FK161129 Preliminary 30-day Post Cruise Report

1. Ship name: Falkor

2. Cruise Dates - Day Departed: 11/29/2016

3. Cruise Dates - Day Returned: 12/19/2016

4. Cruise Number (Example: FK160115): FK161129

5. Departure Port: Guam, Apra Harbor

6. Arrival Port: Guam, Apra Harbor

7. Mid-Cruise Port Call (if any): N/A

8. Mid-Cruise Port Call (if any): N/A

9. Participating Organizations, Institutions, Foundations, Government Agencies, etc.: NOAA, Pacific Marine Environmental Lab, University of Washington, Oregon State University, University of Victoria (Canada), Marine Biological Laboratory (Woods Hole), University of Southampton (UK).

10. Funding Sources. List all a) funding agencies, b) award numbers, and c) project titles: NOAA Office of Exploration and Research. Project title: "Exploring the deep Mariana back-arc basin within the US EEZ to link biodiversity, geochemistry and geophysics". $441,141 awarded to PMEL through NOAA-OER-FFO 2016.

National Geographic Society, Committee for Research and Exploration, Project Title: Deep Diversity in the Mariana Backarc: Connecting the Dots. $10,000 awarded to Verena Tunnicliffe, Univ of Victoria.

11. Describe all of the geographical area(s) where the science occurred: The Mariana back-arc between 14.5 and 18.5°N and the Mariana volcanic arc between 19 and 21.5°N.

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13. Cruise Objectives: 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 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) and the Mariana back-arc still has vast areas that have not been systematically explored for hydrothermal activity. Our major objective for this cruise is to determine the geological, chemical, and biological characteristics of newly discovered vent sites along the Mariana back-arc between 14 and 18°N and to use that information to better understand the links between tectonics and biological community structure.

Figure 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?

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. There was 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 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 (not proposed) element 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 backarc.

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.

14. Cruise Summary: Our initial plan and intention for this expedition was to begin diving at the southern back-arc sites closest to Guam, 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 and forecast 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 high-precision 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. Some outreach activities were conducted (verify with Bill's report).

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 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 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. Our sampling success at

Daikoku was poor, but 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. 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 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 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 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 (venting at 3610-3625 m) and Burke (venting at 3630 m) revealed very similar vent sites. There were no active high-temperature smokers 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 soon after launch due to a ground fault eventually traced to the MAPR after first suspecting and testing the HFPS. After troubleshooting, another dive was started, so we lost only about 3 hours due to science user 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. This was a minor problem, but caused a significant delay.

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 mid-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) with active diffuse venting on the northern rim. 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 venting 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 site further south.

After four successful dives at the Hafa Adai field and vicinity, we moved south to dive at the recent 15.4°N lava flow site and to find the elusive vents a few 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 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 vent area and a second CTD cast over WP9 of the 15.4 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 when there was a significant plume and some visible seafloor venting. Following the CTD operations, we conducted multibeam mapping overnight.

On the morning of December 14, local time, we began to launch the ROV at the 15.5 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 the 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 (approximately 8 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 Guam near the port 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, 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 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 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 a very long dive to maximize the bottom time at the Perseverance 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 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, 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. 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 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. The dive 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. 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 nothing to do with 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.

Summary of problems that caused loss of ROV dives

Date	Dive lost	Reason
11/30/2016	1	High winds (>25 knots)
12/1/2016	1	High winds (>25 knots)
12/4/2016	0.75	High winds (>20 knots) S36 at Chamorro
12/6/2016	1	Ground fault in science equipment
12/11/2016	0.5	High winds (>20 knots) S45 at 15.4 Lava Flow
12/12/2016	1	High winds (>25 knots)
12/13/2016	1	Failed winch brake (chopper)
12/14/2016	1	Winch repair, round-trip transit to Guam for part
12/15/2016	1	Main cable failure, 24 hour repair
12/17/2016	0.75	Telemetry failure early in dive
12/18/2016	0.5	High winds (squall delay and early termination)
12/19/2016	1	High winds (>25 knots)

Overall, we made 14 ROV dives with time spent on the bottom, with a total of 84 hours of bottom time. If everything had gone absolutely perfectly, we could have made 20 ROV dives, with approximately 140 hours of bottom time (assuming 12 hour dives with 5 hours of ascent/descent). In terms of ROV time on the seafloor, we achieved approximately 60% of the theoretical maximum for 12-hour dive days.
This rate of success is certainly within the norms for well-established ROV operations. The major cause for the loss of dive time was weather, accounting for more than 5 ROV dives lost. ROV equipment problems (winch/cable/telemetry) resulted in the loss of 3.75 dive days, and science user equipment resulted in the loss of 0.25 dive day.

The ultimate limitation on what can be accomplished with an ROV on the Falkor is the size of the vessel. A larger vessel could accommodate more ROV and science personnel and allow 24-hour ROV operations, which would greatly increase the time spent on the seafloor collecting data and samples. A capable ROV, as Subastian is proving to be, cannot realize its full potential on a vessel the size of Falkor, so large multidisciplinary projects involving many investigators and lab experiments or significant onboard data analysis can't be attempted with Falkor and Subastian. However, much can still be accomplished with a smaller, focused team, as our expedition demonstrated.

The two Marine Technicians had many responsibilities on this expedition, and it was difficult for them to complete their work and still have time to sleep. We recommend adding a third MT for ROV expeditions. This would make it easier to keep up with the flow of ROV data and conduct non-ROV mapping, CTD, or other operations during non-diving hours.

Strong trade winds occur generally from November through March in the Mariana region, with winds of 20-25 knots being relatively common. It was clear from our expedition that the Falkor cannot reliably hold station when winds are above 25 knots, and the operational policy was that ROV diving should not proceed if average wind speeds stay above 20 knots. This is similar to the policy for other science ROVs. When scheduling ROV operations in the Mariana region in the future, the best months are April and May, after the trade winds have weakened and before tropical storms and typhoons begin to develop.

15. Did you collect Measurements or Samples, including biological specimens? Yes

16. Did you deploy and/or recover any Moorings, Bottom Mounted Gear, or Drifting Systems? Yes

17. Equipment Used: Hydrothermal Fluid and Particle Sampler for fluid chemistry and microbiology. Includes in-situ preservation of RNA/DNA on filters, collection of up to 16 fluid samples per dive, collection of large volume (3-4 liter) samples, in-situ sensing of dissolved oxygen (SeaBird optode) and pH (AMT deep-sea sensor), and temperature measurement.
Titanium gas-tight samplers.
Miniature Autonomous Plume Recorders (depth, temperature, light scattering, redox potential) in real-time mode on the ROV, self-recording on the CTD rosette, and deployed at a diffuse hydrothermal vent.
Array of 45 miniature temperature recorders in an array to measure thermal variability and gradients in temperature in a densely populated hydrothermal habitat.
Temperature recorders in bio-morphic housings (‘robo-critters’) to evaluate internal temperatures experienced by vent fauna.
Solid-phase membrane extraction of organic compounds in-situ to identify complex organic compounds in the environment.

18. Will you be submitting Station Plots? Yes

19. Other: N/A

20. Does Schmidt Ocean Institute have your permission to make this Preliminary Cruise Report publicly available on its website or its data partners' websites? Yes