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Simple Cabled Instrument for Measuring Parameters In Situ (SCIMPI) and Hole 858G CORK replacement

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Abstract

Integrated Ocean Drilling Program Expedition 341S was an engineering expedition dedicated to two separate projects. One was the first deployment of the Simple Cabled Instrument for Measuring Parameters In Situ (SCIMPI) on the Cascadia margin. The second was replacement of the CORK in Hole 858G for formation pressure monitoring in the Middle Valley axial rift of the Juan de Fuca Ridge. Both installations were targeted to be incorporated into the NEPTUNE observatory network.

SCIMPI is a new observatory instrument designed to study dynamic processes in the subseabed based on a simple and low-cost approach. SCIMPI was successfully installed in Hole U1416A. The final tool string consisted of nine modules, with three of these including pressure sensors (modules 1, 5, and 9, at 8, 117, and 234 meters below seafloor, respectively). The second operation with SCIMPI was the deployment of a single module (with a seafloor connector and command module, dubbed SHRIMPI) in Hole U1416B.

The new CORK that was to be installed in Hole 858G was constructed with a simplified seal system designed to survive the overpressures and high temperatures at this location. The new CORK was not installed because the old CORK could not be removed from Hole 858G.

What is SCIMPI?

The Simple Cabled Instrument for Measuring Parameters In Situ (SCIMPI) is a new observatory instrument designed to study dynamic processes in sedimented subseabed regions (Moran et al., 2006). SCIMPI was developed to provide, when appropriate, an alternative to CORK subseafloor observatories that can be more complex, costly, and time consuming to install. SCIMPI makes time series measurements of subseafloor temperature, pressure, and electrical resistivity at several depths that can be tailored for site-specific scientific objectives. SCIMPI's modular design enables custom configuration based on the study goals and the subseafloor characteristics. Battery life can be as long as 4 y, after which batteries can be replaced after recovering a seafloor command module where the data are recorded. The system can also be connected by way of a submarine cable to a land network that can provide a power source and real-time data transmission.

A second installation using a single-module SCIMPI was also prepared for deployment to demonstrate the capability to install an easily deployable, shallowly buried observatory after drilling Integrated Ocean Drilling Program (IODP) sediment holes. This test installation was installed using a "free-fall" installation approach. This single-module SCIMPI was dubbed SHRIMPI for "Short Instrument Modular Probe Installation."

SCIMPI installation site

Expedition 341S is the first full-scale test of the SCIMPI prototype. Nine modules were configured and connected to each other via SCIMPI cable for deployment at Site U1416 (proposed Site CAS05-CORK) (Figs. **F1, F2, F3, F4;** Table **T1**), a site of known gas hydrate occurrence (Riedel, Collett, Malone, and the Expedition 311 Scientists, 2006; Riedel et al., 2006).

The upper 140 meters below seafloor (mbsf) at Site U1416 consists of slope sediments that overlie accreted terrain sediments. The boundary between the slope and accreted sediments, based on seismic stratigraphy, occurs at ~140 mbsf. The bottom-simulating reflector (BSR), interpreted as the base of the gas hydrate stability field, is located at ~225 mbsf. SCIMPI was configured so that modules measure parameters in the slope and accreted sediment as well as above and below the BSR.

The depth of each module (Figs. **F4, F5**) was selected based on the known and estimated physical properties and pore water chemistry from previously drilled Site U1328 (Lado Insua et al., 2012). The command module is at the top of SCIMPI and is used in autonomous SCIMPI mode to control data acquisition and store data. In this first deployment of SCIMPI, the estimated lifetime of the batteries is ~2 y. As Site U1416 is also located within 180 m of an Ocean Networks Canada NEPTUNE observatory junction box, the proposed plan is to connect SCIMPI to the observatory before the end of life for the modules' batteries.

SCIMPI installation plan

SCIMPI is designed so that after installation in a freshly drilled borehole, the borehole walls collapse around the tool, thus leaving the modules with a firm connection to the subseafloor formation. One of the challenges of installation is to drill a hole that remains stable enough for the installation phase when borehole circulation and drill string rotation cannot occur but then collapses after the drill string is pulled out of the hole. Premature collapse of the borehole could cause the drill string to be stuck in the formation.

The first SCIMPI installation procedures were tailored for Hole U1416A and included the following:

1. Complete slow drilling of the borehole to 260 mbsf;
2. With the drill string ~10 m off the bottom of the hole, cease rotation and circulation for ~3 h prior to installing SCIMPI to ensure that the borehole will remain stable for a long enough time period for installation;
3. Lower SCIMPI on the Lamont-Doherty Earth Observatory (LDEO) Borehole Research Group (BRG) wireline with the Multi-Function Telemetry Module (MFTM) and the Electronic RS (ERS) Overshot to the bottom of the hole;
4. Check that SCIMPI is on and collecting data;
5. Release SCIMPI using the wireline release system;
6. Pull the wireline up to the ship:
7. Trip the pipe out of the hole at a constant rate while monitoring the pipe with the vibration-isolated television (VIT) camera; and
8. Use the camera system near the seafloor to inspect the installation.

Actual installation in Hole U1416A followed this plan closely (see **"Operations"** for a detailed description of operations). A small diversion from the plan was that the first release approach was unsuccessful and SCIMPI returned to the surface with the wireline. The second wireline release was successful, resulting in the configuration shown in Figure **F4.** As this was the first operational deployment of the SCIMPI using the ERS and MFTM, bench tests were conducted before the expedition as well as on the ship. These tests and the modifications made to these tools are described in **"Appendix A."**

A second hole (U1416B) was drilled ~40 m north of Hole U1416A to determine the baseline physical properties of the sediment and gas hydrates in Hole U1416B. Prior to selecting a location for the second hole, science party discussions included the rationale for drilling a second hole so close to the primary SCIMPI. A hole located close to the SCIMPI hole could contaminate the in situ fluid flow and pressure signals measured with SCIMPI. Alternatively, a closely spaced hole could serve as a baseline for interpreting SCIMPI observations and for hole-closure monitoring. A decision was made to drill a hole as far as possible from SCIMPI within the previously surveyed area as a baseline and for hole-closure monitoring. Hole-closure monitoring will be conducted in collaboration with NEPTUNE during their semiannual operations and maintenance cruises.

Logging of this hole was not completed because of the excess pressure and flow up the drill string that occurred during final logging preparations (see **"Operations"**). Following pressure and flow mitigation, the drill string was pulled from the seafloor. Because Hole U1416B exhibited fluid and gas flow out of the borehole, a scientific flow-monitoring program was put into place. Using the VIT sonar, surveys at the seafloor and 50, 100, and 150 m above the seafloor were conducted. These surveys detected the gas bubble plume from the borehole to a maximum depth of 150 m above the seafloor. However, this is a minimum depth for the rising gas plume, as the VIT sonar is relatively small and limited in range. Typical naturally occurring gas bubbles observed with ship-mounted sonar in the vicinity of Site U1416 prior to drilling were seen to rise as high as 500 m beneath the sea surface, which coincides with the upper limit of the gas hydrate stability field in the ocean. In addition, SHRIMPI was free-fall deployed ~4 m south of Hole U1416B to serve as a longer term observatory after the R/V *JOIDES Resolution* leaves the site. Installed with a command module and buried at ~1 mbsf, SHRIMPI will be recovered later in 2013 by Ocean Networks Canada's NEPTUNE operations cruise.

Direct visual observations of Hole U1416B ~3 weeks following Expedition 341S during an Ocean Networks Canada's NEPTUNE cruise documented that flow out of the hole had completely ceased.

SCIMPI installation results

As part of the deployment procedures, SCIMPI data were transmitted via the wireline logging cable to the ship. Because the ERS did not fully release during the first SCIMPI deployment attempt, data were recovered for both deployments.

Pressure and temperature measurements (Figs. **F6, F7, F8, F9**) show that the SCIMPI modules moved down the drill string smoothly without changing their separation. They also show that the sensors work properly and document SCIMPI's proper emplacement below the seafloor (e.g., temperature increases). Resistivity was not recorded during deployment.

Hole 858G CORK replacement

Background

As part of Expedition 341S, we planned to reinstrument Hole 858G (Table T1) in the sediment-filled Middle Valley axial rift of the northernmost Juan de Fuca Ridge for long-term hydrologic monitoring. This hole and its companion Hole 857D (Fig. F10) were equipped with the first CORK hydrologic observatories in 1991 during Ocean Drilling Program (ODP) Leg 139 (Davis et al., 1992) to determine the thermal and hydrologic state within the buried permeable igneous crust of the valley and the driving forces for fluid flow through the seafloor in the vent field where Hole 858G is situated. For reasons not fully understood at the time, the CORK seals of Hole 858G failed after roughly 1.4 y, after which the formation sensor recorded only hydrostatic (seafloor) pressure (Fig. F11). This CORK and the one in Hole 857D were replaced during a second phase of drilling in the area, ODP Leg 169. The latter remains operational and the 16 y continuous record of seafloor and formation pressure has provided information well beyond the scope originally anticipated for the experiment. Unfortunately, the Hole 858G CORK failed again, this time in roughly 1 y. Inspection of the failed seals and mineral deposits within the original CORK recovered during Leg 169 suggested that the seals had suffered from exposure to high-temperature formation fluids, although this factor alone cannot have been responsible. Natural formation temperatures at this location do not reach the ~270°C temperature of the Middle Valley hydrothermal system until ~80 mbsf. Temperature at the level of the CORK seals situated at ~1 mbsf should have been close to the bottom water temperature. Failure of some component within the CORK body may have caused initial leakage, leading to increased temperatures, chemical imbrittlement, and ultimate failure of the main CORK seals (see discussion in Fouquet, Zierenberg, Miller, et al., 1998).

Despite these problems, the data collected prior to seal failure provided a valuable complement to those from the CORK in Hole 857D. They provided an approximate lower limit on the formation pressure available to drive flow from the igneous crustal hydrothermal reservoir vertically through seafloor vents, as well as an estimate for the differential pressure available to drive flow within the sediment-sealed permeable reservoir (e.g., Davis and Becker, 1994).

Motivation for revitalizing the Hole 858G CORK

A number of factors have accumulated since the time that the monitoring experiments were originally undertaken, leading us to the Expedition 341S reinstallation effort:

1. From a scientific perspective, long-term monitoring experiments at a number of sites in tectonically active settings (Juan de Fuca Ridge axis and flank, Mariana forearc, Costa Rica prism, and Nankai accretionary prism) have revealed that formation fluid pressure variations provide a sensitive proxy for volumetric strain. Transient events related to coseismic, postseismic, and aseismic deformation have been seen at all of these locations, and the observations are leading to new understanding about the episodic nature of deformation, seismic energy efficiency, and regional interseismic strain accumulation. Some of the best examples come from Middle Valley Hole 857D, which has provided an unprecedented look at seismotectonic processes at ridge axes by virtue of its location, the local sensitivity of pressure to strain, and the very long continuous record of pressure (Fig. **F12**). One example contained in this record shows very clearly how formation pressure responds to coseismic elastic strain produced by three earthquakes, postseismic slip, and hydrologic readjustment (Fig. **F13**). Pressure transients like this are numerous throughout the history of recording in Hole 857D. They reflect strain generated by slip on faults within Middle Valley and in the surrounding region, specifically the neighboring West Valley Rift, the Endeavour axial segment to the south, and the Nootka Fault to the northeast. Future events captured in Middle Valley and at other operational CORK sites in the region will provide new insights into the complex mixture of hydrologic and viscoelastic response to fault rupture and allow them to be separated. Data from one hole by itself makes this separation equivocal, so a combination of data from Holes 857D and 858G would be invaluable.
2. From a technical perspective, a number of things fortified the justification for revitalizing this hole. High reliability of CORK instrumentation has been demonstrated through successful long-term operations at many sites. Instruments deployed during Leg 196 (Nankai) have been operating continuously since their deployment in 2001, those in the Middle America subduction zone off Costa Rica since 2002, and the one in Hole 857D deployed during Leg 169 since 1996. Improvements in power consumption, memory capacity, and resolution now permit detection of much more subtle signals, and connections to the NEPTUNE observatory cable infrastructure will open up great opportunities. Much higher

sampling frequency can be achieved, allowing observations to reach into the seismic frequency band, and the observations can be placed in context of co-located seismic and hydrologic records that will be collected at all NEPTUNE nodes with broad-band seismometers and a variety of seafloor monitoring instruments.

3. From a financial perspective, setting up existing holes like Hole 858G for long-term monitoring in a time-efficient and economical way makes good sense, as it takes advantage of existing infrastructure like NEPTUNE, which will minimize the need for costly and time consuming site visits using a ship and submersible or remotely operated vehicle (ROV).

Operations plan/Drilling strategy

A new scheme was proposed in the Ancillary Project Letter (APL) that led to this project through which pressure monitoring can be reestablished and later access can be gained to the interior of an existing borehole. For Hole 858G, the operations plan consisted of two main operational steps:

1. Removing the existing CORK body and 370 m long thermistor string. This was to be done with the existing ODP CORK pulling tool and would require a single pipe trip. A comparable operation was recently carried out in Hole 395A during IODP Expedition 336, with the data logger and thermistor cable removed and sampled for microbiology when the CORK body reached the rig floor. The thermistor string in Hole 858G was also to be made available for microbiological sampling. Even though the CORK in Hole 395A had been in place since 1997, we knew that the recovery efforts at Hole 858G would be more difficult because of the subseafloor environmental setting. Recovery of the original CORK in Hole 858G during Leg 169, 5 y after its installation, was made challenging by the accumulation of hydrothermal mineral deposits within the CORK body and by corrosion of some of the CORK structural components, including those providing a connection to the latch/unlatch mechanism. Given that >16 y had passed since the second CORK was installed, even greater challenges and risks of failure were expected.
2. Installing the new seal stack and instrument. This step was to follow a pipe trip to clean the hole of any hydraulically resistive mineral deposits precipitated inside the 11¾ inch casing from water ascending the hole over the history of leakage. The seal stack (Fig. **F14**) comprised, from bottom up, (a) three joints of drill collars, their combined weight sufficient to overcome the piston force imposed by the formation overpressure on the seals, roughly 2700 lb; (b) multiple cup

> seals to land inside the top of the 11¾ inch casing below the casing hanger; (c) landing webs to support the stack in the reentry cone/casing hanger; and (d) a section of reinforced 7 inch casing that positions the instrument package at a convenient position for submersible operations. The top of the stack mates with one of the standard IODP CORK running tools and includes a removable axial plug for possible future downhole access. Valved plumbing and ports provide for pressure monitoring and fluid sampling. An instrument package, connected to the hydraulic access line via a pressure-balanced connector and a three-way valve, includes a current-generation high-precision pressure recorder capable of resolving pressure to roughly 10 ppb at 1 Hz sampling frequency, along with a wellhead temperature sensor that has a resolution of the order of ~0.1 mK. It is equipped with batteries to run in autonomous low–sampling rate mode (15–60 s sampling interval) for roughly 15 y, to facilitate initial autonomous (pre-NEPTUNE connection) monitoring and backup operations during cable-power downtime. When cable connected, such instruments automatically switch into continuous 1 Hz sampling mode, with time-stamped pressure and temperature data passed to the cable via an RS422 serial port.

Plans to recover the old CORK from Hole 858G were thwarted, despite concerted efforts (see **"Operations"**). Repeated pulling on the release sleeve, increasing to a peak of >150,000 lb, resulted only in the release sleeve breaking not far below the latch dogs. Corrosion or mineralization apparently kept the sleeve from shifting as designed and the latching ring from disengaging. Use of the running tool during a subsequent pipe trip was also unsuccessful; rough weather and poor VIT camera visibility combined with the very small target offered by the modified running tool precluded mating of the running tool with the upper CORK head.

Fortunately, the vigorous recovery operations, which subjected the wellhead to high pulling forces, large side-loading, and heavy impacts by the bottom-hole assembly drill collars, appear to have resulted in no substantial damage to the CORK body, and there were no signs of leakage from any parts of the CORK at the end of recovery operations. Thus, one contingency remains: to deploy the pressure recording instrument on the wellhead platform and connect it to the valved fluid sampling port on the original CORK wellhead body. This may be attempted as early as June 2013. The unused new CORK body will be stored at IODP/Texas A&M University (TAMU; USA) and be available for use in any other hole where single-interval pressure monitoring or fluid sampling is justified. Alterations may be necessary to ensure compatibility in holes with different casing hangers and internal diameters. Fabrication drawings will be archived at IODP, and the deployment procedure is documented in **"Appendix B."**

Operations

Port call and transit to Hole 858G

Expedition 341S officially began when the ship departed Victoria, Canada, at 1800 h on 19 May 2013.

In the days leading up to departure, the SCIMPI and CORK scientists and engineers moved onboard and began assembling and testing the systems. After a short transit to Hole 858G, our first planned operation was to remove the existing CORK and install a new CORK for pressure monitoring in Middle Valley axial rift of the Juan de Fuca Ridge. Our second planned operation was to make the first installation of SCIMPI on the Cascadia margin. Both installations are to be incorporated into the NEPTUNE Canada observatory network. In addition to the science objectives of installing these two observatory systems, 14 educators and 4 instructors participated in a "School of Rock" during Expedition 341S. This program provides hands-on research experiences for earth and ocean science educators. After the 219 nmi transit at an average speed of 10.1 nmi/h, we arrived at Hole 858G at 1630 h on 20 May.

Hole 858G

We planned to recover the existing CORK and install a new CORK observatory in Hole 858G. The last time this CORK was replaced during Leg 169, the operations were challenging, with the upper and lower parts of the CORK head breaking off, the loss of the data logger, and failed seals, which had led to significant mineralization. We expected that pulling out the CORK during Expedition 341S might present similar difficulties.

After arriving on site, we lowered the thrusters and the hydrophones, deployed a seafloor positioning beacon, and switched to dynamic positioning mode at 1703 h.

Before we could start with our first objective, retrieving the existing CORK in Hole 858G, we had to detorque the cable for the new camera system. Therefore, the rest of the evening of 20 May 2013 was spent lowering the camera system to the seafloor.

Scientists, engineers, and the operations team continued planning for operations and preparing the CORK and SCIMPI observatory systems.

Detorquing of the new camera system's fiber-optic cable was completed when the camera was back on board at 0030 h on 21 May. We then lowered the CORK pulling tool with three stands of drill collars to the seafloor, deployed the camera system, and started maneuvering to lower the CORK pulling tool over the existing Hole 858G CORK head.

Positioning and lowering the CORK pulling tool over the CORK head was complicated by poor environmental conditions. This included swells up to ~3.5 m, waves up to ~5 m, and winds up to 30 nmi/h. After 3 h, we landed and secured the CORK pulling tool to the Hole 858G CORK head.

Once the CORK pulling tool landed over the CORK head, we pulled up to verify that it had successfully latched in. We started to pull upward, but the CORK would not unlatch and come out of the hole. We attempted to pull it out 20 times, starting with ~100,000 lb of overpull but eventually reaching more than ~150,000 lb of overpull. On the last attempt, the CORK pulling tool released from the CORK head at ~1220 h on 21 May.

After inspecting the CORK head again, we maneuvered the CORK pulling tool and lowered it back over the CORK head at ~1350 h on 21 May. This time when we pulled upward, we observed only ~5,000 to 10,000 lb of overpull, and then the weight reduced—the drillers thought that perhaps the CORK head was partly engaged but then slipped out of the pulling tool. Several more attempts to engage and pull the CORK never resulted in more than ~10,000 lb of overpull. On at least one attempt after the weight reduced, the CORK pulling tool rotated back and forth—suggesting that the CORK head was seated in the hole well enough to at least inhibit rotation. Because we suspected that either the CORK pulling tool or CORK head might have been damaged, we decided to retrieve the CORK pulling tool to inspect the J-slot that engages the dogs on the CORK head. We started raising it at 1430 h, and it arrived back on deck at 2000 h on 21 May.

We found that part of the CORK head had broken off inside the CORK pulling tool. The lower latch dogs and the sleeve to which they are attached were wedged inside the CORK pulling tool. Pulling upward on these lugs activates the CORK latching mechanism.

At this point, our only option remaining to retrieve the Hole 858G CORK head was to attempt to latch on to the upper set of dogs on the CORK head using the CORK running tool. We expected this to be a challenging operation given the poor sea state and the very small ⅛ inch clearance between the CORK head and the CORK running tool. Before lowering the CORK running tool, we decided to cut off the tapered cone skirt from the CORK pulling tool and attach it to the CORK running tool.

We finished welding the skirt from the CORK pulling tool onto the CORK running tool at 0145 h and started lowering it to the seafloor. At 0730 h, the CORK running tool was at the seafloor, and we made many attempts to latch onto the Hole 858G CORK head throughout the rest of the day.

We were able to land the running tool over the CORK head multiple times, but heaves up to 3.5 m and the tight fit prevented us from being able engage the dogs in the running tool's J-slots. At midnight, we decided to abandon any further attempts to retrieve the Hole 858G CORK and started to retrieve the drill string. If we were successful in retrieving the CORK after this time, we would not have had sufficient time to install the replacement CORK head. The scientists decided it was better to leave the existing CORK in place (with the potential to access the borehole via an existing port) rather than leaving the hole open and venting.

Transit to Site U1416

After abandoning our attempts to recover the existing CORK from Hole 858G, we recovered the drill string and the CORK pulling tool was back on board at 0500 h on 23 May 2013. We recovered the seafloor positioning beacon and at 0642 h started our transit to the location on the Cascadia margin to deploy SCIMPI (Site U1416; proposed Site CAS05-CORK). After a transit of 75 nmi, we arrived at Site U1416 at 1530 h.

Site U1416

Hole U1416A: SCIMPI installation

Our plan at Site U1416 was to drill a hole to 260 mbsf and install the SCIMPI observatory. We assembled a 9.875 inch tricone bit with a mechanical bit release (MBR) and lowered it to the seafloor. Before we started drilling the hole for SCIMPI, we deployed the seafloor positioning beacon 15 m north of Hole U1416A and conducted a 1.5 h camera survey to verify that the seafloor around Site U1416 was clear of the nearby NEPTUNE observatory platforms and cables. We spudded Hole U1416A at 2153 h on

23 May 2013, jetted in to 12 mbsf, recovered the camera system, and began drilling ahead at 2245 h. As of midnight on 23 May, the bit had reached 26 mbsf. On 24 May, we reached the target depth of 260 mbsf.

Drilling conditions were good, with no drag when raising the bit off the bottom of the hole to make pipe connections and no fill. With the bit at the bottom of the hole, we circulated mud to clean the cuttings out of the hole. We raised the bit to 10 m off bottom and stopped rotation and circulation at 0955 h on 24 May. We waited 3 h to determine if the hole would remain stable for the amount of time it would take us to deploy SCIMPI and pull the drill string clear of the seafloor. After 3 h, the drillers started rotating and circulating without any trouble. The lowermost 10 m of the hole had filled in, but it was “soft” fill. The bit was easily lowered to the bottom of the hole, where we circulated mud to clean the fill/cuttings out of the hole and released the bit. This required two runs of the coring line—the first to shift the MBR and the second to shift the sleeve back down. Then we removed the top drive, raised the drill string to remove a joint of pipe, and added a 5 m pup joint of pipe so that we had the desired end of pipe depth and a pipe connection at the rig floor. We were now prepared to deploy SCIMPI.

The first step was to place the sinker bar into the pipe followed by the lowermost part of the SCIMPI string. Using alternating lifts with two sheaves, the rest of the SCIMPI string was sequentially raised up into the derrick using the preattached yale-grips. At the top, the ERS was attached and tested. Although the data connection to the SCIMPI sensor string was working, the release would not activate. After some diagnosis (and switching out both mechanical parts of the ERS), a faulty cable was identified and replaced. With the ERS working, we zeroed out the wireline winch with the ERS at the top of the drill string and then started lowering the entire SCIMPI-ERS assembly at ~1900 h on 24 May. Originally, we intended to lower it at ~900 m/h but slowed this down to ~600 m/h to ensure sufficient time for all parts of SCIMPI to pass smoothly down the pipe without binding.

SCIMPI was lowered without any problems until the sinker bar reached ~30 m above the end of the pipe. At this depth, the wireline weight indicated that it was encountering something that kept it from going further down. To try to clear the obstruction, we started pumping slowly through the circulating head. After circulating for a short time, SCIMPI could be lowered past the previous obstruction and continued until the sinker bar was at the end of the pipe. Although it did not exit the end of the pipe, we decided to activate the ERS to release SCIMPI. As expected, we stopped receiving the

SCIMPI data through the wireline. For the first ~30 m of retrieving the wireline with the ERS on the end, it was not completely clear from the wireline tension that the ERS had released. After a while, the logging winch speed was increased and the ERS brought back to the ship. As the ERS neared the rig floor, it became apparent from the wireline tension that SCIMPI was still attached and had not released. The ERS was hung off at the rig floor at 2300 h (24 May), and we confirmed SCIMPI was still attached. The ERS had actuated with the dogs retracting enough to stop data communications but not enough to release SCIMPI. We confirmed that the ERS was operational by cycling at the rig floor. Just before midnight on 24 May, we started our second attempt to deploy SCIMPI with the ERS; we pumped slowly while lowering SCIMPI. This time, we slacked off more on the wireline (~5 m instead of ~3 m), activated the ERS, and allowed it to run ~5 min after observing the current spike indicating the ERS was fully open. While retrieving the wireline, the release of SCIMPI was confirmed by a loss of weight reflected in the wireline tension. Then we started pulling the pipe out of the hole. We continued pumping with the circulating head while pulling the uppermost 5 m pup joint and first joint of drill pipe, as well as the subsequent stand of pipe. The remaining pipe was pulled out in stands without circulation. The end of the pipe pulled clear of the seafloor at 0445 h on 25 May. As we continued pulling above the seafloor, we observed ~15–20 m of SCIMPI cable and the command module coming out of the end of the pipe and floating in the water column. This appears to be very close to the length planned to be above seafloor. The first operational deployment of SCIMPI was successful.

Hole U1416B: attempted downhole logging

We retrieved the drill string, and the end of the pipe was back on board at 0720 h on 25 May 2013. Because our primary operations for this expedition were completed and significant time remained in the expedition, we decided to drill and wireline log a second hole 40 m north of Hole U1416A to complement the SCIMPI installation. We assembled a 9.875 inch tricone bit with a MBR and lowered it to the seafloor. We spudded Hole U1416B at 1040 h on 25 May. We reached the total depth of 290 mbsf at 2230 h on 25 May. We circulated the hole with mud, released the bit, and started raising the end of the pipe for logging. We set back the top drive with the end of the pipe at 260 mbsf, after which we continued pulling the pipe up the hole.

Initially, normal backflow was observed at the rig floor as the pipe was pulled. However, while pulling one stand, no backflow was observed (the upper part of the drill string was dry), which was a bit unusual. When the next stand was pulled and disconnected, the backflow substantially increased out of the top of the drill pipe at the rig floor. The flow extended up into in the derrick. This required installation of the drill string safety sub and the circulating head. At this time (0045 h), the end of the end of pipe was at ~113 mbsf.

At 0115 h, we initiated circulation at 35 strokes per minute (spm) at 500 psi. After circulating 1 h, the standpipe pressure had been reduced to the background level of the standpipe (essentially zero). At 0215 h, we deployed the camera system to observe the hole and observed flow coming out of the hole at the seafloor. At 0245 h, we pumped 70 bbl of mud (10.5 ppg) and displaced it into the hole. From 0300 to 0500 h, flow out of the hole at the seafloor ceased, but shortly thereafter it resumed. We then circulated the hole with seawater and spotted 50 bbl of 11 ppg mud in the drill string at 0530 h. We did not observe any backpressure or flow up the drill string, which allowed us to remove the safety sub and circulating head. We pulled the end of the pipe out of the seafloor at 0600 h. After offsetting the ship to flush the mud out of the drill string, we resumed our observations of the seafloor at Hole U1416B with the camera system video and sonar. We observed continuous flow out of the hole from 0630 to 1445 h.

Eventually, we decided to drop a marker on the seafloor to unambiguously mark the location of Hole U1416B. We attached a short length of red polypro rope to a 5 m long piece of metal pipe, added some reflective tape, and free-fall deployed it through the drill string with the ship positioned 4 m south of the hole. Five minutes after deployment it exited the end of pipe. The metal pipe penetrated about halfway into the seafloor adjacent to the hole and was easily visible on the camera system data.

Due to conditions at Hole U1416B, we decided to go back to inspect Hole U1416A, in which SCIMPI is installed. After a short dynamic positioning move (40 m to the south), we started observing the seafloor at Hole U1416A. We could clearly see the above seafloor portion of SCIMPI as we had left it 1.5 days before. We did not observe any flow or bubbles emanating from the hole, nor from the seafloor anywhere in the field of view around the hole. In addition, we did not observe any returns from the VIT camera system's sonar. After monitoring Hole U1416A for 1 h with no indication of flow, we returned to Hole U1416B.

We moved the ship 40 m north back to Hole U1416B and resumed our monitoring of the flow from the hole. We decided to deploy SHRIMPI near Hole U1416B. SHRIMPI consisted of a single sensor module with temperature and conductivity sensors at the bottom, 30 m of cable, and a command module. The ship was positioned 4 m south of the hole (the same location where the marker had been previously placed) and SHRIMPI was free-fall deployed though the drill string. We observed it exit the end of the drill string very close to the marker.

We resumed our video and sonar monitoring of the seafloor at Hole U1416B. At 1800 h on 25 May, we also started periodic (2 h) acquisition of sonar images at multiple heights above the seafloor to better analyze the flow out of the hole over time. On the morning of 27 May, our initial review of the camera and sonar data indicated that the rate and volume of flow had substantially decreased. We continued monitoring of Hole U1416B until we departed for Victoria at 1400 h on 28 May. Expedition 341S ended at 0800 h on 29 May with the first line ashore in Victoria, British Columbia (Canada).

Direct visual observations of Hole U1416B ~3 weeks following Expedition 341S during an Ocean Networks Canada's NEPTUNE cruise documented that flow out of the hole had completely ceased.

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Table T1. Operations summary, Expedition 341S.

Hole	Latitude	Longitude	Water depth (mbsl)	Total penetration (mbsf)	Start date (2013)	End date (2013)	Start time (UTC)	End time (UTC)	Time on hole (days)	Operations
858G	48°27.3588′N	128°42.5342′W	2417	0	21 May	23 May	000	1342	2.6	Attempted CORK recovery; unable to pull CORK
U1416A	48°40.1823′N	126°50.8509′W	1261	260	23 May	25 May	2257	1420	1.6	SCIMPI deployment
U1416B	48°40.2032′N	126°50.8495′W	1261	290	25 May	28 May	1420	2000	3.2	Attempted logging hole; SHRIMPI free-fall deployment; monitor flow from hole
			Total:	550.0					7.5	

Figure F1. Map of Cascadia margin study location, previous IODP drill sites (red), and SCIMPI Site U1416 (black).

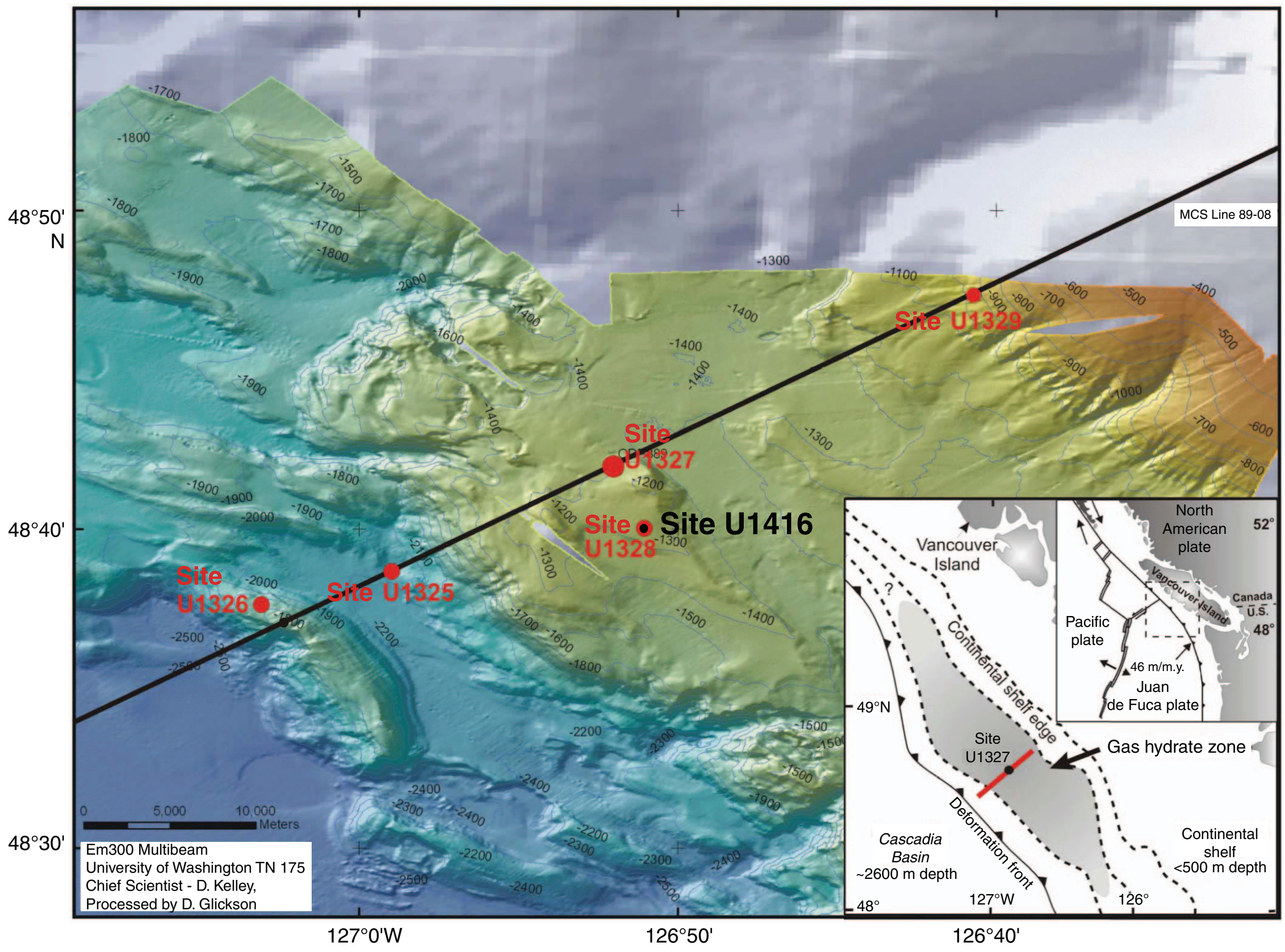


Figure F2. Map showing locations of SCIMPI installation Site U1416, the NEPTUNE cable, previous ODP and IODP drill sites, and seafloor venting.

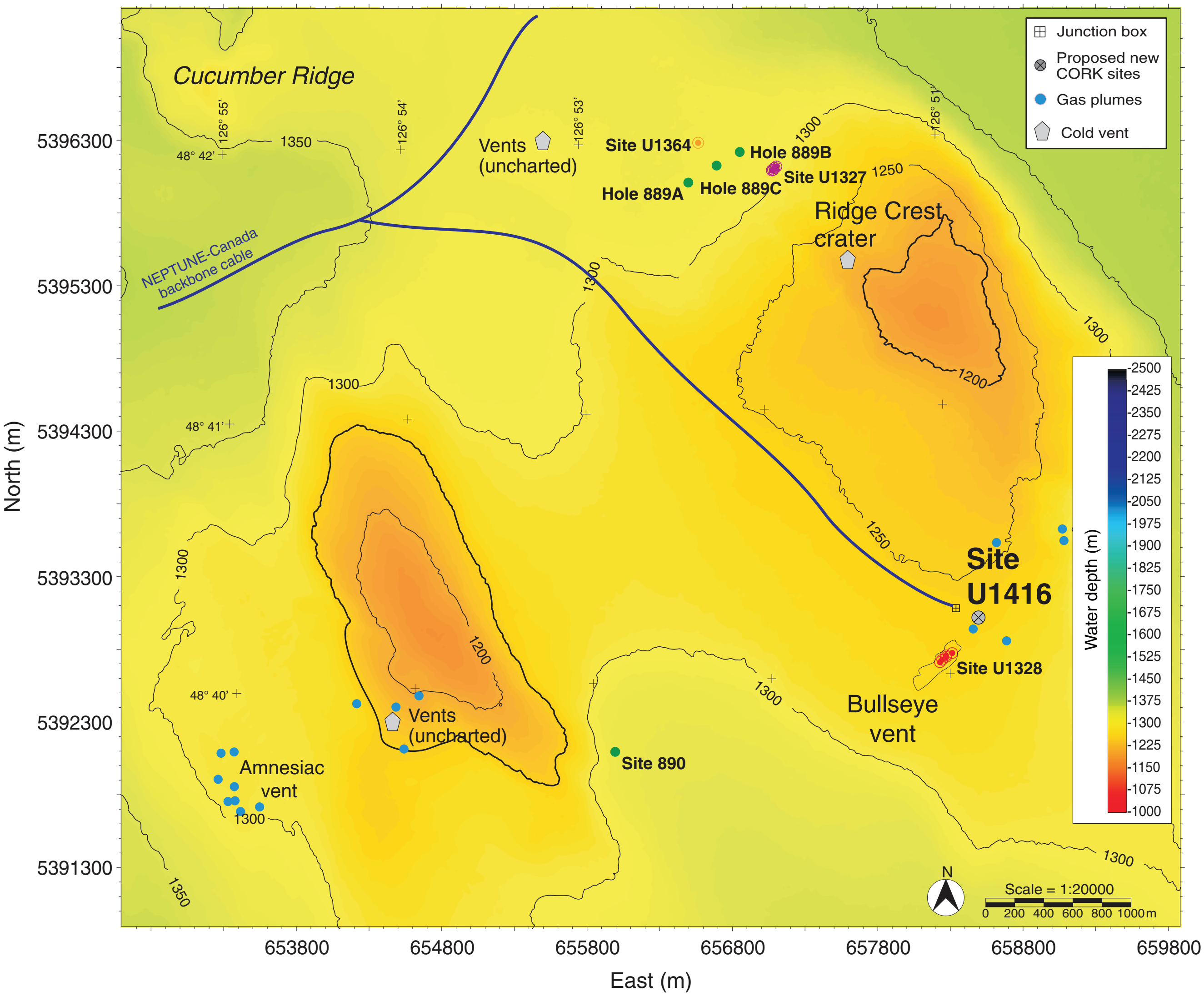


Figure F3. Map showing the location of SCIMPI Hole U1416A and Hole U1416B adjacent to Bullseye Vent. UTM = universal transverse Mercator projection, BPR = bottom pressure recorder, BBS = broadband seismometer, CSEM = controlled-source electromagnetic cable.

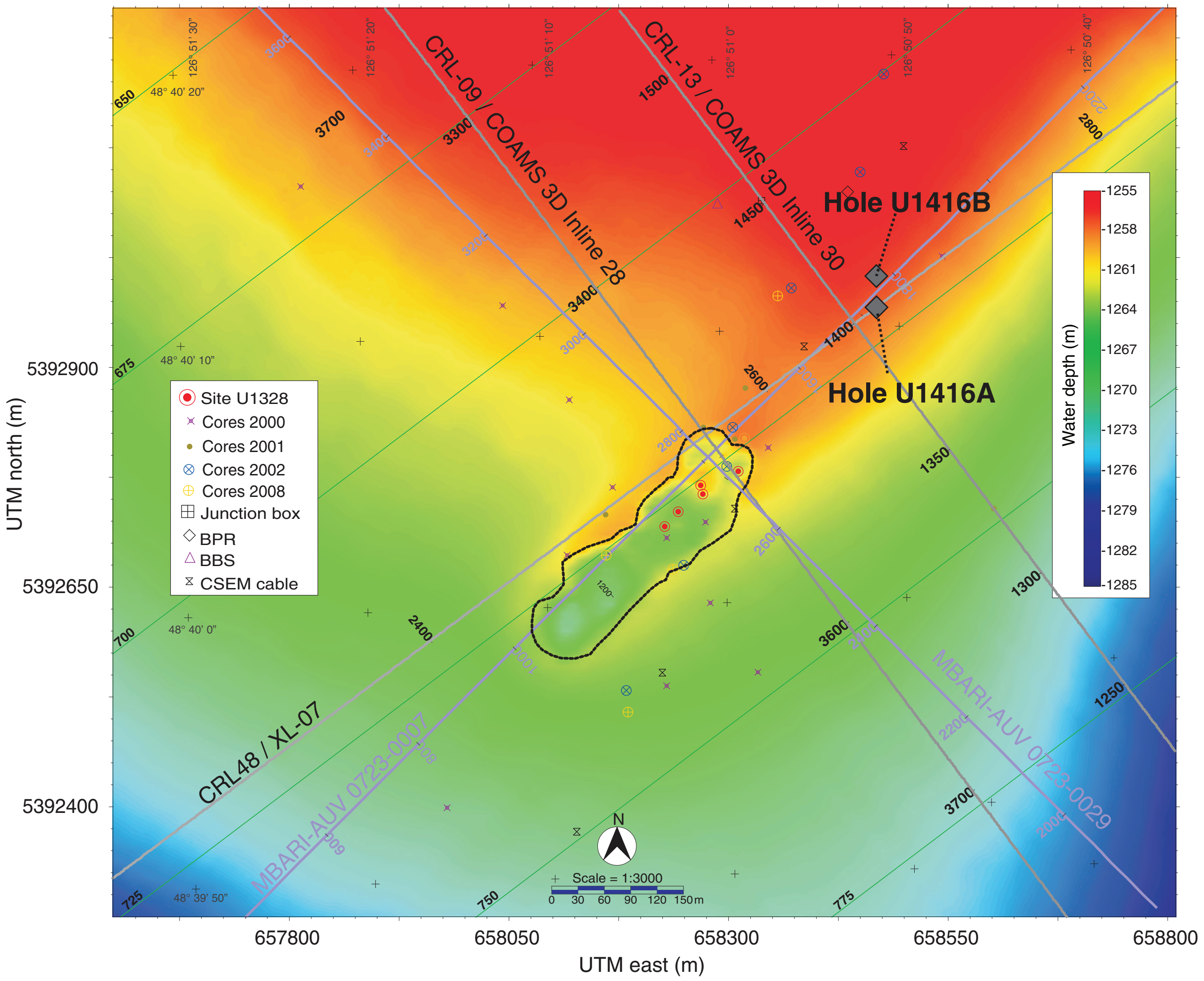


Figure F4. Depths below seafloor selected for the nine SCIMPI modules (not to scale) shown on the seismic reflection record (CRL48-XL07; Kulin et al., 2013) from the Cascadia margin site. Images of the actual SCIMPI sensor module and command module are also shown. Flotation is not shown in this diagram. BSR = bottom-simulating reflector.

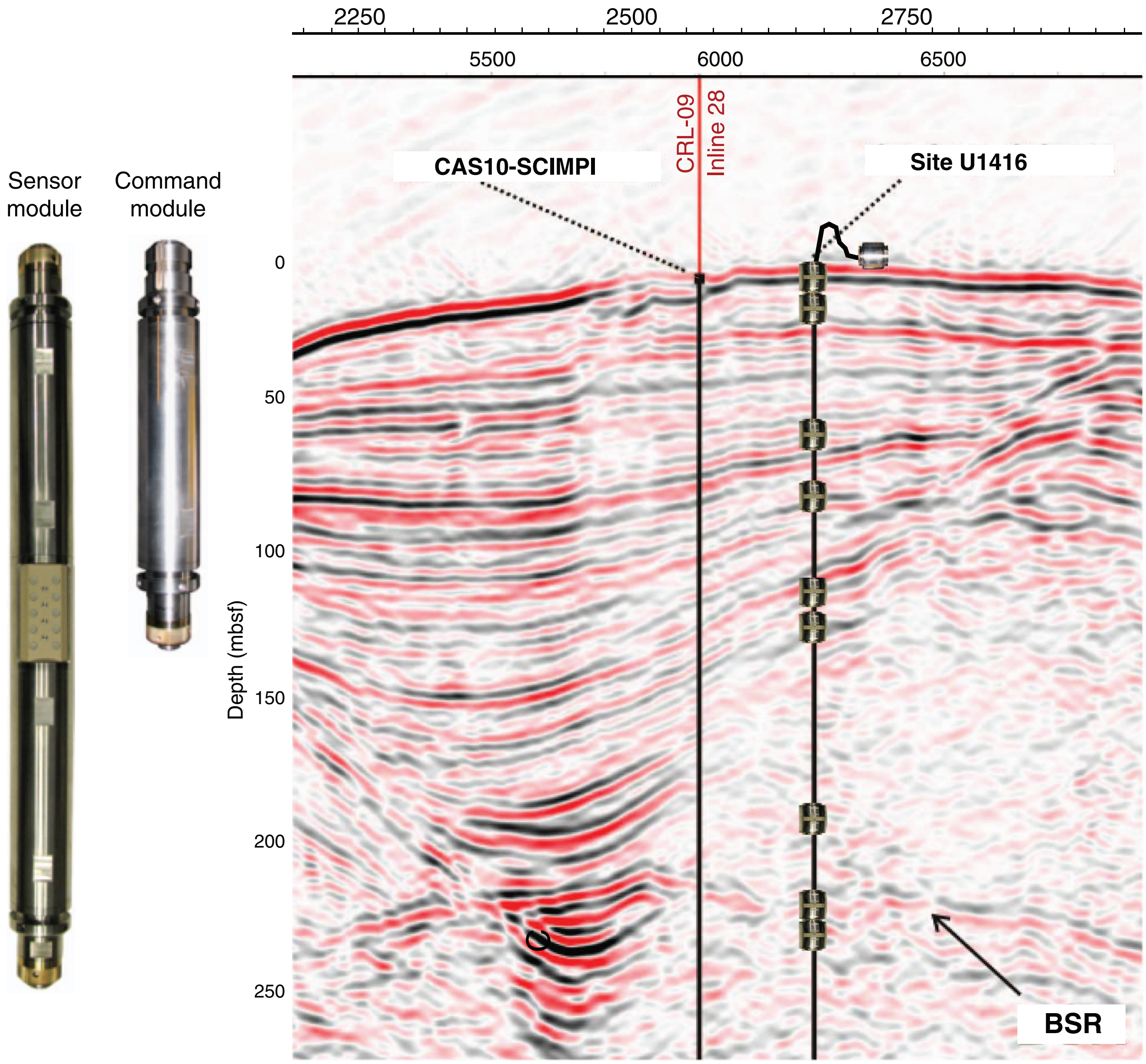


Figure F5. Depths of SCIMPI sensors installed in Hole U1416A. An ROV visit shortly after the expedition will verify exact length of SCIMPI above the seafloor and may alter the sensor depths shown in this figure. MFTM = Multifunction Telemetry Module, ERS = electronic release system.

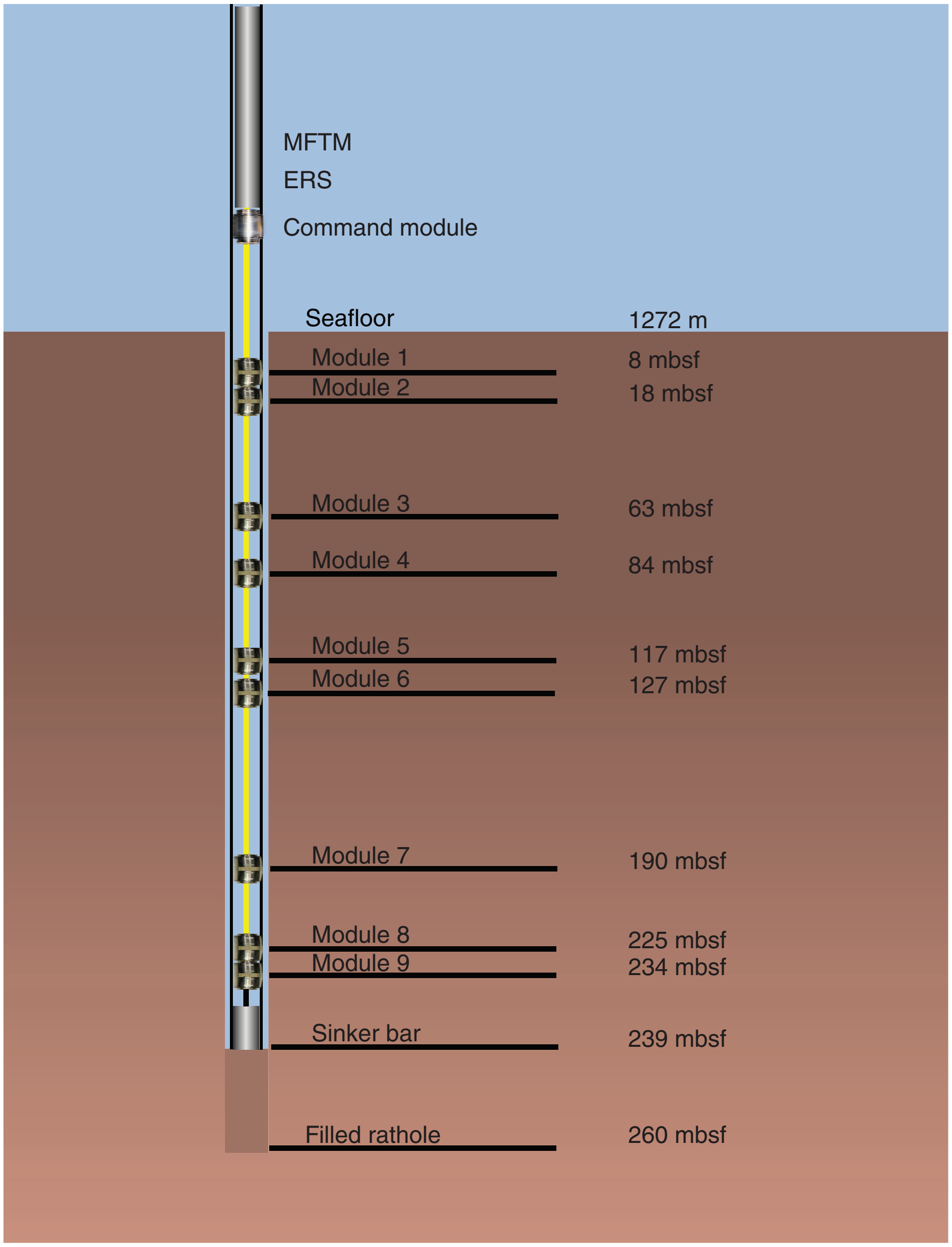


Figure F6. Pressure monitoring during the first SCIMPI deployment attempt. Top blue line = pressure difference of first (shallowest) and fifth (deepest) modules located 110 m apart. Bottom blue line = pressure difference of fifth and ninth modules located 117 m apart. Red lines = 3 point width Gaussian moving average filter.

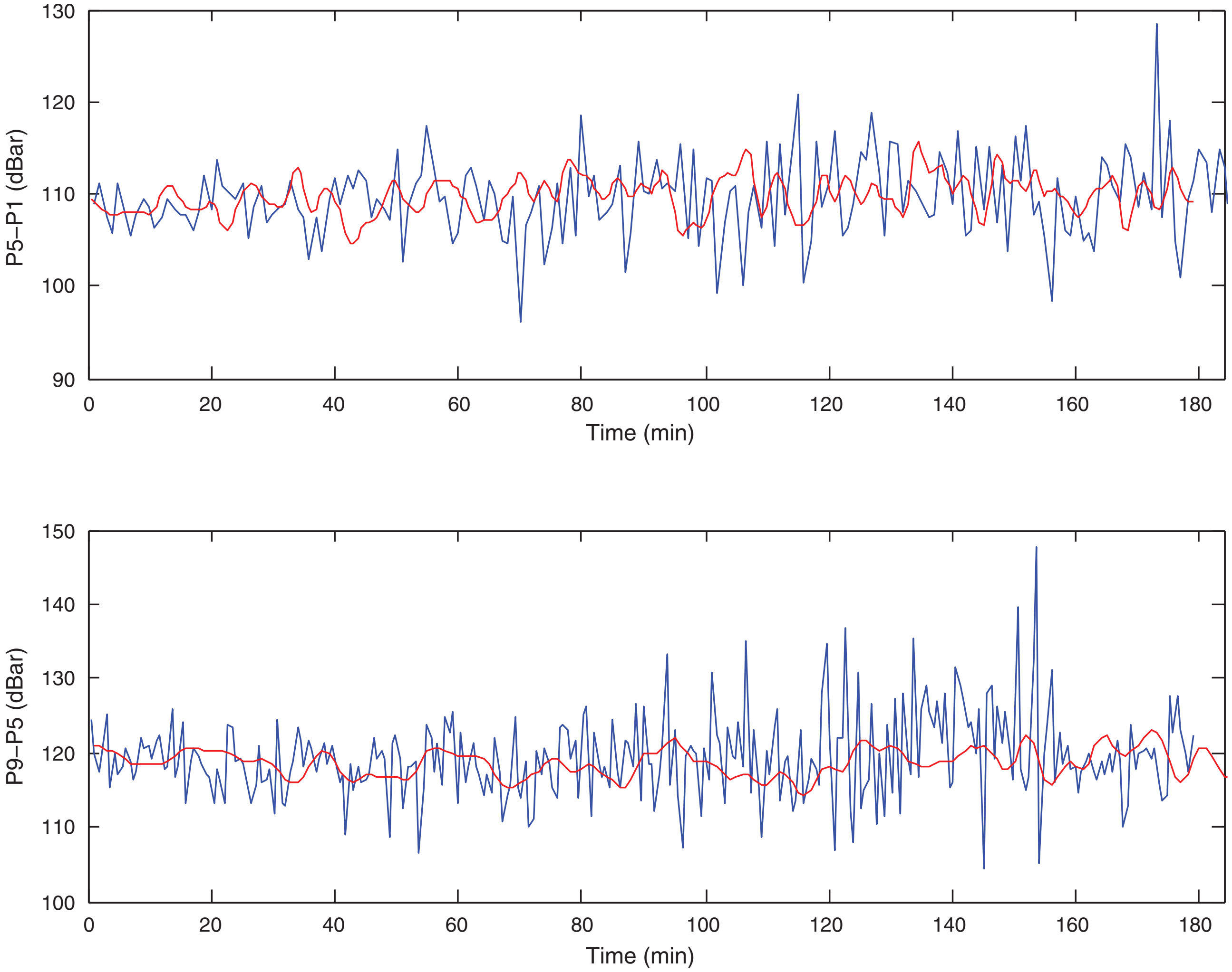


Figure F7. Pressure monitoring during the second SCIMPI deployment attempt. Top blue line = pressure difference of first (shallowest) and fifth (deepest) modules located 110 m apart. Bottom blue line = pressure difference of fifth and ninth modules located 117 m apart. Red lines = 3 point width Gaussian moving average filter. Asterisk = isolated points with high pressure recorded on Module 9 after touching bottom with the sinker bar and lifting pipe 2 m above.

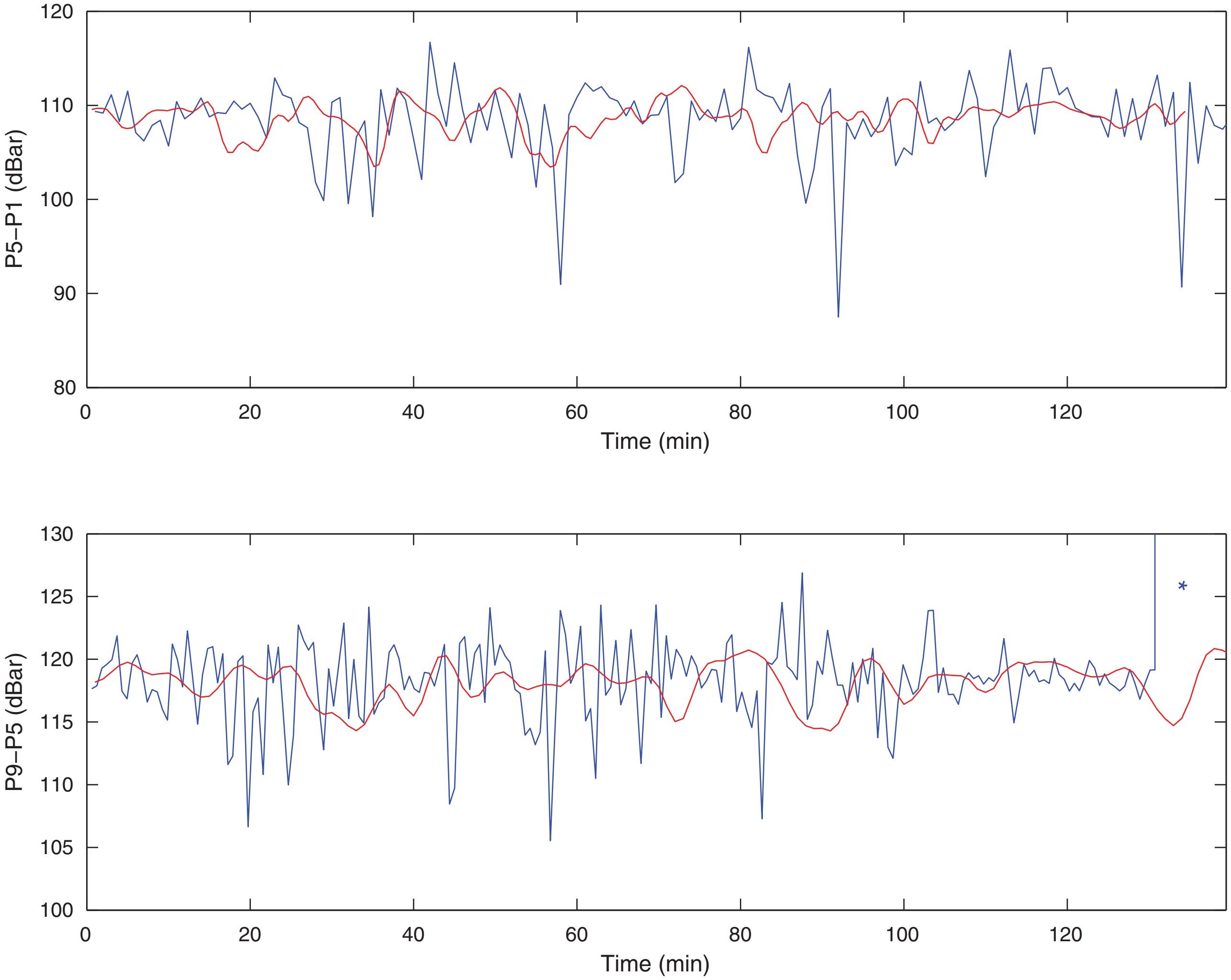


Figure F8. Temperature readings from SCIMPI during its first deployment showing all modules.

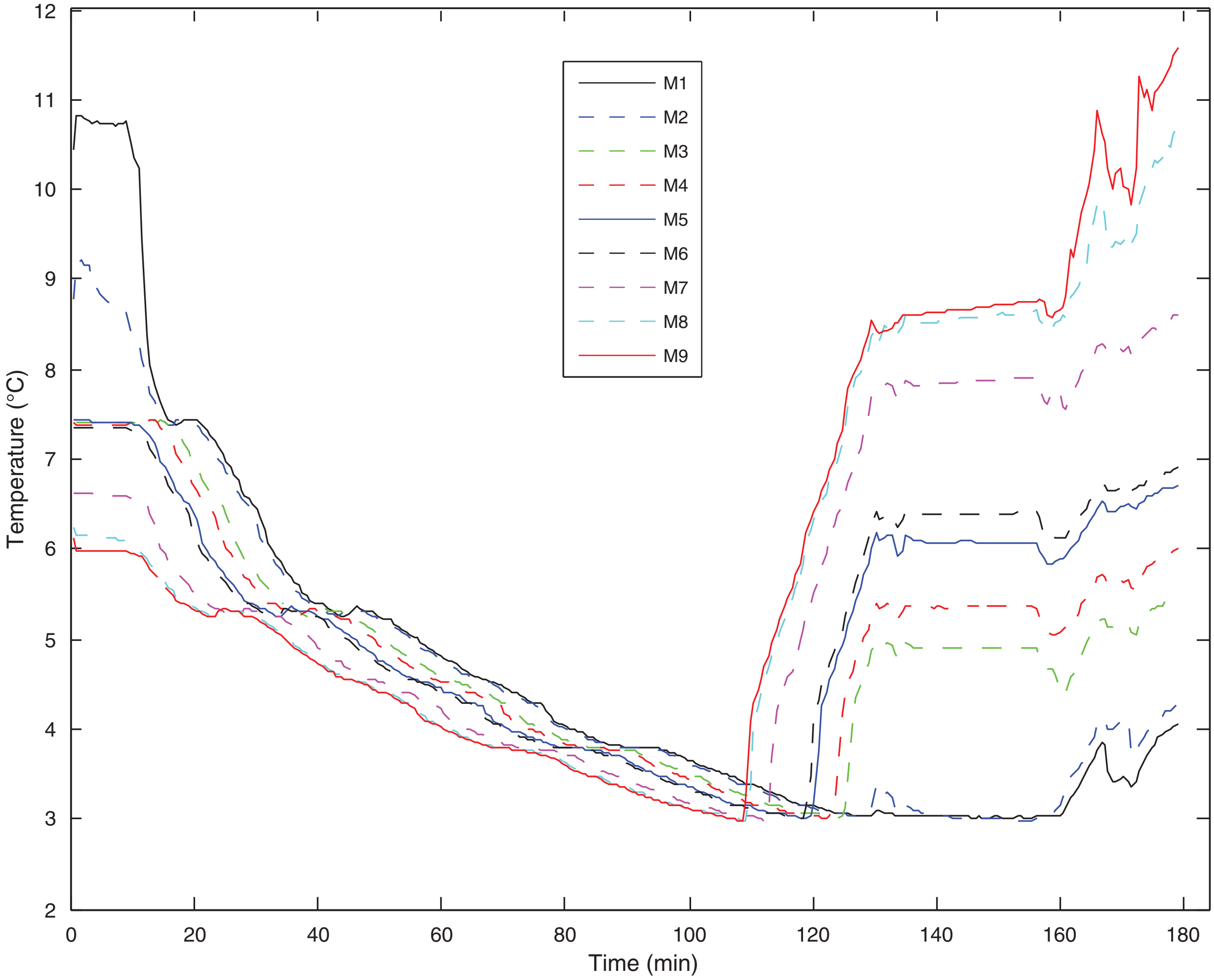


Figure F9. Temperature readings from SCIMPI during its second deployment showing all modules. Asterisk = isolated points with high temperature recorded on Module 9 after touching bottom with the sinker bar and lifting the pipe 2 m above.

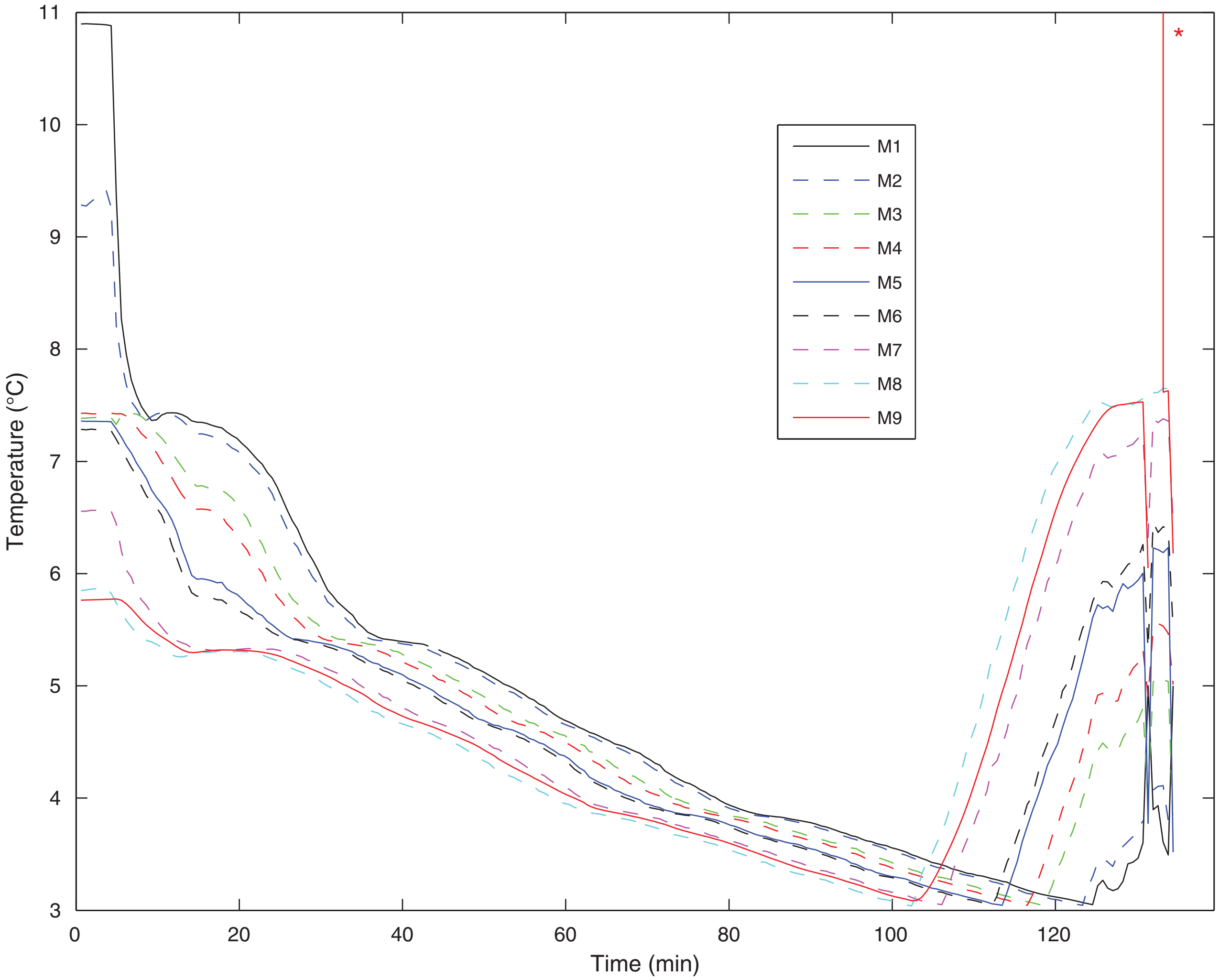


Figure F10. Maps of the sediment-filled Middle Valley Rift of the northernmost Juan de Fuca Ridge, showing ODP observatory holes and NEPTUNE Canada infrastructure.

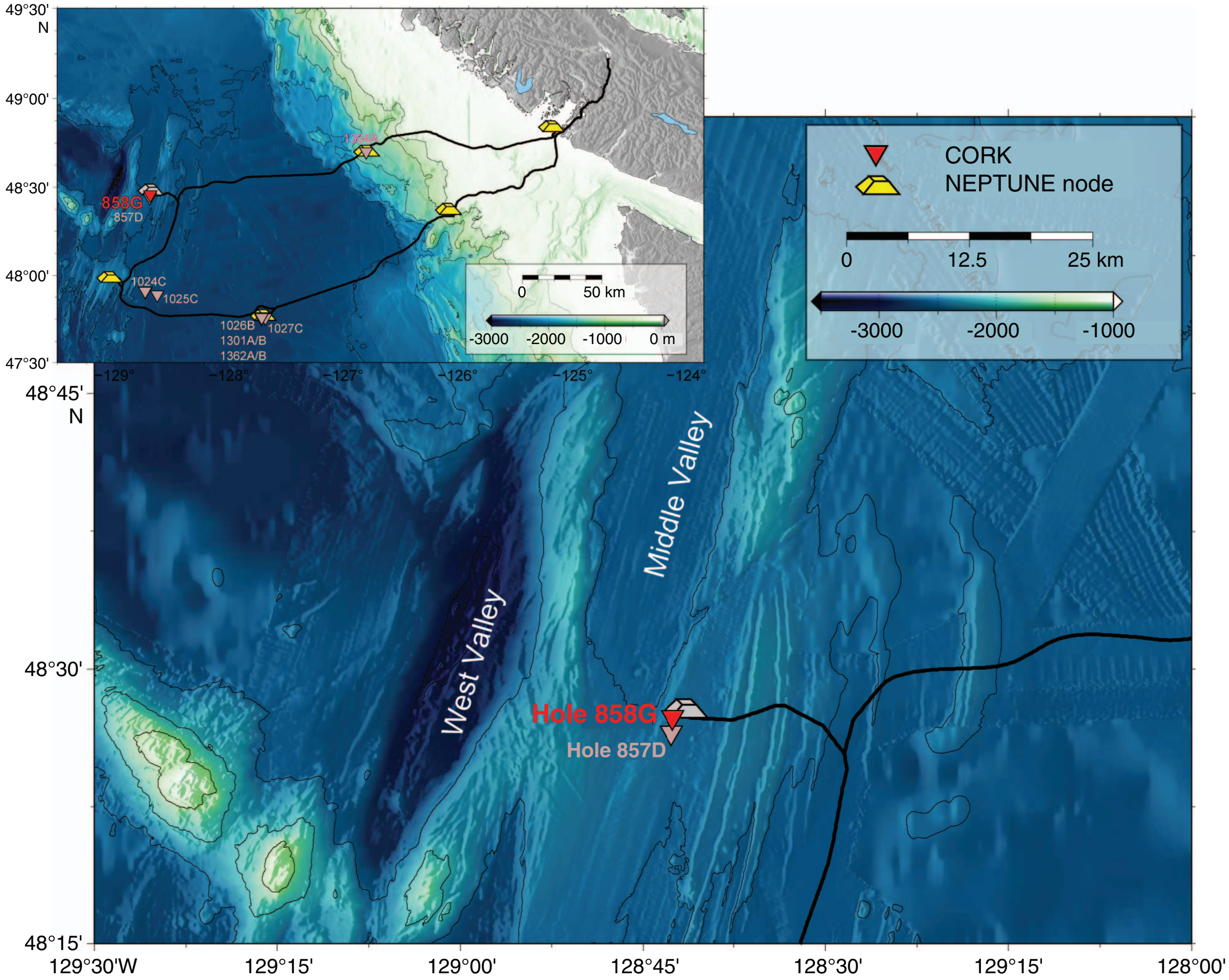


Figure F11. Early histories of pressure recording in Holes 857D and 858G following CORK installations during ODP Legs 139 and 169. Raw data are shown in blue and red; 1 day averaged data and seafloor hydrostatic pressures are shown in black for Hole 858G.

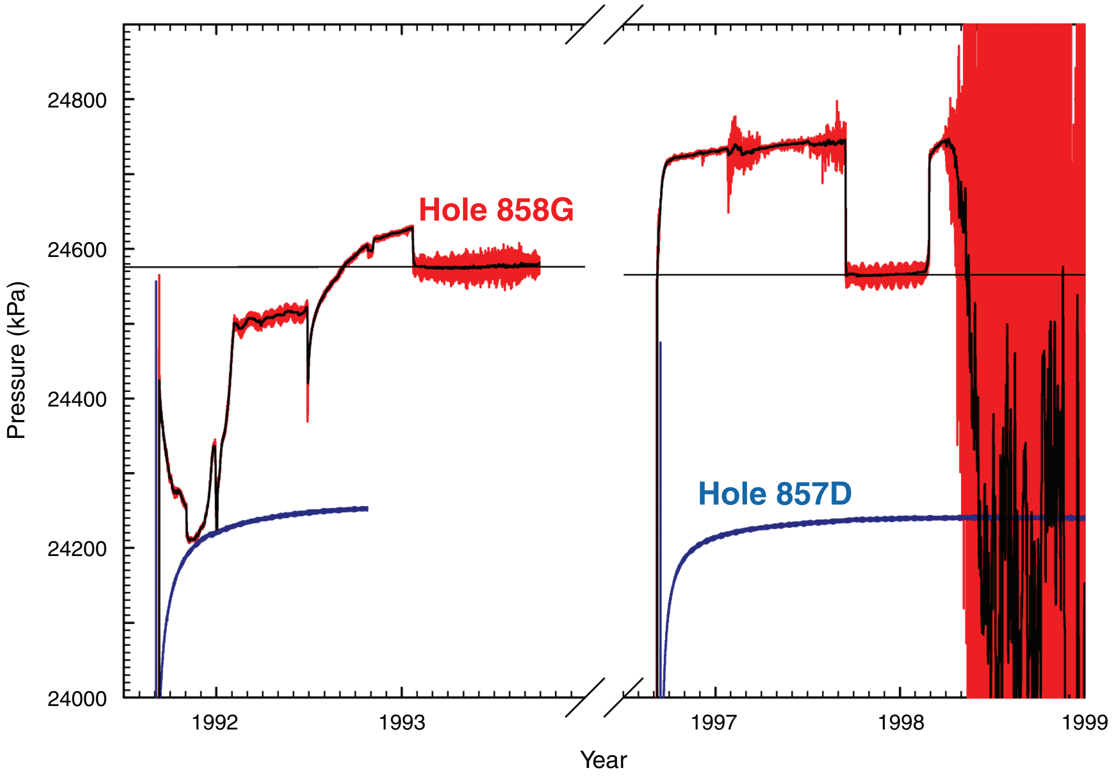


Figure F12. Formation pressures (1 day running averages) in Hole 857D since the second CORK installation during ODP Leg 169. Seismotectonic events from various local and regional sources are indicated with downward pointing arrows. The transient in 2010 (upward arrow) was produced when a parallel current-generation instrument was hydraulically connected for high-resolution monitoring, optical communications system testing, and NEPTUNE-compatibility.

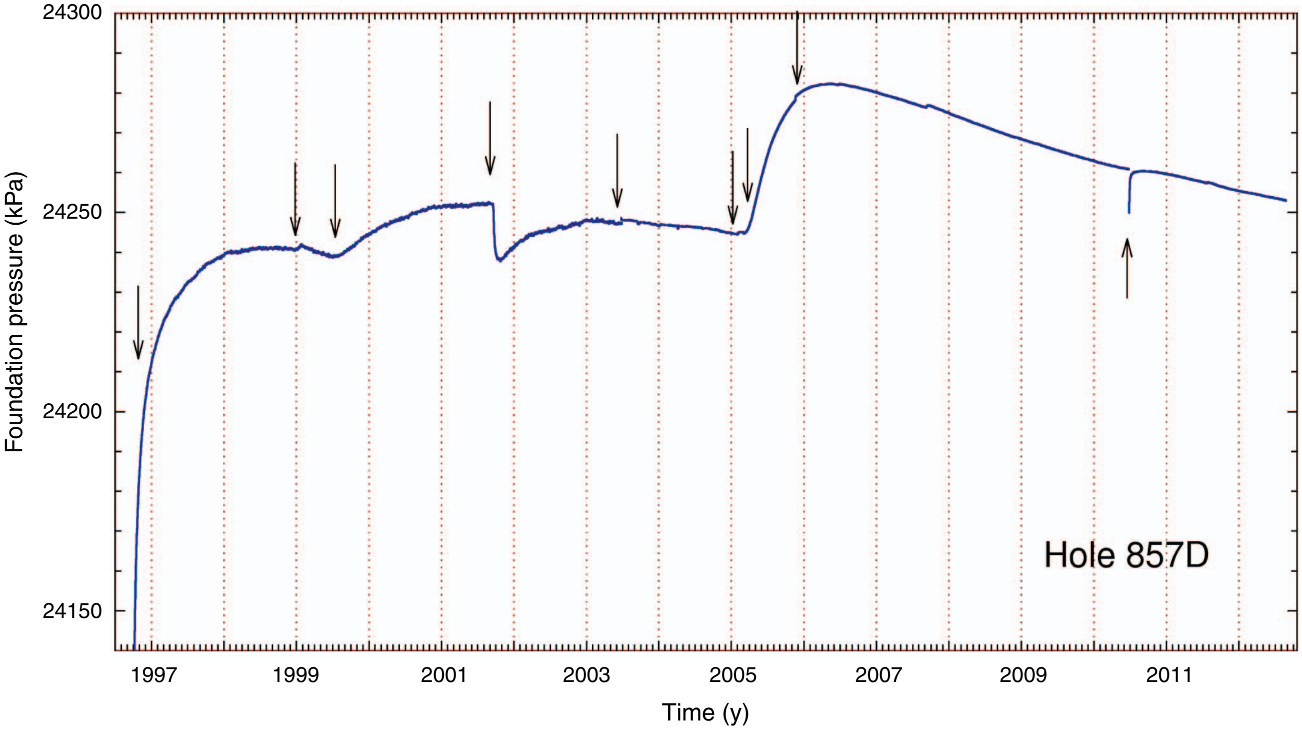


Figure F13. Pressure transient (tides filtered) associated with a seismic swarm in the northern part of Middle Valley. The transient reflects dilatational elastic strain, postseismic strain, and hydrologic diffusion (Davis et al., 2004). Watching future events like this and others seen in Fig. F12 with observatories at both Holes 857D and 858G will allow the hydrologic and geodynamic components to be separated.

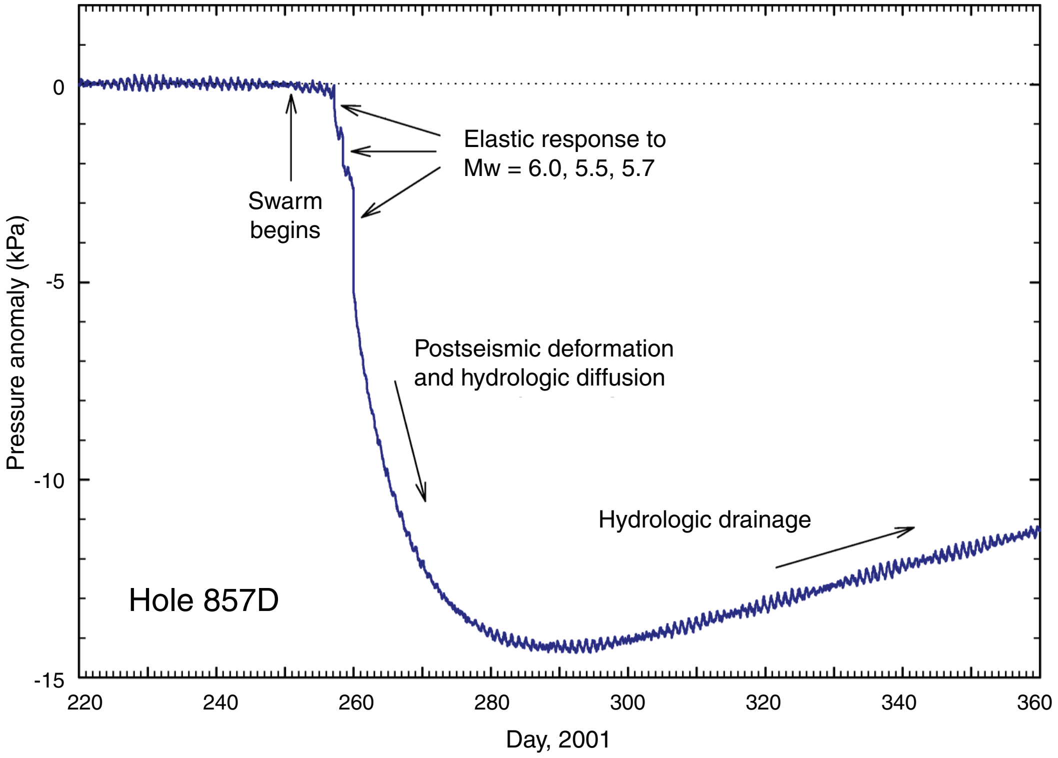


Figure F14. Schematic illustration of the new CORK that was planned for installation in Hole 858G and is now available for use in any suitable hole. **A.** The wellhead seal. (Continued on next page.)

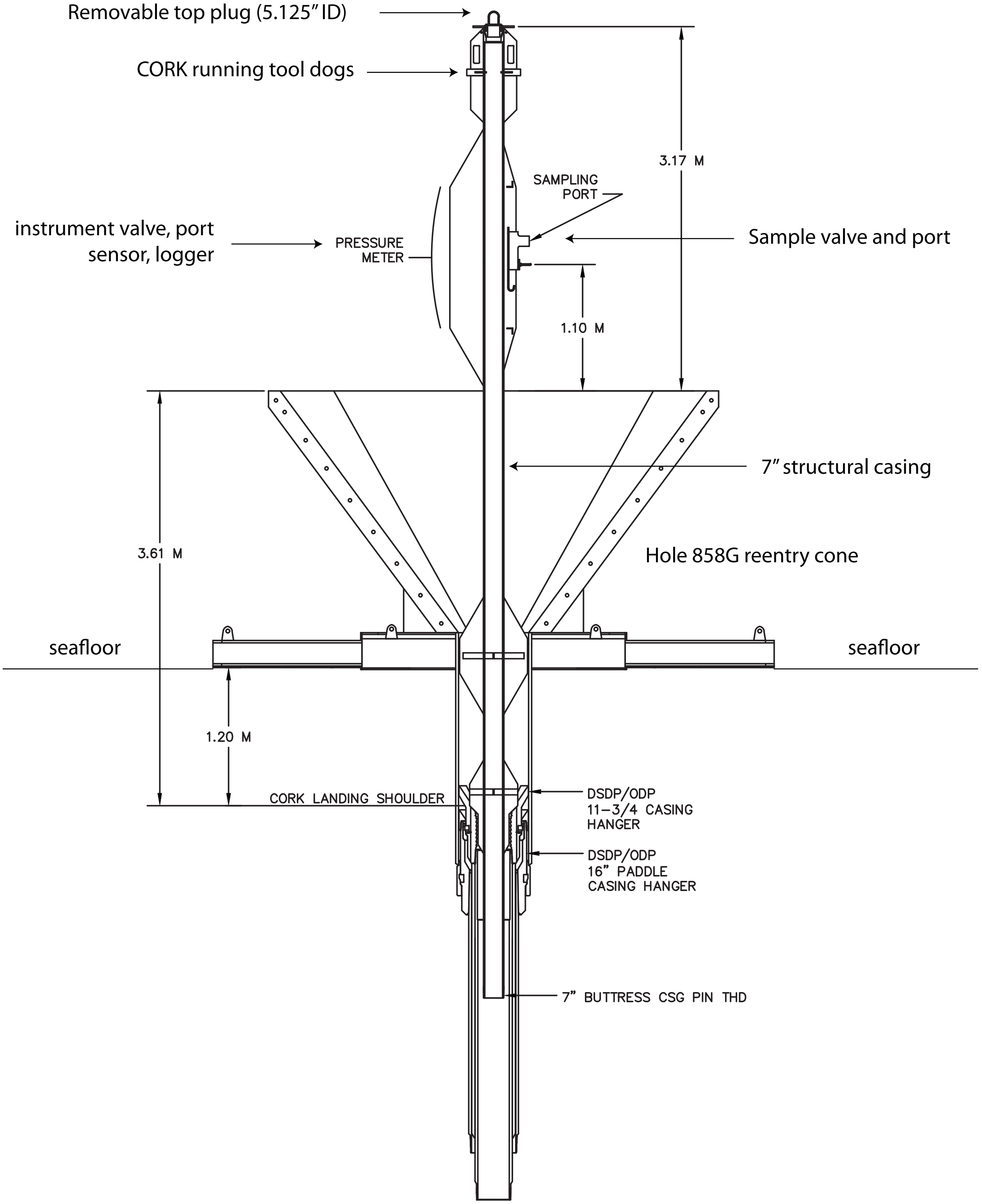


Figure F14 (continued). B. The top plug that seals the inner diameter of the CORK through which the borehole can be accessed. (Continued on next page.)

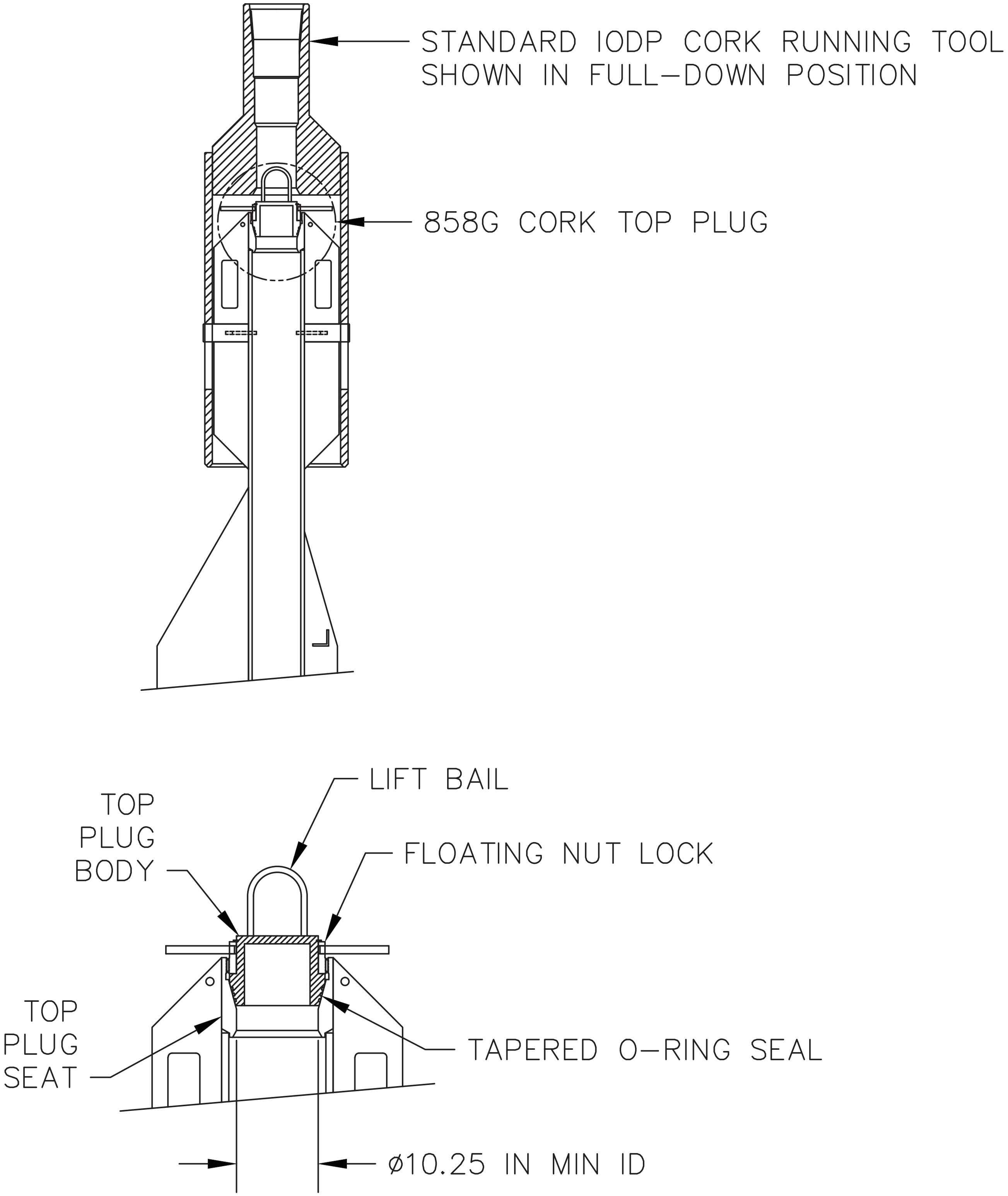


Figure F14 (continued). C. The cup seals that will seal inside the 11.75 inch casing. (Continued on next page.)

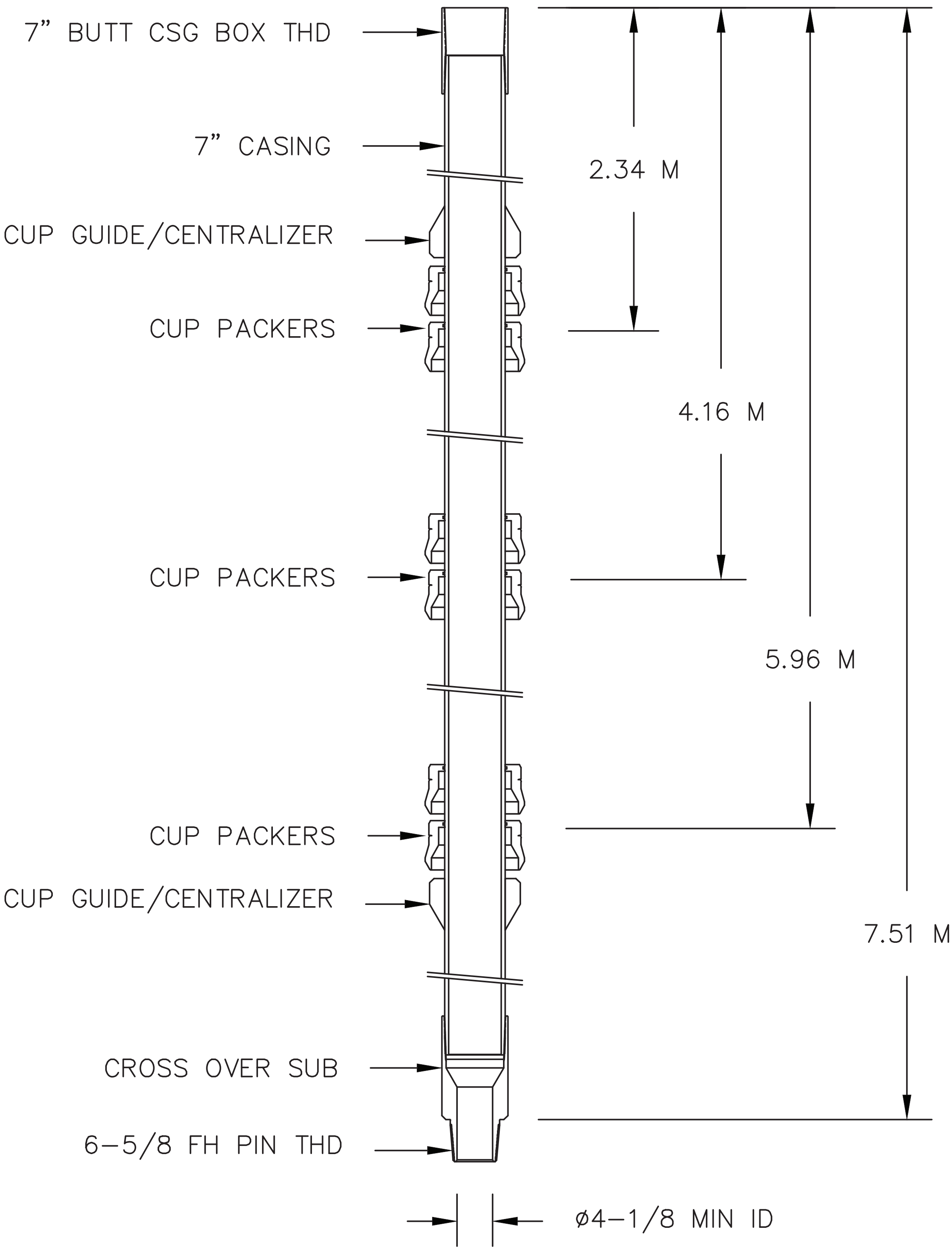
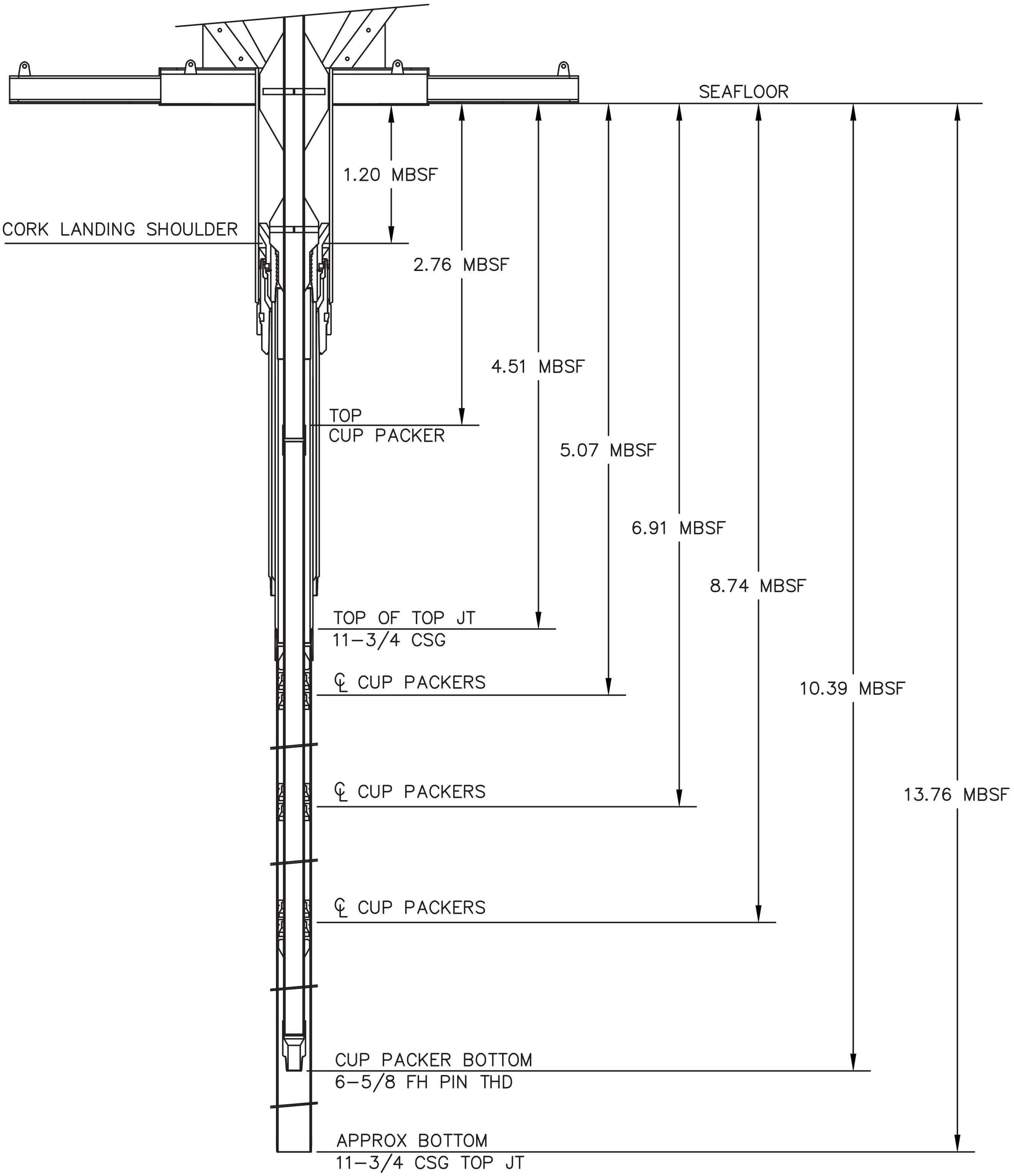


Figure F14 (continued). D. Detail of subseafloor hardware configuration.



Appendix A

ERS-MFTM-SCIMPI bench tests

After encountering performance problems with the ERS in February 21013 during the preliminary bench tests, the system was successfully tested at Lamont-Doherty Earth Observatory in April 2013 using a 19,000 ft long seven-conductor wireline. However, several problems were encountered during the port call and transit when bench testing the system that was going to be used for deploying SCIMPI in Hole U1416A. Below is a description of the problems and the results.

Multi-Function Telemetry Module (MFTM)

Baud rate problems were encountered between the uphole monitoring SCIMPI laptop and the surface panel as well as between the SCIMPI data logger and the MFTM. After investigating the problems, the laptop baud rate was set to 115200 kbps and the communications between SCIMPI and MFTM was set to 9600 kbps. In addition, a voltage regulator was installed in both MFTM tools because the 5V power supply to the modem was not able to maintain the necessary voltage over the longer shipboard wireline cable (~29,000 ft). All of these issues were resolved before leaving Victoria, and the entire SCIMPI string was successfully tested over the wireline after producing a continuous data stream without problems.

Electronic RS (ERS) Overshot

Bench testing also encountered several problems with the ERS tools after cycling the tools several times between the latching and unlatching positions. The ERS1 motor would not retract to the unlatching position, whereas initial tests with the ERS2 motor were successful while cycling approximately eight times between latching and unlatching positions. USIO-LDEO and Schlumberger (SLB) personnel took apart the ERS1 motor and electronics sections for diagnosing the problem. Tests showed that the motor worked well in both directions when direct power was being applied but the voltage on the electronics section dropped to ~14V under a load and this was not sufficient for operating the motor. This pointed to a problem with the electronics section on ERS1.

After an initial assessment of the electronics section on ERS1, the field effect transistor (FET) control board was redesigned with a pair of mechanical relays such that two switches were dedicated, one for forward (latching) and the other for reverse (unlatching) operations. This improved the output voltage by a few volts, allowing the motor to turn on the bench, which was a problem before, but the motor still stalled when it was attached to the mechanical section of the tool. A closer inspection of the ERS1 power supply section revealed that the Vicor (DC-DC converter) did not have the required capacitors as stated in the data sheet from the manufacturer. Installing capacitors found onboard, which were in the approximate required range, increased the voltage to a range between 19 and 20V, which was enough to operate the motor while installed in the mechanical assembly. In addition, a current-limiting resistor that was in the original board was removed because it was no longer necessary with the new relay switch configuration, and this last step increased the total operating motor power to ~22.5V. The final result was that the modified ERS1 electronics section was then responsive and operational in both directions with a far more consistent stroke time.

The final bench test consisted of connecting the shipboard seven-conductor wireline cable, SLB cablehead, MFTM, the modified ERS electronics cartridge, the ERS motor and latching sections, the SCIMPI data logger, and nine SCIMPI modules comprising the entire 250 m SCIMPI assembly that was going to be deployed. The results showed consistent latching and unlatching operations in ~1 min and 50 s during six iterations, as well as reliable communications with the SCIMPI data logger displaying correct formats in the uphole computer for all the modules.

After these successful tests, modifications to the second ERS tool were also performed. These included adding capacitors to keep the Vicor’s voltage at the required level while keeping the rest of the FET board intact.

Appendix B

Hole 858G refit CORK deployment procedures

Hole 858G refit CORK deployment procedures are shown in Figure AF1.

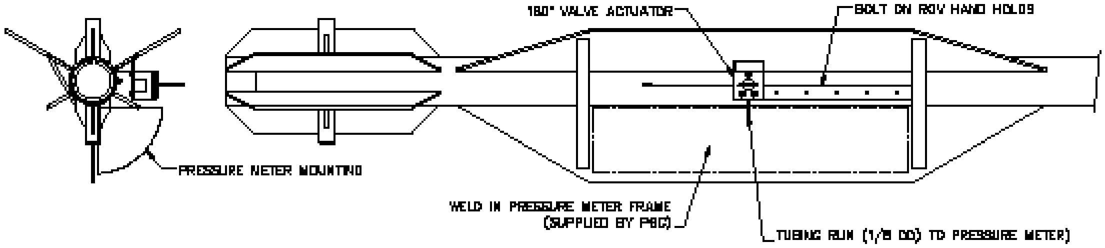
Figure AF1. Hole 858G refit CORK deployment procedures. (Continued on next seven pages.)

858G Refit CORK Deployment Procedures

Revision: 2 27 April 2013

1.0 Predeployment Pressure Meter Preparations

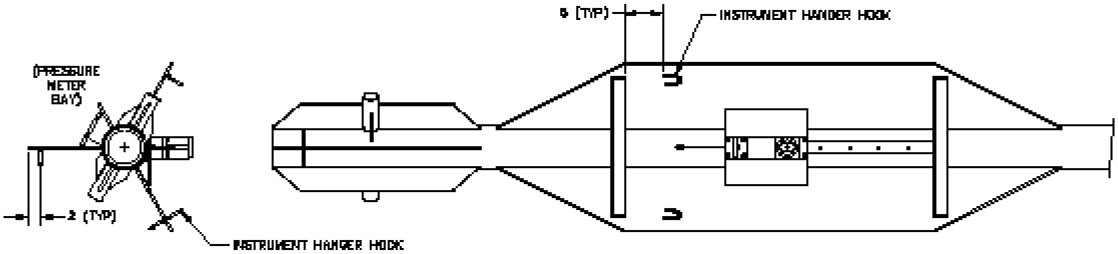
1.1 Weld Pressure Meter Frame (supplied by PGC) in Refit CORK pressure meter bay as instructed by PGC personnel.



858G REFIT CORK PRESSURE METER BAY

1.2 Bolt on ROV hand holds as instructed by PGC personnel.

1.3 Weld on instrument hanger hooks as shown below.



858G REFIT CORK FLUID SAMPLING BAY
SUGGESTED INSTRUMENT HANGER HOOK LOCATIONS

1.4 Install pressure meter.

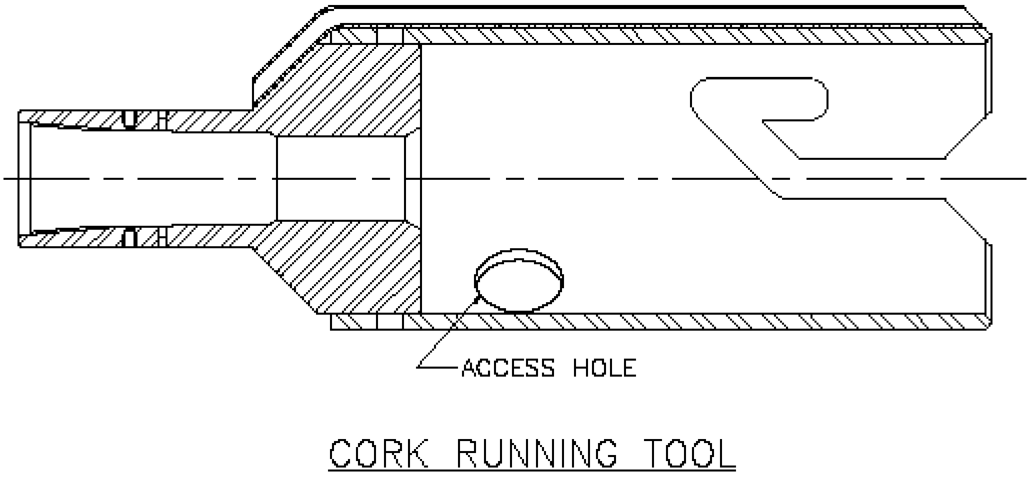
Figure AF1 (continued). (Continued on next page.)

1.5 Plumb pressure meter to 3-way valve in pressure meter bay.

Note: Sorry for the 1/8 tubing connector installed in the 3-way valve pointing up rather than outward. It felt like it was trying to gall and I didn't want to push it any further.

2.0 Predeployment CORK Running Tool Preparations

2.1 Locate CORK Running Tool OJ6310, be sure running tool has access holes in skirt.



2.2 Remove Stinger OJ6895 if installed.

2.3 Make up 1 ea. 1 m or 2 m drill collar pup to running tool.

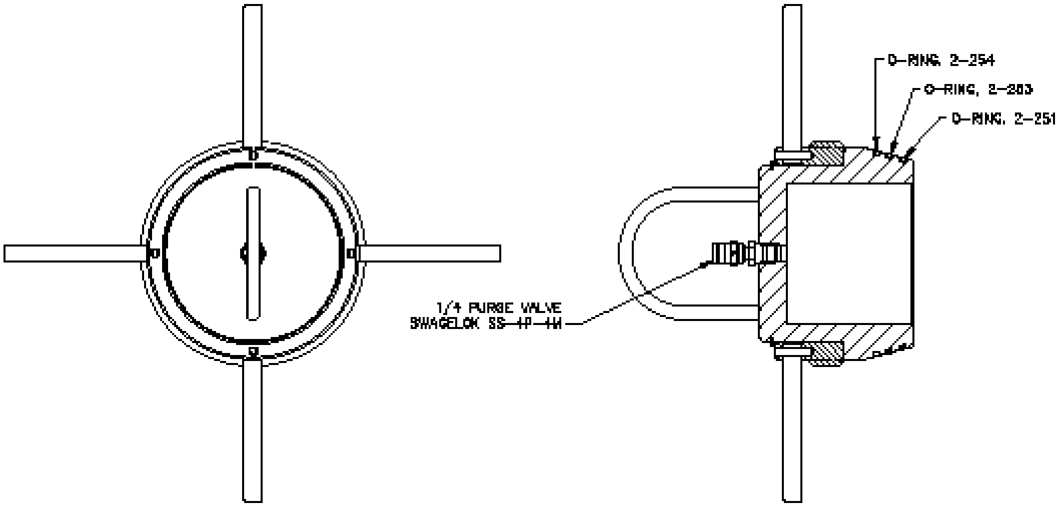
2.4 Make up Lift Nubbin to drill collar pup.

2.5 Set Running Tool aside.

Figure AF1 (continued). (Continued on next page.)

3.0 Predeployment FN Plug Preparation

3.1 Locate FN Plug 12019-100.



FN (FLOATING NUT) PLUG ASSEMBLY

3.2 Inspect o-ring seals and replace if damaged.

3.3 Open Purge Valve by backing off cap until snug.

Note: Cap is crimped to body to prevent it from coming off.

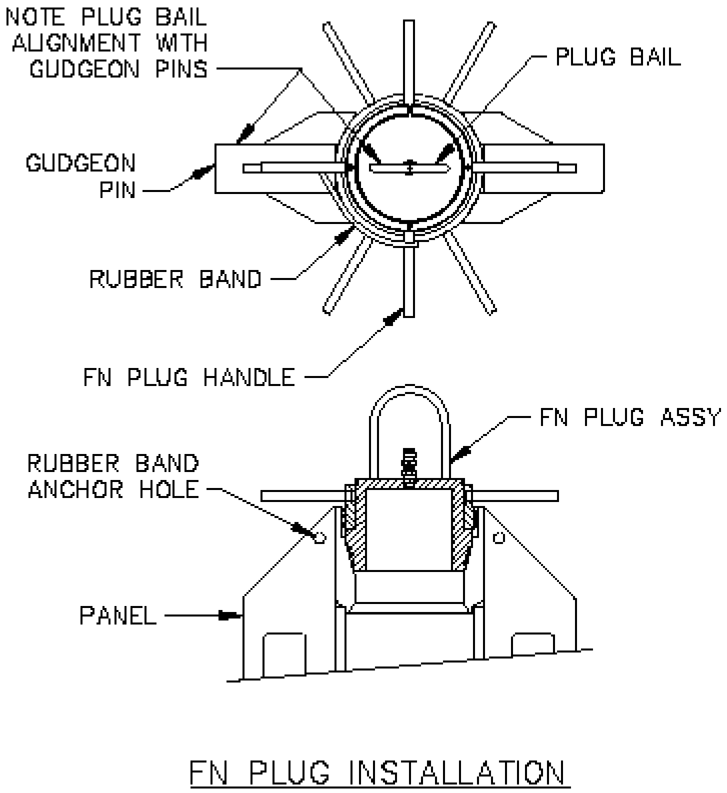
3.4 Apply Aqua Lube or other water proof lubricant to a) the floating nut threads, b) the tapered surface of the plug body, and c) the seat tapered seal surface.

Note: Unfortunately the plug seat egged a little during welding. The threads on the floating nut and in the seat, as well as the tapered seal surface in the seat, had to be buffed down a bit to fit properly. Thus, be sure to grease all mating surfaces with water proof lubricant to prevent them from rusting together.

3.5 Install FN Plug in 858G Refit CORK with the bail aligned with CORK wellhead gudgeon pins (running tool lugs).

Note: The bail must be oriented with the gudgeon pins so as the purge valve can be accessed for closing after the air purging operation.

Figure AF1 (continued). (Continued on next page.)



3.6 Snug floating nut hand tight, DO NOT hammer or torque up with a wrench.

Note: An ROV or submersible must be able to unscrew the floating nut to remove the top plug during future internal instrument deployments.

3.7 Wrap several rubber bands around plug handle and through panel anchor holes as shown.

Note: Rubber bands should be stretched tight so as to keep the floating nut from backing off during deployment.

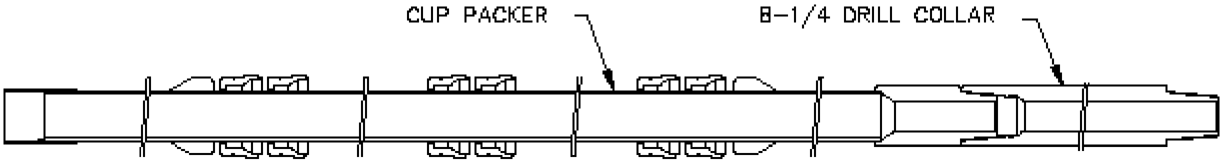
4.0 <u>858G Refit CORK Deployment</u>

4.1 Hang off 1 ea. 8-1/4 drill collar in rotary table.

Note: Remove pin thread protector if installed.

4.2 Make up Cup Packer to drill collar.

Figure AF1 (continued). (Continued on next page.)



CUP PACKER MADE UP TO 8-1/4 DRILL COLLAR

4.3 Hang off cup packer in rotary.

4.4 Spread pipe stabber.

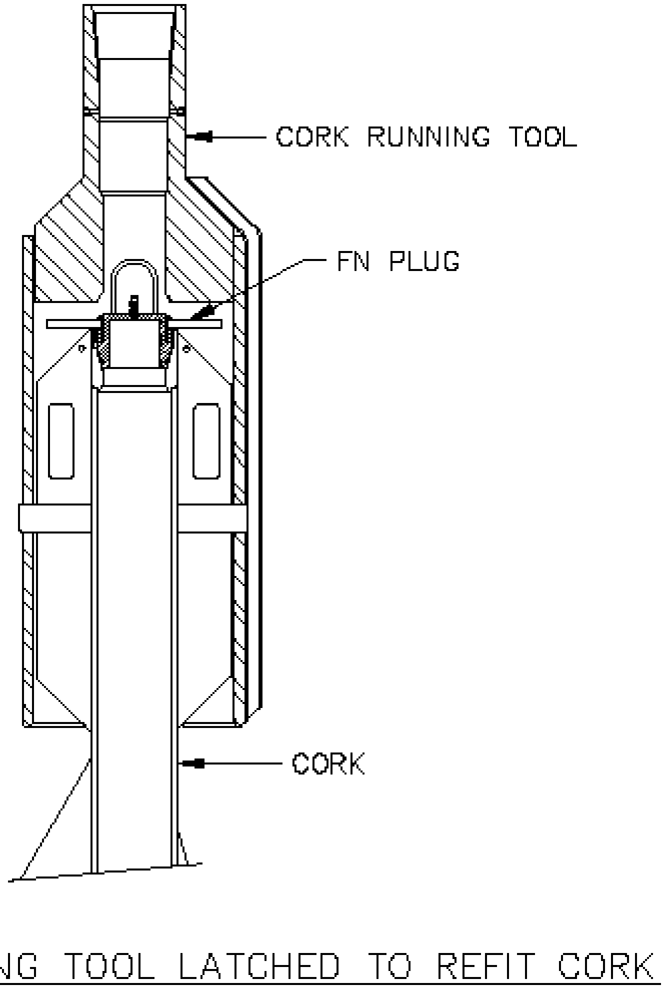
4.5 Move 858G Refit CORK from staging area (CT shop roof) to pipe racker.

4.6 Move 858G Refit CORK into rig floor still in horizontal position.

4.7 Make up Running Tool to 858G Refit CORK.

Note: Be careful not to damage the top plug purge valve while stabbing the running tool over the top of the CORK wellhead.

Figure AF1 (continued). (Continued on next page.)



4.8 Raise CORK in derrick with drawworks.

4.9 Make up CORK to Cup Packer.

4.10 Remove slips, slip bowl, and bushings from rotary.

4.11 Lower CORK through rotary.

4.12 Install bushings, slip bowl, and slips and land running tool drill collar pup in rotary.

4.13 Remove lift nubbin.

4.14 Pick up one stand of drill collars.

4.15 Make up drill collars to running tool drill collar pup.

4.16 Lower CORK into moonpool.

Figure AF1 (continued). (Continued on next page.)

4.17 Carry out final check of CORK.

Pressure meter 3-way valve SET TO MONITOR FORMATION (pointing up).

Fluid sampling valve CLOSED (T-handle vertical).

Note: The fluid sampling valve T-handle was welded on 90 deg off. Thus, the actuator functions backwards. When the valve is CLOSED, the T-handle is aligned with the sampling valve plumbing line (T-handle oriented up and down or vertical). When the valve is OPEN, the T-handle is perpendicular to the sampling valve plumbing line (T-handle oriented horizontal).

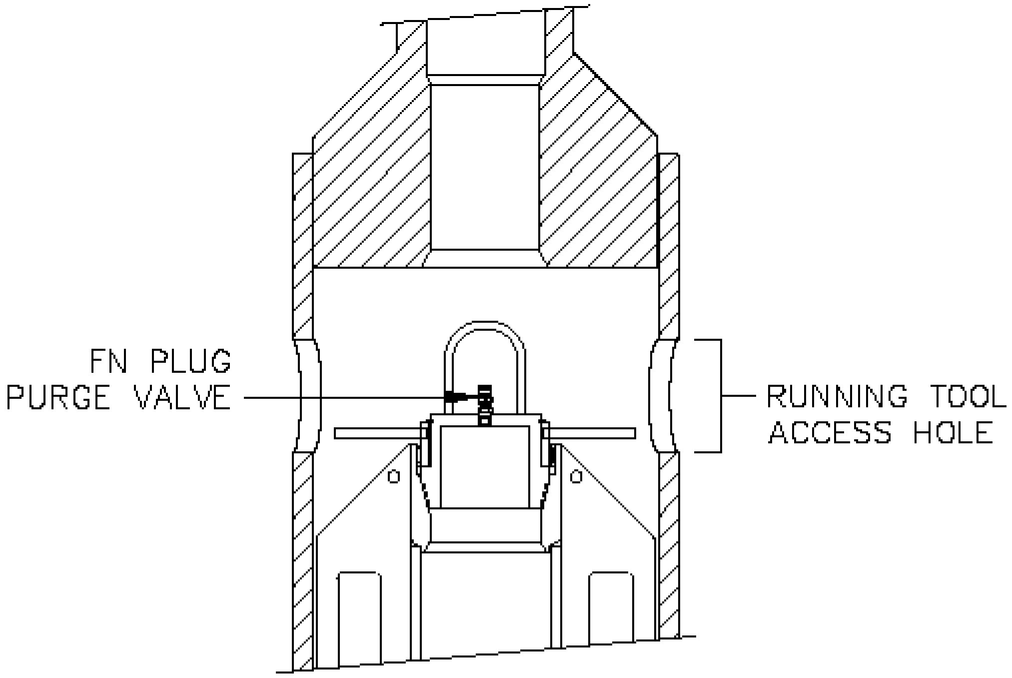
4.18 Install rubber bands on all valve handles to prevent them from vibrating open during deployment.

4.19 Lower CORK below sea surface.

4.20 Wait 10 min to purge all air from inside CORK.

4.21 Raise CORK to moonpool doors.

4.22 Close FN Plug purge valve.



ACCESSING PLUG PURGE VALVE

Figure AF1 (continued).

4.23 Deploy 858G Refit CORK as standard CORK.

Note: When cup packer enters casing, a weight loss of ≤ 2,500 lbs. may be observed due to borehole overpressure.