Falkor 2016 Cruise Report

Mariana Back-arc

FK161129

November 29-December 20, 2016
SuBastian Dives S34-S49

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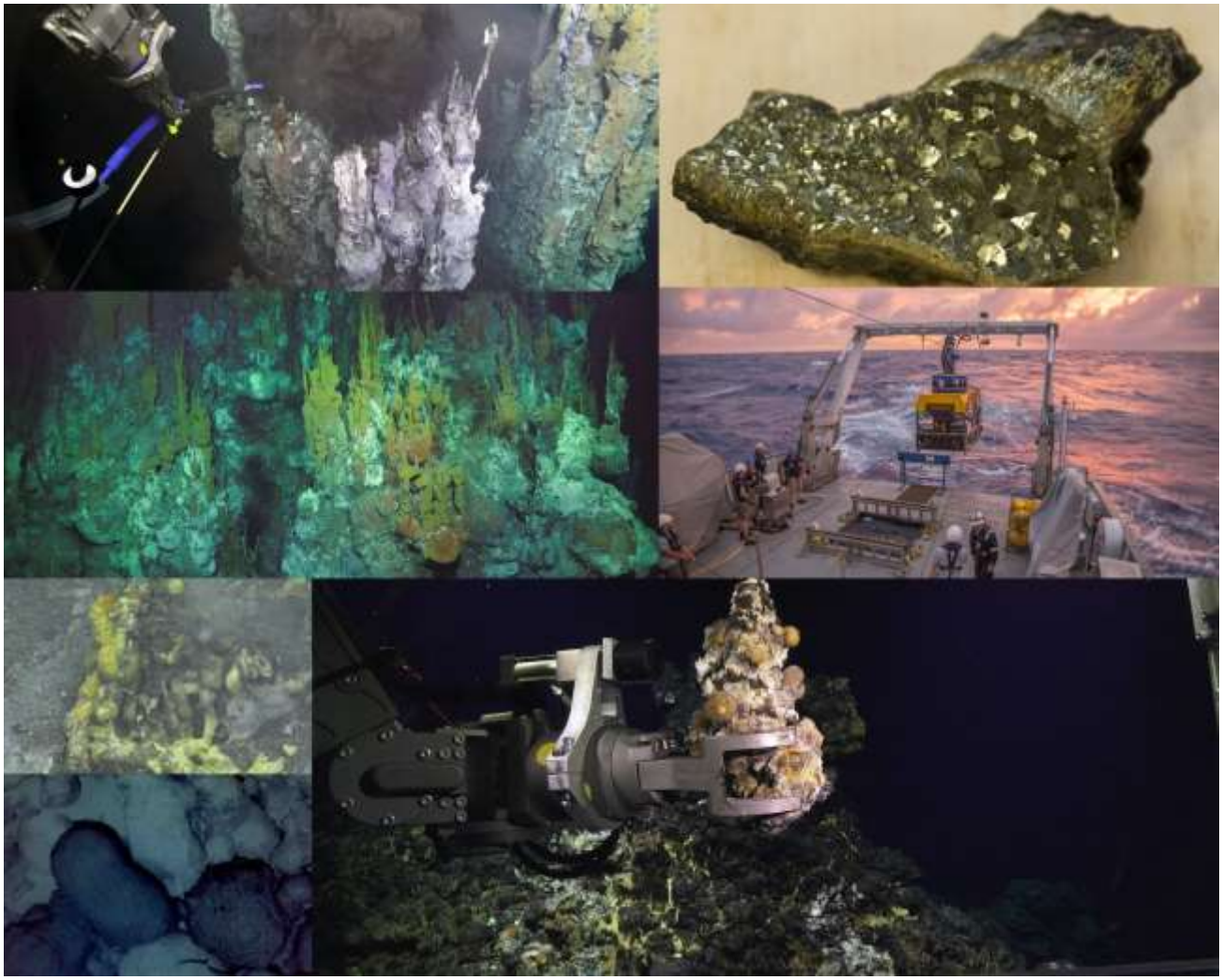

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1 - Expedition Summary

Dave Butterfield, Chief Scientist

This research cruise was the second half of a two-year project in the southern half of the Mariana back-arc made possible by major funding from two sources. The Schmidt Ocean Institute (SOI) provided the research vessel *Falkor* and the ROV *SuBastian*. The NOAA Office of Exploration and Research provided essential science support, including funding for travel and shipping. Additional support came from the National Geographic Society (travel and supplies for V. Tunnicliffe and A. Bates), NOAA PMEL, and from the institutions of all the scientists. The science team is grateful for the opportunity to conduct research in this important ocean region. The entire northern half of the back-arc remains to be explored and we hope to be back.

The science team would also like to thank Captain Heiko and all of the *Falkor*'s crew for making us feel welcome and safe working on board. The ship-handling and station-keeping were excellent during challenging weather conditions. The stewards kept us well-fed, and even delivered treats to the ROV control room! The engineers helped us with lab setup, instrument fabrication ('Hula' array) and replaced a filter canister for HFPS that was lost overboard. We also want to thank Jason Williams, John Dunn, the entire ROV team, and the Marine Techs (Leighton Rolley and Veit Huehnerbach) for their tireless work in getting the ROV in the water as much as possible, making changes as we went along, keeping the data flowing, and running the multibeam system and performing CTD casts. The entire SOI team did everything possible to maximize our productivity during the cruise.

Research Goals

Exploration of deep-sea volcanoes and hydrothermal systems has been pursued actively for nearly 40 years since the discovery of the first hydrothermal vent site at the Galapagos spreading center in the late 1970s. The geological, chemical, and biological observations from the hundreds of known vent sites around the globe have resulted in an emerging realization that plate tectonics and biological communities are linked by multiple processes. Two examples: i) topographic steering of deep ocean currents influences larval dispersal patterns and transport through the water column to colonize distant habitats, and ii) variation in magma composition and volatile content across different geologic settings (ridge, arc, back-arc, hotspot) controls vent fluid chemistry and may thereby limit larval recruitment if environmental conditions in a given setting exceed the physiological tolerance range of organisms evolved in a different geological setting. In the global context, back-arc hydrothermal sites are poorly represented in the vents database (Figure 1-1) and the Mariana back-arc still has vast areas that have not been systematically explored for hydrothermal activity. Only the Alice Springs vent sites near 18.2°N and a few sites near the southern terminus of the back-arc were previously known. Our major objective for this cruise was to determine the geological, chemical, and biological characteristics of several newly discovered vent sites along the Mariana back-arc between 14.5 and 18.5°N and to use that information to better understand the links between tectonics and biological community structure worldwide.

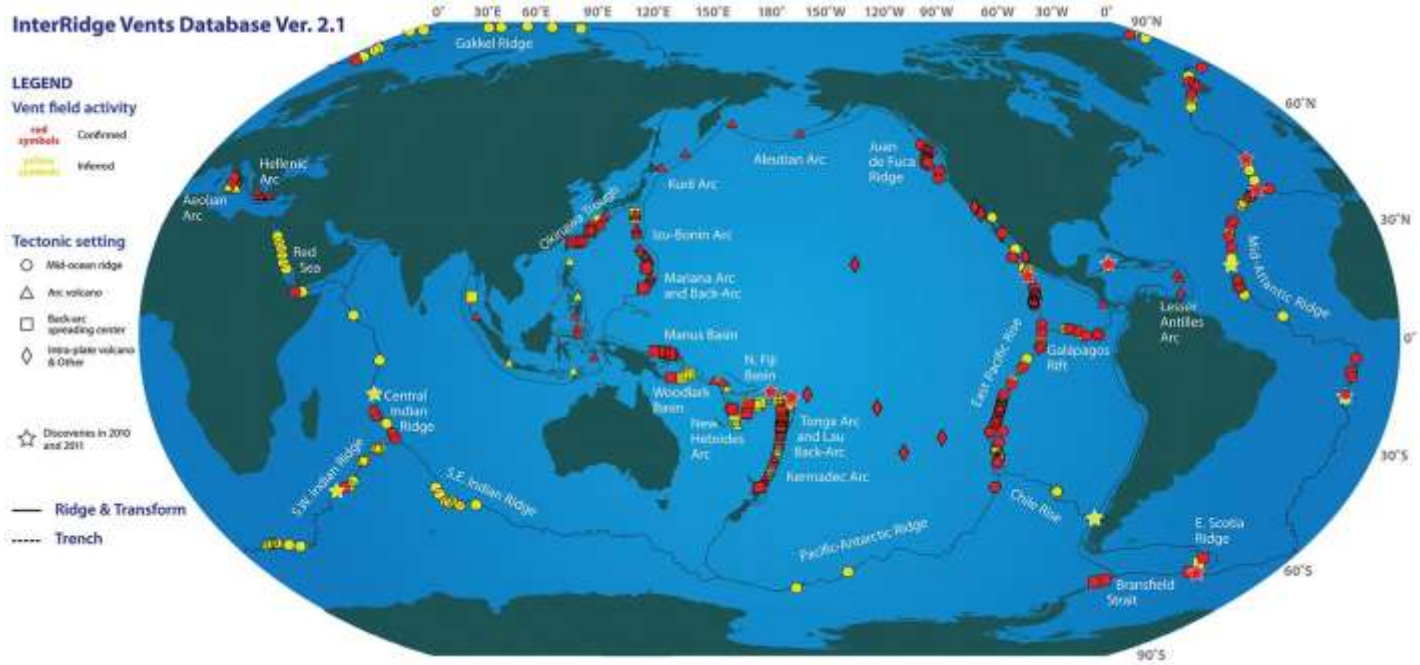

Figure 1-1 Global distribution of deep-sea hydrothermal vent sites. The western Pacific has been a frontier of research on arc and back-arc environments, and the Mariana back-arc represents a significant, underexplored region.

This research can help to answer a host of questions. Does tectonic setting determine the chemistry of hydrothermal fluids and does that in turn limit the species that can colonize sites? What are the systematic variations in fluid chemistry between different geologic settings? Do microbial communities differ across arc and back-arc settings? Are differences in microbial communities directly linked to differences in properties of vent fluids or available chemosynthetic energy? What species occur at arc and back-arc sites that are relatively close together? Is physical transport of larvae from one site to another the key factor in determining biological community structure and the distribution of species around the globe?

The extreme chemical variation at the intersection of the Mariana arc and back-arc provides an ideal place to test the influence of tectonics and chemistry on chemosynthetic ecosystems. Chemical differences in hydrothermal sites are linked directly to the large-scale tectonic environment and the local geology as these two factors control the size, depth, and location of the heat source, the redox chemistry and volatile content, and the hydrothermal circulation pathways. The overarching goal is to discover what factors control the striking differences observed in the biological communities that live at hydrothermal vents in the Mariana arc and back-arc, and what implications this has for links between the solid-earth, the hydrosphere, and the biosphere on a global scale. This research is important because the Mariana vents are at the crossroads between biogeographic provinces of deep-sea vent fauna in the NW and SW Pacific. By conducting this study, we will not only make important advances in the basic understanding of biodiversity, connectivity, and biogeography at deep-sea vents, but also will provide results directly relevant to the conservation and management plan of the new Mariana Trench Marine National Monument.

In order to address the large issue of how tectonics is linked to seafloor biology, we first have to improve our global and regional knowledge of hydrothermal systems. After decades of deep-sea research, there was still very little data from the Mariana back-arc, so we proposed a two-part project to locate new hydrothermal sites through seafloor mapping and water column studies (done in 2015), followed by this 2016 ROV exploration of those new seafloor sites. The data collected during this expedition will complement the extensive data already collected from the Mariana volcanic arc and from the far southern Mariana back-arc. Eventually, we hope to complete the exploration of the northern half of the Mariana back-arc to have a complete regional picture.

Our specific objectives for this research expedition were based on what we could reasonably hope to achieve with a team of 9 scientists on board working with the entirely new SOI ROV *SuBastian*. To achieve our primary goal, we focused on surveying 4 primary back-arc sites, finding hydrothermal activity, and collecting representative vent fauna, hydrothermal

fluids for chemistry and microbiology, volcanic rocks and hydrothermal mineral samples. We considered an additional element (highly desirable for our research goals, but not proposed for this expedition) of larvae collection to address biogeographical questions, but we did not have the specialized larval collection tools nor enough scientists on board to collect the data required to address the problem. We therefore focused on the primary mission of finding and characterizing hydrothermal sites on the back-arc.

A second objective, in addition to the back-arc work, was to gain a better understanding of the ecology of the flatfish (*Symphurus thermophilus*) that are found only on sulfur-rich submarine arc volcanoes. The reasons for the association of this flatfish with actively forming sulfur deposits and its main sources of nutrition are poorly understood, at least in part because few specimens have been collected. Specifically, we wanted to collect enough fish specimens from Daikoku (a known sulfur-rich volcano that erupted in 2014) to do a population study, look for evidence of a symbiosis involving sulfur-cycling microbes, and characterize the fluid chemistry and sedimentary environment where the fish live.

Chronological Summary

Our initial plan and intention for this expedition was to begin diving at the southern back-arc sites, which would be less than 24 hours transit from Guam and would allow us to start with a relatively simple dive (in terms of ROV operations) at the 15.4°N lava flow site. However, winds and seas were too high to allow diving at any of the southern targets, so we quickly decided to continue the transit north, where the weather conditions were much calmer. We left port on the morning of November 29th, as scheduled, and continued in transit north toward Daikoku (intended to be our final dive site, and definitely not a simple site in terms of ROV operations). In transit we continued to monitor the weather in case conditions should improve enough in the south to allow diving at any of the back-arc target sites along the way, and we were at the Alice Springs site at 18.2°N at first light on Dec. 1 to check diving conditions, but it was too rough to dive, so we continued north. We collected multibeam bathymetry data along the way to fill in gaps in the preexisting bathymetry. We continued to set up the science gear (Hydrothermal Fluid and Particle Sampler, fish traps, bioboxes, scoops, markers, MAPR instrument on the ROV for real-time display of ORP data, construction of a temperature recorder array, preparation of the laboratories for sample processing, analysis, and shipboard experiments) write dive plans for Daikoku, plan ROV watch schedules, and set up the ROV control room for data logging. During this cruise we were only able to make 12-hour ROV dives each day (generally from 6am-6pm, local, deck-to-deck) due to the limited staffing and berthing on *Falkor*.

Although we conducted mapping operations during this bad-weather transit, it did cost us 2 dive days (Nov 30 and Dec 1) because we normally would have done the shorter transits between sites overnight and conducted ROV dives during the day.

The default plan for ROV diving was to launch at 0800 and recover at 2000. Due to concern about recovering the ROV in the dark for the first dives, we tried to launch and recover earlier. (First light was about 0630 and sunset was about 1800). We arrived at Daikoku in the early morning of Dec 2 local time, and made some slow multibeam passes over the volcano. Water-column gas bubble plumes were seen emanating from several areas around the summit before the start of the ROV dive. Our first dive (S34) launched shortly after 0700 local time on Dec. 2 and we were on the seafloor by 0742. The ROV dive progressed well. We explored the area around the sulfur pond on the outer slopes of the summit in the NW quadrant. Flatfish (*Symphurus thermophilus*) were numerous throughout this area, as were Gandalfus crabs. Efforts focused on sampling flatfish, recording temperature, pH and Oxygen data in and around sediments, and fluid sampling. In the last third of the dive we tried to observe the molten sulfur pond, which seemed to have retreated down into a depression with steep sulfur walls around it and very poor visibility. While traversing over the sulfur pond there was a burst of material which resulted in a coating of sulfur on the front bottom of the ROV. The dive was terminated slightly early when this occurred. No harm was done, but it was a dramatic and messy, yet highly successful first science dive for *SuBastian*. The ROV and science gear were cleaned up after the dive and S35 got underway the next morning. We continued with fish sampling, fluid sampling, sensor measurements, and observations of molten sulfur and gas venting phenomena. We watched the formation of sulfur-coated gas bubbles blown out of tiny sulfur tubes around the edges of the sulfur pit, saw these sulfur bubbles in the water column near the sulfur pit, and collected surface sediments dominated by them. We transited up to the crater rim to find and sample a tubeworm bush on the inner wall of the crater. Visibility down in the crater was too poor to allow sampling in the deeper parts of the crater, so that part of the dive plan was abandoned. The ROV performed very well during these first two dives at Daikoku. However, sampling the flatfish with the

suction sampler or nets was much more difficult than anticipated, and the fish traps were not very effective. If these dives had occurred after the ROV pilots and scientists had more practice using the suction sampler, we probably would have had better success in sampling the fish. In the end, we did not capture enough fish for a population study. Furthermore, the HFPS did not function well, and we managed to get only 7 successful fluid chemistry samples over the 2 dives. Although our sampling success at Daikoku was poor, the video observations were spectacular, and we collected good data using the in-situ pH and O2 sensors on HFPS.

Because the weather was still poor to the south, we elected to dive on Chamorro seamount (20.8°N, 144.7°E) for the third dive (S36). Weather was marginal at the start, and worsened when we reached the seafloor. With only one hour and twenty minutes total on the seafloor, we located a hydrothermal chimney at 920 meters depth, collected a chimney sample with hairy snails attached, and collected two successful fluid chemistry samples. Maximum measured fluid temperatures here were near 160°C. Although the dive was very short, we were able to make good observations and take essential samples to characterize this moderate-temperature arc site. Verena Tunnicliffe indicated that the snail species at Chamorro was very similar in appearance to one seen only at E. Diamante Seamount further south on the arc, so the samples are significant in a regional context. Weather cost us again on this dive, as the dive had to be terminated early.

We made the transit south to the Alice Springs area (18.2°N, 144.7°E), collecting multibeam data en route. Dive S37 at the Illium vent field began and ended on time. In the nearly 5 hours of bottom time, we explored the area of previously described venting, using our 2015 plume and AUV surveys for guidance, and located diffuse venting sites near the top of a ridge at 3582 m depth. There was a wide range of fauna around the vent sites, including anemones, squat lobsters, hairy snails, crabs, shrimp, barnacles, etc. The depth of the vents did not match the description in the early publications, but we found what appeared to be *Alvin* or *Shinkai* dive weights in several spots, so this was clearly the site of earlier work. There were no high-temperature smoker vents, but many inactive, oxidized chimneys. The following two dives at Alice Springs proper (S39 with venting at 3610-3625 m) and the Burke field (S40 with venting at 3630 m) revealed very similar vent sites. There were no active high-temperature smokers observed at any of the sites, although there was hot (up to 165°C), clear, shimmering water in places. Although we recovered only one good fluid chemistry sample from Illium, we had good success at the Alice Springs and Burke fields. The overall impression of these sites in 2016 is that the chimney-building stage is over, chimneys are in a state of decay, and the heat flux is declining, but there is still sufficient energy to fuel rich and diverse biological communities. We devoted one dive to each vent area and in each case, we were able to collect representative samples of the biology, fluid chemistry, and mineralogy of the sites.

Dive S38 was aborted due to a ground fault eventually traced to the MAPR after first suspecting the HFPS, and by the time it was diagnosed as a bad MAPR cable and fixed, there was insufficient time to make a dive, so we missed one day of diving because of faulty science equipment. The MAPR and HFPS were on the same power circuit, so we could not simply isolate and turn off the MAPR and continue with the dive.

We elected to move south to the 17°N site rather than stay one more day in the Alice Springs area to complete a dive on the 'Central Trough' site at 18.047°N. The priority was to dive at the new, unexplored sites further south. If everything went well for the rest of the expedition, we could potentially come back to the Central Trough site. As it turned out, we did not, so that last vent area at Alice Springs was not revisited.

The next 4 dives (S41-S44) were the most exciting of the expedition. We knew there were spectacular chimneys at this site from one *Okeanos* Explorer ROV dive that took place in April 2016, guided by our results from the December 2015 *Falkor* 'Hydrothermal Hunt' expedition. Having 4 dives (with an average of 8 hours on bottom per dive) to thoroughly explore and sample this high-temperature vent field was very rewarding. The vent field has a clear gradient in vent structures along its west-east trend. There are two massive and tall (16 and 30 meters) chimneys on the western end of the field, with multiple, vigorous, high-temperature black smoker vents, large protruding flange structures, and tall slender chimneys, some active and some inactive and oxide-coated. Animals (hairy snails, crabs, shrimp, limpets, sulfide worms) were moderately abundant near active portions of the chimney structures. To the east of the two largest chimneys were two smaller chimney structures characterized by veritable thickets of small, slender, stick-like chimneys with active high-temperature venting. Continuing east, there is a 40-m diameter, circular crater (named Voodoo Crater) with active diffuse venting in many places on the rim and the interior of the crater. The material making up the crater rim here is

hydrothermal sulfide and not volcanic rock. There were very dense communities of animals at the Voodoo diffuse vents, and we chose this site for an intensive study of the temperature and chemistry of habitat zones around a vigorously flowing diffuse site. Moving further to the east, we found low, flat sulfide mounds with lower temperature and less vigorous diffuse venting. Beyond this, the venting died out. Overall, hydrothermal venting extends for more than 400 m east-west across this vent field, somewhat like a hotspot island track, with the hottest and most active vents on the west, and older, progressively eroded and weaker vents to the east. We collected an excellent set of hydrothermal vent fluid and chimney samples from this vent field, so that we can relate the composition of the vent fluids to the chimneys, and potentially get ages from barite in the chimneys that will help constrain the age and longevity of venting at this site. We named the vent field Hafa Adai for the Chamorro language greeting used in the nearby Mariana islands. This vent field is in a state of very active chimney growth with a high hydrothermal heat and mass flux, in contrast to the weak venting seen at the Alice Springs sites and the 15.5°N site further south.

After four successful dives at the Hafa Adai vent field and vicinity, we moved south to dive at the recent 15.4°N lava flow site and to look for the undiscovered vent site ~6 km north of the lava flow at 15.5°N. After an overnight transit, we began dive S45 at the lava flow on December 12. One year earlier, we had seen significant water column plumes above the lava flow and images of cloudy water were captured by a *Sentry* photo survey, but we saw no active during this dive. The recent pillow lava flow had lots of orange hydrothermal sediments in the crevices and low spots, and the occasional polynoid scale worm swimming in the water just above the bottom, and at least one area with a noticeable ORP anomaly, but no visible hydrothermal flow and no sites that had been colonized by hydrothermal vent fauna. Basalt samples were collected from 6 sites. The wind speed increased to near 25 knots so the dive was ended early after 3 hours and 45 minutes of bottom time. Weather was very rough during the recovery, with the ship rolling and pitching, and it was difficult to get the ROV back on board, but the ROV team handled it well and got the ROV safely on deck.

The end of dive S45 marked the end of a period of good weather and trouble-free ROV dives and the start of a period of marginal-to-bad weather that would last until the end of the expedition, and combined with ROV system problems, made it very challenging to get the ROV back in the water to explore the 15.5°N vent field. We did not see the seafloor again until the afternoon of December 16 local time.

The weather on December 13 was too rough to dive, so we conducted our first CTD ops of the cruise, with one vertical cast over the 15.5°N vent area and a second CTD cast over WP9 of the 15.4°N recent lava flow. There was a clear plume over the vent area to the north, but no apparent plume over the lava flow. This is a significant change from the previous year.

On the morning of December 14, local time, we began to launch the ROV at the 15.5°N vent area, but there was a serious winch power problem and the ROV dive was immediately aborted before launching. The problem was found to be a failed ‘chopper’ or power regulator. The ROV system has two of these units, both needed for operations, and one had failed during the engineering test cruise one week before FK161129. We had no spare on board because the manufacturer could not deliver a new spare in time before we left port. The spare part was in Guam with the agent and our only recourse was to return to Guam (~10 hours transit time), pick up the part and return to our dive site. The part was delivered to the ship just outside the port at 6:30pm local time, and the ship stayed in the lee of the island there long enough to provide a stable ship to do troubleshooting of the satellite internet connection, which had been working very poorly for a couple days. The troubleshooting did not resolve the internet issue, but we returned to the dive site overnight and were on site by first light on Dec 15. After installing and testing the chopper overnight, the ROV group was ready for an early launch. However, shortly after entering the water (Dive S46), there was a dive-terminating ground fault and the dive was aborted. It was quickly determined that there was a short somewhere in the main cable. After some troubleshooting, it was determined that the fault was probably due to a break in the cable sheath and insulation somewhere near the ROV end of the cable. Electrical resistance measurements gave a very rough estimate of how far up the cable the break was. The ROV team took the approach of repeatedly cutting off smaller segments (~50 m length) and testing. Eventually, enough cable (~170 m total) was removed and the short was gone. Cable re-termination was then completed and the ROV was back in the water at 13:45 on Dec 16 to finally begin the search for hydrothermal vents at the 15.5°N site. It was at this time that we decided to name the field ‘Perseverance’.

In order to make up for lost time, the ROV group volunteered to do longer than usual dive to maximize the bottom time at the Perseverance vent field. Dive S47 began in the afternoon of Dec 16, intending to stay on bottom for extended exploration and sampling. However, the dive had to be ended before midnight because of rapid depletion of the hydraulic compensation reservoir (which typically occurs the first dive after a cable re-termination). Following a search pattern based on bathymetry and ORP sensor anomalies from 2015, we found hydrothermal venting within one hour of reaching the seafloor. Active venting was seen at depths from 3915 to 3905 meters, near the SW base of a hill with a summit at ~3890m. During 3 dives with a total of almost 12 hours of bottom time, we searched the slopes of this hill and the valley between this hill and the near-vertical scarp to the west, but we found no other active venting. We did not have time to cover areas farther north, but we covered the areas where the largest ORP anomalies were seen by Sentry in 2015. The chimney structures here were in a state of decline. Large chimneys were tilted or toppled and coated with orange oxides. There were limited areas of hot, clear water venting from sulfide chimneys with white microbial mat coatings (Leaning Tower, Stump of Mystery, and Palisades). Temperatures were up to 265°C and fluids were clear at the orifice (at top of Stump with HFS T probe). Before the end of dive S47, we had sampled vent fauna, chimneys, and fluids (the latter with HFS and a gas-tight sampler).

The science team and the ROV team worked overnight to process samples and prepare for the next dive as soon as possible. The ROV was only on deck for about 4 hours and went back in the water at 0542 on Dec 17 for dive S48. We managed to make a transect up the hillside, finding the vent we would call Palisades, but the dive was terminated after one hour on bottom due to a loss of telemetry, and the ROV was back on deck before noon. The experience of back-to-back dives confirmed that we could not sustain 24-hour operations with the limited number of personnel on board. We would return to a normal schedule and attempt to dive the next morning, weather permitting.

The weather and forecast were indeed marginal at first light on Dec 18 local, and if the weather forecast was accurate, this would very likely be the last dive. Dive S49 launched at 0800 and was at approximately 2500 m depth when a squall passed, winds exceeded 25 knots, and the ship was temporarily blown off-station. Based on standard operating procedure, it was decided to end the dive, but the squall passed quickly and winds dropped significantly, so the decision was reversed (with a good deal of discussion) and the ROV started back down, this time reaching the bottom. We spent a lot of time trying to get a second gas-tight sample from this field, at the top of Stump, but the operation did not go well. We attempted to sample biota, fluids, and microbes from a site called Limpet Canyon near the base of the Leaning Tower vent, with partial success (HFS did not function well and sampling for biology was difficult). We searched the surrounding area again for other vent sites, but found none. The dive was ended due to deteriorating weather after almost 3.5 hours of bottom time.

The weather was now too rough to dive anywhere in our radius of operations, and the forecast was for it to get worse over the next 2 days. This meant that we could not dive on our last potential dive day (Dec 19). Without the ROV, there were no operations possible to address our science goals. We discussed the idea (suggested by Leighton Rolley) of diving on a World War 2 airplane wreck near one of the islands if local weather conditions would allow it, but rejected it because it had no connection to the science objectives of our expedition and we had no expertise in this potentially controversial dive target. We also decided not to put the ROV in the water in the lee of Guam simply to have a last dive (if wind conditions would even allow it), because we had no dive target of interest. It was therefore decided to go into port one day early. Weather conditions did worsen, and it was not possible to dive anywhere within range of Guam on Dec 19. We arrived back in Guam harbor on the morning of Dec 19.

Accomplishments and Relevance.

New knowledge: by exploring and sampling two newly discovered vent fields and re-sampling another three fields not seen since 1992, this mission has established that there is a very consistent vent fauna community across vent fields spaced ~170km apart along the Mariana back-arc. The back-arc vent fauna and back-arc fluid chemistry are significantly different from the shallower nearby volcanic arc sites, supporting the idea that large-scale tectonic processes create diverse geochemical conditions that affect biological communities.

Next steps: the many biological, chemical, and geological samples collected during the mission with the ROV *SuBastian*

must now be analyzed in shore-based laboratories to generate detailed datasets (fluid/gas composition, biological and microbiological species identification/abundance/distribution, volcanic rock and hydrothermal mineral composition) to test these ideas. Project PIs will work together to understand how geological, chemical, and biological processes are linked and how the new regional perspective on back-arc hydrothermal systems fits in a global context.

Who cares?: This work in and near the Mariana Trench Marine National Monument contributes to the overall understanding of deep-sea ecology and reveals amazing new hydrothermal sites on the back-arc to the public, government agencies, and scientists. There was keen national/international public interest in the live streaming of our expedition, and the people of Guam and CNMI are very curious about what exists in the waters surrounding their islands. With growing industrial interest and planning for deep undersea mining of mineral deposits, understanding the ecosystems of hydrothermal vents and how they are affected by disturbance is critical for environmental assessments and minimizing harm to the marine environment that is vital to the health of our planet.

2 - Cruise Participants

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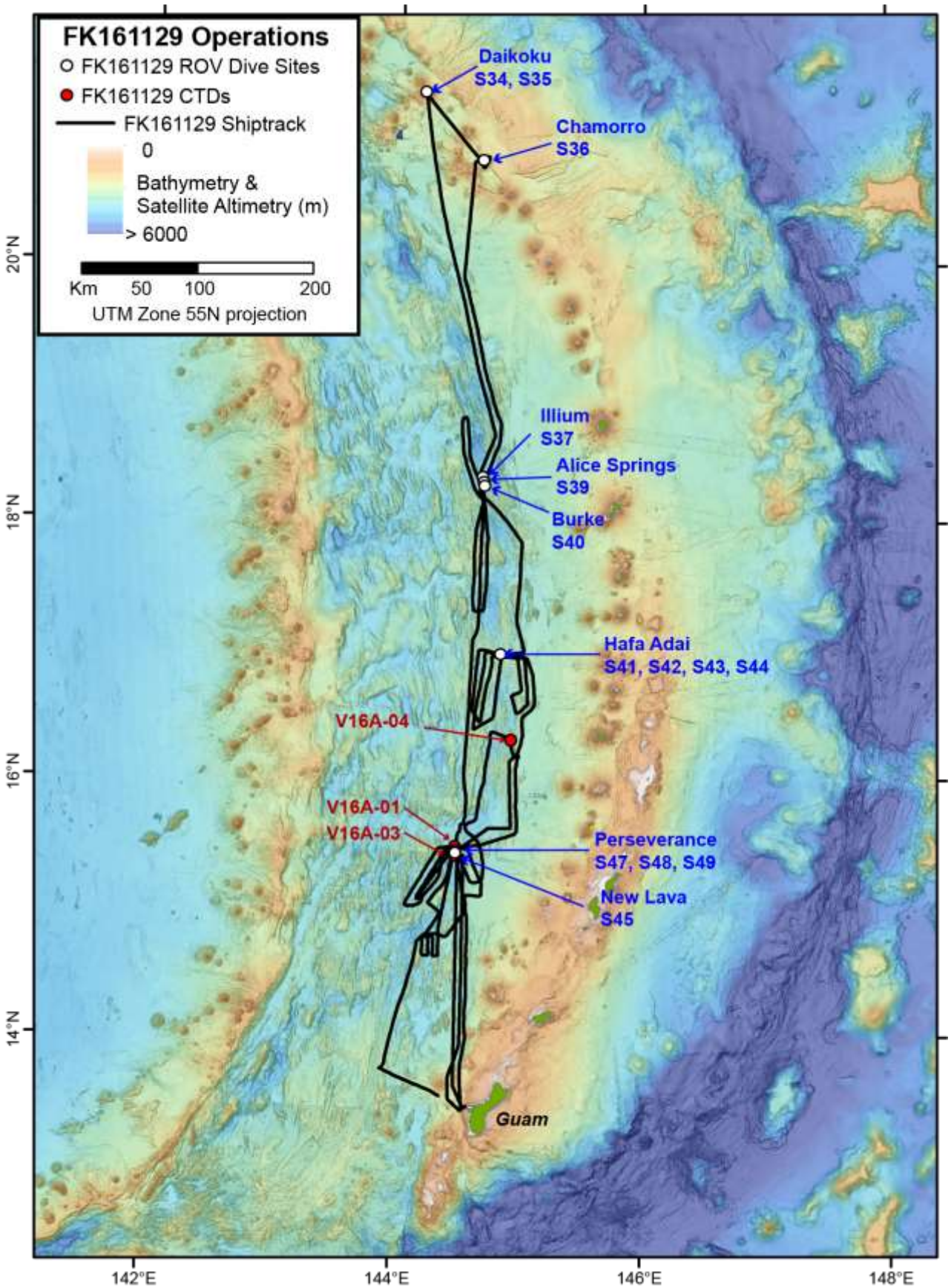
Harry Wetmore	Schmidt Oc. Inst.	ROV	
Russell Coffield	Schmidt Oc. Inst.	ROV	

3 - Operations Log and Map

UTC Date	Time	Local Date	Time	Activity
28-Nov	21:50	29-Nov	7:50	Depart Guam; logging EM302
29-Nov	22:00	30-Nov	7:00	Arrive at Dive Site (New Lava Flow, 15.4°N)
30-Nov	0:58		10:58	Dive canceled due to weather; heading north to Alice Springs
	20:30	1-Dec	6:30	At Alice Springs Site
	20:44		6:44	Dive canceled (weather); heading to Daikoku
1-Dec	21:02	2-Dec	7:02	**Dive S34** at Daikoku; *SuBastian* off deck
2-Dec	4:32		14:32	end S34; *SuBastian* on deck
	6:30		16:30	EM302 survey of Daikoku summit
	21:32	3-Dec	6:00	**Dive S35** at Daikoku; ROV in water
3-Dec	7:21		17:21	S35 off bottom; end of dive
	~08:30		~18:30	Multibeam survey to Chamorro
3-Dec	22:55	4-Dec	8:55	**Dive S36** Begin at Chamorro; *SuBastian* off deck
4-Dec	0:57		10:57	Dive ends prematurely due to wind
	3:15		13:15	Transit to Alice Springs; EM302 mapping
	21:38	5-Dec	7:31	**Dive S37** at Illium; ROV in water
5-Dec	4:54		14:54	S37 off bottom; end dive
				EM302 mapping between dives
	21:00	6-Dec	7:00	*Dive S38 at Alice Springs aborted* due to ground fault
6-Dec	0:15		10:15	**Dive S39** at Alice Springs begin; ROV in water
				EM302 mapping north of site between dives
	21:24	7-Dec	7:24	**Dive S40** at Burke Field; ROV in water
7-Dec	6:31		16:31	S40 off bottom; end dive
				EM302 mapping en route to 17°N site
	20:00	8-Dec	6:00	At 17°N site (Hafa Adai)
	20:58		6:58	**Dive S41** at Hafa Adai begins; ROV in water
8-Dec	7:26		17:36	S41 off bottom; end dive
				EM302 mapping East side arc south of site
	21:05	9-Dec	7:05	**Dive S42** at Hafa Adai begin; ROV in water
9-Dec	7:37		17:37	S42 off bottom; end dive
				EM302 mapping between dives
	21:20	10-Dec	7:20	**Dive S43** at Hafa Adai begins; ROV in water
10-Dec	7:38		17:38	S43 off bottom; end dive
				EM302 mapping between dives
	23:43	11-Dec	9:43	**Dive S44** at Hafa Adai begins; ROV in water
11-Dec	8:21		18:21	S44 off bottom; end dive
	23:03	12-Dec	9:03	**Dive S45** at New Lava Flow site begins: ROV in water
12-Dec	5:06		15:06	S45 off bottom (early due to winds); end dive; scary recovery
	21:58	13-Dec	7:58	**CTD V16A-01** at 15.5°N New Vent Site

UTC Date	Time	Local Date	Time	Activity
13-Dec	2:35		12:35	V16A-01 on surface.
				CTD V16A-02 at WP-09 over new flow; aborted due to noisy LSS.
	6:25		16:25	V16A-02 on deck
	6:30		16:30	**CTD V16A-03** in water at WP-09 (new lava flow site, dive S45).
	21:00	14-Dec	7:00	First attempt at Dive S46 at 15.5°N vent field.
	21:11		7:11	S46 aborted before launch; winch power problem
14-Dec	8:50		18:50	Rendezvous outside Guam harbor to pick up winch part
	20:30	15-Dec	6:30	Second attempt at Dive S46 at 15.5°N vent field: ROV in water
				S46 dive aborted; major faults on ROV; cable re-termination
				CTD V16A-04 at 16.3°N off-axis seamount summit
15-Dec				EM302 multibeam surveying
16-Dec	3:46	16-Dec	13:46	**Dive S47** at Perseverance; ROV in water
	13:28		23:28	S47 off bottom; end of dive.
16-Dec	19:42	17-Dec	5:42	**Dive S48** at Perseverance; ROV in water
	23:07		9:07	S48 off bottom; telemetry problems; end of dive.
17-Dec	22:07	18-Dec	8:07	**Dive S49** at Perseverance; ROV in water
18-Dec	6:00		16:00	S49 off bottom; end of dive
18-Dec	22:00	19-Dec	8:00	Arrived in Guam

Fig. 3.1 Operations map



4 - Discipline Summaries

4.1 Geology

Heidi Berkenbosch and Bill Chadwick

4.1.1 Sulfide Sampling

Sulfide samples were collected by ROV *SuBastian* during *Falkor* cruise FK161129. Sulfide mineralogy and geochemistry will aid in understanding the physicochemical conditions of the vent fluids from which they formed, and the environment upon which biological species are living. Isotopic analysis of the sulfides will also help determine the age of the different hydrothermal sites. Samples of lava were also collected and are described in another section.

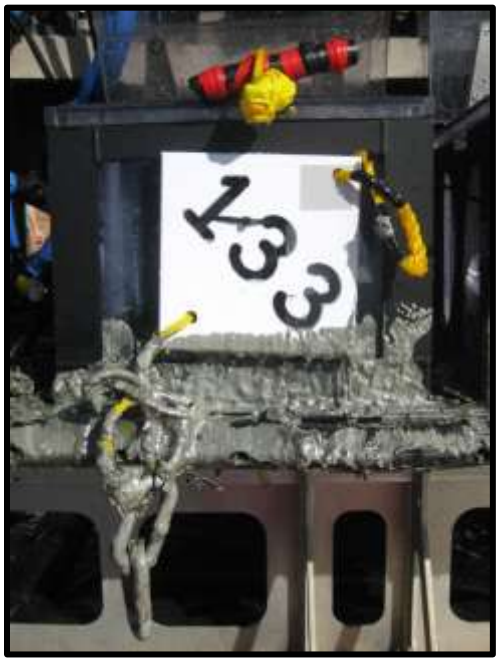


Figure 4.1.1-1 Coating of sulfur from Daikoku on dive S34.

Five samples of native sulfur chimneys and crust were collected at Daikoku seamount (dive S34) including unintentional sampling of quenched molten sulfur on the frame of *SuBastian* (see photo left). One sample was taken from an active chimney venting clear fluids at Chamorro volcano before the dive was aborted (dive S36). One sample of highly oxidized pieces from an old chimney was collected at the Illium vent field (dive S37), as well as a piece of basalt with an alteration rim at the Burke vent field (dive S40) both in the Alice Springs area (18.2°N back-arc segment),

Twelve samples in total were collected at the Hafa Adai vent field on the 17.0°N back-arc segment (dives 41- 44) and will be described here going west to east along the different vents. The Two Towers site was a very large structure (~16 m) that split into two active “branches” at the top. Two active chimney samples were collected here including a thick (~2 cm) piece of chalcopyrite from a chimney vigorously venting black fluids up to 348°C (fluid samples S44-HFS-03, -04, -05, -10, -11 and a gas tight sample S44-GTB-06 located at top of one of the Towers. The Sequoia site was an even larger chimney structure (30 m high) that had a thick trunk from which large flanges protruded, one near the base and one near the top. The flanges were the most active part of the structure. Four chimney samples were taken at Sequoia: three were from active chimneys and the fourth was a piece of sulfide crust taken from near the base. One sample of fresh chimney pieces was collected from the Alba vent site. Three pieces of sulfide were collected from Voodoo Crater. These were thought to be lava samples when collected, and it was a surprise to discover they were made of sulfide. It became clear that the entire cone at Voodoo is formed from apparently exploded sulfide blocks – which remains enigmatic. One large and one small sample of old, inactive chimneys were collected at Waypoint 7 and 8, respectively (older chimneys at the eastern end of the line of vents). One sample of highly oxidized chimney material was collected to the north of Hafa Adai vent field.

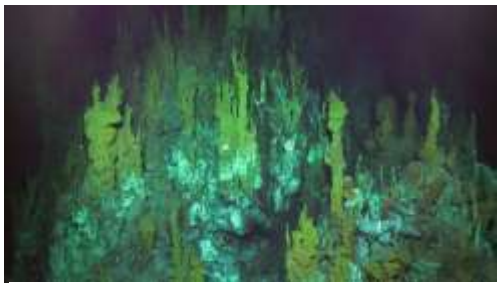


Figure 4.1.1-2 Chimlet Garden site at Hafa Adai.

In general, the active chimneys from Hafa Adai were extremely friable and hard to collect by manipulator arm without breaking into many small pieces. Old chimneys were easier to collect as the most friable material appeared to have worn away leaving stronger chimney remnants behind. The most high-temperature, black-smoker vents were at the west end of Hafa Adai (Sequoia and especially Two Towers), and venting volume and temperatures dropped going east. An interesting occurrence was the formation of many narrow and tall chimneys (“chimlets” of diameter <2 cm and height up to ~60 cm). There were relatively few of these chimlets at Two Towers and more on the flanges at Sequoia, but they became abundant particularly at the central vent sites of Chimlet Garden (image right) and Alba (image below). The chimlets were also prevalent but mostly dead at the most eastern vents at Waypoint 7 and 8, which had only light, diffuse flow.

The final two sulfide samples were collected from the Perseverance vent field (dive S47) at the 15.5°N back-arc segment, both from the “Stump of Mystery” chimney.

Figure 4.1.1-3 Close-up of Alba sulfides at Hafa Adai.

Sulfide samples were sent to Cornel de Ronde at GNS Science. He plans to have them analyzed for bulk geochemistry to determine their composition, S isotopes to detect magmatic sulfur, and Ba isotopes for their ages. A “quick index” is included below lists the sulfides (or altered rock) collected followed by detailed descriptions of each sample.

Table 4.1.1-1 Sulfide Sample Quick Index

Sample Name	Type	Location
S34-Geo-07	Pure Sulfur chimney	Daikoku
S34-Geo-08	Sulfur and ash crust	Daikoku
S34-Bio-09	Grey Sulfur “tadpoles”	Daikoku
S34-Geo-10	Sulfur and ash crust	Daikoku
S34-Geo-12	Sulfur encrusted on *SuBastian*	Daikoku
S36-Geo-01	Fresh chimney pieces	Chamorro
S37-Geo-01	Highly oxidized chimney pieces	Alice Springs- Illium
S39-Geo-11	Pillow basalt	Alice Springs- Alice Springs
S40-Bio-10	Basalt with alteration rim	Alice Springs- Burke
S41-Geo-01	Fresh chimney	Hafa Adai- Two Towers
S41-Geo-08 & 09	Fresh chimney pieces	Hafa Adai- Sequoia
S41-Geo-11	Large, old chimney	Hafa Adai- Waypoint 7
S42-Geo-12	Sulfide rock, inside cone	Hafa Adai- Voodoo Crater
S42-Geo-13	Sulfide rock, outside cone	Hafa Adai- Voodoo Crater
S42-Geo-20	Fresh chimney pieces	Hafa Adai- Sequoia
S42-GTB-21	Fresh chimney pieces	Hafa Adai- Sequoia
S42-Geo-22	Old sulfide crust	Hafa Adai- Sequoia
S42-Geo-23	Small, old chimney	Hafa Adai- Waypoint 8
S43-Geo-02	Highly oxidized chimney pieces	N of Hafa Adai
S43-Geo-08	Fresh chimney pieces	Hafa Adai- Alba
S44-Geo-07	Active, high-T chimney pieces	Hafa Adai- Two Towers
S44-Geo-08	Sulfide rock, outside cone	Hafa Adai- Voodoo Crater
S47-Bio-08	Old chimney piece	Perseverance- Stump of Mystery
S47-Geo-13	Fresh chimney pieces	Perseverance- Stump of Mystery

Sulfide sample descriptions:

Dive S34
First SuBastion scientific dive ever! Daikoku Seamount. Fish Spa area and surrounds, also looked for molten S pools but not seen. Dive aborted due to molten S crusting skids!

S34-Geo-07- Pure S chimney ("chimlet") comprised of fused molten S droplets. Gas bubbles and shimmering fluid were venting when sampled. Was at edge of fissure in sediment releasing gas, white smoke and shimmering fluid, along with other small chimneys. 16 x 9 cm. One main conduit ~4 cm diameter at the base and 2 cm at the top with smaller conduit branching off to the side (4 cm long, 1 cm conduit). Inside conduit is smooth and undulating, mostly dark grey at base and grading to pale yellow at top. Chimney wall is 3 cm thick max at the base and 2 mm at top. Outside has masses of S globules 11-1 mm, pointing outwards or down. Mostly dark grey but bits and globules of pale yellow mixed through, about 25%. Trapped gases bursting globules when brought to surface with popping and little shards flying off. Whole thing very friable and falling apart just sitting on the table. Same location as HSF-03, -04.

S34-Geo-08- S crust that looked very white on video. Was on small mound behind fissure that Geo-07 came from. Fell apart when tried to sample and one piece scooped up, about 17 x 10 cm, but broke into several small pieces when taking it off of ROV. Layered crust of S and ash. S is bright to pale yellow in smooth layers ~3-4 mm thick or aggregates of globules that range from yellow-grey. Ash is grey to white in ~1 mm layers. Whole thing friable and also popped with gas release on surface.

Figure 4.1.1-4 S34-Bio-09 Sulfur tadpoles, globules and Pele's tears.

S34-Bio-09- Collection of grey S "tadpoles", "globules" or "Pele's tears" picked from sediment suctioned for Bio-09 sample. All globules are hollow and have "popped".

S34-Geo-10- Piece taken from edge of large slab of S crust overhanging large pit/fissure. Mostly pale grey but pale yellow areas too. Fine-grained matrix with embedded, grey S globules (all popped) and long S tails. Fragile. One larger piece (8 x 4 x 2 cm), and 6 smaller pieces.

S34-Geo-12- Quenched, molten S encrusted on frame and instruments of *SuBastian*. We flew through smoky area with lots of S "tadpoles" flying in water around us. Could have been ejected up onto the ROV or slightly dipped in frame or both. Many pieces are very smooth and follow contours they are on. Others are thick with a rough surface of elongate strands in uniform direction. Mostly shiny, pale grey-green but with swirls of darker grey and fewer patches of yellow. Some broken pieces show yellow inside. Largest piece is 15 x 9 x 9 cm, 6 medium pieces (6-12 cm) and one small piece with yellow.

Dive S36
Chamorro Seamount. Landed right at one small chimney with another visible in the background. Shimmering fluid with snails. Had to abort dive after sampling because of winds.

S36-Geo-01- Chimney was about 40 cm tall, white, and looked "blocky" with shimmering water coming from between "blocks". Broke while sampling: 4 larger pieces (10- 16 cm), 10 medium pieces (~6 cm), 6 small (<4 cm). Sphalerite and barite-rich with drusy, green-grey pyrite in the conduit (maybe trace chalcopyrite?). Lots of crystals growing into void space, esp. barite, looking fuzzy. Many pieces have a thicker, white layer in the mid-wall, sometimes with larger laths= anhydrite? Inside is anastomosing channels, the largest is 2 cm wide and channels are particularly friable. The piece from the top of the orifice does not show any pyrite.

Dive S37
Alice Springs- Illium area. Landed right at an old, oxidized chimney stump. Sampled water from diffuse venting area then dive aborted because of hydraulic leak.

S37-Geo-01- Piece of highly oxidized chimney, 6 x 6 x 6 cm. Took a few days to dry out and very light. Dark orange to white and porous. Fe-oxides mainly.

Dive S40
Alice Springs- Burke area. Low-temperature, diffuse venting with lots of animals and other sites with milky plume but few animals. High-Fe and low-S? Searching for source of plumes detected by CTD but only diffuse flow and extinct chimney fields found.

S40-Bio-10- Rock collected for limpets from behind shimmering vent. 7.5 x 4.5 x 5 cm. Inside is dark basalt (although slightly spongy?). Outside is white alteration rim to a maximum of 14 mm thick. Orange Fe-staining between basalt and alteration, plus through rim. 2 other small pieces, one mostly altered, the other mostly not.

Dive S41

Hafa Adai vent field. Explored several sites: Two Towers (~16 m chimney super-structure); Sequoia (~30 m chimney super-structure); Chimlet Garden (smaller chimney field); Alba (smaller chimney field); Voodoo Crater (with diffuse venting and animals); and Waypoint 7 (a couple medium chimney clusters with less hydrothermal activity- no black smokers).

S41-Geo-01- Chimney fallen onto flange of Two Towers. Wine-bottle shaped and we got top 15cm, right to the base of the "neck" (base is 5cm wide, neck is 3cm). Looks like could see where it fell from just above. Fresh, no oxidation. Chalcopyrite-lined orifice at the top, 13mm diameter orifice. No distinct orifice at the bottom, but anastomosing cpy-lined channels. The outside is black except for small white patches.

S41-Geo-08 & 09- Outer pieces of bulbous, active chimneys on (lower?) flange area of Sequoia. Chimneys right beside each other and sampled into same box so can't distinguish between the samples. 10 pieces: two are 4-5 cm, three are 3 cm, five are <2 cm. Black/grey on the outside. Fine-grained cpy and other grey mineral inside. Sphalerite? Barite? Inside is very friable. One piece has larger-grained cpy with tiny vents <1 mm.

S41-Geo-11- Large, old chimney from Waypoint 7 vent area. Sticking up from top of small mound, inactive, 40 x 20 x 20 cm. Fragile parts have worn away and harder, cpy-enriched conduits remain, including two "spigots" sticking out from the base on one side. Whole thing is generally cylindrical with conical top, black with some orange and white patches. Top has 6 distinct vents, the central one lined by cpy and elongate (17 mm), not round. Other vents are grey mineral but with smaller cpy conduit inside. The base shows two larger conduits, 4-5 cm diameter, both cpy-lined up to 7 mm. Larger one is orange, Fe-oxide coated inside, and the smaller one is black inside.

Dive S42

Hafa Adai: Voodoo Crater, Sequoia, Waypoint 8 area.

S42-Geo-12- Sulfide rock collected for barnacles from Voodoo Crater. Thought it was lava from the "cinder" cone. 19 x 12 cm. One cpy-lined vent visible, 12 mm, otherwise massive, knobbly sulfide. Thin, black-brown oxidized layer outside and grey inside.

S42-Geo-13- Sulfide rock from outside NE flank of Voodoo Crater. Thought it was lava. 11 x 11 x 6 cm, heavy. Thin (<1mm) Fe-oxide coating on outside, but see py/cpy sulfide when break surface. Generally smooth surface.

S42-Geo-20- Chimney pieces from orange spire on top flange of Sequoia. Fell onto basket while sampling. 3 larger pieces fit together. One larger cpy-lined conduit with 5 mm orifice. Other conduits distinguishable larger-grained cpy lining. Outer rind zoned from orange exterior (<1 mm) to pyrite to brassy mineral to cpy inside. Inside is generally fine-grained cpy and other grey mineral, friable. Largest piece 13 x 11 x 10 cm, other pieces: 10 x 9 cm, 9 x 6 cm, 8 x 6 cm, 6 x 5 cm, and 5 smaller pieces.

S42-GTB-21- Chimney pieces that fell on R side of the basket while taking gas-tight sample, top flange of Sequoia. Had pushed R side of ROV into flange for stability. 3 pieces, one with distinct but poorly-lined orifice: 9 x 6 cm, 8.5 x 5 cm, 7 x 4 cm. Dark matrix and brassy, faint cpy with "sandy" texture. Narrow, anastomosing channels in the other pieces.

S42-Geo-22- Old sulfide crust from base of Sequoia. 16 x 9 cm. Orange on bottom (inside) and orange to black on top (outside). Outside layered with harder exterior, 1-2 mm, slightly overhanging eroded inner layers. Next layer is greenish-brown, clay-like texture, 3 mm, then dark interior. Some white staining between exterior and green-brown layer. Tube worm casings visible on outside. Where rind broken can see small, ~2 mm, cpy-lined conduits.

S42-Geo-23- Small, old chimney from Waypoint 8 vent area. 9.5 x 5 cm. Top is worn away in parts with 2 distinct, grey, orifices. Bottom has one orifice, cpy-lined with thin, oxidized coating in the conduit. Outside is black to white, and appeared blue when sampled (bacterial mat?). Very small orifices visible on the outside <0.5 mm.

Dive S43

Started N of Hafa Adai vent field looking at other, larger volcanic cone, then travelled S over sheet flows to Hafa Adai, Alba site, and ended at Sequoia.

S43-Geo-02- Highly oxidized chimney pieces N of Alba. Whole insides were mush. Chalky, orange crust, 4 mm thick. 2 larger pieces to 5 cm, 7 smaller pieces.

S43-Geo-08- Fresh, active chimney pieces from Alba. Collected with arm knocking into net. Largest piece, 8.5 x 6.5 cm and has 2 poorly-defined conduits at base, 2.5 cm and 8 mm. Also 2 small orifices at top but can't tell how connected to those at the base. Vents ~6 mm wide with 2 mm orifice. Inside is generally fine-grained cpy and other grey mineral, friable, with larger-grained cpy lining conduits. 4 smaller pieces with cpy-lined orifices, 2 partially whole, 2 with conduit exposed. Some cpy is brassy (slightly oxidized?). Another piece has pyrite on the outside instead of the usual black coating. One very small chimlet piece, 3 cm long, 9 mm wide with 3 mm orifice, cpy-lined. Another piece with distinct transition from black outer rind to inner cpy/py matrix inside. All together: 1 large, 6 med, 1 chimlet, 10 small pieces.

Dive S44
Hafa Adai vent field: Started at Waypoint 9 area to Waypoint 8, then to Two Towers and ended at Voodoo Crater.

S44-Geo-07- Active, high-temperature chimney pieces from top of Two Towers. Profuse black smoke and took fluid and gastight samples. 5.5 x 4.5, 6 x 3 cm. Cpy-lined conduit from <1 to 15 mm. Individual crystal faces up to 3 mm. Yellow cpy grades to orange and locally to purple and iridescent (bornite). Outer layer with pyrite and grey sphalerite. Outer rind ~1 mm Fe-oxides and orange to black.

S44-Geo-08- Sulfide piece from W flank of Voodoo Crater. 9 x 9 x 7 cm. Heavy. Oxidized exterior ~2 mm. Cpy and grey (sph?) inside where crust broken. Knobbly, no obvious vents. Exterior dark orange/brown with some bright green areas – secondary malachite? – in curvy lines. When dried, a chalky green coating on one side.

Dive S47
Perseverance vent field- Started among pillow lavas then traversed to Leaning Tower, Palisades, and Stump of Mystery vents.

S47-Bio-08- Piece of slightly older chimney from the flank of Stump of Mystery vent, collected for animals. 12 x 7 cm. Grey matrix with chaotic cpy-lining on one side. No obvious channels. Fe-oxide crust on the other side to 1 mm, orange to dark grey. Local, white sulfate patches but no crystals. Some whiter areas outside and on top – oxidized product? 1 small grey piece with minor cpy, 3 x 3 cm.

S47-Geo-13- Pieces of fresh chimney from the top of Stump of Mystery vent where fluids were sampled. 15 x 7 and 10.5 x 5 cm. Dark grey matrix (mostly sph?) interior with anastomosing channels and rough texture. Some minor cpy as greenish, and some thin cpy conduit linings , <1 mm visible locally. A few more well-defined orifices lined by larger sph hexagonal prisms. Local areas with barite and anhydrite, mostly concentrated towards the exterior. Larger laths/rosettes around some channels. Py and sph also close to exterior as slightly silvery. 1 small piece 3.5 x 3.5 cm, 50% sulfate, 50% sphalerite. Probably mostly anhydrite as not very heavy.

4.1.2 Rock Samples

Rock samples were collected by ROV *SuBastian* during *Falkor* cruise FK161129 primarily to characterize the lava chemistry at each of the visited Mariana back-arc segments. The sulfide samples that were collected are described in a separate section of this report. Two lava samples were collected at the Alice Spring vent field (dive S39) on the 18.2°N back-arc segment, three lava samples were collected in and around the Hafa Adai vent field, at the 17.0°N back-arc segment (dives S42, S43, and S44), and one lava sample was collected from the Perseverance Vent field (dive S48) on the 15.5°N back-arc segment. The rest of the lava samples were collected on or adjacent to one of the 2013-2015 lava flows (dive S45) on the 15.5°N back-arc segment (~7 km south of the Perseverance vent field). This includes 4 samples of the new (2013-2015) lava and two samples of the older surrounding lava flows. Photo graphs of all the FK161129 rock samples are available upon request.

SuBastian dive S45 on the 2013-2015 lavas started ~200 m south of where the *Okeanos* Explorer's Deep Discoverer dive D2-EX1605L1-DIVE09 ended. The *Okeanos* dive on 29 April 2016 was made on the northern-most and thickest of the 2013-2015 lava flows, and they also collected three rock samples from the 2013-2015 lava flows. Those samples:
D2-EX1605L1-DIVE09-SPEC01GEO
D2-EX1605L1-DIVE09-SPEC02GEO
D2-EX1605L1-DIVE09-SPEC03GEO

are archived at the Oregon State University Marine Geology Repository (osu-mgr.org).

The rock samples from FK161129 were sent to Ken Rubin at University of Hawaii. He plans to date the 2013-2015 lava flow samples using uranium series methods. Below is a "quick index" table of all the FK161129 rock samples (the "buckets" refer to how they were shipped to Rubin).

Table 4.1.1-1 Rock Sample Quick Index

Sample Name	Type	Location
S39-Bio-15	Crust of pillow basalt	Alice Springs- Alice Springs
S42-Geo-14	Sheet lava crust	Hafa Adai- between Voodoo & Sequoia
S43-Geo-01	Sheet lava crust	N of Hafa Adai
S44-Geo-01	Large sheet lava crust	Hafa Adai- S of Waypoint 9
S45-Geo-01	Pillow basalt crust	Perseverance- North
S45-Geo-02	Pillow basalt	Perseverance- North
S45-Geo-03	Pillow basalt	Perseverance- North
S45-Geo-04	Pillow basalt	Perseverance- North
S45-Geo-05	Older pillow basalt	Perseverance- North
S45-Geo-06	Older pillow basalt	Perseverance- North
S48-Geo-01	Pillow basalt	Perseverance

Rock Sample descriptions:

Dive S39
Alice Springs Vent Field - Alice Springs vent area (18.2°N back-arc segment). Lots of anemone, snail, crab, shrimp, etc. areas with diffuse venting to 30°C, and milky plume.

S39-Geo-11- Rock collected from marker 131 site for barnacles. 21 x 11 x 11 cm. Piece of pillow basalt.

S39-Bio-15- Rock collected from top of sulfide swath up the slope for small anemones on it. Crust of a pillow basalt with glassy rim on one side. Lightly altered inside.

Dive 42
Hafa Adai Vent Field (17.0°N back-arc segment): Voodoo Crater, Sequoia, Waypoint 8 area.

S42-Geo-14- Sheet lava between Voodoo Crater and Sequoia. 14 x 14 x 9 cm. Half-cylinder shape. Ropy, bark-like texture on the outside and brown to black, some glassy rind. Swirled, Fe-oxide staining on the inside with vesicle/bubble rim 5 x 6 cm. Cross-section vesicles flattened, up to 2 cm wide and 3+ cm long. Outer layer almost split from inner layer and fold-back feature?

Dive 43
Started N of Hafa Adai Vent Field (17.0°N back-arc segment) looking at other, larger cone, then travelled S over sheet flows to Hafa Adai, Alba vent site, and ended at Sequoia vent.

S43-Geo-01- Sheet lava crust from N of Hafa Adai. 16.5 x 15.5 cm. Black and sharp, ropy, bark-like texture on top. Large bubble rim on bottom 11.5+ x 5 cm, with other, smaller bubble features around. Vesicles in cross-section flattened, up to 15 mm wide.

Dive 44
Hafa Adai Vent Field (17.0°N back-arc segment): Started at Waypoint 9 area to Waypoint 8, then to Two Towers and ended at Voodoo Crater.

S44-Geo-01- 3 pieces of large sheet lava from S of Waypoint 9. 27 x 19, 14 x 6, 7 x 4 cm. Ropy, bark-like on top, either smooth, bubble imprints or rough on bottom. Black, somewhat glassy. Cross section vesicles maximum 13 x 25 mm, but most are a couple of mm.

Dive 45
Dive on the new pillow lava flows at the 2013-2015 lava flow site (15.5°N back-arc segment) ~7 km south of Perseverance Vent Field. Dive sampled both the new lavas (01-04) and the surrounding older lavas (only west of the new flow).

Figure 4.1.1-5 S45-Geo-01 basalt crust.

S45-Geo-01- Piece of basalt crust from "exploded" pillow. Arcuate. 13 x 13 cm. Top is rough and wavy, glassy underneath. Lava is black with plag up to 7 mm. Few vesicles to 16 mm, otherwise not vesicular. Bottom is larger pieces of concave glass rims fused together. "New" 2013-2015 lava.

S45-Geo-02- Cylindrical piece of pillow lava, 9 x 13 cm. Outside is glassy rim to 4 mm. Inside with radiating breakage fractures. Plag to 3 mm. Hardly any vesicles. "New" 2013-2015 lava.

S45-Geo-03- 4 pieces of pillow basalt, largest is 8 x 6 cm. All have glassy rim on 2 sides – top and bottom. Plag to 4 mm, hardly any vesicles. Some glass on the bottom side is arcuate with smooth, brown surface like outlining bubble. "New" 2013-2015 lava.

Figure 4.1.1-6 S45-Geo-04 pillow basalt.

S45-Geo-04- Large cylindrical piece of pillow basalt. 10 x 21 cm. One of the tubes is more flattened. Glassy rim to 10 mm. Plag to 4 mm. Hardly any vesicles. "New" 2013-2015 lava.

S45-Geo-05- Triangular piece of older pillow basalt, 8 x 7.5 cm. Thin glass on top to 2 mm. Plag to 4 mm. More phenocrysts than newer lava. Glassy, rough, jagged, brown rim on the bottom. Hardly any vesicles. Older lava from flows at margin of 2013-2015 lava flow.

S45-Geo-06- 3 pieces of older pillow basalt. 2 triangular ~10 x 13 cm, 1 elongate 16 x 5 cm. Glassy rims to 5 mm, turning brown. Lava brown on the outside. Plag to 5 mm (triangular) or 3 mm (elongate). Triangular pieces slightly more vesicular, to 3 mm. Older lava from flows at margin of 2013-2015 lava flow.

Dive 48
Looking around Perseverance Vent Field (15.5°N back-arc segment) for more sources of plume signal. Got one piece of lava from bottom of hill by chimneys. Aborted early because of ROV oil-comp problems.

S48-Geo-01- Cylindrical piece of pillow basalt, 15 x 8 cm. Glassy rim to 6 mm. Plag to 5 mm and mostly in glass. Not very vesicular except a few up to 10 mm.

4.2 Hydrothermal Chemistry

4.2.1 Hydrothermal Fluid Chemistry

Dave Butterfield

Our primary goals for chemistry were to collect samples to characterize high-temperature fluids from each vent site in order to understand conditions in the reaction zone of each vent site, including the influence of high-temperature water-rock equilibrium and input of magmatic gases. We will use the chemistry data to relate the fluids to the mineralogy of the chimney deposits. It was equally important to characterize in some detail the temperature and chemical conditions in diverse vent fauna habitats in order to evaluate potential systematic differences in the chemical environment between arc and back-arc sites. The primary tool for both of these goals (and also for the microbiology of diffuse fluids) was the Hydrothermal Fluid and Particle Sampler (HFPS, a.k.a. the Beast), using a combination of titanium or PVC pistons and Tedlar collapsible bags. HFPS also collected large volume samples and preserved DNA/RNA with in-situ filtration. In addition to HFPS, we had titanium major samplers on board as a backup, but we never used a major sampler with the ROV. To enable quantitative collection and analysis of gases, we also had 10 pre-evacuated titanium gas-tight samplers (UCSB type) from John Lupton and Marv Lilley.

HFPS Setup

In an effort to improve reliability while replacing worn parts, the HFPS was again modified prior to this expedition, and we will briefly document the changes here. We had been using stainless steel multi-port quick disconnect (QD) fittings from Beswick Engineering for 10 years with variable success. They were difficult to maintain and not designed to work well under negative internal pressure (i.e. suction to pull water into samplers). We therefore switched to plastic QD fittings (Colder Products) with O-ring/piston seals, designed to work under suction and to be easier to maintain or replace (at 1/10 the cost of the stainless parts). Testing of these parts in the lab gave excellent results.

A second major change was in the piston sampler design. To reduce the friction, improve piston alignment, and increase reliability, we designed a double-seal piston with a guide extension to keep the piston straight in the cylinder. These also tested extremely well in the lab. The force needed to move the pistons through the cylinders was significantly less and they did not leak under pressure.

A third change was in the collapsible sample bag valve. We have used a Luer-locking valve manufactured by PMC (small company, maker of the collapsible bags) for many years, but there were severe quality issues with the valves, requiring pre-testing of valves before they were assembled on the bags. Both PMC and another company offer a side-stem/septum valve that seals very reliably. We adapted our plumbing to attach the valve stem to the lid of the bag samplers (using a short length of tubing and a hose-barb-to-Luer adapter). Although the valve function works extremely reliably, the seal of the valve base onto the bag is not as robust and reliable as desired because the new valve sealing area is narrow/small, so it requires delicate handling during cleaning, setup, and processing. We found that the bags were reliable with careful handling, but we did lose a few samples due to leaking around the valve base where it seals to the bag.

We installed a new temperature sensor in the intake nozzle during mobe in Guam.

The physical layout of the HFPS on the ROV was separated into two parts, one starboard and one port on the aft of the vehicle approximately 4 feet above deck level. This arrangement made it very easy to work on the sampler on deck. New tubing and connectors were installed to go between the 25-port valve and the sampler racks. We used the same thick-walled polyurethane tubing as in previous setups, although the tubing between valve and racks was approximately twice as long in the setup for *SuBastian* (approximately 4-foot tubing length). We covered the instrument with perforated plastic sheet (1/4” thick) to protect the plumbing and parts from ROV thruster wash. (The mounting location is close to thrusters). The ROV group made an aluminum frame to hold the top cover. The electrical cable for the (newly installed) temperature sensor in the nozzle was routed to the front of the vehicle and attached to the fluid intake hose. The intake hose and temperature cable were covered with thick, blue insulating tubing (from the ROV group) to protect them from heat and abrasion. We provided an aluminum pipe with a flared opening and base clamp for a nozzle holster attached to the

forward starboard corner of the ROV porch. The cable and hose formed a large S shape held by bungie cords attached to the ROV to allow extension and retraction during sampling.

The sampling performance of HFPS was disappointing. A large number of piston and bag samples came up empty, indicating a failure in plumbing. In a few cases, operator setup errors (primarily loose fittings) resulted in leaks that explained the failed samples, but in most of the cases there was no obvious reason for failure. We conducted multiple tests of the plumbing connections, pumps, and valve on deck, but did not find an explanation there either. Suspecting the new QD fittings, we removed one of them and plumbed the lines directly from the valve to the samplers (making manual connections on each sampler). Some of the direct connections also failed with no explanation, so the QD fitting is not the cause. It will take additional testing in the lab to determine the cause of the failed samples. In spite of the poor sampler performance, we collected 52 successful fluid chemistry samples, and we can characterize the chemistry of every vent field. This is a very successful sample return; it just doesn't measure up to what HFPS can do when everything works perfectly. The in-situ sensors add significant data to fill out the picture of how temperature and chemistry vary within diffuse flow areas at each vent field.

Apparently the Schilling Titan arms used on *SuBastian* are significantly more powerful than those used on other ROVs. Our intake nozzle, which has survived more than 100 ROV dives, was almost destroyed. The T-handle was bent, the top plate with hockey puck grip was broken off, and the main shaft (made of ¾" titanium pipe) was bent. Fortunately, the temperature probe was spared and we did not need to replace it during the cruise.

Sampling

Table 4.2.1-1 lists all of the fluid chemistry samples attempted during the expedition, with gas-tights at the top of the table. The metadata information in this table was extracted from the IRLS ROV dive log. Table 4.2.1-2 shows the sample processing for the fluid chemistry samples taken with HFPS. We recovered 52 successful samples for fluid chemistry, listed in Table 4.2.1-2.

Between uses, samplers were cleaned with hot water. Surfaces were wiped clean with a Kim Wipe wetted with ethanol, then rinsed again with de-ionized water, then rinsed with filtered deep seawater collected the previous year from the Mariana back-arc. Filtered deep seawater was used to fill dead volumes of the samplers. The HFPS intake hose, nozzle, and manifold were rinsed with fresh water after each dive, then thoroughly rinsed with seawater during descent. The manifold was rinsed with seawater between sampling sites. Additional deep seawater was collected with Niskin samplers late in the cruise, then filtered through a 0.2 micron filter cartridge and stored in an acid-cleaned Nalgene carboy.

Sample processing and shipboard chemistry

Upon ROV recovery, sample trays were removed from the HFPS and taken into the lab. There was insufficient refrigerator space (only one lab refrigerator on the ship) to store whole sample trays, so piston samples were removed and placed on foam 'eggshell' padding in the refrigerator to await processing. Bag sampler cylinders were stored in the refrigerator with inlets plugged until they could be processed. Bags were removed from their cylinders, weighed on a pan balance to determine volume, sub-sampled for hydrogen and methane analysis by GC and hydrogen sulfide analysis by spectrophotometric molybdate blue method. All sub-sampling was done without exposure of the sample to air. If gas headspace was present in the sample, it was completely removed into one container and the volume of gas and remaining liquid was measured; both phases were analyzed by GC. Samples for pH were stored in 30-ml bottles, filled from the bottom with an extension tube on a syringe to minimize gas exchange and measured at room temperature with a glass pH electrode calibrated with NBS buffers. After pH analysis, a 15-ml aliquot was measured and titrated for alkalinity using a Metrohm Titrino automated titrator with Brinkmann pH electrode and Gran-function endpoint determination. Samples for dissolved silicate analysis were diluted in 0.02N HCl and analyzed by silicomolybdate blue spectrophotometry on board. (Samples from the last dive had to be diluted and brought back to the shore lab for analysis due to the time constraints of offloading). Approximately half of the samples taken were filtered in-situ through 0.4 micron pore size polycarbonate membrane filters that were acid-washed, rinsed, dried, and weighed prior to the cruise. Samples that were filtered in-situ on HFPS were not filtered again during processing. An aliquot for nutrient analysis was syringe filtered into an acid-cleaned HDPE bottle, acidified to pH ~3 with ultra-pure HCl, purged with a nitrogen gas stream to remove H2S, then frozen. Frozen samples were shipped back by air to Seattle. Samples for major ions were syringe

filtered and stored in acid-cleaned 30ml HDPE bottles. Samples for trace metals were transferred to 250ml or 500ml I-Chem clean HDPE bottles and acidified to pH <2 with ultrapure HCl. Samples for DOC analysis were syringe filtered (after the nutrient sample, using the syringe and filter rinsed with sample by the nutrient cut) and frozen in glass containers that were rinsed and heated to 550°C for 8 hours in a muffle furnace then wrapped in clean aluminum foil prior to the cruise. Selected samples for sulfur isotope analysis were transferred to 40-ml glass vials from a syringe with an extension tube (as for pH), 0.5ml of 10% Cd acetate solution was added, vials capped and taped. Selected samples for microbiology (cell counts, single cell genomics, other) were transferred to Falcon tubes or stored in sterile syringes and given to Julie Huber for preservation.

Sensors

HFPS was equipped with a SeaBird (Bellevue, WA) SBE 63 oxygen optode and a deep-sea pH sensor (glass electrode, pressure-compensated, AMT Rostock, Germany). Both sensors were calibrated by the manufacturers in 2016 prior to the expedition. The oxygen optode was rinsed with water between ROV dives. The pH sensor was rinsed with water and stored in 3M KCl solution in a protective storage cap between dives. The pH calibration was checked through the HFPS electronics with NBS buffers on Dec 5 and Dec 18. Sensor performance was consistent through the cruise. Sensor values reported in the ROV log during the first week of the cruise were incorrect due to incorrect calibration constants in the HFPS software. All sensor data will be reprocessed on shore from the HFPS log files. Along with the in-line temperature sensors, the pH and oxygen sensors were used frequently to measure in-situ properties of diffuse vent areas. We recorded approximately 60 spot measurements with the sensors during the cruise. We also recorded vertical profiles of pH and oxygen during ascent or descent (although rarely the entire vertical profile through >3000 meters), and we use these profiles in comparison with the ROV-mounted oxygen sensor or background CTD profiles to evaluate oxygen sensor performance. Generally, both sensors appeared to give consistently good data for the duration of the cruise.

Gas-tight samplers

The gas-tight samplers were evacuated and sealed before the cruise in the Lupton lab. Samplers were set up with snorkel inlets rinsed and filled with deep seawater before they were deployed. Using the gas-tight samplers was one of the more difficult operations for the ROV. The hydraulic trigger ram was mounted on the port manipulator. The design of the ROV makes it difficult to pick up a gas-tight sampler from the front of the porch, and maneuvering the gas-tight into position when the ROV was up close against a chimney was also very difficult. It was our priority to take high-temperature samples from the back-arc sites. We collected 1 gas-tight from Alice Springs, 4 from Hafa Adai 17°N, and 2 from Perseverance 15.5°N. The number of samples collected is small, but we took care with the sampling setup and the quality of many of them appeared to be quite good. Each sampler was labeled after use with the dive location on the sampler body. Samplers were shipped back to Seattle in the container and then forwarded to Newport, Oregon for extraction and analysis in the Lupton lab. We worked with the ROV engineers in the year before the expedition to get the hydraulic trigger ram mounted on the manipulator arm. The ROV team designed a mounting bracket that is easy to adjust and it worked perfectly. It was a good fit for the major sampler syringes also, but space on the ROV porch was in high demand and we did not use them during the cruise.

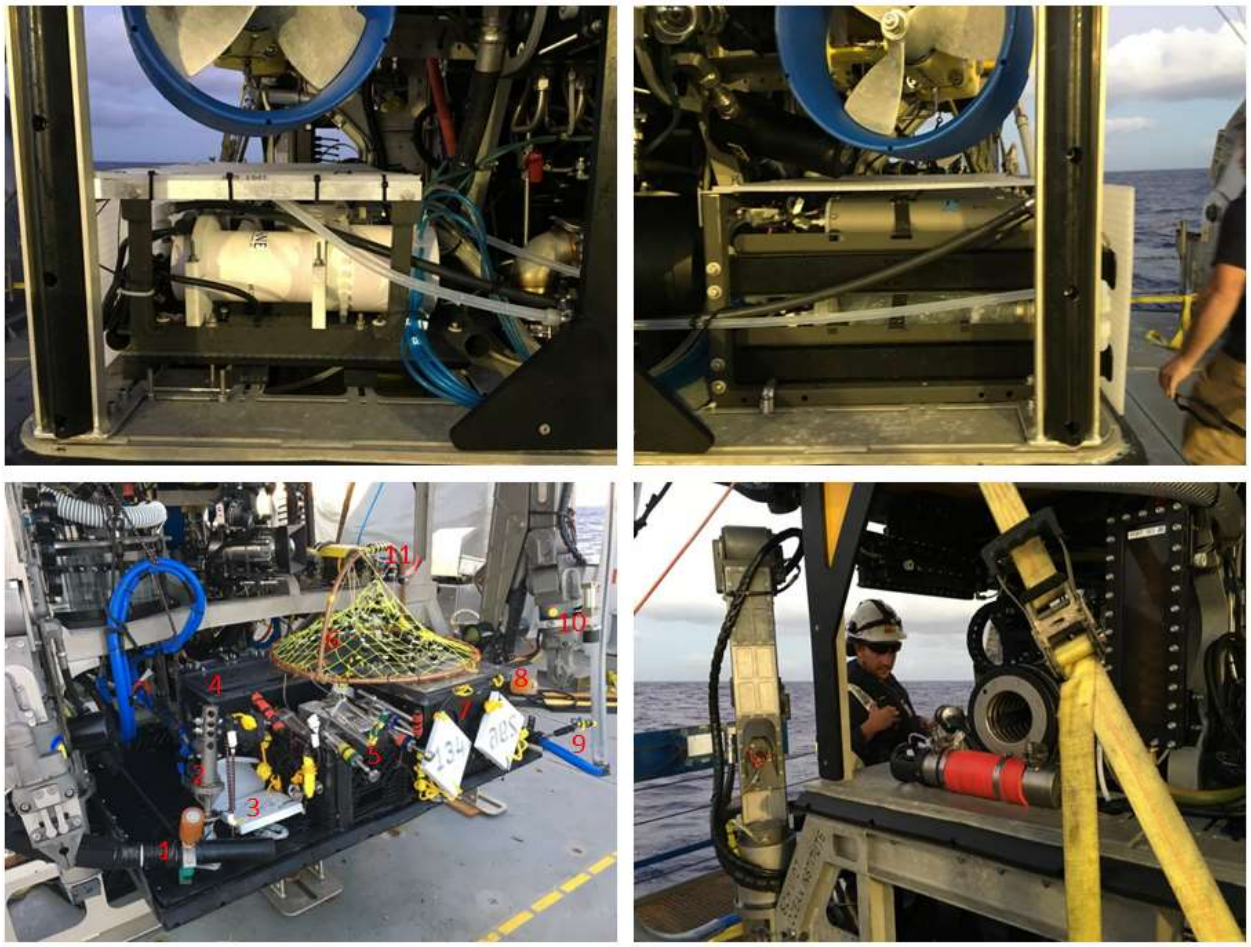


Figure 4.2.1-1. ROV science equipment on *SuBastian*. The ROV engineers left a large space for HFPS at mid-height under the aft thrusters. Top left shows aft view port side with HFS valve/pumps/controller/sensors. Top right is aft view starboard side showing the sampler trays and two hoses connecting the manifold to the flush pump line. Bottom right shows the MAPR (wrapped in red) mounted horizontally with sensors forward near the port forward corner of the ROV. Bottom left shows the front porch setup for dive 42. Equipment from left to right includes: 1) suction sampler intake with orange handle, 2) HFS intake nozzle in holster (after the ROV had broken the T handle and the top part of the nozzle), 3) white seafloor markers, 4) aft large biobox, 5) two gas-tights mounted in cradle made by ROV engineers, 6) 'Hula' temperature array made with copper tubing and net on top of 7) small biobox, 8) scoop tool mounted on side of biobox, 9) ROV temperature probe, 10) hydraulic trigger ram mounted on port arm, and 11) MAPR mounted to ROV and cabled for real-time data display. The two bottom photos show how the base of the manipulator arms are mounted close to the ROV body and within the lateral dimensions of the ROV frame to stay within A-frame constraints. This makes it difficult to use the manipulators close in to the vehicle due to physical interference of the frame and other components.

Table 4.2.1-1 Metadata for all ROV chemistry samples

Dive Number	Date Time (UTC)	Observation	Latitude	Longitude	Depth (m)	Heading	Type
39	12/6/16 05:14	S39-GTB-06 Fired. Yellow #9 GTB. In the hole with good verification of the wand tip in the pilot camera. Sample looked really good.	18.2104	144.7073	3611	312	Gas
41	12/8/16 02:20	S41-GTB-02 Red-green taken from the same orifice the 302deg fluid was measured with the ROV wand. From the west side of the chimney near the base but where the active venting began.	16.9611	144.8669	3274	84	Gas
42	12/9/16 05:58	S42-GTB-21 Fired when saw deflection in the black smoke. Tip moved when the ram was fired (moved away from orifice when it was fired). Same orifice as sampled with HFS.	16.9612	144.8670	3261	134	Gas
43	12/10/16 04:01	S43-GTB-07 Fired. In the black smoke in the smoker in the back of the small chimney in front. When fired saw the wand go further in the orifice. Same hole as the HFS samples here but at a slightly different angle.	16.9612	144.8678	3278	89	Gas
44	12/11/16 04:23	S44-GTB-06 Fired and saw it suck up in perfect position. In the same chimlet as the HFS samples. Good deflection of the flow.	16.9613	144.8666	3269	335	Gas
47	12/16/16 10:57	S47-GTB-09 Fired. Probe was down the hole at Stump of Mystery. Red Gastight #9. Taken from the top of the chimney in a hole that was excavated.	15.4801	144.5076	3907	313	Gas
49	12/18/16 03:08	S49-GTB-04 Fired. This was fired before the view of the bent ram. Saw the tip go into the chimney (not further into the hold) when fired. Questions raised if it actually fired so not logged at the time as a sample.	15.4801	144.5078	3907	317	Gas
34	12/1/16 22:46	S34-HFS-01 Started. Piston #1 in soft sediment surround by flatfish with low pH and 10deg above ambient temperature.	21.3251	144.1917	410	198	HFS
34	12/1/16 22:50	Stopped sample. Tmax=23.6 Tavg=13.5 T2=14 Vol=600 On volcanoclastic sediment with 10deg temperature anomaly at 10cm depth.	21.3251	144.1917	410	199	HFS
34	12/2/16 00:14	This is S34-HFS-04 titanium piston #2. Temperature is above 72deg. pH at this site was down to 4.1.	21.3251	144.1917	409	220	HFS
34	12/2/16 00:17	S34-HFS-05 Start Piston #3 at the exact same location as HFS-04.	21.3251	144.1917	409	220	HFS
34	12/2/16 00:29	S34-HFS-06 Start. DNA filter #13 for Julie Huber at the same location as the previous HFS samples.	21.3251	144.1917	409	219	HFS
34	12/2/16 00:46	Stop. Tmax=67.2 Tavg=59.9 vol=3002 T=35. Same site as pistons 2 & 3.	21.3251	144.1917	409	218	HFS
35	12/2/16 23:09	S35-HFS-01 Filtered Piston #1. PVC piston. In sediment next to black-tape fish trap. Start 23:09.	21.3251	144.1916	410	169	HFS
35	12/2/16 23:13	Stop 23:13. S35-HFS-01. Tmax=23.6 Tavg=19.1 vol=750 T2=15.	21.3251	144.1916	410	169	HFS
35	12/2/16 23:16	S35-HFS-02 Start 23:16 Unfiltered Bag #16. At exact same location as previous sample.	21.3251	144.1916	410	169	HFS
35	12/2/16 23:20	S35-HFS-02 Stop 23:20. Tmax=21.6 Tavg=20.9 vol=530 T2=15	21.3251	144.1916	410	169	HFS
35	12/2/16 23:21	S35-HFS-03 Start 23:21. RNA filter #14 at the same location.	21.3251	144.1916	410	169	HFS
35	12/2/16 23:23	S35-HFS-03. Temp going up to 28degC.	21.3251	144.1916	410	169	HFS

Dive Number	Date Time (UTC)	Observation	Latitude	Longitude	Depth (m)	Heading	Type
35	12/2/16 23:37	S35-HFS-03 Stop 23:37. Tmax=31.5 Tavg=29.8 vol=3000 T2=17. Exact same location as previous.	21.3251	144.1916	410	167	HFS
35	12/2/16 23:48	S35-HFS-05 Start 23:48. Filtered Bag #17. At exact same location.	21.3251	144.1916	410	167	HFS
35	12/2/16 23:51	S35-HFS-05 Stop 23:51. Tmax=28.6 Tavg=27.6 vol=400 T2=16 At same location.	21.3251	144.1916	410	166	HFS
35	12/3/16 00:05	S35-HFS-06 Start 00:05. Filtered Piston #3 with flush pump OFF. At same location. Other piston samples were taken with the flush pump ON.	21.3251	144.1916	410	166	HFS
35	12/3/16 01:19	S35-HFS-07 Start 01:19. Unfiltered Bag #18. In ambient temperature sediment approximately 30m east of the waypoint at Fish Spa. Can see exhaust.	21.3250	144.1919	407	145	HFS
35	12/3/16 01:24	S35-HFS-08 Start 01:24 Filtered Bag #19. At same location.	21.3250	144.1919	407	144	HFS
35	12/3/16 03:09	S35-HFS-11 Start 03:09. Unfiltered Bag #20. Taken at the same location as the tubeworm sample. In a crack at the base of the worms. Inside the crater wall.	21.3238	144.1923	355	139	HFS
35	12/3/16 05:49	S35-HFS-13 Start 05:49. Unfiltered Piston #4. At waypoint 1 site Fish Spa.	21.3251	144.1916	409	164	HFS
36	12/4/16 00:44	S36-HFS-02 Start 00:44. Filtered Piston #1. At the sulfide just sampled on the sulfide mound in the broken up lava flow.	20.8215	144.7071	920	40	HFS
36	12/4/16 00:47	S36-HFS-03 Unfiltered piston #2. Start 00:47. No exhaust. Exact same location.	20.8215	144.7071	920	40	HFS
36	12/4/16 00:50	S36-HFS-04 Start Unfiltered Bag #16. Can see exhaust with the bag sample. Flush pump is on. Same location.	20.8215	144.7071	920	40	HFS
37	12/5/16 02:19	S37-HFS-03 Start 02:19. Piston #2 Unfiltered titanium.	18.2134	144.7074	3583	323	HFS
37	12/5/16 02:30	S37-HFS-04 Start 02:30 Unfiltered bag #16. Visible exhaust flow.	18.2134	144.7080	3583	323	HFS
37	12/5/16 02:39	S37-HFS-06 Start 02:39. LVB #24. Seeing some bubbles and fresh water from exhaust. Same location.	18.2138	144.7071	3583	323	HFS
37	12/5/16 03:07	S37-HFS-07 Start. Unfiltered bag #18. Same location in robosnail patch.	18.2143	144.7073	3583	323	HFS
37	12/5/16 03:14	S37-HFS-08 Start 03:14. Filtered DNA #11.	18.2136	144.7074	3582	323	HFS
37	12/5/16 03:29	S37-HFS-09 Unfiltered piston #8. Start 03:29. Same location.	18.2135	144.7077	3582	323	HFS
37	12/5/16 03:58	S37-HFS-11 Background sample. Unfiltered Bag #20. At the robosnail site. Not seeing any flow.	18.2138	144.7071	3582	323	HFS
37	12/5/16 04:12	S37-HFS-15 Start 04:12. Filtered Piston #3. Background.	18.2137	144.7075	3582	323	HFS
39	12/6/16 03:40	S39-HFS-01 Start 03:40. Unfiltered Piston #2. Have good flow.	18.2101	144.7074	3626	348	HFS
39	12/6/16 04:24	S39-HFS-02 Start 04:24. Filtered Piston #1. At the focused flow at the nav marker snail-001 site where the ROV had a high temperature of 158deg.	18.2104	144.7072	3611	307	HFS
39	12/6/16 04:37	S39-HFS-04 Start 04:37.Filtered Piston #7. At same location snail-001 near the robosnail deployment.	18.2102	144.7074	3611	307	HFS
39	12/6/16 04:39	S39-HFS-05 Start 04:39. Filtered Piston #3. Looks like it is working.	18.2102	144.7075	3611	307	HFS
39	12/6/16 06:11	S39-HFS-07 Start 06:11. LVB #24 Temperature started at about 44-45deg.	18.2103	144.7073	3611	237	HFS

Dive Number	Date Time (UTC)	Observation	Latitude	Longitude	Depth (m)	Heading	Type
39	12/6/16 06:37	S39-HFS-08 Start 06:37. Unfiltered Piston #4 At the same location as the LVB. Near the crack with the 2 snails.	18.2103	144.7074	3611	234	HFS
39	12/6/16 06:43	S39-HFS-09 Start 06:43. Unfiltered Bag #20. Same exact location as the last one.	18.2103	144.7074	3611	234	HFS
39	12/6/16 06:49	S39-HFS-10 Start 06:49. DNA Filter #10. Same exact location.	18.2104	144.7075	3611	234	HFS
39	12/6/16 10:22	baclground seawater 925m during ascent see flow out exhaust Tmax=4.6 Tavg=4.3 Vol=500	18.2104	144.7080	969	295	HFS
40	12/7/16 02:38	S40-HFS-05 Start 02:38. Filtered Piston #1. At the exact location of the last sensor reading just a few inches to the right of the robosnail. Not seeing exhaust flow.	18.1825	144.7199	3630	2	HFS
40	12/7/16 02:43	S40-HFS-06 Start 02:43 Unfiltered Piston #2. Not seeing any flow. Same exact location.	18.1826	144.7198	3630	2	HFS
40	12/7/16 02:52	Stop. Tmax=42.2 Tavg=39.4 vol=400 T2=16.	18.1826	144.7199	3631	2	HFS
40	12/7/16 02:53	S40-HFS-08 Start 02:53. Filtered Bag #21. Can see flow/exhaust. Same location.	18.1826	144.7199	3631	2	HFS
40	12/7/16 03:24	S40-HFS-10 Start 03:24. RNA Filter #11 At the same location.	18.1825	144.7198	3631	2	HFS
40	12/7/16 03:54	S40-HFS-11 Start 03:54. Unfiltered Piston #8 Seeing good exhaust. Same location to the right of the robosnail.	18.1825	144.7199	3631	2	HFS
40	12/7/16 04:26	S40-HFS-14 Start 04:26 Unfiltered Bag #20	18.1824	144.7200	3629	172	HFS
40	12/7/16 04:30	S40-HFS-15 Start 04:30. Filtered Bag #19. Same location in the milky flow as #20.	18.1825	144.7200	3629	172	HFS
41	12/8/16 03:28	S41-HFS-06 Start 03:28 Unfiltered piston #8. With good flow. Tip is in the minerals.	16.9611	144.8670	3274	136	HFS
41	12/8/16 03:34	S41-HFS-07 Start 03:34 Filtered Piston #3 at the same exact location as the unfiltered piston. Good exhaust.	16.9611	144.8670	3274	136	HFS
42	12/8/16 23:40	S42-HFS-01 Start 23:40. Unfiltered Bag #22	16.9617	144.8692	3278	3	HFS
42	12/9/16 00:22	Stop Tmax=124 Tavg=120 vol=650 T2=40.	16.9617	144.8692	3278	359	HFS
42	12/9/16 00:24	S42-HFS-04 Start 00:24 Filtered Piston #3 Same location as reading #8 inside the temperature array near Mkr-171.	16.9617	144.8692	3278	359	HFS
42	12/9/16 00:31	S42-HFS-05 Start 00:31. LVB #24 at location #8 in the array. Brought wand up from hot water just sampled at same exact location a few inches to get cooler water.	16.9617	144.8692	3278	359	HFS
42	12/9/16 00:55	S42-HFS-06 Start 00:55 RNA filter #10 At location #8 (of array readings) inside the temperature array near Mkr-171. Same exact location as HFS-05.	16.9617	144.8692	3278	353	HFS
42	12/9/16 01:35	S42-HFS-07 Start 01:35 Unfiltered Bag#20. Location near the edge of the array near the last reading but after the vehicle was bumped.	16.9617	144.8692	3278	350	HFS
42	12/9/16 01:39	S42-HFS-08 Start 01:39 Filtered Bag #19 Same location as HFS-07 near Location #9 in the array at Mkr-171 (started a bit later as valve needed to move).	16.9618	144.8692	3278	350	HFS

Dive Number	Date Time (UTC)	Observation	Latitude	Longitude	Depth (m)	Heading	Type
42	12/9/16 04:09	S42-HFS-15 Start 04:09 On the NE side of Sequoia at 25m altitude (about 6m from the top). Unfiltered Piston #2 In the black smoke after breaking off about an inch of this chimney.	16.9612	144.8670	3261	219	HFS
42	12/9/16 04:15	S42-HFS-16 Start or:15 Filtered Piston #5. Same location as HFS-15 and looks like tip has not moved.	16.9612	144.8670	3261	219	HFS
42	12/9/16 04:38	S42-HFS-17 Start 04:38 Unfiltered Piston #8 Same exact location with slight movement to get the hottest water.	16.9612	144.8670	3261	219	HFS
42	12/9/16 04:45	S42-HFS-18. Start 04:45 Unfiltered Piston #6 Same exact location with a bit higher temperature.	16.9612	144.8670	3261	218	HFS
42	12/9/16 04:51	S42-HFS-19 Start 04:51. Unfiltered Piston #4. Same exact location.	16.9612	144.8670	3261	218	HFS
43	12/10/16 02:45	S43-HFS-04 Start 02:45. Filtered Piston #1. Seeing some flow in the exhaust but not strong. Vent that was excavated slightly.	16.9613	144.8679	3277	88	HFS
43	12/10/16 02:53	S43-HFS-05 Start 02:53 Unfiltered Piston #2. Same location as HFS-04 on the lower part of Alba Vent. Running the flush pump on this one. Can see some exhaust flow.	16.9613	144.8679	3277	87	HFS
43	12/10/16 03:04	S43-HFS-06 Start 03:04 Filtered Piston #3 Same exact location as the last two samples.	16.9613	144.8679	3277	86	HFS
43	12/10/16 04:54	S43-HFS-10 Start 04:54 RNA Filter #10 Same location as LVB HFS-09.	16.9612	144.8679	3277	96	HFS
43	12/10/16 05:24	S43-HFS-11 Start 05:24 Unfiltered Bag #22 At the same site as the LVB sample on Alba Vent.	16.9613	144.8679	3277	93	HFS
43	12/10/16 05:28	S43-HFS-12 Start 05:28 Filtered Bag #21. Same exact location as HFS-13 and LVB.	16.9613	144.8678	3277	94	HFS
43	12/10/16 05:31	S42-HFS-13 Start 05:31 Unfiltered Bag #20 Same exact location as LVB and previous HFS sample.	16.9613	144.8678	3277	93	HFS
44	12/11/16 02:11	Unfiltered Piston #2 with good exhaust. Near Waypoint #9 20m Mami wata Vent (Water goddess)	16.9608	144.8720	3285	137	HFS
44	12/11/16 02:19	Stop Tmax=13.3 Tavg=7.6 vol=393 ml T2=5.	16.9608	144.8720	3285	139	HFS
44	12/11/16 03:54	Filtered Piston #1. Right in the black smoke at the top of Two Towers. Great location. Can see exhaust.	16.9613	144.8665	3269	349	HFS
44	12/11/16 04:05	Unfiltered Piston #3 At the top of Two Towers same chimlet at the first sample.	16.9613	144.8665	3269	347	HFS
44	12/11/16 04:10	S44-HFS-05 Temp is stable at 345ish. Still at the same chimlet with great placement.	16.9613	144.8665	3269	343	HFS
44	12/11/16 04:14	Stop. Tmax=348. Tavg=346.7 vol=601 T2=74.	16.9613	144.8666	3269	346	HFS
44	12/11/16 05:41	S44-HFS-09 Start 05:41. Unfiltered Piston #5 at recorder #6 inside the array at Voodoo. Not seeing good flow on this one in the exhaust.	16.9618	144.8692	3278	85	HFS
44	12/11/16 05:45	S44-HFS-10 Start 05:45. Unfiltered Piston #6 Same exact location. Not seeing exhaust again.	16.9617	144.8692	3278	85	HFS
44	12/11/16 05:52	S44-HFS-11 Start 05:52. Filtered Bag #19. Getting good exhaust.	16.9618	144.8692	3278	85	HFS

Dive Number	Date Time (UTC)	Observation	Latitude	Longitude	Depth (m)	Heading	Type
44	12/11/16 05:57	S44-HFS-12 LVB #24 Near recorder 6 in the Hula array at the same location as the last samples.	16.9618	144.8692	3278	85	HFS
44	12/11/16 06:22	S44-HFS-13 DNA Filter #10 Same location as LVB and previous water samples in the Hula array.	16.9618	144.8692	3278	86	HFS
44	12/11/16 06:49	Start 06:49 Filtered Bag #16 At the same exact location in the Hula array.	16.9617	144.8692	3278	86	HFS
44	12/11/16 07:48	Start 07:48. Unfiltered Piston #8. In the maximum heat area under the hula array after the array was lifted.	16.9618	144.8692	3278	81	HFS
44	12/11/16 07:55	Start 07:55 Unfiltered Piston #7. Same place in the high-T flow.	16.9617	144.8692	3278	79	HFS
44	12/11/16 08:00	S44-HFS-19 Start 08:00 .Filtered bag #17. Good exhaust.	16.9617	144.8692	3278	79	HFS
47	12/16/16 07:39	S47-HFS-01 Start Unfiltered Bag #16. Believe we are close to waypoint 7 but big bathy offset and will have to determine this later.	15.4799	144.5076	3913	11	HFS
47	12/16/16 07:43	S47-HFS-02 Start. Filtered Piston #1 Not good exhaust. Start/stop pump. Same exact location as HFS-01	15.4799	144.5076	3913	11	HFS
47	12/16/16 07:50	S47-HFS-03. Start 07:50 Unfiltered Piston #2. Not seeing exhaust.	15.4799	144.5076	3913	11	HFS
47	12/16/16 07:53	S47-HFS-04 Start 07:53 Filtered Bag #17 Good flow.	15.4799	144.5076	3913	11	HFS
47	12/16/16 08:32	S47-HFS-06 Start 08:32 DNA Filter #10. At the same exact location as the previous sample.	15.4799	144.5076	3913	10	HFS
47	12/16/16 11:12	S47-HFS-10 Start 11:12. Unfiltered Piston #8. Can see exhaust. Good one.	15.4801	144.5076	3907	313	HFS
47	12/16/16 11:17	S47-HFS-11 Start 11:17. Filtered Piston #7. Can see exhaust. Same exact location as HFS-10 at Stump of Mystery.	15.4802	144.5077	3907	313	HFS
47	12/16/16 11:22	S47-HFS-12 Start 11:22. Unfiltered Piston #6 at same exact location on Stump of Mystery.	15.4802	144.5077	3907	313	HFS
49	12/18/16 00:29	S49-HFS-01. Start 00:29 RNA Filter #11 Background water sample after almost reaching the bottom and dive being canceled.	15.4801	144.5073	3664	53	HFS
49	12/18/16 01:09	Unfiltered Bag #16. Another background water sample while ascending.	15.4795	144.5070	2558	263	HFS
49	12/18/16 01:12	S49-HFS-03 01:12 Background water sample. pH values seem to be low today and probably need to recalibrate. pH=7.15 in the deep water (had been 7.5).	15.4795	144.5070	2433	262	HFS
49	12/18/16 04:22	S49-HFS-08 Start 04:22 Filtered Bag #18 At the same location as last sample at Limpet's Canyon.	15.4798	144.5076	3913	41	HFS
49	12/18/16 04:26	S49-HFS-09 Start 04:26 LVB #24 At same location.	15.4800	144.5077	3913	41	HFS
49	12/18/16 04:57	Start Unfiltered Bag #20 At the same location at Limpet Canyon after the RNA filter.	15.4799	144.5077	3913	44	HFS
49	12/18/16 05:18	S49-HFS-12 Start 05:18 Filtered Piston #3 Taken at the top of Stump of Mystery but not in the hottest water. Not working Aborted.	15.4802	144.5077	3906	346	HFS
49	12/18/16 05:19	S49-HFS-13 Start 05:19. Unfiltered Piston #4. Can see exhaust. Good example at the top but not hottest water at Stump.	15.4802	144.5077	3906	346	HFS

Table 4.2.1-2 Vent Chemistry Sample Splitting Information

***SuBastian* Sample#**	**lab sample#**	**Tmax °C**	**Sample volume mL**	**gas head mL**	**gas-H2O mL**	**pH/Alk mL**	**H2S/Si mL**	**Nutrients**	**DOC mL**	**Majors mL**	**TM mL**	**Microbio**	**S iso-tope**
S34	*Daikoku*												
S34-HFS-01	S34-P1	13.1	303	0	23	35	30	45	35	35	100		
S35	*Daikoku*												
S35-HFS-01	S35-PF1	23.6	270	44	15	35	25	30	45	30	70		20
S35-HFS-06	S35-PF3	28.2	120	87	15	35	20			20	30		
S35-HFS-07	S35-B18	13.5	254		22	35	25	42	35	35	60		
S35-HFS-08	S35-BF19	13.6	111		12	4	20	30	15	20	10		
S35-HFS-11	S35-B20	15.7	200	3	15	35	30	35		35	50		
S35-HFS-13	S35-P4	42.3	130	98	15		15		30	35	35		
S36	*Chamorro*												
S36-HFS-04	S36-B16	139	210	0	32	35	30	50		35	30		
S36-HFS-05	S36-B18	155	200	14	22	35	30	20		30	60		
S37	*18N Illium*												
S37-HFS-09	S37-P8	32.8	750		30	35	30	42	75	35	500		
S39	*18N Alice Springs*												
S39-HFS-01	S39-P2	7.8	722		33	35	35	45	45	35	350	50	
S39-HFS-02	S39-P1	126.5	575		25	35	35	45		35	400		
S39-HFS-03	S39-P8	161.4	745		35	35	30	45	40	35	470		45
S39-HFS-05	S39-PF3	164.8	732		22	35	35	45	45	35	470		45
S39-HFS-07	S39-LVB24	67.7	3000										
S39-HFS-08	S39-P4	33.4	616		23	35	30	45	45	35	350	53	
S39-HFS-09	S39-B20	40.5	414	60	24	35	25	45		35	250		
S39-HFS-16	S39-B16	4.6	506	0	22	35	40	45	40	35	220		
S40	*18N Burke*												
S40-HFS-07	S40-B22	42.2	466	0	22	35	25	40	40	35	220	47	
S40-HFS-08	S40-BF21	47.2	402	0	22	35	25	45	40	35	200		
S40-HFS-09	S40-LVB24	49.5											
S40-HFS-11	S40-P8	48.7	722	0	22	35	25	45	40	35	475	45	
S40-HFS-14	S40-B20	11	464		32	35	25	40	40	35	210	45	

***SuBastian* Sample#**	**lab sample#**	**Tmax °C**	**Sample volume mL**	**gas head mL**	**gas-H2O mL**	**pH/Alk mL**	**H2S/Si mL**	**Nutrients**	**DOC mL**	**Majors mL**	**TM mL**	**Microbio**	**S iso-tope**
S40-HFS-15	S40-BF19	11.1	225	0	22	35	25	40		35	70		
S41	*Hafa Adai*												
S41-HFS-06	S41-P8	302	700		20	35	30	45	40	35	450		45
S41-HFS-07	S41-PF3		462		22	35	30	45		35	250		45
S42	*Hafa Adai*												
S42-HFS-01	S42-B22	25.6	307		not run	32	25			30	100	120	
S42-HFS-02	S42-BF21	30.5	438	0	22	35	25	45	45	35	220		
S42-HFS-07	S42-B20	6	390		22	35	25	45	40	35	120	50	
S42-HFS-16	S42-PF5	209	680		25	35	20	40		35	480		45
S43	*Hafa Adai*												
S43-HFS-03	S43-B16	13.3	412	0	22	35	25	45		35	250		
S43-HFS-04	S43-PF1	209.4	627		22	20	35	45	40	35	420		60 spme
S43-HFS-05	S43-P2	219.1	663		23	35	25	45		35	500		
S43-HFS-06	S43-PF3	238.6	535		22	35	25	45	40	35	280		45
S43-HFS-09	S43-LVB	16.3	82		22	10				20	30		
S43-HFS-11	S43-B22	16.7	422		27	35	25	40	40	35	220		
S44	*Hafa Adai*												
S44-HFS-02	S44-P2	13	542	0	22	35	30	90		35	280	50	
S44-HFS-03	S44-P1	331.8	395		30	35	15			35	225		45
S44-HFS-04	S44-P3	340	635	103	20	35	20	45		35	425		45
S44-HFS-05	S44-P4	340	497	240	22	35	20	45	30	35	255		45
S44-HFS-10	S44-P6	32.5	65							35	30		
S44-HFS-11	S44-BF19	30	480	0	22	35	25	45	45	35	225		
S44-HFS-14	S44-B16	37.7	400	0	25	35	30	45	40	35	190		
S44-HFS-17	S44-P8	91.7	675	0	25	35	25	45	210	35	250	50	
S44-HFS-18	S44-P7	107	682	0	22	35	25	45		35	520		
S44-HFS-19	S44-B17	95	436	0	22	35	30	45		35	230		
S44-HFS-20	S44-B18	2	450		32	35	35	90	40	35	120		
S47	*Perseverance*												
S47-HFS01	S47-B16	43.2	466	4	22	35	25	45		35	230		

***SuBastian* Sample#**	**lab sample#**	**Tmax °C**	**Sample volume mL**	**gas head mL**	**gas-H2O mL**	**pH/Alk mL**	**H2S/Si mL**	**Nutrients**	**DOC mL**	**Majors mL**	**TM mL**	**Microbio**	**S iso-tope**
S47-HFS-04	S47-BF17	26.5	463	0	22	35	35	45	40	35	240		
S47-HFS-10	S47-P8	221.8	737	48	22	35	20	40	40	35	500		45
S47-HFS-15	S47-B18	16.4	305		25	35	25	45		30	95	50	
S47-HFS-16	S47-BF19	73.5	436		22	35	30	45	40	35	215		
S49	*Perseverance*												
S49-HFS-03	S49-BF17	1.4	392		32	35	45	45		35	200		
S49-HFS-08	S49-BF19	21	417		22	35	25	45	40	30	220		
S49-HFS-11	S49-B20	19.3	360		0	35	45	45		35	130	50	20 SPME

4.2.2 Gas Chemistry

Tamara Baumberger, NRC post-doc

In total, 10 pre-evacuated gas-tight bottle samplers (GTB; sampler volumes between about 150 and 165 ml) were sent to the Mariana back-arc for the *R/V Falkor* expedition in Nov/Dec 2016. Seven of these where used at sea to collect high-temperature vent fluid samples at 3 different vent fields, namely Alice Springs (1), Hafa Adai (4) and Perseverance (2). There was no extraction line at sea. Subsampling of the GTBs was done in the NOAA/PMEL Helium isotope laboratory in Newport, OR between Feb 27th and March 2nd 2017. Six of the 7 GTB samples can be expected to yield useable data, one GTB from the field, Hafa Adai, was empty (S42-GTB-21). Total gas concentrations were between 17 and 80 mmol/kg with fluid amounts between 130 and 165 g. Subsampling was conducted into splits of 3 cc aluminosilicate ampules for later helium and neon isotope analysis and in 35 cc Pyrex ampules for later total gas concentration and carbon/hydrogen isotope analysis. Two of the non-triggered GTBs (GTB 10 and GTB 5) were used for the determination of the procedure blank and thus subsampled as well (contained zero to near zero gas).

Gas-tight samples FK161129

Sample #	GTB #	Dive Location	Observation	Latitude	Longitude	Depth (m)	Temp degC	Gas (mmol/kg)	Fluid (g)	#splits 3cc/35cc
S39-GTB-06	GT 6	Alice Springs	S39-GTB-06 Fired. Yellow #9 GTB. In the hole with good verification of the wand tip in the pilot camera. Sample looked really good.	18.21041	144.70728	3611.08	161	17.1	165.77	3/3
S41-GTB-02	GT 7	Hafa Adai: Sequoia	S41-GTB-02 Red-green taken from the same orifice the 302deg fluid was measured with the ROV wand. From the west side of the chimney near the base but where the active venting began.	16.96108	144.8669	3274.25	302	23.4	160.67	3/3
S42-GTB-21 (failed)	GT 12	Hafa Adai: Sequoia	S42-GTB-21 Fired when saw deflection in the black smoke. Tip moved when the ram was fired (moved away from orifice when it was fired). Same orifice as sampled with HFS.	16.96116	144.86696	3261.07	345	Empty	Empty	

Gas-tight samples FK161129

Sample #	GTB #	Dive Location	Observation	Latitude	Longitude	Depth (m)	Temp degC	Gas (mmol/kg)	Fluid (g)	#splits 3cc/35cc
S43-GTB-07	GT 17	Hafa Adai: Alba	S43-GTB-07 Fired. In the black smoke in the smoker in the back of the small chimney in front. When fired saw the wand go further in the orifice. Same hole as the HFS samples here but at a slightly different angle.	16.96124	144.86785	3277.79	239	21.6	153.03	3/3
S44-GTB-06	GT 11	Hafa Adai: Two Towers	S44-GTB-06 Fired and saw it suck up in perfect position. In the same chimlet as the HFS samples. Good deflection of the flow.	16.96132	144.86659	3268.79	340	62.6	130.7	4/4
S47-GTB-09	GT 9	Perseverance: Stump of Mystery	S47-GTB-09 Fired. Probe was down the hole at Stump of Mystery. Red Gastight #9. Taken from the top of the chimney in a hole that was excavated.	15.48012	144.50764	3906.54	264	80.3	149.4	4/4
S49-GTB-04	GT 2	Perseverance: Stump of Mystery	S49-GTB-04 Fired. This was fired before the view of the bent ram. Saw the tip go into the chimney (not further into the hold) when fired. Questions raised if it actually fired so not logged at the time as a sample.	15.4801	144.50776	3906.67	250	35.6	157.11	4/4

Bottles not triggered:

not used	GT 16		Loose hydraulic trigger? Needs fix?					Empty - not sampled	Empty - not sampled	
not used	GT 10		To seafloor and back, not used					0	0	1/1
not used	GT 5		Used for fit testing on ROV, not triggered, did not go to the seafloor					0	0	1/1

4.3 Microbiology

Hydrothermal Vent Microbial Ecology

Julie Huber

The main objectives on this cruise were to (1) quantify microbial biomass in venting fluids; (2) preserve venting fluids for single cell genomic analyses; (3) collect diffuse fluids that were *in situ* filtered and preserved (with RNALater) to determine and quantify functional repertoire of total active microbial communities in venting fluids; (4) conduct shipboard and seafloor stable isotope probing experiments with diffuse vent fluids enriched with labeled DIC under thermophilic and hyperthermophilic conditions to determine which microbes are actively fixing carbon; (5) estimate potential activity and carbon uptake rates by both autotrophs and heterotrophs in venting fluids at 80 ºC; and (6) enrich for a variety of mesophilic, thermophilic, and hyperthermophilic microbes from venting fluids. We sampled fluids with the HFPS, as well as CTD. A number of biological and animal samples were also collected for symbiont analyses. A complete sample table is shown in Table 4.3-1.

Figure 4.3-7 HFS sampling at Mkr-138, Illium area.

I. Vent Fluid Counts: To quantify microbial biomass using epifluorescent microscopy, vent fluid was collected and preserved in labeled scintillation vials, 2 x 18 mL, with 1.8 mL 37% formaldehyde. Vials were mixed via shaking after adding fixative, sealed with electrical tape, and stored at 4 ºC. On land, cells were quantified using DAPI. Results are shown in Table 4.3-2.

II. Vent Fluid Single Cell Genomics: Vent fluid was collected on each dive for single cell genomics. For preservation, 1 mL of fluid was added to a sterile cryovial with 100 µL of filter-sterilized GlyTE buffer. Vials were then inverted for mixing and incubated at room temperature for 5 minutes before being frozen at -80ºC. Triplicate samples were taken for each sample.

III: Metagenomics and metatranscriptomics from vents, background, plume: To better understand the metabolic potential and gene expression patterns of subseafloor communities, we collected samples for ‘omic analyses from multiple vents. For each dive, two filter holders containing a 0.2 µm, 47 mm flat filter with ~20 mL RNALater were loaded onto the HFPS. At each diffuse vent, ~3 L of fluid was pumped through each filter and then the filter was preserved *in situ* with RNALater. Once on deck, filters were removed from their holders, folded into quarters and placed into sterile 50 mL Falcon tubes with ~10 mL of fresh RNALater. Tubes were kept at 4 ºC for 24 hours and then moved to -80 ºC for the remainder of the cruise. DNA extraction was carried out on land using standard Huber lab chloroform-phenol extraction methods, with results of DNA extraction shown in Table 4.3-2.

For background and plume: An ‘omics sample from background seawater and the plume near the soon-to-be confirmed Perseverance site was also collected in a cubitainer from a Niskin. ~15 liters of water was filtered through a 0.2 µm Sterivex filter, preserved in RNALater, placed at 4ºC for 24 hours, then stored at -80ºC.

Table 4.3-1. Summary of Samples Collected for Microbial Analysis

Huber #	Sample #	Counts	SCG	Omics	SIP	Cult	Rates	Chem	Site	Vent
FS919	S34-HFS-06			x					Daikoku	10m eas of Okeanos Fish Spa
S34-GEO-08	S34-GEO-08			x					Daikoku	10m east of Okeanos Fish Spa; Yellow/black globules of sulfur
S34-GEO-10	S34-GEO-10			x					Daikoku	Mkr 132 FK-2016 Fish Spa; Whitish sulfur crust
S34-BIO-03	S34-BIO-03			x					Daikoku	10m east of Okeanos Fish Spa; Sulfur sediment around fish
S35-Bio-10	S35-Bio-10								Daikoku	20m E/5m N WP2 crater rim; Inside wall of big crater near rim
FS921	S35-HFS-16			x					Daikoku	Okeanos Fish Spa
FS922	S37-HFS-06	x	x	x	x	x		x	Ilium	Snail Pile Mkr 138
S39-HFS-01	S39-HFS-01	x							Alice Springs	Diffuse site 22m NE of old Alice Springs
FS923	S39-HFS-07	x	x		x				Alice Springs	Mkr-131 Snail-001 Site
S39-HFS-08	S39-HFS-08	x	x			x			Alice Springs	Mkr-131 Snail-001 Site
FS923	S39-HFS-10			x					Alice Springs	Mkr-131 Snail-001 Site
S40-HFS-07	S40-HFS-07	x	x			x			Burke	Snail Pit Mkr-234
FS924	S40-HFS-09	x	x		x	x	x		Burke	Snail Pit Mkr-234
FS924	S40-HFS-10			x					Burke	Snail Pit Mkr-234
S40-HFS-11	S40-HFS-11	x							Burke	Snail Pit Mkr-234
S40-HFS-14	S40-HFS-14	x							Burke	Milky Flow
FS925	S42-HFS-01	x	x		x				Hafa Adai	Hula Array
FS925	S42-HFS-05				x				Hafa Adai	Hula Array
FS925	S42-HFS-06			x					Hafa Adai	Hula Array
S42-HFS-07	S42-HFS-07	x	x						Hafa Adai	Hula Array
FS926	S43-HFS-09	x	x		x	x	x	x	Hafa Adai	Alba Vent
FS926	S43-HFS-10			x					Hafa Adai	Alba Vent
FS927	S44-HFS-02	x							Hafa Adai	Mami Wati
FS927	S44-HFS-12	x	x		x	x	x		Hafa Adai	Hula array
FS927	S44-HFS-13			x					Hafa Adai	Hula array
FS927	S44-HFS-17	x	x			x			Hafa Adai	Hula array
V16A-01-Btl17	V16A-01-Btl17	x		x					15.5 N	over yet to be explored vent field (Perseverance), in plume
V16A-01-Btl23	V16A-01-Btl23	x		x					15.5 N	over yet to be explored vent field (Perseverance), background
S47-HFS-01	S47-HFS-01	x	x						Perseverance	Leaning Tower
FS928	S47-HFS-05	x	x		x	x	x	x	Perseverance	Leaning Tower
FS928	S47-HFS-06			x					Perseverance	Leaning Tower
S47-HFS-15	S47-HFS-15	x	x						Perseverance	Stump of Mystery
S49-HFS-01	S49-HFS-01			x					Perseverance	Background Seawater 3663 to 2640 m
FS929	S49-HFS-10			x					Perseverance	Limpet Canyon
FS929	S49-HFS-11	x	x						Perseverance	Limpet Canyon

Table 4.3-2. Results of DNA and microbial biomass quantification

Sample	DNA (ng/ul)	Counts (cells/ml)	Site	Vent
S34-HFS-06	0.09		Daikoku	10m eas of Okeanos Fish Spa
S34-GEO-08	x		Daikoku	10m east of Okeanos Fish Spa; Yellow/black globules of sulfur
S34-GEO-10	x		Daikoku	Mkr 132 FK-2016 Fish Spa; Whitish sulfur crust
S34-BIO-03	x		Daikoku	10m east of Okeanos Fish Spa; Sulfur sediment around fish
S35-Bio-10			Daikoku	20m E/5m N WP2 crater rim; Inside wall of big crater near rim
S35-HFS-16	0.66		Daikoku	Okeanos Fish Spa
S37-HFS-06	0.14	2.20E+05	Ilium	Snail Pile Mkr 138
~~S37-HFS-08~~	~~0.42~~		~~Ilium~~	~~Snail Pile Mkr 138~~
S39-HFS-01		3.30E+05	Alice Springs	Diffuse site 22m NE of old Alice Springs
S39-HFS-07		1.80E+05	Alice Springs	Mkr-131 Snail-001 Site
S39-HFS-08		2.10E+05	Alice Springs	Mkr-131 Snail-001 Site
S39-HFS-10	0.12		Alice Springs	Mkr-131 Snail-001 Site
S40-HFS-07		3.30E+05	Burke	Snail Pit Mkr-234
S40-HFS-09		1.80E+05	Burke	Snail Pit Mkr-234
S40-HFS-10	14.93		Burke	Snail Pit Mkr-234
S40-HFS-11		6.60E+04	Burke	Snail Pit Mkr-234
S40-HFS-14		3.50E+05	Burke	Milky Flow
S42-HFS-01		3.20E+05	Hafa Adai	Hula Array
S42-HFS-05			Hafa Adai	Hula Array
S42-HFS-06	1.23		Hafa Adai	Hula Array
S42-HFS-07		2.40E+05	Hafa Adai	Hula Array
S43-HFS-09		2.40E+05	Hafa Adai	Alba Vent
S43-HFS-10	7.18		Hafa Adai	Alba Vent
S44-HFS-02		2.30E+05	Hafa Adai	Mami Wati
S44-HFS-12		4.80E+05	Hafa Adai	Hula array
S44-HFS-13	44.94		Hafa Adai	Hula array
S44-HFS-17		4.80E+05	Hafa Adai	Hula array
V16A-01-Btl17	0.42	1.80E+05	15.5 N	over yet to be explored vent field (Perseverance), in plume
V16A-01-Btl23	0.36	1.50E+05	15.5 N	over yet to be explored vent field (Perseverance), background
S47-HFS-01		3.40E+05	Perseverance	Leaning Tower
S47-HFS-05		1.10E+05	Perseverance	Leaning Tower
S47-HFS-06	0.08		Perseverance	Leaning Tower
S47-HFS-15		4.40E+05	Perseverance	Stump of Mystery
S49-HFS-01	0.07		Perseverance	Background Seawater 3663 to 2640 m
S49-HFS-10			Perseverance	Limpet Canyon
S49-HFS-11	16.9	1.00E+06	Perseverance	Limpet Canyon

IV. RNA-Stable Isotope Probing (RNA-SIP) experiments: Fluid was collected from the HFPS Large Volume Bag (LVB) sampler for determining who the active autotrophs at each site were using RNA Stable Isotope Probing. The LVB was filled with ~4 liters of fluid and used to fill evacuated 500 mL bottles to a volume of 530 mL. To each bottle we added 8.83 mL of either ^{12}C or ^{13}C sodium bicarbonate for a final concentration of 10 mM. After filling, 1-2 mL of 10% HCl was added until the fluid had a pH < 6.5 to ensure the SIP incubation was similar to vent conditions. We then added 20 mL (~900 µmoles) of 99.99% H_2 gas to each bottle for a concentration of ~20 µM H_2 in solution. Our previous work has shown that the addition of hydrogen is necessary for label uptake in our SIP experiments. Bottles were then incubated lying on their sides at either 55 ºC or 80 ºC. It was important to incubate bottles on their sides to keep the hydrogen from escaping through the stopper. The chart below shows the setup and incubation times for all shipboard SIP experiments.

Table 4.3-3. Details of RNA-SIP experiments carried out shipboard

Huber #	Label	Dive	Sample #	Vent	Incubation time
FS922	FS922-80-12DIC-18h	S37	S37-HFS-06	Illium, Snail Pile Mkr 138	18
FS922	FS922-80-13DIC-18h	S37	S37-HFS-06	Illium, Snail Pile Mkr 138	18
FS922	FS922-55-12DIC-18h	S37	S37-HFS-06	Illium, Snail Pile Mkr 138	18
FS922	FS922-55-13DIC-18h	S37	S37-HFS-06	Illium, Snail Pile Mkr 138	18
FS923	FS923-80-12DIC-18h	S39	S39-HFS-7	Alice Springs, Mkr 131 Snail-001 Site	18
FS923	FS923-80-13DIC-18h	S39	S39-HFS-7	Alice Springs, Mkr 131 Snail-001 Site	18
FS924	FS924-80-12DIC-18h	S40	S40-HFS-10	Burke, Snail Pit Mkr 234	18
FS924	FS924-80-13DIC-9h	S40	S40-HFS-10	Burke, Snail Pit Mkr 234	9
FS924	FS924-80-13DIC-18h	S40	S40-HFS-10	Burke, Snail Pit Mkr 234	18
FS924	FS924-55-12DIC-18h	S40	S40-HFS-10	Burke, Snail Pit Mkr 234	18
FS924	FS924-55-13DIC-18h	S40	S40-HFS-10	Burke, Snail Pit Mkr 234	18
FS925	FS925-80-12DIC-18h	S42	S39-HFS-9	Hafa Adei, Hula Array	18
FS925	FS925-80-13DIC-18h	S42	S39-HFS-9	Hafa Adei, Hula Array	18
FS926	FS926-80-12DIC-18h	S43	S43-HFS-09	Hafa Adei, Alba Vent	18
FS926	FS926-80-13DIC-9h	S43	S40-HFS-09	Hafa Adei, Alba Vent	9
FS926	FS926-80-13DIC-18h	S43	S40-HFS-09	Hafa Adei, Alba Vent	18
FS926	FS926-55-12DIC-18h	S43	S40-HFS-09	Hafa Adei, Alba Vent	18
FS926	FS926-55-13DIC-18h	S43	S40-HFS-09	Hafa Adei, Alba Vent	18
FS927	FS927-80-12DIC-18h	S44	S44-HFS-12	Hafa Adei, Hula Array	18
FS927	FS927-80-13DIC-9h	S44	S44-HFS-12	Hafa Adei, Hula Array	9
FS927	FS927-80-13DIC-18h	S44	S44-HFS-12	Hafa Adei, Hula Array	18
FS927	FS927-55-12DIC-18h	S44	S44-HFS-12	Hafa Adei, Hula Array	18
FS927	FS927-55-12DIC-9h	S44	S44-HFS-12	Hafa Adei, Hula Array	9
FS927	FS927-55-13DIC-18h	S44	S44-HFS-12	Hafa Adei, Hula Array	18
FS928	FS928-80-12DIC-18h	S47	S47-HFS-05	Perseverance, Leaning Towers	18
FS928	FS928-80-13DIC-18h	S47	S47-HFS-05	Perseverance, Leaning Towers	18
FS928	FS928-55-12DIC-18h	S47	S47-HFS-05	Perseverance, Leaning Towers	18
FS928	FS928-55-13DIC-18h	S47	S47-HFS-05	Perseverance, Leaning Towers	18

V. NanoSIMS Rate Experiments: The goal of these experiments was to estimate carbon uptake rates by both autotrophs (DIC uptake) and heterotrophs (acetate uptake), as well as general microbial activity. This was done by adding ^{13}C labeled bicarbonate or ^{13}C labeled acetate to vent fluid, together with D_2O. Balch tubes were prepared on land in the anaerobic chamber with 10% labeled substrates. 175 µl of a 600 mM stock solution of HCO_3^- with a ^{12}C:^{13}C ratio of 10 to 1, while for the Acetate incubations it was 63 µL of a 10 mM stock solution of acetate with a ^{12}C:^{13}C ratio of 10 to 1. With ~20 mL of vent fluid added to each tube, this resulted in a final concentration of approximately 5 mM DIC and 30 µM acetate. 2 mL of 99.99% D_2O was also added to each tube for a final concentration of 10%. Each Balch tube was gassed with N_2 before shipment. After vent fluid was added to each tube, 2 bars of hydrogen was added, giving an overlying atmosphere of 50% N_2/50% H_2. Tubes were incubated at 80 °C for 9 and 18 hours. To end the experiment, head space was released and 1 mL of 40% paraformaldehyde was added to each tube for a final concentration of 2%. Each tube was shaken gently and stored at 4 °C.

Rate experiments were performed at sites to correspond to the locations and temperatures of the SIP experiments and the fluid sample came from the same bag as that used for the SIP experiment. For each temperature and site, four separate incubations were performed, as shown in the table below. All tubes were returned to the laboratory and will be analyzed using nanoscale secondary ion mass spectrometry (Nano-SIMS) and microscopy.

Table 4.3-4. Example set up of Nano-SIMS rate experiment.

Tube #	Sample	Temp	Hrs	Label 1	Label 2
MBA1		80	9	none	none
MBA2		80	9	none	none
MBA3		80	9	none	none
MBA4		80	18	none	none
MBA5		80	18	none	none
MBA6		80	18	none	none
MBA7		80	9	D_2O	none
MBA8		80	9	D_2O	none
MBA9		80	9	D_2O	none
MBA10		80	18	D_2O	none
MBA11		80	18	D_2O	none
MBA12		80	18	D_2O	none
MBA13		80	9	D_2O	Acetate
MBA14		80	9	D_2O	Acetate
MBA15		80	9	D_2O	Acetate
MBA16		80	18	D_2O	Acetate
MBA17		80	18	D_2O	Acetate
MBA18		80	18	D_2O	Acetate
MBA19		80	9	D_2O	Bicarbonate
MBA20		80	9	D_2O	Bicarbonate
MBA21		80	9	D_2O	Bicarbonate
MBA22		80	18	D_2O	Bicarbonate
MBA23		80	18	D_2O	Bicarbonate
MBA24		80	18	D_2O	Bicarbonate

Table 4.3-5. Nano-SIMS rate experiments carried out shipboard

Huber #	Sample #	Rates	Site	Vent
FS924	S40-HFS-09	x	Burke	Snail Pit Mkr-234
FS926	S43-HFS-09	x	Hafa Adai	Alba Vent
FS927	S44-HFS-12	x	Hafa Adai	Hula array
FS928	S47-HFS-05	x	Perseverance	Leaning Tower

VI. Enrichment Culturing: ~1 mL of vent fluid sample was added to each tube, along with headspace as necessary. Tubes were incubated in ovens shipboard monitored for turbidity. Media used are shown below.

Table 4.3-6. Media used during the cruise

Target Organism	DSMZ	Label	Notes	Before Inoculating	HS	Temp
Nautilia profundicola	18972	Nau+NO3	In balch tubes	reduce with 0.15ml 2.5% Na2S	H2/CO2	55 and 80
Caminibacter profundus	15016	Cami+NO3	In balch tubes	none	H2/CO2	55 and 80
Thermococcus		CamiOrg	In balch tubes	reduce with 0.15ml 2.5% Na2S	none	55 and 80
Sulfurimonas paralvinella	1251	Sulf+O2	In balch tubes	add up to 10% O2 to headspace	H2/CO2	30 and 55
Sulfurimonas paralvinella	1251	Sulf	In balch tubes	none	H2/CO2	30 and 55

Tubes were analyzed via microscopy on land and cultivars are currently being worked with in the Huber lab. Post-cruise results are shown below.

Table 4.3-7. Microscopic counts of enrichment culturing at sea

Media	Temp	Headspace	Red Agent	# of Positives
Nau+NO3	55	H2/CO2	Na2S	3
CamiOrg	55	none	Na2S	4
CamiOrg	80	none	Na2S	6
Cami+NO3	55	H2/CO2	none	2
Cami+NO3	80	H2/CO2	none	3
Sulf	30	H2/CO2	none	6
Sulf	55	H2/CO2	none	4
Sulf+O2	30	H2/CO2	none	8
Sulf+O2	55	H2/CO2	none	3

4.4 Biology

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Our hydrothermal 'hunting' was quite successful biologically because of the opportunity to examine a very important biogeographic region and to sample in detail. Samples from the dives (see list) will be processed primarily to document species distributions. Our primary objective is to map the diversity and species distributions to compare with the southern backarc, the volcanic arc and with the northwestern Pacific biogeographic region. In addition, we plan detailed work on the biology of the hairy snails (*Alviniconcha*) that we endeavoured to collect at each back-arc site. Additional work will include genetic connectivity along the back arc among populations of this snail and or the shrimp *Chorocaris vandoveri*. To advance population level traits, we also sampled *Alvinoconcha* for gill and gonad tissues at multiple sites. These samples will comprise a basis for describing the reproductive biology of *Alvinoconcha*, as well as to quantify the morphological responses of the gill and bacteriocytes across vents with different fluid chemistry.

Figure 4.4-1 Sample of chimney with snails at Chamorro.

Volcanic Arc Sites – Our dives on Daikoku confirmed the very high abundances of the tonguefish *Symphurus thermophilus*. Repeated sampling of the sediments they inhabit revealed no potential food source for the dense population. Unfortunately, we were unable to collect extensive samples to resolve nutrition sources. The very short dive on Chamorro confirmed that vents were colonized and we did collect a few specimens of a large hairy snail that is probably a species known only from Diamante Seamount.

Figure 4.4-2 Diffuse venting site at Alice Springs.

Alice Springs – The surprise here was i) how small the sites were and ii) how unchanged they appear to be from the sparse description available from 1987 discovery and 1992 visit.

It is unlikely that we collected any more species than those originally recorded. This site may be a testament to long-term stability in venting.

Figure 4.4-3 Sulfides at the Leaning Tower site at Perseverance.

Hafa Adai – This new site offered much greater habitat variability, including the large chimneys. Biomass, however, was relatively low as fluid flux appeared constrained by the non-porous sulphide matrix. We did find mussels but no extensive mussel beds, nor were any tubeworms evident (here or any back-arc field). Shrimp, limpet, hairy snails and crabs were the main components of the biomass and meiofauna was remarkably sparse.

Perseverance – This field appeared to be in decline. The many dead chimneys suggest that venting may have supported a wider array of communities than we encountered. The species collected were those seen further north, and known from sites in the southern back-arc.

In summary, we have confirmed our hypothesis that vent species distributions along the Mariana back-arc, from Snail to Alice Springs span the entire range and that habitat types appear very similar. These large ranges stand in notable contrast to species on the volcanic arc.

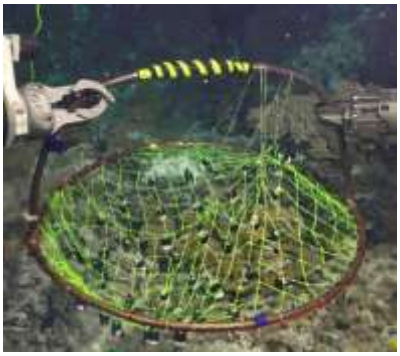


Figure 4.4-4 Temperature grid ("hula-hoop") deployed at Voodoo crater in Hafa Adai.

Small-scale temperature and fluid chemistry –

In additional to regional biodiversity and species biology comparisons, we advanced our understanding of centimeter-scale processes and patterns. We measured the temperature of hydrothermal vents fluids at scales using a grid of 45 temperature loggers deployed over gradient of 100 to 5 ° C covering an area of ~ 0.5 m^2. Within this grid we measured dissolved oxygen concentration and pH using the sensors on HFPS, and deployed "robocritters". Robocritters are

designed to mimic body temperature and are comprised of a temperature logger, embedded in epoxy, and set within a snail or mussel shell. We deployed our temperature grid and robocritters over a 2.5 day observation window with readings at 5 minute intervals. We will (1) compare the temperature of the fluids interpolated from the temperature grid measurements to the temperatures experienced by our robocritters and (2) estimate temporal patterns in dissolved oxygen concentration and pH based on our spatial point measurements.

Table 4.4-1 Biological Samples Recovered

DiveSite	Dive	Date	Sample	On Deck	Latitude	Longitude	Depth	Location
Daikoku	34	12/1/2016	S34-02,-03	Sieved sediments – nearly nothing	21.32509	144.19171	410	10m East of OE Fish Spa
Daikoku	34	12/2/2016	S34-Bio-09	Sediments one polychaete, fish lost	21.32493	144.19165	403	Mkr-132 FK-2016 Fish Spa
Daikoku	34	12/2/2016	S34-11C	9 fish dissected; nothing in sediment	21.32488	144.19175	398	25m E of waypoint 2 (Sulfur pond)
Daikoku	35	2016-12-03	S35-Bio-10	*Lamellibrachia satsumi* tubeworms	21.32378	144.19229	355	20m E/5mN WP2 crater rim
Daikoku	35	2016-12-03	S35-Bio-12	Nothing in sediment	21.32421	144.19205	371	Mkr-137
Daikoku	35	2016-12-03	S35-17 +18	Two crabs	21.32502	144.19165	407	10m SE OE Fish Spa
Chamorro	36	2016-12-04	S36-Geo-01	*Alviniconcha* cf *adamantis* (5)	20.82146	144.70705	919.73	Waypoint 1
Illium	37	2016-12-05	S37-Bio-10	27 snails (*Alvini-concha hessleri*)	18.21359	144.70748	3582	Snail Pile Mkr-138
Illium	37	2016-12-05	S37-Bio-13	Crab, shrimp and debris	18.21359	144.70748	3582	Snail Pile Mkr-138
Illium	37	2016-12-05	S37-Bio-14	~30 shrimp plus debris	18.21359	144.70748	3582	Snail Pile Mkr-138
Alice Springs	39	2016-12-06	S39-Geo-11	~100 barnacle; mussel; gastropods	18.21033	144.70731	3611	Mkr-131 Snail-001 Site
Alice Springs	39	2016-12-06	S39- 12 - 14	3 crabs; 5 hairy snails	18.21033	144.70731	3611	Mkr-131 Snail-001 Site
Alice Springs	39	2016-12-06	S39-Bio-15	2 large anemones; ~20 zoanthids	18.21054	144.70745	3598	Little Anemones
Burke	40	2016-12-07	S40-Bio-01	85 shrimp; one mussel	18.18257	144.71989	3630	Snail Pit Mkr-234
Burke	40	2016-12-07	S40-02, -03	Meiofauna; gastropods, crab	18.18257	144.71989	3630	Snail Pit Mkr-234
Burke	40	2016-12-07	S40-Geo-04	limpets	18.18257	144.71989	3630	Snail Pit Mkr-234
Burke	40	2016-12-07	S40-12, -13	Hairy snails ; Robosnail site	18.18257	144.71989	3631	Snail Pit Mkr-234

DiveSite	Dive	Date	Sample	On Deck	Latitude	Longitude	Depth	Location
Hafa Adai	41	2016-12-08	S41-03, -04	58 hairy snails; shrimp	16.96115	144.86696	3274	Sequoia
Hafa Adai	41	2016-12-08	S41-Bio-05	Crabs; meiofauna	16.96115	144.86696	3274	Sequoia
Hafa Adai	41	2016-12-08	S41-Bio-10	White snail	16.96079	144.87041	3280	Waypoint 7
Hafa Adai	42	2016-12-09	S42-09, -10, -11	Snail shells; 2 white phymorhychids	16.96174	144.86911	3284	Snail Graveyard
Hafa Adai	42	2016-12-09	S42-Geo-12	Barnacles; debris	16.96168	144.86920	3278	Rim above graveyard
Hafa Adai	43	2016-12-10	S43-Bio-14	Solid Phase Micro-extraction puck #4	16.96126	144.86787	3277	Alba Vent
Hafa Adai	44	2016-12-11	S44-Bio-15	Hairy snails; cold part of Hula	16.96175	144.86919	3278	Hula array
Hafa Adai	44	2016-12-11	S44-Bio-16	Hairy snails; hot part of Hula	16.96174	144.86921	3278	Hula array
Perseverance	47	2016-12-16	S47-Bio-07	Hairy snails; shrimp Alvinellid worms	15.4799	144.50763	3913	Leaning Tower
Perseverance	47	2016-12-16	S47-Geo-08	limpet	15.4799	144.50763	3913	Leaning Tower
Perseverance	47	2016-12-16	S47-Bio-14	Alvinellid worms	15.48018	144.50772	3906	Stump of Mystery
Perseverance	47	2016-12-16	S47-Bio-17	Hairy snails; shrimp	15.48018	144.50772	3909	Stump of Mystery
Perseverance	47	2016-12-16	S47-Bio-18	Alvinellid worms; shrimp	15.48018	144.50772	3909	Stump of Mystery
Perseverance	49	2016-12-18	S49-05, 06	Detritus	15.47989	144.50754	3914	Limpet Canyon

4.5 Water Column Studies

Dave Butterfield and Sharon Walker

4.5.1. CTD Operations

CTD operations were not a major part of our planned work. We conducted CTD ops when it was not possible to do ROV dives and when we were not mapping. The two Marine Techs were extremely busy with ROV-related work, and doing CTD ops was not generally possible at night between dives. We managed to complete three successful CTD casts with water sampling (primarily for gas analysis and some microbiological work) during a period of marginal weather and ROV equipment repair. Where indicated with an X, samples were taken for methane and hydrogen analysis by GC on board. We also saved selected samples for nutrient analysis on shore. We took a number of samples near the chlorophyll maximum in the photic zone, to follow up on a curious gas result from 2015, but the results were not conclusive.

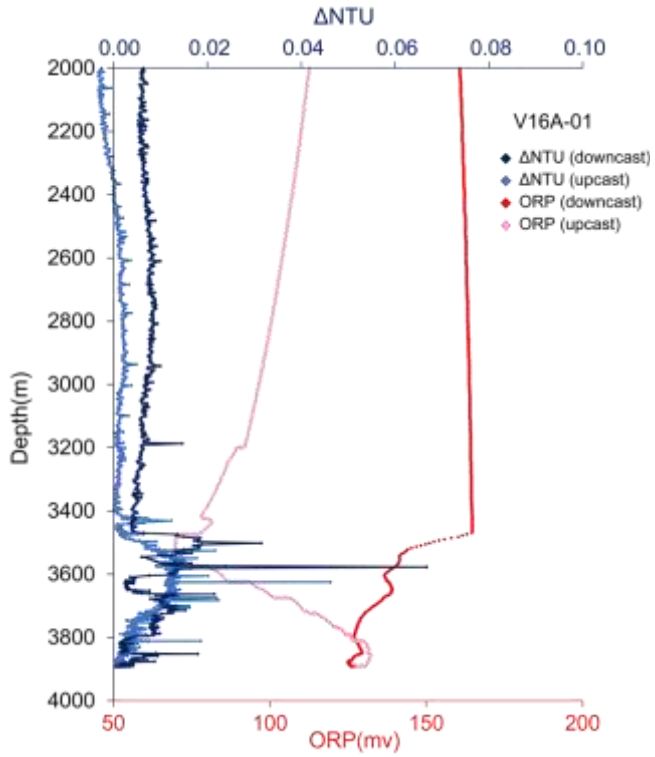


Figure 4.5-1 Turbidity (ΔNTU) and oxidation-reduction potential (ORP) profiles over the 15.5°N "Perseverance" vent field.

To reiterate what we concluded in 2015, the minimal density stratification in water below 3000 meters can lead to large rise heights and more entrainment (so smaller anomalies) than in shallower regions where stratification limits rise height. Background hydrogen concentration for deep water in this region is approximately 1 nmol/liter. Background methane is variable, sometimes less than 1 nM.

The ship's CTD system comprises a Seabird 9*plus* CTD, with additional sensors to measure dissolved oxygen concentration, turbidity (two optical backscatter sensors plus one transmissometer), fluorescence, oxidation-reduction potential (ORP), and altitude. The ship's transmissometer and combined fluorometer/optical backscatter sensor are not sensitive enough and/or do not have adequate resolution to define the hydrothermal plumes in this region. Profiles shown here are from the ORP and optical backscatter sensors supplied by the PMEL-EOI group.

Four vertical CTD casts were conducted during cruise FK161129. The second cast (V16A-02) was aborted after reaching a depth of only 895 m due to unreliable optical backscatter data. This sensor exhibited diminished quality data during the preceding cast (V16A-01 over the 15.5°N vent field, named "Perseverance" during this cruise), however, despite significant hysteresis and background drift during that cast, a plume was well defined by increased turbidity (ΔNTU_{max} ~ 0.02) and a corresponding decrease in ORP (ΔE = -38 mv) from about 3400 m to the seafloor (bottom depth ~ 3900 m). Slightly lower methane and hydrogen concentrations were measured in samples from this cast (methane = 4 nM; hydrogen = 1.8 nM) than were measured in 2015 when maximum methane and hydrogen concentrations were 5 nM and 3 nM, respectively. There was a clear vertical structure to the plume over the Perseverance site in 2016 (Fig 4.5-1).

Our target for vertical cast V16A-01 was one of the plume maxima from T15B-06, and was located ~200 m north of where we eventually found the seafloor vents. As noted in the cruise summary, we are not certain that we found all of the vents that exist near 15.5, but we are reasonably sure that we determined the extent of the one vent field that we found at 15.480°N. The 2015 tow data suggest there may be another vent source between 15.5 and 15.54N. At present, there is not enough detailed chemistry from the 2015 tow samples to say if the plume near 15.48°N is likely to have a different source from the plume near 15.53°N. Unfortunately, we ran out of time in 2016 before we could do a more complete search of the seafloor with the ROV.

Cast V16A-03 was located over the south end of the 15.4°N new lava flow, near the location of samples and the strongest ORP anomaly seen during the tow over this segment in 2015 (T15B-06). (Fig 4.5-2) Only a very small ORP signal (ΔE = -5 mv) was detected within 100 m of the seafloor during V16A-03. No significant particle anomaly was present. (Fig 4.5-3)

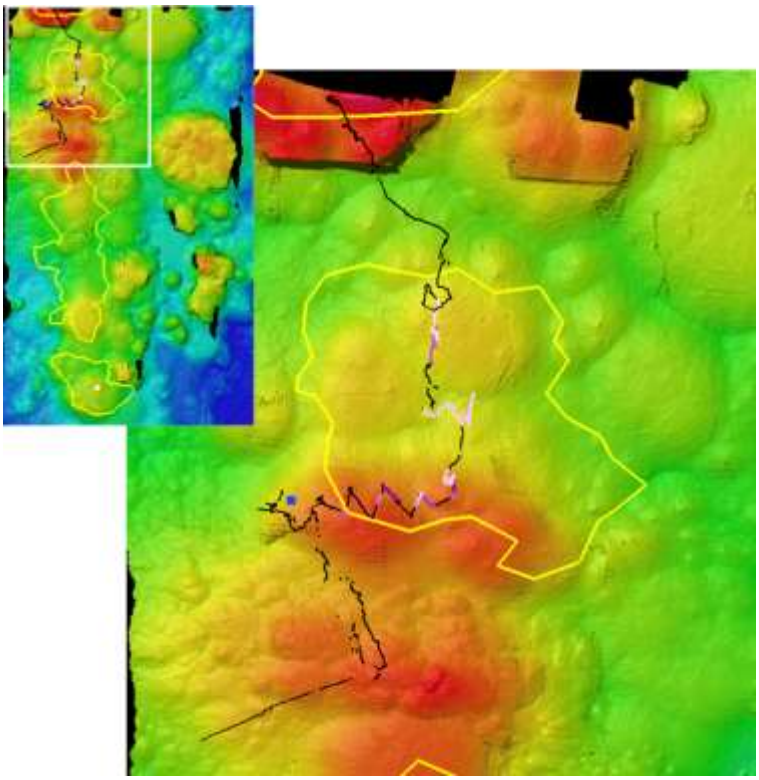


Figure 4.5-2 Location of ORP anomalies (shades of pink, darker colors = larger anomalies) during ROV dive S45 (dive trackline in black) over the new lava flow. Yellow lines outline areas of bathymetry difference > 40 m between 2013 and 2016 multibeam surveys. Inset map is the larger area; white box outlines location of main image. Location of 2015 and 2016 CTD casts are shown by blue and white dots, respectively.

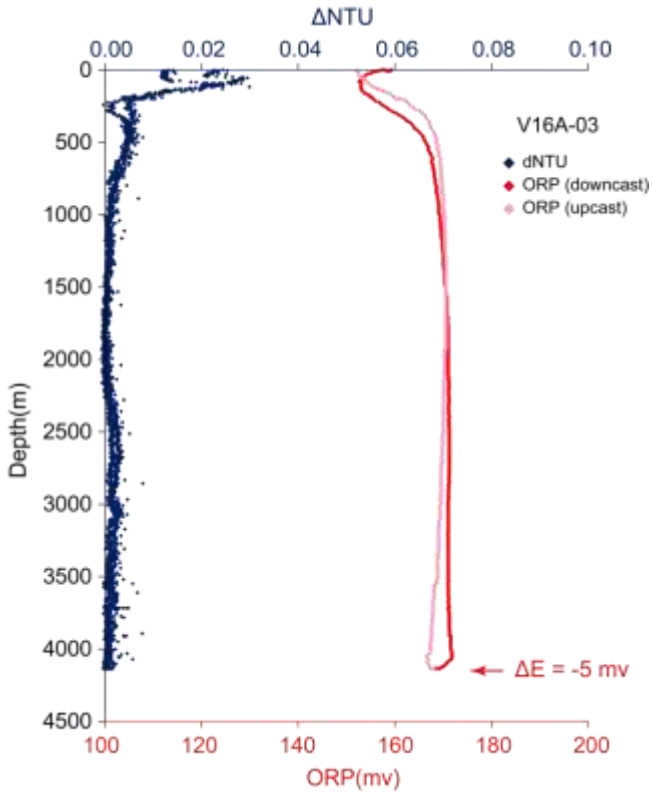


Figure 4.5-3 Turbidity (ΔNTU) and oxidation-reduction potential (ORP) profiles over the 15.4°N lava flow.

The maximum methane concentration was only 3.5 nM in the near-bottom sample (compared to 15 nM in 2015), while the maximum hydrogen concentration (3.0 nM) was measured in the sample ~300 m above the lava flow, and was similar to 2015 values. Note for comparison that the 2015 vertical cast over the new lava flow (V15B-06, 15.424418°N, 144.50295°E) was close to the dive site (S45) this cruise and ~ 2 km north of vertical cast V16A-03. The water column signal over the lava flow is much less pronounced in 2016 than it was in 2015 when the plume was broadly defined by ORP anomalies (ΔE ~ -40 mv) and weak particle anomalies (dNTU < 0.005) 200-500 m above the seafloor over the entire length of the new lava flow (T15B-06). However, during dive S45, ORP anomalies in the MAPR data show the new lava is still cooling and discharging detectable reduced chemical species into the overlying ocean.

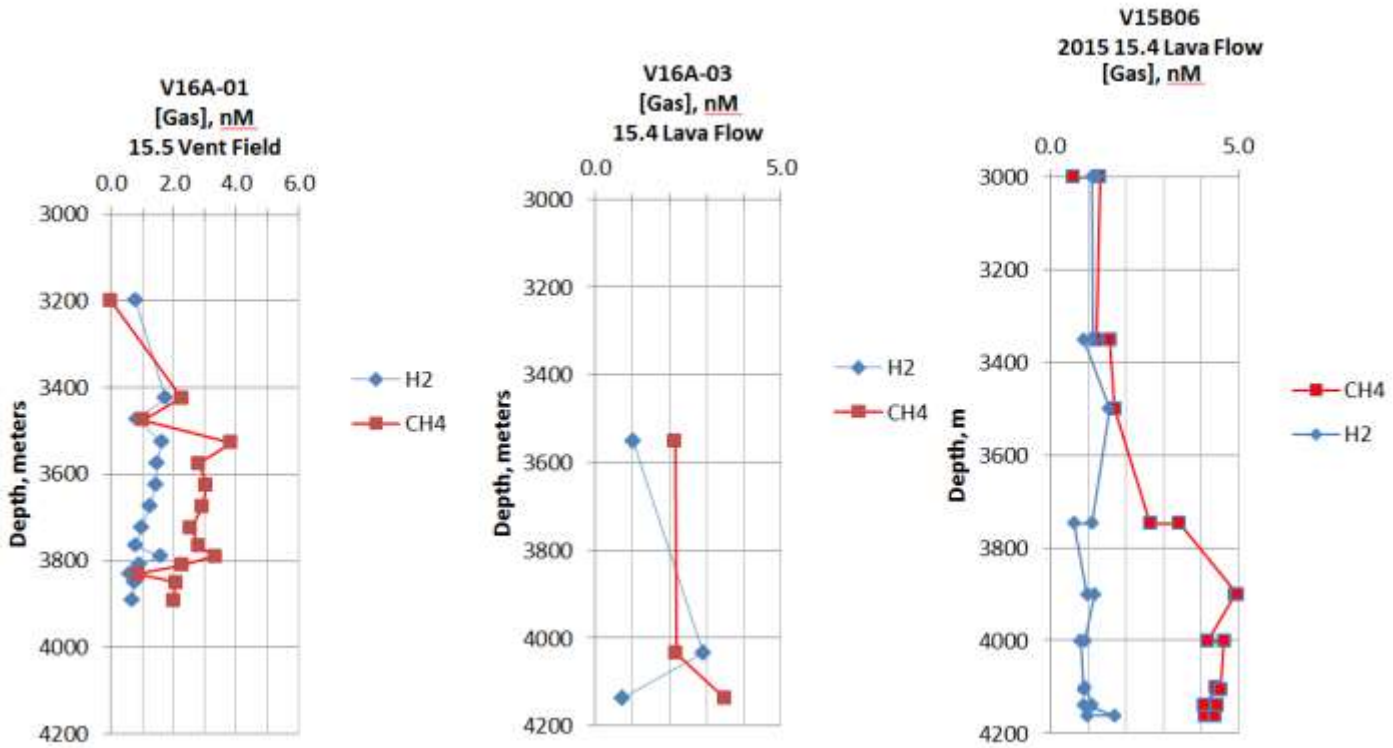


Figure 4.5-4 Vertical cast gas data over the 15.5 Perseverance vent field and the 15.4 lava flow. There is a methane anomaly from near the seafloor to ~3500 m over the vent field in 2016. Over the lava flow, the methane anomaly is much less in 2016 (middle) than it was in 2015 (right).

Cast V16A-04 explored the summit of an off-axis seamount that had never been surveyed before. While there were no definitive signs of hydrothermal activity in this profile, very slight variability in both optical backscatter (ΔNTU < 0.003) and ORP do not completely rule out the presence of very weak diffuse venting here. (Fig 4.5-5)

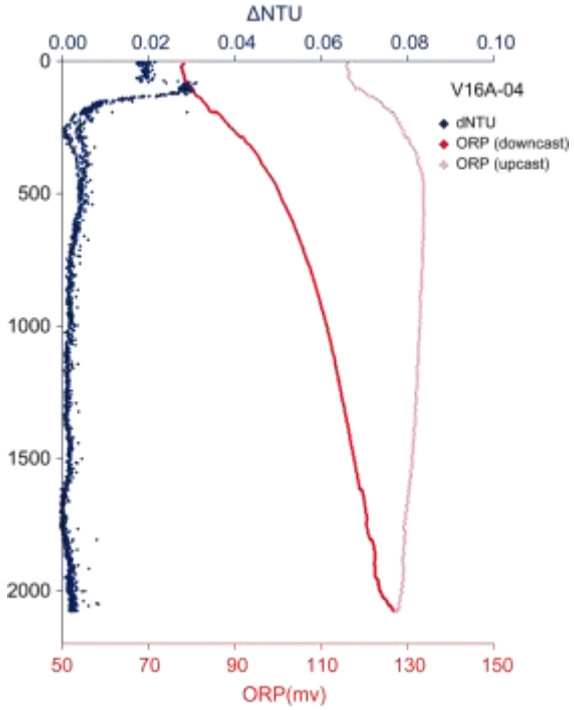


Figure 4.5-5 Turbidity (ΔNTU) and oxidation-reduction potential (ORP) profiles over the summit of the off-axis seamount.

In addition to the CTD casts, a PMEL MAPR (Miniature Autonomous Plume Recorder) attached to ROV *SuBastian* for every dive provided vertical profiles of turbidity, temperature and ORP at each of the back-arc sites. No MAPR data was acquired at the Daikoku dive site (S34 and S35), and only temperature and ORP are available for the dive at the Chamorro site (S36; the optical backscatter sensor was obstructed during this dive due to the way the MAPR was mounted on the ROV). These data provide repeat profiles within a few days and ~400-1000 m radius, and allow an assessment of the variability of the water column plume signals over relatively short temporal and spatial scales, especially at the Perseverance vent field (15.5°N) (Fig 4.5-6), Hafa Adai vent field (17°N)(Fig 4.5-7) and the Alice Springs/Illium/Burke vents (18.2°N) (Fig 4.5-8).

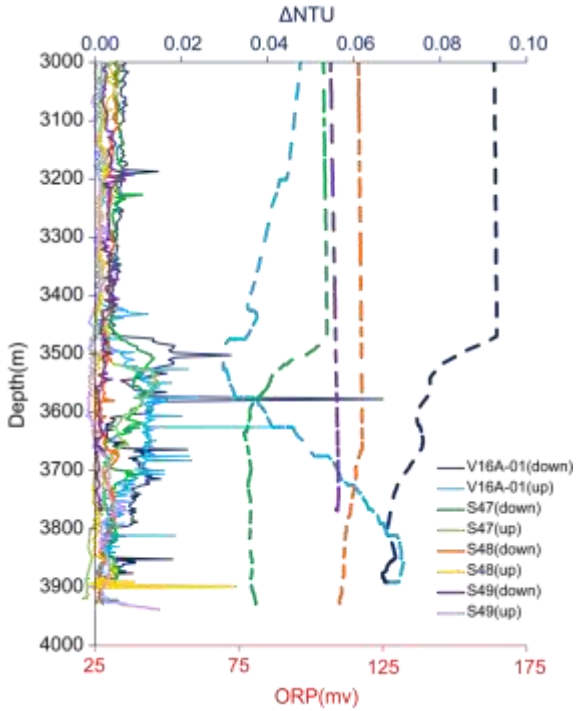


Figure 4.5-6 Variability of Turbidity (solid lines) and oxidation-reduction potential (dashed lines) profiles at the Perseverance (15.5N) vent site over 5.25 days.

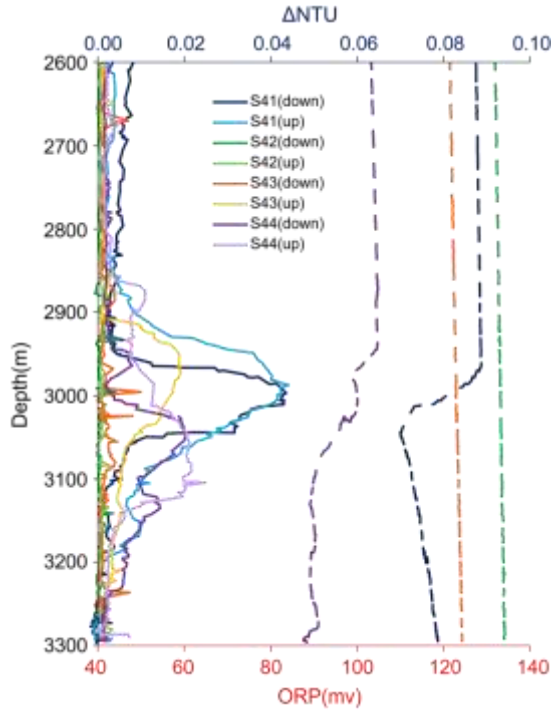


Figure 4.5-7 Variability of Turbidity (solid lines) and oxidation-reduction potential (dashed lines) profiles at the Hafa Adai (17N) vent site over 3.4 days. Dive 41 began just north of the large chimneys on west end of field and ended at vents on east end of field. Dive 42 began mid-field and ended on east side of field. Dive 43 began 1km north of the vent field and ended at the large chimneys. Dive 44 began on east side of field and ended mid-field.

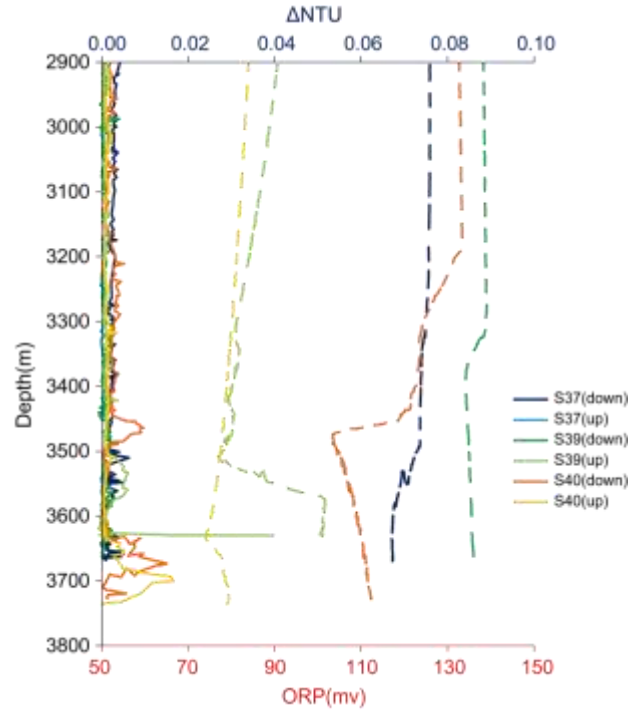


Figure 4.5-8 Variability of Turbidity (solid lines) and oxidation-reduction potential (dashed lines) profiles at Illium (S37), Alice Springs (S39) and Burke (S40) vent sites. Alice Springs and Illium are separated by about 400 m, and these profiles span a time of 1.4 days. The profiles at Burke are separated in time by only the length of the on-bottom time for this dive (~7 hrs), but the distance between the descent and ascent was ~650 m.

Table 4.5-1 CTD Casts

Cast	Location	Latitude	Longitude	Lat-Deg	Lat-Min	Long-Deg	Long-Min
V16A-01	15.5 Vent Field	15.48155	144.50717	15	28.893	144	30.43
V16A-03	Lava Flow	15.40627	144.50628	15	24.376	144	30.377
V16A-04	16.3°N off-axis Seamount	16.31033	144.94817	16	18.62	144	56.89

Table 4.5-2 List of CTD samples.

Cast:	**V16A-01**	**Lat deg**	**Lat min**	**Long deg**	**Long min**
Location:	15.5 Vent Field	15	28.893	144	30.4

Ros. Pos.	Bottle#	Depth	C	T	LSS V	ORP	Date UTC	Time hhmm UTC	CH4/H2	Nutrients	Micro-bio	Save H2O
1	1	3891	3.1816	1.658	0.2466	120	12-Dec	23:56	x	x		
2	2	3891	3.1816	1.658	0.2466	120	12-Dec	23:56				
3	3	3850	3.1798	1.654	0.246	132	13-Dec	00:09	x	x		
4	4	3850	3.1798	1.654	0.246	132	13-Dec	00:09				
5	5	3830	3.1788	1.6502	0.247	131	13-Dec	00:14	x	x		
6	6	3810	3.1784	1.651	0.249	127	13-Dec	00:20	x	x		
7	7	3810	3.1784	1.651	0.249	127	13-Dec	00:20				
8	8	3790	3.177	1.651	0.25		13-Dec	00:24	x	x		
9	9	3790	3.177	1.651	0.25		13-Dec	00:24				
10	10	3766	3.176	1.648	0.25		13-Dec	00:28	x	x		
11	11	3766	3.176	1.648	0.25		13-Dec	00:28				
12		3724	3.175	1.647	0.251	115	13-Dec	00:34	x	x		
13		3724	3.175	1.647	0.251	115	13-Dec	00:34				
14		3675	3.173	1.645	0.257	105	13-Dec	00:40	x	x		
15	15	3675	3.173	1.645	0.257	105	13-Dec	00:40				
16	16	3625	3.17	1.64	0.255	89	13-Dec	00:45	x	x		
17	17	3625	3.17	1.64	0.255	89	13-Dec	00:45		x		
18	18	3575	3.169	1.639	0.256	75	13-Dec	00:51	x	x		
19	19	3527	3.167	1.638	0.255	69	13-Dec	00:56		x		
20	20	3474	3.165	1.638	0.247	75	13-Dec	01:00	x	x		

Cast:	V16A-01	Lat deg	Lat min	Long deg	Long min
Location:	15.5 Vent Field	15	28.893	144	30.4

Ros. Pos.	Bottle#	Depth	C	T	LSS V	ORP	Date UTC	Time hhmm UTC	CH4/H2	Nutrients	Micro-bio	Save H2O
21	21	3425	3.162	1.632	0.248	79	13-Dec	01:04	x	x		
22		3200	3.154	1.635	0.245	91	13-Dec	01:13	x	x	x	x
23		3200	3.154	1.635	0.245	91	13-Dec	01:13			x	
24		3200	3.154	1.635	0.245	91	13-Dec	01:13		x		x

Cast:	V16A-03	Lat deg	Lat min	Long deg	Long min
Location:	LavaFlow	15	24.376	144	30.4

Ros. Pos.	Bottle #	Depth	C	T	LSS V	ORP	Date UTC	Time hhmm UTC	CH4 /H2	Nutrients	DOC	
1	1	4138	3.192	1.6795	0.075	168	13-Dec	08:38:00	x			
2	2	4138	3.192	1.6795	0.075	168	13-Dec	08:38:00				
3	3	4138	3.192	1.6795	0.075	168	13-Dec	08:38:00				
4	4	4035	3.188	1.673	0.075	167	13-Dec	08:46:00	x			
5	5	4035	3.188	1.673	0.075	167	13-Dec	00:00:00				2pH, major, TM
6	6	3551	3.167	1.635	0.075	168	13-Dec	09:00:00				
7	7	3551	3.167	1.635	0.075	168	13-Dec	09:00:00	x	2	2	
8	below	160					13-Dec	10:29:18	x			
9	below	150					13-Dec	10:30:33	x			
10	lower edge	145						10:30:07	x			
11	lower edge	140						10:31:32	x			
12	in max	135						10:32:05	x			
13	in max	130						10:32:35	x			
14	in max	125						10:33:09	x			
15	in max	120						10:33:43	x			
16	in max	110						10:34:46	x			
17	upper edge	100						10:35:58	x			

Cast:	V16A-03	Lat deg	Lat min	Long deg	Long min
Location:	LavaFlow	15	24.376	144	30.4

Ros. Pos.	Bottle #	Depth	C	T	LSS V	ORP	Date UTC	Time hhmm UTC	CH4 /H2	Nutrients	DOC
18	in mix layer	54						10:38:00			

collected deepwater samples for nutrients, DOC, TM, majors, pH/Alk

Cast:	V16A-04	Lat deg	Lat min	Long deg	Long min	
Location:	Seamount	16	18.62	144	56.9	No sign of any plume on this cast. Sampled chlorophyl max for H2/CH4

Ros. Pos.	Bottle#	Depth	C	T	LSS V	ORP	Date UTC	Time hhmm UTC	CH4/H2	Nutrients	DOC	
1	1	2075							x			
2	2	2075										
3	3	140							x			
4	4	134							x			
5	5	130							x			
6	6	125							x			
7	7	120							x			
8	8	115							x			
9	9	110							x			
10	10	105							x			

4.5.2 MAPR Data

In addition to the profiles extracted from the MAPR records for each ROV dive, the MAPR data (turbidity anomaly (ΔNTU), ORP anomaly (ΔE), and in-situ temperature) have been added to Fledermaus scene files that also contain the 2015 CTD tow and Sentry/MAPR data. These files are available in conjunction with this cruise report at:

https://www.pmel.noaa.gov/eoi/marians/scenes/2016-Falkor/15N-2015-2016-WaterColumnData.scene
https://www.pmel.noaa.gov/eoi/marians/scenes/2016-Falkor/17N-2015-2016-WaterColumnData.scene
https://www.pmel.noaa.gov/eoi/marians/scenes/2016-Falkor/18N-2015-2016-WaterColumnData.scene

The files have been created in Fledermaus version 7.5.1, 64 bit version, and can be viewed with the free application iView4D available from QPS: (http://www.qps.nl/display/fledermaus/iview).

Of the 14 successful ROV dives, full MAPR data records were recovered from all of the Mariana back arc sites (dives S37 through S49). No data was recovered from the Daikoku dives (S34 and S35). The optical backscatter sensor was obstructed during dive S36 at Chamorro, but data from the other sensors (pressure, temperature and ORP) is of good quality.

Of particular interest, for dives where it appears considerable time was spent sampling at one location, the ORP sensor appears to reach relatively steady values, which implies the electrodes had reached equilibrium and determining an actual Eh value may be possible. There were significant differences in the value reached at different sites: Illium, Burke and Perseverance reached values of about -67 mv, while values at Hafa Adai were significantly lower at -125 mv. There was some variability in the ORP value from the MAPR that was deployed on the seafloor for ~2.4 days at Hafa Adai as part of the biology experiment, but values varied in a relatively narrow range of -130 to -150 mv.

It will be necessary to evaluate the MAPR data from the ROV dives in the context of what was happening during the dives to properly evaluate the many signals that are present throughout each record.

One other accomplishment during this cruise was the addition of real-time monitoring of MAPR data during the ROV dives. This is a new capability, in its early stages, but the first attempt was reasonably successful and future improvements to the supporting software and procedures will make this more reliable and user-friendly, and will greatly expand the functionality of MAPRs.

We expected that the real-time MAPR data (especially the ORP signal) would help to find vent sites with the ROV by detecting ‘invisible’ water column signals before we could see the vent sites with the cameras. The MAPR ORP sensor did detect a hydrothermal signal at the 15.4°N lava flow in areas covered with thick sediments with no visible sign of fluid flow. However, while searching for vents in the 15.5°N Perseverance area, no ORP signal was detected until well after we had seen cloudy water and arrived at vent sites, apparently because we were approaching from the up-current direction (from the south). The 2015 plume sections at 15.5°N indicate net current flow to the north.

4.6 Multibeam Sonar Mapping

Susan G. Merle, Oregon State University

The R/V *Falkor's* EM302 multibeam sonar system acquired bathymetric data during transits and between ROV dives. The focus was to expand upon the multibeam data collected in the backarc region in 2015 on the *Falkor* (FK151121) and on earlier 2016 surveys with the NOAA ship *Okeanos Explorer* (EX1605) (Figures 4.6-2 – 4.6-4). Prior to 2015, there was scarce multibeam coverage in the central and northern backarc. A recent compilation showing all the multibeam data in the Mariana area is presented here (Figure 4.6-1).

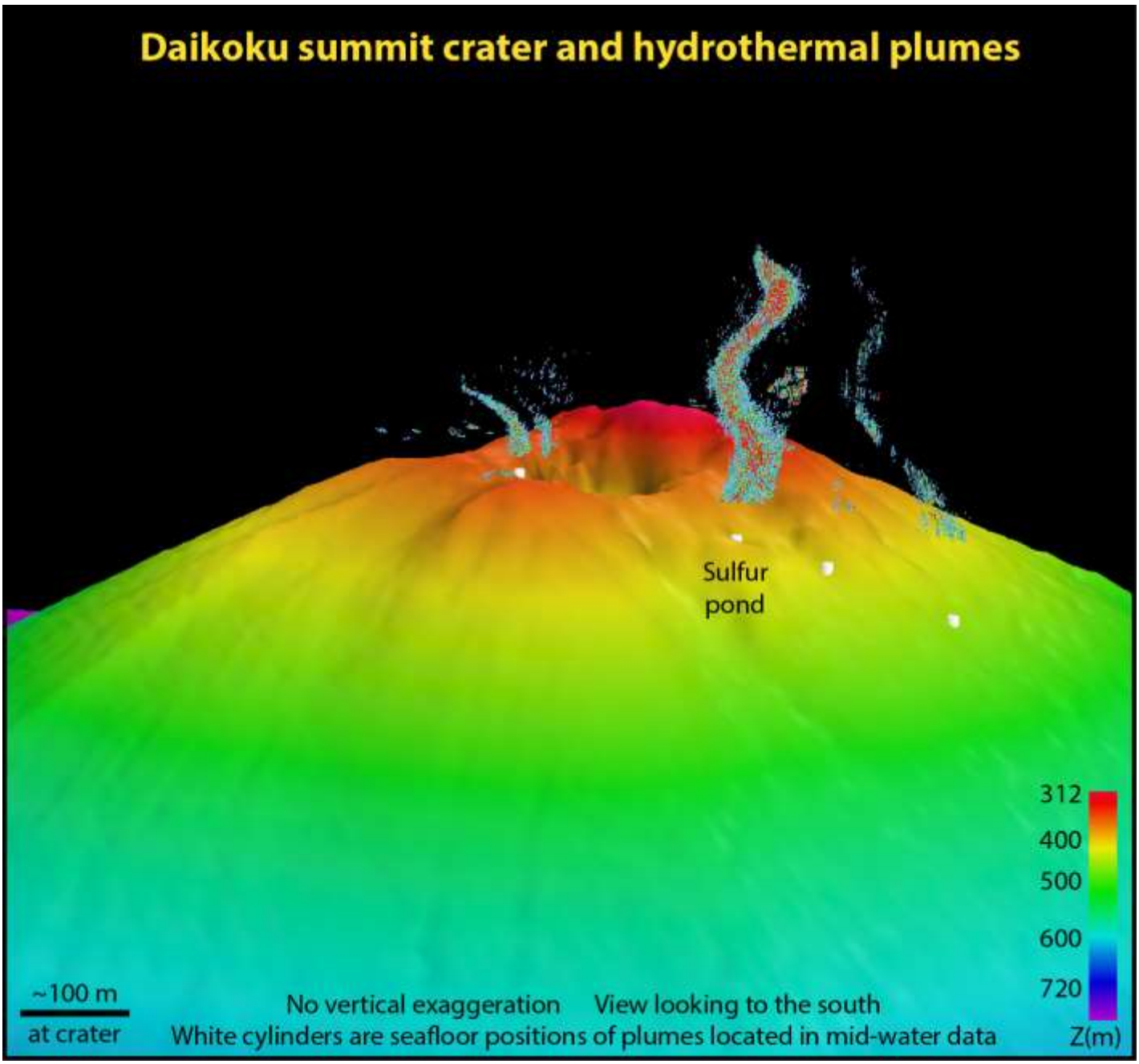


Figure 4.6-6 Water column data collected at Daikoku Seamount showing 5 areas of venting.(S.Merle)

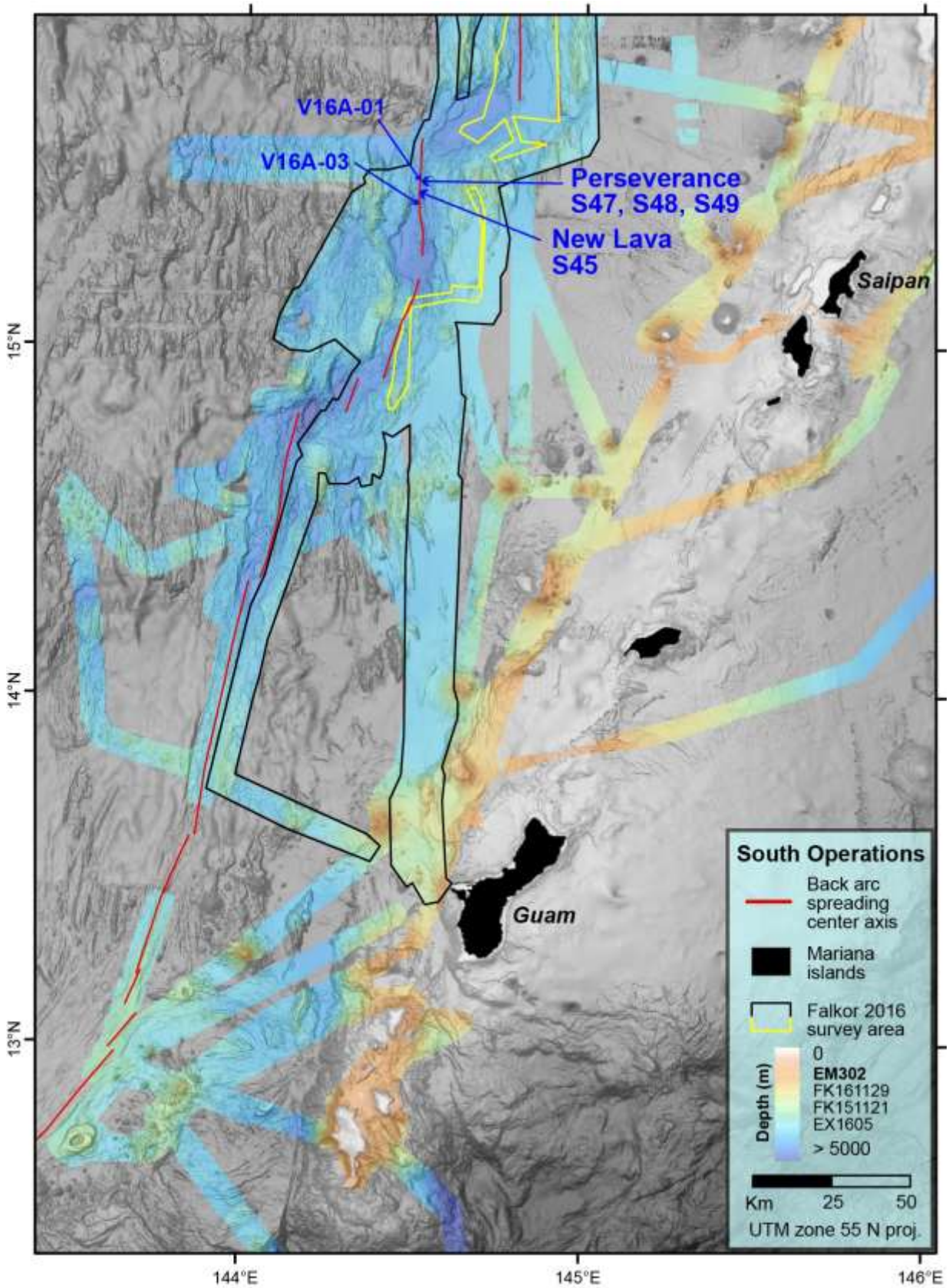


Figure 4.6-2 South area EM302 multibeam data compilation. (S.Merle)

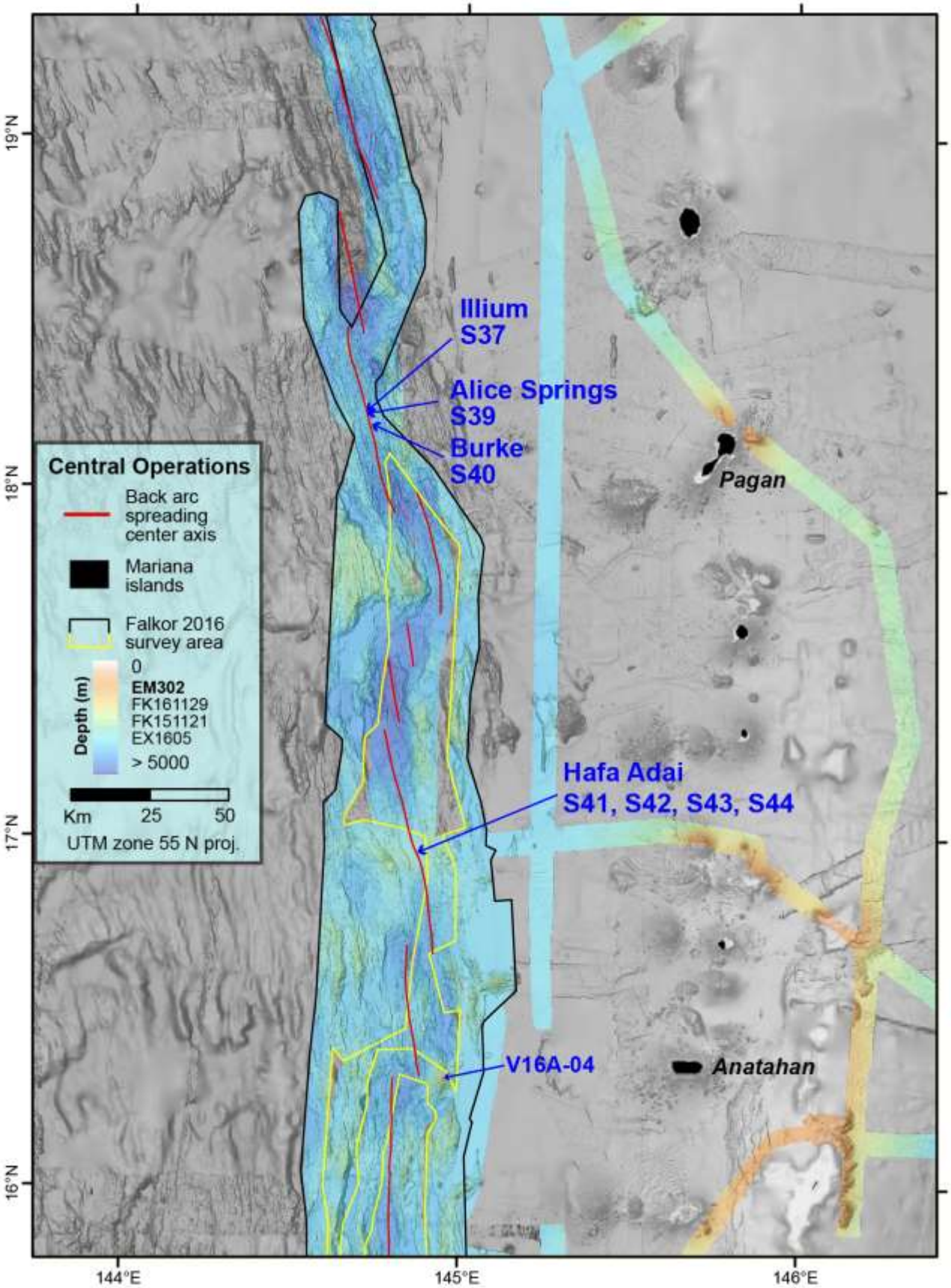


Figure 4.6-3 Central area EM302 multibeam compilation.(S.Merle)

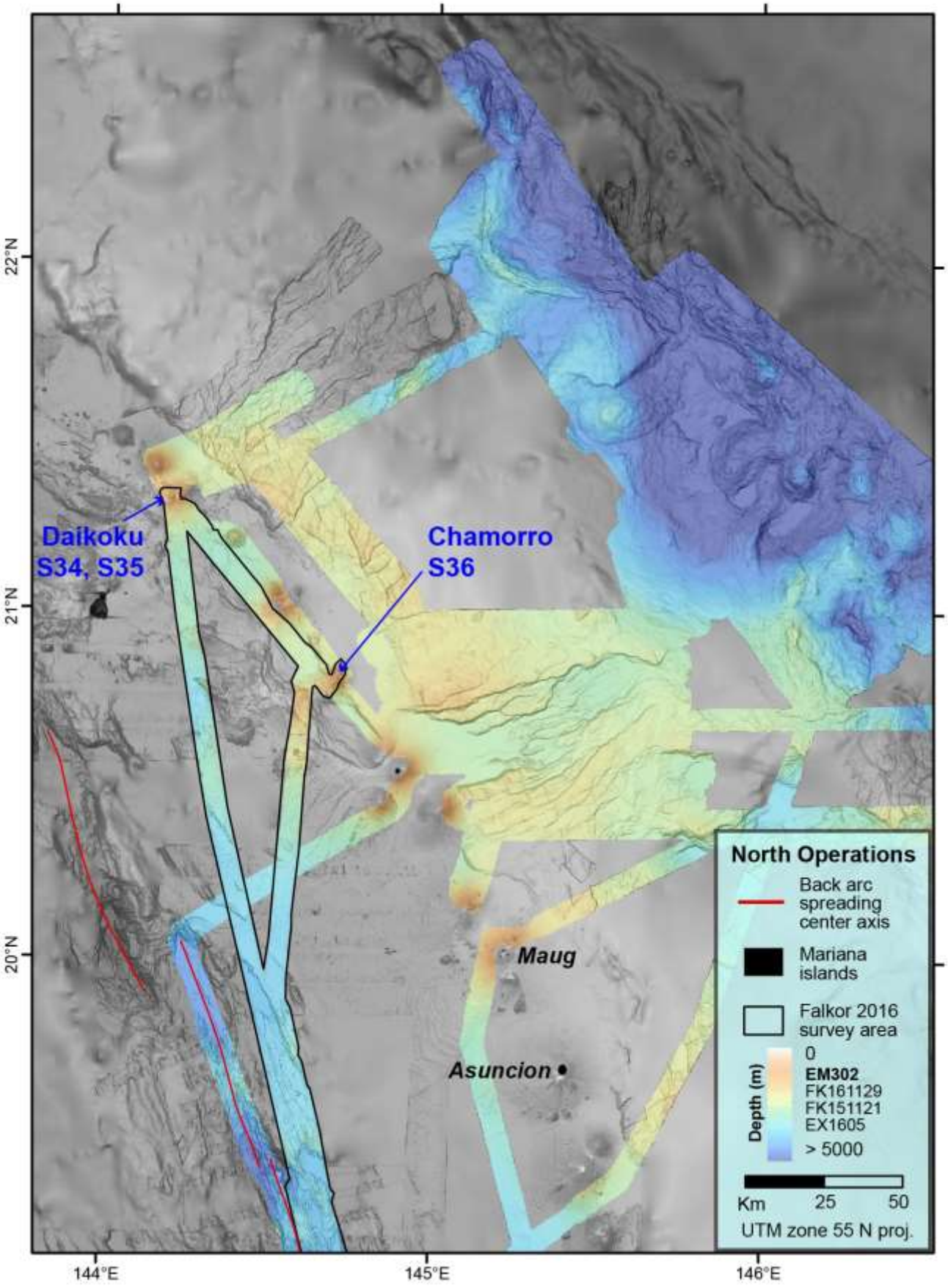


Figure 4.6-4 North area EM302 compilation.(S.Merle)

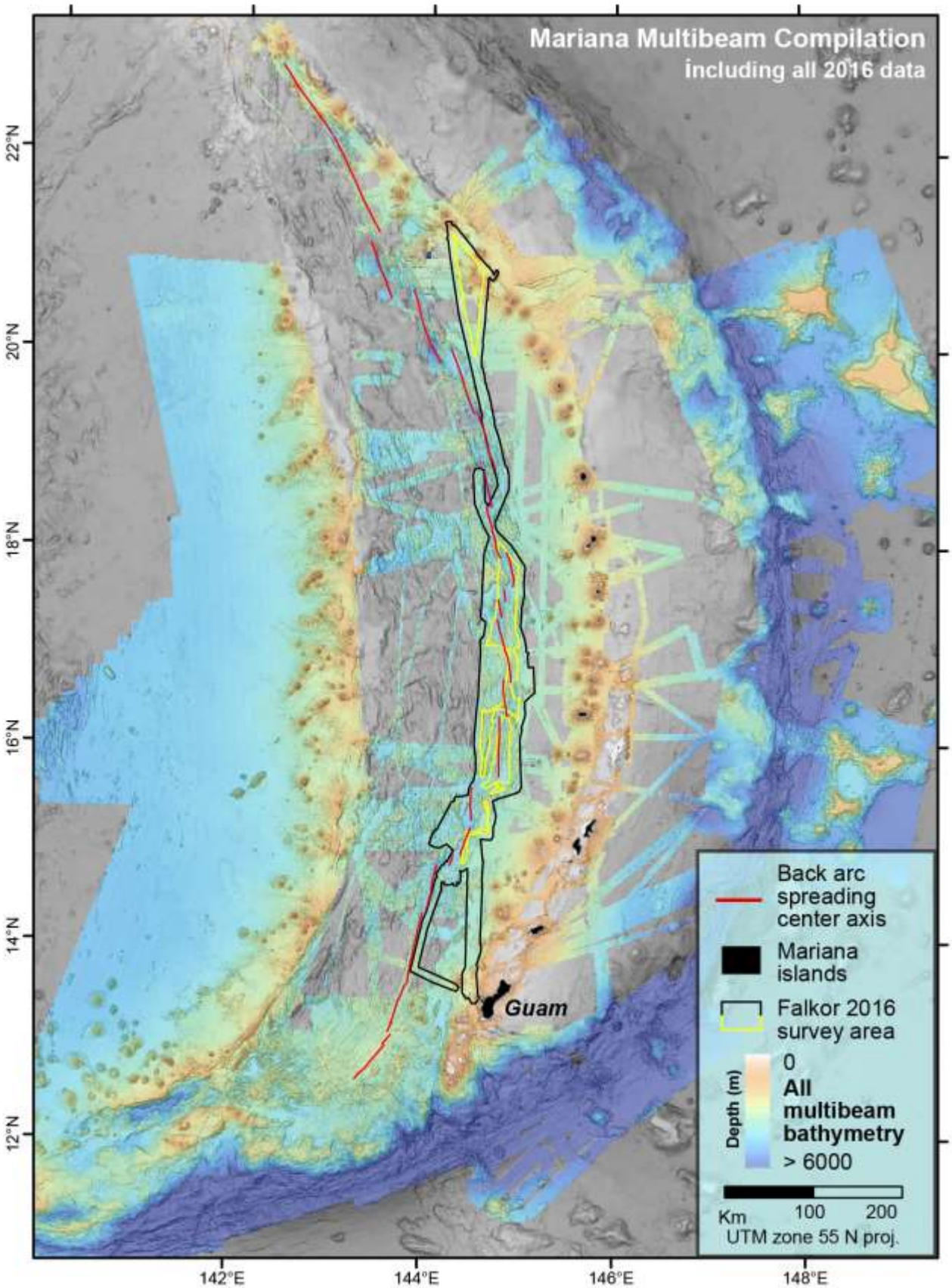


Figure 4.6-5 Compilation of all multibeam bathymetry in the Marianas region.(S.Merle)

During the 2016 *Falkor* expedition, 23,035 km^2 of seafloor was mapped, extending 880 km from south to north. There were large areas of extremely noisy data due to rough seas (Figure 4.6-5). Most of the bathymetry data were recoverable. On the other hand, when the weather was good the data were excellent.

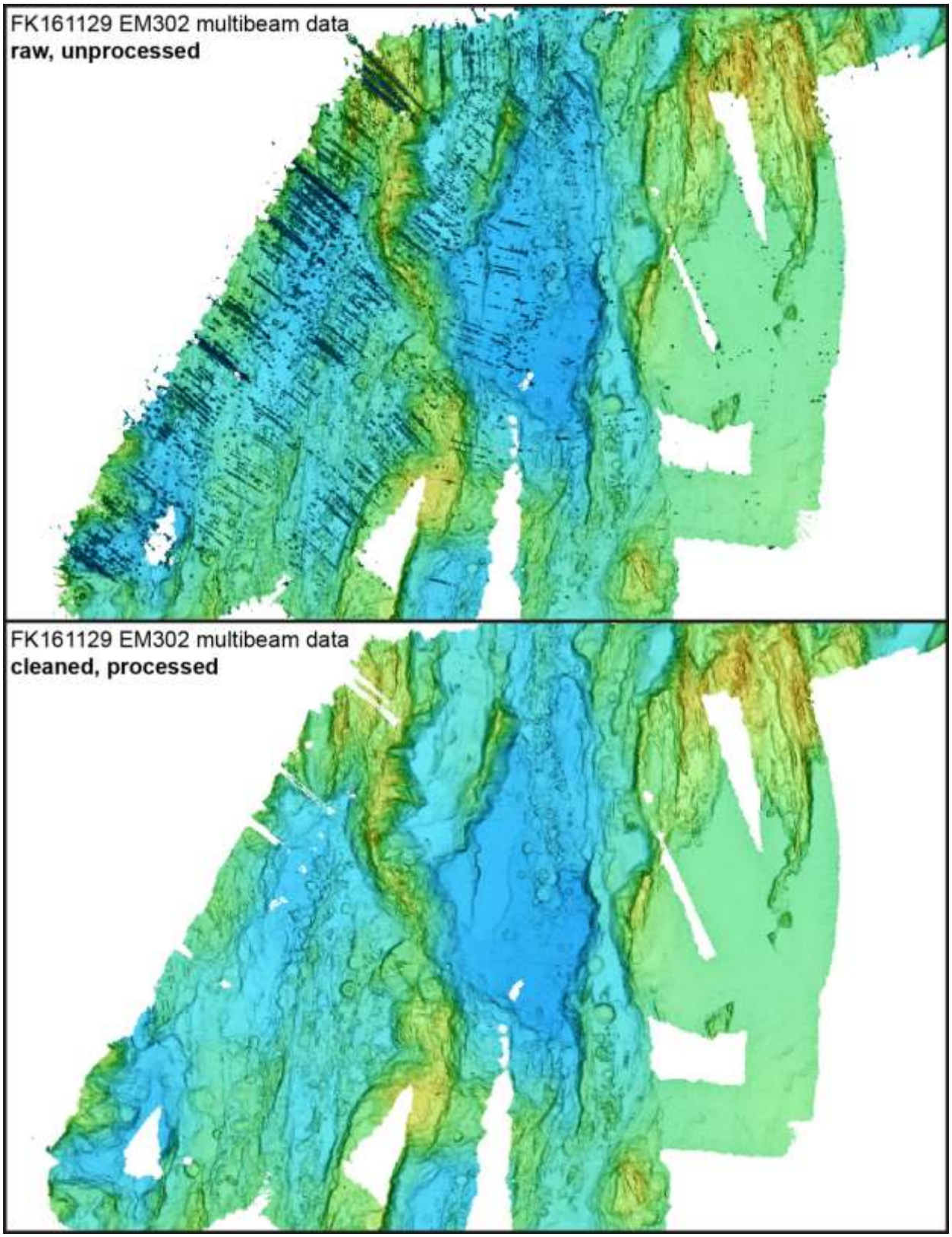


Figure 4.6-6 Examples of multibeam collected in rough seas, before and after processing. (S.Merle)

A slow speed (< 3 knots) seafloor/water column survey was conducted at Daikoku, the result of which was a 10 meter resolution grid of the seamount summit area (Figure 4.6-6). Analysis of the water column data resulted in the identification and geo-location of 5 areas of venting in and near the summit crater. 2 of those venting sites, located west of the sulfur pond, had not been previously known and have never been visited with an ROV.

Bathymetric data collected on the *Okeanos Explorer* and the *Falkor* in 2016 were surface differenced at specific sites (Daikoku, Eifuku, Chamorro, NW Rota-1 and Esmeralda), comparing the 2016 data with older data sets to look for any changes in the seafloor. No depth changes were discerned.

4.7 Outreach

Bill Chadwick and Thom Hoffman

Similar to last year's *Falkor* cruise (FK151121), Bill Chadwick coordinated the outreach activities for the science party and we were fortunate to have Thom Hoffman again from the UK as our on-board videographer. This year, Thom took the lead on writing most of the blog posts for the SOI web site and collecting all the images and video clips. This year's cruise web site was:

https://schmidtocean.org/cruise/searching-life-mariana-back-arc/

Our *Falkor* cruise was also featured on the NOAA/OER web sites:

http://oepreview.nos.noaa.gov/explorations/16marianabackarc/welcome.html

to highlight the coordination between the ROV dives by *Okeanos* Explorer and *Falkor*.

Table 4.7-1 Cruise Logs available at: https://schmidtocean.org/cruise/searching-life-mariana-back-arc/#cruise-log

Date	Cruise Log
12/20/2016	Searching for Life - Expedition Highlights Review
12/16/2016	Hydrothermal Hunt: From 'Wow!' to 'Why?'
12/15/2016	Mighty Microbes of the Deep Ocean
12/14/2016	Searching fo Life - Week Two Highlights - First Views
12/12/2016	A Look into Chimneys - Insights from the Hydrothermal Hunt
12/10/2016	The Animal Life of the Mariana Back-arc
12/7/2016	Going deeper: The Mariana Back-arc
12/6/2016	Searching for Life Week One - The Story So Far
12/5/2016	Insights from Daikoku Seamount
12/4/2016	Daikoku Dive 2: Sulfur so good
12/3/2016	Return to Daikoku
11/29/2016	Setting sail on the Hydrothermal Hunt

Before the cruise left Guam, Bill Chadwick gave a talk at the POETS Club, the weekly lecture series at the University of Guam Marine Lab (accompanied by Verena Tunnicliffe to help answer questions). At sea, one new feature this year was that *Falkor* was equipped to stream live ROV video to shore via the SOI YouTube channel. Thom Hoffman and individuals from the ship's crew and science party interacted with the public during ROV dives via social media. Consequently, all the video from our ROV dives is available in a playlist for FK161129 on-line at this URL:

https://www.youtube.com/user/SchmidtOceanVideos/playlists

Other organizations made use of this live video feed. For example, Underwater World, a public aquarium in Guam in Tumon Bay, featured the ROV video in their "See it here live" section.

Figure 4.7.1 "See it here live" at the Tumon Bay Aquarium in Guam.

Similarly, the popular web site "I Love F***ing Science" (with 50 million followers worldwide) featured our live ROV video on their Facebook page for 4 hours, and it was viewed by 2.4 MILLION people, with over 22,000 watching at the same time at the peak!!! Incredible!

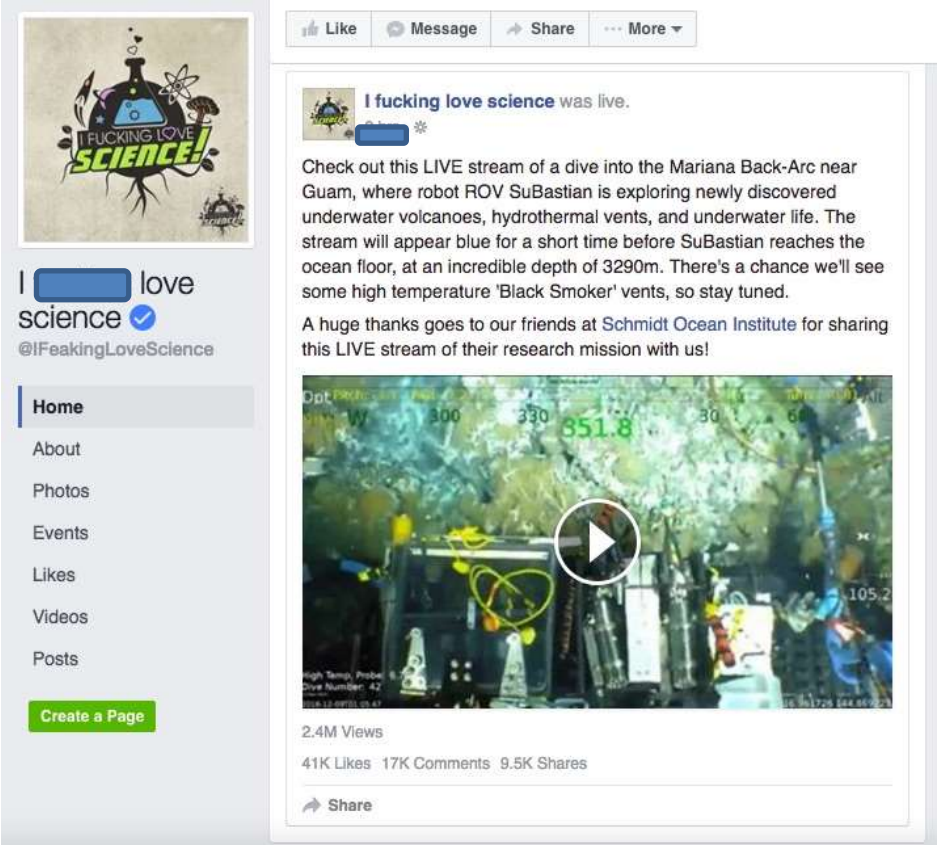


Figure 4.7.2 Example of the number of viewers on "I Love F***ing Science".

In addition, similar to last year, we conducted 13 interactive ship-to-shore video calls (Table 4.7-1) to teachers and classrooms from Guam, Oregon (part of the Oregon Coast STEM Hub), and the east coast, as well as to a public audience at the Hatfield Marine Science Center in Newport, Oregon. One call in particular with EarthEcho International (a marine education organization created by Philippe Cousteau) had 2700 students watching from around the world. Julie Huber and Verena Tunnicliffe from the science party and John Dunn from the ROV helped with these video calls.

Chadwick also helped craft the SOI press release about the cruise and interacted with numerous journalists during and after the cruise who wrote stories about its findings.

Carlie Wiener, Holly Lauridsen, and Logan Mock-Bunting (SOI shore-side outreach specialists) were extremely helpful in coordinating all of the above cruise outreach activities from shore.

Table 4.7-2 Ship to shore video call log.

Group /School	Grade	Contact	Connection	Date	No. Students
Tiyan High School (Guam)	Gr 10-12	Alicia Whitaker	Hangout	Monday December 5	3 classes; 90 students
Oregon Coast STEM Hub: Millicoma School	Gr 5-6	Cait Goodwin/Cody Carlson	Hangout	Monday December 5	30-80
Oregon Coast STEM Hub: Crestview Heights	Gr 5-6	Cait Goodwin/Faith Forshee	Hangout	Monday December 5	86
Oregon STEM Hub: Taft High/Middle	Gr 7-8	Cait Goodwin/Mary Parnell	Hangout	Tuesday December 6	60
Oregon STEM Hub: Sunset	Gr 7-8	Cait Goodwin/Shirley Tremel	Hangout	Tuesday December 6	90
Oregon STEM Hub: East Elementary	Gr 5-6	Cait Goodwin/Caryn Sutter	Hangout	Tuesday December 6	30
Annalisa Bracco Kindergarten	SK	Annalisa Bracco/Jessie Metaferia	Hangout	Wednesday December 7	21
Earth Echo	Gr. 6-8	Stacey R' stacey@earthecho.org	Hangout	Wednesday December 7	2700
Oregon STEM Hub: Newport High School	Gr 9-12	Cait Goodwin/Liz Fox/Dave Campbell	Hangout	Thursday December 8	50
Oregon STEM Hub: Jewell School	Gr 9-12	Cait Goodwin/Don Anderson	Hangout	Thursday December 8	30
War in the Pacific National Historical Park (Guam)	Public	Art Davtian	Hangout	Saturday December 10	55
Hatfield Marine Science Center	Public	William Hanshumaker	Hangout	Saturday December 10	30
Simon Sanchez High School (Guam)	Gr 10-12	Melanie Blas	Hangout	Friday December 16	3 classes; 75 students

5 - ROV Imagery and Video Notes

ROV SuBastian data logging, imagery, and video recording systems

Bill Chadwick

During FK161129, ROV *SuBastian* used the IRLS logging system (adapted from *ROPOS*) for both data logging and capturing video frame grabs. ROV video was recorded in the control room on *R/V Falkor* in several formats. Since this was the first science expedition for ROV *SuBastian* on *R/V Falkor*, there were many things about the data logging, frame-grab capturing, and video recording system that were "not yet ready for primetime". This section describes the state of the logging system, and the imagery and video recorded during the cruise.

Table 5-1 Summary of the number of framegrabs (logger-captures) for each ROV *SuBastian* dive.

Dive number	Number of framegrabs	Filenames
S34	369	Mix of epoch time & sequential
S35	605	Mix of epoch time & sequential
S36	105	Mix of date/time & sequential
S37	493	Mix of date/time & sequential
S39	603	Mix of date/time & sequential
S40	796	Mix of date/time & sequential
S41	1326	Mix of date/time & sequential
S42	843	Mix of date/time & sequential
S43	986	Mix of date/time & sequential
S44	616	Mix of date/time & sequential
S45	444	Mix of date/time & sequential
S47	557	Mix of date/time & sequential
S48	128	Mix of date/time & sequential
S49	327	Mix of date/time & sequential
TOTAL	8198	

In addition, there were a few time intervals when all the 1Hz framegrabs were saved for a limited time interval of interest. These files had to be copied manually and are not included in the totals above.

Table 5-2 Summary of the cumulative file size of video recorded for each ROV *SuBastian* dive.

Dive number	4K Highlights (GB)	HD Continuous (GB)	H.264 Continuous (GB)
S34	361	472	7.62
S35	322	552	17.06
S36	107	182	none
S37	273	471	7.49
S39	255	664	20
S40	170	717	12.66
S41	696	863	15.28
S42	360	877	20.23
S43	254	848	14.28
S44	172	691	12.32
S45	25	362	6.08
S47	37	1300	5.97
S48	0.073	32	1.1
S49	80	397	6.32
TOTAL	3112	8428	146.41

<u>IRLS logging system</u>

• The IRLS logging system on *Falkor* was set up to interface with a frame grabber operating in the background that collected a framegrab every second. For each log entry, the logger had the choice of picking a framegrab to go with it.

This image is saved in the IRLS folders at two resolutions (see below). At the end of a dive, the “unused” framegrabs are “purged” (deleted), and only those associated with a log entry are saved.
• We discovered there is a timing ambiguity in IRLS under some circumstances. When you first create a new observation, it creates an "observation time", and it selects navigation & sensor data at the same time. If you happen to select an image created at the same time as the "observation time" (the time you clicked "create a new observation"), everything is fine. But if you select an image captured at a different time, all the navigation & sensor data are changed to correspond to the image time. However, the problem is that the "observation time" is not changed. So when you output data, the "observation time" does not correspond with the sensor data (the sensor data recorded were not collected at the "observation time").

• One of the many recommendations we have made to SOI is to add an option in IRLS on the logging screen to take a frame grab immediately, without going to a secondary page and having the option to add text and switch images, etc. Another is to enable taking a framegrab automatically at a set time interval.

• Another quirk about IRLS is that it gives you the option of outputting to HTML or CVS files. When you output to HTML directly from IRLS, you do not get the full resolution framegrab files, you only get a lower resolution “x-large” files, which are 1920x1080 and typically 200-500 Kb in size. Another recommendation would be to have the full-resolution framegrabs (3840x2160 and 1-3 Mb in size) available and linked to the HTML output from IRLS. You only save the full resolution framegrabs when the IRLS administrator outputs the dives as a “data package” at the end of the cruise, then they are in the IRLS>DiveXX>framegrabs folder. This folder was not available on the public directory during the expedition and would be useful for individual scientist interested in particular imagery. A future update should include creating these directories automatically after each dive and making them available at sea.

Still imagery (video frame-grabs)
• There was no independent digital still camera for recording still images.

• The GMT date and time was not consistently used as the filenames for the video frame grabs in the IRLS system. Dives S34-S35 only have date/time info in a few of the filenames, and those are in “epoch time” (= unix time), which is seconds since January 1, 1970 UTC (like 1480635684132S5K09846.jpg, which includes 3 milliseconds digits, followed by “S5K” and a sequential file number). Other filenames only include the S5K sequential file number. The rest of the ROV dives, S36-S49, have date/time info in about half of the filenames and the rest just have the S5K sequential file numbers as filenames. For the image files that do not have date/time info in the filenames, one would have to refer back to the IRLS logs to get that information.

• For a few of the dives, we requested that all the 1-second framegrabs be saved for certain time intervals, for example during the deployment and recovery of the temperature array at Voodoo vent. These amounted to tens of thousands of images, which seems more than is reasonable, so we suspect multiple images were saved for each framegrab or images were captured at faster than 1 Hz by the frame grabber. This makes for a confusing array of framegrab files in the IRLS data packages.

• For our cruise it is very difficult to find the full-resolution image files that correspond to the images files in the HTML output because of all the filename irregularities and the intervals with huge numbers of images.

Video recordings
• ROV video (generally from the 4K Science camera) was recorded in several formats to video recorder decks in the ROV control room. Because of large file sizes, full 4K resolution video (3840 × 2160 pixels and about 200 Gb/hr) was only recorded as short highlights when the video logger turned the recorder on/off. HD resolution video (1920 x 1080 pixels) was recorded continuously in Apple ProRes422 format (at a data rate of ~50-100 Gb/hr). This is the same format as ROV *Jason* records highlights in usually. We had requested that ROV *SuBastian* video also be recorded continuously in a more compressed H.264 format (1920 x 1080 but a data rate of only 1-2 Gb/hr, similar to ROV *Jason*), but it was not possible to implement this properly before the cruise. We attempted to transcode the video from HD to H.264 in realtime during the cruise, but the computer doing the transcoding could not keep up. Consequently, the H.264 files have periodic temporal “hic-ups” in which the video pauses and then speeds up, making them jittery, and the files have no timecode or audio.

• Originally, there was no timecode being recorded to any of the video formats. For most of the dives, timecode was embedded in the 4K and HD video files, but not in the H264 files. Likewise, eventually control room audio from the headset by the “hot seat” was included with the 4K and HD video, but not the H264 video.

• The GMT date and time was not used as the filenames for the 4K and HD video files, but was able to be used for most of the H264 video files (because of an optional feature in the transcoding software). The 4K and HD video filenames are generally sequential, but are not consistent.
• Video file lengths were short and variable for the 4K highlight clips. The HD and H264 continuous video files were about (but not exactly) an hour, and were started and stopped manually by the video logger, because there was no automated system in place to make smaller, more manageable file sizes (for example, ROV *Jason* makes 15-minute H264 files).

• The auto-iris and auto-ISO controls on the Science Camera where not working during the cruise, and were not easy to change manually, so the video is often too light or too dark during the earlier dives. Eventually, manual controls were added to a portable keyboard to allow scientists in the control room to change them more easily, and to operate the pan/tilt/zoom controls with a joystick.

Table 5-3 Video 4K Highlight log

Highlight	Time ON	Time OFF	Description
S34 - Daikoku			
1	21:48	22:16	First look at bottom. Near Fish Spa. White smoker, sediments with mat. Lots of fish.
2	22:46	22:59	Pele's tears of sulfide during sampling; sediment close-up; sampling area with fish.
3	00:07	00:14	Start of HFS-04 sample. Close-up of sediment, sulfur, crabs.
4	00:17	00:22	Crab on sampler and Verena talking about it during HFS-05.
5	00:27	00:29	Crab and vent fissure with yellow sulfur; bubbles and white smoke.
6	00:35	00:40	Site of HFS sample -04,-05,-06. Larger view, chimney.
7	00:42	00:42	Crab on sulfur chimney.
8	00:55	01:02	While scooping sulfur chimney.
9	01:16	01:23	White geo sample.
10	02:37	02:38	Sampling of sulfur crust but not in focus.
11	02:39	02:40	Sampling of sulfur crust (try again). Also not great.
12	02:41	02:43	Sampling of overhanging sulfur crust, take 3. Success!
13	02:57	03:01	Looking for sulfur pond. At bottom of smoking pit? Black but hard to tell.
14	03:07	03:10	Other side of overhang by MKr-132. Great sulfur layering.
15	03:24	03:25	Different fish, replacing fish trap after recovery from rolling downhill.
16	03:57	04:00	Strings of sulfur falling down and smoky waters. Pick up fish trap. Don't know if captured any sulfur falling.
S35 - Daikoku			
1	22:04	22:10	Lots of fish-some crabs on ash covered slope with scattered sulfur crust, smoky white plume. First area on bottom.
2	22:23	22:46	Sulfur finger chimneys by small venting crater and fissure. Fish and crabs again. Near initial landing spot.
3	23:13	23:15	Close-up of sediments and fish.
4	23:16	23:19	Sulfur bubble and strands in sediment.
5	00:15	00:17	*SuBastian* grabbing HFS with fish trap in background.
6	00:44	00:50	*SuBastian* deploying second fish trap.
7	02:41	02:45	Sampling tubeworms ~20m NE from waypoint 2. Not successful.
8	03:10	03:12	Tubeworm.
9	03:25	03:35	Tubeworms.
10	05:11	05:15	Fissure with bubbles, sulfur, crabs, fish. Getting HFS ready.
11	05:44	06:05	Same fissure. Molten sulfur droplet ejecting out.
12	06:09	06:09	Got smoked out.
13	06:13	06:30	Molten sulfur ejected and crab. SO COOL!!

Highlight	Time ON	Time OFF	Description
S36 - Chamorro			
1	23:54	00:07	White chimney when first on bottom.
2	00:10	00:12	Squat lobster.
3	00:26	00:38	Sampling chimney.
4	00:43	00:48	HFS from chimney base.
5	01:00	01:01	HD recording stopped working. See a little at bottom.
S37 - Illium			
1	01:50	01:55	Flow with snails.
2	01:57:20	02:01:22	At Illium vent field. Diffuse vent with snails.
3	02:02:15	02:06:25	Deployment of robosnail.
4	02:12	02:40	Critters crawling around vent while sampling.
5	02:40	02:52	New view of same scene.
6	03:37	03:50	Temperature probe by robosnail.
7	03:55	04:00	Scoop sample of snails and shrimp.
8	04:03	04:12	Suction sample of little things on surrounding rock.
9	04:14	04:19	Thom's overview filming of whole area. Crabs fighting.
S39 - Alice Springs			
1	03:07	03:29	First shimmering vents. Lots of anemones, mussels, squat lobsters and barnacles.
2	03:47	03:48	Red shrimp floating by. Not a great shot though.
3	03:55	03:59	Another low temp vent up the hill with snails.
4	04:02	04:05	Higher flow area from the same seep.
5	05:08	05:20	Gas tight sample.
6	06:49	06:52	Crabs.
7	06:54	07:02	Crab fight: cannibalism.
8	07:33	07:46	Sampling snails.
9	08:13	08:19	Imaging anemone field near diffuse venting.
10	08:21	08:22	New area of venting. Moving up vertical wall with active venting.
11	08:23	08:25	A lot of venting.
12	08:53	08:58	Venting wall to white unknowns.
S40 - Burke			
1	00:22	00:28	Milky crack area.
2	00:36	00:42	Next venting site. With snails (First Snails nav marker)
3	01:04	01:11	Approaching First Snails again.
4	01:37	01:40	Deploy robosnail.
5	01:41	01:48	Suction sampling of shrimp.
6	01:54	01:58	Suction sample 2 (midway) of macro-fauna.
7	03:22	03:26	Snail pits- shrimp, snails, crabs, anemones.
8	03:36	03:45	Barnacles cirri.
9	03:46	03:50	Close-up of area again.
10	04:09	04:11	Suction sampling snails.
11	04:27	04:30	Milky crack, squat lobster and anemone.
S41 - Hafa Adai			
1	23:05	23:57	First large chimney with smoking flanges. Sample geo-01.(Two Towers)
2	0:01	00:06	Approaching flange again.
3	0:46	00:58	Temperature attempt at top of black smoker.
4	1:08	01:11	Approaching next chimney.
5	1:12	01:28	Again-approaching next chimney.
6	2:31	02:50	Suction sampling bio-03.
7	3:02	03:12	Suction rock faces bio-05.

Highlight	Time ON	Time OFF	Description
8	3:12	03:15	Looking around.
9	3:34	03:50	Looking around and sampling chimney.
10	04:02	04:09	Sampling chimney at second site.
11	04:10	04:43	Highlight while surveying second chimney (WP-02 Sequoia)
12	04:49	04:54	Chimlets at WP-03 (Chimlet Garden)
13	05:27	05:30	WP-04 chimney. (Alba)
14	06:15	06:19	WP-06 crater approach (Voodoo).
15	06:31	06:37	High concentration of snails area in crater.
16	06:53	07:00	Chimneys at WP-07.
17	07:04	07:07	Chimneys just past WP-07. Sample white snails and old chimney?
18	07:11	07:19	Sampling white snail and old chimney.
19	07:21	07:25	Sample old chimney.
S42 - Hafa Adai			
1	23:06	23:12	Temperature recording before hula hoop.
2	23:12	23:28	Deploying hula hoop.
3	02:05	02:07	
4	02:08	02:10	Hula array leaving site.
5	02:11	02:13	Entering snail graveyard
6	02:14	02:37	Suction sampling snail shells.
7	03:02	03:04	Venting NW rim of cinder crater (Voodoo)
8	03:05	03:08	Mkr-171 fly-over.
9	03:27 (?)	03:35	Sheet flow with drain-out feature. Rock sample.
10	03:44	03:53	Approaching Sequoia.
11	04:20	04:22	Close-up while sampling Sequoia.
12	04:55	05:05	Again-approaching Sequoia and geo-20.
13	05:36	05:36	Sea cucumber floating by.
14	06:47	06:50	Sequoia overview.
15	07:17	07:33	New chimney site.
S43 - Hafa Adai			
1	01:40		Alba chimney.
2	01:59		Crab grab of shrimp.
3	02:02		Critter close-up.
4	02:20		Around Alba.
5	02:47		Highlights on.
6	06:20		SPME sampling.
7	06:46		First pass of biology survey of Sequoia.
8	07:09		Second pass of biology survey of Sequoia.
9	07:28		Third pass of biology survey of Sequoia.
S44 - Hafa Adai			
1	01:45	01:49	Overview of Mami Wata
2	02:24	02:28	Mami Wata biology.
3	02:41	02:41	Mami Wata white patch.
4	02:51	02:58	WP-07 area.
5	03:23	03:29	Two Towers.
6	03:29	03:32	Two Towers, different side.
7	03:32	03:35	Two Towers, different side continued.
8	03:37	03:38	Top of Two Towers, black smoke.
9	04:01	04:02	Top of Two Towers with HFS.
10	04:02:40	04:03:40	Top of Two Towers with HFS.
11	04:07	04:08	Fluid sampling top of Two Towers.

Highlight	Time ON	Time OFF	Description
12	04:11	04:14	Biology close-up while fluid sampling at top of Two Towers.
13	05:21	05:27	Highlights on/off.
14	05:41	05:53	Highlights off; temperature array.
S45 - New Lava Site			
1	01:45	01:50	Slope of lavas.
2	01:53	01:56/57	Iron staining; fractured pillow. (2 highlight pieces).
S47 - Perseverance			
1	06:22	06:23	Old sulfide/oxide crust.
2	07:17	07:18	Venting area.
3	07:20	07:23	Venting area again.
4	07:40	07:50	Close-up of critters.
5	08:19	08:21	*Paravinella/Shinkai* limpets.
6	08:51	08:54	*Paravinella*; worms; limpets; high-flow.
7	10:13	end of dive	Permanent highlights on due to complete power outage in control room.
S48 - Perseverance			
no highlights			
S49 - Perseverance			
1	02:37	02:38	Circling Stump of Mystery.

Recommendations to SOI after the cruise by co-chief scientist Chadwick

• Recording continuously in HD 1080p (Apple ProRes422) seems like overkill and is onerous for data management by the MTs. Too much data is generated from each dive and takes too much time to copy, transfer, and back-up between dives. Most scientists will be happy if the continuous video is saved in a compressed H264 format. This will make video data management much more efficient and less time consuming. A high priority for scientists is to get copies of the continuous ROV dive video as soon as possible after each dive, and at least multiple copies made to multiple members of the science party before the end of the cruise. Video is data to the science party and everyone wants to leave the ship with it - not wait for weeks or months for it after the cruise. For example, on this cruise the MTs are struggling to even make one copy of all the video for the science party before the end of the cruise. The total amount of video data is just unmanageable with the current set up.

• Following on the comments above, I would recommend that video highlights only get recorded in 4K and HD 1080p format (Apple ProRes422), and the continuous recording only be recorded in H264. This will greatly reduce the time and effort needed to manage (copy, transfer, backup) the video data and will allow the MTs to provide the science party with multiple copies of the ROV dive video on a dive by dive basis - a very high priority for the science party. All the video recorded should have timecode and the audio from the headset in the Control Room. Even better would be to have the option to have an overlay on the continuous H264 video (perhaps as a subtitle file) with date/time, dive number, lat, lon, depth, and heading information. In addition, all the video files should have filenames that include date and time for the start time of the recorded file, or both the start and end times.

• The video matrix was shown to be vulnerable as a single-point-of-failure, when during dive S47 the UPS in the Control Room shut down (after days of beeping) and every monitor connected to the matrix in the control room and the library went dark, right in the middle of an ROV dive with the ROV on the bottom. This took about 30 minutes to rectify and was a major disruption to the dive, including all the video recordings. Although power was not lost to the ROV, the pilots had no control information to go by for several minutes until an independent laptop with the Greensea display was brought in .

• During dive S48, the files that were recorded by the HD 1080 video recorder were black. In other words, the recorder made .mov files that were many GB in size, but there was apparently no video input into the recorders. This was the dive immediately after the incident with the video matrix going down, so may be a consequence of that. In any case, this shows the need for review and quality control of the video files after each dive and before the next dive. If this had been found more quickly, we could have saved the video recorded in the ROV container, but they had already been reformatted for the next dive. Fortunately, the H264 files still recorded, although they are gittery and do not have timecode or Control Room audio.

• In addition, there were many recommendations for improving the IRLS logging system (not reproduced here).

6 – ROV *SuBastian* Dives

6.1 Dive Statistics

Dive	Date Start	In Water	On Bottom	Off Bottom	Bottom Time H:MM	Location	notes
S34	12/1/2016	21:07	12/1/2016 21:42	12/2/2016 4:06	6:24	Daikoku	Sulfur coated ROV
S35	12/2/2016	21:32	12/2/2016 21:57	12/3/2016 7:21	9:24	Daikoku	Crater had zero vis
S36	12/3/2016	22:59	12/3/2016 23:49	12/4/2016 1:11	1:22	Chamorro	Weather ended due to winds.
S37	12/4/2016	21:38	12/5/2016 0:05	12/5/2016 4:54	4:49	Illium	Found old Alvin weights
S38							Aborted
S39	12/6/2016	00:15	12/6/2016 2:38	12/6/2016 9:10	6:32	Alice Springs	Lower temps than 1987
S40	12/6/2016	21:24	12/6/2016 23:23	12/7/2016 6:31	7:08	Burke	Small diffuse sites
S41	12/7/2016	20:58	12/7/2016 22:52	12/8/2016 7:26	8:34	Hafa Adai	Named chimneys
S42	12/8/2016	21:05	12/8/2016 22:56	12/9/2016 7:37	8:41	Hafa Adai	Deployed Hula
S43	12/9/2016	21:20	12/9/2016 23:10	12/10/2016 7:38	8:28	Hafa Adai	North exploration
S44	12/10/2016	23:43	12/11/2016 1:29	12/11/2016 8:21	6:52	Hafa Adai	Recover Hula
S45	12/11/2016	23:03	12/12/2016 1:22	12/12/2016 5:06	3:44	New Lava Flow	Weather ended dive early. Damaged cable on recovery.
S46							Aborted
S47	12/16/2016	03:46	12/16/2016 6:12	12/16/2016 13:28	7:16	Perseverance	Navigation-bathymetry mismatch
S48	12/16/2016	19:42	12/16/2016 22:02	12/16/2016 23:07	1:05	Perseverance	Telemetry problems; short dive
S49	12/17/2016	22:07	12/18/2016 2:31	12/18/2016 6:00	3:29	Perseverance	Weather on the edge

6.2 Dive Summaries

S34 Daikoku

Landed just 10m east of WP-01 (Fish Spa) on white sulfur crust, smoke and fish. Measured temperature of white sediments with ROV probe, Tmax=23.73°C. Collected 1 HFS and 2 fish suction samples at this landing site. Moved slightly west to a white smoker and gas bubbles emanating from adjacent cracks. Lost visibility and moved slightly east to take 3 HFS samples from hole emitting gas and fluids. Collected sulfur chimlet and sediment sample from this site. Returned to original landing site to deploy Fish Trap and Mkr-132 near crusty edge. Collected suction sample of fish and piece of the sulfur crust at Mkr-132. Attempted to view sulfur pit before moving to WP-04 but couldn't see sulfur pond due to poor visibility. Molten sulfur from the plume coated the vehicle. Returned to Mkr-132 and Fish Trap had rolled down hill. Recovered trap and redeployed about 12.5m SE from the marker, it contained about 2 fish. Attempted to net some fish but sulfur coating would not allow net to unfurl. Visibility decreased, recovered fish trap before ascending.

10 samples total: 2 HFS; 4 Biology; 4 Geology (including the sulfur adhered to the ROV); 2 failed HFS

S35 Daikoku

Landed on bottom just NE of WP-01 (Fish Spa). Observed small chimneys along a crack/vent leading to the edge of a sulfur pit. Deployed Fish Trap in area of white sediments with flat fish. Collected 6 HFS samples in darker sediment near this Fish Trap. Observed sulfur bubbles and strands forming. Recovered Fish Trap after sampling. Moved upslope, away from pit, to area with increased fish density, ~30m SE of WP-01. Deployed 2 Fish Traps at this location, one on darker sediment next to area of white sediment and the other one on darker sediments. Collected 2 HFS and one suction of fish at this site. Deployed **Mkr-133** at this site and recovered one of the fish traps that didn't have any fish. Transited south and upslope over sulfur crust populated with fish lying on sediments. Redeployed the Fish Trap in area with high fish density on a sedimented, steep slope. Deployed **Mkr-137** at this new deployment site (~50mN of WP-02). Transited to **WP-02**, inner wall of Daikoku's crater where clumps of tubeworms were observed in the rock edges. Collected ~8 tubeworms from the inside wall of the crater and then one HFS sample. Drove counter-clockwise inside crater wall and then mid-water, across crater, toward WP-03 (*Okeanos* white smoker). No visibility with wall 8m in front of ROV. Transited back to Mkr-137 site to recover the Fish Trap. No fish inside trap but observed many fish surrounding the trap. Collected a scoop of sediment from the site. Transited upslope and north to recover the second Fish Trap at Mkr-133. Followed a local ridge then over sulfur crusts and massive slabs leading to a pit. Drove over pit and found Mkr-133. Redeployed empty fish trap at Mkr-133 with the other trap. Left trap and headed back to sample the venting along a crack site at Fish Spa seen on S34. Collected 4 HFS samples. Tmax=43.7°C while observing erupting, molten sulfur marbles. Transited back to Mkr-133 and recovered both fish traps. Collected crab sample with suction at this site. Moved west, toward sulfur pit, and collected some crabs which were more abundant here, ~12m SE of WP-01.

18 samples total: 7 HFS (6 failed); 5 biology.

S36 Chamorro

Dive began downslope of WP-01 (Venting site observed on 2016 *Okeanos* dive), in broken lava flows and small chimneys with diffuse flow. Moved upslope and began sampling small chimney at **WP-01** site with snails. Surface winds elevated to 30kts. ROV temperature wand had a high temperature of 65°C, *Okeanos* had a Tmax of 48°C. Collected piece of small chimney with animals and 4 HFS samples (Tmax=155.3°C). Dive ended due to winds with about 1.5 hours of bottom time.

5 samples total: 1 geology; 2 HFS (2 failed).

S37 Illium

Dive began downslope of the 1987 Illium vent site target in pillow rubble. Problems with navigation at the beginning of the dive with significant jumps in position while switching between INS and USBL Encountered old chimneys while moving upslope through areas of intact pillows and took a geology sample of an old chimney. Moved upslope until reached target depth of old Illium. Proceeded laterally to east when found active hydrothermal venting and more old chimneys. Moved east and then west across the slope to determine range of hydrothermal deposits and then upslope along highest extent of biology and hydrothermal features. Sampled in an area with high biology concentration, **Snail Pile** site. Took 11 HFS samples, 3 biology (1 scoop and 2 suctions of snails), deployed Robosnail and **Mkr-138**. Diffuse flow with maximum temperature of 32.8°C. After sampling, followed the hydrothermal staining upslope to top of ridge which consisted of mounds of inactive sulfides, dead chimneys and an *Alvin* weight. Explored top of ridge and found no active venting but another *Alvin* weight. Ended dive after going down nose of ridge (pillow lavas) due to ROV hydraulic leak.

15 samples total: 2 HFS (9 failed); 3 biology; 1 geology.

S39 Alice Springs:

Began dive downslope of the 1987 Alice Springs location on a steep slope of pillow lava. Encountered sulfides and anemones while moving NE along the 1987 Alice Springs vent target depth. Followed sulfides upslope encountering an area of inactive chimneys. Descended back to target depth and then followed depth laterally along ridge to the east. Moved upslope and then came back to west through areas of anemones but not sulfides/chimneys. Drove back into the

sulfide zone and found diffuse flow with a crabs, squat lobsters, mussels, barnacles, scale worms and anemones. Took one HFS sample at **Diffuse Site**. Moved upslope following anemones through patches of diffuse venting and animals. Encountered focused venting site with the addition of snails to the biology, **Snail 001** Site. Took 8 HFS, 1 gas-tight and 4 biology (1 rock with biology, 1 mussel, scoop and suction) samples and a Robosnail deployment/recovery. Deployed **Mkr-131** at Snail 001. Maximum temperature recorded was 164.8°C. After sampling, continued upslope facing the slope encountering shimmering from cracks with milky flows in some areas and high concentrations of anemones. Moved back downslope to Mkr-131 and descended deeper into old sulfides and chimney stumps. Moved upslope again toward carpet of anemones. Sampled a rock with biology in the **Little Anemone** site. Dive ended.

16 samples total: 9 HFS (1 failed); 4 biology; 1 geology (had biology); 1 gas

S40 Burke:

Dive began south and downslope of an ORP target (WP-01) from the 2016 *Okeanos* expedition. This site was also due south of the 1987 Anemone Heaven site. Climbed a pillow tube hill with staining and found some diffuse flow and few animals. As continued to climb toward the 1987 Anemone Heaven target (WP-03), observed concentrations of anemones and hydrothermal staining 22m SW of target. In this area found a bottle on a rope which looked deliberately placed as a marker. Moved north and upslope into an area with diffuse-milky flow but only sparse biology confined to a crack (**Milky Crack Navigational marker**). Followed the biology upslope into an area with mussels, shrimp, limpets, scaleworms, barnacles and crabs (**First Snails Navigational marker**). Surveyed area and then came back to area for sampling, **Snail Pit**. Deployed a Robosnail prior sampling. Collected 3 biology suction samples, 1 rock with limpets and 7 HFS samples (51°C). Recovered Robosnail and the real snails attached to it. Did a final suction of snails that had been underneath the Robosnail location. Deployed physical **Mkr-234** at this site named **Snail Pit**. Moved back over to the **Milky Crack** target area. Took 2 HFS samples in the milky crack (11°C). Long transit NW to WP-06 area up and down lava flow slopes. Just south of the waypoint came into area with hydrothermal staining and old chimneys. Primarily anemones and small shimmer with a tiny pH anomaly from the HFS sensors but no sampling.

15 samples total: 7 HFS (2 failed); 5 biology; 1 geology (with biology).

S41 Hafa Adai 17N:

Dive began in sheet flows north of the target location of westernmost chimney at WP-01, (not visited on the *Okeanos* dive) from the Sentry bathymetry. Chimney (named **Two Towers**) is an active smoker, with flanges, diffuse and black smoke venting standing 16.5m above the seafloor. Structure appears to be two chimneys joined at the base, southern side is most active. Conducted a survey from top to bottom of the chimney on its east and north sides. Sampled broken chimney-sulfides on top of a flange on east side approximately 13m above the seafloor. Measured temperature under the flange at 280°C and took one gas-tight sample. Transited east to WP-02, larger chimney (first visited by *Okeanos*) to the east, named **Sequoia**. Took a gas-tight, 3 biology suction, 2 HFS and a chimney fragment sample on west side at black smoker measured at 302.5°C near the base where chimney bulged and active venting began. Marker accidently dropped/deployed (**Mkr-254**) while retrieving a scoop from the basket and later observed at northside of chimney base. Conducted visual survey of chimney's west side from base to top (31m) and then back down the east side. Transit to WP-03 where observed 3m chimlets **(Chimlet Garden**) and measured fluid at 20°C. Transited to next site at WP#4 (**Alba**) with 25°C fluid. Next location explored was the cone at WP-05 (**Voodoo**) where a site survey of the SE quadrant of the cone for deploying Amanda's temperature array was made. Deployed **Mkr-171** at the potential snail experiment site for a future dive. Next transited over sheet flows to **WP-07** where many chimneys/chimlets and diffuse flow observed. Took one suction sample of white snails and piece of inactive chimney spire.

11 samples total: 4 biology; 4 geology; 1 gas; (2 failed HFS).

S42 Hafa Adai 17N:

Began dive at east rim of **Voodoo Crater** (WP-06) and quickly moved to **Mkr-171** to deploy the Hula temperature array. After deployment, took 8 HFS samples and took HFS sensor readings within the array. Deployed 3 Robosnails inside the array and a MAPR just on the outside of the hoop. Moved down into the crater to the **Snail Graveyard** and took 3

biology, suction samples. Moved up the crater wall just above the graveyard to a diffuse, milky venting site. Collected a rock with barnacles from this site, just inside the southern rim. Drove along the rim of the crater to the west (clockwise) from this site. Observed diffuse venting on the northwest rim. Stopped rim transit after reaching Mkr-171. Moved over to the NE quadrant over the rim and took an altered rock sample outside of the cone. Began transit to Sequoia (WP-02) over sheet flows. Took a sample of the sheet flow west of Voodoo.

23 samples total: 6 HFS (7 failed); 3 biology; 6 geology; 1 gas (failed).

S43 Hafa Adai 17N:

Began dive west of **Breached Cone** and sampled lava from a collapse feature (**WP-10**) in jumbled sheet flow. Climbed the west wall of the cone and then descended into the floor while facing the sheer wall. Traveled out the east side of the cone through the breach just past WP-2 before heading south toward the Hafa Adai chimney field. Drove through lava flows and small craters as approached WP-14. Around **WP-14** found tiny, inactive chimneys and old venting. Took sample of altered chimney in sheet flows near WP-14. Quickly drove south through sheet flows and some hydrothermal deposits to **Alba Vent** (WP-04). Traveled over older chimneys just north of Alba. Small visual survey of Alba before taking 9 HFS, 1 Gas, 1 sulfide and one SPME puck samples (Tmax=238.6°C). Drove west in mid-water to **Sequoia** chimney and landed at its base where **Mkr-254** (the marker that fell from the basket previously) was located. Conducted biological-video survey of the north side of Sequoia from base to top. Second video survey of Sequoia from its west side, base to top. Then did a third survey from the east side. Dive ended after third survey.

14 samples total: 7 HFS (2 failed); 1 biology; 2 geology; 1 gas.

S44 Hafa Adai 17N:

Dive began near **Mami Wata** (WP-09) in area of old sulfides/chimneys in flat flow with some hydrothermal sediment. Collected rock sample in older lavas with some sulfides near Mami Wata (navigation jumps). Moved west slightly into terrace structure with diffuse venting and took HFS sample (13.3°C) and did a video survey of the site. Transited to **WP-07** over old chimneys, sulfide deposits and jumbled flow. At WP-07 surveyed chimney and pagoda-like flanges where the S41 chimney sample was taken. Explored larger chimney to the north which had some mussels. Transit to **Two Towers** (WP-01) over sheet flows. Conducted video survey of the east side of Two Towers from base to top. Surveyed the west side of the chimney from top to bottom. East tower is more active than the west tower at the top. Sampled black smoker near top of east tower, 331°C (3 HFS, 1 Gas and chimlet samples). Transited to **Voodoo** on the north side of Sequoia to avoid collision. Sampled a sulfide on outside wall of Voodoo's west wall (some major navigational jumps on Voodoo approach). At Voodoo, recovery of instruments and sampling at Hula array (MAPR recovery, 9 HFS samples, 2 Robosnail recoveries, 1 Robomussel recovery, Hula array recovery, 2 biology suction samples).

20 samples total: 13 HFS (1 failed); 2 biology; 3 geology; 1 gas.

S45 New Lava:

Began dive from the north at **WP-01** (greatest dE from Sentry MAPR anomaly) in new lava pillows. Collected a piece of lava about 10m west of WP-01. Moved southerly to **WP-02** over new pillows and tubes including a lava flowing over an escarpment (lava waterfall). Some hydrothermal staining but no diffuse flow. Collected lava sample near base of scarp. Continued south toward **WP-03** in continuous new lava with some hydrothermal sediment but no shimmering water. Collected pillow crust going upslope halfway between WP-02 and WP-03. Scaleworms near WP-03 and a sharp drop in ORP sensor. Headed west with temperature and ORP anomalies but no evidence of water flow. Zig-zagged while continuing west to **WP-05**. Near WP-05 and steep flow observed dripping hydrothermal sediments. Collected lava from a claw-like feature. As continued west downslope, passed into old lava. Explored the contact zone between new and old lavas. Collected piece of older lava near **WP-06**. Turned to SE toward **WP-07** through thinner new lava flow with less hydrothermal deposits and eventually all older flows. Collected piece of older pillow crust west of WP-07. Dive ended.

6 samples total: 6 geology.

S47 Perseverance:

Landed on bottom in heavy hydrothermal sediment and an inactive chimney near **WP-01**. Navigation had a large depth offset so drove west to scarp to orient the bathymetry map. Encountered a couple of dead chimneys and large hydrothermal deposits but no flow. At escarpment, explored fissures to NW before turning back east. East run over sedimented pillows and then old chimney with heavy hydrothermal sediments in the flatter area. Drove north to base of large feature and climbed slope before moving back west and off the slope to further determine navigational offsets. Entered region with older chimneys and active, diffuse flow (large ORP signal). Observed many animals (shrimp, crab, snails, scaleworms, sulfide worms). At a chimney (**Leaning Tower**), collected 6 HFS and 2 biology samples (suction and sulfide with animals), Tmax=45.5°C. Adjacent to this chimney encountered an interesting, active chimney named **Palisades** which looked like a crown. Both located at base of slope. Upslope of Palisades at a heading of 070 a zone of chimneys extruding from the steep basalt slope with diffuse flow. Followed line of chimneys upslope and then downslope when discovered a chimney with snails at the top indicating a hotter flow (**Stump of Mystery**). Took one gas-tight, 5 HFS, 5 bio and 1 sulfide samples, Tmax=265.7°C. End of dive.

20 samples total: 7 HFS (4 failed); 7 biology (2 with rocks); 1 geology; 1 gas.

S48 Perseverance:

Landed on bottom in sedimented pillow lavas 40m due south of Leaning Tower/Palisades and north of old chimney encountered at beginning of S47. Drove east and found old sulfide rubble surrounded by pillows. Drove further east in pillows and then went north to edge of slope and followed the edge to the west. Went as far as west as **Leaning Tower & Palisades**. Headed upslope NE from these active chimneys. Took a sample of pillow buds as headed upslope. Further upslope ORP signal dropped with a lot of particulates in the water, the temperature rose and there was increased hydrothermal sediment. Patches of sulfides but did not see any diffuse flow. Dive ended prematurely with telemetry problems.

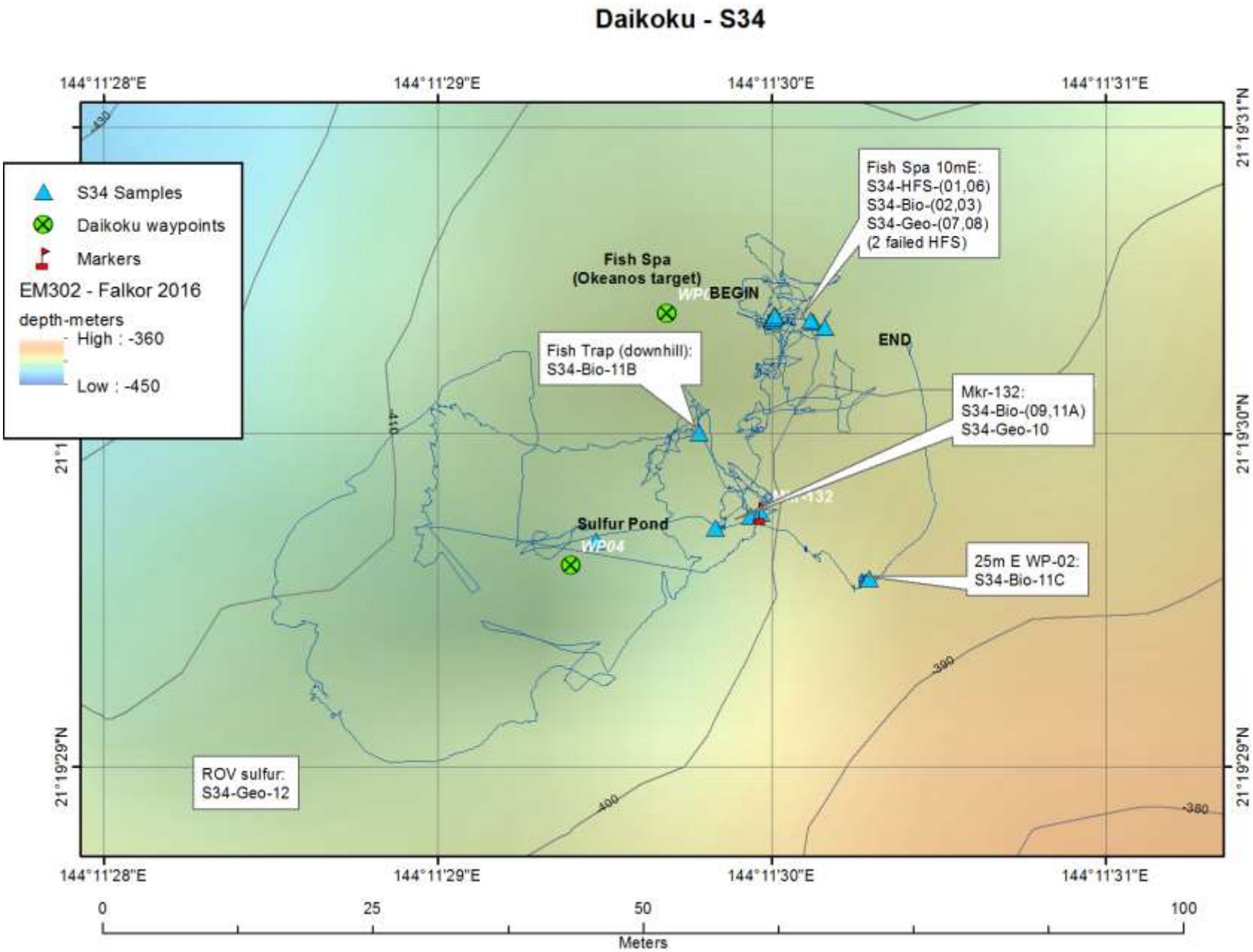
1 geology sample total.

S49 Perseverance:

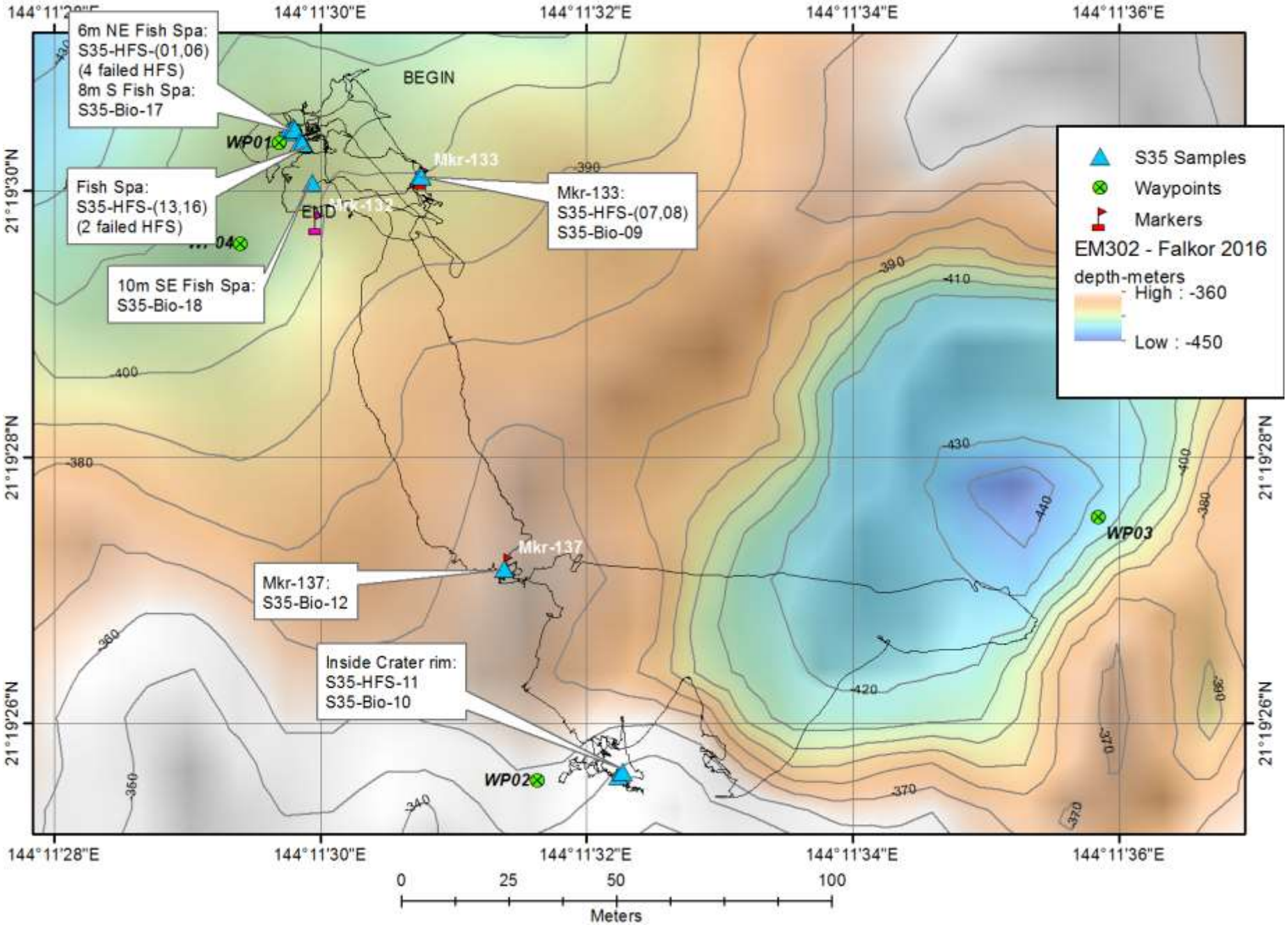
Dive began on the margin of weather acceptability for the ROV at 8am local time (2200 UTC). At 00:20 UTC with bottom within 150m, weather deteriorated and dive was canceled. Several background water samples were taken on the ascent. At 01:30 UTC, weather improved and decision was made to continue the dive and on the bottom at 02:30 near the **Palisades** site. (Big ORP signal drop on MAPR). From Palisades looking upslope observed pile of old chimneys on bottom. Moved upslope to **Stump of Mystery** and took at GTB. Moved back down toward Palisades/Leaning Tower looking for diffuse water emanating from the basalts. Took suction samples for biology in the flow from the cracks near the base of **Leaning Tower at Limpet Canyon**. Moved slightly after suctioning to take HFS samples from the diffuse flow. After sampling, returned to **Stump of Mystery** for HFS water sampling. Afterward, continued upslope along the ridge then down the slope looking for ORP signals. Could not find signal nor observed anything very active. Returned to Leaning Tower/Palisades area and deployed **Mkr-255 at Palisades**. End of final dive at 06:00 UTC.

13 samples total: 5 HFS (5 failed); 2 biology; 1 gas.

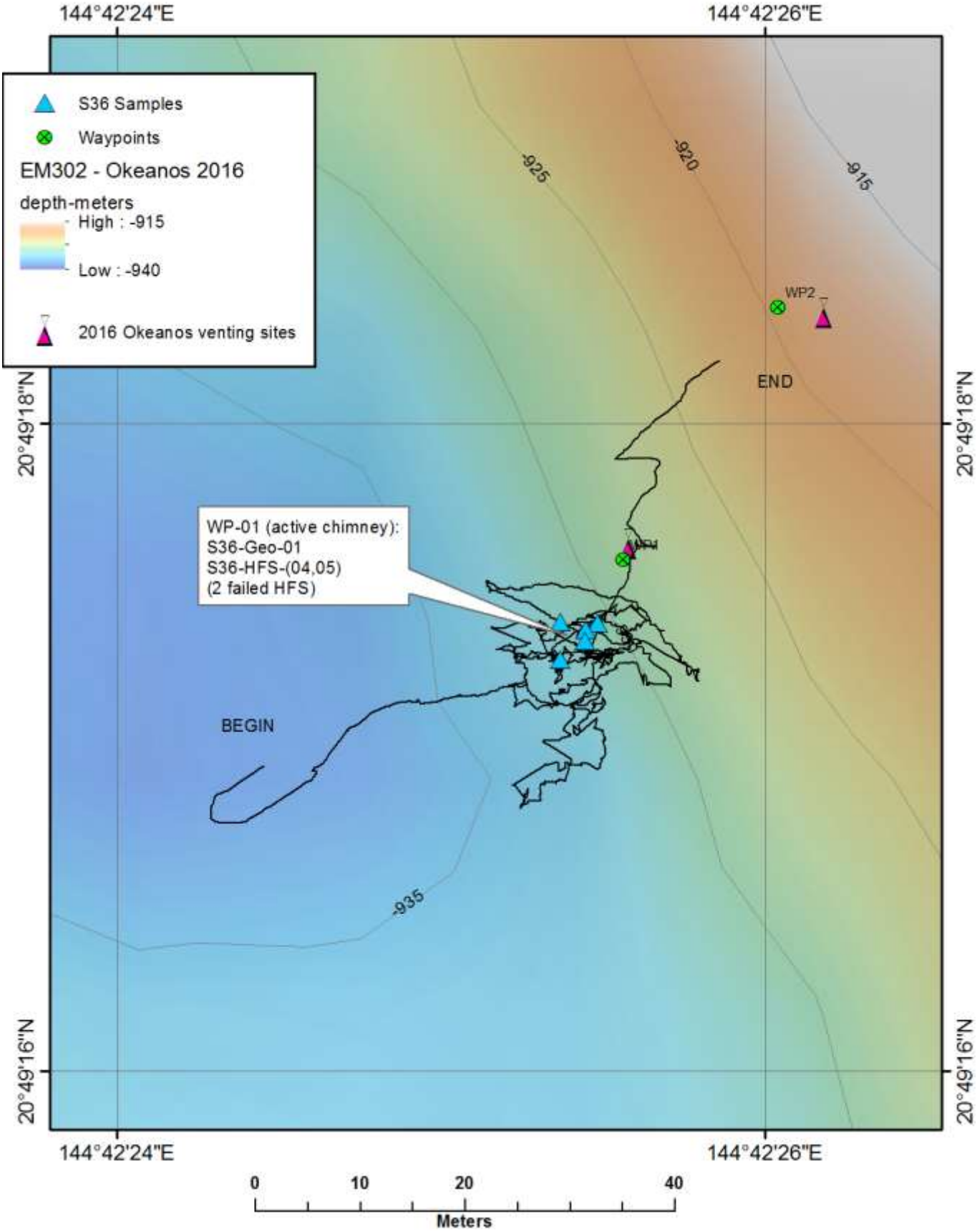
6.3 Dive Maps

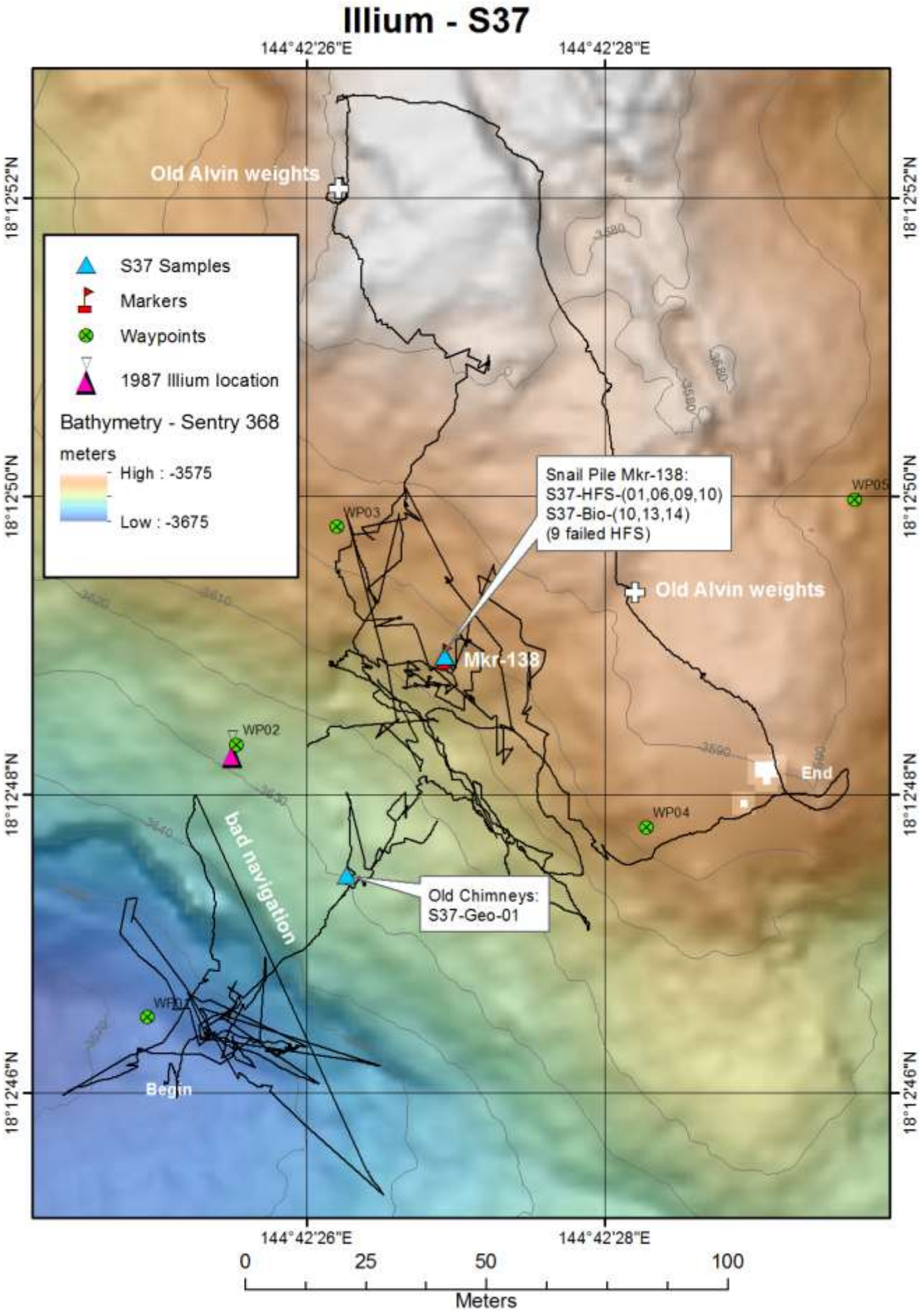

Daikoku - S34
144°11'28"E
144°11'29"E
144°11'30"E
144°11'31"E
21°19'31"N
21°19'30"N
21°19'29"N
S34 Samples
Daikoku waypoints
Markers
EM302 - Falkor 2016
depth-meters
High : -360
Low : -450
Fish Spa 10mE:
S34-HFS-(01,06)
S34-Bio-(02,03)
S34-Geo-(07,08)
(2 failed HFS)
Fish Spa
(Okeanos target)
WP
BEGIN
END
Fish Trap (downhill):
S34-Bio-11B
Mkr-132:
S34-Bio-(09,11A)
S34-Geo-10
Sulfur Pond
WP04
25m E WP-02:
S34-Bio-11C
ROV sulfur:
S34-Geo-12
-430
-410
-390
-400
-380
0
25
50
100
Meters

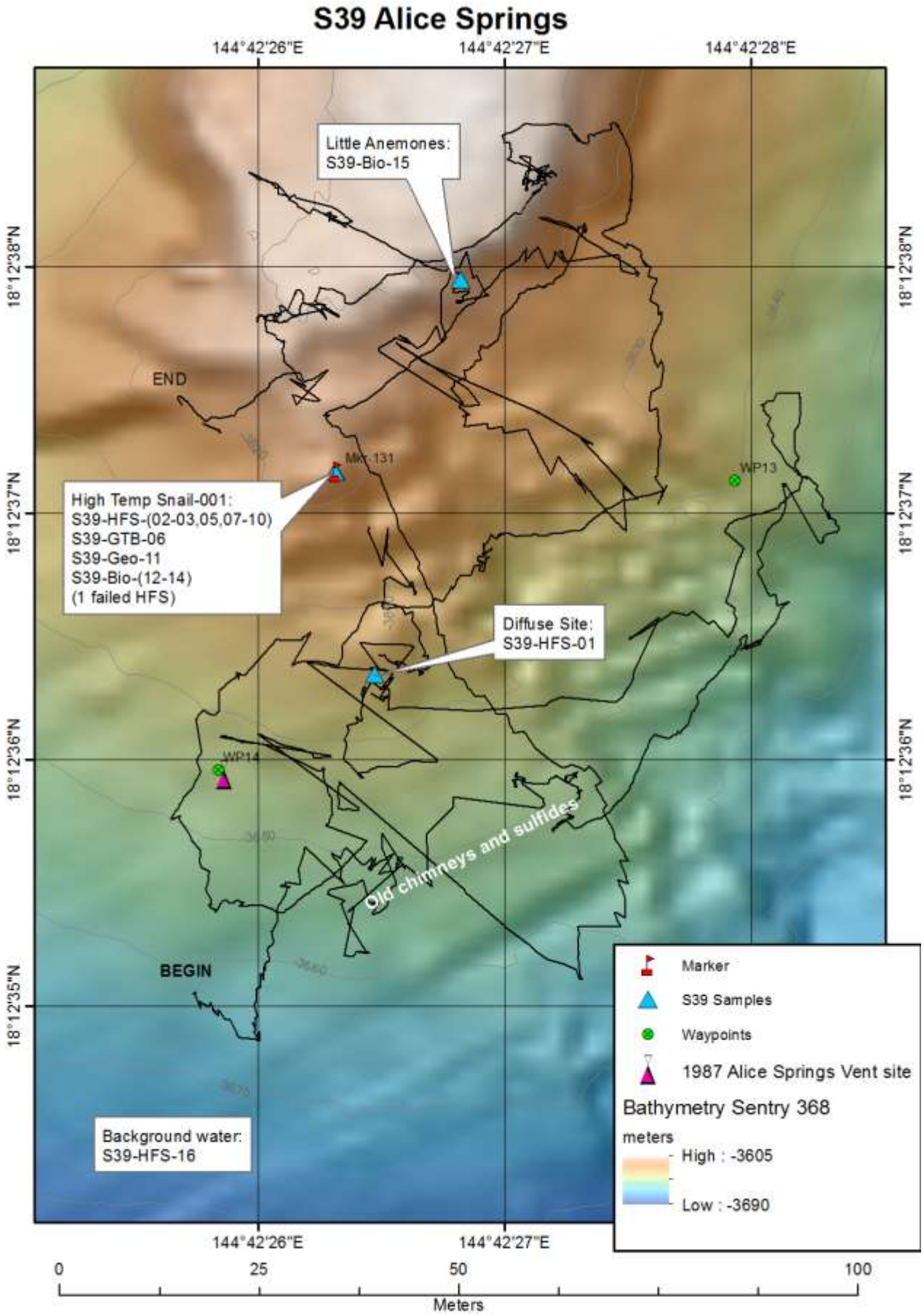
Daikoku - S35


6m NE Fish Spa:
S35-HFS-(01,06)
(4 failed HFS)
8m S Fish Spa:
S35-Bio-17
BEGIN
WP01
Mkr-133
Fish Spa:
S35-HFS-(13,16)
(2 failed HFS)
END
Mkr-133:
S35-HFS-(07,08)
S35-Bio-09
10m SE Fish Spa:
S35-Bio-18
S35 Samples
Waypoints
Markers
EM302 - Falkor 2016
depth-meters
High : -360
Low : -450
Mkr-137
Mkr-137:
S35-Bio-12
WP03
Inside Crater rim:
S35-HFS-11
S35-Bio-10
WP02
144°11'28"E
144°11'30"E
144°11'32"E
144°11'34"E
144°11'36"E
21°19'30"N
21°19'28"N
21°19'26"N
0
25
50
100
Meters

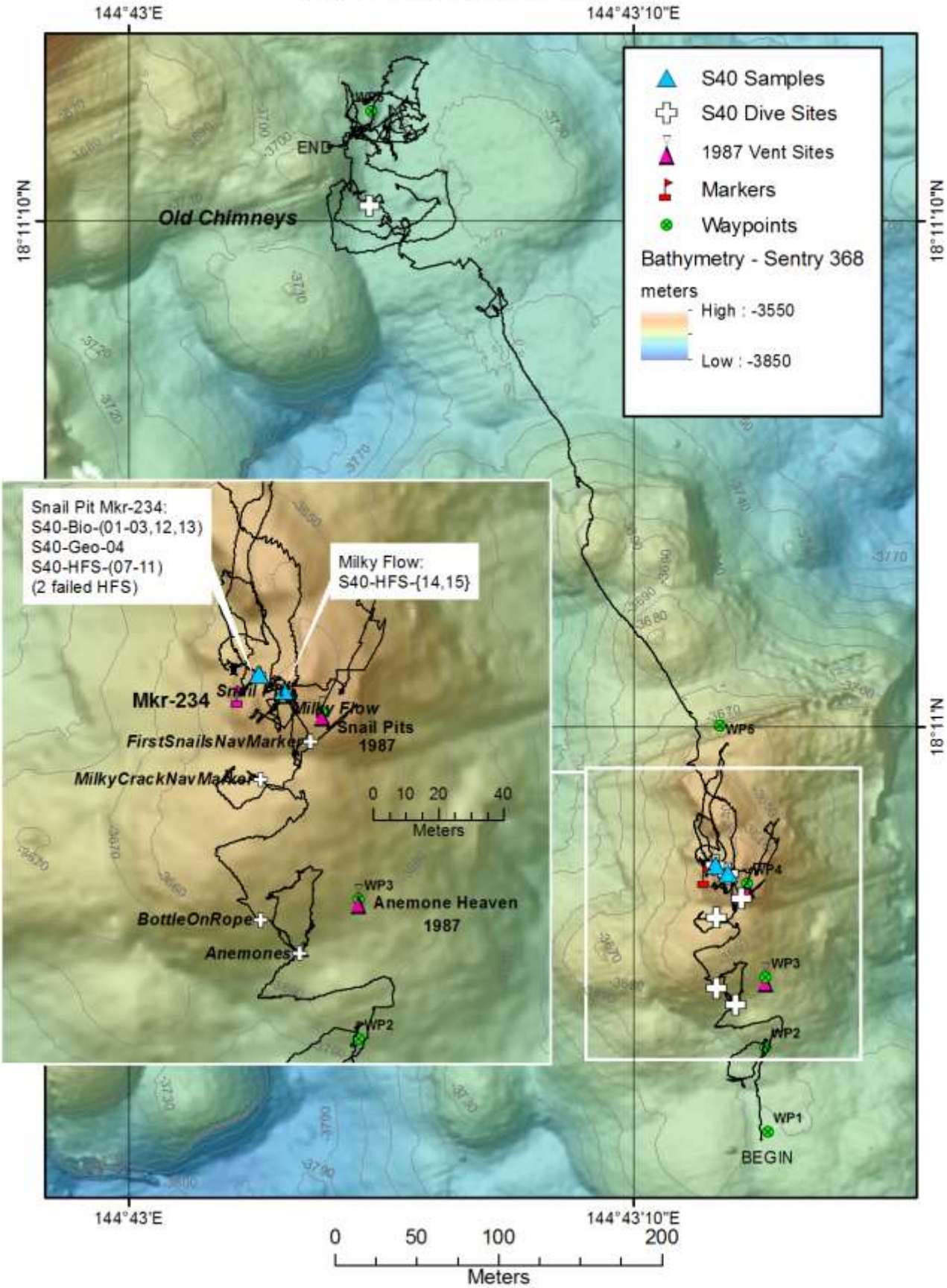
Chamorro S36



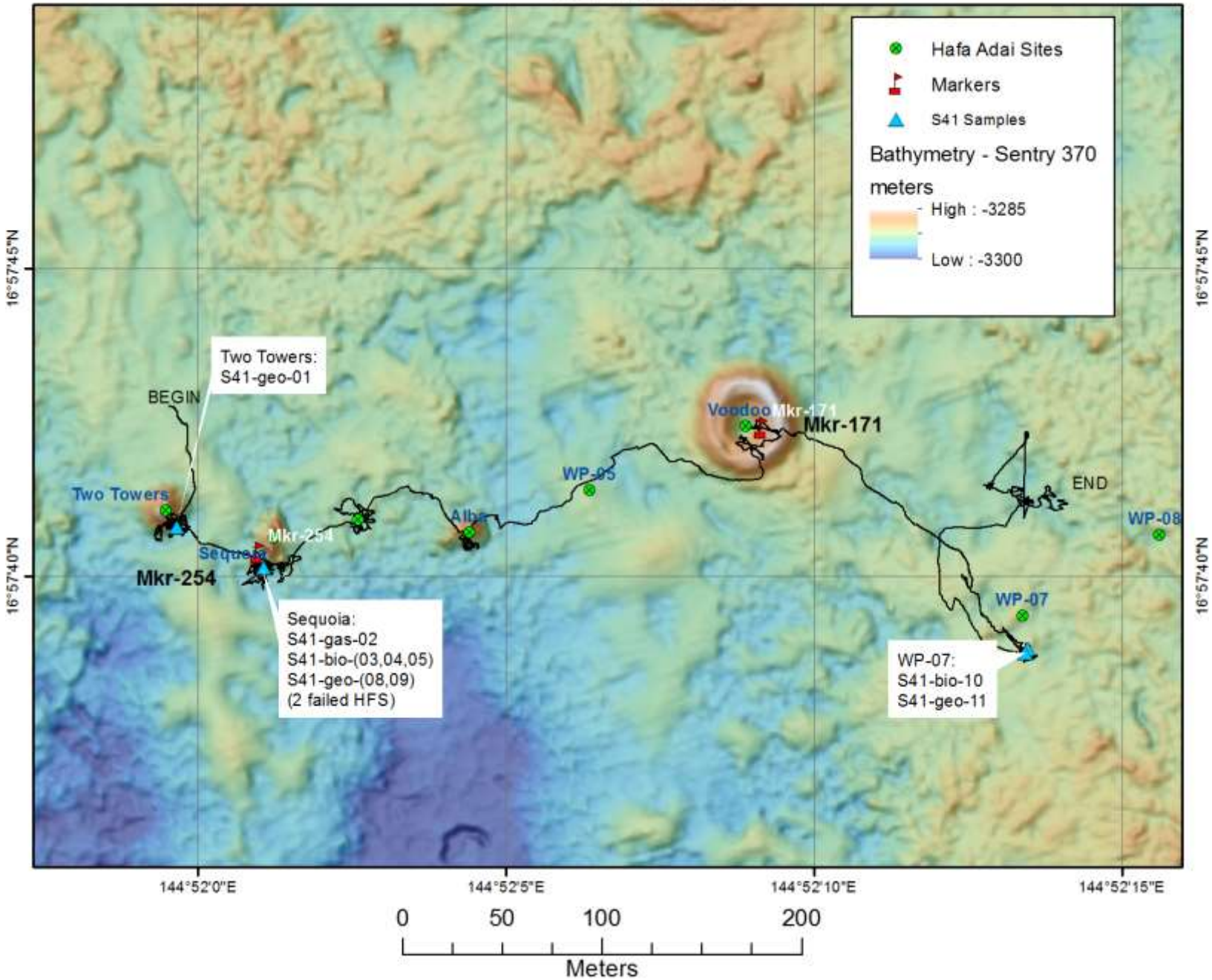

Illium - S37
144°42'26"E
144°42'28"E
18°12'52"N
18°12'50"N
18°12'48"N
18°12'46"N
Old Alvin weights
S37 Samples
Markers
Waypoints
1987 Illium location
Bathymetry - Sentry 368
meters
High : -3575
Low : -3675
Snail Pile Mkr-138:
S37-HFS-(01,06,09,10)
S37-Bio-(10,13,14)
(9 failed HFS)
WP03
WP05
Old Alvin weights
Mkr-138
WP02
End
WP04
bad navigation
Old Chimneys:
S37-Geo-01
Begin
0
25
50
100
Meters


S39 Alice Springs
144°42'26"E
144°42'27"E
144°42'28"E
18°12'38"N
18°12'37"N
18°12'36"N
18°12'35"N
Little Anemones:
S39-Bio-15
END
Mkr 131
WP13
High Temp Snail-001:
S39-HFS-(02-03,05,07-10)
S39-GTB-06
S39-Geo-11
S39-Bio-(12-14)
(1 failed HFS)
Diffuse Site:
S39-HFS-01
WP14
Old chimneys and sulfides
BEGIN
Background water:
S39-HFS-16
Marker
S39 Samples
Waypoints
1987 Alice Springs Vent site
Bathymetry Sentry 368
meters
High : -3605
Low : -3690
0
25
50
100
Meters

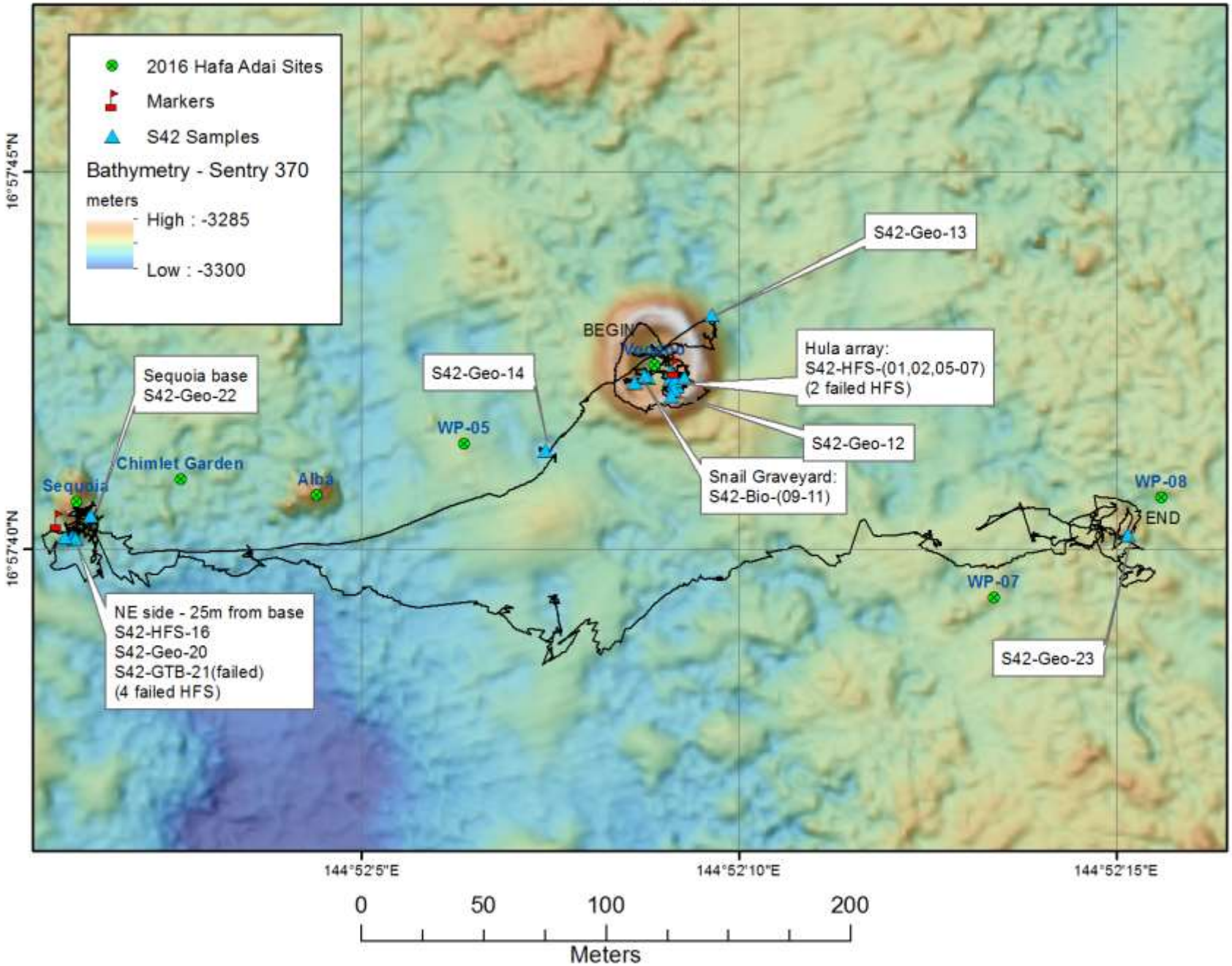
S40 - Burke Field

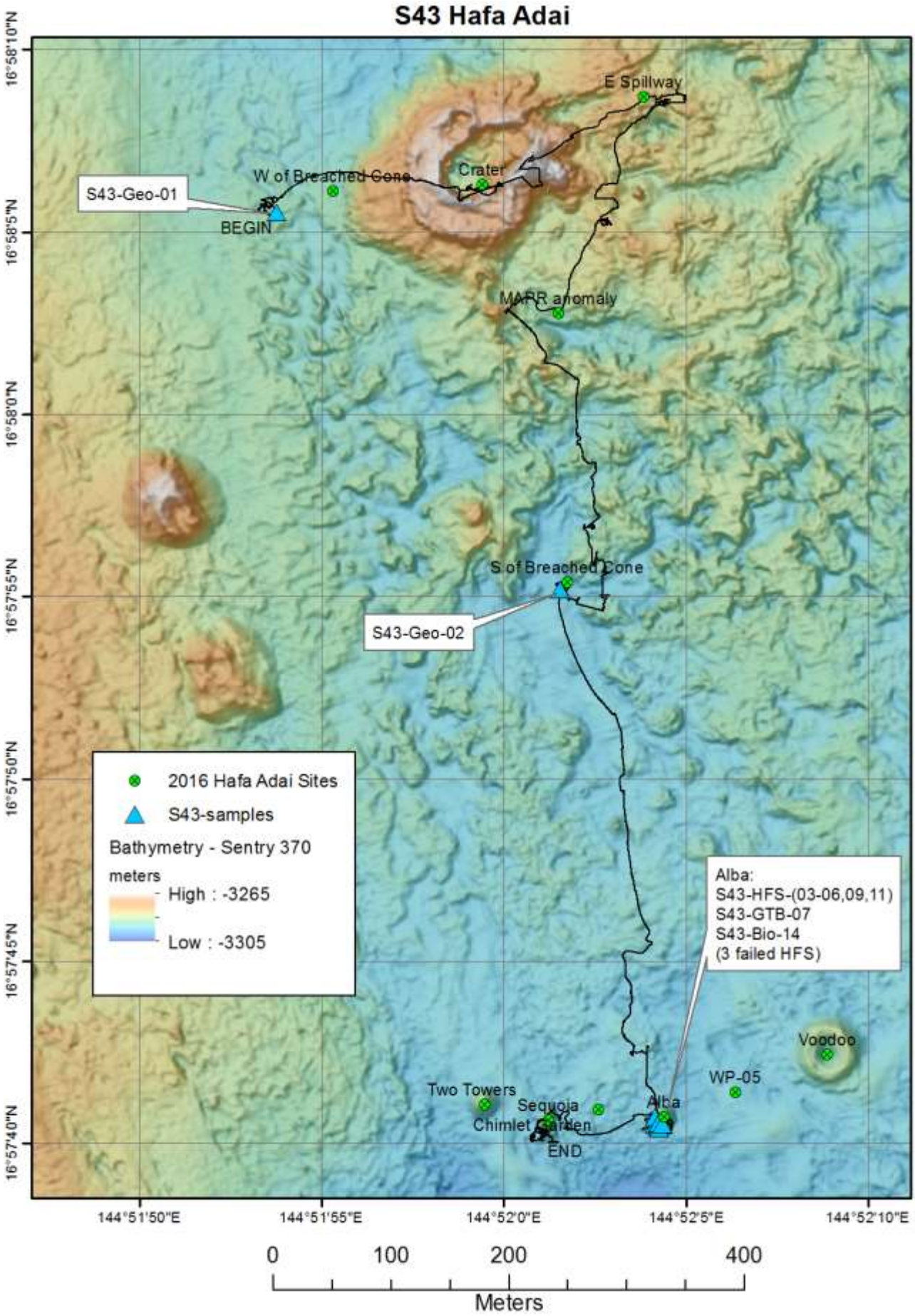


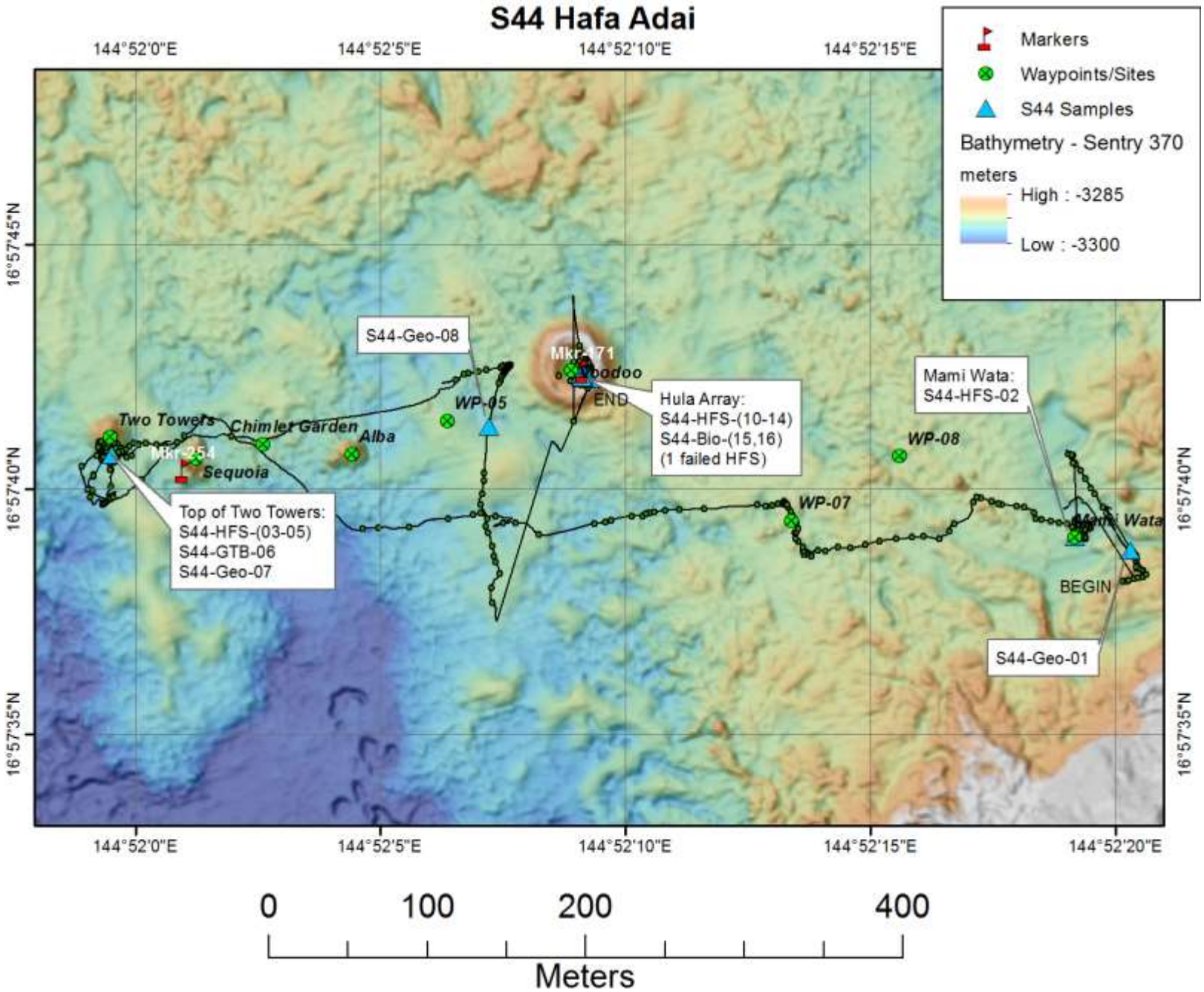
S41 Hafa Adai



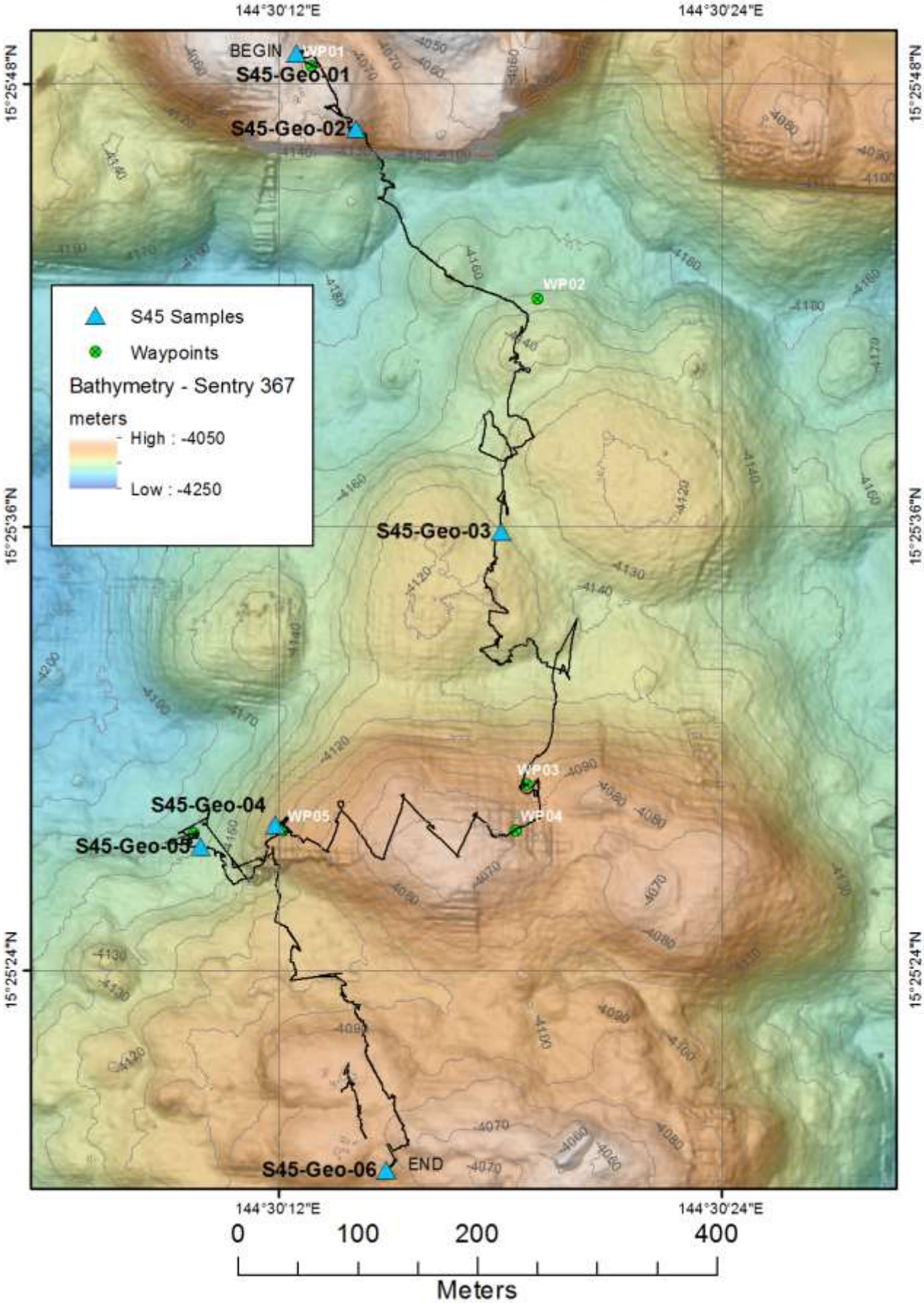
S42 Hafa Adai



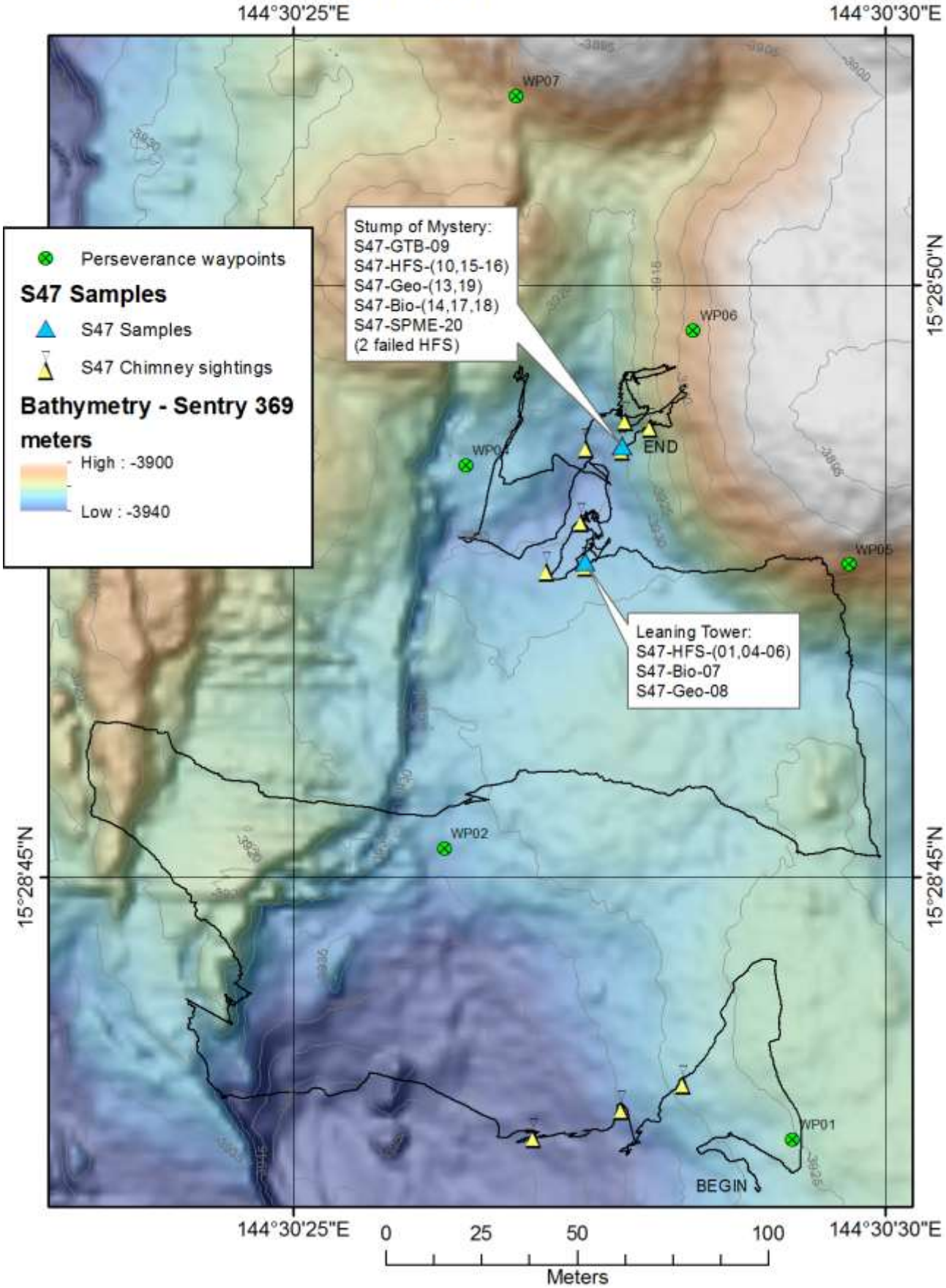

S43 Hafa Adai
E Spillway
W of Breached Cone
Crater
S43-Geo-01
BEGIN
MARR anomaly
S of Breached Cone
S43-Geo-02
2016 Hafa Adai Sites
S43-samples
Bathymetry - Sentry 370
meters
High : -3265
Low : -3305
Alba:
S43-HFS-(03-06,09,11)
S43-GTB-07
S43-Bio-14
(3 failed HFS)
Voodoo
WP-05
Two Towers
Sequoia
Chimlet Garden
Alba
END
16°58'10"N
16°58'5"N
16°58'0"N
16°57'55"N
16°57'50"N
16°57'45"N
16°57'40"N
144°51'50"E
144°51'55"E
144°52'0"E
144°52'5"E
144°52'10"E
0
100
200
400
Meters


S44 Hafa Adai
Markers
Waypoints/Sites
S44 Samples
Bathymetry - Sentry 370
meters
High : -3285
Low : -3300
144°52'0"E
144°52'5"E
144°52'10"E
144°52'15"E
144°52'20"E
16°57'45"N
16°57'40"N
16°57'35"N
S44-Geo-08
Mkr-171
Voodoo
END
Hula Array:
S44-HFS-(10-14)
S44-Bio-(15,16)
(1 failed HFS)
WP-05
Two Towers
Chimler Garden
Alba
Mkr-254
Sequoia
Top of Two Towers:
S44-HFS-(03-05)
S44-GTB-06
S44-Geo-07
WP-08
WP-07
Mami Wata:
S44-HFS-02
Mami Wata
BEGIN
S44-Geo-01
0
100
200
400
Meters

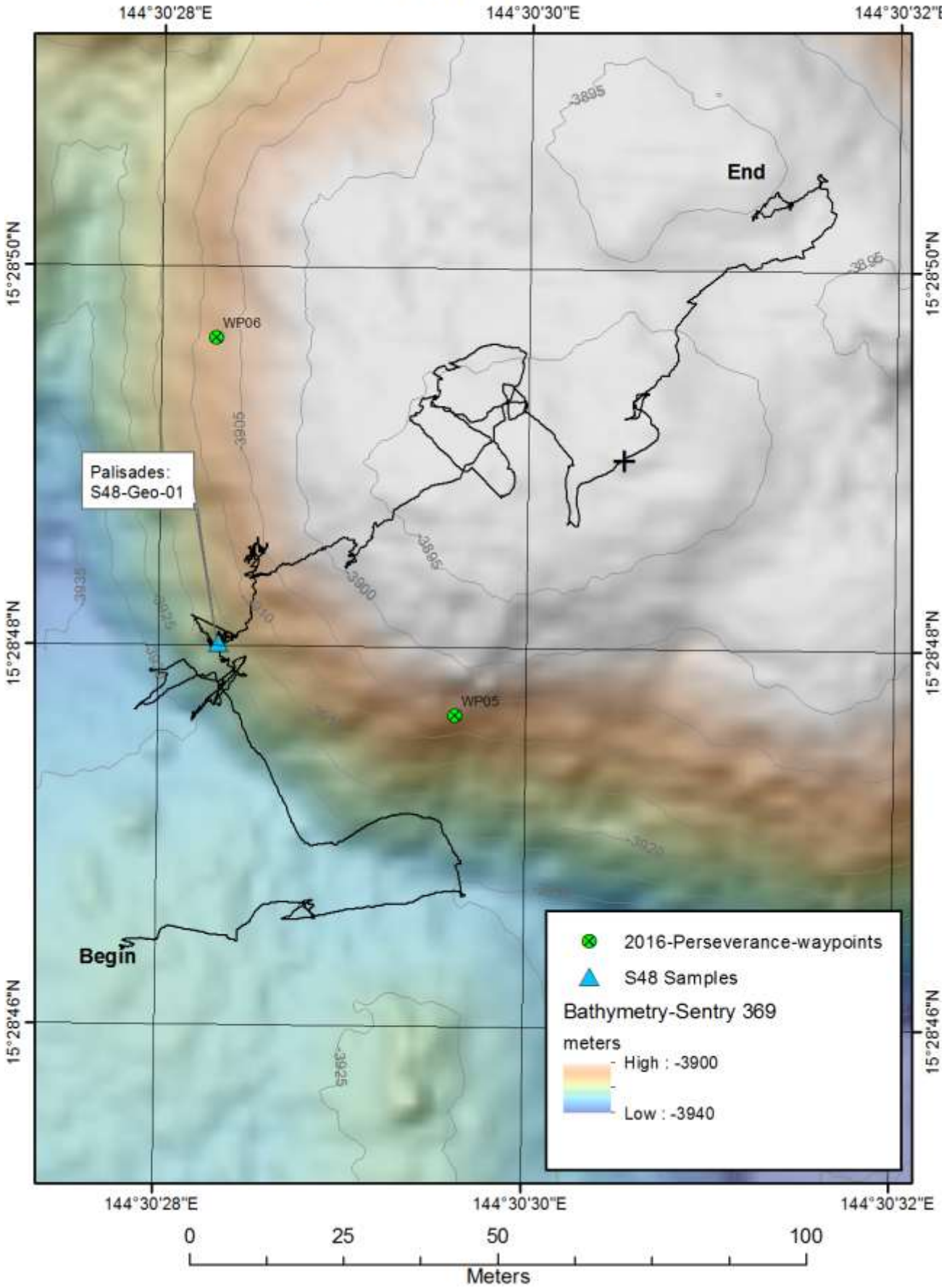
S45 - New Lava Site



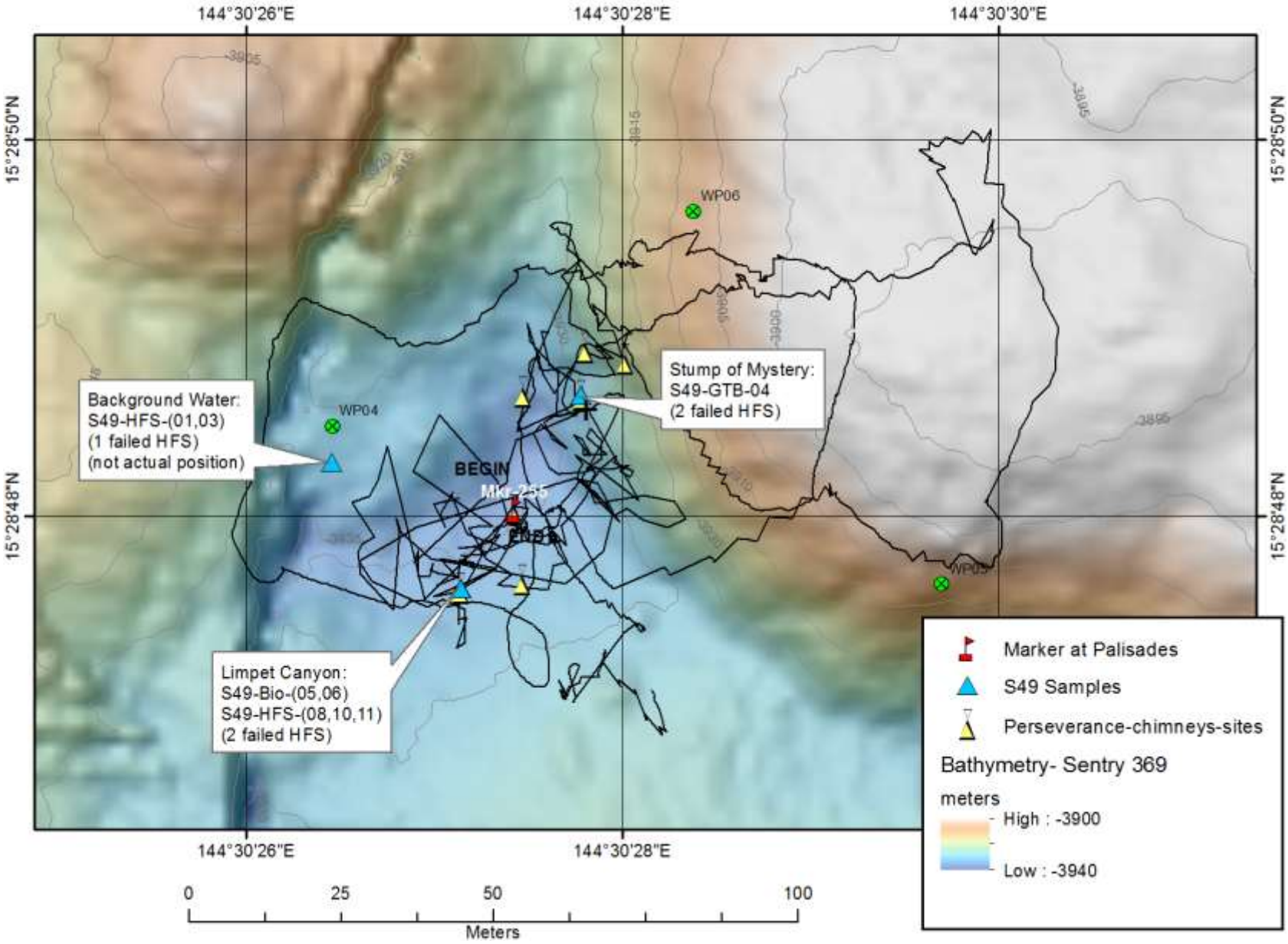
Perseverance S47



Perseverance S48



Perseverance - S49



6.4 ROV Navigation, ROV Depth, and ROV Data

Andra Bobbitt, Sharon Walker, Bill Chadwick

6.4.1 ROV Navigation and depth discrepancies

ROV depth discrepancies are noted in this report but are unresolved at this time. NOAA EOI will discuss these issues further with the SOI ROV team to try to get to the bottom of this apparent problem.

ROV *SuBastian* navigation data was analyzed in comparison to bathymetry collected by AUV *Sentry* in 2015, *Okeanos* 2016 ROV dives and results published from the 1987 Alvin dives for various locations. Table 6.4.1-1 summarizes various navigation (geographic) and bathymetry discrepancies. The *Sentry* bathymetry data had been processed internally (Susan Merle, EOI/CIMRS) to best fit its bathymetric swaths. This process could have created some geographic, X-Y, shifts. Offsets between features discernable between *Sentry* bathymetry and bathymetry collected by ship-mounted systems (primarily EM302) were known prior the expedition but the differences in resolution did not allow for confident shifts to align the data sets prior to ROV *SuBastian* dives. The depth offsets noted in Table 6.4.1-1 between EM302 bathymetry and *SuBastian* depths could also be attributed to geographic offsets. However, the April 2016 *Okeanos* dive at Hafa Adai (EX1605L1-Dive 11) did provide enough information prior to our *SuBastian* dives to align the Sentry bathymetry grids to match the *Okeanos* ROV navigation. *SuBastian* dives allowed further refinement in aligning the bathymetry post-cruise. Descriptions of the 1987 site visits at Alice Springs by Alvin were not numerous and dive data (written logs or digitally recorded) were not attainable or do not exist. The published results for these Alvin dives were more descriptive in nature.

We compared depth data from *SuBastian's* Paroscientific DigiQuartz pressure sensor to the depths calculated from its SBE49 (Seabird) FastCAT CTD. A sample of ROV-Paros-sensor depths compared with depths calculated from CTD pressure (in db) for latitude 15.45° from dive S-45 indicates the ROV-Paros depths are shallower by ~21 m (Table 6.4.1-2). Figure 6.4.1-2 shows the converted CTD depths more consistently match the EM302 bathymetry than the ROV-Paros depth tracks. This is similar to the apparent offset between the ROV-Paros depths and depths recorded by the PMEL MAPR instrument, which was on the vehicle for most dives. ROV-Paros depths are 8-25 m shallower than MAPR depths, and the difference increases with overall water depth. For example, ROV-Paros depths range from 8-20 m shallower than MAPR depths at the 17N site which generally has a bottom depth of ~3290-3295 m (from the bathymetry grids), but at the 15.4N lava flow where bathymetry depth of ~4100 m, the ROV-Paros depth is 18-25 m shallower than the MAPR depth. Since the CTD and MAPR depths agree fairly well, are both more similar to the bathymetric depth data, this suggests that the problem lies with the ROV-Paros depth sensor.

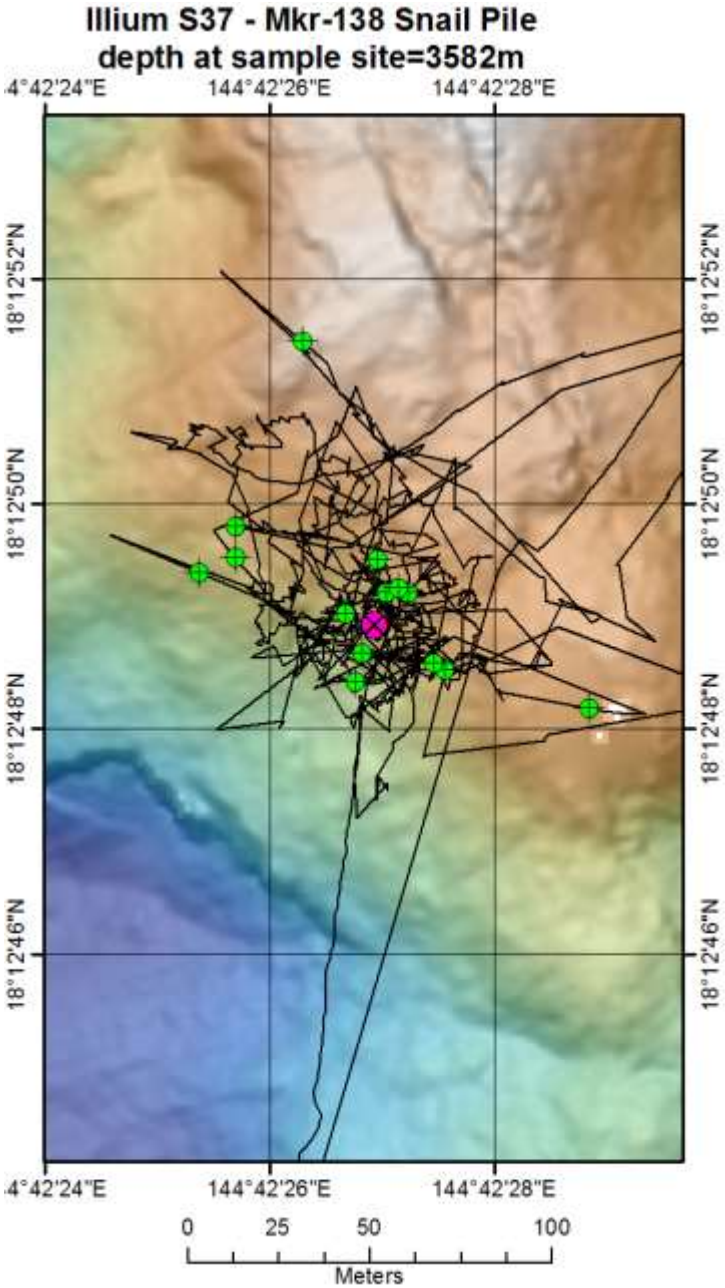
The Paroscientific DigiQuartz pressure sensor should be better than the strain gauge sensors of the SBE49 or the MAPR, so these large differences definitely indicate a problem. The Paroscientific sensor uses calibration coefficients to calculate depth, so one thing to check is to confirm the calibration coefficients are entered correctly with the appropriate number of decimal places. Part of the difference could potentially be due to using an incorrect latitude in the calculation of depth(m) from pressure(db), but the difference between depth(m) calculated from 4000 psi using 0 (the equator) vs 15.5 N is less than 2 m so it is likely more than that.

In addition to these depth discrepancies, not having a functioning alitmeter on *SuBastian* adversely impacted reconciling navigation with the bathymetry. The only depths usable for comparison with bathymetry from *SuBastian* were when the ROV was on the absolute bottom while sampling. In all comparisons of depth values between *SuBastian* and other measurements (see table below), *SuBastian* always has significantly shallower readings. The differences are larger than can be accounted by the addition of depth from an altimeter. This difference included depths compared with the 2016 *Okeanos* ROV at the Hafa Adai chimney field.

For many of the dives, ROV navigation while stationary (sampling) had to be disregarded due to the amount of erroneous positions logged. Figure 6.4.1-1 shows the navigation while the ROV was stationary at two different depths. For the Illium site (deep water), navigation wandered significantly from the approach to the bottom and until lift-off after sampling. Positions for sampling sites in these deep-water situations had to be estimated from the first and last good navigation and within the scatter. The shallow dives did not have significant scatter so the originally recorded positions for sampling were retained, even though they aren't exact. No filter or post-processing similar to ROV Jason was provided nor applied to the

data. The erroneous positions were excised from the sample, point and line shapefiles for creating the dive maps of the deeper sites.

Overall, the ROV *SuBastian* navigation system is OK, but not great. The DVL Doppler sonar on the ROV basically did not work most of the time (regardless of the bottom slope, type of bottom, depth, etc, we are working on). USBL was OK, but we had occasional times when it has dropped out for significant time periods. During those times the INS navigation went on crazy "walk-abouts" which are invalid and distracting to the pilots, the bridge, and the scientists in the Control Room. For example, if we plot the navigation for a given dive in map view, it looks like a rat's nest with huge fliers in all directions, and a poor representation of where the ROV went on the bottom. However, if we edit out all the time periods during which the ROV was stationary on the bottom while sampling, then the ROV track is not so bad. Basically the current software works well if it has all its expected inputs - USBL, DVL, and INS. But if it does not have one of more of these inputs - which is not uncommon - it performs very poorly. If the software were able to take input from the navigator to tell it that the ROV is actually stationary on the bottom, and to ignore any signals from the INS that say otherwise (especially if there are no recent USBL fixes), that would be a huge improvement and could potentially eliminate the bogus fliers.



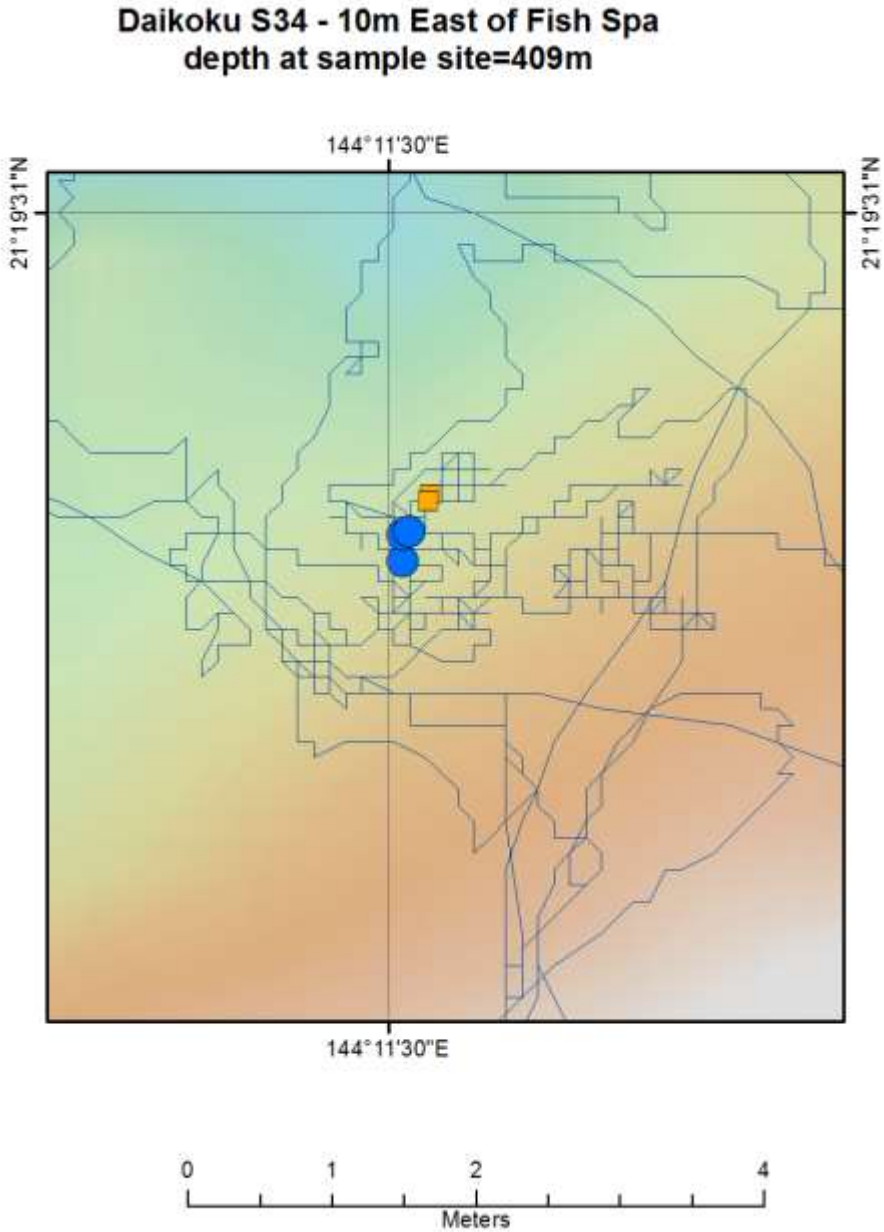


Figure 6.4.1-1 Examples of ROV *SuBastian* Navigation while stationary.

Table 6.4.1-1 Summary of *SuBastian* navigation offsets

		Depth readings in meters					Depth differences (meters)				
Dive	**Site**	**ROV *SuBastian***	***Sentry***	**EM302**	***Okeanos* ROV**	**Notes**	**Sub-*Sentry***	**Sub-EM302**	**Sub-*Okeanos***	**Sentry Dive Grid**	**Shifts-meters (dec. degrees)**
S34-S35 Daikoku	Fish Spa	408			410	May not be precise same location.					
	Tubeworms	356			355						
S36-Chamorro	chimney site (WP-01)	920			930	Not exact same location and on a slope.					
S37-Illium	Snail Pile	3582	3603	3611		1987: *Alvin* depth 3595	-21	-29		368	(no shifts)
	Old Chimney	3610	3630	3654			-20	-44			
	top of ridge	3563	3572-shallowest in grid	3584-shallowest in grid		1987: 3595 Illium vent on ridge crest	-14	-26			
	along ridge top	3559									
	Dead chimneys/Alvin weight (Illium?)	3558									
S39-Alice Springs	Old chimneys-Sulfides	3629-3639	3648-shallowest at crest			1987 high temp site: *Alvin* depth 3640 on crest of axial ridge; small patch of dead chimneys				368	(no shifts)
	Diffuse sample site	3625	3633	3662			-8	-37			(no shifts)
	Mkr-131 Snail001 (high temp)	3611	3630-(crest of ridge is 3617)	3644			-19	-33			(no shifts)

		Depth readings in meters					Depth differences (meters)				
Dive	**Site**	**ROV *SuBastian***	***Sentry***	**EM302**	***Okeanos* ROV**	**Notes**	**Sub-*Sentry***	**Sub-EM302**	**Sub-*Okeanos***	**Sentry Dive Grid**	**Shifts-meters (dec. degrees)**
S40-Burke	Snail Pit	3630.5	3643	3679		1987: *Alvin* Snail Pit 3660	-12.5	-48.5		368	(no shifts)
S41-S44 Hafa Adai	Voodoo Rim (S42)	3276	3286		3290	Altimeter not working but depths not too far offset between Sentry 370 & *SuBastian*.	-10		-14	370	shifted: -16S / +4Y (*Okeanos* nav shifted 42X / 10Y)
	Snail Graveyard	3284	3293		3294		-9		-10		
	Sequoia Top	3255	3284		3267		-29		-12		
S45-New Lava	Top of mini-cone	4132	4151			Bathy shifts based on waterfall and transit of a small mound.	-19			367	shifted: 60X / 20 Y (.00547/.000181)
S47-S49 Perseverance	Cone to scarp; along scarp	3920	3932			Bathy shifts from S49 transit from base of mound across to scarp and then south along scarp.	-12			369	shifted: -70X / -10 Y
	S48 edge of mound	3912	3929				-17				
	S47 edge of mound	3914	3929				-15				

		15.5N	
ROV-Paro(m)	ROV-CTD(db)	ROV-CTD(m)	difference (CTD-Paro)
3895.86	3976.363	3916.328	20.5
3895.58			
3889.39			
3889.46	3969.849	3909.970	20.5
3890.03	3970.529	3910.633	20.6
3898.53	3979.448	3919.339	20.8
3889.98	3970.878	3910.974	21.0
3888.02	3968.791	3908.937	20.9
3885.38	3966.093	3906.304	20.9
3882.22	3962.765	3903.055	20.8
3876.96	3957.131	3897.556	20.6
3879.04	3959.409	3899.779	20.7
3881.91	3962.259	3902.561	20.7
3885.57	3966.048	3906.260	20.7
3889.63	3970.362	3910.470	20.8
3888.48	3969.102	3909.241	20.8
3887.69	3968.272	3908.430	20.7
3889.41	3969.796	3909.918	20.5

Table 6.4.1-2 Sample of depth values recorded on S-45 with the Paroscientific gauge and the converted CTD depths.

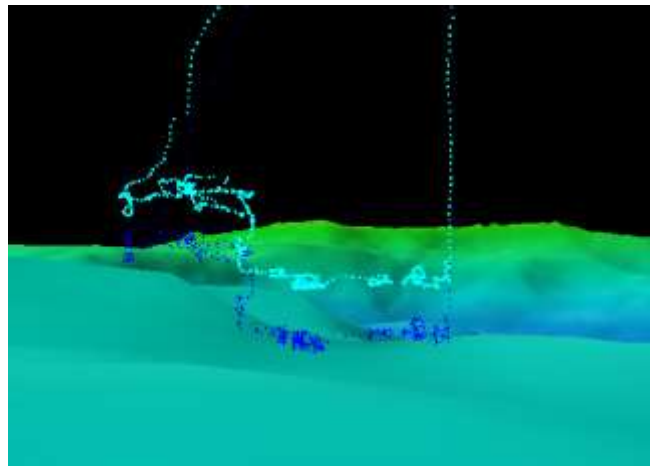


Figure 6.4.1-2 Dive S-48 ROV navigation comparison of converted CTD pressure to depth (dark blue) and pressure gauge (light blue).

The following are notes on the navigation and data for each dive.

S34-S35 Daikoku

Shallow dive with great navigation on both dives. Navigation did not wander much (only 3-4m) while sampling. *SuBastian* navigation had a slight offset with the 2016 *Okeanos* navigation (which was much noisier than *SuBastian*) at the tubeworm site (WP-02). *Okeanos* ROV was 20m west of *SuBastian* but the Fish Spa (WP-01) and Sulfur pond (WP-04) locations corresponded. No depth offset between *SuBastian* sampling depth and *Falkor* 2016 EM302 bathymetry. (See Figure 6.4-1) (Higher-resolution bathymetry SM2K data is no longer usable at this site due to more recent volcanology resulting in altered topography.)

S36 Chamorro

Extremely short dive due to deteriorating weather. Dive not long enough to analyze navigation.

S37 Illium

Problems with navigation at the beginning of the dive with significant jumps in position while switching between INS and USBL. While sampling at these deeper depths (~3600m) and ROV not moving, navigation had extremely erratic positions. Significant offsets in depth between 1987 dive location, Sentry 368 bathymetry and *SuBastian* depths. In all cases, *SuBastian* depths are significantly shallower than previous data from *Sentry*/EM302/*Alvin*. (See Figure 6.4-1)

Depth differences (meters):
Sampling:
Snail Pile Site: *SuBastian*=3582, *Sentry*=3603, EM302=3611
Old Chimney Site: *SuBastian*= 3610, *Sentry*=3630, vs EM302=3654

1987 Illium Site Description: *Alvin* depth=3595; Temperature 250-290°C. (1987: Crest of ridge, several active chimneys. Low mound (20-30m diameter) with cracks of 50°C water & hairy snails).

S39 Alice Springs:

Bathy/Nav discrepancies:
1987 Alice Springs site description for high-temp site: Depth=3640; Temperature 250-290°C along a ~200m of northern axial ridge near its midpoint @18°12'N; in small patch of dead chimneys. *SuBastian* encountered dead chimneys and sulfides at the beginning of the dive (no venting observed) and depths were 3629-3639. During this period there were a few altimeter readings which would then match the 1987 depths.

SuBastian depth at Little Anemone site was 3598m and Sentry 368 bathy grid max depth is 3606, there are no places shallower. Would have to move the bathy grid ~20m south to have this sampling site at the 3606m depth. All the sampling sites' depths are offset from the *Sentry* bathy (shallower than map) indicating the bathy grid should shift south.

Navigational errors: Encountered Mkr-131 three times (deployment and twice transiting). Transit locations agree fairly well since not precisely at marker while transiting, it is in view.

S40 Burke:.

In the vicinity of the 1987 Anemone Heaven site (~20m SW), concentrated areas of Anemones were observed by *SuBastian*. The depth range of *SuBastian* was 3648-3654, not too offset from the 1987 3660 reported depth. This where the bottle on a rope was also observed and could have been deliberately placed on the seafloor, 3639 meters depth.

1987 *Alvin* described the Snail Pit site as an open fissure at 3660m. *SuBastian* encountered a milky crack running N-S SW of the reported 1987 position but encountered no distinct fissures. (Sentry 368 bathymetry did not reveal any distinct fissure in the area.) Moving upslope along the crack, *SuBastian* encountered snails at the First Snails Navigational Marker

and the Snail Pit sampling site. *SuBastian*'s depth along the crack ranged from 3628-3624 (*SuBastian* depths: First Snails 3628; Snail Pit 3630).

S41-S44 Hafa Adai 17N:

Drove the rim of Voodoo on S42 and used this to do the final alignment of the Sentry 370 bathymetry to the *SuBastian* navigation. Shifted the bathymetry 16m south and 4m east for the best match at Voodoo. *Okeanos* navigation was then shifted to best match *SuBastian* and the shifted bathymetry. Navigation is still offset at Two Towers from the bathymetry after this shift (needs to move a further 10m south and 4m east). S43 navigation at the Breached Cone (furthest positions from Voodoo) are still offset about 15m to the east and may have an offset in the Y direction as well but without an altimeter during transiting this could not be ascertained. Prior the *Falkor* dives, the *Okeanos* navigation and comments indicated a navigational offset and the data was shifted to coincide prior the *SuBastian* dives. This further revealed that *Okeanos* had not visited the first waypoint as believed, that dive actually began at Sequoia and not Two Towers.

Depths from *SuBastian* are also offset from both the *Sentry* 370 bathymetry and the *Okeanos* ROV. *SuBastian* is 10-14m shallower than the *Okeanos* ROV at the same locations (in Voodoo and the top of Sequoia). *SuBastian* is also shallower than the *Sentry* 370 bathymetry, by 10-15m.

Okeanos ROV shifted nav : 42x and 10y to match *SuBastian*.

Sentry 370 shifted grids: -16x and +4y to

S45 New Lava Site:

Scarp at beginning of dive (lava waterfall) and reference to small mound indicated navigation and bathymetry did not align. Shifted *Sentry* 367 20mN and 60mE to better match. Altimetry data would have been extremely useful in this site to rectify the differences since *SuBastian* transited up and down over distinct features. Shifted bathymetry in decimal degrees: .000547x/.000181y Z factor for hillshade/slope: .00000932

Bad navigation at end of dive (in the old-new lava contact area) with big jumps while sampling.

S47-S49 Perseverance: (Bathy shift now at 10w/70s)

S47 was confusing at the beginning of the dive as features and depths were not coinciding with the *Sentry* 369 data. The original dive plan was diverted to the west to cross a significant scarp in the hopes of orienting *SuBastian* to the bathymetry. The bathymetry data was shifted after S47 to better navigate the subsequent dives, however, there was a more significant N-S offset than originally determined after the expedition.

S48 navigation was offset 20m east compared to S47 but poor telemetry ended the dive early and could have been the issue.

Bottom time was also used spent on this dive to further determine the navigation offset from the *Sentry* bathymetry by traversing west from the edge of the cone to the scarp and then continuing south along the scarp. This produced the post-cruise10w/70s bathymetry shift which reconciled all 3 dives to the bathymetry. Much of this dive was devoted to sampling which produced erratic navigational fixes with the ROV on the bottom. S49 1-second navigation positions do not match IRLS comments positions at the beginning of the dive. After the first sampling run, positions seem to match. (Very bad weather?)

6.4.2 Markers and Sites

Markers:

Markers were deployed in nine locations during operations. (Table 6.4-2 and Figure 6.4-2) The majority of markers were deployed to denote sampling locations and/or instrument deployment sites. One marker (Mkr-254) was deployed accidently (S41) when it fell while working with instruments in the basket and the vehicle at 13m above the seafloor at Sequoia chimney. This marker was later located at the base of Sequoia on a subsequent dive (S43). The final deployment of Mkr-255 was at Palisades, an active chimney, that was adjacent to the sampled Stump of Mystery. Significant sites and chimney locations are listed in Table 6.4-3 for the expedition. Positions were determined from *SuBastian* navigation.

Table 6.4.2-1 Markers deployed by *SuBastian*

		Deployment dive (Time UTC)								
Marker	**Dive**	**Date**	**time**	**Latitude**	**Longitude**	**Z**	**Gyro**	**Location**	**Observation**	**Best_Image**
Mkr-132	S34-Daikoku	12-02	07:22	21.32493	144.19166	403	214	Fish Spa	Marker is ~20m 2SE of WP-01 at *Okeanos* Fish Spa next to first fish trap deployment. Near edge of sulfur crust rim.	S5K17341.jpg
Mkr-133	S35-Daikoku	12-03	01:49	21.32503	144.19188	407	143	Fish Trap Site 1	Marker is ~30m SE of Fish Spa (WP-01).	S5K15907.jpg
Mkr-137	S35-Daikoku	12-03	02:15	21.32422	144.19205	371	84	Fish Trap Site 2	~50m N of WP-02 at fish trap deployment site. No fish collected. One sediment scoop from site.	S5K24717.jpg
Mkr-138	S37-Illium	12-05	04:22	18.21359	144.70748	3582	323	Snail Pile	Marker is just to the left of where the snail and water sampling occurred while facing 322deg.	2016-12-05T04_23_54.336244_S5K.jpg
Mkr-131	S39-AliceSprings	12-06	08:03	18.21033	144.70731	3611	229	Snail 001	At the Robosnail deployment site.	2016-12-06T08_05_06.338523_S5K.jpg
Mkr-234	S40-Burke	12-07	04:12	18.18251	144.71984	3631	360	Snail Pit	At snail pit site where Robosnail deployed.	2016-12-07T04_15_05.967132_S5K.jpg

Deployment dive (Time UTC)

Marker	Dive	Date	time	Latitude	Longitude	Z	Gyro	Location	Observation	Best_Image
Mkr-254	S41-HafaAdai	12-08	03:55	16.96122	144.86693	3282	123	Sequoia	Base of Sequoia: Dropped the marker down to the base of the chimney which is 13m below. Position is from S43 (06:42) when marker was viewed on the bottom.	(S43) 2016-12-10T06_43_06.686161_S5K.jpg
Mkr-171	S41-HafaAdai	12-08	06:40	16.96178	144.86920	3277	92	Voodoo	Marker is near the east crater rim on the inside but further down from the rim in a flatter area with snails. Site of the HulaHoop experiment.	2016-12-09T03_06_16.901719_S5K.jpg
Mkr-255	S49-Perseverance	12-18	05:57	15.48001	144.50762	3914	22	Palisades	Palisades is located near the Stump of Mystery (which is further upslope).	2016-12-18T05_58_34.673793_S5K.jpg

Images of markers deployed:

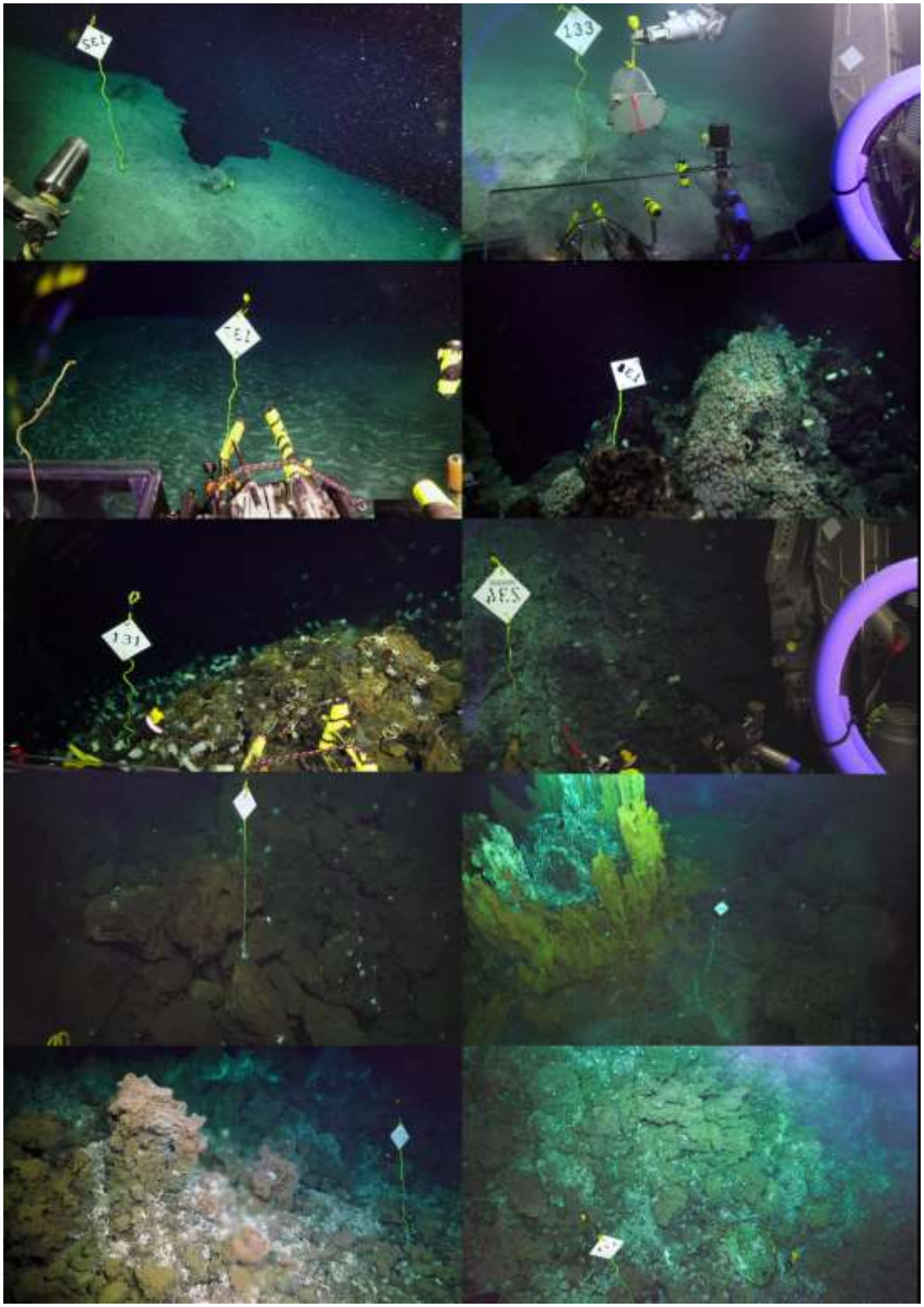


Figure 6.4.2-1 Markers deployed by SuBastian: By row (top to bottom) and left to right: Mkr-132 (Daikoku Fish Spa); Mkr-133 (Daikoku Fish Trap Site 1); Mkr-137 (Daikoku Fish Trap Site 2); Mkr-138 (Illium Snail Pile); Mkr-131 (Alice Springs Snail-001); Mkr-234 (Burke Snail Pit); Mkr-254 (Sequoia); Mkr-255 (Perseverance Palisades); both images, Mkr -171 (Hafa Adai Voodoo)

Table 6.4.2-2 Vents and significant sites visited by *SuBastian*

Name	Vent or Site	Latitude	Longitude	Depth	Description	Sampling
Daikoku-WP01	diffuse	21.32510	144.19158	410	Fish Spa	sampled
Daikoku-WP02	diffuse	21.32377	144.19212	360	Tubeworms inside S crater wall	sampled
Daikoku-WP03	vent	21.32432	144.19329	375	White smoker vent inside East crater wall	not sampled
Daikoku-WP04	diffuse	21.32489	144.19150	417	Near molten sulfur pond	sampled
Daikoku Mkr-137	diffuse	21.32422	144.19205	371	Fish Trap Site 2	sampled
Chamarro-WP1	vent	20.82149	144.70707	928	vent-7m SW of original waypoint	sampled
Old Chimneys (Illium)	dead	18.21318	144.70730	3610	Old sulfide Chimneys	sampled
Snail Pile Mkr-138 (Illium)	diffuse	18.21359	144.70748	3582	Diffuse flow with lots of biology	sampled
Old Alvin weights (Illium)	site	18.21371	144.70784		Old Alvin weights	not sampled
Old Alvin weights (Illium)	site	18.21446	144.70728		Old Alvin weights	not sampled
Diffuse Site (Alice Springs)	diffuse	18.21010	144.70735	3626	Diffuse site 21m NE of old Alice	sampled
Snail 001 (Mkr-131) (Alice Springs)	diffuse	18.21033	144.70731	3611	Diffuse flow with snails	sampled
Little Anemones (Alice Springs)	site	18.21054	144.70745	3598	Concentrated area of small anemones	sampled
Burke-WP6	site	18.18672	144.71800	3730	ORP-north anomaly	not sampled
Old Chimneys (Burke)	site	18.18619	144.71799		old chimneys near WP-06 (ORP anomaly_	not sampled
Snail Pit Mkr-234 (Burke)	diffuse	18.18257	144.71989	3630	Mkr-234 diffuse flow with snails (21m NW of Old Snail Pits)	sampled
First Snails Nav Marker (Burke)	diffuse	18.18238	144.72004		diffuse flow with snails	not sampled
Milky Crack Nav Marker	diffuse	18.18228	144.71990		diffuse flow	not sampled
Anemones (Burke)	site	18.18180	144.72000	3647	concentration of anemones (24m SW of Old Anemone Heaven)	not sampled
Bottle On Rope (Burke)	site	18.18189	144.71990		probable old marker or trash	not sampled
Milky Flow (Burke)	diffuse	18.18252	144.71996	3629	Diffuse flow area	sampled
Two Towers (Hafa Adai)	vent	16.96137	144.86667	3292	Large active chimney	sampled
Sequoia (Hafa Adai)	vent	16.96123	144.86713	3295	30-m chimney - active venting	sampled
Chimlet Garden (Hafa Adai)	vent	16.96135	144.86760	3294	Chimlet Garden - small sulfide chimneys (active)	not sampled
Alba (Hafa Adai)	vent	16.96127	144.86803	3295	Alba (active venting)	sampled

Name	Vent or Site	Latitude	Longitude	Depth	Description	Sampling
Hafa Adai-WP05	vent	16.96150	144.86843	3294	vent	not sampled
Voodoo (Hafa Adai)	diffuse	16.96175	144.86927	3290	Voodoo Crater (active diffuse venting)	sampled
Hafa Adai-WP07	diffuse	16.96093	144.87038	3292	vent	sampled
Hafa Adai-WP08	diffuse	16.96130	144.87100	3292	vent	sampled
Mami Wata (Hafa Adai)	diffuse	16.96100	144.87218	3294	Mami Wata	sampled
Hafa Adai-WP11	site	16.96842	144.86650	3285	Breached Cone Crater	not sampled
Stump of Mystery (Perseverance)	vent	15.48018	144.50772	3907	Stump of Mystery	sampled
slope chimney (Perseverance)	site	15.48025	144.50772		chimney on steep slope	not sampled
slope chimney (Perseverance)	site	15.48023	144.50778		chimney on steep slope	not sampled
old chimney (Perseverance)	site	15.48018	144.50763		lg chimney beyond Palisades	not sampled
Leaning Tower	vent	15.47991	144.50763	3912	Leaning Tower	sampled
Palisades (Perseverance)	vent	15.48001	144.50762	3915	Palisades	not sampled
old chimney (Perseverance)	site	15.47869	144.50786		old chimney	not sampled
old chimney (Perseverance)	site	15.47856	144.50751		old chimney	not sampled
old chimney (Perseverance)	site	15.47863	144.50771	0	old chimney	not sampled
Limpet Canyon (Perseverance)	diffuse	15.47989	144.50754	3913	diffuse venting	sampled

6.5 Dive Samples

All samples attempted are listed by dive in the Table 6.5-1. Those samples that were not successful are shaded in gray. Positions shaded in a lighter gray indicate an estimated position was applied after the dive (see section 6.4 about bad positions while stationary). A secondary table lists the original image associated with each sample. This image may not be an actual view of the sample being taken (such as during long HFS sampling runs when the camera was used to view the surrounding biology and landscape). The image file name and its time/date listing will provide some guidance in locating other imagery associated with the sample. See the discussion regarding image nomenclature in section 5 (Imagery).

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
Dive S34 - Daikoku									
S34-HFS-01	12/1/2016	22:46	**S34-HFS-01** Start 22:46. Filtered Piston #1 in soft sediment surround by flatfish with low pH and 10deg above ambient temperature. On volcanoclastic sediment at 10cm depth; pump working fine. Stop 22:50. Tmax=23.6 Tavg=13.5 T2=14 Vol=600ml	21.32509	144.19170	410	198	10m East of *Okeanos* Fish Spa	Butterfield
S34-Bio-02	12/1/2016	23:05	**S34-Bio-02** Start 23:05 Stop 23:17. Suction of fish into Chamber #6 2mm mesh. At least 4 fish seen in chamber.	21.32509	144.19170	410	196	10m East of *Okeanos* Fish Spa	Tunnicliffe
S34-Bio-03	12/1/2016	23:25	**S34-Bio-03** Start 23:23 Stop 23:32. Suction of fish in chamber #7 2mm mesh. Vehicle repositioned slightly forward. Quite a bit of sediment and only a few fish.	21.32509	144.19171	410	187	10m East of *Okeanos* Fish Spa	Tunnicliffe
S34-HFS-04	12/2/2016	0:12	**S34-HFS-04** Started 00:12 Stop 00:16. Unfiltered Piston #2. Tmax=74.3 Tavg=69.7 vol=602 T2=40. pH at this site was down to 4.1. Volcanoclastic sand near gas bubbles and sulfur smoke.	21.32509	144.19167	409	220	10m East of *Okeanos* Fish Spa	Butterfield

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S34-HFS-05	12/2/2016	0:17	**S34-HFS-05** Start 00:17 Stop 00:22 Piston #3 at the exact same location as HFS-04. Tmax=70.5 Tavg=68.8 vol=603 T2=35.	21.32510	144.19167	409	220	10m East of *Okeanos*Fish Spa	Butterfield
S34-HFS-06	12/2/2016	0:29	**S34-HFS-06** DNA filter #13 Start 00:29 Stop 00:46. Tmax=67.2 Tavg=59.9 vol=3002 T=35. (Julie Huber) at the same location as the previous HFS samples.	21.32510	144.19167	409	219	10m East of *Okeanos* Fish Spa	Huber
S34-Geo-07	12/2/2016	1:01	**S34-Geo-07** Sulfur chimlet for Heidi. Placed in STBD forward box.	21.32510	144.19167	409	218	10m East of *Okeanos* Fish Spa	Berkenbosch
S34-Geo-08	12/2/2016	1:21	**S34-Geo-08** Scoop of white-solid material that was near the chimlets. Going in the aft biobox in the STBD side of the box. Small piece fell off the scoop but still have a large piece.	21.32510	144.19167	409	221	10m East of *Okeanos* Fish Spa	Berkenbosch
S34-Bio-11A	12/2/2016	1:41	**S34-Bio-11A** Original location of fish trap deployment near FK16-Fish Spa on sulfur crust on edge. Mkr-132 deployed at site after trap deployed.	21.32493	144.19166	403	214	Mkr-132 FK-2016 Fish Spa	Tunnicliffe
S34-Bio-09	12/2/2016	1:49	**S34-Bio-09** Start 01:49. Stop 02:05. Suctioning fish into 1mm mesh chamber #5. Suction within 1m of the fish trap, further from the edge of the crust-ledge.	21.32493	144.19165	403	215	Mkr-132 FK-2016 Fish Spa	Tunnicliffe
S34-Geo-10	12/2/2016	2:42	**S34-Geo-10** Piece of sulfur crust from the edge of the sulfur pit. Had a fish nearby before taken. (Julie Huber)	21.32492	144.19162	403	180	Mkr-132 FK-2016 Fish Spa	Berkenbosch
S34-Bio-11B	12/2/2016	3:13	**S34-Bio-11B** Found location of Fish Trap. Second location after rolled down the hill. Grabbed it and redeployed at a third location.	21.32500	144.19161	407	156	downhill of Mkr-132 (FK-2016 Fish Spa)	Tunnicliffe

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S34-Bio-11C	12/2/2016	3:24	**S34-Bio-11C Deployed 03:24. Recovered 03:59.** Fish trap at third location which is 12.5m SE from the original location at Mkr-132. Bearing is 122deg.	21.32488	144.19175	398	153	25m E of waypoint 2 (Sulfur pond)	Tunnicliffe
S34-Geo-12	12/2/2016	4:04	**S34-Geo-12** The sulfur that has adhered to the ROV will be collected as a sample. The sulfur was erupted from the pond as liquefied globules which cooled and stuck to the vehicle. Location is based on a general position over the pond.	21.32491	144.19152	402		Over sulfur pond	Berkenbosch
Dive S35 - Daikoku									
S35-HFS-01	2016-12-02	23:09:08	**S35-HFS-01** Filtered Piston #1. PVC piston. In sediment next to black-tape fish trap. Start 23:09. Stop 23:13. Tmax=23.6 Tavg=19.1 vol=750 T2=15.	21.32513	144.19161	410	169	6m EofN Fish Spa	Butterfield
S35-HFS-02	2016-12-02	23:16:48	**S35-HFS-02** Start 23:16 Unfiltered Bag #16. At exact same location as previous sample. Stop 23:20. Tmax=21.6 Tavg=20.9 vol=530 T2=15	21.32513	144.19161	410	169	6m EofN *Okeanos* Fish Spa	Butterfield
S35-HFS-03	2016-12-02	23:21:40	**S35-HFS-03** Start 23:21. RNA filter #14. Stop 23:37. Tmax=31.5 Tavg=29.8 vol=3000 T2=17. Exact same location as previous.	21.32512	144.19160	410	169	6m EofN *Okeanos* Fish Spa	Huber
S35-HFS-04	2016-12-02	23:41:57	**S35-HFS-04** Start 23:41 Unfiltered piston #2. Stop 23:46. Tmax=29.2 Tavg=29.1 vol=700 T2=17 At same location.	21.32512	144.19160	410	167	6m EofN *Okeanos* Fish Spa	Butterfield
S35-HFS-05	2016-12-02	23:48:46	**S35-HFS-05** Start 23:48. Stop 23:51. Filtered Bag #17. At exact same location.	21.32513	144.19161	410	167	6m EofN *Okeanos* Fish Spa	Butterfield

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S35-HFS-06	2016-12-03	00:05:08	**S35-HFS-06** Start 00:05. Filtered Piston #3 Stop 00:08. Tmax=28.2 Tavg=19.0 vol=600 T2=15 Sample in same location but with the flush pump OFF.	21.32513	144.19161	410	166	6m EofN *Okeanos*Fish Spa	Butterfield
S35-HFS-07	2016-12-03	01:19:55	**S35-HFS-07** Start 01:19. Unfiltered Bag #18. Stop 01:23. Tmax=13.5 Tavg=13.4 vol=500 T2=13.6 In ambient temperature sediment approximately 30m east of the waypoint at Fish Spa. Can see exhaust.	21.32503	144.19188	407	145	Mkr-133	Butterfield
S35-HFS-08	2016-12-03	01:24:05	**S35-HFS-08** Start 01:24. Stop 01:26. Tmax=13.6 Tavg=13.5 vol=500 T2=13.7 Filtered Bag #19. At same location.	21.32503	144.19187	407	144	Mkr-133	Butterfield
S35-Bio-09	2016-12-03	01:45:35	**S35-Bio-09** Suction sample of sediment near fish trap deployment 30m east of Fish Spa. Sample is in chamber #7.	21.32503	144.19188	407	143	Mkr-133	Tunnicliffe
S35-Bio-10	2016-12-03	02:52:40	**S35-Bio-10** Sample of about 8 tubeworms. Taken from the inside wall of the big crater near the rim. In the area of waypoint #2 (20m east and 5m north of *Okeanos* site).	21.32378	144.19229	355	137	20m E/5mN WP2 crater rim inside wall	Tunnicliffe
S35-HFS-11	2016-12-03	03:09:26	**S35-HFS-11** Start 03:09. Unfiltered Bag #20. Taken at the same location as the tubeworm sample. In a crack at the base of the worms. Inside the crater wall. Stop 03:13. Tmax=15.7 Tavg=15.6 vol=501 T2=15.7. Vehicle moved just at end of the sample.	21.32379	144.19230	355	139	20m E/5mN WP2	Butterfield
S35-Bio-12	2016-12-03	04:27:42	**S35-Bio-12** Scoop of sediment near the recovered (but empty) fish trap and Mkr-137. Taking several swipes with the sediment scoop.	21.32421	144.19205	371	55	Mkr-137	Tunnicliffe

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S35-HFS-13	2016-12-03	05:49:16	**S35-HFS-13** Start 05:49. Unfiltered Piston #4. Stop 05:52. Tmax=42.3 Tavg=36.1 vol=480 T2=14. At waypoint 1 site Fish Spa.	21.32510	144.19162	409	164	*Okeanos* Fish Spa	Butterfield
S35-HFS-14	2016-12-03	05:53:33	**S35-HFS-14** Start 05:53. Unfiltered Piston #8 Titanium. Stop 05:56. Tmax=43.7 Tavg=28.4 vol=602 T2=14. At same location.	21.32510	144.19163	409	164	*Okeanos*Fish Spa	Butterfield
S35-HFS-15	2016-12-03	05:58:54	**S35-HFS-15** Start 05:58. LVB #24. Stop 06:15. Tmax=69.2 Tavg=45.9 vol=3800 T2=14. At the same location.	21.32510	144.19163	409	165	*Okeanos* Fish Spa	Huber
S35-HFS-16	2016-12-03	06:16:20	**S35-HFS-16** Start 06:16. RNA Filter #13. Stop 06:29. Tmax=49.2 Tavg=33.2 vol=3000. At same exact location.	21.32510	144.19163	409	164	*Okeanos*Fish Spa	Huber
S35-Bio-17	2016-12-03	06:53	**S35-Bio-17** Suction of a crab at the fluid sampling site near Fish Spa at 06:53. Did not know the crab was in chamber #4 until recovering the fish traps. Location of sample was 21deg 19.5017 (21.32336) 144deg 11.4962 (144.19160) 408m of depth.	21.32336	144.19160	408	178	8m S of *Okeanos* Fish Spa	Tunnicliffe
S35-Bio-18	2016-12-03	07:16:05	**S35-Bio-18** Crab suction into chamber 5. Looks like some were suctioned into chamber.	21.32502	144.19165	407	160	10m SE *Okeanos* Fish Spa	Tunnicliffe
Dive S36 - Chamorro									
S36-Geo-01	2016-12-04	00:30:19	**S36-Geo-0**1. Sample of small chimney with animals. Location is at Waypoint #1 (venting site found by *Okeanos* Explorer). Small active chimney on a sulfide mound located on a broken up lava flow.	20.82146	144.70705	920	41	Waypoint 1	Berkenbosch

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S36-HFS-02	2016-12-04	00:44:55	**S36-HFS-02** Start 00:44. Filtered Piston #1. Stop. 00:47 Tmax=154.7 Tavg=135. vol=550 At the sulfide just sampled on the sulfide mound in the broken up lava flow.	20.82150	144.70708	920	40	Waypoint 1	Butterfield
S36-HFS-03	2016-12-04	00:47:43	**S36-HFS-03** Unfiltered piston #2. Start 00:47. Stop 00:49. Tmax=148 Tavg=107 vol=490 No exhaust. Exact same location.	20.82149	144.70707	920	40	Waypoint 1	Butterfield
S36-HFS-04	2016-12-04	00:50:52	**S36-HFS-04** Start 00:50. Unfiltered Bag #16. Stop 00:53. Tmax=139 Tavg=120 vol=480 Can see exhaust with the bag sample. Flush pump is on. Same location.	20.82148	144.70707	920	40	Waypoint 1	Butterfield
S36-HFS-05	2016-12-04	00:53:20	**S36-HFS-05** Start 00:53. Unfiltered Bag #18 Stop 00:55. Tmax=155.3 Tavg=149.4 vol=460 T2=40. At same location. Can see exhaust.	20.82150	144.70705	920	40	Waypoint 1	Butterfield
Dive S37 - Illium									
S37-Geo-01	2016-12-05	01:10:19	**S37-Geo-01**. Old chimney downslope of Ilium vent target. Old chimney on an old lava tube flow as we came up the slope. Squat lobsters at the base. Going in port-aft section of the forward biobox. (Piece went in STBD part of box as well).	18.21318	144.70730	3610	42	Old Chimney	Berkenbosch
S37-HFS-02	2016-12-05	02:16:15	**S37-HFS-02** Start 02:16. Unfiltered Titanium Piston #1. Titanium. In the clump of snails just .5m from the robosnail. Wand tip buried half-way down in the snails. Not seeing exhaust. (No data.)	18.2136	144.70748	3583	323	Snail Pile Mkr-138	Butterfield

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S37-HFS-03	2016-12-05	02:19:21	**S37-HFS-03** Start 02:19. Piston #2 Unfiltered titanium. Stop 02:28. Tmax=27.4 Tavg=26.8 vol=193. No exhaust visible. Same location.	18.2136	144.70748	3583	323	Snail Pile Mkr-138	Butterfield
S37-HFS-04	2016-12-05	02:30:45	**S37-HFS-04** Start 02:30 Unfiltered bag #16. Stop 02:33. Tmax=28.7 Tavg=25.8 vol=402. T2=2.2 Visible exhaust flow. Same location.	18.2136	144.70748	3583	323	Snail Pile Mkr-138	Butterfield
S37-HFS-05	2016-12-05	02:34:49	**S37-HFS-05** Start 02:34. Filtered Bag #17. No flow in exhaust. Stop 02:37. Tmax=27.0 Tavg=23.6 vol=454 T2=8. Same location.	18.2136	144.70748	3583	323	Snail Pile Mkr-138	Butterfield
S37-HFS-06	2016-12-05	02:39:15	**S37-HFS-06** Start 02:39. LVB #24. Stop 03:06 Tmax=32.3 Tavg=30.4 vol=3297 T2=13 Seeing some bubbles and fresh water from exhaust. Same location.	18.2136	144.70748	3583	323	Snail Pile Mkr-138	Huber
S37-HFS-07	2016-12-05	03:07:41	**S37-HFS-07** Start 03:07. Unfiltered bag #18. Stop. 03:10 Tmax=27.6 Tavg=21.8 vol=500. T2=10 Sample probably not good-no exhaust. Same location in robosnail patch.	18.2136	144.70748	3583	323	Snail Pile Mkr-138	Butterfield
S37-HFS-08	2016-12-05	03:14:29	**S37-HFS-08** Start 03:14. Filtered DNA #11. Stop 03:27. Tmax=24.1 Tavg=20.6 vol=3000 T2=10. Same location.	18.2136	144.70748	3582	323	Snail Pile Mkr-138	Huber
S37-HFS-09	2016-12-05	03:29:04	**S37-HFS-09** Unfiltered piston #8. Start 03:29. Stop 03:37. Tmax=32.8 Tavg=28.2 vol=637 T2=13. Same location.	18.2136	144.70748	3582	323	Snail Pile Mkr-138	Butterfield
S37-Bio-10	2016-12-05	03:54:59	**S37-Bio-10** Scoop of biology in the same location as HFS samples. Mainly snails but other species in scoop.	18.2136	144.70748	3582	323	Snail Pile Mkr-138	Tunnicliffe

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S37-HFS-11	2016-12-05	03:58:06	**S37-HFS-11** Background sample (wand is in holster). Unfiltered Bag #20. At the robosnail site. Not seeing any flow. Stop 04:00. Tmax=2.7 Tavg=2.6 vol=500 T2=2.25.	18.2136	144.70748	3582	323	Snail Pile Mkr-138	Butterfield
S37-HFS-12	2016-12-05	04:02:07	**S37-HFS-12** Start 04:02 Filtered bag #21. Stop 04:03. Tmax=2.6 Tavg=2.5 vol=500 T2=2.4 Background sample (wand in holster).	18.2136	144.70748	3582	323	Snail Pile Mkr-138	Butterfield
S37-Bio-13	2016-12-05	04:03:58	**S37-Bio-13** Suction of small biology bits into container #2. Mesh size=500. Few shrimp as well. Lifted up clumps of snails to get underneath while suctioning.	18.2136	144.70748	3582	323	Snail Pile Mkr-138	Tunnicliffe
S37-Bio-14	2016-12-05	04:08:11	**S37-Bio-14** Suction into jar #3. Trying to get some shrimp. Jar contains shrimp and snail.	18.2136	144.70748	3582	323	Snail Pile Mkr-138	Tunnicliffe
S37-HFS-15	2016-12-05	04:12:14	**S37-HFS-15** Start 04:12. Filtered Piston #3. Stop 04:17. Tmax=2.9 Tavg=2.7 vol=700 T2=2.6 Background.	18.2136	144.70748	3582	323	Snail Pile Mkr-138	Butterfield
Dive S39 - Alice Springs									
S39-HFS-01	2016-12-06	03:40:11	S39-HFS-01 Start 03:40. Unfiltered Piston #2. Stop. Tmax=7.8 Tavg=7.4 vol=597 T2=4 Have good flow.	18.21010	144.70735	3626	348	Diffuse site 22m NE of old Alice Springs	Butterfield
S39-HFS-02	2016-12-06	04:24:59	S39-HFS-02 Start 04:24. Filtered Piston #1. Stop 04:28 Tmax=126.5 Tavg=124.2 T2=26 vol=550. At the focused flow at the nav marker snail-001 site where the ROV had a high temperature of 158deg.	18.2103	144.70731	3611	307	Mkr-131 Snail-001 Site	Butterfield

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S39-HFS-03	2016-12-06	04:30:30	S39-HFS-03 Start 04:30. Unfiltered Piston #8. Stop. Tmax=161.4 Tavg=158.5 vol=700 T2=32. Using barbed to six-port. Seeing exhaust.	18.2103	144.70731	3611	307	Mkr-131 Snail-001 Site	Butterfield
S39-HFS-04	2016-12-06	04:37:12	S39-HFS-04 Start 04:37.Filtered Piston #7. Stop 04:38. Tmax=161.4 Tavg=161.2 vol=250 T2=30 Don't think it worked. At same location snail-001 near the robosnail deployment.	18.2103	144.70731	3611	307	Mkr-131 Snail-001 Site	Butterfield
S39-HFS-05	2016-12-06	04:39:59	S39-HFS-05 Start 04:39. Filtered Piston #3. Stop. Tmax=164.8 Tavg=163.1 T2=32 vol=606 Looks like it is working.	18.2103	144.70731	3611	307	Mkr-131 Snail-001 Site	Butterfield
S39-GTB-06	2016-12-06	05:14:07	S39-GTB-06 Fired. Yellow #9 GTB. In the hole with good verification of the wand tip in the pilot camera. Sample looked really good.	18.2103	144.70731	3611	312	Mkr-131 Snail-001 Site	Lupton
S39-HFS-07	2016-12-06	06:11:19	S39-HFS-07 Start 06:11. LVB #24 Stop 06:35. Tmax=67.7 Tavg=35.2 vol=3217 T2=16. Temperature started at about 44-45deg.	18.2103	144.70731	3611	237	Mkr-131 Snail-001 Site	Huber
S39-HFS-08	2016-12-06	06:37:39	S39-HFS-08 Start 06:37. Unfiltered Piston #4 Stop. Tmax=33.4 Tavg=26 vol=601 T2=10. At the same location as the LVB. Near the crack with the 2 snails.	18.2103	144.70731	3611	234	Mkr-131 Snail-001 Site	Butterfield
S39-HFS-09	2016-12-06	06:43:31	S39-HFS-09 Start 06:43. Unfiltered Bag #20. Stop 06:47. Tmax=40.5 Tavg=32 vol=600 T2=13. Same exact location as the last one.	18.2103	144.70731	3611	234	Mkr-131 Snail-001 Site	Butterfield

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S39-HFS-10	2016-12-06	06:49:16	S39-HFS-10 Start 06:49. DNA Filter #10. Stop. Tmax=78 Tavg=42 vol=2944 T2=25. Same location.	18.2103	144.70731	3611	234	Mkr-131 Snail-001 Site	Huber
S39-Geo-11	2016-12-06	07:24:21	S39-Geo-11 Rock is for Biologist Aft-port quarter of the forward biobox. Collected with an anemone on it just below the snails.	18.2103	144.70731	3611	234	Mkr-131 Snail-001 Site	Tunnicliffe
S39-Bio-12	2016-12-06	07:27:44	S39-Bio-12 One mussel taken near the rock and last fluid sample site below the snails. Mussel was damaged while sampling. In aft-stbd quarter of forward biobox.	18.2103	144.70731	3611	234	Mkr-131 Snail-001 Site	Tunnicliffe
S39-Bio-13	2016-12-06	07:35:19	S39-Bio-13 Scooped once but they came out when scoop was jostled. Will try some more.	18.2103	144.70731	3611	234	Mkr-131 Snail-001 Site	Tunnicliffe
S39-Bio-14	2016-12-06	07:51:04	S39-Bio-14 Suction sample of biology. Same location into jar #2. 500 mesh.	18.2103	144.70731	3611	230	Mkr-131 Snail-001 Site	Tunnicliffe
S39-Bio-15	2016-12-06	09:06:07	S39-Bio-15 Got one in the grips. Rock with little zooanthids and large anemone on it. Into right forward bio box partition.	18.21054	144.70745	3598	299	Little Anemones	Tunnicliffe
S39-HFS-16			Background 900m at end of dive					900m background	Butterfield
Dive S40 - Burke									
S40-Bio-01	2016-12-07	01:41:54	S40-Bio-01 .Suction sample of shrimp into jar 4. About 15 snails in the jar #4.	18.18257	144.71989	3630	3	Snail Pit Mkr-234	Tunnicliffe
S40-Bio-02	2016-12-07	01:50:10	S40-Bio-02. Suctioning to the left of the robosnail. Suctioning up the crud.	18.18257	144.71989	3630	2	Snail Pit Mkr-234	Tunnicliffe
S40-Bio-03	2016-12-07	01:59:53	S40-Bio-03 Suction hold of a mussel and then extruded into the forward-stbd portion of the forward biobox.	18.18257	144.71989	3630	2	Snail Pit Mkr-234	Tunnicliffe

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S40-Geo-04	2016-12-07	02:07:59	S40-Geo-04 Rock with biology for Verena. To the right of the robosnail. Had limpets on it. Went into the aft-stbd quadrant of the forward biobox.	18.18257	144.71989	3630	2	Snail Pit Mkr-234	Tunnicliffe
S40-HFS-05	2016-12-07	02:38:58	S40-HFS-05 .Start 02:38. Filtered Piston #1. Stop. Tmax=51.5 Tavg=50.7 vol=569 T2=19. At the exact location of the last sensor reading just a few inches to the right of the robosnail. Not seeing exhaust flow.	18.18257	144.71989	3630	2	Snail Pit Mkr-234	Butterfield
S40-HFS-06	2016-12-07	02:43:09	S40-HFS-06 Start 02:43 Unfiltered Piston #2. Stop. Tmax=49.8 Tavg=39.7 vol=872 Did not stop on its own so probably no good. Not seeing any flow. Same exact location.	18.18257	144.71989	3630	2	Snail Pit Mkr-234	Butterfield
S40-HFS-07	2016-12-07	02:49:23	S40-HFS-07 Start 02:49. Unfiltered Bag #22 There is flow in the exhaust. Stop. Tmax=42.2 Tavg=39.4 vol=400 T2=16. Same exact location to the right of the robosnail.	18.18257	144.71989	3631	2	Snail Pit Mkr-234	Butterfield
S40-HFS-08	2016-12-07	02:53:05	S40-HFS-08 Start 02:53. Filtered Bag #21. Stop. Tmax=47.2 Tavg=43.6 vol=400 T2=16.17 Can see flow/exhaust. Same location.	18.18257	144.71989	3631	2	Snail Pit Mkr-234	Butterfield
S40-HFS-09	2016-12-07	02:59:36	S40-HFS-09 Start 02:59. LVB #24 at the same location. Stop 03:22 Tmax=49.5 Tavg=42.7 vol=3318 T2=17. Good flow in exhaust.	18.18257	144.71989	3631	2	Snail Pit Mkr-234	Huber
S40-HFS-10	2016-12-07	03:24:12	S40-HFS-10 Start 03:24. RNA Filter #11 Stop 03:50 Tmax=48.8 Tavg=37.4 vol=3000 T2=17 (High temp occurred just at end). At the same location.	18.18257	144.71989	3631	2	Snail Pit Mkr-234	Huber

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S40-HFS-11	2016-12-07	03:54:15	S40-HFS-11 Start 03:54. Unfiltered Piston #8 Seeing good exhaust. Stop 03:58 Tmax=48.7 Tavg=45.5 vol=650 T2=17 Good sample. Same location to the right of the robosnail.	18.18257	144.71989	3631	2	Snail Pit Mkr-234	Butterfield
S40-Bio-12	2016-12-07	04:05:49	R40-Bio-12 Sample of snails hitchhiking on the robosnail.	18.18257	144.71989	3631	2	Snail Pit Mkr-234	Bates
S40-Bio-13	2016-12-07	04:08:08	S40-Bio-13 Suction of snails that were located under the Robosnail into Jar #7.	18.18257	144.71989	3631	360	Snail Pit Mkr-234	Bates
S40-HFS-14	2016-12-07	04:26:47	S40-HFS-14 Start 04:26 Unfiltered Bag #20. Stop 04:39 Tmax=11.0 Tavg=10.2 vol=400 T2=6	18.18252	144.71996	3629	172	Milky Flow	Butterfield
S40-HFS-15	2016-12-07	04:30:05	S40-HFS-15 Start 04:30. Filtered Bag #19. Same location in the milky flow as #20. Stop 04:32 Tmax=11.1 Tavg=9.8 vol=400 T2=5.5	18.18252	144.71996	3629	172	Milky Flow	Butterfield
Dive S41 - Hafa Adai									
S41-Geo-01	2016-12-07	23:53:18	S41-Geo-01. Piece of chimney that had fallen on top of the flange on the east side of the Two Towers Chimney. About 13m up the chimney on east side.	16.96133	144.86657	3271	248	Two Towers	Berkenbosch
S41-GTB-02	2016-12-08	02:19:59	S41-GTB-02 Red-green taken from the same orifice the 302deg fluid was measured with the ROV wand. From the west side of the chimney near the base but where the active venting began. Saw the firing as it sucked the water in.	16.96115	144.86696	3274	83	Sequoia	Lupton

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S41-Bio-03	2016-12-08	02:34:29	S41-Bio-03 Suction of snails located to the right of the gas tight sample. Going to jar #7 with a 2mm mesh.	16.96115	144.86696	3274	81	Sequoia	Tunnicliffe
S41-Bio-04	2016-12-08	02:55:44	S41-Bio-04 Suction of small-red shrimp into jar #5. Still on the west side of the chimney where the gas tight was taken.	16.96115	144.86696	3274	110	Sequoia	Tunnicliffe
S41-Bio-05	2016-12-08	03:01:25	S41-Bio-05 Suction of 'crud' and some small shrimp into jar #3. Same location as the previous biology suctions.	16.96115	144.86696	3274	111	Sequoia	Tunnicliffe
S41-HFS-06	2016-12-08	03:28:38	S41-HFS-06 Start 03:28 Unfiltered piston #8. Stop Tmax=132.5 Tavg=110 vol=600 T2 32. With good flow. Tip is in the minerals.	16.96115	144.86696	3274	136	Sequoia	Butterfield
S41-HFS-07	2016-12-08	03:34:44	S41-HFS-07 Start 03:34 Filtered Piston #3 Stop. Tmax=85.5 Tavg=76 vol=500 T2=27. At the same exact location as the unfiltered piston. Good exhaust.	16.96115	144.86696	3274	136	Sequoia	Butterfield
S41-Geo-08	2016-12-08	03:49:58	S41-Geo-08 Piece of smoking chimney just above where the last fluid samples were taken on the west side of the 30m chimney. Fragments of the chimney.	16.96115	144.86696	3275	122	Sequoia	Berkenbosch
S41-Geo-09	2016-12-08	04:07:24	S41-Geo-09 Got a piece of the second rock (which broke the scoop) Forward-stbd portion of the biobox with the last geo sample.	16.96115	144.86696	3274	110	Sequoia	Berkenbosch
S41-Bio-10	2016-12-08	07:16:22	S41-Bio-10 Suction of white snails into jar #6 from a cluster of 4. Looked like all four went into the hose but only one has come into the jar.	16.96079	144.87041	3280	236	Waypoint 7	Tunnicliffe

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S41-Geo-11	2016-12-08	07:21:47	S41-Geo-11 Inactive sulfide that was on the top of the chimney at waypoint #7. Looking to the west.	16.96076	144.87040	3281	268	Waypoint 7	Berkenbosch
Dive S42 - Hafa Adai									
S42-HFS-01	2016-12-08	23:40:33	S42-HFS-01 Start 23:40. Unfiltered Bag #22 Stop. Tmax=25.6 Tavg=21.0 vol=425 T2=12.2	16.96172	144.86921	3278	3	Hula array	Butterfield
S42-HFS-02	2016-12-08	23:44:18	S42-HFS-02 Start 23:44. Filtered Bag #21. Stop. Tmax=30.5 Tavg=25.7 vol=425 T2=12.1 At the same location as HFS-01	16.96174	144.86919	3278	2	Hula array	Butterfield
S42-HFS-03	2016-12-09	00:19:07	S42-HFS-03 Start 00:19. Unfiltered Piston #1 Stop Tmax=124 Tavg=120 vol=650 T2=40. This is the hole inside the temperature array with hotter water.	16.96171	144.86922	3278	0	Hula array	Butterfield
S42-HFS-04	2016-12-09	00:24:27	S42-HFS-04 Start 00:24 Filtered Piston #3 Stop. Tmax=128.1 Tavg=126 vol=308 T2=40. Same location as reading #8 inside the temperature array near Mkr-171.	16.96174	144.86921	3278	359	Hula array	Butterfield
S42-HFS-05	2016-12-09	00:31:54	S42-HFS-05 Start 00:31. LVB #24 at location #8 in the array. Stop 00:53. Tmax=100.3 Tavg=38.6 vol=3228 T2=20.Brought wand up from hot water just sampled at same exact location a few inches to get cooler water.	16.96173	144.86921	3278	359	Hula array	Huber
S42-HFS-06	2016-12-09	00:55:48	S42-HFS-06 Start 00:55 RNA filter #10 At location #8 (of array readings) inside the temperature array near Mkr-171. Stop 01:21. Tmax=58.6 Tavg=30.2 vol=3000 T2=20.Same exact location as HFS-05.	16.96174	144.86924	3278	353	Hula array	Huber

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S42-HFS-07	2016-12-09	01:35:24	S42-HFS-07 Start 01:35 Unfiltered Bag#20. Stop 01:38. Tmax=7.1 Tavg=6.0 vol=452 T2=5.4Location near the edge of the array near the last reading but after the vehicle was bumped.	16.96170	144.86921	3278	350	Hula array	Butterfield
S42-HFS-08	2016-12-09	01:39:52	S42-HFS-08 Start 01:39 Filtered Bag #19 Stop 01:44. Tmax=6.1 Tavg=5.2 vol=450 T2=4.7Same location as HFS-07 near Location #9 in the array at Mkr-171 (started a bit later as valve needed to move).	16.96177	144.86920	3278	350	Hula array	Butterfield
S42-Bio-09	2016-12-09	02:18:01	S42-Bio-09 Suction of many dead snails into Jar #7.	16.96174	144.86911	3284	160	Snail Graveyard	Tunnicliffe
S42-Bio-10	2016-12-09	02:40:26	S42-Bio-10 Suction of a single white snail (alive) in the Snail Graveyard. Placed in the aft-aft quadrant of the biobox. I	16.96173	144.86906	3284	165	Snail Graveyard	Tunnicliffe
S42-Bio-11	2016-12-09	02:42:27	S42-Bio-11 Full strength suction of crud into Jar #4 at the Snail Graveyard. A couple of suctions under the dead shells.	16.96175	144.86910	3284	160	Snail Graveyard	Tunnicliffe
S42-Geo-12	2016-12-09	02:54:07	S42-Geo-12 Rock holding the barnacles. Located above the snail grave yard on the south inside rim of the cone.	16.96168	144.86920	3278	119	Rim above graveyard	Tunnicliffe
S42-Geo-13	2016-12-09	03:17:21	S42-Geo-13 Piece of altered rock from the outside of the cone on the NE side. About fist-sized put in the aft-port quarter of the forward biobox.	16.96197	144.86935	3285	227	outside wall NE Voodoo	Berkenbosch
S42-Geo-14	2016-12-09	03:31:23	S42-Geo-14 Small piece in port-forward quarter of small biobox. Need to get another piece.	16.96148	144.86873	3285	222	sheet flow west of Voodoo	Berkenbosch

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S42-HFS-15	2016-12-09	04:09:37	S42-HFS-15 Start 04:09 On the NE side of Sequoia at 25m altitude (about 6m from the top). Unfiltered Piston #2 In the black smoke after breaking off about an inch of this chimney. Stop 04:12. Tmax=274.6 Tavg=261 vol=603 T2=63.	16.96116	144.86699	3261	219	NE Sequoia 25m up	Butterfield
S42-HFS-16	2016-12-09	04:15:13	S42-HFS-16 Start or:15 Filtered Piston #5. Stop 04:21. Tmax=209.9 Tavg=163 vol=640 T2=30.Same location as HFS-15 and looks like tip has not moved.	16.96115	144.86699	3261	219	NE Sequoia 25m up	Butterfield
S42-HFS-17	2016-12-09	04:38:56	S42-HFS-17 Start 04:38 Unfiltered Piston #8 Stop 04:42. Tmax=271.5 Tavg=256.9 vol=650 T2=63.Same exact location with slight movement to get the hottest water.	16.96115	144.86700	3261	219	NE Sequoia 25m up	Butterfield
S42-HFS-18	2016-12-09	04:45:29	S42-HFS-18. Start 04:45 Unfiltered Piston #6 Stop 04:50. Tmax=338.4 Tavg=332 vol=790 T2=78.Same exact location with a bit higher temperature.	16.96115	144.86700	3261	218	NE Sequoia 25m up	Butterfield
S42-HFS-19	2016-12-09	04:51:49	S42-HFS-19 Start 04:51. Unfiltered Piston #4. Stop 04:56. Tmax=345.9 Tavg=343 vol=650 T2=79.Same exact location.	16.96115	144.86700	3261	218	NE Sequoia 25m up	Butterfield
S42-Geo-20	2016-12-09	05:05:05	S42-Geo-20 Chimney from Sequoia that was knocked down when trying to get the other chimney that fell on top of the biobox. ROV in same location as the previous HFS samples.	16.96115	144.86701	3261	218	NE Sequoia 25m up	Berkenbosch

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S42-GTB-21	2016-12-09	05:58:59	S42-GTB-21 Fired when saw deflection in the black smoke. Tip moved when the ram was fired (moved away from orifice when it was fired). Same orifice as sampled with HFS. Yellow-Green #12.	16.96116	144.86696	3261	134	NE Sequoia 25m up	Lupton
S42-Geo-22	2016-12-09	06:42:19	S42-Geo-22 Piece of sulfide from base of Sequoia. Going in aft-stbd large biobox.	16.96123	144.86706	3279	198	Sequoia base	Berkenbosch
S42-Geo-23	2016-12-09	07:35:05	S43-Geo-23 Blue-colored chimlet from wild-looking chimney upon arriving at Waypoint #8. Top of chimney was venting. Maybe animals on the chimney.	16.96117	144.87088	3282	112	Chimney at WP-08	Berkenbosch
Dive S43 - Hafa Adai									
S43-Geo-01	2016-12-09	23:21:10	S43-Geo-01 Piece of lava from a collapse feature taken from outside of the cone near waypoint 10. Placed in aft-port quarter of biobox.	16.96820	144.86493	3280	152	West of Breached Cone	Chadwick
S43-Geo-02	2016-12-10	01:01:40	S43-Geo-02 Piece of old altered chimney due S of the cone. South of WP 14. In sheet flows.	16.96533	144.86710	3285	183	South of Breached Cone	Berkenbosch
S43-HFS-03	2016-12-10	02:04:28	S43-HFS-03 Start 02:04 Unfiltered Bag #16 Stop 02:21. Tmax=13.3 Tavg=9.6 vol=559 T2=4. Not a good sample. Base of Alba Vent in a crack where the shimmering water is coming over. Can see some exhaust.	16.96126	144.86782	3277	101	Alba Vent	Butterfield
S43-HFS-04	2016-12-10	02:45:29	S43-HFS-04 Start 02:45. Filtered Piston #1. Stop 02:51. Tmax=209 Tavg=166 vol=650 T2=10. Seeing some flow in the exhaust but not strong. Vent that was excavated slightly.	16.96127	144.86786	3277	88	Alba Vent	Butterfield

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S43-HFS-05	2016-12-10	02:53:33	S43-HFS-05 Start 02:53 Unfiltered Piston #2. Stop 03:02. Tmax=219 Tavg=193 vol=625 T2=50.Same location as HFS-04 on the lower part of Alba Vent. Running the flush pump on this one. Can see some exhaust flow.	16.96127	144.86787	3277	87	Alba Vent	Butterfield
S43-HFS-06	2016-12-10	03:04:55	S43-HFS-06 Start 03:04 Filtered Piston #3 Stop 03:13. Tmax=238.6 Tavg=120 vol=800 T2=50.Same exact location as the last two samples.	16.96125	144.86787	3277	86	Alba Vent	Butterfield
S43-GTB-07	2016-12-10	04:01:47	S43-GTB-07 Fired. White #17. In the black smoke in the smoker in the back of the small chimney in front. When fired saw the wand go further in the orifice. Same hole as the HFS samples here but at a slightly different angle.	16.96124	144.86785	3278	89	Alba Vent	Lupton
S43-HFS-09	2016-12-10	04:30:50	S43-HFS-09 Start 04:30 LVB #24. Stop 04:53. Tmax=16.3 Tavg=14.7 vol=3200ml T2=8.In diffuse flow just below the black smokers sampled near the base of Alba Vent. See exhaust.	16.96131	144.86782	3277	99	Alba Vent	Huber
S43-HFS-10	2016-12-10	04:54:59	S43-HFS-10 Start 04:54 RNA Filter #10 Stop. Tmax=16.4 Tavg=14.1 vol=3002 T2=8. Same location as LVB HFS-09.	16.96122	144.86785	3277	96	Alba Vent	Huber
S43-HFS-11	2016-12-10	05:24:49	S43-HFS-11 Start 05:24 Unfiltered Bag #22 Stop 05:27. Tmax=16.7 Tavg=16 vol=401 T2=8At the same site as the LVB sample on Alba Vent.	16.96126	144.86786	3277	93	Alba Vent	Butterfield

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S43-HFS-12	2016-12-10	05:28:12	S43-HFS-12 Start 05:28 Filtered Bag #21. Stop 05:30. Tmax=16.6 Tavg=15.5 T2=9 vol=403 Same exact location as HFS-13 and LVB.	16.96126	144.86785	3277	94	Alba Vent	Butterfield
S43-HFS-13	2016-12-10	05:31:41	S43-HFS-13 Start 05:31 Unfiltered Bag #20 Stop 05:34. Tmax=16.1 Tavg=15.4 T2=8.5 vol=401ml/l. Same exact location as LVB and previous HFS sample.	16.96126	144.86785	3277	93	Alba Vent	Butterfield
S43-Bio-14	2016-12-10	06:19:04	S43-Bio-14 SPME #4 Puck squeezing in the diffuse flow of the LVB sample at Alba Vent. Stopped 06:32.	16.96126	144.86787	3277	64	Alba Vent	Tunnicliffe
Dive S44 - Hafa Adai									
S44-Geo-01	2016-12-11	01:36:14	S44-Geo-01 Big lava rock taken south of waypoint #9 upon arriving on the seafloor at Hafa Adai. Looks like about 20m due south of waypoint. Older lavas with some sulfides.	16.96076	144.87231	3284	94	south of Mami Wata	Chadwick
S44-HFS-02	2016-12-11	02:11:21	S44-HFS-02 Start 02:11. Stop 02:19 Unfiltered Piston #2 with good exhaust. Stop Tmax=13.3 Tavg=7.6 vol=393 ml T2=5. Near Waypoint #9 20m Mami wata Vent (Water goddess)	16.96084	144.87199	3285	137	Mami Wata	Butterfield
S44-HFS-03	2016-12-11	03:54:38	S44-HFS-03 Filtered Piston #1. Stop. Tmax=331.8 Tavg=327.5 vol=260 T2=66 Right in the black smoke at the top of Two Towers. Great location. Can see exhaust.	16.96131	144.86653	3269	349	Two Towers	Butterfield

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S44-HFS-04	2016-12-11	04:05:17	S44-HFS-04 Unfiltered Piston #3 Stop Tmax=342.3 Tavg=333.5 vol=520 T2=65 At the top of Two Towers same chimlet at the first sample.	16.96131	144.86653	3269	347	Two Towers	Butterfield
S44-HFS-05	2016-12-11	04:10:10	S44-HFS-05 Temp is stable at 345ish. Stop. Tmax=348. Tavg=346.7 vol=601 T2=74. Still at the same chimlet with great placement.	16.96131	144.86653	3269	343	Two Towers	Butterfield
S44-GTB-06	2016-12-11	04:23:40	S44-GTB-06 Fired and saw it suck up in perfect position. In the same chimlet as the HFS samples. Good deflection of the flow.	16.96131	144.86653	3269	335	Two Towers	Lupton
S44-Geo-07	2016-12-11	04:37:01	S44-Geo-07 From the chimlet that the water & gas samples were taken. Tiny piece in the jaw. Put in the STBD-aft biobox. Some pieces on the sled.	16.96131	144.86653	3269	322	Two Towers	Berkenbosch
S44-Geo-08	2016-12-11	05:11:46	S44-Geo-08 Sample of sulfide just outside the cone on the west wall. Material is definitely not basalt as it crumbles easily. In the port-front biobox in the stbd-forward quarter.	16.96146	144.86867	3284	118	Outside Voodoo Crater	Berkenbosch
S44-HFS-09	2016-12-11	05:41:58	S44-HFS-09 Start 05:41. Unfiltered Piston #5 at recorder #6 inside the array at Voodoo. Stop. Tmax=32.3 Tavg=30.0 vol=486 T2=12. Not seeing good flow on this one in the exhaust.	16.96175	144.86924	3278	85	Hula array	Butterfield
S44-HFS-10	2016-12-11	05:45:23	S44-HFS-10 Start 05:45. Unfiltered Piston #6 Stop. Tmax=32.5 Tavg=23.5 vol=700 T2=10. Same exact location. Not seeing exhaust again.	16.96174	144.86924	3278	85	Hula array	Butterfield

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S44-HFS-11	2016-12-11	05:52:35	S44-HFS-11 Start 05:52. Filtered Bag #19. Stop. Tmax=31.2 Tavg=27 vol=450 T2=11 Getting good exhaust.	16.96176	144.86920	3278	85	Hula array	Butterfield
S44-HFS-12	2016-12-11	05:57:49	S44-HFS-12 LVB #24 Stop. Tmax=35 Tavg=29.7 vol=3402 T2=12. Near recorder 6 in the Hula array at the same location as the last samples.	16.96176	144.86919	3278	85	Hula array	Huber
S44-HFS-13	2016-12-11	06:22:21	S44-HFS-13 DNA Filter #10 Same location as LVB and previous water samples in the Hula array. Stop. Tmax=37.4 Tavg=30.9 vol=3002 T2=11.	16.96176	144.86921	3278	86	Hula array	Huber
S44-HFS-14	2016-12-11	06:49:00	S44-HFS-14 Start 06:49 Filtered Bag #16 Stop Tmax=37.7 Tavg=34.9 vol=451 T2=12.5 At the same exact location in the Hula array.	16.96174	144.86920	3278	86	Hula array	Butterfield
S44-Bio-15	2016-12-11	07:30:43	S44-Bio-15 in the Hula array at the low-T HFS sample site within the array. Hula array just lifted away. Going into jar #7.	16.96175	144.86919	3278	85	Hula array	Tunnicliffe
S44-Bio-16	2016-12-11	07:35:58	S44-Bio-16 Start suction of snails. This is the 30degC HFS sample site within the array. Put into jar #6.	16.96174	144.86921	3278	83	Hula array	Tunnicliffe
S44-HFS-17	2016-12-11	07:48:17	S44-HFS-17 Start 07:48. Unfiltered Piston #8. Stop. Tmax=91.7 Tavg=86.6 vol=596 In the maximum heat area under the hula array after the array was lifted.	16.96176	144.86919	3278	81	Hula array	Butterfield
S44-HFS-18	2016-12-11	07:55:45	S44-HFS-18 Start 07:55 Unfiltered Piston #7. Stop. Tmax=107 Tavg=87 vol=537 Same place in the high-T flow.	16.96175	144.86920	3278	79	Hula array	Butterfield

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S44-HFS-19	2016-12-11	08:00:10	S44-HFS-19 Start 08:00 .Filtered bag #17. Stop. Tmax=95.1 Tavg=54.8 vol=400 T2=20bGood exhaust. Same location.	16.96174	144.86920	3278	79	Hula array	Butterfield
S44-HFS-20			background SW end of dive 2000-1900m					Background water	Butterfield
Dive S45 - New Lava									
S45-Geo-01	2016-12-12	01:36:31	S45-Geo-01 Piece of new lava about 10m west of waypoint #1 in the new lava flow. Port-forward quarter of forward milk crate.	15.43023	144.50347	4045	292	10m W of WP-01	Chadwick
S45-Geo-02	2016-12-12	02:02:52	S45-Geo-02 Lava toe from the base of a pillow. Taken near the base of the scarp south of waypoint #1. Port box in bin #7.	15.42966	144.50392	4112	310	60m S of WP-01	Chadwick
S45-Geo-03	2016-12-12	02:49:21	S45-Geo-03 Piece of crust from the pillow taken going up the slope toward waypoint #3. Taken with stbd arm. In compartment #1 of the stbd-milk crate.	15.42663	144.50501	4107	188	between WP-02 & WP-03	Chadwick
S45-Geo-04	2016-12-12	03:50:03	S45-Geo-04 Lava sample from a claw-like finger taken near waypoint #5 on a hill. Going in the port forward crate and piece went into compartment #10. Looks like a toe. Remaining pieces into bin #9.	15.42443	144.50331	4099	40	near WP-05	Chadwick
S45-Geo-05	2016-12-12	04:08:54	S45-Geo-05 Piece from the top crust of an older pillow. Taken at the contact between the new flow and older flow about 10m SW of waypoint #6.	15.42426	144.50275	4140	319	10m SW of WP-06	Chadwick

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S45-Geo-06	2016-12-12	04:54:32	S45-Geo-06 Grabbed a triangular piece of older pillow crust due west of Waypoint #7 (navigation jumps). Sample went into bin #3 in the STBD milk crate.	15.4218	144.50415	4063	112	125m W of WP-07	Chadwick
Dive S47 - Perseverance									
S47-HFS-01	2016-12-16	07:39:11	S47-HFS-01 Start Unfiltered Bag #16. Stop 07:41. Tmax=43.2 Tavg=37.9 vol=403 T2=15 Believe we are close to waypoint 7 but big bathy offset and will have to determine this later.	15.4799	144.50763	3913	11	Leaning Tower	Butterfield
S47-HFS-02	2016-12-16	07:43:19	S47-HFS-02 Start. Filtered Piston #1 Not good exhaust. Start/stop pump. Stop 07:45. Tmax=40.0 Tavg=22.8 vol=350 T2=10 Not a good sample. Same exact location as HFS-01	15.4799	144.50763	3913	11	Leaning Tower	Butterfield
S47-HFS-03	2016-12-16	07:50:23	S47-HFS-03. Start 07:50 Unfiltered Piston #2. Not seeing exhaust. Stop 07:52. Tmax=33.7 Tavg=31.1 vol=250 T2=11 Not good sample.	15.4799	144.50763	3913	11	Leaning Tower	Butterfield
S47-HFS-04	2016-12-16	07:53:25	S47-HFS-04 Start 07:53 Filtered Bag #17 Stop 08:02. Tmax= 26.5, ave= 23.2, vol= 414, T2= 9 Good flow.	15.4799	144.50763	3913	11	Leaning Tower	Butterfield
S47-HFS-05	2016-12-16	08:07:32	S47-HFS-05 Start 08:07. LVB #24. Stop 08:30. Tmax= 40.8, ave 33.7, vol= 3400, T2= 15	15.4799	144.50763	3913	10	Leaning Tower	Huber
S47-HFS-06	2016-12-16	08:32:01	S47-HFS-06 Start 08:32 DNA Filter #10. Stop 08:56. Tmax=45.5 Tavg=37.7 vol=2723ml. T2=12 At the same exact location as the previous sample.	15.4799	144.50763	3913	10	Leaning Tower	Huber

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S47-Bio-07	2016-12-16	09:08:32	S47-Bio-07 Suction of snails (got a few shrimp as well). At the same site as the HFS samples. Into Jar #7.	15.4799	144.50763	3913	12	Leaning Tower	Tunnicliffe
S47-Geo-08	2016-12-16	09:14:33	S47-geo-08 Rock from where all the other samples were just taken. Near the snails. There were shrimp on the rock and eggs (the shrimp left). In forward-stbd quarter of the stbd biobox.	15.4799	144.50763	3913	13	Leaning Tower	Tunnicliffe
S47-GTB-09	2016-12-16	10:57:13	S47-GTB-09 Fired. Probe was down the hole at Stump of Mystery. Red Gastight #9. Taken from the top of the chimney in a hole that was excavated. High temp after all HFS samples was 265.7degC.	15.4802	144.50772	3907	313	Stump of Mystery	Lupton
S47-HFS-10	2016-12-16	11:12:16	S47-HFS-10 Start 11:12. Unfiltered Piston #8. Stop 11:16. Tmax=221.8 Tavg=218 vol=629 T2=57. Can see exhaust. Good one.	15.4802	144.50772	3907	313	Stump of Mystery	Butterfield
S47-HFS-11	2016-12-16	11:17:11	S47-HFS-11 Start 11:17. Filtered Piston #7. Stop 11:21. Tmax=224.3 Tavg=217 vol=700 T2=55. Can see exhaust. Same exact location as HFS-10 at Stump of Mystery.	15.4802	144.50772	3907	313	Stump of Mystery	Butterfield
S47-HFS-12	2016-12-16	11:22:15	S47-HFS-12 Start 11:22. Unfiltered Piston #6 at same exact location on Stump of Mystery. Stop 11:26. Tmax=240.9 Tavg=233.4 vol=677 T2=58.	15.4802	144.50772	3907	313	Stump of Mystery	Butterfield
S47-Geo-13	2016-12-16	11:49:03	S47-Geo-13 Sample of chimneys at the top of the chimney including the one sampled for water and gas.	15.4802	144.50772	3906	313	Stump of Mystery	Berkenbosch

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S47-Bio-14	2016-12-16	12:04:53	S47-Bio-14 Suction of sulfide worms from top of the chimney where the other samples came from. Into Jar #4.	15.4802	144.50772	3906	313	Stump of Mystery	Tunnicliffe
S47-HFS-15	2016-12-16	12:23:50	S47-HFS-15. Unfiltered Bag #18. Start 12:25. Stop 12:27. Tmax= 16.4, ave= 15.3, vol= 403, T2= 6.5 In clump of snails on Stump of Mystery where sensor reading #3 taken.	15.4802	144.50772	3909	318	Stump of Mystery	Butterfield
S47-HFS-16	2016-12-16	12:42:20	S47-HFS-16. Filtered bag #19. Stop 12:44. Tmax= 73.3, ave= 69.6, vol= 400, T2= 19. Same location as reading #5.	15.4802	144.50772	3909	321	Stump of Mystery	Butterfield
S47-Bio-17	2016-12-16	12:56:01	S47-Bio-17 Suctioning snails(some shrimp as well) into Jar #6 at Stump of Mystery. Same location as sensor reading #3 and S47-HFS-15.	15.4802	144.50772	3909	323	Stump of Mystery	Tunnicliffe
S47-Bio-18	2016-12-16	12:58:31	S47-Bio-18 Suctioning sulfide worms (and some snails) at the same location as reading #4. Into Jar #5.	15.4802	144.50772	3909	323	Stump of Mystery	Tunnicliffe
S47-Geo-19	2016-12-16	13:06:12	S47-Geo-19 Orange piece of Stump of Mystery. Hoping there is some animals on it. Into rear port bio box, rear stbd partition.	15.4802	144.50772	3909	324	Stump of Mystery	Tunnicliffe
S47-Bio-20	2016-12-16	13:10:00	S47-Bio-20 SPME #1. Solid phase extractor puck: control sample held for 10 min on ascent.	15.4802	144.50772	3909	326	Stump of Mystery	Tunnicliffe
Dive S48 - Perseverance									
S48-Geo-01	2016-12-16	22:38:49	S48-Geo-01 Bud of pillow lava near the bottom of the slope of the pillow mound after turning north from Palisades. Sampling was difficult due to the crumbly nature of these pillows.	15.48000	144.50789	3909	28	Pillow mound north of Perseverance	Chadwick

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
Dive S49 - Perseverance									
S49-HFS-01	2016-12-18	00:29:30	S49-HFS-01. Start 00:29 RNA Filter #11 Background water sample after almost reaching the bottom and dive being canceled. Sample ended on its own while ascending 02:55. 27 minutes to fill. Tmax=1.2 Tavg=1.1 vol=3001.	15.48008	144.50735	3664	53	Background water	Huber
S49-HFS-02	2016-12-18	01:09:25	S49-HFS-02 Unfiltered Bag #16. Another background water sample while ascending. Stop 01:11. Tmax=1.3 Tavg=1.2 vol=401 ml	15.47946	144.50697	2558	263	Background water	Butterfield
S49-HFS-03	2016-12-18	01:12:59	S49-HFS-03 01:12 Background water sample. pH values seem to be low today and probably need to recalibrate. pH=7.15 in the deep water (had been 7.5).	15.47946	144.50697	2433	262	Background water	Butterfield
S49-GTB-04	2016-12-18	03:08:55	S49-GTB-04 Fired. ~03:06 Fired when chimney broke/ram bent. This was fired before the view of the bent ram. Saw the tip go into the chimney (not further into the hold) when fired. Questions raised if it actually fired so not logged at the time as a sample.	15.4802	144.50772	3907	317	Stump of Mystery	Lupton
S49-Bio-05	2016-12-18	03:42:35	S49-Bio-05 Suctioning into Jar #2 from the cracks in the seafloor near the base of Leaning Tower. White cracks with floc coming out but aiming for sediment. Limpets and scaleworm.	15.4799	144.50754	3914	137	Limpet Canyon	Tunnicliffe
S49-Bio-06	2016-12-18	03:49:01	S49-Bio-06 Suction along the surface of the orange rock next to the white crack sampled on bio-05. Into Jar #3.	15.4799	144.50754	3914	139	Limpet Canyon	Tunnicliffe

Sample	Date	time	Observation	Latitude	Longitude	Depth	Heading	Location	PI
S49-HFS-07	2016-12-18	04:19:38	S49-HFS-07 Start 04:19 Unfiltered Bag #18 Stop 04:22 Tmax=20.8 Tavg=19.0 vol=400 T2=8.8 Taken from diffuse flow with limpets and shrimp near the base of Leaning Tower in crack with shimmer.	15.4799	144.50754	3913	41	Limpet Canyon	Butterfield
S49-HFS-08	2016-12-18	04:22:44	S49-HFS-08 Start 04:22 Unfiltered Bag #18 Stop 04:25 Tmax=21.0 Tavg=19.0 vol=400 T2=9 At the same location as last sample at Limpet's Canyon.	15.4799	144.50754	3913	41	Limpet Canyon	Butterfield
S49-HFS-09	2016-12-18	04:26:04	S49-HFS-09 Start 04:26 LVB #24 At same location. No flow/bad sample-aborted.	15.4799	144.50754	3913	41	Limpet Canyon	Huber
S49-HFS-10	2016-12-18	04:30:38	S49-HFS-10. RNA filter #10. Same location as previous sample. Stop 04:56 Tmax=21 Tavg=17.7 T2=8 vol=2997 ml. Seeing flow this time.	15.4799	144.50754	3913	41	Limpet Canyon	Huber
S49-HFS-11	2016-12-18	04:57:45	S49-HFS-11 Start Unfiltered Bag #20 Stop 05:00 Tmax=19.3 Tavg=18.3 T2=8.7 vol=420 ml. At the same location at Limpet Canyon after the RNA filter.	15.4799	144.50754	3913	44	Limpet Canyon	Huber
S49-HFS-12	2016-12-18	05:18:24	S49-HFS-12 Start 05:18 Filtered Piston #3 Taken at the top of Stump of Mystery but not in the hottest water. Not working Aborted.	15.4802	144.50772	3906	346	Stump of Mystery	Butterfield
S49-HFS-13	2016-12-18	05:19:50	S49-HFS-13 Start 05:19. Unfiltered Piston #4. Stop 05:22 Tmax=44.7 Tavg=38.3 vol=500 T2=15. Can see exhaust. Good example at the top but not hottest water at Stump.	15.4802	144.50772	3906	346	Stump of Mystery	Butterfield

Table 6.5-2 Sample images

Sample	Image	Dive Site	Location	PI
Dive S34 - Daikoku				
S34-HFS-01	S5K06541.jpg	Daikoku	10m East of Okeanos Fish Spa	Butterfield
S34-Bio-02	S5K07711.jpg	Daikoku	10m East of Okeanos Fish Spa	Tunnicliffe
S34-Bio-03	S5K08913.jpg	Daikoku	10m East of Okeanos Fish Spa	Tunnicliffe
S34-HFS-04	S5K11725.jpg	Daikoku	10m East of Okeanos Fish Spa	Butterfield
S34-HFS-05	S5K12034.jpg	Daikoku	10m East of Okeanos Fish Spa	Butterfield
S34-HFS-06	S5K12743.jpg	Daikoku	10m East of Okeanos Fish Spa	Huber
S34-Geo-07	S5K14666.jpg	Daikoku	10m East of Okeanos Fish Spa	Berkenbosch
S34-Geo-08	S5K15855.jpg	Daikoku	10m East of Okeanos Fish Spa	Berkenbosch
S34-Bio-11A	S5K17065.jpg	Daikoku	Mkr-132 FK-2016 Fish Spa	Tunnicliffe
S34-Bio-09	S5K17507.jpg	Daikoku	Mkr-132 FK-2016 Fish Spa	Tunnicliffe
S34-Geo-10	S5K20690.jpg	Daikoku	Mkr-132 FK-2016 Fish Spa	Berkenbosch
S34-Bio-11B	S5K22587.jpg	Daikoku	downhill of Mkr-132 (FK-2016 Fish Spa)	Tunnicliffe
S34-Bio-11C	S5K23259.jpg	Daikoku	25m E of waypoint 2 (Sulfur pond)	Tunnicliffe
S34-Geo-12	(no image taken)	Daikoku	Over sulfur pond	Berkenbosch
Dive S35 - Daikoku				
S35-HFS-01	S5K06163.jpg	Daikoku	6m EofN Fish Spa	Butterfield
S35-HFS-02	S5K06623.jpg	Daikoku	6m EofN Okeanos Fish Spa	Butterfield
S35-HFS-03	S5K06914.jpg	Daikoku	6m EofN Okeanos Fish Spa	Huber
S35-HFS-04	S5K08131.jpg	Daikoku	6m EofN Okeanos Fish Spa	Butterfield
S35-HFS-05	S5K08537.jpg	Daikoku	6m EofN Okeanos Fish Spa	Butterfield
S35-HFS-06	S5K09523.jpg	Daikoku	6m EofN Okeanos Fish Spa	Butterfield
S35-HFS-07	S5K14009.jpg	Daikoku	Mkr-133	Butterfield
S35-HFS-08	S5K14260.jpg	Daikoku	Mkr-133	Butterfield
S35-Bio-09	S5K15549.jpg	Daikoku	Mkr-133	Tunnicliffe

Sample	Image	Dive Site	Location	PI
S35-Bio-10	S5K19574.jpg	Daikoku	20m E/5mN WP2 crater rim inside wall	Tunnicliffe
S35-HFS-11	S5K20381.jpg	Daikoku	20m E/5mN WP2	Butterfield
S35-Bio-12	S5K25423.jpg	Daikoku	Mkr-137	Tunnicliffe
S35-HFS-13	S5K30170.jpg	Daikoku	Okeanos Fish Spa	Butterfield
S35-HFS-14	S5K30427.jpg	Daikoku	Okeanos Fish Spa	Butterfield
S35-HFS-15	S5K30748.jpg	Daikoku	Okeanos Fish Spa	Huber
S35-HFS-16	S5K31794.jpg	Daikoku	Okeanos Fish Spa	Huber
S35-Bio-17	S5K33980.jpg	Daikoku	8m S of Okeanos Fish Spa	Tunnicliffe
S35-Bio-18	S5K35379.jpg	Daikoku	10m SE Okeanos Fish Spa	Tunnicliffe

Dive S36 - Chamorro

S36-Geo-01	2016-12-04T00_30_18.839543_S5K.jpg	Chamorro	Waypoint 1	Berkenbosch
S36-HFS-02	S5K02434.jpg	Chamorro	Waypoint 1	Butterfield
S36-HFS-03	2016-12-04T00_47_42.852709_S5K.jpg	Chamorro	Waypoint 1	Butterfield
S36-HFS-04	S5K02791.jpg	Chamorro	Waypoint 1	Butterfield
S36-HFS-05	2016-12-04T00_53_19.842745_S5K.jpg	Chamorro	Waypoint 1	Butterfield

Dive S37 - Illium

S37-Geo-01	2016-12-05T01_10_19.200984_S5K.jpg	Illium	Old Chimney	Berkenbosch
S37-HFS-02	S5K21119.jpg	Illium	Snail Pile Mkr-138	Butterfield
S37-HFS-03	2016-12-05T02_19_20.244787_S5K.jpg	Illium	Snail Pile Mkr-138	Butterfield
S37-HFS-04	2016-12-05T02_30_45.270230_S5K.jpg	Illium	Snail Pile Mkr-138	Butterfield
S37-HFS-05	2016-12-05T02_34_48.254938_S5K.jpg	Illium	Snail Pile Mkr-138	Butterfield
S37-HFS-06	2016-12-05T02_39_14.254246_S5K.jpg	Illium	Snail Pile Mkr-138	Huber
S37-HFS-07	2016-12-05T03_06_52.282143_S5K.jpg	Illium	Snail Pile Mkr-138	Butterfield
S37-HFS-08	2016-12-05T03_14_28.303870_S5K.jpg	Illium	Snail Pile Mkr-138	Huber
S37-HFS-09	2016-12-05T03_29_04.318531_S5K.jpg	Illium	Snail Pile Mkr-138	Butterfield
S37-Bio-10	S5K27093.jpg	Illium	Snail Pile Mkr-138	Tunnicliffe
S37-HFS-11	2016-12-05T03_58_05.329973_S5K.jpg	Illium	Snail Pile Mkr-138	Butterfield

Sample	Image	Dive Site	Location	PI
S37-HFS-12	S5K27521.jpg	Illium	Snail Pile Mkr-138	Butterfield
S37-Bio-13	2016-12-05T04_03_57.321675_S5K.jpg	Illium	Snail Pile Mkr-138	Tunnicliffe
S37-Bio-14	2016-12-05T04_08_10.344472_S5K.jpg	Illium	Snail Pile Mkr-138	Tunnicliffe
S37-HFS-15	2016-12-05T04_12_14.358400_S5K.jpg	Illium	Snail Pile Mkr-138	Butterfield

Dive S39 - Alice Springs

S39-HFS-01	1480995610562S5K14955.jpg	Alice Springs	Diffuse site 22m NE of old Alice Springs	Butterfield
S39-HFS-02	S5K17643.jpg	Alice Springs	Mkr-131 Snail-001 Site	Butterfield
S39-HFS-03	S5K17974.jpg	Alice Springs	Mkr-131 Snail-001 Site	Butterfield
S39-HFS-04	2016-12-06T04_39_59.192988_S5K.jpg	Alice Springs	Mkr-131 Snail-001 Site	Butterfield
S39-HFS-05	2016-12-06T04_39_59.192988_S5K.jpg	Alice Springs	Mkr-131 Snail-001 Site	Butterfield
S39-GTB-06	2016-12-06T05_14_07.230523_S5K.jpg	Alice Springs	Mkr-131 Snail-001 Site	Lupton
S39-HFS-07	2016-12-06T06_11_19.280853_S5K.jpg	Alice Springs	Mkr-131 Snail-001 Site	Huber
S39-HFS-08	S5K25603.jpg	Alice Springs	Mkr-131 Snail-001 Site	Butterfield
S39-HFS-09	S5K25956.jpg	Alice Springs	Mkr-131 Snail-001 Site	Butterfield
S39-HFS-10	S5K26301.jpg	Alice Springs	Mkr-131 Snail-001 Site	Huber
S39-Geo-11	2016-12-06T07_24_20.338705_S5K.jpg	Alice Springs	Mkr-131 Snail-001 Site	Tunnicliffe
S39-Bio-12	2016-12-06T07_27_44.339526_S5K.jpg	Alice Springs	Mkr-131 Snail-001 Site	Tunnicliffe
S39-Bio-13	S5K29127.jpg	Alice Springs	Mkr-131 Snail-001 Site	Tunnicliffe
S39-Bio-14	2016-12-06T07_52_10.330046_S5K.jpg	Alice Springs	Mkr-131 Snail-001 Site	Tunnicliffe
S39-Bio-15	S5K34511.jpg	Alice Springs	Little Anemones	Tunnicliffe
S39-HFS-16	none taken	background	900m background	Butterfield

Dive S40 - Burke

S40-Bio-01	2016-12-07T01_41_53.934807_S5K.jpg	Burke	Snail Pit Mkr-234	Tunnicliffe
S40-Bio-02	1481075410362S5K17273.jpg	Burke	Snail Pit Mkr-234	Tunnicliffe
S40-Bio-03	2016-12-07T01_59_51.943283_S5K.jpg	Burke	Snail Pit Mkr-234	Tunnicliffe
S40-Geo-04	2016-12-07T02_07_57.922797_S5K.jpg	Burke	Snail Pit Mkr-234	Tunnicliffe
S40-HFS-05	2016-12-07T02_38_57.931242_S5K.jpg	Burke	Snail Pit Mkr-234	Butterfield

Sample	Image	Dive Site	Location	PI
S40-HFS-06	2016-12-07T02_43_08.912108_S5K.jpg	Burke	Snail Pit Mkr-234	Butterfield
S40-HFS-07	2016-12-07T02_49_21.919110_S5K.jpg	Burke	Snail Pit Mkr-234	Butterfield
S40-HFS-08	2016-12-07T02_53_04.947180_S5K.jpg	Burke	Snail Pit Mkr-234	Butterfield
S40-HFS-09	2016-12-07T02_59_35.922594_S5K.jpg	Burke	Snail Pit Mkr-234	Huber
S40-HFS-10	1481081051099S5K22914.jpg	Burke	Snail Pit Mkr-234	Huber
S40-HFS-11	1481082855176S5K24718.jpg	Burke	Snail Pit Mkr-234	Butterfield
S40-Bio-12	2016-12-07T04_05_48.960604_S5K.jpg	Burke	Snail Pit Mkr-234	Bates
S40-Bio-13	1481083688449S5K25551.jpg	Burke	Snail Pit Mkr-234	Bates
S40-HFS-14	1481084807132S5K26670.jpg	Burke	Milky Flow	Butterfield
S40-HFS-15	2016-12-07T04_30_04.953892_S5K.jpg	Burke	Milky Flow	Butterfield

Dive S41 - Hafa Adai

S41-Geo-01	S5K11893.jpg	Hafa Adai	Two Towers	Berkenbosch
S41-GTB-02	2016-12-08T02_19_58.526742_S5K.jpg	Hafa Adai	Sequoia	Lupton
S41-Bio-03	2016-12-08T02_34_28.587850_S5K.jpg	Hafa Adai	Sequoia	Tunnicliffe
S41-Bio-04	S5K22839.jpg	Hafa Adai	Sequoia	Tunnicliffe
S41-Bio-05	2016-12-08T03_01_24.593236_S5K.jpg	Hafa Adai	Sequoia	Tunnicliffe
S41-HFS-06	2016-12-08T03_28_37.604368_S5K.jpg	Hafa Adai	Sequoia	Butterfield
S41-HFS-07	2016-12-08T03_34_43.611372_S5K.jpg	Hafa Adai	Sequoia	Butterfield
S41-Geo-08	S5K26093.jpg	Hafa Adai	Sequoia	Berkenbosch
S41-Geo-09	S5K27140.jpg	Hafa Adai	Sequoia	Berkenbosch
S41-Bio-10	2016-12-08T07_16_20.703918_S5K.jpg	Hafa Adai	Waypoint 7	Tunnicliffe
S41-Geo-11	2016-12-08T07_21_54.706742_S5K.jpg	Hafa Adai	Waypoint 7	Berkenbosch

Dive S42 - Hafa Adai

S42-HFS-01	2016-12-08T23_40_32.762757_S5K.jpg	Hafa Adai	Hula array	Butterfield
S42-HFS-02	2016-12-08T23_44_17.786454_S5K.jpg	Hafa Adai	Hula array	Butterfield
S42-HFS-03	2016-12-09T00_19_06.811418_S5K.jpg	Hafa Adai	Hula array	Butterfield
S42-HFS-04	1481243066915S5K12519.jpg	Hafa Adai	Hula array	Butterfield

Sample	Image	Dive Site	Location	PI
S42-HFS-05	2016-12-09T00_31_53.811769_S5K.jpg	Hafa Adai	Hula array	Huber
S42-HFS-06	2016-12-09T01_00_01.837003_S5K.jpg	Hafa Adai	Hula array	Huber
S42-HFS-07	2016-12-09T01_36_57.848762_S5K.jpg	Hafa Adai	Hula array	Butterfield
S42-HFS-08	2016-12-09T01_39_51.858412_S5K.jpg	Hafa Adai	Hula array	Butterfield
S42-Bio-09	2016-12-09T02_18_00.887841_S5K.jpg	Hafa Adai	Snail Graveyard	Tunnicliffe
S42-Bio-10	2016-12-09T02_40_25.910729_S5K.jpg	Hafa Adai	Snail Graveyard	Tunnicliffe
S42-Bio-11	1481251347111S5K20799.jpg	Hafa Adai	Snail Graveyard	Tunnicliffe
S42-Geo-12	1481252040103S5K21492.jpg	Hafa Adai	Rim above graveyard	Tunnicliffe
S42-Geo-13	2016-12-09T03_17_20.937736_S5K.jpg	Hafa Adai	outside wall NE Voodoo	Berkenbosch
S42-Geo-14	2016-12-09T03_34_29.929175_S5K.jpg	Hafa Adai	sheet flow west of Voodoo	Berkenbosch
S42-HFS-15	1481256577254S5K26029.jpg	Hafa Adai	NE Sequoia 25m up	Butterfield
S42-HFS-16	1481256912244S5K26364.jpg	Hafa Adai	NE Sequoia 25m up	Butterfield
S42-HFS-17	2016-12-09T04_38_55.943271_S5K.jpg	Hafa Adai	NE Sequoia 25m up	Butterfield
S42-HFS-18	2016-12-09T04_45_28.968238_S5K.jpg	Hafa Adai	NE Sequoia 25m up	Butterfield
S42-HFS-19	2016-12-09T04_51_48.948333_S5K.jpg	Hafa Adai	NE Sequoia 25m up	Butterfield
S42-Geo-20	1481259904215S5K29356.jpg	Hafa Adai	NE Sequoia 25m up	Berkenbosch
S42-GTB-21	2016-12-09T05_58_59.019020_S5K.jpg	Hafa Adai	NE Sequoia 25m up	Lupton
S42-Geo-22	2016-12-09T06_42_18.075084_S5K.jpg	Hafa Adai	Sequoia base	Berkenbosch
S42-Geo-23	2016-12-09T07_35_05.105609_S5K.jpg	Hafa Adai	Chimney at WP-08	Berkenbosch

Dive S43 - Hafa Adai

S43-Geo-01	1481325669508S5K10309.jpg	Hafa Adai	West of Breached Cone	Chadwick
S43-Geo-02	S5K16339.jpg	Hafa Adai	South of Breached Cone	Berkenbosch
S43-HFS-03	2016-12-10T02_04_27.562454_S5K.jpg	Hafa Adai	Alba Vent	Butterfield
S43-HFS-04	2016-12-10T02_45_28.568287_S5K.jpg	Hafa Adai	Alba Vent	Butterfield
S43-HFS-05	2016-12-10T02_53_32.546326_S5K.jpg	Hafa Adai	Alba Vent	Butterfield
S43-HFS-06	2016-12-10T03_04_55.559459_S5K.jpg	Hafa Adai	Alba Vent	Butterfield
S43-GTB-07	1481342489809S5K27129.jpg	Hafa Adai	Alba Vent	Lupton

Sample	Image	Dive Site	Location	PI
S43-HFS-09	S5K28889.jpg	Hafa Adai	Alba Vent	Huber
S43-HFS-10	S5K30330.jpg	Hafa Adai	Alba Vent	Huber
S43-HFS-11	2016-12-10T05_24_48.630237_S5K.jpg	Hafa Adai	Alba Vent	Butterfield
S43-HFS-12	2016-12-10T05_28_11.616844_S5K.jpg	Hafa Adai	Alba Vent	Butterfield
S43-HFS-13	2016-12-10T05_31_40.637732_S5K.jpg	Hafa Adai	Alba Vent	Butterfield
S43-Bio-14	2016-12-10T06_17_59.669205_S5K.jpg	Hafa Adai	Alba Vent	Tunnicliffe

Dive S44 - Hafa Adai

S44-Geo-01	2016-12-11T01_36_13.698353_S5K.jpg	Hafa Adai	south of Mami Wata	Chadwick
S44-HFS-02	S5K10187.jpg	Hafa Adai	Mami Wata	Butterfield
S44-HFS-03	1481428477805S5K16487.jpg	Hafa Adai	Two Towers	Butterfield
S44-HFS-04	2016-12-11T04_05_16.786259_S5K.jpg	Hafa Adai	Two Towers	Butterfield
S44-HFS-05	2016-12-11T04_11_14.778411_S5K.jpg	Hafa Adai	Two Towers	Butterfield
S44-GTB-06	2016-12-11T04_23_39.797330_S5K.jpg	Hafa Adai	Two Towers	Lupton
S44-Geo-07	2016-12-11T04_37_00.807459_S5K.jpg	Hafa Adai	Two Towers	Berkenbosch
S44-Geo-08	2016-12-11T05_11_45.849272_S5K.jpg	Hafa Adai	Outside Voodoo Crater	Berkenbosch
S44-HFS-09	1481434917399S5K22926.jpg	Hafa Adai	Hula array	Butterfield
S44-HFS-10	2016-12-11T05_45_21.870903_S5K.jpg	Hafa Adai	Hula array	Butterfield
S44-HFS-11	2016-12-11T05_52_34.878645_S5K.jpg	Hafa Adai	Hula array	Butterfield
S44-HFS-12	1481435869056S5K23878.jpg	Hafa Adai	Hula array	Huber
S44-HFS-13	2016-12-11T06_22_20.903567_S5K.jpg	Hafa Adai	Hula array	Huber
S44-HFS-14	2016-12-11T06_48_59.936849_S5K.jpg	Hafa Adai	Hula array	Butterfield
S44-Bio-15	2016-12-11T07_30_42.949903_S5K.jpg	Hafa Adai	Hula array	Tunnicliffe
S44-Bio-16	1481441758045S5K29767.jpg	Hafa Adai	Hula array	Tunnicliffe
S44-HFS-17	1481442496969S5K30506.jpg	Hafa Adai	Hula array	Butterfield
S44-HFS-18	2016-12-11T07_55_44.962406_S5K.jpg	Hafa Adai	Hula array	Butterfield
S44-HFS-19	1481443209256S5K31218.jpg	Hafa Adai	Hula array	Butterfield
S44-HFS-20	(none taken)		Background water	Butterfield

Sample	Image	Dive Site	Location	PI
Dive S45 - New Lava				
S45-Geo-01	1481506591039S5K10002.jpg	New Lava Flow	10m W of WP-01	Chadwick
S45-Geo-02	2016-12-12T02_02_51.561504_S5K.jpg	New Lava Flow	60m S of WP-01	Chadwick
S45-Geo-03	2016-12-12T02_49_21.581462_S5K.jpg	New Lava Flow	between WP-02 & WP-03	Chadwick
S45-Geo-04	S5K18014.jpg	New Lava Flow	near WP-05	Chadwick
S45-Geo-05	S5K19145.jpg	New Lava Flow	10m SW of WP-06	Chadwick
S45-Geo-06	S5K21883.jpg	New Lava Flow	125m W of WP-07	Chadwick
Dive S47 - Perseverance				
S47-HFS-01	2016-12-16T07_39_10.195319_S5K.jpg	Perseverance	Leaning Tower	Butterfield
S47-HFS-02	2016-12-16T07_43_19.183971_S5K.jpg	Perseverance	Leaning Tower	Butterfield
S47-HFS-03	2016-12-16T07_50_22.212362_S5K.jpg	Perseverance	Leaning Tower	Butterfield
S47-HFS-04	1481874804655S5K17461.jpg	Perseverance	Leaning Tower	Butterfield
S47-HFS-05	2016-12-16T08_07_32.221912_S5K.jpg	Perseverance	Leaning Tower	Huber
S47-HFS-06	2016-12-16T08_32_01.230829_S5K.jpg	Perseverance	Leaning Tower	Huber
S47-Bio-07	1481879311504S5K21968.jpg	Perseverance	Leaning Tower	Tunnicliffe
S47-Geo-08	2016-12-16T09_14_33.286271_S5K.jpg	Perseverance	Leaning Tower	Tunnicliffe
S47-GTB-09	2016-12-16T10_57_12.305104_S5K.jpg	Perseverance	Stump of Mystery	Lupton
S47-HFS-10	1481886735450S5K29392.jpg	Perseverance	Stump of Mystery	Butterfield
S47-HFS-11	1481887030569S5K29687.jpg	Perseverance	Stump of Mystery	Butterfield
S47-HFS-12	1481887335371S5K29992.jpg	Perseverance	Stump of Mystery	Butterfield
S47-Geo-13	2016-12-16T11_49_03.331575_S5K.jpg	Perseverance	Stump of Mystery	Berkenbosch
S47-Bio-14	2016-12-16T12_04_52.368689_S5K.jpg	Perseverance	Stump of Mystery	Tunnicliffe
S47-HFS-15	2016-12-16T12_23_49.381350_S5K.jpg	Perseverance	Stump of Mystery	Butterfield
S47-HFS-16	2016-12-16T12_42_20.406529_S5K.jpg	Perseverance	Stump of Mystery	Butterfield
S47-Bio-17	2016-12-16T12_56_00.382107_S5K.jpg	Perseverance	Stump of Mystery	Tunnicliffe
S47-Bio-18	2016-12-16T12_58_31.406495_S5K.jpg	Perseverance	Stump of Mystery	Tunnicliffe
S47-Geo-19	2016-12-16T13_06_12.409190_S5K.jpg	Perseverance	Stump of Mystery	Tunnicliffe

Sample	Image	Dive Site	Location	PI
S47-Bio-20	1481893799599S5K36456.jpg	Perseverance	Stump of Mystery	Tunnicliffe

Dive S48 - Perseverance

S48-Geo-01	2016-12-16T22_38_06.074122_S5K.jpg	Perseverance	Pillow mound north of Perseverance	Chadwick

Dive S49 - Perseverance

S49-HFS-01	none taken	Perseverance	Background water	Huber
S49-HFS-02	none taken	Perseverance	Background water	Butterfield
S49-HFS-03	none taken	Perseverance	Background water	Butterfield
S49-GTB-04	2016-12-18T03_08_46.571937_S5K.jpg	Perseverance	Stump of Mystery	Lupton
S49-Bio-05	2016-12-18T03_42_34.643035_S5K.jpg	Perseverance	Limpet Canyon	Tunnicliffe
S49-Bio-06	2016-12-18T03_49_00.614695_S5K.jpg	Perseverance	Limpet Canyon	Tunnicliffe
S49-HFS-07	2016-12-18T04_19_37.628871_S5K.jpg	Perseverance	Limpet Canyon	Butterfield
S49-HFS-08	1482034963911S5K24835.jpg	Perseverance	Limpet Canyon	Butterfield
S49-HFS-09	2016-12-18T04_28_30.616671_S5K.jpg	Perseverance	Limpet Canyon	Huber
S49-HFS-10	1482035437819S5K25309.jpg	Perseverance	Limpet Canyon	Huber
S49-HFS-11	2016-12-18T04_57_44.644985_S5K.jpg	Perseverance	Limpet Canyon	Huber
S49-HFS-12	1482038136809S5K28008.jpg	Perseverance	Stump of Mystery	Butterfield
S49-HFS-13	2016-12-18T05_19_49.648406_S5K.jpg	Perseverance	Stump of Mystery	Butterfield

6.6 *SuBastian* Dive logs

This version of the cruise report does not contain the dive logs. The full-version (with logs) can be found at:

https://www.pmel.noaa.gov/eoi/marianas/Falkor-2016-FK161129-report-with-logs.pdf

This shorter version is also available online at:

https://www.pmel.noaa.gov/eoi/marianas/Falkor-2016-FK161129-report-NO-logs.pdf