# International Ocean Discovery Program
# Expedition 385T Scientific Prospectus

## Panama Basin Crustal Architecture and Deep Biosphere
## Revisiting Holes 504B and 896A

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# Abstract

International Ocean Discovery Program (IODP) Expedition 385T will revisit two Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) legacy sites—Holes 504B and 896A on the Costa Rica Rift flank—to advance lithostratigraphic, hydrogeological, and deep biosphere studies of upper oceanic crust. Hole 504B has served as a standard reference site for upper oceanic crust for decades despite low core recovery during drilling operations. Hole 896A serves as an analog site of crustal alteration for examining biogeography in the crustal deep biosphere. During Expedition 385T, we will advance lithostratigraphic records of in situ crustal architecture through Formation MicroScanner (FMS) logging, with priority for these operations in Hole 504B. The new logs from Hole 504B will reveal whether unrecovered intervals are highly fractured and/or brecciated and whether alteration style and intensity are correlated to volcanic architecture, which will allow for assessment of the hypothesis that hydrothermal alteration and mineralization style are spreading-rate dependent. We will also advance crustal hydrogeological and deep biosphere research through temperature logging and water sampling in both holes, with priority for these operations in Hole 896A. The new FMS-based lithostratigraphy coupled with new fluid assessment will also allow for improvements on the thermal limits of microbial life and seawater-basalt reactions. These operations in Holes 504B and 896A have direct relevance to Challenges 5, 6, 9, 10, 13, and 14 of the IODP 2013–2023 Science Plan. To achieve these data and sample recoveries from these legacy sites, existing wireline observatories installed in both holes will be removed and the remaining cased holes will be left open for possible future installation of next-generation observatories. The expedition will be implemented as an abbreviated (10 operational days) expedition with no new coring.

# Expedition schedule

Expedition 385T is based on International Ocean Discovery Program (IODP) Ancillary Project Letters 769-APL2 (Revealing the in situ crustal architecture in DSDP/ODP Hole 504B) and 921-APL (Restoring and sampling ODP Hole 896A for linked crustal, fluid, and biosphere studies), which are available at **http://iodp.tamu.edu/scienceops/expeditions/panama_basin_crustal_architecture.html**. Following evaluation by the IODP Scientific Advisory Structure, the expedition was scheduled for the R/V *JOIDES Resolution*, operating under contract with the *JOIDES Resolution* Science Operator (JRSO). At the time of publication of this Scientific Prospectus, the expedition is scheduled to start in Antofagasta, Chile, on 18 August 2019 and to end in San Diego, USA, on 16 September. A total of 29 days will be available for the transit, CORK removals, and downhole measurements described in this report, with ~10 days estimated for on-site activities. For the current detailed schedule, see **http://iodp.tamu.edu/scienceops**. Further details about the facilities aboard *JOIDES Resolution* can be found at **http://iodp.tamu.edu/publicinfo/drillship.html**.

# Introduction

Hydrothermal circulation within fast- to intermediate-spreading upper oceanic crust impacts the transport of heat from Earth's interior and global elemental cycling. Our understanding of these processes stem, in large part, from coring and logging operations in a handful of archetype reference holes drilled over several decades, including Deep Sea Drilling Project (DSDP)/Ocean Drilling Program (ODP) Hole 504B, Ocean Drilling Program (ODP)/Integrated Ocean Drilling Program/IODP Hole 1256D, and Integrated Ocean Drilling Program Holes U1301A, U1301B, U1362A, and U1362B in the Pacific Ocean. Borehole observatories installed in some of these holes and in other ocean crust locations have been critical for determining fluid flow properties, chemical cycling, and microbiological impacts in the subseafloor biosphere. Revisiting such reference holes to deepen our understanding of upper oceanic crust processes with application of more advanced tools is a cost-effective leveraging of these important legacy sites. Expedition 385T will revisit two legacy holes on the Costa Rica Rift flank, Holes 504B and 896A (Figure **F1**), to further the understanding of the link among mid-ocean ridge to off-axis volcanic crust construction and hydrological, geochemical, and microbiological processes.

## Motivation for examining the in situ crustal architecture in Holes 504B and 896A

Hole 504B, located on 5.9 Ma crust south of the Costa Rica Rift in the eastern equatorial Pacific (Figure **F1**), is one of the best-studied holes in the history of ocean drilling and has been a "reference site" of intermediate-spreading upper ocean crust (Becker, 1989; Wheat et al., 1996; Dilek, 1998; Fisher, 1998; Alt and Teagle, 1999; Schouten and Denham, 2000; Chan et al., 2002; Furnes et al., 1999; Bach and Edwards, 2003; Bach et al., 2003; Johnson and Pruis, 2003; Peucker-Ehrenbrink et al., 2003; Alt and Bach, 2004). Results from Hole 504B revealed important information on hydrology and chemical flux in the upper ocean lithosphere, including heat flow, alteration petrology, and hydrothermal geochemistry and their implications on the deep biosphere. These results also revealed information on the geophysical characteristics of the upper ocean crust, including magnetic and physical properties and seismic expression. However, many of these studies inevitably relied on the shipboard lithostratigraphy, which was extrapolated from recovered cores with very low recovery rate (~30%) and thus could be highly subjective.

The downhole lithostratigraphy, which is representative of the architecture of upper ocean crust, plays a key role in understanding the evolution of both axial and off-axis hydrothermal alteration. It has been a great challenge, however, to derive a reliable downhole stratigraphy model of any drilled upper crustal section because of low core recovery rates (typically <30%). Therefore, any conventional shipboard lithostratigraphy includes a great degree of uncertainty due to (1) biased recovery of rock, fractures, and alteration types (e.g., loss of highly altered breccia materials and fracture fillings); (2) uncertainty of the in situ location of recovered core pieces; and (3) inconsistent core description criteria on board between several cruises (Barr et al., 2002; Tominaga et al., 2009). Consequently, critical elements are missing in understanding the crustal accretion system, crustal hydrogeology, crustal alteration processes, and changes in physical properties in ocean crust.

Integrating wireline logging and recovered core data can provide an important compliment to shipboard lithostratigraphic records, which is the case for archetype crustal reference Hole 1256D in superfast-spreading 15 Ma crust on the Cocos plate (Tominaga et al., 2009). From the Hole 1256D logging data, quasi-2-D resistivity contrast images of the borehole wall, the so-called electrofacies acquired by Formation MicroScanner (FMS) logging runs, were found particularly useful in deciphering the detailed crustal architecture with unprecedented resolution (i.e., centimeter scale). A volcanostratigraphy model was built by translating these FMS electrofacies into end-member lava flow types observed in the modern day East Pacific Rise. The stratigraphy model provides the structure of downhole permeability and sheds new light on crustal construction processes (Tominaga et al., 2009; Tominaga and Umino, 2010). Hole 1256D logging analyses demonstrate that unrecovered intervals in drilled basement are permeable structures, such as highly fractured sections and breccias. FMS logging in Hole 1256D revealed that nearly 50% of the in situ architecture is composed of these lithologies; most of them were not recovered and hence were never recognized in the shipboard lithostratigraphy. This discrepancy between shipboard lithostratigraphy and FMS logging results makes it clear that a shipboard lithostratigraphy in a drilled hole with very low core recovery rates can lead to erroneous conclusions in critical elements for understanding of the evolution of the oceanic crust and the mechanism of global chemical fluxes.

Core-based lithostratigraphy indicates that the crustal architecture in Hole 504B includes a 274.5 m pelagic sediment section (cased), a 571.5 m volcanic section, a 209 m extrusive–intrusive transition zone, and a 1056 m sheeted dike complex. A full suite of wireline logging operations was conducted during the last visit to this site in 1993 (Ayadi et al., 1996; Ayadi et al., 1998a, 1998b). Although FMS logging was used to characterize physical and electrical properties in Hole 504B (Pezard et al., 1996), the existing FMS data have only 15% lateral coverage at best because only one FMS run was made and one of the four pads failed at the beginning of the logging operation (Figure **F2**). Thus, previous logging results in Hole 504B provide little detailed crustal architectural resolution.

Likewise, the collection of new FMS logs from nearby Hole 896A (Figure **F1**) will allow assessment of the lateral extension of lithostratigraphic units in upper ocean crust in this archetype intermediate-spreading crust. Moreover, new FMS logs will also enable comparison of the in situ crustal architecture to interpretations of fluid flow units in Hole 896A from prior temperature and resistivity logging (Figure **F3**), which are inferred to connect with various lithostratigraphic units (Becker et al., 2004).

With the collection of more accurate downhole lithostratigraphy by multiple FMS logging runs in Hole 504B, we can test fundamental hypotheses integral to priorities established in the IODP Science Plan and recent Building U.S. Strategies Workshop reports: Challenge 9: how are seafloor spreading and mantle melting linked to ocean crustal architecture? and Challenge 10: what are the mechanism, magnitude, and history of chemical exchanges between the oceanic crust and seawater?

## Motivation for fluid sampling to examine the crustal deep biosphere in Holes 504B and 896A

The best-characterized subsurface crustal deep biosphere is located on the Juan de Fuca Ridge flank (Fisher et al., 2012; Orcutt and Edwards, 2014). Over a decade of research at this site has demonstrated a dynamic and active archaeal, bacterial, and viral biosphere residing in fluids and on rock surfaces in this ridge flank crustal habitat (Orcutt et al., 2011; Jungbluth et al., 2013, 2014, 2016; Lin et al., 2014; Robador et al., 2015, 2016; Baquiran et al., 2016; Smith et al., 2016; Nigro et al., 2017). Although fluid chemistry in this buried ridge flank system has varied little over time and space (Wheat et al., 2010; Lin et al., 2014), repeated sampling has revealed dynamic changes in microbial community structures (Jungbluth et al., 2014, 2016; Baquiran et al., 2016; Smith et al., 2016). The parameters that drive this diversity are unknown.

Hole 896A on the Costa Rica Rift flank near Hole 504B (Figure **F1**), originally drilled in 1993 at ODP Site 678 (Shipboard Scientific Party, 1993), represents a unique parallel ridge flank environment for comparison to the Juan de Fuca Ridge flank (Table **T1**). Both sites are located on buried basement highs with inferred fluid flow on the order of hundreds of liters per hour (Becker et al., 2004), and both sites are characterized by pillow and sheet-flow plagioclase-olivine phyric basalts with alteration products (i.e., saponite and celadonite vein filling) that indicate complex hydrothermal evolution of crustal systems (Alt et al., 1996; Hunter et al., 1999). These sediment-covered basalt ridge systems experience similar upper-basement fluid conditions (Table **T1**). Hole 896A has an undefined fluid circulation pathway in the upper crust compared with the Juan de Fuca Ridge flank, where fluid flow between basement outcrops on the ridge flank is well constrained (Fisher et al., 2014; Neira et al., 2016). However, both Hole 896A and the boreholes on the Juan de Fuca Ridge freely discharge formation fluid when the boreholes are open to the seafloor.

Although the Juan de Fuca Ridge flank has been sampled extensively, only one sample has ever been collected for deep biosphere analysis from Hole 896A (Becker et al., 2004; Nigro et al., 2012). In 2001, a wireline system with a camera documented substantial quantities of flocculent material in open basement deeper than 230 meters below seafloor (mbsf) (Figure **F3**). After this inspection, a wireline CORK was deployed in the hole. Fifteen months later, a submersible dive to the site collected biofilms on the borehole structure that was exposed to discharging formation fluids and bottom currents. Analysis of this sample revealed the presence of biofilm-forming microbial species such as the Gammaproteobacteria *Thiomicrospira*. This community was strikingly different from the communities observed in the Juan de Fuca Ridge flank environment (Table **T1**). It is important to note, however, that the biofilm samples previously collected from Hole 896A were collected above the sediment/water interface and represent a mixture of seawater-influenced fluids. Pristine borehole fluids or biofilms have yet to be recovered from Hole 896A, but visual (Figure **F3**) and DNA data indicate that the microbial communities in the two hydrothermal systems are different. Thus, a major motivation for fluid sampling in Hole 896A is to collect pristine crustal fluids from various depths in the borehole (representing different temperatures [Figure **F3**] that span the ~64°C temperature range of fluids of the comparison site on the Juan de Fuca Ridge flank) to examine fluid chemistry, microbial biomass density, and microbial community composition and function.

Determining the temperature limits of the subsurface deep biosphere is a major aim of the scientific ocean drilling community (Challenge 6: what are the limits of life in the subseafloor?). Recently, IODP Expedition 370 sought to characterize the thermal limits of life in the organic-rich sediment deep biosphere (Heuer et al., 2017), but this drilling program did not cross the currently known temperature limit of life at 122°C (Kashefi and Lovley, 2003). The temperature limits of life may reach or exceed 150°C, according to recent thermodynamic hypotheses (Hoehler, 2007). For example, thermal stability of DNA is potentially the limiting factor in a cell's heat tolerance; however, supercoiling and the addition of cationic proteins may modulate DNA and prevent denaturation (Hoehler, 2007). Factors accumulated inside the cell serve to stabilize or repair macromolecules, including potassium ions, small organic phosphates, and heat-shock proteins (Holland and Baross, 2003). Therefore, long-term exposure to stable high temperatures may select for additional, previously unidentified adaptations permitting biological activity well above currently recognized limits. However, recent studies from Expedition 370 suggest a lower temperature of life in the subsurface, where other factors, such as nutrient availability, may depress the temperature of life (Heuer et al., 2017). Thus, Hole 504B, which reaches an estimated bottom-hole temperature of ~180°–190°C at ~2000 mbsf (Figure **F4**) (Guerin et al., 1996), is an ideal setting to test fundamental hypotheses about thermal limits of life. Moreover, a repeat temperature log in Hole 504B is scientifically important in terms of verifying a no-downhole-flow condition and potentially shedding new light on the depth variation of heat flow after ~10 y of hole sealing.

### Seismic studies/site survey data

The supporting site survey data for Expedition 385T are archived at the IODP Site Survey Data Bank (**https://ssdb.iodp.org/SSDBquery/SSDBquery.php**; select 385T for proposal number).

## Scientific objectives

### Determining in situ crustal architecture

We will test our primary crustal architecture hypothesis that hydrothermal alteration and mineralization style are spreading-rate dependent (e.g., Hole 504B versus Hole 1256D) through the following objectives:

- Improve current Hole 504B shipboard lithostratigraphy through collection of multiple FMS logs to reveal sections that were not recovered but are expected to be highly fractured and brecciated sections;
- Use the improved FMS-based lithostratigraphy record from Hole 504B to compare with Hole 1256D records (Tominaga et al., 2009; Tominaga and Umino, 2010) to determine whether alteration styles and intensities correlate with differences in their volcanic architecture; and
- Examine whether a new FMS-based lithostratigraphy model changes estimates of global chemical flux from rock-water reactions (e.g., the estimation of $CO_2$ uptake by hydrothermal alteration in upper ocean crust).

In addition, if time permits, we will examine a secondary crustal architecture hypothesis:

- Determine whether fluid flow in upper oceanic crust correlates with lithostratigraphy by collecting additional FMS-logs in Hole 896A for comparing FMS-based lithostratigraphy to earlier temperature and resistivity interpretations of flow units.

### Documenting crustal fluid deep biosphere biogeography

Our primary crustal deep biosphere hypothesis is that microbial community structure and functional potential within upper basaltic basement is primarily influenced by fluid geochemical and thermal conditions (i.e., the same species are found everywhere, and the environment selects for them to be dominant). We will examine this hypothesis with the following objectives:

1. Collect pristine crustal fluid samples and temperature records from multiple depths (temperatures) in Hole 896A for microbiological and geochemical analysis and
2. Compare Hole 896A crustal fluid microbiology and geochemistry with conditions at the Juan de Fuca Ridge flank sites.

A secondary crustal deep biosphere hypothesis we aim to examine is that no microbial life exists above the currently known temperature limit for life (122°C). We will examine this hypothesis, if time permits, through the collection of pristine crustal fluid samples and temperature records in Hole 504B for microbiological and geochemical analyses, with samples collected below, at, and above the known thermal limit.

## Operations plan

Our general operations plan is to conduct activities in Hole 504B before moving to Hole 896A (Table **T2**). We estimate having 10 days for these operations. At both sites, we will first have to remove observatory systems that are currently installed in each borehole. Once these systems are removed, the first operations will involve borehole fluid temperature measurements and in situ water sampling before any additional disturbance occurs, following previously used methods (Fryer et al., 2018). Depending on time availability, multiple fluid sampling runs may take place. After fluid sampling and hole conditioning, the FMS logging suite will be run into the holes to collect multiple logging runs following previously used logging operational plans (Expedition 309/312 Scientists, 2006). After wireline operations, both partially cased boreholes will be left open for possible future installation of CORK-Lite borehole observatories (Wheat et al., 2012). More details about the operations are provided below.

### Removing observatory infrastructure currently installed in Holes 504B and 896A

A wireline version of a CORK hydrological observatory was installed in Hole 504B from the R/V *Revelle* in August 2001 (Becker et al., 2004), and its useful lifetime has been exceeded. The wireline CORK in Hole 504B included a single inflatable packer near the top of the 275 m long casing and a sensor string (thermistor cable plus pressure umbilical) that extended only into the upper ~75 m of basement. The packer has most likely deflated by now, so the entire device should be easy to pull out of the hole. Overall weight is a few thousand pounds in water. The wireline CORK design includes a support package in the reentry cone with a central strength member of nominal 6 inch schedule 40 steel pipe. Two parallel vertical plates of 1 inch steel were welded to the top of the 6 inch pipe ~1 inch apart. Each plate has a 1 inch diameter hole, and for deployment a large bolt through both plates allowed using the hook of an electrical release tool between the plates. The wireline CORK deployment went smoothly in Hole 504B, and the release properly disengaged. The result is that a properly dimensioned overshot tool should be able to slip over the two parallel plates and engage the 6 inch steel pipe for removal using the drill string (Figure **F5**).

The wireline CORK deployed in 2001 in Hole 896A had a similar support package in the reentry cone and was designed to include two packers, one in the casing and the other a few tens of meters into the open hole (Becker et al., 2004). Unfortunately, that deployment did not go well; the lower packer got stuck in the open hole ~20 m above its intended deployment depth. It could not be worked free, so a decision was made to pull from *Revelle* until a weak link immediately above the packer broke, allowing the rest of the instrumentation to be recovered. However, that weak link held, and a supposedly stronger weak link broke immediately below the deployment vehicle. The support package fell back into the cone, but the wireline CORK was not functional and the tether between deployment vehicle and wireline CORK was left on the installation. During a 2002 human occupied vehicle (HOV) *Alvin* dive to both wireline CORKs, most of the tether was cut away and recovered, but the electrical release is still in place at the top of the wireline CORK along with a remnant of the tether (Figure **F6**). Therefore, the overshot approach to recovery planned at Hole 504B is not feasible. An assortment of spears and hooks are being prepared to engage other parts of the CORK installation. In addition, the packer may remain stuck in the open hole even after the support package is recovered, and we may need to conduct a separate pipe trip with either a fishing overshot to engage the packer or a clean-out mill to grind the ~5 m long packer element.

## Downhole logging/sampling strategy in Holes 504B and 896A

### Water sampling and temperature measurement

In each hole, immediately after removal of the wireline CORK observatory systems and prior to hole conditioning for logging, the Elevated Temperature Borehole Sensor, possibly with the developmental high-temperature (60°–200°C) fluid sampling tool, will be run into the open borehole to collect pristine crustal fluids and log temperatures following previously used methods (Fryer et al., 2018). As a backup, we will also bring the Water Sampling Temperature Probe (WSTP) and a Kuster water sampling tool used recently during Expedition 374. Although the developmental fluid sampling tool will use a shape memory alloy to trigger sampling at multiple temperatures in one run, the backup tools will be triggered more traditionally at programmed times. Time-based triggering may affect the quality of the sample collected (i.e., sampling triggering might not occur at the target depth/temperature).

Nearly every prior revisit to Hole 504B has started with temperature logging after recovery from prior drilling disturbances, so the thermal state in Hole 504B is reasonably well understood (Guerin et al., 1996; Becker et al., 2004). If time allows in Hole 504B, we will try multiple fluid sampling runs at and above the current temperature limit of life (122°C). In Hole 896A, we will also run the fluid sampler(s) multiple times to collect fluids above, at, and below the interval where fluid flow is inferred and flocculent material was observed (i.e., ~220 mbsf) (Figure **F3**). Our successful experience with logging a legacy borehole after observatory removal for biomass quantification (i.e., logging in Hole 395A during Integrated Ocean Drilling Program Expedition 336 [Expedition 336 Scientists, 2012; Salas et al., 2015]) suggests that these objectives have a high probability of success even if hole perturbation occurs.

Depending on the quantity and quality of fluid samples collected, we plan to distribute and preserve aliquots for the following shore-based analyses, including but not limited to depending on shore-based sample requests:

- Major, minor, and trace ion concentrations and stable isotopic compositions;
- pH, alkalinity, and chlorinity concentrations;
- Microbial cell biomass density (i.e., cell counts): preserved with formaldehyde in buffer;
- DNA sequencing, two collection methods: freezing whole water with glycerol-salt buffer or filtering and freezing;
- Dissolved organic carbon concentrations;
- Reduced gas concentrations (i.e., methane, ethane, propane, hydrogen, and carbon monoxide);
- Nutrient ($NO_x$, $PO_x$, Si) concentrations;
- Dissolved organic carbon stable carbon isotope measurements;
- Dissolved inorganic carbon radioisotope measurements;
- RNA sequencing: filtering, preservation in RNAlater, and freezing; and
- Spore density measurements.

### Hole conditioning

After the temperature and fluid sampling runs, the hole will be washed out and conditioned following previously used protocols (Expedition 309/312 Scientists, 2006). These protocols will entail running pipe, circulating, and rotating the clean-out/logging bit from an initial bottom-hole assembly position in the casing (for the temperature logging) to the desired maximum logging depth. Depending on the maximum logging depth and borehole temperature, several hours of freshwater circulation could be required before pulling the bit to the best position for the planned FMS logs. Freshwater is used to reduce the contrast between borehole fluid and the borehole wall, which enhances the FMS microresistivity signal.

### FMS logging

In each hole, we will run the FMS logging tool with a gamma ray sonde (for depth-matching purposes) for at least two passes from the deepest possible part of the hole to the bottom of the casing following previously used methods (Expedition 309/312 Scientists, 2006). As a backup, in case the FMS logs are distorted and/or there is extra time available, the Ultrasonic Borehole Imager (UBI) tool will be run to generate complimentary borehole imagery data.

We will closely monitor the borehole temperature in Hole 504B (Figure **F4**) to assess the maximum depth of the FMS logging operation because the ODP Leg 148 FMS pad failure near the beginning of the logging was probably due to the high formation temperature (Alt et al., 1993). We estimate that our logging will take place from ~1200 mbsf (estimated to be where we encounter the maximum temperature limit of the FMS tool string) to the bottom of the casing to thoroughly cover different volcanostratigraphy and degrees of alteration suggested from core sample observations. Past temperature measurements indicate a temperature of ~150°C at ~1200 mbsf and 175°C at ~1600 mbsf (Alt et al., 1993). The FMS tool encountered ledges at several depth intervals during Leg 148. Thus, we will operate FMS logging at ~275 m/h. We will run the FMS From 275 mbsf to at least 1200 mbsf (proposed to 1600 mbsf, but this will depend on the formation and borehole temperature), not to exceed the temperature limit of the tool string (Figure **F4**). The newly obtained data will be matched with the FMS logs from Leg 148 to maximize the lateral coverage.

If time allows, we will follow a similar FMS logging strategy in Hole 896A, although the borehole temperatures are not expected to be as high (Figure **F3**) and the total depth of open hole is much less in Hole 896A than in Hole 504B.

# Risks and contingency

## CORK removal

In both Holes 504B and 896A, some or all of the CORK equipment may be stuck, break off, or otherwise not be removable, which would compromise any scientific work planned in the holes. We will trying to mitigate this risk by having at least three methods and a variety of tools at our disposal to grab, hook, or spear the CORK equipment at the seafloor (Figures **F5**, **F6**). CORK removal in Hole 896A has significant added risk because of the release tool attached at the top of the neck, which eliminates the preferred method (overshot) of CORK removal.

## Wireline logging

Once the CORK is removed, wireline logging in Hole 504B is a relatively low-risk situation given the casing in the upper ~275 m and the nature of the rocks to be logged. However, the following risks do exist:

- The hole is not clear (i.e., ledges or bridges preventing the logging string from descending), which would require a pipe trip and hole remediation with a drill bit and be costly in terms of time;
- A tool string may get stuck in the hole; and
- High heave may adversely affect the log quality.

# Time allocation for operations in Holes 504B and 896A

Removing the wireline CORK from Hole 504B is estimated to take 1.2 days if the first attempt succeeds (Table T2). Subsequent wireline logging of temperature and fluid sampling followed by an additional log with the FMS is estimated to take 3.8 days, for a total of 5.0 days of operations in Hole 504B. Removing the CORK and the stuck packer from Hole 896A is estimated to take 2.4 days. Additional challenges and operational risk exist in Hole 896A compared with Hole 504B, as outlined above.

Time allocation for operations in Holes 504B and 896A is prioritized as per recommendation from the JOIDES Resolution Facility Board and JRSO. First, we will attempt to complete operations in Hole 504B in 7.0 days. The two-day contingency time allows for as many as three different attempts at removing the CORK and/or additional time needed to open or condition Hole 504B to at least 1200 mbsf before logging. No more than 7.0 days after arriving at Hole 504B, the ship will move to Hole 896A and we will attempt to remove the CORK and packer and then conduct fluid sampling and wireline logging operations if time permits.

# Sampling and data sharing strategy

Shipboard and shore-based researchers should refer to the IODP Sample, Data, and Obligations Policy and Implementation Guidelines posted on the Web at **http://www.iodp.org/program-documents**. This document outlines the policy for distributing IODP samples and data to research scientists, curators, and educators. The document also defines the obligations that sample and data recipients incur. The Sample Allocation Committee (SAC; composed of Co-Chief Scientists, Expedition Project Manager, and IODP Curator on shore and curatorial representative on board, if applicable) will work with the entire scientific party to formulate a formal expedition-specific sampling plan for shipboard and post-cruise sampling.

Shipboard scientists are expected to submit sample requests (at **http://iodp.tamu.edu/curation/samples.html**) three months before the beginning of the expedition. Based on sample requests (shore based and shipboard) submitted by this deadline, the SAC will prepare a tentative sampling plan, which will be revised on the ship as dictated by recovery and cruise objectives. The sampling plan will be subject to modification depending upon the actual material recovered and collaborations that may evolve between scientists during the expedition. Modification of the strategy during the expedition must be approved by the SAC.

No coring is currently planned for Expedition 385T. Should we collect water samples or any other material serendipitously, we will collect, curate, and analyze it according to JRSO protocols and compliant with the IODP Data Policy.

# Expedition scientists and scientific participants

The current list of participants for Expedition 385T can be found at **http://iodp.tamu.edu/scienceops/expeditions/panama_basin_crustal_architecture.html**.

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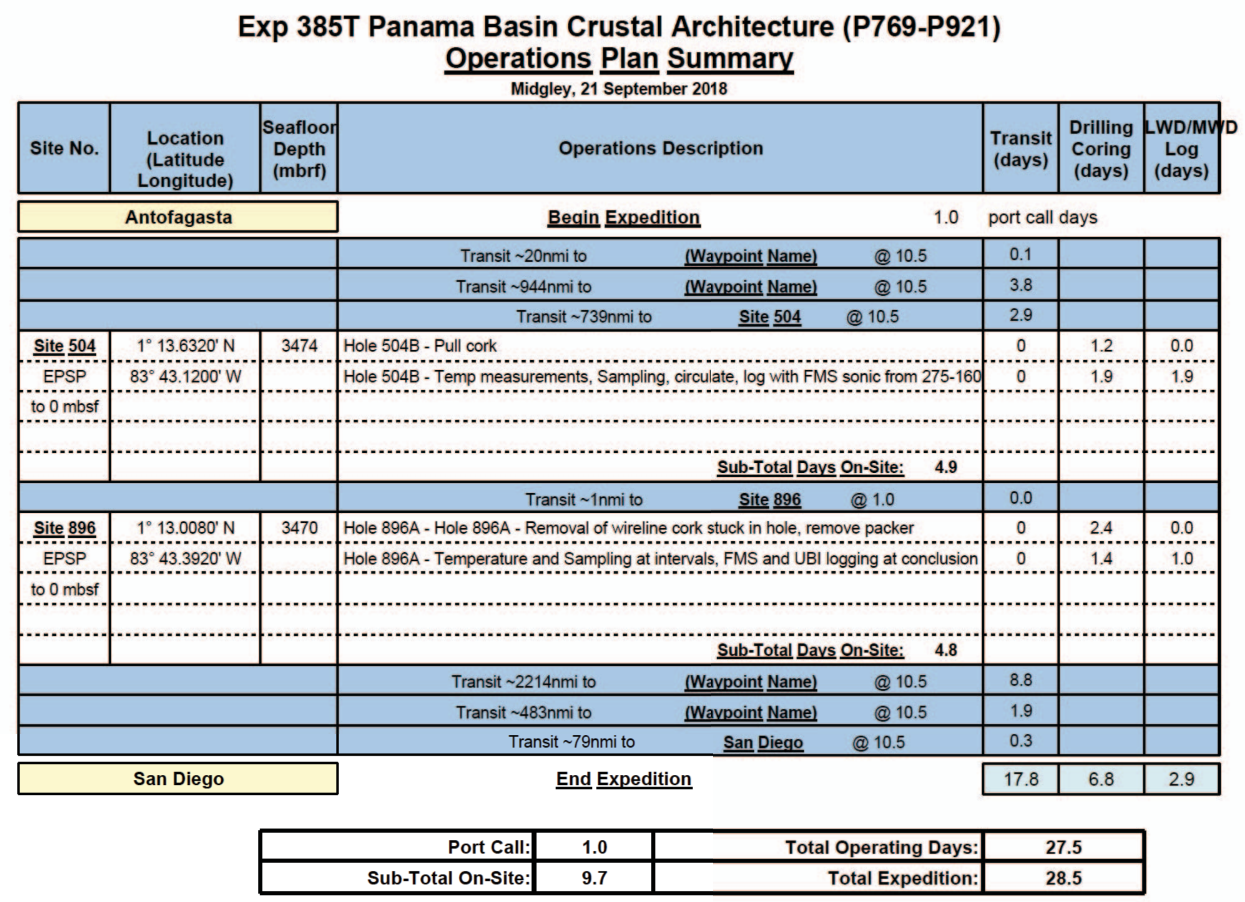
Table T1. Upper basement conditions in Holes 896A (Figure F1) and U1301A on the Juan de Fuca Ridge flank. Data from Mottl (1989), Wheat et al. (2010) and Nigro et al. (2012).

| Condition | Hole 896A | Hole U1301A |
|---|---|---|
| Temperature (°C) | 58 | 64 |
| Calcium (mM) | 51 | 55 |
| Magnesium (mM) | 8.5 | 2 |
| Sulfate (mM) | 18.5 | 17.7 |
| Alkalinity (mM) | 0.6 | 0.4 |
| Crustal age (Ma) | 6–7 | 3–4 |
| Dominant bacterial groups | Proteobacteria | Firmicutes |

Table T2. Operations and time estimates, Expedition 385T.



**Exp 385T Panama Basin Crustal Architecture (P769-P921)**

**Operations Plan Summary**

**Midgley, 21 September 2018**

| Site No. | Location (Latitude Longitude) | Seafloor Depth (mbrf) | Operations Description | Transit (days) | Drilling Coring (days) | LWD/MWD Log (days) |
|---|---|---|---|---|---|---|
| **Antofagasta** | | | **Begin Expedition** 1.0 | port call days | | |
| | | | Transit ~20nmi to (Waypoint Name) @ 10.5 | 0.1 | | |
| | | | Transit ~944nmi to (Waypoint Name) @ 10.5 | 3.8 | | |
| | | | Transit ~739nmi to Site 504 @ 10.5 | 2.9 | | |
| Site 504 | 1° 13.6320' N | 3474 | Hole 504B - Pull cork | 0 | 1.2 | 0.0 |
| EPSP | 83° 43.1200' W | | Hole 504B - Temp measurements, Sampling, circulate, log with FMS sonic from 275-160 | 0 | 1.9 | 1.9 |
| to 0 mbsf | | | | | | |
| | | | Sub-Total Days On-Site: 4.9 | | | |
| | | | Transit ~1nmi to Site 896 @ 1.0 | 0.0 | | |
| Site 896 | 1° 13.0080' N | 3470 | Hole 896A - Hole 896A - Removal of wireline cork stuck in hole, remove packer | 0 | 2.4 | 0.0 |
| EPSP | 83° 43.3920' W | | Hole 896A - Temperature and Sampling at intervals, FMS and UBI logging at conclusion | 0 | 1.4 | 1.0 |
| to 0 mbsf | | | | | | |
| | | | Sub-Total Days On-Site: 4.8 | | | |
| | | | Transit ~2214nmi to (Waypoint Name) @ 10.5 | 8.8 | | |
| | | | Transit ~483nmi to (Waypoint Name) @ 10.5 | 1.9 | | |
| | | | Transit ~79nmi to San Diego @ 10.5 | 0.3 | | |
| **San Diego** | | | **End Expedition** | 17.8 | 6.8 | 2.9 |

| | | | |
|---|---|---|---|
| **Port Call:** | **1.0** | **Total Operating Days:** | **27.5** |
| **Sub-Total On-Site:** | **9.7** | **Total Expedition:** | **28.5** |

Figure F1. Location of Holes 504B and 896A on the Costa Rica Rift flank in the Panama Basin. Basemap is from Global Multi-Resolution Topography (**https://www.ldeo.columbia.edu/research/marine-geology-geophysics/mgds-global-multi-resolution-topography-gmrt-create-maps-and-grid**).

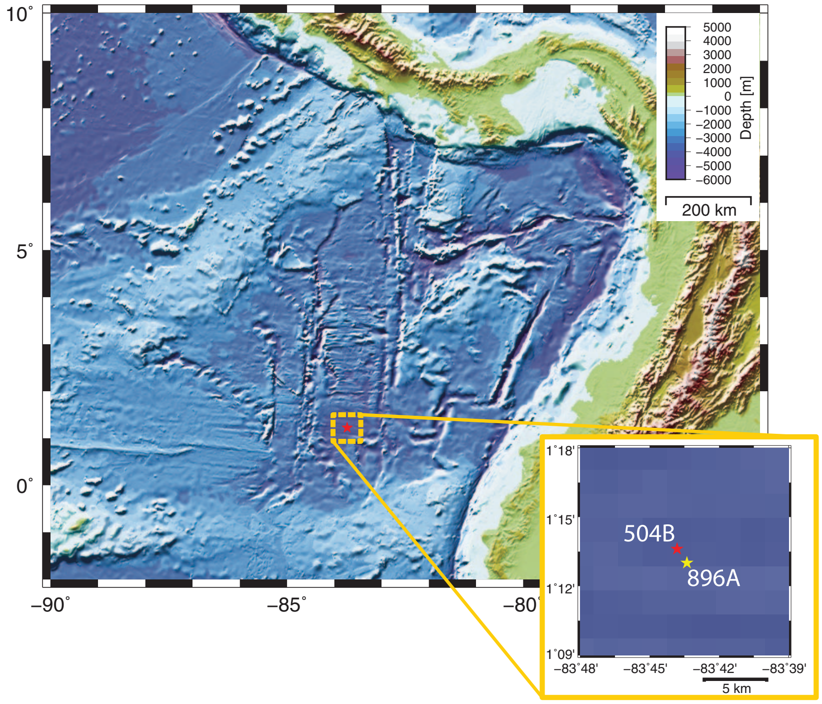


Figure F2. Summary of Hole 504B logging data available from two previous expeditions.

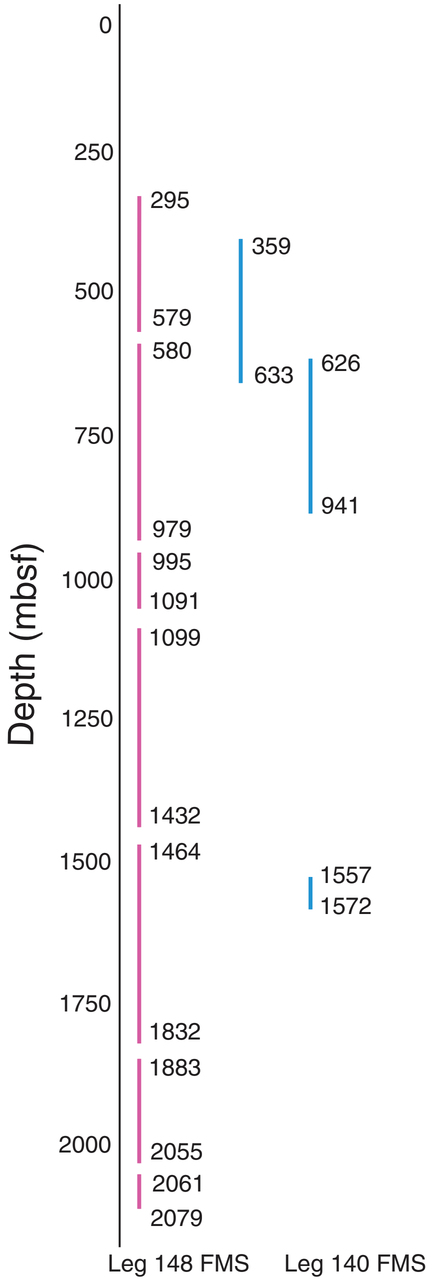


Figure F3. Caliper, resistivity, temperature, and visual logs, Hole 896A. Arrows = interpreted positions of independent sources of fluids entering the hole from the formation: 1 = cooler fluids (* in images), 2 = warmer fluids (** in images), 3 = warmest fluids (*** in images). Flocculent material was observed in images from deeper than 230 mbsf. Reprinted with permission from Becker et al. (2004).

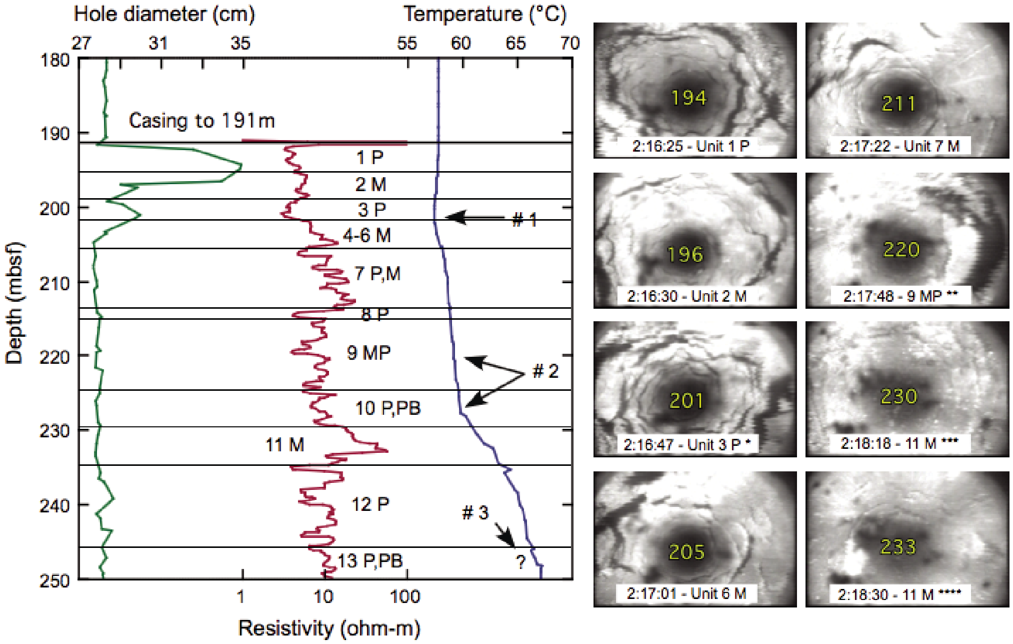


Figure F4. Temperature log showing temperatures above current thermal limit of life (122°C), Hole 504B. From Guerin et al., 1996.

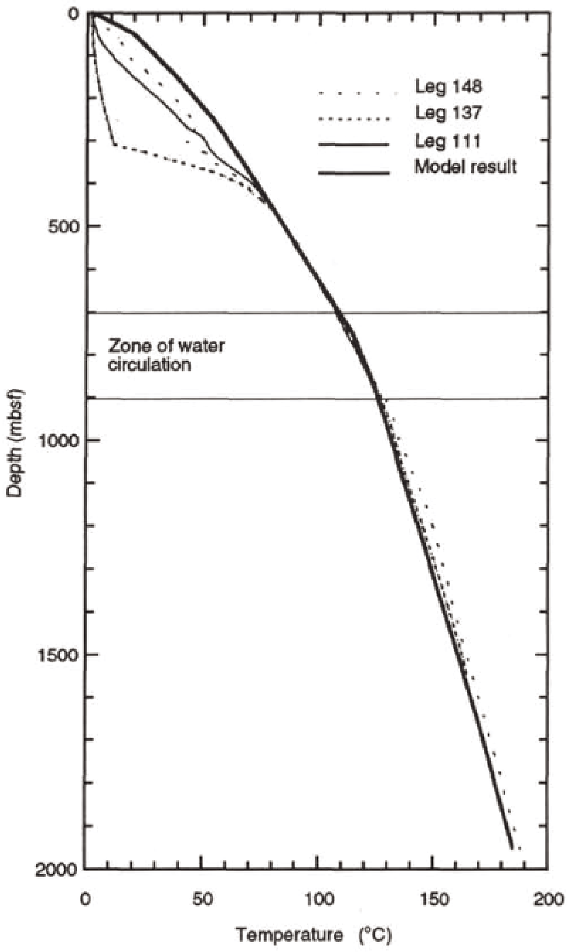
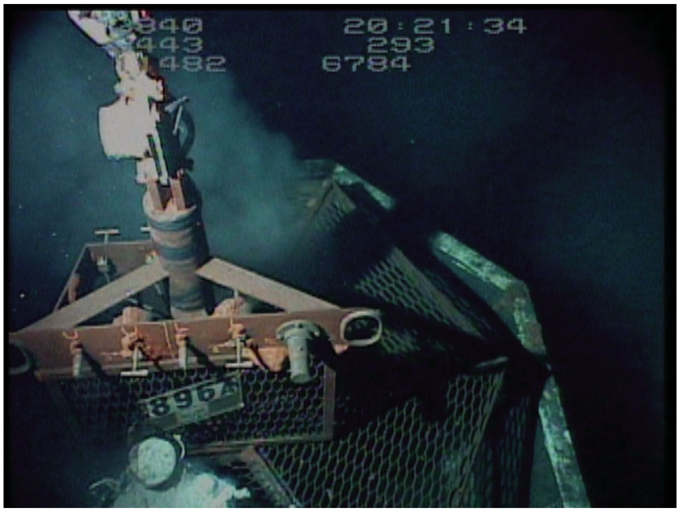


Figure F5. Top of wireline CORK observatory in Hole 504B. Frame grab from 2002 human occupied vehicle (HOV) *Alvin* video.

Figure F6. Top of wireline CORK observatory in Hole 896A. Image is a frame grab from 2002 human occupied vehicle (HOV) *Alvin* video.



# Site summaries

## Hole 504B

| | |
|---|---|
| Priority: | Primary |
| Position: | 1.2272°N, 83.68533°W |
| Water depth (m): | 3460 |
| Target drilling depth (mbsf): | Not applicable |
| Approved maximum penetration (mbsf): | Not applicable |
| Objective(s): | Remove CORK and obtain detailed crustal architecture by running temperature log and water sampling tool and then multiple FMS logging after hole conditioning |
| Drilling program: | Not applicable |
| Logging/Downhole measurements program: | Temperature, Kuster sampler, Water Sampling Temperature Probe or new tool, FMS |
| Nature of rock anticipated: | Igneous rocks |

## Hole 896A

| | |
|---|---|
| Priority: | Primary |
| Position: | 1.2168°N, 83.7232°W |
| Water depth (m): | 3459 |
| Target drilling depth (mbsf): | Not applicable |
| Approved maximum penetration (mbsf): | Not applicable |
| Objective(s): | Remove CORK and obtain detailed crustal architecture by running temperature log and water sampling tool and then multiple FMS logging after hole conditioning |
| Drilling program: | Not applicable |
| Logging/Downhole measurements program: | Temperature, Kuster sampler, Water Sampling Temperature Probe or new tool, FMS |
| Nature of rock anticipated: | Igneous rocks |