Research Expedition Return to the Lost City 2018

R/V Atlantis AT42-01 with the ROV Jason

September 8 – October 1, 2018

Lost City Hydrothermal Field

30°N Mid-Atlantic Ridge

Supported by NSF Project:

OCE - 1536702 / 1536405 / 1535962 to PIs Lang, Brazelton, Lilley, Kelly, and Früh-Green

With additional support from:

Deep Carbon Observatory funding supported the development of new sampling technologies, including improvements to the Hydrothermal Organic Geochemistry (HOG) sampler (Lang) and the development of the Titan Gas Tight sampler (to Früh-Green)

NASA Astrobiology Institute and C-DEBI provided funds to support personnel costs to Brazelton and Orcutt

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University of Utah

Acknowledgements:

After thirteen years, three hurricanes, and one massive tropical storm, we were able to collect fresh samples and carry out new investigations at the Lost City Hydrothermal Field. We would not have achieved so much science in so little time without the hard work and expertise of Captain Derek Bergeron and the crew of the R/V Atlantis, as well as Jason Expedition Leader Tito Collasius and the entire, highly-skilled Jason group.

Before, during, and after the expedition we were given an incredible amount of support by our shore-based colleagues. Deborah Kelley (Univ Washington) provided critical guidance, insights, and knowledge. Christopher Thornton (Univ Utah) helped to build and maintain the Lost City 2018 website, allowing us to post incredible video and pictures as they came in. Katrina Twing (Univ Utah) established methods used throughout the cruise and provided critical post-cruise support along with Melitza Crespo-Medina (Inter-American Univ Puerto Rico). Bryan Benitez-Nelson and Allen Frye (Univ South Carolina) did the heavy lifting of ensuring that the HOG worked its first time in the water.

We are very grateful to the National Science Foundation for funding the expedition (Biological Oceanography 1536702 / 1536405 / 1535962 to PIs Lang, Brazelton, Lilley, Kelley, Früh-Green). The science party received additional funding support from the Deep Carbon Observatory, C-DEBI, and NASA Astrobiology Institute, which helped to maximize our time by supporting personnel and new instrumentation.

1. Introduction

Mantle rocks comprise significant portions of the seafloor, and microbial communities hosted within them may be important mediators of carbon and energy exchange between the deep Earth and the surface biosphere. Given the abundant metabolic energy potentially available in these ubiquitous mantle rocks, the microbial communities hosted within them may represent a significant proportion of the active subsurface biosphere.

Recent studies have highlighted, however, the lack of alkalithermophiles that are capable of survival at the high pH (9-11) and elevated temperatures found in these systems. The almost complete lack of ΣCO_2 represents a second, and possibly more significant, limitation to growth. To better understand the extent of the serpentinite subsurface, the goal of this project was to address the question: *What limits biological activity in the serpentinite subsurface?* Specifically, our goals were to address the hypotheses: (1) microbial diversity spans a wider range of temperature-pH conditions than currently recognized and (2) the scarcity of ΣCO_2 is a key biological limitation to serpentinization-driven ecosystems that can be overcome by the metabolic activity of one or a few foundation species.

2. Participants

Science Party
Susan Lang, University of South Carolina, Chief Scientist
William Brazelton, University of Utah, Co-Chief Scientist

Osama Alian, Michigan State University, Microbiology
Karmina Aquino, ETH Zurich, Geology and geochemistry
Tamara Baumberger, Oregon State University, Volatile geochemistry
David Butterfield, University of Washington, Aqueous geochemistry
Timothy D'Angelo, Bigelow Laboratory for Ocean Sciences, Microbiology
Anna Davidson, University of California, Davis, Art and Documentation
Mitchell Elend, University of Washington, Photography and data management
Aled Evans, University of Southampton, Geology and geochemistry
Jessica Frankle, University of South Carolina, Geochemistry
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Cameron Henderson, University of South Carolina, Organic geochemistry
Julia McGonigle, University of Utah, Microbiology
Shahrzad Motamedi, University of Utah, Microbiology
Marvin Lilley, University of Washington, Volatile geochemistry
Aaron Mau, University of Washington, Geochemistry
Heather Lizethe Pendleton, University of Utah, Microbiology
Elaina Thomas, Carleton College, Microbiology
Sharon Walker, NOAA/Pacific Marine Environmental Lab, Sensors and CTD Operations
Wee Shu Ying, Texas A&M University, Microbiology

Jason Crew

Tito Collasius, Woods Hole Oceanographic Institution	Expedition Leader
Christopher Judge, Woods Hole Oceanographic Institution	Tech
Christopher Lathan, Woods Hole Oceanographic Institution	Tech
John Webb Pinner, Woods Hole Oceanographic Institution	Tech
James Varnum, Woods Hole Oceanographic Institution	Tech
Scott McCue, Woods Hole Oceanographic Institution	Tech
Hugh Popenoe, Woods Hole Oceanographic Institution	Tech
Andrew Billings, Woods Hole Oceanographic Institution	Tech
Mario Fernandez, Jr., Woods Hole Oceanographic Institution	Tech

Shipboard Support

Catherine Graver, Woods Hole Oceanographic Institution	SSSG
Elizabeth Ricci, UNOLS	SSSG

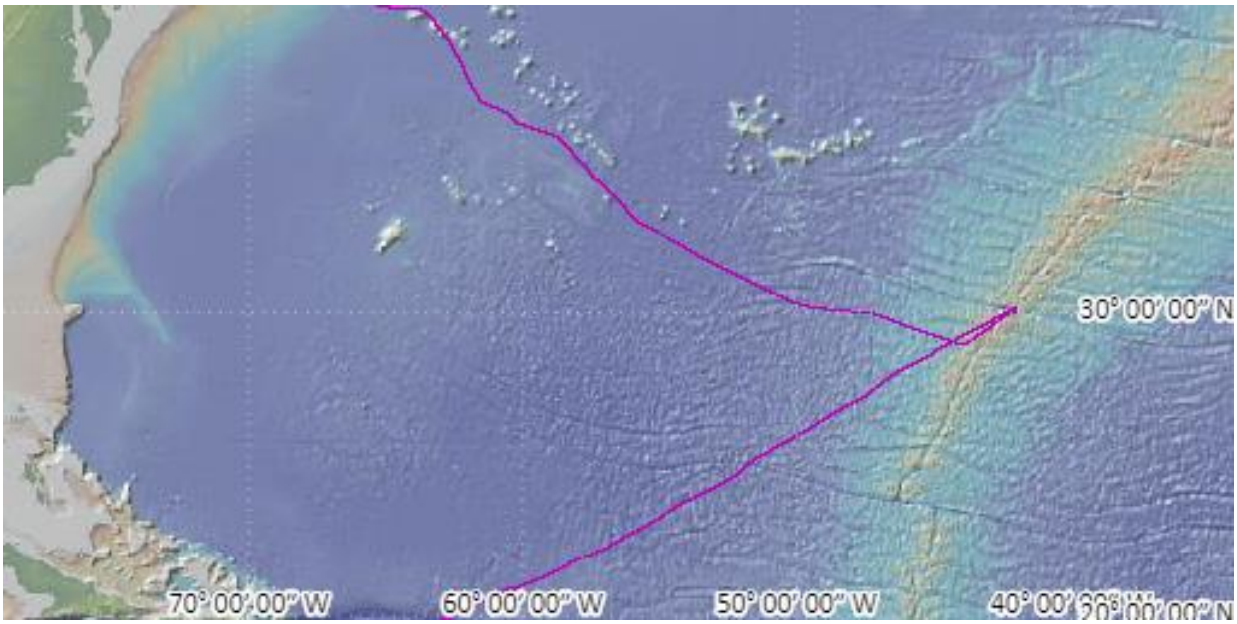
Atlantis Personnel

Derek Bergeron	Master
Jennifer Hickey	Chief Mate
Max Kantor	Second Mate
Kenny Beaver	Third Mate
Jim Panter	Com/ET
Patrick Hennessy	Bosun
Raul Martinez	AB
Patrick Neumann	AB
Ronnie Whims	AB
Robert Arthur	OS
Janusz Miynarski	OS
Chris Morgan	Chief Eng
Alex Deveaux	1st Engr
Paul Ruh	2nd Engr
Bill Robinson	3rd Engr
Troy Pew	Electrician
Mike Spruill	Oiler
Corey Lawton	Oiler
Clindor Cacho	Wiper/OS
Liz Zacharias	Steward
Tanzi Edwards	Cook
Cecile Hall	Mess Attendant

3. Summary of Cruise Operations

3.1. Shipboard Data

Shipboard and underway data is available at the Rolling Deck to Repository, doi: 10.7284/908111



3.2. Summary of Jason Operations

Six ROV Jason dives were conducted at the Lost City hydrothermal field (J2_1107 through J2_1112) from 16 September 2018 to 21 September 2018. In addition, a short test dive (J2_1106) with Jason was conducted during the transit to Lost City while waiting for bad weather to pass. The main focus of the Jason dives was the collection of large volumes of hydrothermal fluid venting from the Lost City chimneys. Water samples were collected by Jason with the new HOG sampler, the new Titan Gas Tight sampler, regular Gas Tight samplers, paired Major samplers, and a Niskin bottle. In addition, opportunistic grab samples and suction slurp samples of chimney materials and occasional rocks were collected. A total of 182 water and chimney samples were collected during the six Jason dives at Lost City.

The main targets for Jason dives were actively venting chimneys with a goal of collecting a complete set of all sample types from each chimney in order to maximize the potential for integrating multidisciplinary datasets from as close to the same source material as possible. Therefore, we prioritized comprehensive sampling of a few key targets rather than a broad survey of many locations. On each dive, two primary targets (e.g. Posiedon and IMAX Flange on dive J2_1107) were identified, and all sample types were collected from each location whenever possible. Comprehensive sampling using all samplers was conducted at 9 locations during the expedition, and partial sample sets were collected

from an additional 8 locations. Each location was an actively venting structure at the Lost City hydrothermal field, with one exception being Borehole 72B.

In addition to sampling activities, ROV Jason operations included the recording of extensive high-resolution video, the collection of data by onboard sensors, and photographic surveys of the seafloor. Each of these activities is described in more detail below.

3.3. Summary of collection devices and sensors used during Jason and CTD operations

3.3.1. Hydrothermal Organic Geochemistry (HOG) sampler [PI: Lang]

The HOG sampler (Fig. 1) was designed to collect hydrothermal fluids for biogeochemical and microbiological analyses. It consists of seven 2-liter and two 11-liter sample chambers for natural abundance geochemistry connected to a titanium intake nozzle with an in situ temperature probe. A second titanium intake nozzle with an in situ temperature probe is connected to seven 2-liter sample chambers devoted to incubation experiments, and five Sterivex filters for trapping microbial cell-sized particles. The HOG Sampler was deployed on all but one dive and is described in more detail in the methods section.

Funding for the HOG sampler was provided by NSF grant BIO-OCE 1536702 as well as from a Deep Life Initiative grant through the Deep Carbon Observatory (to Lang)

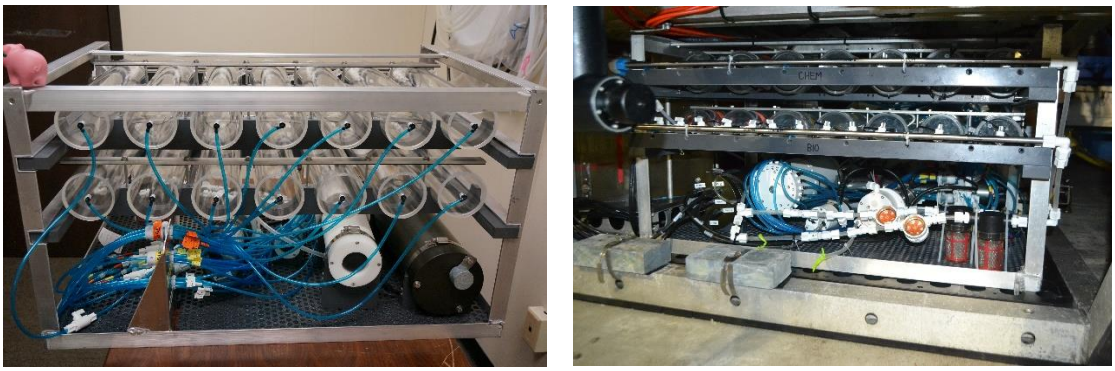


Figure 1. Back connections (left) and front connections (right) of the HOG sampler.

3.3.2. Gas Tight Samplers [PI: Lilley]

Gas Tight samplers collect 150 mL of fluid and maintain them at pressure until the sampler can be extracted on a vacuum line at the surface (Fig. 2A). They have long been used to collect samples for the analysis of gas concentrations and isotopes. Three or four Gas Tight samplers were deployed on each dive.

3.3.3. Titan Gas Tight Sampler [PIs: Früh-Green and Lilley]

The Titan Gas Tight Sampler is a scaled-up version of the Gas Tight samplers (Fig. 2B). It is used to collect 1500 mL of hydrothermal fluid and gas samples. The larger volumes will allow for enough methane to be collected that the analysis of isotopologues can be accomplished. The Titan sampler was deployed on all but one dive.

Funding to build the Titan Gas Tight Samplers was provided by the Deep Carbon Observatory through a grant to G. Früh-Green

3.3.4. MAPR [PI: Walker]

The Minature Autonomous Plume Recorder (MAPR) sensor (courtesy of Sharon Walker, NOAA/PMEL), incorporates a temperature sensor, an oxidation-reduction potential (ORP) sensor (PMEL), and a high sensitivity optical backscatter sensor (OBS; Seapoint Turbitdity Meters 0-5 NTU range). It operates autonomously on battery power. The MAPR was deployed on the brow of the vehicle on every dive.

3.3.5. Flow through sensor system [PIs: Walker and Lilley]

A series of sensors was mounted on the starboard side of Jason, including a CTD sensor (courtesy of Jason Group; Seabird), a METS methane sensor (courtesy of MARUM, University of Bremen, Frantech S/N 1507), an oxidation-reduction potential (ORP) sensor (courtesy of NOAA/PMEL, S/N 3), and a pump (Fig. 2C). A titanium intake with a t-handle was mounted on the front of Jason, and sampled fluids pass through the sensors into an open Niskin bottle that could be closed to trap the pumped fluids.

3.3.6. Multidisciplinary Instrumentation in Support of Oceanography (MISO) Camera [Supplied courtesy of Dr. Dan Fornari, WHOI]

The MISO camera was pointed downward (Fig. 2G) with strobes mounted on the two swing arms of Jason (Fig. 2E). It consisted of an Ocean Imaging Systems digital still camera (model DSC 24,000, S/N 003). Strobes were mounted on the side arms and were triggered simultaneously with the shutter. It was used to photomosaic the seafloor at the top of the massif and was mounted on every dive.

3.3.7. Borehole plug connector [Supplied courtesy of Dr. Beth Orcutt, Bigelow Laboratory for Ocean Sciences]

During IODP Expedition 357, a series of boreholes were drilled across the top of the Atlantis Massif. In some locations, borehole plugs were installed to allow later fluid sampling from sealed holes. They consist of swellable packers at the base of a titanium pipe, with a valve at the top. The borehole plug connectors were designed to open this valve and allow fluid flow. One connector was sent down with string on the outtake port as a visual indicator of fluid flow. A second connector was sent down with a check valve and conical sampling port that would allow multiple different sampler intakes (Fig. 2F; HOG sampler, Gas Tight sampler, Major Samplers) to seal against it and collect fluids.

3.3.8. Major samplers with ICL temperature link [Supplied courtesy of the Alvin Group]

Major samplers are 750 mL titanium samplers that have been used to collect hydrothermal fluids for decades. On the current expedition they were set up as double major pairs with an ICL temperature link. They were deployed on all but two dives (Fig. 2D).

3.3.9. SLURP sampler [Supplied courtesy of the Jason Group]

A hydraulic vacuum SLURP with five chambers was used to collect friable carbonate material from chimneys and veins (Fig. 2H). It was deployed on all dives.

3.3.10. Push Cores [Supplied courtesy of the Jason Group]

Six push core samplers with pre-drilled holes for rhizome sampling were supplied by the Jason Group. They were deployed on one dive to collect carbonate sands at the top of the Atlantis Massif (Fig. 2I).

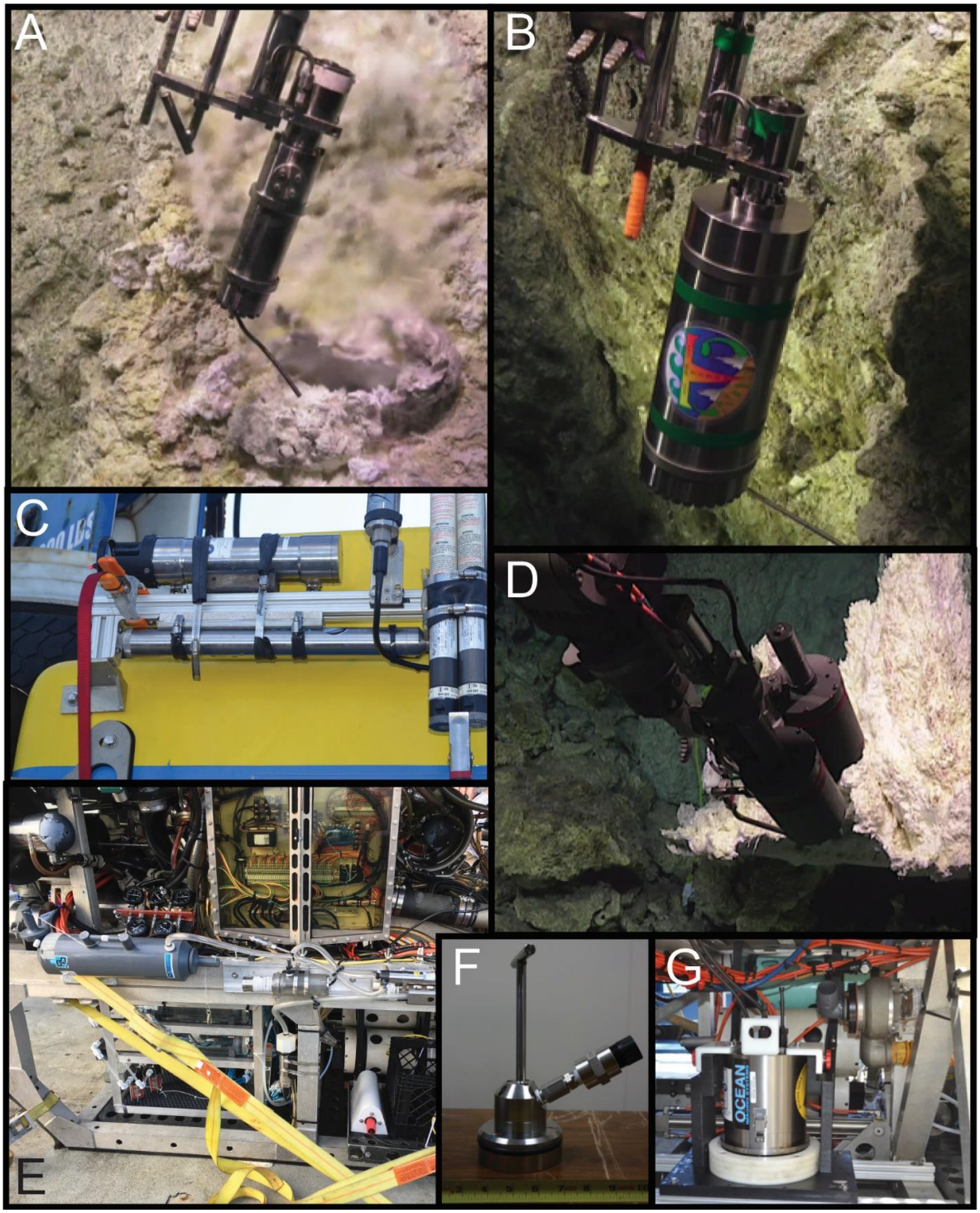


Figure 2. Sampling Equipment. A: Gas Tight Sampler B: Titan Gas Tight Sampler C: CTD and sensor package flow through system D: Double Major with ICL link E: CTD flow through system and Strobe of MISO camera system mounted on the swing arm F: Bore hole plug connector with a check valve G: MISO camera H: Intake of Slurp Sampler I: Push Core Samplers

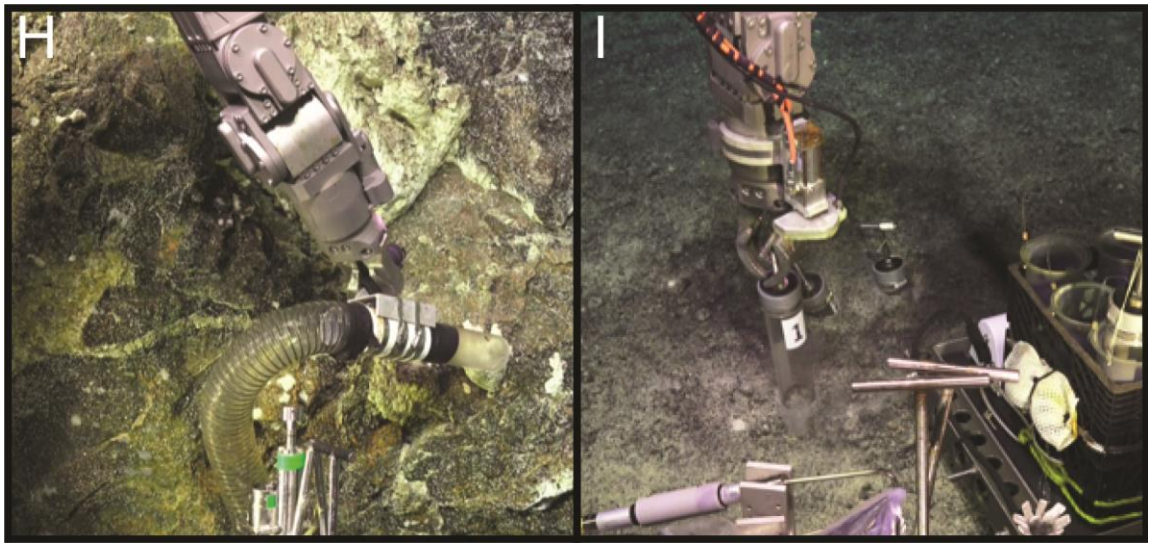


Figure 2, cont. Sampling Equipment. A: Gas Tight Sampler B: Titan Gas Tight Sampler C: CTD and sensor package flow through system D: Double Major with ICL link E: Strobe of MISO camera system mounted on the swing arm F: Bore hole plug connector with a check valve G: MISO camera H: Intake of Slurp Sampler I: Push Core Samplers

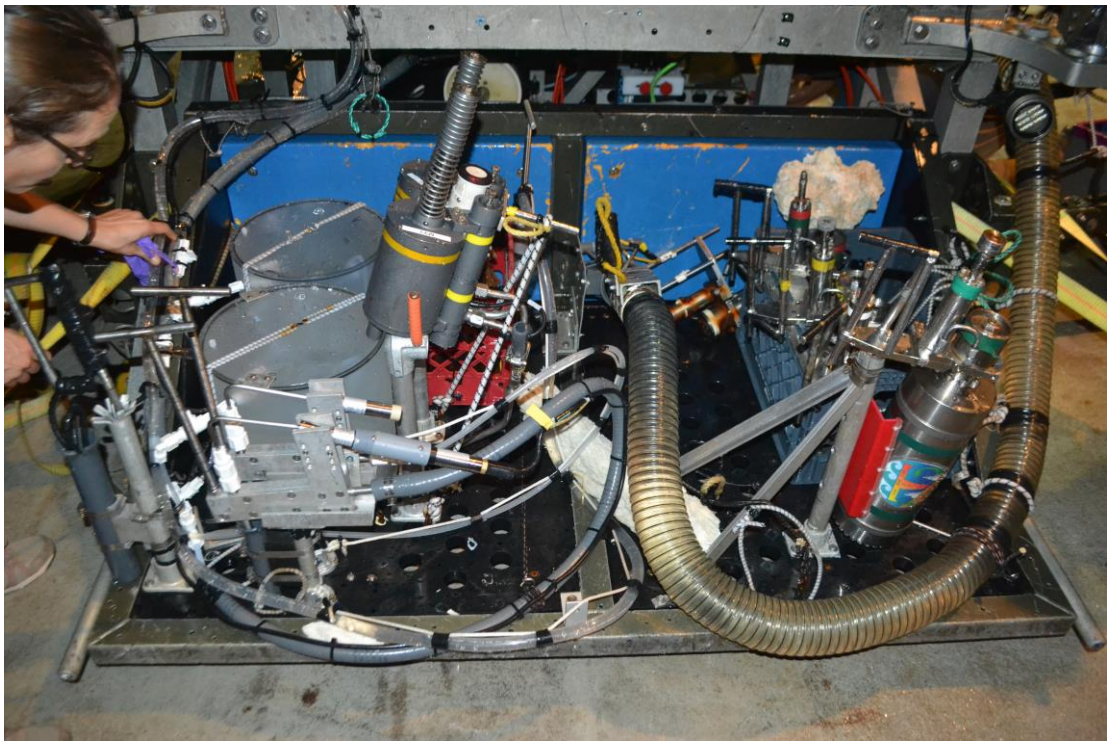


Figure 3. Front basket on a typical dive, upon recovery.

3.4. Summary of Time Spent

NSF funded 12 Science days. Even without weather, however, we would have had only 11 days on station. The time spent at the dock (10 h during mobilization; 16 during demobilization) was unaccounted for by the ship schedule:

Schedule without weather
Saturday Sept 8, 10 am departure
Friday Sept 14, 10 am arrival on station (6 days transit)
Tuesday, Sept 25, 8 am depart station (11 days on station)
Monday, Oct 1, 8 am arrival in Puerto Rico (6 days transit)

Schedule with weather
Saturday Sept 8, 10 am departure
Saturday Sept 15, 6 pm arrival on station (6 days transit + 32 h to avoid hurricane Florence)
Sunday Sept 16, 6 am Jason in the water (after 12 h tether replacement)
Friday Sept 21, 10 pm End of window that Jason could be in the water (134 h of Jason ops; 99.5 h bottom time + 37 h on-deck turnaround time)
Monday, Sept 24, 8 am End of window that ship could remain on station (2.5 days of CTD casts)
Monday, Oct 1, 8 am arrival in Puerto Rico (6 days transit + 82 h to avoid tropical storm Leslie)

3.5. Lost City Expedition Website

An expedition website (https://lostcity.biology.utah.edu) was built by Alex Hyer and Christopher Thornton in the Brazelton lab. The website contained background educational material on the Lost City, and frequent blog posts during the expedition updated the public about cruise operations, including new photos and videos recorded by ROV Jason on the seafloor. The website hosted >9,000 page views and >1,000 users during the expedition. We plan to continue to update the website with additional blog posts, photos, videos, exciting results, and publications so that it remains the primary portal by which we communicate Lost City news to the public.

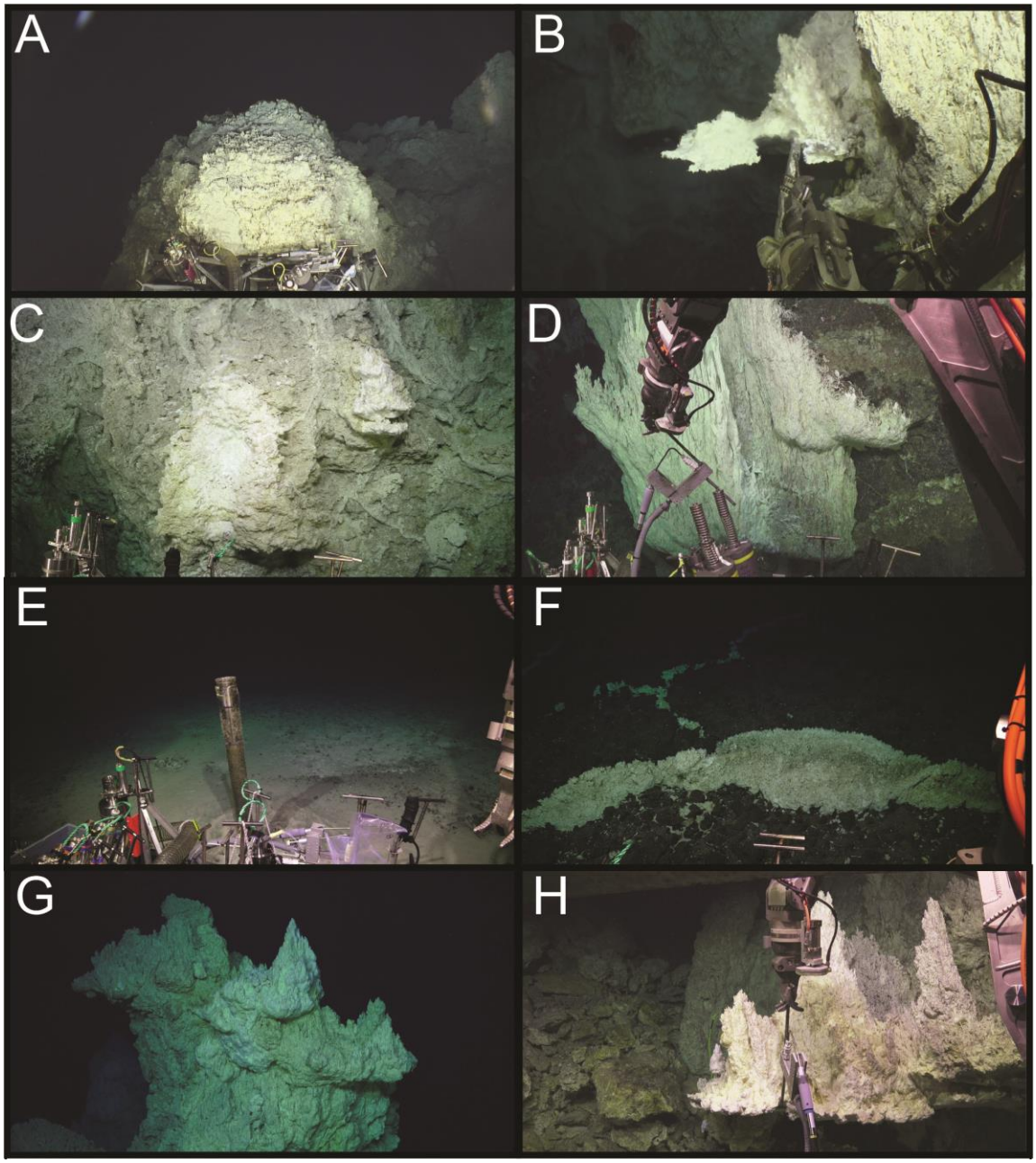


Figure 4. Primary sampling locations. A) Poseidon North Spire, B) Marker 2 (IMAX Flange), C) Beehive, D) Calypso, E) Borehole 72B, F) Carbonate cap, G) Sombrero, H) Marker C, I) Marker 8, J) Poseidon Camel Humps, K) Marker 6, L) Marker 6 close-up.

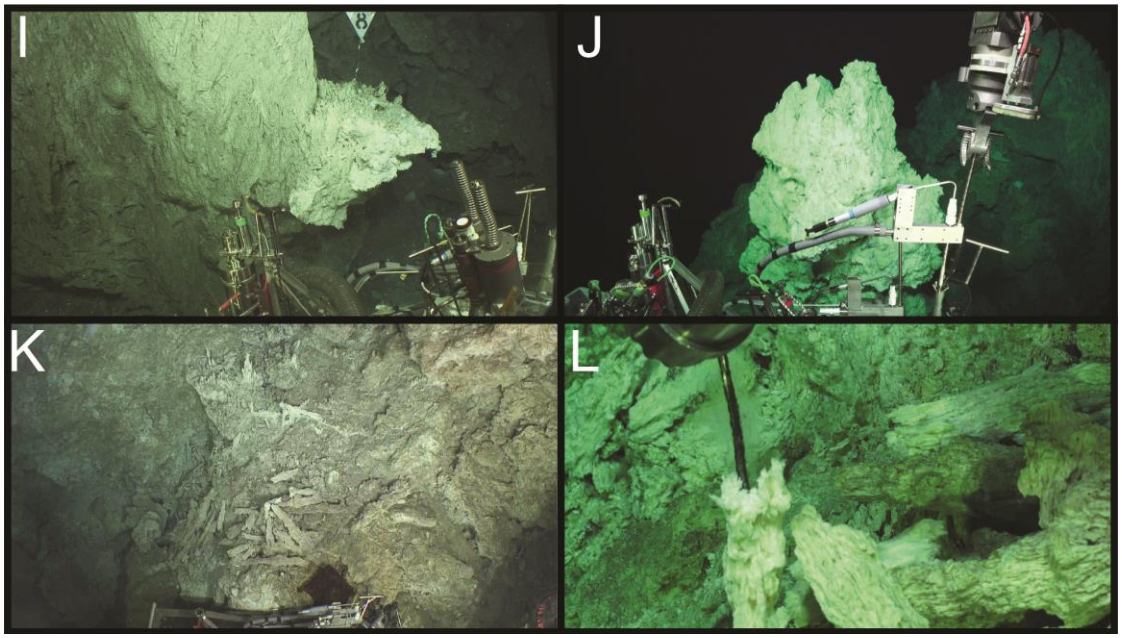


Figure 4, cont. Primary sampling locations. A) Poseidon North Spire, B) Marker 2 (IMAX Flange), C) Beehive, D) Calypso, E) Borehole 72B, F) Carbonate cap, G) Sombrero, H) Marker C, I) Marker 8, J) Poseidon Camel Humps, K) Marker 6, L) Marker 6 close-up.

4. Scientific Summaries of Jason Dives

Please note: Images of the sampling locations can be found in Figure 4.

4.1. Jason Dive J2_1106

September 11: Test dive during transit to Lost City

Date, Time in the water (UTC): September11, 14:25 UTC

Date, Time recovered (UTC): September 11, 16:45 UTC

Position: En route to Lost City: 35° 22.378 N 58° 49.1061 W

A test dive (J2_1106) with ROV Jason was performed mid-transit for the purposes of testing newly developed scientific equipment. Jason was deployed and descended to approximately 450 m water depth. The newly developed Hydrothermal Organic Geochemistry (HOG) sampler was powered up and successfully communicated. Five samples were collected that were later confirmed to contain the expected volume of sample.

The newly developed Titan Gas Tight sampler (1500 mL fluid sample maintained under pressure) was triggered in the Jason basket. It was later determined to contain the approximate amount of fluid as anticipated.

A series of sensors was mounted on the starboard side of Jason, including a CTD sensor (from Jason; Seabird 19*plus*V2 S/N 6952), a METS sensor (courtesy of MARUM, University of Bremen, S/N 1507), ORP sensor (courtesy of NOAA/PMEL, S/N 3), and a pump. All successfully communicated. A MISO camera and associated strobes (courtesy of Dan Fornari, WHOI), were powered on but did not respond. It was later determined that the strobes blew the power supply. The strobes were replaced with some from Jason that draw lower power.

On completion of testing, Jason ascended and was recovered.

4.2 Jason Dive J2_1107

September 16: First Jason dive at Lost City: Poseidon and Marker 2 (IMAX flange).

Date, Time in the water (UTC): 16 September 2018 10:11 UTC

Date, Time recovered (UTC): 17 September 2018 00:11 UTC

Position: Lost City: 30° 7'26", 42° 7'12"

Goal: The primary goal of the first ROV Jason dive at Lost City was to collect a complete set of fluid samples (i.e. fill up all samplers) and return Jason to deck as quickly as possible so that we could begin the shipboard processing of the first set of samples while Jason goes back into the water for a second dive.

Summary: We arrived on station above Lost City around 6 pm ship time on Saturday, September 15. The first ROV Jason dive was planned for 8 pm ship time, but a problem with the Jason-Medea tether was discovered during pre-dive. The tether was replaced, and the first dive was rescheduled for the following morning, Sunday, September 16.

We launched Jason and Medea at 10:11 UTC (6:11 am ship time) Sunday, September 16 and landed a few hundred meters from Lost City due to lat-long miscommunication. We approached Lost City for ~20 minutes, spun out the cable for Medea for ~20 minutes, and began approaching Lost City when a problem with the winch occurred at 11:39 UTC. An object from the winch blower became dislodged and wrapped around the winch. Ship's crew and Jason crew reacted rapidly and were able to restore operation to the winch without recovering Jason. Approach to Lost City resumed at 12:27 UTC.

We believed we reached our destination of Marker 3 (Poseidon) at 12:50 UTC. The bucket lid marker was missing. We sampled active flow from the top of Poseidon that reached temperatures around 55 ºC. After the dive, we realized that the sampling spot was on the north spire of Poseidon, not the southern camel humps where temperatures up to 88 ºC had been sampled by previous expeditions. We returned to Poseidon during dive J2_1111 to sample the southern camel humps.

At Poseidon North Spire, we collected:

- HOG water samples for chemistry, incubation experiments, and DNA/RNA.
- Titan gas-tight sample and one regular gas-tight sample
- Two slurp samples of carbonate deposits and four chimney grab samples

We finished sampling at Poseidon and moved to Marker 2 (IMAX flange) at 17:35 UTC. We surveyed the IMAX flange and surrounding area with 4K video at the direction of Mitch Elend prior to sampling. At 18:10, we approached the flange for sampling, which was a delicate and difficult maneuver for Jason.

At Marker 2, we collected:

- HOG water samples for chemistry, incubation experiments, and DNA/RNA.
- Two regular gas-tight samples
- One double-major water sample
- Two slurp samples of carbonate deposits and a chimney grab sample

Jason and Medea were recovered at 00:11 UTC (Sunday Sept 16 8 pm ship time) and turned around in 4 hours for launch of dive J2-1108 at 04:00 UTC Monday Sept 17 (Midnight ship time).

4.3 Jason Dive J2_1108

September 17: Jason dive at Lost City Markers BH, H, and 7.

Science Dive Report J2_1108

Date, Time in the water (UTC): 17 September 04:06 UTC

Date, Time recovered (UTC): 18 September 2018 00:08 UTC

Position: Lost City: 30° 7'26", 42° 7'12"

Goals: Collect water and chimney samples from Lost City chimneys and to deploy the Sylvan chimney incubation experiment.

Summary: We turned around Jason from previous dive in 4 hours, deploying Jason again just after midnight ship time (late Sunday night = 04:00 UTC Monday September 17). We quickly arrived at our first target, Marker BH (Beehive chimney) at 04:48 UTC.

At Marker BH (Beehive), we collected:

- HOG water samples for chemistry, incubation experiments, and DNA/RNA.
- Titan gas-tight sample and one regular gas-tight sample
- One double-major water sample
- Several chimney grab samples, including material to be used for an incubation experiment.

Next, we explored Marker H (Nature Tower), recorded excellent 4K video footage, and recovered a gas-tight sampler lost during the 2005 expedition (10:40 UTC). We were unable to find a good source of hydrothermal fluids for sampling at Marker H. We continued exploring the cliff face wall behind Marker H (12:20 UTC) and searched, unsuccessfully, for carbonate deposits in fractures indicating fluid flow directly from basement rocks. Samples of coral and a basement rock were collected.

An incubation experiment (containing carbonate material collected from the Beehive) was deployed near Marker G at a relatively flat and stable position at 14:53 UTC.

During a test of the MISO camera loaned by Dan Fornari, Jason experienced an electrical outage at 15:20 UTC. Power was restored at 15:44, and the dive resumed.

We arrived at Marker 7 at 16:28 UTC, though the physical marker was missing. We explored the Calypso structure and discovered abundant active venting at the top of the structure with temperatures of 20-55 ºC.

At Calypso, we collected:

- HOG water samples for chemistry, incubation experiments, and DNA/RNA.
- Two regular gas-tight samples
- Two chimney slurp samples and two chimney grab samples.

With all samplers full, we recovered Jason at 8pm ship time (2400 UTC).

4.4 Science Dive Report J2_1109

September 18: Jason dive at boreholes from IODP Expedition 357

Date, Time in the water (UTC): 18 September 2018 12:14 UTC

Date, Time recovered (UTC): 19 September 2018 12:14 UTC

Position: Atlantis Massif boreholes: 30° 7'30", 42° 7'9"

Goal: Visually document and attempt to sample boreholes from IODP Expedition 357.

Summary: We found borehole 72B ~15 m from lat-long coordinates at a depth of 820 m. Jason brushed off the top of the borehole plug, inserted the first borehole plug connector (with stringy flow meter), twisted ~45º, and then Jason lost power due to power supply failure. Jason was brought to the surface for power cycling and troubleshooting at ~10:00 local ship time (1400 UTC). Jason was towed at 0.5 knots during troubleshooting, which successfully restored power.

We returned to the site at 1 pm ship time (17:06 UTC) and returned to borehole 72B. The connector remained inserted into the borehole during the Jason power troubleshooting. Jason was able to rotate the connector, but no flow out of the connector with stringy flow meter was apparent. It was unclear whether the connector had been rotated sufficiently to open the borehole valve. The connector was removed and replaced with a connector containing a sampling port. Jason was able to rotate the connector, but after turning ~45º the borehole pipe itself began to also rotate with the plug and connector. Jason attempted to hold the pipe with one arm and turn the connector with the other arm, but the pipe continued to rotate. No flow was apparent out of the sampling port, and it was unclear if the valve was open.

The HOG chemistry nozzle with ICL temp probe was inserted into the sampling port, and no difference from ambient seawater temp (10.96 ºC) was detected. We attempted to insert the nozzle further into the sampling port, and communication with the ICL temp probe was lost, presumably due to over-stretching the cable. The Jason High-Temp probe was also inserted into the sampling port, and no temperature anomaly was detected.

We attempted to remove the connector, but it could not be unscrewed without also removing the top cap seal of the borehole plug (leaving an open hole). When this occurred, a tiny bit of shimmering was detected above the open borehole, so we inserted the intake for the flow through CTD sensor on Jason (19:06 UTC). A drop in ORP was detected down to -220 mV and the temperature increased slightly from 9.5 to 9.8°C. No response was detected on the methane sensor. Therefore, we collected samples from the open borehole pipe.

At borehole 72B, we collected:

- HOG water samples for chemistry and DNA.
- One regular gas-tight sample

After sampling, we re-inserted the borehole plug and connector and again attempted to return the top cap seal and detach the borehole plug connector. This attempt was unsuccessful and it was determined it would be preferable for future researchers to leave the hole open instead of sealed with the borehole plug connector attached, which could result in the top cap not being able to be removed at all in the future. The top of the borehole was therefore left open and the top cap seal and borehole plug connector were stowed in the rock box.

We moved to borehole 76 and conducted a survey of the seafloor with the MISO camera and strobes during the ~500 m transit. At the coordinates for site 76, we found a pipe from IODP Exp. 357 lying horizontally on the seafloor, but we were unable to find holes 76A and 76B.

We moved to borehole 69 and conducted a survey of the seafloor with the MISO camera and strobes during the transit. We found a rusty pipe inserted into borehole 69A and inserted the CTD inlet into the open borehole. No temperature or ORP anomalies were detected, and no samples were collected from the borehole. We collected three push core samples approximately 5 m from borehole 69A.

We returned to the Lost City hydrothermal field and inspected carbonate veins in the basement rock along the way. In between Markers 6 and 7 we discovered vigorous venting at the top of a large carbonate edifice (03:27 UTC). This structure was previously named "Sombrero", but we think this is the first time active venting was noticed. A high temperature of 57 ºC was measured, and we collected samples.

At Sombrero, we collected:

- HOG water samples for chemistry, incubation experiments, and DNA/RNA
- Two regular gas-tight samples
- Titan gas-tight sample
- A Niskin bottle sample connected to the CTD sensors
- Three chimney grab samples

Next, we searched for carbonate veins and springs along the ridge leading up to the summit of the Atlantis Massif and conducted another photo survey with the MISO camera. Active flow from a carbonate vein with a temperature one degree higher than ambient was discovered at 09:16 UTC.

At the diffusely flowing carbonate vein, we collected:

- One HOG water sample for chemistry

- Three slurp samples of the carbonates and one grab sample of the carbonates

At the end of the dive, we returned to Marker BH (Beehive) and measured a temperature of 93 ºC. We collected one slurp sample of the chimney (10:59 UTC) and ended the dive.

4.5 Science Dive Report J2_1110

September 19: Jason dive at Lost City Markers C and 8.

Date, Time in the water (UTC): 19 September 2018 20:00 UTC

Date, Time recovered (UTC): 20 September 2018 10:35 UTC

Position: Lost City: 30° 7'26", 42° 7'12"

Goals: Collect water and chimney samples from Lost City chimneys at Markers C and 8.

Summary: This dive was focused on collecting extensive water samples from chimneys at Markers C and 8, both of which we had not yet seen during this expedition. First, we visited Poseidon to consider collecting a gas-tight sample, but decided not to because it would take too much time to find a good sampling spot at this location.

We found Marker C at 21:22 UTC. The physical marker had fallen down into the rubble below the flange, and we recovered it and placed it again to the left of the Marker C flange.

At Marker C, we collected:

- HOG water samples for chemistry, incubation experiments, and DNA/RNA.
- Titan gas-tight sample and one regular gas-tight sample
- One double-major water sample
- One Niskin bottle sample
- One slurp sample of carbonate chimney material

We moved to Marker 8 at 02:25 UTC and identified the physical marker, which had been grown over by carbonates and cemented into place. Temperature in the visible flow reached 40-50 ºC.

At Marker 8, we collected:

- HOG water samples for chemistry, incubation experiments, and DNA/RNA.
- Two regular gas-tight samples
- One slurp sample and one grab sample of chimney material

Next, we explored to the west of the main Lost City vent field. We identified Marker 4 at 07:38 UTC south of Marker 8 in a location very different than shown on the map. We continued west, tracing a carbonate vein in the basement rock and collected two very lithified and old-looking carbonate samples. The dive ended at 09:17 when Jason's recovery line was somehow severed. The vehicle was recovered safely.

4.6 Science Dive Report J2_1111

September 20: Jason dive at Lost City (Sombrero, Poseidon, and IMAX Flange)

Date, Time in the water (UTC): 20 September 2018 20:07 UTC

Date, Time recovered (UTC): 21 September 2018 20:57 UTC

Position: Lost City: 30° 7'26", 42° 7'12"

Goals: Collect water and chimney samples from Lost City chimneys at Sombrero, Poseidon, and IMAX flange to fill in missing gaps in our dataset. Recovering the incubation experiment that was deployed earlier was also a high-priority goal.

Summary: We expected this to be the last long dive of the expedition because bad weather was moving in. One additional quick dive was conducted after this one (J2_1112). This dive was focused on collecting extensive water samples from chimneys at Sombrero and Poseidon, both of which we had sampled earlier in the expedition, but our preliminary data indicated that the samples were not high quality.

First, we recovered the Sylvan incubation experiment, which was deployed near Marker G earlier in the expedition. We recovered at the beginning of the dive to ensure recovery in case the dive ended prematurely. The milk crate housing the experiment was easily found and recovered at 20:46 UTC

We found the Sombrero (which we also sometimes referred to as Marker 6.5, though there is no physical marker other than the distinctive Sombrero shape at the top of the structure) at 21:19 UTC. We surveyed the structure and tested several possible sampling sites before settling on a site with active flow up to 60 ºC at 23:05 UTC.

At Sombrero, we collected:

- HOG water samples for chemistry, incubation experiments, and DNA/RNA.
- One regular gas-tight sample
- Two slurp samples of carbonate chimney material

We moved to Poseidon at 02:30 UTC and again tested several possible sampling sites. Eventually, we found abundant flow with a maximum temperature of 85 ºC on a flange emerging from the tallest of the three southern camel humps at the top of Poseidon. This sampling location was different than the sampling location on the north spire sampled during dive J2_1107.

At Poseidon South Camel Humps, we collected:

- HOG water samples for chemistry, incubation experiments, and DNA/RNA.
- One regular gas-tight sample

Before leaving Poseidon, we collected excellent 4K video footage of the structure (06:15 to 06:45 UTC).

We moved to Marker 2 (IMAX) at 06:58 UTC and collected:

- Titan gas-tight sample and one regular gas-tight samples
- Niskin bottle connected to CTD sensors

The rest of the dive was focused on collecting inactive chimneys and searching for springs along the eastern wall. Five grab samples were collected from inactive chimneys and small chimneys growing directly from rocks along the eastern wall. In addition, one HOG sample was collected of water flowing from the base of a small chimney with a maximum temperature of 22 ºC (11:43 UTC). This venting vein appeared to be connected with a series of carbonate deposits along a similar depth.

Next, we searched for borehole 68B and found a pipe inserted into the hole at 17:15 UTC. The pipe was rusty but appeared to be intact. No temperature anomaly was detected in the hole with the High-Temp probe. A short photomosaic with the MISO camera was carried out to document the borehole and surrounding seafloor.

We moved to boreholes 75A-B, arriving at 19:35 UTC. Borehole 75A is a visible hole, and borehole 75B has a plugged pipe. No visible flow and no temperature anomaly were detected at the base of the pipe with the High-Temp probe inserted into the hole around the base of the pipe. The dive ended here.

4.7 Science Dive Report J2_1112

September 21: Jason dive at Lost City Marker 6

Date, Time in the water (UTC): 21 September 2018 22:41 UTC

Date, Time recovered (UTC): 22 September 2018 02:08 UTC

Position: Lost City: 30° 7'26", 42° 7'12"

Goal: Quick final dive at Lost City to collect samples from Marker 6, which we had not been able to sample yet.

Summary: This was a quick, final dive enabled by the Jason team turning around the vehicle in less than two hours. A storm was approaching, and we only needed a few more hours to significantly improve our sample set by visiting Marker 6. We found the marker at 23:47 UTC and found a small chimney venting fuids up to 54 ºC.

At Marker 6 we collected:

- three gas-tight samples
- a water sample with the double major sampler
- a Niskin bottle connected to CTD sensors
- two grab samples of chimney material

The dive ended immediately after sample collection due to deteriorating weather, and Jason left bottom at 01:16 UTC.