Integrated Ocean Drilling Program
Expedition 321T Preliminary Report

Juan de Fuca hydrogeology: cementing operations at the Hole U1301A and Hole U1301B borehole observatories (CORKs)

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Expedition 321T Scientists

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Disclaimer

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Expedition 321T participants

Expedition 321T scientists

Andrew Fisher
Chief Scientist
Earth and Planetary Sciences Department
University of California, Santa Cruz
1156 High Street
Santa Cruz CA 95064
USA
afisher@es.ucsc.edu

Kusali Gamage
Expedition Project Manager/Staff Scientist
Integrated Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
gamage@iodp.tamu.edu

Louise Anderson
Logging Staff Scientist
Department of Geology
University of Leicester
Leicester LE1 7RH
United Kingdom
lma9@le.ac.uk

Dustin Winslow
Scientist
Earth and Planetary Sciences Department
University of California, Santa Cruz
1156 High Street
Santa Cruz CA 95064
USA
dmwinslow@gmail.com

School of Rock participants

Leslie Peart
Director, Education
Consortium for Ocean Leadership
1201 New York Ave NW, Fourth Floor
Washington DC 20005
USA
lpeart@oceanleadership.org

John Firth
SOR Instructor
Integrated Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
firth@iodp.tamu.edu

Katherine (Katie) Inderbitzen
SOR Instructor
Division of Marine Geology and Geophysics
Rosenstiel School of Marine and Atmospheric Science
4600 Rickenbacker Causeway
University of Miami
Miami FL 33149-1098
USA
kinderbitzen@rsmas.miami.edu

Leslie Sautter
SOR Instructor
Department of Geology and Environmental Geosciences
College of Charleston
Charleston SC 29424
USA
SautterL@cofc.edu

Phil Rumford
SOR Instructor
Integrated Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
rumford@iodp.tamu.edu

Elizabeth Abernathy
SOR Teacher
Bedichek Middle School
6800 Bill Hughes Road
Austin TX 78745
USA
eabernat@austinisd.org

Malinda Burk
SOR Teacher
Lincoln High School
2229 J Street
Lincoln NE 68510
USA
mburk@lps.org

Patricia Cleary
SOR Teacher
Department of Geosciences
University of Wisconsin, Parkside
900 Wood Road
Kenosha WI 53141
USA
cleary@uwp.edu

Edward Cohen
SOR Teacher
Quibbletown Middle School
99 Academy Street
Piscataway NJ 08854
USA
ecohen@pway.org

William Finnegan
SOR Teacher
Davidson High School
3900 Pleasant Valley Road
Mobile AL 36609
USA
dhs.earth@gmail.com

Cynthia Fong
SOR Teacher
Hilo Intermediate School
587 Waianunue Avenue
Hilo HI 96720
USA
cynthia_fong/HILOI/HIDOE@notes.k12.hi.us

Dudley Friskopp
SOR Teacher
Litchfield Public Schools
PO Box 167
Litchfield NE 68852
USA
dfriskop@esu10.org

Cheryl Hammons
SOR Teacher
Dan Powell Intermediate School
8875 Oak Grove Road
Fort Worth TX 76140
USA
chammons@eisd.org

Kevin Kurtz
SOR Teacher
Science Factory Children's Museum and Planetarium
PO Box 1518
Eugene OR 97440
USA
sfeducation@sciencefactory.org

Joe Monaco
SOR Teacher
Redlands East Valley High School
31000 East Colton Avenue
Redlands CA 92374
USA
joe_monaco@redlands.k12.ca.us

Heather Renyck
SOR Teacher
White Mountains Regional High School
127 Regional Road
Whitefield NH 03598
USA
hrenyck@sau36.org

Jean Luc Berenguer
SOR Teacher
SISMOS à l'École
Centre International de Valbonne
BP 97
06902 Valbonne
Sophia Antipolis
France
berenguer@unice.fr

Hélder Pereira
SOR Teacher
Grupo de Biologia e Geologia
Escola Secundária de Loulé
Avenida Laginha Serafim
8100-740 Loulé
Portugal
hpereira@es-loule.edu.pt

Norihito Kawamura
SOR Teacher
1 Rokuban-cho
Marugame
Kagawa 763-8512
Japan
nori-ka@jt2.so-net.ne.jp

Yasuhiro Taguchi
SOR Teacher
130-1 Tabaru-cho
Sasebo
Nagasaki 857-0136
Japan
yasutaguchi@yahoo.co.jp

Shipboard personnel and technical representatives

Chieh Peng
Laboratory Officer

Steve Prinz
Assistant Laboratory Officer

Heather Barnes
Assistant Laboratory Officer

Michael Storms
Operations Superintendent

Bob Arko
IT (LDEO)

Ted Baker
IT (LDEO)

Grant Banta
Marine Computer Specialist

John Beck
Imaging Specialist

Gerald Bode
Curator

Lisa Brandt
Chemistry Laboratory

Chad Broyles
Curator

Etienne Claassen
Marine Instrumentation Specialist

Trevor Cobine
Paleomagnetism Laboratory

David Divins
Director, Ocean Drilling

David Fackler
Applications Developer

Paul Foster
Applications Developer

Kazuho Fujine
Chemistry Laboratory

Gus Gustafson
Downhole Tools/Thin Section Laboratory

Margaret Hastedt
Paleomagnetism Laboratory

Michael Hodge
Marine Computer Specialist

Dwight Hornbacher
Applications Developer

Sarah-Jane Jackett
Core Laboratory

Jurie Kotze
Marine Instrumentation Specialist

Zenon Mateo
Core Laboratory

Mike Meiring
Engineer

Erik Moortgat
Underway Geophysics Laboratory

Matt Nobles
Marine Computer Specialist

Bob Olivas
X-ray/Microbiology Laboratory

Debbie Partain
Publications Specialist

Dan Quoidbach
IT (LDEO)

Louis "Jim" Ramos
Cement Engineer

Kerry Swain
Schlumberger Logging Engineer

Andrew Trefethen
Marine Computer Specialist

Maxim Vasilyev
Petrophysics Laboratory

Mike Votaw
IT Vendor

Hai (James) Zhao
Applications Developer

Abstract

Integrated Ocean Drilling Program (IODP) Expedition 321T pumped cement into reentry cones around subseafloor borehole observatories in IODP Holes U1301A and U1301B in order to seal the systems and permit later completion of long-term hydrogeologic monitoring, sampling, and experiments. There was no scientific program during Expedition 321T and no collection of data or samples. Only observatory sealing operations were conducted. Reentry and cementing operations went well, and it appears that the functional objective of this short expedition was achieved. The cones around both observatories were filled completely with cement, and additional cement poured over the edges of the cones and filled the depressions in the seafloor around the cones. We will know if the observatories are sealed hydraulically when researchers return to the observatories with a submersible in August 2009 and download pressure data recording subseafloor conditions.

Introduction

Integrated Ocean Drilling Program (IODP) Expedition 301 was part of a series of expeditions and experiments to quantify hydrogeologic, lithologic, biogeochemical, and microbiological properties, processes, and linkages on the eastern flank of the Juan de Fuca Ridge (Fig. **F1**). Operations during Expedition 301 included replacing one existing subseafloor borehole observatory (CORK), drilling two basement holes and installing two new long-term observatories, coring the upper ~300 m of basement and shallow sediments above basement, and collecting in situ hydrogeologic and geophysical data from basement. Subsequent remotely operated vehicle (ROV) and submersible expeditions have serviced IODP observatories, collecting pressure and temperature data and fluid and microbiological samples and replacing components as needed to maintain these systems for future use. Another drilling expedition (approved by the IODP Science Planning Committee and awaiting scheduling by the Operations Task Force) is planned to emplace three more borehole observatories and initiate crosshole tests, and additional ROV and submersible expeditions will conduct long-term experiments and recover subseafloor data and samples.

Borehole observatories installed during Expedition 301 were designed to seal open holes so that thermal, pressure, and chemical conditions could equilibrate following the dissipation of the drilling disturbance; to facilitate collection of fluid and microbiological samples and temperature and pressure data using autonomous samplers

and data logging systems; and to serve as long-term monitoring points for large-scale crustal testing (Fisher et al., 2005). Unfortunately, the CORKs installed in IODP Holes U1301A and U1301B were not sealed as intended (Fisher, Urabe, Klaus, et al., 2005), and data and samples collected during subsequent ROV and submersible servicing operations have shown that both observatory systems are leaking. The objective of IODP Expedition 321T was to seal these observatories by pumping cement into the reentry cones surrounding the CORK wellheads, allowing the remaining components of the full experimental program to be completed during subsequent drilling and submersible expeditions.

Background

Ocean Drilling Program (ODP) Leg 168 completed a drilling transect of eight sites across 0.9–3.6 Ma seafloor east of the Juan de Fuca Ridge; collected sediment, rock, and fluid samples; determined thermal, geochemical, and hydrogeologic conditions in basement; and installed a series of CORK observatories in the upper crust (Davis, Fisher, Firth, et al., 1997). Two of the Leg 168 observatories were placed in 3.5–3.6 Ma seafloor near the eastern end of the drilling transect, in ODP Holes 1026B and 1027C (Fig. **F1**). Expedition 301 returned to this area and drilled deeper into basement; sampled additional sediment, basalt, and microbiological materials; replaced the borehole observatory in Hole 1026B; and established two multilevel observatories at IODP Site U1301 for use in long-term, three-dimensional hydrogeologic experiments.

Hole 1026B was drilled to 295 meters below seafloor (mbsf), cased across the sediment/basement interface, and extended to 48 meters subbasement (msb) during Leg 168 (Davis, Fisher, Firth, et al., 1997). The original CORK installed in Hole 1026B included a data logger, pressure sensors, thermistors at multiple depths, and a fluid sampler, all of which (except for the fluid sampler, which fell deeper into the hole) were recovered in 1999. The Hole 1026B CORK was never completely sealed after being installed in 1996, and because crustal fluids are overpressured with respect to ambient hydrostatic conditions at ODP Site 1026 (e.g., Davis, Fisher, Firth, et al., 1997), this hole discharged fluid for years until it was replaced during Expedition 301. As of the start of Expedition 301, warm (~64°C) altered basement fluid vented freely through the top of the wellhead. The original Leg 168 CORK installed in Hole 1026B was replaced successfully during Expedition 301.

Site U1301 was positioned 1 km south-southwest of Site 1026, where sediment thickness is 260–265 m above a buried basement high (Fig. **F1**). Hole U1301A was drilled without coring to 370 mbsf (107 msb). The casing was extended into the upper 15 m of basement, but poor hole conditions prevented installation of longer casing, coring, or deeper drilling. A depth check prior to CORK deployment in Hole U1301A revealed that much of the lower part of the hole had filled in with rocks from the rubbly formation around the hole.

Hole U1301B was positioned 36 m away from Hole U1301A and penetrated to a total depth of 583 mbsf (318 msb). Uppermost basement was drilled without coring, and casing was installed to 85 msb. Basement was cored from 86 to 318 msb, with mean recovery of 30%, a value typical for upper basement rocks from young crust. The upper 100 m of the cored interval in Hole U1301B was irregular in diameter, often much larger than the maximum inflation diameter of packers used for hydrogeologic testing and CORK observatories. However, the lower 100 m of the hole was stable and to gauge, allowing collection of high-quality wireline logs and providing several horizons suitable for setting drill string and CORK casing packers.

Both of the Site U1301 boreholes contained four nested casing strings: 0.50 m (diameter = 20 inches) casing in the uppermost sediments, 0.41 m (16 inches) casing extending just across the sediment/basement interface, 0.27 m (10¾ inches) casing extending into basement, and a 0.11 m (4½ inches) inner CORK casing that houses instrument strings and plugs (Fig. **F2**). The two largest casing strings were sealed by collapse of unconsolidated sediments, and the 0.41 m string was also cemented across the sediment/basement interface. The annulus between 0.41 and 0.27 m casing strings at Site U1301 was supposed to contain a rubber mechanical casing seal near the seafloor, but this component was not available for use during Expedition 301 as planned. An attempt was made to seal the 0.27 m casing strings at depth with cement, but rubbly basement prevented this cement from sealing between the casing and borehole wall. Operations were additionally complicated in Hole U1301B by the separation of the unwelded 0.27 m casing string into two sections, leaving a gap just above the sediment/basement interface (Fig. **F2B**). The CORK installed in Hole U1301A included a casing packer (as part of the 0.11 m inner casing) that was set inside 0.27 m casing. In contrast, the CORK installed in Hole U1301B included two casing packers set in open hole, intended to hydraulically isolate sections of the upper crust (Fig. **F2B**).

Expedition 301 CORKs and the preexisting CORK in Hole 1027C were visited with the ROV *ROPOS* soon after the drilling expedition in September 2004 and again in September 2005 with the submersible *Alvin*. Data recovered during these dives showed that the Hole 1026B observatory was sealed and operating as intended, although the pressure in Hole 1026B was recovering slowly from the thermal perturbation associated with 8 y of upflow of warm formation fluid (from when this CORK observatory had been unsealed, prior to Expedition 301). The CORKs in Holes U1301A and U1301B were incompletely sealed, allowing cold ocean-bottom water to flow into the formation following CORK installation. The flow of cold water into the crust at Site U1301 caused a measurable pressure perturbation at ODP Site 1027, 2.4 km away, comprising an inadvertent crosshole test (Fisher et al., 2008).

Attempts to seal Hole U1301B using a cement delivery system with the submersible *Alvin* in summer 2006 and 2007 were unsuccessful. The submersible could not deliver a sufficient quantity of cement to the cone. Shimmering fluid was observed discharging from Hole U1301A during and after summer 2007 dive operations. No such evidence for upflow from the borehole was observed during earlier visits, suggesting that Hole U1301A must have "turned around" sometime between 2006 and 2007 servicing operations. In fact, downhole temperature loggers recovered from Hole U1301A in summer 2008 provide a detailed record of this flow reversal. Remarkably, Hole U1301B continued to draw fluid rapidly into basement as of summer 2008, even though it is located just 36 m from Hole U1301A, which is vigorously discharging warm formation fluid to the ocean. Understanding of the pressure and thermal interactions between Holes U1301A and U1301B, and implications for local and regional crustal hydrogeology, will require additional investigation. Sealing both observatory systems at the seafloor is important for completing the experimental and monitoring program begun with Expedition 301 (Fisher et al., 2005).

The ROV platform installed at Hole U1301A was based on an older design, with a solid surface perforated by eight 12 inch diameter holes (Fig. **F3A**). Screens were welded below these holes prior to platform installation so that instrumentation being deployed or manipulated by a submersible or ROV would not fall through the holes. In contrast, the ROV platform at Hole U1301B has a series of radial support arms covered by the same screen material as was welded to the bottom of the platform at Hole U1301A (Fig. **F3B**). By the time the ROV platform was deployed at Hole U1301B, Expedition 301 participants realized that it would likely be necessary to cement the cone to achieve a hydraulic seal around the CORK, and a slot was cut through the screen to facilitate this operation. Several barrels of cement were pumped into the cone near

the end of Expedition 301, after passing the end of the drill string through the slot in the ROV platform, but the quantity of cement available at that time was insufficient to achieve a seal.

Operations

San Diego port call

Expedition 321T began at 1715 h on 22 June 2009 in San Diego, California, with the first line ashore Berth 10-7 at the 10th Avenue Marine Facility. The Expedition 321 scientists disembarked, and personnel associated with Expedition 321T boarded the ship. These included the Expedition 321T shipboard scientific party (the Co-Chief Scientist, United States Implementing Organization Staff Scientist, logging scientist, and an additional researcher), a BJ Services cementing engineer, 15 School of Rock (SOR) school teachers, 4 SOR instructors, 1 SOR coordinator, and other Expedition 321T technical support personnel. Two vendor representatives from Hadco came aboard for the transit to inspect and certify all Transocean lifting gear. Core samples from Expedition 321 were offloaded. One empty core liner box was removed and limited other freight, including a Schlumberger transmission/gear box, were offloaded. Four P-trucks (1391 sacks; 65.4 short tons) of "blended" (contained Cello-Flake lost circulation material [LCM]) bulk cement was loaded into P-Tank 8 and 225 sacks (9.7 short tons) of neat cement was loaded to top off P-Tank 6. In addition, six 45 gallon drums of sodium silicate "cement extender" were loaded. Fresh fruit and vegetables for catering were also brought aboard. The day was busy in the afternoon, with ship tours and other public relations events taking place.

Transit to Site U1301

The ship departed San Diego on schedule with the last line away from the dock at 0700 h on 24 June 2009. The San Diego pilot departed the ship at 0800 h; however, the US Navy diverted the ship on a southerly and then westerly course before being allowed to transit northward on our desired route. Average speed for the remainder of the first day exceeded 11 kt. The first half of the second day of transit continued with an excellent speed of 12.6 kt. By afternoon, a weather system began moving in and ship speed slowed to an average of 8.7 kt. By the morning of the third day, the full effect of an opposing current and a Force 8 gale with heavy seas and large swells was impacting the ship. Only 156 nmi were covered on the third day at an average

speed of 6.5 kt. The fourth day of transit was not much different, covering another 163 nmi at an average speed of 6.8 kt. As of midnight on Saturday, 27 June, the vessel was 431 nmi from Hole U1301B and had averaged 8.1 kt for the transit at that point. By the morning of the fifth day (Sunday), conditions began improving. Sea and swell height began to come down as the ship moved father to the north and the "fetch" shortened. Wind speed remained brisk at 25–30 kt but was expected to also diminish over time. The ship ultimately arrived on location at 0000 h on 29 June, covering the 1154 nmi distance at an average speed of 8.4 kt. This was slightly slower than the 9.0 kt originally estimated for the transit, largely as a result of encountering the gale, which had not been anticipated.

Cementing operations

Upon arrival at Site U1301, the vessel was positioned using Global Positioning System input only, as cementing operations did not require a significant amount of time in the hole nor any appreciable depth below seafloor (~1–1.5 m). Cementing operations began with Hole U1301B, as reentry at this hole was somewhat less challenging through the open slot on the platform compared to reentry through a screened 12 inch diameter opening in Hole U1301A (Table **T1**).

Hole U1301B

Position: 47°45.229′N, 127°45.826′W

Seafloor: 2667.8 meters below rig floor (mbrf)

Top of cone rim: 2668.9 mbrf (1.1 m below seafloor)

After lowering thrusters and stabilizing the ship over the location coordinates, the cementing bottom-hole assembly was picked up. This consisted of the cementing stinger (made from a joint of 5½ inch drill pipe cut in half at a 60° angle and with four staggered 3 inch diameter holes drilled in the lower 9 inches), 1 joint of 5½ inch transition drill pipe, crossover, two 8¼ inch diameter control length drill collars, tapered drill collar, and another joint of 5½ inch transition drill pipe. The drill string was run to 1376.2 mbrf and the vibration-isolated television (VIT)/subsea TV was deployed. There was an initial delay with the deployment because the coaxial winchline counter stopped working. Eventually the VIT was run in using cable tension and TV video as a reference. The line counter was removed, repaired, and put back on for the later trip out. The drill string trip was then completed to 2664.3 mbrf (4.4 m above reentry cone rim) and spaced out for reentry. A drill string wiper "pig" was pumped down to clean any remnant mud from the pipe. Pump strokes were monitored and

timed as a crosscheck on the calculated displacement of the drill string. The exit of the pig was marked by a large cloud of mud that billowed out of the end of the drill pipe upon its arrival. The low-torque valve and cementing system integrity was then pressure tested, and vessel maneuvering for the first reentry attempt began at 1030 h on 30 June 2009. The reentry target was a pie shaped window in the Hole U1301B CORK platform (Fig. **F3B**). The platform was reentered at 1215 h after 2 h and 15 min of maneuvering (Fig. **F4**). The driller's task was made more complicated by the fact that the top of the cone (TOC) rim was 1.1 m below seafloor depth. This meant each time the drill string left the cone/platform vicinity it would drag into seafloor and/or drill cuttings, which stirred up the mud and obscured visibility for several minutes.

At 1245 h, after observing the drill string and seafloor installation for stability and heave-out potential, the decision was made to move forward with the cementing operation. Preparations began for mixing the first batch of cement. At 1300 h, the actual cementing mixing operation was initiated, and by 1350 h a total of 60 barrels (bbls) of 15.8 pound per gallon (ppg) class G neat cement blended with Cello-Flake LCM was mixed with freshwater and displaced into the pipe. This was chased with 20 bbls of freshwater using the Halliburton cementing pump and followed by 120 bbls of seawater displaced with the Triplex rig pumps. The drill string was pulled clear of the TOC at 1420 h on 30 June, with ~10 bbls of cement still falling from the drill string. This was done to avoid the potential of pumping water into the reentry cone and diluting the cement slurry.

Hole U1301A

Position: 47°45.210′N, 127°45.833′W

Seafloor: 2667.3 mbrf

Top of cone rim: 2668.7 mbrf (1.4 m below seafloor)

The cementing unit was cleaned and the tanks flushed while offsetting the ship 35 m to Hole U1301A. The drill pipe was also flushed and a drill string pig was pumped to wipe away any remnant cement. Maneuvering for reentry in Hole U1301A began at 1530 h on June 30. This time the reentry target was more challenging: one of eight 12 inch diameter holes in the old style "solid" CORK platform (Fig. **F3B**). Reentering through one of these holes required using the cement stinger to push through the steel grating that had been tack-welded in place below the platform during Expedition 301, requiring careful timing and control of weight on bit. The Hole U1301A platform was reentered at 1815 h after only 2¾ h of maneuvering time (Fig. **F5**). The cone rim at this site was 1.4 mbsf and covered with a layer of fine sediment. When-

ever the bit dragged on the platform surface it stirred up a cloud of sediment, obscuring visibility for several minutes.

For this hole, a total of 114 bbls of 15.8 ppg "blended" cement was mixed and displaced in the same manner as in Hole U1301B. Mixing ended at 2000 h, and the batch was chased with 20 bbls of freshwater using the Halliburton cementing pump followed by an additional 120 bbls of seawater using the rig pumps. The pipe was pulled clear of the TOC at 2020 h on 30 June, with another ~10 bbls of cement still falling from the drill string.

Return to Hole U1301B

The cementing unit was once again cleaned and the tanks were flushed while offsetting the ship 35 m back to Hole U1301B. The drill pipe was flushed and another drill string pig was pumped. Maneuvering for reentry began at 2145 h and the Hole U1301B platform was reentered for the second time at 2250 h, requiring a mere 65 min. Preparations for mixing the second batch of cement for the hole started immediately. A total of 70 bbls of 15.8 ppg blended cement was displaced into the pipe. The cement was chased with 20 bbls of freshwater using the Halliburton cementing pump and an additional 120 bbls of seawater using the rig pumps. The pipe was pulled clear of the TOC at 2355 h on 30 June, again with ~10 bbls of cement still falling from the drill string. Visual observations at Hole U1301B indicated that cement appeared to fill the reentry cone as well as surrounding the area outside of the cone (Fig. **F6**).

Return to Hole U1301A

For the third and final time, the cementing unit was cleaned and the tanks flushed while offsetting the ship 35 m again to Hole U1301A. The drill pipe was flushed and another drill string pig was pumped. Visual observations at Hole U1301A indicated that cement appeared to fill the reentry cone as well as the surrounding area outside of the cone (Fig. **F7**). The cementing equipment was rigged down, the VIT/subsea TV was recovered, and the drill pipe was tripped back to the surface, ending cementing operations at Site U1301 at 0900 h on 1 July 2009.

Transit to Victoria, British Columbia, Canada

Cementing operations ended three full days ahead of the projected schedule. However, because of the unavailability of berths, the ship remained on location until 4 July 2009. The vessel departed Site U1301 at 0730 h on 4 July bound for Victoria, British Columbia, Canada. The short transit was uneventful other than moderate vessel

roll resulting from being crosswise to the predominant swell. The transit was made at a slightly slower speed because time was available. Expedition 321T officially ended at 0800 h on 5 July 2009 with the first line ashore Ogden Point Berth South-A, Outer Harbor, Victoria. The 195 nmi transit from Site U1301 to the Victoria pilot station was made in 1.0 day at an average "reduced" speed of 7.8 kt.

Preliminary scientific assessment

Expedition 321T included only cementing operations. No scientific data or samples were collected. Researchers will visit the two CORKs in August 2009 with the submersible *Alvin* to download data, determine if the observatories are now sealed, and replace downhole instrument strings in preparation for completing the full suite of interdisciplinary experiments.

Expedition 321T completed all planned operations more quickly and with less difficulty than had been anticipated. We were fortunate to have excellent weather and sea conditions; this is an area where working conditions can be poor, even during an optimal weather window. In addition, we benefited from the experience, advice, skill, and patience of the ship and rig crews and officers, especially the dynamic positioning system operators, cementing personnel, and drillers. Even under optimal weather and sea conditions, this was a delicate and challenging set of operations. We were fortunate to sail with such a capable and dedicated crew.

References

Davis, E.E., Fisher, A.T., Firth, J.V., et al., 1997. *Proc. ODP, Init. Repts.,* 168: College Station, TX (Ocean Drilling Program). **doi:10.2973/odp.proc.ir.168.1997**

Fisher, A.T., Davis, E.E., and Becker, K., 2008. Borehole-to-borehole hydrologic response across 2.4 km in the upper oceanic crust: implications for crustal-scale properties. *J. Geophys. Res.,* 113(B7):B07106. **doi:10.1029/2007JB005447**

Fisher, A.T., Urabe, T., Klaus, A., and the Expedition 301 Scientists, 2005. *Proc. IODP,* 301: College Station, TX (Integrated Ocean Drilling Program Management International, Inc.). **doi:10.2204/iodp.proc.301.2005**

Fisher, A.T., Wheat, C.G., Becker, K., Davis, E.E., Jannasch, H., Schroeder, D., Dixon, R., Pettigrew, T.L., Meldrum, R., McDonald, R., Nielsen, M., Fisk, M., Cowen, J., Bach, W., and Edwards, K., 2005. Scientific and technical design and deployment of long-term, subseafloor observatories for hydrogeologic and related experiments, IODP Expedition 301, eastern flank of Juan de Fuca Ridge. *In* Fisher, A.T., Urabe, T., Klaus, A., and the Expedition 301 Scientists, *Proc. IODP,* 301: College Station, TX (Integrated Ocean Drilling Program Management International, Inc.). **doi:10.2204/iodp.proc.301.103.2005**

Zühlsdorff, L., Hutnak, M., Fisher, A.T., Spiess, V., Davis, E.E., Nedimovic, M., Carbotte, S., Villinger, H., and Becker, K., 2005. Site surveys related to IODP Expedition 301: ImageFlux (SO149) and RetroFlux (TN116) expeditions and earlier studies. *In* Fisher, A.T., Urabe, T., Klaus, A., and the Expedition 301 Scientists, *Proc. IODP,* 301: College Station, TX (Integrated Ocean Drilling Program Management International, Inc.). **doi:10.2204/iodp.proc.301.102.2005**

Table T1. Expedition 321T cementing operations summary.

Integrated Ocean Drilling Program - Phase II
Expedition 321T - Juan de Fuca (JDF) Cementing

Summary of Operations Statistics

(22 June 2009 to 5 July 2009)

Data Entry Cell | Calculated Cell | Calculated Cell

Expedition Summary	Days	Percent
Total Days in Port	1.57	12.5%
Total Days In Transit	6.73	53.3%
Total Days on Site	4.31	34.2%
Total Days	12.61	100.0%

Breakdown of Operating Days On-Site	Days	Percent
Drilling & Coring	0.47	10.9%
Logging & Downhole	0.00	0.0%
Reentry Cone/Casing/Cementing	0.78	18.1%
Hole Trouble/Remedial Action	0.00	0.0%
Engineering/Cork/Completion	0.00	0.0%
Lost Time (WOW/Ice or Breakdown)	0.00	0.0%
Miscellaneous/Other	3.06	71.0%

Other Expedition Statistics	
Total Distance Traveled (Nm):	1351
Average Transit Speed (knots):	8.3
Total Number of Sites:	1
Total Number of Holes:	2
Total No. of Cores Attempted:	0
Total Interval Cored (meters):	0
Total Core Recovery (meters):	0.00
Percent Core Recovery:	N/A
Total Interval Drilled (meters):	0.0
Total Penetration (meters):	0.0
Max Penetration (meters):	0.0
Min Penetration (meters):	0.0

Dynamic Positioning (DP) Statistics		
No. Moves Between Sites in DP Mode:	0	
Total VIT Deployments	TBD	DP on
No. of Positioning Beacons Used:	O	GPS Only
No. of Beacon Deployments:	O	
No. of Lost Beacon's:	N/A	
Total Number of Reentries:	3	
Max Sea Floor Depth (m to DES):	2667.8	
Min Sea Floor Depth (m to DES):	2667.3	

Figure F1. Maps showing IODP Expeditions 301 and 321T field area. **A.** Index map showing locations of ODP Leg 168 drilling transect (thick black line), IODP Expedition 301 work area (gold star), Juan de Fuca Ridge, and nearby continental areas. Inset profile shows locations of Leg 168 sites. **B.** Regional bathymetric map showing locations of ODP Holes 1026B and 1027C and IODP Site U1301. **C.** Map of basement relief created from bathymetric and seismic data, showing locations of ODP and IODP drill sites. Areas marked in white are present-day basement outcrops. Figure modified from Zühlsdorff et al. (2005).

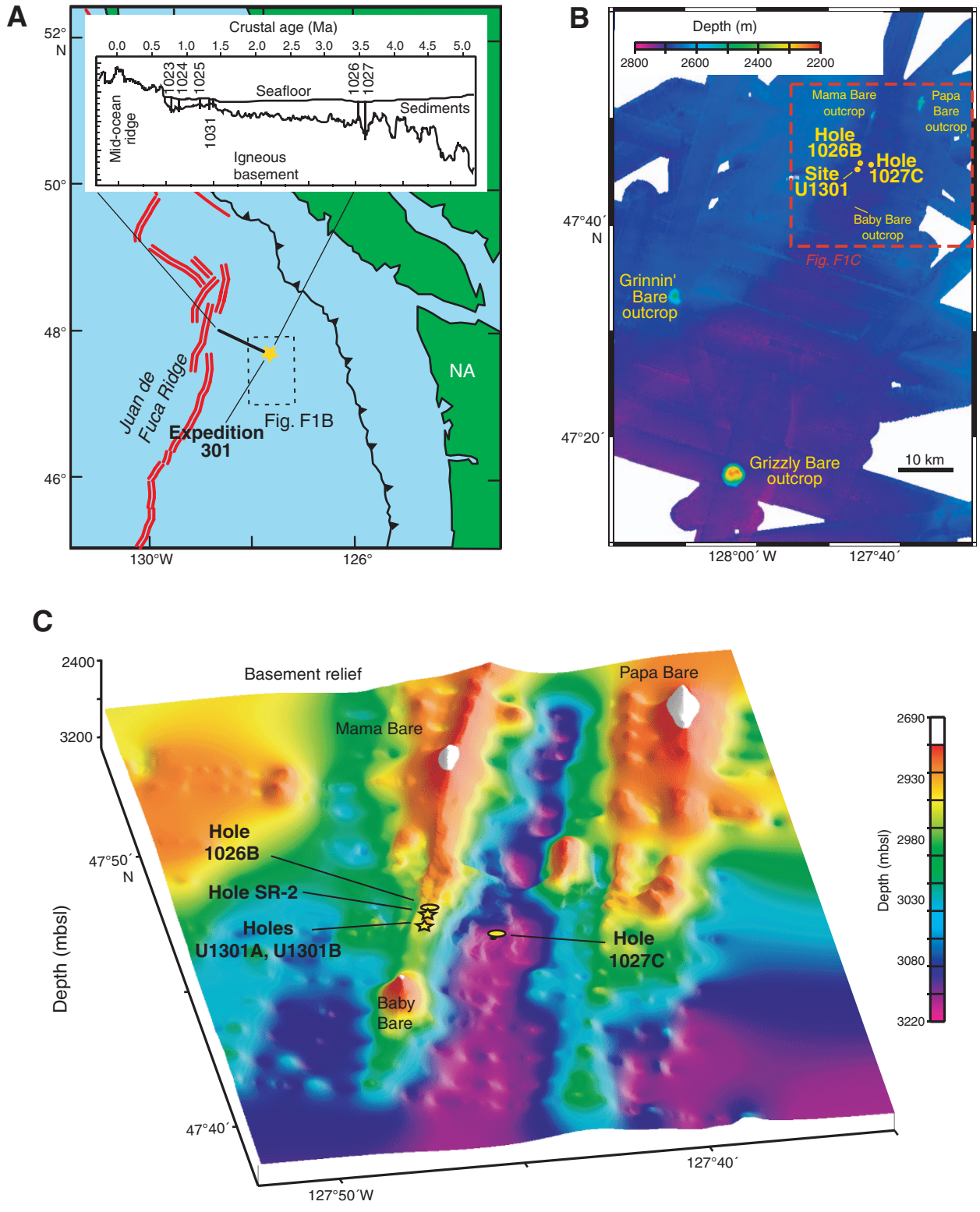

Figure F2. Summary of basement and borehole observatory characteristics in Holes U1301B and U1301A (modified from Fisher et al., 2008). **A.** Basement recovery, primary lithology, borehole size, and bulk density from Hole U1301B (Fisher, Urabe, Klaus, et al., 2005). Basement cores were collected from ~355 to 575 mbsf (~100 to 320 msb), with recovery indicated by black intervals next to depth column. Borehole diameter was measured with wireline caliper tool. Bulk density log (line) and analyses of pieces of rock (diamonds) show evidence for considerable porosity in uppermost basement and a layered basement structure, especially below 470 mbsf (220 msb), with alternating more and less dense intervals. Horizontal bands indicate depths where subseafloor borehole observatory (CORK) casing packers and the drill string packer used for hydrogeologic testing were set against the borehole wall. **B.** Casing and CORK configurations in Holes U1301B and U1301A. Observatories in both holes lack a critical seal between 0.27 m and 0.41 m casing, which is needed to prevent the flow of cold bottom water into shallow basement or the flow of warm formation fluid out into the ocean. More information on CORK and hole configurations is available in Fisher, Urabe, Klaus, et al. (2005) and Fisher et al. (2005). TD = total depth. (**Figure shown on next page.**)

Figure F2 (continued). (Caption shown on previous page.)

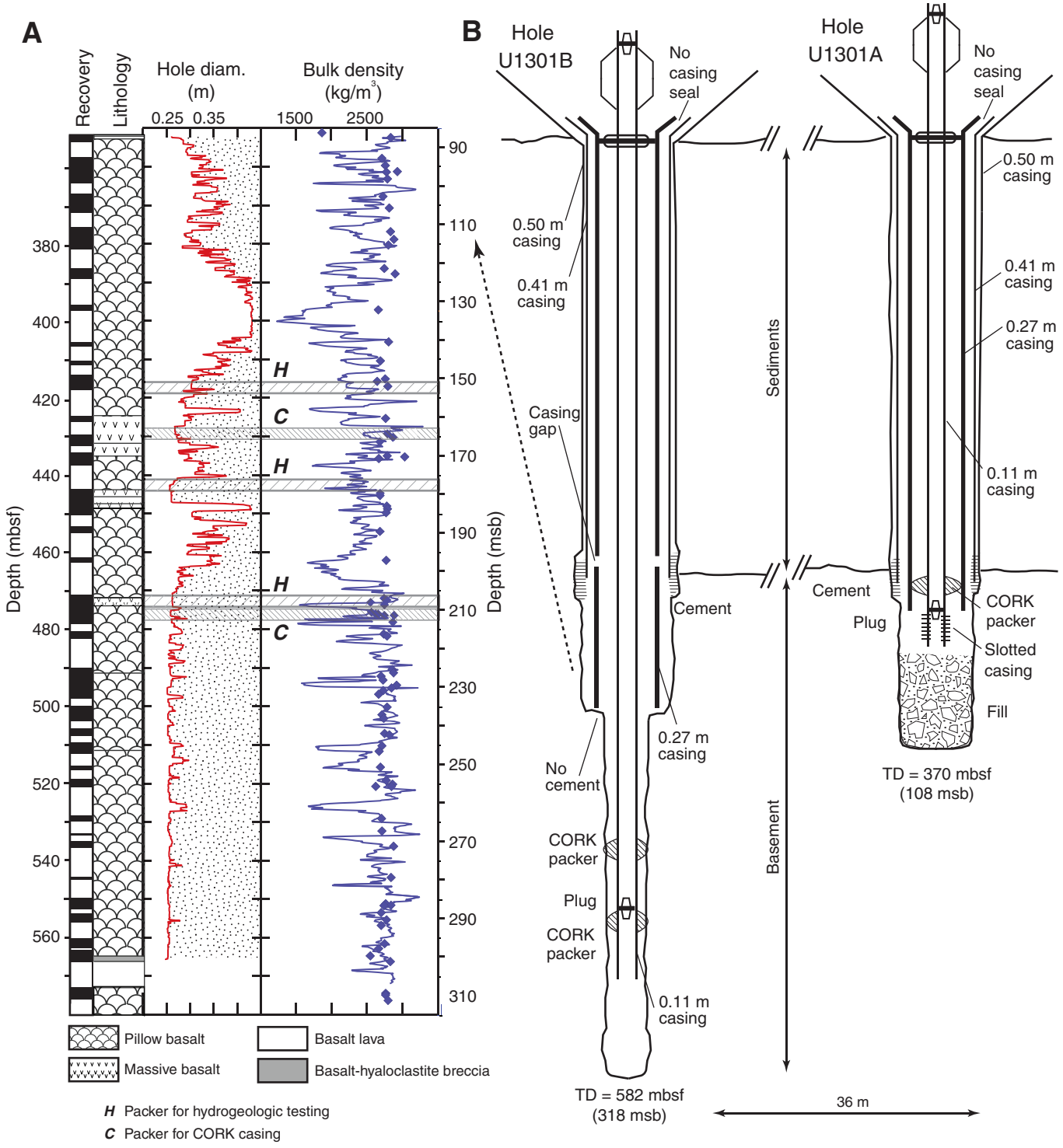

Figure F3. Photographs of Hole U1301A and U1301B CORK configurations taken with the submersible *Alvin* in summer 2008. **A.** Hole U1301A has an older generation of ROV platform, which is solid metal perforated by eight 12 inch diameter holes. Screens were welded behind the holes during Expedition 301 prior to platform deployment. **B.** Hole U1301B has a screen platform with one radial section cut out. Inset shows detail of platform cutout.

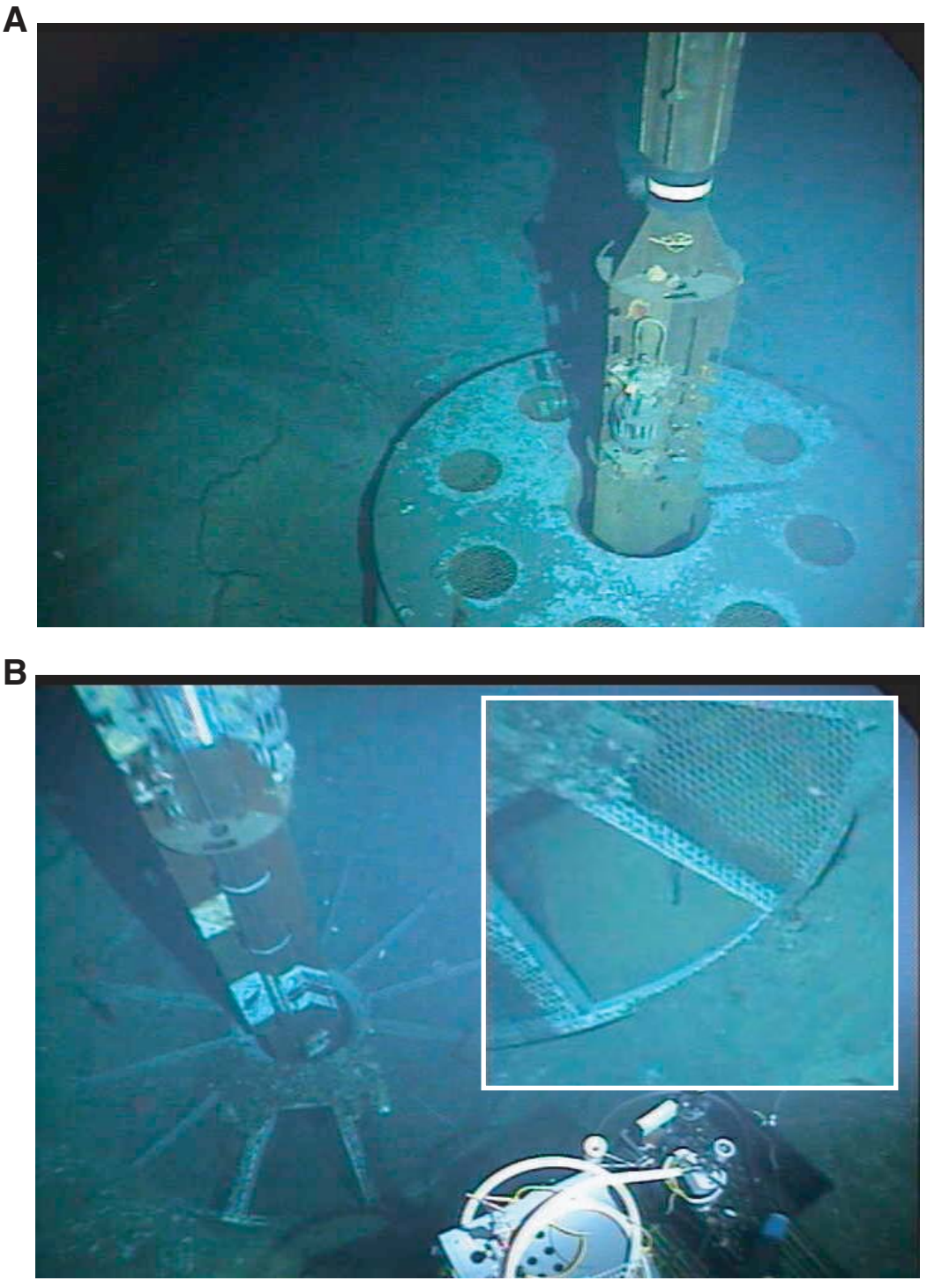

Figure F4. Photograph of cement stinger inserted into Hole U1301B platform, prior to the start of cementing operations. CORK well head is visible to the left of the cement stinger.

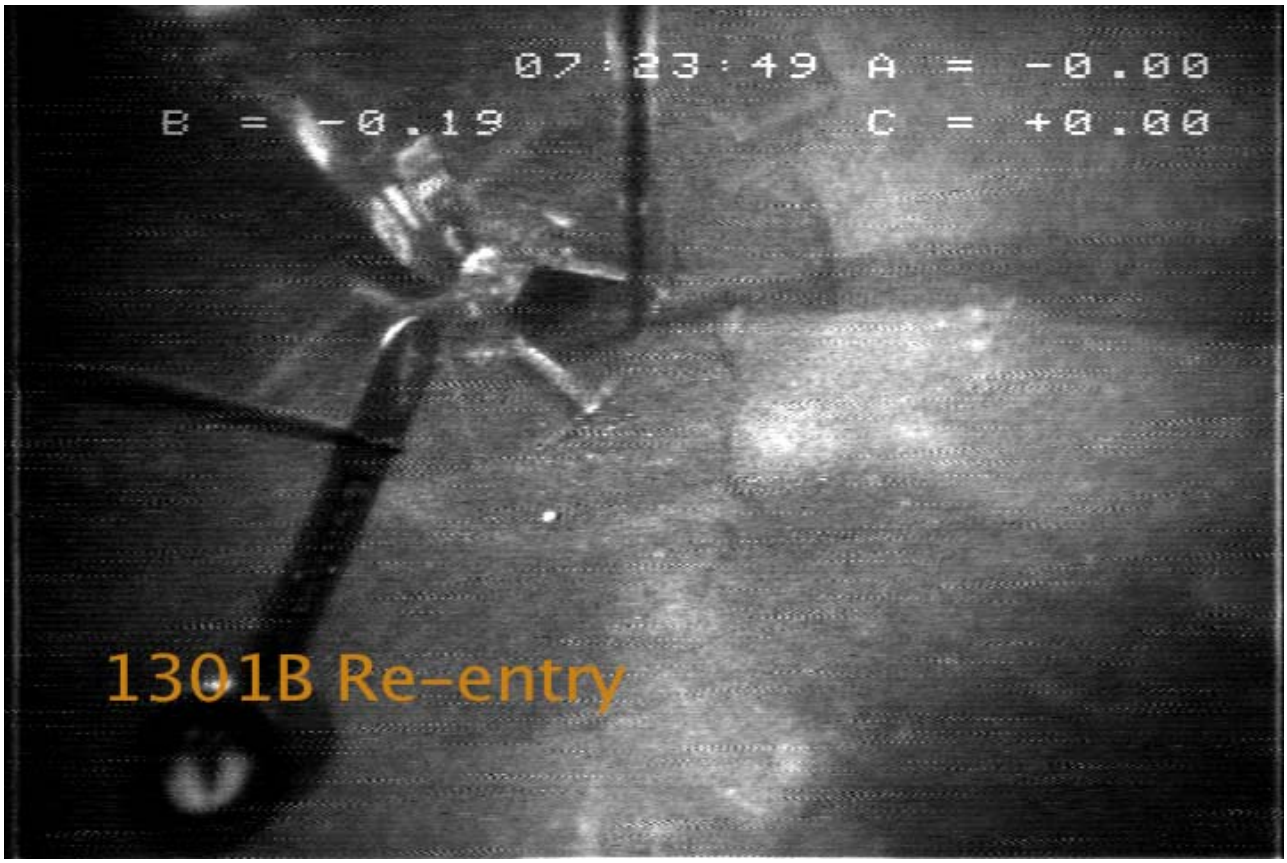

Figure F5. Photograph of cement stinger inserted into Hole U1301A platform, prior to the start of cementing operations. CORK well head is visible to the right of the cement stinger.

Figure F6. Photograph of completed cement job, Hole U1301B. Platform is barely visible, and cement can be seen to have completely filled the cone and flowed out onto the surrounding seafloor.

Figure F7. Photograph of completed cement job, Hole U1301A. Platform is not visible, having been completely covered by cement.