IODP Expedition 385T:
Panama Basin Crustal Architecture and Deep Biosphere: Revisiting Sites 504 and 896

Sites 504 and 896 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Expedition 385T aimed to 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 and incomplete understanding of downhole lithostratigraphy. Hole 896A serves as an analog site of crustal alteration for examining biogeography in the crustal deep biosphere, and fluid sampling in Hole 504B would allow for examination of the thermal limits of life in deep oceanic crust. We aimed to 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 would reveal whether unrecovered intervals are highly fractured and/or brecciated, and whether alteration style and intensity are correlated to volcanic architecture, which would allow for assessment of the hypothesis that hydrothermal alteration and mineralization style are spreading-rate dependent. We also aimed to 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 would also allow for improvements on the thermal limits of microbial life and seawater-basalt reactions. These operations in Holes 504B and 896A would 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 would need to be removed. The preexpedition plan was to conduct these operations as an abbreviated (10 operational days) expedition with no new coring.

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

1. 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;
2. Use the improved FMS-based lithostratigraphy record from Hole 504B to compare with Hole 1256D records to determine whether alteration styles and intensities correlate with differences in the volcanic architecture of the oceanic crust;

3. 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); and

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

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 the dominant groups). We aimed to 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 aimed to examine is that no microbial life exists above the currently known temperature limit for life (122°C). We aimed to examine this hypothesis 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 of life.

Operations

After a delay in departure from Antofagasta, Chile, due to customs clearance, the ship completed the 1724 nmi transit to Hole 896A in 5.75 d at an average speed of 12.5 kt, arriving at 1254 h on 25 August 2019. During transit, the science party and IODP JRSO technical staff prepared the new Multi-Temperature Fluid Sampler (MTFS), the Elevated Temperature Borehole Sonde (ETBS), and two Kuster fluid sampling tools.

To conduct temperature measurements and fluid sampling in Holes 504B and 896A, we first had to remove the legacy CORKs installed during the ODP phase. The first bottom-hole assembly (BHA) was made up and deployed with an overshot tool, followed by deployment of the subsea camera system. With the drill pipe just above the seafloor at 3461 m below rig floor (mbrf), the Hole 896A reentry system and wireline CORK frame were located quickly and surveyed before we moved 0.75 nmi to Hole 504B in dynamic positioning (DP) mode with the subsea camera deployed.

We arrived at Hole 504B at 0245 h on 26 August. During the subsequent 4 h, we attempted to capture the short pipe sticking up from the wireline CORK frame with a 6⅝ inch diameter overshot tool. After three unsuccessful attempts to engage, we decided to recover the drill string. The overshot tool was removed and a three-pronged "fishing" spear, which had been fabricated by JRSO staff for this specific purpose as a backup tool, was attached to the BHA. At 1300 h, deployment of the drill string began while the ship moved back to Hole 896A in DP mode. The spear successfully penetrated into the CORK frame at 2215 h. We pulled the spear with the Hole 896A CORK frame out of the hole and, in order to find out how much of the CORK cabling with packers we had pulled out of the hole along with the CORK frame, we attempted to lay it all out on the seafloor. A brief investigation of the seafloor did not reveal either the packer or the lead-in package, although some of the cabling was visible. Because the next step was to move over to Hole 504B and remove the wireline CORK there, three attempts were made to release the Hole 896A CORK frame from the spear on the seafloor, but the CORK frame remained firmly attached to the fishing spear. At 0300 h on 27 August we started to retrieve the drill string with the CORK frame attached, which arrived on deck at 0955 h. Portions of the CORK frame had to be cut away to remove the fishing spear. The science party removed the old data logger canisters from the frame, which had all flooded. A few data loggers with dead internal power were recovered for shore-based attempts to revive them and download the data.

At 1100 h we began to lower the drill string with the spear back to the seafloor to recover the Hole 504B wireline CORK, while the vessel moved to Hole 504B in DP mode. The CORK frame was quickly engaged at 1905 h. Given our lack of success in getting a visual on the seafloor of the elements below the Hole 896A CORK frame, we decided to pull this CORK frame directly to the rig floor after offsetting to prevent anything from falling back into the hole. The spear arrived on deck at 0400 h on 28 August with bent tines and without the Hole 504B CORK frame, which must have fallen to the seafloor after the subsea camera had been retrieved.

Operating under the assumption that the Hole 504B wireline CORK had been successfully removed from the hole, we decided to proceed with the logging and hydrogeologic objectives of the expedition. A logging BHA was deployed to allow deployment of fluid sampling and temperature measurement tools with the coring line as well as the FMS tool with the wireline logging line. An initial seafloor survey did not locate the lost CORK frame from Hole 504B. We reentered Hole 504B at 1815 h and soon tagged an obstacle at 19 m below seafloor (mbsf), which was the expected depth of the top packer that had been deployed in 2001. We were not able to push the packer downhole with the logging BHA and we pulled out of the hole, clearing the seafloor at 1905 h. We then moved over to Hole 896A in DP mode and reentered Hole 896A at 2130 h. As in the previous hole, we tagged an obstacle at 57 mbsf, which was presumed to be a stuck packer. Because we were able to push the packer only ~9 m downhole in half an hour with 10 klb of force, we decided that a milling job was needed and we retrieved the drill string.

A new BHA was made up with additional drill collars and a milling bit to remove the packers left in both holes. At 0800 h on 29 August we began lowering the drill pipe while moving the vessel to Hole 504B in DP mode. After deploying the subsea camera and installing the top drive, we reentered Hole 504B for the second time at 1550 h. The packer was again encountered at

19 mbsf. After recovering the subsea camera, we milled and worked the junk baskets with a maximum weight of 20 klb and pumped sweeps of high-viscosity mud to remove the debris. At 0630 h on 30 August, with the milling bit at 70 mbsf and a lack of advance for several hours, we pulled out of the hole after lowering the subsea camera.

We thought it was prudent to have a try at Hole 896A while the milling BHA was in place. We moved over to Hole 896A in DP mode to see if the packer in that hole could be milled and pushed down more easily. We located Hole 896A and reentered it for the second time at 1252 h. The packer was tagged at 66 mbsf. After retrieving the subsea camera, we milled with up to 20 klb of weight on the packer, which slid from 72 to 88 mbsf. We continued to mill until 1700 h, when we reached 95 mbsf with diminishing rate of advance. With ~15 h of time on the mill, we decided it was time to retrieve and inspect the milling bit and junk baskets. We retrieved the drill string while moving the vessel to Hole 504B in DP mode. The milling bit arrived at the rig floor at 0005 h on 31 August, with an estimated 95% of the tungsten carbide missing from the mill's face. The junk baskets were emptied and ~35 lb of packer debris were removed from the two boot-type junk baskets, consisting of a mixture of the Swagelok connectors from the top of the packers, steel baffling slats, rubber, and copper threads from the cabling.

We made up and deployed a new milling bit assembly and reentered Hole 504B for the third time at 1042 h. After installing the top drive and retrieving the subsea camera, we tagged the packer at 70 mbsf and began milling, pumping 25-barrel mud sweeps and applying a maximum weight of 22 klb. At 2330 h we had advanced to 110 mbsf and decided to retrieve the drill string due to diminishing advance, with the bit arriving on deck at 0615 h on 1 September. The junk baskets were disassembled, emptied, and cleaned, yielding ~34 lb of metal debris mostly made up of steel baffling slats that were part of the central packer.

We made up and deployed the third milling bit assembly and reentered Hole 504B for the fourth time at 1537 h. Milling resumed from 110 mbsf, and at 0200 h on 2 September the bit had advanced to 134 mbsf within the casing. With ~8 h on the bit, we retrieved the drill string and the bit cleared the rig floor at 0900 h. The junk baskets were disassembled, emptied, and cleaned, again yielding ~35 lb of packer debris mostly made up of steel slats.

We made up and deployed the fourth milling bit assembly, this time with an additional stand of drill collars for additional weight instead of the junk baskets, and Hole 504B was reentered for the fifth time at 2042 h. Milling resumed from 133 mbsf, with rotation stopped several times and additional weight (up to 40 klb) applied in an effort to move the packer down the casing. At 1200 h on 3 September we had advanced to 141 mbsf. With ~13 h on the bit, we retrieved the drill string and the milling bit cleared the rig floor at 1910 h. The bit face showed severe wear with three concentric patterns thought to be caused by the packer's lower end cap (1½ inch central hole), remains of its casing (4¾–5¾ inch ring groove), and metal debris outside the bit (honed edge).

At this point, obtaining downhole temperature measurements, fluid samples, or FMS logs had become impossible in the remaining time. The only goal left was to keep trying to open Hole 504B for potential future use. We made up and deployed the fifth milling bit, this time again with the junk baskets. At 2015 h we began to lower the drill string to the seafloor and deployed the subsea camera at 0200 h on 4 September. As the camera was lowered, a shorted circuit in the camera system's slip ring prevented it from being powered and the camera was retrieved. The milling bit was deployed to 3425 mbrf and the top drive was installed in anticipation of a successful and timely camera system repair. At 1245 h we determined that the camera could not be repaired in time to allow for reentry into Hole 504B to continue milling operations. The rig crew started to perform rig maintenance and to break down the 5½ inch drill pipe stands for storing aboard and offloading in port for inspection. The rig floor was secured for the transit to San Diego, California, which began at 1318 h on 5 September.

In summary, we spent 48 h actively milling the packer in Hole 504B, plus associated pipe trips for the five milling runs, succeeding in removing a significant amount of packer material, 104 lb of which was captured in the BHA junk baskets, and pushing the packer from 19 to 141 mbsf. Likewise, we spent 2 h on the same activities in Hole 896A, managing to move the packer from 57 to 95 mbsf.

Principal Results

To achieve the science objectives, the Expedition 385T operational plan required removing previously installed wireline CORKs from Holes 504B and 896A, ensuring open hole conditions while collecting fluid samples and temperature logs, and conditioning the hole for logging with the FMS logging tool. The challenge to remove the wireline CORK packers and related cables from inside the casing in Holes 504B and 869A was a significant operational hurdle that could not be overcome during the expedition, thus preventing the collection of any samples or data. The operations in Holes 504B and 896A were concluded without accomplishing any of the scientific objectives of Expedition 385T.