RV *Falkor* & HROV *Nereus*

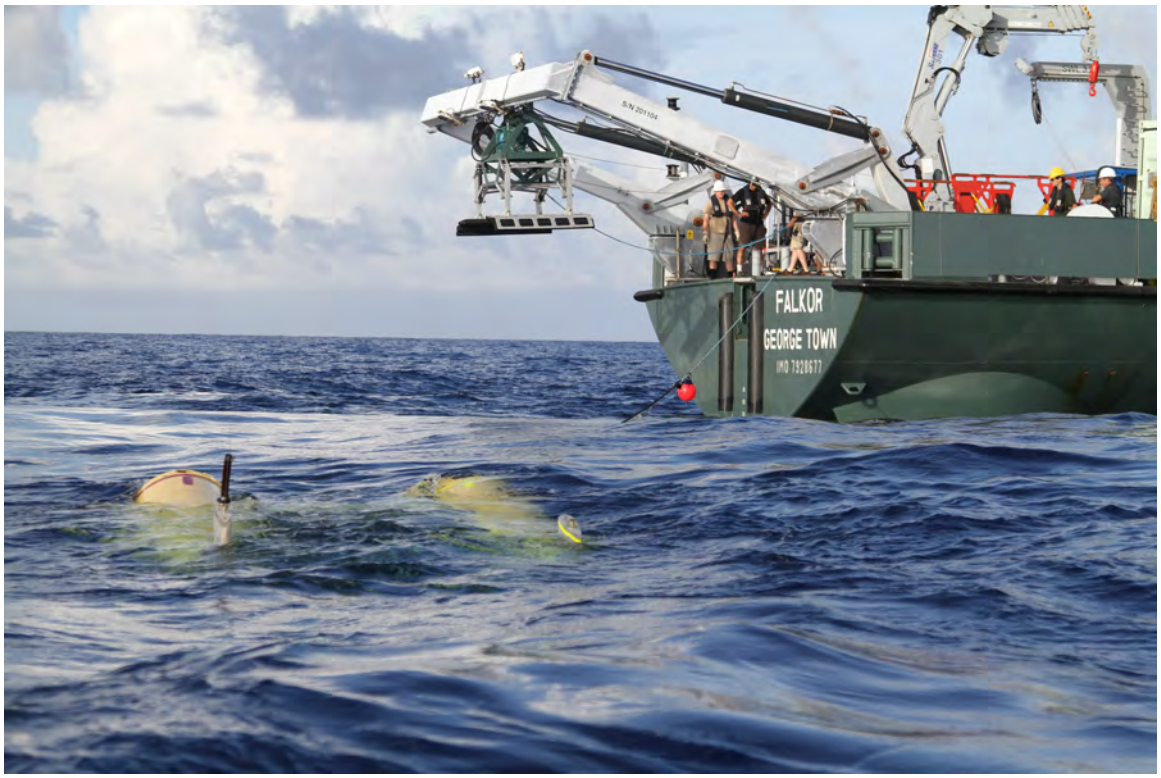
FK008 (OASES 2013)

Cruise Report – June 2013

Chief Scientist: C.German (WHOI)
Cruise Coordinator: L.Rolley (SIO)
Expedition Leader: C.Machado (WHOI)

1. Summary

RV “Falkor” Cruise FK008 sailed to the Mid-Cayman Rise to study novel hydrothermal systems and explore for additional sources of hydrothermal venting over two legs, using the RV Falkor’s swath bathymetry and CTD-rosette systems coupled with the WHOI Deep Submergence Laboratory’s HROV vehicle *Nereus.* The cruise was divided into two legs with Nereus used in AUV mode on Leg 1 (St. Petersburg, Florida – Montego Bay, Jamaica; May 30-June 17, 2013) and in ROV mode on Leg 2 (Montego Bay, Jamaica – Montego Bay Jamaica, June 18-July 1, 2013). On Leg 1, AUV operations were coupled with extensive use of the CTD rosette and *in situ* and shipboard geochemical analyses to explore for new sources of hydrothermal activity as well as to conduct AUV-based surveys at the Von Damm hydrothermal field and biogeochemical investigations using the CTD-rosette to sample young buoyant and non-buoyant plume material above both the Von Damm and Piccard hydrothermal fields. On Leg 2 a series of ROV dives were conducted to both the Von Damm and Piccard hydrothermal fields which were closely co-ordinated with Japanese colleagues aboard the RV Yokosuka (PI Ken Takai, JAMSTEC) who were conducting Shinkai 6500 Human Occuppied Vehicle tests at the same sites. In parallel, we continued to conduct further swath mapping of the ridge axis and to collect additional water samples from above each site using the CTD rosette between ROV dives.



2. Contents

3. Personnel

3a) RV *Falkor*

Heiko Volz	Captain
Phillipp Günther	Chief Officer
Thiago da Silva*	2nd Officer
Helge Jürgensen	2nd Officer
Paul Shepherd	2nd Officer
Miroslav Mirchev	Chief Engineer
Dan Bühler	2nd Engineer
Jeremy Jansen	ETO Engineer
Ramon Tabaque	2nd Engineer
Götz Förster	3rd Engineer
Lars Tönsfeldt	Bosun
Michael Utley**	Lead Deckhand
Mateusz Wróblewski*	Deckhand
Lisa Spitzhüttl	Deckhand
Kyrylo Ierofieiev**	Deckhand
Edwin Pabustan	Fitter
Sonny Castro	Fitter
Adriana Zamudio	Purser
Verena Neher	Stewardess
Leny Pancito	Stewardess
Grzegorz Kuberski	Head Chef
Arkadiusz Ochocki	Chef
Leighton Rolley	Cruise Coordinator
Nathan Cunningham	Marine Technician
Paul Duncan	Marine Technician

* Leg 1 only

** Leg 2 only

3b) HROV *Nereus*

Leg 1 (AUV mode)

Casey Machado	WHOI
James Kinsey	WHOI
Mike Jakuba	WHOI
Daniel Gomez-Ibanez	WHOI
Loral Ohara	WHOI
Mario Gomez	WHOI

Leg 2 (ROV mode)

Casey Machado	WHOI
James Kinsey	WHOI
Andrew Bowen	WHOI
Christopher Taylor	WHOI
Jonathon Howland	WHOI
Clifford Pontbriand	WHOI
Mario Gomez	WHOI

3c) Scientific Party

Leg 1

Christopher German (Chief Scientist)	WHOI
John “Chip” Breier	WHOI
Max Coleman	NASA-JPL & U.Reading, UK
Meg Estapa	WHOI
Jill McDermott	WHOI-MIT Joint Program
Ko-ichi Nakamura	AIST, Japan
Eoghan Reeves	MARUM/U.Bremen, Germany
Cody Sheik	U.Michigan
Sean Sylva	WHOI

Leg 2

Christopher German (Chief Scientist)	WHOI
John “Chip” Breier	WHOI
Max Coleman	NASA-JPL & U.Reading, UK
Julie Huber	MBL
Jill McDermott	WHOI-MIT Joint Program
Julie Reveillaud	MBL
Jeffrey Seewald	WHOI
Sean Sylva	WHOI
Cindy Van Dover	DUML

4. Cruise Narrative

4a) Summary

RV Falkor Cruise FK008 took place over two legs exploring for and investigating new and recently discovered seafloor hydrothermal fields on the Mid-Cayman Rise between May 30th and July 1st, 2013. A complete list of all events is provided in Appendix 1: Event Log. [Note: this RV *Falkor* log is in reverse chronologic order].

4b) Leg 1: May 30th – June 17th, 2013.

Mobilization was in St Petersburg, Florida and began on May 26th with Nereus fully installed aboard ship and ready for departure at 13:00 UTC on May 30th. Transit to the work area on the Mid-Cayman Rise included shake-down stations for the Nereus vehicle in AUV mode, focused primarily on testing the ship's ability to launch and recover the vehicle (May 30th) and a test/background station for the CTD-rosette (CTD01) on May 31st.

Upon arrival in the work area, the first priority was to conduct two CTD casts for biogeochemical and microbial sampling over the Von Damm hydrothermal field near 18°22'N, 81°50'W (2300m) quickly followed by a further cast to test the acoustic release on the system being used for the USBL navigation calibration exercise which followed this sequence of events (CTD02-CTD04; 10:42-19:52 UTC on June 2nd). Upon completion of the ~12h USBL calibration we were ready to attempt our first *Nereus* AUV dive of the cruise (*Nereus* 047) also at the Von Damm hydrothermal field. Unfortunately a problem was encountered with the ballasting of the vehicle once it had arrived on bottom and the dive was quickly aborted so that the vehicle could be recovered inboard (10:49-18:32 UTC on June 3rd). While the vehicle was being prepared for re-deployment, the ship relocated north to the Piccard hydrothermal field (18°33'N, 81°43'W) where two CTD stations were occupied, back-to-back to collected biogeochemical and microbial water column samples from directly above the Beebe Vents area near 4850m water depth (CTD05-06; 21:11 UTC on June 3rd – 08:58 UTC on June 4th). Once these preliminary stations at each of the new vent sites were completed we returned to the Von Damm field and conducted a brief but successful dive running multiple operational tests with *Nereus* in seafloor mapping and water column sensing modes (*Nereus* 048; 12:32-21:01 UTC, June 4th).

Unfortunately, by this stage of the cruise it was already apparent that the RV *Falkor* would not be able to support full 24h round-the-clock operations for this particular cruise with the specific knock-on effect that there was no safe mode to conduct deep-water (~5000m) operations in AUV mode with *Nereus*, even though that had been the primary objective for use of this vehicle during Leg 1 of the cruise. Instead, to continue with our highest priority exploration objectives, it was necessary to suspend further *Nereus* AUV operations and, instead, rely exclusively upon vertical CTD-rosette profiling operations to attempt to track a new hydrothermal field to source in the Walsh area in the SW corner of the Mid Cayman Rise. This was a rather frustrating necessity but between

08:16 UTC on June 5th and 01:51 UTC on June 8th the shipboard scientists managed to maintain round-the-clock watches for CTD operations that occupied a series of stations (CTD07-CTD16) in and around the SW corner of the Mid Cayman Rise, 17°50-18°00'N, 81°45-55'W. CTD work was interspersed with episodes of multibeam re-mapping of the ridge-crest when time was required to recover between intensive CTD-cast and post-cast sampling operations.

Following this first sequence of CTD casts in and around the SW Mid Cayman Rise, it was decided to break off from exploration mode and to begin AUV surveys at and around the shallow Von Damm hydrothermal field where AUV dives could be conducted from launch to recovery within the window available for such operations on this cruise (nominally, 04h00 local time to sunset). Regrettably, the third attempted dive of *Nereus* on this cruise (*Nereus* 049; 08:06 -13:05 UTC on June 8th) also had to be aborted within an hour of arriving on bottom because of further vehicle malfunction. Returning to the "Walsh" area in the SW Mid Cayman Rise we then conducted a further series of 4 final CTD stations (CTD 17-21; from 16:34 UTC on June 8th to 21:47 UTC on June 9th) by which time we had both narrowed down the source of the weak hydrothermal venting signals to within ≤1km associated with an oceanic core complex close to 17°50'S, 81°50'W (CTD 21) and, at the preceding station, established the maximum depth to which the Falkor's CTD rosette could safely be deployed (5250m) which, sadly, was about 250m or more shallower than the remaining unexplored deep Mid Cayman Rise rift valley. At this point it was decided to discontinue exploration for new deep vent-sites on the Mid-Cayman Rise and devote the remainder of Leg 1 to our secondary objectives: more extensive time series investigations of the hydrothermal plumes at Piccard and Von Damm (above and beyond what had already been achieved with CTDs 01-05) plus AUV operations in and around the Von Damm hydrothermal field.

Following a further ~12h period of multibeam mapping (22:17 UTC June 9th-06:52 UTC June 10th), RV *Falkor* returned to the Von Damm field for *Nereus* dive 050 (07:58-21:07 UTC, June 10th) which successfully conducted a high resolution multi-beam mapping and magnetics survey (30m line spacing) over the Von Damm hydrothermal field. This was followed by CTD 22 over the Von Damm site (22:38 UTC on June 10th – 00:04 UTC on Jun 11th), CTDs 23 & 24 over the Piccard field (08:07-19:37 UTC on Jun 11th) and CTD 25 back at the Von Damm field (01:19-04:00 UTC on June 12th). *Nereus* dive 051 (08:20-22:44 UTC on June 12th) was a second successful geophysical mapping survey over the Von Damm hydrothermal field that produced a much higher resolution 3D magnetic survey of this system than had been achieved during the prior ROV *Jason* (Oases 2012) cruise by this same team to the same area and continued to extend that geophysical survey further west. Because of the depth/timing limitations for AUV work aboard RV *Falkor* we could not pursue the same approach at the much deeper Piccard field and so, instead, it was decided to pursue further AUV-based exploration across the remainder of the Mt Dent oceanic core complex where prior cruises aboard both RV *Cape Hatteras* (Oct-Nov 2009) and RRS *James Cook* (April 2010) had previously reported further weak hydrothermal anomalies, similar to those detected on this cruise during CTDs 07-21 in the "Walsh" area.

Following a further CTD cast directly over the Von Damm field (CTD 26; 23:32 UTC on June 12th – 01:36 UTC on June 13th), *Nereus* dive 052 (08:05-22:45 UTC on June 13th) achieved a notable engineering first by conducting a "porpoising yo-yo" survey flying in a grid pattern both directly over, and to the SW away from, the Von Damm hydrothermal field where the vehicle intercepted, on multiple occasions, *in situ* water column sensor signals indicative of both the known plume that disperses to the SW away from the Von Damm field and a second distinct set of hydrothermal plume signals, at a separate depth, consistent with prior assertions that there should be a second source of seafloor venting further West atop the summit of the Mt Dent core complex.

While CTD 27 (00:37-03:14 UTC on June 14th) was again conducted right over the Von Damm field, *Nereus* Dive 53 (08:02-22:44 UTC on June 14th) completed a further new set of operations never performed by the vehicle in AUV mode, returning close up photographic images – including fields of both dead mussels and live tube worms - from the hydrothermally active spur that extends south and east away from the central Von Damm spire. Following this dive there was time for one more CTD-rosette water-sampling cast during Leg 1, over the Von Damm mound (23:43 UTC on June 14th to 03:25 UTC on June 15th) before our final AUV dive of the cruise (*Nereus* 054; 08:21-19:42 UTC on June 15th) which continued the near-bottom swath mapping surveys West of the Von Damm hydrothermal field that were started during *Nereus* 051, in an area underlying the "additional" plume signals detected on *Nereus* 052. This Nereus dive 053 revealed further evidence for weak near-bottom hydrothermal plume anomalies close to 18°22.75'N, 81°48.25'W, approx. 1km WNW of the known Von Damm vent-site. [*The source of these signals was subsequently located and confirmed as a novel form of seafloor fluid flow that awaits detailed characterization during the closing stages of a subsequent research cruise that was informed by these results aboard the EV Nautilus (Cruise NA034) in August 2013*].

Leg 1 of RV *Falkor* cruise FK008 ended with a requirement to repeat the USBL-Cassius navigation calibration survey conducted at the outset of the cruise and this was completed between 20:05 UTC on June 15th and 08:09 on June 16th.
RF *Falkor* then proceeded to its scheduled port-call in Jamaica, collecting multibeam survey data underway until the ship exited Cayman Island waters. Leg 1 of the cruise was formally complete with the ship tied up alongside in Montego Bay at 10:30 UTC on June 17th where an exchange of key members of both the Engineering and Scientific personnel occurred as the *Nereus* vehicle was converted from AUV to ROV mode.

4c) Leg 2: June 18-July 1, 2013.

RV *Falkor* left port from Montego Bay at 23:09 UTC on June 18th and moved to anchor off the coast of Jamaica overnight to await a series of tests of the reconfigured *Nereus* vehicle, now converted to ROV mode which commenced at 11:13 UTC on June 19th and continued until 01:38 UTC on June 20th.

The ship then proceeded back to the Mid Cayman Rise work area, arriving on station at the Von Damm site on June 21st where instead of completing a first ROV dive, our first

activity was to recover the USBL navigation beacon that had been deployed but never recovered upon completion of the USBL-Cassius calibration at the end of Leg 1. For Leg 2, a regular pattern was established in which we aimed to launch Nereus at 04h00 local time (10:00 UTC) each day to maximize the amount of time available for each dive before we had to leave bottom to effect recovery in daylight. While this often meant that we finished dives with up to 50% battery capacity unused, it was the only way to guarantee that whenever we needed to recover the vehicle (even if a problem arose early in a dive) we could do so safely and efficiently in daylight without having to leave the vehicle untended for any extended period in the high-energy surface ocean: a condition that would have been imposed on us if *Nereus* ever surfaced after dark.

CTD 029 was occupied at the Von Damm vent-site from 11:49-13:37 UTC on June 21st and this was followed swiftly with a foreshortened first ROV dive with *Nereus* (Dive 055) to the Von Damm hydrothermal field from 15:38-23:01 UTC on the same day. While this was a very brief visit to the seafloor it was still successful in that: a) we were able to dive to the summit of the Von Damm mound and provide the *Nereus* pilots with a first look at the work area ahead of subsequent dives; b) collect first time-series samples for our Leg 2 scientists most of whom had just joined for this Leg but had previously sampled the same systems with the ROV *Jason* aboard the RV *Atlantis* in January 2012; and c) provide the first live video-feed from the seafloor via YouTube so that interested scientists and the public, alike, could begin to follow our expedition live, on line. *Nereus* dive 056 followed the same pattern and returned to the Von Damm hydrothermal field from 11:19 UTC to 17:42 UTC on June 22nd when the fiber-optic cable that connects *Nereus* back to the ship, via its depressor weight, failed prematurely while *Nereus* was sampling 220°C hydrothermal vent-fluids.

By the start of Leg 2, the RV *Yokosuka* from JAMSTEC (Japan) had already arrived in the vicinity and the two Chief Scientists quickly agreed a plan that would see us spend 3 dives each at first Von Damm then Piccard (*Falkor*) or Piccard then Von Damm (*Yokosuka*) followed by 2 more dives each, at each site, in the same order. This was primarily arranged so that RV Yokosuka could dive to the 5000m Piccard hydrothermal field, Earth's deepest (yet) known vent-site for a single day of live outreach that they had scheduled for June 22nd. Accordingly, despite the problems encountered during *Nereus* dive 056, RV *Falkor* relocated to the Piccard hydrothermal field overnight on June 27th ready for a series of 3 dives at this deeper location.

Unhappily, *Nereus* dive 057 suffered an even shorter fate than *Nereus* dive 056 when, following a launch at 10:13 UTC, the fiber-optic cable parted at 12:16 before the vehicle had descended even halfway to the seabed. Upon recovery aboard ship (15:38 UTC) it was recognized that a problem in the spooling of the fiber-optic cable was probably responsible for raising tension on the dispensed cable on each of dives 056 and 057 and this was remedied for subsequent operations. With the time suddenly available for non-*Nereus* operations at Piccard, two CTD casts were conducted for additional water column sampling. CTDs 30 and 31 were completed between 16:26 UTC on June 23rd and 00:09 UTC on June 24th, followed by a short multi-beam swath-mapping survey in the time available (02:09-07:33 UTC) before the next *Nereus* dive.

Nereus dive 058 (08:11 UTC on June 24th-00:02 UTC on June 25th) was our first successful dive to the ~5000m deep Piccard hydrothermal field with the ROV *Nereus*. Highlights included time-series sampling of end member vent-fluids up to 398°C (some of the hottest vent-fluids on Earth as well as the deepest), microbial sampling with the novel SUPR sampler deployed for the first time on this cruise, macro-biological sampling and collection and broadcast of some spectacular High Definition video of these particularly striking vents. Also noted (and ominous for what was to follow) was that there were extensive lengths of rather thick yellow cable strewn across the seafloor which had NOT been present when our science team previously investigated these sites in January 2012.

After a single CTD cast (CTD 32; 00:24-02:21 UTC) to collect "background" waters at 2300m depth for our microbiology colleagues at the same location (20km distant from the same-depth Von Damm hydrothermal field, and 2700m directly above the 5000m deep Piccard vent), RV *Falkor* conducted a brief swath bathymetry survey (02:22-10:22 UTC on Jun 25th) before *Nereus* was deployed once more to the Piccard vent-site. On this dive, the primary dive target was the Hot Chimlets vent-site, to the north of, and deeper than, the 398°C Beebe Vents mound. Following successful time-series sampling at that site, ROV *Nereus* then successfully transited West through the water column up to 100m above the rift-valley floor to reach a separate segment of axial volcanic ridge where we were able to successfully recover an ~$40,000 valued piece of sampling equipment that had been deployed and (temporarily) abandoned by *Nereus* during a prior sampling expedition aboard the RV *Cape Hatteras* in 2009. Once again, the presence of extensive lengths of yellow cable were noted during our operations close to and around the Beebe Vents mound at the Piccard hydrothermal field.

During subsequent ship-to-ship discussions, we were advised by Prof. Ken Takai (JAMSTEC) that these lengths of cable were from the RV *Yokosuka* which had attached a 5000m cable with a fiber-optic core to the submersible Shinkai 6500 on their June 22nd "outreach" dive but that this cable had been parted by the ship's propellers at the ocean surface, during the course of the dive, such that the full 5000m of cable had, hence, fallen to the seafloor and was now strewn across the Piccard hydrothermal field. Dr Takai assured us that the next two dives of the Shinkai 6500, scheduled to be conducted at the Piccard hydrothermal field, would be dedicated to removing those cables from what had previously been a particularly pristine deep-ocean hydrothermal field - ahead of our return to that area with the ROV *Nereus*. Armed with that information, we completed a further CTD cast above the Piccard site (CTD 33: 22:54 UTC on June 25th – 02:36 UTC in June 26th) and then returned south to the Von Damm hydrothermal field.

Nereus dive 060 (08:11-21:53 UTC on June 26th) was another particularly successful dive. Arriving on the spur to the SE of the central spire (the same locale photographed in AUV mode on Leg 1 dive 053) we were able to conduct our first ROV investigations from this cruise of the tube-worm fields that only occur at this location before proceeding to collect time-series fluids from both the ~110°C Old Man Tree vent and then

continuing up to the summit of the central Von Damm spire where further excellent HD video footage was both broadcast and collected. Upon collection of a further CTD cast worth of water column samples (CTD 034; 22:11 UTC on June 26th to 00:00 on June 27th) the ship stood by while the science team worked up samples from *Nereus* dive 060 until it was time to begin the next *Nereus* dive.

Nereus dive 061 (10:18-21:19 UTC on June 27th was our last dive to the Von Damm hydrothermal vent-field. Starting to the north of the Von Damm spire, we collected a series of vent-fluid, microbial and macrobiological samples from lower-temperature (130-150°C) fluid flow sites, including several that had not been sampled in 2012, and then continued around the East side of the mound to the southern spur where further sampling was conducted before, for the last time, proceeding back to the summit of the Von Damm Spire to complete our scientific operations at this site. Following recovery of the ROV at the end of this dive, a further set of swath mapping was conducted from 23:52 UTC on June 27th to 09:39 UTC on June 28th before transiting back to the Piccard hydrothermal field.

Nereus dive 062 (10:14-22:51 UTC on June 28th) began at the same Hot Chimlet site as dive 059, to the North and down-hill from the Beebe Vents mound, and was devoted to biogeochemical and microbial sampling of mixed fluids at intermediate temperatures at multiple sites across the northern flanks of the mound as *Nereus* proceeded continuously, uphill to the South. A single CTD cast (CTD 35) was completed following this dive (23:27 UTC on June 28th – 01:35 on June 29th). The final dive of the cruise, *Nereus* 063 to the Piccard hydrothermal field (08:09-21:46 UTC) came very close to disaster. After arriving at the seafloor to the NE of the Beebe Vents mound, *Nereus* proceeded to these high temperature vents and collected high temperature vent fluids (380°C) collected and broadcast extensive footage of the high temperature chimneys and then conducted a detailed buoyant plume sampling operation rising up to 100m above the vent-site while holding position within the rising plume for more than an hour (12:55-14:05 UTC). Having completed all operations at the Beebe Vents mound, our next priority was to visit the Beebe Woods site (a prime focus of the *Shinkai* 6500 outreach dive on June 22nd) to complete our first time-series sampling at that site. As we approached, uphill, from the West of the Beebe Woods mound, however, we suddenly encountered more of the Yokosuka cable suspended in mid-water between extinct sulphide structures that had allowed us to pass under the cable, unaware, and then rise up the slope of the sulfide mound until we had the cable both draped over *Nereus* and wrapped around its port-side stern propeller. Clearly extensive amounts of the *Yokosuka* cable remained, strewn across the seafloor at the Piccard hydrothermal field, despite the *Shinkai* 6500's best efforts to remove their contamination of the site. After approximately 1 hour (14:20-15:10 UTC) the *Nereus* pilots were able to both seize and sever the cable ahead of *Nereus* using the vehicle's manipulator and then, by referring to their vehicle engineering data immediately prior to the entanglement, to calculate the direction (post vs starboard, hence, clockwise vs anticlockwise) and number of revolutions required to disentangle the stern propeller from the *Yokosuka* cable. By 15:30 the vehicle was free of the entrapment and the decision was taken to relocate due West, far away from the Piccard field completely, and then circle around to

the far north of the site so that the vehicle could approach the Beebe Sea mound from the North and East, a region where no observations of the *Yokosuka* cable had been reported from our prior *Nereus* ROV dives. The Beebe Sea site was reached by 16:00 UTC and two sets of high temperature fluid samples were collected before the fiber optic cable finally failed on us (happily when we were far from any entanglement hazards and had a full suite of samples collected) at 17:00 UTC. Upon recovery of the vehicle aboard ship, time was taken for one final CTD cast (CTD 36) over the Piccard hydrothermal field (22:20 UTC on June 29th – 03:30 UTC on June 30th) after which all science operations were completed and the ship made way for port. RV *Falkor* Cruise 008 was formally completed when the ship tied up alongside once more in Montego Bay, Jamaica on the morning of July 1st.

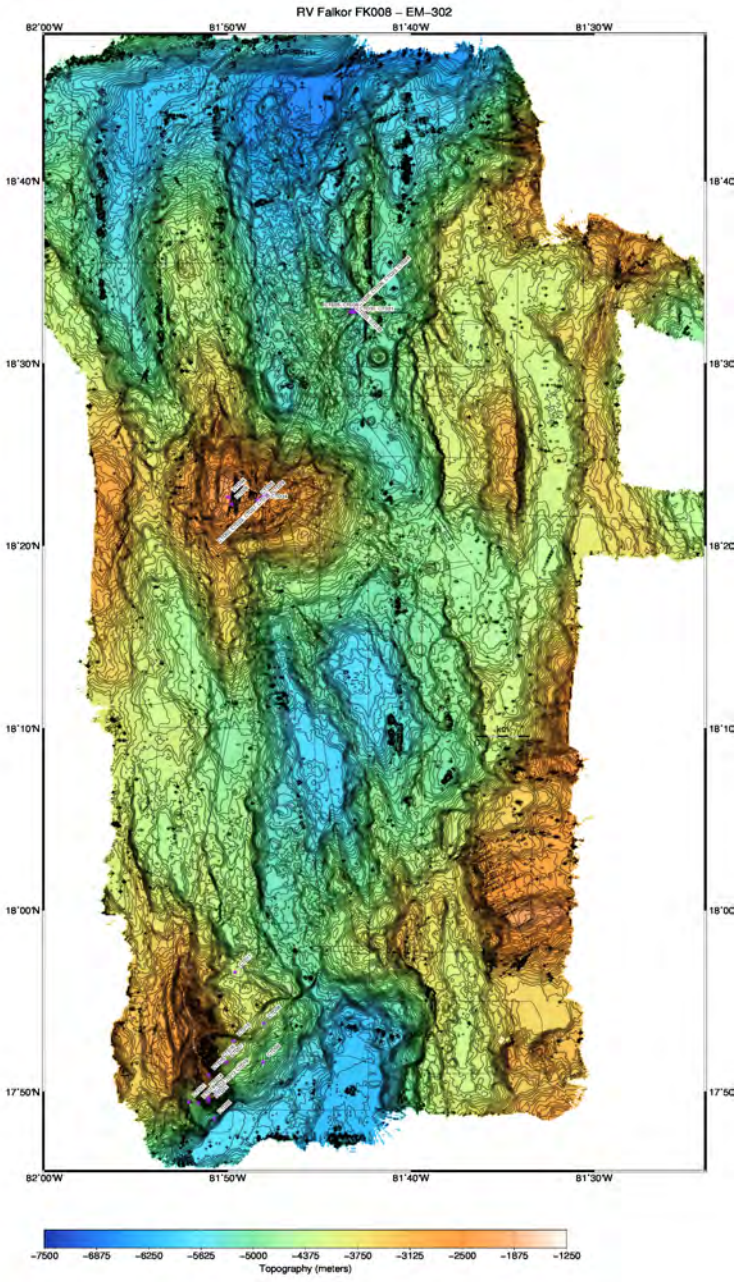


***Fig.4.1**: Map showing multibeam coverage acquired and CTD station locations during RV Falkor cruise FK-008*

5. Multibeam Operations (N.Cunningham & P.Duncan)

5a) Introduction

Multibeam activities were planned to augment existing bathymetry data from the NOAA ship *Okeanos Explorer*. *Falkor* has the same Kongsberg EM-302 echo sounder as the *Okeanos Explorer*. The *Okeanos Explorer*'s system differs from the *Falkor*'s in that it is optimized to survey depths around 3000m. The surveys conducted consisted generally of areas in excess of 4000m depth and/or previously unsurveyed regions.

5b) Equipment & Software

Seapath 320 with differential corrections provided by a C-Nav 3050.
Kongsberg EM-302
Kongsberg K-Sync
Valeport Midas sound velocity profiler
Turo Devil XBT System
Kongsberg SiS V3.8.3 build 89 DB V19.0
SVP Editor V1.03 from Jonathan Beaudoin of UNH/CCOM.
MB-System V5.3.2042 (processing based on scripts written by David Caress for FK-007)

5c) Calibration

Calibration was last performed in February 2013 shortly before FK-007 by members of University of New Hampshire. A calibration report is available upon request.

5d) Procedures

Cruise Data was logged using SiS to a project called FK008_EM302, the data were automatically backed up every 24 hours to the Cruise Data networked storage area. The data were also copied to the primary multibeam processing computer. The EM302 was setup using Feb 2012 calibration coefficients and operated as per Kongsberg recommended procedures. All the MTs have received full Kongsberg training for the acoustic systems on the R/V *Falkor*.

The processing procedures were as follows:
For daily processing we used the script below which produced a cleaned bathymetry grid file:

```
#############################################################
#
# Processing of Kongsberg EM302 and EM710 multibeam data
# R/V Falkor
# Expedition FK008 Processed by Nathan Cunningham and Paul Duncan
# 8 June 2013
# Based on script written by David W. Caress, 9 March 2013 on
# FK007 Science Cruise
#
#############################################################
#
# Preliminary processing:
# Create data list for each day and do preprocessing
#
chmod -x *.all
chmod +r *.all
/bin/ls -1 *all | awk '{print $1" 58"}' > datalist_raw.mb-1
mbkongsbergpreprocess -I datalist_raw.mb-1 -V

# Get datalist of raw *.mb59 files plus ancilliary files
/bin/ls -1 *.mb59 | grep -v "p.mb59" | awk '{print $1" 59"}' > datalist.mb-1
mbdatalist -V -O -Z
# Automatically clean data
# Use the following to flag any beams which deviate by more than 20%
# from the local median depth or which produce a slope greater than
# 3.5 (74 degrees). Also flag data with absolute deviation away from a median
# of greater than 100m. Include a simple high/low filter â only
# accept 500m â 7000m

mbclean -Idatalist.mb-1 -A100 B500/7000 -M1 -C3.5 -D0.01/0.20 -G0.80/1.20 -Q

# Edit bathymetry
# mbedit -I datalist.mb-1
# mbeditviz -I datalist.mb-1

#Get tide models and set for use by mbprocess
mbotps -I datalistp.mb-1 -M -D60.0 -V

# process amplitude and sidescan
mbbackangle -I datalist.mb-1 -A1 -A2 -Q -V -N87/86.0 -R50 -G2/85/1500.0/85/100
mbset -PAMPCORRFILE:datalist.mb-1_tot.aga
mbset -PSSCORRFILE:datalist.mb-1_tot.sga

# Process the data
mbprocess

# Filter the sidescan
mbfilter -Idatalistp.mb-1 -S2/5/3


#############################################################
#
# Generate first cut swath plots
#
# Navigation plot
mbm_plot -I datalistp.mb-1 \
        -N0.05/0.25/1/0.1/0.1/0 \
        -L"Rv Falkor Fk008 - 20130608 - EM302":"Topography (meters)" \
        -Pe -O Znav -V
./Znav.cmd

# Bathymetry color shaded relief and navigation
mbm_plot -I datalistp.mb-1 \
        -G2 -N0.25/0.25/1.0 \
        -L"Rv Falkor Fk008 - 20130608 - EM302":"Topography (meters)" \
        -Pe -O Zbathshade -V
./Zbathshade.cmd
```

```
mbm_plot -I datalistp.mb-1 \
        -G1 -N0.25/0.25/1.0 -C \
        -L"Rv Falkor Fk008 - 20130608 - EM302":"Topography (meters)" \
        -Pb -O Zbathcontour -V
Zbathcontour.cmd

mbm_plot -I datalistp.mb-1 \
        -G4 -S \
        -L"Rv Falkor Fk008 - 20130608 - EM302":"Topography (meters)" \
        -Pc -O Zamp -V
./Zamp.cmd

mbm_plot -I datalistp.mb-1 \
        -G5 -S \
        -L"Rv Falkor Fk008 - 20130608 - EM302":"Topography (meters)" \
        -Pc -O Zss -V
./Zss.cmd
```

Each day we made a combined plot of all the processed data. This used the files created by the daily processing, in particular the FBT files which contain the flagged bathymetry from the mbclean process. The combined plot was used to give an overview of all the multibeam surveying and compare it to the bathymetry from the *Okeanos Explorer*. There were two scripts, one which pulled together all the data from the daily surveys and produced the gridded data, and another script to actually make the plot with information showing where CTD casts had been performed. The first script is below:

```
#############################################################
#
# Processing of Kongsberg EM302 and EM710 multibeam data
# R/V Falkor
# Expedition FK008 Processed by Nathan Cunningham and Paul Duncan
# 8 June 2013
# Based on script written by David W. Caress, 9 March 2013 on
# FK007 Science Cruise
#
#############################################################
#
# Update the data list first of all
./builddatalist

# Generate grid and plots to Active area
#       -X -Kbackground_grid \
mbgrid -I datalistp.mb-1 \
        -A2 -F5 -N \
        -C2 -O ZTopo -V

mbgrdviz -I ZTopo.grd &

mbm_grdplot -I ZTopo.grd \
        -O ZTopoSlopeNav \
        -G5 -D0/1 -A1 \
        -L"RV Falkor FK008 - EM-302":"Topography (meters)" \
        -MGLfx5/1/35.75/1.0+l"km" \
        -MNIdatalistp.mb-1 \
        -Pc -V
./ZTopoSlopeNav.cmd
convert ZTopoSlopeNav.ps ZTopoSlopeNav.jpg

# Topo slope map
mbm_grdplot -I ZTopo.grd \
        -O ZTopoSlope \
        -G5 -D0/1 -A1 \
        -L"RV Falkor FK008 - EM-302":"Topography (meters)" \
        -MGLfx8/1/35.75/1.0+l"km" \
```

```
        -Pc -V
./ZTopoSlope.cmd
convert ZTopoSlope.ps ZTopoSlope.jpg

mbm_grdplot -I ZTopo.grd \
        -O ZTopoCont \
        -G1 -C -A1 -MCW0p \
        -L"RV Falkor FK008 - EM-302":"Topography (meters)" \
        -MGLfx8/1/35.75/1.0+l"km" \
        -Pc -V
./ZTopoCont.cmd
convert ZTopoCont.ps ZTopoCont.jpg

# Re-Generate ZTopoSlopeNav and plot with contours for printing.
mbm_grdplot     -I ZTopo.grd \
                -O ZTopoSlopeNav \
                -G5 \
                -D0/1 \
                -A1 \
                -L"RV Falkor FK008 - EM-302":"Topography (meters)" \
                -MGDPLOT_DEGREE_FORMAT/dddmmF \
                -MGLf-80/18/18/5.0+l"km" \
                -MNIdatalistp.mb-1 \
                -PA0 \
                -C50 \
                -V
./ZTopoSlopeNav.cmd
convert ZTopoSlopeNav.ps ZTopoSlopeNav.jpg

# Make GeoTiff
#Shaded relief view
mbm_grdtiff -IZTopo.grd -G2 -A0.4/45 -X -U2 -V -Obath_shade
./bath_shade_tiff.cmd

# Print on plotter
#lpr -Pdesignjet *.ps
```

The second script is shown below. It refers to a file called ctd-stations.txt which contains positions and labels for the CTD stations:

```
#! /bin/csh -f
#
# Shellscript to create Postscript plot of data in grd file
# Created by macro mbm_grdplot
#
# This shellscript created by following command line:
# mbm_grdplot -I ZTopo.grd -O ZTopoSlopeNav -G5 -D0/1 -A1 -LRV Falkor FK008 - EM
-302:Topography (meters) -MGDPLOT_DEGREE_FORMAT/dddmmF -MGLf-81.583/18.16/18.16/
5.0+lkm -MNIdatalistp.mb-1 -PA0 -C50 -V
#
# Define shell variables used in this script:
set PS_FILE         = ZTopoSlopeNav.ps
set CPT_FILE        = ZTopoSlopeNav.cpt
set MAP_PROJECTION  = m
set MAP_SCALE       = 37.0
set MAP_REGION      = -82.0/-81.4/17.761678/18.8
set X_OFFSET        = 7.7702
set Y_OFFSET        = 6
#
# Save existing GMT defaults
echo Saving GMT defaults...
gmtdefaults -L > gmtdefaults4$$
#
# Set new GMT defaults
echo Setting new GMT defaults...
gmtset MEASURE_UNIT inch
gmtset PAPER_MEDIA A0+
```

```
gmtset ANOT_FONT Helvetica
gmtset LABEL_FONT Helvetica
gmtset HEADER_FONT Helvetica
gmtset ANOT_FONT_SIZE 24
gmtset LABEL_FONT_SIZE 24
gmtset HEADER_FONT_SIZE 30
gmtset FRAME_WIDTH 0.075
gmtset TICK_LENGTH 0.075
gmtset PAGE_ORIENTATION PORTRAIT
gmtset COLOR_BACKGROUND 0/0/0
gmtset COLOR_FOREGROUND 255/255/255
gmtset COLOR_NAN 255/255/255
gmtset PLOT_DEGREE_FORMAT ddd:mm
#
# Set user defined GMT defaults
echo Setting user defined GMT defaults...
gmtset PLOT_DEGREE_FORMAT dddmmF
#
# Make color pallette table file
echo Making color pallette table file...
echo  -7500  37  57 175  -6875  40 127 251 > $CPT_FILE
echo  -6875  40 127 251  -6250  50 190 255 >> $CPT_FILE
echo  -6250  50 190 255  -5625 106 235 255 >> $CPT_FILE
echo  -5625 106 235 255  -5000 138 236 174 >> $CPT_FILE
echo  -5000 138 236 174  -4375 205 255 162 >> $CPT_FILE
echo  -4375 205 255 162  -3750 240 236 121 >> $CPT_FILE
echo  -3750 240 236 121  -3125 255 189  87 >> $CPT_FILE
echo  -3125 255 189  87  -2500 255 161  68 >> $CPT_FILE
echo  -2500 255 161  68  -1875 255 186 133 >> $CPT_FILE
echo  -1875 255 186 133  -1250 255 255 255 >> $CPT_FILE
#
# Define data files to be plotted:
set DATA_FILE        = ZTopo.grd
set INTENSITY_FILE   =
#
# Get slope array
echo Getting slope array...
echo Running grdgradient to get x component of the gradient...
grdgradient $DATA_FILE -A90 -G$DATA_FILE.drvx -M
echo Running grdgradient to get y component of the gradient...
grdgradient $DATA_FILE -A0 -G$DATA_FILE.drvy -M
echo Running grdmath to get slope magnitude...
grdmath $DATA_FILE.drvx 2.0 POW \
        $DATA_FILE.drvy 2.0 POW ADD SQRT \
        -1 MUL \
        = $DATA_FILE.slope
/bin/rm -f $DATA_FILE.drvx $DATA_FILE.drvy
#
# Make color image
echo Running grdimage...
grdimage $DATA_FILE -J$MAP_PROJECTION$MAP_SCALE \
        -R$MAP_REGION -C$CPT_FILE \
        -I$DATA_FILE.slope \
        -P -X$X_OFFSET -Y$Y_OFFSET -K -V >! $PS_FILE
#
# Make contour plot
echo Running grdcontour...
grdcontour $DATA_FILE -J$MAP_PROJECTION$MAP_SCALE \
        -R$MAP_REGION \
        -C50 \
        -L-7049.96337891/-1760.26879883 -Wc1p\
        -P -K -O -V >> $PS_FILE
#
# Make swath nav plot
echo Running mbcontour...
mbcontour -F-1 -I datalistp.mb-1 \
        -J$MAP_PROJECTION$MAP_SCALE \
        -R$MAP_REGION \
```

```
        -D100000/100000/100000/0.15 \
        -P -K -O -V >> $PS_FILE
#
# Make color scale
echo Running psscale...
psscale -C$CPT_FILE \
        -D8.7848/-2.1277/17.5695/0.6383h \
        -B":Topography (meters):" \
        -P -K -O -V >> $PS_FILE
# Make basemap
echo Running psbasemap...
psbasemap -J$MAP_PROJECTION$MAP_SCALE \
        -R$MAP_REGION \
        -B10m/10m:."RV Falkor FK008 - EM-302": \
        -Lf-81.583/18.16/18.16/5.0+lkm \
        -P -O -K -V >> $PS_FILE
#
# Put CTD waypoints here
#
# One blob for every CTD station...
psxy ctd-stations.xy -J$MAP_PROJECTION$MAP_SCALE -R$MAP_REGION  -A -Gpurple  -O
 -K -Sa0.5c >>$PS_FILE

pstext ctd-stations.txt -J$MAP_PROJECTION$MAP_SCALE -R$MAP_REGION -D0.2/0.2vpurp
le -Gblack -Wwhite -C -O >>$PS_FILE
#
# Delete surplus files
echo Deleting surplus files...
/bin/rm -f $CPT_FILE
#
# Reset GMT default fonts
echo Resetting GMT fonts...
/bin/mv gmtdefaults4$$ .gmtdefaults4
#
# Run ghostview
echo Running ghostview in background...
ghostview ZTopoSlopeNav.ps &
#
# All done!
echo All done!
```

5e) Maintenance and Troubleshooting

The EM302 performed well throughout the cruise and collect high quality data to depths over 6000m.

5f) Recommendations

1. Increase the spec of the processing PC. Running the scripts for MB-Systems really pushed the PC to the maximum. This PC needs to have a much higher spec for 3D processing and visualization work.
2. Continue to investigate MBClean and improve the auto cleaning.
3. Manual editing and cleaning of the data is recommended as there are improvements that could be made to the cleaning of the data.

6. CTD Operations (N.Cunningham, L.Rolley & P.Duncan)

6a) Introduction

The CTD performed well throughout cruise. Regularly used to depths of 5000m, it collected important data for the research of hydrothermal vents in the Mid Cayman Rise area. On the first leg of the cruise the CTD prospected for new vent sites and identified potential new dive sites for future exploration. On both legs, the CTD also collected water samples from directly above active vent sites and their dispersing plumes. This section describes the operation of the CTD on FK008. A complete listing of operations is provided as Appendix 2: CTD casts. See Section 9 for all discussions of the water samples collected from the CTD for biogeochemical analyses.

6b) Equipment

The standard CTD and winch on the RV Falkor are:

- Seabird Underwater Unit for 9/11plus CTD (6800m housing) with Wet pluggable connectors on CTD, T&C sensors, pump and pressure sensor (0-10,000 psia / 6800m)
- Secondary T-C sensors, 6800 m, with TC Duct, Pump with wet-pluggable connectors.
- Seabird carousel water sampler (standard) fitted with 24-x 12 litre PVC sample bottles (internal Teflon coated springs).
- Seabird Deck Unit for 9/11plus CTD (Firmware V5) with added NMEA input.
- SEASOFT Software (Seasave V7, SBE Data Processing, Seaterm V2).
- MacArtney MASH CTD Oceanographic Winch (Type 10000/8,2-31-RA) fitted with 10,000m of 0.322” EM coax wire. The coax wire is managed with routing via flag sheave to the A-Frame.
- SWL on the wire is 1744kg. Thus, the CTD can achieve a maximum deployment depth (reached on this cruise) of ca. 5250m (5500m wire out)

Extra Sensors integrated with the CTD for this cruise included:

- Turbidity Meter (Seapoint STM11; provided by science party)
- Eh Sensor (Custom; provided by science party),
- Oxygen (SBE 43),
- Transmissometer (Wet Labs C-Star),
- Altimeter (PSA-916 Teledyne Benthos)

6c) Calibration Parameters Used on FK008

Temperature (serial number 5483).
Calibrated on 23-Feb-12:

G : 4.29788686e-003
H : 6.24754454e-004
I : 1.90126087e-005
J : 1.37626459e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

Conductivity (serial number 3916).
Calibrated on 15-Mar-12:

G : -1.03593733e+001
H : 1.60754577e+000
I : -8.03238200e-004
J : 1.59956234e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

Pressure, Digiquartz with TC (Serial number 1087). Calibrated on 13-Mar-12:

C1 : -3.864344e+004
C2 : 3.241783e-001
C3 : 1.389640e-002
D1 : 3.376600e-002
D2 : 0.000000e+000
T1 : 3.019184e+001
T2 : -1.977133e-004
T3 : 4.596520e-006
T4 : 4.018770e-009
T5 : 0.000000e+000
Slope : 1.00000000
Offset : 0.00000
AD590M : 1.281700e-002
AD590B : -9.046489e+000

Temperature 2 (serial number 5549).
Calibrated on 13-Mar-12:

G : 4.32169056e-003
H : 6.25258783e-004
I : 1.90806457e-005
J : 1.37420650e-006
F0 : 1000.000
Slope : 1.00000000
Offset : 0.0000

Conductivity 2 (serial number 4003).
Calibrated on 07-Mar-12:

G : -1.01978406e+001
H : 1.53524151e+000
I : -2.27452306e-003
J : 2.58938252e-004
CTcor : 3.2500e-006
CPcor : -9.57000000e-008
Slope : 1.00000000
Offset : 0.00000

Turbidity Meter (Seapoint). Provided by WHOI. Calibrated May 2013:

Gain setting : 5 x
Scale factor : 1.000

EH Sensor. Provided by WHOI:

A0 : -500.00000000
A1 : 200.00000000
A2 : 0.00000000
A3 : 0.00000000

Oxygen, SBE 43 (serial number 2330).
Calibrated on 04-May-12:

Equation : Sea-Bird
Soc : 4.65000e-001
Offset : -4.97200e-001
A : -3.32460e-003
B : 1.45280e-004
C : -2.05350e-006
E : 3.60000e-002
Tau20 : 2.42000e+000
D1 : 1.92634e-004
D2 : -4.64803e-002
H1 : -3.30000e-002
H2 : 5.00000e+003
H3 : 1.45000e+003

Transmissometer, WET Labs C-Star (serial number CST-1476DR). Calibrated on : 13-Oct-2011:

M : 21.1914
B : 0.0000
Path length : 0.250

Altimeter (serial number 59545). Calibrated on 14Mar2013:

Scale factor : 15.000
Offset : 0.000

6d) Procedures

The CTD was recovered and deployed as per R/V CTD Operation SOP. This is based on recommendations provided by Seabird that outline the major steps involved in taking a cast with a Profiling CTD (www.seabird.com/FAQs/FAQsRecommendedPractices.htm#ProfilingSteps).

Each CTD Profile was acquired and displayed in real-time using SBE Seasave V7. A tailored GUI setup was configured (FK008V.psa) and used for each CTD cast. The raw data file was immediately backed up to the cruise data area. The CTD profile was then converted, edited, processed and plotted using specific modules in the SBE Data Processing software. The major steps followed for collecting and processing CTD data were:

Procedure 1: Acquisition using Seasave

1) Check that FK008V.psa is the setup file used when Seasave starts. If not open it from the File menu.
2) Check the correct instrument configuration is selected from the Configure Inputs menu. For this cruise it is FK008_1087_DO-T-Alt-EH-LSS.xmlcon (shown in section 7c, above).
3) Modify the display windows to fit the upcoming CTD cast (modify ranges, check the fire button is available etc.) using options from the Display menu or right clicking in the window being modified. Please note some options are available from the Real-Time Control menu.
4) Select Start from the Real-Time Data menu
5) Select the Output Data File Name. This needs to follow the naming convention
   a) {Cruise-ID}_{CTDnumber}_{Date} in the format [FK###_CTD###_YYYYMMDD] e.g. FK008_CTD001_20130531
6) The Configuration options should match the input configuration file (the software will match this automatically) for this cruise FK008_1087_DO-T-Alt-EH-LSS.xmlcon.
7) Select Start and enter the Ship Name, the CTD number and the operator.
8) When aft deck has given the Ready confirmation turn on the deck unit
9) Select OK and real-time data display and acquisition will start.
10) Check the status line to verify that the CTD values are correct.
11) Call the winch operator and have them start the cast down. Typical lowering speed is 1 m/sec, modified for conditions as needed.
12) As you get to within 30 meters of the bottom, slow the cast to 0.5 m/sec. If you wish to get closer than 10 m above the bottom, slow to 0.2 m/sec.
13) When the CTD reaches the maximum cast depth, call the winch operator and stop the descent.

14) Start the CTD upcast. Stop the CTD ascent at any other bottle closure depths.
15) As the CTD approaches the surface follow the *Falkor* CTD Operations SOP.
16) Stop data acquisition and power off the CTD.
17) Ensure all data files are backed up to the cruise data CTD directory:
    a) Config file e.g. FK008_CTD001_2130531.XMLCON
    b) Data File e.g. FK008_CTD001_2130531.hex
    c) Bottle File e.g. FK008_CTD001_2130531.bl
    d) Header File e.g. FK008_CTD001_2130531.hdr

Procedure 2: Processing data using SBE Data Processing software

1) Run the Data Conversion Module to make the *.cnv file
    a) Select the instrument configuration file (the file written with the cast) e.g. FK008_CTD001_2130531.XMLCON.
    b) Tick match instrument configuration to input file radio button.
    c) Select the input directory and data file e.g. C:\CTD\ FK008_CTD001_2130531.hex. This must be the same as the config file. Seasave V7 and SBE Data Processing check that the serial number in the configuration file matches the instrument serial number in the .dat or .hex data file. If they do not match it will produce an error.
    d) Select the output directory (normally the same as the input directory e.g. C:\CTD\)
    e) Do not append a name
    f) Go through the Data Setup options. These should be discussed with the Chief Scientist before the first cast. Typically you need to change 4 things:
        output format – ASCII
        convert data upcast & downcast
        create both data and bottle file
        source time stamp from NMEA time (UTC).
    Select the appropriate output variables .
    The miscellaneous settings are normally left as the defaults.
    g) Click start process and the .cnv (converted) and .ros (rosette) files will be written e.g. FK008_CTD001_2130531.cnv and FK008_CTD001_2130531.ros
    h) Exit and select Yes to save changes to DatCnv.psa

2) Run the Bin Average module to make the *_BA.cnv file
    a) Select the input directory and data file e.g. C:\CTD\ FK008_CTD001_2130531.cnv

b) Select the output directory (normally the same as the input directory e.g. C:\CTD\)
c) Append name _BA (bin average).
d) Go through the Data Setup options. These should be discussed with the Chief Scientist before the first cast. You must discuss how the scientists want to organize their data. It is critical that the correct bin type is selected (e.g. averaged by pressure/depth or by time). For FK008 all data were averaged into 1 second bins. This was to allow for maximum flexibility post-cruise to intercompare data collected from both vertical profiles and from tow-yo and/or drift-yo data in which the CTD did not have the same downcast and upcast locations because the package was continuously repositioned (tracked by USBL navigation) when searching for plume/vent signatures. Because the entire cast (i.e. both the downcast and upcast) collected unique and valuable information, both were selected to be processed. The rest of the options chosen were typically defaults.
e) Exit and Yes to save changes.

3) Run Bottle Summary module to make the *.btl file
   a) Select the instrument configuration file (the file written with the cast) e.g. FK008_CTD001_2130531.XMLCON.
   b) Select the input directory and data file e.g. C:\CTD\ FK008_CTD001_2130531.ros. This must be the same as the config file.
   c) Select the output directory (normally the same as the input directory e.g. C:\CTD\)
   d) Data Setup - we normally used the default values.
   e) Click Start Process to summarize data from water sampler bottle .ros file, and create a .btl file.
   f) Exit and Yes to save changes.

4) Run ASCII Out to make *.asc plain text file
   a) Select the input directory and data file – normal the bin average.cnv file e.g. C:\CTD\ FK008_CTD001_2130531_BA.cnv
   b) Select the output directory (normally the same as the input directory e.g. C:\CTD\)
   c) Do not append a name
   d) On the data setup tab
      Tick output header
      Tick output data file
      Select label columns at top of file
      Select column separator (tab is usually the easiest to parse into other programs)

Select date and time formats for output data file (applicable if date/time selected as output variable, which it normally is).
Other options are not normally used.

e) Click start process to generate the ascii file. This file is the one, normally, that most scientists want.
f) Exit and Yes to save changes.

5) Run Sea Plot to create a jpeg graph of the key profile data.
   a) You need to discuss this with the Chief Scientist as it will change for each cruise.
   b) Refer to the help file for detailed information on setting up the seaplot. Typically you want to plot the data used to generate the .asc file. So select the *bin averaged* .cnv file.
      Configure the output to jpeg
      Select a good size for the plot (e.g. 1600 x 1200)
      The output directory should be the same as the input directory
      On plot setup give the title as the cruise name, CTD cast number etc.
      Select other settings as appropriate.
      For the Y axis you normally select depth (m) [or time (s)]
      For the other axis choose scales, colors and ranges appropriately.
   c) Click Start Process to produce JPEG image.
   d) From the display window, select File Save and name it something sensible
   e) Select File Print to make a paper copy of the CTD cast for the scientists' records etc.
   f) Exit and Yes to save changes.

6e) Maintenance and Troubleshooting

As per Seabird recommendations the CTD is washed down with freshwater, with special focus given to the SBE32 rosette. The temperature, conductivity and oxygen sensors are soaked in MilliQ water. Finally the CTD is covered to prevent sun damage, if another cast is not to be performed within a few hours. Throughout FK-008 we experienced several modulo errors per cast. The modulo errors are caused by dropped scans in the stream of data coming up from the underwater unit. If data errors are seen across all data channels then this indicates a problem with the termination. One of the problems we had was modulo errors which only seemed to be coincidental with errors on the primary conductivity sensor and occasionally pressure. This convinced us to replace the cable between the primary conductivity sensor and the main CTD unit. Full diagnostics on this type of problem are difficult.

As part of the problem solving procedures we did the following:

1. Ran an insulation and resistance check on the entire sea cable, run from the deck unit to the CTD.

2. ETO upgraded the cable between the slip ring junction box and the winch deck junction box.
3. Checked and cleaned all wet-pluggable connectors.

The changing out of the cable between the slip junction box and the winch deck junction box resulted in a voltage increase at the CTD of 4V, to 264V.

Bottle Problems:

1. Inspection and regreasing of O-rings with DC4.
2. Loss of a bottle during the early part of the cruise due to failure of both jubilee clips.
3. Holes in at least two bottles due to suspected misalignment of locating lugs and mounting.
4. Corroded 16mm circlips (used to tension the spring on the mounting).

In an effort to make bottles more air/water tight all O-rings on all bottles have been inspected and re-greased. Since the loss of a bottle due to the failure of the jubilee clips (AKA hose clamps), all other bottles have had their jubilee clips checked. We suspect some of them may have been over-tightened. In addition to this we have started using a rope fed through the handles of all bottles, so that if jubilee clips on a bottle fail in the future, this should not result in the loss of the bottle. There are three locating lugs loosely located in the back of each bottle. These are used to correctly position the bottle mounting mechanism, which is attached to the bottle itself using jubilee clips. In the case of two bottles, the bottle has been punctured underneath one of the lugs. We suspect that this may have been caused by the bottle mounting mechanism not being correctly located before the jubilee clips were tightened. 16mm circlips are used to correctly tension springs on the locking shaft that is part of the bottle mounting mechanism. A number of these circlips were found to be close to failure (fell into multiple pieces when moved). The circlips are not manufactured from stainless steel or titanium and therefore can corrode relatively quickly in a marine environment. We are purchasing the correct grade external circlips.

6f) Recommendations

1. The SOP needs updating to reflect Seabird recommended practices.
2. Full freshwater rinsing and use of the cover on the CTD.
3. More frequent inspection of bottles, especially mounting hardware.
4. Circlips on the attaching mechanism all need replacing with appropriate grade 16mm seawater-resistant steel.
5. Review of spares and re-order parts used.

7. AUV *Nereus* Operations (C.German & J.Kinsey)

As discussed above, this was the first cruise to use *Nereus* scientifically in AUV mode. Operationally, this was highly successful and allowed us to demonstrate the vehicle's capability in a variety of modes over a series of dives at and around the Von Damm hydrothermal field at the Summit of Mt. Dent. Given the early success of the vehicle in this region (N50), our intellectual preference would have been to conduct similar high-resolution geophysical surveys over the Piccard hydrothermal field as well, and to use the AUV in water column mode to search more precisely for additional deep venting at the Walsh site in the southern MCR. Because of operational limitations aboard ship, however (no possibility for overnight recoveries between sunset and 8am) it was decided insufficiently rewarding to plan ~5000m AUV dives that would only allow for 4-6h survey time at the seafloor. Instead, additional dives to explore the summit of Mt Dent were selected.

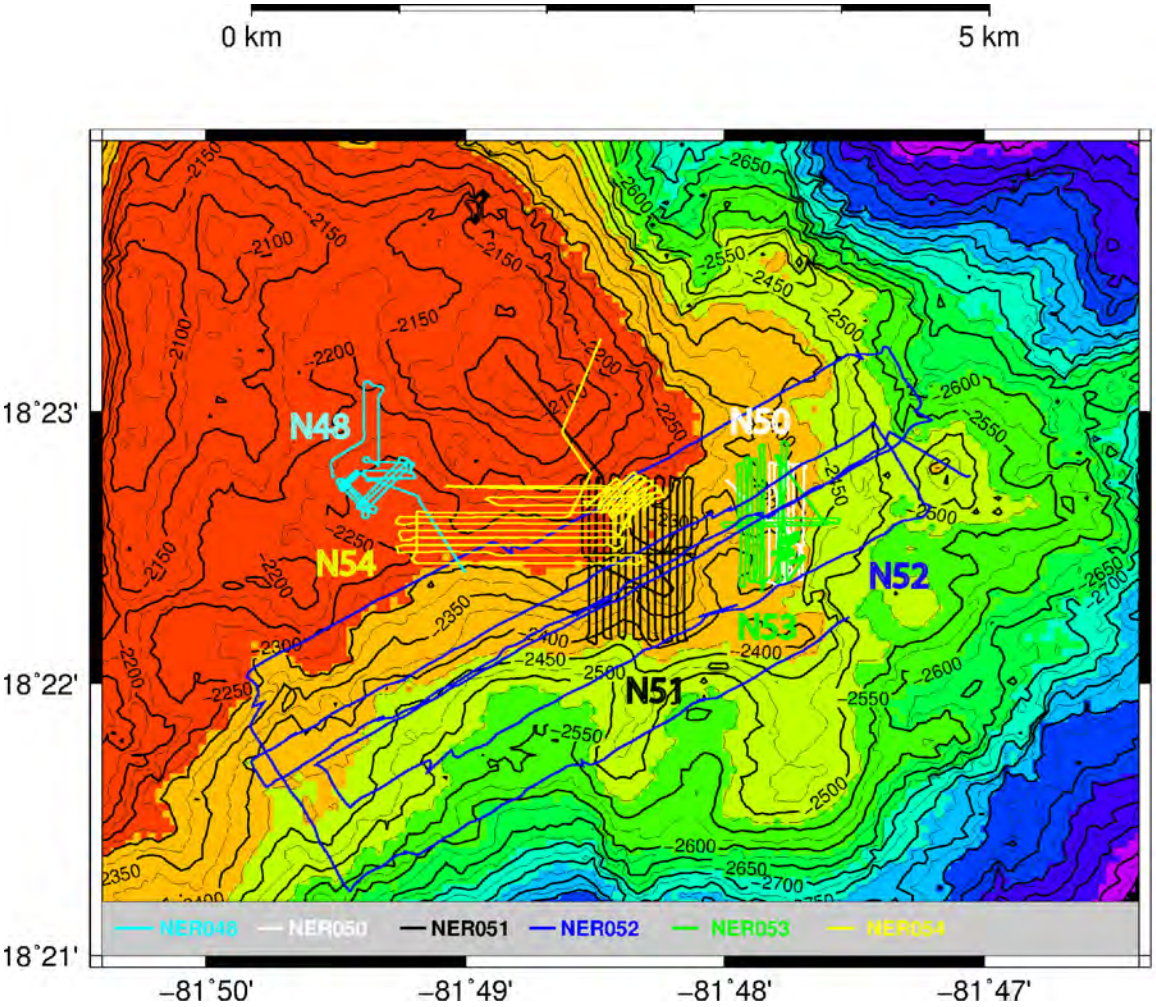


Fig.7.1 *Map showing Nereus dive trajectories superposed on shipboard Mt. Dent multi-beam bathymetry for all AUV dives completed during Leg 1 of RV Falkor cruise FK-008.*

Following aborted dives N48 and N49 (which never reached the seafloor), Dive N050 and later, Dive N053, were used to conduct a detailed high-resolution survey over the central Von Damm field and collect high resolution 3-component magnetometer data over the site – at higher resolution than had been collected previously when surveying the same site with ROV *Jason* in 2012. Although our initial preference prior to the cruise, would have been to conduct similar qualities of survey at the Piccard site, instead – it was decided to use the time available to prove diverse operational capabilities of Nereus in AUV mode. Dive N051 and later, Dive N054, were used to conduct near-bottom surveys of the seafloor to the West of the Von Damm mound, in a region where seafloor AUV surveys with AUTOSUB had previously detected evidence for Eh anomalies. Dive N052 was perhaps the most innovative of the cruise in which the vehicle flew a water column survey at broadly spaced survey lines but also undulated along each track line, thereby generating the equivalent of a high-speed and high spatial resolution of the CTD Tow-Yo surveys that had been used to track venting to a source atop Mt Dent originally. Importantly that work (which included a precise re-occupation of the initial survey line, extending SW away from the Von Damm Spire, at the end of the dive) revealed consistent evidence for two discrete sources of venting entering the ocean at two distinct depth/density horizons. One of these could clearly be traced back to the Von Damm spire's summit but the other, deeper, appeared to exhibit strongest plume signals to the West, away from the Von Damm site, consistent with the presence of some additional source of venting which, because it was deeper in the water column but was strongest over shallower terrain, need not be indicative of a high temperature system. A final new capability demonstrated by Nereus in AUV mode arose on dive N053 which used the opportunity, while surveying over the southernmost parts of the Von Damm site to collect near-bottom photographs over the flat-lying terrain of the tube-worm fields to the SE of the Spire, once all the 3-component magnetometer data had been collected. Finally, during N054, adaptive surveying capability with the Nereus AUV (originally used aboard Cape Hatteras in 2009) was employed once it had been confirmed that strongest in situ signals from the Eh sensor were to be found in the area of overlap between the N51 and N54 boxes.

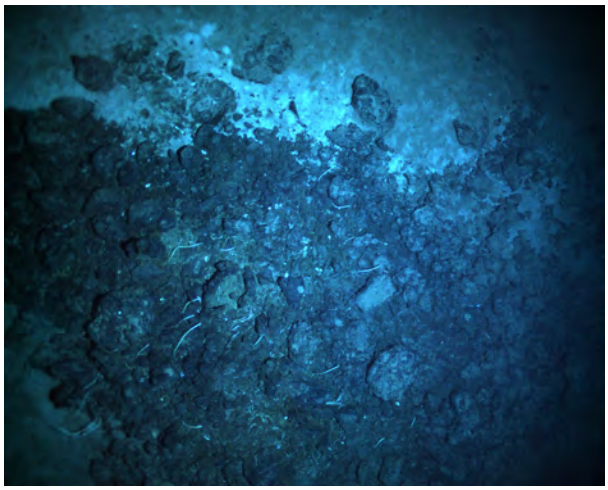


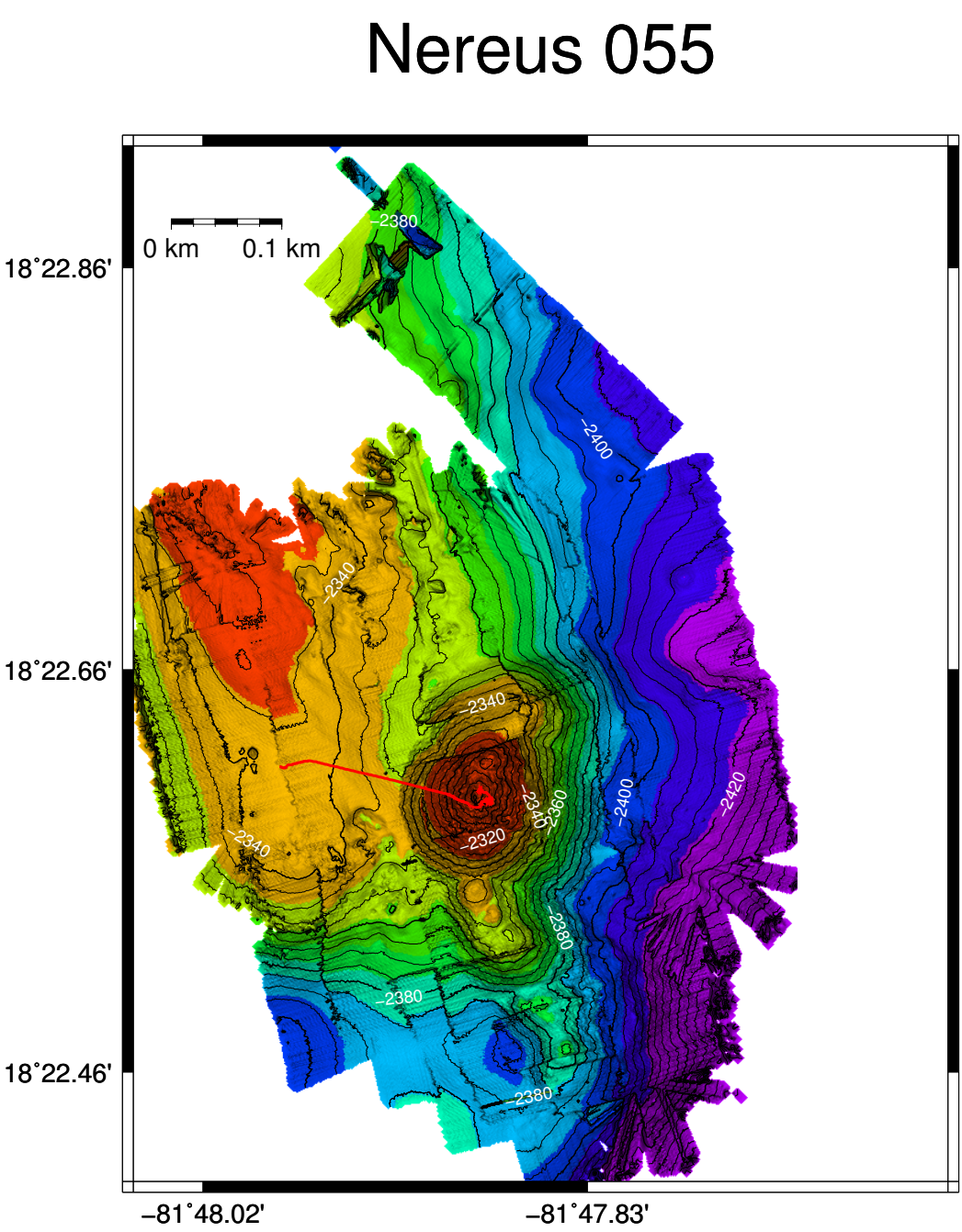
Fig.7.2 *First example of seafloor photographs taken by HROV Nereus in AUV mode on Dive N053. Clearly apparent are elongate tube-worms (white) against the dark rocky outcrop that hosts venting. Light patches represent microbial staining of the sediments at the limits of the outcrop/sediment interface.*

8. ROV *Nereus* Operations (C.German & J.Kinsey)

Summaries and dive tracks for each ROV dive are given below. For dive plans, basket sketches and sample lists for all dives see Appendices 3-5, respectively.

Nereus Dive 055

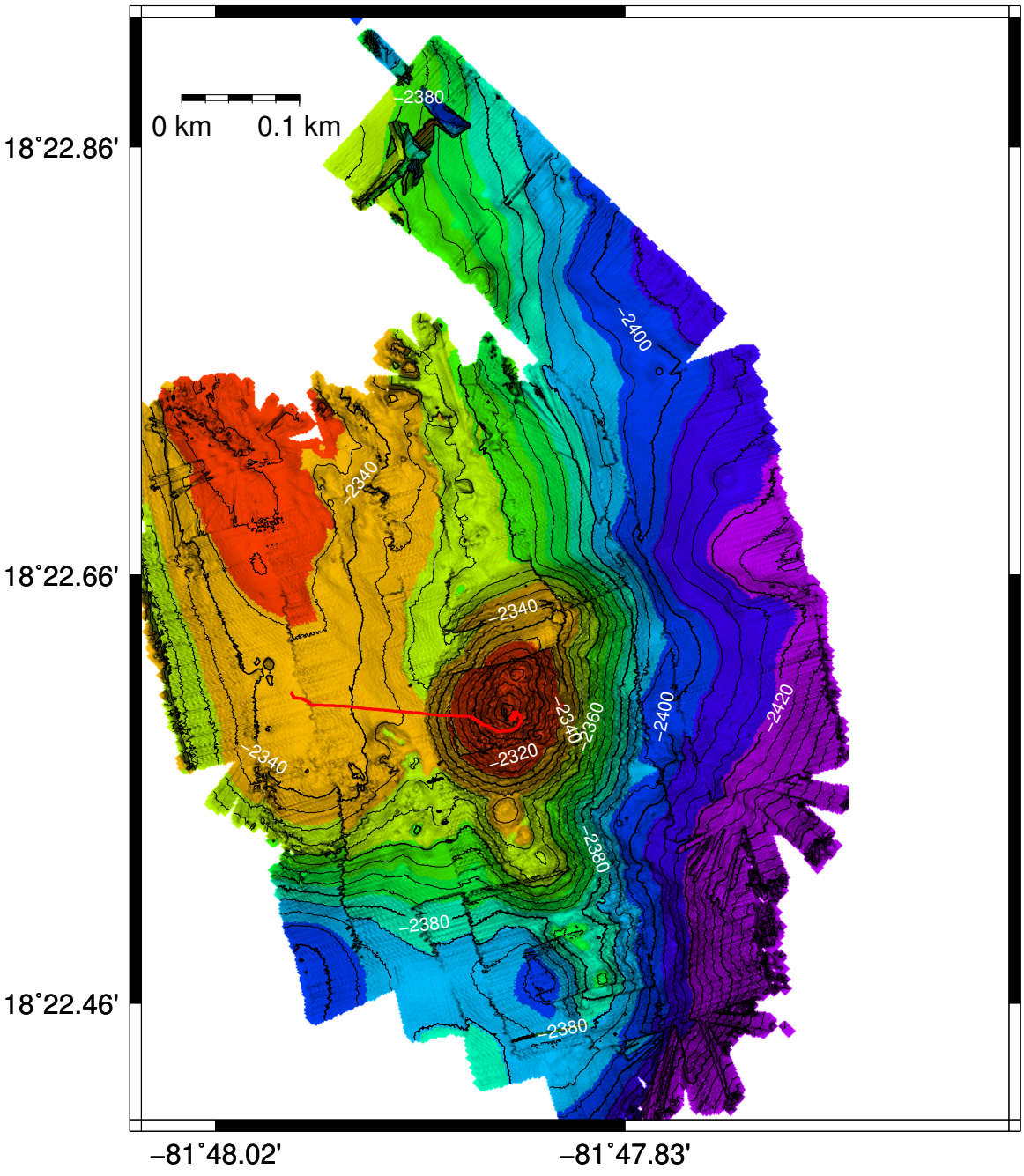
This was an initial (brief) dive to the summit of the Von Damm Spire to collect shrimp (slurp-pump), vent fluids (IGT bottles) and conduct first sampling with the SUPR sampler for both microbial and biogeochemical investigations.



Nereus Dive 056

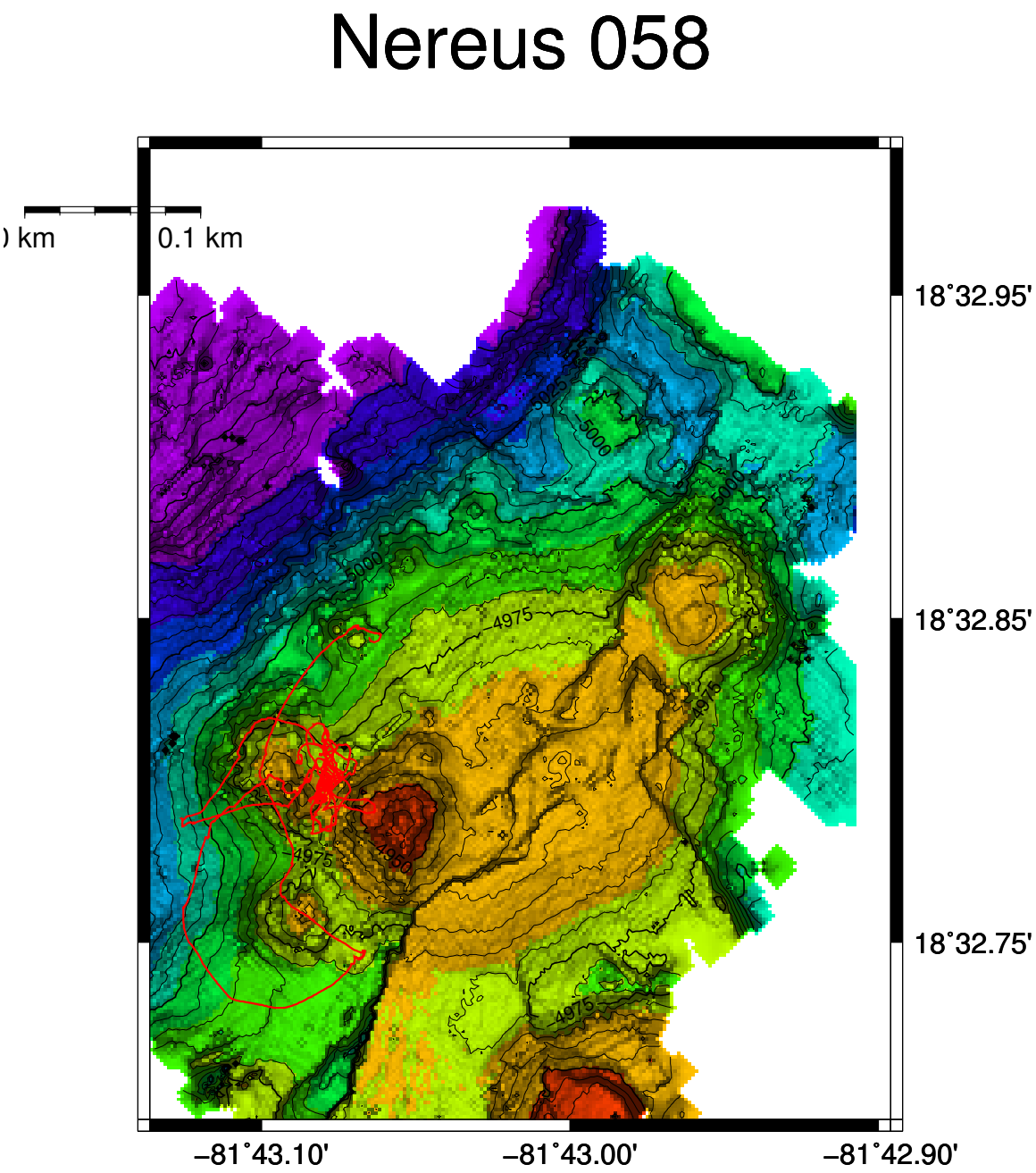
This was an even shorter dive to Von Damm. Despite detailed sampling objectives, the optical fiber connecting Nereus to the ship failed early in the dive while Nereus was conducting first high-temperature fluid sampling at the summit of the Von Damm Spire. Subsequent Dive 057 failed even faster during descent.

Nereus 056



Nereus Dive 058

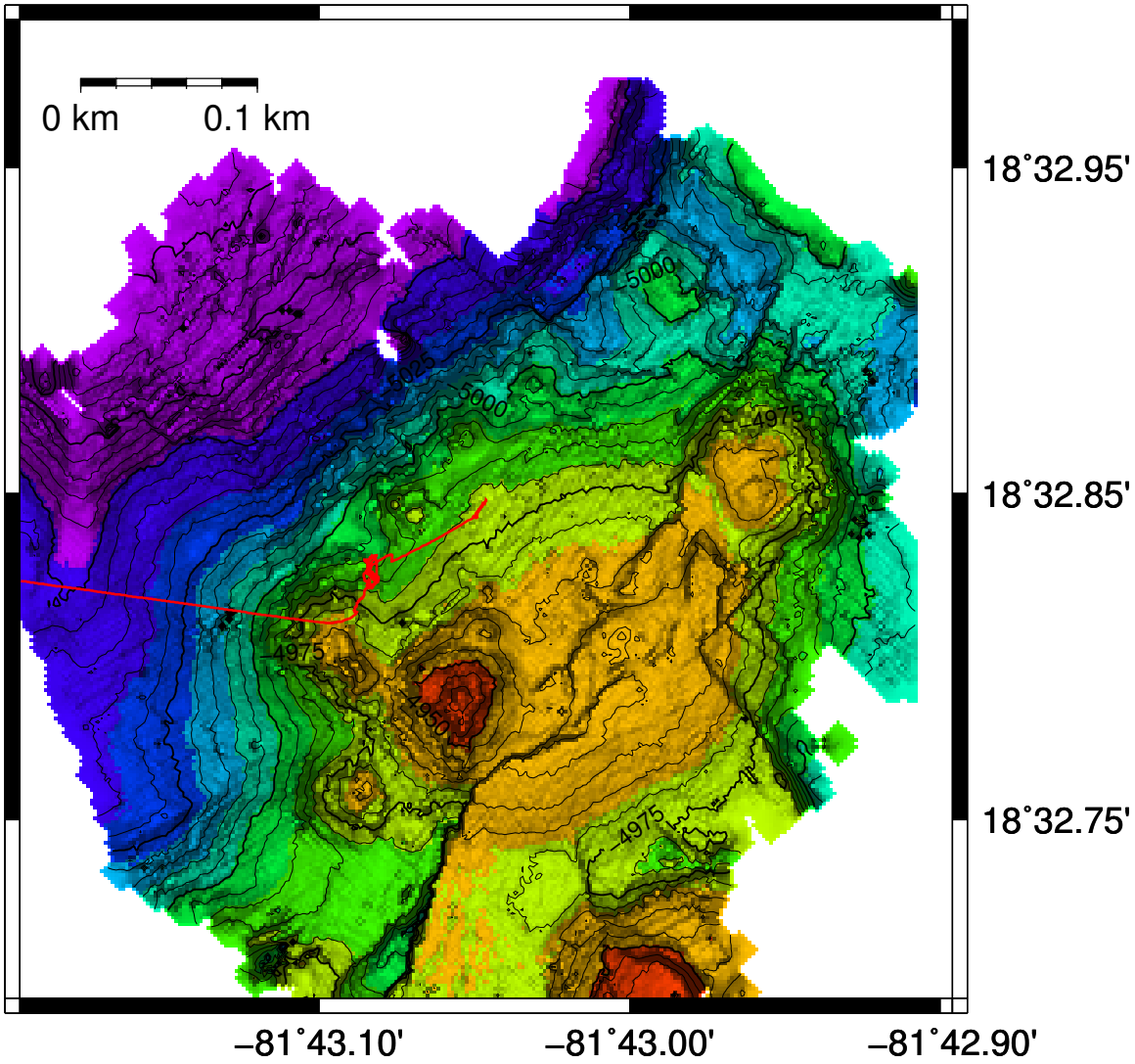
This was our first successful Nereus dive to the Piccard hydrothermal field. Primary achievements included collection of end-member vent-fluids from the Beebe Vents mound (BV#4, 398°C) followed by sampling from the overlying buoyant plume. Shrimp sampling was also conducted near Hot Chimlet.



Nereus Dive 059

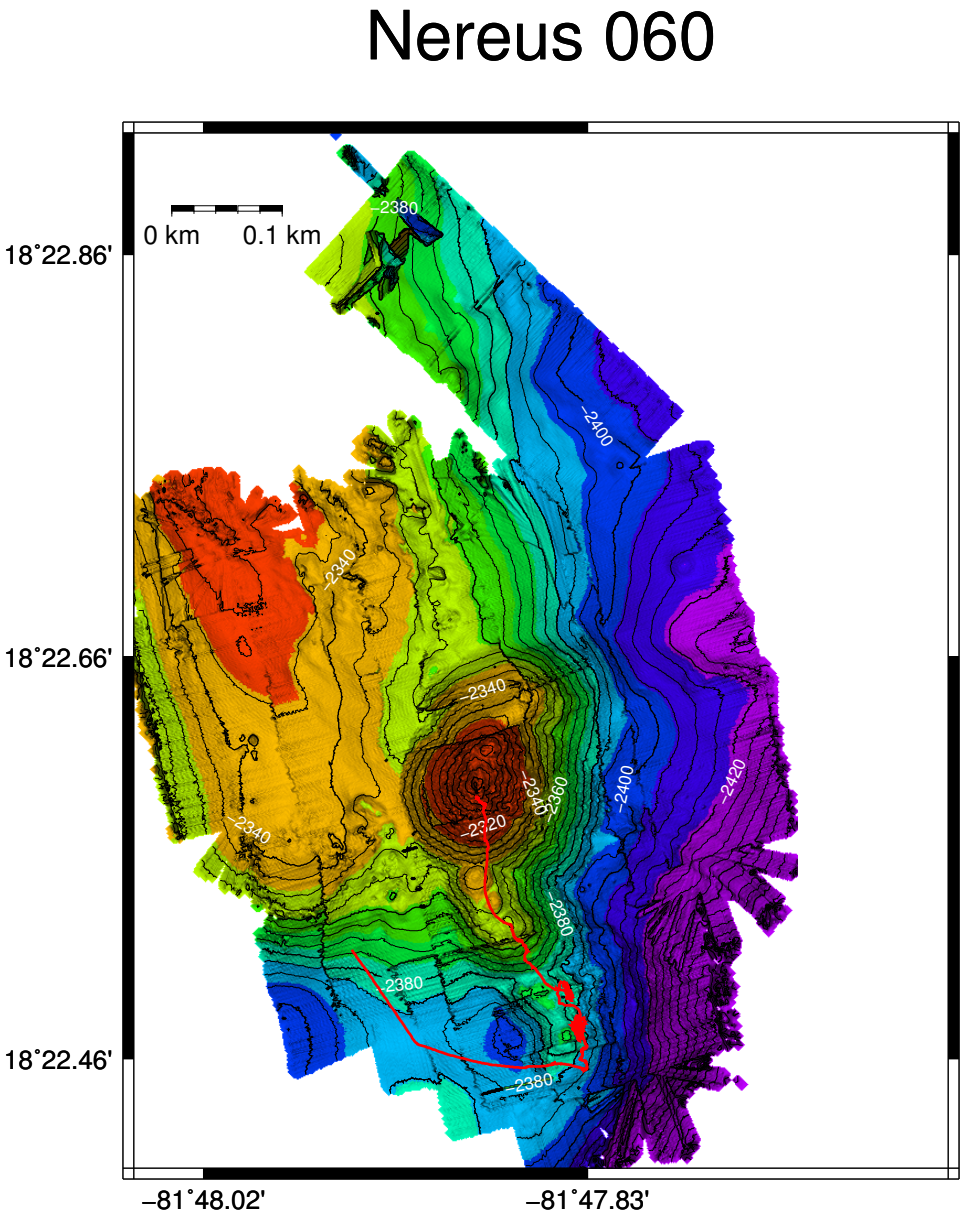
This second dive to the Piccard hydrothermal field conducted extensive time-series sampling at the Hot Chimlet site – for fluids (up to 85°C) and microbiota after which the vehicle transitted a long distance to the West (not shown) to recover an IGT sampler left behind by Nereus at the seafloor on our 2009 cruise.

Nereus 059



Nereus Dive 060

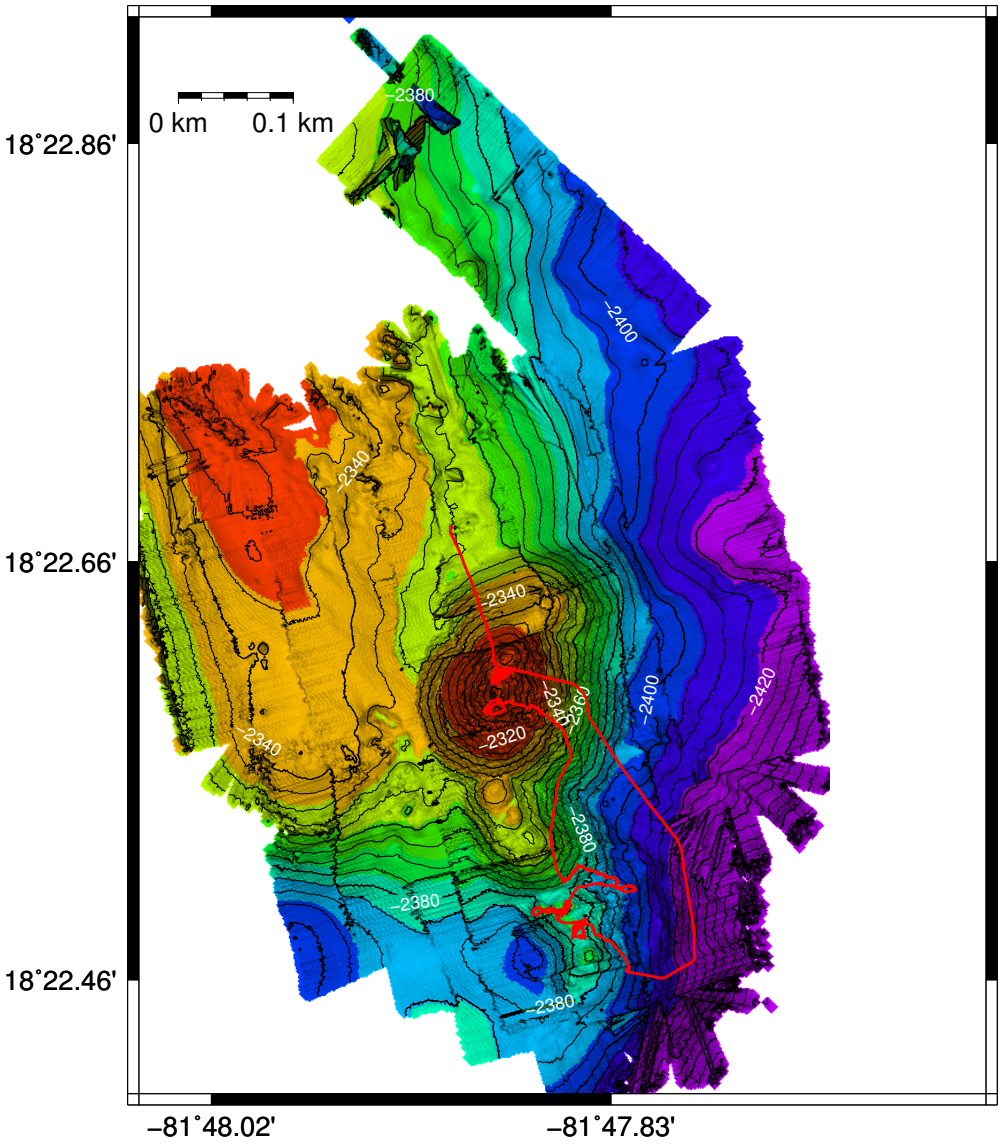
The primary objectives of this dive were to return to the X-18 area to the SE of the Von Damm spire where a bone-deployment recruitment/colonization “bone-bag” experiment had been deployed by ROV *Jason* in 2012. Additional SUPR sampling was then carried out in the same area for microbial studies. Once those goals had been achieved, Nereus continued north to collect samples of high-temperature fluids from a new site located immediately to the south of the Von Damm summit and named “Twin Peaks” (128°C fluids collected by IGT). Microbial sampling (SUPR) and sparse shrimp sampling (Slurp) were also completed at this new “Twin Peaks” location.



Nereus Dive 061

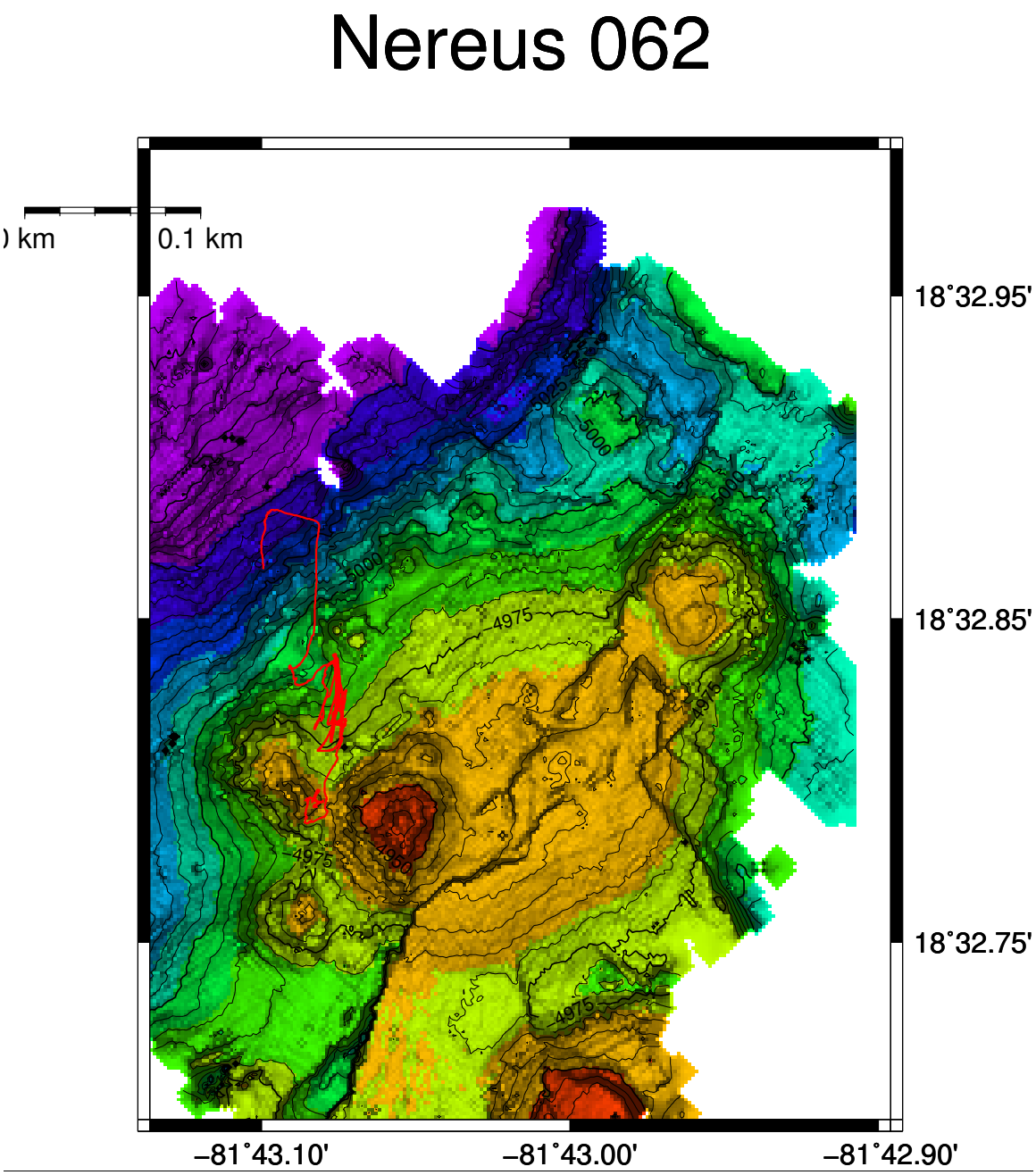
This was an extremely productive dive. Starting to the North of the Von Damm Spire, a series of novel sites were sampled, immediately to the north of the White Castle and Ginger Castle sites identfied during the ROV *Jason* “Oases 2012” cruise. Vent fluids up to 146°C and microbial samples at 61°C and 75°C were collected from this region (Shrimp Buttery, Bartizan sites). From there, Nereus proceeded to the SE to collect numerous shrimp from where they were sparsely spaced close to X-18 and then further microbial time-series sampling was conducted at the Old Man Tree site, south of the Von Damm spire (109-114°C). Following a search for mussels, *Nereus* paid one last visit to the Spire’s summit.

Nereus 061



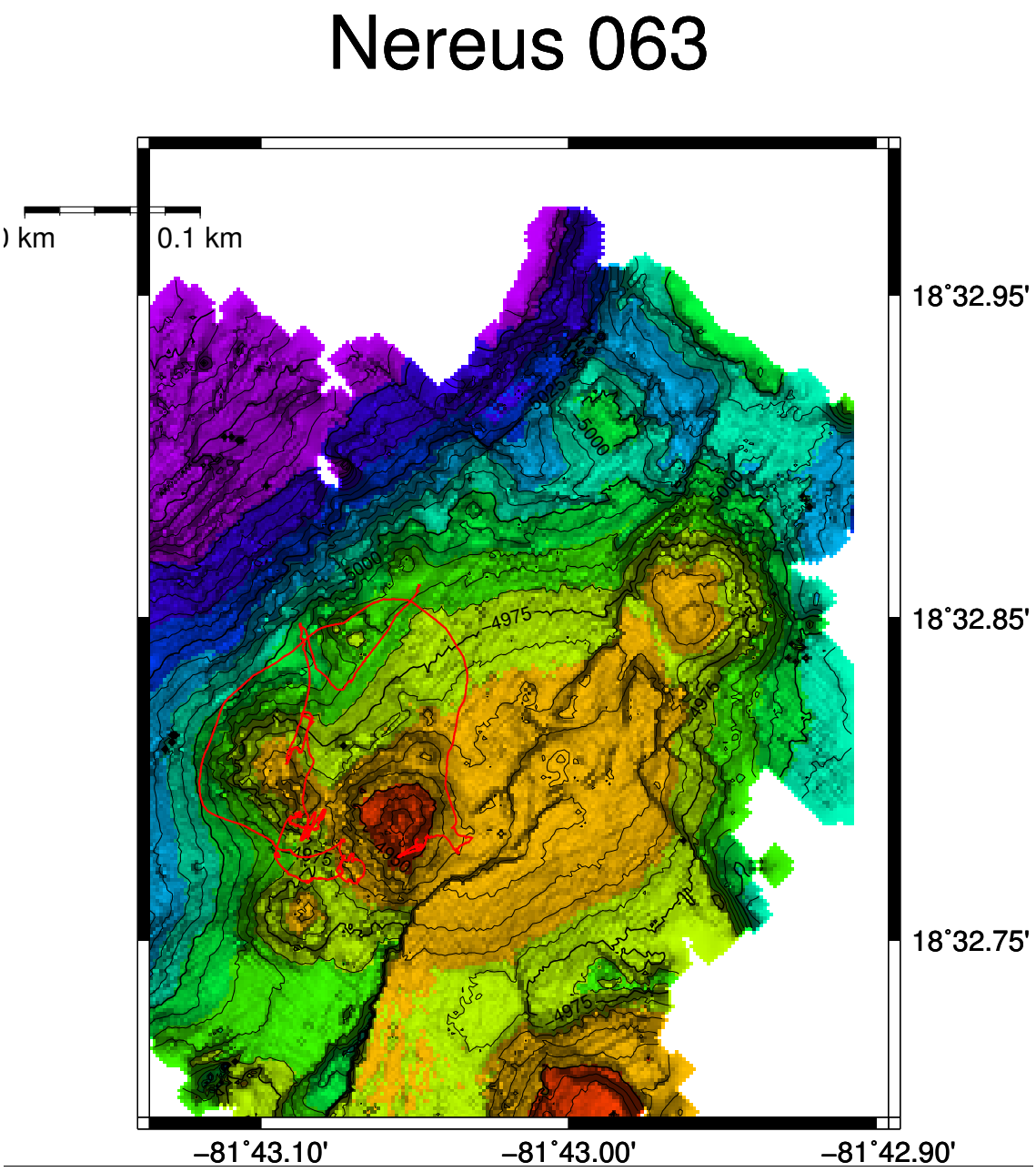
Nereus Dive 062

The priority for this dive was low-temperature fluid and microbial sampling at the Piccard hydrothermal field. Starting downhill to the north of the Beebe Vents mound, close to Hot Chimlet, a combination of primarily SUPR sampling was conducted (along with IGT fluids to 101°C at 4983m) upslope, ending with a suite of SUPR samples (and an additional slurp sample of shrimp) at a new low-T site (31-34°C) immediately adjacent to the Beebe Vents 1-5 named Shrimp Valley.



Nereus Dive 063

This was our final dive of the cruise. Following rock sampling for microbes at the Furry Walls site, we collected a series of samples at up to 100m above the seafloor in the buoyant plume overlying the 380°C BV#4 vent that had been sampled by IGT earlier in the cruise for time-series vent-fluid compositions. Following our aborted attempt to visit the Beebe Woods site for time-series IGT sampling, we followed a wide arc to the west and north of the Piccard field after breaking free of the Shinkai 6500 cable to arrive at the Beebe Sea site where low-T (42-78°C) time-series fluids were collected by IGT from Shrimp Gulley.



9. Science Objectives and Achievements

9a) Overview

As originally proposed, the plan for RV *Falkor* cruise FK-008 was to use Leg 1 to identify depths of new plume signals from CTD-rosette casts and then deploy the AUV *Nereus* to dive to these plumes (target 5000m depth) and locate their sources precisely using methods established previously with this and other deep-diving WHOI AUVs. During Leg 2, our ideal would then have been to dive to these new sites of seafloor venting to image and sample. Because that proved operationally impossible, early in Leg 1, a new strategy was developed. First, because it was not possible to dive the vehicle to 5000m depths in a sustainable way without taking undue risks with vehicle safety, it was decided to restrict all AUV operations to method development and operational work (see section 7). Next, as soon as the CTD had been used to confirm the presence of low-temperature diffuse venting at the Walsh site (see section 4) where we also reached the limit of how deep it was safe to continue to work, within the SWL, it was decided to divide the scientific goals for the cruise into two parts each of which are described below. First, we continued to use the CTD rosette above known sites of hydrothermal venting (at depths that *could* be reached safely) for on-going plume biogeochemical studies including some quite novel approaches. Those studies were conducted across both Leg 1 and Leg 2. Second, during Leg 2 only, we used the HROV Nereus in ROV mode to conduct time-series sampling and investigation of the Piccard and Von Damm hydrothermal fields. These dives included both re-occupation of know sites of fluid flow and, importantly, first sampling at additional locations - both already known and freshly discovered sites of seafloor fluid flow. The following two sections detail the primary activities conducted during the cruise under each of these groupings.

9b) CTD-rosette based hydrothermal plume investigations

9b.i Eh Sensing (K.Nakamura):

Description of the Eh sensor:
Eh is the measure of electric potential of aquatic solution in a standardized way. The Eh or electric (redox) potential value of a specific ionic reaction in water is expressed against the Standard Hydrogen Electrode (SHE). For practical measurement, several types of reference electrodes are commonly used. In the CTD operation for this cruise, the reference electrode was a Ag-AgCl electrode in saturated KCl solution. A 0.7-mm diameter Pt-wire electrode was used as the inert electrode. The Eh values expressed throughout this cruise report are the raw values of the Pt electrode voltage when compared against the reference electrode (Ag-AgCl electrode in saturated KCl solution) and are not converted to the values against the SHE.

An analog transformer mounted in a pressure housing was inserted between the electrodes and the SBE 9plus CTD auxiliary connector 2 (Voltage 2). This transformer had two functions:
1. To separate the ground between the electrode side and the CTD system side. Because the electrodes measure the voltage of seawater and are directly grounded to seawater, it is essential to avoid any ground loop problem.
2. Eh values of seawater vary between about 350 mV (surface well-oxygenated water) and -150 mV (black smoker vent fluid or H_2S rich cold seep), whereas the SBE system only accepts positive voltage values, between 0 and 5 volts. So the transformer converts electrode inputs ranging between -500 mV and +500 mV to output voltages that range between 0 and 5 volts.

To display the raw value of Eh in real time on the CTD data display, the following equation was embedded as a user polynomial within the SEASAVE software:
(Eh in mV) = -500 + 200 x (Voltage 2 where Eh sensor was connected in V)
The A/D converter for all auxiliary channels of the SBE-9plus is 12 bit. (6 bit = 64, 12 bit = 64 x 64 = 4096, Appendix of SBE-9plus manual, p.48, p.50). Because of this, the maximum resolution of Eh values that could be obtained from the Eh sensor mounted on the SBE-9plus CTD rosette was limited to 1000 mV/4096 = 0.244 mV.

Formally, in any electrochemistry textbook, electric potential is the measure obtained under equilibrium conditions and in many practical experimental textbooks caution is expressed to ensure that equilibrated measurements are taken. On a moving platform like a CTD in seawater, however (a heterogeneous and complex aquatic solution), equilibrated measurements cannot be expected. For example, even the CTD winch speed can affect *in situ* measurements. Caution should be paid when examining the data therefore, especially for any upcast data, which include measurement under highly variable winch speeds including stationary periods when the rosette is halted to undertake water sampling.

9b.ii Optical Oceanographic Studies (M.Estapa):

Sampling for optical studies

Bottle samples were collected from selected CTD casts for measurements of multispectral beam attenuation and particle size. CTD-001 served as a background and method testing cast. Profiles of particles in the rising and neutrally-buoyant plumes at Piccard were collected from CTDs 005 and 023. Samples of the Von Damm plume were collected from CTD 022 (single depth) and CTD 027 (profile). In all casts, sampling was focused at depths where upcast 650 nm beam attenuation (c(650) was at least 0.001 m^{-1} above the baseline. In each cast at least one bottle represented “optical background” and was chosen as the deepest bottle with a baseline c(650) signal.

Sampling for supporting materials (metals, Si):

Whole-water metals and 0.2 μm-filtered silicate samples were collected along with optical samples from CTD 005, CTD 023, and CTD 027. Acid-washed HDPE containers were triple-rinsed with sample water before filling. Silicate samples were frozen, then thawed for 0.2μm syringe filtration (Sterivex GV) on 16-June.

Methods used for at sea optical studies

In situ beam attenuation on CTD (and on Nereus):

Beam attenuation at 650nm was measured with two different transmissometers (both 25 cm pathlength C-Star, WETLabs) mounted on the CTD/rosette and on the HROV *Nereus*. The rosette transmissometer (belonging to the R/V *Falkor*) was mounted horizontally at the bottom of the rosette with its open path facing upwards towards the bottles. The *Nereus* transmissometer was mounted vertically inside the front end of the port pontoon. Both transmissometers were deployed without flow tubes. Prior to every CTD cast and *Nereus* dive, the transmissometers' optical windows were cleaned 5x with Milli-Q water and dried with lint-free tissue, then an air reading was taken. These readings and the minimum deep-water attenuation values were used to track instrument drift during the cruise.

Analog voltages were logged from the CTD/rosette transmissometer, while digital counts were logged from the *Nereus* transmissometer. Maximum deepwater voltages and counts were used to calibrate the two transmissometers. Air readings, while indicating negligible instrument drift during Leg 1 of the cruise, were not as consistent as deep water readings. As with the ac9 (see below), *in situ* deep water readings for both transmissometers were higher than for the ship's MilliQ water, indicating some residual absorption in the MilliQ supply. Upper ocean data from the CTD/rosette transmissometer displayed consistent evidence of uncorrected thermal shock (downcast always lower than upcast in the thermocline only), but bottom waters of interest were not affected by this effect. The *Nereus* transmissometer's digital output was internally corrected for temperature effects.

Bottle samples:

Multispectral (412, 440, 488, 510, 532, 555, 650, 676, 715 nm) beam attenuation measurements of bottle samples were made using a 25-cm pathlength absorption and beam attenuation meter (ac9, WETLabs). Particle size distribution measurements were made with a laser diffraction particle sizer (LISST-100X Type C, Sequoia Scientific).

Bubble-free, 150 mL samples were collected in duplicate or triplicate by syringe directly from rosette bottles. Generally, one whole-water replicate was analyzed without other manipulation in the ac9, another replicate was syringe-filtered (0.2μm, Sterivex GV) directly into the ac9, and when *in situ* c(650) was high, a third whole-water replicate was collected and analyzed in the LISST. Syringes were triple-rinsed with sample water prior to filling. Syringe plunger tips and

barrels were cleaned of silicone lubricant and tips were wrapped in PTFE tape to avoid particle adhesion.

The ac9 absorption side light source burned out after the first background cast (CTD 001), so spectral absorption measurements were not performed. Both LISST and ac9 were zeroed vs. MilliQ water (Milli-Q Direct8). Clean water offsets for the ac9 were measured prior to and during each sample run by repeatedly cleaning the optics and flow paths until stable values were achieved. Samples were introduced into the flow tubes (ac9) and sample chamber (LISST) through 1/8" ID tygon tubing in a gas-tight manner to avoid entraining bubbles. Data files were recorded over 1-2 minute periods to average over periodicity due to ship's roll, which affected the ac9. Sample and clean water temperatures were recorded immediately after measurement in the ac9.

Multispectral beam attenuation data were median-filtered to remove rare spikes and averaged over the 1-2 minute recording period. Mean spectra were corrected for temperature-dependent absorption by water (Sullivan et al. 2006) and had clean-water offsets subtracted. In some casts the deep "background" sample had lower 0.2μm-filtered attenuation than the MilliQ zero, likely due to residual absorption in the MilliQ water. In these cases the deep background bottle was taken as "zero".

9b.iii Water Column Geochemistry (J.McDermott, S.Sylva & E.Reeves)

During the course of the cruise we performed a total of 28 CTDs, and sampled for the following:

Methane:
For methane, we sampled 3 CTDs at Von Damm vent field [2 full bottom profiles (CTD03, CTD27) and 1 two-depth profile (CTD02)], 2 CTDs at Piccard vent field [2 full bottom profiles (CTD05, CTD23)], 15 CTDs at Walsh plume [all full bottom profiles (CTD07 through CTD21, inclusive)], and 2 CTDs at Europa plume [2 full bottom profiles (CTD25, CTD26)]. Methane samples were analyzed shipboard according to methods described by German et al. (PNAS, 2010).

Methanol and ammonia/ammonium abundance:
For methanol and ammonia/ammonium abundance, we sampled 2 CTDs at Von Damm [select bottles from full bottom profile (CTD03, CTD27)] and 1 CTD at Piccard [select bottles from full bottom profile (CTD05)]. Sample aliquots were preserved at -30°C for on-shore analysis by E. Reeves (MARUM U. Bremen) and J. McDermott (WHOI).

Nitrate and ammonia/ammonium abundance and isotopes, DIC:
For nitrate isotopes and abundance, ammonia/ammonium isotopes and abundance, and DIC isotopes and abundance, we sampled 1 background bottle each from 1 CTD at Von Damm (CTD27), and from 1 CTD at Piccard (CTD23). Sample aliquots for nitrogen species were filtered through 0.22μm Sterivex Millipore® filters, and preserved at -30°C for on-shore analysis by J. McDermott

and S. Wankel (WHOI). Samples for DIC were collected in evacuated serum vials and stored for on-shore analysis by J. McDermott and S. Sylva (WHOI).

He isotopes:
For He isotopes, we sampled 1 CTD at Walsh [full bottom profile (CTD21)]. Samples were collected in copper tubes and stored for on-shore analysis by M. Kurz (WHOI).

9b.iv Plume Sampling for Viruses and Other Microbiology (C.Sheik)

Project methodology.

Cell Counts:
Fifty-milliliter aliquots of water were subsampled from each Niskin bottle from a given CTD cast. Samples were chosen based on the detection of methane in the water column profile. Samples were kept at 4^{o}C until filtering and processed within hours of sampling. All 50ml of seawater were filtered onto 0.22µm, 25mm diameter Isopore polycarbonate filter (Millipore, GTTP02005) with a glass-backing filter (Millipore, AP15002500) using a Millipore filtration manifold. Pressures were kept at 4 psi for filtering. Cells were fixed with 3 ml of 3% formaldehyde diluted in 1x phosphate buffered saline. Cells were washed once with sterile 1x phosphate buffered saline, dried in the dark and frozen at -20^{o}C until cell counts could be completed in the shore laboratory.

Viral and microbial metagenomic sampling:
Niskin bottles were gravity drained into 20L collapsible carboys and stored at 4^{o}C until filtering could be completed. 100L of plume-influenced seawater was filtered onto a single 0.2µm, 142mm diameter Supor filter (Pall-66549) using a peristaltic pump and custom polycarbonate filter housing. Supor filters were removed with sterile forceps, folded and placed into a 15ml conical tube to which 10 mL of RNA preservation solution was added. Finally, filters were frozen at minus 80^{o}C. Filtered water was collected and 2ml of a 10g/L ferric chloride solution was added. Iron amended waters were allowed to incubate and then filtered a second time using a 1.2µm, 142mm diameter Isopore filter (Millipore, RTTP-14250) to collect the precipitated iron. Filters were collected and stored together in a single sterile 50ml conical tube at 4^{o}C. Samples were then transferred back to the shore laboratory for DNA and RNA extraction and sequencing from all filters.

Overview of bottles sampled for microbiology analysis.

CTD-01: 20L of sample was taken for a trial filtering run.
CTD-02: Viral focused cast at Von Damm: viral and cell counts taken. 200L filtered for coupled viral and microbial metagenome & metatranscriptome analysis. Sampled above vent in background waters and in the rising plume.
CTD-06: Not sampled, 1st viral cast but missed plume: got a case of blue bottles.
CTD-07: Sampled all 24 bottles for cell counts as a test of methods.
CTD-09: Sampled bottles 3-7 where methane was detected

CTD-12: Filtered water from bottles 4-10 for cell counts
CTD-13: Filtered water from bottles 4-7, 9-12, and 16-19 for cell counts
CTD-21: Took samples from all 24 bottles for cell counts
CTD-22: Filtered water for Max ~288 L, Filtered through two filters.
CTD-23: Took samples from bottles 1-22 for cell counts.
CTD-24: Filtered water from two sites in the Piccard field for viral community analysis. A lower temperature diffuse flow (likely Beebe Sea), and a buoyant rising plume. Viral and cell counts taken, and 200L filtered for coupled viral and microbial metagenome and metatranscriptome analysis.

9b.v Plume Sampling for Lipids (M.Coleman, C.Sheik, C.Van Dover)

Introduction

Lipids are biochemical compounds that form the cell walls of microbes but are also very important in higher organisms. Previous work on hydrothermal vent fauna, especially shrimp, has suggested that some of these lipids, though present only as a small part of the total, are essential for growth and reproduction. However, some of these essential lipids are thought to be produced only by organisms that gain their nutrition through photosynthesis and are not produced by the chemosynthetic bacteria that contribute most significantly to the food chain of vent ecosystems. To test and quantify these concepts further, our objective was to undertake analyses of the lipids in various organisms at the ~5000m deep Piccard vent field to compare with the ~2300m Von Damm equivalents where the shallower setting might provide a better opportunity to access photosynthetic debris settling from the ocean surface.

Our goal was to sample water column bacteria from which lipids could be separated. Because some of the essential lipids are present only in small amounts and because the mass of bacteria per unit volume is relatively small, it was necessary to filter all the microorganisms from a large volume of water.

Methods

We sampled using a CTD rosette fitted with the usual sensors but with the addition of an Eh sensor (*section 9b.i*) and equipped with 12 x 12 L Niskin bottles. By use of the Eh sensor (± the temperature sensor for near-bottom stations close to vent sites) we identified suitable depths and locations where it seemed apparent that we had intercepted plume-waters suitable for sampling and fired all the available bottles at that depth. After recovering the CTD, the contents of all bottles were transferred to the lab, where they were passed as rapidly as possible through two parallel 0.22µm pore-size, 142mm diameter Supor® PES Membrane Disc Filters, using a peristaltic pump. For each of the successful sampling efforts the filters were folded, wrapped in aluminum foil, placed in sterile bags and frozen at -80°C. A small portion of each filter was also cut out, to be used for DNA analysis from which it will be possible to identify the microbial community structure.

Activities

We attempted to sample three CTD casts on Leg 1 together with seven further casts on Leg 2. On seven of those 9 casts samples were taken successfully. The exceptions were stations CTD 28 on Leg 1 at Von Damm and CTD 30 on Leg 2 at Piccard where drift directions at depth meant that the CTD-rosette failed to intercept the dispersing hydrothermal plume and, consequently, no samples were taken. Table 9.1 shows the full list of casts dedicated to lipid sampling.

Table 9.1 Lipid sampling casts occupied during RV Falkor cruise FK-008.

Cast #	Location	Depth/Details
CTD 002	Von Damm	2058m, 1750m
CTD 022	Von Damm	1981m
CTD 028	Von Damm	Missed plume: no samples
CTD 029	Von Damm	2040m
CTD 030	Piccard	Missed plume: no samples
CTD 031	Piccard	4960m
CTD 033	Piccard	4980m
CTD 034	Von Damm	2376m
CTD 035	Piccard	4974m
CTD 036	Piccard	4973m

9c) ROV based seafloor investigations

9c.i Vent-fluid Geochemistry (J.Seewald, S.Sylva, J.McDermott)

The scientific objectives of the fluid sampling program were to examine the influence of the relatively high pressure associated with the high water depth (4960m) at Piccard upon fluid-rock interactions and to expand our understanding of fluid-rock interactions at what is postulated to be an ultramafic-hosted hydrothermal system at Von Damm. A major goal for our efforts at both sites is to constrain the extent of abiotic organic synthesis so that we can assess the role that these systems may have played in the origin of life on early Earth. Characterization of reduced carbon compounds delivered to the seafloor in hot-spring systems also allows constraints to be placed on the sources and composition of carbon compounds utilized by vent communities. We also focused upon an examination of both biotic and abiotic reactions that could influence the composition of vent fluids following mixing of high temperature end-member fluids with seawater prior to venting in subseafloor environments. Accordingly, our sampling strategy involved collection of fluids at both high temperature focused flow vents and areas of lower temperature diffuse venting.

A total of 13 fluid samples were collected using isobaric gas-tight fluid (IGT) samplers from 3 distinct orifices at the Von Damm vent field and from 4 distinct

orifices at the Piccard vent field. Clogging of the sampler inlet snorkel resulted in the loss of an eighth attempted sample (N063-IGT4). Temperatures of sampled fluids measured using the IGT temperature probes during collection varied from 138 to 215°C at Von Damm and from 41 to 398°C at Piccard. The highlight of the fluid sampling program was the location and recovery of an isobaric gas-tight sampler left on the seafloor near the Piccard vent field in 2009.

In addition to the fluids collected using the isobaric gas-tight fluid samplers, selected fluids collected using the SUPR sampler (see next section) were also analyzed by our team for dissolved H_2, CH_4, H_2S & pH (25°C). Further samples of these fluids were also taken for analysis of additional inorganic aqueous species in the shore laboratory at WHOI.

Aboard ship, fluid samples were analyzed for dissolved H_2, CH_4, and CO concentrations by gas chromatography, for pH (25°C) using a Ag/AgCl combination reference electrode, and for H_2S concentration by titration and precipitation as Ag_2S to be followed by shore-based gravimetric determination. Fluid aliquots were also archived for shore-based analysis of dissolved major and trace cations by inductively coupled plasma – mass spectrometry (ICPMS), the abundance and isotopic composition (carbon and hydrogen) of low molecular weight hydrocarbons and CO_2 by isotope ratio monitoring – gas chromatography mass spectrometry (irm-GCMS), for dissolved anions by ion chromatography, for methanol by purge-and-trap gas chromatography, and for the abundance and isotopic composition of aqueous N-species by colorimetry, flow injection analysis, and isotope ratio mass spectrometry.

Table 9.2 List of vent-fluid samples collected during FK-008.

Sample #	Vent Field	Orifice	IGT Tmax
N55-IGT4	Von Damm	East Summit	215°C
N56-IGT6	Von Damm	East Summit	138°C
N58-IGT7	Piccard	Beebe Vent #5	390°C
N58-IGT8	Piccard	Beebe Vent #5	398°C
N59-IGT6	Piccard	Hot Chimlet #1	81°C
N59-IGT4	Piccard	Hot Chimlet #1	85°C
N60-IGT7	Von Damm	Twin Peaks	138°C
N60-IGT8	Von Damm	Twin Peaks	138°C
N61-IGT4	Von Damm	Bartizan	142°C
N61-IGT6	Von Damm	Bartizan	147°C
N62-IGT8	Piccard	Nr. Hot Chimlet	101°C
N62-IGT7	Piccard	Nr. Hot Chimlet	97°C
N63-IGT4	Piccard	No Sample Collected	78°C
N63-IGT6	Piccard	Shrimp Gulley	80°C

Table 9.3 List of SUPR samples collected for geochemical analyses.

Dive #	SUPR Bottle #	Methane	Hydrogen	H_2S	pH
N55	Bottle 03	x	x	x	x
N55	Bottle 06	x	x	x	x
N58	Bottle 05	x	x		
N58	Bottle 07	x	x		
N58	Bottle 09	x	x		
N58	Bottle 11	x	x		
N59	Bottle 01	x	x	x	x
N59	Bottle 03	x	x	x	x
N60	Bottle 01	x	x	x	x
N60	Bottle 03	x	x	x	x
N60	Bottle 05	x	x	x	x
N61	Bottle 01	x	x	x	x
N61	Bottle 03	x	x	x	x
N61	Bottle 05	x	x	x	x
N61	Bottle 07	x	x	x	x
N61	Bottle 09	x	x	x	x
N62	Bottle 01	x	x	x	x
N62	Bottle 03	x	x	x	x
N62	Bottle 05	x	x	x	x
N62	Bottle 07	x	x	x	x
N63	Bottle 02	x	x		
N63	Bottle 06	x	x		
N63	Bottle 10	x	x		
N63	Bottle 14	x	x		

9c.ii Seafloor Microbiology (J.Huber & J.Reveillaud)

Our participation in the cruise was as part of a larger Deep Carbon Observatory project “Deep Life I: Microbial Carbon Transformations in Rock-Hosted Deep Subsurface Habitats.” which encompasses investigators from 11 laboratories spanning 7 countries and has a focus on describing and quantifying the metabolic activities of microorganisms in the rock-hosted subsurface biosphere. The project consists of concerted observational studies of key understudied deep subsurface environments coupled with experimental investigations aimed at elucidating the physiological underpinnings of microbial adaptations to these

environments. The central goal of the research is to understand how microbial communities interact with Earth's deep carbon cycle through their growth and metabolism. The work draws upon cutting-edge technologies in the Biogeosciences including next generation sequencing approaches, bioinformatics, stable isotope probing, and high pressure microbial cultivations. Dr. Huber is the MBL Lead PI on this grant, and Dr. Reveillaud is a postdoctoral scholar fully supported on this grant.
A primary motivation behind our microbial ecology research is to constrain the relationship between the population structure and diversity of microbial communities and their local geochemical environment. In this regard, the Mid Cayman Rise (MCR) represents an ideal natural laboratory in which to examine two key understudied aspects of vent microbiology: the role of pressure and of ultra-mafic substrates. A relatively large literature exists for the microbial ecology of basalt- and sulfide-hosted hydrothermal systems shallower than 3500 m, but much less is known regarding microbial populations in ultramafic-hosted or extremely deep hydrothermal settings.

Given our previous results from these sites in 2012, we had identified targets at each site that cross the temperature gradient from known microbial life (<122 °C) to unknown microbial life (>122 °C). We designed specific experiments to examine carbon metabolism and the influence of hydrogen on that metabolism over this temperature gradient with stable isotope tracing experiments that target organisms that can either use or generate methane with hydrogen (autotrophs). These experiments are to be incubated back at MBL at various temperatures to examine when and where these metabolisms are occurring.

Three types of sample were collected: vent fluids, microbial mats, and shrimp. Vent fluids were collected using Chip Breier's SUPR version 2 sampler (see next section) adapted with 0.22µm Sterivex filters for *in situ* filtration and concentration of biomass for nucleic acid extraction and analysis on land. In addition, whole water was collected in 1L bottles on the SUPR sampler for cell counts, chemistry, stable isotope tracing experiments, and single cell genomics. Splits of all samples were given to the Seewald lab for chemical analysis (H_2S, pH, volatiles, major and minor elements). One rock with fuzzy white microbial filaments was collected into the biobox and preserved for microscopy and nucleic acid analysis. Dissected shrimp and their symbionts were collected for nucleic acid analysis in collaboration with Cindy Van Dover and Max Coleman (see next section).

In total, we collected vent fluids from 10 distinct sites (6 from Von Damm, 4 from Piccard), 1 mat sample (from Piccard), and 23 shrimp symbiont tissues. Finally, background seawater was collected at 2300 m for nucleic acid analysis and stable isotope analysis using the CTD. Table 9.4 lists all samples collected for microbial analysis.

Table 9.4 List of Seafloor Samples Taken during FK-008 for Microbial Analysis

Sample#	Dive	Type	Date	Depth	Tmax	Vol (L)	Hdg	X	Y	Vent
N058-3	N-058	IGT-8	6/24/2013	4495	398		10	3374	5167	Piccard
N055-4	N-055	Sterivex	6/21/2013	2293	80	0.75	310	1970	1099	Von Damm
N055-5	N-055	Bottle	6/21/2013	2293	120	4.18	306	1970	1100	Von Damm
N055-6	N-055	Sterivex	6/21/2013	2293	130	3.17	306	1970	1100	Von Damm
N055-7	N-055	Bottle	6/21/2013	2293	128	2.51	301	1970	1100	Von Damm
CTD032	CTD032	CTD	6/24/2013	2300m						
N059-8	N-059	Sterivex	6/25/2013	4985	85	4	108	3365	5226	Piccard
N059-7	N-059	Bottle	6/25/2013	4985	85	5.7	108	3365	5226	Piccard
N059-6	N-059	Bottle	6/25/2013	4985	85	5.6	108	3365	5226	Piccard
N060-3	N-060	Bottle	6/26/2013	2372	30	5.79	63	2056	894	Von Damm
N060-4	N-060	Sterivex	6/26/2013	2372	30	8.44	63	2056	894	Von Damm
N060-5	N-060	Bottle	6/26/2013	2372	30	6.41	63	2056	894	Von Damm
N060-6	N-060	Sterivex	6/26/2013	2369	140	7.35	97	2045	921	Von Damm
N060-7	N-060	Bottle	6/26/2013	2369	140	6.85	97	2046	923	Von Damm
N061-5	N-061	Bottle	6/27/2013	2304	131	6.41	171	1980	1129	Von Damm
N061-6	N-061	Sterivex	6/27/2013	2304	131	7.79	201	1980	1129	Von Damm
N061-12	N-061	Bottle	6/27/2013	2369	29	6.85	255	2028	911	Von Damm
N061-13	N-061	Sterivex	6/27/2013	2369	29	6.94	256	2028	911	Von Damm
N061-14	N-061	Bottle	6/27/2013	2369	29	6.79	257	2023	914	Von Damm
N061-17	N-061	Sterivex	6/27/2013	2370	114	8.21	274	2021	921	Von Damm
N061-18	N-061	Bottle	6/27/2013	2370	114	8.28	273	2021	921	Von Damm
N061-19	N-061	Bottle	6/27/2013	2370	114	7.44	274	2021	929	Von Damm
N061-15	N-061	Shrimp	6/27/2013	2368			257	2023	914	Von Damm
N061-15	N-061	Shrimp	6/27/2013	2368			257	2023	914	Von Damm
N061-15	N-061	Shrimp	6/27/2013	2368			257	2023	914	Von Damm
N061-15	N-061	Shrimp	6/27/2013	2368			257	2023	914	Von Damm
N061-15	N-061	Shrimp	6/27/2013	2368			257	2023	914	Von Damm
N061-15	N-061	Shrimp	6/27/2013	2368			257	2023	914	Von Damm
N061-15	N-061	Shrimp	6/27/2013	2368			257	2023	914	Von Damm
N061-15	N-061	Shrimp	6/27/2013	2368			257	2023	914	Von Damm
N061-15	N-061	Shrimp	6/27/2013	2368			257	2023	914	Von Damm
N061-15	N-061	Shrimp	6/27/2013	2368			257	2023	914	Von Damm
N062-9	N-062	Bottle	6/28/2013	4983	73	7.04	217	3374	5224	Piccard
N062-10	N-062	Sterivex	6/28/2013	4983	57	8.03	217	3374	5224	Piccard
N062-11	N-062	Bottle	6/28/2013	4983	57	7.39	190	3375	5227	Piccard
N062-19	N-062	Sterivex	6/28/2013	4960	35	5.07	90	3361	5175	Piccard
N062-20	N-062	Bottle	6/28/2013	4960	34	6.67	90	3361	5175	Piccard
N062-21	N-062	Sterivex	6/28/2013	4960	35	0.17	90	3361	5175	Piccard
N062-22	N-062	Bottle	6/28/2013	4960	34	7	90	3361	5175	Piccard
N062-24	N-062	Shrimp	6/28/2013	4960			91	3361	5175	Piccard
N062-24	N-062	Shrimp	6/28/2013	4960			91	3361	5175	Piccard
N062-24	N-062	Shrimp	6/28/2013	4960			91	3361	5175	Piccard
N062-24	N-062	Shrimp	6/28/2013	4960			91	3361	5175	Piccard
N062-24	N-062	Shrimp	6/28/2013	4960			91	3361	5175	Piccard
N062-24	N-062	Shrimp	6/28/2013	4960			91	3361	5175	Piccard
N062-24	N-062	Shrimp	6/28/2013	4960			91	3361	5175	Piccard
N062-24	N-062	Shrimp	6/28/2013	4960			91	3361	5175	Piccard
N062-24	N-062	Shrimp	6/28/2013	4960			91	3361	5175	Piccard
N062-24	N-062	Shrimp	6/28/2013	4960			91	3361	5175	Piccard
N062-24	N-062	Shrimp	6/28/2013	4960			91	3361	5175	Piccard
N062-24	N-062	Shrimp	6/28/2013	4960			91	3361	5175	Piccard
N062-24	N-062	Shrimp	6/28/2013	4960			91	3361	5175	Piccard
N063-1	N063	Rock	6/29/2013	4980			262	3362	5214	Piccard

9c.iii Macrobiology Sampling (C.Van Dover)

Biological specimens were collected from the Von Damm and Piccard vent-sites, with an emphasis on the shrimp, *Rimicaris hybisae.* Total length and carapace length was recorded for each individual sample and abdominal muscle tissue from 102 individuals was preserved in 200% EtOH and RNALater for subsequent genetic analyses. In addition, gut contents of 10 shrimp were examined and preserved and an additional bulk sample of 58 shrimp preserved whole which may be used for further gut content analyses. Examination of gut contents from N060-15 indicated that the larger, peripheral shrimp (morphologically identical to the swarming shrimp) were carnivorous whereas the shrimp in the swarms were bactivorous.

In addition to abdominal tissues for genetics, scrapings from branchiostegites and “lipid”-rich red tissues of juvenile shrimp were provided to Max Coleman for isotopic analyses.

A subset of shrimp from N061, N062, and N063 were further dissected to remove paired tissue subsamples (frozen and 70%EtOH), primarily hepatopancreas (presumed to be depositories of metals) and abdominal tissue (presumed to be metal free).

Bacterial samples (inner branchiostegite surface, scaphognathites, and hindguts) from a subset of shrimp from N062 and N063 were preserved by J Reveillaud for single cell genomic studies.

By-catch collected over the course of the cruise included 1 eelpout, 27 *Iheyaspira* snails, 4 *Lebbeus* shrimp, and 7 *Alvnocaris*. Tissues from each of these were preserved for genetics.

We searched for live mussels at the Von Damm site during Leg 2, using images captured by *Nereus* when in AUV mode on Leg 1 (see earlier), but failed to sample any individuals. There remains a remote chance that the ‘Best Bet’ mussel site had one or two live mussels.

9c.iv Sulfide Sampling (M.Coleman)

Where possible, samples of hydrothermal chimney material formed from sulfide minerals are taken for comparison with fluids sampled from the same vent, to evaluate the relationships between major and trace elements in the fluid and a solid. During FK008 such sampling was only undertaken during Nereus 058 (Beebe Vent #5, Piccard hydrothermal field). Fragments of chimney that had been collected using the Nereus manipulator and placed in the mil-crate were placed in labeled bags upon recovery and frozen at -80°C for return to WHOI.

10. Engineering Report – SUPR Samplers (J.Breier)

10a) AUV-SUPR Developments

This cruise represented the first at sea deployment of a large volume filtering and water sampling system for Autonomous Underwater Vehicles (AUV). The AUV-Suspended Particulate Rosette (SUPR) sampling system is the newest and smallest of a family of deep-sea vehicle sampling instruments developed at WHOI. It was deployed on *Nereus* during two Leg 1 dives (N047 and N048) when *Nereus* was configured in AUV mode. These deployments successfully tested both the structural integration of the AUV-SUPR system with *Nereus* as well as the autonomous sampling control system developed by Nereus engineers Daniel Gomez-Ibanez and Mike Jakuba. The AUV-SUPR system development was based on the larger SUPR V2 sampling system that was used on Leg 2 of cruise FK008 (see next section).

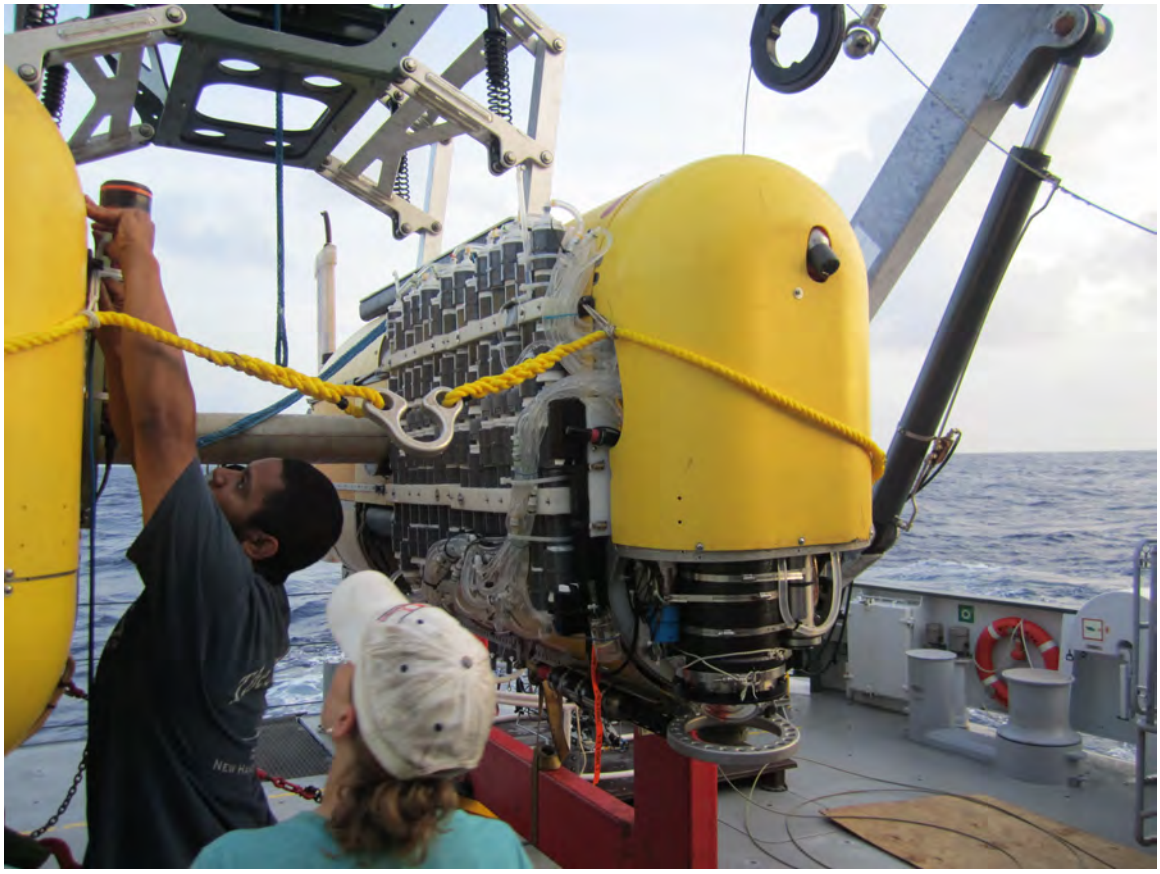


Fig. 10.1 *The AUV-SUPR system mounted on Nereus. Visible are the 14 sets of sampling containers mounted on the interior side of the port hull. Each sample line contains a 1L whole water bottle, a filter holder, and a 1L filtrate bottle.*

10b) Buoyant Plume Geochemical Sampling

Using *Nereus* in ROV mode and the SUPR V2 sampling instrument, we sampled the buoyant hydrothermal plume rising above the Beebe Vents mound of the Piccard hydrothermal field. During *Nereus* dives N058 and N063 near-endmember vent fluids were collected from within <0.5 m of the vent orifice and then again, repeatedly, at a series of locations that were occupied, progressively, at increasing height within the buoyant hydrothermal plume. In the case of dive N063, we were amazingly able to stay within the heart of the rising plume up to 100m above the vent orifice in part by allowing *Nereus* to rise with the buoyant water. A total of 21 sample sets were collected from the Beebe Vents plume. These samples will be used by Breier and Estapa to study the partitioning of metals between the dissolved and particulate phases with the ultimate goal of understanding the mechanisms controlling the dispersal of hydrothermal material in the deep sea environment. Shipboard, aliquots of these samples were analyzed to determine the particle size distribution of the solid phase plume material. Aliquots for whole and filtered particulate metals were also collected along with aliquots to measure mixing tracers including dissolved methane and silicate. These are novel measurements that will provide insight into the transport controls on plume material. This was also the first deployment of the SUPR V2 system on *Nereus* and the first time that *Nereus* has been used to conduct this type of geochemical sampling.

11. Acknowledgements

Primary support for this cruise, in the form of all support for the RV *Falkor* and the HROV *Nereus* came from an award of the Schmidt Ocean Institute to cruise PI, C.R.German. Importantly, however, it should be recognized that SOI operates as a facility provider, rather than as a research grant-awarding entity. Consequently, none of the scientific achievements described in this report and – indeed – none of the participation of any of the scientific party aboard ship, would have been possible without significant financial support of our research team from a variety of agencies –to participate in the cruise and for post-cruise work up: of data, samples and writing of this report! Accordingly, we would like to acknowledge the research agencies and grants listed below that made the entirety of the RV Falkor cruise FK-008's achievements possible.

We thank Capt.H.Volz and the officers and crew of the RV Falkor on this, their first attempt to support a cutting-edge, 24h/day, deep-ocean expedition and especially acknowledge the efforts of Cruise Coordinator Leighton Rolley and his fellow Marine Technicians Nathan Cunningham and Paul (Jimbo) Duncan who provided an internationally competitive level of support to our science operations. Likewise to our *Nereus* expedition leaders for the cruise, Casey Machado and James Kinsey and the entire HROV *Nereus* team. This cruise provided some of the most challenging encounters in my career to-date: both on deck and at the seafloor. Your expertise and endurance were certainly tested by events but you were never found wanting. Kudos!

Full List of Grant Awarding Agencies (with code numbers where appropriate)

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