesicles are filled with black chloritic clay. A subangular clast in breccia. MnOx crust is >0.5 mm thick. **Unit A**. 2: 8 x 8 x 7 cm brown-grey aphyric basalt. A dense and non-vesicular block. Small domains of dark grey fresher lava occur as islands within a pervasively weathered	TS, GC, Ar TS, GC, Ar

		brown wispy matrix. A subangular clast from the breccia. MnOx crust 2 cm thick. **Unit B**. 3: 6 x 4 x 3 cm dark grey olivine basalt. 5% olivine phenocrysts pseudomorphed by iddingsite and up to 2 mm across, traces of plagioclase phenocrysts up to 2 mm across. Dense and non-vesicular. **Unit C**. 4: 8 x 7 x 4 cm deeply weathered aphyric basalt. A dense grey core surrounded by brown weathered lava 1.5 cm thick. MnOx crust 1 cm thick. **Unit D**. 5: 7 x 5 x 4 cm **Unit D**, but pervasively weathered brown. 6: 12 x 11 x 6 cm **Unit D** as for 157DR-05, but MnOx crust on the breccia is 3 cm thick. 7: 7 x 7 x 5 cm **Unit C**, but more weathered and probably too small to use. MnOx crust is 5 cm thick. 8: 8 x 6 x 3 cm blue-grey aphyric basalt. 30% vesicles to 1 mm across which are empty, but the block is probably too small to use. MnOx crust 4.5 cm thick. **Unit E**. 9: 19 x 9 x 7 cm coralline limestone. Blue-grey-white consisting of foram sands, orange shell fragments and black MnOx specks. Many open voids. MnOx crust 2.5 cm thick. **Unit F**. 10: 16 x 13 x 8 cm breccia. Subrounded clasts of deeply weathered lavas to 0.5 mm across now pseudomorphed by apple green clay (serpentine?, smectite?). Clast supported, locally with cream foram sands in the matrix. MnOx crust 2 cm thick. **Unit G**.	 TS, GC, Ar
158 DR Louisville Ridge 37	21.11 09:39 35°28.87' S 170°21.98' W 2107 m 21.11 12:17 35°28.13' S 170°21.63' W 1814 m	1: 14 x 12 x 8 cm dark grey aphyric basalt. An extremely dense and hard subangular boulder. Surface weathered yellow-brown with discoloration only to 2 mm, interior is fresh with no significant weathering along fractures. Possibly an intrusive. **Unit A**. 2: 15 x 10 x 7 cm black aphyric basalt. Trace plagioclase phenocrysts to 2 mm across. An extremely hard and dense subangular boulder from a breccia, locally with weak columnar jointing. Surface weakly weathered yellow-brown, but otherwise fresh. Possibly an intrusive. **Unit B** (which is possibly still Unit A). 3: 17 x 14 x 12 cm dark grey aphyric basalt. Trace olivine phenocrysts pseudomorphed by iddingsite to 2 mm across. Again dense and hard, also jointed but not columnar. Weakly weathered, with white zeolite and clay along one side. A clast in the breccia. MnOx crust 2 mm thick. **Unit C**. 4: 10 x 10 x 9 cm **Unit B**. 5: 13 x 7 x 6 cm **Unit B**, but smaller and more weathered, with discoloration to 1.5 cm depth. 6: 11 x 7 x 6 cm **Unit B**, but more weathered than 158DR-05 with brown wisps throughout and pervasive weathering in the outer 2 cm. 7: 13 x 12 x 6 cm grey plagioclase (?) basalt. 20% small (<1 mm) greenish white crystals (plagioclase? possibly olivine) and trace olivine phenocrysts pseudomorphed by iddingsite to 1 mm across. A rounded boulder. Surface weathered brown with discoloration to 2 cm depth. MnOx crust 2 cm thick. **Unit D**. 8: 10 x 5 x 5 cm **Unit B**. 9: Two pieces, each 13 x 10 x 7 cm, representing a very large 1 m diameter breccia boulder which contained 158DR-02 and -03. Clast supported, with most clasts deeply weathered and of various lithologies up to 1.5 cm	1: TS, GC, Ar 2: TS, GC, Ar 3: TS, GC, Ar 4: TS 5: TS 7: TS, GC, Ar

		in diameter. Matrix is yellow foram sand. A 10 cm clast is still in one piece. MnOx crust 3 mm thick. **Unit E**. 10: 11 x 5 x 4 cm breccia of deeply weathered rock chips 3 mm across in sand-silt volcaniclastic matrix. **Unit F**. 11: 14 x 10 x 9 cm pale grey siltstone. Silt and sand-sized volcaniclastic material with minor clay and rare deeply weathered lava pebbles up to 2 cm across. Worm burrows up to 3 cm long by 2 mm wide are filled with finer grained clay. **Unit G**. 12: 12 x 10 x 6 cm brown silty claystone. Rare worm burrows and volcaniclastic lenses. **Unit H**.	
159 DR Louisville Ridge "X"	21.11 22:52 36°04.46' S 169°34.87' W 2188 m 22.11 00:45 36°04.92' S 169°34.18' W 1629 m	1: 14 x 11 x 8 cm grey olivine basalt. 25% olivine phenocrysts pseudomorphed by iddingsite to 5 mm across (most 2 mm). 20% small vesicles <1 mm across, of which 5% are lined with zeolite. Vesicles are arranged in bands. A subangular boulder overlain by yellow foram clay 1 cm thick. MnOx crust 1 cm thick. **Unit A**. 2: 18 x 15 x 8 cm **Unit A**. 3: 15 x 11 x 8 cm **Unit A**, but MnOx crust is 2 cm thick. 4: 18 x 7 x 7 cm **Unit A**, but some olivines up to 6 mm across and MnOx crust only 3 mm thick. 5: 13 x 10 x 7 cm **Unit A**, but more weathered (zeolites) and MnOx crust 2 cm thick. 6: 19 x 13 x 7 cm grey olivine basalt. 10% olivine phenocrysts pseudomorphed by iddingsite to 2 mm across. 20% small vesicles <1 mm across with 50% of these lined by blue-grey zeolite. Probably a lava flow. MnOx crust 3 cm thick. **Unit B**. 7: 14 x 11 x 10 cm grey-brown sandy claystone. A soft boulder with forams and sand-silt sized volcaniclastic fragments in a clayy matrix. MnOx crust 1 mm thick. **Unit C**. 8: 17 x 13 x 9 cm coralline limestone. Yellow and white calcite cemented clays and forams with coralline fragments. MnOx crust 1 mm thick. **Unit D**.	TS, CC TS, CC TS, CC TS, CC
160 PN	22.11 09:55 37°01.98' S 169°45.88' W 0 m 22.11 10:08 37°02.16' S 169°46.18' W 0 m	Plankton net, trawled at 1.2 knots.	
161 DR Louisville Ridge 38	22.11 11:01 37°01.11' S 169°45.78' W 1805 m 22.11 12:05 37°00.91' S 169°45.47' W 1620 m	1: 16 x 14 x 6 cm grey pyroxene-olivine basalt. 20% olivine phenocrysts pseudomorphed by iddingsite to 4 mm across (most 2 mm across) and 5% pyroxene phenocrysts altered to black chlorite(?) to 2 mm across. 15% vesicles to 1 cm across (most 2 mm) filled or lined with white zeolite. A subangular clast in a breccia of deeply weathered lavas (most clasts 0.5 mm long). MnOx crust 3 cm thick. **Unit A**. 2: 7 x 7 x 5 cm **Unit A**. A smaller pebble in the same breccia. 3: 7 x 6 x 4 cm brownish grey olivine basalt. 10% olivine phenocrysts pseudomorphed by iddingsite to 3 mm across, with trace pyroxene phenocrysts altered to black chlorite(?) to 2 mm across. A dense and non-vesicular clast in the breccia. **Unit B**. 4: 12 x 12 x 10 cm white foram sandstone. Foram sands with minor yellow clay, moderately lithified. **Unit C**.	TS, CC TS, CC TS, GC

162 DR Louisville Ridge 38	22.11 13:50 37°01.52' S 169°46.79' W 2221 m 22.11 16:10 37°00.63' S 169°46.37' W 1673 m	1: 14 x 11 x 7 cm brown-grey olivine basalt. 20% olivine phenocrysts pseudomorphed by iddingsite to 2 mm, but many are fragmented crystals and the size distribution is very poorly sorted. 25% vesicles to 3 mm across, with ~50% filled by white zeolite. Vesicles are in 1-2 cm bands. A large clast from the breccia. **Unit A**.	TS, CC
		2: 8 x 6 x 6 cm **Unit A**.	TS, CC
		3: 8 x 7 x 7 cm **Unit A**, but a smaller well-rounded boulder. Locally all vesicles are filled with white zeolite.	TS, CC
		4: 12 x 10 x 5 cm **Unit A**.	TS
		5: 6 x 6 x 3 cm **Unit A**.	
		6: 13 x 11 x 8 cm, as for 162DR-01 but with 40% vesicles and all are filled by white zeolite. Also a clast in the breccia. **Unit B**.	TS
		7: 8 x 8 x 6 cm brown olivine basalt. 15% olivine phenocrysts pseudomorphed by iddingsite to 1 mm across, many appear fragmented. 40% vesicles to 3 mm across, locally lined by soft greenish clay. Rock is soft in comparison to Unit A, and more weathered. **Unit C**.	TS, CC
		8: 14 x 9 x 5 cm deeply weathered **Unit C**.	TS, CC
		9: 8 x 6 x 5 cm deeply weathered **Unit C**.	
		10: 12 x 8 x 6 cm deeply weathered **Unit C** in breccia, with an MnOx crust 6 mm thick.	
		11: 12 x 8 x 7 cm **Unit C**, but with 50% of vesicles filled by white zeolite.	
		12: 6 x 6 x 4 cm **Unit C**, but with all vesicles filled by white zeolite.	
		13: 15 x 12 x 12 cm breccia. Subangular clasts of Units A, B and C in white foram sandstone, calcite and zeolite cemented. Most vesicles in the clasts are filled by zeolite. Contains all Unit A, B and C samples listed above. **Unit D**.	
		14: 18 x 12 x 10 cm deeply weathered breccia. All clasts are deeply weathered Unit C and ~1 cm across, well-sorted but subangular. Matrix is soft pale brown clay. MnOx crust is 3 mm thick. **Unit E**.	
		15: 14 x 11 x 4 cm **Unit E**. Deeply weathered breccia with the matrix weathered greenish yellow and very soft.	
		16: 13 x 12 x 9 cm white-yellow coralline limestone. Reef material with a 4 cm thick MnOx crust. **Unit F**.	
163 DR Louisville Ridge 38	22.11 17:45 37°00.97' S 169°46.20' W 1840 m 22.11 18:54 37°00.54' S 169°46.33' W 1653 m	1: 14 x 13 x 11 cm brown olivine basalt. 10% olivine phenocrysts pseudomorphed by iddingsite to 2 mm across. 20% vesicles to 3 mm across of which 30% are lined or partly filled by grey-white zeolite. Matrix is rather weathered and marginal for geochemistry. MnOx crust 1 cm thick. **Unit A**.	TS, CC
		2: 8 x 6 x 5 cm brown olivine basalt. 5% olivine phenocrysts pseudomorphed by iddingsite to 2 mm across. Plagioclase is present as a groundmass phase. 30% vesicles filled with white-grey zeolite. MnOx crust 5 mm thick. **Unit B**.	TS
		3: 10 x 8 x 5 cm breccia. Deeply weathered Unit B clasts in a sandy-silty matrix of the same material. MnOx crust 1.5 cm thick. **Unit C**.	
		4: 5 x 3 x 3 cm dolerite(?). Deeply weathered fine grained rock. Occurs as a small subangular pebble enclosed by MnOx crust 1 cm thick. **Unit D**.	
164 DR Louisville Ridge 39	23.11 05:39 37°28.29' S 169°26.72' W	1: 10 x 7 x 7 cm black MnOx crust. Overlies a deeply weathered breccia with pebbles to 2.5 cm across, which might be usable with extreme care. Crust is 1 cm thick.	

	2340 m 23.11 07:10 37°27.97' S 169°26.20' W 1800 m	**Unit A**. 2: 7 x 5 x 5 cm **Unit A**. 3: 5 x 5 x 4 cm **Unit A**, but mostly pebbles with the crust stripped off. Probably the best pieces. 4: 6 x 3 x 3 cm **Unit A**.	
165 DR Louisville Ridge 39	23.11 10:30 37°32.56' S 169°25.32' W 2677 m 23.11 12:43 37°31.36' S 169°24.95' W 2079 m	1: 10 x 9 x 7 cm brownish grey pyroxene-olivine basalt. 20% olivine phenocrysts pseudomorphed by iddingsite to 4 mm across (most 2 mm) and 5% pyroxene phenocrysts altered to black chlorite to 4 mm across (most 2 mm). 20% vesicles <1 mm across of which 30% are filled with grey-white zeolite. MnOx crust 6 mm thick. **Unit A**. 2: 13 x 9 x 9 cm **Unit A**, from a large 1 m diameter block. 3: 9 x 8 x 5 cm **Unit A**, a subrounded boulder. 4: 12 x 11 x 7 cm **Unit A**, a subrounded boulder. 5: 12 x 10 x 8 cm **Unit A**, a subrounded boulder. 6: 8 x 7 x 5 cm brownish grey pyroxene-olivine basalt. As for 165DR-01, but most olivine is 3 mm across. Probably a different unit. A subrounded boulder. **Unit B**. 7: 10 x 7 x 5 cm **Unit A**, but 60% of vesicles are filled with white-grey zeolite. 8: 8 x 7 x 7 cm grey olivine basalt. 10% olivine phenocrysts pseudomorphed by iddingsite to 3 mm across (most 1 mm), and trace pyroxene phenocrysts altered to black chlorite. 20% very small vesicles <0.5 mm across, of which 75% are filled by white-grey zeolite. Much denser than Units A and B. A subrounded boulder. MnOx crust 1 cm thick. **Unit C**. 9: 18 x 14 x 5 cm dark grey-brown coralline limestone. Microcrystalline brown carbonate flecked with MnOx and small breccia and iddingsite fragments <0.5 mm across. MnOx crust to 1 cm thick. **Unit D**. 10: 12 x 11 x 5 cm **Unit D**. 11: 16 x 12 x 9 cm breccia of deeply weathered Unit A clasts. MnOx crust 3 cm thick. **Unit E**. 12: 18 x 16 x 8 cm **Unit E**. Clasts to 1 cm across in a finer matrix of the same breccia cemented with yellow-orange carbonate. MnOx crust 1 cm thick. 13: 10 pieces of **Unit A** taken as a bulk sample. Subrounded boulders to 10 cm in diameter, variably weathered and with variable degrees of zeolite infilling vesicles.	TS, CC TS, CC TS, CC TS TS, CC TS
166 PN	23.11 13:43 37°31.67' S 169°25.19' W 0 m 23.11 14:00 37°31.96' S 169°25.47' W 0 m	Plankton net, trawled at 1.4 knots.	
167 DR Louisville Ridge 39	23.11 15:38 37°31.99' S 169°18.49' W 1950 m 23.11 19:16 37°32.05' S 169°18.44' W 1982 m	1: 11 x 5 x 4 cm dark grey aphyric basalt. Dense and non-vesicular. A jointed block, possibly representing a dyke. Surface has an MnOx crust 1 mm thick and is discolored brown to 1 cm depth. **Unit A**. 2: 6 x 6 x 3 cm **Unit A**, but with trace plagioclase phenocrysts to 2 mm across. Also a few convolute white zeolite veinlets to 0.5 mm across. A clast in the breccia. 3: 5 x 4 x 2 cm **Unit A**, as for 167DR-02. 4: 4 x 3 x 3 cm grey olivine basalt. 15% olivine phenocrysts pseudomorphed by iddingsite to 2 mm across. 5% vesicles which are mostly empty, but breccia and/or white zeolite occurs in others. A rather weathered clast	TS, Ar TS, GC

		from the breccia. **Unit B**. 5: 5 x 3 x 3 cm brown olivine basalt. 5% olivine phenocrysts pseudomorphed by iddingsite to 1 mm across. 5% vesicles to 2 mm across with most filled by white zeolite. Deeply weathered clast from the breccia. **Unit C**. 6: 11 x 8 x 3 cm coralline limestone. Consists of brown microcrystalline micritic material, white forams and MnOx specks. MnOx crust 0.5 mm thick. **Unit D**. 7: 6 x 4 x 3 cm cream brown aphyric pumice. 40% vesicles to 5 mm across. Brittle and weathered, but no MnOx. **Unit E**. 8: 12 small pebbles, largest 4 cm across, of variably weathered **Unit A** extracted from the breccia. 9: 20 x 20 x 12 breccia. Subangular lava clasts to 4 cm across (most 1 cm) of variably weathered Unit A and rarely Units B and C. Matrix supported, with the matrix being sand-sized volcaniclastics in white zeolite. Weakly bedded at 4 cm scale. All clasts above are from this. MnOx crust 0.2 mm thick. **Unit F**.	
168 DR Louisville Ridge 39	23.11 20:51 37°31.96' S 169°18.42' W 1925 m 23.11 22:17 37°31.85' S 169°18.25' W 1766 m	1: 16 x 14 x 14 cm brownish grey pyroxene-olivine basalt. 25% olivine phenocrysts pseudomorphed by iddingsite to 4 mm across (most 2 mm) and 10% very large black pyroxene phenocrysts to 6 mm across (often >3 mm). A dense and non-vesicular lava with numerous fractures to 0.5 mm wide filled by white zeolite. Occurs as a large subangular clast in breccia. MnOx crust 0.2 mm thick. **Unit A**. 2: 11 x 8 x 5 cm **Unit A**, but more weathered and fractured, and the rock-breccia contact is hard to pick. 3: 11 x 9 x 8 cm **Unit A**, but denser and less fractured. Maybe ok for geochemistry as it is. 4: 9 x 5 x 3 cm **Unit A**, but few fractures and is ok for geochemistry. 5: 17 x 14 x 9 cm breccia. Clasts of deeply weathered subrounded olivine (pseudomorphed by iddingsite) basalt up to 6 cm across (most 5 mm) in a grey-white carbonate-zeolite matrix. MnOx crust <0.1 mm thick. **Unit B**. 6: 16 x 12 x 8 cm coralline limestone. Brown microcrystalline micritic material flecked with MnOx and white-grey carbonate-zeolite, locally corals and other biota. MnOx crust 0.1 mm thick. **Unit C**.	TS, CC TS, CC TS, CC TS, GC
169 DR Louisville Ridge 39	24.11 01:37 37°26.68' S 169°16.62' W 1877 m 24.11 06:27 37°26.70' S 169°16.51' W 1921 m	Empty dredge. 20 m of cable damaged (kinked by abrasion on seafloor) and removed.	
170 PN	24.11 13:44 37°43.88' S 168°55.71' W 0 m 24.11 13:57 37°43.70' S 168°55.33' W 0 m	Plankton net, trawled at 2.0 knots.	
171 DR	24.11 18:46	1: 10 x 6 x 6 cm dark grey aphyric basalt. Trace black	TS, GC, Ar

Louisville Ridge 40	37°38.18' S 169°09.80' W 2283 m 24.11 20:54 37°37.29' S 169°09.69' W 1481 m		pyroxene phenocrysts to 3 mm across. Very dense, non-vesicular, fresh and hard. Contains plagioclase in the groundmass. Trace vesicles are filled by pale green-white zeolite or calcite. A fragment broken from a boulder >1 m in diameter. MnOx crust 1 mm thick. **Unit A**.	(CC)
		2:	15 x 9 x 8 cm grey olivine basalt. 30% olivine phenocrysts pseudomorphed by iddingsite to 6 mm across (most 3 mm), with relic dark green cores in some. A dense non-vesicular lava. Some fractures <0.5 mm wide that are filled by black chlorite. MnOx crust 5 mm thick. **Unit B**.	TS, GC, Ar
		3:	12 x 8 x 4 cm **Unit B**.	TS, GC, Ar
		4:	9 x 6 x 5 cm **Unit B**.	TS, GC
		5:	18 x 14 x 13 cm **Unit B**, but more weathered and with all olivine phenocrysts pseudomorphed by iddingsite. Also more fractures filled with black chlorite. Possibly an older unit. MnOx crust is 1 cm thick.	TS, GC
		6:	15 x 11 x 8 cm grey olivine basalt. 10% olivine phenocrysts pseudomorphed by iddingsite to 2 mm across. 10% vesicles to 3 mm across filled with white-grey zeolite. MnOx crust 2 cm thick. **Unit C**.	TS, CC (GC, Ar)
		7:	15 x 8 x 7 cm **Unit C**. Difficult to distinguish olivine from vesicles, as much olivine is only partly pseudomorphed by iddingsite.	TS, CC (GC)
		8:	11 x 6 x 6 cm as for 171DR-07, but maybe more olivine (15%) and some of the zeolite could be plagioclase phenocrysts. Surface weathered brown but no MnOx crust. **Unit D**.	TS, CC (GC, Ar)
		9:	11 x 7 x 6 cm **Unit D**.	
		10:	12 x 11 x 6 cm grey olivine basalt. 10% olivine phenocrysts pseudomorphed by iddingsite to 3 mm across. Dense and non-vesicular, but fractures into sub-blocks several cm in diameter separated by fractures filled with black chlorite and white zeolite. Surface weathered brown-black. **Unit E**.	
		11:	8 x 7 x 5 cm **Unit E**, with traces of breccia on one side.	TS, GC
		12:	13 x 10 x 6 cm brown-grey olivine basalt. 5% olivine phenocrysts pseudomorphed by iddingsite to 5 mm across (most 1 mm), and some are still green. Trace vesicles to 2 mm across and most filled by white zeolite. More deeply weathered on one side. MnOx crust 1 mm thick. **Unit F**.	TS, GC, Ar
		13:	12 x 9 x 6 cm grey olivine basalt. 5% olivine phenocrysts pseudomorphed by iddingsite to 8 mm across, with the olivine having a very irregular size distribution including some relic green crystals. Trace vesicles to 2 mm across filled with green-white zeolite. A sub-rounded clast in the breccia. MnOx crust 2 mm thick. **Unit G**.	TS, GC
		14:	9 x 7 x 4 cm grey olivine basalt. 10% olivine phenocrysts pseudomorphed by iddingsite to 4 mm across (most 1 mm), and still with a few relic green cores. Trace vesicles to 2 mm across filled with green-white zeolite. MnOx crust 2 mm thick. **Unit H**.	TS, GC
		15:	5 x 5 x 3 cm grey olivine basalt. 20% olivine phenocrysts pseudomorphed by iddingsite to 4 mm across. Dense and non-vesicular. Surface weathered brown. **Unit I**.	
		16:	9 x 6 x 3 cm grey olivine-pyroxene basalt. 10% olivine phenocrysts pseudomorphed by iddingsite to 3 mm across and 10% black pyroxene phenocrysts replaced by	

		chlorite to 2 mm across. A fractured small pebble from the breccia. MnOx crust 7 mm thick. **Unit J**. 17: 10 x 6 x 3 cm sandstone. White clay (30%) and varicolored deeply weathered sand-sized volcaniclastics. Well sorted. MnOx crust 2 mm thick. **Unit K**. 18: 18 x 17 x 9 cm green-yellow breccia. Clast-supported, with lava fragments to 3 cm across (most 5 mm) pseudomorphed by green chlorite-smectite-serpentine, and set in a matrix of white-grey zeolite. MnOx crust to 3 mm thick. **Unit L**. 19: 11 x 9 x 5 cm **Unit L**, but coarser grained with most clasts ~1 cm in diameter. 20: 4 pieces of **Unit B** taken as a bulk sample. 21: 3 pieces of the more weathered **Unit B** variant. 22: 9 x 8 x 6 cm **Unit C**. 23: 4 pieces of **Unit D** taken as a bulk sample. 24: 20 cm diameter **Unit A** boulder, representing the same larger block from which 171DR-01 was extracted.	
172 DR Louisville Ridge 40	25.11 03:56 37°43.48' S 168°55.72' W 2333 m 25.11 09:00 37°43.40' S 168°56.05' W 2205 m	1: 15 x 15 x 13 cm brown-grey aphyric basalt. 30% vesicles to 1 mm across, locally grading to large vugs up to 3 cm across. About 20% of the vesicles are filled by white zeolite or calcite, and locally the rock is cut by thin veinlets <1 mm wide of the same material. Needs coarse crushing and hand picking. Surface discolored brown to 1 cm depth. MnOx crust 4 mm thick. **Unit A**. 2: 15 x 9 x 8 cm **Unit A**. 3: 17 x 11 x 5 cm **Unit A**, but 70% of the vesicles are filled by white zeolite or calcite. 4: 6 x 6 x 5 cm **Unit A**, but only 10% of the vesicles are filled by white zeolite or calcite. 5: 7 x 6 x 5 cm **Unit A**, as for 172DR-04. A clast from a breccia. 6: 9 x 5 x 4 cm **Unit A**, as for 172DR-04. 7: 10 x 7 x 6 cm **Unit A**. 8: 12 x 8 x 7 cm **Unit A**. 9: 8 x 6 x 5 cm **Unit A**. 10: 13 x 8 x 6 cm **Unit A**, but 70% of the vesicles are filled by white zeolite or calcite, or in some cases by light green soft clay. 11: 14 x 11 x 11 cm breccia. Subangular clasts of variably to deeply weathered Unit A up to 4 cm across (most 5 mm). Matrix is white-grey zeolite, calcite and carbonate. MnOx crust 1 cm thick. **Unit B**. 12: 12 x 11 x 6 cm **Unit B**, but more weathered and better sorted (finer grained). MnOx crust 3 cm thick. 13: 17 x 8 x 7 cm **Unit B**, but most clasts are 3 mm across. On one side is a band 4 cm wide consisting of cream clay, brown microcrystalline carbonate, forams and MnOx specks. MnOx crust 1 cm thick.	1: TS, CC 2: TS, CC 3: TS, CC 4: CC
173 DR Louisville Ridge 42	25.11 17:58 38°14.90' S 168°08.49' W 2192 m 25.11 21:13 38°14.73' S 168°08.05' W 1906 m	1: 18 x 10 x 9 cm dark grey aphyric basalt. Dense, hard and non-vesicular. Rare fractures <0.5 mm wide are filled with white zeolite, but this shouldn't be a problem. Weathered brown-grey discoloration persists to 2 cm depth. Sample represents a large boulder >1 m in diameter. MnOx crust 1 mm thick. **Unit A**. 2: 15 x 13 x 8 cm **Unit A**. 3: 21 x 11 x 10 cm **Unit A**. 4: 14 x 12 x 6 cm **Unit A**, but somewhat more weathered and fractured. 5: 14 x 13 x 8 cm breccia. Subangular clasts to 2 cm (most	1: TS, GC, Ar 2: TS, GC, Ar 3: TS, GC, Ar

		1 cm) across of Unit A, variably weathered and some altered green (chlorite). Matrix supported, matrix being zeolite and chlorite with sand-sized angular rock chips. **Unit B**. 6: 16 x 14 x 7 cm conglomerate. Well-rounded Unit A pebbles to 4.5 cm across (most 5 mm), often only weakly weathered. Matrix is a ferruginous orange clay with sand-silt sized rock fragments. Clearly a beach deposit. MnOx crust 2.5 cm thick. **Unit C**.	
174 PN	26.11 09:33 38°54.35' S 171°12.85' W 0 m 26.11 09:49 38°54.14' S 171°12.51' W 0 m	Plankton net, trawled at 1.2 knots.	
175 PN	27.11 09:30 40°04.93' S 176°52.55' W 0 m 27.11 09:43 40°04.80' S 176°52.55' W 0 m	Plankton net, trawled at 1.0 knots.	
176 PN	28.11 10:37 41°08.99' S 177°52.83' W 0 m 28.11 10:51 41°08.74' S 177°52.60' W 0 m	Plankton net, trawled at 1.2 knots.	

APPENDIX 3: SAMPLES COLLECTED FROM 'ATA ISLAND

A brief 2 hour landing on the uninhabited 'Ata Island by Tim Worthington and Sisi Tonga'onevai took place on 18 October. Marginal sea conditions did not permit a longer stay. 'Ata Island is broadly triangular in shape, and has three intrusive plug complexes (NW, NE and S) that outcrop as erosional remnants. The largest of these is the NW plug complex, which forms near vertical sea cliffs and remnant stacks along the northern and western coastlines. Between these three plug complexes are exposures of younger stacked lava successions, breccias, tephra beds and sub-vertical dykes. These younger successions are in turn sub-divided by several angular unconformities. The softer young successions are also much eroded, and it is only buttressing by the old erosion-resistant plug complexes that allows the volcano to remain partly emergent.

The northern coastline of 'Ata Island between the NW and NE plug complexes was mapped while the *SONNE* completed a circle around the island. The 10 samples collected are briefly described below.

<u>**Sample**</u>	<u>**Description and location**</u>
A 01	Grey plagioclase andesite, trace dark green pyroxene phenocrysts to 2 mm across and 10% plagioclase phenocrysts to 2 mm across. Scree block in chute draining from the NE plug-dyke complex, sampled 50m above the beach.
A 02	Dark grey plagioclase andesite, trace dark green pyroxene phenocrysts to 1 mm across and 10% plagioclase phenocrysts to 2 mm across. 10% irregularly shaped vesicles to 3 mm across. Lava flow overlying A 03 with angular unconformity, central NE coastline.
A 03	Dark grey plagioclase andesite, trace dark green pyroxene phenocrysts to 1 mm across and 5% plagioclase phenocrysts to 3 mm across (all but one are 1 mm). 10% irregularly shaped vesicles to 5 mm across. Old flat-lying lava flow outcropping along the central N coastline.
A 04	Dark reddish grey plagioclase andesite, 5% plagioclase phenocrysts to 2 mm across (most are 1 mm). Groundmass is a mosaic of dark grey and red oxidised domains 1-2 mm across. 5% irregularly shaped vesicles grading to pull-aparts up to 3 cm long. 2m wide dyke dipping at 80° and cross-cutting the old and stacked lava flows (A 02 and A 03) at the central N coast.
A 05	Dark grey pyroxene-plagioclase andesite, 5% dark green pyroxene phenocrysts to 2 mm across and 15% plagioclase phenocrysts to 2 mm across (most are 1 mm). 5% irregularly shaped vesicles to 6 mm long. Thin 2m-thick lava flow from base of stacked flow succession overlying A 03 and to the west of the dyke (A 04). Older than the dyke.
A 06	Grey pyroxene-plagioclase andesite, 15% green pyroxene phenocrysts to 3 mm across and 20% plagioclase phenocrysts to 2 mm across. Strongly porphyritic lava. 10% irregularly shaped vesicles grading to pull-aparts up to 1 cm long. Thin 2m-thick lava flow from base of stacked flow succession along the NW coastline (not correlative with A 05 flows).
A 07	Pale grey pyroxene-plagioclase andesite, 5% dark green pyroxene phenocrysts to 2 mm across and 20% plagioclase phenocrysts to 2 mm across (most are 1 mm). Scree boulder on beach at site of A 06, presumably from the upper part of the flow succession.
A 08	Blue-grey pyroxene-plagioclase andesite, 5% dark green pyroxene phenocrysts to 2 mm across and 10% plagioclase phenocrysts to 2 mm across. Numerous sub-parallel incipient pull-aparts to 5 mm long with development of dark grey clays along these. Old lava flow >2m thick at sea-level, NW coastline near NW plug-dyke complex.
A 09	Grey pyroxene-plagioclase andesite, 10% dark green pyroxene phenocrysts to 2 mm across and 20% plagioclase phenocrysts to 2 mm across. 3m wide dyke dipping at 80° and cross-cutting A 08 and the overlying ash beds.
A 10	Red-grey pyroxene-plagioclase andesite, 10% dark green pyroxene phenocrysts to 2 mm across and 20% plagioclase phenocrysts to 2 mm across. NW plug-dyke complex at the coastline, from the easternmost plug.

APPENDIX 4: TV - GRAB (GTV) AND OFOS DESCRIPTIONS

Station 44 GTV-A; commenced 22-10-02; page 1 of 6

Time	Ship		Cable	Sub		Comment
(UTC)	Lat. (°S)	Long. (°W)	(m)	Lat. (°S)	Long. (°W)	
18:03:21	22.21638	176.60952				begin of station 44 GTV-A
18:32:22	22.21644	176.60974	1499	22.21708	176.60996	1500 m cable length
18:40:15	22.21653	176.60997	1677	22.21724	176.60980	tapes on, lights on, water depth 1769 m
18:42:12	22.21646	176.61004	1759	22.21701	176.61005	bottom within view
18:42:56	22.21643	176.61002	1761	22.21729	176.61019	1761 m water depth
18:44:30	22.21635	176.60991	1765	22.21751	176.61000	going 200 m northward
18:45:21	22.21630	176.60985	1769	22.21729	176.61000	some sediment on irregular surface
18:46:44	22.21621	176.60976	1768	22.21747	176.60996	blocks and fragments, soft sediment on top
18:48:25	22.21615	176.60967	1764	22.21660	176.60995	still rubbly material
18:48:44	22.21615	176.60966	1764	22.21713	176.61002	pillar structures
18:49:11	22.21613	176.60963	1764	22.21695	176.61002	some sediment on blocks
18:50:09	22.21610	176.60951	1760	22.21696	176.61004	on the slope, slab-like material
18:50:45	22.21607	176.60944	1759	22.21708	176.61000	moving upwards
18:51:08	22.21606	176.60942	1754	22.21702	176.61018	heterogeneous sediment, no animals
18:51:33	22.21605	176.60941	1755	22.21699	176.60987	lot of scoria
18:51:54	22.21604	176.60941	1756	22.21670	176.60937	slumped material
18:52:33	22.21604	176.60943	1752	22.21704	176.60921	heterogeneous talus
18:53:20	22.21602	176.60949	1749	22.21676	176.60982	reddish sediment on blocks
18:54:42	22.21596	176.60956	1748	22.21682	176.60926	crinoid on block
18:54:59	22.21595	176.60957	1748	22.21663	176.60936	still moving upward
18:55:16	22.21594	176.60959	1744	22.21696	176.60971	1745 m water depth
18:57:26	22.21586	176.60963	1753	22.21615	176.60968	blocky outcrop
18:58:19	22.21585	176.60952	1759	22.21689	176.60990	slumps, still covered by sediment, with some brownish staining
18:59:01	22.21585	176.60948	1757	22.21645	176.61027	concretionary structures, pillar on the left
18:59:53	22.21584	176.60947	1757	22.21708	176.60993	shrimp -> no hydrothermal signal
19:00:35	22.21584	176.60949	1757	22.21690	176.60949	rubble
19:01:31	22.21579	176.60955	1755	22.21690	176.60953	shrimp, blocky outcrop, scarp
19:02:32	22.21570	176.60953	1757	22.21620	176.60985	some layering, moving slope upwards
19:03:18	22.21565	176.60951	1759	22.21690	176.60983	aristeid prawn
19:04:24	22.21556	176.60952	1758	22.21625	176.60963	loose talus
19:05:27	22.21542	176.60957	1764	22.21640	176.60963	striation on wall
19:05:48	22.21537	176.60958	1763	22.21641	176.60904	moving up the scarp
19:06:03	22.21533	176.60959	1761	22.21615	176.60934	gorgonian
19:07:54	22.21501	176.60954	1769	22.21681	176.60994	sandy sediment, rubble
19:08:24	22.21499	176.60956	1770	22.21645	176.61005	slumped material
19:08:44	22.21498	176.60957	1771	22.21613	176.60992	talus
19:09:10	22.21496	176.60959	1767	22.21591	176.61005	aristeid prawn
19:09:51	22.21497	176.60959	1769	22.21639	176.61021	cracks, structuring front
19:10:16	22.21498	176.60958	1770	22.21692	176.60963	water is getting cloudy, smoke?
19:10:41	22.21498	176.60956	1775	22.21621	176.60950	lots of sediment, increasing sediment
19:11:12	22.21496	176.60957	1777	22.21566	176.61022	sediment covers the wall
19:11:35	22.21496	176.60957	1776	22.21659	176.60947	fragmented material, lots of sediment
19:12:22	22.21493	176.60958	1779	22.21623	176.60999	rock fragments, grey sediment
19:13:09	22.21489	176.60958	1780	22.21596	176.60982	outcrop of massive flow, vertical break
19:13:31	22.21489	176.60955	1781	22.21633	176.60970	sediment, talus
19:13:56	22.21487	176.60950	1782	22.21601	176.60965	striation
19:14:26	22.21487	176.60943	1781	22.21646	176.60987	1781 m water depth
19:15:24	22.21489	176.60937	1781	22.21599	176.61002	heading to the east
19:15:49	22.21490	176.60936	1779	22.21646	176.60992	increasing white dots in the water
19:16:04	22.21491	176.60935	1776	22.21580	176.60998	moving upward
19:16:51	22.21494	176.60928	1774	22.21532	176.60988	blocky outcrop
19:17:22	22.21493	176.60921	1773	22.21579	176.60943	fragments, not very hard
19:18:12	22.21491	176.60913	1766	22.21513	176.60954	rock talus
19:18:29	22.21490	176.60911	1764	22.21594	176.60936	reddish sediment
19:19:40	22.21484	176.60906	1768	22.21574	176.60978	blocky material
19:20:02	22.21483	176.60906	1766	22.21600	176.60941	still sediment
19:20:33	22.21482	176.60906	1765	22.21574	176.60954	some animals
19:21:06	22.21477	176.60901	1766	22.21601	176.60936	sandy sediment, slumps
19:21:22	22.21475	176.60898	1767	22.21581	176.60967	striation, black and white colour
19:21:41	22.21472	176.60894	1764	22.21621	176.60919	ripple marks
19:22:03	22.21470	176.60890	1763	22.21627	176.60931	very rubbly material, breaks
19:22:32	22.21468	176.60886	1763	22.21618	176.60931	massive flows covered by sediment
19:23:19	22.21469	176.60882	1761	22.21550	176.60934	steep slope
19:23:33	22.21470	176.60881	1759	22.21650	176.60959	loose material
19:24:02	22.21474	176.60881	1756	22.21611	176.60962	wall of rubble
19:24:44	22.21479	176.60884	1758	22.21569	176.60973	fragmented talus material

Station 44 GTV-A; commenced 22-10-02; page 2 of 6						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
19:24:59	22.21482	176.60885	1757	22.21576	176.60981	reddish sediment
19:25:24	22.21485	176.60888	1757	22.21594	176.60947	a lot of white dots in the water
19:26:41	22.21502	176.60893	1755	22.21561	176.60951	ship going eastward
19:26:59	22.21506	176.60892	1758	22.21594	176.60938	rubble, friable material
19:27:15	22.21509	176.60891	1756	22.21537	176.60953	reddish sediment
19:27:57	22.21516	176.60889	1754	22.21575	176.60926	rubbly surface, some lineation
19:28:21	22.21521	176.60888	1753	22.21604	176.60933	angular blocks
19:28:41	22.21524	176.60888	1753	22.21608	176.60970	big block
19:28:55	22.21526	176.60889	1753	22.21555	176.60945	silty material
19:29:08	22.21528	176.60889	1749	22.21596	176.60924	blocks
19:29:35	22.21531	176.60887	1749	22.21597	176.60895	scarp
19:30:26	22.21535	176.60879	1744	22.21577	176.60946	something white
19:30:54	22.21537	176.60876	1744	22.21642	176.60950	white dots on bottom
19:31:44	22.21542	176.60876	1735	22.21609	176.60933	edge
19:31:55	22.21543	176.60877	1734	22.21617	176.60926	rubble
19:32:03	22.21544	176.60877	1733	22.21632	176.60902	crinoid
19:32:10	22.21544	176.60878	1732	22.21563	176.60904	get closer
19:32:35	22.21547	176.60882	1731	22.21570	176.60882	rhodalid -> hydrothermal signal?
19:33:09	22.21552	176.60887	1731	22.21604	176.60921	reddish sediment, dark
19:33:36	22.21555	176.60892	1730	22.21671	176.60923	blocky material, interstitial hydrothermal material
19:34:10	22.21559	176.60896	1728	22.21614	176.60923	edge of the field?
19:34:28	22.21561	176.60896	1731	22.21656	176.60900	lots of reddish sediment
19:34:59	22.21564	176.60896	1730	22.21608	176.60921	no biological activity
19:35:12	22.21565	176.60896	1729	22.21588	176.60857	flow, less sediment
19:35:26	22.21567	176.60895	1728	22.21702	176.60926	too far to the south?
19:35:42	22.21568	176.60893	1730	22.21666	176.60924	biogeneous material
19:36:02	22.21569	176.60891	1726	22.21599	176.60927	sandy material, pyroclastic?
19:36:24	22.21570	176.60887	1727	22.21636	176.60948	still blocky outcrop
19:36:44	22.21573	176.60883	1727	22.21692	176.60927	sandy sediment on top and in fractures of blocks
19:37:24	22.21575	176.60879	1727	22.21653	176.60923	a lot of sand, shiny
19:38:02	22.21577	176.60878	1724	22.21663	176.60887	still rubbly top, sand, flow structures
19:38:29	22.21578	176.60874	1725	22.21661	176.60925	flow top
19:39:13	22.21579	176.60868	1727	22.21716	176.60907	lots of sand, brownish
19:39:34	22.21581	176.60869	1724	22.21685	176.60926	irregular blocks
19:39:51	22.21582	176.60869	1724	22.21686	176.60922	sand, white and dark patches
19:41:05	22.21585	176.60857	1717	22.21732	176.60909	scarp, large block
19:41:29	22.21585	176.60855	1716	22.21690	176.60907	striation
19:41:53	22.21588	176.60856	1713	22.21693	176.60921	white patches on sediment
19:42:24	22.21590	176.60855	1712	22.21636	176.60879	white material = silica?
19:42:41	22.21590	176.60855	1713	22.21713	176.60855	scarp,
19:43:14	22.21592	176.60853	1712	22.21637	176.60887	flow banded structured fragments
19:43:38	22.21592	176.60853	1708	22.21664	176.60899	on top of the flow, white patches
19:43:54	22.21594	176.60852	1709	22.21718	176.60905	more rubble
19:44:20	22.21595	176.60850	1709	22.21640	176.60887	white patches on blocks
19:44:36	22.21595	176.60848	1709	22.21685	176.60874	flow banded blocks
19:45:03	22.21597	176.60847	1707	22.21676	176.60867	rubble and dark, sandy sediment
19:45:57	22.21601	176.60849	1707	22.21683	176.60871	very coarse rubble, large blocks, white patches
19:46:31	22.21601	176.60843	1708	22.21677	176.60898	dark patches = Mn-oxides ?
19:46:56	22.21602	176.60837	1709	22.21719	176.60882	rhodalids
19:47:42	22.21603	176.60831	1709	22.21737	176.60840	dark spot
19:47:50	22.21602	176.60831	1708	22.21681	176.60921	rubbly material
19:48:10	22.21605	176.60829	1705	22.21756	176.60810	big block
19:48:59	22.21607	176.60832	1700	22.21710	176.60848	a lot of silica
19:49:15	22.21609	176.60837	1700	22.21698	176.60872	hydrothermal sediment
19:49:32	22.21611	176.60842	1699	22.21644	176.60831	Mn-coating, silica
19:50:00	22.21615	176.60850	1699	22.21704	176.60851	silica and Mn-oxides
19:50:22	22.21619	176.60856	1698	22.21633	176.60797	moving up a scarp
19:50:42	22.21619	176.60859	1698	22.21693	176.60875	dusty
19:51:14	22.21621	176.60858	1698	22.21755	176.60869	more rubble, less silica, shrimp
19:51:38	22.21621	176.60853	1699	22.21663	176.60885	not much sediment, large blocks
19:51:53	22.21621	176.60851	1700	22.21682	176.60892	very massive block
19:52:09	22.21621	176.60847	1701	22.21737	176.60900	more silica
19:52:17	22.21622	176.60846	1701	22.21672	176.60897	very blocky rubble
19:53:04	22.21623	176.60837	1704	22.21699	176.60897	angular blocks, smooth surface, flows
19:53:35	22.21624	176.60831	1703	22.21694	176.60864	dark sand between blocks
19:53:52	22.21625	176.60828	1703	22.21656	176.60896	gorgonian
19:54:03	22.21627	176.60826	1702	22.21757	176.60864	reddish sediment
19:54:12	22.21627	176.60825	1701	22.21706	176.60859	lava flow, covered by sediment
19:54:34	22.21629	176.60821	1700	22.21767	176.60873	some silica
19:54:49	22.21630	176.60818	1700	22.21642	176.60871	no animal life
19:55:00	22.21629	176.60817	1700	22.21750	176.60862	sandy material

Station 44 GTV-A; commenced 22-10-02; page 3 of 6						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
19:55:19	22.21630	176.60815	1700	22.21697	176.60911	brown coating on block
19:55:39	22.21631	176.60811	1700	22.21649	176.60853	heavy sediment cover on the flow
19:56:02	22.21630	176.60808	1700	22.21700	176.60912	lineation of silica
19:56:15	22.21632	176.60807	1700	22.21736	176.60842	yellow lines
19:56:33	22.21632	176.60805	1698	22.21716	176.60862	big block
19:56:47	22.21632	176.60803	1697	22.21737	176.60850	big block was a pillow
19:58:24	22.21639	176.60794	1699	22.21718	176.60858	coarse rubble
19:58:47	22.21640	176.60793	1699	22.21651	176.60862	spatter ?
19:59:44	22.21646	176.60789	1696	22.21713	176.60827	flow top
20:00:15	22.21650	176.60787	1697	22.21825	176.60826	still very structured lava, nice flow top
20:00:53	22.21650	176.60785	1696	22.21792	176.60804	outcrop, almost pahoe-like
20:01:17	22.21656	176.60783	1696	22.21796	176.60827	actinian
20:01:37	22.21656	176.60783	1695	22.21756	176.60825	actinian
20:02:00	22.21658	176.60782	1693	22.21739	176.60849	looks like fresh lava
20:02:25	22.21661	176.60781	1692	22.21731	176.60827	on top of the ridge?
20:02:41	22.21663	176.60780	1692	22.21766	176.60841	crinoid
20:03:25	22.21668	176.60779	1690	22.21807	176.60816	gorgonian, big flow top
20:03:57	22.21673	176.60782	1689	22.21738	176.60741	fresh lava
20:04:09	22.21674	176.60785	1689	22.21746	176.60797	gorgonians
20:04:36	22.21678	176.60792	1689	22.21725	176.60783	collapsed?, too rough
20:05:06	22.21682	176.60799	1689	22.21714	176.60801	still clinkerded material covered by sediment
20:05:51	22.21690	176.60808	1687	22.21719	176.60775	antipatharian
20:06:40	22.21695	176.60820	1685	22.21716	176.60803	pillars?, very clinkered, no basalt
20:07:44	22.21700	176.60834	1681	22.21779	176.60769	Munidopsis
20:08:22	22.21701	176.60840	1682	22.21704	176.60794	aa-looking like flow
20:08:38	22.21701	176.60842	1684	22.21797	176.60795	seastar
20:08:56	22.21700	176.60844	1685	22.21711	176.60851	dark stuff, manganese? gorgonian,
20:10:17	22.21699	176.60854	1689	22.21721	176.60816	gorgonian, still manganese material?
20:10:49	22.21699	176.60858	1690	22.21802	176.60760	antipatharian?
20:11:24	22.21698	176.60862	1693	22.21817	176.60814	sponge
20:11:44	22.21697	176.60866	1693	22.21809	176.60813	very thick rubble flow top, gorgonian
20:12:14	22.21695	176.60870	1694	22.21813	176.60761	more sediment
20:12:27	22.21695	176.60872	1694	22.21719	176.60848	too far southeast
20:12:50	22.21691	176.60877	1696	22.21759	176.60896	irregular large blocks
20:13:04	22.21690	176.60879	1696	22.21825	176.60801	ripple marks, with huge blocks on the top, crinoids
20:13:52	22.21683	176.60886	1695	22.21811	176.60817	lot of sediment, white patches
20:15:29	22.21663	176.60891	1701	22.21802	176.60847	massive flow, blocky
20:16:27	22.21652	176.60892	1704	22.21743	176.60897	ledge, massive flow
20:17:40	22.21638	176.60899	1705	22.21778	176.60861	scarp
20:18:20	22.21633	176.60902	1706	22.21734	176.60872	same outcrop
20:18:43	22.21628	176.60904	1707	22.21761	176.60875	massive flow
20:19:17	22.21624	176.60908	1709	22.21748	176.60876	a scarp
20:19:35	22.21621	176.60910	1711	22.21753	176.60883	vertical scarp
20:21:01	22.21609	176.60920	1721	22.21740	176.60894	all rubble at the basin of the scarp
20:21:48	22.21602	176.60927	1722	22.21704	176.60905	same scarp already 20 m
20:22:50	22.21590	176.60930	1728	22.21711	176.60903	scarp already 27 m
20:23:47	22.21579	176.60930	1734	22.21667	176.60913	going northward
20:24:10	22.21576	176.60929	1735	22.21687	176.60923	very irregular clinky material
20:25:01	22.21569	176.60927	1738	22.21715	176.60959	moving along the scarp
20:25:53	22.21567	176.60927	1740	22.21713	176.60947	surface is getting flatter at the edge of the scarp
20:27:35	22.21562	176.60927	1747	22.21729	176.60889	clams
20:27:42	22.21562	176.60928	1747	22.21622	176.60968	Calyptogena
20:28:10	22.21561	176.60929	1747	22.21663	176.60938	shrimp, hydrothermal sediment
20:28:32	22.21561	176.60931	1748	22.21618	176.60955	not reddish
20:28:51	22.21560	176.60932	1747	22.21640	176.60918	maybe talus
20:31:53	22.21549	176.60946	1753	22.21649	176.60900	slumps of lava?
20:32:14	22.21546	176.60944	1755	22.21637	176.60917	fresh talus -> no sediment
20:32:49	22.21541	176.60941	1757	22.21624	176.60942	irregular talus
20:33:16	22.21535	176.60939	1758	22.21650	176.60953	angular blocks -> talus
20:33:35	22.21532	176.60937	1758	22.21643	176.60926	partial sedimented
20:34:29	22.21520	176.60931	1757	22.21630	176.60944	fragments of hydrothermal material, when it breaks->sandy
20:35:14	22.21511	176.60927	1756	22.21639	176.60961	all talus
20:35:43	22.21505	176.60925	1757	22.21616	176.60956	much more sediment, rocks between not soft
20:36:19	22.21502	176.60922	1756	22.21582	176.60983	looks like a pillar
20:37:01	22.21498	176.60921	1756	22.21595	176.60948	another pillar
20:37:18	22.21498	176.60921	1755	22.21575	176.60954	edge of a lava lake
20:39:00	22.21510	176.60927	1759	22.21677	176.60955	rhodalid
20:40:14	22.21522	176.60936	1762	22.21624	176.60936	strong sedimented, radial joint
20:40:41	22.21525	176.60939	1762	22.21620	176.60968	massive flow
20:40:58	22.21527	176.60941	1762	22.21597	176.60938	flow top, sedimented
20:41:43	22.21531	176.60946	1762	22.21623	176.60945	far to far northwest

Station 44 GTV-A; commenced 22-10-02; page 4 of 6

Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
20:42:17	22.21533	176.60949	1762	22.21592	176.60914	rock talus
20:43:11	22.21538	176.60952	1763	22.21641	176.60950	irregular blocks
20:44:06	22.21542	176.60950	1763	22.21653	176.60960	more sediment
20:44:33	22.21542	176.60948	1764	22.21578	176.60942	sediment on rubble
20:45:12	22.21543	176.60940	1765	22.21618	176.60950	still sediment covered rubble
20:45:57	22.21542	176.60930	1763	22.21601	176.60976	a pillar
20:46:11	22.21542	176.60927	1763	22.21640	176.60967	polychaete worm
20:47:08	22.21543	176.60914	1759	22.21686	176.60969	rock talus
20:48:05	22.21546	176.60905	1754	22.21571	176.60976	still talus
20:48:51	22.21550	176.60903	1749	22.21717	176.60986	still rock talus
20:50:05	22.21565	176.60910	1741	22.21639	176.60983	scarp
20:51:52	22.21586	176.60921	1739	22.21683	176.60936	fissure?
20:52:05	22.21587	176.60922	1738	22.21593	176.60900	striation, manganese material?
20:52:38	22.21592	176.60924	1741	22.21722	176.60962	flow surface
20:52:50	22.21595	176.60924	1741	22.21630	176.60919	clinkery surface
20:53:33	22.21600	176.60925	1743	22.21639	176.60945	ripples on sediment
20:53:51	22.21604	176.60925	1743	22.21701	176.60961	on top of the flow?
20:55:00	22.21612	176.60923	1744	22.21693	176.60968	white spots-> sessile fauna
20:55:44	22.21616	176.60924	1746	22.21656	176.60938	sediment ripple marks
20:55:55	22.21618	176.60923	1744	22.21730	176.60950	jointed lava
20:56:18	22.21618	176.60924	1740	22.21701	176.60933	scarp
20:56:44	22.21620	176.60922	1740	22.21706	176.60934	clinkery scarp
20:57:15	22.21621	176.60923	1739	22.21640	176.60915	top of the scarp
20:57:31	22.21622	176.60923	1739	22.21733	176.60944	going eastward
20:57:45	22.21623	176.60923	1739	22.21724	176.60940	still clinkery rubble
20:58:29	22.21624	176.60924	1739	22.21641	176.60945	coarse blocks
20:59:11	22.21626	176.60926	1740	22.21797	176.60897	fault scarp
20:59:23	22.21627	176.60924	1740	22.21768	176.60907	aristeid prawn
21:00:45	22.21622	176.60920	1738	22.21709	176.60886	all rubble, fault scarp
21:01:57	22.21616	176.60909	1737	22.21744	176.60917	still rubble
21:02:16	22.21614	176.60907	1736	22.21657	176.60953	going along the scarp
21:02:53	22.21613	176.60902	1734	22.21717	176.60953	looks like a fish
21:03:13	22.21612	176.60900	1733	22.21696	176.60919	clinkered material
21:03:33	22.21611	176.60897	1731	22.21709	176.60929	fracture
21:04:04	22.21610	176.60894	1729	22.21721	176.60910	crack
21:04:15	22.21610	176.60894	1730	22.21699	176.60967	massive flow
21:04:54	22.21606	176.60892	1728	22.21738	176.60891	ledge on the scarp; talus rubble
21:06:19	22.21613	176.60885	1729	22.21727	176.60924	still in the scarp; rubble
21:07:11	22.21619	176.60882	1727	22.21700	176.60942	still rubble
21:08:06	22.21626	176.60881	1723	22.21614	176.60926	still rubble
21:08:44	22.21629	176.60880	1722	22.21748	176.60931	fish -> macrourid fish
21:09:50	22.21631	176.60879	1718	22.21751	176.60901	scarp is a big structure
21:10:03	22.21630	176.60879	1718	22.21664	176.60882	sediment
21:10:48	22.21626	176.60879	1713	22.21677	176.60863	flow top
21:12:11	22.21620	176.60879	1713	22.21654	176.60894	collapsed flow with sediment between pillars
21:12:32	22.21617	176.60878	1713	22.21644	176.60914	silica patches (white)
21:13:37	22.21614	176.60873	1713	22.21683	176.60928	irregular surface, a pillar?
21:14:08	22.21612	176.60870	1714	22.21724	176.60906	still white patches
21:14:30	22.21611	176.60867	1714	22.21692	176.60889	getting flatter
21:15:19	22.21607	176.60862	1708	22.21707	176.60870	we hit something
21:15:43	22.21605	176.60859	1704	22.21654	176.60877	hit something friable at the sharp scarp
21:16:46	22.21599	176.60850	1707	22.21738	176.60866	back to bottom
21:17:02	22.21598	176.60849	1709	22.21703	176.60882	a big block
21:17:25	22.21595	176.60848	1710	22.21675	176.60893	dark patches
21:17:37	22.21594	176.60847	1709	22.21692	176.60883	sulfide
21:17:50	22.21594	176.60847	1709	22.21714	176.60871	white patches
21:18:03	22.21594	176.60847	1709	22.21678	176.60870	a lot of silica
21:18:14	22.21594	176.60847	1708	22.21720	176.60871	looks like a chimney slope
21:18:41	22.21596	176.60849	1706	22.21698	176.60910	sulfide talus
21:19:13	22.21598	176.60848	1705	22.21652	176.60882	sulfide -> yellow
21:19:32	22.21601	176.60848	1705	22.21693	176.60892	not active, no animals yet
21:20:26	22.21611	176.60848	1706	22.21702	176.60906	big structure
21:21:16	22.21617	176.60849	1704	22.21652	176.60872	still silica patches
21:21:33	22.21619	176.60850	1705	22.21689	176.60874	lot of silics patches, also sulfide sediment
21:22:10	22.21622	176.60850	1703	22.21712	176.60868	rock talus and between hydrothermal sediment
21:23:00	22.21624	176.60849	1700	22.21729	176.60878	hydrothermal sediment = yellow
21:23:27	22.21625	176.60848	1700	22.21695	176.60829	sulfide -> chimney
21:24:01	22.21625	176.60847	1705	22.21760	176.60857	tried to grab, grab fall over
21:26:10	22.21618	176.60841	1697	22.21683	176.60872	back to bottom
21:26:28	22.21617	176.60840	1699	22.21698	176.60874	still in the field
21:27:27	22.21612	176.60835	1696	22.21678	176.60861	in the scarp

Station 44 GTV-A; commenced 22-10-02; page 5 of 6						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
21:27:53	22.21610	176.60833	1693	22.21715	176.60870	lots of silica patches
21:28:12	22.21608	176.60831	1690	22.21756	176.60847	chimney
21:30:44	22.21597	176.60812	1702	22.21728	176.60883	out of the field?
21:30:58	22.21596	176.60809	1702	22.21694	176.60877	lava flow
21:31:27	22.21596	176.60805	1705	22.21678	176.60873	no silica patches
21:31:58	22.21595	176.60799	1706	22.21680	176.60853	going back to west
21:32:32	22.21594	176.60794	1708	22.21720	176.60840	clams?
21:32:50	22.21594	176.60792	1710	22.21721	176.60847	clams?
21:34:22	22.21598	176.60802	1707	22.21671	176.60837	rubble
21:36:57	22.21607	176.60832	1707	22.21666	176.60813	white dots maybe biology -> mussels
21:37:41	22.21607	176.60837	1707	22.21678	176.60790	mussels
21:38:29	22.21605	176.60841	1705	22.21667	176.60808	white dots also mussels?
21:39:40	22.21604	176.60838	1706	22.21709	176.60852	some dark spots
21:39:58	22.21605	176.60837	1705	22.21662	176.60841	look like mussels?
21:40:30	22.21608	176.60835	1703	22.21635	176.60847	silica patches
21:41:17	22.21612	176.60835	1704	22.21699	176.60849	scarp, or collapsed flow; sponges
21:42:48	22.21623	176.60845	1704	22.21705	176.60832	smoke?
21:43:09	22.21625	176.60849	1704	22.21653	176.60839	rock talus
21:43:28	22.21630	176.60853	1702	22.21650	176.60832	slumping material from an outcrop?, manganese too?
21:44:08	22.21637	176.60862	1702	22.21711	176.60817	sulide and silica patches
21:44:23	22.21641	176.60867	1697	22.21659	176.60853	shrimp
21:44:46	22.21645	176.60873	1696	22.21701	176.60843	chimney
21:44:56	22.21647	176.60877	1696	22.21682	176.60825	tried to grab
21:45:21	22.21653	176.60884	1693	22.21684	176.60822	didn`t get it
21:46:32	22.21669	176.60910	1702	22.21789	176.60862	back to bottom
21:48:07	22.21688	176.60941	1711	22.21775	176.60892	silica patches
21:49:13	22.21700	176.60950	1713	22.21695	176.60867	replaced color-tape
21:49:59	22.21705	176.60953	1717	22.21666	176.60895	out of the field
21:50:20	22.21710	176.60952	1718	22.21797	176.60829	lava flows, clinkered
21:51:03	22.21710	176.60950	1718	22.21665	176.60910	going eastward
21:52:04	22.21710	176.60937	1715	22.21677	176.60905	try to go back to 36,5' W
21:52:57	22.21708	176.60924	1713	22.21784	176.60888	still rocky outcrop
21:56:08	22.21702	176.60908	1707	22.21850	176.60974	black sand
21:56:56	22.21698	176.60902	1708	22.21838	176.60898	ripple marks, covered by other fragments
21:57:59	22.21695	176.60897	1706	22.21817	176.60925	sandy sediment
21:59:04	22.21695	176.60894	1706	22.21797	176.60911	still sediment
22:01:57	22.21704	176.60898	1702	22.21753	176.60912	still lots of sediment
22:03:35	22.21710	176.60898	1702	22.21768	176.60907	a fish?
22:04:02	22.21711	176.60898	1702	22.21757	176.60907	rubble
22:04:38	22.21713	176.60897	1701	22.21774	176.60906	still too far to the west
22:05:05	22.21714	176.60895	1702	22.21818	176.60912	sediment covered flow top
22:05:38	22.21714	176.60893	1701	22.21772	176.60916	shrimps
22:06:13	22.21714	176.60891	1700	22.21796	176.60865	gorgonian
22:08:06	22.21709	176.60887	1697	22.21822	176.60887	still sediment covered flow top
22:11:04	22.21707	176.60866	1694	22.21833	176.60900	still sediment covered flow top
22:11:33	22.21707	176.60862	1694	22.21824	176.60896	dark sediment; sulfide -> yellow
22:11:58	22.21707	176.60860	1694	22.21837	176.60882	big scarp
22:12:46	22.21704	176.60854	1694	22.21858	176.60864	a lot of sulfur
22:13:39	22.21699	176.60849	1707	22.21786	176.60827	try to grab-> fall over
22:14:29	22.21696	176.60846	1697	22.21728	176.60871	didn't get it
22:14:48	22.21695	176.60846	1688	22.21793	176.60894	reddish hydrothermal sediment
22:15:34	22.21692	176.60844	1694	22.21830	176.60866	scarp
22:15:43	22.21692	176.60844	1696	22.21772	176.60864	back to bottom
22:15:57	22.21691	176.60844	1697	22.21814	176.60857	2 gorgonians
22:17:06	22.21695	176.60842	1694	22.21802	176.60851	angular blocky talus
22:18:05	22.21700	176.60841	1695	22.21823	176.60850	gorgonian
22:18:23	22.21701	176.60840	1695	22.21767	176.60851	dark patch -> manganese?
22:18:39	22.21703	176.60839	1694	22.21821	176.60871	gorgonian
22:19:42	22.21711	176.60839	1693	22.21762	176.60874	Pennatularia
22:20:03	22.21713	176.60839	1694	22.21760	176.60814	still rock talus, gorgonians
22:20:58	22.21719	176.60839	1690	22.21789	176.60855	going northward
22:21:11	22.21720	176.60839	1690	22.21817	176.60820	gorgonian
22:21:58	22.21723	176.60841	1690	22.21793	176.60870	dark patches, manganese ?, crinoid
22:23:24	22.21729	176.60854	1687	22.21761	176.60801	gorgonian
22:24:09	22.21727	176.60861	1686	22.21777	176.60817	rubble talus
22:24:48	22.21723	176.60866	1686	22.21792	176.60814	looks like a sponge
22:26:03	22.21707	176.60868	1689	22.21781	176.60791	minor sediment, rubble
22:26:29	22.21701	176.60866	1691	22.21845	176.60865	white patches
22:26:59	22.21694	176.60862	1693	22.21844	176.60861	white patches of silica
22:27:17	22.21689	176.60860	1694	22.21770	176.60869	lots of manganese?
22:28:02	22.21680	176.60858	1696	22.21815	176.60877	heavily sedimented + manganese?, gorgonian

Station 44 GTV-A; commenced 22-10-02; page 6 of 6						
Time (UTC)	Ship Lat. (°S)	Long. (°W)	Cable (m)	Sub Lat. (°S)	Long. (°W)	Comment
22:29:24	22.21671	176.60865	1697	22.21722	176.60850	gorgonian
22:29:50	22.21669	176.60870	1698	22.21736	176.60832	big scarp, manganese? on the bottom + silica
22:30:43	22.21666	176.60880	1702	22.21735	176.60859	ripple marks
22:31:05	22.21663	176.60881	1701	22.21772	176.60861	lots of sediment
22:31:20	22.21662	176.60881	1700	22.21769	176.60869	scarp
22:32:09	22.21652	176.60876	1700	22.21790	176.60852	still sandy sediment
22:33:27	22.21641	176.60865	1704	22.21763	176.60878	sediment on the clinkery flow surface
22:33:53	22.21641	176.60864	1705	22.21784	176.60886	striation of the sediment
22:34:26	22.21642	176.60864	1706	22.21778	176.60885	silica patches
22:34:58	22.21646	176.60866	1707	22.21730	176.60888	pillar -> collapsed flow top
22:35:47	22.21651	176.60869	1707	22.21750	176.60851	silica patches
22:37:04	22.21651	176.60874	1706	22.21727	176.60826	crinoid
22:37:16	22.21650	176.60875	1707	22.21724	176.60812	actinian
22:38:21	22.21638	176.60886	1707	22.21729	176.60875	stalked crinoid
22:38:46	22.21631	176.60891	1707	22.21734	176.60876	white silica patches
22:39:01	22.21627	176.60894	1706	22.21704	176.60858	scarp
22:39:52	22.21618	176.60896	1709	22.21730	176.60872	crinoid
22:40:34	22.21613	176.60892	1710	22.21718	176.60899	still silica patches
22:42:26	22.21604	176.60881	1714	22.21737	176.60848	going eastward
22:42:44	22.21603	176.60881	1716	22.21691	176.60892	crack
22:43:17	22.21602	176.60880	1716	22.21686	176.60831	fault scarp
22:44:32	22.21601	176.60878	1718	22.21683	176.60917	slope with small cracks and dark sediment stripes
22:45:29	22.21602	176.60870	1718	22.21675	176.60883	sedimented flow top
22:46:31	22.21605	176.60858	1712	22.21734	176.60875	scarp, reddish sediment
22:46:59	22.21607	176.60854	1708	22.21639	176.60884	sessile benthos
22:48:40	22.21615	176.60836	1707	22.21653	176.60873	sulfide talus
22:48:57	22.21616	176.60834	1714	22.21730	176.60877	tried to grab it -> fall over ->didn't get it
22:50:20	22.21623	176.60822	1687	22.21707	176.60879	replaced black & white tape
22:51:09	22.21629	176.60816	1662	22.21699	176.60879	start heaving
22:55:55	22.21668	176.60806	1498	22.21701	176.60812	1500 m cable length, winch driver runs away
23:23:00	22.21674	176.60807	1498	22.21743	176.60798	GTV on deck, end of station

Station 45 GTV-A; commenced 22-10-02; page 1 of 2						
Time (UTC)	Ship Lat. (°S)	Long. (°W)	Cable (m)	Sub Lat. (°S)	Long. (°W)	Comment
23:44:58	22.21652	176.60811	9992	22.21605	176.60934	TV grab in water, begin of station 45 GTV
23:50:34	22.21567	176.60740	101	22.21598	176.60743	100 m cable length
00:02:47	22.21617	176.60932	797	22.21666	176.60951	start of dive
00:18:12	22.21688	176.60836	1546	22.21729	176.60868	technical problem with the keyboard
00:23:37						contact in loose spatter fragmented caotic bottom, sandy dark sediment on gentle slope
00:29:35						gorgonian, still along the slope of scarp
00:31:09						loose slumped scoria-like irregular debris + block, sandy sediment
00:32:00						ropy lava-surface
00:33:19						white biogeneous material (~10%), star fish?, sediment
00:34:32						~20% biogeneous material on sandy sediment with ripples
00:36:59						blocky and layered lava flow, scarp
00:39:15						layered flow on scarp
00:40:23						sediment + spatter-like lava fragments (large boulders)
00:42:25	22.21716	176.60839	1686	22.21768	176.60804	still dark sandy sediment between blocky material
00:43:26	22.21716	176.60842	1687	22.21764	176.60780	going northward
00:44:55	22.21710	176.60844	1686	22.21760	176.60850	gorgonian, patches of dark sandy material
00:46:14	22.21702	176.60847	1686	22.21811	176.60830	still gorgonians
00:47:50	22.21688	176.60853	1688	22.21745	176.60820	gorgonians, Bathyferox (=fish), lava flow
00:50:17	22.21664	176.60840	1698	22.21799	176.60789	white biogeneous? material (~20%) on dark sediment
00:50:40	22.21662	176.60836	1699	22.21751	176.60828	dark sandy material, crinoids
00:51:34	22.21660	176.60832	1697	22.21804	176.60805	gorgonian
00:52:40	22.21659	176.60835	1694	22.21774	176.60816	blocky lava
00:54:06	22.21655	176.60840	1696	22.21723	176.60821	going northwest
00:54:23	22.21654	176.60840	1697	22.21747	176.60815	many gorgonians
00:54:41	22.21654	176.60841	1697	22.21709	176.60791	white patches -> sponges?
00:55:10	22.21653	176.60842	1696	22.21729	176.60834	or silica material; loose volcanic material, flow striation of the flow
00:56:05	22.21652	176.60850	1697	22.21712	176.60797	silica patches
00:56:44	22.21652	176.60854	1698	22.21744	176.60840	dark material: mangenese, or fresh flow
00:57:17	22.21650	176.60856	1704	22.21720	176.60826	try to grab -> fall over, reddish cloud

Station 45 GTV-A; commenced 22-10-02; page 2 of 2						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
00:57:53	22.21649	176.60858	1709	22.21759	176.60764	empty
00:58:18	22.21649	176.60859	1709	22.21759	176.60764	material looked like hydrothermal material
00:59:23	22.21652	176.60864	1709	22.21759	176.60764	winch turned off (failed), cable length 1709 m
01:00:15	22.21658	176.60867	1706	22.21759	176.60764	winch functions again
01:03:19	22.21649	176.60857	1697	22.21706	176.60835	back to bottom
01:03:32	22.21650	176.60857	1697	22.21710	176.60852	scarp
01:03:51	22.21653	176.60858	1697	22.21702	176.60766	scarp with white staining
01:06:20	22.21661	176.60853	1701	22.21743	176.60789	sheet flow with thin film of sediment
01:06:55	22.21659	176.60850	1702	22.21796	176.60846	hydrothermal sediment
01:07:18	22.21658	176.60849	1702	22.21700	176.60828	white patches
01:08:08	22.21654	176.60846	1700	22.21682	176.60810	dark patches manganese?
01:08:47	22.21652	176.60844	1698	22.21750	176.60849	flat surface
01:09:32	22.21651	176.60844	1697	22.21720	176.60825	dark material
01:10:04	22.21653	176.60844	1693	22.21746	176.60822	scarp
01:11:18	22.21657	176.60842	1696	22.21769	176.60861	fractured surface, like breadcrust, sulfur
01:14:25	22.21650	176.60854	1695	22.21724	176.60807	pillar
01:15:18	22.21644	176.60856	1693	22.21760	176.60762	blocky lava, white staining
01:16:33	22.21643	176.60859	1692	22.21701	176.60843	flow material
01:18:32	22.21645	176.60850	1694	22.21715	176.60829	going northwestward
01:19:23	22.21649	176.60847	1696	22.21677	176.60857	small scarp with blocky lava
01:20:01	22.21654	176.60848	1697	22.21689	176.60802	white patches
01:20:35	22.21657	176.60851	1697	22.21693	176.60851	very blocky material, with smooth surface
01:21:21	22.21654	176.60850	1695	22.21762	176.60819	chimney
01:21:54	22.21650	176.60849	1702	22.21735	176.60822	tried to grab -> fall over -> empty
01:22:26	22.21648	176.60850	1696	22.21727	176.60862	cable length: 1696 m
01:24:03	22.21655	176.60858	1697	22.21699	176.60821	back to bottom
01:26:33	22.21642	176.60854	1696	22.21674	176.60834	flow outcrop with hydrothermal silica, maybe a breccia
01:27:09	22.21642	176.60853	1695	22.21785	176.60825	very blocky lava
01:30:19	22.21647	176.60845	1701	22.21753	176.60848	flow material with white staining in cracks and on surface
01:31:06	22.21651	176.60844	1698	22.21684	176.60865	hydrothermal sediment in the faults
01:32:12	22.21661	176.60847	1695	22.21668	176.60852	blocky lava -> flow outcrop
01:32:42	22.21667	176.60849	1697	22.21706	176.60828	rubble and dust of sediment
01:33:43	22.21674	176.60853	1695	22.21723	176.60790	white patches (biology or silica)
01:34:03	22.21674	176.60852	1695	22.21724	176.60777	scarp
01:35:52	22.21662	176.60841	1700	22.21709	176.60839	pillar
01:36:52	22.21656	176.60840	1696	22.21734	176.60830	going northward
01:38:09	22.21650	176.60842	1698	22.21742	176.60837	flat ledge, covered by volcanoclastic sediment
01:41:31	22.21634	176.60839	1697	22.21724	176.60814	white staining
01:42:44	22.21626	176.60836	1699	22.21715	176.60825	sediment covered volcanic debris
01:43:31	22.21622	176.60836	1697	22.21731	176.60771	sulfur, try to grab
01:44:22	22.21619	176.60837	1707	22.21741	176.60815	grab fall over, empty
01:47:03	22.21622	176.60833	1685	22.21631	176.60818	sample sediment
01:47:58	22.21632	176.60834	1664	22.21774	176.60817	start heaving
01:50:35	22.21655	176.60851	1625	22.21707	176.60776	turned tapes off
02:45:20	22.21676	176.60886	9991	22.21718	176.60892	GTV with sample on deck, end of station

Station 48 GTV-A; commenced 23-10-02; page 1 of 2						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
07:43:40	22.21587	176.60826	9948	22.21718	176.60892	begin of station 48 GTV-A
08:12:03	22.21616	176.60837	1501	22.21708	176.60783	1500 m cable length
08:15:13	22.21602	176.60841	1610	22.21686	176.60795	turned tapes on
						technical problem with the keyboard
08:28:10	22.21559	176.60807	1709	22.21664	176.60790	up to now: clinkery material, white staining, ifremeria next to flow outcrop, lava shelves, young flow top, 08:24 tried to grab -> fall over-> empty (1716 m cable length)
08:28:53	22.21566	176.60807	1717	22.21631	176.60752	crinoid
08:29:15	22.21567	176.60807	1716	22.21623	176.60704	flow top
08:29:25	22.21569	176.60807	1716	22.21655	176.60811	gorgonians
08:30:29	22.21575	176.60807	1714	22.21622	176.60773	very clinkery material
08:31:13	22.21577	176.60811	1714	22.21645	176.60744	irregular surface
08:31:57	22.21571	176.60810	1713	22.21619	176.60715	gorgonian
08:32:11	22.21570	176.60810	1713	22.21665	176.60732	still clinkery flow top
08:32:24	22.21569	176.60810	1713	22.21636	176.60772	polychaete worm
08:32:58	22.21568	176.60809	1713	22.21717	176.60748	still clinkery flow top
08:35:31	22.21593	176.60812	1711	22.21664	176.60798	crinoid, clinkery flow surface
08:36:32	22.21600	176.60811	1708	22.21689	176.60738	good flow surface

Station 48 GTV-A; commenced 23-10-02; page 2 of 2						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
08:37:21	22.21602	176.60811	1709	22.21663	176.60732	shells
08:37:50	22.21599	176.60812	1706	22.21654	176.60779	friable glassy flow
08:38:49	22.21598	176.60818	1707	22.21655	176.60754	all rubbly surface
08:40:19	22.21597	176.60835	1706	22.21717	176.60783	look like a fissure
08:40:46	22.21595	176.60837	1705	22.21713	176.60762	still rubbly surface
08:41:30	22.21587	176.60840	1708	22.21708	176.60797	shells
08:41:46	22.21582	176.60839	1709	22.21686	176.60721	->mussels
08:42:00	22.21577	176.60837	1709	22.21692	176.60814	Ifremeria (snails)?
08:43:22	22.21545	176.60818	1731	22.21642	176.60804	dead snails -> but fresh
08:44:00	22.21528	176.60805	1739	22.21668	176.60729	try to grab snails
08:44:22	22.21517	176.60797	1738	22.21658	176.60801	got snails, without sediment?
08:45:05	22.21505	176.60787	1730	22.21681	176.60758	start heaving
08:45:54	22.21500	176.60782	1718	22.21655	176.60806	snails are maybe Ifremeria
08:50:54	22.21523	176.60795	1528	22.21660	176.60734	tapes off
09:19:30	22.21545	176.60827	9995	22.21593	176.60839	turned off light,
09:20:00						GTV with sample on deck, end of station

Station 50 GTV-A; commenced 23-10-02; page 1 of 3						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
09:59:06	22.21580	176.60775	9990	22.21593	176.60839	begin of station 50 GTV-A
10:27:37	22.21589	176.60860	1499	22.21654	176.60798	1500 m cable length
10:31:30	22.21609	176.60841	1654	22.21700	176.60791	tapes on
10:32:42	22.21610	176.60828	1702	22.21707	176.60745	bottom within view
10:33:07	22.21605	176.60823	1707	22.21630	176.60807	sedimented flow surface
10:34:10	22.21589	176.60811	1706	22.21679	176.60759	looks like a lava tube
10:34:40	22.21585	176.60808	1708	22.21722	176.60797	Ifremeria
10:35:02	22.21584	176.60807	1707	22.21653	176.60793	irregular rubble -> flow top
10:35:42	22.21588	176.60809	1707	22.21621	176.60782	still rubble
10:36:30	22.21598	176.60815	1705	22.21648	176.60723	very clinkery, very little sediment
10:37:29	22.21601	176.60821	1706	22.21603	176.60789	pillars -> collapsed flow
10:38:39	22.21581	176.60817	1706	22.21608	176.60708	same flow surface, minimal sediment
10:39:01	22.21573	176.60815	1706	22.21721	176.60717	brittle star?
10:39:49	22.21564	176.60813	1706	22.21710	176.60670	still clinkered flow top
10:42:10	22.21585	176.60831	1713	22.21636	176.60762	still rubbly surface
10:42:52	22.21592	176.60839	1712	22.21601	176.60742	sediment fills depressions
10:43:20	22.21593	176.60844	1712	22.21629	176.60728	gorgonians
10:44:20	22.21592	176.60852	1710	22.21663	176.60771	still clinkered lava
10:45:33	22.21580	176.60856	1714	22.21679	176.60796	white dots ->small
10:45:49	22.21577	176.60856	1714	22.21677	176.60764	lots of Ifremeria on the bottom between the flows
10:46:20	22.21573	176.60856	1714	22.21612	176.60779	lots of mussels -> dead, Calyptogena?
10:46:56	22.21568	176.60856	1712	22.21611	176.60773	still lot of mussels
10:47:27	22.21566	176.60856	1713	22.21654	176.60834	white patches of silica, yellow material
10:48:10	22.21563	176.60855	1712	22.21608	176.60774	chimney?
10:48:50	22.21566	176.60855	1710	22.21689	176.60720	still silica
10:49:46	22.21568	176.60859	1709	22.21675	176.60753	possible tube
10:50:31	22.21568	176.60855	1709	22.21666	176.60803	lots of hydrothermal silica
10:51:44	22.21565	176.60851	1709	22.21638	176.60783	silica
10:52:01	22.21563	176.60849	1710	22.21624	176.60833	pillar
10:52:37	22.21559	176.60842	1707	22.21614	176.60782	yellowish sediment in between boulders
10:54:16	22.21561	176.60829	1718	22.21629	176.60852	still silica
10:54:27	22.21563	176.60828	1718	22.21675	176.60765	rubble
10:55:23	22.21581	176.60828	1721	22.21671	176.60761	yellowish sediment too
10:55:59	22.21593	176.60828	1721	22.21642	176.60754	still silica patches
10:57:17	22.21618	176.60825	1717	22.21632	176.60703	rough surface with lot of sediment
10:57:49	22.21626	176.60825	1714	22.21597	176.60732	shallow flow surface covered by sediment
10:58:43	22.21629	176.60825	1710	22.21629	176.60734	pillar?
10:59:24	22.21623	176.60824	1708	22.21652	176.60702	white biogeneous material
11:00:16	22.21607	176.60821	1706	22.21717	176.60759	going northwestward
11:00:37	22.21604	176.60821	1704	22.21638	176.60724	animal -> kind of medusa?
11:02:17	22.21607	176.60832	1705	22.21681	176.60820	scarp
11:03:10	22.21606	176.60840	1705	22.21676	176.60708	still rubble
11:04:17	22.21607	176.60845	1706	22.21646	176.60784	tube
11:05:26	22.21605	176.60850	1705	22.21639	176.60789	white biogeneous material
11:06:45	22.21597	176.60851	1705	22.21672	176.60799	still blocky lava with sediment in between
11:08:25	22.21585	176.60850	1705	22.21614	176.60719	finer rubble
11:08:39	22.21585	176.60850	1705	22.21602	176.60798	still flow

Station 50 GTV-A; commenced 23-10-02; page 2 of 3						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
11:10:43	22.21582	176.60867	1705	22.21623	176.60656	dead clams
11:11:38	22.21580	176.60879	1705	22.21623	176.60656	surface is a little bit smoother
11:12:17	22.21579	176.60888	1707	22.21623	176.60656	silica patches
11:13:17	22.21568	176.60897	1710	22.21623	176.60656	sediment on flow surface
11:14:50	22.21550	176.60905	1713	22.21623	176.60656	lots of silica
11:15:38	22.21547	176.60907	1713	22.21623	176.60656	collapse feature
11:15:54	22.21546	176.60907	1710	22.21623	176.60656	different kind of flow, with smoother surface
11:17:19	22.21534	176.60908	1712	22.21623	176.60656	scarp
11:17:36	22.21532	176.60908	1713	22.21623	176.60656	hydrothermal silica at the side
11:18:55	22.21529	176.60908	1717	22.21623	176.60656	highly crevased or pitted surface
11:20:17	22.21518	176.60907	1722	22.21623	176.60656	lost online screen
11:20:44	22.21512	176.60905	1710	22.21627	176.60842	back online
11:21:49	22.21498	176.60895	1725	22.21625	176.60818	lava
11:22:09	22.21493	176.60893	1726	22.21607	176.60890	animal
11:22:27	22.21490	176.60891	1728	22.21540	176.60880	rubble, clinkered surface, according to the map of Fouquet we should be in the hydrothermal field
11:23:31	22.21496	176.60891	1733	22.21604	176.60812	minor sediment
11:24:22	22.21509	176.60896	1736	22.21573	176.60859	smoother surface, tubular
11:26:12	22.21516	176.60893	1730	22.21542	176.60816	pitted and crevased surface
11:27:32	22.21510	176.60887	1728	22.21584	176.60808	flow outcrop is hard -> maybe less vesicular
11:29:03	22.21509	176.60890	1730	22.21656	176.60886	animal
11:29:27	22.21508	176.60888	1731	22.21656	176.60886	gorgonian?
11:29:43	22.21508	176.60887	1731	22.21595	176.60774	going southward
11:30:48	22.21506	176.60883	1733	22.21517	176.60849	gorgonians
11:32:00	22.21511	176.60881	1734	22.21580	176.60852	more sediment
11:32:55	22.21522	176.60883	1731	22.21551	176.60862	dark glassy fragments and brighter sandy sediment
11:34:04	22.21539	176.60886	1730	22.21497	176.60790	blow outcrop, silica patches
11:36:36	22.21543	176.60893	1720	22.21552	176.60804	swell becomes stronger
11:36:51	22.21542	176.60894	1719	22.21495	176.60766	silica
11:37:48	22.21544	176.60897	1718	22.21589	176.60788	smoother flow surface
11:38:53	22.21549	176.60904	1719	22.21579	176.60803	sediment on flow surface
11:39:35	22.21553	176.60912	1717	22.21557	176.60845	not much tectonic
11:41:23	22.21566	176.60928	1717	22.21499	176.60627	scarp
11:43:10	22.21577	176.60929	1724	22.21484	176.60657	sediment
11:43:38	22.21578	176.60928	1724	22.21484	176.60657	lots of sediment
11:43:58	22.21579	176.60929	1725	22.21442	176.60749	ripple marks on the sediment
11:45:12	22.21589	176.60932	1727	22.21638	176.60802	lots of sediment
11:47:21	22.21604	176.60934	1730	22.21587	176.60875	lava outcrop
11:48:28	22.21610	176.60932	1736	22.21610	176.60830	ripple marks on sediment
11:48:56	22.21615	176.60932	1735	22.21597	176.60800	still nice ripples
11:49:30	22.21622	176.60932	1737	22.21674	176.60872	smoother flow surface, more sediment
11:50:30	22.21631	176.60931	1736	22.21633	176.60849	going up at a scarp
11:50:55	22.21634	176.60931	1735	22.21651	176.60880	rubble
11:52:18	22.21640	176.60927	1730	22.21643	176.60883	clinkered material
11:52:59	22.21644	176.60925	1729	22.21691	176.60871	still clinkered flow
11:53:26	22.21647	176.60922	1728	22.21707	176.60839	still going up
11:53:36	22.21648	176.60921	1727	22.21715	176.60882	very rubbly surface
11:55:04	22.21661	176.60923	1722	22.21626	176.60908	flow surface smoother
11:55:37	22.21662	176.60928	1721	22.21626	176.60908	lots of cracks
11:56:06	22.21663	176.60933	1722	22.21626	176.60908	fissure
11:56:17	22.21664	176.60933	1722	22.21626	176.60908	still smoother flow
11:58:06	22.21662	176.60932	1719	22.21632	176.60850	scarp
11:58:52	22.21656	176.60928	1720	22.21632	176.60850	irregular surface, but still smooth
12:01:06	22.21666	176.60916	1719	22.21723	176.60789	went eastward
12:03:18	22.21695	176.60907	1715	22.21713	176.60815	clinkered surface again
12:04:20	22.21693	176.60899	1712	22.21676	176.60839	reddish material, after we hit something
12:05:08	22.21694	176.60895	1711	22.21685	176.60896	scarp
12:05:43	22.21695	176.60895	1706	22.21685	176.60896	lost signal for the grab
12:07:00	22.21694	176.60897	1704	22.21661	176.60846	lot of sediment
12:07:35	22.21691	176.60896	1702	22.21661	176.60846	sediment is material we sampled already with the grab
12:08:58	22.21694	176.60899	1702	22.21661	176.60846	lots of sediment
12:09:50	22.21695	176.60899	1702	22.21730	176.60801	highly sedimented
12:11:47	22.21692	176.60900	1702	22.21663	176.60886	animal
12:13:55	22.21704	176.60895	1700	22.21691	176.60788	still lots of sediment
12:15:38	22.21708	176.60871	1696	22.21750	176.60867	still lots of sediment
12:15:53	22.21709	176.60869	1695	22.21784	176.60808	patches of hydrothermal sediment
12:17:08	22.21711	176.60862	1696	22.21797	176.60836	still yellow hydrothermal sediment
12:17:48	22.21714	176.60859	1708	22.21762	176.60791	try to grab-> fall over
12:18:38	22.21712	176.60860	1712	22.21762	176.60791	cable length 1712 m
12:19:59	22.21712	176.60860	1696	22.21894	176.60889	almost empty, open the grab again
12:21:07	22.21721	176.60866	1692	22.21700	176.60833	back to bottom

Station 50 GTV-A; commenced 23-10-02; page 3 of 3						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
12:21:20	22.21723	176.60868	1693	22.21774	176.60767	gorgonian
12:21:39	22.21724	176.60870	1693	22.21736	176.60822	more gorgonians
12:22:01	22.21725	176.60870	1690	22.21803	176.60812	going northward
12:22:17	22.21724	176.60870	1690	22.21809	176.60776	rubble, minor sediment
12:23:44	22.21720	176.60872	1690	22.21760	176.60745	still some gorgonians
12:24:25	22.21722	176.60873	1689	22.21764	176.60837	greyish material
12:25:01	22.21720	176.60875	1691	22.21755	176.60818	gorgonian
12:26:42	22.21705	176.60882	1692	22.21749	176.60764	still rubble with minor sediment
12:27:25	22.21702	176.60886	1694	22.21809	176.60793	white patch of silica?, shrimps
12:27:55	22.21701	176.60888	1696	22.21798	176.60726	lots of sediment
12:28:58	22.21703	176.60891	1692	22.21733	176.60819	greyish material -> altered
12:30:27	22.21694	176.60899	1696	22.21810	176.60905	animal
12:30:35	22.21693	176.60900	1695	22.21749	176.60719	yellowish sediment
12:31:07	22.21693	176.60902	1694	22.21760	176.60777	lots of sediment, rough blocks between
12:36:45	22.21681	176.60929	1707	22.21701	176.60817	sedimented flow surface
12:38:12	22.21673	176.60933	1710	22.21739	176.60847	rubble flow surfacw, minor sediment
12:39:17	22.21666	176.60936	1713	22.21698	176.60833	very irregular flow surface, looks clinkery again, minor sediment
12:40:51	22.21662	176.60946	1718	22.21723	176.60900	going down, smoother surface
12:42:11	22.21653	176.60948	1718	22.21709	176.60787	crevase, clinkery surface
12:43:44	22.21651	176.60939	1721	22.21749	176.60869	still going down
12:47:05	22.21629	176.60924	1724	22.21675	176.60916	still clinkery lava
12:48:21	22.21628	176.60925	1725	22.21651	176.60957	animal
12:49:18	22.21625	176.60922	1725	22.21689	176.60880	still rubble
12:51:53	22.21600	176.60918	1726	22.21654	176.60866	still clinkered material
12:53:39	22.21585	176.60920	1731	22.21624	176.60856	biogeneous material?
12:54:00	22.21583	176.60921	1731	22.21667	176.60861	lots of sediment
12:54:30	22.21583	176.60923	1731	22.21680	176.60938	going southwestward
12:57:16	22.21611	176.60930	1735	22.21595	176.60779	still rubbles
12:58:02	22.21626	176.60935	1731	22.21614	176.60895	start heaving
13:00:23	22.21659	176.60955	1698	22.21590	176.60803	tapes off
13:05:48	22.21642	176.60931	1500	22.21692	176.60882	1500m
13:34:46	22.21736	176.60889	9993	22.21758	176.60859	GTV on deck, end of station

Station 56 OFOS; commenced 24-10-02; page 1 of 5						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
03:37:47	22.42271	176.68719	0	22.21728	176.60886	begin of station 56 OFOS
04:12:25	22.42308	176.68713	1701	22.42253	176.68704	cable length 1700 m
04:17:07	22.42313	176.68702	1701	22.42231	176.68697	tapes on
04:22:36	22.42310	176.68721	1921	22.42228	176.68738	bottom within fiew
04:25:03	22.42321	176.68714	1924	22.42244	176.68715	clinkered rubble
04:26:41	22.42328	176.68732	1919	22.42210	176.68742	sponge
04:26:59	22.42330	176.68737	1920	22.42236	176.68749	3 different secies of sponges
04:27:58	22.42334	176.68744	1919	22.42227	176.68741	pillar structures
04:28:34	22.42337	176.68740	1920	22.42203	176.68721	clinkered slabs with minor sediment
04:29:05	22.42339	176.68739	1921	22.42259	176.68776	irregular rough surface
04:29:39	22.42344	176.68739	1922	22.42295	176.68746	increasing sediment (25%)
04:30:13	22.42348	176.68740	1924	22.42239	176.68777	shrimp
04:30:51	22.42354	176.68741	1919	22.42244	176.68810	blocks over 1.5 m to less then 10 cm
04:31:38	22.42367	176.68749	1918	22.42304	176.68978	no sediment
04:32:11	22.42377	176.68754	1913	22.42263	176.68802	large slab
04:32:20	22.42381	176.68756	1916	22.42263	176.68802	releave on flow in acsess of 1 m
04:33:00	22.42394	176.68761	1911	22.42428	176.69109	gorgonian
04:33:34	22.42398	176.68759	1912	22.42397	176.69025	sedimented flow top,linkered blocks
04:34:05	22.42404	176.68758	1913	22.42199	176.68838	smooth surface, 80% sediment
04:34:46	22.42413	176.68755	1911	22.42366	176.68808	plateau on a flow surface
04:35:41	22.42427	176.68756	1914	22.42258	176.68842	highly sedimented flow surface, irregular clinkered blocks
04:36:57	22.42445	176.68758	1927	22.42324	176.68862	finer breccia fragments from 20 cm to 1m
04:37:27	22.42451	176.68759	1927	22.42294	176.68818	minor sediment
04:38:11	22.42460	176.68755	1928	22.42338	176.68838	smooth flow surface, structured top
04:38:51	22.42465	176.68753	1931	22.42275	176.68904	large blocks > 2.5 m
04:39:56	22.42479	176.68757	1931	22.42324	176.68763	gorgonian
04:40:10	22.42483	176.68759	1932	22.42350	176.68826	aristeid prawn
04:40:50	22.42492	176.68765	1935	22.42331	176.68856	finer breccia < 20 cm blocks with sediment, smooth surface
04:41:50	22.42500	176.68763	1937	22.42351	176.68762	smooth surface as before
04:42:21	22.42503	176.68763	1935	22.42337	176.68836	occasional block >1.5 m; pebbly surface with sediment

Station 56 OFOS; commenced 24-10-02; page 2 of 5						
Time (UTC)	Ship Lat. (°S)	Long. (°W)	Cable (m)	Sub Lat. (°S)	Long. (°W)	Comment
04:43:21	22.42509	176.68761	1934	22.42334	176.68842	large clinkered blocks > 2m
04:44:16	22.42512	176.68758	1939	22.42345	176.68848	aristeid prawn
04:44:38	22.42514	176.68757	1939	22.42337	176.68765	sedimented flow top
04:45:42	22.42520	176.68767	1943	22.42391	176.68827	blocky flow top with sediment, blocks range from 20 cm to 1.5 m
04:46:20	22.42525	176.68770	1943	22.42351	176.68779	up to now going down about 30 m
04:46:46	22.42529	176.68773	1946	22.42405	176.68809	more blocky rubble, blocks 20 cm to 1 m, no sediment, gorgonian
04:47:40	22.42536	176.68775	1950	22.42401	176.68793	same as before
04:47:49	22.42537	176.68776	1951	22.42384	176.68790	possible flank breccia
04:48:22	22.42539	176.68778	1955	22.42404	176.68746	macrourid fish
04:48:39	22.42540	176.68778	1956	22.42341	176.68837	sediment surface
04:49:19	22.42547	176.68790	1956	22.42413	176.68829	blocky breccia, temperature is rising a little bit
04:50:23	22.42556	176.68801	1954	22.42388	176.68767	massive jointed lava surface
04:51:06	22.42562	176.68807	1954	22.42450	176.68795	large block in axess of 2 m
04:51:26	22.42564	176.68809	1954	22.42334	176.68912	with sediment
04:52:10	22.42571	176.68814	1958	22.42431	176.68799	large slab, block > 5 m
04:52:48	22.42573	176.68819	1957	22.42420	176.68790	jointed block
04:53:09	22.42576	176.68821	1958	22.42455	176.68823	seastar in sediment
04:53:37	22.42577	176.68822	1955	22.42435	176.68778	seastar
04:53:49	22.42577	176.68823	1956	22.42445	176.68848	irregular clinkered surface, blocks < 1 m with larger slabs
04:55:29	22.42581	176.68835	1950	22.42430	176.68887	blocky breccia, blocks < 1 m to 20 cm
04:55:49	22.42583	176.68838	1951	22.42466	176.68768	gorgonian
04:56:15	22.42583	176.68842	1952	22.42418	176.68795	large block > 3 m
04:56:35	22.42583	176.68845	1954	22.42499	176.68831	gorgonian
04:56:55	22.42584	176.68850	1953	22.42455	176.68817	blocky breccia, 20 cm to > 1 m blocks, no matrix
04:57:45	22.42584	176.68859	1950	22.42458	176.68835	drop in elevation
04:58:26	22.42586	176.68867	1952	22.42478	176.68814	poorly sorted breccia, sediment dusting, blocks < 25 cm
04:58:59	22.42586	176.68871	1954	22.42458	176.68783	same as before, possible flank breccia, blocks < 35 cm
04:59:28	22.42588	176.68876	1955	22.42480	176.68863	gorgonian
04:59:54	22.42589	176.68879	1957	22.42468	176.68819	large block 3 m
05:01:03	22.42592	176.68886	1959	22.42454	176.68887	flow banded structured surface, block?
05:01:40	22.42594	176.68893	1954	22.42498	176.68855	same as before
05:02:19	22.42595	176.68900	1951	22.42483	176.68855	same as before
05:02:52	22.42597	176.68899	1953	22.42474	176.68903	gorgonian
05:03:05	22.42597	176.68899	1953	22.42491	176.68865	brecciated surface
05:03:30	22.42599	176.68899	1950	22.42445	176.68861	smoother structured surface, ropy
05:04:49	22.42602	176.68900	1950	22.42518	176.68931	large slabs >1,5 m on smooth surface
05:06:20	22.42619	176.68928	1953	22.42504	176.68979	slaby block breccia surface, minor sediment
05:07:18	22.42629	176.68936	1957	22.42548	176.69217	reddish stained sediment, DV on
05:07:47	22.42633	176.68936	1955	22.42527	176.68979	pebbly sediment, iron coloured
05:08:22	22.42638	176.68936	1951	22.42511	176.68959	same as before
05:08:37	22.42639	176.68936	1950	22.42516	176.69003	same as before, occational clinkered block
05:09:14	22.42646	176.68936	1944	22.42546	176.68996	stalked crinoid
05:09:23	22.42648	176.68937	1945	22.42546	176.68996	blocky flow surface , sedimented
05:10:33	22.42665	176.68939	1942	22.42570	176.69218	blocky breccia surface, blocks up to 1 m
05:11:00	22.42671	176.68941	1938	22.42522	176.69017	red staining
05:11:10	22.42675	176.68940	1937	22.42602	176.69008	in sediment
05:11:27	22.42677	176.68938	1938	22.42583	176.68978	smooth sediment surface
05:11:46	22.42679	176.68934	1938	22.42546	176.69003	DV off
05:12:09	22.42681	176.68931	1934	22.42569	176.69038	gorgonian, still smooth sedimented surface
05:12:34	22.42685	176.68926	1932	22.42540	176.68986	still iron stained sediment
05:13:25	22.42702	176.68926	1929	22.42614	176.68983	pebbly sedimented surface with large blocks
05:14:10	22.42717	176.68923	1931	22.42615	176.69001	smooth sediment surface
05:15:03	22.42731	176.68922	1931	22.42566	176.69005	going back into flow surface, crinoids, gorgonian
05:15:53	22.42746	176.68920	1931	22.42601	176.69060	sedimented surface
05:16:54	22.42755	176.68915	1935	22.42543	176.69059	still sedimented surface
05:17:49	22.42767	176.68914	1945	22.42586	176.69073	sedimented pebbly surface?
05:18:11	22.42772	176.68918	1949	22.42541	176.69027	pillows brocken up
05:18:44	22.42781	176.68921	1950	22.42510	176.68996	heavily sedimented surface
05:19:46	22.42795	176.68927	1957	22.42652	176.69020	very smooth surface now, sedimented with rubble
05:21:08	22.42810	176.68935	1964	22.42616	176.68964	possible brocken pillows, minor sediment
05:22:04	22.42822	176.68943	1972	22.42621	176.68974	jointed flow
05:23:05	22.42831	176.68945	1974	22.42634	176.68979	rubbly flow top, pillows, minor sediment
05:23:29	22.42835	176.68945	1973	22.42630	176.68955	gorgonian
05:23:37	22.42836	176.68946	1970	22.42639	176.68966	flow top rubble, minor sediment
05:23:59	22.42839	176.68945	1970	22.42657	176.68991	sediment dusting
05:24:35	22.42844	176.68947	1966	22.42631	176.68973	gorgonian
05:25:06	22.42849	176.68949	1969	22.42690	176.69057	blocky rubble
05:25:19	22.42852	176.68950	1971	22.42623	176.68962	possible scarp nearby
05:25:52	22.42856	176.68956	1972	22.42690	176.69011	ropy surface

Station 56 OFOS; commenced 24-10-02; page 3 of 5						
Time	Ship		Cable	Sub		Comment
(UTC)	Lat. (°S)	Long. (°W)	(m)	Lat. (°S)	Long. (°W)	
05:26:10	22.42859	176.68958	1972	22.42732	176.69047	no sediment
05:26:29	22.42863	176.68962	1971	22.42638	176.68950	scarp?
05:27:02	22.42868	176.68967	1976	22.42637	176.69015	flow surface
05:27:16	22.42869	176.68969	1978	22.42699	176.68992	structured surface
05:28:16	22.42877	176.68977	1978	22.42672	176.68922	structured flow surface, clean, linear striation features
05:28:54	22.42881	176.68984	1980	22.42709	176.68958	euplectellid sponge
05:29:59	22.42886	176.68993	1983	22.42702	176.69014	possible pillow
05:30:58	22.42890	176.69000	1992	22.42728	176.69016	brown staining sediment with angular blocky rubble
05:31:25	22.42891	176.69003	1987	22.42768	176.69000	flow banded possible ropy surface
05:32:10	22.42893	176.69006	1989	22.42721	176.68972	structured flow surfacce, linear features, minor sediment
05:32:52	22.42894	176.69008	1988	22.42738	176.69018	brittle star
05:33:10	22.42894	176.69009	1989	22.42821	176.68993	irregular, ropy linear surface, gorgonian
05:34:46	22.42883	176.69027	1987	22.42775	176.68974	linear flow structured surface, possible tube
05:36:52	22.42897	176.69030	1987	22.42830	176.69076	possible lava tube surface, linear features, minor sediment
05:37:56	22.42908	176.69033	1994	22.42819	176.69102	steep slope, rubble, minor sediment
05:38:58	22.42927	176.69036	1993	22.42919	176.69330	blocks, rubble? tubes breccia?
05:39:56	22.42945	176.69035	1998	22.42952	176.69317	more rubble,
05:40:23	22.42950	176.69032	1989	22.42795	176.69140	pillar
05:40:49	22.42955	176.69031	1993	22.42825	176.69116	massive linear structured tubes?
05:41:32	22.42960	176.69028	2001	22.42860	176.69095	gorgonian
05:41:49	22.42961	176.69027	2003	22.42808	176.69118	structured ropy pillowed surface, minor sediment, minor breccia
05:42:37	22.42967	176.69023	2007	22.42841	176.69125	iron stained sediment
05:43:13	22.42969	176.69020	2007	22.42832	176.69152	linear structured tube surface, minor breccia and sediment
05:43:40	22.42971	176.69020	2003	22.42795	176.69087	gorgonian
05:44:16	22.42977	176.69018	2008	22.42863	176.69083	iron stained sediment and rubble
05:44:32	22.42980	176.69018	2006	22.42808	176.69120	could be a pillow breccia
05:45:35	22.42993	176.69018	2010	22.42848	176.69073	still iron staining sedimen, patchy
05:46:00	22.42998	176.69018	2011	22.42848	176.69101	irregular flow surface, structured, probable tubes
05:46:34	22.43004	176.69018	2013	22.42832	176.69128	DV on
05:47:31	22.43015	176.69020	2005	22.42906	176.69137	iron staining rubbly brecciated flow surface with sediment
05:48:08	22.43023	176.69021	2003	22.42856	176.69092	DV off 1 min
05:49:13	22.43036	176.69026	1997	22.42877	176.69119	DV on
05:49:45	22.43042	176.69028	1989	22.42854	176.69086	gorgonian on a irregular breccia with sediment
05:50:22	22.43049	176.69029	1987	22.42875	176.69094	sponge
05:50:43	22.43053	176.69030	1988	22.42895	176.69129	looks like brocken tubes rubble, minor sediment
05:51:49	22.43064	176.69031	1985	22.42878	176.69119	angular rubble, sediment
05:52:35	22.43073	176.69032	1984	22.42909	176.69105	more massiv flow tubes
05:53:42	22.43089	176.69033	1983	22.42948	176.69156	DV off 5 min
05:54:23	22.43099	176.69033	1979	22.42996	176.69215	fish
05:54:56	22.43109	176.69032	1981	22.42967	176.69156	more rubble flow surface, linear features, tubes?
05:56:32	22.43138	176.69033	1982	22.42956	176.69187	gorgonian
05:56:47	22.43140	176.69033	1983	22.43020	176.69196	possible tube
05:57:25	22.43147	176.69033	1991	22.43001	176.69156	textured sediment
05:58:31	22.43158	176.69035	1998	22.42953	176.69129	sponge?
05:59:13	22.43164	176.69037	2001	22.43010	176.69127	pillow forms with dusted sediment
06:00:40	22.43176	176.69042	2005	22.42973	176.69173	still pillows and some sediment dusting
06:01:05	22.43180	176.69045	2009	22.42945	176.69108	large tubular pillows, sediment interstitial, brocken up fragments of flows
06:02:54	22.43198	176.69056	2001	22.43012	176.69094	less sediment, collapse features
06:03:43	22.43205	176.69062	1995	22.43024	176.69131	pillar or ledge?
06:04:07	22.43207	176.69066	1996	22.43024	176.69131	gorgonian
06:04:32	22.43212	176.69068	1999	22.43090	176.69109	tubular flow with no sediment
06:04:47	22.43213	176.69070	1999	22.43034	176.69071	talus pile, reddish colour dusting on talus pile
06:05:51	22.43225	176.69082	1991	22.43055	176.69062	tubular flows and slumped debris of pillows and blocky material
06:06:32	22.43231	176.69090	1992	22.42986	176.69057	talus, partially sedimented
06:07:48	22.43239	176.69103	1988	22.43056	176.69115	gorgonian
06:08:26	22.43240	176.69109	1989	22.43104	176.69069	still pillow lava, tubular, gorgonian, pillow tubes, small scarp
06:10:04	22.43249	176.69127	2000	22.43041	176.69084	talus on top of large pillow tubes, very little sediment
06:12:07	22.43259	176.69139	2010	22.43092	176.69105	still tubular lava with dusted sediment, rounded blocks of pillow lava
06:13:36	22.43270	176.69134	2011	22.43129	176.69180	insitu outcrop of massive flows covered by pillow fragments, gorgonian
06:15:24	22.43296	176.69158	2004	22.43150	176.69122	rounded block of pillow lava with some pelagic sediment
06:15:45	22.43297	176.69160	2001	22.43134	176.69146	detached block from an outcrop of clinkery material, ropy texture on an elongated flow
06:16:46	22.43303	176.69167	2001	22.43077	176.69112	talus, slightly sedimented
06:17:40	22.43307	176.69173	1997	22.43154	176.69131	irregular blocks partially detached from the outcrop
06:18:07	22.43309	176.69173	1996	22.43181	176.69191	loose massive blocks

Station 56 OFOS; commenced 24-10-02; page 4 of 5						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
06:18:34	22.43310	176.69172	1994	22.43184	176.69177	passing waypoint 3
06:19:16	22.43311	176.69169	1982	22.43148	176.69167	gorgonians
06:19:48	22.43314	176.69164	1977	22.43183	176.69159	gorgonian
06:19:55	22.43313	176.69164	1974	22.43113	176.69199	scarp
06:20:15	22.43314	176.69161	1971	22.43177	176.69151	massive flows
06:20:40	22.43316	176.69157	1969	22.43210	176.69169	same scarp
06:21:27	22.43321	176.69151	1969	22.43195	176.69200	going up the scarp, massive flows
06:21:54	22.43326	176.69147	1967	22.43172	176.69186	gorgonian
06:24:17	22.43350	176.69163	1974	22.43263	176.69218	massive blocky flows on the scarp with talus on the foot, red staining
06:24:54	22.43357	176.69172	1976	22.43202	176.69235	interstitial sediments
06:28:09	22.43376	176.69207	1981	22.43233	176.69195	tubular lava talus,.sediment 40% on the flow surface, sandy rock debris
00:00:00		0.29476	2			60 % sediment
06:30:01	22.43385	176.69211	1973	22.43297	176.69197	80 % sediment, thin sediment cover on flow surface
06:30:26	22.43386	176.69211	1974	22.43249	176.69203	maybe on a sheet flow
06:32:43	22.43400	176.69214	1973	22.43305	176.69229	lava tubes on top of a sedimented bottom
06:33:08	22.43402	176.69214	1974	22.43285	176.69276	pillar like formation with talus at the foot
06:33:38	22.43406	176.69215	1974	22.43296	176.69235	sediment dusting on top of tubular lava
06:34:36	22.43417	176.69222	1971	22.43295	176.69250	flat ledge
06:35:02	22.43420	176.69222	1971	22.43349	176.69278	could be a lava lake
06:35:26	22.43422	176.69219	1973	22.43300	176.69308	talus, rounded blocks, unsorted material
06:36:12	22.43428	176.69215	1971	22.43284	176.69265	talus on a slope
06:36:26	22.43429	176.69214	1972	22.43313	176.69250	layered ledges and talus
06:36:55	22.43432	176.69212	1963	22.43321	176.69248	gorgonian
06:37:59	22.43440	176.69209	1963	22.43299	176.69303	2 gorgonian on massive lava flow
06:38:28	22.43445	176.69208	1959	22.43300	176.69258	gorgonians
06:39:30	22.43455	176.69206	1963	22.43339	176.69290	tubular flow on a slope
06:39:52	22.43460	176.69206	1962	22.43331	176.69237	scarp
06:40:19	22.43465	176.69207	1966	22.43361	176.69258	same scarp or wall of a fissure
06:41:58	22.43477	176.69210	1976	22.43365	176.69242	gorgonian
06:42:42	22.43484	176.69212	1976	22.43348	176.69283	gorgonian
06:43:03	22.43487	176.69213	1977	22.43382	176.69280	sedimented rubbly surface, possible pilow breccia
06:43:40	22.43495	176.69214	1978	22.43375	176.69324	macrourid fish
06:44:04	22.43501	176.69215	1976	22.43336	176.69265	gorgonian
06:44:17	22.43503	176.69214	1975	22.43435	176.69309	relatively flat brecciated surface with sediment
06:44:52	22.43510	176.69211	1971	22.43439	176.69307	brocken tube
06:45:52	22.43520	176.69207	1971	22.43393	176.69329	gorgonian
06:46:01	22.43522	176.69206	1971	22.43445	176.69304	blocky rubble breccia, blocks up to 1 m
06:46:18	22.43525	176.69205	1972	22.43373	176.69292	possilbe pillow fragment
06:46:30	22.43527	176.69205	1967	22.43429	176.69379	gorgonian
06:46:43	22.43529	176.69206	1968	22.43421	176.69329	gorgonian
06:47:16	22.43536	176.69206	1969	22.43407	176.69269	sponge
06:47:51	22.43541	176.69209	1970	22.43415	176.69311	gorgonian
06:48:17	22.43546	176.69212	1972	22.43363	176.69263	scarp
06:49:14	22.43554	176.69219	1979	22.43404	176.69270	gorgonian
06:49:32	22.43558	176.69221	1983	22.43484	176.69286	rubble breccia, sediment, broken tubes and finer breccia
06:50:51	22.43571	176.69225	1991	22.43474	176.69265	finer breccia and sediment, blocks < 20 cm
06:51:35	22.43581	176.69228	1996	22.43444	176.69278	gorgonian
06:52:29	22.43590	176.69229	1999	22.43460	176.69314	crinoid, rubble/ tube breccia and sediment
06:53:45	22.43603	176.69229	2001	22.43475	176.69341	euplectellid sponge
06:54:13	22.43608	176.69229	2002	22.43457	176.69293	gorgonian, ripples on sediment on top of tube rubble breccia
06:55:35	22.43624	176.69229	2005	22.43516	176.69341	gorgonian
06:55:57	22.43629	176.69228	2006	22.43481	176.69309	gorgonian, sponge
06:57:23	22.43638	176.69215	2008	22.43497	176.69307	DV on
06:57:58	22.43642	176.69212	2002	22.43506	176.69309	lophiide fish
06:58:24	22.43648	176.69213	2004	22.43538	176.69317	gorgonian
06:58:47	22.43654	176.69214	2007	22.43499	176.69304	irregular tube breccia and sediment
07:01:16	22.43697	176.69231	2021	22.43568	176.69332	pebbly sedimented surface with blocks
07:02:34	22.43717	176.69236	2027	22.43515	176.69320	tube/pillow breccia
07:03:03	22.43725	176.69238	2033	22.43535	176.69363	fish
07:04:07	22.43741	176.69242	2032	22.43512	176.69280	small scarp exposing pebbly rubble, gorgonian
07:05:12	22.43755	176.69247	2025	22.43598	176.69330	sponge
07:05:22	22.43757	176.69247	2024	22.43543	176.69318	gorgonian
07:06:03	22.43764	176.69249	2027	22.43605	176.69320	gorgonian
07:07:20	22.43778	176.69255	2033	22.43562	176.69350	coarse meter-sized slabs, probable tubes, gorgonian
07:08:45	22.43790	176.69262	2030	22.43578	176.69345	gorgonian
07:09:12	22.43795	176.69265	2031	22.43647	176.69334	slaby structured flow surface, minor sediment
07:10:52	22.43804	176.69272	2030	22.43618	176.69307	slaby rubble, meter-sized blocks, minor sediment
07:12:40	22.43813	176.69283	2039	22.43612	176.69231	chaotic rubble, poor sorting, no sediment or matrix

Station 56 OFOS; commenced 24-10-02; page 5 of 5

Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
07:13:27	22.43817	176.69288	2039	22.43648	176.69251	possible talus
07:14:47	22.43823	176.69289	2028	22.43668	176.69298	small crevasse
07:15:14	22.43825	176.69291	2030	22.43653	176.69270	possible large blocks, several meters in size
07:16:00	22.43830	176.69294	2033	22.43668	176.69339	coarse rubble, meter-sized blocks to pebbles
07:16:48	22.43836	176.69298	2037	22.43665	176.69278	small scarp
07:17:55	22.43844	176.69305	2049	22.43719	176.69318	rubble, pebble- to boulder-size, finer material, moderately sorted
07:18:58	22.43851	176.69310	2055	22.43703	176.69267	gorgonian
07:19:35	22.43856	176.69311	2052	22.43689	176.69369	structured surface
07:19:59	22.43861	176.69311	2052	22.43725	176.69322	possible tubes
07:20:46	22.43866	176.69312	2054	22.43705	176.69304	sediment dust on coarse rubble
07:21:41	22.43875	176.69314	2059	22.43699	176.69337	possible scarp, rubble-like base
07:23:18	22.43892	176.69314	2064	22.43720	176.69373	sediment dust on rubble
07:24:38	22.43907	176.69309	2065	22.43799	176.69391	gorgonian
07:24:57	22.43911	176.69309	2067	22.43799	176.69391	coarse rubble, minor sediment cover
07:26:18	22.43926	176.69307	2068	22.43809	176.69361	coarse and pebble-sized rubble, thin sediment
07:27:24	22.43938	176.69302	2070	22.43780	176.69393	gorgonian
07:27:41	22.43941	176.69300	2071	22.43809	176.69442	gorgonian
07:27:55	22.43945	176.69298	2072	22.43802	176.69371	coarse to fine rubble, minor sediment
07:28:30	22.43952	176.69297	2074	22.43779	176.69458	gorgonian
07:28:47	22.43954	176.69297	2076	22.43838	176.69394	tube fragments, sediment cover
07:29:18	22.43960	176.69298	2078	22.43871	176.69415	euplectellid sponge
07:29:40	22.43962	176.69298	2064	22.43854	176.69391	start heaving
07:30:29	22.43968	176.69298	2023	22.43791	176.69354	DV off 34 min
07:36:26	22.44325	176.69133	1830	22.44062	176.69264	tapes off
07:37:30	22.43989	176.69315	1811	22.43876	176.69364	1811 m cable length
08:12						OFOS on deck
08:20						end of station

Station 58 OFOS; commenced 24-10-02; page 1 of 5

Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
20:08:42	22.54181	176.71628	0	22.44089	176.69515	begin of station 58 OFOS
20:38:46	22.54132	176.71593	1600	22.54213	176.71514	1600 m water depth
20:42:37	22.54111	176.71610	1723	22.54149	176.71501	photo: starting at picture 351
20:43:13	22.54106	176.71613	1752	22.54146	176.71518	tapes on
20:44:45	22.54102	176.71614	1819	22.54206	176.71501	bottom within view
20:45:48	22.54105	176.71616	1816	22.54213	176.71550	large tube?
20:45:58	22.54105	176.71616	1816	22.54164	176.71524	lightly sedimented
20:46:16	22.54106	176.71617	1816	22.54157	176.71504	biogeneous material, mussels?
20:46:30	22.54107	176.71617	1815	22.54176	176.71528	smooth surface, fractured, lightly sedimented
20:46:57	22.54111	176.71618	1814	22.54169	176.71535	DV on
20:47:07	22.54112	176.71618	1814	22.54157	176.71521	altered basalt of Herzig 1989 ?
20:48:20	22.54122	176.71618	1811	22.54166	176.71538	smooth fractured surface, lightly sedimented
20:49:45	22.54120	176.71618	1812	22.54143	176.71524	looks like a crust giving a smooth but fractured surface with fractures containing orange material
20:50:26	22.54116	176.71623	1813	22.54127	176.71528	Munidopsis
20:51:17	22.54116	176.71632	1812	22.54142	176.71539	crust is brocken exposing darker material
20:52:31	22.54112	176.71641	1812	22.54134	176.71530	smooth lightly sedimented fractured surface, still orange material, but less
20:53:59	22.54100	176.71649	1814	22.54142	176.71542	still smooth surface, fewer fractures, light sedimented
20:54:31	22.54092	176.71652	1816	22.54161	176.71514	less orange coloured
20:55:00	22.54085	176.71656	1816	22.54092	176.71550	still smooth surface, linear features, lightly sedimented
20:55:39	22.54076	176.71660	1816	22.54142	176.71552	fissures
20:56:12	22.54069	176.71664	1816	22.54137	176.71555	same as before, gorgonian
20:56:48	22.54063	176.71669	1815	22.54137	176.71521	brittle star
20:56:58	22.54061	176.71669	1815	22.54165	176.71523	very smooth surface
20:57:12	22.54060	176.71671	1814	22.54095	176.71528	platy fragments on smooth surface, dark sediment
20:57:53	22.54057	176.71676	1813	22.54090	176.71552	still platy fragments
20:58:11	22.54056	176.71679	1813	22.54104	176.71522	sponge
20:58:30	22.54056	176.71680	1814	22.54116	176.71597	ripple marks, dark and white sites
20:58:54	22.54055	176.71684	1816	22.54156	176.71497	dark stuff is manganese?
20:59:21	22.54052	176.71684	1816	22.54118	176.71586	still ripples
20:59:48	22.54047	176.71684	1818	22.54126	176.71584	still sedimented with dark patches
21:00:09	22.54043	176.71683	1818	22.54152	176.71582	snail shell
21:00:29	22.54038	176.71681	1819	22.54128	176.71548	clam shell, orange material and darker material
21:00:56	22.54030	176.71679	1819	22.54101	176.71577	ripples

Station 58 OFOS; commenced 24-10-02; page 2 of 5						
Time	Ship		Cable	Sub		Comment
(UTC)	Lat. (°S)	Long. (°W)	(m)	Lat. (°S)	Long. (°W)	
21:01:16	22.54024	176.71677	1819	22.54132	176.71555	smooth surface, black sediment
21:01:50	22.54013	176.71676	1819	22.54126	176.71559	aristeid prawn
21:02:10	22.54007	176.71675	1819	22.54071	176.71554	same as before
21:02:30	22.54001	176.71677	1819	22.54092	176.71571	smooth surface, hydrothermal sediment
21:02:56	22.53995	176.71678	1819	22.54106	176.71592	DV off 16 min
21:03:32	22.53987	176.71682	1817	22.54071	176.71591	hydrothermal mound
21:05:10	22.53964	176.71691	1813	22.54111	176.71567	still hydrothermal sediment, also dark material, gorgonian
21:06:02	22.53954	176.71694	1811	22.54047	176.71570	temerature decreases
21:06:22	22.53950	176.71695	1810	22.54078	176.71599	dark material = manganese?
21:07:17	22.53942	176.71693	1809	22.54100	176.71579	ripples, balanced, smooth surface, hydrothermal sediment
21:08:27	22.53932	176.71690	1806	22.54032	176.71606	some larger clasts in the sediment
21:09:19	22.53924	176.71689	1804	22.54039	176.71568	set marker 3
21:09:32	22.53923	176.71689	1805	22.54087	176.71604	lots of dark material
21:10:19	22.53916	176.71687	1802	22.54016	176.71587	temperature increases
21:10:35	22.53914	176.71686	1802	22.54024	176.71557	DV on, gorgonian
21:10:53	22.53911	176.71686	1801	22.54091	176.71609	set marker 4
21:11:06	22.53909	176.71685	1799	22.53998	176.71584	maybe crust is brocken
21:11:27	22.53906	176.71683	1801	22.53991	176.71565	temperature anomaly 0.05 °C
21:11:47	22.53902	176.71685	1800	22.53993	176.71624	slope of a mound, marked by white sediment
21:12:10	22.53897	176.71684	1799	22.54078	176.71576	temperature anomaly 0.01 °C, not 0.05 °C as written before
21:12:29	22.53893	176.71684	1800	22.54053	176.71579	gorgonian
21:12:42	22.53891	176.71684	1800	22.53963	176.71609	coarser sediment at the edge of the mound
21:13:27	22.53879	176.71685	1797	22.54027	176.71593	DV off 3min
21:14:06	22.53869	176.71686	1796	22.54105	176.71605	sponge
21:14:17	22.53866	176.71687	1795	22.53973	176.71590	orange to reddish sediment
21:15:29	22.53848	176.71692	1792	22.54019	176.71593	ripples, manganese-rich or volcaniclastic-rich sediment
21:15:53	22.53843	176.71694	1792	22.54002	176.71583	coarser debris on mound
21:16:29	22.53835	176.71695	1788	22.54011	176.71571	smooth mound surface, Munidopsis
21:17:02	22.53828	176.71698	1789	22.54031	176.71607	hydrothermal crust, chimneys, Munidopsis
21:17:22	22.53824	176.71699	1786	22.54007	176.71620	temperature increases
21:17:34	22.53821	176.71699	1787	22.53962	176.71574	ripples, dark sediment
21:18:15	22.53811	176.71700	1788	22.54032	176.71590	black manganese-rich? Sediment, smooth
21:18:31	22.53808	176.71700	1789	22.53963	176.71575	temperature is still rising
21:18:45	22.53805	176.71701	1791	22.53927	176.71601	temperature anomaly 0.06 °C
21:19:03	22.53802	176.71700	1792	22.54018	176.71582	black sediment, cloudy water, low visibility
21:19:41	22.53794	176.71701	1798	22.53999	176.71571	shell of a clam
21:19:52	22.53792	176.71701	1800	22.53967	176.71556	rippled sediment, debris block
21:20:14	22.53788	176.71703	1799	22.53879	176.71632	sulfide debris?
21:20:28	22.53785	176.71704	1801	22.53991	176.71571	temperature still increases
21:20:48	22.53781	176.71705	1802	22.53996	176.71620	DV on before 2 min.
21:21:24	22.53774	176.71706	1805	22.53920	176.71604	very cloudy, smooth surface, grey colour, black patches
21:21:57	22.53769	176.71707	1810	22.53911	176.71570	chimney
21:22:05	22.53767	176.71706	1810	22.53903	176.71589	many chimneys
21:22:28	22.53764	176.71707	1811	22.53960	176.71633	Munidopsis
21:22:39	22.53761	176.71707	1812	22.53915	176.71582	smooth surface of mound
21:23:12	22.53757	176.71707	1814	22.53922	176.71570	some debris, smooth surface
21:23:26	22.53755	176.71707	1815	22.53876	176.71624	aristeid prawn
21:23:50	22.53751	176.71707	1816	22.53862	176.71606	chimney
21:23:58	22.53749	176.71707	1816	22.53895	176.71629	temperature anomaly 0.12 °C
21:24:30	22.53744	176.71707	1817	22.53844	176.71610	smooth surface on mound, mottled grey-black surface
21:25:12	22.53737	176.71707	1817	22.53899	176.71619	temperature decreases
21:25:25	22.53735	176.71707	1817	22.53881	176.71636	DV off 7 min
21:25:44	22.53731	176.71708	1817	22.53928	176.71641	reddish sediment, mottled grey-black smooth surface on mound
21:26:14	22.53726	176.71709	1815	22.53918	176.71606	cracks
21:27:21	22.53712	176.71709	1817	22.53805	176.71655	mottled grey surface on mound
21:27:43	22.53707	176.71709	1818	22.53818	176.71641	coarser debris, black clasts
21:28:13	22.53701	176.71709	1818	22.53846	176.71631	temperature still high
21:29:09	22.53691	176.71708	1819	22.53814	176.71631	clam shells on smooth surface
21:30:31	22.53675	176.71704	1821	22.53777	176.71610	mottled grey-black surface. some fractures
21:31:23	22.53665	176.71703	1822	22.53832	176.71649	temperature still high
21:31:43	22.53661	176.71702	1823	22.53804	176.71605	reddish sediment, mottled surface
21:32:11	22.53656	176.71701	1824	22.53804	176.71575	coarser debris, black clasts
21:32:29	22.53653	176.71701	1823	22.53791	176.71609	going down the hill
21:32:46	22.53650	176.71700	1824	22.53859	176.71660	rippled black sand
21:32:59	22.53648	176.71700	1822	22.53823	176.71610	temperature is dropping, following topographie
21:33:21	22.53645	176.71699	1823	22.53741	176.71636	DV on, sulfide talus
21:33:40	22.53643	176.71697	1824	22.53836	176.71635	sulfide talus sand
21:34:02	22.53639	176.71697	1825	22.53777	176.71619	temperature increases a bit
21:34:30	22.53635	176.71696	1829	22.53781	176.71550	macrourid fish

Station 58 OFOS; commenced 24-10-02; page 3 of 5						
Time (UTC)	Ship Lat. (°S)	Long. (°W)	Cable (m)	Sub Lat. (°S)	Long. (°W)	Comment
21:34:44	22.53632	176.71694	1831	22.53764	176.71616	brocken chimney debris
21:35:03	22.53629	176.71693	1833	22.53776	176.71624	back to mottled grey-black sediment
21:35:48	22.53621	176.71691	1840	22.53822	176.71603	temperature decreases
21:36:11	22.53616	176.71691	1841	22.53731	176.71619	same as before, smooth surface
21:36:31	22.53612	176.71691	1842	22.53773	176.71578	DV off 3 min
21:36:59	22.53605	176.71689	1845	22.53734	176.71599	shell of clams
21:37:15	22.53601	176.71689	1845	22.53698	176.71606	increasing biology in black rippled sand
21:37:48	22.53593	176.71688	1845	22.53741	176.71610	DV on
21:38:02	22.53590	176.71687	1845	22.53691	176.71608	shells, ripples
21:38:30	22.53583	176.71684	1845	22.53737	176.71587	shells have been transported? -> not so close together
21:38:58	22.53578	176.71684	1845	22.53676	176.71663	rippled black sand
21:39:21	22.53573	176.71680	1846	22.53709	176.71599	grey sand with black sand-sized debris
21:40:02	22.53567	176.71677	1841	22.53688	176.71577	black rippled sand
21:40:18	22.53565	176.71674	1837	22.53779	176.71588	DV off 3 min
21:41:18	22.53560	176.71667	1832	22.53650	176.71567	rippled sand, some coarser debris
21:41:46	22.53558	176.71663	1828	22.53709	176.71610	temperature increases
21:42:01	22.53557	176.71661	1826	22.53693	176.71581	coarser debris
21:42:44	22.53551	176.71656	1822	22.53662	176.71576	crust, chimney talus , silica
21:42:58	22.53549	176.71655	1822	22.53646	176.71635	solid surface, smooth, covered by dark sediment
21:43:19	22.53545	176.71652	1822	22.53689	176.71578	many gorgonians
21:43:35	22.53543	176.71652	1823	22.53635	176.71551	black sand
21:43:50	22.53541	176.71653	1823	22.53671	176.71614	temperature is dropping
21:44:02	22.53538	176.71651	1823	22.53569	176.71619	rippled sand, temperature anomaly 0.05°C
21:44:31	22.53531	176.71652	1824	22.53622	176.71576	gorgonian
21:44:42	22.53528	176.71652	1824	22.53603	176.71586	sponge
21:44:51	22.53525	176.71652	1824	22.53655	176.71579	smooth rippled surface
21:45:50	22.53505	176.71655	1827	22.53645	176.71601	smooth surface
21:46:30	22.53493	176.71656	1827	22.53630	176.71537	rippled sand, diffuse venting?
21:47:11	22.53481	176.71661	1829	22.53633	176.71595	mottled grey-black surface
21:47:27	22.53479	176.71663	1829	22.53633	176.71595	gorgonian
21:47:45	22.53476	176.71664	1830	22.53592	176.71572	actinian, aristeid prawn
21:48:00	22.53474	176.71666	1830	22.53638	176.71558	DV on
21:48:22	22.53471	176.71667	1830	22.53648	176.71557	same mottled surface
21:49:11	22.53466	176.71671	1832	22.53593	176.71567	clam shells
21:49:25	22.53465	176.71672	1832	22.53567	176.71559	mottled grey-black surface, some black debris
21:50:21	22.53465	176.71676	1832	22.53577	176.71579	rippled black surface
21:51:05	22.53459	176.71681	1833	22.53526	176.71560	mottled grey-black sediment
21:51:58	22.53448	176.71686	1835	22.53490	176.71578	ditto
21:52:32	22.53440	176.71688	1838	22.53523	176.71554	some black debris in grey sediment, smooth surface
21:52:56	22.53434	176.71687	1839	22.53504	176.71565	still temperature anomaly
21:53:24	22.53427	176.71688	1842	22.53493	176.71590	DV off 6 min
21:54:08	22.53417	176.71688	1845	22.53554	176.71530	mottled grey sediment, black debris, temperature back to background
21:55:02	22.53404	176.71691	1848	22.53454	176.71607	smooth surface, grey sediment, black debris
21:56:01	22.53391	176.71701	1852	22.53465	176.71614	mottled grey-black surface, some ripples
21:57:19	22.53378	176.71715	1858	22.53438	176.71560	DV on
21:57:43	22.53376	176.71719	1859	22.53467	176.71551	mottled grey-black smooth surface
21:58:20	22.53373	176.71725	1861	22.53455	176.71586	same as before, some minor black debris
21:59:08	22.53372	176.71732	1863	22.53455	176.71592	DV off 2 min
22:02:00	22.53378	176.71743	1875	22.53371	176.71634	T back to background
22:02:19	22.53381	176.71744	1877	22.53410	176.71581	still smooth sedimented surface, hydrothermal sediment (yellowish)
22:02:46	22.53384	176.71746	1877	22.53389	176.71599	hard material -> debris
22:03:29	22.53390	176.71744	1878	22.53392	176.71635	sediment on a crust
22:03:44	22.53391	176.71744	1879	22.53356	176.71593	temperature still at backround
22:04:39	22.53397	176.71745	1881	22.53374	176.71652	sea urchin
22:06:55	22.53388	176.71759	1884	22.53320	176.71661	brittle star
22:08:04	22.53375	176.71777	1886	22.53377	176.71625	mottled surface, still hydrothermal sediment, brittle star
22:08:38	22.53366	176.71788	1887	22.53352	176.71659	many gorgonians
22:08:48	22.53363	176.71791	1886	22.53326	176.71602	contact between light and dark sediment
22:09:10	22.53358	176.71798	1887	22.53338	176.71688	flow ledges -> contact with hydrothermal sediment
22:09:40	22.53349	176.71806	1888	22.53399	176.71618	ledges are partially buried by sediment
22:10:33	22.53332	176.71819	1893	22.53379	176.71654	hard bottom (moderately)
22:10:50	22.53327	176.71822	1894	22.53423	176.71633	thin crust of hyaloclastites
22:12:15	22.53302	176.71828	1904	22.53390	176.71631	slumped debris on top of hydrothermal sediment
22:12:49	22.53295	176.71827	1908	22.53425	176.71629	debris of hard material buried partially by sediment
22:13:24	22.53288	176.71826	1909	22.53416	176.71649	rounded debris, scattered on hydrothermal sediment
22:14:31	22.53278	176.71824	1914	22.53376	176.71648	clam shells
22:15:39	22.53264	176.71826	1914	22.53326	176.71663	brittle star
22:15:50	22.53261	176.71826	1915	22.53413	176.71653	smooth surface, grey sediment, black debris
22:16:12	22.53255	176.71828	1914	22.53404	176.71671	coarser sand, black fragments and debris

Station 58 OFOS; commenced 24-10-02; page 4 of 5						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
22:17:09	22.53238	176.71834	1908	22.53397	176.71650	temperature rises a little bit
22:17:22	22.53235	176.71835	1908	22.53418	176.71668	smooth surface, grey colour, some black and grey debris
22:18:12	22.53221	176.71840	1903	22.53414	176.71664	grey debris, grey sand, smooth surface
22:18:56	22.53210	176.71845	1898	22.53421	176.71676	volcanic debris? debris is grey and typically < 10 cm
22:19:48	22.53197	176.71851	1891	22.53382	176.71662	still grey debris on a smooth surface
22:20:23	22.53189	176.71854	1887	22.53410	176.71672	coarser volcanic debris, blocks > 20 cm to sand-size
22:21:28	22.53178	176.71859	1878	22.53355	176.71659	coarser debris, scattered on mottled gey black smooth surface
22:22:29	22.53170	176.71864	1867	22.53337	176.71685	grey-black mottled sediment surface
22:22:42	22.53168	176.71865	1864	22.53227	176.71723	scattered debris (volcanic)
22:23:26	22.53161	176.71866	1859	22.53256	176.71716	debris marks gentle edge of slope
22:24:07	22.53156	176.71867	1850	22.53328	176.71714	gentle slope
22:24:39	22.53151	176.71868	1848	22.53272	176.71675	coarser debris, talus 1m to cm, no sediment cover
22:25:17	22.53145	176.71869	1843	22.53260	176.71715	same as before
22:25:57	22.53138	176.71869	1838	22.53278	176.71739	coarse debris, possible scarp
22:26:16	22.53135	176.71870	1835	22.53226	176.71689	silica, manganese material
22:26:41	22.53129	176.71869	1832	22.53295	176.71714	chimney debris
22:26:59	22.53125	176.71869	1831	22.53267	176.71680	more chimneys
22:27:10	22.53123	176.71870	1831	22.53207	176.71736	shimmering water
22:27:17	22.53121	176.71869	1828	22.53207	176.71736	sulfide talus
22:27:34	22.53117	176.71870	1826	22.53228	176.71744	0.15 °C temperature anomaly
22:27:55	22.53111	176.71870	1828	22.53227	176.71737	chimney, Munidopsis
22:28:06	22.53108	176.71871	1826	22.53287	176.71716	chimney
22:28:16	22.53106	176.71871	1824	22.53207	176.71768	Munidopsis
22:28:27	22.53103	176.71871	1822	22.53152	176.71764	80 cm high chimney, temperature rises
22:28:50	22.53096	176.71872	1823	22.53283	176.71734	large chimney
22:29:03	22.53092	176.71872	1823	22.53218	176.71724	temperature anomaly 0.23°C, scarp
22:29:21	22.53087	176.71873	1824	22.53282	176.71709	very cloudy
22:29:49	22.53078	176.71874	1826	22.53156	176.71771	reddish brown sulfides?
22:30:02	22.53074	176.71874	1826	22.53253	176.71660	cloudy water
22:30:13	22.53070	176.71875	1827	22.53224	176.71715	temperature drops
22:30:59	22.53056	176.71877	1838	22.53168	176.71741	volcanic debris, maybe top of a flow
22:31:22	22.53049	176.71877	1842	22.53237	176.71697	DV off 5 min
22:31:56	22.53039	176.71879	1848	22.53170	176.71722	slumped debris on a slope
22:32:17	22.53034	176.71881	1851	22.53216	176.71727	gorgonian
22:32:26	22.53031	176.71881	1852	22.53220	176.71712	gorgonian
22:32:52	22.53026	176.71882	1858	22.53239	176.71735	lava outcrop
22:33:09	22.53022	176.71883	1858	22.53170	176.71736	tubes
22:33:28	22.53019	176.71885	1860	22.53242	176.71728	water still cloudy, temperature back to background
22:33:51	22.53015	176.71885	1864	22.53210	176.71736	gorgonian
22:33:58	22.53014	176.71885	1865	22.53173	176.71791	still tubes
22:34:21	22.53011	176.71885	1870	22.53213	176.71737	brecciated tubes
22:34:55	22.53007	176.71885	1874	22.53221	176.71758	large tube
22:35:07	22.53006	176.71884	1875	22.53150	176.71717	black sediment
22:35:14	22.53006	176.71885	1877	22.53150	176.71717	sediment on tubes (hydrothermal?), actinian
22:35:50	22.53002	176.71886	1883	22.53154	176.71777	rippled black sand, gorgonian
22:36:04	22.53001	176.71885	1885	22.53143	176.71726	sand covering volcanic material
22:36:17	22.52999	176.71885	1885	22.53118	176.71713	brocken pillow
22:36:30	22.52998	176.71885	1886	22.53078	176.71794	tube
22:36:43	22.52996	176.71885	1887	22.53115	176.71752	hydrothermal material
22:36:56	22.52994	176.71885	1885	22.53073	176.71788	scarp, pillow lava
22:37:39	22.52988	176.71885	1886	22.53110	176.71742	following the scarp?
22:37:53	22.52986	176.71885	1889	22.53131	176.71754	sediment at basin of scarp
22:38:22	22.52981	176.71883	1894	22.53078	176.71728	hydrothermal material
22:39:07	22.52973	176.71884	1899	22.53100	176.71737	slumped debris
22:39:33	22.52968	176.71884	1903	22.53065	176.71781	coarser debris, tube, clinkery material -> flow
22:40:05	22.52961	176.71884	1907	22.53041	176.71805	volcanic debris
22:40:44	22.52953	176.71885	1912	22.52989	176.71806	contact between debris and motteld grey-black sediment
22:41:21	22.52944	176.71887	1916	22.53071	176.71765	rippled dark material
22:41:49	22.52936	176.71888	1919	22.53070	176.71735	rippled sediment
22:42:19	22.52928	176.71889	1920	22.53002	176.71778	brittle stars
22:42:32	22.52925	176.71890	1919	22.53037	176.71789	rippled hydrothermal sediment
22:43:01	22.52917	176.71892	1920	22.53064	176.71741	sea star
22:43:11	22.52915	176.71892	1918	22.53074	176.71750	still rippled sediment
22:43:50	22.52905	176.71894	1918	22.52998	176.71808	still rippled sediment
22:44:24	22.52897	176.71896	1919	22.53081	176.71726	rippled sediment
22:45:02	22.52887	176.71897	1921	22.53081	176.71726	brittle star
22:45:27	22.52882	176.71899	1921	22.52995	176.71800	still rippled sediment
22:45:58	22.52874	176.71900	1922	22.53096	176.71747	lighted grey rippeld sediment
22:46:43	22.52863	176.71901	1924	22.52975	176.71832	smooth surface, mottled grey-black, no ripples, current from northwest

Station 58 OFOS; commenced 24-10-02; page 5 of 5						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
22:48:06	22.52846	176.71904	1927	22.53065	176.71730	mottled grey-black surface
22:49:19	22.52833	176.71906	1931	22.52956	176.71747	mottled grey-black sediment, smooth
22:49:53	22.52825	176.71904	1933	22.52956	176.71747	temperature already back to bottom
22:50:52	22.52813	176.71905	1938	22.52994	176.71747	same as before, minor debris
22:51:59	22.52801	176.71903	1941	22.52935	176.71754	contact with rippled grey sand
22:52:31	22.52795	176.71903	1943	22.52923	176.71754	gorgonian
22:52:59	22.52789	176.71902	1945	22.52857	176.71802	mottled grey sediment, small chimney debris?
22:53:25	22.52784	176.71901	1946	22.52952	176.71781	brittle star. rippled sediment
22:53:48	22.52780	176.71902	1947	22.52865	176.71788	some pebbles
22:54:47	22.52769	176.71900	1948	22.52852	176.71750	still rippled sediment
22:55:30	22.52763	176.71899	1947	22.52881	176.71756	same as before
22:56:21	22.52754	176.71897	1946	22.52890	176.71812	same as before, black pebbles, sedimented basin
22:58:36	22.52731	176.71896	1935	22.52912	176.71726	same as before
22:58:49	22.52729	176.71897	1934	22.52912	176.71726	no ripples
22:59:39	22.52719	176.71895	1928	22.52578	176.71790	rippled sediment
23:00:43	22.52706	176.71895	1922	22.52776	176.71795	cloudy water, black sand
23:01:09	22.52699	176.71895	1920	22.52872	176.71766	black and grey sand
23:01:19	22.52696	176.71896	1919	22.52795	176.71775	minor ripples
23:01:57	22.52686	176.71897	1915	22.52772	176.71799	mottled grey-black sediment, smooth surface, tubes
23:02:20	22.52681	176.71898	1912	22.52749	176.71816	tubes partially sedimented by black material, scarp
23:02:56	22.52671	176.71900	1906	22.52848	176.71757	DV on
23:03:13	22.52666	176.71901	1904	22.52767	176.71792	same as before
23:03:30	22.52663	176.71903	1903	22.52777	176.71784	tube covered by sediment, debris
23:03:51	22.52657	176.71904	1902	22.52706	176.71811	grey debris, black sand
23:04:19	22.52651	176.71906	1900	22.52775	176.71780	mottled grey and black sand
23:04:46	22.52645	176.71909	1898	22.52775	176.71780	rippled black sand
23:05:09	22.52639	176.71910	1896	22.52769	176.71755	pillow debris? in black rippled sand
23:05:34	22.52633	176.71913	1892	22.52724	176.71788	gorgonian
23:05:42	22.52631	176.71914	1891	22.52726	176.71787	small scarp, tube, gorgonian
23:05:57	22.52628	176.71916	1887	22.52757	176.71773	gorgonian on tube
23:06:15	22.52622	176.71917	1886	22.52722	176.71829	black sand and grey debris
23:06:36	22.52617	176.71920	1883	22.52777	176.71773	brittle star
23:06:49	22.52613	176.71921	1882	22.52718	176.71794	mottled grey-black sediment, smooth surface, some grey debris
23:07:13	22.52605	176.71923	1881	22.52696	176.71765	sulfide! temperature rises
23:07:42	22.52597	176.71928	1879	22.52748	176.71783	platy fragments-> brocken crust
23:07:56	22.52593	176.71929	1878	22.52747	176.71755	contact between hydrothermal crust and black sand
23:08:17	22.52586	176.71932	1878	22.52759	176.71787	pillow partially covered by black sand
23:09:06	22.52571	176.71937	1876	22.52760	176.71759	slabs, possible hydrothermal crust
23:09:31	22.52563	176.71940	1876	22.52760	176.71759	rippled black sand
23:09:43	22.52559	176.71942	1877	22.52549	176.71741	native sulfur
23:10:08	22.52552	176.71945	1877	22.52629	176.71746	rippled black sand, smooth surface
23:10:35	22.52544	176.71947	1878	22.52722	176.71776	same as before
23:10:48	22.52540	176.71948	1878	22.52639	176.71830	brittle star
23:10:59	22.52537	176.71949	1878	22.52686	176.71797	temperature anomaly 0.05 °C
23:11:13	22.52534	176.71950	1879	22.52740	176.71785	grey surface, smooth, some grey debris
23:11:45	22.52525	176.71950	1880	22.52750	176.71734	brittle star
23:12:01	22.52521	176.71951	1882	22.52747	176.71743	mottled grey rippled sand with sulfide debris? (orange colour)
23:12:33	22.52514	176.71952	1883	22.52692	176.71773	rippled sand
23:12:58	22.52509	176.71952	1884	22.52692	176.71773	temperature drops, grey and black rippled sand
23:13:26	22.52503	176.71951	1885	22.52708	176.71720	same as before
23:14:13	22.52494	176.71951	1887	22.52682	176.71758	lots of grey and black sand
23:14:30	22.52491	176.71952	1888	22.52700	176.71809	ripples
23:14:45	22.52489	176.71951	1887	22.52665	176.71828	gorgonians?
23:15:00	22.52487	176.71951	1885	22.52723	176.71797	rippled grey-black sand, brittle stars
23:15:27	22.52484	176.71950	1885	22.52662	176.71764	brittle star
23:15:40	22.52483	176.71949	1885	22.52629	176.71818	brittle star
23:15:57	22.52482	176.71947	1883	22.52704	176.71773	contact grey sand with rippled grey and black sand
23:17:29	22.52480	176.71942	1890	22.52576	176.71827	mottled grey-black sand
23:18:13	22.52479	176.71938	1895	22.52594	176.71823	rippled grey and black sediment, cloudy water
23:18:44	22.52479	176.71935	1897	22.52559	176.71804	same as before
23:19:49	22.52481	176.71926	1903	22.52554	176.71790	smooth and rippled grey-black sediment
23:20:30	22.52483	176.71921	1906	22.52587	176.71825	grey-black rippled sediment
23:20:54	22.52484	176.71919	1906	22.52552	176.71808	DV off 18 min, start heaving
23:33:57	22.52505	176.71898	1323	22.52463	176.71851	tapes off
00:03:15	22.52410	176.72010	29	22.52441	176.71996	OFOS on deck
00:21:00						end of station

Station 59 OFOS; commenced 25-10-02; page 1 of 6						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
01:40:41	22.55046	176.71896	1	22.52383	176.71952	OFOS in the water, begin of station 59 OFOS
02:13:06	22.54933	176.71933	1752	22.54864	176.71853	tapes on
02:15:40	22.54931	176.71934	1830	22.54888	176.71853	bottom within view
02:15:55	22.54932	176.71933	1832	22.54927	176.71804	motteled grey-black, smooth surface
02:17:35	22.54932	176.71923	1832	22.54887	176.71833	same as before
02:18:04	22.54933	176.71919	1830	22.54875	176.71821	sandy material
02:18:31	22.54934	176.71916	1831	22.54907	176.71809	flat, smooth surface
02:19:35	22.54932	176.71909	1831	22.54895	176.71835	biogenious stuff
02:20:00	22.54929	176.71908	1832	22.54891	176.71849	mottled sandy surface with biogenuos material
02:21:22	22.54918	176.71910	1833	22.54862	176.71819	same as before
02:22:11	22.54912	176.71913	1833	22.54867	176.71831	same as before
02:24:36	22.54896	176.71918	1836	22.54865	176.71797	shell and other biogeneous material in mottled grey sand
02:25:23	22.54888	176.71917	1837	22.54928	176.71811	shell
02:25:30	22.54886	176.71917	1837	22.54928	176.71811	more shells
02:26:15	22.54879	176.71917	1837	22.54823	176.71956	random distributet clam shells
02:26:30	22.54877	176.71918	1837	22.54823	176.71956	grey mottled sediment
02:28:05	22.54865	176.71919	1838	22.54663	176.71916	same as before
02:28:46	22.54862	176.71919	1839	22.54663	176.71916	aristeid prawn
02:29:34	22.54860	176.71919	1839	22.54669	176.71899	same as before
02:30:16	22.54857	176.71917	1835	22.54834	176.71840	contact between sediment and talus
02:30:44	22.54855	176.71916	1834	22.54813	176.71860	talus of sulfides??
02:31:28	22.54851	176.71916	1836	22.54813	176.71808	sand is getting darker
02:31:48	22.54848	176.71916	1835	22.54822	176.71810	gorgonian
02:32:08	22.54845	176.71915	1834	22.54795	176.71809	contact between sediment and rubble? scarp
02:32:37	22.54841	176.71915	1835	22.54829	176.71844	big scarp
02:32:47	22.54840	176.71915	1834	22.54823	176.71843	hydrothermal sediment on top of pillow lavas?
02:33:15	22.54834	176.71912	1833	22.54825	176.71800	still going down scarp
02:34:01	22.54827	176.71908	1835	22.54832	176.71852	mottled grey sediment at the bottom of the scarp
02:34:41	22.54821	176.71905	1837	22.54820	176.71792	shell
02:35:21	22.54814	176.71901	1836	22.54858	176.71816	contact between mottled grey sediment and something else?
02:36:19	22.54802	176.71899	1832	22.54766	176.71818	-> possible volcanics
02:36:54	22.54795	176.71899	1832	22.54799	176.71838	smooth mottled sediment, thin layer
02:38:18	22.54780	176.71897	1828	22.54638	176.71953	mottled grey sandy sediment with blocks in it
02:38:59	22.54774	176.71894	1826	22.54638	176.71953	clam shell
02:39:21	22.54771	176.71892	1825	22.54638	176.71953	grey mottled sandy sediment with some shells
02:40:48	22.54758	176.71885	1819	22.54638	176.71953	same as before
02:42:30	22.54746	176.71877	1814	22.54751	176.71801	same as before
02:43:28	22.54740	176.71871	1810	22.54772	176.71784	same as before
02:44:10	22.54736	176.71867	1811	22.54741	176.71797	shells
02:44:59	22.54730	176.71861	1809	22.54725	176.71793	ditto
02:46:23	22.54716	176.71855	1802	22.54698	176.71787	ditto
02:48:18	22.54697	176.71849	1798	22.54681	176.71765	shells
02:49:35	22.54688	176.71842	1798	22.54692	176.71775	grey mottled sediment, black dots, maybe manganese?
02:50:41	22.54680	176.71835	1797	22.54746	176.71733	grey sediment with clasts
02:52:15	22.54669	176.71825	1799	22.54658	176.71774	grey mottled sediment
02:54:29	22.54653	176.71811	1804	22.54669	176.71782	ditto
02:55:01	22.54651	176.71808	1806	22.54645	176.71717	some debris on the sediment
02:55:43	22.54646	176.71805	1807	22.54632	176.71765	biogeneous material increasing
02:55:57	22.54644	176.71804	1807	22.54654	176.71794	sediment thinning? underlying rubble?
02:57:49	22.54628	176.71794	1809	22.54615	176.71775	ditto
02:59:08	22.54614	176.71793	1809	22.54613	176.71739	fish
02:59:29	22.54609	176.71795	1810	22.54591	176.71721	ditto
03:00:33	22.54596	176.71794	1811	22.54594	176.71736	sandy grey mottled material, smooth
03:01:59	22.54582	176.71788	1815	22.54461	176.71793	ditto
03:02:09	22.54579	176.71786	1816	22.54461	176.71793	sponge?
03:02:36	22.54575	176.71785	1817	22.54461	176.71793	wire?
03:03:48	22.54562	176.71777	1820	22.54375	176.71690	shells
03:04:06	22.54560	176.71776	1822	22.54375	176.71690	grey sandy sediment, smooth
03:05:35	22.54550	176.71767	1823	22.54394	176.71709	linear elements -> animal tracks?
03:06:42	22.54542	176.71761	1827	22.54556	176.71721	ditto
03:08:37	22.54528	176.71757	1838	22.54531	176.71728	ditto
03:09:20	22.54523	176.71757	1840	22.54517	176.71729	ditto
03:09:55	22.54519	176.71756	1842	22.54494	176.71674	more biogeneous material on grey sandy sediment
03:11:42	22.54503	176.71756	1846	22.54532	176.71715	ditto
03:13:51	22.54482	176.71755	1847	22.54463	176.71681	only a small plume is produced when the pilot weight touches the ground, however, sediment coverage might be some dm thick because of the smooth topography, probably a strong current which removes fine grained material
03:16:26	22.54457	176.71756	1852	22.54236	176.71712	some linear features in sediment, possible ripples
03:18:07	22.54444	176.71758	1855	22.54430	176.71668	ripples?

Station 59 OFOS; commenced 25-10-02; page 2 of 6						
Time (UTC)	Ship Lat. (°S)	Long. (°W)	Cable (m)	Sub Lat. (°S)	Long. (°W)	Comment
03:18:56	22.54436	176.71757	1855	22.54438	176.71615	few clasts, grey detritus
03:19:34	22.54430	176.71756	1857	22.54425	176.71665	tubular flows partially sedimented with thin film of sediment on top
03:20:25	22.54421	176.71755	1856	22.54436	176.71629	going back to sandy sedimented bottom
03:20:48	22.54418	176.71755	1857	22.54436	176.71629	partially volcanic outcrop
03:21:07	22.54414	176.71756	1857	22.54393	176.71672	looks like volcanic material
03:21:44	22.54404	176.71759	1859	22.54408	176.71641	black patches of light yellowish coloured sediment, slumping debris
03:22:51	22.54386	176.71766	1862	22.54388	176.71708	sandy mottled sediment with more biogeneous material
03:23:33	22.54376	176.71769	1864	22.54332	176.71797	yellowish material, DV on
03:23:59	22.54369	176.71769	1862	22.54332	176.71797	also white material -> silica
03:24:16	22.54364	176.71769	1864	22.54332	176.71797	hydrothermal field ?
03:24:41	22.54358	176.71770	1864	22.54332	176.71797	mussel
03:25:03	22.54353	176.71771	1863	22.54159	176.71676	DV off 1 min
03:25:20	22.54348	176.71771	1862	22.54159	176.71676	shells
03:25:54	22.54340	176.71771	1858	22.54168	176.71712	small depression
03:26:10	22.54336	176.71770	1858	22.54133	176.71660	crusty material
03:26:22	22.54333	176.71770	1856	22.54181	176.71746	exposed crust
03:26:47	22.54327	176.71771	1853	22.54171	176.71690	hydrothermal yellowish material
03:28:23	22.54305	176.71771	1846	22.54372	176.71681	grey sediment
03:28:42	22.54301	176.71770	1843	22.54123	176.71710	black sandy bottom
03:29:23	22.54290	176.71771	1838	22.54346	176.71679	sulfide talus
03:29:34	22.54287	176.71771	1836	22.54358	176.71654	sulfide talus, hydrothermal mound?
03:30:50	22.54267	176.71772	1830	22.54419	176.71716	DV on
03:31:16	22.54259	176.71772	1826	22.54347	176.71672	still hydrothermal material, DV off 1min
03:31:45	22.54249	176.71774	1827	22.54312	176.71684	contact with dark coloured sediment bottom
03:32:06	22.54243	176.71774	1827	22.54334	176.71658	black and greyish material
03:32:32	22.54234	176.71774	1829	22.54319	176.71685	black sand with ripples
03:33:13	22.54220	176.71773	1831	22.54306	176.71633	white clasts in rippled, dark sand
03:33:37	22.54213	176.71772	1832	22.54363	176.71669	recent debris on top of ripples
03:34:33	22.54198	176.71770	1831	22.54326	176.71716	scarp, hard outcrop
03:34:55	22.54192	176.71767	1830	22.54294	176.71677	gorgonians
03:35:04	22.54190	176.71766	1831	22.54312	176.71652	rippled sand
03:35:21	22.54185	176.71764	1833	22.54254	176.71695	rocky topography
03:35:46	22.54180	176.71760	1833	22.54298	176.71644	sediment at the basin of a scarp, DV on
03:36:01	22.54177	176.71758	1835	22.54302	176.71670	increasing biogeneous debris
03:36:50	22.54167	176.71750	1833	22.54275	176.71693	DV off 1 min
03:37:14	22.54163	176.71748	1829	22.54269	176.71701	DV on
03:37:27	22.54160	176.71747	1826	22.54192	176.71698	black rippled sand, scattered biogeneous material
03:38:09	22.54149	176.71745	1824	22.54247	176.71721	DV off 2 min
03:38:30	22.54144	176.71746	1821	22.54155	176.71727	ripples
03:38:53	22.54139	176.71747	1821	22.54276	176.71667	ripples with several directions on dark sand
03:40:28	22.54120	176.71744	1816	22.54244	176.71646	mottled dark sediment
03:40:49	22.54116	176.71743	1815	22.54217	176.71661	aristeid prawn
03:41:10	22.54112	176.71740	1814	22.54183	176.71650	still rippled dark sediment
03:41:57	22.54104	176.71733	1813	22.54154	176.71644	no ripples
03:42:11	22.54102	176.71731	1813	22.54173	176.71685	volcaniclastic outcrop with sediment
03:42:37	22.54097	176.71727	1810	22.54158	176.71691	scoria-pebbles?
03:42:54	22.54093	176.71723	1809	22.54206	176.71705	gorgonian
03:43:01	22.54092	176.71723	1807	22.54206	176.71705	shells
03:43:09	22.54091	176.71721	1807	22.54206	176.71705	volcanic debris partially buried by sandy sediment, fish
03:43:53	22.54082	176.71713	1807	22.53960	176.71713	hydrothermal, reddish and whitish material
03:44:21	22.54076	176.71710	1804	22.53758	176.71755	contact with sandy material
03:44:36	22.54073	176.71709	1805	22.53758	176.71755	hydrothermal mound
03:44:49	22.54070	176.71709	1805	22.53758	176.71755	structural lineations
03:45:06	22.54066	176.71709	1806	22.53758	176.71755	fissures? sponge?
03:45:42	22.54059	176.71709	1812	22.53758	176.71755	dark sandy sediment on the slope, gorgonian
03:46:03	22.54054	176.71707	1813	22.53758	176.71755	shells
03:46:09	22.54054	176.71709	1813	22.53758	176.71755	outcrop -> hydrothermal, chimneys
03:46:31	22.54049	176.71707	1812	22.53758	176.71755	no temperature increase
03:47:04	22.54043	176.71706	1807	22.53758	176.71755	black sediment again
03:47:20	22.54040	176.71705	1807	22.53880	176.71701	hydrothermal yellowish-red deposits
03:47:51	22.54035	176.71702	1805	22.54048	176.71656	grey sedimented bottom
03:48:16	22.54031	176.71700	1805	22.54092	176.71656	shells
03:48:34	22.54028	176.71700	1805	22.54084	176.71668	dark sediment
03:48:45	22.54025	176.71698	1806	22.54112	176.71634	ripples
03:48:58	22.54022	176.71697	1807	22.54085	176.71642	crossing ripples on sandy sediment
03:49:17	22.54018	176.71696	1808	22.54058	176.71681	brownish-red deposits, chimney, DV on
03:49:44	22.54012	176.71695	1806	22.54045	176.71642	fish
03:50:09	22.54006	176.71696	1800	22.54077	176.71628	DV off 1 min
03:50:37	22.53998	176.71697	1806	22.54077	176.71628	fish

Station 59 OFOS; commenced 25-10-02; page 3 of 6						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
03:50:41	22.53997	176.71697	1808	22.54077	176.71628	rippled mottled grey sediment
03:51:19	22.53986	176.71700	1806	22.54081	176.71612	crinoid
03:51:32	22.53982	176.71701	1805	22.54060	176.71660	rippled sediment, black, gorgonian, shell
03:52:24	22.53968	176.71704	1806	22.54022	176.71621	change slope, rippled black sediment
03:52:46	22.53963	176.71704	1809	22.54018	176.71650	debris in sediment
03:53:22	22.53955	176.71704	1808	22.54018	176.71645	contact rippled black sediment, debris
03:53:50	22.53949	176.71703	1808	22.54015	176.71639	again rippled black sediment
03:54:18	22.53943	176.71701	1807	22.54044	176.71622	debris in black sediment
03:54:57	22.53936	176.71696	1803	22.54030	176.71629	sulfide talus, chimney
03:55:55	22.53926	176.71688	1801	22.54049	176.71600	changes slope, black rippled sediment
03:56:18	22.53922	176.71685	1800	22.53990	176.71666	chimney was at the edge of a structure
03:56:46	22.53915	176.71681	1800	22.53985	176.71597	grey mottled sediment, ripple
03:57:31	22.53902	176.71678	1801	22.54011	176.71607	debris in sediment
03:57:43	22.53898	176.71677	1799	22.53989	176.71601	rippled black sediment
03:57:56	22.53893	176.71677	1798	22.53935	176.71660	black sediment ripples, sulfide crust and debris
03:58:19	22.53885	176.71677	1797	22.53967	176.71624	tube outcrop
03:58:44	22.53876	176.71677	1795	22.53923	176.71649	temperature starts to increase
03:58:57	22.53870	176.71678	1795	22.53975	176.71591	black sediment
03:59:32	22.53857	176.71679	1794	22.53952	176.71565	grey sand with black pebbels
04:00:03	22.53846	176.71680	1794	22.53990	176.71595	black rippled sand
04:00:17	22.53841	176.71680	1793	22.53908	176.71638	native sulfur along fractures?
04:00:34	22.53835	176.71680	1792	22.53961	176.71585	DV off 2 min
04:01:14	22.53822	176.71680	1790	22.54029	176.71590	crust of sulfide
04:01:38	22.53815	176.71679	1784	22.54029	176.71590	changes slope, dropping several metres
04:02:48	22.53796	176.71676	1793	22.53956	176.71591	7 m to base, grey sediment at base
04:03:10	22.53792	176.71675	1793	22.53928	176.71545	temperature increases a little bit
04:03:26	22.53787	176.71672	1794	22.53902	176.71625	dropping again
04:03:37	22.53785	176.71670	1798	22.53894	176.71616	rippled sediment
04:05:31	22.53764	176.71652	1801	22.53875	176.71597	technical problems
04:05:56	22.53761	176.71646	1804	22.53729	176.71541	gorgonian, rippled sediment
04:06:12	22.53758	176.71644	1804	22.53623	176.71582	sulfides, chimney??
04:06:28	22.53757	176.71640	1802	22.53623	176.71582	chimney
04:06:42	22.53755	176.71638	1804	22.53623	176.71582	chimney
04:09:24	22.53716	176.71615	1796	22.53798	176.71586	pebbly sediment
04:09:53	22.53708	176.71616	1792	22.53797	176.71592	ripples
04:10:50	22.53688	176.71617	1792	22.53770	176.71608	dark sediment
04:11:05	22.53683	176.71619	1792	22.53790	176.71515	ripple
04:11:27	22.53673	176.71620	1792	22.53809	176.71572	some detritus on black rippled sand
04:12:07	22.53660	176.71619	1794	22.53779	176.71579	chimney, covered by black rippled sand (partially)
04:13:01	22.53647	176.71616	1798	22.53781	176.71565	grey sediment
04:13:30	22.53640	176.71613	1803	22.53781	176.71565	black and grey sand, rippled
04:14:03	22.53634	176.71609	1805	22.53809	176.71473	rippled sand, yellowish white
04:14:24	22.53630	176.71606	1802	22.53775	176.71473	scarp
04:14:42	22.53627	176.71602	1799	22.53800	176.71518	sediment > 40 cm high layer
04:15:10	22.53623	176.71598	1801	22.53750	176.71547	scarp, dropping
04:15:23	22.53620	176.71595	1807	22.53805	176.71546	base of scarp grey sediment of detritus
04:16:15	22.53611	176.71585	1816	22.53774	176.71563	shell
04:17:23	22.53596	176.71573	1823	22.53686	176.71533	mottled grey-black sediment, ripples
04:18:18	22.53582	176.71563	1820	22.53663	176.71548	chimney
04:18:33	22.53579	176.71561	1817	22.53701	176.71488	temperature rises a bit
04:19:04	22.53572	176.71557	1819	22.53631	176.71559	lava outcrop
04:19:20	22.53568	176.71554	1818	22.53668	176.71555	debris
04:19:25	22.53567	176.71554	1816	22.53639	176.71545	gorgonians
04:19:31	22.53566	176.71553	1816	22.53639	176.71545	DV off 1min
04:19:44	22.53563	176.71551	1815	22.53644	176.71532	shells
04:19:53	22.53561	176.71551	1814	22.53648	176.71527	sediment
04:20:13	22.53557	176.71549	1813	22.53650	176.71485	sulfide talus
04:20:45	22.53551	176.71546	1808	22.53606	176.71555	dark sand
04:21:02	22.53547	176.71544	1805	22.53633	176.71527	ripples
04:21:34	22.53542	176.71542	1809	22.53607	176.71512	light patches
04:21:55	22.53538	176.71540	1810	22.53615	176.71538	temperature anomaly 0.08 °C
04:22:16	22.53534	176.71538	1809	22.53607	176.71500	grey sediment with black pebbles, ripples
04:22:52	22.53528	176.71536	1810	22.53591	176.71515	detritus-sulfides, DV on
04:23:06	22.53525	176.71535	1810	22.53571	176.71527	hydrothermal sediment
04:23:57	22.53516	176.71531	1812	22.53602	176.71526	shrimp
04:24:20	22.53511	176.71529	1819	22.53586	176.71508	DV off 1 min
04:24:48	22.53507	176.71527	1819	22.53568	176.71519	shells
04:24:55	22.53506	176.71527	1820	22.53568	176.71519	fissure, hard outcrop
04:25:27	22.53500	176.71523	1821	22.53472	176.71547	altered volcanics
04:25:41	22.53498	176.71523	1821	22.53472	176.71547	hydrothermal? crusts
04:25:54	22.53495	176.71523	1821	22.53472	176.71547	ripples on sand

Station 59 OFOS; commenced 25-10-02; page 4 of 6						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
04:26:33	22.53487	176.71523	1820	22.53367	176.71516	chimney?
04:26:43	22.53485	176.71524	1821	22.53367	176.71516	thick ripples
04:27:27	22.53470	176.71524	1820	22.53360	176.71545	solid outcrop
04:27:42	22.53467	176.71526	1819	22.53369	176.71495	small fan-like gorgonians
04:27:57	22.53461	176.71526	1819	22.53369	176.71495	gorgonians
04:28:30	22.53452	176.71529	1817	22.53500	176.71494	euplectellid sponge
04:28:57	22.53443	176.71530	1819	22.53566	176.71487	silica
04:29:27	22.53433	176.71531	1821	22.53532	176.71452	chimneys
04:29:38	22.53430	176.71532	1823	22.53540	176.71459	sulfide debris partially sedimented
04:29:55	22.53424	176.71532	1823	22.53533	176.71476	silica alteration, yellowish native sulfur?
04:30:23	22.53414	176.71534	1818	22.53513	176.71447	rippled sediment
04:30:46	22.53406	176.71534	1825	22.53498	176.71474	contact between white pebbly sand and black rippled sand
04:31:19	22.53395	176.71536	1826	22.53508	176.71410	rippled black sand
04:31:44	22.53388	176.71536	1828	22.53546	176.71395	gorgonian
04:31:51	22.53385	176.71536	1827	22.53546	176.71395	gorgonian
04:32:02	22.53382	176.71536	1829	22.53464	176.71443	antipatharian
04:32:19	22.53377	176.71536	1831	22.53479	176.71455	hydrothermal altered rocks
04:32:31	22.53374	176.71535	1833	22.53488	176.71455	sulfur on top?
04:32:41	22.53372	176.71536	1834	22.53432	176.71481	hydrothermal debris on sediment
04:33:17	22.53363	176.71533	1833	22.53506	176.71423	gorgonian
04:33:28	22.53361	176.71532	1834	22.53476	176.71437	dark rippled sand
04:34:07	22.53352	176.71528	1838	22.53450	176.71459	ditto
04:34:26	22.53348	176.71525	1841	22.53512	176.71407	grey mottled sediment
04:34:54	22.53343	176.71521	1842	22.53512	176.71407	ripples
04:35:10	22.53341	176.71520	1844	22.53512	176.71407	shells
04:35:28	22.53339	176.71516	1847	22.53292	176.71390	debris
04:35:36	22.53337	176.71514	1847	22.53224	176.71431	hydrothermal altered outcrop
04:35:50	22.53336	176.71512	1848	22.53443	176.71411	rippled sediment
04:36:08	22.53333	176.71508	1851	22.53399	176.71441	small chimney and debris
04:36:29	22.53331	176.71504	1851	22.53365	176.71490	shrimp, gorgonian
04:36:51	22.53329	176.71499	1855	22.53402	176.71457	shells
04:37:03	22.53328	176.71496	1851	22.53433	176.71463	coarser debris
04:37:25	22.53327	176.71492	1854	22.53433	176.71463	still shells
04:37:45	22.53326	176.71487	1857	22.53433	176.71463	yellowish alteration, small hydrothermal ridges
04:38:10	22.53326	176.71482	1858	22.53218	176.71379	debris on rippled sediment
04:38:24	22.53326	176.71479	1859	22.53412	176.71430	dark sediment
04:39:05	22.53319	176.71470	1856	22.53386	176.71453	rippled black sediment
04:39:30	22.53314	176.71467	1856	22.53338	176.71469	debris on rippled sediment, pebbly
04:40:20	22.53303	176.71460	1857	22.53278	176.71488	ditto
04:41:25	22.53289	176.71456	1855	22.53165	176.71463	changes slope, dropping
04:41:48	22.53283	176.71455	1858	22.53169	176.71461	debris on darker sediment
04:42:46	22.53271	176.71452	1857	22.53310	176.71444	grey mottled sediment
04:43:19	22.53264	176.71449	1856	22.53347	176.71384	lineation of dark sediment
04:43:38	22.53260	176.71448	1854	22.53296	176.71430	ripple marks
04:44:53	22.53244	176.71448	1849	22.53283	176.71441	dark rippled sediment
04:45:33	22.53235	176.71447	1850	22.53295	176.71427	ditto
04:46:31	22.53224	176.71441	1847	22.53296	176.71363	ditto
04:46:49	22.53222	176.71441	1847	22.53269	176.71371	grey mottled sediment
04:47:28	22.53216	176.71436	1847	22.53266	176.71396	ditto
04:48:07	22.53210	176.71432	1849	22.53253	176.71402	lava outcrop, antipatharian
04:48:31	22.53205	176.71429	1848	22.53253	176.71402	scoria like outcrop, hydrothermal / volcanic?
04:49:00	22.53199	176.71427	1850	22.53244	176.71424	fissure before outcrop
04:49:44	22.53189	176.71426	1854	22.53189	176.71397	change of OFOS-track heading to the east, towards Hine Hina to get an east-west-traverse
04:50:32	22.53182	176.71429	1850	22.53176	176.71394	talus of volcanic material from 40 cm to several cm
04:51:06	22.53180	176.71434	1848	22.53163	176.71441	brittle star
04:51:37	22.53180	176.71438	1846	22.53138	176.71443	grey mottled sediment
04:51:50	22.53181	176.71440	1845	22.53182	176.71449	scarp with gorgonian
04:52:18	22.53182	176.71444	1846	22.53167	176.71411	still scarp
04:52:43	22.53184	176.71450	1849	22.53158	176.71416	still scarp
04:54:17	22.53193	176.71482	1864	22.53132	176.71474	scarp ca 11 m, at bottom: grey sediment covering debris
04:54:50	22.53196	176.71490	1867	22.53114	176.71429	grey mottled sediment
04:55:03	22.53197	176.71494	1868	22.53142	176.71439	block?
04:55:27	22.53199	176.71499	1869	22.53128	176.71416	black rippled sediment
04:55:46	22.53200	176.71504	1871	22.53086	176.71440	contact between grey mottled and black rippled sediment
04:56:28	22.53204	176.71513	1870	22.53112	176.71411	rippled sediment
04:57:00	22.53206	176.71521	1870	22.53112	176.71411	large block
04:57:23	22.53207	176.71526	1870	22.53095	176.71416	black rippled sediment alternating with grey mottled sediment
04:58:25	22.53212	176.71543	1866	22.53095	176.71469	gorgonian, chimney?
04:59:08	22.53217	176.71553	1867	22.53075	176.71494	more rubble

Station 59 OFOS; commenced 25-10-02; page 5 of 6						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
04:59:41	22.53219	176.71561	1866	22.53069	176.71480	dark rippled sediment
05:00:05	22.53221	176.71566	1866	22.53128	176.71456	gorgonians on a block
05:00:48	22.53224	176.71574	1867	22.53117	176.71453	debris
05:01:32	22.53227	176.71579	1868	22.53088	176.71488	grey motteld and black rippled sediment
05:02:03	22.53228	176.71583	1869	22.53099	176.71476	grey mottled sediment
05:02:37	22.53231	176.71586	1870	22.53134	176.71544	ditto
05:03:10	22.53232	176.71588	1869	22.53114	176.71501	ditto
05:03:34	22.53234	176.71590	1870	22.53103	176.71488	grey mottled sediment, some debris
05:03:48	22.53234	176.71591	1869	22.53114	176.71500	more debris
05:04:01	22.53235	176.71591	1869	22.53118	176.71497	gorgonian
05:04:38	22.53237	176.71593	1868	22.53101	176.71489	grey mottled, rippled sediment
05:05:28	22.53241	176.71597	1871	22.53111	176.71556	grey mottled sediment
05:06:32	22.53248	176.71604	1869	22.53232	176.71685	ditto
05:07:50	22.53261	176.71616	1871	22.53063	176.71802	black rippled sediment
05:08:30	22.53269	176.71622	1874	22.53126	176.71572	euplectellid sponge, gorgonian
05:08:58	22.53274	176.71627	1876	22.53114	176.71571	gorgonians
05:09:19	22.53277	176.71631	1878	22.53179	176.71601	lava outcrop in sediment
05:11:08	22.53292	176.71656	1885	22.53146	176.71610	grey sediment with rubble on surface
05:11:53	22.53297	176.71663	1890	22.53114	176.71607	grey mottled sediment
05:12:50	22.53302	176.71673	1895	22.53152	176.71576	can?
05:13:35	22.53306	176.71690	1898	22.53148	176.71635	grey mottled sediment
05:14:08	22.53310	176.71700	1903	22.53167	176.71601	ditto
05:14:42	22.53315	176.71710	1903	22.53175	176.71605	ditto
05:15:49	22.53322	176.71728	1906	22.53048	176.71828	ditto
05:16:30	22.53326	176.71735	1907	22.53167	176.71576	ditto
05:18:53	22.53334	176.71751	1909	22.53222	176.71701	ditto
05:19:53	22.53340	176.71759	1909	22.53169	176.71648	animal tracks
05:20:46	22.53345	176.71770	1908	22.53188	176.71600	ditto (tracks from holoturian)
05:21:14	22.53348	176.71776	1909	22.53200	176.71709	grey mottled sediment
05:21:36	22.53350	176.71781	1908	22.53202	176.71696	debris (blocks up to 40 cm) on grey mottled sediment
05:22:10	22.53355	176.71789	1909	22.53236	176.71688	gorgonian
05:22:28	22.53356	176.71790	1907	22.53229	176.71678	volcanic debris on sediment
05:22:46	22.53357	176.71791	1908	22.53208	176.71660	aristeid prawn
05:23:31	22.53362	176.71798	1904	22.53188	176.71758	ditto
05:24:22	22.53368	176.71803	1905	22.53224	176.71712	grey mottled sediment, no debris
05:25:19	22.53374	176.71807	1904	22.53200	176.71768	volcanic debris
05:25:32	22.53376	176.71807	1903	22.53232	176.71740	DV on
05:25:58	22.53378	176.71807	1902	22.53234	176.71780	volcanic debris could be talus
05:26:46	22.53383	176.71804	1903	22.53242	176.71759	still volcanic debris
05:27:03	22.53385	176.71802	1904	22.53218	176.71765	mottled sediment, minor debris
05:27:20	22.53387	176.71800	1902	22.53196	176.71763	volc. debris could be scoria-pyroclastic
05:29:02	22.53395	176.71789	1904	22.53275	176.71748	grey mottled sediment
05:30:36	22.53403	176.71784	1906	22.53246	176.71767	gorgonian
05:30:46	22.53403	176.71783	1905	22.53246	176.71767	scarp
05:31:18	22.53405	176.71780	1905	22.53248	176.71756	pyroclastic material or lava outcrop?
05:31:45	22.53407	176.71777	1906	22.53292	176.71762	volcaniclastic material exposed at a small scarp, could be talus, possible pyroclastic
05:32:46	22.53410	176.71772	1908	22.53262	176.71710	grey mottled sediment and black rippled sediment
05:33:28	22.53413	176.71768	1907	22.53290	176.71744	shells
05:33:37	22.53413	176.71768	1908	22.53274	176.71741	DV off 8 min
05:34:41	22.53416	176.71763	1906	22.53289	176.71744	grey mottled sediment
05:35:28	22.53418	176.71760	1905	22.53278	176.71748	ditto
05:35:36	22.53418	176.71759	1905	22.53278	176.71748	going southeastward
05:37:01	22.53420	176.71755	1902	22.53427	176.71839	volcanic debris (scoria?) on grey mottled sediment
05:38:17	22.53423	176.71751	1900	22.53427	176.71839	ditto
05:39:01	22.53427	176.71749	1897	22.53427	176.71839	contact between grey mottled sediment and volcanic debris
05:39:19	22.53427	176.71748	1898	22.53241	176.71844	10 cm blocks, possible scoria, covered by grey mottled sediment
05:40:05	22.53431	176.71744	1896	22.53327	176.71746	volcanic debris as before (scoria)
05:41:03	22.53435	176.71739	1892	22.53292	176.71731	volcanic debris on sediment
05:41:25	22.53437	176.71737	1890	22.53290	176.71689	coarse volcanic debris on scarp
05:41:50	22.53439	176.71735	1886	22.53320	176.71720	volcanic debris covered by thin (dm thick) sediment
05:42:33	22.53443	176.71732	1884	22.53314	176.71711	minor volcanic debris on sediment
05:43:07	22.53446	176.71729	1883	22.53276	176.71723	ripples
05:43:26	22.53448	176.71727	1883	22.53312	176.71718	gorgonian
05:43:43	22.53450	176.71726	1882	22.53314	176.71718	grey mottled sediment, local ripples, defined by black material
05:45:41	22.53459	176.71717	1878	22.53317	176.71711	finer grey sand
05:46:58	22.53465	176.71713	1876	22.53323	176.71700	grey sand
05:47:48	22.53468	176.71709	1875	22.53363	176.71703	ditto
05:48:15	22.53469	176.71708	1873	22.53324	176.71669	going northward

Station 59 OFOS; commenced 25-10-02; page 6 of 6						
Time (UTC)	**Ship Lat. (°S)**	**Ship Long. (°W)**	**Cable (m)**	**Sub Lat. (°S)**	**Sub Long. (°W)**	**Comment**
05:49:22	22.53467	176.71707	1872	22.53337	176.71638	grey mottled sediment
05:50:48	22.53454	176.71718	1867	22.53398	176.71645	ditto
05:52:20	22.53437	176.71723	1865	22.53405	176.71652	changes slope
05:53:18	22.53428	176.71722	1868	22.53390	176.71766	ditto
05:56:37	22.53403	176.71720	1873	22.53235	176.71730	grey mottled sediment
05:57:46	22.53396	176.71719	1879	22.53353	176.71678	ditto
05:58:30	22.53391	176.71718	1878	22.53332	176.71651	ditto
06:00:59	22.53379	176.71721	1886	22.53315	176.71713	DV on
06:01:46	22.53376	176.71728	1889	22.53311	176.71687	ditto
06:03:18	22.53371	176.71745	1890	22.53305	176.71674	black sand with ripples
06:04:31	22.53368	176.71751	1890	22.53324	176.71678	DV off 4 min
06:05:05	22.53367	176.71751	1861	22.53305	176.71703	start heaving until 1850 m, than going west into deeper water, because of problems with the winch
06:58:37	22.53328	176.72348	2071	22.53258	176.72230	bottom within view
06:59:07	22.53327	176.72344	2067	22.53247	176.72271	heaving a little bit
07:03:17	22.53328	176.72361	2019	22.53190	176.72307	get down again
07:17:00						start heaving
08:14:00						OFOS on deck, end of station

Station 60 GTV-A; commenced 25-10-02; page 1 of 2						
Time (UTC)	**Ship Lat. (°S)**	**Ship Long. (°W)**	**Cable (m)**	**Sub Lat. (°S)**	**Sub Long. (°W)**	**Comment**
09:02:22	22.54157	176.71511	9988	22.53144	176.72173	GTV into water, beginning of station 60 GTV-A
09:36:46	22.54124	176.71620	1595	22.53819	176.71229	1600 m cable length
09:43:12	22.54127	176.71619	1599	22.53991	176.71189	technical problems with the winch driver monitor
09:48:49	22.54144	176.71652	1756	22.53373	176.69765	tapes on
09:50:29	22.54138	176.71660	1807	22.53800	176.70159	bottom view
09:51:12	22.54137	176.71661	1812	22.53800	176.70159	technical problem with coloured monitor
09:51:49	22.54133	176.71662	1810	22.53800	176.70159	grey and black mottled sediment with ripples
09:52:27	22.54129	176.71663	1810	22.53800	176.70159	fractured crust?
09:53:00	22.54125	176.71663	1810	22.53800	176.70159	Comments lost
09:53:19	22.54124	176.71663	1812	22.53800	176.70159	try to grab
09:53:27	22.54123	176.71663	1816	22.53800	176.70159	cable length 1822 m
09:54:46	22.54117	176.71659	1815	22.53800	176.70159	start heaving
09:58:11	22.54102	176.71645	1797	22.54130	176.71140	grab didn't close completely, opened it again
09:58:48	22.54102	176.71642	1807	22.54130	176.71140	bottom view
10:00:05	22.54104	176.71640	1805	22.54130	176.71140	loose material, rubble and smaller-sized sediment
10:00:50	22.54109	176.71636	1804	22.54130	176.71140	brittle star
10:02:33	22.54113	176.71636	1804	22.54130	176.71140	ditto
10:05:38	22.54108	176.71655	1804	22.54130	176.71140	sedimented bottom (grey)
10:05:53	22.54108	176.71657	1805	22.54130	176.71140	looks like crusty material
10:06:44	22.54113	176.71663	1808	22.54130	176.71140	dark sediment with slumped debris
10:07:17	22.54117	176.71665	1811	22.54130	176.71140	flat fragments-> from a crust
10:07:46	22.54120	176.71667	1812	22.54130	176.71140	black rippled sand
10:08:50	22.54124	176.71665	1814	22.54130	176.71140	sedimented surface, not very thick
10:09:17	22.54123	176.71663	1815	22.54130	176.71140	sandy sediment
10:09:28	22.54123	176.71662	1815	22.54130	176.71140	grey mottled sediment
10:10:58	22.54117	176.71656	1816	22.54130	176.71140	rippled grey and black sediment
10:13:19	22.54105	176.71663	1813	22.54005	176.70409	ditto
10:14:24	22.54102	176.71668	1813	22.54005	176.70409	ditto
10:16:34	22.54097	176.71659	1810	22.54079	176.71268	ditto
10:18:13	22.54092	176.71665	1810	22.53975	176.70898	grey mottled sediment
10:18:38	22.54091	176.71666	1811	22.53975	176.70898	alternating with darker sediment
10:19:11	22.54089	176.71667	1810	22.53975	176.70898	big block->lava?
10:19:34	22.54089	176.71666	1810	22.53975	176.70898	small scarp
10:20:24	22.54087	176.71664	1808	22.53975	176.70898	antipatharian
10:21:17	22.54087	176.71662	1808	22.53975	176.70898	again grey mottled sediment alternating with black rippled sediment
10:23:13	22.54084	176.71667	1808	22.53287	176.67639	ditto
10:25:18	22.54079	176.71676	1809	22.53287	176.67639	ditto
10:25:48	22.54075	176.71673	1810	22.53287	176.67639	sediment with debris
10:27:40	22.54068	176.71665	1807	22.53287	176.67639	more debris on grey mottled sediment
10:29:08	22.54064	176.71665	1803	22.53287	176.67639	angular fragments, blocky material in sediment
10:30:42	22.54065	176.71665	1799	22.53287	176.67639	debris on sediment
10:31:50	22.54065	176.71664	1800	22.52350	176.66510	grey and black sediment with debris
10:33:02	22.54062	176.71662	1800	22.52350	176.66510	chimney
10:33:24	22.54061	176.71662	1803	22.52350	176.66510	try to grab -> fall over

Station 60 GTV-A; commenced 25-10-02; page 2 of 2

Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
10:33:45	22.54060	176.71663	1807	22.52350	176.66510	maybe outcrop and no chimney?
10:34:07	22.54058	176.71663	1808	22.54019	176.71646	grab was empty
10:36:38	22.54041	176.71668	1793	22.53934	176.71599	bottom view
10:37:46	22.54037	176.71670	1796	22.53930	176.71674	fractured hard material
10:38:12	22.54036	176.71667	1796	22.53949	176.71592	looks like crust, no reddish colour
10:39:40	22.54031	176.71650	1798	22.53958	176.71820	rippled sediment
10:40:15	22.54029	176.71648	1798	22.53958	176.71820	black rippled sediment
10:40:40	22.54030	176.71648	1798	22.53958	176.71820	coarser material
10:41:05	22.54030	176.71650	1797	22.53958	176.71820	crusts?
10:42:09	22.54031	176.71649	1796	22.53907	176.71608	black sediment on a smooth surface
10:43:30	22.54033	176.71648	1797	22.53889	176.71608	dark sandy sediment
10:45:28	22.54033	176.71642	1797	22.53958	176.71793	grey mottled and black rippled sediment
10:46:13	22.54032	176.71640	1798	22.53917	176.71707	black rippled sediment
10:47:49	22.54021	176.71625	1797	22.53967	176.71601	ditto
10:49:44	22.54001	176.71604	1794	22.53883	176.71536	still grey and black sediment
10:51:50	22.53990	176.71595	1797	22.53959	176.71612	try to grab
10:51:57	22.53989	176.71594	1802	22.53959	176.71612	hydrothermal sediment?
10:53:38	22.53987	176.71595	1813	22.53807	176.71813	start heaving
10:54:47	22.53987	176.71602	1792	22.53807	176.71813	sampled something
10:55:22	22.53988	176.71606	1779	22.53860	176.71459	grabed hydrothermal sediment with some debris?
11:14:57	22.53958	176.71591	861	22.53908	176.71582	tapes off
11:32:53	22.53964	176.71595	9990	22.53941	176.71571	GTV with sample on deck, end of station

Station 65 GTV-A; commenced 25-10-02; page 1 of 2

Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
20:04:06	22.54136	176.71484	0	22.53941	176.71571	begin of station 65 GTV-A
20:04:45	22.54135	176.71484	7	22.53941	176.71571	GTV in water
20:39:46	22.54190	176.71471	1600	22.54117	176.71585	no Black&White video
20:40:23	22.54192	176.71469	1618	22.54117	176.71567	1623 m cable length
20:44:36	22.54172	176.71458	1840	22.54171	176.71556	colour tape on
20:45:21	22.54165	176.71455	1864	22.54134	176.71581	bottom within view
20:45:47	22.54161	176.71454	1872	22.54186	176.71566	grey mottled sediment
20:47:24	22.54148	176.71447	1871	22.54142	176.71591	aristeid prawn
20:47:53	22.54144	176.71445	1871	22.54142	176.71591	more debris
20:48:31	22.54140	176.71442	1870	22.54142	176.71591	some scoria on top of the sediment, shells
20:49:40	22.54132	176.71436	1868	22.54142	176.71591	grey mottled sediment
20:50:21	22.54127	176.71434	1866	22.54142	176.71591	scoria on surface of sediment
20:51:58	22.54113	176.71437	1864	22.54142	176.71591	block, smaller debris, Sediment
20:53:17	22.54103	176.71443	1857	22.54142	176.71591	blocky debris covered by sediment
20:54:58	22.54096	176.71448	1848	22.54185	176.71531	volcanic? debris and sediment
20:56:45	22.54099	176.71449	1842	22.54151	176.71705	grey mottled sediment
20:57:52	22.54102	176.71449	1841	22.53708	176.71789	loose volcanic sand with debris
21:01:25	22.54083	176.71453	1836	22.54133	176.71763	big blocks
21:01:56	22.54078	176.71453	1834	22.54217	176.71622	volcanic outcrop partially buried by sand
21:03:20	22.54064	176.71453	1834	22.54177	176.71618	ditto
21:04:02	22.54058	176.71453	1834	22.54202	176.71549	volcanic debris on and covered by sediment
21:04:34	22.54054	176.71452	1835	22.54202	176.71549	sediment = volcanic sand
21:05:23	22.54052	176.71449	1835	22.54202	176.71549	brocken tubes?
21:06:42	22.54048	176.71446	1835	22.54018	176.71578	block -> part of a tube?
21:07:05	22.54047	176.71446	1835	22.54084	176.71579	euplectellid sponge
21:07:37	22.54045	176.71446	1834	22.54107	176.71486	rounded volcanic talus blocks
21:08:22	22.54041	176.71446	1833	22.54158	176.71600	fresh talus, no sediment cover
21:09:19	22.54034	176.71448	1835	22.54127	176.71540	ditto
21:10:55	22.54020	176.71451	1837	22.54127	176.71540	ditto
21:12:50	22.54009	176.71456	1835	22.54122	176.71556	ditto
21:14:47	22.54010	176.71463	1833	22.54109	176.71606	ditto
21:15:32	22.54010	176.71466	1833	22.53995	176.71571	debris formed by autobrecciation?
21:16:30	22.54009	176.71470	1831	22.54043	176.71481	scarp?
21:17:02	22.54008	176.71472	1829	22.54032	176.71512	gorgonians
21:17:54	22.54006	176.71475	1829	22.54032	176.71512	big blocks and small debris -> volcanic material
21:19:04	22.54004	176.71479	1827	22.54029	176.71590	debris partially buried by sandy material
21:20:28	22.53998	176.71484	1820	22.54220	176.71545	debris or volcanic outcrop buried by sediment
21:21:15	22.53994	176.71485	1820	22.54220	176.71545	looks like volcanic tubes
21:21:44	22.53991	176.71485	1819	22.54220	176.71545	tubular flow?
21:22:44	22.53986	176.71484	1819	22.54031	176.71598	still rocky blocks
21:23:02	22.53984	176.71483	1820	22.53991	176.71625	brownish material

Station 65 GTV-A; commenced 25-10-02; page 2 of 2						
Time	**Ship**		**Cable**	**Sub**		**Comment**
(UTC)	**Lat. (°S)**	**Long. (°W)**	**(m)**	**Lat. (°S)**	**Long. (°W)**	
21:23:19	22.53983	176.71483	1819	22.53980	176.71612	grey mottled sediment
21:25:04	22.53974	176.71481	1817	22.54015	176.71610	brittle star
21:25:53	22.53968	176.71479	1818	22.54015	176.71610	grey mottled sediment
21:28:46	22.53951	176.71478	1822	22.54080	176.71567	increasing biogeneous material
21:30:27	22.53946	176.71475	1823	22.53931	176.71611	ditto
21:32:26	22.53942	176.71475	1822	22.53966	176.71605	black patches on grey mottled sediment
21:35:47	22.53939	176.71490	1819	22.53925	176.71778	grey mottled sediment
21:37:33	22.53936	176.71496	1815	22.53935	176.71582	debris on grey mottled sediment
21:39:00	22.53936	176.71501	1811	22.53893	176.71775	volcanic outcrop
21:39:24	22.53935	176.71502	1809	22.54018	176.71577	massive tubular? flow
21:40:52	22.53935	176.71508	1805	22.53850	176.71651	gorgonians, shells
21:41:21	22.53934	176.71509	1804	22.53850	176.71651	volcanic talus and debris
21:42:00	22.53934	176.71511	1803	22.53850	176.71651	much debris
21:44:16	22.53935	176.71517	1797	22.53850	176.71651	grey mottled sediment
21:45:34	22.53936	176.71522	1797	22.53917	176.71594	ditto
21:48:02	22.53932	176.71531	1794	22.53917	176.71594	ditto
21:50:16	22.53918	176.71539	1793	22.53917	176.71594	more debris
21:51:04	22.53911	176.71541	1790	22.53917	176.71594	crust?
21:51:41	22.53906	176.71542	1791	22.53917	176.71594	debris on sediment
21:52:09	22.53903	176.71545	1791	22.53951	176.71638	gorgonian
21:52:38	22.53901	176.71545	1792	22.53951	176.71638	rippled grey mottled sediment
21:54:06	22.53898	176.71551	1791	22.54062	176.71913	crust
21:54:13	22.53898	176.71552	1791	22.54062	176.71913	very smooth surface, reddish brown colours
21:55:21	22.53901	176.71557	1795	22.54145	176.71797	tried to grab
21:55:37	22.53902	176.71558	1788	22.54145	176.71797	already went over?
21:55:51	22.53902	176.71560	1782	22.54145	176.71797	fall over
21:56:38	22.53905	176.71564	1783	22.54145	176.71797	stoped grabing
21:57:05	22.53906	176.71568	1789	22.54145	176.71797	still crust
21:57:58	22.53910	176.71572	1788	22.53853	176.71660	still hydrothermal crust with orange colours at cracks
21:59:49	22.53901	176.71584	1788	22.53813	176.71714	black sand
22:00:25	22.53895	176.71589	1787	22.53813	176.71714	still crust, partially covered by sand
22:00:57	22.53888	176.71593	1788	22.53813	176.71714	hydrothermal crust
22:01:24	22.53882	176.71595	1801	22.53922	176.71594	tried to grab
22:01:46	22.53876	176.71597	1796	22.53922	176.71594	same material as yesterday
22:01:56	22.53873	176.71598	1791	22.53922	176.71594	stoped to grab
22:02:52	22.53856	176.71602	1793	22.53922	176.71594	sand and debris from the crust -> angular, platy
22:03:35	22.53843	176.71605	1790	22.53922	176.71594	black sand and brocken crust
22:04:08	22.53839	176.71604	1789	22.54555	176.71610	silica
22:04:12	22.53838	176.71604	1789	22.54555	176.71610	fractured crust
22:04:38	22.53835	176.71605	1790	22.54555	176.71610	Munidpopsis
22:04:50	22.53833	176.71605	1792	22.54555	176.71610	black sand and hydrothermal crust debris
22:05:35	22.53825	176.71605	1791	22.54555	176.71610	crust, sometimes sand covered
22:07:39	22.53811	176.71612	1786	22.54237	176.71738	grey to black sand covering a crust?
22:09:04	22.53810	176.71619	1783	22.54377	176.71758	flat surface, hydrothermal crust covered by sediment
22:09:32	22.53809	176.71622	1781	22.54377	176.71758	silica
22:09:50	22.53807	176.71625	1779	22.54377	176.71758	try to grab
22:11:31	22.53799	176.71639	1786	22.53862	176.71678	start heaving
22:12:31	22.53792	176.71645	1776	22.53862	176.71678	get something
22:12:50	22.53790	176.71647	1773	22.53982	176.71662	start heaving
22:17:34	22.53782	176.71622	1700	22.53771	176.71729	coloured tape off
22:52:38	22.53764	176.71639	9988	22.53722	176.71676	GTV with sample on deck
22:52:48	22.53764	176.71638	9988	22.53722	176.71676	end of station

Station 66 GTV-A; commenced 25-10-02; page 1 of 3						
Time	**Ship**		**Cable**	**Sub**		**Comment**
(UTC)	**Lat. (°S)**	**Long. (°W)**	**(m)**	**Lat. (°S)**	**Long. (°W)**	
23:17:15	22.54128	176.71586	9989	22.53722	176.71676	begin of station 66 GTV-A
23:47:18	22.54104	176.71582	1600	22.54126	176.71660	1600 m cable length
23:52:08	22.54089	176.71583	1779	22.54122	176.71656	tapes on
23:52:48	22.54093	176.71581	1800	22.54088	176.71664	bottom within view
23:55:40	22.54097	176.71582	1804	22.54115	176.71643	grey mottled sediment
23:59:19	22.54073	176.71592	1806	22.54090	176.71699	ditto, some biogenous material
00:00:06	22.54065	176.71595	1805	22.54144	176.71646	pillow
00:00:43	22.54058	176.71596	1804	22.54144	176.71646	tubes
00:01:22	22.54051	176.71598	1800	22.54217	176.71640	sponge
00:01:43	22.54047	176.71599	1799	22.54172	176.71631	gorgonian
00:02:22	22.54039	176.71599	1796	22.54224	176.71635	scarp, rubble

Station 66 GTV-A; commenced 25-10-02; page 2 of 3

Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
00:03:05	22.54031	176.71600	1794	22.54149	176.71677	large tubular flow, covered with brocken up fragments
00:03:39	22.54024	176.71600	1795	22.54275	176.71611	gorgonian
00:04:05	22.54019	176.71601	1796	22.54275	176.71611	tubular flow
00:04:19	22.54016	176.71601	1797	22.54275	176.71611	sandy sediment at contact with tubular flow
00:04:39	22.54012	176.71601	1798	22.54246	176.71623	100% volcanic sand
00:04:59	22.54008	176.71601	1797	22.54246	176.71623	partially with fragments, gorgonian
00:05:31	22.54001	176.71600	1797	22.54246	176.71623	white dots
00:06:25	22.53991	176.71600	1794	22.54246	176.71623	mottled surface
00:07:00	22.53983	176.71599	1792	22.54246	176.71623	some crusts
00:07:10	22.53981	176.71599	1791	22.54246	176.71623	associated with volcanic sand
00:09:25	22.53955	176.71597	1786	22.54159	176.71620	crust with volcanic sand
00:10:50	22.53939	176.71598	1784	22.54220	176.71626	still crust
00:11:10	22.53935	176.71598	1784	22.54220	176.71626	flat surface
00:11:57	22.53925	176.71599	1787	22.54220	176.71626	ripple marks, black volcanic sand
00:12:58	22.53911	176.71600	1789	22.54220	176.71626	contact black sand/something white
00:13:40	22.53901	176.71602	1791	22.54220	176.71626	volcanic debris on top of volcanic sand
00:14:28	22.53888	176.71604	1792	22.54154	176.71629	volcanic debris on sandy surface
00:14:50	22.53884	176.71605	1791	22.53977	176.71692	slaby fragments
00:15:23	22.53877	176.71606	1790	22.53917	176.71629	hydrothermal crust
00:15:38	22.53874	176.71606	1788	22.53917	176.71629	volcanic debris, gorgonian
00:15:51	22.53872	176.71606	1787	22.53917	176.71629	antipatharian
00:16:09	22.53870	176.71607	1786	22.53917	176.71629	debris, bombs
00:16:32	22.53867	176.71608	1786	22.54344	176.71709	gorgonian
00:16:55	22.53865	176.71608	1785	22.54344	176.71709	massive volcanic outcrop
00:17:22	22.53863	176.71609	1787	22.54022	176.71686	black sand on top of volcanic outcrop
00:17:41	22.53862	176.71609	1788	22.54022	176.71686	hydrothermal crust, mixed with sand
00:18:09	22.53860	176.71610	1787	22.54022	176.71686	slabs
00:18:15	22.53859	176.71609	1787	22.54022	176.71686	crust, white patches
00:19:20	22.53856	176.71610	1789	22.53979	176.71617	hydrothermal crust associated with sandy volcanic sediment, debris
00:20:23	22.53853	176.71609	1790	22.53960	176.71693	still crust, black sand below
00:21:25	22.53850	176.71609	1790	22.53960	176.71693	crust and sand, gorgonian
00:21:54	22.53848	176.71609	1790	22.53855	176.71702	ripple marks
00:22:10	22.53847	176.71610	1789	22.53855	176.71702	sandy bottom
00:24:24	22.53833	176.71614	1784	22.53887	176.71690	black sand
00:25:56	22.53817	176.71617	1781	22.53800	176.71725	yellow and white material in black sands
00:26:38	22.53809	176.71619	1782	22.53800	176.71725	white and yellow hydrothermal deposits
00:27:14	22.53801	176.71620	1780	22.53800	176.71725	white silica
00:28:44	22.53780	176.71622	1781	22.53800	176.71725	white hydrothermal mud, yellow material, associated with black sands
00:29:22	22.53772	176.71622	1782	22.53800	176.71725	white mud on a fissure
00:30:27	22.53774	176.71614	1786	22.53800	176.71725	contact to dark material, margin of a mound
00:31:44	22.53776	176.71613	1791	22.53800	176.71725	sandy bottom with ripple marks
00:33:23	22.53773	176.71617	1793	22.53800	176.71725	black sand, ripple marks
00:34:27	22.53778	176.71619	1793	22.53800	176.71725	white staining on sandy bottom
00:36:43	22.53774	176.71622	1795	22.53800	176.71725	grey sand with ripple marks
00:37:33	22.53769	176.71621	1797	22.53808	176.71703	white sand with ripples
00:38:07	22.53769	176.71620	1796	22.53808	176.71703	scarp on the left
00:38:41	22.53769	176.71619	1795	22.53808	176.71703	pillar
00:40:40	22.53770	176.71618	1795	22.53808	176.71703	gorgonian
00:40:50	22.53770	176.71619	1795	22.53808	176.71703	volcanic material covered with white sand
00:41:52	22.53771	176.71619	1796	22.53808	176.71703	tubes
00:42:25	22.53772	176.71619	1796	22.53808	176.71703	hydrothermal crust on top
00:48:40	22.53733	176.71632	1802	22.53808	176.71703	euplectellid sponge
00:50:22	22.53712	176.71634	1790	22.53808	176.71703	heaving, problems with the scarp
00:59:19	22.53682	176.71595	1809	22.53715	176.71700	bottom within view
01:00:17	22.53677	176.71594	1810	22.53707	176.71693	black sand, ripples
01:01:18	22.53674	176.71592	1807	22.53707	176.71693	sandy sediment, mottled
01:01:57	22.53674	176.71589	1804	22.53630	176.71697	black sand
01:02:31	22.53677	176.71588	1803	22.53772	176.71694	white staining on black riplled sand
01:06:33	22.53673	176.71599	1801	22.53681	176.71653	ripple marks, sulfide block?
01:08:48	22.53682	176.71600	1804	22.53711	176.71645	brittle star
01:09:17	22.53684	176.71599	1804	22.53711	176.71645	brown crust
01:09:35	22.53685	176.71600	1804	22.53711	176.71645	shrimp, hydrothermal?
01:12:19	22.53679	176.71604	1808	22.53711	176.71645	black sand on slope
01:15:42	22.53681	176.71600	1807	22.53711	176.71645	still at the slope
01:18:48	22.53685	176.71594	1807	22.53711	176.71645	ditto
01:20:22	22.53691	176.71597	1805	22.53711	176.71645	sponge
01:25:46	22.53685	176.71602	1809	22.53680	176.71713	still on sandy slope
01:29:59	22.53670	176.71601	1812	22.53680	176.71713	black sand with some white material
01:30:37	22.53664	176.71598	1809	22.53680	176.71713	fragments of volcanic rocks, some sandy sediment

Station 66 GTV-A; commenced 25-10-02; page 3 of 3						
Time (UTC)	Ship Lat. (°S)	Long. (°W)	Cable (m)	Sub Lat. (°S)	Long. (°W)	Comment
01:30:59	22.53661	176.71597	1808	22.53680	176.71713	volcanic debris
01:31:36	22.53656	176.71594	1805	22.53680	176.71713	gorgonian
01:32:03	22.53653	176.71591	1806	22.53680	176.71713	some crust
01:32:17	22.53652	176.71590	1807	22.53680	176.71713	black sand with ripple marks
01:33:16	22.53647	176.71586	1812	22.53680	176.71713	going down a sandy slope
01:34:11	22.53641	176.71584	1814	22.53710	176.71683	shells
01:34:39	22.53638	176.71584	1814	22.53710	176.71683	a lot of shells
01:35:02	22.53634	176.71583	1813	22.53710	176.71683	brittle stars, black rippled sand
01:35:29	22.53630	176.71583	1811	22.53710	176.71683	we hit something
01:37:17	22.53614	176.71574	1804	22.53638	176.71704	going up sandy slope
01:38:53	22.53599	176.71566	1803	22.53638	176.71704	hydrothermal crust on black sand
01:39:31	22.53593	176.71563	1804	22.53638	176.71704	broken hydrothermal crust
01:40:28	22.53585	176.71557	1805	22.53681	176.71654	black sand, ripple marks
01:41:14	22.53585	176.71552	1805	22.53681	176.71654	crust
01:41:34	22.53586	176.71552	1805	22.53681	176.71654	crust, fissure with white and yellow material
01:43:04	22.53583	176.71563	1806	22.53681	176.71654	crack with some yellow colour
01:45:09	22.53585	176.71567	1823	22.53681	176.71654	grab crust
01:49:27	22.53569	176.71548	1798	22.53596	176.71671	start heaving
02:49:02	22.53437	176.71746	3	22.53406	176.71760	GTV with sample on deck
02:52:00						end of station

Station 68 GTV-A; commenced 26-10-02; page 1 of 1						
Time (UTC)	Ship Lat. (°S)	Long. (°W)	Cable (m)	Sub Lat. (°S)	Long. (°W)	Comment
06:08:00						GTV in water
06:16:27	22.53307	176.71871	244	22.53406	176.71760	begin of station 68 GTV-A
06:17:17	22.53301	176.71871	270	22.53406	176.71760	after 260 m grab will brought back on deck since there are troubles with the responder
06:53:22	22.53334	176.71862	30	22.53452	176.71735	GTV in water
06:53:41	22.53334	176.71864	30	22.53452	176.71735	transponder failed; external transponder 30 m above TV-Grab
07:23:36	22.53317	176.71899	1601	22.53327	176.71983	1600 m cable length
07:28:35	22.53306	176.71876	1816	22.53297	176.71983	tapes on
07:29:54	22.53307	176.71881	1867	22.53297	176.71994	bottom within view
07:31:03	22.53306	176.71883	1870	22.53274	176.72053	grey mottled sediment with blocks on surface
07:35:09	22.53324	176.71863	1870	22.53335	176.72010	grey mottled sediment with volcanic debris on surface
07:35:58	22.53318	176.71858	1871	22.53364	176.71955	more shells
07:36:25	22.53316	176.71854	1871	22.53353	176.72001	volcanic outcrop
07:37:44	22.53310	176.71841	1870	22.53378	176.71988	lava flow partially sedimented
07:38:09	22.53307	176.71838	1870	22.53347	176.71988	breccia -> brocken tube
07:38:39	22.53303	176.71836	1867	22.53374	176.71928	volcaniclastic debris on surface
07:39:25	22.53295	176.71837	1865	22.53373	176.71937	volcanic debris, talus
07:40:04	22.53289	176.71835	1860	22.53366	176.71933	rubble at a slope
07:40:23	22.53288	176.71831	1858	22.53344	176.71977	tube and lots of debris
07:41:20	22.53288	176.71816	1856	22.53359	176.71934	rubble
07:41:31	22.53289	176.71814	1854	22.53315	176.71961	chimney, sulfide debris
07:42:09	22.53287	176.71809	1857	22.53315	176.71961	try to grab
07:43:26	22.53276	176.71805	1833	22.53329	176.71951	heaving a little bit
07:44:13	22.53272	176.71798	1812	22.53352	176.71942	sampled something
07:46:24	22.53270	176.71787	1736	22.53295	176.71940	start heaving
07:47:56	22.53261	176.71790	1663	22.53242	176.71896	tapes off
08:23:50	22.53281	176.71825	9991	22.53306	176.71826	GTV with sample on deck, end of station

Station 69 GTV-A; commenced 26-10-02; page 1 of 3						
Time (UTC)	Ship Lat. (°S)	Long. (°W)	Cable (m)	Sub Lat. (°S)	Long. (°W)	Comment
08:26:35	22.53279	176.71807	9989	22.53306	176.71826	GTV in water, begin of station 69 GTV-A
08:29:32	22.53308	176.71777	30	22.53306	176.71826	transponder 30 m above TV-grab
08:56:51	22.53317	176.71828	1512	22.53275	176.71925	1500 m cable length
09:06:12	22.53342	176.71804	1841	22.53397	176.71889	tapes on
09:07:17	22.53336	176.71806	1877	22.53347	176.71929	bottom within view
09:07:30	22.53336	176.71806	1881	22.53348	176.71929	grey mottled sediment with some volcanic debris
09:09:01	22.53338	176.71804	1874	22.53311	176.71955	ditto
09:09:16	22.53340	176.71802	1875	22.53344	176.71901	shell

Station 69 GTV-A; commenced 26-10-02; page 2 of 3						
Time (UTC)	**Ship Lat. (°S)**	**Ship Long. (°W)**	**Cable (m)**	**Sub Lat. (°S)**	**Sub Long. (°W)**	**Comment**
09:10:27	22.53355	176.71797	1874	22.53296	176.71934	gorgonian
09:10:39	22.53358	176.71796	1874	22.53296	176.71934	grey mottled sediment with rubble on it
09:11:13	22.53369	176.71793	1875	22.53314	176.71930	gorgonian
09:11:20	22.53372	176.71792	1876	22.53314	176.71930	volcanic rubble
09:12:47	22.53402	176.71783	1885	22.53327	176.71940	still volcanic talus material
09:14:54	22.53423	176.71778	1898	22.53360	176.71933	grey mottled sediment with debris
09:16:41	22.53420	176.71775	1903	22.53406	176.71911	grey mottled sediment with minor debris
09:17:05	22.53418	176.71774	1904	22.53405	176.71908	fish
09:19:42	22.53415	176.71768	1902	22.53408	176.71918	grey mottled sediment
09:19:58	22.53419	176.71769	1901	22.53434	176.71902	black sand, rippled
09:21:19	22.53450	176.71774	1900	22.53444	176.71889	grey mottled sediment
09:21:52	22.53504	176.71788	1901	22.53526	176.71921	black rippled sand
09:23:40	22.53347	176.71767	1903	22.53415	176.71901	grey mottled sediment
09:25:24	22.53327	176.71772	1899	22.53374	176.71867	ditto
09:25:39	22.53325	176.71772	1897	22.53374	176.71857	hydrothermal crust
09:26:34	22.53322	176.71772	1894	22.53354	176.71903	hydrothermal crust, lightly sedimented
09:27:46	22.53319	176.71770	1886	22.53337	176.71873	block, possible tube on sediment
09:28:28	22.53319	176.71767	1884	22.53366	176.71872	more debris on surface ->
09:28:55	22.53318	176.71765	1880	22.53335	176.71887	striped surface
09:29:25	22.53317	176.71763	1882	22.53332	176.71888	black sand under small debris
09:30:15	22.53312	176.71760	1880	22.53336	176.71884	lot of debris
09:30:38	22.53310	176.71760	1878	22.53337	176.71859	black sand under debris
09:32:03	22.53300	176.71755	1876	22.53315	176.71882	ditto
09:33:31	22.53292	176.71747	1874	22.53324	176.71869	gorgonian
09:34:12	22.53290	176.71743	1873	22.53262	176.71875	ditto
09:37:03	22.53308	176.71737	1877	22.53295	176.71866	ditto
09:38:45	22.53321	176.71729	1883	22.53300	176.71882	debris
09:39:00	22.53323	176.71728	1884	22.53298	176.71876	shell
09:39:04	22.53322	176.71727	1884	22.53298	176.71876	gorgonian
09:41:34	22.53316	176.71710	1893	22.53335	176.71833	ditto
09:42:38	22.53313	176.71703	1896	22.53354	176.71809	sandy sediment with some debris
09:43:12	22.53311	176.71701	1897	22.53339	176.71820	grey mottled sediment with debris
09:44:32	22.53311	176.71696	1899	22.53302	176.71816	shell
09:44:59	22.53312	176.71694	1900	22.53316	176.71824	ditto
09:46:48	22.53312	176.71687	1904	22.53298	176.71809	grey sediment with more debris
09:48:40	22.53308	176.71676	1905	22.53305	176.71829	grey sediment with debris-> getting coarser
09:49:24	22.53307	176.71673	1906	22.53304	176.71775	hydrothermal crust, fractured
09:50:06	22.53305	176.71669	1906	22.53298	176.71808	grey mottled sediment
09:52:34	22.53292	176.71663	1905	22.53331	176.71768	ditto
09:55:07	22.53266	176.71659	1906	22.53289	176.71741	hydrothermal crust? underlying the grey sediment
09:56:14	22.53264	176.71656	1906	22.53285	176.71730	blocks on sediment
09:57:42	22.53274	176.71654	1905	22.53246	176.71751	thin layer of grey sediment on a crust?
10:00:21	22.53296	176.71661	1905	22.53241	176.71777	ditto
10:00:31	22.53295	176.71663	1905	22.53235	176.71777	cracks in the crust, crust covered with thin sediment
10:03:24	22.53306	176.71677	1905	22.53243	176.71776	still hydrothermal crust, covered by thin layer of sediment
10:05:17	22.53314	176.71689	1906	22.53254	176.71776	ditto
10:07:29	22.53329	176.71697	1906	22.53354	176.71667	fractured hydrothermal crust with minor debris
10:08:37	22.53335	176.71700	1906	22.53354	176.71667	thin layer of grey mottled sediment
10:10:57	22.53338	176.71697	1906	22.53533	176.71860	ditto
10:13:51	22.53334	176.71701	1905	22.53310	176.71830	thin layer of grey ottled sediment on a hydrothermal crust?
10:16:53	22.53336	176.71720	1904	22.53294	176.71836	ditto
10:17:47	22.53335	176.71726	1903	22.53314	176.71821	minor debris on grey mottled sediment
10:21:38	22.53311	176.71739	1896	22.53331	176.71840	approaching the scarp?
10:23:12	22.53302	176.71736	1889	22.53339	176.71827	lots of talus
10:24:12	22.53299	176.71729	1887	22.53324	176.71854	veneer on debris
10:24:50	22.53297	176.71724	1885	22.53321	176.71835	gorgonian
10:27:04	22.53292	176.71712	1887	22.53290	176.71841	grey mottled sediment with minor debris
10:30:14	22.53285	176.71707	1891	22.53253	176.71839	ditto
10:31:07	22.53283	176.71710	1892	22.53274	176.71800	going eastward
10:41:08	22.53309	176.71639	1906	22.53339	176.71753	still grey mottled sediment
10:45:11	22.53275	176.71621	1904	22.53309	176.71719	nice track
10:46:47	22.53275	176.71617	1904	22.53281	176.71747	ditto
10:52:08	22.53267	176.71628	1901	22.53241	176.71733	ditto
10:58:51	22.53275	176.71634	1901	22.53213	176.71723	grey mottled sediment
11:01:47	22.53328	176.71652	1906	22.53215	176.71742	grey mottled sediment, with some animal tracks
11:06:49	22.53382	176.71661	1901	22.53286	176.71770	ditto
11:07:09	22.53386	176.71662	1900	22.53279	176.71768	rippled grey and black sand
11:07:55	22.53393	176.71667	1898	22.53282	176.71760	grey sand again
11:08:52	22.53401	176.71676	1898	22.53283	176.71758	brittle star
11:12:04	22.53421	176.71713	1894	22.53340	176.71759	ditto
11:16:07	22.53414	176.71736	1885	22.53366	176.71789	patch of black rippled sand

Station 69 GTV-A; commenced 26-10-02; page 3 of 3						
Time (UTC)	Ship		Cable (m)	Sub		Comment
	Lat. (°S)	Long. (°W)		Lat. (°S)	Long. (°W)	
11:17:00	22.53412	176.71743	1886	22.53355	176.71835	again black rippled sand alternating with grey mottled sand
11:18:20	22.53416	176.71757	1889	22.53344	176.71819	brittle star
11:19:11	22.53418	176.71761	1895	22.53399	176.71817	some debris on the sediment
11:20:37	22.53417	176.71765	1901	22.53377	176.71862	more debris
11:20:52	22.53415	176.71766	1901	22.53383	176.71863	gorgonian
11:21:37	22.53409	176.71766	1902	22.53393	176.71838	grey mottled sediment with minor debris
11:22:04	22.53405	176.71766	1902	22.53412	176.71876	gorgonian
11:23:39	22.53390	176.71765	1903	22.53426	176.71861	ditto
11:25:04	22.53386	176.71762	1902	22.53390	176.71871	ditto
11:25:46	22.53388	176.71761	1902	22.53395	176.71865	debris increasing
11:27:02	22.53389	176.71758	1904	22.53346	176.71888	debris? with sediment
11:28:44	22.53391	176.71756	1908	22.53348	176.71882	grey mottled sediment
11:29:37	22.53391	176.71757	1908	22.53393	176.71803	shell
11:30:51	22.53379	176.71760	1908	22.53393	176.71803	shell
11:33:32	22.53359	176.71754	1904	22.53485	176.71966	some dark stripes at the sediment
11:34:26	22.53358	176.71744	1902	22.53439	176.71923	little debris (pebble-size) on a sandy sediment
11:35:13	22.53358	176.71737	1902	22.53508	176.71942	lots of volcanic debris
11:35:42	22.53358	176.71733	1903	22.53431	176.71989	Munidopsis
11:37:06	22.53357	176.71725	1904	22.53334	176.71863	coarser debris
11:37:18	22.53358	176.71725	1903	22.53334	176.71863	macrourid fish
11:40:09	22.53361	176.71732	1905	22.53291	176.71821	grey mottled sediment
11:42:27	22.53362	176.71742	1905	22.53328	176.71832	more debris
11:43:55	22.53364	176.71745	1905	22.53337	176.71879	fish
11:44:18	22.53365	176.71745	1905	22.53330	176.71848	fish
11:44:52	22.53366	176.71745	1906	22.53324	176.71899	debris
11:46:17	22.53369	176.71741	1904	22.53344	176.71854	tried to grab
11:46:29	22.53369	176.71740	1901	22.53338	176.71870	heaving
11:46:37	22.53369	176.71740	1899	22.53338	176.71870	tried to sample volcanic debris
11:50:56	22.53366	176.71739	1876	22.53306	176.71821	heaving
11:51:48	22.53366	176.71743	1860	22.53313	176.71854	sampled something
11:53:23	22.53364	176.71752	1820	22.53330	176.71833	tapes off
12:56:52	22.53349	176.71660	9992	22.53301	176.71658	GTV with sample on deck
13:00:00						end of station

Station 72 OFOS; commenced 26-10-02; page 1 of 10						
Time (UTC)	Ship		Cable (m)	Sub		Comment
	Lat. (°S)	Long. (°W)		Lat. (°S)	Long. (°W)	
19:56:28	22.22030	176.60811	30	22.21972	176.60817	begin station 72 OFOS
20:24:05	22.22042	176.60800	1497	22.22053	176.60900	1500 m cable length
20:26:20	22.22034	176.60791	1606	22.22055	176.60907	tapes on
20:27:33	22.22032	176.60782	1662	22.22045	176.60894	bottom within view
20:28:10	22.22032	176.60778	1666	22.22049	176.60888	slaby rubble
20:28:23	22.22032	176.60776	1666	22.22063	176.60918	slope
20:29:21	22.22034	176.60769	1669	22.22045	176.60885	sediment covered slabs
20:29:42	22.22035	176.60767	1670	22.22046	176.60892	irregular shaped slaby blocks, light sediment cover
20:30:27	22.22034	176.60763	1669	22.22041	176.60890	gorgonian
20:30:48	22.22032	176.60762	1669	22.22049	176.60868	slaby rubbled surface
20:31:39	22.22023	176.60759	1670	22.22044	176.60867	irregular slaby surface
20:32:02	22.22017	176.60757	1670	22.22038	176.60877	resemble aa-lava, slaby rubble surface, light sediment cover
20:34:57	22.21980	176.60754	1672	22.22009	176.60878	possible slope
20:35:23	22.21977	176.60754	1672	22.21999	176.60844	gorgonian, looks like aa-lava
20:36:29	22.21967	176.60751	1674	22.22018	176.60886	some sediment in a fault
20:37:19	22.21959	176.60747	1673	22.22013	176.60858	blocks up to 1 m in size
20:38:06	22.21952	176.60742	1675	22.21979	176.60844	clinkered blocks, fissure?
20:39:03	22.21943	176.60735	1678	22.21974	176.60868	crumbly, clinkered blocks
20:39:41	22.21939	176.60730	1679	22.21970	176.60869	irregular clinkered rubble, volcanic sediment cover on slaby clinkered rubble, gorgonian
20:41:15	22.21931	176.60719	1681	22.21980	176.60862	slump
20:42:40	22.21926	176.60712	1682	22.21954	176.60879	no sediment, coarse clinker
20:43:30	22.21919	176.60708	1684	22.21925	176.60873	sponge? volcanic sediment
20:43:53	22.21916	176.60707	1683	22.21939	176.60839	scarp with talus, blocks up to 1.5 m, black strikes
20:44:39	22.21908	176.60705	1684	22.21916	176.60837	sediment covered rubble?
20:44:53	22.21906	176.60705	1684	22.21913	176.60827	gorgonian
20:45:04	22.21904	176.60705	1685	22.21921	176.60860	sandy sediment cover
20:45:42	22.21897	176.60703	1685	22.21910	176.60833	sart of slaby rubble
20:46:02	22.21892	176.60703	1686	22.21906	176.60836	gorgonian

Station 72 OFOS; commenced 26-10-02; page 2 of 10						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
20:46:19	22.21888	176.60704	1686	22.21902	176.60827	sediment at base of slope, sponge
20:46:37	22.21883	176.60704	1687	22.21900	176.60839	coarse slaby rubble, flowline structured
20:47:01	22.21876	176.60705	1685	22.21900	176.60839	large slabs > 1 m
20:48:49	22.21847	176.60708	1688	22.21881	176.60834	sediment covered slab
20:49:01	22.21844	176.60709	1689	22.21870	176.60823	slaby rubble
20:49:47	22.21832	176.60712	1690	22.21859	176.60824	light sediment cover on slaby rubble
20:50:19	22.21824	176.60714	1691	22.21842	176.60811	gorgonian
20:50:51	22.21815	176.60716	1693	22.21847	176.60827	clinkered, slaby rubble
20:52:01	22.21799	176.60719	1691	22.21833	176.60853	grey volcanic sediment on top of lava
20:52:38	22.21791	176.60721	1691	22.21817	176.60833	gorgonian
20:53:26	22.21782	176.60724	1689	22.21804	176.60883	coarse, slaby clinkered rubble, lightly sedimented, gorgonians
20:54:16	22.21774	176.60727	1690	22.21820	176.60840	gorgonian, rubble sometimes more blocky, slaby rubble, light sediment cover
20:56:13	22.21755	176.60734	1689	22.21800	176.60864	break in slope
20:57:13	22.21746	176.60735	1691	22.21793	176.60818	some steps, going down a slope, more sediment at base
20:58:12	22.21734	176.60735	1694	22.21800	176.60844	gorgonian
20:59:23	22.21716	176.60733	1694	22.21808	176.60882	slaby rubble, minimum sediment
20:59:48	22.21711	176.60733	1694	22.21783	176.60851	gorgonian
21:00:06	22.21706	176.60733	1695	22.21781	176.60830	crinoid
21:01:17	22.21690	176.60731	1696	22.21751	176.60864	sediment covered rubble
21:01:28	22.21688	176.60730	1696	22.21744	176.60857	gorgonian
21:02:47	22.21675	176.60727	1694	22.21741	176.60864	euplectellid sponge
21:03:13	22.21670	176.60725	1695	22.21716	176.60829	light sediment cover on rubble
21:07:15	22.21615	176.60724	1699	22.21698	176.60863	some sediment, euplectellid sponge, gorgonians
21:07:50	22.21606	176.60724	1700	22.21680	176.60861	gorgonians
21:08:25	22.21598	176.60725	1702	22.21640	176.60835	light sediment, some black sand, covering rubble
21:09:05	22.21589	176.60727	1705	22.21644	176.60849	gorgonian
21:09:36	22.21582	176.60729	1704	22.21643	176.60809	more biology, gorgonians
21:09:51	22.21579	176.60730	1704	22.21635	176.60866	coarse rubble, partially covered by grey and black sand
21:10:30	22.21570	176.60733	1706	22.21607	176.60831	slight break in slope, gorgonian
21:11:42	22.21552	176.60735	1710	22.21599	176.60855	sediment covering rubble
21:11:58	22.21549	176.60735	1710	22.21597	176.60840	break in slope
21:12:38	22.21539	176.60737	1714	22.21591	176.60853	sediment covering rubble at base of slope
21:13:16	22.21530	176.60738	1714	22.21599	176.60835	gorgonian
21:13:39	22.21524	176.60739	1715	22.21542	176.60867	another break in slope
21:13:53	22.21521	176.60740	1715	22.21549	176.60865	black sand around blocks
21:14:09	22.21517	176.60740	1716	22.21585	176.60835	sea star
21:14:28	22.21513	176.60741	1714	22.21586	176.60860	sea star on sediment covered rubble
21:15:10	22.21502	176.60743	1711	22.21551	176.60845	more sediment covering rubble
21:15:27	22.21498	176.60744	1713	22.21566	176.60865	rubble maybe transported, possible talus
21:16:30	22.21483	176.60746	1717	22.21561	176.60861	cloudy water?
21:16:42	22.21480	176.60746	1718	22.21540	176.60879	rubble finer, more sediment cover, transported?
21:17:14	22.21473	176.60747	1722	22.21535	176.60840	white patches
21:17:38	22.21467	176.60747	1722	22.21544	176.60862	temperature anomaly at white patches!!!
21:18:11	22.21459	176.60748	1723	22.21526	176.60856	temperature anomaly
21:18:28	22.21455	176.60749	1724	22.21537	176.60879	finer rubble, transported? no sediment cover
21:18:59	22.21448	176.60749	1725	22.21524	176.60864	still temperature anomaly
21:19:20	22.21443	176.60749	1726	22.21511	176.60848	temperature anomaly 0.1 °C
21:19:40	22.21438	176.60749	1726	22.21555	176.60892	sediment covered patches, 1-2 m wide between rubble, still high temp
21:20:45	22.21421	176.60749	1727	22.21502	176.60840	cloudy water, break in slope, sediment covered at base
21:21:29	22.21409	176.60748	1728	22.21507	176.60882	break in slope again
21:22:00	22.21402	176.60748	1730	22.21514	176.60887	sediment covered rubble at base
21:22:28	22.21395	176.60747	1730	22.21485	176.60853	also some irregular conductivity, still high temperature, DV on
21:23:25	22.21382	176.60743	1730	22.21499	176.60865	sediment covered rubble surface
21:24:02	22.21374	176.60741	1726	22.21478	176.60836	gorgonians
21:24:21	22.21369	176.60740	1726	22.21477	176.60873	temperature increasing, scarp
21:24:54	22.21363	176.60737	1730	22.21452	176.60845	gorgonian
21:24:59	22.21362	176.60737	1729	22.21452	176.60845	sediment covered rubble, black and grey sand, crinoids
21:26:01	22.21349	176.60732	1729	22.21449	176.60863	gorgonian
21:26:10	22.21348	176.60732	1727	22.21448	176.60905	black sand covering rubble, young gorgonian
21:26:41	22.21343	176.60730	1724	22.21448	176.60892	DV off 5 min
21:27:06	22.21340	176.60728	1723	22.21429	176.60825	temperature now at background
21:27:26	22.21338	176.60726	1722	22.21429	176.60825	gorgonians
21:27:43	22.21336	176.60725	1723	22.21422	176.60872	more sediment cover, few clinkered blocks
21:28:04	22.21335	176.60723	1725	22.21419	176.60887	temperature anomaly was 0.12 °C
21:28:38	22.21333	176.60722	1723	22.21391	176.60854	temperature increases again, gorgonian
21:29:05	22.21331	176.60721	1724	22.21385	176.60891	sediment covered clinkered rubble
21:30:16	22.21323	176.60721	1727	22.21365	176.60857	clinkered rubble, finer blocks, partially covered by seds

Station 72 OFOS; commenced 26-10-02; page 3 of 10

Time	Ship		Cable	Sub		Comment
(UTC)	Lat. (°S)	Long. (°W)	(m)	Lat. (°S)	Long. (°W)	
21:30:51	22.21318	176.60720	1727	22.21379	176.60857	end of temperature anomaly: 0.07 °C, gorgonian sediment covered clinkered rubble, finer sized blocks
21:32:14	22.21300	176.60720	1728	22.21436	176.60917	change direction to west, temperature increases
21:32:54	22.21291	176.60720	1729	22.21347	176.60847	black and grey sand, covering rubble, gorgonian
21:34:05	22.21276	176.60719	1731	22.21338	176.60861	temperature peak
21:34:17	22.21274	176.60718	1731	22.21340	176.60857	partially sediment covered clinkered slump
21:35:01	22.21268	176.60720	1733	22.21309	176.60861	gorgonian
21:36:11	22.21266	176.60728	1737	22.21272	176.60819	grey mottled sed, temperature drops again, temperature anomaly was 0.08 °C
21:37:32	22.21269	176.60741	1740	22.21276	176.60858	still sediment cover, few clinkered blocks
21:38:33	22.21273	176.60750	1741	22.21273	176.60822	gorgonian
21:38:47	22.21275	176.60751	1741	22.21272	176.60808	temperature and conductivity now normal
21:39:06	22.21276	176.60754	1742	22.21262	176.60823	euplectellid sponge
21:39:34	22.21279	176.60757	1743	22.21270	176.60836	crinoids, irregular topography, sediment covered depression between clinkered blocks
21:42:18	22.21269	176.60774	1741	22.21251	176.60837	scarp
21:42:58	22.21262	176.60780	1742	22.21243	176.60864	sediment cover at base of scarp, sediment covers slaby rubble
21:44:38	22.21251	176.60796	1741	22.21237	176.60861	black sand covering rubble
21:45:47	22.21248	176.60809	1746	22.21279	176.60807	slabs
21:46:30	22.21248	176.60818	1741	22.21279	176.60807	break in slope
21:46:53	22.21249	176.60822	1740	22.21316	176.61002	going upward
21:47:19	22.21251	176.60826	1740	22.21316	176.61002	scarp
21:47:51	22.21253	176.60830	1739	22.21340	176.60964	finer slaby rubble near scarp, transported?
21:49:15	22.21262	176.60832	1746	22.21249	176.60892	change direction to south
21:51:01	22.21278	176.60832	1749	22.21273	176.60900	partially sediment covered slab
21:52:17	22.21285	176.60843	1752	22.21265	176.60922	partially sediment covered slaby rubble
21:54:16	22.21284	176.60857	1754	22.21274	176.60927	sediment covered rubble
21:56:18	22.21296	176.60859	1754	22.21300	176.60947	begin of temperature anomaly
21:56:34	22.21300	176.60858	1755	22.21295	176.60953	sediment covered slaby rubble
21:58:10	22.21323	176.60846	1763	22.21307	176.60915	end of very small temperature anomaly black sand with slaby rubble sticking through sand
21:59:41	22.21341	176.60836	1763	22.21298	176.60953	rippled black sand grey mottled volcanic sand with lava fragments (10-15 cm)
22:01:06	22.21348	176.60834	1761	22.21312	176.60936	little scarp
22:01:21	22.21349	176.60834	1759	22.21312	176.60936	large clinkered slabs
22:04:18	22.21363	176.60825	1757	22.21324	176.60955	grey mottled sediment between large clinkered slabs
22:05:09	22.21375	176.60823	1754	22.21354	176.60951	gorgonian
22:05:36	22.21381	176.60822	1752	22.21318	176.60934	more gorgonians
22:06:33	22.21393	176.60822	1750	22.21363	176.60947	gorgonian
22:06:46	22.21395	176.60822	1750	22.21303	176.60917	temperature increases
22:07:06	22.21399	176.60821	1749	22.21350	176.60958	clinkered slab
22:08:30	22.21411	176.60817	1747	22.21348	176.60917	partially sediment covered clinkered rubble, blocks < 60 cm
22:10:35	22.21427	176.60821	1741	22.21343	176.60925	ditto
22:11:06	22.21429	176.60824	1741	22.21346	176.60930	end of little temperature anomaly
22:11:27	22.21431	176.60825	1740	22.21346	176.60930	more sediment, gorgonian
22:11:49	22.21432	176.60826	1738	22.21409	176.60927	gorgonian
22:12:01	22.21433	176.60827	1738	22.21394	176.60924	more gorgonians
22:12:25	22.21436	176.60827	1739	22.21416	176.60922	gorgonians
22:12:37	22.21437	176.60827	1739	22.21417	176.60921	begin of temperature anomaly
22:13:03	22.21440	176.60827	1738	22.21373	176.60925	gorgonian
22:13:15	22.21442	176.60827	1738	22.21419	176.60942	sediment covered clinkered rubble, Ceriantharia
22:14:07	22.21451	176.60823	1737	22.21401	176.60913	more sediment
22:14:40	22.21457	176.60821	1737	22.21418	176.60916	more sediment, possible ripples, few clinkered blocks, increase in conductivity
22:15:35	22.21470	176.60819	1737	22.21429	176.60909	spiking temperature
22:16:00	22.21477	176.60818	1737	22.21399	176.60912	partially sediment covered rubble
22:17:07	22.21496	176.60817	1736	22.21431	176.60931	peak in temperature
22:17:20	22.21500	176.60817	1736	22.21418	176.60887	large slabs, partially sediment covered
22:17:46	22.21507	176.60816	1737	22.21388	176.60916	cloudy water
22:17:58	22.21510	176.60816	1738	22.21389	176.60926	gorgonian
22:18:15	22.21515	176.60816	1737	22.21397	176.60902	heterogeneous large and small blocks
22:19:12	22.21530	176.60812	1739	22.21450	176.60918	gorgonian
22:19:36	22.21537	176.60811	1740	22.21450	176.60918	temperature peak, sedimented rubble surface
22:20:12	22.21547	176.60809	1739	22.21414	176.60916	high peaks are in temperature and conductivity
22:20:57	22.21559	176.60808	1739	22.21360	176.60931	temperature peak
22:21:20	22.21565	176.60809	1740	22.21434	176.60940	sedimented slaby surface, temperature peak
22:22:44	22.21582	176.60811	1741	22.21664	176.61008	irregular clinkered slabs, slightly sedimented, DV on
22:23:14	22.21587	176.60814	1741	22.21432	176.60919	temperature peak, cloudy water
22:23:46	22.21593	176.60816	1740	22.21428	176.60909	more shells

Station 72 OFOS; commenced 26-10-02; page 4 of 10						
Time (UTC)	Ship Lat. (°S)	Long. (°W)	Cable (m)	Sub Lat. (°S)	Long. (°W)	Comment
22:23:59	22.21595	176.60818	1740	22.21445	176.60916	snails!!!
22:24:21	22.21599	176.60819	1738	22.21470	176.60899	vent crab, mussels alive, clinkers
22:25:01	22.21607	176.60821	1737	22.21521	176.60892	temperature dropping dramatically, minor shells to 0
22:25:37	22.21616	176.60823	1737	22.21509	176.60914	sedimented surface
22:25:51	22.21620	176.60824	1736	22.21502	176.60909	temperature peaks again
22:26:15	22.21626	176.60823	1736	22.21489	176.60878	very cloudy water, sediment covered rubble, large block of lava
22:27:05	22.21641	176.60822	1736	22.21537	176.60892	more lobate flows possible tubes, still clinkered blocks
22:27:57	22.21653	176.60819	1733	22.21476	176.60906	huge temperature anomaly
22:28:21	22.21659	176.60819	1733	22.21534	176.60899	cloudy water
22:28:46	22.21664	176.60817	1732	22.21508	176.60898	lobate type flow
22:28:59	22.21667	176.60817	1729	22.21529	176.60935	scarp, temperature anomaly was 0.25 °C, white patches
22:30:11	22.21680	176.60817	1725	22.21535	176.60906	lobate flows, temperature anomaly low, tubes, white patches, black sand
22:30:42	22.21685	176.60815	1722	22.21518	176.60910	shrimp
22:30:48	22.21686	176.60815	1722	22.21544	176.60937	mussels
22:31:17	22.21691	176.60814	1718	22.21580	176.60931	lobate flow
22:31:24	22.21691	176.60812	1718	22.21580	176.60931	black sediment, white patches
22:31:36	22.21694	176.60813	1717	22.21566	176.60912	tubes, lot of hydrothermal material, mussels
22:32:02	22.21698	176.60811	1717	22.21579	176.60888	normal deep temperature
22:32:09	22.21699	176.60811	1717	22.21579	176.60888	still clinkered slabs
22:32:19	22.21701	176.60810	1716	22.21565	176.60911	mussels, looking alive
22:32:53	22.21706	176.60809	1713	22.21557	176.60892	lot of snails
22:33:34	22.21714	176.60809	1711	22.21587	176.60920	lobate flows, mussels
22:33:56	22.21719	176.60808	1706	22.21587	176.60920	large tubes
22:34:09	22.21722	176.60808	1705	22.21590	176.60896	white patches on lobes, still clinker breccia
22:34:41	22.21729	176.60809	1703	22.21605	176.60914	DV off 12 min
22:34:47	22.21731	176.60809	1704	22.21605	176.60914	dusting of sediment on rubble
22:35:39	22.21744	176.60809	1702	22.21630	176.60908	lobate flow, little temperature anomaly
22:36:19	22.21753	176.60809	1699	22.21626	176.60921	clinkered rubble, light sediment dusting
22:37:16	22.21765	176.60809	1696	22.21607	176.60909	temperature anomaly was nothing
22:37:29	22.21767	176.60808	1696	22.21625	176.60907	sediment dusting on lobate flow surface
22:37:52	22.21771	176.60808	1694	22.21622	176.60913	temperature peak
22:38:08	22.21774	176.60808	1694	22.21640	176.60895	black sand between clinkered blocks
22:38:42	22.21779	176.60808	1692	22.21632	176.60925	tube, black sand and clinkers between lobes
22:39:06	22.21782	176.60808	1690	22.21649	176.60893	gorgonian
22:39:16	22.21784	176.60808	1688	22.21643	176.60922	temperature anomaly was only 1 peak, temperature anomaly: 0.1 °C, gorgonian
22:39:35	22.21786	176.60809	1685	22.21675	176.60909	clinker blocks, gorgonian
22:39:46	22.21788	176.60809	1684	22.21651	176.60916	temperature peak
22:40:14	22.21791	176.60809	1684	22.21690	176.60897	shrimp over clinkered rubble
22:40:31	22.21793	176.60809	1683	22.21690	176.60897	gorgonians
22:40:46	22.21795	176.60810	1683	22.21898	176.60946	sand covering rubble surface
22:41:01	22.21797	176.60810	1681	22.21709	176.60883	temperature went down again
22:41:14	22.21798	176.60811	1680	22.21714	176.60885	gorgonian
22:41:44	22.21801	176.60812	1680	22.21707	176.60893	sand covered rubble surface
22:42:33	22.21807	176.60814	1678	22.21737	176.60918	black sand, clinkered slabs
22:43:31	22.21815	176.60815	1676	22.21753	176.60884	clinkered blocks, light sediment dusting
22:44:36	22.21827	176.60814	1674	22.21767	176.60896	mottled sediment
22:44:58	22.21831	176.60814	1675	22.21757	176.60896	contact with clinkered, blocky flows
22:46:20	22.21850	176.60812	1677	22.21793	176.60904	clinkered material covered by black sand, gorgonians
22:47:16	22.21864	176.60810	1677	22.21771	176.60900	gorgonian
22:47:50	22.21872	176.60811	1678	22.21712	176.60895	sediment covering clinkered flow, gorgonian
22:48:52	22.21885	176.60815	1675	22.21752	176.60906	gorgonian
22:49:01	22.21887	176.60815	1675	22.21798	176.60899	partially sediment covered clinker
22:50:28	22.21903	176.60818	1674	22.21804	176.60874	coarse slabs
22:50:49	22.21906	176.60819	1671	22.21816	176.60890	euplectellid sponge, gorgonian
22:51:07	22.21909	176.60819	1672	22.21800	176.60894	little temperature anomaly
22:51:19	22.21911	176.60820	1669	22.21799	176.60902	gorgonian
22:51:57	22.21917	176.60821	1671	22.21800	176.60911	gorgonian
22:52:12	22.21919	176.60822	1668	22.21823	176.60916	some more gorgonians, ridges of clinkered rubble, separated by black volcanic sand
22:52:48	22.21926	176.60823	1668	22.21804	176.60915	small temperature peak
22:53:03	22.21928	176.60823	1667	22.21802	176.60898	gorgonian
22:53:31	22.21932	176.60824	1666	22.21809	176.60903	more gorgonians
22:55:02	22.21946	176.60828	1664	22.21867	176.60914	partially sediment covered clinkered rubble
22:56:24	22.21957	176.60828	1661	22.21876	176.60908	gorgonian
22:56:46	22.21960	176.60829	1660	22.21858	176.60917	ditto
22:57:38	22.21970	176.60829	1657	22.21887	176.60915	numerous particle feeders, irregular sediment covered rubble
23:00:32	22.22005	176.60818	1655	22.21927	176.60933	black sediment covering slaby rubble

Station 72 OFOS; commenced 26-10-02; page 5 of 10						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
23:00:58	22.22010	176.60815	1656	22.21952	176.60933	gorgonian
23:02:09	22.22023	176.60802	1664	22.21922	176.60938	rubble at base of small scarp
23:03:41	22.22037	176.60791	1664	22.21961	176.60910	gorgonian
23:04:07	22.22041	176.60790	1665	22.21948	176.60902	irregular slaby lava, blocks, black mottled sediment
23:07:57	22.22040	176.60807	1667	22.22001	176.60903	sediment between large clinkered slabs, euplectellid sponge
23:09:54	22.22005	176.60830	1666	22.21975	176.60917	turn for next track
23:10:50	22.21987	176.60840	1667	22.21962	176.60923	heavily sedimented rubbly surface
23:12:06	22.21969	176.60857	1666	22.21938	176.60918	slaby rubble
23:12:50	22.21964	176.60866	1661	22.21975	176.60906	black and grey sand
23:14:12	22.21963	176.60877	1662	22.21972	176.60932	black sand on rubble
23:14:55	22.21966	176.60883	1662	22.21973	176.60891	gorgonian
23:16:00	22.21971	176.60893	1662	22.21953	176.60953	partially sediment covered field
23:17:17	22.21977	176.60903	1665	22.21987	176.60966	2 m slab, partially sediment covered
23:18:43	22.21982	176.60918	1668	22.21957	176.60967	sedimented rubble surface
23:19:43	22.21984	176.60926	1674	22.21983	176.60987	turn to north
23:21:27	22.21975	176.60938	1681	22.21985	176.60974	rubble surface, partially sediment covered
23:24:57	22.21908	176.60964	1689	22.21947	176.60950	scarp
23:25:19	22.21904	176.60964	1687	22.21947	176.60950	talus, black sand
23:25:52	22.21900	176.60964	1685	22.21795	176.60995	black sediment, large slab blocks
23:26:35	22.21894	176.60963	1683	22.21795	176.60995	increasing temperature
23:27:05	22.21889	176.60961	1684	22.21795	176.60995	heavily sedimented slab
23:28:09	22.21878	176.60957	1691	22.22015	176.61082	heavily sedimented slaby surface, still temperature anomaly 0.05 °C, sedimented rubble surface, black sand
23:32:05	22.21844	176.60944	1706	22.21895	176.60917	very clinkered surface, minor sediment
23:33:37	22.21839	176.60939	1702	22.21903	176.61053	sedimented rubble surface
23:34:13	22.21836	176.60937	1703	22.21879	176.61046	a fish
23:34:45	22.21837	176.60935	1704	22.21894	176.61065	heavily sedimented rubble surface
23:37:35	22.21873	176.60920	1710	22.21842	176.61047	heavily sedimented rubble surface
23:39:11	22.21883	176.60927	1712	22.21857	176.61020	heavily sedimented flow surface
23:40:04	22.21878	176.60933	1709	22.21868	176.61026	areas of grey-black sediment with few clinkered fragments between areas of blocky, slaby lava with minor sediment dusting, sediment fills irregularities on flow top
23:42:19	22.21837	176.60942	1706	22.21884	176.61029	ditto
23:43:51	22.21812	176.60953	1711	22.21853	176.61055	possible small scarp
23:46:15	22.21786	176.60962	1712	22.21853	176.61060	sedimented rubble surface on lip of scarp
23:47:55	22.21770	176.60962	1715	22.21828	176.61040	slaby clinkered rubble, no sediment, gorgonian, scarp
23:50:47	22.21735	176.60969	1715	22.21786	176.61037	crevasse or scarp
23:51:39	22.21731	176.60967	1720	22.21801	176.61061	2.5 m deep scarp
23:52:26	22.21733	176.60959	1730	22.21803	176.61057	sedimented rubble, scarp was over 10 m
23:53:13	22.21732	176.60952	1732	22.21778	176.61041	still rubbled, clinkered surface
23:53:44	22.21730	176.60947	1734	22.21785	176.61032	still going down slope
23:54:14	22.21725	176.60944	1736	22.21755	176.61030	rubble surface, partially covered by sediment
23:54:40	22.21719	176.60941	1735	22.21776	176.61040	fish
23:55:02	22.21713	176.60939	1732	22.21773	176.61038	little scarp
23:55:39	22.21706	176.60935	1730	22.21784	176.61071	going upward
23:56:21	22.21700	176.60929	1730	22.21785	176.61028	rubbled surface partially covered by black sand, brittle star
23:56:54	22.21694	176.60925	1731	22.21755	176.61024	heavily sedimented rubble
23:57:41	22.21686	176.60921	1729	22.21766	176.61041	going up again
23:58:09	22.21680	176.60918	1730	22.21758	176.61034	sedimented rubbled surface, rubbled surface, heavily sedimented with black and grey sediment
23:59:22	22.21666	176.60915	1721	22.21749	176.61037	scarp, gorgonian
00:00:03	22.21658	176.60915	1720	22.21723	176.61039	clinkery flow
00:00:31	22.21654	176.60915	1718	22.21713	176.61035	aristeid prawn
00:00:51	22.21651	176.60915	1718	22.21705	176.61025	slaby material
00:01:40	22.21645	176.60915	1719	22.21707	176.61021	aristeid prawn
00:03:20	22.21634	176.60913	1728	22.21689	176.61054	ditto
00:04:57	22.21625	176.60913	1734	22.21657	176.61027	still clinkery flow outcrop
00:05:13	22.21622	176.60916	1735	22.21655	176.60996	dusted sandy sediment
00:05:55	22.21616	176.60918	1734	22.21662	176.61021	crinoid
00:06:31	22.21610	176.60920	1735	22.21650	176.61001	clinkery brecciated material
00:07:55	22.21596	176.60920	1738	22.21646	176.61019	more sandy sediment
00:08:04	22.21594	176.60920	1739	22.21647	176.61008	sediment partially covers the clinkery flow, heavily sedimented by sandy black and grey sediment, with isolated clinkered material
00:10:18	22.21575	176.60914	1740	22.21633	176.61008	ditto
00:11:20	22.21567	176.60911	1738	22.21611	176.61023	clinkery flow outcrop
00:12:12	22.21561	176.60909	1739	22.21593	176.61003	contact massive flow / grey mottled sediment
00:12:39	22.21558	176.60909	1738	22.21606	176.61030	channel of black sand cutting through clinkery flow
00:13:21	22.21552	176.60910	1738	22.21585	176.60993	crinoid
00:13:53	22.21547	176.60911	1740	22.21592	176.61024	sandy sediment partially covering a clinkery flow
00:14:39	22.21539	176.60914	1741	22.21574	176.61043	talus, irregular shape

Station 72 OFOS; commenced 26-10-02; page 6 of 10						
Time (UTC)	Ship		Cable (m)	Sub		Comment
	Lat. (°S)	Long. (°W)		Lat. (°S)	Long. (°W)	
00:15:39	22.21527	176.60920	1744	22.21555	176.61019	still clinkery outcrop partially coverd by sediment
00:17:26	22.21503	176.60924	1751	22.21545	176.61006	blocky fragments of volcanic debris
00:17:40	22.21500	176.60925	1752	22.21567	176.61020	on top of a crust?
00:18:20	22.21493	176.60926	1754	22.21545	176.61009	cloudy water
00:18:45	22.21488	176.60927	1757	22.21547	176.61016	more sediment
00:20:13	22.21474	176.60927	1765	22.21532	176.61029	outcrop partially covered by more or less sediment
00:21:27	22.21463	176.60924	1765	22.21525	176.61040	almost no sediment
00:22:24	22.21454	176.60924	1765	22.21514	176.61052	still clinkery volcanic outcrop, debris with dusted sediment
00:23:04	22.21447	176.60922	1766	22.21490	176.60994	detached fragmented rocks
00:23:46	22.21439	176.60922	1766	22.21503	176.61043	tubular-like flow formation
00:24:23	22.21431	176.60920	1765	22.21478	176.61005	back into clinkery flow
00:24:41	22.21427	176.60919	1765	22.21514	176.61062	abundantly fragmented
00:25:23	22.21420	176.60919	1764	22.21504	176.61059	scarp, gorgonian
00:25:59	22.21413	176.60918	1762	22.21470	176.61023	clinkery lava with dusted sediment
00:26:28	22.21408	176.60916	1764	22.21472	176.61027	aristeid prawn
00:26:55	22.21404	176.60915	1765	22.21472	176.61041	gorgonian
00:27:10	22.21401	176.60915	1765	22.21454	176.61011	clinkered material partially covered by more or less sediment
00:27:40	22.21398	176.60914	1764	22.21448	176.61022	aristeid prawn
00:27:49	22.21396	176.60913	1763	22.21450	176.61008	gorgonian
00:28:11	22.21394	176.60913	1764	22.21448	176.61037	gorgonian
00:29:57	22.21385	176.60912	1765	22.21424	176.61014	gorgonian
00:30:15	22.21384	176.60912	1765	22.21426	176.61032	more sediment
00:30:49	22.21382	176.60912	1765	22.21424	176.61030	gorgonian
00:31:24	22.21378	176.60911	1765	22.21410	176.61041	clinkered outcrop with minor sediment cover
00:31:46	22.21376	176.60911	1764	22.21415	176.61032	gorgonians
00:32:35	22.21369	176.60911	1771	22.21412	176.61017	1 m high scarp
00:34:04	22.21357	176.60916	1768	22.21376	176.61033	still very scoriaceous type of flow, dusty sediments
00:35:31	22.21341	176.60926	1773	22.21367	176.61027	change of colour tape
00:36:31	22.21329	176.60931	1775	22.21355	176.61017	gorgonian
00:36:50	22.21326	176.60933	1776	22.21351	176.61002	scarp
00:37:31	22.21320	176.60934	1776	22.21365	176.61018	still scarp
00:38:21	22.21312	176.60933	1781	22.21353	176.60985	slabs associated with clinker, layered structures
00:39:00	22.21307	176.60931	1784	22.21372	176.61024	slumped debris
00:39:44	22.21299	176.60926	1788	22.21357	176.61009	scarp with gorgonian
00:40:37	22.21290	176.60920	1790	22.21348	176.60999	gorgonian
00:41:43	22.21279	176.60920	1786	22.21320	176.61011	gorgonian
00:42:34	22.21269	176.60923	1788	22.21313	176.61019	still clinkery material
00:43:01	22.21263	176.60924	1790	22.21315	176.61037	sediment with clinkered material
00:43:29	22.21257	176.60926	1792	22.21307	176.61044	euplectellid sponge
00:43:58	22.21251	176.60928	1790	22.21304	176.61023	rough clinkered surface, fish
00:44:28	22.21245	176.60931	1792	22.21280	176.61041	changing direction, moving southward to way point in order to cross the field from west to east
00:46:17	22.21236	176.60939	1792	22.21254	176.61026	scarps
00:46:44	22.21239	176.60943	1792	22.21253	176.61017	ditto
00:47:12	22.21244	176.60947	1794	22.21257	176.61015	gorgonian
00:47:30	22.21247	176.60950	1795	22.21251	176.61038	gorgonian
00:48:22	22.21256	176.60957	1798	22.21261	176.61021	clinkered surface
00:49:20	22.21267	176.60963	1801	22.21251	176.61038	small scarp
00:49:54	22.21275	176.60965	1803	22.21258	176.61030	large block
00:51:06	22.21290	176.60967	1810	22.21266	176.61034	sediment at base of scarp (7 m high)
00:51:36	22.21295	176.60968	1812	22.21222	176.61030	sediment covered surface
00:53:00	22.21310	176.60973	1815	22.21250	176.61047	gorgonian
00:54:10	22.21320	176.60982	1817	22.21250	176.61031	eel-shaped fish
00:54:59	22.21327	176.60986	1819	22.21296	176.61060	still scarp
00:55:27	22.21331	176.60988	1819	22.21290	176.61066	still large scarp
00:55:46	22.21333	176.60989	1822	22.21263	176.61048	oblique to the ridge about 2 m deep
00:56:50	22.21343	176.60988	1825	22.21290	176.61055	lightly sediment dust on rubble
00:57:34	22.21351	176.60986	1824	22.21298	176.61050	small scarp
00:58:00	22.21356	176.60984	1820	22.21308	176.61072	still scarp
00:58:29	22.21362	176.60981	1823	22.21292	176.61073	sediment at base of scarp (4 m)
00:58:57	22.21368	176.60980	1825	22.21294	176.61062	heavily sedimented flow surface
00:59:37	22.21378	176.60976	1829	22.21283	176.61097	fish?
01:00:16	22.21386	176.60977	1827	22.21292	176.61062	gorgonians
01:01:00	22.21395	176.60979	1826	22.21303	176.61087	much sediment on slope
01:01:46	22.21402	176.60985	1826	22.21292	176.61078	gorgonian
01:02:03	22.21404	176.60987	1823	22.21283	176.61078	scarp
01:03:24	22.21412	176.60999	1821	22.21346	176.61073	clinkery flow surface
01:03:43	22.21413	176.61001	1822	22.21334	176.61072	partially sedimented
01:04:13	22.21415	176.61006	1819	22.21350	176.61071	talus, lots of clasts 15 to 10 cm
01:05:34	22.21417	176.61014	1815	22.21377	176.61064	shrimp

Station 72 OFOS; commenced 26-10-02; page 7 of 10							
Time	Ship		Cable	Sub		Comment
(UTC)	Lat. (°S)	Long. (°W)	(m)	Lat. (°S)	Long. (°W)	
01:05:39	22.21418	176.61014	1815	22.21369	176.61065	still scarp
01:06:21	22.21420	176.61013	1811	22.21386	176.61077	gorgonian
01:06:30	22.21420	176.61014	1812	22.21398	176.61082	still scarp
01:06:37	22.21421	176.61012	1812	22.21384	176.61041	gorgonians
01:06:50	22.21422	176.61012	1813	22.21387	176.61096	tubular flows
01:07:15	22.21424	176.61010	1814	22.21464	176.60992	tubular flow on top of clinkered surface, aristeid prawn
01:08:57	22.21439	176.60999	1825	22.21643	176.61142	scarp
01:09:43	22.21450	176.60994	1825	22.21281	176.61066	scarp
01:09:56	22.21453	176.60993	1823	22.21281	176.61066	clinkery outcrop
01:10:19	22.21458	176.60991	1824	22.21281	176.61066	polychaete worm
01:10:36	22.21461	176.60990	1822	22.21281	176.61066	gorgonian
01:11:49	22.21472	176.60986	1821	22.21384	176.61085	still scarp
01:12:20	22.21475	176.60984	1821	22.21414	176.61081	sedimented surface with debris
01:13:09	22.21476	176.60981	1817	22.21471	176.61081	heavily sediment on top
01:14:34	22.21472	176.60970	1813	22.21452	176.61095	tubular flow, shrimp
01:14:56	22.21473	176.60964	1811	22.21452	176.61046	still tube and blocks
01:15:40	22.21477	176.60951	1807	22.21471	176.61077	clinkered material, sediment on top
01:16:06	22.21479	176.60946	1803	22.21447	176.61079	DV on
01:16:11	22.21479	176.60945	1801	22.21447	176.61079	still going up the flow
01:16:51	22.21479	176.60938	1800	22.21450	176.61053	scarp > 25 m high
01:18:07	22.21477	176.60929	1793	22.21488	176.61031	still going up a slope
01:19:05	22.21479	176.60918	1789	22.21485	176.61057	clinkered material
01:19:05	22.21479	176.60918	1789	22.21485	176.61057	scarp already 50 m high
01:20:26	22.21478	176.60901	1784	22.21486	176.61044	steep slope -> still going up
01:21:07	22.21479	176.60893	1779	22.21502	176.61035	euplectellid sponge
01:21:48	22.21479	176.60885	1774	22.21507	176.61039	still going up, gorgonian, scarp already 60 m high, fault, gorgonian
01:24:34	22.21474	176.60864	1760	22.21500	176.60997	gorgonian
01:24:43	22.21474	176.60863	1759	22.21488	176.60977	some sediment on slope surface, gorgonian, still going up, scarp already 70 m high, looks like talus
01:26:45	22.21472	176.60844	1745	22.21482	176.60977	scarp was about 75 m high, gorgonian, slaby and tubular flow
01:28:13	22.21468	176.60835	1746	22.21499	176.60929	sediment covered top -> becoming flatter
01:29:07	22.21466	176.60828	1743	22.21486	176.60951	sediment covered rubble surface
01:29:48	22.21464	176.60822	1743	22.21470	176.60948	grey mottled sediment covering a rubble? surface
01:30:06	22.21464	176.60818	1743	22.21502	176.60935	sea star
01:30:35	22.21465	176.60812	1744	22.21502	176.60923	lobate flow
01:30:49	22.21465	176.60809	1744	22.21508	176.60918	lobate flow -> tube
01:31:01	22.21465	176.60807	1743	22.21488	176.60911	gorgonians
01:31:09	22.21466	176.60806	1745	22.21488	176.60911	sediment covered top of a flow, crinoid
01:31:57	22.21466	176.60799	1741	22.21492	176.60907	gorgonian
01:32:13	22.21466	176.60797	1741	22.21495	176.60925	lobate flows?
01:32:40	22.21464	176.60794	1742	22.21500	176.60923	macrourid fish
01:32:48	22.21464	176.60793	1740	22.21478	176.60926	lobate flow
01:33:04	22.21463	176.60792	1739	22.21480	176.60924	little scarp
01:33:09	22.21463	176.60792	1738	22.21480	176.60924	some yellow staining in the crack, its getting cloudy, grey mottled sediment covered surface
01:34:33	22.21458	176.60784	1735	22.21507	176.60889	black sand on surface
01:34:48	22.21458	176.60782	1736	22.21490	176.60872	no temperature anomaly
01:35:05	22.21458	176.60780	1736	22.21519	176.60896	black sediment with debris
01:35:46	22.21457	176.60773	1736	22.21488	176.60854	lobate flow, partially covered by sediment
01:36:03	22.21457	176.60770	1736	22.21501	176.60873	white patches
01:36:10	22.21457	176.60769	1737	22.21501	176.60873	dark material: manganese?
01:36:24	22.21458	176.60766	1736	22.21487	176.60883	temperature anomaly 0.15 °C
01:36:38	22.21459	176.60763	1736	22.21479	176.60862	dark material = scoria
01:36:59	22.21460	176.60760	1735	22.21475	176.60887	still lobate flow
01:37:10	22.21460	176.60758	1735	22.21489	176.60857	temperature rises again
01:37:25	22.21461	176.60755	1734	22.21492	176.60888	breccia of lobate material
01:37:35	22.21461	176.60753	1734	22.21458	176.60857	crinoids
01:37:51	22.21463	176.60750	1733	22.21493	176.60877	gorgonian
01:38:05	22.21464	176.60747	1734	22.21503	176.60857	still cloudy
01:38:12	22.21465	176.60746	1735	22.21503	176.60857	lobate flow
01:38:53	22.21467	176.60739	1732	22.21495	176.60870	still lobate flow
01:39:05	22.21468	176.60737	1729	22.21474	176.60860	broken lobate flow
01:39:20	22.21469	176.60735	1730	22.21497	176.60851	gorgonian
01:39:43	22.21469	176.60731	1730	22.21485	176.60847	temperature anomaly 0.18 °C, crinoid
01:40:21	22.21469	176.60726	1727	22.21490	176.60843	sedimented rubble, scarp
01:40:46	22.21469	176.60723	1723	22.21471	176.60846	gorgonians
01:40:52	22.21468	176.60723	1723	22.21471	176.60846	looking more slaby
01:41:03	22.21468	176.60721	1722	22.21473	176.60861	DV off 25 min
01:41:31	22.21467	176.60718	1721	22.21489	176.60858	lobate flow

Station 72 OFOS; commenced 26-10-02; page 8 of 10						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
01:42:02	22.21467	176.60715	1718	22.21485	176.60846	ridge parallel structure
01:42:26	22.21467	176.60711	1720	22.21474	176.60832	temperature dropping
01:42:37	22.21467	176.60710	1719	22.21471	176.60839	clinkered material
01:43:08	22.21468	176.60705	1721	22.21497	176.60824	black sand between rubble, clinkered material, partially sedimented
01:44:05	22.21469	176.60694	1722	22.21495	176.60840	crinoid
01:44:17	22.21470	176.60693	1719	22.21481	176.60794	scarp
01:44:27	22.21470	176.60691	1720	22.21473	176.60798	ridge parallel scarp
01:44:47	22.21471	176.60688	1721	22.21486	176.60815	gorgonians
01:45:27	22.21471	176.60683	1721	22.21460	176.60804	gorgonians
01:46:32	22.21471	176.60677	1724	22.21494	176.60797	still some gorgonians
01:47:06	22.21470	176.60674	1727	22.21497	176.60778	rubble partially sedimented
01:47:42	22.21469	176.60672	1728	22.21489	176.60758	gorgonians
01:48:07	22.21470	176.60670	1729	22.21488	176.60785	gorgonian
01:49:09	22.21472	176.60665	1728	22.21502	176.60765	gorgonians
01:49:26	22.21472	176.60662	1729	22.21501	176.60750	gorgonian
01:49:37	22.21472	176.60661	1729	22.21487	176.60759	still clinkered material
01:50:39	22.21478	176.60653	1730	22.21480	176.60773	antipatharian
01:51:22	22.21481	176.60649	1731	22.21496	176.60753	temperature rises
01:51:47	22.21482	176.60646	1731	22.21466	176.60761	sediment cover
01:52:25	22.21482	176.60643	1732	22.21494	176.60758	some patches of dark sediment
01:52:48	22.21482	176.60642	1732	22.21491	176.60738	antipatharian
01:52:59	22.21482	176.60641	1732	22.21518	176.60752	temperature drops
01:53:09	22.21482	176.60641	1732	22.21500	176.60752	temperature anomaly 0.1 °C
01:54:12	22.21479	176.60638	1731	22.21501	176.60734	heavy mottled sediment cover
01:54:29	22.21478	176.60638	1731	22.21494	176.60731	gorgonian
01:54:47	22.21477	176.60638	1731	22.21517	176.60762	tube?
01:55:11	22.21475	176.60637	1732	22.21496	176.60710	crinoid
01:55:45	22.21472	176.60636	1732	22.21505	176.60720	little scarp
01:55:52	22.21472	176.60636	1732	22.21505	176.60720	gorgonian
01:56:13	22.21472	176.60634	1732	22.21506	176.60710	lobate flow
01:56:24	22.21472	176.60634	1732	22.21506	176.60719	yellowish hydrothermal staining on top of a tubular flow?
01:57:34	22.21475	176.60624	1732	22.21503	176.60718	grey and black sediment
01:57:48	22.21476	176.60622	1732	22.21516	176.60719	gorgonians
01:58:07	22.21477	176.60619	1731	22.21488	176.60674	temperature rising
01:58:56	22.21478	176.60613	1732	22.21484	176.60695	clinkered material
01:59:48	22.21478	176.60609	1732	22.21480	176.60716	temperature anomaly 0.08 °C
02:01:54	22.21485	176.60599	1733	22.21494	176.60733	sediment on flow surface
02:02:33	22.21489	176.60595	1733	22.21493	176.60698	fish
02:03:17	22.21493	176.60591	1734	22.21504	176.60686	clinkered material
02:03:59	22.21498	176.60589	1736	22.21494	176.60714	slaby lava, sediment dusted
02:03:59	22.21498	176.60589	1736	22.21494	176.60714	gorgonian
02:05:45	22.21510	176.60589	1734	22.21488	176.60689	gorgonians
02:06:01	22.21511	176.60590	1732	22.21498	176.60644	clinkered, slaby lava, minor sediment, grey mottled sediment, heavy sediment cover
02:08:28	22.21527	176.60599	1734	22.21493	176.60653	slaby material
02:10:13	22.21543	176.60599	1733	22.21528	176.60663	sediment on top of a flow, lava is more blocky not so much clinkery
02:11:17	22.21553	176.60595	1733	22.21536	176.60671	heavily sediment cover
02:12:20	22.21561	176.60591	1732	22.21528	176.60672	sediment
02:14:54	22.21571	176.60597	1734	22.21545	176.60666	mottled sediment
02:15:09	22.21572	176.60598	1733	22.21547	176.60673	hydrothermal sediment -> little temperature anomaly
02:15:54	22.21576	176.60598	1734	22.21579	176.60679	yellowish staining -> hydrothermal sediment
02:17:45	22.21581	176.60599	1733	22.21585	176.60697	crinoid
02:18:05	22.21582	176.60599	1731	22.21561	176.60657	slaby lava, sediment cover
02:19:25	22.21583	176.60605	1731	22.21558	176.60663	sandy sediment with debris
02:20:25	22.21584	176.60611	1731	22.21566	176.60702	light sediment patch -> altered?
02:20:52	22.21585	176.60615	1731	22.21581	176.60674	gorgonian
02:21:47	22.21585	176.60625	1732	22.21581	176.60678	mottled grey sediment, with some debris
02:23:58	22.21586	176.60648	1729	22.21586	176.60714	ditto
02:24:48	22.21587	176.60657	1729	22.21555	176.60720	clinkery meterial, partially covered by sediment
02:25:30	22.21586	176.60664	1728	22.21568	176.60711	scarp
02:26:24	22.21586	176.60672	1730	22.21591	176.60714	slabs, sediment dustings
02:26:52	22.21587	176.60676	1728	22.21596	176.60710	gorgonian
02:28:10	22.21588	176.60686	1728	22.21585	176.60717	sedimented surface, slabs
02:28:37	22.21589	176.60689	1728	22.21567	176.60722	gorgonian
02:28:42	22.21589	176.60690	1726	22.21567	176.60722	little scarp
02:28:51	22.21589	176.60691	1726	22.21591	176.60739	still going up on the scarp
02:29:05	22.21590	176.60693	1726	22.21621	176.60674	gorgonian, clinkery material
02:30:07	22.21588	176.60702	1725	22.21721	176.60799	tube?
02:30:15	22.21587	176.60703	1725	22.21721	176.60799	another scarp

Station 72 OFOS; commenced 26-10-02; page 9 of 10						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
02:30:40	22.21586	176.60707	1724	22.21721	176.60799	tubes? on side of the scarp
02:31:09	22.21585	176.60713	1724	22.21701	176.60802	sediment cover on top
02:31:41	22.21584	176.60719	1724	22.21667	176.60758	tracks, DV on
02:32:17	22.21583	176.60726	1726	22.21588	176.60762	DV off 1 min
02:32:25	22.21583	176.60727	1726	22.21588	176.60762	clinkered slabs
02:33:08	22.21582	176.60734	1726	22.21587	176.60754	regular clinkered surface, sediment between
02:33:26	22.21581	176.60737	1725	22.21587	176.60754	gorgonian
02:33:36	22.21581	176.60738	1722	22.21588	176.60758	going up a scarp
02:34:04	22.21581	176.60743	1722	22.21594	176.60784	volcanic crust on top, breaks up at scarps
02:35:18	22.21584	176.60753	1721	22.21570	176.60770	clinkered surface, rubble
02:36:09	22.21585	176.60760	1721	22.21593	176.60762	crinoid
02:36:33	22.21586	176.60763	1718	22.21585	176.60796	clinkered material still
02:37:09	22.21587	176.60768	1716	22.21579	176.60799	black sand between debris
02:38:35	22.21588	176.60779	1712	22.21581	176.60844	outcrop getting more lobate
02:39:45	22.21589	176.60790	1711	22.21571	176.60816	climb a small scarp
02:40:12	22.21589	176.60793	1711	22.21559	176.60808	temperature is rising
02:40:26	22.21589	176.60796	1711	22.21584	176.60811	lobate lava
02:41:22	22.21590	176.60806	1716	22.21577	176.60841	tubes
02:41:47	22.21590	176.60811	1717	22.21576	176.60846	tubes again
02:42:13	22.21590	176.60815	1715	22.21579	176.60846	scarp
02:43:24	22.21588	176.60830	1718	22.21581	176.60862	tubular flow
02:44:37	22.21584	176.60846	1723	22.21570	176.60871	sediment dusting on flows
02:45:01	22.21583	176.60851	1722	22.21581	176.60862	cloudy water, temperature peak
02:45:52	22.21581	176.60862	1723	22.21572	176.60881	DV on
02:46:08	22.21580	176.60865	1723	22.21572	176.60888	high temperature peak
02:46:23	22.21579	176.60869	1723	22.21587	176.60873	scarp
02:46:46	22.21579	176.60874	1725	22.21583	176.60895	tubes, tube breccia, some sessile fauna
02:47:09	22.21579	176.60877	1727	22.21573	176.60860	scarp, yellow staining -> native sulfur?
02:47:59	22.21581	176.60887	1728	22.21575	176.60882	sedimented tubes, crinoid
02:48:27	22.21583	176.60891	1728	22.21584	176.60891	barnacles
02:48:45	22.21585	176.60894	1726	22.21574	176.60900	again temperature peak
02:49:02	22.21586	176.60895	1726	22.21575	176.60891	yellow stuff
02:49:45	22.21589	176.60901	1722	22.21590	176.60911	DV off 5 min, hydrothermal patches, red and yellow
02:50:37	22.21592	176.60907	1714	22.21568	176.60928	scarp
02:51:14	22.21593	176.60911	1715	22.21589	176.60946	talus with hydrothermal precipitates on walls, temperature is low again, temperature anomaly was 0.28 °C
02:53:05	22.21594	176.60929	1717	22.21581	176.60954	edge of the scarp
02:53:39	22.21593	176.60936	1717	22.21596	176.60951	getting clinkery now
02:56:21	22.21591	176.60976	1734	22.21586	176.60975	turn to NNE
02:59:20	22.21603	176.60995	1755	22.21696	176.60979	steep slope, talus
03:00:59	22.21603	176.60992	1764	22.21634	176.61026	ditto
03:01:20	22.21602	176.60992	1766	22.21614	176.60990	talus breccia, smooth blocks
03:03:09	22.21591	176.60990	1771	22.21635	176.61058	scarp
03:04:21	22.21586	176.60984	1777	22.21623	176.61044	sediment covered minor rubble
03:06:08	22.21587	176.60972	1781	22.21644	176.61052	heavy sediment cover
03:07:39	22.21584	176.60964	1779	22.21600	176.61072	heavy sediment cover, few blocks
03:11:51	22.21560	176.60955	1774	22.21609	176.61032	some blocks with sediment between
03:12:42	22.21559	176.60947	1773	22.21614	176.61042	fragmented talus
03:12:59	22.21559	176.60945	1772	22.21608	176.61043	scarp
03:14:07	22.21555	176.60939	1769	22.21611	176.61031	scarp
03:18:39	22.21536	176.60919	1761	22.21582	176.60996	Ceriantharia
03:20:24	22.21525	176.60909	1757	22.21590	176.60984	dislocated material, talus
03:20:59	22.21521	176.60906	1758	22.21572	176.60998	massive and tubular lava
03:23:06	22.21509	176.60894	1757	22.21591	176.60980	scarp
03:23:19	22.21507	176.60892	1756	22.21562	176.60960	tubular lava
03:24:29	22.21503	176.60885	1754	22.21548	176.60994	black sand and scoriaceous material
03:26:17	22.21496	176.60872	1751	22.21536	176.60959	still scarp
03:26:46	22.21495	176.60868	1752	22.21571	176.60976	sediment on clinkery material
03:26:57	22.21495	176.60867	1751	22.21540	176.60925	first lobate flow
03:28:06	22.21491	176.60858	1755	22.21538	176.60965	rhodalid?
03:28:38	22.21489	176.60854	1754	22.21544	176.60966	all fragmented material
03:28:51	22.21489	176.60853	1754	22.21547	176.60928	heavily sedimented rubble
03:30:02	22.21485	176.60844	1749	22.21513	176.60916	tube lava
03:30:31	22.21484	176.60841	1748	22.21537	176.60927	heavily sedimented rubble, gorgonian
03:31:21	22.21481	176.60836	1746	22.21535	176.60915	sediment covered tubes
03:31:38	22.21481	176.60833	1745	22.21537	176.60941	crinoid?
03:33:02	22.21475	176.60824	1740	22.21531	176.60918	scarp
03:33:22	22.21473	176.60822	1738	22.21535	176.60925	tubular flow
03:34:06	22.21471	176.60817	1740	22.21508	176.60908	black sand in a depression
03:34:52	22.21468	176.60813	1744	22.21529	176.60892	mottled sediment
03:36:09	22.21463	176.60806	1740	22.21506	176.60874	sediment on rubble, gorgonian

Station 72 OFOS; commenced 26-10-02; page 10 of 10						
Time (UTC)	**Ship Lat. (°S)**	**Ship Long. (°W)**	**Cable (m)**	**Sub Lat. (°S)**	**Sub Long. (°W)**	**Comment**
03:37:49	22.21456	176.60798	1737	22.21510	176.60910	tubular flows, sedimented
03:38:31	22.21452	176.60795	1736	22.21511	176.60879	heavily mottled grey sedimented
03:39:08	22.21448	176.60793	1734	22.21504	176.60871	white patches
03:39:23	22.21446	176.60793	1735	22.21494	176.60857	rubble material -> very black, temperature rises
03:39:46	22.21443	176.60792	1736	22.21510	176.60869	white patches on rubble
03:40:09	22.21440	176.60791	1735	22.21491	176.60853	shimmering water
03:40:20	22.21439	176.60791	1735	22.21494	176.60870	DV on
03:40:29	22.21438	176.60791	1735	22.21510	176.60856	gastropods
03:41:04	22.21433	176.60791	1734	22.21490	176.60853	temperature anomaly 0.15 °C
03:41:27	22.21429	176.60791	1737	22.21507	176.60851	yellow patches
03:41:58	22.21424	176.60793	1738	22.21505	176.60854	aristeid prawn
03:42:28	22.21417	176.60793	1736	22.21479	176.60850	white patches, barnacles
03:43:01	22.21410	176.60795	1735	22.21490	176.60842	rubble, clinkery flow, white patches
03:43:17	22.21406	176.60796	1734	22.21504	176.60854	tubes, temperature rising again
03:43:52	22.21398	176.60797	1736	22.21474	176.60851	yellow patches between debris!
03:44:10	22.21393	176.60798	1736	22.21465	176.60843	tubes
03:44:43	22.21385	176.60799	1739	22.21471	176.60841	still lobate flow with yellow patches
03:45:06	22.21379	176.60799	1737	22.21462	176.60854	yellow staining (native sulfur)
03:45:41	22.21370	176.60799	1737	22.21466	176.60851	seems to be young
03:45:58	22.21366	176.60800	1737	22.21476	176.60844	new temperature rise
03:46:09	22.21363	176.60800	1736	22.21443	176.60836	ropy lava tubes
03:46:20	22.21360	176.60799	1736	22.21493	176.60849	tube
03:46:32	22.21357	176.60800	1736	22.21460	176.60864	still yellow patches
03:46:43	22.21354	176.60800	1736	22.21487	176.60881	gorgonian
03:46:52	22.21351	176.60800	1738	22.21487	176.60881	gorgonian
03:47:38	22.21339	176.60803	1737	22.21453	176.60833	gorgonians
03:47:46	22.21338	176.60803	1736	22.21456	176.60825	DV off 7 min
03:48:01	22.21334	176.60805	1735	22.21444	176.60831	no sediment
03:48:27	22.21329	176.60808	1736	22.21425	176.60842	gorgonians
03:49:02	22.21322	176.60813	1738	22.21409	176.60858	clinkered material, temperature anomaly 0.20 °C
03:50:08	22.21309	176.60821	1741	22.21397	176.60864	still clinkered material
03:51:32	22.21297	176.60820	1744	22.21396	176.60892	still clinkered material
03:52:09	22.21296	176.60814	1743	22.21367	176.60868	irregular coarse clinkery surface
03:52:48	22.21296	176.60808	1745	22.21382	176.60888	temperature at background
03:54:53	22.21287	176.60795	1745	22.21353	176.60875	gorgonian
03:55:05	22.21286	176.60795	1745	22.21352	176.60902	gorgonian
03:55:27	22.21284	176.60796	1746	22.21355	176.60884	rough clinkered surface, sediment between blocks, structure
03:57:04	22.21274	176.60800	1746	22.21325	176.60887	clinkered surface, no sediment
03:58:57	22.21272	176.60796	1748	22.21310	176.60763	ditto
04:00:57	22.21280	176.60780	1744	22.21497	176.60850	ditto
04:03:22	22.21275	176.60769	1746	22.21306	176.60854	still clinkered, sedimented lava
04:05:00	22.21263	176.60767	1745	22.21337	176.60841	small scarp
04:07:53	22.21229	176.60780	1747	22.21288	176.60841	sediment dusted clinker
04:08:24	22.21223	176.60784	1743	22.21274	176.60827	crinoid
04:09:22	22.21213	176.60787	1736	22.21227	176.60760	possible scarp
04:12:56	22.21198	176.60777	1749	22.21248	176.60835	ditto
04:15:27	22.21183	176.60769	1753	22.21250	176.60823	scarp
04:20:01	22.21126	176.60778	1757	22.21284	176.60785	ditto
04:23:20	22.21098	176.60798	1763	22.21157	176.60882	clinkered flow
04:23:32	22.21096	176.60799	1757	22.21143	176.60890	start heaving,1763 m cable length, tapes off
05:07:07	22.21115	176.60800	9917	22.21050	176.60808	OFOS on deck, end of station

Station 73 OFOS; commenced 27-10-02; page 1 of 7						
Time (UTC)	**Ship Lat. (°S)**	**Ship Long. (°W)**	**Cable (m)**	**Sub Lat. (°S)**	**Sub Long. (°W)**	**Comment**
08:14						OFOS in water, begin of station 73 OFOS
08:50:14	22.68249	176.73766	1814	22.68352	176.73774	bottom within view
08:51:03	22.68245	176.73776	1817	22.68350	176.73782	sediment with some debris
08:52:29	22.68236	176.73790	1818	22.68326	176.73776	ditto
08:53:05	22.68232	176.73792	1818	22.68321	176.73779	some sediment, reddish staining, volcanic debris
08:53:53	22.68226	176.73791	1818	22.68327	176.73784	tapes on
08:54:37	22.68223	176.73786	1816	22.68350	176.73773	still reddish stained sediment
08:55:05	22.68221	176.73782	1817	22.68316	176.73786	very flat surface, sediment covered volcanic debris, possible bombs
08:55:51	22.68218	176.73777	1818	22.68341	176.73795	DV on
08:56:58	22.68214	176.73777	1819	22.68304	176.73787	still red staining, some hydrothermal crust

Station 73 OFOS; commenced 27-10-02; page 2 of 7						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
08:57:36	22.68212	176.73781	1820	22.68311	176.73788	single debris
08:58:29	22.68208	176.73785	1820	22.68328	176.73809	ditto
08:59:08	22.68204	176.73786	1819	22.68329	176.73785	big ripples on yellow-orange sediment
09:00:05	22.68197	176.73783	1818	22.68288	176.73768	sediment covered crust, few blocks of volcanic debris
09:00:57	22.68192	176.73780	1816	22.68316	176.73775	brittle star
09:01:06	22.68190	176.73780	1816	22.68295	176.73771	some ripples
09:01:14	22.68190	176.73779	1815	22.68295	176.73771	DV off 5 min
09:01:40	22.68187	176.73779	1815	22.68286	176.73773	DV on, sulfides - oxides
09:02:18	22.68182	176.73777	1813	22.68302	176.73782	flat sediment covered mound, volcanic debris
09:03:28	22.68176	176.73776	1811	22.68280	176.73783	volcanic debris
09:03:37	22.68176	176.73776	1811	22.68283	176.73811	DV off 3 min
09:04:30	22.68171	176.73777	1811	22.68260	176.73780	hard black and grey sand
09:04:56	22.68168	176.73778	1811	22.68317	176.73775	black sand
09:05:07	22.68168	176.73779	1811	22.68271	176.73796	flat surface
09:06:16	22.68162	176.73782	1809	22.68302	176.73792	grey mottled sediment, some red staining without temperature anomaly
09:06:42	22.68160	176.73783	1809	22.68277	176.73774	gorgonians, black sand with ripples
09:07:27	22.68156	176.73785	1808	22.68260	176.73781	black sand, orange material
09:08:09	22.68152	176.73786	1806	22.68267	176.73758	gorgonian
09:08:34	22.68150	176.73786	1806	22.68256	176.73759	black sand, ripples, brittle star
09:08:47	22.68149	176.73785	1804	22.68277	176.73775	some orange colouration
09:09:21	22.68144	176.73783	1803	22.68236	176.73775	volcanic outcrop
09:09:51	22.68140	176.73780	1802	22.68268	176.73812	sponge and gorgonian, volcanic outcrop, covered by black sand
09:10:27	22.68135	176.73776	1800	22.68244	176.73786	lot of orange debris
09:10:42	22.68132	176.73774	1800	22.68273	176.73775	sponge
09:10:56	22.68130	176.73773	1799	22.68262	176.73767	volcanic outcrop, lobate
09:11:51	22.68122	176.73768	1795	22.68260	176.73800	scarp
09:12:20	22.68118	176.73766	1796	22.68240	176.73752	lobate lava along the scarp
09:13:02	22.68112	176.73764	1799	22.68221	176.73762	black sand at base of scarp (6 m)
09:13:32	22.68108	176.73763	1799	22.68210	176.73772	small orange oxidized clasts
09:14:02	22.68104	176.73763	1796	22.68224	176.73757	DV on, lobate outcrop
09:14:22	22.68102	176.73763	1795	22.68229	176.73763	orange coloration along fractures
09:14:46	22.68101	176.73763	1794	22.68227	176.73748	scarp
09:14:57	22.68099	176.73763	1794	22.68228	176.73745	DV off, 1 min
09:15:25	22.68094	176.73764	1795	22.68194	176.73747	patches of black sand on crust
09:15:58	22.68090	176.73765	1795	22.68168	176.73759	thin platy-like fragments -> broken hydrothermal crust, orange in colour, in black sand
09:17:00	22.68080	176.73769	1793	22.68221	176.73727	black sand with hydrothermal crust fragments, gorgonian
09:17:22	22.68072	176.73770	1793	22.68166	176.73764	rippled black sand
09:18:07	22.68049	176.73770	1793	22.68165	176.73758	grey mottled sediment, some ripples
09:19:21	22.68076	176.73780	1791	22.68184	176.73736	some biogeneous material
09:19:44	22.68073	176.73780	1790	22.68207	176.73776	grey mottled sediment, flat surface
09:21:09	22.68059	176.73776	1790	22.68176	176.73776	biology: young gorgonians or polychaete worms?
09:21:39	22.68052	176.73774	1790	22.68150	176.73760	grey mottled sediment, minor debris
09:22:29	22.68044	176.73769	1788	22.68164	176.73746	ditto
09:22:58	22.68038	176.73765	1787	22.68177	176.73758	grey mottled sediment, flat surface, antipatharian
09:23:53	22.68029	176.73759	1787	22.68141	176.73748	black sand
09:24:53	22.68019	176.73752	1786	22.68140	176.73758	brittle star
09:25:34	22.68013	176.73748	1786	22.68147	176.73742	rippled black and grey sand
09:26:06	22.68008	176.73745	1786	22.68142	176.73743	minor volcanic debris, rippled sediment
09:26:31	22.68005	176.73743	1785	22.68155	176.73740	volcanic outcrop, sediment cover, crinoids
09:27:01	22.68000	176.73742	1785	22.68119	176.73760	gorgonians, mottled grey sediment, black sand patches
09:27:55	22.67995	176.73743	1786	22.68143	176.73716	rippled grey mottled sediment
09:28:41	22.67992	176.73749	1784	22.68108	176.73714	black sand
09:29:01	22.67991	176.73752	1784	22.68125	176.73729	actinians
09:29:18	22.67989	176.73753	1782	22.68128	176.73724	DV on
09:30:00	22.67986	176.73758	1779	22.68096	176.73714	grey mottled sediment
09:30:08	22.67985	176.73759	1779	22.68078	176.73726	DV off 1 min
09:30:22	22.67984	176.73760	1780	22.68109	176.73731	scarp, volcanic debris
09:30:42	22.67982	176.73762	1779	22.68070	176.73714	going down the scarp, looks like lobate lava at the scarp surface
09:32:08	22.67971	176.73766	1784	22.68079	176.73715	still lobate lava, scarp going deeper
09:32:59	22.67964	176.73767	1781	22.68083	176.73713	lobate lava
09:34:05	22.67954	176.73767	1784	22.68100	176.73725	volcanic outcrop, crinoids, brittle stars
09:34:26	22.67952	176.73766	1785	22.68076	176.73733	lobate lava
09:34:56	22.67946	176.73765	1789	22.68069	176.73731	going down a scarp, some grey mottled sediment, volcanic debris
09:35:40	22.67940	176.73763	1795	22.68066	176.73736	volcanic debris
09:36:05	22.67935	176.73762	1798	22.68048	176.73759	10-20 cm fragments, irregular, densely packed
09:36:29	22.67931	176.73761	1800	22.68047	176.73746	gorgonians

Station 73 OFOS; commenced 27-10-02; page 3 of 7						
Time (UTC)	**Ship Lat. (°S)**	**Ship Long. (°W)**	**Cable (m)**	**Sub Lat. (°S)**	**Sub Long. (°W)**	**Comment**
09:37:09	22.67925	176.73759	1801	22.68041	176.73724	scarp like before, lobate flows, crinoids
09:37:40	22.67920	176.73757	1805	22.68043	176.73722	sponges
09:38:13	22.67915	176.73754	1809	22.68052	176.73736	stalked crinoids
09:38:24	22.67913	176.73754	1809	22.68011	176.73730	grey mottled sediment, volcanic detritus
09:39:05	22.67906	176.73750	1813	22.68035	176.73719	sedimented flow surface
09:39:51	22.67900	176.73745	1818	22.68045	176.73720	more debris, still flow surface
09:40:46	22.67891	176.73740	1823	22.68027	176.73728	grey mottled sediment, minor volcanic detritus
09:41:38	22.67882	176.73735	1828	22.68032	176.73725	ditto
09:43:00	22.67870	176.73726	1831	22.67975	176.73719	still grey mottled sediment, few ripples
09:43:48	22.67863	176.73722	1830	22.67968	176.73701	volcanic outcrop, covered by grey mottled sediment, 2 brittle stars
09:44:17	22.67858	176.73718	1830	22.67981	176.73705	sponge
09:44:27	22.67856	176.73717	1829	22.67991	176.73706	volcanic sediment, volcanic debris
09:45:33	22.67848	176.73709	1824	22.67974	176.73698	grey mottled sediment, brittle star
09:46:54	22.67837	176.73700	1816	22.67961	176.73710	grey mottled sediment, minor volcanic detritus
09:47:22	22.67833	176.73697	1813	22.67964	176.73701	black sand, volcanic detritus
09:48:27	22.67823	176.73693	1804	22.67970	176.73696	volcanic outcrop? covered by volcanic sediment
09:48:55	22.67819	176.73691	1801	22.67946	176.73680	lobate flow
09:49:30	22.67813	176.73689	1798	22.67962	176.73661	sediment on flow surface
09:50:17	22.67806	176.73685	1799	22.67962	176.73686	antipatharia, volcanic detritus
09:50:44	22.67802	176.73684	1798	22.67938	176.73684	crinoid
09:51:00	22.67799	176.73682	1797	22.67938	176.73685	volcanic detritus and sediment, actinian
09:51:56	22.67791	176.73678	1798	22.67938	176.73673	volcanic detritus, black sand
09:52:21	22.67788	176.73676	1798	22.67886	176.73666	lots of volcanic detritus
09:53:08	22.67782	176.73673	1800	22.67908	176.73659	ditto
09:53:54	22.67775	176.73670	1803	22.67927	176.73664	volcanic sediment, minor volcanic debris, along a slope
09:54:37	22.67769	176.73668	1805	22.67901	176.73674	aristeid prawn
09:55:06	22.67766	176.73668	1808	22.67888	176.73664	crinoid
09:55:21	22.67764	176.73669	1809	22.67891	176.73671	volcanic debris, some staining
09:56:19	22.67759	176.73671	1808	22.67872	176.73675	hydrothemal crust fragments, brittle star
09:56:53	22.67755	176.73672	1807	22.67899	176.73663	nice crust, black sand below crust, similar to Hine Hina
09:57:34	22.67750	176.73672	1805	22.67878	176.73645	brittle star on grey mottled sediment
09:57:54	22.67748	176.73672	1804	22.67841	176.73659	aristeid prawn, grey mottled sediment on hydrothermal crust
09:58:32	22.67743	176.73672	1805	22.67856	176.73661	brittle star on hydrothermal crust
09:58:48	22.67741	176.73671	1805	22.67867	176.73653	platy fragments of crust
09:59:07	22.67739	176.73670	1805	22.67869	176.73626	brittle star
09:59:31	22.67735	176.73669	1806	22.67862	176.73637	brittle star, hydrothermal crust fragments
10:00:17	22.67730	176.73667	1805	22.67867	176.73635	grey mottled sediment, orange hydrothermal crust fragments
10:00:40	22.67726	176.73666	1804	22.67827	176.73635	brittle star
10:01:11	22.67722	176.73664	1803	22.67853	176.73654	ditto
10:01:22	22.67721	176.73663	1802	22.67841	176.73637	brittle star, some ripples
10:01:58	22.67717	176.73660	1801	22.67849	176.73657	yellow-orange staining
10:02:38	22.67712	176.73657	1798	22.67825	176.73631	DV on, contact to altered crust fragments
10:03:39	22.67705	176.73654	1795	22.67836	176.73659	grey sediment with orange hydrothermal crust fragments
10:04:20	22.67699	176.73651	1792	22.67815	176.73637	volcanic outcrop, scarp
10:04:45	22.67697	176.73650	1788	22.67795	176.73641	orange staining on scarp walls
10:05:03	22.67695	176.73649	1785	22.67823	176.73621	DV off, 2 min
10:05:22	22.67691	176.73648	1785	22.67804	176.73629	top of scarp, grey mottled sediment on crust, orange staining
10:06:46	22.67680	176.73642	1779	22.67820	176.73626	grey mottled sediment, some volcanic debris, outcrop, brittle star, much pen-like biology
10:08:15	22.67667	176.73635	1775	22.67791	176.73631	black sediment, ripples
10:09:19	22.67660	176.73630	1775	22.67770	176.73609	cable length 1774 m
10:09:46	22.67656	176.73627	1775	22.67769	176.73610	slope
10:10:35	22.67650	176.73622	1776	22.67782	176.73621	rubble and sandy sediment, going down now
10:11:43	22.67640	176.73638	1777	22.67732	176.73632	grey mottled sediment
10:12:22	22.67634	176.73612	1778	22.67749	176.73586	sponge, grey mottled sediment
10:13:07	22.67627	176.73608	1779	22.67749	176.73603	fish
10:13:28	22.67625	176.73607	1780	22.67742	176.73598	brittle star
10:14:18	22.67616	176.73604	1783	22.67782	176.73597	grey mottled sediment
10:14:31	22.67615	176.73603	1784	22.67726	176.73579	gorgonian
10:14:45	22.67613	176.73603	1785	22.67732	176.73583	minor volcanic debris
10:15:14	22.67610	176.73601	1786	22.67733	176.73574	gorgonian
10:15:33	22.67608	176.73601	1788	22.67738	176.73568	yellow staining along a contact between detritus and sediment?
10:16:19	22.67604	176.73601	1790	22.67703	176.73588	2 brittle stars
10:16:43	22.67601	176.73601	1791	22.67705	176.73594	gorgonian, 3 brittle stars
10:17:20	22.67597	176.73602	1789	22.67724	176.73578	3 brittle stars
10:17:53	22.67594	176.73603	1790	22.67701	176.73587	minor volcanic detritus

Station 73 OFOS; commenced 27-10-02; page 4 of 7						
Time	Ship		Cable	Sub		Comment
(UTC)	Lat. (°S)	Long. (°W)	(m)	Lat. (°S)	Long. (°W)	
10:18:26	22.67589	176.73605	1791	22.67658	176.73576	grey mottled sediment, minor volcanic debris
10:18:45	22.67588	176.73605	1791	22.67703	176.73556	orange fragments
10:19:04	22.67586	176.73606	1790	22.67700	176.73567	orange crust fragments
10:19:34	22.67583	176.73607	1789	22.67706	176.73579	outcrop, little scarp
10:20:12	22.67579	176.73608	1788	22.67698	176.73581	gorgonian
10:20:28	22.67577	176.73608	1787	22.67691	176.73575	grey mottled sediment, volcanic debris
10:21:05	22.67572	176.73609	1787	22.67704	176.73584	?Ceriantharia?
10:21:21	22.67570	176.73609	1788	22.67678	176.73591	lobate volcanic outcrop, sediment contact
10:21:54	22.67566	176.73609	1789	22.67704	176.73590	grey mottled sediment
10:22:16	22.67564	176.73609	1791	22.67652	176.73569	gorgonian
10:22:27	22.67562	176.73609	1791	22.67675	176.73559	volcanic debris/outcrop
10:23:11	22.67557	176.73608	1793	22.67650	176.73578	grey mottled sediment
10:24:01	22.67552	176.73605	1796	22.67654	176.73567	grey mottled sediment, volcanic debris
10:25:08	22.67544	176.73600	1798	22.67683	176.73610	grey mottled sediment
10:25:54	22.67538	176.73597	1798	22.67641	176.73581	volcanic outcrop
10:26:08	22.67536	176.73596	1797	22.67672	176.73569	little scarp
10:26:36	22.67532	176.73594	1797	22.67644	176.73578	grey mottled sediment
10:27:08	22.67528	176.73592	1797	22.67628	176.73576	some volcanic debris
10:27:48	22.67523	176.73589	1799	22.67655	176.73564	volcanic outcrop on a little scarp
10:29:35	22.67510	176.73578	1804	22.67628	176.73575	grey mottled sediment, minor volcanic debris/outcrops
10:30:00	22.67506	176.73576	1804	22.67604	176.73575	outcrop of lobate flow, little scarp
10:30:56	22.67499	176.73570	1804	22.67613	176.73563	talus at base of scarp
10:31:23	22.67495	176.73567	1805	22.67612	176.73559	scarp is parallel to track
10:32:18	22.67487	176.73561	1806	22.67594	176.73553	antipatharian
10:32:26	22.67486	176.73560	1806	22.67604	176.73535	tube
10:32:42	22.67484	176.73559	1807	22.67583	176.73542	grey mottled sediment
10:35:03	22.67466	176.73543	1811	22.67605	176.73535	grey mottled sediment, minor volcanic debris/outcrop
10:36:12	22.67459	176.73538	1812	22.67565	176.73516	ditto
10:36:31	22.67458	176.73537	1813	22.67571	176.73525	sea star
10:37:14	22.67454	176.73537	1814	22.67581	176.73514	some volcanic debris/outcrop with orange staining, sediment cover
10:38:36	22.67448	176.73541	1812	22.67544	176.73508	grey mottled sediment, volcanic debris
10:40:34	22.67440	176.73551	1813	22.67528	176.73505	grey mottled sediment, volcanic debris/outcrop
10:41:36	22.67432	176.73551	1816	22.67524	176.73510	ditto
10:42:08	22.67428	176.73550	1815	22.67501	176.73508	volcanic outcrop, looks like lobate flow
10:43:48	22.67413	176.73546	1815	22.67519	176.73506	volcanic sediment, minor volcanic debris/outcrop
10:44:35	22.67406	176.73543	1816	22.67493	176.73512	little scarp
10:45:53	22.67395	176.73536	1816	22.67517	176.73508	back to grey mottled sediment
10:47:10	22.67384	176.73531	1818	22.67492	176.73484	ditto
10:47:42	22.67380	176.73530	1819	22.67452	176.73512	sponge
10:48:42	22.67371	176.73527	1819	22.67493	176.73518	grey mottled sediment veneer to underlying lobate flow
10:49:54	22.67362	176.73525	1818	22.67467	176.73471	sediment ranges from cm to dm in thickness, locally exposing underlying flow giving surface the appearance of volcanic blocks and bombs
10:52:39	22.67339	176.73524	1817	22.67459	176.73501	hydrothermal sediment
10:56:20	22.67310	176.73523	1822	22.67418	176.73481	grey mottled sediment, some volcanic fragments
10:59:48	22.67284	176.73522	1824	22.67388	176.73486	ditto
11:02:16	22.67262	176.73513	1826	22.67394	176.73459	ditto
11:05:16	22.67235	176.73491	1832	22.67364	176.73464	ditto
11:08:05	22.67206	176.73467	1832	22.67350	176.73466	light and dark coloration along a structure
11:09:01	22.67196	176.73460	1830	22.67328	176.73451	grey mottled sediments, some volcanic fragments/outcrop
11:11:09	22.67177	176.73446	1822	22.67302	176.73431	ditto
11:13:34	22.67158	176.73439	1823	22.67295	176.73400	ditto
11:13:59	22.67154	176.73438	1825	22.67291	176.73402	shrimp
11:16:08	22.67137	176.73434	1828	22.67260	176.73389	ditto
11:16:26	22.67134	176.73433	1829	22.67267	176.73389	aristeid prawn
11:26:50	22.67057	176.73395	1814	22.67172	176.73347	slab
11:27:00	22.67055	176.73395	1814	22.67143	176.73374	volcanic outcrop
11:28:24	22.67047	176.73388	1816	22.67164	176.73376	sandy sediments
11:32:22	22.67023	176.73369	1812	22.67112	176.73320	ditto
11:33:34	22.67015	176.73362	1811	22.67136	176.73322	gorgonian
11:34:46	22.67005	176.73358	1812	22.67101	176.73337	some volcanic fragments with sandy sediment
11:41:43	22.66952	176.73332	1824	22.67067	176.73289	ditto
11:42:19	22.66948	176.73329	1826	22.67061	176.73266	tapes stopped
11:43:06	22.66942	176.73326	1828	22.67041	176.73280	euplectellid sponge
11:51:06	22.66884	176.73323	1827	22.66981	176.73247	ditto
11:55:08	22.66859	176.73315	1821	22.66965	176.73249	sponge
11:56:07	22.66853	176.73312	1820	22.66954	176.73266	flat sandy surface, minor volcanic fragments, cable length 1816 m
12:01:50	22.66810	176.73282	1807	22.66954	176.73248	sponge
12:03:38	22.66795	176.73270	1806	22.66910	176.73229	sandy sediments, minor volcanic fragments

Station 73 OFOS; commenced 27-10-02; page 5 of 7						
Time (UTC)	**Ship Lat. (°S)**	**Ship Long. (°W)**	**Cable (m)**	**Sub Lat. (°S)**	**Sub Long. (°W)**	**Comment**
12:06:20	22.66774	176.73254	1803	22.66883	176.73219	gorgonians
12:08:28	22.66757	176.73245	1799	22.66846	176.73223	prawn
12:08:49	22.66755	176.73243	1798	22.66884	176.73186	outcrop of crust, little scarp
12:09:12	22.66751	176.73243	1798	22.66860	176.73217	lobate flows along scarp, black sand + talus
12:11:04	22.66738	176.73238	1795	22.66830	176.73228	start new tapes
12:11:53	22.66733	176.73237	1793	22.66861	176.73228	small temperature anomaly 0.03 °C
12:13:40	22.66721	176.73234	1789	22.66829	176.73198	rising temperature, still grey mottled sediment, no hydrothermal discolouration
12:15:43	22.66709	176.73230	1783	22.66807	176.73210	gorgonian, sponge
12:16:21	22.66704	176.73229	1780	22.66835	176.73212	volcanic outcrop, covered by sediment
12:18:02	22.66691	176.73224	1775	22.66808	176.73183	some ripples in dark sediment
12:18:17	22.66689	176.73223	1774	22.66782	176.73190	sea star
12:19:02	22.66683	176.73221	1772	22.66790	176.73205	gorgonians, lobate flows, little scarp
12:19:52	22.66676	176.73219	1769	22.66785	176.73181	ripples in black sand
12:20:06	22.66674	176.73218	1769	22.66785	176.73181	red staining
12:20:48	22.66670	176.73216	1767	22.66784	176.73194	many gorgonians
12:22:16	22.66658	176.73213	1765	22.66766	176.73179	sponges, volcanic outcrop, covered by black and grey sand
12:22:58	22.66654	176.73211	1764	22.66760	176.73178	sea star
12:23:40	22.66649	176.73208	1764	22.66771	176.73182	sponges, sea star, gorgonians
12:25:25	22.66636	176.73201	1763	22.66723	176.73183	more sponges
12:26:54	22.66623	176.73194	1763	22.66764	176.73162	volcanic outcrop partially covered by sediment
12:27:19	22.66620	176.73191	1764	22.66752	176.73177	many sponges
12:27:50	22.66615	176.73188	1764	22.66722	176.73157	sea star
12:28:01	22.66614	176.73187	1764	22.66747	176.73168	sponges
12:28:14	22.66612	176.73186	1764	22.66734	176.73201	ripple marks
12:29:47	22.66599	176.73178	1766	22.66733	176.73136	volcanic outcrop partially covered by sediments, sponges
12:31:27	22.66587	176.73172	1770	22.66711	176.73171	aristeid prawn
12:31:44	22.66584	176.73171	1771	22.66670	176.73163	sea star
12:31:59	22.66583	176.73171	1772	22.66718	176.73146	volcanic outcrop partially coverd by sediment, grey and black sand, lobate flow
12:33:09	22.66575	176.73168	1775	22.66683	176.73128	temperature rises
12:33:26	22.66573	176.73167	1776	22.66692	176.73128	shells, scarp
12:33:41	22.66571	176.73167	1777	22.66691	176.73152	sponge
12:35:42	22.66558	176.73164	1786	22.66699	176.73154	grey mottled sediment, volcanic debris/outcrop
12:36:16	22.66555	176.73163	1788	22.66674	176.73130	gorgonian
12:38:25	22.66541	176.73158	1795	22.66622	176.73115	black sand
12:39:05	22.66536	176.73156	1797	22.66645	176.73105	sea star
12:39:55	22.66530	176.73153	1799	22.66637	176.73127	gorgonian
12:40:07	22.66528	176.73152	1800	22.66636	176.73126	ripple marks
12:40:39	22.66524	176.73150	1802	22.66628	176.73103	antipatharian
12:42:07	22.66511	176.73143	1806	22.66599	176.73124	grey mottled sediment, volcanic debris or buried outcrop
12:45:56	22.66474	176.73120	1821	22.66584	176.73084	still a long plateau in temperature, slowly increasing conductivity - diffuse venting?
12:48:49	22.66451	176.73105	1834	22.66585	176.73093	sponge
12:49:49	22.66442	176.73100	1837	22.66563	176.73064	conductivity AND temperature dropping, sponge
12:52:44	22.66421	176.73088	1844	22.66537	176.73104	slow increase in temperature and conductivity?
12:54:11	22.66410	176.73079	1845	22.66528	176.73047	grey mottled sediment
12:58:50	22.66361	176.73046	1854	22.66458	176.73012	there was no increase in temperature, plateau was ~ 0.05 °C above background
13:00:34	22.66339	176.73038	1860	22.66479	176.73000	still grey mottled sediment
13:02:11	22.66317	176.73031	1861	22.66441	176.72997	some ripple marks
13:03:17	22.66302	176.73027	1857	22.66450	176.72958	sea star
13:03:43	22.66297	176.73025	1857	22.66467	176.73021	crinoid
13:04:41	22.66287	176.73020	1856	22.66423	176.72974	grey mottled sediment
13:06:22	22.66271	176.73015	1859	22.66393	176.72960	gorgonian
13:07:19	22.66260	176.73013	1861	22.66401	176.72949	small scarp
13:08:01	22.66252	176.73012	1863	22.66317	176.72731	some staining at scarp
13:10:22	22.66231	176.73005	1863	22.66387	176.72973	sponge, scarp
13:11:40	22.66219	176.73002	1865	22.66370	176.72964	volcanic fragments at base of scarp
13:12:33	22.66210	176.72999	1863	22.66364	176.72967	still some staining
13:13:38	22.66197	176.72997	1856	22.66346	176.72931	contact to black sand
13:14:30	22.66185	176.72995	1851	22.66300	176.72952	volcanic outcrop, some staining
13:15:28	22.66171	176.72992	1844	22.66288	176.72936	scarp
13:16:29	22.66155	176.72988	1838	22.66280	176.72938	lobate flows on scarp
13:17:15	22.66142	176.72985	1835	22.66279	176.72960	still on scarp, tube
13:18:09	22.66127	176.72983	1835	22.66283	176.72957	still on scarp, parallel to the ridge
13:19:01	22.66114	176.72980	1842	22.66275	176.72920	rising temperature
13:19:23	22.66108	176.72979	1845	22.66276	176.72940	talus
13:20:54	22.66089	176.72972	1847	22.66242	176.72914	temperature anomaly was only a little peak
13:21:26	22.66083	176.72970	1845	22.66235	176.72941	still on scarp, scarp parallel to OFOS-track?
13:22:02	22.66076	176.72968	1842	22.66220	176.72936	some talus, temperature increases, still on the scarp

Station 73 OFOS; commenced 27-10-02; page 6 of 7						
Time	Ship		Cable	Sub		Comment
(UTC)	Lat. (°S)	Long. (°W)	(m)	Lat. (°S)	Long. (°W)	
13:22:52	22.66067	176.72964	1840	22.66234	176.72923	still on scarp, temperature peak
13:23:42	22.66058	176.72961	1842	22.65878	176.72813	mottled sediment
13:25:23	22.66038	176.72957	1847	22.65878	176.72813	grey mottled sediment
13:26:09	22.66030	176.72954	1847	22.66097	176.72713	sponge
13:26:51	22.66022	176.72953	1847	22.66186	176.72904	sponges
13:27:47	22.66012	176.72950	1848	22.66136	176.72895	volcanic debris, grey mottled sediment
13:28:22	22.66005	176.72948	1847	22.66179	176.72921	volcanic outcrop, scarp, lobate flow, some black sand
13:28:53	22.65999	176.72947	1846	22.66163	176.72895	gorgonian
13:29:17	22.65995	176.72946	1848	22.66141	176.72918	some small peaks in temperature
13:29:39	22.65991	176.72944	1849	22.66116	176.72848	relatively flat surface covered by grey mottled sediment, some volcanic debris locally
13:31:09	22.65974	176.72940	1857	22.66097	176.72878	black sand
13:31:58	22.65965	176.72939	1862	22.66091	176.72874	gorgonian
13:32:08	22.65963	176.72938	1863	22.66092	176.72907	sponge
13:32:30	22.65959	176.72937	1865	22.66081	176.72871	geology: same as before
13:36:56	22.65913	176.72925	1884	22.66021	176.72873	scarp
13:37:34	22.65907	176.72923	1882	22.66056	176.72876	crust on top?, temperature and conductivity drop
13:38:10	22.65901	176.72921	1883	22.66029	176.72868	grey mottled sediment, minor volcanic debris
13:39:07	22.65891	176.72918	1882	22.66025	176.72894	temperature anomaly was ~ 0.05 °C
13:39:32	22.65887	176.72917	1881	22.65992	176.72860	gorgonian
13:40:01	22.65882	176.72916	1881	22.66021	176.72876	thin cover of soft sediment
13:41:40	22.65864	176.72913	1882	22.66014	176.72848	contact to black sediment
13:42:23	22.65856	176.72910	1884	22.65990	176.72841	again grey mottled sediment
13:45:24	22.65822	176.72897	1884	22.65934	176.72831	grey mottled sediment
13:48:40	22.65783	176.72883	1880	22.65937	176.72837	outcrop, gorgonian
13:48:49	22.65781	176.72883	1880	22.65904	176.72833	outcrop partially sedimented
13:49:19	22.65775	176.72880	1878	22.65914	176.72840	sponge
13:49:25	22.65773	176.72880	1877	22.65914	176.72840	gorgonians
13:50:30	22.65761	176.72874	1879	22.65918	176.72828	gorgonian
13:51:09	22.65753	176.72871	1883	22.65909	176.72834	ditto
13:51:21	22.65751	176.72870	1882	22.65912	176.72850	orange colouration
13:52:03	22.65743	176.72866	1883	22.65909	176.72818	heavy sediment
13:52:18	22.65740	176.72866	1886	22.65905	176.72818	return to more homogeneous sediment cover
13:53:33	22.65726	176.72860	1891	22.65885	176.72808	grey mottled sediment
13:54:39	22.65713	176.72856	1894	22.65868	176.72849	ditto
13:57:45	22.65676	176.72844	1897	22.65807	176.72801	flat topography, grey and black mottled sediment
13:58:56	22.65662	176.72839	1903	22.65779	176.72793	brittle star
14:00:10	22.65647	176.72834	1908	22.65801	176.72816	flat surface, black and grey mottled sediment
14:00:28	22.65644	176.72833	1908	22.65805	176.72765	scarp coming up
14:01:10	22.65635	176.72829	1908	22.65774	176.72816	return to be flat, grey mottled sediment
14:02:11	22.65623	176.72824	1904	22.65704	176.72550	volcanic outcrop, talus at basin of scarp with gorgonian
14:03:25	22.65608	176.72819	1894	22.65779	176.72807	crevasse
14:03:31	22.65607	176.72819	1892	22.65760	176.72774	lobate flow outcrop
14:03:51	22.65603	176.72817	1893	22.65775	176.72748	lobate flow with sediment on top
14:04:06	22.65600	176.72816	1894	22.65779	176.72804	back to grey mottled sediment
14:04:44	22.65592	176.72813	1891	22.65743	176.72765	black sediment with striation
14:05:13	22.65586	176.72812	1888	22.65769	176.72780	DV on
14:06:01	22.65576	176.72808	1884	22.65724	176.72758	altered fragments, orange coloured
14:06:30	22.65570	176.72806	1882	22.65720	176.72783	larger volcanic clasts (orange colour) in black sand
14:07:29	22.65558	176.72802	1880	22.65749	176.72753	back to grey mottled sediment
14:08:18	22.65548	176.72798	1883	22.65716	176.72771	block in sediment
14:08:46	22.65543	176.72796	1887	22.65707	176.72770	lot of black sand
14:09:21	22.65536	176.72793	1892	22.65720	176.72771	black sand
14:09:41	22.65532	176.72791	1895	22.65719	176.72768	grey mottled sediment
14:11:05	22.65516	176.72783	1903	22.65677	176.72770	grey sediment with some fragments, slight slope
14:11:42	22.65508	176.72780	1900	22.65687	176.72769	smooth flat surface, black and grey mottled sediment
14:12:58	22.65494	176.72773	1905	22.65667	176.72771	grey mottled sediment
14:13:07	22.65492	176.72772	1906	22.65658	176.72760	fish
14:13:51	22.65483	176.72768	1907	22.65621	176.72729	more volcanic outcrop
14:14:22	22.65476	176.72766	1905	22.65662	176.72740	sediment covered outcrop, sponge
14:14:39	22.65473	176.72765	1905	22.65611	176.72754	gorgonian
14:15:14	22.65465	176.72761	1906	22.65619	176.72763	volcanic outcrop, lightly sedimeneted
14:16:21	22.65451	176.72756	1908	22.65609	176.72725	gorgonians
14:16:30	22.65450	176.72754	1907	22.65647	176.72750	ditto
14:16:58	22.65444	176.72751	1906	22.65601	176.72710	scarp
14:17:09	22.65442	176.72751	1907	22.65620	176.72710	lobate outcrop partially sedimented
14:17:56	22.65432	176.72747	1906	22.65601	176.72706	rubble on flow top, lightly sedimented
14:18:23	22.65426	176.72744	1906	22.65574	176.72737	pillar, scarp
14:18:52	22.65420	176.72741	1906	22.65555	176.72741	blocky rubble
14:19:13	22.65416	176.72738	1906	22.65577	176.72695	lobate outcrop, some rubble
14:19:52	22.65408	176.72734	1905	22.65542	176.72692	broken tube

Station 73 OFOS; commenced 27-10-02; page 7 of 7						
Time (UTC)	**Ship Lat. (°S)**	**Ship Long. (°W)**	**Cable (m)**	**Sub Lat. (°S)**	**Sub Long. (°W)**	**Comment**
14:20:06	22.65405	176.72732	1904	22.65546	176.72696	sedimented flow top
14:20:15	22.65402	176.72732	1904	22.65568	176.72725	gorgonians
14:20:33	22.65399	176.72730	1904	22.65568	176.72699	gorgonians
14:21:00	22.65392	176.72727	1904	22.65540	176.72681	slab
14:21:13	22.65390	176.72726	1905	22.65539	176.72704	grey mottled sediment cover
14:21:40	22.65384	176.72723	1904	22.65571	176.72675	flatter surface, grey mottled sediment
14:23:51	22.65356	176.72709	1895	22.65558	176.72737	ditto
14:26:57	22.65317	176.72692	1885	22.65496	176.72689	some volcanic fragments on grey mottled sediment
14:29:18	22.65285	176.72678	1879	22.65470	176.72668	sponge
14:30:07	22.65274	176.72673	1877	22.65481	176.72655	grey mottled sediment
14:31:16	22.65259	176.72666	1875	22.65454	176.72654	more outcrop sticking through sediment
14:32:38	22.65242	176.72658	1873	22.65424	176.72643	sponge
14:33:20	22.65233	176.72654	1873	22.65173	176.72584	grey mottled sediment
14:35:18	22.65206	176.72643	1879	22.65381	176.72667	more outcrop sticking through sediment
14:35:47	22.65200	176.72640	1881	22.65359	176.72611	grey mottled sediment
14:36:21	22.65192	176.72638	1879	22.65374	176.72624	start heaving, DV off
14:37:09	22.65182	176.72634	1866	22.65389	176.72622	tapes off
15:19:53	22.65114	176.72250	9989	22.65112	176.72327	OFOS on deck
15:20:12	22.65113	176.72247	9989	22.65112	176.72327	end of station

Station 77 OFOS; commenced 28-10-02; page 1 of 4						
Time (UTC)	**Ship Lat. (°S)**	**Ship Long. (°W)**	**Cable (m)**	**Sub Lat. (°S)**	**Sub Long. (°W)**	**Comment**
01:16:47	22.85778	176.73976	3	22.85301	176.74066	begin of station 77 OFOS
01:55:03	0.00000	0.00000	2001	22.85667	176.74102	2000 m cable length
01:58:22	22.85634	176.73974	2149	22.85632	176.74089	tapes on
01:59:18	22.85635	176.73977	2178	22.85596	176.74092	bottom within view
01:59:35	22.85635	176.73978	2183	22.85596	176.74092	fault scarp
01:59:53	22.85636	176.73979	2184	22.85720	176.74235	outcrop, lobate flow
02:00:42	22.85639	176.73982	2186	22.85604	176.74089	light dusted sediment, looks like YOUNG lava outcrop
02:01:25	22.85640	176.73985	2187	22.85628	176.74085	first picture at no. 512
02:01:38	22.85641	176.73986	2188	22.85617	176.74089	lobate flow breccia
02:02:01	22.85642	176.73987	2189	22.85584	176.74106	talus?
02:02:28	22.85644	176.73988	2191	22.85599	176.74102	antipatharian
02:02:53	22.85644	176.73990	2192	22.85637	176.74092	light sediment cover, gorgonian
02:03:17	22.85646	176.73991	2193	22.85601	176.74098	sediment on ledge? or bottom
02:03:41	22.85647	176.73993	2194	22.85628	176.74099	grey sediment covering the outcrop
02:04:05	22.85649	176.73994	2195	22.85616	176.74106	grey sediment with debris (talus?)
02:04:33	22.85652	176.73995	2196	22.85613	176.74100	recent tectonic, broken tube
02:05:05	22.85655	176.73997	2198	22.85574	176.74057	no gorgonians!
02:05:26	22.85657	176.73999	2198	22.85628	176.74135	highly vesicular?
02:05:37	22.85658	176.74000	2198	22.85624	176.74123	gorgonian
02:05:48	22.85659	176.74001	2199	22.85582	176.74112	still going down a scarp
02:06:24	22.85661	176.74006	2200	22.85623	176.74113	ditto
02:06:31	22.85662	176.74006	2200	22.85623	176.74113	still talus
02:07:06	22.85664	176.74010	2204	22.85602	176.74120	light sediment cover on talus
02:07:54	22.85667	176.74016	2205	22.85585	176.74084	still talus
02:08:32	22.85670	176.74019	2207	22.85640	176.74121	deep fault
02:08:49	22.85671	176.74020	2208	22.85605	176.74126	lot of talus
02:09:24	22.85674	176.74023	2209	22.85604	176.74119	going up
02:10:04	22.85676	176.74030	2207	22.85580	176.74090	gorgonian
02:10:41	22.85678	176.74036	2209	22.85542	176.74104	shrimp
02:10:51	22.85679	176.74038	2209	22.85557	176.74105	talus
02:10:59	22.85678	176.74040	2209	22.85557	176.74097	still on a scarp, moving along a scarp
02:11:26	22.85680	176.74044	2210	22.85567	176.74094	minor sediment on talus
02:12:43	22.85683	176.74059	2215	22.85593	176.74123	ditto
02:13:29	22.85684	176.74067	2218	22.85552	176.74097	gorgonian
02:14:14	22.85686	176.74075	2219	22.85595	176.74101	still talus along the scarp
02:14:27	22.85686	176.74077	2220	22.85560	176.74108	gorgonian
02:14:35	22.85686	176.74078	2221	22.85540	176.74082	broken tube
02:14:54	22.85686	176.74081	2222	22.85561	176.74100	gorgonian
02:15:32	22.85687	176.74087	2224	22.85563	176.74109	looking at the scarp wall, talus, almost no sediment
02:17:09	22.85688	176.74104	2231	22.85574	176.74124	lobate outcrop, lightly sedimented
02:17:53	22.85688	176.74112	2235	22.85557	176.74139	rubbly outcrop
02:18:27	22.85688	176.74119	2237	22.85557	176.74170	on top of the flow
02:19:01	22.85689	176.74125	2237	22.85564	176.74131	tube
02:19:08	22.85689	176.74127	2237	22.85600	176.74134	tubular flow

Station 77 OFOS; commenced 28-10-02; page 2 of 4						
Time	Ship		Cable	Sub		Comment
(UTC)	Lat. (°S)	Long. (°W)	(m)	Lat. (°S)	Long. (°W)	
02:19:15	22.85690	176.74128	2237	22.85564	176.74150	with irregular top breccia
02:19:45	22.85691	176.74134	2239	22.85574	176.74164	more sediment covering the top
02:20:10	22.85692	176.74139	2239	22.85579	176.74182	ropy surface
02:20:28	22.85693	176.74142	2238	22.85590	176.74142	large tubes
02:21:07	22.85693	176.74150	2240	22.85612	176.74171	small fissure
02:21:20	22.85693	176.74154	2241	22.85588	176.74140	picture 569 -> fissure
02:21:26	22.85693	176.74154	2241	22.85609	176.74127	thin sediment cover on flat flow surface
02:21:51	22.85691	176.74161	2242	22.85581	176.74142	thin sediment on flat flow surface -> sheet lava?
02:22:21	22.85690	176.74168	2241	22.85561	176.74109	vertical wall at scarp
02:23:01	22.85688	176.74178	2233	22.85557	176.74108	ledge
02:23:15	22.85687	176.74181	2233	22.85600	176.74123	coarser sediment, still going up the scarp
02:23:39	22.85685	176.74186	2231	22.85558	176.74096	hydrothermal alteration?
02:24:02	22.85685	176.74191	2229	22.85558	176.74096	still going up
02:24:19	22.85685	176.74195	2226	22.85580	176.74075	sedimented ledge
02:24:28	22.85684	176.74197	2226	22.85568	176.74131	scarp 14 m high
02:24:41	22.85684	176.74200	2226	22.85571	176.74089	heavily sedimented surface
02:25:22	22.85683	176.74209	2228	22.85592	176.74206	local volcanic debris on grey sediment
02:25:59	22.85683	176.74218	2227	22.85569	176.74110	heavily sedimented surface , grey sediment
02:26:51	22.85684	176.74229	2232	22.85579	176.74207	left the active area
02:27:03	22.85684	176.74232	2233	22.85585	176.74204	scarp
02:27:26	22.85684	176.74237	2231	22.85614	176.74201	volcanic outcrop, ridge
02:27:46	22.85685	176.74241	2235	22.85562	176.74177	back to heavily sedimented surface
02:28:14	22.85685	176.74247	2237	22.85585	176.74198	maybe older flows here and younger lobate flows in the rift
02:28:49	22.85686	176.74256	2238	22.85567	176.74208	sedimented lobate flows
02:29:33	22.85686	176.74267	2243	22.85563	176.74169	heavily sedimented surface
02:30:02	22.85684	176.74274	2247	22.85553	176.74154	brittle star 2x
02:30:21	22.85684	176.74280	2248	22.85580	176.74184	heavily sedimented surface, grey, fine
02:30:52	22.85682	176.74288	2249	22.85542	176.74145	brittle star
02:31:00	22.85681	176.74290	2250	22.85542	176.74145	heavy pelagic sediment
02:31:15	22.85680	176.74294	2250	22.85586	176.74159	brittle star-> need organic material in the sediment -> pelagic sediment, not only volcanic
02:32:05	22.85678	176.74306	2251	22.85575	176.74110	scarp, same we already saw
02:32:46	22.85675	176.74316	2257	22.85574	176.74178	big scarp
02:33:30	22.85671	176.74326	2275	22.85590	176.74194	bottom is coming up, already 24 m high
02:33:46	22.85671	176.74329	2280	22.85578	176.74138	heavily sedimented surface
02:34:44	22.85666	176.74341	2289	22.85561	176.74149	heavily sedimented flow surface
02:35:18	22.85663	176.74348	2294	22.85578	176.74118	fine, grey sediment with some debris
02:35:44	22.85660	176.74355	2296	22.85573	176.74157	total height of scarp: 48 m
02:36:11	22.85659	176.74360	2300	22.85553	176.74160	heavily sedimented surface, some debris or outcrop sticking through, gorgonian
02:36:44	22.85657	176.74367	2304	22.85587	176.74159	brittle star, pelagic sediment
02:37:12	22.85655	176.74372	2306	22.85585	176.74155	brittle star
02:37:24	22.85654	176.74375	2307	22.85564	176.74191	grey, fine-grained sediment
02:38:39	22.85648	176.74390	2308	22.85561	176.74231	gorgonian
02:38:48	22.85648	176.74391	2308	22.85553	176.74218	heavily sedimented, minor debris
02:39:10	22.85646	176.74396	2307	22.85550	176.74291	brittle star
02:39:47	22.85643	176.74402	2307	22.85583	176.74273	ditto
02:41:09	22.85637	176.74418	2309	22.85555	176.74258	brittle star
02:42:38	22.85628	176.74434	2317	22.85588	176.74255	ditto
02:43:15	22.85624	176.74441	2321	22.85556	176.74300	gorgonian
02:44:07	22.85618	176.74450	2325	22.85539	176.74280	contact to little bit darker sediment
02:44:31	22.85616	176.74454	2327	22.85547	176.74267	heavily sedimented surface, fine-grained grey sediment, minor debris
02:45:53	22.85606	176.74466	2332	22.85547	176.74259	ditto
02:46:10	22.85605	176.74469	2333	22.85492	176.74347	undisturbed sediment
02:46:33	22.85603	176.74472	2334	22.85542	176.74341	brittle star
02:46:58	22.85601	176.74477	2333	22.85534	176.74327	scarp
02:47:27	22.85598	176.74481	2331	22.85524	176.74313	stalked crinoid
02:47:52	22.85597	176.74485	2331	22.85541	176.74380	lightly sedimented outcrop
02:48:25	22.85595	176.74490	2334	22.85518	176.74370	still little scarp
02:48:36	22.85594	176.74492	2336	22.85514	176.74357	back to sediment
02:49:11	22.85589	176.74499	2340	22.85483	176.74371	sediment, grey, fine-grained, homogeneous
02:49:37	22.85589	176.74503	2343	22.85518	176.74370	crinoid
02:50:22	22.85586	176.74512	2347	22.85516	176.74294	brittle star
02:51:01	22.85583	176.74518	2349	22.85516	176.74294	ditto
02:52:54	22.85577	176.74540	2356	22.85507	176.74326	brittle star
02:54:02	22.85573	176.74553	2360	22.85504	176.74393	brittle star
02:54:32	22.85572	176.74560	2360	22.85497	176.74429	patch with darker sediment, brittle star
02:55:00	22.85570	176.74565	2358	22.85517	176.74364	some animal tracks
02:55:30	22.85567	176.74571	2359	22.85498	176.74343	volcanic outcrop sticking through sediment
02:56:21	22.85563	176.74582	2362	22.85504	176.74385	still outcrop sticking through sediment

Station 77 OFOS; commenced 28-10-02; page 3 of 4						
Time (UTC)	**Ship Lat. (°S)**	**Ship Long. (°W)**	**Cable (m)**	**Sub Lat. (°S)**	**Sub Long. (°W)**	**Comment**
02:56:48	22.85561	176.74587	2363	22.85518	176.74411	outcrop ridges, lobate flow, partially covered by grey sediment
02:57:32	22.85557	176.74596	2367	22.85510	176.74406	brittle star
02:58:10	22.85553	176.74603	2368	22.85497	176.74363	brittle star
02:58:33	22.85551	176.74608	2368	22.85513	176.74372	homogeneous sediment, some debris or outcrop sticking through
02:59:19	22.85545	176.74618	2370	22.85503	176.74505	brittle star
02:59:34	22.85543	176.74621	2371	22.85493	176.74406	lobate flows projecting through grey sediment
02:59:52	22.85542	176.74625	2372	22.85467	176.74421	brittle star
03:00:18	22.85538	176.74630	2373	22.85456	176.74469	blocky fragments, densely packed, probably talus
03:00:53	22.85534	176.74637	2374	22.85501	176.74455	back to grey sediment, was only little ridge of talus
03:02:08	22.85528	176.74653	2374	22.85479	176.74491	brittle star
03:03:29	22.85519	176.74671	2373	22.85499	176.74493	shrimp
03:04:15	22.85514	176.74681	2369	22.85460	176.74497	ridge, scarp? small step
03:04:31	22.85513	176.74684	2366	22.85472	176.74545	back to sediment
03:04:41	22.85511	176.74686	2365	22.85449	176.74509	sedimented slope
03:05:07	22.85509	176.74691	2361	22.85443	176.74451	brittle star
03:05:13	22.85508	176.74693	2360	22.85443	176.74451	brittle star
03:05:31	22.85507	176.74696	2358	22.85476	176.74485	brittle star
03:05:56	22.85503	176.74701	2354	22.85410	176.74500	outcrop of lobate flow sticking through sediment
03:06:17	22.85501	176.74706	2353	22.85456	176.74514	sponge
03:06:29	22.85501	176.74707	2352	22.85470	176.74524	cucumber
03:07:07	22.85496	176.74715	2351	22.85482	176.74544	outcrop, red staining on
03:07:51	22.85492	176.74723	2347	22.85464	176.74444	still outcrop sticking through -> looks like rubble
03:08:12	22.85489	176.74727	2344	22.85450	176.74462	scarp, talus
03:08:26	22.85488	176.74730	2342	22.85454	176.74503	still going up, outcrop
03:09:02	22.85484	176.74737	2335	22.85466	176.74541	some ledges at scarp
03:09:19	22.85482	176.74740	2332	22.85466	176.74541	sedimented top or ledge
03:10:29	22.85474	176.74753	2324	22.85275	176.74826	on top, sedimented surface
03:12:26	22.85460	176.74772	2316	22.85426	176.74581	grey homogeneous sediment, minor debris or outcrop
03:13:50	22.85452	176.74784	2316	22.85417	176.74643	DV on
03:15:17	22.85445	176.74795	2321	22.85436	176.74620	ditto
03:15:44	22.85442	176.74799	2323	22.85390	176.74663	fish
03:16:21	22.85439	176.74804	2321	22.85436	176.74650	brittle star
03:16:41	22.85437	176.74806	2322	22.85408	176.74614	brittle star
03:18:04	22.85429	176.74816	2326	22.85395	176.74689	ditto
03:18:39	22.85426	176.74821	2329	22.85386	176.74711	brittle star
03:20:17	22.85416	176.74834	2338	22.85394	176.74704	ditto
03:21:48	22.85409	176.74849	2345	22.85357	176.74725	brittle star
03:22:56	22.85403	176.74863	2351	22.85361	176.74746	brittle star
03:23:32	22.85402	176.74870	2354	22.85378	176.74770	2 brittle stars
03:24:22	22.85398	176.74880	2357	22.85340	176.74798	brittle star
03:24:30	22.85399	176.74882	2357	22.85340	176.74798	brittle star
03:24:45	22.85398	176.74885	2359	22.85383	176.74829	relative high population of brittle stars-> relative high amount of organic matter in sediment
03:25:34	22.85394	176.74896	2361	22.85379	176.74762	brittle star
03:25:43	22.85393	176.74898	2362	22.85337	176.74674	brittle star
03:25:55	22.85393	176.74900	2363	22.85344	176.74770	brittle star
03:26:04	22.85392	176.74902	2363	22.85325	176.74767	brittle star
03:26:22	22.85391	176.74906	2362	22.85322	176.74751	outcrop sticking through sediment
03:26:45	22.85388	176.74910	2359	22.85310	176.74641	small step
03:26:58	22.85386	176.74914	2359	22.85363	176.74736	brittle star on homogenous grey sediment
03:27:33	22.85383	176.74920	2360	22.85339	176.74797	grey sediment
03:28:00	22.85380	176.74925	2360	22.85349	176.74838	brittle star
03:28:50	22.85375	176.74935	2362	22.85318	176.74736	ditto
03:30:01	22.85367	176.74948	2368	22.85339	176.74721	ditto
03:30:16	22.85367	176.74951	2368	22.85331	176.74711	brittle star
03:30:39	22.85364	176.74955	2369	22.85293	176.74855	brittle star
03:31:45	22.85359	176.74967	2366	22.85269	176.74724	grey, homogeneous sediment
03:33:59	22.85348	176.74989	2369	22.85308	176.74828	ditto
03:34:07	22.85346	176.74991	2369	22.85308	176.74828	brittle star
03:34:47	22.85343	176.74997	2368	22.85314	176.74854	brittle star
03:35:02	22.85341	176.75000	2368	22.85272	176.74847	brittle star
03:36:23	22.85333	176.75013	2363	22.85264	176.74829	ditto
03:37:00	22.85329	176.75019	2359	22.85286	176.74862	ditto
03:38:16	22.85321	176.75031	2352	22.85272	176.74912	ditto
03:38:45	22.85318	176.75036	2349	22.85281	176.74883	brittle star
03:38:55	22.85317	176.75037	2348	22.85279	176.74899	brittle star
03:39:12	22.85315	176.75040	2346	22.85277	176.74932	brittle star
03:39:19	22.85313	176.75041	2346	22.85277	176.74932	ditto
03:39:41	22.85311	176.75044	2344	22.85292	176.74904	grey sediment

Station 77 OFOS; commenced 28-10-02; page 4 of 4

Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
03:40:20	22.85308	176.75050	2341	22.85267	176.74854	brittle star
03:40:54	22.85305	176.75055	2338	22.85274	176.74882	going up a hill
03:41:08	22.85303	176.75057	2336	22.85255	176.74908	some outcrop sticking through the sediment
03:41:28	22.85301	176.75060	2334	22.85288	176.74923	gorgonian
03:41:50	22.85298	176.75063	2332	22.85281	176.74933	gorgonian
03:42:10	22.85296	176.75066	2332	22.85238	176.74909	grey sediment
03:43:13	22.85289	176.75073	2330	22.85248	176.74923	talus, volcanic outcrop, sedimented
03:43:44	22.85286	176.75076	2327	22.85284	176.74898	outcrop sticking through sediment
03:44:10	22.85284	176.75079	2324	22.85263	176.74994	gorgonian
03:44:18	22.85282	176.75080	2323	22.85221	176.74983	still going up
03:44:47	22.85280	176.75082	2318	22.85258	176.74949	still volcanic outcrop
03:45:00	22.85279	176.75084	2316	22.85243	176.74971	sheet flow? sticking through sediment
03:45:20	22.85278	176.75085	2314	22.85251	176.75015	back to grey sediment
03:45:44	22.85277	176.75087	2317	22.85238	176.74970	brittle star
03:45:56	22.85278	176.75088	2318	22.85240	176.75029	back to grey sediment
03:46:16	22.85278	176.75090	2319	22.85258	176.75039	going down
03:46:37	22.85280	176.75091	2321	22.85242	176.75093	grey sediment
03:47:00	22.85282	176.75092	2321	22.85242	176.75028	shrimp
03:47:22	22.85283	176.75093	2318	22.85233	176.75103	start heaving
03:47:41	22.85285	176.75093	2309	22.85254	176.75058	tapes off
03:47:47	22.85285	176.75094	2303	22.85254	176.75058	DV off 35 min
04:35:25	22.85214	176.75329	9919	22.85238	176.75334	OFOS on deck, end of station
04:38:00	22.85214	176.75329	9919	22.85238	176.75334	end of station

Station 98 OFOS; commenced 01-11-02; page 1 of 5

Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
19:06:28	24.60014	176.91344	35	24.59978	176.91393	begin of station 98 OFOS
19:07:14	24.60018	176.91344	70	24.59992	176.91401	lowering to 600 m; 793 m water depth
19:09:48	24.60017	176.91342	190	24.60027	176.91374	total length of traverse: 1800 m
19:16:20	24.60000	176.91335	601	24.60028	176.91366	cable length: 600 m
19:20:18	24.60013	176.91344	715	24.60025	176.91388	ship's position, OFOS approx. 60 m to the west
19:22:02	24.60016	176.91336	790	24.60039	176.91371	bottom sight, moving downslope
19:22:20	24.60016	176.91337	794	24.60036	176.91374	sediment covered
19:22:38	24.60016	176.91337	795	24.60038	176.91368	fine-grained sand
19:23:12	24.60014	176.91338	795	24.60037	176.91367	fish
19:23:20	24.60012	176.91337	794	24.60056	176.91376	white sediment more fine-grained, darker a bit more coarse-grained; mottled appearance
19:24:24	24.60003	176.91332	796	24.60041	176.91352	tapes and DV on
19:25:14	24.59992	176.91330	795	24.60039	176.91367	detritus, larger blocks, 25 cm block
19:25:40	24.59986	176.91331	794	24.60050	176.91355	'animal'
19:25:59	24.59981	176.91332	794	24.60045	176.91331	patchy; sediment cover of debris
19:26:19	24.59976	176.91333	793	24.60036	176.91329	volcaniclastic debris; sediment-covered, larger blocks (25 cm)
19:26:58	24.59966	176.91338	794	24.60032	176.91325	large blocks with sedimentary matrix; subrounded
19:27:29	24.59957	176.91343	795	24.60023	176.91334	now more fine-grained; not much change in depth
19:27:54	24.59949	176.91342	796	24.60010	176.91328	back to grey mottled sediment
19:28:08	24.59944	176.91338	796	24.60034	176.91346	black patches might represent volcaniclastic sediment
19:28:39	24.59934	176.91331	797	24.60008	176.91352	coarser debris; patchy distribution of coarse-grained grey volcaniclastics; partially buried
19:29:18	24.59923	176.91324	798	24.60003	176.91359	another bomb
19:29:30	24.59920	176.91323	798	24.59999	176.91343	back to sediment cover
19:29:49	24.59915	176.91320	798	24.59997	176.91366	large variation in grain sizes; poorly sorted
19:30:23	24.59907	176.91317	798	24.59975	176.91366	sediment is covering coarser debris, cm-size; some sorting
19:30:47	24.59901	176.91317	798	24.59978	176.91348	getting coarser
19:31:01	24.59897	176.91320	799	24.59972	176.91353	back to more fine-grained sediment; layer on top of the breccia
19:31:49	24.59886	176.91330	799	24.59962	176.91345	still sediment-covered debris
19:32:05	24.59882	176.91333	799	24.59972	176.91350	DV out
19:32:49	24.59874	176.91338	799	24.59964	176.91353	very coarse debris
19:33:31	24.59866	176.91345	803	24.59948	176.91347	densely packed sediment debris; bombs > 20 cm
19:34:01	24.59861	176.91352	805	24.59930	176.91346	more finer sediment, still with blocky debris; 40 cm block, round shape, sand on top
19:34:35	24.59855	176.91360	808	24.59929	176.91350	sandy debris - and back into the volcaniclastic breccia
19:34:56	24.59852	176.91365	807	24.59942	176.91366	going down; much less sediment
19:35:18	24.59849	176.91371	807	24.59927	176.91366	little patches of sediment
19:35:44	24.59845	176.91379	809	24.59915	176.91382	blocks still rounded; no matrix between; 20-50 cm in size

Station 98 OFOS; commenced 01-11-02; page 2 of 5						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
19:36:19	24.59840	176.91388	812	24.59906	176.91381	back to the ejecta, bombs; no sediment
19:36:41	24.59839	176.91391	813	24.59913	176.91381	some white sediment
19:37:01	24.59839	176.91389	814	24.59910	176.91388	DV on
19:37:19	24.59839	176.91387	815	24.59896	176.91388	banding?, patchy appearance; fine-grained sediment covering blocky debris
19:37:49	24.59837	176.91385	814	24.59913	176.91385	fine-grained sediment cover
19:38:09	24.59836	176.91384	815	24.59888	176.91422	still sediment, few blocks sticking through the sediment; flat section
19:38:41	24.59832	176.91382	816	24.59881	176.91406	back in the volcaniclastics again; coarse volcaniclastic breccia, up to 30 cm poorly sorted
19:39:54	24.59818	176.91384	818	24.59874	176.91389	areas of volcaniclastic debris, coarse-grained and areas of fine sediment in between
19:40:58	24.59808	176.91395	819	24.59885	176.91388	fine sediment cover, few boulders/talus; densely packed debris
19:41:37	24.59801	176.91402	819	24.59857	176.91382	well rounded blocks in between> 50 cm
19:42:09	24.59795	176.91411	820	24.59861	176.91405	most blocks are around 10 cm
19:42:53	24.59788	176.91422	820	24.59854	176.91399	primary rounded debris blocks
19:43:11	24.59784	176.91428	822	24.59871	176.91392	fine sediment dusting on top
19:43:27	24.59781	176.91433	824	24.59848	176.91400	finer debris unit, moderately sorted; variation in sizes and sorting while going down slope
19:44:05	24.59775	176.91446	825	24.59847	176.91411	large block, 40 cm
19:44:17	24.59772	176.91451	826	24.59854	176.91399	patches of fine sediment cover
19:45:04	24.59764	176.91469	828	24.59838	176.91414	small deposits of unsedimented coarser grained blocks
19:45:54	24.59757	176.91489	831	24.59830	176.91423	temperature curve looks strange; related to depth variation
19:46:43	24.59741	176.91492	832	24.59824	176.91429	heavily sedimented; reddish patches in fine-grained sediment
19:47:21	24.59728	176.91492	835	24.59834	176.91428	few blocks/bombs on top of the sediment
19:47:41	24.59722	176.91494	835	24.59812	176.91446	DV off
19:48:22	24.59711	176.91499	835	24.59802	176.91439	sediment cover again, few blocks
19:48:48	24.59704	176.91504	837	24.59808	176.91454	back to fine-grained sediment, some reddish patches; sediment cover
19:49:28	24.59695	176.91511	840	24.59805	176.91459	mottled sediment, some talus? is sticking through
19:49:57	24.59689	176.91518	841	24.59791	176.91471	another patch of coarse debris, up to 40 cm
19:50:56	24.59672	176.91520	844	24.59764	176.91482	very fine sediment cover
19:51:26	24.59662	176.91518	845	24.59775	176.91501	black-white-red patches
19:51:49	24.59655	176.91518	846	24.59781	176.91504	another patch/deposit of blocky talus
19:52:14	24.59649	176.91518	846	24.59764	176.91511	fish macroids?
19:52:33	24.59645	176.91520	847	24.59755	176.91509	red and white patches on fine-grained sediment
19:52:51	24.59641	176.91520	847	24.59762	176.91507	one single large block, gorgonian
19:53:12	24.59637	176.91520	848	24.59733	176.91531	no indication for any currence
19:53:39	24.59632	176.91521	848	24.59741	176.91534	fine-grained sediment cover
19:54:20	24.59624	176.91524	849	24.59712	176.91500	still strange temperature curve while going down slope
19:54:56	24.59619	176.91527	852	24.59723	176.91537	greyish sedment, with light sandy material in between
19:55:16	24.59615	176.91530	852	24.59697	176.91537	pebble-sized blocks in between
19:56:20	24.59606	176.91539	854	24.59701	176.91528	fine sediment covering on volcaniclastic debris, red patches
19:56:54	24.59600	176.91542	853	24.59694	176.91537	big sediment plume after hitting the bottom - very fine-grained sediment
19:57:29	24.59596	176.91544	856	24.59674	176.91546	blocks partially covered by sediment; outcrop
19:58:09	24.59590	176.91548	859	24.59651	176.91549	again a temperature peak?
19:58:40	24.59586	176.91549	860	24.59649	176.91556	large blocks; scorious pumice?
19:59:02	24.59582	176.91548	861	24.59645	176.91550	back to fine-grained sediment
19:59:36	24.59577	176.91547	861	24.59661	176.91567	some larger blocks show flow structure
20:00:23	24.59570	176.91545	862	24.59633	176.91538	darker sand, few larger blocks up to 10 cm
20:00:55	24.59566	176.91544	863	24.59639	176.91577	gorgonians on larger blocks; rounded blocks
20:01:40	24.59560	176.91543	864	24.59626	176.91556	fine-grained light sediment with deposits of black sand
20:04:33	24.59539	176.91540	865	24.59603	176.91556	temperature profile smoothes down; we are on a small plateaus
20:05:20	24.59532	176.91540	866	24.59595	176.91553	sediment covers blocky debris, reddish patches may outline larger blocks underneath
20:07:33	24.59509	176.91539	868	24.59563	176.91538	heavy sediment cover, small deposits of black sand
20:09:03	24.59491	176.91551	869	24.59546	176.91530	still the same
20:09:41	24.59483	176.91559	870	24.59557	176.91556	patchy network of dark sandy material, with light sediment in the center - buried outcrop?
20:11:29	24.59458	176.91584	875	24.59528	176.91566	more of the dark sandy material; still reddish patches
20:12:09	24.59446	176.91587	876	24.59532	176.91579	still on the plateau
20:12:57	24.59432	176.91588	879	24.59528	176.91574	very coarse blocks on fine-grained sediment
20:13:30	24.59422	176.91589	881	24.59499	176.91554	relatively gentle slope; irregular patchy distribution of the fine light sand
20:14:22	24.59410	176.91596	883	24.59508	176.91572	red patches due to weathering
20:15:34	24.59395	176.91614	887	24.59492	176.91592	still the same sediment cover on top of more coarse-grained blackish sand and/or outcrop

Station 98 OFOS; commenced 01-11-02; page 3 of 5						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
20:16:29	24.59384	176.91634	891	24.59493	176.91592	lighter coloured blocks or thin sediment cover?
20:17:26	24.59372	176.91658	894	24.59455	176.91619	back to very fine-grained sediment, no visible black material nor blocks
20:17:56	24.59366	176.91666	896	24.59472	176.91631	smooth homogeneous light fine-grained sediment, few larger blocks < 10 cm in size
20:19:06	24.59355	176.91682	902	24.59441	176.91646	still in fine-grained sediment
20:19:24	24.59352	176.91686	903	24.59442	176.91638	fish
20:19:37	24.59349	176.91687	903	24.59429	176.91644	fine sediment with round red patches indicating blocky weathering material underneath
20:20:38	24.59337	176.91692	905	24.59438	176.91653	smooth declining temperature curve
20:20:55	24.59332	176.91692	908	24.59429	176.91650	single larger blocks
20:21:07	24.59329	176.91692	909	24.59412	176.91654	some larger blocks, possibly sticking through the sediment
20:21:57	24.59314	176.91688	913	24.59421	176.91651	small patches of black sand, few blocks sticking through
20:22:56	24.59295	176.91686	915	24.59409	176.91684	DV on
20:23:30	24.59284	176.91687	920	24.59386	176.91677	gorgonians
20:23:53	24.59278	176.91687	922	24.59378	176.91671	still the same sediment as described before
20:24:28	24.59269	176.91691	924	24.59374	176.91705	fine-grained light sediment with red patches and few pebble-sized talus
20:25:12	24.59261	176.91696	926	24.59368	176.91681	more pebbly, the amount of blackish pebbles increase slightly
20:25:48	24.59253	176.91703	925	24.59357	176.91698	volcaniclastic material increases
20:27:02	24.59241	176.91721	930	24.59330	176.91721	back to the heavily sedimented area
20:27:18	24.59239	176.91726	934	24.59331	176.91724	fish
20:27:30	24.59238	176.91730	935	24.59341	176.91728	light grey sediment, red patches, few pebble- to boulder-sized blocks
20:28:21	24.59230	176.91746	947	24.59325	176.91750	large slope with outcrop of blocky lava
20:28:41	24.59228	176.91751	952	24.59315	176.91751	some finer material, entirely fragmental debris
20:29:04	24.59226	176.91755	956	24.59306	176.91755	almost sorted sand, few blocks on top
20:29:38	24.59225	176.91760	961	24.59301	176.91771	outcrop
20:29:56	24.59224	176.91763	966	24.59289	176.91748	crinoid before
20:30:19	24.59223	176.91765	970	24.59296	176.91781	sedimented area, blocks sticking through
20:31:45	24.59223	176.91767	987	24.59286	176.91780	all volcaniclastic sediment; 45 cm sized blocks, unsorted deposits of sandy material
20:32:19	24.59222	176.91765	990	24.59285	176.91763	actinian
20:32:53	24.59221	176.91761	995	24.59271	176.91777	plateau, more sediment, large single blocks
20:33:35	24.59218	176.91757	998	24.59283	176.91809	loose lapilli-sized material
20:34:00	24.59216	176.91756	998	24.59271	176.91774	large block > 1m; rubble around
20:34:38	24.59212	176.91754	999	24.59260	176.91762	antipatharian
20:35:27	24.59207	176.91755	1000	24.59272	176.91787	dark sandy material, lapilli-sized fragments
20:36:09	24.59201	176.91757	1002	24.59272	176.91773	fish
20:36:50	24.59195	176.91760	1005	24.59267	176.91788	fine-grained sediment, pebbles and blocks sticking through, reddish colors
20:37:23	24.59190	176.91763	1008	24.59257	176.91762	small slope; volcaniclastites, buried by fine-grained sediment
20:38:36	24.59176	176.91773	1015	24.59254	176.91786	another patch of lapilli-sized dark sand
20:39:53	24.59167	176.91774	1023	24.59252	176.91806	lapilli-sized volcaniclastics, few larger blocks, patchy white sediment
20:41:01	24.59155	176.91774	1030	24.59230	176.91785	lapilli- and block-sized fragments
20:41:18	24.59151	176.91774	1030	24.59234	176.91774	large block >60 cm in size; single occurrence
20:42:14	24.59137	176.91776	1038	24.59223	176.91774	same volcaniclastics, partially covered by fine-grained sediment
20:42:50	24.59131	176.91777	1039	24.59204	176.91777	lot of volcaniclstics, blocks
20:43:53	24.59123	176.91782	1045	24.59212	176.91779	fish
20:44:08	24.59122	176.91783	1048	24.59199	176.91794	large block sitting in lapilli-sized sediment; sub-rounded material, loose
20:45:09	24.59118	176.91792	1053	24.59182	176.91800	single large block in same material
20:46:31	24.59110	176.91800	1062	24.59164	176.91809	few larger blocks in the lapilli-sized material
20:47:16	24.59105	176.91803	1069	24.59162	176.91814	minor fine sediment in the matrix of the pebbly material; approx. 30% are larger blocks
20:47:55	24.59101	176.91806	1072	24.59181	176.91826	sediment patches covering the dark material, no sediment matrix in between the blocks
20:48:58	24.59095	176.91810	1078	24.59162	176.91826	single large block, approx. 60 cm
20:49:14	24.59093	176.91810	1079	24.59166	176.91797	more of rounded blocks in the lapilli-sized material
20:50:14	24.59087	176.91812	1085	24.59171	176.91836	'animal'
20:50:30	24.59086	176.91812	1086	24.59160	176.91841	lapilli stone, blocks, scoriaceous material?
20:51:10	24.59083	176.91812	1090	24.59162	176.91839	pumiceous to scoriaceous blocks, easy to move
20:52:13	24.59076	176.91809	1094	24.59149	176.91830	lapilli block size, some are light, some heavy, rounded
20:52:39	24.59073	176.91808	1095	24.59118	176.91819	area dominated by blocks
20:53:12	24.59070	176.91807	1096	24.59139	176.91836	finer sediment again
20:53:39	24.59066	176.91808	1098	24.59140	176.91848	sediment, but different from the light (yellow) one further up the slope

Station 98 OFOS; commenced 01-11-02; page 4 of 5						
Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
20:54:53	24.59055	176.91815	1102	24.59132	176.91841	patchy areas of lapilli-sized material and more fine-grained sand
20:55:50	24.59046	176.91821	1106	24.59144	176.91862	sediment cover on lapilli sediment
20:56:11	24.59043	176.91825	1107	24.59142	176.91868	fish
20:56:42	24.59038	176.91829	1111	24.59116	176.91841	DV off
20:57:09	24.59034	176.91833	1114	24.59116	176.91848	shrimp
20:58:06	24.59025	176.91839	1118	24.59114	176.91847	thicker sediment cover, few blocks
20:58:47	24.59019	176.91843	1121	24.59091	176.91848	lot of sediment cover
20:59:01	24.59017	176.91843	1124	24.59107	176.91860	fish
20:59:15	24.59014	176.91844	1127	24.59088	176.91852	relief; down slope finer grained material
21:00:19	24.59005	176.91845	1133	24.59103	176.91859	fish
21:00:40	24.59002	176.91845	1136	24.59100	176.91870	rounded block on lapilli-sized material
21:01:26	24.58996	176.91843	1139	24.59091	176.91901	same material, sedimented
21:01:52	24.58993	176.91842	1142	24.59097	176.91858	larger blocks approx. 30 cm, on lapilli-sized material, well sorted
21:02:22	24.58989	176.91841	1144	24.59077	176.91878	well sorted material
21:03:10	24.58981	176.91840	1149	24.59060	176.91839	ceriantharian
21:04:47	24.58961	176.91841	1155	24.59057	176.91849	much less sediment
21:05:05	24.58957	176.91842	1157	24.59052	176.91857	euplectellid sponge
21:05:38	24.58950	176.91844	1160	24.59025	176.91854	still well sorted lapilli-sized material
21:06:18	24.58942	176.91848	1163	24.59024	176.91856	very well-sorted material
21:07:05	24.58931	176.91854	1166	24.59049	176.91856	same material, poorly sedimented
21:08:26	24.58910	176.91866	1174	24.59023	176.91849	still the same material, possibly more fine-grained
21:09:00	24.58900	176.91872	1178	24.59013	176.91862	fish
21:09:07	24.58899	176.91874	1178	24.59010	176.91851	volcaniclastic debris, slightly sedimented by light fine-grained material
21:09:57	24.58885	176.91887	1185	24.59001	176.91845	coarser material
21:11:05	24.58870	176.91911	1192	24.58986	176.91861	medusa
21:11:22	24.58867	176.91918	1196	24.58995	176.91860	gorgonarian
21:11:34	24.58865	176.91924	1198	24.58996	176.91864	patchy distribution of more coarse-grained volcaniclastics and light fine-grained
21:12:15	24.58858	176.91940	1203	24.59005	176.91858	DV on
21:12:43	24.58852	176.91950	1207	24.58989	176.91913	lighter patches on the light grey sediment
21:13:23	24.58844	176.91960	1213	24.58977	176.91894	gorgonians?
21:14:10	24.58835	176.91965	1220	24.58956	176.91927	single large block, sedimented
21:15:01	24.58829	176.91966	1226	24.58950	176.91935	still same material, fine-grained sediment cover
21:16:19	24.58818	176.91972	1237	24.58942	176.91973	heavily sedimented area, blocks sticking through
21:16:38	24.58816	176.91974	1240	24.58944	176.91988	coarse blocky subrounded breccia/talus
21:17:36	24.58809	176.91980	1248	24.58931	176.92001	lapilli-sized material,. white spots, possibly biogenic?
21:18:22	24.58803	176.91987	1253	24.58900	176.92019	single large block
21:19:16	24.58797	176.91997	1260	24.58924	176.92038	again large block, >60 cm, sedimented
21:19:45	24.58795	176.92004	1264	24.58897	176.92026	still white patches in the sediment, irregularly distributed
21:20:26	24.58792	176.92012	1269	24.58869	176.92032	fine-grained sediment cover on volcaniclastic debris
21:21:08	24.58791	176.92018	1273	24.58874	176.92042	volcaniclastics partially covered by sediment
21:21:31	24.58791	176.92020	1276	24.58852	176.92034	blocks up to approx. 30 cm
21:21:52	24.58792	176.92022	1278	24.58880	176.92050	still white specks on the sediment
21:22:16	24.58792	176.92021	1279	24.58864	176.92057	more blocky material
21:22:37	24.58793	176.92020	1281	24.58860	176.92058	still white patches in between
21:23:28	24.58794	176.92015	1285	24.58854	176.92036	white specks possibly outline a block underneath the sediment; roundish appearance
21:24:31	24.58793	176.92007	1290	24.58864	176.92055	very fine-grained sdiment cover on larger blocks/lapilli-sized volcaniclastics
21:25:53	24.58791	176.91988	1290	24.58840	176.92033	still lots of white specks in the sediment, fine-grained and lapilli-sized
21:26:20	24.58791	176.91980	1289	24.58843	176.92056	more block-rich, sedimented, still lapilli-sized volcaniclastics
21:27:07	24.58789	176.91968	1289	24.58859	176.92037	few light sediment but large blocks of about 60 cm
21:27:43	24.58786	176.91960	1288	24.58857	176.92048	back to the sediment, white specks, one larger animal?
21:28:18	24.58784	176.91955	1286	24.58841	176.92037	another deposit of rubbly material (80-90%) pebble and cobble size
21:28:59	24.58780	176.91951	1285	24.58862	176.92029	white specks may increase in more fine-grained sediment?
21:29:52	24.58774	176.91948	1283	24.58875	176.92001	more rubble with larger blocks (30 cm)
21:30:16	24.58771	176.91947	1283	24.58849	176.92017	lots of white specks in the fine-grained sediment
21:30:47	24.58767	176.91947	1283	24.58846	176.92001	fish
21:30:57	24.58766	176.91948	1283	24.58850	176.92029	sedimented blocks
21:31:47	24.58758	176.91949	1284	24.58825	176.92013	thicker sediment cover, ring-like appearance of white specks (outlining blocks/outcrop underneath?)
21:33:23	24.58742	176.91954	1286	24.58845	176.91988	fine sediment, more irregularly distributed specks
21:35:28	24.58716	176.91965	1291	24.58803	176.92003	still fine-grained sediment with white specks
21:36:22	24.58705	176.91974	1296	24.58786	176.91969	another deposit of more coarse-grained volcaniclastics
21:36:47	24.58700	176.91978	1298	24.58799	176.91955	well rounded

Station 98 OFOS; commenced 01-11-02; page 5 of 5

Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
21:38:13	24.58693	176.92000	1305	24.58769	176.92029	high density of white specks
21:38:30	24.58690	176.92004	1307	24.58782	176.92042	rounded volcaniclastics
21:41:35	24.58685	176.92039	1320	24.58753	176.92065	same light fine-grained sediment, few larger blocks, white specks, not much variation
21:44:07	24.58683	176.92046	1331	24.58760	176.92056	sediment cover on the volcaniclastics, brownish sediment plume, white specks
21:45:45	24.58669	176.92050	1335	24.58774	176.92071	small fish
21:45:56	24.58668	176.92049	1335	24.58754	176.92057	not a fish but aristeid prawn or shrimp
21:46:58	24.58656	176.92051	1337	24.58734	176.92046	still heavily sedimented area of buried volcaniclastics sticking through the sediment cover, white specks still there
21:48:11	24.58643	176.92057	1340	24.58734	176.92065	few rocks sticking through the sediment
21:49:45	24.58626	176.92068	1343	24.58730	176.92060	large blocks on fine-grained sediment
21:50:11	24.58621	176.92072	1345	24.58737	176.92048	blocks are largely unsedimented
21:51:28	24.58604	176.92082	1349	24.58710	176.92054	DV tape completely recorded, off
21:52:11	24.58594	176.92090	1353	24.58712	176.92064	large slightly sedimented blocks
21:53:18	24.58582	176.92103	1357	24.58713	176.92082	lot of larger blocks sticking through fine sediment, but not sedimented
21:53:56	24.58576	176.92112	1361	24.58702	176.92069	still lot of white specks
21:54:13	24.58574	176.92116	1363	24.58696	176.92085	fine sediment with patchy appearance
21:55:11	24.58564	176.92120	1366	24.58702	176.92119	250 to go
21:55:17	24.58564	176.92120	1366	24.58695	176.92097	gorgonian
21:55:33	24.58561	176.92120	1367	24.58697	176.92098	sedimented blocks
21:55:49	24.58558	176.92119	1368	24.58659	176.92100	still lot of white specks
21:56:19	24.58552	176.92114	1371	24.58669	176.92119	large patch of white specks
21:56:59	24.58545	176.92108	1373	24.58667	176.92112	large sedimented blocks (1 m)
21:57:18	24.58542	176.92105	1374	24.58672	176.92124	white patch of specks
21:57:43	24.58537	176.92102	1376	24.58662	176.92105	another large sedimented block
21:58:36	24.58526	176.92099	1378	24.58662	176.92131	irregular distribution of white specks
21:59:36	24.58511	176.92101	1381	24.58656	176.92120	single large block; sediment cover on buried volcaniclastics
22:00:14	24.58501	176.92097	1384	24.58651	176.92130	lapilli-sized sediment, with white specks in between, 5-20 cm, densely packed
22:01:50	24.58478	176.92085	1387	24.58623	176.92118	sponge
22:02:12	24.58473	176.92085	1387	24.58589	176.92128	larger sized blocks
22:02:35	24.58467	176.92085	1388	24.58608	176.92130	fine-grained sediment, still white specks
22:03:02	24.58461	176.92086	1389	24.58580	176.92148	large block >1.5 m, sedimented
22:04:22	24.58441	176.92093	1392	24.58586	176.92137	lapilli-sized volcaniclastics, white specks in between and on sediment cover
22:05:41	24.58421	176.92095	1396	24.58589	176.92097	few blocks on fine-grained sediment, still white specks
22:06:46	24.58404	176.92096	1398	24.58579	176.92108	fine-grained sediment, densely packed volcaniclastics, covered completely by fine-grained sediment, white specks
22:07:52	24.58386	176.92101	1401	24.58540	176.92099	sediment accumulation
22:08:09	24.58382	176.92103	1402	24.58533	176.92081	end of OFOS track
22:08:29	24.58378	176.92105	1401	24.58524	176.92084	off bottom
22:09:04	24.58371	176.92109	1384	24.58508	176.92090	435 slides; tapes off
22:12:06	24.58336	176.92075	1300	24.58488	176.92153	1300 m water depth
22:43:24	24.58367	176.92088	9994	24.58376	176.92124	OFOS out of water
22:44:13	24.58367	176.92088	9990	24.58376	176.92124	OFOS on deck, end of station

Station 113 OFOS; commenced 06-11-02; page 1 of 2

Time (UTC)	Ship Lat. (°S)	Ship Long. (°W)	Cable (m)	Sub Lat. (°S)	Sub Long. (°W)	Comment
20:03	29.2432'	178.0619'				Start 113-OFOS, Water Depth 1827 m, position: 29°24.32'S, 178°06.19'E
20:12:17	29.70478	178.10296	539	29.70443	178.10368	Start 113-OFOS at 20:03 UTC
20:32:39	29.70472	178.10265	1662	29.70366	178.10301	video tapes on
20:34:04	29.70468	178.10258	1730	29.70396	178.10267	bottom within view
20:34:24	29.70466	178.10255	1740	29.70355	178.10269	digital camera on
20:34:51	29.70465	178.10251	1744	29.70370	178.10280	sedimented solid surface
20:35:02	29.70465	178.10250	1742	29.70377	178.10296	crinoids
20:35:33	29.70463	178.10244	1742	29.70370	178.10301	very light soft sediment on rough surface
20:36:11	29.70462	178.10237	1738	29.70355	178.10302	blocky talus
20:37:21	29.70458	178.10222	1732	29.70356	178.10282	pillow textures
20:38:29	29.70457	178.10210	1730	29.70378	178.10258	still sedimented blocky talus
20:38:39	29.70456	178.10209	1730	29.70357	178.10252	gorgonian
20:40:28	29.70464	178.10204	1738	29.70370	178.10208	less sedimented blocky outcrop
20:40:48	29.70467	178.10204	1740	29.70366	178.10225	gorgonians

Station 113 OFOS; commenced 06-11-02; page 2 of 2						
Time	**Ship**		**Cable**	**Sub**		**Comment**
(UTC)	**Lat. (°S)**	**Long. (°W)**	**(m)**	**Lat. (°S)**	**Long. (°W)**	
20:43:14	29.70494	178.10229	1752	29.70365	178.10146	still the same weakly sedimented outcrop, pillow textures
20:45:16	29.70519	178.10252	1760	29.70361	178.10154	Ceriantharia
20:50:00	29.70575	178.10295	1765	29.70432	178.10164	gorgonian
20:50:26	29.70579	178.10299	1767	29.70364	178.10195	sedimented outcrop
20:52:18	29.70603	178.10312	1781	29.70417	178.10175	euplectellid sponge
20:54:28	29.70632	178.10327	1797	29.70428	178.10191	still very coherent sedimented outcrop
20:55:53	29.70649	178.10338	1807	29.70435	178.10188	pumice fragment
20:58:45	29.70681	178.10368	1815	29.70439	178.10214	weakly sedimented outcrop
21:02:50	29.70738	178.10392	1831	29.70508	178.10240	increasing sediment
21:03:16	29.70745	178.10394	1833	29.70494	178.10252	smoother surface
21:05:23	29.70777	178.10401	1847	29.70536	178.10321	more rubbly outcrop again
21:07:06	29.70801	178.10413	1858	29.70533	178.10325	crinoid
21:07:16	29.70803	178.10415	1859	29.70554	178.10312	gorgonian
21:09:41	29.70833	178.10434	1878	29.70591	178.10043	still sedimented outcrop of pillowed and blocky basalts
21:17:14	29.70922	178.10481	1939	29.70679	178.10345	still the same coherent pillowed and blocky lava
21:18:08	29.70933	178.10483	1946	29.70663	178.10357	gorgonian
21:18:17	29.70935	178.10484	1948	29.70688	178.10376	increase of sediment; smoother surface
21:18:38	29.70939	178.10484	1952	29.70661	178.10422	soft sediment; thin layer
21:20:22	29.70962	178.10486	1961	29.70702	178.10402	holothurians
21:23:04	29.70997	178.10488	1979	29.70703	178.10360	many holothurians
21:23:35	29.71002	178.10490	1982	29.70696	178.10258	gorgonians; sea star?
21:27:19	29.71030	178.10531	2002	29.70794	178.10384	end of the OFOS track, still in sediment
21:27:40	29.71032	178.10535	2001	29.70777	178.10363	off bottom
21:27:50	29.71033	178.10537	1997	29.70802	178.10403	tapes off; digital camera off
22:11:11	29.71038	178.10685	9995	29.71013	178.10711	OFOS out of water
22:12:13	29.71041	178.10690	9989	29.71013	178.10711	OFOS on deck
22:13:34	29.71045	178.10695	9989	29.71013	178.10711	end of station