

ROV Drilling Operations for TN183-184 Cruise – Sept. 2005
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Cruise Number: TN183-184

Drill Site: Juan de Fuca Ridge, Mothra/Endeavour Sites (hydrothermal vents)

Dates of Drilling Operations: September 1-7, 2005

Vehicle: Jason2 ROV with ROV drill sled

Research Vessel: T.G. Thompson

Ports: University of Washington, Seattle, WA

1. ROV Drill Dive/Hole Summary

<u>Dive Number</u>	<u>Date</u>	<u>Hole Description and Results</u>
J165	09/04	Poor Man's incubator: Mothra site, Faulty Towers Incubator not installed due to difficulty trying to insert (blocked hole?). Only reamer bit employed: observed depth 8"-10", sample core length ~6". Drill time: ~50 min. Drill data file: dive165_Faulty_Tower.txt
J165	09/04	Standard incubator with data collector: Mothra site, Roane Tower. Incubator installed with data collector placed on top plateau of tower. Reamed existing hole to a depth of 18"-20". Drill time: ~70 min. Drill data file: dive165_Roane_Tower.txt
J166	09/06	Incubator #3 with data collector: Hulk site, south of Hulk Tower. Instrument installed. Coring observed depth 18"-20", sample core length ~10". Drill time: ~40 min. Reamed hole to same depth. Drill time: ~15 min. Drill data file: dive166_Hulk_1.txt
J166	09/06	Poor Man's incubator: Hulk site, just north of prior hole. Instrument installed. Coring observed depth 18"-20", sample core length ~8". Drill time: ~10 min. Reamed hole 2 in. past cored hole. Drill time: ~11 min. Drill data file: dive166_Hulk_2.txt

J167	09/07	Poor Man's incubator: Roane Tower, south/SE side at base. Instrument installed. Coring observed depth 20"-21", sample core length 18". Drill time: ~65 min. Reamed hole to same depth. Drill time: ~55 min. Drill data file: dive167_raw.txt
J168	09/07	Incubator with data collector: East side of Giraffe structure. Instrument installed. Coring observed depth 20"-21", sample core length ~8". Drill time: ~50 min. Reamed hole to same depth. Drill time: ~15 min. Drill data file: dive168_raw.txt

1.1. Core Summary

<u>Dive number</u>	<u>Length (approx. due to the nature of the material)</u>
J165 (reamer)	15 cm (no pic available)
J166-1	25 cm
J166-2	20 cm
J167	45 cm
J168	20 cm

2. Operations Summary

2.1. ROV Jason2 and ROV drill mobilization/demobilization in Seattle

The drill sled hydraulic power was supplied directly from the Jason2 AUX manifold. This configuration is different from when the drill was last used 2 years ago, where hydraulics were supplied from the lines to the Schilling manipulator (which was removed last time to also save on weight). The Schilling did not have to be removed this time because syntactic foam was added to help offset the weight of the drill (5 blocks of 36# foam and 3 blocks of 34# foam strapped within the drill sled frame) and extra side/top pieces were installed on Jason2's main foam pack over the past couple of years.

While in port, the pressure relief valve on Jason2's main hydraulic manifold was opened up from 1750 psi to 2750 psi. This was required to optimize hydraulic requirements for the drill sled that would: a) improve removal of material during the drilling process, and b) ensure that the rotational speed of the bit would be in the range from 200-300 rpm. Two DSPL mini cameras with integrated LED's were mounted such that the drill string coupler and the compression string (along with the mounted ruler in the background) could be monitored.

Demobilization consisted of tarping the sled on deck while not in use due to the possibility of the Paraflex hydraulic hose bursting while in direct sunlight. One hose exhibited this failure and is still in need of repair. The charge and detonator were removed and returned for safe keeping to the captain. All exposed electrical connections were either dummied off with their respective plugs or capped with latex glove finger tips. Shipment of the ROV drill back to WHOI consisted of the sled being strapped and bolted to a pallet with a plywood cover. The sides were wrapped with plastic shipping wrap. The tote with coring/reamer bits and associated drill strings (serviced and ready for the next drilling ops) in protective tubes were also strapped within the frame for transport. The fish crate with spare parts was packed and shipped with the system back to Woods Hole. The drill system currently resides in the Clark South Highbay at WHOI.

2.2 Jason2 Hydraulic System Configuration

On the first dive, the drill was only able to rotate at approximately 100 rpm. The hydraulic motor on the sled has a minimum displacement of 12 L/min; thus flow is the limiting factor versus pressure. Miscommunication with the pilots resulted in an error in hydraulic setup through the ROV hydraulic control interface. Once this was realized, selecting the next GUI set point in the ROV's hydraulic controls provided maximum flow and resulted in adequate rotational speeds during drilling at pressures much less than 2750 psi. The miscommunication likely arose from the 2 mechanical engineers who understood and modified the hydraulics not communicating this to the other two ROV pilots. This has been noted for future operations. It appears that pressure is often the main consideration, esp. for manipulator operation, but in this case, flow was the predominant factor for proper drill sled operation. Pressure is more of a concern for the advance/retraction ram, which is pressure reduced at the drill sled manifold (~4:1 ratio). On this issue, although the ram's motion was painfully slow (but tolerable), it was not until the end of the drilling ops that the needle valve and brass setscrews on the drill sled manifold were adjusted to alleviate the annoyance. This too has been noted for future operations in the hopes of avoiding these problems.

2.3. Site Selection and Set-up Recommendations

Site selection and ROV set-up were again determined to be key considerations for successful drilling. There was some degree of relearning about this process from the experience two years ago. The ideal scenario is with the ROV sitting on a flat, stable surface with both drill sled front-points engaged (3 degrees of freedom under control) for sequential drilling of a cored hole followed by reaming of the hole without repositioning. The latter criteria (i.e. engaged front points) is a must for successful reaming of a hole (pre-existing or cored beforehand) to eliminate 2 degrees of freedom (primarily yaw, and to a much lesser degree, roll). For the 2nd hole on Roane (J165, existing cored hole to be reamed), this was not an option on the narrow tower at an altitude of several meters; thus, the possibility of the reamer binding was highly likely, which is what occurred.

As a secondary consideration of reaming an existing hole, aligning the reamer on a pre-existing hole can only be carried out by "stabbing" the hole with the reamer exposed beyond the explosive cutter face and "flying" the ROV into the hole. Therefore, the likelihood of the reamer being axially aligned with the hole is quite small; this could cause binding during retraction. Since several of the selected sites were marginal in terms of ROV stability, the hydraulic motor became detached numerous times from the drill shaft due to binding of the reaming bit in the hole during retraction (NB; the reaming bits are not designed for back cutting).

Due to the geometry of the coring bit (cutter head approx. the same size as the drill string shaft), more tolerance can be given to the selected site set up, and the necessity of both the drill-points making contact with the face can be ignored with caution (e.g., this is how the second hole drilled in Hulk and another at the base of Roane were accomplished). *It should be noted that binding or detachment of the drill shaft from the motor did not occur during any of the coring operations.* The pre-existing hole on Roane, which exhibited worst-case stability criteria, is another example of a successful coring operation. Dale Graves from MBARI stressed that a significant amount of time was spent searching for a good site to drill during ROV operations 2 years ago. He also mentioned the necessity of "pecking" a reamed hole (advance a few inches and then retract all the way out). This procedure is employed to

avoid binding by clearing out material accumulating behind the reamer, and opens up the hole on subsequent drilling pecks, allowing more tolerance for vehicle drift.

According to Paul Tucker (MBARI contractor), this procedure was not necessary in soft material, and after becoming concerned about decoupling the drill shaft after the first decoupling incident, the group decision was made not to “peck” to ensure that the end result was a fully reamed hole albeit at the expense of a defunct drill sled. ***It should be said that this is not an acceptable, recommended procedure for future drilling operations since the ROV must forcefully remove the reamer.*** On this note, perhaps the decoupling of the motor shaft actually helped in the removal of the bit since it allowed the drill string to float with respect to the ROV, and it provided an effective ramming action. More importantly, the heading and pitch of the ROV should be recorded prior and during drilling to monitor vehicle drift. This may also aid in the removal of the bit if binding occurs by adjusting the ROV heading accordingly while pulling out. On two occasions this proved useful information for the pilot when a forceful removal was necessary.

Another consideration for reamed holes entails movement of the vehicle, whether from excessive drift following coring or returning to the site after the coring operation. It's virtually impossible to realign the vehicle for reaming. ***In most cases, the recommendation is to start over such that coring and reaming occur sequentially in the same vehicle orientation. Therefore, the advice is not to ream existing holes.***

Another general recommendation is for the science team to provide a hole marker or homer beacon for drilled holes; typically the instrument to be installed is on the elevator to be retrieved after drilling. In addition, the pilot should be reminded to remove any biological material from the face of the structure before drilling. This was a real issue on the first hole, which disappeared in the bed of tubeworms. Finally, for hydrothermal vent instruments and drilling into active chimneys, the science party should discuss with the pilot whether measurement of the exiting fluid temperature immediately post drilling is important. If it is, take a measurement after coring and prior to reaming, to evaluate whether the hole will be suitable for the particular experiment.

2.4. Pre-Dive Installation of Detonator and Charge- Explosive Cutter - Checklist

- ☐ Clear area in front of drill sled. Install warning sign on front of cutter. Check continuity of controller detonator cable before start of dive series.
- ☐ Install cutter charge with large diameter surface facing inward, and styrofoam backing in place (visible when installed; use tape if foam not available).
- ☐ Inspect o-ring and Teflon backing ring (inside or dry side). With shorting plug in place (small spring across pins) and o-ring in place, install detonator behind charge. Install large nut with cleaned threads and Blue Goop applied. Seat by hand (obvious with clean threads) and then snug with wrench.
- ☐ Verify controller side of detonator cable is shorted with pink colored dummy plug
- ☐ Ensure battery is disconnected from controller at battery housing.
- ☐ Remove shorting spring from detonator pins, and connect to controller detonator cable.

NOTE: Keep in mind to have detonator shorted during installation and removal. Any static charge in the system may cause detonation.

REMINDER: Disconnect detonator from controller and install shorting plug (pink colored), and then disconnect the battery at the battery housing immediately after a dive. Place WARNING sign on front of cutter.

REMINDER: LED OFF = DISARMED**LED ON = ARMED****LED BLINKING = ARMED and COUNTING DOWN****3. Daily Operations Logs****3.1. September 1, 2005**

Integration on deck- ROV hydraulics modified by Matt H. to provide adequate pressure and flow to the drill sled. Pressure relief increased from 1750 to 2750 psi. Hydraulics taken directly off the second (AUX) manifold. From Dale Graves, I believe the hydraulic lines were taken off the main manifold or from the lines supplying the Schilling (also removed to possibly save weight) 2 years ago to provide maximum flow (main max = 3 Gal/min, AUX = 2 Gal/min). Check on this. Turns out that coming off the AUX proved adequate during the actual drilling ops.

Full extension of drill string on deck successful. Modified service loop with camera cable o.k.

Camera test with ROV powered up: locations are good.

Water pump test with hose attached: flow indicator shows zero, although deck test showed positive flow through the system with positive pressure. Stuck sensor vane? Noticed that the pump could not displace water from a bail when primed. Something is amiss.

Diagnosis: pump cover was removed. Paul Tucker discovered gasket was too thin, which resulted in impeller being compressed and hindered by cover (polished score marks visible on inside of cover). Paul cut out a new gasket out of 1/8" thick rubber sheeting.

3.2. September 2, 2005

Integration continued- Water pump: gasket not the main problem. Motor controller not tuned properly – erratic behavior evident while running. Replaced controller with old unit (spare).

NOTE: while installing controller noticed BLK/240V-COM and RED/+240V wires connected in reverse order (i.e. BLK = +240V and RED = 240V-COM. Leads need to be reversed at bulkhead connector. This was not done due to time constraints, and therefore, needs to be dealt with in the future.

Pump test: successful on deck and at depth (checked the next day during the dive).

3.3. September 3, 2005

First dive with drill sled- Dive #165, 8:45AM PST. Dive aborted due to Medea failure at a depth of ~850 meters. Cause: water penetration into the newly installed electronics bottle.

Water pump test showed good flow on the indicator (Visual Basic GUI).

Pressure sensor switch activated between 100 and 200 meters. Able to arm/disarm explosive cutter.

3.4. September 4, 2005

Second dive with drill sled-Dive #165 (revisited), 7:40 PM PST.

Pressure switch activated at 125 meters.

Flow pump indicates 6.7 L/min at max motor speed without drill string attached.

Hole description: Mothra site, Faulty Towers, Juan de Fuca ridge.

Start depth: 2270 meters

Bit #: Reamer, L62880

File: dive165_Faulty_Tower.txt

Hydraulic test at 1000 meters. Results: Checked front gate and hydraulic motor at low and high speed modes. O.K.

Charge detonation battery voltage unusually low at ~10:30 PM PST. Jumping around 0.20 V. Voltage at dive time ~12.4 V.

Differential pressure and weight on bit (WOB) displays are way off. Diff. = 95 and WOB = 100,000. Something is obviously amiss.

ROV hydraulic motor speed set at 1500 rpm and 2500 psi (no load). Going up to 1750 rpm and 2200 psi as an initial set point for drilling.

Water pump flow with drill string attached: 3.3 L/min.

Drill not able to turn in high-speed mode (test before drilling). Not a good idea to switch from low to high -> for some reason the shaft locked up at max. pressure (drill shaft retracted all the way). Able to unlock by reversing and forwarding (bumped) hyd. motor direction several times. On later dives, there is an indication that the speed-mode switch in the motor itself might stick half way given a certain condition state.

Bio material quite thick at hole site, very difficult to see how far hole was actually drilled, but more importantly, hard to find hole after drilling to place instruments.

NOTE: remember to swipe away biology with manipulator before drilling.

After drilling: hole seems shallow (~3-4 inches) since pilot was not able to stick probe in as desired (8-10 inches) even though ruler on drill sled indicated adequate drill depth. Core sample indicates 4-6 inches of material, which likely corresponds to 8-10 inches of hole depth in this type of material (see table in summary, which shows that core sample length is not indicative of actual drilled depth).

Next hole: Roane Tower near the top-

Hole Description: Upper hole, Roane Tower, Mothra site - Juan de Fuca

Depth of hole: approx. 18-20 inches reaming of existing hole (plugged prior)

Vehicle: Jason II onboard Thompson

Bit Number: #4 = reaming bit = #L62880

File: dive165_Roane_Tower.txt

Hole description: reaming out existing hole. Lining up ROV prior to drilling too difficult. Next plan: bit extended 4-6 inches beyond cutter face prior to "stabbing" existing hole, which

once contained a titanium plug (pipe). Paul Tucker recommended reaming the hole in one forward motion considering the softness of the material. This is against the recommendation of Dale Graves who advised a “pecking” method to remove tailing material which accumulates behind the bit during reaming ops. After further consideration (after drilling leg), the theory extends more to the wandering nature of the bit versus tailing buildup.

Note: log file started 10-15 minutes after drilling commenced (~2 inches of drilling depth after making contact with tower).

Flow rate nominally at 2.4 L/min. Drill shaft speed (at loading) = 100 rpm (at no load = ~115 rpm).

NOTE: something amiss with the max shaft speed at low-speed mode. Should be able to obtain 200-400 rpm. Check hydraulics on ROV side.

Hole reamed (>18”), but having issues removing bit. Bit rotation stops once in awhile on retraction until at one point it was stalled with all options exhausted. Finally, action of retracting shaft resulted in decoupling hyd. motor from drill shaft. Pilot was able to pull out drill shaft/string/bit after 3 tries using reverse ramming scenario. The last attempt was successful in part by adjusting ROV heading to improve drill string/hole alignment.

3.5. September 6, 2005

Analog module in controller not functioning properly after WOB pressure sensor failure, which literally blew apart at depth. Failure difficult to explain. Sensor membranes on either side intact -> hydraulic fluid contained and seawater prevented from entering hydraulics. Installed dummy plug in place of sensor and capped off hydraulic ends. Replaced analog module in DGH stack with spare. Calibration error: Actual battery voltage delta = 15.25 (GUI) – 11.95 (actual) = 3.3 V.

NOTE: New procedure - measure battery voltage with multimeter before launch of vehicle. Don't rely on GUI.

New reamer bit installed (#L74440) after removing core samples (~ 4-6 inches; ~ 25 small and large pieces). Keep in mind this is after using the reamer twice on the same dive (poor man's hole and reaming existing hole); although, the characteristics of the sample suggest it's from the first hole, esp. since the second hole was pre-existing.

Dive #166. Launch time 6:30 AM PST (13:34 UDT). On bottom at 8:15 AM PST.

Drill string basket location	Coring bit #
1	90024
2	90028
3	90038

Flow meter at 300 meters (no drill string) = 6.45 L/min.

After being on the bottom for several hours, it appears differential pressure sensor has become inoperative. Paul McGill has been checking it. It pegged out at 100,000 (similar to WOB sensor) soon after reaching bottom, but then went into an intermittent working state. Battery gauge was working correctly until 11:14 AM PST (~3 hours on bottom). It appears the differential sensor has also taken out the DGH analog module again.

NOTE: hydraulic motor RPM significantly higher than yesterday. Turns out that the pilots were only applying set point 1, which is only a small percentage of available output from the system. Set point 2 provides max flow output.

IMPORTANT: Ask for full flow, which is a must for the drill sled hydraulic motor, esp. considering the minimum displacement spec (12 L/min).

NOTE: Remember to bring hole markers or homer probes for drilled holes; typically the instrument to be installed is on the elevator to be retrieved after drilling.

Made addition to drill sled: installed brass rod to mark ruler for “enhanced” drill depth precision. Coring bit just protrudes from cutter face at a mark of 24 inches on the ruler. Small hose clamp is flush with motor assembly main plate indicating zero spring compression.

NOTE: Replace the wooden ruler with a well marked and permanent metal or plastic ruler.

Drilling continued- Note: this is a coring bit; therefore, only use advance direction since any retraction will break core sample.

Hole description: Hulk site, south of Hulk Tower

Depth: 2201 meters

Start time: 2:45 PM PST

File: dive166_Hulk_1.txt

Bit#: Coring bit 90024

Start depth of hole marker: 15 inches (contact made)

Pump flow: 1.2 L/min before and during drilling (reduced flow likely due to increased flow restriction difference between reamer and coring strings).

Ruler mark (in.)	Actual hole depth (in.)	Time (PM PST)
11	4	2:50
9	6	3:01
7	8	3:07
5	10	3:10
0	15	3:13
-3	18	3:20

Nominal hyd. drilling speed: 269 rpm (in the green on GUI).

Note: Camera on hydraulic motor mount repositioned perpendicular to drill motor travel. This also allows visual of mechanical stop on the advance/retraction ram.

NOTE: ROV in stable location, sitting on bottom with both points (on drill sled) engaged.

Note: on retraction, check out right side of hydraulic manifold to inspect diff. pressure sensor for damage -> sensor appears intact.

Pump flow up to 2.1 L/min at 3:07 PM.

At 9" (actual hole depth), punched into a void or mush. Around 12 to 13", hit more solid material again. ~2-3" void/mush.

Stopped drilling at 3:20 PM. Delta drilling time = 40 min. Depth of hole = 18-20".

Procedure for removal (Paul Tucker's input): slowly stop bit rotation, slightly retract string to allow chinese finger in cutter bit to grab sample and break it off, bring speed up on bit (slow = 5%), and retract. ALWAYS monitor for binding of bit in hole. Keep water pump flow at maximum.

Note: during retraction, water pump flow went down to zero and remained there even after bit change to reamer string. Stopped and restarted pump -> o.k. at 2.8 L/min.

Reamer action on cored hole- speed = 230 rpm

Ruler mark (in.)	Actual hole depth (in.)	Time (PM PST)
15	0	3:47
13	2	3:48 flow = 3.2 L/min
11	4	3:49
9	6	3:53
7	8	3:55 flow = 4 L/min
5	10	3:56 void encountered
3	12	3:58
-3	18	4:00

Delta time for reaming ops: 14 minutes -> indicates soft material and/or large percentage of voids.

Retraction speed reduced to 170 rpm. Water pump flow = 2.4 L/min during entire retraction.

Note: reamer was not "pecked" (typical procedure) as per Dale's suggestion; the group's decision -> straight in and then out. Since we had the drill shaft decouple from the hydraulic motor on the last dive, we decided on this procedure to ensure we have a hole to place an instrument (lower risk) even if we lost further usage of the drill sled. Everything went per textbook on this one. No issues with binding and such. This indicates the necessity of the ROV being in a stable, determined position during the drilling ops. This is something Dale confirmed on the phone last night. Much of their time 2 years ago was spent searching for an adequate site. Any heading change (esp. in soft material) during the reaming action is detrimental to binding the reamer in the hole during retraction. More on this in the summary.

Note: try uncoupling drill string during retraction before making contact with "potato chip" on drill string with basket coupling/decoupling disk to prevent binding/mashing of plastic "potato chip" -> successful. This requires a lower hydraulic pressure setting or flow set point on the ROV side.

Flow after decoupling reamer: 5.6 L/min.

Note: used only moderate spring compression pressure (WOB) during drilling (~1-2 inches of compression). Also, it appears difficult to compress spring fully at either end of the ram stroke. Is this an issue? Likely it has to do with the ROV manifold pressure only at 1200 psi and 1750 rpm (load condition while drilling).

Drilling continued – second hole on Hulk structure

Hole description: hole for poor man's incubator, just to the north of the first hole

File: dive166_Hulk_2.txt

NOTE: ROV hovering in front of structure with both front points not engaged; cutter face directly on drilling surface. This is likely to present a binding situation on removal of the reamer. Asked pilot to clean drilling location prior to drilling.

Asked Paul McGill to assist with taking notes due to the rapid advancement of the drill string.

- Hole started at 23 in. (ruler mark; drilling "smoke" evident). ROV is positioned on the lip of an edge. No compression on spring. 01:43 UDT
- At 16 in. : still no evident spring compression. 01:45 UDT
- At 11 in. : still no evident spring compression. Material very soft or full of voids. 01:46 UDT
- At 7.5 in. : finally seeing spring compression. 01:48 UDT
- Not nearly as much tailing/drilling "smoke" coming out of the hole as seen on previous drilling ops.
- At 5 in. : 01:52 UDT
- Stopped at 4 in. 01:53 UDT. Delta drilled depth = ~19 in. Delta time: 10min
- Coring bit retracted and decoupled without problems. 02:02 UDT
- Reamer bit coupled and advancing. 02:05 UDT
- Shaft rpm = 250
- Tailing smoke visible at 22 in. 02:09 UDT
- At 12 in. : 02:13 UDT
- At 6 in. : finally observing spring compression. 02:17 UDT
- At 2 in. : Reaming stopped. 02:19 UDT. Delta reamed hole depth = 21"
- Retracting drill string with slowness and caution. Rotation of bit stopped at 16.5 in. Can't restart rotation. Obviously bound up in hole. 02:24 UDT
- Bit will advance, but not retract. Likely decoupled from motor spline coupler. Yes, it happened again.
- Backing up ROV to pull bit out of hole. Very easy this time around. 02:28 UDT.
- Pushing drill string back into drill sled by pushing against tower surface. Not very successful. 02:32 UDT
- Inserting incubator. Went all the way in. 02:37 UDT
- Pulling reamer bit back into drill sled with Kraft manip. by grabbing it just aft of the cutter assembly on the front. Pulled in as far as possible (hard stop); probably not a good idea. Successful. 02:39 UDT

NOTE: It's best to pull the decoupled drill string back into the drill sled until the bit is still visible past the cutter face. Any further and the risk of decoupling the drill shaft from the drill string can occur, which may result in the drill shaft residing on the seafloor.

3.6. September 7, 2005

Battery (for cutter charge detonation) voltage = 12.05V.

Test of reamer #4 coupling failed on deck.

Cause: Brass retaining sleeve jammed inside; thus allowing ball bearings to fall out (2 out of 4; one was evident at the bottom of the coupler, which caused the jam). Likely this occurred on the last dive when the manip. was used to pull the decoupled drill shaft/string back into the drill sled. Better to push or pull defunct assembly just past cutter face (protruding and visible). That is, do not grab drill string in basket area and force it aft such that it clashes with the drill motor.

Improvement to motor/shaft spline coupler: since only one clamp screw is employed on the motor side (rolled pin on shaft side), 2 more clamp screws were added (the _-28 separation screw converted to clamp screw and a _-20 near the edge). Also, the hexagonal stop on the inside was ground down for a loose fit to allow more tolerance. In general, the coupler is way too stout for the screws to adequately clamp onto the motor spline. Marine grease added to coupler spline as was evident prior to disassembly. This might be a mistake since we desire more friction in this area. Later it was discovered that Paul Tucker added epoxy to the connection; likely making the situation even worse. On the last dive we cleaned the junction thoroughly and also applied epoxy.

NOTE: Motor spline clamp needs to be redesigned along with the coupler on the drill string end. Oh what the heck, just redesign the entire motor drill shaft from end to end.

Removed differential pressure sensor (green corrosion spots from electrolysis visible on housing). Seawater intrusion likely even though housing appears intact. Dummied off cable end with female connector from WOB sensor, with wire end waterproofed with rubber sealing tape (couldn't find the proper dummy in the tool van). Supply voltage on connector reads 10.9V, but GUI indicates DGH module is kaput/damaged/corrupted. Note: when sensor cable was removed, seawater literally poured out of connector. Need to take apart sensor.

Front-end coupler on motor shaft loose due to stressing the 4 solid pins that hold in place. Paul tucker tried to remove pins, but this proved unsuccessful given the time required. Inserted 3/8"L x 1/4" dia. rolled pin into the one pin location, which was deep enough to accept something. Coupler appears quite rigid. Time will tell.

Drilling continued –

Hole description: Roane Tower, south/SE side at base, incubator hole (> 18" depth)

Depth: 2276 meters, 4.1 meters off the bottom.

Coring Bit #1 employed: 90024

File: dive167_raw

Time start: 18:34 UDT

- Start at 21" (mark on ruler), flow = 3.6 L/min, RPM = 208
- At 18": ROV heading = 3.6 deg., pitch = -13 deg. (crossbow reading). 18:40 UDT
- At 17": Prominent drilling resistance encountered.
- At 16": flow = 3.4 L/min. 18:49 UDT
- Broke through resistance at 16 to 15.5 inches.
- ROV hydraulics: 1500 psi, 1500 rpm, set point 2 (max flow)
- At 14.5": ROV movement, heading = 1.1 deg., pitch = -12.5 deg., drill motor bouncing around (significant chatter). Lots of tailing "smoke". Likely the bit has hit a soft mixture of rock with a "protruding" hard section to one side.
- At 13": heading = 0.6, pitch = -12.5. 19:03 UDT
- At 12": heading = 0.5, pitch = -12.3, flow = 2.9 L/min. 19:08 UDT
- At 11": h = 0.5, p = -12.4, f = 2.9. 19:13 UDT
- At 10": h = 0.4, p = -12.6 (crossbow reading, Octans shows -13.6 deg.), f = 2.7. 19:16 UDT
- At 8": h = 0.5, p = -14.2, f = 2.5. 19:22 UDT
- Paul Tucker takes over; Robert goes to lunch; soft material hit soon after. Full extension of drill string at ~19:40 UDT. Ruler mark not recorded. heading = 3.1, pitch = -14, flow = 2.1. Pulling out drill string, some binding evident. Continuing ever so slowly.
- At 17": 19:47 UDT
- At 21": 19:49 UDT. Clear from hole.
- GUI RPM meter not reading anything. Happened earlier when bit stalled/bound up in hole (~15" mark on ruler). This may indicate that the motor spline has pulled out partially from the coupler, which contains the magnet used for reading rotational speed.
- Reaming action: heading = 2.9 deg., pitch = -13.2 (Octans reading).
- After decoupling coring bit, flow = 5.4 L/min
- With reamer coupled, flow = 3.3 L/min
- Hole start: 22" (ruler mark). 20:05 UDT
- ROV hydraulic stats: 1500 psi, 1750 rpm, set point 2.
- Try full retraction (peck) after drilling 6 inches. This was negated later by group consensus to reduce risk of decoupling reamer and having to recover vehicle.
- At 18": h = 1.9 deg. (note: went down to 359 at 17"), p = 13.5, f = 3.6 L/min. 20:15 UDT
- At 16 3/4 ": RPM meter came back to life indicating motor coupler pushed back onto motor spline. RPM = 299. Modification to coupler spline by adding additional clamping screws not working, esp. with marine grease in combination with epoxy. 20:21 UDT
- Decision to continue reaming without retracting to lower risk of decoupling from motor. All would be lost. Game over.
- At 16": h = 1.8, p = -13.6, rpm = 306. 20:26 UDT
- At 14": h = 1.6, p = -13.5, rpm = 302, flow = 3.4. 20:29 UDT
- At 12": h = 1.5, p = -13.7, rpm = 297, flow = 3.4. 20:33 UDT
- At 10": h = 1.5, p = -13.7. 20:36 UDT
- At 8": h = 1.7, p = -13.8. 20:39 UDT
- At 6": h = 1.6, p = -13.9, f = 3.3. 20:43 UDT
- At 4": h = 1.8, p = -14, rpm = 266, f = 3.5. Soft material encountered, drill shaft chattering noticeably. Smooths out at 3", but then chatters again on advancement. 20:48 UDT

- At 2": h = 1.8, p = -14.2, f = 3.5. 20:53 UDT
- At 0": h = 2.4, p = -14.8, f = 3.8. Pulling out very slowly with rpm = 270. Serious tailing smoke. 20:58 UDT
- At 1": h = 2.4 deg.
- At 3": h = 3.0, p = -14.4, rpm = 270, f = 3.4. 21:02 UDT
- At 6": h = 3.3, p = -14.7, rpm = 265, f = 3.7. Bit slowing down on occasion indicating stalling condition. 21:12 UDT
- At 9": Stalled in hole again. Decoupled from motor again. Are we happy? Not. At least hole is ready for instrument. After temp measurement, it appears hole is too "cold" to be of any use. Time to recover Jason for a quick turn around.

Dive #168 after turning around Jason for last hole to be drilled

Fast turn around for last hole to be re-drilled since last hole was too cold for science. Would have been nice to have known this prior to using reamer. Motor/shaft spline cleaned thoroughly with alcohol, dried, and 5 minute epoxy applied liberally to mating parts.

Going down pre-coupled with coring bit to save time and lower risk of coupling action failing at depth.

Front-end coupler on motor shaft loose again.

Hydraulic flow was modified on drill sled manifold for the advance/retract cylinder to increase travel speed, which appeared painfully slow during prior drilling ops at depth. This is done by adjusting the SS needle valve located on the front of the manifold and the brass set screws on the manifold on the manifold (A & B). **Check manual to verify the action of the brass screws and/or talk to Dale Graves about it.**

NOTE: To save time, it was suggested to science to take a temperature measurement after coring, and before the risky reaming operation to ensure venting seawater temperature is adequate.

Hole description: East side of Giraffe structure for incubator (>18" reamed)

Depth: 2266 meters

Coring bit #2: 90028

File: dive168_raw.txt

Start time: 5:37 UDT

- At 19" (ruler mark): contact with rock face. heading = 329 deg., pitch = -12.3 deg., water flow = 3.1 L/min. 5:37 UDT
- At 17": h = 329, p = -12.5, f = 3.5. 5:42 UDT
- At 15": h = 329, p = -12.5, f = 3.1, rpm = 270. 5:52 UDT
- At 13": broke through into void or very soft material. 5:54 UDT
- At 10": back into harder material, tailing "smoke" disappeared after 13" mark, perhaps diverted up void/vent? h = 329, p = -12.6, f = -3.2.
- At 8": 6:00 UDT
- At 6": h and p solidly stable. f = 3.5, rpm = 275. 6:02 UDT
- Tailing smoke appeared again after passing 6" mark.
- At 4": hit hard material (very hard). 6:06 UDT

- Bit has not significantly moved forward. $h = 329$, $p = -13$, $f = 3.65$, $\text{rpm} = 263$. 6:21 UDT
- Broke through hard layer and tailing smoke resumed. 6:22 UDT
- At 2": 6:24 UDT
- At 0": 6:26 UDT
- At -2": 6:27 UDT
- Retraction went well. Slowed rpm down to 150-175. Cautiously watching for bit binding in hole.
- Reaming action:
- At 19": $h = 329$, $p = -12.4$, $f = 3.6$, $\text{rpm} = 280$. 6:36 UDT
- At 17": nice volume of smoke tailings visible. 6:38 UDT
- At 15": 6:39 UDT
- At 10": 6:41 UDT
- At 8": $h = 329$, $p = -12.7$, $f = 3.6$, $\text{rpm} = 279$. 6:43 UDT
- At 6": 6:46 UDT
- At 4": No hard material encountered as before. Zero spring compression.
- Retracting at 6:49 UDT.
- Finished at 6:53 UDT. Went smoothly.
- Total hole depth reamed ~21".

Note: On this last dive, the vehicle was recovered in the late morning while I was sleeping – off-watch. I left instructions on how to disconnect the explosive cutter battery connector from the housing and install the shorting plug on the detonator cable. But such instructions are useless when it's dark and people are exhausted from the very chaotic schedule.

NOTE: Although the controller can was adequately labeled and the shorting plug color matched the cable connector, they were overlooked, and the end result was disconnecting the wrong cable (flow meter sensor), and shorting out the water pump controller cable. Must make this more foolproof!

Repair: One of the Paraflex hoses burst while out in the sun (disconnected from Jason). See suggestions for improvements.

4. Example Photographs (video framegrabs) of ROV Drilling During Cruise TN183-184 Juan de Fuca Ridge

4.1. Photos from Incubator insert #1, top of Roane tower, reaming existing hole

Frame grab #471: existing hole before reaming

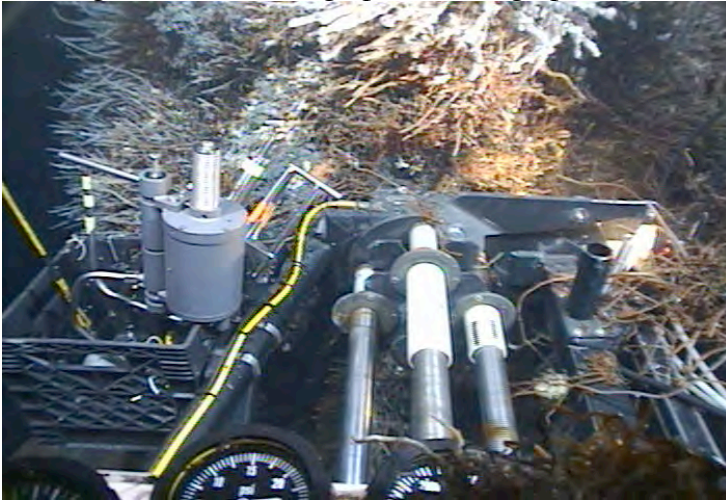


Frame grab #543: close-up shot of reamed drill hole, gas-tight sample being taken



4.2. Incubator Insert #3: Hulk formation

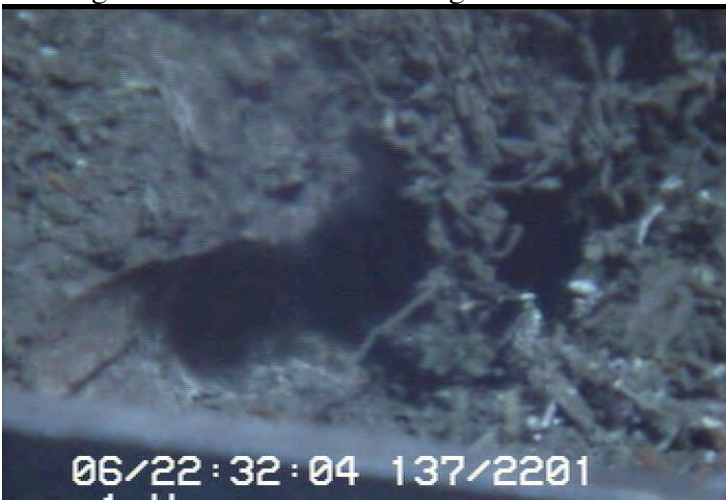
Frame grab #1285: setting up for drilling operation



Frame grab #1308: coring operation (prior to reaming)



Frame grab #1312: hole after coring



Frame grab #1319: reaming operation, beginning of cut



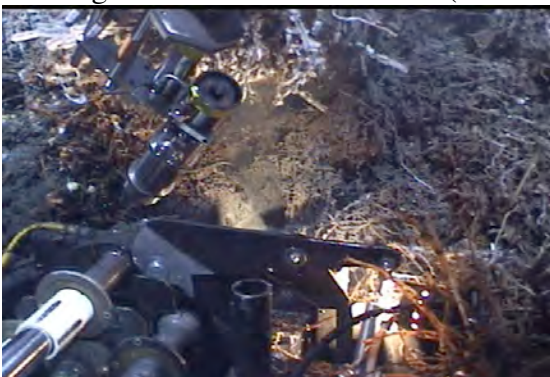
Frame grab #1324: reaming continued, ~3 inch depth of cut



Frame grab #1327: reaming completed; close-up of drill hole



Frame grab #1338: same as above (far field view); gas-tight sample in progress.



5. Drill Core Photographs

Dive# J166

J166_090605_core2218 - drill core from insert#3 deployment into Hulk diffuse vent



J166_090705_core0202 - drill core from poor man's#2 deployment into another Hulk diffuse vent adjacent to insert#3 site.



Dive# J167

J167_070905_core_1935 - drill core from poor man's#1 deployment into Roane base.



Dive# J168

J168_090805_core_0631 - drill core from insert#2 deployment into Giraffe.



6. Suggestions for Improving the ROV Drill System

The operational experience with the ROV drill system during this cruise provided an opportunity to reevaluate the operational status of various components of the system and to make recommendations on how to incrementally improve it for subsequent field programs. The listing below is divided into items that will be done within the scope of the current budget and planning for the drill system, and other items that would require more effort and funds to implement. We plan to discuss this with DESSC and NSF program managers, as well as members of the oceanographic community who are interested in future use of the drill system for their research.

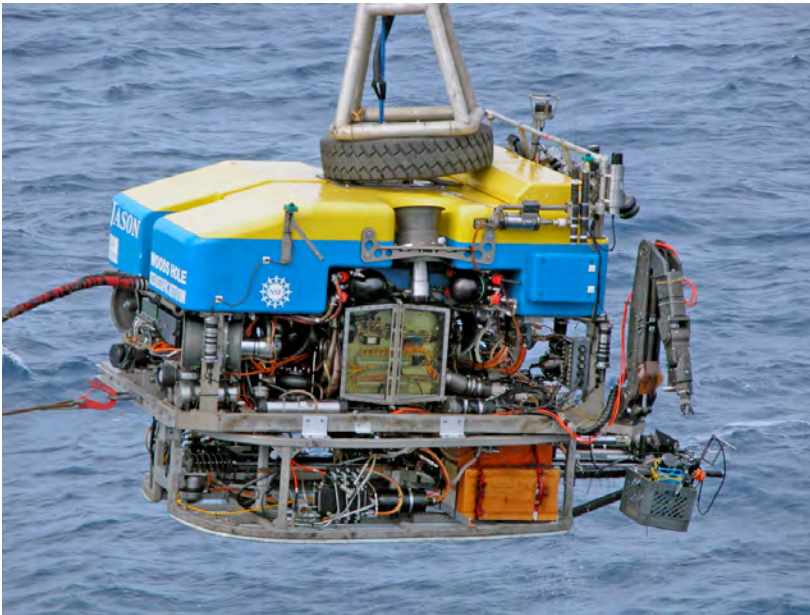
6.1 Short-Term Action Items and Improvements

1. Flush hydraulic system for storage.
2. Order extra dummy plugs and cables as required.
3. Replace pressure sensors and DGH analog modules - both sensors failed early in the drilling program (discuss with MBARI regarding them having spares and providing replacement sensors and DGH modules as part of the purchase).
4. Repair drill shaft, repair coupler sleeve – think about improvements to drill shaft design.
5. Install a temperature sensor on the front of explosive cutter.
6. Install protective cross bars on bottom of frame for hydraulic manifold.
7. Install a full retraction indicator/sensor to safeguard rotation of drill string basket.
8. Fix Blk/Red wire connections (reversed) on bulkhead connector on water pump housing.
9. Fix Paraflex hydraulic hose; it ruptured on deck while exposed to the sun.
10. Improve GUI interface: clarify how controls are differentiated from status indicators and for logging; log event with description field at a button push. Also, improve logging process/functions on the GUI.
11. Since reversal of the drilling motor may cause any one of several connections to unscrew, implement protocol for warning the operator before applying this mode, and only offer it at a reduced RPM percentage and bumping-only permitted.
12. Separate analog module for measuring cutter battery voltage (isolated from other sensors that might fail and hence, bring down the corresponding DGH module).
13. Identify safer location for Jason2 Doppler sensor when using drill system sled.
14. Improve method to measure hole depth drilled. Replace wooden ruler.
15. Redesign the process/path to disarm the explosive cutter (disconnecting battery and shorting out detonator cable), even when people are unfamiliar with the system and/or tired while in darkness.
16. Investigate use of subsea lasers for ‘bore-sighting’ alignment to holes.

6.2. Long-Term Improvements

1. Servo motor to replace advance/retract ram for accurate weight-on-bit reading, or add proportional valve to advance/retract ram.
2. Hydraulic drawer or platforms for placing science instruments (instead of having to return to elevator).
3. Design substitute release for explosive cutter as a fail-safe mechanism.
4. Redesign drill shaft coming off the hydraulic motor.
5. Purchase 2nd LED camera to monitor drill functions (1 was purchase jointly with NDSF for the Kelley cruise)
6. Acquire 5 additional cubic feet of syntactic foam. (3- 1 cu.ft. blocks were acquired out of recycled foam from other WHOI equipment, other foam was provided by UW for Kelley cruise). Investigate separate foam pack under front portion of drill system to correct impact to vehicle pitch when drill system is on Jason2.
7. Review core orientation mechanisms.
8. Review feasibility of back-cutting reamer bits.
9. Improve water pump assembly used for flushing drilling tailings – explore options for increasing flow rate.

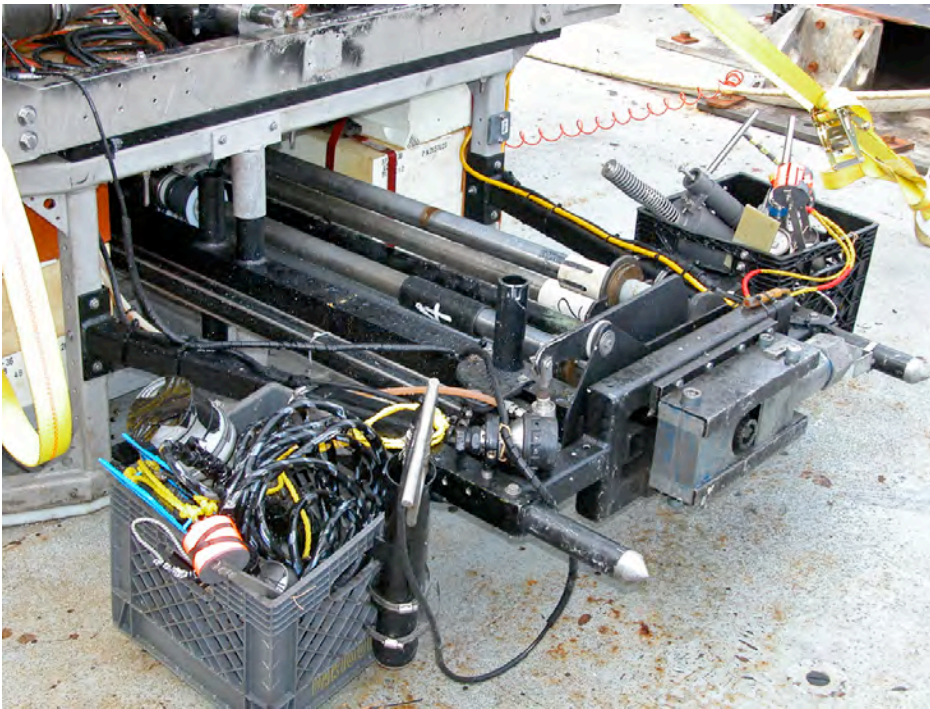
7. ROV Drill Operations Photographs



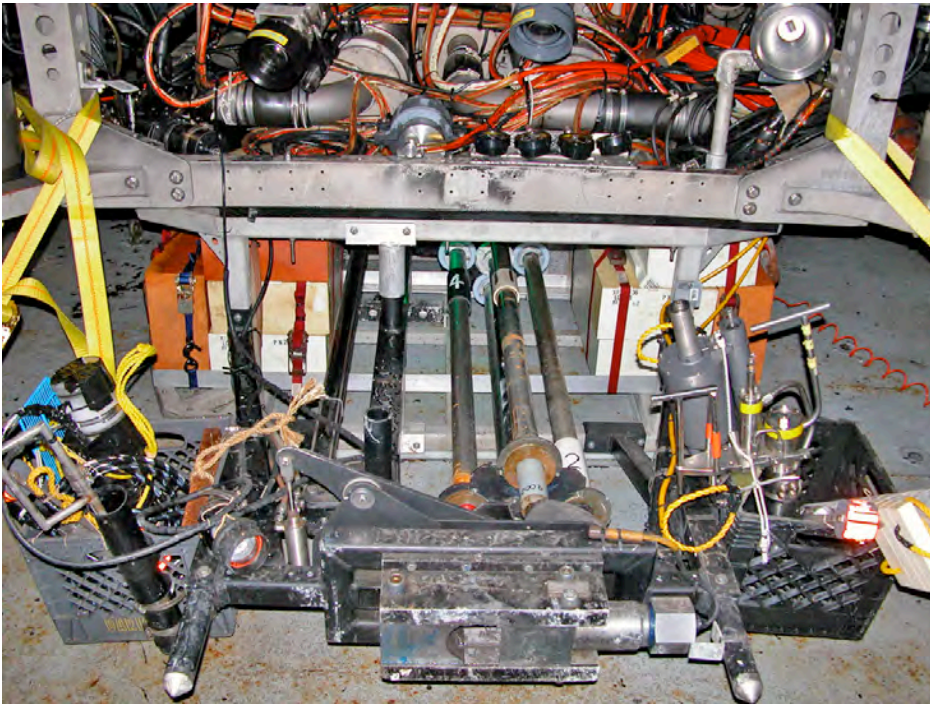
Jason2 ROV with drill system mounted. Orange blocks strapped to the forward part of the Drill System are syntactic foam.



Front of Jason2 ROV showing drill system barrels and 'points' used to anchor the ROV to the seafloor outcrop/structure during drilling. Baskets on either side are holding instruments to be deployed in drilled holes and fluid samplers.



Close up of ROV Drill System mounted on Jason2. Box structure on forward end of the drill is the explosive cutter assembly. Note reamer bit is visible just inside cutter opening.



View looking down the ROV Drill System coring barrels. White and orange blocks are syntactic foam used to help reduce the in-water weight of the system.