AT26-09 Expedition Report
Dorado Outcrop and Costa Rica CORKs
December 2013

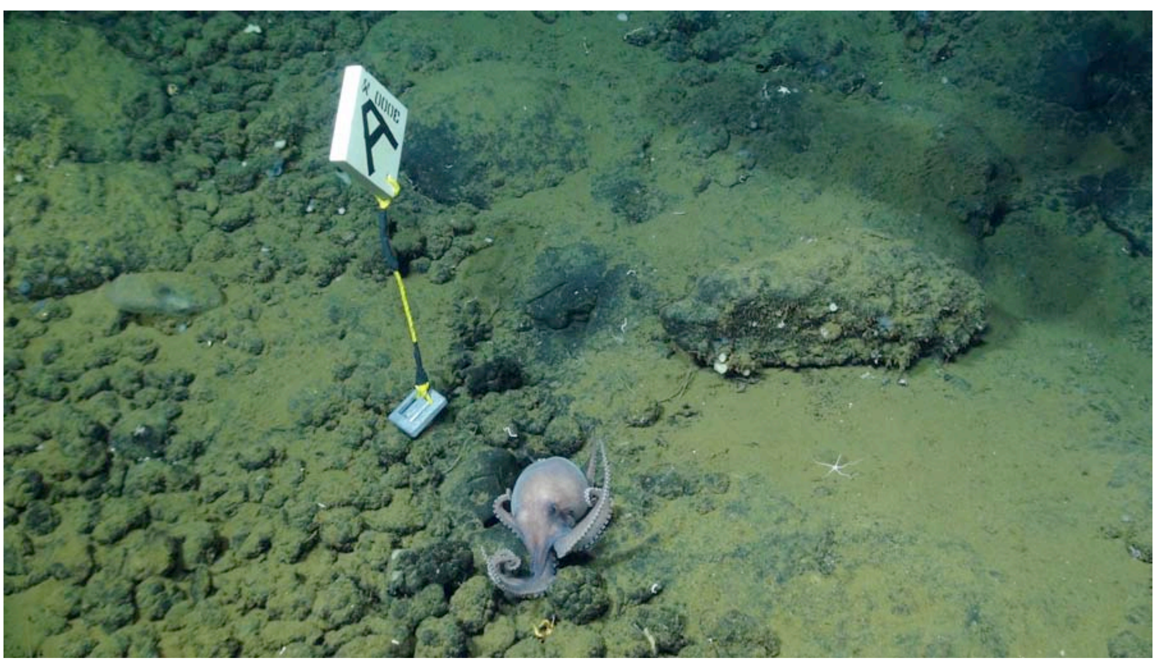
R/V Atlantis (Woods Hole Oceanographic Institution)
ROV Jason II/Medea (Woods Hole Oceanographic Institution)
AUV Sentry (Woods Hole Oceanographic Institution)

December 7-23, 2013 (ports: Puntarenas, Costa Rica)

Chief Scientist: C. Geoffrey Wheat (wheat@mbari.org)

NSF award OCE 1130146 “Collaborative Research: Discovery, sampling, and quantification of flows from cool yet massive ridge flank hydrothermal springs on Dorado Outcrop, eastern Pacific Ocean” to Wheat, Fisher and Hulme. Additional support was provided by C-DEBI through Research Grants (Orcutt, McManus, Vidoudez) and Post doctoral Fellowships (Bertics, Briggs, and Inderbitzen). Some project co PIs did not sail. Some of these shore-based partners have supplemental funding for related work.

Cruise prospectus available online:
http://www.darkenergybiosphere.org/research/docs/Dorado%20Outcrop%20Sci%20Prospectus_submitted.pdf



An octopus bathing in a warm spring on the northwestern portion of Dorado Outcrop

Overview

There were many successes in the expedition to Dorado Outcrop and to the CORKs at ODP Holes 1253A and 1255A despite losing a week of scheduled ship, Jason, and Sentry time to accommodate HOV *Alvin* certification. Major accomplishments at Dorado Outcrop include: (1) proving correct the hypothesis that Dorado outcrop is a regional focus of massive, low-temperature, hydrothermal discharge, (2) locating, sampling, and deploying experiments in numerous springs of low-temperature hydrothermal fluid emanating from the outcrop; (3) completion of 72 measurements of heat flow on and around Dorado outcrop, most co-located on chirp or seismic lines; and (4) conducting extensive surveys from which we produced bathymetric, sediment thickness, and water column temperature anomaly maps. Major accomplishment at the ODP Hole 1253A and 1255A CORKs include: (1) downloading long-term pressure data from both holes; and (2) recovering the downhole instrument string from ODP Hole 1253A. The weather and crews of the Atlantis, Jason and Sentry made it possible for us to utilize all assets to collect the most complete data set possible in the given time frame.

We had 16 days of operation from the time we left port until the time we returned and departed for home on Christmas Eve. Forty hours were devoted to transits and the initial ship-based multi-beam survey, which served as the bias for the initial Sentry and Jason dives. Forty-eight hours were required to get the CORK work completed, including the transit to the CORKs and back to Dorado Outcrop. This allowed us to spend 12.3 days on Dorado Outcrop with Jason and Sentry. During this period, Jason was in the water 79% of the time and Sentry was in the water 50% of the time. The only loss of Jason time resulted from recovery of the vehicle during descent because of a ground fault with science gear, termination of a 100-hr dive because of the loss of both vertical thrusters, termination of a 15-hour dive because of the loss of telemetry, and deployment, recovery and avoidance of Sentry.

Operationally, joint Jason, Sentry, and elevator operations evolved though out the expedition. Overall our goal was to keep Jason on the seafloor making measurements and collecting samples. Elevators were used to swap out samples and equipments. Meanwhile Sentry was deployed for specific missions that ranged from bathymetric mapping to dedicated Chirp Sonar dives to the detection of thermal plumes while taking images of the seafloor. Initially, Sentry required Jason to be off the bottom during launch and well before recovery. By the end of the expedition, Sentry was launched while Jason was on the seafloor conducting sampling and measurement operations. By the end of the expedition Sentry was able to drive to the ship during recovery, thus minimizing the time Jason was off the bottom, which was limited to the final aspects of Sentry recovery.

<u>Sample and data collections on AT26-09</u>:

Kilometers of high resolution bathymetric, chirp, magnetometer, and thermal anomaly data,
Tens of thousands of images of Dorado Outcrop,
Discrete fluids from low temperature hydrothermal springs,
Measurements of heat flow,
Measurements of temperature,
Sediment push cores,

Rocks,
Pressure and temperature data from ODP Holes 1253A and 1255A,
Borehole OsmoSampler package from ODP Hole 1253A, and
Bottom water via Niskin bottles on the elevator and on Jason,

Deployments on AT26-09:

Markers for future reference,
Seafloor OsmoSampler packages with temperature loggers,
Enrichment experiments, and
A top plug for ODP Hole 1253A.

Education, outreach and diversity efforts included

Participation of under representative groups (7 Females out of 18 science party),
Multi-national participation (US, German, French),
A range of backgrounds and expertise:
- Undergraduate students (2)
- Graduate students (4)
- Post-Doctoral Fellows (3, an additional 2 involved in shore-based work)
- Teachers of teachers and students (2)

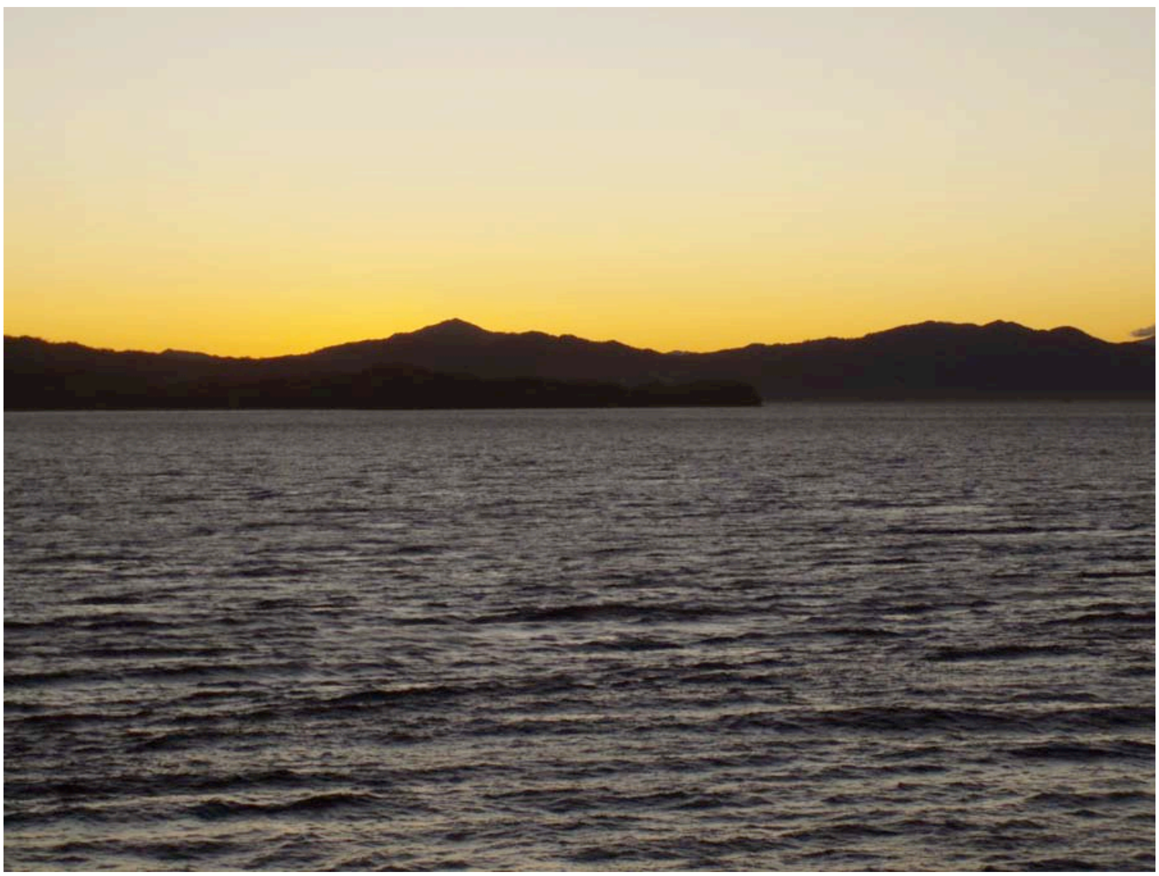
A blog (darkenergybiosphere.org/dorado) that reached ~200 4th grade students and 40 college students in science education in Columbia, Missouri,
A press release, and
Follow-up appearances at 4th grade classes in Columbia, Missouri.

Data and sample access:

R/V *Atlantis* underway data to be deposited at R2R - http://www.rvdata.us/catalog/Atlantis
ROV Jason "Virtual Van" data available online: http://4dgeo.whoi.edu/jason/
All Sentry data and Jason HD videos available from chief scientist
Bathymetry data available from Hulme and will be deposited at LDEO
Heat flow and temperature data archived by Fisher
Fluid and sediment samples archived by chief scientist and Orcutt
Rock samples archived by graduate student Lee in Katrina Edwards' lab

Dorado and Costa Rica CORKs 2013: Operational Details

Travel: Most folks arrived and stayed at the Holiday Inn Airport San Jose Costa Rica ($120/night) or the Hampton Inn and Suites ($140/night). These hotels have adjoining properties and a free airport shuttle that is shared between the two hotels. The shuttle bus arrives every 15 minutes outside of immigration and across the street. Both hotels are quite nice. Travel to Puntarenus is possible via taxi or tourist van. A taxi at the airport costs about $100 for the one-way trip. A hired van from the front desk at the Holiday Inn costs $250 for 12 people and $450 for 15 people, stopping for dinner. Some people stayed in Puntarenus at the Alamar ($120/night).
http://www.costaricanhotels.com/alamar_apartotel_costa_rica.html



This was a view of the sunset from the R/V Atlantis while we waiting for the shuttle to take us ashore.

Note: This document is in local time except when listed (for GMT subtract 6 hours)

This report is displayed in the following order:

Saturday December 7, 2013

We left port shortly after the last launch around 0830. During the transit to Dorado Outcrop we used the ship multi-beam to improve the regional bathymetric map. In a decade since the last mapping effort, multi-beam systems have improved by an order of magnitude. This new data served as the base map for the first Sentry and Jason dives. We collected multi-beam data until we were ready for the first Sentry dive (27 hours after leaving port).

Jason Dives J2-750 and J2-751 – Dorado Outcrop

Dorado Outcrop 9°5.0´N 87°5.72´W Water Depth 3100 m (maximum)



Figures above: Left, basket (temperature probe, heat flow probe, heat flow insertion platform, 10 push cores [5 with hole for rhizones and oxygen electrode] suction sampler. Center, port side (4 cow and 4 squeezer fluid samplers [Red]). Right, starboard side (basket for rocks and markers on the swing arm and Niskin bottle above).

Figure Left: layout of the Elevator used on 751 (10 push cores, two bioboxes with microbial experiments (3) and markers (3), scoop sampler, and fluid samplers (not shown).

Dive J2-750 was aborted during descent. There was a ground fault with the heat flow probe and an intermittent ground fault with the manipulator. Jason was recovered and the ground faults were corrected. The heat flow probe was "condomized" without any further issues.

Dive J2-751 was a 100-hour-long dive. The focus was to locate the "fire hose" of water that should be emanating from Dorado. We started out with a heat flow transect to stay out of the way of Sentry that was mapping the entire feature. Once Sentry had cleared the area, Jason moved in and started a program of looking for flow using visual clues and poking the sediment and under slabs of basalt with the temperature probe starting with the SE end of the outcrop but then moving NW to the NW end of the outcrop. No visual cues of venting (i.e. shimmering water) were evident until reaching the summit of a pinnacle feature at the NW end of the outcrop, where the first evidence of shimmering hydrothermal fluids was documented (roughly 8°C as measured by the high-temperature temperature probe on Jason). Other venting features were found in this area. The warmest temperatures appear to be associated with blackened areas. For example, the Marker A area, just to the SE of the pinnacle feature, contains a dozen holes where warm water is evident. This water clearly shimmers as it exits the seafloor and mixes with bottom seawater. The maximum apparent temperature of water emanating from a crack in this area was 13.1°C, as determined with the Jason high-temperature probe. This probe showed a bottom water temperature of 3.3 °C, whereas the actual temperature of bottom water is ~1.8°C (as determined during earlier surveys, the heat flow surveys on AT26-09, and with Jason and Sentry CTD surveys), so the actual discharging fluid temperature was 11.6°C, about 10°C warmer than bottom water. All temperatures measured with the Jason probe that are discussed in this report are apparent values, uncorrected for the offset with bottom water.

During the dive we collected shimmering water in the 4 cow samplers and the 4 squeezer samplers (RED), although seawater entrainment was an issue. No other samples were collected on this dive.

We used the collection of Sentry data, Jason heat flow, Jason temperature probe, and Jason CTD data from this dive as the foundation for a search pattern once we returned after conducting the CORK work.

The presence of Jason and Sentry in the water at the same time required that Jason come off the seafloor occasionally. Jason moved off the seafloor when the two vehicles were too close and when Sentry was deployed and recovered. Time lost to Jason operations included: 2 hours to avoid Sentry, 2.5 hours to recover Sentry after Dive 213, 3 hours because of the manual switch in the navigation feed (human induced; ship based); 3 hours to deploy Sentry on Dive 214, 2 hours to recover Sentry on Dive 214, and 1 hour to avoid Sentry. Total time lost was 13.5 hours, which is 13.5% of the dive (lasted 100 hours). The elevator took 4 hours to deploy, swap sampling tools and samples, and recover. The dive was terminated because of vehicle issues. At one point we lost a vertical thruster. The dive was terminated when we lost the second vertical thruster.

Jason Dive J2-752 – Dorado Outcrop

Dorado Outcrop 9°5.0´N 87°5.72´W Water Depth 3100 m (maximum

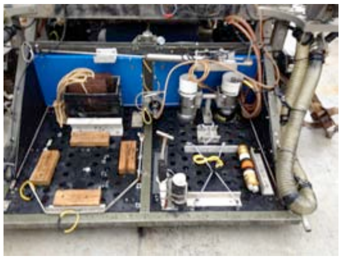
Figures above: Left, basket (temperature probe, heat flow probe, standard OsmoSampler), 10 push cores [5 with hole for rhizones and oxygen electrode] and suction sampler. Center, port side (4 cow and 4 squeezer fluid samplers [Yellow]). Right, starboard side (Niskin bottle and a biobox for rocks. During descent the biobox held 3 markers and 3 each of microbial year-long experiments).

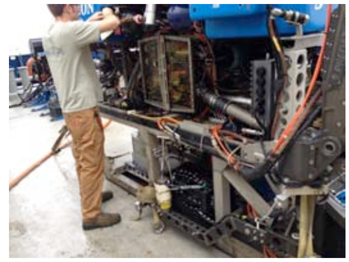
This dive was focused on sample collection. We descended on the northeast flank of the ridge at a heat flow target. When we arrived it was too rocky to make a heat flow measurement. We headed northeast along the transect and stopped at the first place we were able to collect a heat flow measurement. The heat flow measurement was not high enough so Jason headed to heat flow station HF-751-14, the highest heat flux in the area. We found Jason's track at heat flow measurement HF-751-14. We made another heat flow measurement and collected 4 push cores. We then went to the location of heat flow measurement HF-751-15. We were unable to get much penetration. We were able to collect two cores. After searching and trying to collect a push core we went back to heat the location of HF-751-14. There we collected 3 cores. One core was broken during the attempt to collect sediment.

We moved to Marker A and measured the apparent temperature (13.1°C compared to a bottom water reading of 3.3°C). We collected rocks in the scoop sampler and bio box; however, the scoop was lost during Jason recovery after falling out of bungees on basket. Then we collected fluid samples (4 Cow and 2 Squeezers – Yellow; 2 squeezers did not trip) and deployed the OsmoSampler and three enrichment experiments. The dive ended as planned.

Jason Dive J2-753 – Hole 1253A CORK

ODP Site 1253 9°38.8583´N 86°11.4337´W Water Depth 4376.0 m





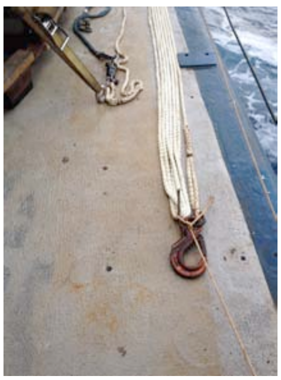


Figure Above Left: The basket
Figure Above Center: Port side
Figure Above Right: Starboard Side
Figure Left: Hook to recover the OsmoString. Note that there was a football float on the line about 4 to 5 meters from the hook (not shown). This made the operation safe and effective.

Before the dive a rope with a weak line was attached to the release on Medea. The other end of the rope had a football float (this was an important addition that made line handling much easier) about 14 feet from the hook at the end. This was a dedicated dive to recover the downhole string (Figure 1). We entered the water at 08:00 and located the wellhead ~11:00 am. When we arrived we noticed that the spectra line was bent over and disappeared into one of the holes on the ROV platform. This means that the shackle to the float above came loose and the float disappeared. Jason tugged on the spectra to get it free but it was stuck. Jason surveyed the top of the wellhead and we noticed the ring and weight that was put there by Alvin, but it was not tied to the spectra and we could not use it to pull. Jason went down to cut the line on the ROV platform. In the process of putting tension on the spectra, the spectra came loose. Jason then went to get the hook hanging from Medea and traveled back to the wellhead to make the connection. Medea and Jason ascended in tandem to take the slack out of the spectra. Once the slack was sufficiently removed Jason descended to observe the spectra. Medea continued to ascend at 6 m per minute and we watched the spectra become tight. Medea continued to rise with Jason in layback mode at 6 m per minute until the string was out of the borehole. Jason was recovered at 5:15 and the OsmoSampler string was pulled up shortly there after.

The dive ended as planned.

PUMPS	**per mil in fresh water reservoir**
UPPER	
1-membrane (F)-1-copper	16 per mill
1-membrane (G)-1-teflon	0 per mil
1-membrane (G)-1-teflon	0 per mil
MIDDLE	
1-membrane (B)-1-copper	0 per mil
1-membrane (C)-1-teflon	0 per mil
6-membrane (M)-MBIO	off scale and had a sulfide smell (no other pumps had a sulfide smell)
LOWER	
3-membrane (K)-3-teflon	off scale
1-membrane 2ML4	4 per mil

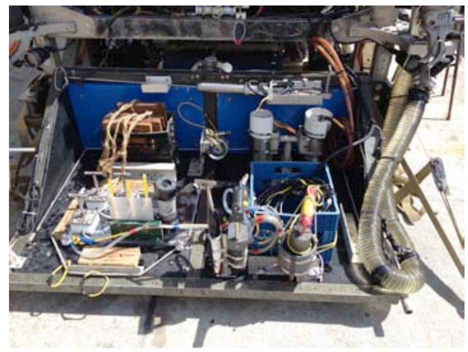
Temperature in ODP Hole 1253A is about ~16.4°C, based on Anderaa temperature recorders that were recovered with the OmsoSampler string.

Jason Dive J2-754 – Holes 1253A and 1255A CORKs

ODP Site 1253 9°38.8583´N 86°11.4337´W Water Depth 4376.0 m
ODP Site 1255 9°39.2716´N 86°11.1492´W Water Depth 4311.6 m

These two sites are 0.94 km apart.





Figures Above: Three different views of the basket for 754 and 755. Items in the basket included the toilet brush, flow meter manifold, two (only one was used on 754) Seacon connectors, knife, weights, temperature probe, and heat flow probe.

The dive started at Hole 1255A. A hydrostatic valve switching was completed. The SEACON connecter was deployed but there was a short. They tried several software methods. They also tried to re-connect. It did not work. This particular Seacon connector had a 9V function. This function provided power to the logger so that the download did not tax the battery life of the logger. The decision was made to try the data download at Hole 1253A to see if it was the connector or the data logger. At Hole 1253A we conducted a hydrostatic test and tried the connector. Once again it did not work. The top plug was inserted. The dive was aborted so that they could examine the connector and add an older connector that they used in the past. The older (second connector) is the original one that does not use Jason power and the download is powered by the pressure data logger.

Once Jason was recovered, the Jason crew replaced the starboard manipulator because the claw was not opening and there was a minor ground fault. The dive ended because of the lack of ability of the Seacon to communicate with the logger. The Seacon that was used on this dive had a successful deck test before the dive. Both Seacons had successful deck tests after this dive.

Jason Dive J2-755 – Holes 1253A and 1255A CORKs

ODP Site 1253	9°38.8583´N	86°11.4337´W	Water Depth 4376.0 m
ODP Site 1255	9°39.2716´N	86°11.1492´W	Water Depth 4311.6 m

These two sites are 0.94 km apart.

Same basket as J2-754 except there is the addition of the second Seacon connector.

With the replacement of the starboard manipulator and the second Seacon connecter Jason started at Hole 1253A. The download was attempted with the 9V Seacon. There was a ground fault. The other (older) Seacon was used and data were successfully downloaded after ~50 minutes. Jason then moved to Hole 1255A. On the way they passed the decollement. At 1255 they successfully downloaded data. After the data were downloaded we went to the sample port bay. We hooked the flow meter manifold up to the Upper Right connector. There was no indication of flow. We opened the lower valve and observed the port. No sign of fluid flow from that port. We looked at the top of the CORK. The stainless steel plug looked like new but had several rust stains near the contact with the borehole. It was not clear if this staining was from contact or seepage. It probably is from contact because (based on Juan de Fuca CORKS) fluid flow had a much broader affect on staining. The dive ended because operations were completed.

Jason Dive J2-756 and J2-757– Dorado Outcrop

Dorado Outcrop 9°5.0´N 87°5.72´W Water Depth 3100 m (maximum)

The same basket configuration was used for both dives

Figures above: Left, basket (temperature probe, heat flow probe, 3 markers, 10 push cores [5 with hole for rhizones and oxygen electrode] and suction sampler. Center, port side (4 cow and 4 squeezer fluid samplers [Blue]). Right, starboard side (basket for rocks with a divider on the swing arm and Niskin bottle above).

Prior to this dive, a grid of search blocks was created for Dorado Outcrop, based on bathymetry and temperature anomalies, to guide bottom surveys for hydrothermal venting. Also, the underlying navigation map in the Jason van was changed to help watch leaders determine their locations in the grid. Jason dive J2-756 started with a heat flow line to the northeast of the southern end of the outcrop while Sentry was mapping the summit and the southeast side. The heat flow survey continued to the wall. Because of poor navigation with Sentry when Jason was at the wall (Block 10), the proximity of Jason to Sentry caused some concern. The wall seemed to have no thermal anomalies. When Sentry was recovered the ship had to move to pick up Sentry. This caused a 2-hour delay in Jason operations. When Sentry was recovered the watch decided to start in the nearby block below the ship (Block 25). The dive was terminated when Jason lost telemetry. There are two broken fibers in the tether between Medea and Jason. Once on deck the Jason crew shifted communications to the third and final fiber of the tether.

No samples were collected. The dive was terminated because of lack of telemetry.

Jason Dive J2-757 started on the summit (Block 22). Most of the block (top of the summit) was cold. We found shimmering water at Marker E and collected water there. The temperature was 9.1°C in several holes (all temperatures are as recorded with the Jason probe, which has an offset of +1.5 °C relative to true temperature, as described earlier). Shrimp were observed in these warm holes and an octopus was hanging out. Marker E is in the corner of the Blocks 22/21 western boundary. This is a good site for an OsmoSampler and long-term temperature probe. Next was a track around the summit knoll in Block 23. We found lots of shimming water in this area around marker D. Further along in this block we measured 14.0°C. We continued to search for venting. We sampled water at Marker E. Following fluid sampling we moved to the flats to measure heat flow and collect push cores.

Elevator #2 was deployed and samples were replaced. We recovered fluid samplers (squeezers and cow syringes), 4 rocks, and 9 push cores. We deployed a fresh rack of 10 push cores, 6 exposure experiments, 2 OsmoSamplers, 4 sets of temperature recorders, 4 markers, a crowbar and a spike, and fluid samples (4 cow syringes and 4 squeezers).

It took 2 hours to return to the Marker D area. On the way we stopped and deployed Marker K. Temperatures reached 13.7°C. Water samples were collected and an OsmoSampler, 3 enrichment experiments, and one temperature logger were deployed. We then deployed 3 enrichment experiments, a temperature logger and an OsmoSampler about 10 m to the west of the previous deployment. Water here was warm, too. We then spend the next day looking for warm water. Some of the best flow was found at the southwest portion of the outcrop. Water was flowing vigorously. Another 13.9°C measurement was made deeper and to the west of Marker K. No other thermal measurements warrant description here. We deploy a temperature logger at Marker A with the OsmoSampler and 3 exposure experiments that were deployed on a previous dive.

The dive continued with measurements of heat flow. We got too close to Sentry, which resulted in problems for Sentry. Coupled with the elevator deployment, Sentry was out of place for about 4 hours.

Elevator #3 was deployed and the samples were replaced. We recovered fluid samplers (squeezers and cow syringes), 2 rocks, and 8 push cores that were placed on the elevator. We moved 3 exposure experiments, 1 OsmoSampler, 2 markers, and fluid samples (4 cow syringes and 4 squeezers [White]) from the elevator to the ROV. A Niskin was triggered once we approached the elevator.

After the elevator we made more measurements of heat flow on the ridge and on Line 3A before heading to the southern portion of the outcrop to collect fluids at the intensely flowing site.

We had to delay Jason operations to recover Sentry: 1.5-hour delay for Sentry recovery on 217 and 1.5-hour delay for Sentry recovery on 218, 3 hours for Sentry recovery on 219 and 0.5 hours for Sentry recovery on 220 (this was a science error) and 2 hours for Sentry recovery on 220 (total hours lost, 8.5 hours ~8%).

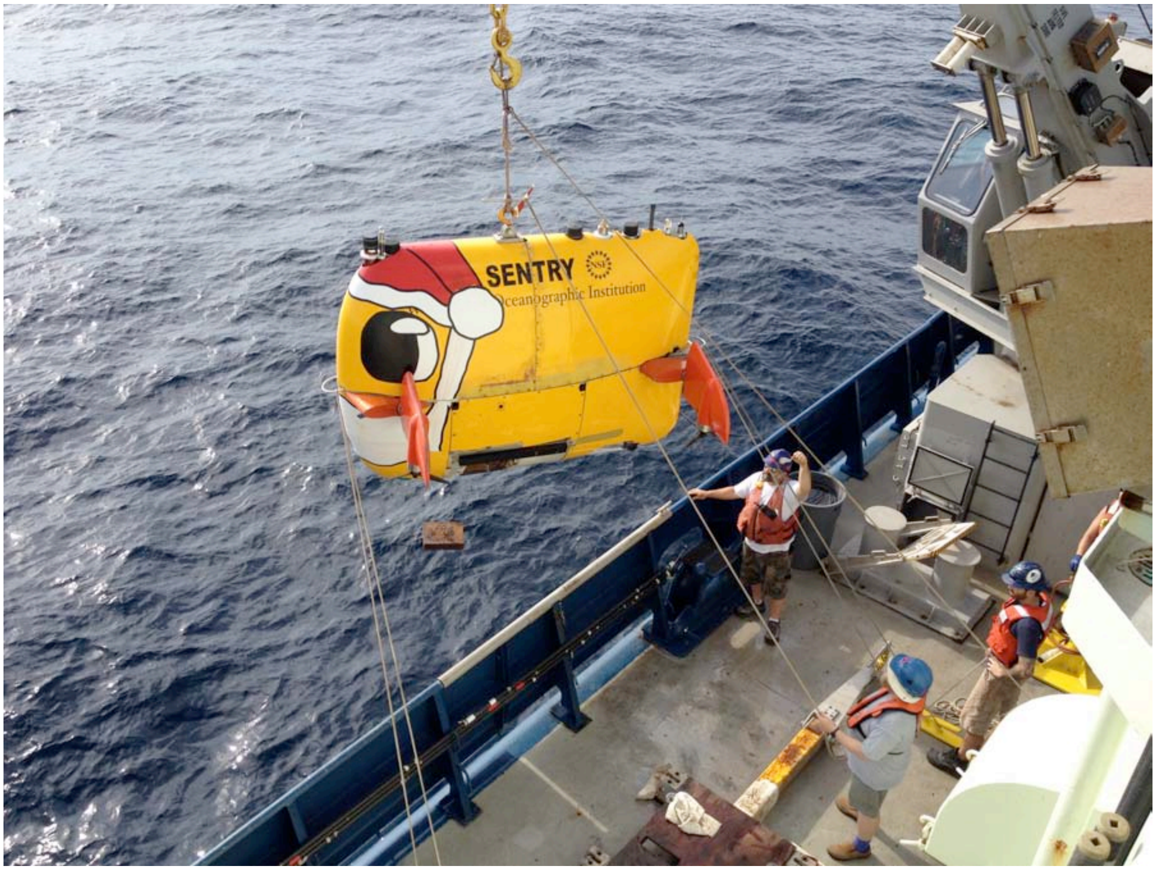
Elevator #2 took 4.5 hours.

Elevator #3 took 4 hours.

The dive was terminated because we ran out of time.

Sentry Dive 213 – Dorado Outcrop

Dorado Outcrop 9°5.0´N 87°5.72´W Water Depth 3100 m (maximum)



This dive was dedicated to a general bathymetric map of the feature. Most of the track-lines were along the strike of the feature with a few crossing lines. The vehicle was flying at 60 m above the seafloor. At the end of the dive there were a few lower crossings to test out the chirp sonar. These crossings were 30 m above the bottom. There were a few thermal anomalies associated with this dive. The sides-can data were not usable because of the focus on the chirp sonar data.

Sentry Dive 214 – Dorado Outcrop

Dorado Outcrop 9°5.0´N 87°5.72´W Water Depth 3100 m (maximum)

This dive was dedicated to get chirp data along lines that were perpendicular to the strike of the Dorado feature. These lines were designed for future heat flow surveys. The lines were run at 30 m above the bottom. The side-scan data for this dive are not usable because of the desire to get the best chirp data as possible. There were some thermal anomalies along the western side near the summit in the south. There were additional temperature anomalies detected.

Sentry Dive 215 – Dorado Outcrop

Dorado Outcrop 9°5.0´N 87°5.72´W Water Depth 3100 m (maximum)

This dive was dedicated to bathymetry and photos, flying 5 m above the bottom. The dive started on the ridge but north of the main hill to the southeast. After this rectangle was completed Sentry completed two postage stamp areas at the end of the northwest side before finishing with some work on the eastern side about in the middle of the outcrop. There were some thermal anomalies along the ridge, but not much in the two postage stamps nor in the eastern section. The side scan data were good. Much of the dive occurred at 5 m above the bottom.

Sentry Dive 216 – Dorado Outcrop

Dorado Outcrop 9°5.0´N 87°5.72´W Water Depth 3100 m (maximum)

The goal for this dive was to collect thermal and photographic data on top of the summit and the surrounding area. The dive started on the summit and the area to the northwest then move to the southern side of the summit. Finally the dive would work up the western slope that flanks the summit. The navigation was poor. Actual track lines overlap and cross, in contrast to the programmed lines that were parallel. Sentry hit the seafloor several times. This affected navigation. There were plenty of thermal anomalies detected during this dive. The intent was to dive 5 m above the bottom to collect photographs; however, this depth was changed from 5 m to 40 m on the southern side of the summit and then in the range of 7 to 10 m on the slope of the topographic high to the southeast. This variety of elevations was necessary, given the problems Sentry encountered with the steep relief (hitting the seafloor). Thus many of the images did not register the seafloor. The side-scan data should be good.

Sentry Dive 217 – Dorado Outcrop

Dorado Outcrop 9°5.0´N 87°5.72´W Water Depth 3100 m (maximum)

The goal for this dive was to collect thermal and photographic data on and across the feature just south of the northern pinnacle near Marker A. The swath was deigned to go across the strike of the feature. The dive was programmed in to have the vehicle fly at a 7 m above bottom. There were no excitable thermal anomalies.

Sentry Dive 218 – Dorado Outcrop

Dorado Outcrop 9°5.0´N 87°5.72´W Water Depth 3100 m (maximum)

The goal for this dive was to collect thermal and photographic data on and across the feature to the north of the northern pinnacle near Marker A. One swath was designed to go across the strike of the feature to the north of the topographic high. The second swath was designed to get data on the eastern side of the northern section. This swath overlapped with data collected during Sentry dive 215. Only one line was completed on the second swath. The dive was programmed in to have the vehicle fly at a 5 m above bottom. There were no excitable thermal anomalies.

Sentry Dive 219 – Dorado Outcrop

Dorado Outcrop 9°5.0′N 87°5.72′W Water Depth 3100 m (maximum)

The goal for this dive was to collect bathymetry and chirp data at 30 m above the bottom with line spacing at 50 to 70 m. The focus was the northern section of Dorado. The data will help clean up the bathymetric data and provide addition chirp sonar lines.

Sentry Dive 220 – Dorado Outcrop

Dorado Outcrop 9°5.0′N 87°5.72′W Water Depth 3100 m (maximum)

The goal for this dive was to collect ADCP and thermal data in a box around the main venting site on the western slope of Dorado. The idea was to use these data to constrain the total output of fluid from Dorado. This survey had navigation issues and Jason issues. We lost about 4 hours of data collection because Jason was in the way.

Heat Flow Report

The heat flow team was led by A. Fisher and R. Lauer from UCSC, with considerable assistance at sea from H. Villinger and A. Sturm (U. Bremen), C. Steinmetz (UCSC), and watch leaders C. G. Wheat (UAF), S. Hulme (MLML) and B. Orcutt (Bigelow). The primary goal of the heat flow program was to collect data that could be used to help quantify the total heat fluid output from Dorado outcrop. This cannot be done by direct measurement of fluid discharge because of the distributed nature of vent sites. Instead, the method used (as described in the NSF proposal) involved measuring heat flow along transects adjacent to the edges of the outcrop, co-located with seismic and Chirp data from which sediment thickness data could be determined, followed by analytical and numerical modeling to determine rates and patterns of fluid flow necessary to maintain observed thermal conditions.

The primary tool used for collection of new heat flow data was a 66-cm Alvin-style heat flow probe with five thermistors (spacing = 10 cm) and in-situ thermal conductivity capability. This instrument was operated from the Jason van using a Java-based graphical program that allowed setting of the probe measurement interval, power and timing of the heat pulse for thermal conductivity, and automated logging of formatted data. This program was developed at UCSC prior to AT26-09, and was left with the Jason technical team for potential use on future expeditions.

In addition, the UCSC team also developed a heat flow probe insertion frame system for use in maintaining a vertical orientation of the probe when it was pushed into the seafloor. This device consisted of a square, stainless steel and Delrin base, and a stainless steel, PVC and aluminum guide tube oriented perpendicular to the base. A circular clap placed on the pressure case of the heat flow probe was attached to clamp arms and a block at the top, allowing the Jason manipulator to push the probe into the guide tube when desired. A prototype of this system was tested on AT26-03 in Summer 2013, and found to work reasonably well, but some modifications were made to the system prior to deployment on AT26-09.

A listing of heat flow measurement locations and other information is presented in Table 4, and a plot showing locations and preliminary values (binned within ranges of interest) is shown in Figure 3. Seventy-two heat flow measurements were made, with the majority located along transects oriented roughly perpendicular to Dorado Outcrop. A few measurements were made on the top or along steep slopes of the outcrop, where there was sufficient sediment to allow penetration of at least three of the probes five thermistors. In-situ thermal conductivity was determined during most tool penetrations, and data were generally of high quality. Final processing of AT26-09 will require a careful assessment of data quality, sensor by sensor, and compilation of thermal conductivity values for use in deriving a subseafloor function to be used in lieu of direct measurements when the latter were not possible. In addition, careful analysis will be required for assessment of several measurements in which may indicate non-conductive conditions.

Geochemistry Report

The geochemistry team was led by G. Wheat and J. McManus with considerable assistance at sea from T Fournier, K. Inderbitzen, M.J. Zirbe, K. Soto and T. Mellett. The primary goal of the geochemical program was to collect pristine hydrothermal fluids that would undergo a series of analyses to determine the composition of the hydrothermal fluid and deviations from seawater values. On the basis of prior work, we hypothesized that the hydrothermal fluid will have a similar composition to seawater. Therefore, we anticipated any chemical anomalies to be minimal (<5% of sweater values) and took care to analyze multiple background samples with those expected to be hydrothermal in origin.

Fluids were collected with cow syringes (100 ml), squeezer samplers (200-ml), and a 5-l Niskin bottle. The cow syringes and squeezer samplers were rinsed in dilute bleach, rinsed in 10% HCl, rinsed in milli-q water (18.2 mega ohms) and primed with bottom seawater that was filtered. Additional fluids were extracted from sediment push cores using rhizones and from squeezing in the cold room (~4°C). Rhizone sampling occurred at 2-cm intervals and we extracted ~10 ml of fluid after discarding the initial 1 ml. Pore fluids also were extracted by squeezing through plastic "mud juicers". Extracted volumes were about 10 ml for a 2-cm-long interval. All fluids were aliquoted into hot-acid-washed-HDPE bottles, glass ampoules and other glass containers for shipboard and shore-based analyses.

At sea we measured the pH, alkalinity, and nitrate in fluids collected using cow syringes, squeezer samplers, and Niskin bottles. We also measured the nitrate concentration in pore fluids. Initial results indicate that the spring fluid samples had seawater concentrations of nitrate; however, these hydrothermal fluids had a slightly lower pH and alkalinity. Pore fluid nitrate concentrations indicate nitrification and denitrification in the sediment. No sulfide odor was present in any sediment samples.

Four OsmoSampler systems with temperature probes were deployed to assess the temporal composition of venting fluids and to collect pristine fluids. OsmoSampler intakes were jammed into holes beyond where fluid samplers could reach. Because of the slow draw of fluids in OsmoSamplers, we anticipate that these fluids will not be diluted with bottom seawater, thus providing the most pristine fluids when they are recovered in 2014.

Microbiology Report

The primary objective of Team MBIO (participants Orcutt, Carr, and Lee) was to determine the influence of the suspected "fire hose" of low temperature hydrothermal venting on the rock, sediment and fluid microbial communities of Dorado outcrop. Our approach was to collect shallow sediment push cores, seawater-exposed rocks, venting fluids, and bottom water for shipboard and shore-based analyses, and to also deploy custom rock exposure experiments at several sites for a ~year incubation (Table 1). Several warm (up to ~14°C with the temperature probe) vents were located on Dorado outcrop, primarily at the southeastern end, with varying degrees of basalt alteration observed at the vent sites.

Shipboard oxygen measurements in sediment push cores documented that all cores became anoxic within a few centimeters of the sediment-water interface, several cores had shallowly buried Mn crusts, and one core exhibited upward flow of oxygen, suggesting oxic conditions in the Dorado subsurface. None of the cores had a sulfidic odor. A dozen rocks were collected from around Dorado - all had thick Mn crusts on the exterior, and several had iron oxide staining and clay alteration. Discrete fluid samples were chemically very similar to bottom water, and spot analysis of fluid samples indicated near bottom water oxygen concentrations.

Exposure experiments consisting of pyrite and pyrrhotite and glass wool were deployed at four different locations on the outcrop. One set was deployed at Marker A with 13.1°C fluids in a venting seam with Mn-crusted basalts, another set was deployed at Marker K with 13.7°C fluids in altered basalts, another set was deployed at Marker D with 7.1°C fluids in rocks that showed extensive iron oxide staining, and a final set was deployed at Marker M on pillow basalts without evidence of venting. OsmoSampler packages were also deployed at Marker A, Marker K and near Marker M by Wheat's group.

A secondary objective of Team MBIO was to recover and sample a FLOCS experiment that had been deployed in the ODP Hole 1253A CORK in 2009. Incubation experiments were set up to analyze the potential for sulfate reduction in the recovered samples, and samples were preserved for shore-based analyses.

Table 1. MBIO Sample overview

Dive	# rocks for MBIO	#push cores for MBIO	#fluid samples for MBIO	MBIO FLOCS recoveries	MBIO EE deployments
J2-751	0	0	6	0	0
J2-752	6	4	5	0	3
J2-753	0	0	0	1	0
J2-754	0	0	0	0	0
J2-755	0	0	0	0	0
J2-756	0	0	0	0	0
J2-757	6	7	6	0	9

Education and Outreach

Media

Prior to the start of the Dorado expedition, the University of Southern California media office worked with C-DEBI to develop a press release about the cruise (http://pressroom.usc.edu/december-expedition-to-explore-life-in-hydrothermal-vent/), which was broadly distributed. Orcutt was interviewed by Los Angeles radio station KCRW in relation to this press release, and Orcutt also promoted the expedition on Twitter at #DoradoOutcrop and #CDEBI.

Blogging

http://www.darkenergybiosphere.org/dorado/

The cruise to the Dorado outcrop expedition gave an opportunity to share the scientific processes with the general public and, specifically, with Grade 4-8 teachers and their students. A blog page entitled, "Discovering Dorado," was developed on the C-DEBI website prior to departure. Included were categories and pages dedicated to, among other things, background, facts and insights about the purpose of the expedition, the ship, the scientists, the crew and technical equipment specialists on board, and informative links expanding related research topics explained at an appropriate grade level. Author bios and first blogs personalized this "learn-with-us journey" by educators with relatively little science and technology training.

Because the ship was leaving from Puntarenas, Costa Rica, coverage began several days prior first from San Jose, Costa Rica, with a focus on nearby cultural and natural features such as museums, the market, a volcano, a coffee plantation, and an animal reserve and waterfall park. The "tour" of the area continued on the central Pacific coastal region with a naturalist-guided hike through Manuel Antonio National Park. Photos, videos, interviews and blogs showcasing scenes, wildlife and the biodiversity of the area in general were created with the intention of capturing a glimpse of the country whose offshore waters and seafloor would soon be the subject of the science team's research. Connecting the land and ocean environments and habitats provided a broad-perspective link for those following along.

Upon boarding the R/V Atlantis, reporting of the ship's activities began with interviews with the crew and scientists, along with an overview of daily life anecdotes and description of science-team. Since life on a research vessel was not a normal experience for either educator, and that was likely the case for the majority of the classroom and public audience, essentially any information about the experience could inform them. However, the key goals of the blog page were to alert its readers of 1) the mission of the science party and how scientists plan and record their activities in the field, 2) how it is to live on a research vessel for the length of an expedition, 3) how different groups interact – from the crew to the scientists to the robotics (Sentry, JASON,) teams, and 4) current technological innovations that offer scientists the opportunity to gather and process data with increasing efficiency.

In order to encourage readers to communicate with the authors through the blog page channel, a comment thread was activated. Other means of contact available were personal and work email addresses. The majority of input and questions came through the latter. It was observed that along with the authors, the scientists, the crew and the robotic teams also shared the blog link with family, friends, and work associates to inform them about their experiences at sea. In terms of connecting to teachers and students, notification about the blog went to the following: all middle school science classes as well as all fourth and fifth grade classes in the Columbia, MO, school district and five middle school classrooms in Monterey, CA, and one in Cupertino, CA. In addition, a science teaching methods class at the University of Missouri was invited to follow the blog.

In reflecting on the experience in its entirety, the authors agreed that it provided an incredible insight for them, personally and professionally in terms of gaining understanding of the breadth of planning and organization that goes into such an undertaking. The blog, itself, was intended to serve as an format for communication to the outside; an eye into the goings on aboard the R/V Atlantis, and ultimately allowed for a unique chronicling and highlighting of the science team's activities during the expedition. In this, it succeeded.

The authors also determined that there are technical issues inherent in an offshore setting that impact the ability to contribute to a blog in a seamless fashion. Because of a slow and sporadic Internet connection on the ship, the blog program was inconsistent. Admittedly, the authors' knowledge of the development and management of the blog page was limited. And, although support was available and the authors' skill levels increased during the cruise, it would have been beneficial to ensure greater familiarity with the blog page program through a more thorough training experience. This would have at least given the authors insight as to when problems that occurred were their mistakes or simply technical difficulties.

The blog page will remain on the C-DEBI website for an indefinite period, and so will offer a standing accounting of time on the ship during the Dorado excursion that can be used as classroom learning tool. Beyond that, the broader experience will be shared in person during spring semester 2014 by one of the authors in various Columbia, Missouri, elementary, middle and university classrooms. In addition, the authors' increased understanding of the exploration science and technology used on the R/V Atlantis and life on the ship, in general, will be instrumental in developing the technology-oriented coursework for the K-6 RETINA program and the related grade 5-8 LASER summer camp. In the event that a future scientific cruise blog is planned for education outreach, the Discovering Dorado blog format as it has been developed may provide a useful structure to follow.

Figure 1. Layout and depth of components in the ODP Hole 1253A downhole string.

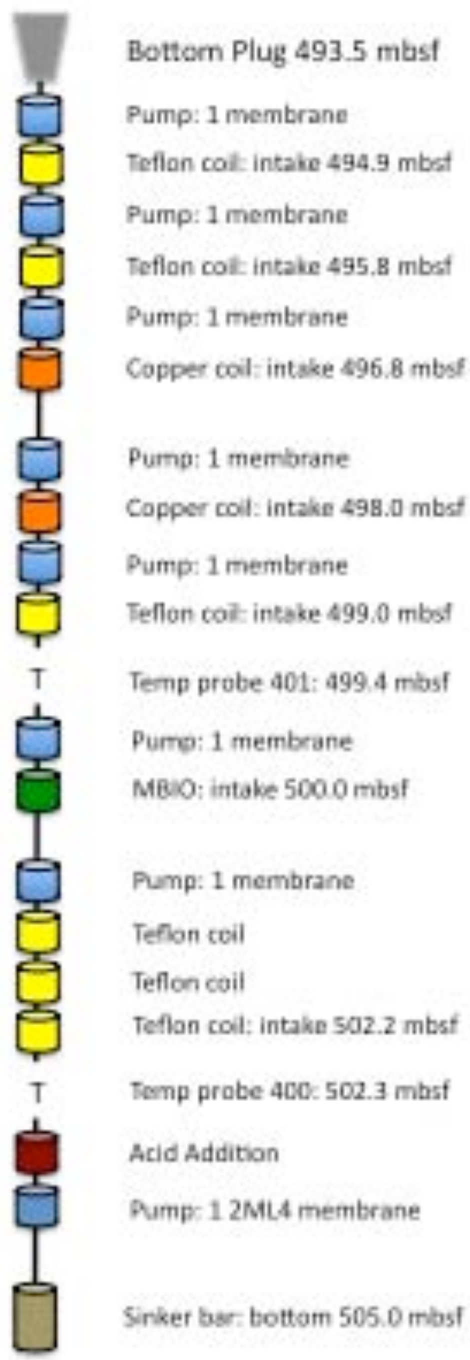


Figure 2. Bathymetric map based on multi-beam from several Sentry dives with 10-m contours.

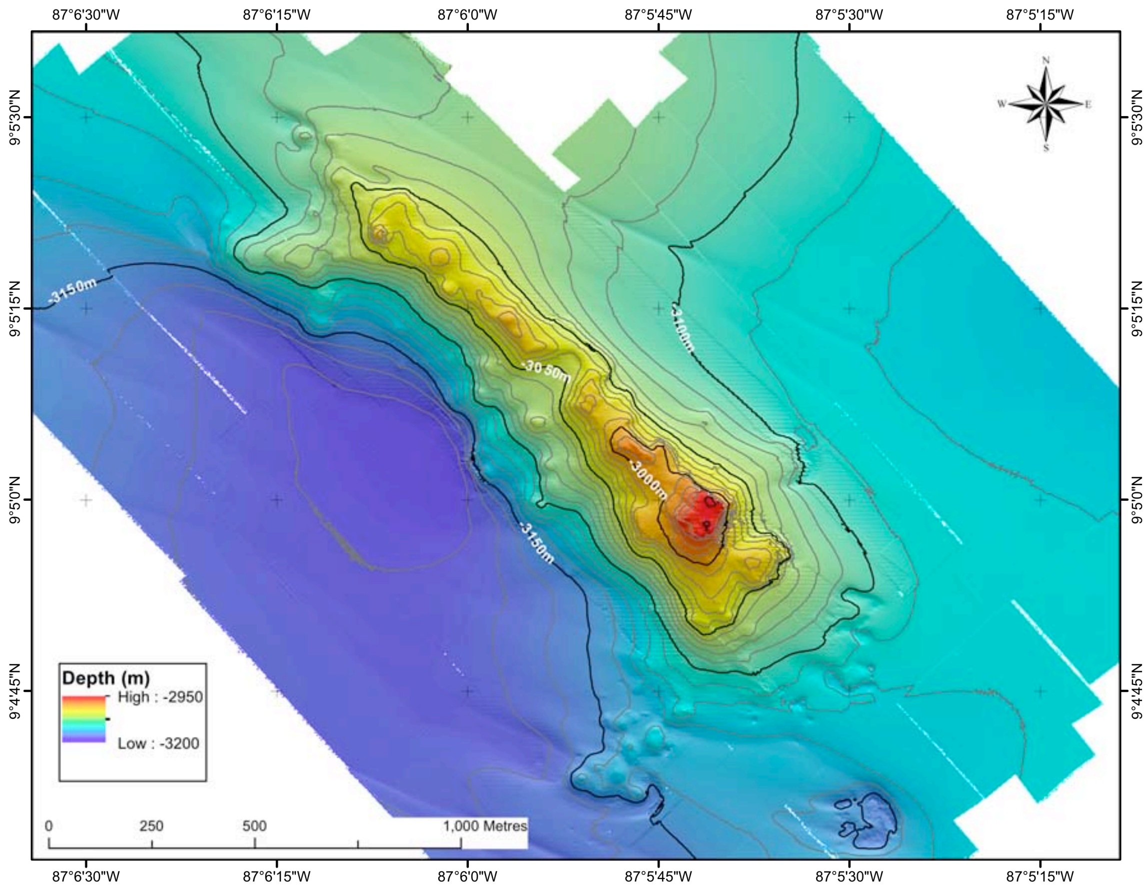


Figure 3. Heat flow results

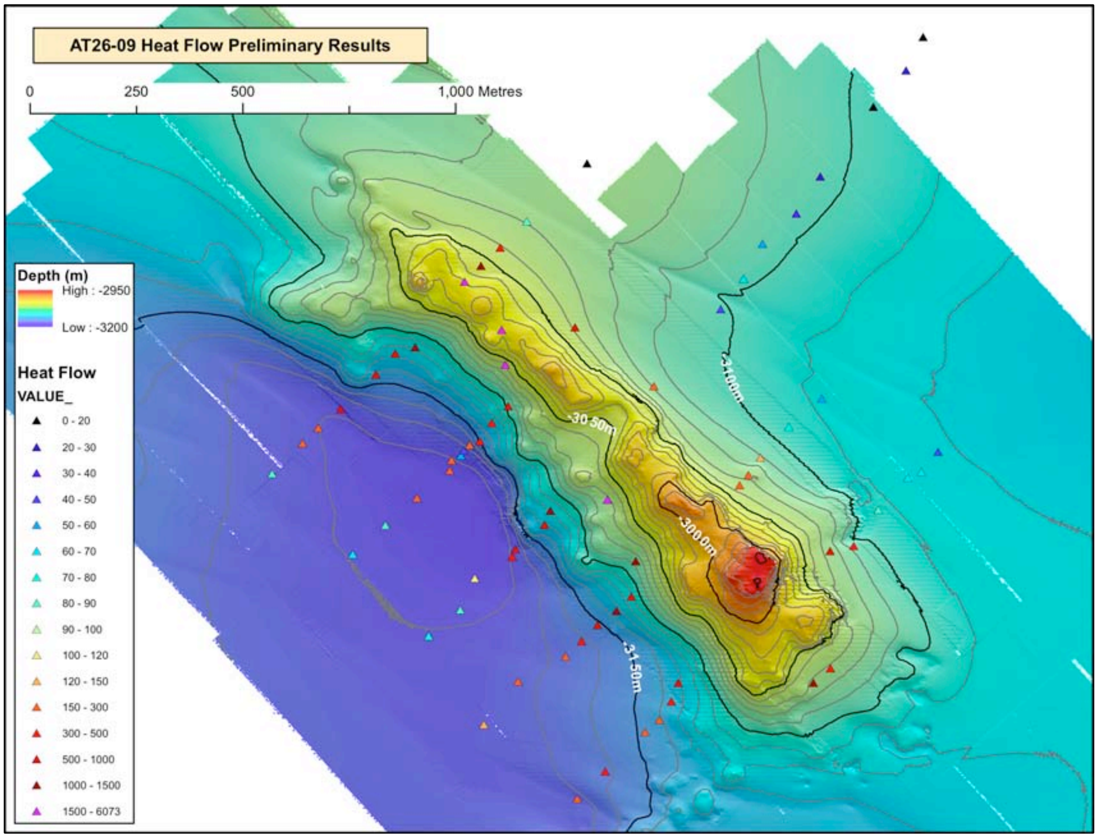


Figure 4. Sample locations.

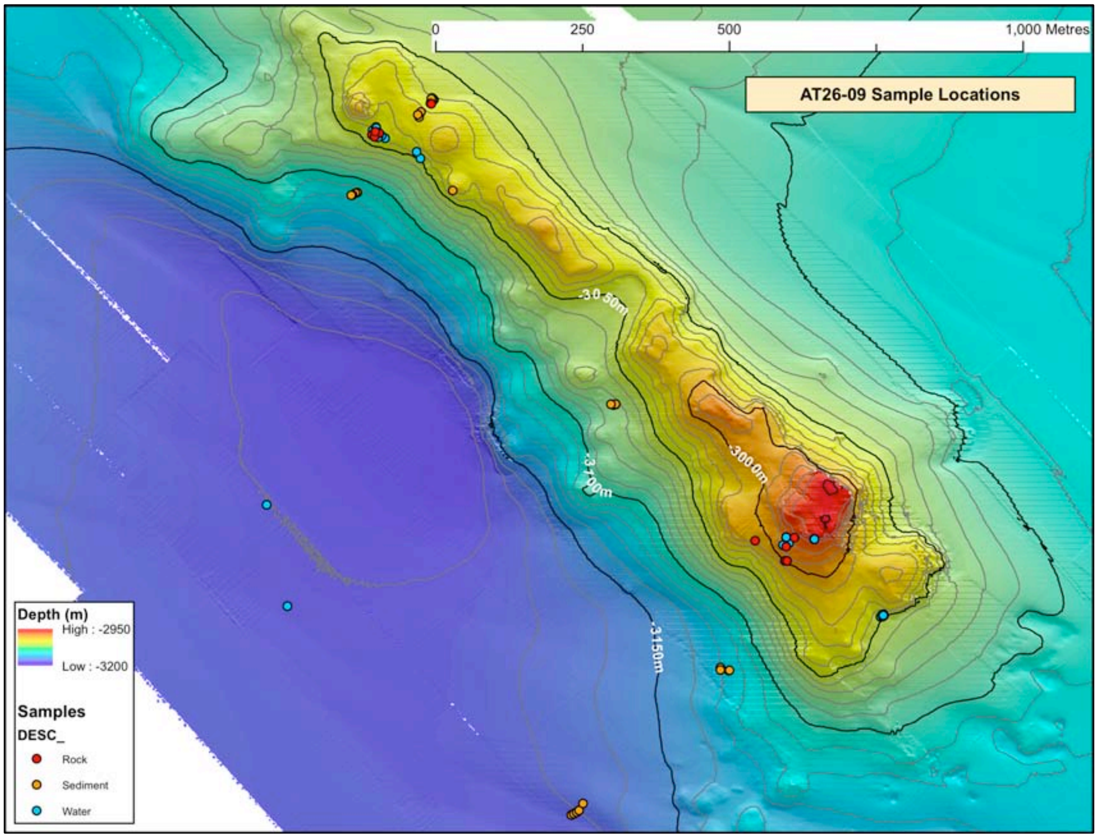


Figure 5. Measurements with the temperature probe

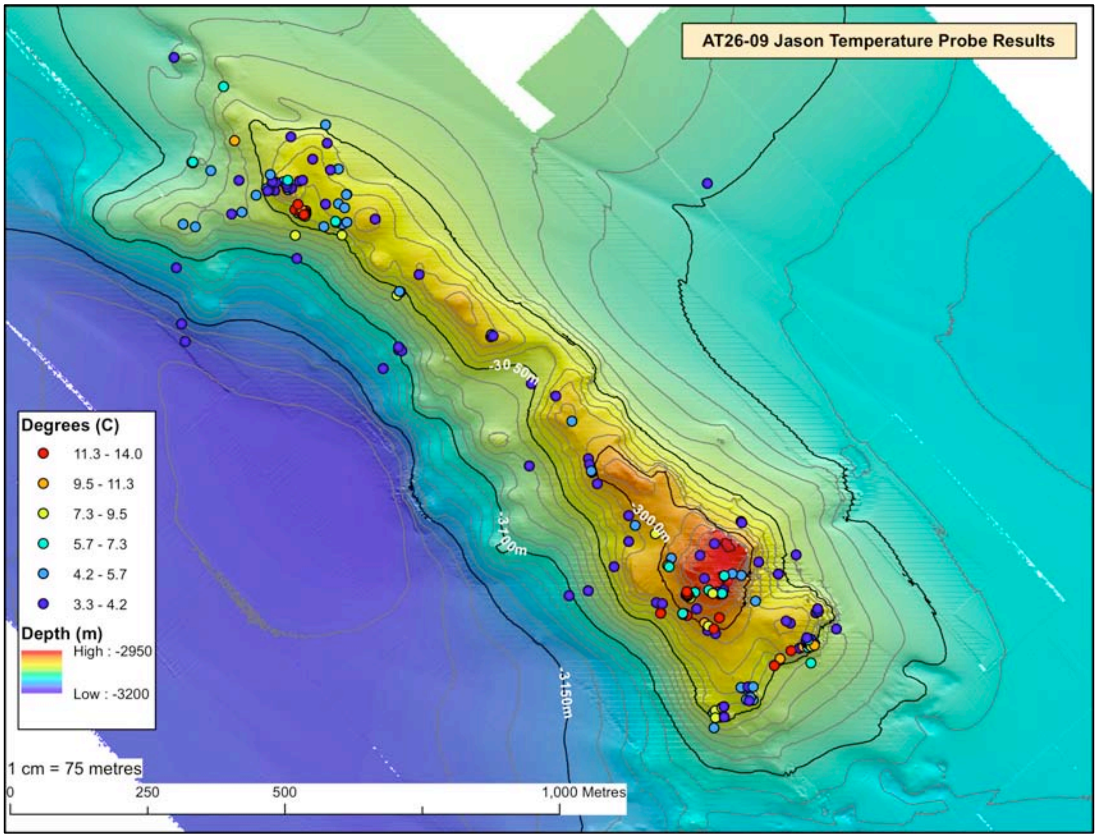


Figure 6. All Sentry thermal anomalies (various depths above seafloor).

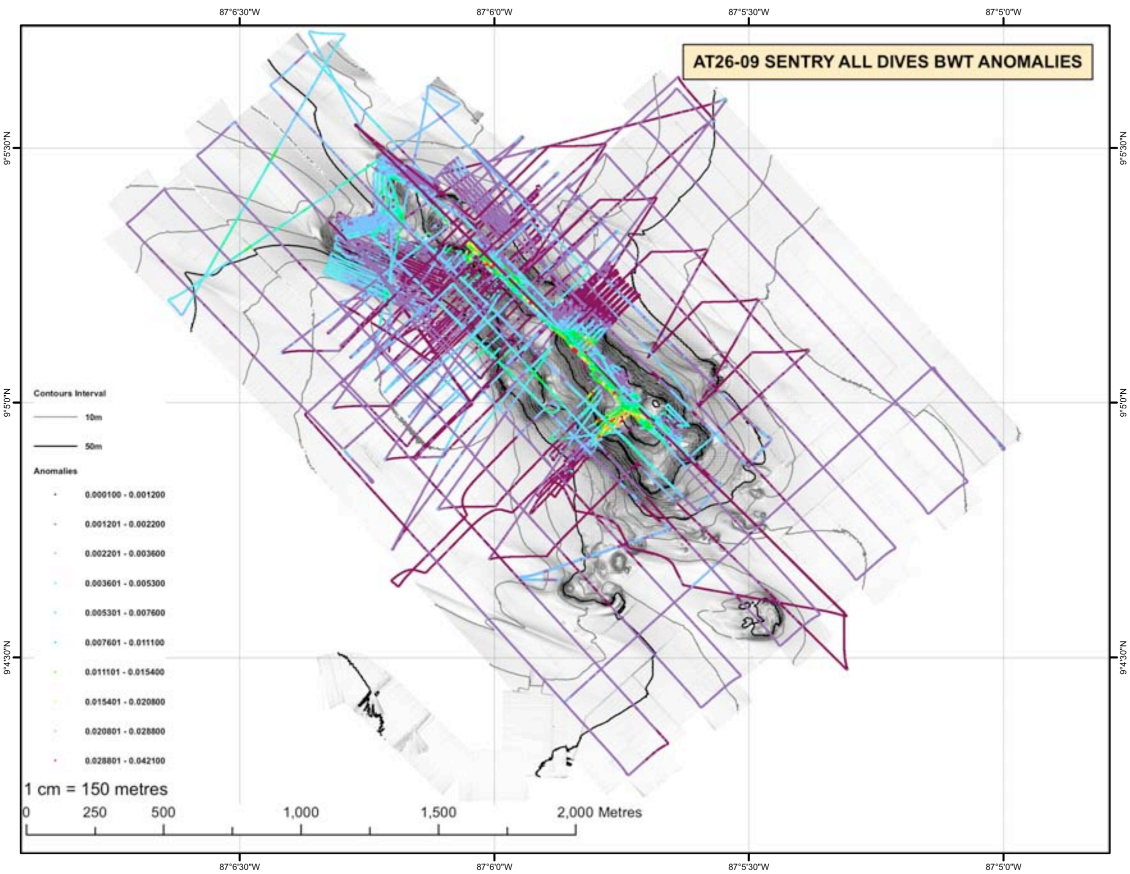


Table 1. Ship and Shore-based Scientific Participants on AT26-09.

#	Name		Location	Email	Position	Funding
	Shipboard					
1	Geoff Wheat	M	UAF	wheat@mbari.org	Professor	NSF Funded
2	Trevor Fournier	M	UAF	tfournier@csumb.edu	Grad. Student	
3	Katie Inderbitzen	F	UAF	kinderbitzen@alaska.edu	Post Doc	C-DEBI funded
4	Andy Fisher	M	UCSC	afisher@ucsc.edu	Professor	NSF Funded
5	Rachel Lauer	F	UCSC	rlauer@ucsc.edu	Post Doc	
6	Travis Mellett	M	UCSC	tmellett@ucsc.edu	Student	
7	Cory Steinmetz	M	UCSC	csteinme@ucsc.edu	Student	
8	Sam Hulme	M	MLML	samiam0101@gmail.com	Professor	NSF Funded
9	Chris Trebaol	M	MLML	chris.trebaol@gmail.com	technician	
10	Kenji Soto	M	MLML	ksoto@mlml.calstate.edu	Grad. Student	
11	Beth Orcutt	F	Bigelow	borcutt@bigelow.org	Professor	C-DEBI funded
12	Michael Lee	M	USC	leemd@usc.edu	Grad. Student	
13	Heiner Villinger	M	Bremen	vill@uni-bremen.de	Professor	
14	Arne Schwab	M	Bremen	aschwab@uni-bremen.de	Grad. Student	
15	Marnie Jo Zirbe	F	OSU	mjzirbel@coas.oregonstate.edu	Technician	C-DEBI funded
16	Stephanie Carr	F	Colorado School of Mines	scar@mymail.mines.edu	Post Doc	C-DEBI funded
17	Gail Underwood	F	UM/UAF	gail.underwo@gmail.com	Educator	
18	Karen Monahan	F	UM/UAF	nmaeng@aol.com	Educator	
	Shore-based					
19	Brandon Briggs	M	MUO	briggsbr@muohio.edu	Post Doc	C-DEBI funded
20	Charles Vidoudez	M	Harvard	charlesvidoudez@gmail.com	Post Doc	C-DEBI funded
21	Scott Wankel	M	WHOI	sdwankel@whoi.edu	Professor	

Table 2. Cruise log (Local time)

Cruise Log Event	AT26-09 Duration (hrs)	(days)	StartDayTime	EndDayTime
Transit	11.5	0.48	12/7/13 8:30	12/7/13 20:00
Ship Multibeam	14.5	0.60	12/7/13 20:00	12/8/13 10:30
Sentry Dive, 213	20	0.83	12/8/13 11:30	12/9/13 7:30
Jason Dive, 750	3	0.13	12/8/13 14:30	12/8/13 17:30
Jason Dive, 751	100	4.17	12/8/13 19:15	12/12/13 23:15
Sentry Dive, 214	16.5	0.69	12/10/13 15:30	12/11/13 8:00
Elevator 1	4	0.17	12/11/13 8:30	12/11/13 12:30
Sentry Dive, 215	22.5	0.94	12/12/13 8:30	12/13/13 7:00
Jason Dive, 752	12	0.50	12/13/13 8:00	12/13/13 20:00
Ship Multibeam	11	0.46	12/13/13 20:30	12/14/13 7:30
Jason Dive, 753	9	0.38	12/14/13 8:00	12/14/13 17:00
Jason Dive, 754	9	0.38	12/14/13 20:15	12/15/13 5:15
Jason Dive, 755	11	0.46	12/15/13 12:00	12/15/13 23:00
Ship Multibeam	8	0.33	12/16/13 0:00	12/16/13 8:00
Sentry Dive, 216	12.5	0.52	12/16/13 8:30	12/16/13 21:00
Jason Dive, 756	15	0.63	12/16/13 12:00	12/17/13 3:00
Sentry Dive, 217	14	0.58	12/17/13 8:30	12/17/13 22:30
Jason Dive, 757	102	4.25	12/17/13 10:00	12/21/13 16:00
Sentry Dive, 218	14	0.58	12/18/13 8:00	12/18/13 22:00
Elevator 2	4.5	0.19	12/18/13 22:30	12/19/13 3:00
Sentry Dive, 219	20	0.83	12/19/13 12:30	12/20/13 8:30
Sentry Dive, 220	26.5	1.10	12/20/13 21:00	12/21/13 23:30
Elevator 3	4.5	0.19	12/21/13 13:00	12/21/13 17:30
Transit to port	14	0.58	12/22/13 16:00	12/23/13 6:00
Target arrival:				12/23/13 7:00
Total Days:	**on site**	**14.83**	**port to port**	**15.94**

Table 3. Samples collected on AT26-09, Dorado Outcrop and ODP Sites 1253 and 1255.

Identification of Sample	J750	J751	J752	J753	J755	J756	J757
Location	Dorado	Dorado	Dorado	1253A	1253-1255	Dorado	Dorado
CS Fluid	0	4	4	0	0	0	10
E Experiment	0	0	3	0	0	0	9
Flow Meter	0	0	0	0	1	0	0
Heat Flow	0	37	3	0	0	6	28
Niskin	0	1	1	0	0	0	2
OsmoSampler	0	0	1	1	0	0	3
Push Cores	0	0	10	0	0	0	19
Rock Samples	0	0	6	0	0	0	5
Site markers	0	3	0	0	0	0	6
Squeeze Fluids	0	4	4	0	0	0	12
T Probe	0	110	3	0	0	0	68
Pressure data	0	0	0	0	2	0	0
T Loggers	0	0	0	0	0	0	4

Table 4. Summary of heat flow measurement locations, number of sensors used, and deepest penetration.

Measurement ID	Latitude (°N) [a]	Longitude (°E) [a]	N sensors [b]	Deepest (m) [c]
HF-751-01	9.094	-87.091	4	0.70
HF-751-02	9.094	-87.092	3	0.55
HF-751-03	9.093	-87.092	3	0.65
HF-751-04	9.092	-87.093	4	0.48
HF-751-05	9.091	-87.094	4	0.50
HF-751-06	9.090	-87.095	3	0.41
HF-751-07	9.089	-87.095	4	0.41
HF-751-08	9.089	-87.096	4	0.40
HF-751-09	9.087	-87.097	4	0.40
HF-751-10	9.092	-87.098	4	0.40
HF-751-11	9.090	-87.100	3	0.88
HF-751-12	9.090	-87.100	3	0.31
HF-751-13	9.089	-87.101	4	0.42
HF-751-14	9.089	-87.101	5	0.55
HF-751-15	9.089	-87.101	4	0.44
HF-751-16	9.088	-87.102	5	0.48
HF-751-17	9.087	-87.103	5	0.65
HF-751-18	9.086	-87.104	5	0.60
HF-751-19	9.086	-87.104	5	0.58
HF-751-20	9.086	-87.104	5	0.58
HF-751-21	9.085	-87.105	4	0.58
HF-751-22	9.083	-87.103	5	0.55
HF-751-23	9.084	-87.103	4	0.50
HF-751-24	9.085	-87.102	5	0.59
HF-751-25	9.085	-87.101	5	0.56
HF-751-26	9.086	-87.101	4	0.57
HF-751-27	9.086	-87.101	4	0.38
HF-751-28	9.086	-87.100	5	0.45
HF-751-29	9.087	-87.100	4	0.35
HF-751-30	9.081	-87.094	5	0.55
HF-751-31	9.081	-87.093	5	0.58
HF-751-32	9.083	-87.093	5	0.59
HF-751-33	9.084	-87.093	5	0.67
HF-751-34	9.084	-87.093	5	0.50
HF-751-35	9.085	-87.092	5	0.52
HF-751-36	9.085	-87.091	4	0.62
HF-751-37	9.086	-87.091	4	0.60
HF-752-01	9.088	-87.099	5	0.60
HF-752-02	9.089	-87.101	5	0.80
HF-756-01	9.087	-87.093	5	0.54
HF-756-02	9.086	-87.094	5	0.58
HF-756-03	9.085	-87.095	5	0.58

HF-756-04	9.085	-87.095	3	0.32
HF-756-05	9.085	-87.095	5	0.58
HF-757-01	9.081	-87.096	3	0.36
HF-757-02	9.080	-87.096	5	0.58
HF-757-03	9.080	-87.097	5	0.53
HF-757-04	9.080	-87.097	3	0.37
HF-757-05	9.079	-87.098	5	0.61
HF-757-06	9.078	-87.098	5	0.60
HF-757-07	9.080	-87.100	5	0.68
HF-757-08	9.081	-87.100	5	0.60
HF-757-09	9.088	-87.102	4	0.36
HF-757-10	9.086	-87.101	5	0.58
HF-757-11	9.085	-87.101	5	0.60
HF-757-12	9.082	-87.102	5	0.63
HF-757-13	9.082	-87.101	5	0.62
HF-757-14	9.084	-87.098	4	0.35
HF-757-15	9.086	-87.101	3	0.36
HF-757-16	9.087	-87.100	3	0.29
HF-757-17	9.088	-87.100	5	0.51
HF-757-18	9.084	-87.099	5	0.58
HF-757-19	9.084	-87.099	5	0.59
HF-757-20	9.083	-87.100	5	0.45
HF-757-21	9.083	-87.100	5	0.60
HF-757-22	9.099	-87.101	4	0.37
HF-757-23	9.081	-87.099	5	0.59
HF-757-24	9.082	-87.098	5	0.57
HF-757-25	9.082	-87.098	5	0.61
HF-757-26	9.082	-87.098	5	0.57
HF-757-27	9.083	-87.097	3	0.27
HF-757-28	9.083	-87.097	3	0.24

[a] Measurement locations are rounded to nearest 0.001°.
[b] Number of sensors that penetrated the seafloor and appear to have provided useful data.
[c] Subseafloor depth of deepest usable sensor, based on a depth shift required to pass the observed gradient through bottom water at the seafloor.