IODP Expedition 362T: Transit and Hole U1473A Remedial Operations
Site U1473 Summary
12–21 July 2016 (Transit: 4 July–6 August 2016)

Introduction

Hole U1473A, located at 32°42.3622′S, 57°16.6880′E, in the central part of the Atlantis Bank, SW Indian Ridge, at 710.2 m water depth, was drilled during Expedition 360 (30 November 2015 to 30 January 2016) to a total depth of 789.7 m DSF (drilling depth below seafloor) and recovered 469.2 m of gabbroic rocks. Following coring, wireline logs were successfully acquired on 23–25 January. Logging operations included the use of a mechanical bit release (MBR), which saved the time of a full pipe trip before logging by dropping the bit on the seafloor next to the reentry system. When the pipe was retrieved after completion of logging, the MBR retainer sleeve (MBR-RS), a steel ring that is part of the bit release mechanism made up with the bottom-hole assembly (BHA), was missing and presumed lost in the hole. Subsequent runs on 25–26 January with the rotary core barrel (RCB) coring bit and the reverse circulation junk basket (RCJB) confirmed that the MBR-RS was at the bottom of the hole. At that point, no more time was available for operations during Expedition 360. The primary objective of the Expedition 362T remedial operation is to remove the MBR-RS at the bottom of the hole. Additional objectives include cementing multiple fault zone intervals to stabilize them, obtaining a borehole temperature log across the fault zones (at the beginning of operations), and deepening the hole by taking two RCB cores.

Several fault zones were encountered while coring in Hole U1473A during Expedition 360. These were identified by distinctive features in the recovered rocks and log data as well as intervals of lower-than-expected core recovery. Fault zones were precisely located by caliper, temperature, and resistivity wireline log data between 160 m and 580 m WMSF (wireline log matched depth below seafloor). Below 580 m, log data as well as high core recovery indicate that Hole U1473A is very smooth and lacks faults. A secondary objective of the remedial operation is to cement the faulted intervals in the hope of stabilizing the upper part of the hole, in particular to prevent debris from falling onto the bit and/or BHA during future coring.

A borehole temperature anomaly in the log data correlates with the most intensely faulted zone at 430–470 m WMSF. During Expedition 362T, we will attempt a temperature log to learn how that signal evolved since we logged Hole U1473A in January 2016.

Our last objective is for two new cores to be taken to document the feasibility of returning to core in Hole U1473A in the future. Two cores is the limit imposed by the *JOIDES Resolution* Facility Board (JRFB) to minimize the risk of compromising the cleaned hole and to ensure this will be a remedial operation and not a mini-science expedition.

A total of nine days of remedial operations were allocated, with four additional days of contingency time given the potentially disruptive weather during this season. The following was the sequence of planned operations:

1. Enter the hole with a temperature logging string and acquire temperature data (~1.2 d).

2. Attempt to recover the MBR-RS, starting with the reverse circulation junk basket (RCJB), which successfully retrieved two roller cones during Expedition 360. In the best-case scenario, we will retrieve the ring in the first attempt (~0.6 d). Multiple tool runs are possible with the RCJB, the fishing magnet, and/or a milling tool. In the worst case, the entire available time is used to keep fishing and/or milling.

3. As soon as the hole is clear of the retainer ring, attempt to cement multiple fault intervals between 580 m and 160 m DSF identified in the Expedition 360 log data (~0.9 d).

4. After cementing is complete, drill through the cement plugs and ~5 m into the formation at the bottom of the hole using a tricone non-coring bit (~3.9 d).

5. If time is still available, switch to a RCB coring bit and cut two cores (~1.2 d).

Furthermore, we will:

- Curate any material recovered from the hole per standard operating procedures.

- Take the same whole-round section measurements as were taken on Expedition 360 (imaging, magnetic susceptibility, gamma ray attenuation, and natural gamma radiation) as well as section half measurements (images, point magnetic susceptibility, color reflectance, and magnetic remanence).
- Store all recovered material on the *JOIDES Resolution* and ship it to the Kochi Core Center (KCC) at the end of Expedition 362 (October 2016), where it will be made available to the Expedition 360 science party for detailed description and postcruise research.

Transit

Transit 362T began on 4 July in Cape Town, South Africa. We completed the 2080 nmi of transit at an average speed of 11.2 kt and arrived at Hole U1473A 0n 12 July at 1315 h. By 1415 h, the thrusters, hydrophones, and beacon were deployed. During the transit, the local time was adjusted in four increments to Sri Lanka time (UTC + 5.5 h).

Logging

A logging bottom-hole assembly (BHA) was made up and deployed to the seafloor. The subsea camera was deployed and at 1900 h on 12 July, Hole U1473 was reentered for the first time on Expedition 362T and for the 25th time overall. The camera was retrieved and the logging bit was set at 75.6 m DSF in preparation for logging. We made up and deployed a temperature and natural gamma ray logging tool string, and by midnight downhole logging had just begun.

Temperature and natural gamma ray logs were acquired while the logging tool string descended into Hole U1473A. At midnight the tool string had reached 276.7 m WSF (wireline log depth below seafloor), where a bridge or ledge in the hole prevented further descent. We acquired log data while pulling the tool to the seafloor, then retrieved the tool string and rigged it down by 0200 h. We lowered the drill string to find out if the obstruction could be knocked down with the logging bit, in the hope that another, deeper logging run could be attempted. However, the bit could not be lowered beyond a hard tag at 276 m DSF (drillers depth below seafloor). We pulled the drill string and the bit was back on the rig floor at 0700 h on 13 July. We spent 0.7 d logging compared to 1.2 d planned.

The new log data from the upper 277 m of Hole U1473A show significantly lower temperatures (11.8°C) than the same interval had during Expedition 360 (16°–17°C). However, just as observed during Expedition 360, the interval has almost constant temperature today (slightly warmer by ~0.5°C towards the top), without an expected geothermal gradient similar to that in the lowermost 250 m of the hole. Although the new data acquired do not provide data across the fault zones that extend to 580 m, they may nevertheless offer a constraint for thermal modeling and the role of thermal diffusion and convection.

Fishing for the lost MBR retainer sleeve

Next we made up a 9.75 inch tricone drilling assembly to try and reach the bottom of the hole using a cautious procedure involving rigorous use of circulation and mud sweeps. At 1257 h on 13 July we reentered Hole U1473A for the second time on this expedition (the 26th time overall) and engaged the top drive. The hole was reamed and swept from 277 to 354 m DSF, reached at 0145 h, using three 30-barrel high-viscosity mud sweeps at 280, 320, and 331 m. From there on, we were able to trip the pipe to 442 m with the top drive engaged. Lowering the drill string further with the top drive disengaged, drag was encountered and the bit tagged another obstruction at 464 m at 0345 h on 14 July. We reengaged the top drive and reamed the interval from 442 to 456 m for more than 7 h, pumping four high-viscosity 30-barrel mud sweeps. We were not able to advance farther. At 1130 h on 14 July, we decided to trip the pipe so we could assess the wear on the bit and draw conclusions on the situation at the bottom of the hole. The bit was back on the rig floor at 1530 h. It showed the common abrasion of the peripheral cutters and signs of bearing damage. Moreover, it had broken cutters on the inner rows of the cones, indicating contact with an angular object in the center of the hole. This object was unlikely to be metal (i.e., one of the two broken-off roller cones probably left in the hole on Expedition 360) because that would have damaged the matrix of the tricone bit's cones.

A new tricone bit was made up and deployed to the seafloor, reentering Hole U1473A for the third time at 2100 h on 14 July. The drill string was lowered without a problem until it tagged the bridge at 445 m. The top drive was engaged and drilling resumed at 2400 h. We continued to ream and work Hole U1473A with the second tricone drilling assembly, which took half a day to advance from 445 to 471 m DSF, along with pumping four 30-

barrel high-viscosity mud sweeps at 449, 459, 462, and 471 m. From 1200–1300 h on 15 July, we advanced more rapidly to 487.6 m, experiencing significant torque and drag, and finally breaking through the bridge. We continued to lower the bit with the top drive engaged so that we could circulate mud sweeps at 490, 530, 580, 650, and 720 m. At 0115 h on 16 July we reached the bottom of the hole established during Expedition 360 (789.7 m). No fill was identified at the bottom of the hole. Two 50-barrel high-viscosity mud sweeps, followed by twice the hole volume of water, were circulated to sweep cuttings out of the hole.

At 0245 h we began a wiper trip by raising the bit first to 731 m, where the top drive was disengaged, and then to 147 m (0500 h). Next, the pipe was lowered again, first to 760 m where the top drive was reengaged, then to the bottom at 789.7 m (1045 h). No rotation with the top drive was needed, which indicated good hole conditions. Finally, the drill pipe and tricone bit assembly were recovered, first to 760 m where the top drive was disengaged, and then to the surface, with the bit arriving on the rig floor at 1500 h on 16 July.

Inspection of the tricone bit revealed the same broken-off cutter inserts on the inner row as were seen in the first tricone bit. The bit was ~0.25 inch out of gauge. The remainder of the bit was in good condition.

Given the good hole conditions, we decided hours earlier that cementing the fault zones was not necessary or helpful to stabilize the hole at this time. We made up a reverse circulation junk basket (RCJB) assembly (1530–2015 h) to try to recover the mechanical bit release retainer sleeve (MBR-RS) presumably left at the bottom of the hole at the end of Expedition 360. At 2015 h we began deploying the RCJB assembly and Hole U1473A was reentered for the fourth time on this expedition (the 28th time overall) at 2106 h on 16 July. We continued to lower the RCJB assembly to 763 m DSF without the top drive and from 763 m to the bottom of the hole at 789.7 m with the top drive engaged. At 0145 h on 17 July, a 30-barrel high-viscosity mud sweep was circulated before the RCJB was worked up and down three times by ~2 m with heavy circulation on and off to capture remaining small debris in the tandem boot baskets located above the main basket with mill guide. Next the reverse circulation activating steel ball was dropped down the pipe, and with heavy circulation and high rotation rate (~80 rpm) the mill guide was advanced into new formation by 0.5 m (0145–0330 h). The drill pipe and RCJB assembly

were subsequently retrieved, first with the top drive to 763 m, then without top drive to the rig floor (0330–0750 h). No drag or overpull was registered during the ascent.

Breaking down the RCJB components, we found the tandem boot baskets empty, indicating a clean hole. Next we extracted an 18 cm diameter, 36 cm long solid rock core from the main basket (Core U1473A-92M). We found no sign of the missing mechanical bit release retainer sleeve (MBR-RS).

This was an unexpected situation because (1) we were certain that the MBR-RS was at the bottom of the hole when we deployed the RCJB on our last run 24 on Expedition 360, based on multiple tool marks on three cobbles retrieved with that run matching the MBR-RS features exactly; and (2) we were certain that we drilled a new core with this latest RCJB bit run 4 on Expedition 362T, and nothing could have been between the bit and the top of Core 92M based on perfect tricone bit marks on top of the core. Our only explanation was that the MBR-RS was recovered out of the hole with the last run on Expedition 360 and fell out of the basket and to the seafloor while pipe was being tripped to the surface, whereas the cobbles remained in the basket. The repeated acceleration and deceleration during pipe tripping may have separated steel from rock. This explanation could also apply to the two broken-off roller cones that have never been accounted for during Expedition 360.

Coring

Feeling confident that we had a very clean hole, we made up a rotary core barrel (RCB) coring assembly (0945–1330 h, 17 July). The assembly was deployed and we reentered Hole U1473A for the fifth time on Expedition 362T (the 29th time overall) at 1552 h on 17 July. The drill string was further lowered to 760 m without the top drive, and to the bottom of the hole at 790.2 m by 2100 h. By midnight coring had advanced 4.8 m to 795.0 m. This was the advance possible for this core based on rig space configuration, and we decided to core the remainder of the 20 m approved coring interval in three additional 4.8 m increments (half cores). Core U1473A-93R (790.2–795.0 m DSF) arrived on deck at 0205 h on 18 July with a recovery of 3.1 m (65%). We then cut Cores 94R through 96R (each penetrating 4.8 m), from 795 to 809.4 m, with recoveries of 2.35 m, 7.32 m, and 3.78 m (49%, 153%, and 79%), respectively. The low recovery for Core 94R and excessively high recovery of 95R were the result of about half the core cut for 94R remaining at the bottom of the hole and Core 95R retrieving the stub left behind

in addition to the newly cut core. At 1215 h on 18 July the coring program approved for the Hole U1473A remediation project was concluded. The total RCB-cored interval was 19.2 m and total recovery was 16.55 m (86%).

Cores were curated by arranging the pieces in sections of ~1.5 m length and labeling and registering all pieces and sections. Core sections were run through the Whole-Round Multisensor Logger (WRMSL) to measure gamma ray attenuation (GRA), bulk density, and magnetic susceptibility (MS), followed by natural gamma radiation (NGR) measurements in the Natural Gamma Radiation Logger (NGRL). Next, we took images of the whole-round section surfaces using the appropriate configuration on the Section Half Imaging Logger (SHIL). After splitting the cores, we ran the archive halves through the SHIL for split surface images, and the Section Half Multisensor Logger (SHMSL) to measure magnetic susceptibility with the contact probe (MSP) as well as reflectance spectroscopy and colorimetry (RSC). Paleomagnetic measurements could not be taken because of issues with the superconducting rock magnetometer (SRM) software; these issues will be resolved, and the Expedition 362T archive section halves measured, during the early part of Expedition 362.

The cores recovered on Expedition 362T closely resemble those described on Expedition 360. They consist mostly of medium to coarse-grained subophitic olivine gabbro with varying amounts of oxide (as indicated by the magnetic susceptibility records). Most intervals are isotropic, others show weak magmatic fabric including irregular, subhorizontal to subvertical contacts between medium and coarse-grained size domains. Magmatic veins (e.g., Section 93R-2) and metamorphic veins (e.g., amphibole vein in Section 93R-3) are observed. Core 94R is characterized by foliation associated with a subvertical shear vein extending through much of the section, and a porphyroclastic (protomylonitic?) interval at the bottom. In Section 96R-3 a 25 cm thick oxide rich mylonite is underlain by a porphyroclastic (protomylonitic?) interval.

Cementing

At 1215 h on 18 July the bit was raised to 585 m DSF and preparations were made for cementing the unstable faulted zones. We decided to cement the four fault zones identified on Expedition 360 caliper logs in four separate installments rather than in one delivery as originally planned. This would allow us to tag the top of each cement plug

after an appropriate curing time (~12–24 h), determine if the calculated volume was adequate to fill the target interval, and take corrective action if deemed necessary.

The first cement target interval was ~574–509 m DSF. We positioned the bit at 584 m, pumped 50 barrels of 16.8 ppg (pounds per gallon) class G cement and emplaced it with 680 barrels of seawater using the rig pumps (1430–1715 h). The volume of cement was 25% over the target interval capacity calculated using the caliper log to ensure filling of all cavities.

At 1715 h on 18 July the cement circulation head was removed and the bit raised to 381 m DSF. The drill string was flushed with three times the annular hole and pipe volume before it was further raised to ~84 m above the seafloor and flushed again with two times the pipe volume. The drill string was then retrieved with the bit arriving on the rig floor at 2325 h on 18 July. This was still the same coring bit used to cut Cores U1473A-93R through 96R, and it now showed signs of damage or wear.

We began making up a tricone bit assembly (which is more suitable for cementing than the coring bit) for the next three cementing intervals, and deployed it to ~138 m above the seafloor. We then waited from 0215 h until 0630 h on 19 July for the first cement interval to cure before reentering Hole U1473A for the sixth time on Expedition 362T (the 30th reentry overall) at 0726 h on 19 July. The bit was lowered until it tagged the top of the first cement plug with 10 klb weight at 500 m. This is 9 m above the target, i.e., the cement plug is filling an interval of 83 m instead of the 65 m planned, which is an excellent result.

The second target interval for cementing was 484–409 m. We raised the bit to 489 m and initiated cement mixing and pumping. A plugged cement line forced us to abort this attempt and flush the low-density cement out of the hole (1045–1200 h). After the cementing lines were cleared we started over, pumping 70.7 barrels of 15 ppg class G cement and emplacing it with seawater (1200–1330 h). The drill string was pulled to 227 m DSF and flushed with twice the annular volume of pipe and hole, and then to ~112 m above the seafloor where it was flushed once more with twice the pipe capacity (1330–1600 h). We waited for the cement in the second interval to cure before reentering Hole U1473A for the seventh time (the 31st time overall) at 2220 h on 19 July. We continued lowering the bit into Hole U1473A and tagged the top of the second cement

interval at 461 m DSF with 10 klb weight (0215 h on 20 July). We had therefore cemented only the lowermost 23 m of the 75 m target interval (484–409 m). After pumping 10 barrels of drill water and pressure testing the lines, we mixed and pumped another 26 barrels, which achieved a density of 13.5 ppg, and emplaced it at 459 m with 72 barrels of sea water (0430–0500 h). The cement density was below the 16.5 ppg specified as the ideal density because the cement kept plugging the lines leading to the mixing tank, probably due to old cement that is not breaking down during fluffing efforts. We had to abort the cement operation again before we could emplace the intended volume. We raised the bit to 149 m DSF and flushed the drill string with two times the pipe capacity. Then we raised the bit to ~125 m above seafloor where we stood by to let the cement cure.

At 1457 h on 20 July we reentered Hole U1473A for the eighth time on Expedition 362T (the 32nd time overall). At 1745 h we tagged the top of the cement at 443 m DSF with 10 klb weight. This added another 18 m to the cement in the hole, but the top of the cement plug was still in the middle of the main fault zone and did not extend up to the desired depth of 409 m.

After pumping 10 barrels of drill water and pressure testing the lines again, we mixed and pumped another 55 barrels of 16.5 ppg class G cement, followed up with 71 barrels of seawater, with the bit at 443 m (1930–2000 h). Then the drill string was raised to 188 m DSF and flushed with two times the pipe capacity of seawater before it was pulled to ~112 m above the seafloor (2130 h on 20 July).

We were standing by with the drill string suspended at ~112 m above the seafloor to let the last cement emplaced cure. At 0655 h on 21 July we reentered Hole U1473A for the ninth time on this expedition (the 33rd time overall). We lowered the pipe until it tagged the top of the cement plug at 443 m DSF with 5 klb weight. This meant that our third attempt to cement this second interval has not added to the vertical extent of the cement plug and we infer that the borehole in the fault zone was enlarged enough to accommodate the 55 barrels of cement slurry laterally. Our three attempts with a total of ~152 barrels of cement pumped to stabilize the main fault (our second target interval from 484 to 409 m DSF) resulted in a cement plug extending from 489 to 443 m DSF (46 m thick).

At this point we had no more cement left to use. We retrieved the drill string with the bit arriving on the rig floor at 1345 h. The positioning beacons were released and recovered, the ship was secured for transit, and we departed Site U1473 at 1430 h on 21 July for the transit to Colombo, Sri Lanka.