Dorado Outcrop 2014 Expedition (Scientific Prospectus)

R/V Atlantis Expedition AT26-24 with the Submersible Alvin

Voyage Information:

Pre-mobilization in San Francisco, CA, October 20, 2014

Mobilization: November 28-29, 2014 - Puntarenas, Costa Rica
Departure: November 30, 2014
Arrival: December 12, 2014 - Puntarenas, Costa Rica
Demobilization: December 13, 2014

Supported by NSF project:

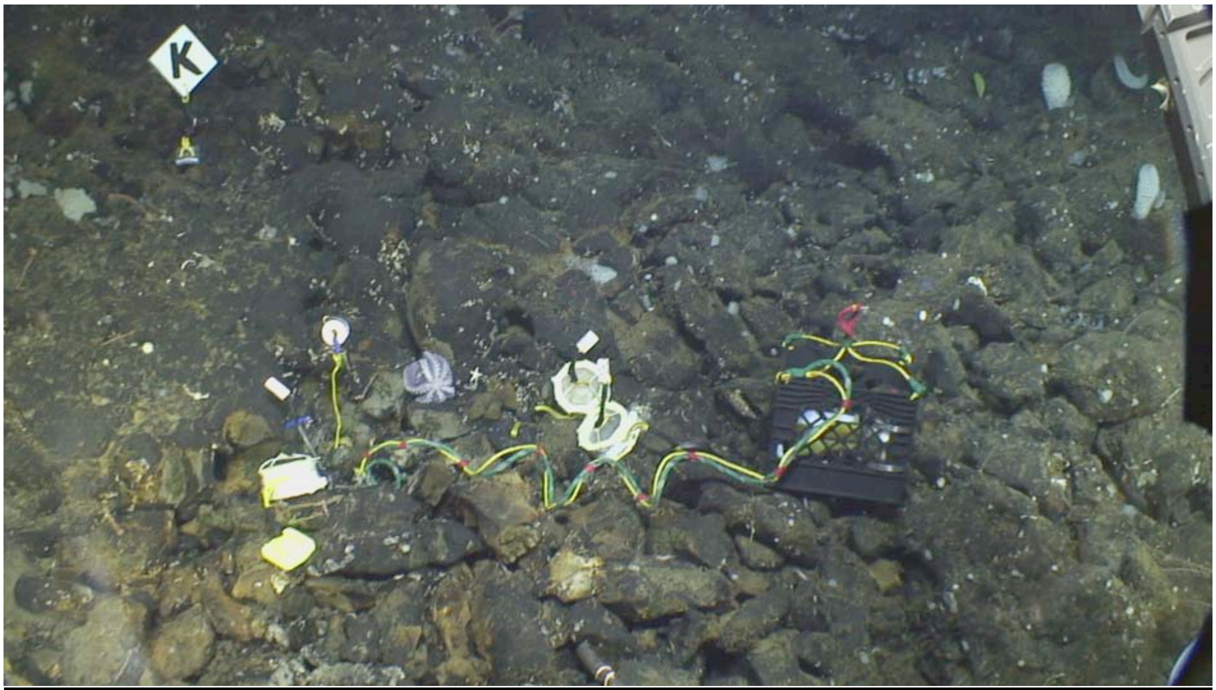
OCE-1260548 Wheat (and linked proposals to Fisher and Hulme);

With C-DEBI Research Grants or Postdoc Grants to Buchwald (postdoc); McManus (research); Orcutt (research); and Wankel (research)

Project Co-PIs:

A. T. Fisher, S. Hulme, J. McManus, B. Orcutt, and C. G. Wheat[1]

[1] AT26-24 Chief-scientist and primary contact: University of Alaska Fairbanks, PO Box 475, Moss Landing, CA 95039; 831-633-7033; wheat@mbari.org



Marker K, OsmoSampler, temperature probe, and exposure experiments were deployed in cool (<20°C) hydrothermal fluids. These and three other sampling and experimental systems will be recovered during the upcoming expedition. Note the upside down octopus. Octopi were found wherever warm fluids vented.

Dorado Outcrop

1. Overview and General Results from the Dorado Outcrop Expedition in 2013

Over thirty years ago Edmond at al. [1979] proposed that seafloor hydrothermal systems could have a major influence on oceanic geochemical budgets. This concept and associated observations and calculations provided a mechanism, for example, to balance the global oceanic budget for Mg, one of the major cations in seawater. In the past three decades hundreds of vents and thousands of hydrothermal fluid samples have been collected from mid-ocean, back arc, and hot-spot hydrothermal systems, which are driven mainly by the heat from magma that was intruded into the lithosphere. Recently collected samples are still expanding our views of these systems [e.g., Embley et al., 2007; Resing et al., 2009]. The variety of fluid samples collected from these systems demonstrates a wide range in compositions, illustrating how hydrothermal processes can influence geochemical budgets and elemental recycling. Hydrothermal fluid samples have led to refined global flux estimates, with the most constrained flux being that of heat, which is considerably less than that inferred by Edmond et al. [1979] [e.g., Mottl, 2003]. In fact, most of the hydrothermal heat extracted from the seafloor is not associated with high-temperature, magma-driven hydrothermal systems; the vast majority of hydrothermal heat is extracted on ridge flanks, through hydrothermal systems driven by lithospheric cooling and influenced by variations in sediment thickness and basement relief [e.g., Slater et al., 1980; Stein and Stein, 1994; Fisher and Wheat, 2010]. The amount of water that passes through ridge flank hydrothermal systems (RFHS) is orders of magnitude greater than that carried by magma-driven systems, rivaling the riverine input to the oceans [Johnson and Pruis, 2003; Wheat et al., 2003].

Despite their importance for transporting heat and fluids, chemical fluxes associated with typical RFHS are poorly constrained, although alteration of oceanic basalts clearly show their cumulative influence on the bulk chemical composition and physical properties of the crust [Staudigel et al., 1981; Jacobson, 1992]. Uncertainties in chemical fluxes from RFHS arise because pristine fluids have been sampled from only ***one*** such system: Baby Bare outcrop which is an exit point for an anomalously warm RFHS, where little regional heat is extracted by flowing fluids [Davis et al., 1999; Fisher et al., 2003a; Hutnak et al., 2006]; Note that another seep was located on Zona Bare, north of Baby Bare, in 2013, but sampled fluids were diluted with bottom seawater. Here crustal conditions cause the hydrothermal fluid to warm to ~65°C and become significantly altered with a depleted Mg concentration, as occurs in magma-driven hydrothermal system. Although changes in the fluid composition are dramatic at these warm temperatures, the global heat flow and sediment thickness data suggest that lower temperature (5-20°C) RFHS transport the vast majority of heat and fluids through ridge flanks [Wheat et al., 2003]. Such cool systems transport orders of magnitude more fluid than their magma-driven counterparts; as a result, chemical anomalies for some solutes that are a fraction of those from magma–driven systems could have the same or greater impact on oceanic geochemical budgets. Yet, springs from such a "typical" hydrothermal system had never been sampled before, until last year during the Dorado Outcrop expedition in November-December, 2013 (AT26-09).

There were many successes that resulted from the expedition to Dorado Outcrop in 2013 (AT26-09) (Figures 1-5). Operationally, we employed joint Jason, Sentry and elevator operations. Our goal was to keep Jason on the seafloor making measurements and collecting samples. Elevators were used to swap out samples and experiments. Sentry was deployed for specific missions that ranged from bathymetric mapping to dedicated Chirp Sonar dives to the detection of thermal plumes while taking images of the seafloor. Data from the Sentry bathymetric mapping work was imbedded within the broader ship-based multi-beam mapping program and the Jason data. Together, these tools allowed us to achieve several major accomplishments during the expedition: (1) proving correct the hypothesis that Dorado outcrop is a regional focus of massive, low-temperature, hydrothermal discharge, (2) locating, sampling, and deploying experiments in numerous springs of low-temperature hydrothermal fluid emanating from the outcrop; (3) completion of 72 measurements of heat flow on and around the Dorado outcrop, most co-located on chirp or seismic lines; and (4) conducting extensive surveys from which we produced bathymetric, sediment thickness, and water column temperature anomaly maps.

<u>Sample and data collections on Dorado Outcrop in 2013 (AT26-09)</u>:

- Kilometers of high resolution bathymetric, chirp, magnetometer, and thermal anomaly data,
- Tens of thousands of images of Dorado Outcrop,
- Discrete fluids from low temperature hydrothermal springs,
- Measurements of heat flow,
- Measurements of temperature,
- Sediment push cores,
- Rocks, and
- Bottom seawater via Niskin bottles on the elevator and on Jason.

<u>Deployments on Dorado Outcrop in 2013 (AT26-09)</u>:
- Markers for future reference,
- Seafloor OsmoSampler packages with temperature loggers, and
- Polished rock colonization "enrichment experiments".

<u>Education, outreach and diversity efforts included</u>
- Participation of under representated groups (7 Females out of 18 science party),
- Multi-national participation (US, German, French),
- A range of backgrounds and expertise:
    - Undergraduate students (2)
    - Graduate students (4)
    - Post-Doctoral Fellows (3)
    - Teachers of teachers and students (2)
- A blog (darkenergybiosphere.org/dorado) that reached ~200 4th grade students and 40 college students in science education in Columbia, Missouri,
- Follow-up appearances at 4th grade classes in Columbia, Missouri, and
- Regular expedition updates posed on social media.

2. Operational Overview for Dorado Outcrop Expedition in 2014

Our operational plan will build from the 2013 expedition with Jason II and Sentry. During the 2013 expedition we located focused venting on the southern and northern portion of Dorado Outcrop (Figures 3 and 4). At each of these sites we deployed an OsmoSampler, enrichment experiment, and a miniature temperature logger. We also found a larger (tens of meters by tens of meters) area with ubiquitous flow and deployed two additional systems (OsmoSampler, enrichment experiment, and temperature). At each of these sites we will recover the systems, sample venting fluids, video document the extent of venting (area of venting), measure fluid outflow rates using a variety dye–based systems, and measure in situ temperature and dissolved oxygen concentrations.

Fluids will be collected using the glass squeezer samplers that were used on the 2014 Alvin expedition to the Juan de Fuca CORKS (AT26-18), which only require a manipulator for operation. We will also bring the "Cow" syringes that were used at this site in 2013; however, cow syringes require the use of two manipulators to collect a fluid sample. We will only use the Titanium Major samplers if someone needs extensive amounts of fluid. Given that these fluids are diffuse, we will minimize the amount of mixing with bottom seawater using a variety of funnels, from 4-inch to 6-inch to 12-inch PVC end-caps with rubber skirts (inter-tubes filled with a saturated salt solution and excess salt) to help seal the base of the end-cap on uneven hard terrain. At each of these sites, we will need to measure temperature with Alvin's low temperature probe (Temperatures will be <20°C). In addition to temperature we will measure dissolved oxygen with an Aanderaa Optode that will have a tee handle attached to it. For both the temperature probe and dissolved oxygen sensor, data will be read in real-time by Alvin observers and logged on computers in the submersible. In some cases we will leave an RBR temperature/oxygen sensor in a vent/spring for a period of days.

Flow rates will be determined based on visual cues of shimmering water and fluids injected with tracer (rhodamine). Two types of systems will be used. One will utilize a solid form of the dye within a funnel system to document changes in color as the dye dissolves and is transported out of the funnel system. The other method will be to have a 4-gallon mixture of bottom seawater and dye with an out flow that is positioned with a tee handle and a valve to start the flow. Associated with this flow will be 50-cm-long marked "sticks" and possibly a board to assess flow rates using visual cues.

In addition to these known point source sampling areas, we will survey the outcrop to locate other sites of venting, measure heat flow and constrain fluid flow rates through thin sediment based on systematic variations in pore water chemical profiles, and collect basaltic rocks. This survey aspect will be aided with the use of a CTD on the Alvin. CTD data will be used to distinguish areas with diffuse fluid venting based on thermal anomalies (such measurements from CTDs mounted on Jason and Sentry were instrumental in 2013 in locating sites of focused venting).

During non-Alvin diving periods, we plan to do CTD hydrocasts, gravity coring, and multibeam data collection. We plan to do several CTD hydrocasts: one immediately prior to or after the first dive (depending on time on site) to collect sound velocity profiles and water; one near the end of the expedition and potentially several in the middle of the expedition. Gravity coring operations will take place most evenings following dinner, with the expectation of collecting two 1.5-m-long gravity cores each night using two metal-barrel gravity corers (Mooring Systems) provided by the science party (two systems will enable quick turnaround time). A metal barrel is necessary due to the expectation of hitting hard rock during penetration, which would break the plastic barrel systems available on Atlantis. Each gravity core should take about 3 hours in 3,150 m of water (about 1 hour down, one hour up, and one hour deploying and recovering the corer). We request the use of a pinger on the wire (50 m above the corer) to determine position above bottom. The coring system can be run on the hydrowire or the trawl wire; decision is pending based on expected snap load, bosun input and other deck operation needs. Initial gravity coring operations will focus on the sediment overlap on the NE side of the outcrop with highest heat flow (Figure 5), with a following priority for the SW area with high heat flow (Figure 5), and perhaps also including around the Tengosed Outcrop (Figure 1). When time is available, multi-beam mapping with the ship's 3.5 kHz system will be conducted in areas that were not surveyed in 2013 (Figure 1).

Finally, if all goes well and time is available, we will explore for venting at other small outcrops in the region, as we have a two degrees by two degrees working area.

During 2013 we mapped most of this area with the Atlantis's multi-beam system (Figure 1). This survey revealed several small outcrops like Dorado; such sites are likely locations of fluid egress.

3. Operational Needs for Dorado Outcrop Expedition AT26-24 in 2014

The following is a list of materials and equipment that are needed to accomplish our scientific goals.

Alvin

- Electrical connection for an Aanderaa oxygen Optode (5-12 volts, RS232) connected to a science-supported laptop. Contact: Wheat
- "Alvin" heat flow probe. Electrical through-hull connection. Please note that Andy Fisher also has two of these probes. Contact: Fisher
- Electrical connection for the low temperature probe. The maximum temperature of venting fluids should be 20°C.
- Elevator (likely 2 depoyments): with milk crates for recovering miniature temperature loggers (not pressure certified for recovery on Alvin) and potentially other experiments like OsmoSamplers or Enrichment experiments.
- Basket: Sediment push cores (2 x 9 cores), bio boxes, scoops, rock boxes/partitioned milk crates, potentially Titanium majors.
- CTD integrated with Atlantis navigation data.

Atlantis

- Subbottom 3.5 kHz system (Science party to provide processing capabilities).
- Pinger to attach to the wire during sediment coring.
- Multi-beam mapping system (Science party to provide processing capabilities),
- CTD system with Niskin bottles.
- XBT for velocity profile to be used with multi-beam operations.
- Either trawl or hydro wire for gravity coring.
- MQ water system that is full when the ship comes into port.
- Ultralow temperature freezers.
- Both walk-in cold rooms at 4°C.
- Potential storage of some science gear after the expedition.

Science supplied equipment

- Wheat will bring squeezer samplers, markers, OsmoSamplers for long-term deployment, a variety of dye tracer experiments and "sticks" to detect rates of fluid flow, funnels to aide fluid sampling, funnels to gauge fluid flow rates, push cores with holes pre-drilled for rhizones, Oxygen Optode for use as a probe, and RBR oxygen/temperature probes.
- UCSC/Lauer will bring heat flow probes and long-term miniature temperature probes.
- Orcutt will bring will bring two 1.5-m length metal gravity coring systems (Mooring Systems - http://www.mooringsystems.com/sediment.htm).
- Hulme will be bringing computers and monitors for multibeam data processing.

- USC will bring a bio box for Alvin use.

4. Staffing, Mobilization, and Demobilization

We anticipate sailing 24 scientific and education and public outreach (EPO) personnel, in addition to the regular WHOI technical support and Alvin support teams (Table 1).

General information on WHOI Cruise Planning can be found here:
http://www.whoi.edu/main/cruise-planning

Information on the R/V *Atlantis* is available here:
http://www.whoi.edu/main/ships/atlantis

Information on the Submersible *Alvin* is available here:
http://www.whoi.edu/main/hov-alvin

Information for members of the science/EOC party is available here:
http://www.whoi.edu/page.do?pid=8232

There is a set of information and forms (some of which are discussed below) that all expedition participants should review and complete (as needed): You will need to fill out the Scientific Personnel Form or Scientific Personnel Form and Waiver (non UNOLS participants). If you are shipping materials (including putting them on the ship in San Francisco) you will need to fill out the US Customs Form 4455. If you are putting materials on the ship in San Francisco, each item will need a Science Stowage Identification label.

Pre-mobilization will take place in San Francisco on Oct 20, 2014. All science party gear should be shipped to the ship's agent (below) the week of Oct. 13-17, 2014 or delivered directly to the ship via truck from MBARI (Wheat) on the morning of Oct. 20. Science party members grouping gear shipments with Wheat should have gear to MBARI no later than October 15. Scientists loading gear in San Francisco should provide Benway with TWIC information.

We can move on the ship November 28 and must depart by December 13, 2014.

Post-cruise shipment of gear from Puntarenas is expected. Discussions are underway with the local ship's agent to work out best solution. Science party members planning to ship gear from Puntarenas are strongly encouraged to use plastic container pallets or metal containers that meet international shipping norms to speed processing; note that wood pallets are not acceptable and will not be able to pass through US customs.

Any members of the science party planning to ship samples to the US should coordinate with Orcutt on needs for cold storage, dry ice, or liquid nitrogen. We anticipate sending one or two shipments via World Courier to the US east and/or west coasts, which would then be split and shipped domestically upon receipt.

5. Safety and Hazardous Materials

All members of the shipboard party must have closed toed and closed backed shoes on board the vessel. Open toed and open backed shoes are only allowed in cabins. Crocks, sandals, and similar types of shoes are NOT considered closed toed and are NOT allowed on deck or in the laboratory. Sneakers, boots, hiking and similar shoes are considered closed toed and allowed on deck and in the laboratory. Steel-toed shoes are recommended when working on deck. If you will be deploying instruments over the side, like moorings or large deployments, steel-toed shoes are required.

Anyone bringing hazardous materials must read this page and associated links, and fill out forms as needed:

http://www.whoi.edu/page.do?pid=8336#0

All hazardous materials should be loaded on Atlantis during the pre-mobilization in October and MUST be properly labeled with PI name and expedition number AT26-24. Limited hazardous waste can be stored on Atlantis following the expedition, with the expectation that it will be removed when Atlantis next visits an American port on the US Gulf or East Coast in summer 2015. Orcutt will be the primary contact for arranging hazardous waste storage and removal by the science party

Radioisotopes: No radioisotope work is planned for this cruise

6 Ship's Agent

Address for San Francisco:

Master R/V *ATLANTIS*
Attn: *Scientist's Name - AT26-23*
c/o BAE Systems Ship Repair
Foot of 20th Street
San Francisco, CA 94107
BAE Shipping Office contact: Don Merrill, office (415) 829-0267, cell (415) 314-6431
email address: donald.merrill@baesystems.com

WHEN YOU SHIP - Please remember to email Eric Benway and Vasile Tudoran.

Eric Benway – ebenway@whoi.edu

Contact: Vasile Tudoran
Phone: (562) 882-5590
Fax: (562) 434-9800
Email: vtudoran@aol.com

If necessary, supplies and equipment can be sent to meet the ship in Puntarenas.

Local Address for Large Shipments:
Master R/V *Ship Name*
Attn: *Scientist's Name*
IN TRANSIT
SERMAR SA
Aptdo 76
Puntarenas, Costa Rica
Attn: Manuel Fernandez
Phone: 011-506-2661-1529
Fax: 011-506-2661-2779

Manuel Fernandez, cell #011 506 8862 6787
Note: Agent and WHOI contacts (Eric Benway) should be copied on all communications.

7. Laboratory Space

There will be plenty of space for all.

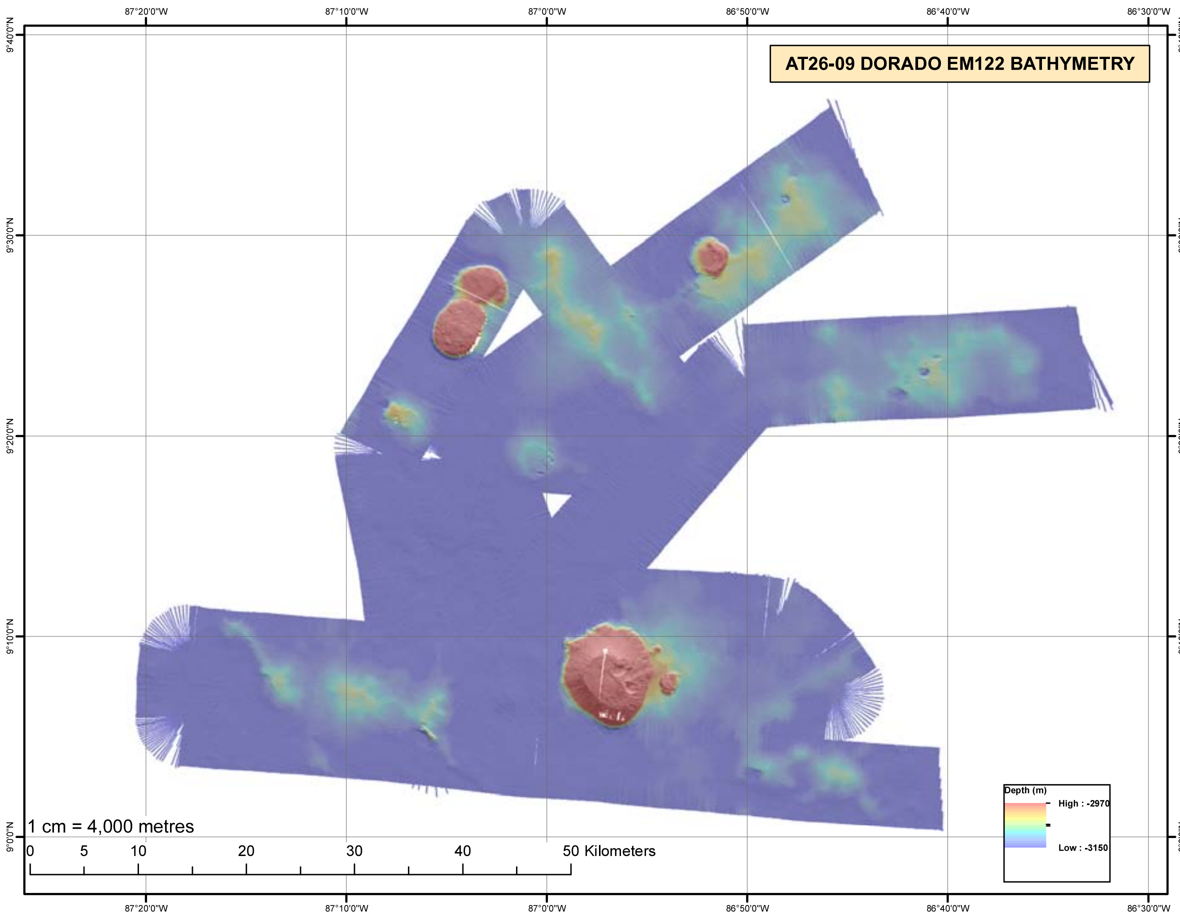


Figure 1. Multi-beam data collected in 2013 near Dorado Outcrop, which is west of the big (red) seamount in the southern portion of the map.

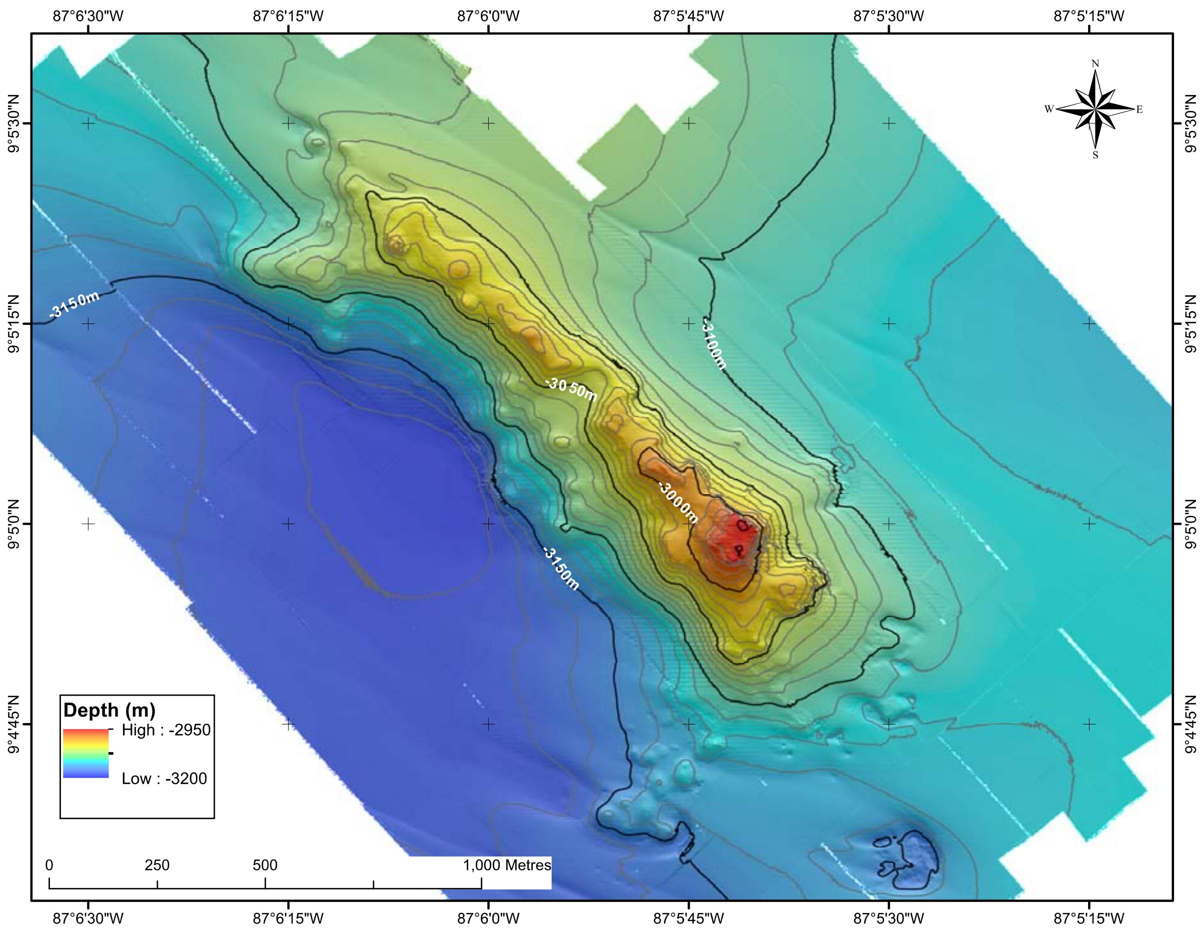
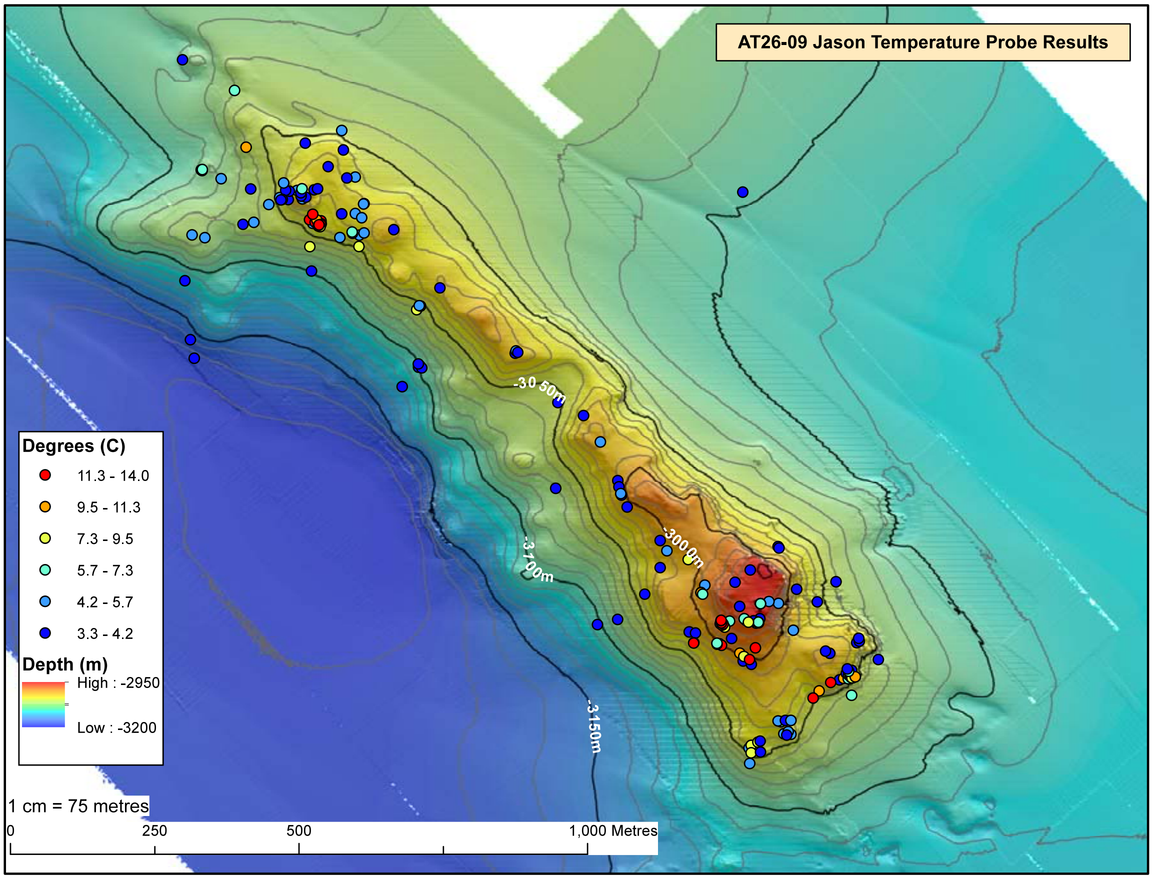


Figure 2. Bathymetric map of Dorado Outcrop developed from the 2013 Sentry data.



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igure 3. Temperature measurements made using the Jason temperature probe in 2013.

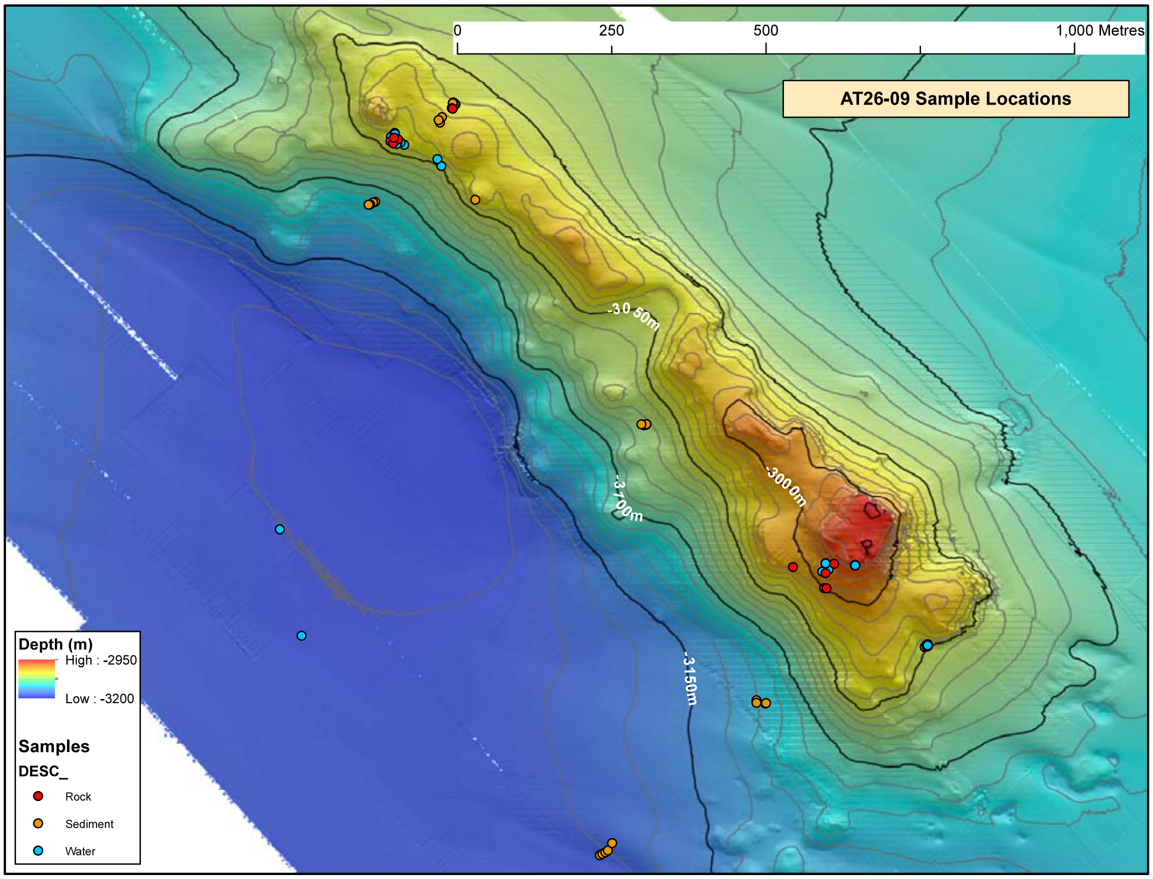

Figure 4. Locations for samples that were collected in 2013. Four systems (OsmoSampler, temperature recorders, and exposure experiments) were deployed where fluids samples were collected (the most northern and southern sites and two from the site west of the summit).

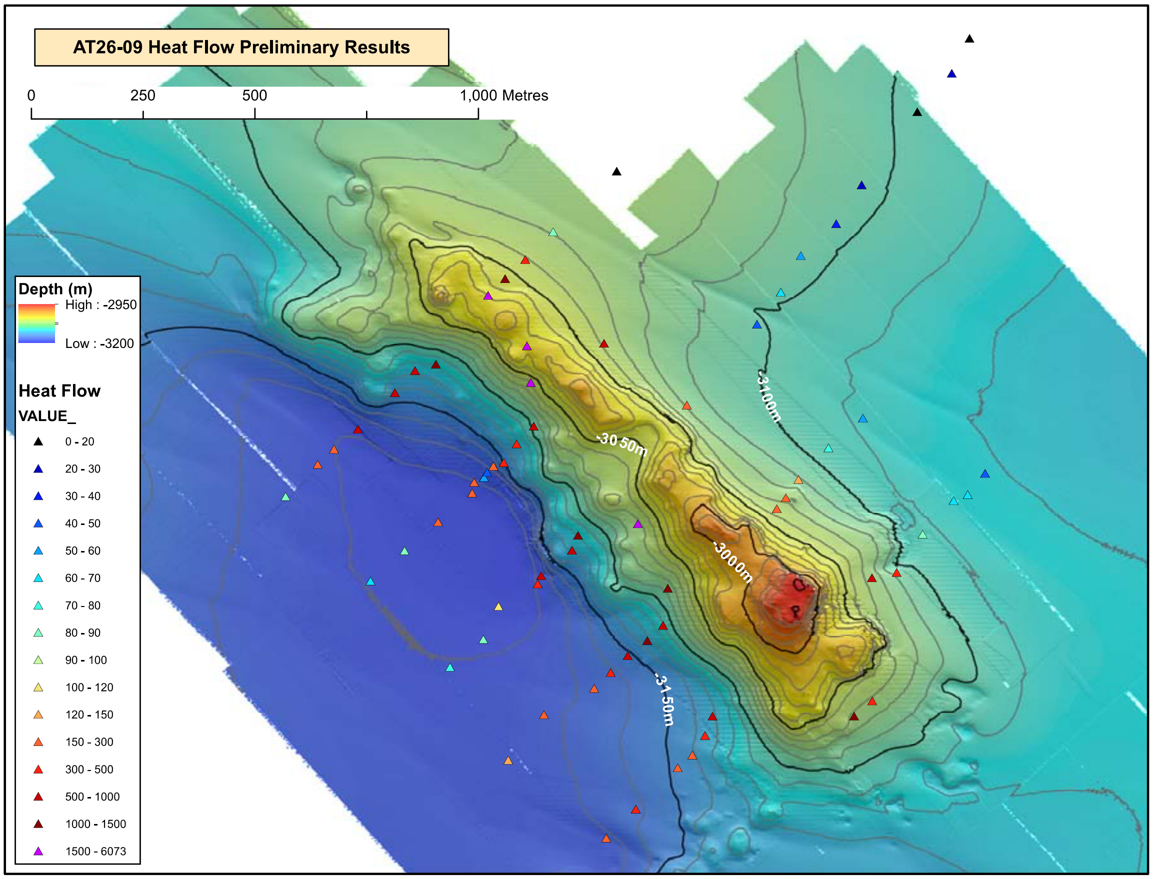

Figure 5. Calculated heat flow values from measured thermal and sediment conductivity data.

Table 1. Participants on AT26-24 as of September 6, 2014 who have already provided passport information. This list will change as the expedition approaches.

#	Name		Location	Email	Position	Funding
1	Charles Geoffrey Wheat	M	UAF	wheat@mbari.org	Professor	NSF Funded
2	Trevor Fournier	M	UAF	tfournier@csumb.edu	Grad. Student	
3	Katie Inderbitzen	F	UAF	kinderbitzen@alaska.edu	Post Doc	C-DEBI funded
4	Rachel Lauer	F	UCSC	rlauer@ucsc.edu	Post Doc	NSF Funded
5	Sam Hulme	M	MLML	samiam0101@gmail.com	Professor	NSF Funded
6	Chris Trebaol	M	MLML	chris.trebaol@gmail.com	Technician	
7	Beth Orcutt	F	Bigelow	borcutt@bigelow.org	Senior Scientist	C-DEBI funded
8	Michael Lee	M	USC	leemd@usc.edu	Grad. Student	
9	James McManus	M	Akron	jmcmanus@uakron.edu	Professor	C-DEBI funded
10	Bo Ryan Montanye	F	Akron	Brm63@zips.uakron.edu	Grad. Student	
11						
12	Graham Shimmield	M	Bigelow	gshimmield@bigelow.org	Professor	
13	Carla Buchwald	F	WHOI	cbuchwald@whoi.edu	Post Doc	C-DEBI funded
14	Natalie Anna Murray	F	Akron	Nam81@zips.uakron.edu	Grad. Student	
15	Anne Marie Hartwell	F	Akron	ahartwell@uakron.edu	Research Associate	
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Potential participants: Julia DeMarines (EPO) <julia.demarines@gmail.com>??
Film folks