# Integrated Ocean Drilling Program
# Expedition 301 Preliminary Report

## Juan de Fuca Hydrogeology

## The hydrogeologic architecture of basaltic oceanic crust: compartmentalization, anisotropy, microbiology, and crustal-scale properties on the eastern flank of Juan de Fuca Ridge, eastern Pacific Ocean

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# ABSTRACT

Integrated Ocean Drilling Program Expedition 301 is the first part of a two-expedition, multidisciplinary program to evaluate the formation-scale hydrogeologic properties within oceanic crust; determine how fluid pathways are distributed within an active hydrothermal system; establish linkages between fluid circulation, alteration, and microbiological processes; and determine relations between seismic and hydrologic anisotropy. During Expedition 301, we replaced one existing borehole observatory penetrating the upper oceanic crust on the eastern flank of the Juan de Fuca Ridge and established two new observatories penetrating to depths as great as 583 meters below seafloor or 318 m into basement. We sampled sediments, basalt, fluids, and microbial samples; collected wireline logs; and conducted hydrogeologic tests in two basement holes. Shore-based studies will help us to learn where microbiological communities live in the crust and how these communities cycle carbon, alter rocks, and are influenced by fluid flow paths.

During a follow-up expedition, we will conduct the first multidimensional, cross-hole experiments attempted in the oceanic crust, including linked hydrologic, microbiological, seismic, and tracer components. After completion of drillship operations, we will initiate multiyear tests using the new network of subseafloor observatories, allowing us to examine a much larger volume of the crustal aquifer system than has been tested previously. By monitoring, sampling, and testing within multiple depth intervals, we can evaluate the extent to which oceanic crust is connected vertically and horizontally; the influence of these connections on fluid, solute, heat, and microbiological processes; and the importance of scaling on hydrologic properties. This work is helping us to understand the nature of permeable pathways, the depth extent of circulation, the importance of permeability anisotropy, and the significance of hydrogeologic barriers in the crust.

# INTRODUCTION

Thermally driven fluid circulation through oceanic crust profoundly influences the physical, chemical, and biological evolution of the lithosphere and ocean. Although much work over the last 30 years has focused on hot springs along mid-ocean ridges, global advective heat loss from ridge flanks (crust older than 1 m.y.) is more than three times that at the axis (e.g., Parsons and Sclater, 1977; Stein and Stein, 1994), and the ridge-flank mass flux is at least 10 times as large (Mottl and Wheat, 1994). Ridge-flank circulation generates enormous solute fluxes; alters sediments and basement rocks; supports a vast subseafloor biosphere; and influences thermal, mechanical, and chemical processes as plates are subducted (e.g., Alt, 1995; Cowen et al., 2003; Elderfield and Schultz, 1996). These processes cross-cut all three primary themes motivating the Initial Science Plan for the Integrated Ocean Drilling Program (IODP). It is appropriate that the first expedition of IODP launches a new class of experiments designed to resolve the fundamental nature of fluid pathways in the crust and the dynamic influences of fluid circulation on Earth evolution.

Despite the importance of ridge-flank hydrothermal processes, little is known about the distribution of hydrologic properties; the extent to which crustal compartments are well connected or isolated (laterally and with depth); linkages between fluid circulation, alteration, and geomicrobial processes; or quantitative relations between seismic and hydrologic properties. IODP Expedition 301 explored these properties, processes, and relations and will help to address topics of fundamental interest to a broad community of hydrogeologists working in heterogeneous water-rock systems: the nature and significance of scaling phenomena and the applicability of equivalent porous-medium representations of discrete fracture-flow processes.

IODP Expedition 301 benefits from operational and scientific achievements of the Ocean Drilling Program (ODP), particularly ODP Leg 168, which focused on hydrothermal processes within uppermost basement rocks and sediments along an age transect across a young ridge flank (Davis, Fisher, Firth, et al., 1997). Leg 168 emphasized the fundamental physics and chemistry of ridge-flank hydrothermal circulation, and the associated alteration of sediments and shallow basement, through sampling, downhole measurements, and post-drilling observations within the upper tens of meters of basement. Although it was extremely successful (or perhaps *because* it was so successful), ODP Leg 168 raised many new questions about hydrothermal properties and processes within ridge flanks. IODP Expedition 301 focuses on the eastern end of the Leg 168 drilling transect, leveraging and extending results from ODP Leg 168 in three primary ways:

- Through deeper drilling, coring, and downhole measurements within basement;
- By expanding the multidisciplinary mixture of ridge-flank research in a single area, including microbiological and biogeochemical analyses of sediments and basement rocks; and
- By establishing a three-dimensional network of borehole observatories, to be used in long-term, crustal-scale experiments.

IODP Expedition 301 comprises the first part of a two-expedition program; it is important to understand the complete experimental plan to place Expedition 301 planning, operations, and results in context. A second IODP expedition to this area (to be scheduled) will add two additional boreholes and observatories to the three-dimensional network and will initiate a series of controlled, multidisciplinary, cross-hole experiments. The complete program of drilling, sampling, measurements, observatory installation, and experiments was divided into two expeditions for several operational and scientific reasons, as described below, but the first expedition was also designed to generate high-quality samples and data, to initiate a new phase of passive monitoring within ridge-flank basement rocks, and to address outstanding hydrogeologic and related questions.

The primary goals of Expedition 301 included replacement of two borehole observatory systems established at Sites 1026 and 1027 during Leg 168 and establishment of two new observatories extending up to 400 m into basement at Site U1301 (Second Ridge) (Figs. **F1, F2**). This effort dovetails with plans under way to develop a cabled network of seafloor observatories across the Juan de Fuca Plate, which should facilitate active and passive monitoring experiments for the next 10–20+ y. Other Expedition 301 goals included coring, sampling, and short-term downhole measurements in basement and limited collection of high-quality advanced piston corer (APC) sediment cores at Site U1301. Secondary objectives included drilling, coring, and sampling one or more holes in a region of known hydrothermal seepage at First Ridge (Figs. **F1, F2**), where sediment thins above a buried basement high, and drilling, coring, and sampling a much thicker sediment section to the east, Deep Ridge (Figs. **F1, F2**), where basement temperatures and alteration should be more extreme. We achieved all of our primary goals during Expedition 301, with the exception of replacing the borehole observatory in Hole 1027C (Table **T1**). This observatory can be replaced during the follow-up expedition.

# BACKGROUND

## Geological Setting

The Endeavour segment of the Juan de Fuca Ridge (JFR) generates lithosphere west of North America at ~3 cm/y (Davis and Currie, 1993; Johnson and Holmes, 1989). Topographic relief produces barriers to turbidites from the continental margin, resulting in the accumulation of sediment and burial of the eastern flank of the JFR within a region known as Cascadia Basin (Figs. **F1, F2**). Sedimentation rates were very high in Cascadia Basin during Pleistocene sea level low-stands, when the continental shelf was largely exposed and rivers and estuaries delivered large sediment fluxes directly to the deep ocean (Davis, Fisher, Firth, et al., 1997; Underwood et al., in press). This resulted in burial of oceanic basement rocks under thick sediments throughout much of the basin at an unusually young age. Oceanic basement is exposed to the west, where the crust is very young, and the sedimented seafloor is relatively flat to the east, except over (relatively rare) seamounts and other outcrops found near the eastern end of the Leg 168 transect (Figs. **F1, F3**). Basement relief is dominated by linear ridges and troughs oriented subparallel to the spreading center and produced mainly by faulting, variations in magmatic supply at the ridge, and off-axis volcanism (Davis and Currie, 1993; Kappel and Ryan, 1986). Basement relief is relatively low (±100–200 m) near the ridge and higher (±300–700 m) to the east. Low-permeability sediment limits advective heat loss across most of the ridge flank, leading to strong thermal, chemical, and alteration gradients in basement.

The study area contains structural features common to most ridge flanks: extrusive igneous basement overlain by sediments, abyssal hill topography, high-angle faulting, and basement outcrops. Although the work sites may not be typical of all ridge-flank settings (higher than average sedimentation rate, younger buried basement, and stronger lateral gradients in temperature), the field area is ideal, in part because of these extreme conditions. High gradients result in strong signals that rise above natural and experimental noise. The high sedimentation rate allows us to work on crust that is much younger than we could study otherwise, providing indications of ridge-crest as well as ridge-flank properties and allowing study of sites in different hydrologic settings that are close together. Because many experiments have been completed in this area (seismic, thermal, geochemical, and surface/borehole), we can “calibrate” and compare interpretations based on different methods.

## Site Survey for IODP Expedition 301

Marine geophysical surveys in this region began in the 1950s and 1960s, but the first detailed studies of this ridge flank intended to resolve the existence and influence of hydrothermal circulation were completed in mid- to late 1980s (Davis et al., 1989, 1992; Mottl and Wheat, 1994; Rohr, 1994). These studies included single- and multichannel seismic, gravity, magnetics, heat flow, and coring (with associated sediment and pore fluid analyses). Becker et al. (2000) show results from a 1992 *John P. Tully* survey that collected seismic data in the Second Ridge area, with an emphasis on nearby basement outcrops. Seismic results from two later surveys are summarized by Rosenberger et al. (2000). Davis et al. (1997a) compiled heat flow data collected between 1978 and 1995.

Extensive site surveys in support of IODP Expedition 301 were completed by the *Sonne* and the *Thomas G. Thompson* in 2000 (ImageFlux and RetroFlux Expeditions, respectively), and an additional seismic line across the Deep Ridge sites was collected during another expedition in 2002. Example seismic lines illustrate key features of sediments and uppermost basement at IODP Expedition 301 sites (Fig. **F4**). The Second Ridge area is characterized by typical basement relief of 300–400 m, usually overlain by 250–600 m of sediment. To the north and south of Expedition 301 sites there are basement outcrops where basalt edifices rise above the seafloor (Davis et al., 1992; Mottl et al., 1998). Seismic data show that basement relief results in part from high-angle faults with offsets of tens to >100 m (e.g., Fig. **F4A,** common depth points [CDP] 570 and 600; Fig. **F4B,** CDPs 980 and 1020). There also appear to be at least two kinds of constructional structures on the top of basement throughout this area. First, there are small buried basement highs onto which sediment was subsequently draped. (Fig. **F4A,** CDP 450; Fig. **F4B,** CDP 840). There are also places where the uppermost basement reflector is unusually strong and flat. Becker et al. (2000) identified several such features in seismic lines crossing the Baby Bare outcrop and suggested that they were sills, and similar features appear in seismic data west of Site 1026 (Fig. **F4B,** CDPs 1100–1140).

The sediment section shows two main zones with distinctive seismic characteristics. The uppermost 200–300 ms two-way traveltime (TWT) include prominent subhorizontal reflectors that clearly illustrate the geometry of distributary channels for turbidites that flowed from the north. Sites 1026 and U1301 are located near the western edge of one such channel, which thickens considerably over Site 1027. There are patches of acoustically incoherent sediment within these channels, where subhorizontal layering is disrupted, and high-angle, small-offset faults that are present throughout the uppermost sediment (e.g., Fig. F4A, CDP 600). The lowermost 100–200 ms TWT of sediment is generally acoustically transparent, particularly where basement is deepest. Weak layering within this section onlaps and often pinches out against basement highs.

## Selected Results from ODP Leg 168

An 80 km transect comprising 10 sites was drilled on the eastern flank of the JFR during ODP Leg 168 (Fig. F2). These sites were organized into three main ridge-flank environments. The western end of the drilling transect spanned a transition between hydrologically open and more isolated crust, documenting lateral gradients in basement temperatures, water compositions, and crustal physical properties. The rough basement area at the eastern end of the transect included considerable basement relief, large variations in sediment thickness, and isolated outcrops. The central part of the Leg 168 transect included sites located farther from regions of known basement exposure, where sediment thickness is more uniform.

Sediments recovered during Leg 168 included mainly sandy and silty turbidites and hemipelagic mud, with carbonate-rich intervals found just above basement at most sites (Davis, Fisher, Firth, et al., 1997; Underwood et al., in press). Sediments were generally unaltered by underlying hydrothermal processes, except for relatively subtle indications close to basement (Buatier et al., 2001). Shallow basement rocks were mainly fresh to altered pillow lavas and massive flows having a tholeiitic composition, but hyaloclastite breccia and a diabase sill were recovered at Sites 1026 and 1027, respectively. The extent of alteration generally increased from west to east, along with crustal age and basement temperature, and there was no indication that basement rocks had experienced temperatures in excess of those observed during Leg 168 (Giorgetti et al., 2001; Hunter et al., 1999; Marescotti et al., 2000). Alteration minerals included clays, carbonates, zeolites, and sulfides.

Heat flow and upper basement temperatures along the Leg 168 drilling transect show several notable trends (Davis and Becker, 2002; Davis et al., 1999; Davis, Fisher, Firth, et al., 1997; Fisher et al., 1997; Pribnow et al., 2000). Heat flow values determined during Leg 168 increase over the western 20 km of the transect, from Site 1023 to Sites 1030 and 1031 (Fig. F2). These values vary from well below to well above standard reference curves for conductively cooling lithosphere (e.g., Parsons and Sclater, 1977; Stein and Stein, 1994). Heat flow in the middle and eastern end of the drilling transect is broadly consistent with reference curves, but local (sometimes large) variations in heat flow result from vigorous hydrothermal circulation within rugged basement below the seafloor (Fig. **F2B**). This circulation locally homogenizes uppermost basement temperatures such that seafloor heat flow patterns follow basement relief (e.g., Davis and Becker, 2002; Davis et al., 1997b; Spinelli and Fisher, 2004). Upper basement temperatures tend to increase monotonically from west to east along the drilling transect, from ~15°C at Site 1023 to ~64°C at Sites 1026 and 1027 (Fig. **F2B**) (Davis and Becker, 2002).

Thermal observations along the Leg 168 transect may be interpreted to indicate that the dominant direction of fluid flow is from the west to the east (Davis et al., 1999; Davis, Fisher, Firth, et al., 1997; Stein and Fisher, 2003), but pore fluid samples obtained from sediments collected immediately above basement, in combination with samples from basement boreholes and shallow sediment cores, demonstrate that this interpretation is not consistent with observations (Fig. **F2C**). The western end of the drilling transect shows increasing alteration from west to east, consistent with rising temperatures in upper basement, but fluid recovered from Sites 1030 and 1031 is more altered than would be predicted on the basis of inferred temperatures in upper basement. In fact, this fluid has a geochemical signature consistent with alteration at 65°–70°C, much like the fluid recovered from Sites 1026 and 1027 and from springs on Baby Bare outcrop (Elderfield et al., 1999; Monnin et al., 2001; Mottl et al., 1998; Rudnicki et al., 2001; Wheat et al., 2000, 2002, 2003; Wheat and Mottl, 2000).

In addition, fluid samples that were subjected to $^{14}C$ analysis demonstrated that, although there is a progression in fluid age from west to east along the western end of the Leg 168 transect, fluids from Site 1030 are younger than those to the west, and fluids from Site 1026 are younger still (Fig. **F2C**) (Elderfield et al., 1999). It is not possible for waters recharging the basement aquifer near the western end of the Leg 168 transect to gain "youth" as they travel to the east and become increasingly altered; another source of hydrothermal recharge is required. Wheat et al. (2000) showed that there is geochemical evidence for *along-strike* (south-to-north) fluid transport in basement. Fisher et al. (2003) presented thermal data and calculations based on the hydrogeologic properties of basement rocks and sediment and showed that recharge of Baby Bare (and Site 1026) basement fluids most likely occurs ~50 km to the south, through Grizzly Bare outcrop (Fig. **F3A**).

Interpretation of fluid ages and rates of fluid flow in basement is difficult on the basis of $^{14}C$ data alone because interpretation of radiotracer data from heterogeneous water-rock systems requires application of enormous corrections to account for diffusive and dispersive losses (e.g., Bethke and Johnson, 2002; Fisher, 2004; Fisher et al., 2003; Sanford, 1997; Stein and Fisher, 2003). Actual particle velocities within ridge-flank hydrothermal systems may be 100–10,000 times greater than indicated by simple plug-flow considerations of apparent fluid ages.

Collectively, geochemical data collected along the Leg 168 transect suggest that there are distinct “regions” of hydrothermal circulation within the upper basement and that fluids within each of these regions are hydrogeologically isolated from each other. The first region contains relatively young water at the western end of the drilling transect that has reacted minimally with the formation at 15°–40°C. This fluid becomes older, warmer, and more reacted to the east. The second region is associated with the first buried basement ridge below Sites 1030 and 1031. Fluid from this crustal region reacted with basement at temperatures of 65°–70°C, but the fluid must have cooled during or after ascent from depth because upper basement temperatures are only 40°C. This fluid is young relative to the less reacted fluid to the west. The third chemically distinct region is within crust below Sites 1026 and 1027. This younger fluid mixes vigorously within upper basement at temperatures near 65°C.

Although there was no wireline logging in basement during Leg 168 because penetration was too shallow, borehole packer experiments and analyses of open-hole thermal data were completed to determine local hydrogeologic properties (Becker and Davis, 2003; Becker and Fisher, 2000; Fisher et al., 1997). These experiments indicated near-borehole formation permeabilities of $10^{-14}$ to $10^{-10}$ $m^2$, with the highest permeabilities determined for the youngest sites, at the western end of the drilling transect. The data are consistent with the rest of the global seafloor data set and also suggest two notable trends (Fig. F5): a decrease in uppermost basement permeability with increasing age and spatial scaling of permeability estimated using different methods (Becker and Davis, 2003; Fisher, 1998, in press).

Borehole (CORK) observatories were installed during Leg 168 at western Sites 1024 and 1025 and at eastern Sites 1026 and 1027 (Davis and Becker, 2002, 2004). These systems were instrumented to monitor borehole fluid pressure and temperature and to collect long-term fluid samples. Consideration of borehole fluid responses to tidal pressure variations and to regional tectonic events suggests that basement around the boreholes has even higher effective permeability than suggested by packer experiments and thermal logs (Davis et al., 2000, 2001). Because the different estimates of formation permeability were made using different methods and assumptions, it remains unclear if the apparent scaling tells us something important about the nature of basement permeability or is an artifact. This question is being addressed by IODP Expedition 301 and related experiments.

Similarly high permeabilities, on the order of $10^{-9}$ $m^2$, were inferred on the basis of steady-state numerical models that used a conductive proxy for coupled heat-fluid flow and extrapolation of relations between permeability and mixing efficiency at lower permeabilities (Davis and Becker, 2002; Davis et al., 1997b; Wang et al., 1997). Fully coupled, transient models of ridge flank circulation have shown that permeabilities this high need not be present throughout the upper crust; if fluid flow is highly channeled (Tsang and Neretnieks, 1998), considerable efficiency in heat transport can be achieved by advection through a small fraction of the crust (Fisher and Becker, 2000; Fisher et al., 1994; Spinelli and Fisher, 2004). In fact, having very high permeability distributed pervasively throughout the upper oceanic crust actually limits the efficiency of lateral fluid flow in transporting heat (Davis et al., 1999; Fisher and Becker, 1995; Rosenberg et al., 2000).

Hole 1026B yielded some of the first direct microbiological observations of ridge-flank fluids. Rock and fluid samples collected during Leg 168 indicated the possible presence of microbes (Bach and Edwards, 2003; Fisk et al., 2000), and a "BioColumn" experiment assessed microbial biomass and diversity in fluids venting from the CORK observatory. Cells collected from the BioColumn included bacteria and archaea, comprising nitrate reducers, thermophilic sulfate reducers, and thermophilic fermentative heterotrophs (Cowen et al., 2003). These tantalizing results encouraged study of the basement biosphere during IODP Expedition 301.

# SCIENTIFIC AND OPERATIONAL OBJECTIVES OF EXPEDITION 301

This section highlights the fundamental scientific goals of IODP Expedition 301 and related experiments. Some of the discussion includes operations that are to take place during future drilling and submersible/remotely operated vehicle (ROV) expeditions. This information is included so that the rationale for Expedition 301 operations, and the extent of our successes, will be clear.

Despite extensive survey and drilling work in the eastern flank of JFR prior to Expedition 301, we began the expedition with little information on the geological nature of permeable pathways, the depth extent of fluid circulation, the magnitude of permeability anisotropy, or the significance of hydrogeologic barriers in the crust. We knew that the upper oceanic crust is home to diverse microbiological communities, but we knew little about their populations or ecology or how their distribution relates to primarily crustal stratigraphy, fluid flow paths, water chemistry, or rock alteration. We did not know the concentrations and nature of nonliving organic matter within crustal fluids or how this material influences and is influenced by ocean carbon cycling. We did not understand the scales over which solute transport occurs in oceanic basement rocks or how transport and mixing are influenced by crustal structure and fabric. We did not know how to relate seismic velocities and velocity anisotropy to hydrogeologic properties.

Although some of these topics were addressed during ODP Leg 168 and related surveys and experiments, earlier drilling included penetration of only the uppermost few tens of meters of basement, leaving many questions unresolved. For example, CORK observatories installed at Sites 1026 and 1027 allow determination of upper basement temperatures and fluid pressures, but despite evidence for extremely rapid fluid convection in basement, it was not possible to determine if the dominant fluid flow direction is from Site 1026 to 1027, in the opposite direction, or perhaps perpendicular to both sites. Work during IODP Expedition 301 and related surveys and experiments will help resolve this quandary and will address all of the topics listed above.

Basement work at Second Ridge sites (1026, 1027, and U1301) was given the highest priority and focused on numerous questions, including:

- What is the primary lithostratigraphic and hydrogeologic structure of the upper 400 m of basement?
- What is the nature and influence of crustal alteration, and how is it related to fluid flow and associated processes?
- How have tectonic and magmatic processes contributed to formation and hydrogeologic evolution of the crust at Second Ridge?
- What are typical temperatures in the upper 400 m of basement, and what do these temperatures indicate with respect to the vigor and directions of circulation?
- How does fluid chemistry relate to stratigraphy and alteration history, and are there distinct hydrogeologic compartments distributed vertically within upper basement?
- What microbiological communities exist within distinct crustal intervals, what is their ecology, and how are they related?

- How are solutes transported through the upper 400 m of basement, and what is the effective porosity of fluid conduits?
- What are the lateral and vertical gradients in pressure, temperature, and formation fluid chemistry along and across the Second Ridge?

Successfully addressing these and related questions required a combination of conventional and nonstandard scientific drilling approaches. In the rest of this section, we highlight unusual aspects of Expedition 301 and related experiments. Other components of the scientific program that are essential to the overall effort (e.g., petrographic analysis, inorganic geochemistry, and measurements of sediment temperature) are well established within the scientific drilling community and are not discussed. Some of the discussion includes work to be done during future drilling or submersible operations; this information is presented to provide context for planning and prioritization during Expedition 301 and beyond.

## Hydrogeologic Testing

Two primary kinds of active hydrologic tests were completed prior to Expedition 301 in the Deep Sea Drilling Project (DSDP) and ODP: slug tests and injection/flow tests (Becker and Davis, 2003; Fisher, 1998). Both kinds of tests have involved a single borehole and a drill string packer. Another form of flow test involves monitoring the movement of fluid into or out of a borehole resulting from natural pressure differences, after removal of a low-permeability sediment seal (e.g., Becker and Davis, 2003; Fisher et al., 1997). During a slug test, formation pressure is abruptly modified through rapid injection of a small fluid volume, and the pressure-time response of the isolated interval allows estimation of transmissivity (T) and storativity (S). Transmissivity is hydraulic conductivity (ease of fluid flow) multiplied by aquifer thickness within a horizontal system. Storativity is a measure of aquifer and fluid compressibility within a horizontal system. Although slug tests can be used to assess transmissivity in the immediate vicinity of a borehole, they are notoriously poor at constraining storativity and are not very useful in formations that are highly permeable. Single hole injection and flow tests provide little information on storage properties, although they can be used to estimate bulk transmissivities with a radial scale that is somewhat greater than slug tests. The radius of investigation of any seafloor hydrologic test depends mainly on T and S and the duration of the test (Becker and Davis, 2003; Fisher, 1998).

CORK observations of formation pressure response to tidal forcing have also been used to estimate hydraulic diffusivity (T/S) and storativity within oceanic crust (e.g., Davis et al., 2000), but as with interpretation of packer experiments, interpretation of passive CORK observations requires assumptions regarding the hydrologic homogeneity and isotropic nature of oceanic crust, as well as the geometry of the flow system and the magnitude, timing, and location of the source function. Observational data (geological, geochemical, and geophysical) demonstrate that the oceanic crust is highly heterogeneous and anisotropic (e.g., Becker and Davis, 2003; Fisher, 2004; Fisher and Becker, 2000). Numerical models have not helped to resolve discrepancies between properties estimated using different techniques because the models themselves are highly idealized. Applying a suite of techniques is the best way to assess the true nature of crustal permeability, including scaling phenomena (Fig. **F5**), and the validity of simplified representations of these systems.

Two ODP expeditions, Legs 169 and 171A, completed uncontrolled (and largely unplanned) cross-hole experiments using CORK observatories (Fouquet, Zierenberg, Miller, et al., 1998; Moore, Klaus, et al., 1998). On each of these expeditions, previously installed observatories were used to monitor formation fluid pressure tens of meters or more from a site of active drilling. IODP Expedition 301 was the first to be designed with cross-hole experiments being a primary goal. Through use of multilevel CORK observatories, we will isolate and monitor discrete depth intervals in basement, allowing assessment of both vertical and horizontal hydrogeologic connections between sites. Because we anticipated very high basement permeabilities and the perturbation resulting from drilling and observatory installation will take many months to dissipate (Davis and Becker, 2004), the complete cross-hole experiment can not be run until after Expedition 301. This will allow pressure, chemical, and thermal equilibration of the formation below newly installed CORKs so that small changes resulting from active experiments can be readily detected.

During a future drilling expedition, a 24 h packer test will be initiated in a borehole drilled at Site SR-2, between Sites 1026 and U1301 on Second Ridge. This 24 h packer test will be ~50 times longer than any injection test into oceanic crust prior to Expedition 301. Based on a range of apparent bulk properties from packer tests, flow tests, tidal response, and numerical models (Becker and Davis, 2003; Becker and Fisher, 2000; Davis and Becker, 2002; Davis et al., 2000; Fisher et al., 1997), a readily measurable pressure response should be apparent at Sites 1026, 1027, and U1301 (Fig. **F6**). By subsequently waiting an additional 6–12 months for borehole equilibration, then opening one or more vent valves in a Site SR-2 CORK, we can release overpressured formation fluid for a year or more. This will initiate a free flow ("artesian") well test that will allow an even larger-scale assessment of crustal properties (Figs. F5, F6).

The results of these experiments will have implications well beyond oceanic crust, as there is an ongoing debate concerning the scaling of hydrogeologic properties within heterogeneous systems (Butler and Healy, 1998; Clauser, 1992; Neuman and Di Federico, 2003; Renshaw, 1998; Rovey and Cherkauer, 1995). Results of cross-hole testing in basement holes, combined with other observations and modeling results, can also be used to test equivalent-porous-medium and other representations of the fractured upper crust. The seafloor is an ideal place to address these issues because a single test can be run for a very long time, effectively delineating the scale-dependence of hydrologic properties using a single measurement method. Such tests are generally not possible on land because of logistical and environmental concerns and a lack of demonstrated horizontal continuity. Generating cross-hole data within seafloor boreholes will also allow application of models developed for use in fractured aquifers (Barker, 1988; Moench, 1984) that have not previously been applied to the seafloor.

## Microbiological Analyses

Based on estimates of prokaryotic biomass in ODP sediment cores (Fig. F7), it has been suggested that the marine subseafloor biosphere is enormous, perhaps exceeding the cumulative biomass of all other ecosystems on Earth (Parkes et al., 1994; Whitman et al., 1998). This hypothesis is compelling, but it remains highly speculative, as it is based on global extrapolations from marine sediments at a relatively small number of sites. Extrapolation of microbiological conditions and densities from the sediment section into basement is also problematic. Cell densities in basement are likely to be low where fluids are old and carbon and nutrient sources are limited, but ridge-flank locations where basement fluids are young and nutrients are abundant might support considerably greater biomass. Also, the size of the subseafloor microbial biosphere does not equate to activity or importance. Cell-count studies in sediments have revealed cell densities exceeding $10^5$/mL, but it is difficult to distinguish living cells from inactive or dead ones. The size of the subseafloor biosphere also tells us little about the magnitude of biogeochemical fluxes into or out of the system.

Little is known about microbial community composition and microbial metabolism in hydrothermally active ridge flanks. The importance of thermal, lithologic, hydrogeological and geochemical controls, and relations between sediment- and basement-hosted communities remains to be determined. Can cell-density trends from marine sediments be extrapolated into basement, or do cell densities increase (or decrease) rapidly once hydrologically active intervals are encountered? The only way to address these questions is through careful sampling and monitoring of sediments, basement rocks, and pore fluids. Five primary techniques are being used to assess the microbiological state of subseafloor environments: (1) total cell counts, (2) cultivation experiments, (3) fluorescence in situ hybridization (FISH), (4) molecular biological techniques based on ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) sequences, and (5) in vitro rate measurements of biological activity.

Recovering pristine formation fluids from oceanic basement is challenging because any formation having significant permeability will be deeply invaded by fluid pumped during drilling, casing, and other operations, including cold, oxygenated seawater and freshwater (the latter often used with drilling mud). Petroleum wells are typically "produced" for weeks or months to recover pristine formation fluids, and in fact, this is the best approach for recovering uncontaminated formation fluid and microbiological samples from a hole in permeable ocean crust. Sites 1026 and U1301 are overpressured; fluids can be extracted for days to months to years from CORKs installed at these sites, minimizing contamination, allowing assessment of population changes over time, and facilitating long-term testing.

Expedition 301 and related experiments include three principal stages of microbiological and biogeochemical study. The first stage comprises biological sampling and analysis of the sediment column, in combination with pore fluid chemistry and in situ temperature measurement, to resolve the nature of sedimentary microbiological communities (e.g., D'Hondt, Jørgensen, Miller, et al., 2003) and compare them to those found in basement. Collection of uncontaminated sediment during drilling requires care but is possible with careful planning (House et al., 2003; Smith et al., 2000). With regard to Expedition 301 objectives, studies of microbial populations in sediment are most compelling in the near-basement environment.

The second stage of microbiological studies comprises sampling and analysis of basement rock. Collection of basalt samples for direct microbiological study is also complicated by contamination, but the use of perfluorocarbon tracer (PFT) during coring operations helps to determine the more and less contaminated samples (Smith et al., 2000). Results will be compared to laboratory and in situ incubation experiments (Edwards et al., 2003, 2002) and to lithologic and alterations studies (e.g., Alt and Teagle, 1999, 2003; Fisk et al., 1998; Furnes and Staudigel, 1999), to relate basement alteration and microbial activity.

The third stage of microbiological studies involves time-series analyses of biological communities and formation fluids. Time-series studies are initiated at the time of CORK installation and will continue for years. CORK sensor strings contain continuous fluid samplers and colonization substrate. These samples will document community succession and biogeochemical response to formation recovery following drilling operations. Additional sampling will occur when we open CORK valves at Site SR-2 6–12 months after installation of these systems. This will allow attachment of sensors and samplers at the seafloor to collect time-series data, fluids, and microbiological materials from multiple depths. After completion of initial long-term flow experiments, additional seafloor valves at other sites can be opened. Through combined molecular biological and geochemical approaches and modeling (Cowen et al., 2003; Reysenbach and Shock, 2002), these samples will provide new insights into the responses of microbial ecosystems to geochemical conditions and the influence of microbial activity on fluid and basement geochemistry. Sampling and analysis of dissolved organic matter, an integrated and long-lasting signature of microbial activity, will elucidate carbon cycling in the crust. In addition to in situ incubation, flow-through incubation at the seafloor will allow system monitoring and manipulation and may allow additional options for temperature and pressure control once power to the site is provided by a (planned) cabled observatory system. This third stage of microbiological sampling and analysis is the only one that will collect high-quality samples from the hydrogeologically most important stratigraphic intervals in the crust.

## Tracer Tests

The extent of water mixing and water-rock interaction within an aquifer depends on properties such as effective porosity (the fraction of open space involved in fluid flow) and dispersivity (mechanical mixing and spreading of water and solutes by diffusion). Understanding these properties is critical to successful reactive-transport modeling and to understanding the age distribution of fluids in the seafloor, but these properties have never been assessed using tests in any DSDP or ODP hole. Effective porosity varies with flow direction in heterogeneous systems as a result of flow channeling (Tsang and Neretnieks, 1998) and must be tested directly. Like permeability, dispersivity varies as a function of test scale and must be determined at the scale of interest (Gelhar et al., 1992; Neuman, 1990; Novakowski, 1992). Tracer experiments will help to quantify rates of fluid transport in basement. We consider tracer tests in a broad sense to include the use of natural tracers, tests initiated through standard IODP operations (e.g., pumping surface seawater during drilling), and experiments involving injection and sampling of specific compounds.

Wheat et al. (2003) used major element chemistry determined on samples recovered by long-term deployments of OsmoSamplers in several sealed ODP Leg 168 boreholes to estimate the rate of equilibration of borehole fluids and flow rates within the surrounding formation. Fluid chemistry changed rapidly during the first 40–60 days after borehole sealing, as drilling fluid was replaced by formation fluid. A slower rate of chemical evolution was documented over the subsequent 1150 days as fluid continued to move through the borehole and borehole fluid in the open hole mixed vertically with fluid in the casing. Formation flow rates estimated from these experiments are comparable to estimates based on other geochemical and thermal considerations (Wheat et al., 2003).

Carbon-14 was used as a natural tracer to estimate rates of transport along the ODP Leg 168 transect (Elderfield et al., 1999), but consideration of nonconservative and mixing behavior must be included in analysis of flow within this heterogeneous crustal system (e.g., Stein and Fisher, 2003). For example, kilometer-scale tracer studies within the Mirror Lake fractured rock system suggest that effective chemical diffusivity of the rock matrix may be much greater than initially thought (Becker and Shapiro, 2000; Shapiro, 2001). Rock transmissivity is highly heterogeneous, and high effective diffusivity may result from preferential tracer migration along a few fractures, the rest being well connected only over short distances (Shapiro and Hsieh, 1998).

We have used (and will use) different tracers in different holes, and at different depth intervals so that single hole, cross-hole, and cross-level transport can be differentiated and quantified. Tracers injected during Expedition 301 included surface seawater, drilling mud, and PFT. Tracers being injected within CORK borehole observatories comprise a mixture of rare earth elements. Candidate tracers for injection at Site SR-2 during a future drilling expedition include one or more varieties of PFT, Br salts, $SF_6$, $^3He$, and rhodamine-WT, all of which are readily transported to the ship, environmentally benign, easily introduced into fluids pumped into the borehole, and detectable at low concentrations.

Tracers injected at Site SR-2 might not be sampled at Sites 1026, 1027, or U1301, but we have good reason to be optimistic for success over the long term. Fluid flow velocities in basement along Second Ridge appear to be hundreds to thousands of meters per year (Fisher et al., 2003). Similar rates were inferred in basement along the western end of the Leg 168 transect (Stein and Fisher, 2003). By isolating limited depth intervals in the CORK observatories and instrumenting them with long-term samplers, we optimize chances for detection of cross-hole fluid transport. In addition, each observatory is being used for single-hole tracer experiments (Altman et al., 2002; Novakowski et al., 1998). Interpretation of these kinds of tests, like those for cross-hole tests, is accomplished using forward and inverse modeling techniques, to obtain a match to the observed solute-time history (Becker and Shapiro, 2000; Clemo and Smith, 1997). Future tracer experiments can be run using seafloor pumps once the three-dimensional borehole network is established.

## Borehole and Offset-Vertical Seismic Profile Experiments

Much of what we know about oceanic crustal stratigraphy is based on seismic refraction and reflection data, but correlations between lithology and physical properties are often ambiguous. Relating outcrop or core properties to seismic-scale measurements is difficult (Jarrard et al., 2003), and relations between seismic and hydrologic properties are essentially unconstrained. There has long been evidence for anisotropy in seismic velocities in the upper crust, with faster velocities in the along-strike direction (e.g., Detrick et al., 1998; Stephen, 1985), but it remains to be determined whether the same crustal fabric includes significant pathways for fluid flow. Expedition 301 included a conventional vertical seismic profile (VSP) experiment to help assess interval velocities and identify gross seismic layering in the upper crust; a future expedition will include an offset-VSP to assess seismic velocity anisotropy. The conventional VSP uses one or more geophones clamped within an open or cased hole and a seismic source at the surface. We used the three-component Well Seismic Tool (WST) and an air gun source run from the drillship. Conventional VSP data from Sites U1301 and SR-2 may allow us to assess earlier interpretations of a seismically distinct boundary at 600 m into basement based on multichannel seismic (MCS) data (e.g., Davis et al., 1996). An offset-VSP, run during the second drilling expedition with the assistance of colleagues on a shooting ship that circles the drillship, will help to assess anisotropy in seismic properties.

# OPERATIONAL STRATEGY AND OVERVIEW OF EXPEDITION ACHIEVEMENTS

## Operational Strategy

Second Ridge Site U1301 was positioned ~1 km south-southwest of Site 1026 (Table T2). Both sites are located above a buried basement ridge (Figs. F2, F3, F4), where sediment thins to 250–265 m. The plan originally proposed for Site U1301 was to complete all operations in a single hole, so as to minimize the possibility of creating a hydrogeologic "short circuit" between basement and the ocean. However, discussion with engineering and operations personnel during initial planning stages for Expedition 301 in Fall 2003 led to development of a two-hole basement strategy for achieving primary technical and scientific objectives. One hole was intended to penetrate through the sediments and into uppermost basement, with a maximum penetration of 100 m into basement. The second hole was planned to be cased through the least stable parts of upper basement, allowing coring and downhole measurements at greater depths. This hole was originally proposed to extend 600 m into basement, but once the time requirements for the two-hole strategy became clear, the depth objective for the deeper Site U1301 hole was reduced to 300–400 m into basement.

Both holes were designed to be sealed with CORK observatories, the first monitoring uppermost basement and the second monitoring three additional zones at greater depths in the crust. These two holes were planned to be as close together as operationally feasible so that monitoring of conditions at different depths would be a true test of vertical connectivity within the crust. The actual distance between Holes U1301A (shallow) and U1301B (deep) ended up being just 36 m, which we believe to be the smallest intended spacing between adjacent basement holes drilled in the history of DSDP and ODP.

The standard approach for establishing basement reentry holes is to first drill one or more exploratory holes to determine sediment properties and thickness. We decided to proceed directly with reentry holes at Site U1301 for several reasons. First, we already had a good understanding of sediment thickness and properties based on extensive site survey data and prior drilling at Site 1026 during ODP Leg 168. Additional seismic coverage across Second Ridge provided clear indication of the depth to the sediment/basement contact. Second, we began at-sea operations <24 h after leaving port and we were concerned that there would be insufficient time following remobilization of the *JOIDES Resolution* to prepare the laboratories and train shipboard scientists for core handling, particularly that involving microbiological sampling and analysis. Third, we wanted to save sediment coring options for times later in the expedition, perhaps when packer testing or observatory installation operations could not be completed because of weather or sea state and/or until we had confidence of achieving higher-priority basement and observatory objectives. Fourth, delaying sediment coring operations gave the scientific party a chance to learn more about regional geology and decide where such coring should take place. Finally, we did not want any holes adjacent to the observatories that might penetrate the sediment/basement interface and risk a hydrologic "short-circuit" between basement and the seafloor.

Basement drilling and coring plans were unconventional in other ways. First, we planned to drill the deeper hole first. This would allow us to assess the depth extent of unstable basement with a bottom-hole assembly (BHA) well suited for this environment, including a tricone (noncoring) bit. This decision meant that we would not have core or logs from uppermost basement to help with assessing where to set casing and would rely instead upon drilling parameters and other qualitative indicators of formation stability. However, experience has shown that recovery and log quality are notoriously poor in upper basement, and rapid drilling would provide the best chance for establishing a stable hole and installing casing. Also, by taking this approach we would have two opportunities for casing off unstable upper basement; if the first attempt failed, that hole could be used for shallow basement monitoring and we could offset and start a second hole.

Upper basement coring on Second Ridge had been attempted at Site 1026 during Leg 168 but yielded low recovery and an unstable hole that required a liner (5½ inch drill pipe) to keep the hole open. As it turned out, the first attempt to penetrate the upper 100 m of basement with a tricone bit was successful, but we failed to land the long 10¾ inch casing string necessary to keep the hole open (see discussion below about casing seals and cementing). This hole became our shallow basement completion, with casing installed across only the upper 15 m of basement, and a second hole was started nearby for deeper basement penetration.

In addition to installing CORK borehole observatories at Site U1301, we also planned to replace the earlier-generation CORK systems in Holes 1026B and 1027C. Replacing the CORK in Hole 1026B was a higher priority than that in Hole 1027C for several reasons. First, the Hole 1026B CORK began leaking soon after it was emplaced during ODP Leg 168. The cause for the leak is not known with certainty, but it may have resulted from broken hydraulic tubing. The net result was that it was not possible to determine with certainty the formation pressure in upper basement because an unknown amount of excess pressure leaked past the seafloor seal. Second, the instruments originally deployed in Hole 1026B had been removed years before Expedition 301, and there was no data logger installed for recording formation pressure.

In contrast, Hole 1027C remains well sealed below a first-generation CORK, and pressure monitoring continues through the present. However, Hole 1027C includes a single monitored interval comprising two distinct hydrogeologic regions: uppermost ("true") oceanic crust and a shallower section of sills and sediment. Also, Hole 1027C offers excellent potential for geochemical and microbiological monitoring of upper basement once casing packers are installed in the open hole because this will separate the long section of metal casing above from the monitored intervals. Replacement of the Hole 1027C CORK was scheduled for the end of Expedition 301 with the intent that time necessary for this operation might instead be needed for other CORK activities. See **"Operations"** for site by site descriptions of operations.

We also planned 2 days of sediment coring during IODP Expedition 301, and an additional 1.5 days was scheduled as contingency time at the end of the expedition in case we had problems with CORK deployments or other basement operations. The primary focus of sediment coring was on microbiological and geochemical objectives, particularly in the interval close to basement, and we knew that rotary core barrel (RCB) and extended core barrel (XCB) coring would likely lead to significant contamination and poor recovery. We began Expedition 301 with a good lithostratigraphic record of Second Ridge from nearby Site 1026, so we were free to select a strategy intended to maximize other scientific (mainly sampling) objectives. Thus we elected to attempt APC spot-coring through the sediment section at Site U1301, an approach that was largely successful. Sediment coring also provided an opportunity to assess the thermal state of the sediment column at Site U1301, which was important to the overall hydrogeologic and observatory objectives.

## Overview of Expedition Achievements

The most important objectives of IODP Expedition 301 were achieved. We created two new basement holes, Holes U1301A and U1301B, that penetrate 108 and 320 m into basement, respectively, and instrumented each of these holes with multilevel CORK observatories (Fig. **F8**). We also successfully replaced the CORK observatory in Hole 1026B. All of the holes have multiple isolated intervals to monitor and sample pressure, temperature, chemistry, and microbiology and will serve as observatory points for planned cross-hole experiments. In Holes 1026B and U1301A, the uppermost of two intervals comprise entirely cased hole—these intervals are to be monitored to help assess how well the CORK systems are operating and the extent to which the packers are sealed. Lower zones in these holes monitor conditions in basement. In Hole U1301B, we isolated basement zones comprising both the uppermost (brecciated and highly fractured) crust and the underlying, more massive rock. Logging data from the lower interval of Hole U1301B indicate that the hole is to gauge and that the crust is highly layered. Comparison to other upper crustal holes shows that we achieved our fundamental basement objective: isolating separately the upper and lower parts of the extrusive section of the crust.

Packer experiments completed in Holes U1301A and U1301B show that the upper crust is highly permeable, but preliminary analysis suggests that there may be a decrease in bulk permeability with depth. We cored upper basement in Hole U1301B with ~30% recovery overall, typical for basaltic crust. Samples were collected for alteration, microbiology, paleomagnetism, and physical property studies, most of which will occur postcruise. Approximately 9% of recovered basement rocks were sampled as whole rounds and dedicated to microbiological analysis, a first for scientific ocean drilling.

Actual Expedition 301 operations differed from the plan outlined in the *Scientific Prospectus* in two significant ways: we did not replace the CORK in Hole 1027C and did not achieve as much basement penetration in Hole U1301B as originally hoped. Both of these deviations from the plan outlined in the *Scientific Prospectus* primarily resulted from not being able to set 10¾ inch casing deep into the crust with a seafloor seal inside 16 inch casing, as was planned, and from difficulties that ensued as a result of unsuccessful cementing operations that were attempted in the absence of a seafloor casing seal.

During planning for the expedition, we developed a two-hole strategy at Site U1301 to give us two chances to achieve our deeper crustal objectives. If the first hole became unstable, we could set shallow casing for the uppermost basement observatory and attempt a second hole to achieve the deeper objectives. As part of this strategy, we should have brought to sea two sets of mechanical casing seals, allowing 10¾ inch casing to seal inside 16 inch casing, so (1) we would not have to depend on cement to achieve a seal at the 10¾ inch casing shoe in fractured and broken uppermost basement and (2) we could maintain the two-hole strategy and be able to make either hole the shallow or deep observatory. Despite extensive Expedition 301 planning, only one seal was fabricated for the expedition. Ultimately, we decided not to use the single mechanical seal. This seal appeared to have been built with incorrect tolerances and had not been test fit, nor were we able to verify the clearances had been checked before being sent to the ship. The shipboard operations and engineering staff decided that it was best not to risk the installation by attempting to deploy the seal. Thus, completion of expedition goals at Site U1301 required successful cementing in upper basement.

One difficulty with using a conventional cementing approach in upper basement is that it requires pausing to attach the cementing swivel and manifold when running the 10¾ inch casing into the open basement hole. After drilling Hole U1301A to target depth, we returned to the hole to run casing, but when we stopped advancing the casing to attach the cementing manifold (an operation requiring ~16 min), we were subsequently unable to lower the casing the last few meters into the hole. We eventually shortened the casing string in Hole U1301A by 85 m, to case off only uppermost basement, and then attempted to cement this casing into place with a substantial length of open hole below. We could have tried to remove a single joint (~14 m) of casing for the second attempt, but we decided to shorten the casing string by 85 m to increase our chances of being able to install the string (the area where we were stuck appeared to be well above the bottom of the hole) and to increase our chances of being able to get a good cement seal back up into the base of the 16 inch casing. We had similar difficulties running casing in Hole U1301B, but after considerable hole conditioning and two attempts with running long strings of 10¾ inch casing, we finally landed a full-length casing string. However, the cementing job at the base of the 10¾ inch casing here was not successful, in that the cement did not form a solid bond with the formation around the casing shoe. Subsequent drilling out of the cement in the casing and RCB coring operations caused the casing to unscrew from the bottom, and ~100 m of the casing fell 5–6 m to the bottom of the hole, leaving a gap in the 10¾ inch casing string. This led to numerous difficulties during pipe trips and forced an early end to coring operations in Hole U1301B to attempt remedial cementing.

In addition, the 10¾ inch casing gap led us to run dozens of bow-spring centralizers on the 500 m long CORK casing string initially run into Hole U1301B in order to centralize the CORK casing/packer/screen assembly as it passed through the casing gap. After reentering the hole with the bottom of the CORK, something hung up, preventing the CORK from passing freely into the hole. The 4½ inch casing failed, and the rest of the CORK casing was run out onto the seafloor. We suspect that the failure was caused by the bow-spring centralizers hanging up in the throat of the reentry cone or by accumulating too much friction once the first six to eight were run into the 10¾ inch casing. It is clear that the failure happened long before the end of the CORK encountered the gap in the base of the 10¾ inch casing. The fundamental problem was that the CORK casing string was deployed without sufficient weight at the bottom to "pull" the casing into the hole and keep the casing string in tension. This lack of weight also made it difficult for the drillers to observe a weight loss when it hung up.

We used the CORK head from the first CORK attempt in Hole U1301B and other parts intended for use in Hole 1027C to build a new CORK observatory for Hole U1301B. For this string we added 10,000 lb of drill collars on the bottom and used only three spring centralizers, and it was deployed into the hole with no major problems. We finished operations in Hole U1301B by cementing the CORK observatory into the reentry cone in an attempt to seal between the 16 inch and 10¾ inch casing strings. We noted that CORK deployment in Hole 1027C would benefit from limited deepening of the hole so that weight might be added to the bottom for its CORK casing string, but we lacked both time and components to complete work in Hole 1027C during Expedition 301.

With primary goals achieved during Expedition 301, we are ready to press forward with the second half of the experimental program, including the multidisciplinary, cross-hole experiments. A planned second expedition will also replace the CORK in Hole 1027C and complete additional remedial cementing in the cones around the CORKs in Holes U1301A and U1301B to assure that these systems are fully sealed for the next 5+ y of hydrogeologic experiments.

# SITE RESULTS

## Site 1026

Three CORK borehole observatories were installed during Expedition 301, in Holes 1026B, U1301A, and U1301B (Fig. **F8**). The first of these systems replaced a CORK observatory deployed during an earlier expedition; the second and third are in newly drilled and cased holes. The new Hole 1026B CORK system was the simplest of the systems deployed during Expedition 301. It comprised a CORK-II body with 4½ inch casing extending to 201.5 meters below seafloor (mbsf) and a single packer element set in casing near the bottom of the 4½ inch casing. No 4½ inch casing was installed below the packer element sub because the hole was completely cased to a depth below the liner, and there was no need to provide additional protection for the instruments hanging below the bottom plug.

The umbilical run in Hole 1026B comprised a single ½ inch packer inflation line and three ¼ inch pressure-monitoring and fluid-sampling lines. The three ¼ inch lines were run through the single packer and ended in small wire-wrapped screens that were attached just below the inflation element. All of the CORK systems deployed during Expedition 301 included nine pass-throughs within the packers and across the upper 10¾ inch casing seal so that we could use a single design for these systems and achieve sampling and monitoring goals within multiinterval CORKs. Most of the extra pass-throughs in the Hole 1026B CORK were capped, but one line through the 10¾ inch casing seal was plumbed into a two-way valve in the CORK head so that during a future submersible or ROV dive expedition it will be possible to check pressure below the casing seal but above the packer element. If the pressure monitored below the packer is different from that above the packer, this will give a positive indication that the CORK system is properly sealed. As with all other valves in the CORK head, this one was left open during deployment to prevent air from being trapped in the sampling and monitoring lines.

The Hole 1026B instrument string included three OsmoSampler packages and two autonomous temperature loggers. One OsmoSampler contains copper coils for gas sampling, another has Teflon tubing for fluid sampling and tracer injection, and the third contains microbiological incubation substrate and an acid-addition OsmoSampler for metals analyses.

## Site U1301

Work at Site U1301 comprised operations in and around four holes (Table **T2**). Hole U1301A included penetration of 262 m of sediment and the upper 108 m of basement, installation of casing, short-term hydrogeologic testing, and emplacement of a single-level CORK-II borehole observatory. Hole U1301B penetrated through 265 of sediment and 318 m of basement. This hole was RCB cored over the lower 232 m of basement, logged, subjected to hydrogeologic testing within multiple depth intervals, and fitted with a multilevel CORK-II borehole observatory. Hole U1301C was discontinuously APC cored to 265 mbsf, and in situ temperatures were determined to evaluate the thermal state of uppermost basement. Hole U1301D was APC spot cored to recover sediment from an interval that had not been cored in Hole U1301C.

## Sediments

The lithology of sediments at Site U1301 was found to be virtually the same as that cored at Site 1026 during ODP Leg 168, 1–2 km to the north along the same buried basement ridge, comprising fine- to coarse-grained turbidites, debris flows, and hemipelagic clay. Resampling much of the same sedimentary interval during Expedition 301 was justified because APC coring had not previously penetrated below 100 mbsf in this area, and we wished to collect high-quality samples for microbiological and geochemical analyses, especially in the interval close to the sediment/basement interface and the underlying crustal aquifer. Time constraints prevented continuous coring of the complete sedimentary section, but intervals that were cored generally yielded excellent recovery and high-quality samples. Exceptions to this rule included intervals where coarse sand or gravel prevented complete penetration of the APC barrel.

Silt-rich and clay-rich APC cores from Holes U1301C and U1301D are of exceptionally high quality, even from depths below 250 mbsf. Cores recovered from sandy and gravely intervals are generally of poorer quality and often include intervals within which there was complete resuspension and settling of clastic particles. Because of discontinuous coring, irregular recovery, and extensive whole-round sampling, we were unable to determine well-constrained lithologic boundaries for the primary stratigraphic units in Hole U1301C. Unit I is an upward-fining turbidite sequence with gravel interbeds, and Unit II is a hemipelagic clay sequence. The true boundary between Units I and II is present somewhere within the noncored interval between 197 and 236 mbsf, but its approximate location may be inferred from its equivalent depth in Hole 1026C (216 mbsf).

There are differences between the lithologies recovered at Site U1301 and those documented at Site 1026. The coarsest layers recovered at Site 1026 comprised mainly muddy sand and mud clasts, whereas coarse sediments from Hole U1301C included clasts of serpentinite, green amphibolite, quartzite, felsic volcanics, calcareous sandstone, and shallow-water shell fragments. One explanation for the difference is that the two sites sampled different parts of the turbidite distributary channel network, but it seems just as likely that coarse intervals were simply not recovered during XCB and RCB coring during Leg 168. The other significant difference was the greater thickness of the hemipelagic clay unit, which is at least 27 m thick in Hole U1301C but was only 13 m thick at Site 1026. This may result from subtle differences in basement relief and depositional regime, which influence whether hemipelagic clay or finegrained turbidites dominate deposition over basement highs (e.g., Giambalvo et al., 2000; Spinelli et al., 2004).

Pore water chemical-depth profiles from Site U1301 are similar to those from ODP Site 1026. As observed in numerous DSDP and ODP holes drilled to basaltic basement, there are two biogeochemical zones identified on the basis of steep geochemical gradients at the seawater/sediment and sediment/basement interfaces. The gradients are particularly well defined in the dissolved sulfate, manganese, and iron profiles. The downhole pattern of sulfate concentrations indicates active sulfate reduction at ~50 and ~125 mbsf and diffusive sources from bottom seawater and the basaltic formation fluid, respectively. Concentrations of dissolved barium are high in between these depths. Alkalinity, chlorinity, and ammonium profiles are also nearly identical at Sites U1301 and 1026 and have end-member compositions that approach those of spring fluids from Baby Bare outcrop 6 km away.

However, there are several significant differences in the profiles from these two sites for the minor elements, most notably for dissolved iron. Data from IODP Site U1301 have a maximum iron concentration of 133 µmol/kg, compared to 14.8 µmol/kg at ODP Site 1026. This highlights the importance of squeezing the sediment under a nitrogen atmosphere. Other differences between chemical profiles from IODP Site U1301 and ODP Site 1026 exist for Mn, B, Sr, and Li. For these elements the upper portion of the profiles are identical but differences are present within the basal sediments. These differences are likely caused by differences in composition and not sampling artifacts, as was the case for iron because each of these elements is highly reactive within the sediment section. The carbon content of the pore water increases in the first 40 m of sediment, reaching a maximum at 47 mbsf. From 179 mbsf to the bottom of the hole, dissolved carbon concentrations are very low.

The depth profile of methane varies inversely with sulfate and indicates the presence of two sulfate/methane interfaces. Methane concentrations are low in the upper part of the sediment but increase sharply in the depth interval between 60 and 70 mbsf and reach a maximum near 100 mbsf. Higher molecular weight hydrocarbon gases were not detected in samples from Site U1301. The highest methane concentrations are present within the interval where sulfate is nearly depleted. This relationship indicates that the methane results from microbiological production. The disappearance of almost all of the methane at the depths of sulfate depletion indicates that most of this methane is likely consumed by anaerobic methane oxidation. Consequently, methane concentrations remain low in zones without active methanogenesis.

The solid phase of recovered sediments has relatively low organic carbon, nitrogen, and hydrogen contents. Organic carbon contents are highest close to the sediment/water interface (0.9 wt%) but decrease rapidly and fluctuate around 0.3 wt% throughout the sediment column. Total nitrogen averages around 0.04 wt% and has a depth trend similar to organic carbon. Calculated atomic C/N ratios generally indicate organic matter of marine origin. In some discrete sediment layers, however, elevated C/N ratios indicate a significant input of terrestrial organic matter. We also find distinct layers with highly elevated carbonate contents below the postulated lower zone of anaerobic methane oxidation. Observed carbonate peaks coincide with elevated carbonate levels found at Site 1026 below the lower zone of anaerobic methane oxidation and at the sediment/basement interface.

Microbiological samples were collected from all sediment cores. PFT was pumped during all coring operations to help in evaluating core contamination. PFT concentrations were evaluated across the cut faces of the cores, and results of these tests indicate that contamination was generally minimal, usually indicating a ratio of introduced to native cells of $10^{-9}$ or fewer. We found no relationship between drilling fluid contamination and core depth or lithology (clay versus sand).

Total cell counts decreased slightly with depth, from near-surface concentrations of $7.5 \times 10^8$ to concentrations of $1.8 \times 10^7$ cells/cm$^3$ at 248 mbsf. Overall, the profile of microbial cell densities follows a similar trend to that defined for other ODP sites. Tiny coccoid-shaped cells dominated throughout the sediment column. Numbers of rod-shaped cells fluctuated strongly. Aggregates of up to 30 microbial cells were detected in four horizons between 63 and 90 mbsf. Interestingly, an increase in cell numbers was observed near the sediment/basement interface. This increase in biomass may be supported by upward flux of electron acceptors from hydrothermal fluids in the underlying bedrock. Sulfate may be an important oxidizer in the deepest part of the sediment column, illustrating how water in the basaltic crust might support microbial growth in overlying sediments.

Approximately 1000 enrichment cultures of indigenous microorganisms were inoculated on board using three methods. Samples were cultured in various forms using different media and incubation temperatures ranging from 5° to 85°C. None of the anaerobically incubated enrichments showed growth during Expedition 301. The incubation time was probably too short for most of the microorganisms to grow, and studies will be continued on shore.

Physical properties from Hole U1301C are highly bimodal, with clay- and sand-rich sediments showing distinctive trends for most measurements. Magnetic susceptibility data show trends that are typical for turbidites, with higher values in the coarse sandy layers and lower values in clay-rich layers. In contrast, natural gamma radiation levels were not particularly helpful in distinguishing primary lithology. Bulk density of the clay layers increases systematically from 1.4 $g/cm^3$ at the seafloor to ~2 $g/cm^3$ at 100 mbsf and correlates with a ~30% decrease in porosity over the same depth interval. The porosity of sand layers remains relatively constant at ~40% to a depth of 115 mbsf. No core was recovered from two large continuous sections below 100 mbsf, prohibiting analysis of trends at greater depth. Bulk density values from clay lithologies recovered in the 30 m above basement vary slightly about a mean of 1.9 $gm/cm^3$. The bulk density of sand layers is relatively consistent at 2.0 ± 0.1 $g/cm^3$. Grain density is remarkably consistent at 2.8 ± 0.1 $g/cm^3$ regardless of depth or lithology. The higher than expected grain density could be attributable to pyrite, which has a grain density of ~5 $g/cm^3$.

Thermal conductivity was strongly controlled by lithology, with values for clay being significantly less than values for sand, averaging 1.12 ± 0.12 and 1.53 ± 0.19 W/(m·K), respectively. A systematic increase of thermal conductivity is apparent in the upper 100 mbsf within clay-rich layers. A matrix thermal conductivity of ~2.5 W/(m·K) was indicated for clay-rich layers, a value ~1 W/(m·K) less than estimated by Shipboard Scientific Party (1997) in Hole 1026A. *P*-wave velocity values range from ~1480 to 1780 m/s over the 265 m cored interval, with an increase of ~10% present within the uppermost 50 mbsf. We found no evidence for velocity anisotropy. Undrained shear strength was also found to increase with depth through the sediment section.

Two attempts to determine in situ temperatures in Hole U1301C were made with the APC tool and three with the Davis-Villinger Temperature Probe (DVTP). One of each kind of measurement was unsuccessful, but the remaining data were sufficient to determine both the temperature of uppermost basement and heat flow through the sediments. The upper basement temperature is ~62°C, approximately the same as that measured at nearby Sites 1026 and 1027, and heat flow through the sediments is 280 $mW/m^2$ and entirely conductive.

## Basement

The geology of the uppermost 85 m of basement is poorly known at Site U1301 because no coring was attempted from the sediment/basement interface to this depth.

The decision to drill and case off uppermost basement at Site U1301 was made during planning for Expedition 301 on the basis of general and local experience, as discussed earlier (see **"Operational Strategy,"** in Operational Strategy and Overview of Expedition Achievements). RCB core recovery was only 5% within the upper 40 m of Hole 1026B (Shipboard Scientific Party, 1997), and that hole required installation of a liner at depth to keep basement "open" for testing and monitoring.

Records of drilling penetration rates within the upper 100 m of basement at Site U1301 provide limited lithostratigraphic insight (Fig. **F9**). Penetration rates <3–4 m/h generally corresponded to relatively massive rock and stable hole conditions, whereas penetration rates >8–10 m/h were usually accompanied by hole instability. Although there is not a one-to-one correspondence between penetration rates at equivalent basement depths in the two holes, there are gross similarities. For example, the interval from 55 to 65 m into basement drilled relatively slowly in both holes, whereas the interval from 65 to 80 m into basement drilled much more quickly. We initially attempted to place casing across this fast-drilling interval in Hole U1301A but failed to land the original casing string. We had to shorten this string and cased off only the uppermost 15 m of basement in this hole. We subsequently cased of most of this fast-drilling interval in Hole U1301B.

Basement was cored in Hole U1301B from 351 to 583 mbsf (86 to 317.6 m subbasement [msb]) in Hole U1301B. The 69.1 m of recovered core, comprising recovery of 30%, consisted of: (1) basalt-hyaloclastite breccia, (2) aphyric to highly phyric pillow basalt, and (3) massive basalt. Eight basalt units were defined on the basis of changes in lava morphology, rock texture, and grain size (Fig. **F10**). Pillow lava units (Units 1, 3, 5, 7, and 8) were subdivided based on changes in phenocryst mineralogy and abundances. Massive lava units (Units 2, 4, and 6) were subdivided into individual cooling units, based on the presence of chilled margins.

Pillow basalt was the most abundant rock type recovered from Hole U1301B. Pillow lavas were identified by the presence of curved chilled margins, oblique to the vertical axis of the core, with perpendicular radial cooling cracks. Pillow fragments have dominantly hypocrystalline textures with a glassy to microcrystalline groundmass. They are sparsely to highly plagioclase ± clinopyroxene ± olivine phyric. Observed basalt textures vary from glassy to hyalo-ophitic (typically with sheaf-spherultic or plumose textures) to glomeroporphyritic, seriate, and intersertal. The pillows are sparsely vesicular, containing 1%–5% round gas vesicles, and are slightly to moderately altered. Alteration styles include interstitial groundmass replacement, vesicle fill, vein formation (with associated alteration halos) and the complete replacement of olivine phenocrysts. An almost complete section through a single pillow was recovered in one 45 cm long interval of essentially continuous core.

Several pieces of basalt-hyaloclastite breccia were recovered and defined as subunits. These thin breccias (<1 m of recovered core) are composed of clasts of basalt that are similar to the underlying basalts, some with glassy margins. Given the low recovery of these intervals, and the dedicated use of most of the recovered rock for microbiological analysis, it is not possible to determine the relationship between the hyaloclastite portions and underlying lavas, specifically whether or not they are part of the same cooling unit.

Massive basalts consist of continuous sections of up to 4.5 m of similar lithology, which increases in grain size toward the center of the flows. Some massive flows have upper and/or lower planar glassy chilled margins. High recovery, up to 100% in one case, allows individual lava flows or cooling units to be distinguished. Mineralogically, the massive lavas are very similar to the sparsely phyric pillow basalts, containing plagioclase, olivine, and clinopyroxene as phenocryst as well as groundmass phases. The massive basalts are sparsely to highly vesicular, with an average of 1%–5% round gas vesicles, up to 3 mm in diameter. The vesicles are generally concentrated in the upper portions of the flows, but one unit has a distinct 20 cm wide band in its center, of which 15% is vesicles. The massive flows are slightly to moderately altered and exhibit similar alteration styles to the pillow basalts: vesicle fill, vein formation (and the development of associated alteration halos), and the complete replacement of olivine phenocrysts. However, the massive basalts contain fewer fractures and veins than the pillow basalts, allowing better core recovery and the retrieval of individual pieces up to 94 cm long.

Geochemical analysis of basalt samples indicates that they are normal depleted mid-ocean-ridge basalt (MORB). The consistency of cross plots such as $TiO_2$ versus Zr suggests that all the basalt recovered from Hole U1301B came from the same magmatic source. All of the basement rocks recovered from Hole U1301B have undergone alteration. Most pieces are slightly to moderately altered, with secondary minerals (1) lining or filling vesicles and cavities, (2) filling fractures and veins, (3) replacing phenocrysts, or (4) replacing interstitial mesostasis and glass. Thin section observations indicate that the degree of alteration varies from ~5% to 25%, excluding the hyaloclastite breccia, which is ~60% altered. The freshest rocks are the interior, dark gray cores of most pieces, which have a saponitic background alteration. Fresh olivine appears only as microphenocrysts in some glass margins and elsewhere is completely replaced. Clay minerals are the most abundant secondary minerals and are the principal constituent of all four styles of alteration (vesicle fill, vein fill, phenocrysts replacement, and background mesostasis alteration). Saponite is the most abundant of the clay minerals, identified in every thin section. It is present as cryptocrystalline granular or fibrous aggregates and varies in color from black to dark greenish brown to pale blue in hand specimen and tan-brown to olive-green in thin section. Saponite lines or fills vesicles, is the most common olivine phenocryst replacement, appears in mono- and poly-minerallic veins, replaces mesostasis and glassy margins, and forms the matrix of the hyaloclastite breccia.

Celadonite, bright blue-green in hand specimen and bright green in thin section, also fills vesicles and veins and replaces olivine phenocrysts and mesostasis. However, celadonite is typically restricted to the alteration halos, frequently present as intergrowths with saponite and/or iron oxyhydroxide. Iddingsite, a mixture of clay minerals and iron oxyhydroxide, is the second most abundant alteration product identified in Hole U1301B cores, producing a characteristic red-orange or reddish brown color in both hand specimen and thin section. It fills veins and vesicles, stains primary minerals, and is intergrown with the clays that replace olivine. Calcium carbonate was observed in only six cores, filling vesicles and veins and as a minor component of the basalt-hyaloclastite breccia matrix. Secondary pyrite was observed lining vesicles, as fine grains within saponite vesicle linings, with saponite ± calcium carbonate in veins, and as disseminated fronts bounding some alteration halos. Zeolites (analcime and phillipsite) were tentatively identified in several basalt samples in veins as well as in the matrix of the hyaloclastite breccia.

A total of 2301 veins were identified in the core recovered from Hole U1301B, with an average frequency of 31 veins/m of recovered core. Saponite is the most abundant vein-filling mineral, present in 98% of the veins. Iron oxyhydroxide was documented in 1010 veins, whereas celadonite was identified in only 93 veins, typically appearing with iron oxyhydroxide ± saponite. Pyrite was observed in 59 veins and is typically associated with saponite. Calcium carbonate was observed in 38 veins, with saponite ± pyrite. Clay-bearing veins are ubiquitous in the rocks recovered from Hole U1301B and vary in width from 10 µm to 6 mm, averaging 0.2 mm. The maximum width of the simple dark green saponite veins is 2 mm. These predominantly narrow veins are prolific in pillow fragments, with saponite filling many of the radial cooling cracks along pillow margins. Iron oxyhydroxide- and celadonite-bearing clay veins vary in width from 10 µm to 6 mm, and average 0.2 mm. They are most common in the pillow lavas, but the most spectacular iron oxyhydroxide-bearing vein appears in a massive lava flow and is 6 mm wide with a 10–25 mm wide alteration halo. Goethite and minor celadonite were identified within this vein by X-ray diffraction.

The dips of 647 veins and fractures were measured in the recovered cores from Hole U1301B. Four types of fractures were distinguished in the cores: (1) veins flanked by alteration halos, (2) veins not flanked by alteration halos, (3) calcite-filled shear veins with slickenfibers (microfaults with contemporaneous displacement and secondary mineral growth), and (4) microveins (<0.05 mm wide), identified in thin sections. Haloed veins were the most frequently observed structures, typically 3–10 mm wide and predominantly black to dark green, depending on the secondary clay alteration assemblage present. Nonhaloed veins were identified in the massive lavas and some pillow lava pieces. Calcite-filled shear veins or faults were identified in three of the recovered pieces. These steeply dipping structures have calcite slickenfibers or overlapping fibers. The fibers define a steeply plunging lineation with asymmetrical calcite crystals, indicating dip-slip motion. This extensional style of deformation may relate to regional normal faulting. Interestingly, a compilation of dip angles shows that rocks recovered from Hole U1301B have dominantly high-angle fracture dips, despite the expected bias toward sampling of low-angle features by coring a vertical hole.

Paleomagnetic measurements of basement rocks from Hole U1301B were made on 158 discrete samples. Characteristic remanent magnetization directions from the samples thought to be most reliable are highly scattered when plotted versus depth in the hole. The mean inclination within the upper 100 m of the cored interval is 50°–60°, somewhat shallower than that expected based on the current (and past) latitude of the site, and data from the lowest 150 m of the hole show a more complex pattern. There is more variability in apparent inclinations, and some intervals include dominantly negative inclinations. Given the known basement age, it seems unlikely that these rocks cooled from magma during a period of dominantly reversed magnetic polarity. It might be supposed that there could have been short periods of magnetic reversal within dominantly positive magnetic polarity, but the samples yielding negative inclinations are often closely associated with other samples that yielded positive inclination.

Two other explanations are self-reversal or remagnetization. Reversed magnetization could occur if alteration and magnetic mineral replacement occur during a period of time with an opposite magnetic polarity. This seems the most likely explanation for negative inclinations in some Hole U1301B samples because geologic observations indicate pervasive hydrothermal alteration and because shipboard paleomagnetic studies point to multiple magnetization components as well as the appearance of pyrrhotite in some samples. Pyrrhotite is a mineral that is a common by-product of the dissolution of magnetic minerals, such as magnetite, and the conversion of the iron into iron sulfide minerals. If this interpretation is correct, then the negative inclinations may correspond to zones where greater alteration has occurred.

Of 69.1 m of hard rock core recovered in Hole U1301B, 9% was taken as whole-round samples on the catwalk and dedicated to microbiological analyses. Shipboard scientists attempted to make total cell counts in samples fixed in ethanol and containing small pieces of basalt and basalt that had been crushed to powder. However, the material showed high amounts of celllike structures (small crystals and needles) with strong fluorescent signals. Even after testing a variety of dilutions that had been filtered and stained, it was impossible to distinguish cells from other particulate matter.

PFT analyses were completed to evaluate potential for microbiological contamination and the efficacy of cleaning and heating techniques for removing PFT. PFT removal by flame-heating and washing was highly effective for sample exteriors, and little or no PFT was detected in solid rock interiors.

We inoculated ~300 rock and rock-powder samples in test tubes in 12 different growth media at five different temperatures (20º–85ºC). After 2 weeks of incubation, we observed cell growth in <10% of total cultures. We obtained cells that could grow at near in situ temperature, potentially suggesting successful enrichment of indigenous microbes from the warm, shallow basalt aquifer. Microscopic observations of 4′,6-diamidino-2′-phenylindole-dihydrochloride (DAPI)-stained cells revealed coccoid-shaped cells attached to iron sulfide particles. These particles were part of the growth medium. Curiously, in these enrichments no cells were found in association with basalt particles. Considering the chemical composition of the growth medium, these microorganisms probably grow with the provided substrates as carbon sources and ferrous iron as an electron donor. In other enrichments at room temperature, we found anaerobic mesophilic microbes, likely to be fermenters and/or heterotrophic sulfate-reducers. There are three conceivable explanations for the retrieval of mesophilic strains: microbes might be derived from sediment above basement, contaminants imported by drilling fluid, or relics transferred to the basaltic oceanic crust by hydrothermal circulation. Further physiological and phylogenetic characterizations of retrieved microbes will be performed as part of shore-based studies.

Parts of whole-round basalt cores were run through the multisensor track (MST) prior to splitting. Magnetic susceptibility ranged from 0 to ~4000 × $10^{-6}$ SI, with the highest values corresponding to massive lava flows. Other lithologies (pillow lava and hyaloclastite) generally yielded much lower values.

Sixty-eight basalt samples were tested for thermal conductivity, yielding values of 1.17–1.84 W/(m·K), with an average of 1.70 ± 0.10 W/(m·K) over the depth range of 351.2–576.3 mbsf. There is no statistically significant change in thermal conductivity with depth. Values >1.75 W/(m·K) consistently came from large, massive samples (length > 6 cm), recovered in either massive flows or pillow basalts. The lowest values of 1.17 and 1.37 W/(m·K) correspond to the two hyaloclastite samples, suggesting that recovery and sampling biases toward unfractured basalt skew the data toward higher values and likely provide an upper bound on the effective thermal conductivity of uppermost basement in this region.

*P*-wave velocities were measured on 106 discrete samples, yielding values of 3.9–5.8 km/s (Fig. **F10**), with an average of 5.1 ± 0.3 km/s. This average value is greater than that estimated at a regional scale based on seismic reflection data but is consistent with shipboard values from Leg 168. This value is also slightly greater than the 5.0 km/s interval velocity determined for 110–160 msb determined by the VSP experiment. The lowest velocity was measured on a highly vesicular sample recovered from within a massive flow unit. Additional samples recovered from the same lithologic unit include velocities as great as ~5500 m/s, demonstrating the extent of small-scale heterogeneity. There is no statistically significant overall velocity trend with depth, although *P*-wave velocity may be reduced locally by alteration and fracturing.

Moisture and density properties were determined on 83 discrete samples from Hole U1301B. Bulk density values were 1.86–3.03 g/cm³, with an average of 2.75 ± 0.13 g/cm³. Grain density exhibited a range of 2.23–3.11 g/cm³, with a mean of 2.86 ± 0.09 g/cm³. The lowest values of both grain and bulk density were made in a highly brecciated hyaloclastite sample, whereas the highest densities come from the boundary between massive and pillow basalt. Porosity values span the range of 1.9%–30.3%, with a mean of 5.8% ± 3.5%. Grain density variability decreases with decreasing porosity, as seen in previous studies of upper basement rocks. Similarly, seismic velocity and porosity are inversely correlated, and velocity displays a weak positive correlation with grain density.

Four wireline logging strings were run in Hole U1301B to characterize formation properties at a scale intermediate between hand samples and regional seismic data. The triple-combination (triple combo) tool string (natural gamma ray, lithodensity, porosity, and spontaneous potential) penetrated essentially to total depth (TD), yielding excellent data over most of the open hole (350–580 mbsf; 100–320 msb). Unfortunately, subsequent logging strings (Formation MicroScanner [FMS]-sonic, borehole televiewer, and vertical seismic profile) could not penetrate across an obstruction at 410 mbsf (150 msb), limiting data collection to the uppermost part of the cored interval. Data were also collected through casing, but data from this interval are highly attenuated.

Much of the upper 100 m of open hole is washed out, with the caliper logs open to full scale near 400 mbsf (Fig. **F10**). The lower 120 m of the hole is almost entirely in gauge, being only slightly larger in diameter than the 9⅞ inch coring bit. Formation bulk density varies from 1.5 to nearly 3.0 g/cm$^3$, but the lowest apparent values were measured in washed-out zones and should be used cautiously. In the deeper part of Hole U1301B, variations in bulk density are consistent with observations from numerous other basement holes and with physical property measurements (Fig. **F10**). There are thin (meter-scale) intervals of lower density separated by thicker (~10 m scale) intervals of higher density, interpreted to comprise more fractured and massive rock, respectively. Near-hole formation resistivity generally increases with depth in the hole, particularly below the upper 100 m. The spontaneous potential log shows several regions where the curve deflects to the higher values, but it is difficult to interpret these signals hydrogeologically because the logs were collected so soon after drilling, while the formation was still thermally disturbed. Collectively, logging data from the triple combo tool string help to define two main regions in basement. The uppermost 100 m of open hole is enlarged, with highly variable bulk density and very low electrical resistivity. The lower 120 m of open hole has a diameter close to that of the coring bit, less variable bulk density, and higher electrical resistivity. The boundary between these two zones, at ~460 mbsf (210 msb), is an important one for subsequent packer testing and CORK monitoring, as described later (Fig. **F10**).

*P*-wave velocities determined with the sonic log in the upper 80 m of open basement are generally in the range of 4–6 km/s and are broadly consistent with physical property measurements (Fig. **F10**). A VSP run over a depth range of ~360–420 mbsf (100–160 msb) indicates an interval velocity in upper basement of 5.0 km/s (Fig. **F10**).

Unfortunately, no data are available at present from the borehole imaging tools (FMS and borehole televiewer). There are apparently problems with the new wireline heave compensator and/or the acceleration module used with the tools; hopefully, post-cruise processing will also useful images to be generated.

Drill string packer experiments were conducted in Holes U1301A and U1301B to assess hydrogeologic properties near the boreholes (Fig. **F10**). We originally intended to run the packer in "straddle mode" in Hole U1301B, to assess permeabilities within one or more narrow zones, but because of difficulties encountered in passing a gap in the 10¾ inch casing (see **"Site U1301,"** in "Operations"), we elected to run the packer only in single-element mode.

Inflation of the packer within the open-hole section of Hole U1301A was precluded by poor hole conditions and the large diameter of the hole, which was drilled with a 14¾ inch bit. The packer was positioned at 267 mbsf, 10 m above the casing shoe. A depth check before testing found an obstruction at 34 msb, compared to total drilled depth of 107.5 msb. We assume that the obstruction was incomplete and that the hydraulically tested interval comprises the 92.6 m section between casing and total drilled depth. After packer inflation, we recorded sealed-hole pressure and then ran a series of five constant-rate injection tests at 15–100 strokes/min (spm). Following each period of injection, the pressure recovery was monitored for a period of the same duration as the respective pumping time.

Pressure records recovered from downhole gauges after these tests will require considerable processing in order to determine formation properties because of the confounding influences of pressure changes induced through density differences between cold ocean water and warm formation fluids and of formation recovery from the disturbance because of drilling. However, a crude estimate of apparent formation permeability suggests a value on the order of $10^{-11}$ to $10^{-10}$ $m^2$, considerably greater than determined by packer or flow testing within the upper part of basement in Hole 1026B.

A longer series of packer tests were conducted in Hole U1301B, with the packer set at three depths in open hole. The three packer seats were at 472 mbsf (207 msb), 442 mbsf (177 msb), and 417 mbsf (152 msb). These test depths allow us to assess bulk hydrogeologic properties within the lower formation around Hole U1301B and (by difference) conditions within the upper part of the hole. Packer inflation in the open hole also allowed us to test potential CORK packer seats. After setting the packer at each seat, we conducted two to three injection tests at pumping rates of 11–30 spm. As with data from Hole U1301A, considerable effort will be required to separate the influence of pressure differences associated with formation recovery from drilling and pumping of cold ocean water during the tests themselves. Nevertheless, a crude estimate of near-borehole formation permeability suggests values on the order of $10^{-11}$ $m^2$, possibly with lower values in the deeper part of the hole.

A CORK system was installed in Hole U1301A to monitor a single depth interval including as much as 92 m of open hole. The large diameter of the borehole ($14\frac{3}{4}$ inches) precluded setting a CORK packer in open hole, so the packer was set near the bottom of the $10\frac{3}{4}$ inch casing. Slotted $4\frac{1}{2}$ inch casing was extended below the packer element to protect the OsmoSamplers and temperature loggers.

The CORK in Hole U1301A used an umbilical comprising a single $\frac{1}{2}$ inch packer inflation line, six $\frac{1}{4}$ inch pressure-monitoring and sampling lines, and one $\frac{1}{8}$ inch sampling line. The $\frac{1}{4}$ inch and $\frac{1}{8}$ inch lines were run through the packer and ended in small wire-wrapped screens. Four of the screens attached to $\frac{1}{4}$ inch lines were attached to the $4\frac{1}{2}$ inch casing just below the packer element, and the remaining screens and lines were terminated roughly in the middle of the $4\frac{1}{2}$ inch slotted casing. As with the Hole 1026B CORK, the pass-through across the $10\frac{3}{4}$ inch casing seal that was not plumbed to a formation sampling or monitoring line was connected to a three-way valve and manifold for future installation of pressure-monitoring instrumentation at the wellhead. This plumbing will allow monitoring of fluid pressure below the casing seal and above the packer element, to evaluate system integrity. An OsmoSampler was attached to one of the fluid-sampling manifolds at the wellhead for short-term collection of fluids during the initial few weeks of CORK equilibration.

The Hole U1301A instrument string includes four OsmoSampler packages. The uppermost OsmoSampler contains a copper coil for gas sampling. The next OsmoSampler contains microbiological incubation substrate. The third OsmoSampler has Teflon tubing for fluid sampling and rare earth element tracer injection. The final OsmoSampler includes a module for acid injection into the sampling line, to prevent precipitation of metal compounds. There is a single, self-contained temperature logger in each of the OsmoSamplers (3.7 m apart), and two additional temperature instruments were installed 2.5 and 7.5 m above the bottom plug. Thus, temperature monitoring in Hole U1301A extends across ~24.2 m of upper basement.

The CORK borehole observatory installed in Hole U1301B includes monitoring of three intervals. We initially attempted to set a CORK system in Hole U1301B with three casing packers, all set in open hole, but this system was seriously damaged during deployment and we had to modify its design. The final Hole U1301B CORK system included two casing packers set in open hole. The lowermost packer element isolates the deepest ~120 m of the hole, whereas this and the shallowest packer isolate a 42 m thick interval above. A third monitored interval includes uppermost basement and the 10¾ inch casing string below the cone but includes only pressure and temperature monitoring. It should be possible to assess the quality of the hydrogeologic seal at the seafloor using the pressure monitoring line and valve into this interval.

The Hole U1301B CORK system used an umbilical containing nine separate lines: a single ½ inch packer inflation line, four ¼ inch pressure-monitoring and sampling lines, and four ⅛ inch sampling lines. There was a separate ½ inch Tefzel (Teflon variant) microbiological sampling line run to the deepest monitored zone. Four small intake screens were deployed below each of the packer elements. The bottom of the CORK installation included 35 m of drill collars and cross-overs below the lower packer, comprising ~10,000 lb of metal. This configuration was selected to provide enough weight to pull the long CORK casing string into the hole. Sampling and monitoring valves at the wellhead were left open on deployments, and three OsmoSamplers were attached to the fluid-sampling manifolds for short-term collection of fluids during the initial few weeks of CORK equilibration. Two of these will be recovered during the first visit to the CORK by ROV, whereas the third will be left installed for the first year of reequilibration. This OsmoSampler will be recovered when two new instruments are installed by submersible during Summer 2005.

The downhole sensor and sampling string in Hole U1301B included 14 autonomous temperature loggers, six OsmoSampler packages, and three microbiological incubation packages. Temperature monitoring extends from ~1 m below the top of basement to 263 m into basement, with typical sensor spacing of ~20–25 m. All of the downhole OsmoSamplers and incubators have their intake lines extending beyond the bottom of the CORK casing system, in open hole. The uppermost OsmoSampler contains a copper coil for gas sampling. The next OsmoSampler contains microbiological incubation substrate and flow cell. The third OsmoSampler has Teflon tubing for fluid sampling and additional incubation substrate. The fourth OsmoSampler includes a module for acid injection into the sampling line, to prevent precipitation of metal compounds. The fifth OsmoSampler will inject rare earth element tracers, and the final OsmoSampler module is configured for acid addition.

After deployment of the submersible/ROV platform, we "reentered" the cone through a hole in the landing platform and pumped a plug of bentonite followed immediately by cement, in an effort to seal the annulus between 10¾ inch and 16 inch casing strings. Final operations around Hole U1301B included fishing one remaining piece of CORK casing from the initial deployment that was sticking vertically from the seafloor and might have composed a hazard to submersible and ROV operations. We conducted a camera survey of the area around Holes U1301A and U1301B and found no other items on the seafloor that might pose a hazard for future operations at the site.

# OPERATIONS

## Astoria, Oregon, Port Call

After the 17 day transit across the Pacific Ocean, the ship arrived in Astoria ~1.5 days ahead of schedule at 1600 h on 18 June 2004. All times presented in this report are local ship time, which was Universal Time Coordinated (UTC) – 7 h. The Astoria port call leading up to Expedition 301 was extensive because of the activities required to remobilize the *JOIDES Resolution* for IODP operations as well as loading all of the special hardware required for Expedition 301. The mobilization actually began long before Astoria with the official acceptance of the drillship *JOIDES Resolution* on 31 May 2004 in Gamagori, Japan. In Japan we (1) loaded laboratory equipment and supplies required to bring the shipboard laboratories back up to operational status, (2) loaded some bits and BHA subs, (3) had the Active Heave Compensator serviced.

In Astoria, ~40 truckloads were used to deliver the materials required for remobilization and Expedition 301. Items loaded included drill pipe, all bulk materials (mud and cement), casing, all remaining operations drilling equipment, a new heave compensated logging line/winch, laboratory equipment and supplies, and all of the specialty hole completion equipment required for replacing two existing CORKS and installing two new CORK systems.

The Astoria port call was scheduled for 8 days, but was completed in just over 7 days. The Expedition 301 portion of the Astoria port call officially began at 0600 h on 27 June. Because of the early ship arrival, excellent weather, and exceptionally efficient loading activities and coordination, the ship was ready to depart Astoria only 1 h after the "official" Expedition 301 port call began. Once the oncoming Captain was satisfied with the ship's readiness for sea and the last of the expedition hardware was loaded, the ship was deemed ready to depart Astoria for the first site.

# SITE U1301

## Transit to Site U1301 (Proposed Site SR-1A)

All major operations conducted during Expedition 301 are listed in Table T2. The last line away Pier 1 took place at 0833 h on 27 June. The forward and aft tugs were released and the *JOIDES Resolution* proceeded down the Columbia River and across the Columbia Bar. The pilot was dispatched via helicopter and at 1030 h the vessel was under way at full speed on a course of 302° for Site U1301 (SR-1A). The transit was quick and uneventful, making the 172 nmi transit in 16.6 h at an average speed of 10.4 kt. After reducing speed upon approach to the site, the thrusters and hydrophones were lowered and the vessel switched to dynamic positioning (DP) control at 0321 h on 28 June.

## Hole U1301A

### *Arrival on Site and Jet-in Test*

The DP operator positioned the ship over the Global Positioning System (GPS) coordinates for Site U1301, and a Datasonics model 354M, 15 KHz, 208 Db beacon (SN 2202) was deployed at 0722 h on 28 June. For the jet-in test only, we offset the ship 10 m north and 10 m west from the primary site coordinates for the jet-in test.

The initial operation was to move the previously assembled reentry cone off of the moonpool doors, lay out the upper guide horn, and pick up eight drill collars from the forward pipe rack. The BHA and other drill string components were strapped (measured) and drifted (through bore clearance check) as they were made up and lowered through the rig floor. The camera/sonar system was deployed and the bit was observed tagging the seafloor at 2667.5 meters below rig floor (mbrf) as measured from the dual elevator stool (DES). This depth was later adjusted to 2667.3 mbrf.

A jet-in test to verify how much 20 inch casing could be washed beneath the reentry cone was initiated using an 18½ inch tricone drill bit fitted with three number 16 jets. The jet-in test required more strokes per minute with the rig circulating pumps and higher weight on bit (WOB) than was required for the jet-in test conducted for Hole

1026B (ODP Leg 168) located ~1 nmi away. The jet-in test was terminated after 5.75 h at 41.4 mbsf. After recovering the jet-in assembly we discovered that one of the bit jets was plugged. This may partially explain the higher pump pressures and slower jetting process; however, we decided to reduce the length of 20 inch casing from ~75 to ~39 m.

### *Deployment of Reentry Cone and 20 Inch Casing*

We distinctively painted the reentry cone for Hole U1301A with a black rim around the top of the cone and one internal panel painted black with white lettering that reads "1301A" (Fig. **F11**). The opposite panel was left gray but lettered with white lettering that reads "1301A." We also painted a black ring painted internally halfway down the cone. On the outside there were two opposing panels painted with white numbers that read "1301A."

After moving the reentry cone back over center in the moonpool, the rig floor was prepared for running 20 inch casing. This casing assembly consisted of a shoe joint cut to the appropriate length and welded out to a standard 20 inch Texas pattern casing shoe, two joints of 20 inch casing (94 lb/ft; K-55; range-3; buttress thread), a standard 20 inch casing pup joint, and a 20 inch Dril-Quip (DQ) casing hanger. The hanger was latched into the reentry cone bore, and latch ring engagement was verified by visually observing that the latch ring was in the appropriate position as viewed through the disengagement holes. Because the typical "audible" latch ring engagement snapping sound was not heard, the hanger was tack-welded in four places in the casing hanger flutes. This was done as added insurance against an inadvertent disengagement during the trip to the seafloor. After assembling the BHA, the DQ casing running tool was made up to the 20 inch casing hanger and the entire assembly was ready for lowering. At 1600 h on 29 June, Hole U1301A was spudded as the 20 inch casing shoe tagged the seafloor. Jetting of the 20 inch conductor casing proceeded well, and 7 h later we landed and released the reentry cone base at the seafloor. Release of the DQ running tool was executed perfectly at 2300 h and the drill string was tripped back to the surface.

### *Drilling a 20 Inch Hole in Sediment for the 16 Inch Casing*

The first change to the initial operations plan for this site came with the drilling of the hole for the 16 inch casing string. The original plan called for drilling a nominal 21½ inch diameter hole using a bicentered reamer (Downhole Design, Inc. [DDI]; B182X215). This tool was used successfully during ODP Leg 206 to drill two basement holes. In talking with members of the drill crew and the ODP Operations Superintendent for that leg we learned that the tool was not without problems. They were able to drill successfully in basement rock; however, the 9⅞ inch tricone bit used as a pilot for the bicentered reamer assembly catastrophically failed twice, leaving bit cones in the hole. This was attributed to lateral loading of the bit during the bicenter functioning of the reamer head. For our expedition, DDI provided a 9⅞ inch stabilizer sub to run directly above the pilot bit. In addition, a specially designed 9⅞ inch pilot "wobble" bit was provided to replace the conventional 9⅞ inch tricone bit. The Leg 206 crew also indicated that the bicenter reamer did not drill a very good hole in the softer sediments overlying the hard basement rock. It was believed that this may have contributed to problems emplacing the 16 inch casing strings on Leg 206. With this added knowledge, we modified the operations plan for Expedition 301. We decided to deploy a more conventional "arm style" underreamer to drill the sediment section of the hole to be followed, after a drill string round trip, with the bicenter reamer assembly to drill the upper ~15 m of basement. We decided to accept the penalty of another pipe trip in order to avoid both the problems experienced on Leg 206 and having to drill with the conventional "arm" style underreamer in basement rock, which historically has had integrity problems that led to underreamer failure.

A Hole Opener Company (HOC) model DTU 1175 underreamer outfitted with three number 12 jets was made up with the same 18½ inch tricone bit (fitted with three number 16 jets) and used in jetting-in the 20 inch casing and reentry cone. The underreamer was function-tested in the moonpool by pumping with a circulating head and visually observing and measuring the opening or extension diameter of the underreamer arms at 20 inches. This underreamer had recently been refurbished on shore, and the function test was successfully completed by 1230 h on 30 June.

The drilling assembly was lowered, the camera/sonar system was deployed, and Hole U1301A was reentered for the first time after <5 min. Once inside the 20 inch casing the top drive was picked up, the camera was recovered, and drilling commenced at 1530 h. After an initial slow advance of 6 m directly below the 20 inch casing shoe (to keep from opening the underreamer arms inside the casing), the underreamer was opened up and drilling continued to 262.2 mbsf. An abrupt change in rate of penetration (ROP), coupled with the typical "basalt bounce" associated with hard rock drilling, was a clear indication that we had reached our basement target originally projected to be at ~275 mbsf. Overall net ROP (including connection time) with the conventional underreamer in sediment was 16.5 m/h. Actual drilling ROP was 22.3

m/h. Control drilling techniques were employed to ensure that a good quality hole was obtained.

The hole was swept with 50 bbl of sepiolite drilling mud. The drill string was recovered and the underreamer and pilot bit were laid out by 1130 h on 1 July.

### Drilling a 21½ Inch Hole in Basement for the 16 Inch Casing

A DDI bicenter reamer (BCR; B182X215) assembly, including a 9⅞ inch stabilizer and a 9⅞ inch pilot wobble bit, was made up to the BHA and lowered to the seafloor. This BCR configuration is designed to drill a 21½ inch diameter hole yet be able to pass through a diameter of 18¼ inch—this would allow it to safely pass through the 20 inch casing string, which has a nominal internal diameter (ID) of 19⅛ inch. After another 5 min reentry, the drilling assembly was lowered to 233.7 mbsf without incident. The top drive was picked up and the pipe was lowered the remaining distance to the bottom of the hole. At 1900 h on 1 July basement drilling with the BCR commenced. Drilling proceeded well at first with 7.3 m of advance drilled at an average ROP of 1.5 m/h. The last 1.8 m only drilled at 0.6 m/h, and after sweeping the hole with 50 bbl of sepiolite mud a wiper trip back above the basement contact at 262.2 mbsf was made. Two more wiper trips were made through this interval interspersed with two more 50 bbl sepiolite mud sweeps. The lowermost 2–4 m of hole never did clean up adequately and it was felt that attempting to advance the hole further with this drilling assembly was not prudent and risked tool failure. Significantly elevated drilling torque, 450+ A rather than the earlier 150 A, led us to abandon further attempts at deepening the hole with the BCR assembly, and we elected to recover the drill string short of our original target depth of 272–276 mbsf. The hole was displaced with sepiolite mud and the drill string was recovered on the rig floor at 1400 h on 2 July.

### Deploying and Cementing the 16 Inch Casing

The subsea release (SSR) plug assembly was made up to the DQ casing running tool and secured in the derrick. After conducting a safety meeting, preparations were made for running 16 inch casing. The shoe joint was picked up and the cementing float shoe was attached to the lowermost joint of 16 inch casing. Another 19 joints of standard 16 inch (75 lb/ft buttress) casing were made up, and the 16 inch casing hanger was then attached to the top of the string. The casing running tool was engaged with the 16 inch casing hanger, and the string was lowered to 2643 mbrf and spaced out for reentry. Another quick reentry (10 min) was made into Hole U1301A at 0045 h on

3 July. The casing string was lowered without resistance to 2902 mbrf (234.3 mbsf), where the top drive was picked up. We continued washing down the casing to 2924 mbrf (256.3 mbsf) and the cementing manifold was picked up. The 16 inch hanger was landed and latch-in verified at 0315 h. The cementing operation proceeded smoothly with 18 bbl of 15.8 lb per gallon (ppg) cement mixed up and displaced downhole. The cementing dart landed at the proper amount of strokes (~1220) indicated by a standpipe pressure rise to 2600 psi. The SSR dart/wiper plug assembly also landed at the proper amount of strokes (~1600) and a pressure of 500 psi was maintained. After releasing the pressure at the standpipe, a check was made to confirm that no flowback was occurring. The cementing swivel hose was disconnected and, after 3¼ turns to the right, the casing running tool was released. The end of the drill string was pulled clear of the reentry cone and secured for a routine servicing of the drill line (slip and cut) prior to retrieving the drill string. By 1230 h the drill string was back on the rig floor. The casing running tool was detorqued and laid out with the SSR assembly.

### *Drilling 14¾ Inch Hole in Basement for the 10¾ Inch Casing*

A new 14½ inch tricone drill bit (Varel type ETD617) was made up and six 8¼ inch drill collars were picked up from the forward tubular rack. A five-stand drilling BHA was assembled, which allowed us to drill 130 m past the 16 inch casing shoe without placing the tapered drill collar (TDC) in open hole. Therefore, the drilling assembly exposed to open hole would consist entirely of slickwall pipe (8¼ inch drill collars) all the way down to the top of the 14¾ inch tricone drill bit.

The drill string was lowered to 2658.9 mbrf, stopping to fill the pipe every 30 stands. After spacing out the drill string, another 5 min reentry was made into the Hole U1301A. After retrieving the camera system, the pipe was lowered an additional four stands and the top drive was picked up in preparation for drilling. At 2130 h on 3 July the top of the 16 inch wiper plug was contacted and we commenced drilling out the wiper plug, dart, and float shoe assembly. Once through the shoe, the hole cleaning continued to 270.3 mbsf (1.0 m off bottom) when the bit was 8.1 m into basement. Drilling operations then continued with the drilling of the 14¾ inch diameter hole for the 10¾ inch casing string.

At 0015 h on 5 July we terminated drilling the 14¾ inch hole at 3037.0 mbrf (369.7 mbsf). This was 107.5 m into basement. The upper ~42 m of basement drilled at 3.0 to 3.5 m/h. At a ~304 mbsf the ROP began to steadily increase to ~8.0 m/h and this continued to ~357 mbsf. Only a few relatively thin spots (<0.5 m) of 4 m/h drilling rates were interspersed through this interval. The zones of rapid penetration concerned us, and those fears proved to be well founded. The next 20+ h were spent fighting hole problems. Multiple wiper trips, reaming operations, mud sweeps, and so on were required before the hole eventually cleaned up to what we considered reasonable for attempting to emplace casing. The hole was displaced with sepiolite mud and at 2000 h on 5 July we made one final pipe trip up inside the 16 inch casing hanger at 259.3 mbsf. We then lowered the bit back into open hole without rotation or circulation. The bit reached 3016 mbrf (348.3 mbsf) before taking 20,000 lb weight. The driller then broke circulation and proceeded to wash down to bottom. The hole was swept one final time with 50 bbl of sepiolite and then displaced with sepiolite mud. The drill string was recovered on board by 0400 h on 6 July.

### First Attempt at Deploying the $10\frac{3}{4}$ Inch Casing

Twenty-seven joints of $10\frac{1}{2}$ inch casing (40.5 lb/ft; K-55; range 3; buttress thread) were made up with a standard Halliburton cementing float shoe on the bottom and a conventional DQ $10\frac{3}{4}$ inch casing hanger/pup joint at the top. After attaching the casing running tool, the casing assembly was lowered to the seafloor. Once the camera system could see the bottom, we reentered Hole U1301A with the casing string within 5 min (at 1415 h). Problems ensued almost immediately. The $10\frac{3}{4}$ inch casing shoe encountered resistance ~4 m below the 16 inch casing shoe (~3 m into basement). The casing was worked past this ledge, and by 2030 h we had managed to work the $10\frac{3}{4}$ inch casing to 355.6 mbsf or 93.2 m into basement. This was just 4.5 m shy of our hanger landing depth. With confidence mounting we shut down circulation and picked up the cementing manifold and swivel assembly. Once operations resumed (~16 min later) we found that we were unable to move the casing down any further. The hole appeared to be collapsing in above us, although we still were able to maintain uninhibited circulation. We not only could not pass 3023.3 mbrf (355.6 mbsf); we also had problems pulling back uphole (20,000 to 40,000 lb overpull). The casing could be pulled back up with overpull but would not go back down. After pulling the casing shoe back to 309.3 mbsf (46.9 m into basement) all drilling parameters returned to normal. Speculation was that "ratchet" rocks fell in from above and would only allow movement in the upward direction. Once this material was below us the casing was once again free to move up or down freely. By 2400 h on 6 July the casing had been once again lowered to 3010.8 mbrf (343.1 mbsf). At this point the upper hole problems again prevented us from advancing any further. At 0400 h on 7 July we stopped attempting to land the casing and decided instead to recover the casing string, shorten it up considerably, and make Hole U1301A an installation to monitor uppermost basement.

After pulling the casing string back to the ship we laid out the casing hanger and then began to lay out the first of what was supposed to be a total of seven joints of 10¾ inch casing. The first joint was laid out correctly. The second joint appeared to be slightly bent. The next five joints were noticeably bent, so we continued on and checked the next two joints beyond the original number of joints we intended to take out of the casing string. The sixth joint was also bent, but from that point on the string was all right. All bent joints had been above the seafloor during the attempts at getting past the problem zone.

### *Second Attempt at Deploying the 10¾ Inch Casing*

A single "replacement" joint of 10¾ inch casing was picked up and made part of the original casing string. All six of the recovered bent joints were marked and stored in the riser hold. The 10¾ inch casing hanger was then made up, the running tool was attached, the remainder of the BHA was assembled, and the 10¾ inch casing string was lowered for the second time. Space out for the new casing string was designed to place the casing shoe into the upper portion of basement above the zone of rapid ROP and fairly close to the sediment/basement interface so as to have the best chance of a good cement seal and limited lateral dispersion of the cement into the formation. We felt that attempting to place the 10¾ inch casing shoe too far into the upper "fractured" basement would risk not getting the cement to reach back up to the 16 inch casing shoe, which was essential for sealing the hole for the CORK hydrologic experiment. The objective of the shallow sampling hole was to sample the "upper" few tens of meters of basement; our planned 10¾ inch casing shoe depth would achieve this, and placing it deeper into the "upper" basement would not improve upon this goal.

The subsequent reentry of Hole U1301A was made more interesting than the previous ones due to a great cloud of drilling mud that was suspended in and around the reentry cone, significantly obscuring visibility. Instead of the camera, the sonar system was used primarily to locate the cone and was also a major contributor in helping to make the reentry itself. After 45 min, Hole U1301A was reentered for the sixth time and the shortened version of the 10¾ inch casing string was lowered into the hole and landed without incident, placing the 10¾ inch casing shoe at 277.1 mbsf, or 14.9 m into basement. Hanger latch engagement was confirmed with 15,000 lb of overpull, and the shoe was cemented in place with 10 bbl of 15.2 ppg class G cement. The cementing operation using the SSR system was completed without incident, and at

0035 h on 8 July the casing running tool was released. The initial phase of operations in Hole U1301A was completed with the recovery of the drill string at 0800 h on 8 July.

We decided to temporarily halt operations in Hole U1301A to allow the cement to set, to allow the hole time to equilibrate, and to initiate operations in Hole U1301B.

## Transit to Hole U1301B

Hole U1301B was located only 36 m northeast of Hole U1301A, so the ship was offset in DP mode while the drill crew continued to retrieve the drill string. The scientists wanted to have Hole U1301B as close as technically possible for the potential of being able to investigate vertical flow. Because of the close proximity of the holes a jet-in test was considered unnecessary.

## Hole U1301B

### *Deployment of Reentry Cone and 20 Inch Casing*

The reentry cone for Hole U1301B was painted distinctively (Fig. **F12**) so as to readily distinguish it from the Hole U1301A reentry cone. The reentry cone for Hole U1301B had three alternating black panels internally with a black rim on the top of the black panels only; the rims of the nonpainted panels were painted black on the corners only. The center black panel was lettered "1301B" with white lettering. On the outside of the internally lettered panels were letters painted "1301B" in white against a black box/background.

The newly painted reentry cone was moved over center in the moonpool, and the rig floor was prepared for running 20 inch casing. This assembly consisted of a shoe joint previously cut to the appropriate length and welded out to a standard 20 inch Texas pattern casing shoe, two joints of 20 inch casing (94 lb/ft; K-55; range-3; buttress thread), a standard 20 inch casing pup joint, and a 20 inch DQ casing hanger. The hanger was latched into the reentry cone and latch ring engagement was verified by visually observing that the latch ring was in the appropriate position as viewed through the disengagement holes. Unlike the previous 20 inch latch-in operation, this time the distinctive "audible snap" was heard as the latch ring engaged. After assembling the BHA, the casing running tool was made up to the 20 inch casing hanger and the entire assembly was ready for lowering. At 2000 h on 8 July, Hole U1301B was spudded as the 20 inch casing shoe tagged the seafloor. Jetting of the 20 inch conductor casing proceeded well, and 6.5 h later we landed and released the reentry cone base at the seafloor. Release of the DQ running tool was again executed perfectly, and by 0900 h on 9 July the drill string was back on board ship.

### *Drilling a 20 Inch Hole for the 16 Inch Casing*

The same Smith 18½ inch Model 2JS tricone drill bit (jetted with one number 16, and two number 24 nozzles) and the same HOC model DTU 1175 underreamer (outfitted with three number 12 jets) were made up and prepared for and running in the hole. As is customary, the underreamer was function-tested by pumping with a circulating head to visually observe that the underreamer arms would open correctly. Even with 90 spm and 900 psi pressure the arms failed to extend. At 1300 h on 9 July we decided to suspend operations long enough to rebuild the single set of large underreamers that we had on board. Drilling the hole only with the 18½ inch bit was discussed and rejected, as was the use of the 21½ inch BCR (per previous experience discussed earlier). The underreamer was torn down by placing the body vertically in the rotary table. The seals were replaced, and 3.75 h later the tool had been rebuilt and successfully function-tested.

The drilling assembly was lowered to the seafloor, the camera system was deployed, and the drill crew serviced the drill line (slip and cut). Prior to reentry we lowered the pipe and visually observed the bit tag the seafloor adjacent to the reentry cone. Seafloor depth for Hole U1301B was confirmed to be 1.0 m higher than Hole U1301A at 2666.5 mbrf. This depth was later adjusted to 2667.8 mbrf. Hole U1301B was reentered for the first time in virtually seconds. As the bit was lifted off the seafloor it swung directly over the reentry cone and the reentry was made at 2245 h on 9 July.

Once inside the 20 inch casing the top drive was picked up, the camera was recovered, and drilling commenced at 0015 h on 10 July. After an initial slow advance of ~9 m directly below the 20 inch casing shoe (to keep from opening the underreamer arms inside the casing), the underreamer was opened up and drilling continued to 2933.0 mbrf (265.2 mbsf). An abrupt change in ROP at 1015 h, coupled with the typical "basalt bounce" associated with hard rock drilling, was a clear indication that we had reached our basement target 4.1 m shallower than we did in Hole U1301A. The underreamer, with arm extension set at 20 inches, was installed ~8 m above the bit. The 18½ inch tricone bit with the 20 inch underreamer above drilled the sediment at an average rate of 35.0 m/h. The average "net" ROP in sediment was ~23 m/h (including connection time). We continued drilling in basement to 2943.0 mbrf (275.2 mbsf). The ROP for the 18½ inch bit in basement (first 8 m) was 3.6 m/h using a WOB of

~15,000 lb. An additional 2 m of basement was then drilled with the underreamer penetrating the top of basement, placing the depth of the 20 inch hole at 2935.0 mbrf (267.2 mbsf). The actual ROP for the 2 m of basement drilled with the 20 inch underreamer was ~1.3 m/h using a reduced WOB of 10,000–12,000 lb. Other notable drilling parameters were rotation = 60–70 rpm, two pumps at 80 spm each, and pump pressure = 1450–1475 psi.

We then raised the bit to 2910.0 mbrf (242.2 mbsf), set back the top drive, and continued up to 2707.0 mbrf (39.2 mbsf). While lowering back into the hole we began to take weight at 2906.0 mbrf (238.2 mbsf). The top drive was picked up and we continued to wash and ream the hole at 2906.0 mbrf (238.2 mbsf) and from 2910.0 mbrf (241.2 mbsf) to 2943.0 mbrf (275.2 mbsf). There was no fill encountered at TD.

We swept the hole with 50 bbl of sepiolite mud and then made another wiper trip to 2900.0 mbrf (232.2 mbsf) and back to TD. We checked the hole condition at that point by lowering the drilling assembly without pump or rotation until encountering a ledge at 2935.0 mbrf (267.2 mbsf). This was <1.0 m below our target depth for the 16 inch casing shoe of 267.5 mbsf and was considered too close for comfort. We therefore elected to drill an additional 1.0 m of hole into basement. With the 18½ inch hole depth now at 2944.0 mbrf (276.2 mbsf) and the 20 inch hole depth at 2936.0 mbrf (268.2 mbsf) we again swept the hole with 50 bbl of sepiolite mud and proceeded to conduct one last hole inspection to 2900.0 mbrf (232.2 mbsf) and back to TD without rotation or circulating. This time the hole was deemed in acceptable condition for 16 inch casing deployment.

The hole was swept a final time with 50 bbl of sepiolite mud and then displaced with another 304 bbl of sepiolite prior to retrieving the drill string. When the drill string was recovered the underreamer arms were still in the expanded position. We were unable to retract the arms. The underreamer and drill bit assembly was laid out by 0615 h on 11 July.

### Deploying and Cementing the 16 Inch Casing

By drilling the upper 3.0 m of basement with the underreamer assembly we eliminated the need for another drill string round trip to deploy the bicentered bit assembly. Therefore our attention turned to making up and deploying the 16 inch casing string. A total of 19 joints of 16 inch casing (75 lb/ft; K-55; range 3) was made up with a cementing float shoe on the bottom and a standard 16 inch casing hanger on the top. The special 16 inch seal bore pup joint was not used, however, because of insufficient clearance (0.015 inch per side) with the $10\frac{3}{4}$ inch seal sub assembly designed to mate with the seal bore hanger.

To enhance our chances of successfully landing the casing hanger we amended our operating procedures. We made up a single joint of drill pipe to the bottom of the cementing manifold. In this way we hoped to speed up the process of adding the cementing manifold to the drill string later. It was during this time that previously, with the circulation pumps shut down, we are most vulnerable to packing of the hole annulus and the attendant problems with getting the casing string moving downhole once again.

The casing string was lowered to the seafloor, the camera system was deployed, and Hole U1301B was reentered for the second time at 1620 h on 11 July. After picking up the top drive, the casing was lowered into open hole and the casing hanger landed without incident at 1800 h. Latch engagement was verified with 15,000 lb of overpull. The 16 inch casing shoe was subsequently cemented in place with 18 bbl of 15.2 ppg cement at a 270.9 mbsf. The casing running tool was released with $3\frac{1}{4}$ turns to the right and the drill string/cementing manifold were thoroughly flushed with seawater prior to retrieval.

After recovering and detorquing the casing running tool, the underreamer was placed in the rotary table.

### Drilling a $14\frac{3}{4}$ Inch Hole in Basement for the $10\frac{3}{4}$ Inch Casing

At 0130 h on 12 July we began making up the $14\frac{3}{4}$ inch tricone drilling assembly. A five-stand BHA was run so that we could keep the top of the $8\frac{1}{4}$ inch drill collars inside casing and out of open hole. In this way we minimized our chances of getting stuck while drilling the $14\frac{3}{4}$ inch diameter hole.

Hole U1301B was reentered for the third time at 0700 h on 12 July, and by 1030 h the float shoe and cement were drilled out and the hole was cleaned up to TD at 2944.0 mbrf (276.2 mbsf). At 1030 h we began drilling the $14\frac{3}{4}$ inch hole in basement required for the $10\frac{3}{4}$ inch casing string.

Basement drilling was conducted using a new Varel $14\frac{3}{4}$ inch ETD617 tricone drill bit (SN174706) jetted with three number 20 nozzles. The first 50.0 m of basement drilling was achieved in 13.5 h at an average "net" drilling rate (including connection time) of 3.7 m/h. The actual ROP through this section varied from as much as 6.0 to <1.0

m/h. Drilling was uneventful until reaching 327.2 mbsf. While picking up to make a connection, the driller noted 20,000 lb of overpull and significantly elevated pump pressures. It appeared that the hole had packed off. The driller continued to fight hole problems including loss of rotation, loss of circulation, overpull, and elevated pump pressure for the next >11 h. Finally, at 1130 h on 13 July, the hole appeared to be stabilized and forward progress continued. By 1530 h the hole had been advanced to the target depth of 3018.0 mbrf (350.2 mbsf) or 85.0 m into basement.

The hole was swept multiple times with sepiolite mud and we continued to wash/ream the hole until we were comfortable that hole stability was adequate for casing deployment. By 0215 h the morning of 14 July the bit was back on board ship and preparations for running the 10¾ inch casing string began.

### First Attempt at Installing the 10¾ Inch Casing

Twenty nine joints of 10¾ inch casing (40.5 lb/ft; K-55; Range 3) were made up along with a cementing float shoe and the 10¾ inch casing hanger. Total string length was 342.50 m. The casing running tool was made up and lowered to the seafloor. The camera was deployed and Hole U1301B was reentered for the fourth time at 1140 h on 14 July. The casing was lowered to 2964.0 mbrf and the top drive was picked up. The casing was washed to 3002.0 mbrf (334.2 mbsf) without incident. After picking up the cementing manifold we found we could not pass 3002.0 mbrf. Nearly 7 h were spent attempting to move the casing further downhole but all efforts were in vain. The string was entirely free above 3000.0 mbrf but could not be moved any further down the hole. At 1930 h we abandoned our efforts to install the casing, laid out the cementing manifold, and retrieved the casing string. There were no problems or indications of drag or overpull identified while pulling the casing in open hole. By 0530 h on 15 July, the 10¾ inch casing string had been disassembled and stored away in the riser hold.

### Reaming of the 14¾ Inch Hole in Basement

A 14¾ inch tricone bit and five-stand drilling BHA was assembled and lowered to the seafloor. Reentry number 5 was made into Hole U1301B in short order, and at 1015 h 15 July we began to lower the bit to 2965.0 mbrf, where the top drive was picked up. The bit was washed to 2998.0 mbrf (330.2 mbsf) before encountering any significant resistance. At that depth the driller noted that he was meeting resistance (taking weight). The next 6 h were spent washing, reaming, and pumping multiple sepiolite mud sweeps to clean and condition the hole once again from 2998.0 mbrf to TD at

3018.0 mbrf. By 2000 h on 15 July we were comfortable with the shape the hole was in. We then pulled the pipe back up into the 16 inch casing shoe and waited 1 h for the hole to equilibrate. No overpull or drag was encountered during the trip up to the casing shoe, which was a good sign. At 2130 h we began lowering the pipe slowly to TD with minimal pump (30 spm) and no rotation. At TD we swept the hole one final time with 50 bbl of sepiolite mud and pulled out of the hole. No significant resistance was encountered, and we felt certain that the last remaining vestiges of problem spots had been removed. By 0500 h on 16 July the bit was on deck and we began making up the 10¾ inch casing string for the second time.

### Second Attempt at Deploying the 10¾ Inch Casing

The same casing string consisting of 29 joints of 10¾ inch (40.5 lb/ft; K-55; range 3) casing was made up along with a cementing float shoe and the 10¾ inch casing hanger. Total string length was held constant at 342.50 m. The DQ running tool was made up, and the casing was deployed via the drill string. The vibration-isolated television (VIT) camera was installed, and Hole U1301B was reentered for the sixth time at 1425 h on 16 July. The casing was run in hole to 2964.5 mbrf, and the top drive was picked up. Lowering continued to ~3005 m, where minor resistance was met. The casing was encouraged to move down another meter by increasing the pump strokes. The cementing manifold with a pre-made up drill pipe single was made up and the cementing hose was connected.

This new technique worked beautifully and mud pump circulation was shut down for only 2 min, 55 s. With the manifold in the string we resumed lowering casing and landed the casing hanger at 1615 h on 16 July 2004. Proper latch engagement was verified with 15,000 lb of overpull. The 10¾ inch casing shoe was cemented at 346.1 mbsf with 32 bbl of 15.2 to 15.8 ppg cement. Heavier cement was pumped at the shoe. The cement was displaced with the rig mud pumps, the cementing dart was released, and the SSR plug was landed with 500 psi. The pressure was vented at the standpipe manifold, and a check for backflow proved negative. The casing running tool was released with 3¼ turns of right-hand rotation and it was raised to 2657.0 mbrf. After flushing and laying out the cementing manifold, we set back the top drive and recovered the camera. Prior to retrieving the drill string, the drilling line was serviced (slip and cut). The pipe trip was completed while the ship moved to Hole 1026B. A positioning beacon (SN 2193; 14.0 KHz; 208 Db) was deployed at 2356 h, and by 0045 h on 17 July the casing running tool was detorqued and laid out, ending Hole U1301B for now.

## Transit to/from Site 1026

Before continuing further operations at Site U1301, we decided to move over to Hole 1026B to remove a mini-reentry cone installed in the top of the existing CORK. See "Site 1026," in Operations, for a detailed description of these operations. We conducted the 1.08 km transit to and from Hole 1026B in dynamic positioning mode while retrieving the drill string.

## Return to Site U1301

### *Depth Measurement Check in Holes U1301A and U1301B*

The first operation during this occupation of Hole U1301B was to drill out the 10¾ inch casing shoe, the SSR plug/dart assembly, and any remaining cement. A 9⅞ inch tricone drill bit was made up to a three-stand BHA and lowered to the seafloor.

Prior to reentry into Hole U1301A, we decided to conduct a thorough depth check in both Holes U1301A and U1301B. Using the drill string pipe tally and the camera system, we visually verified the seafloor depth, the depth for the top of the cuttings mound (at a single location), and the depth to the top rim of the installed reentry cones. By taking these measurements simultaneously over a 30 min period, we essentially eliminated tidal effects (Fig. F13), giving us accurate depth references for each hole as well as accurate comparison depths between holes. These data were important in accessing whether the final resting locations of the reentry cones were likely to present future ROV or submersible accessibility problems to the CORK head instrumentation bays. It was determined that both reentry cone rims were below the seafloor and that, to be safe, the Hole U1301B CORK would have to be raised 2.0 m prior to installation. Later in the expedition we received a helicopter transfer with the required equipment to extend the height of the CORK head. The Hole U1301B CORK required extension because of the additional 1.0 m buildup of cuttings above the tagged seafloor depth.

## Hole U1301A

### *Drilling out the 10¾ Inch Casing Shoe*

With the depth measurement exercise completed, Hole U1301A was reentered for the seventh time at 1940 h on 17 July. The camera was recovered back on board ship while the pipe was lowered into the hole run and the top drive was picked up. The float shoe was drilled out in 45 min and the bit was then lowered without rotation and without circulation to see how much unrestricted depth of hole was available. Tag depth was recorded at 2963.5 mbrf with 15,000 lb of weight set down. This equates to 296.2 mbsf, which is 34.0 m into basement or 19.1 m below the $10\frac{3}{4}$ inch casing shoe. The $9\frac{7}{8}$ inch drilling assembly was retrieved, and at 0315 h on 18 July the bit and bit sub were laid out and we began preparing for hydrologic (packer) testing.

### *Hydrologic (Packer) Testing*

A packer testing BHA was assembled consisting of a clean-out bit, an $8\frac{1}{4}$ inch 10 ft long drill collar pup, the TAM International packer assembly with a 5 ft element, eight $8\frac{1}{4}$ inch drill collars, and a TDC. This BHA was lowered and the camera/sonar system was deployed. Prior to reentry and offset from the reentry cone, a drill pipe wiper pig was pumped through the drill string to wipe out any rust or corrosion residue remaining; this was to ensure that any residue would not interfere with the hydrologic testing. Hole U1301A was reentered for the eighth time at 0901 h on 18 July. After recovering the camera, lowering pipe to 2941.0 mbrf, and picking up the top drive, the packer assembly was positioned inside the last (shoe) joint of $10\frac{3}{4}$ inch casing (2941.0 mbrf). A packer setting go-devil was deployed and 1 h was spent recording a hydrostatic baseline pressure. At 1200 h on 18 July, the packer was inflated with 1000 psi pressure and 10,000 lb of weight was set down on the packer to keep it from creeping uphole. Another 1 h was used standing by for a formation baseline pressure, and at 1300 h a series of constant-rate injection tests were conducted into the formation. Injection testing was completed at 2330 h, at which time the packer was deflated and the wireline was lowered to recover the packer go-devil. The drill string was retrieved back on the rig floor by 0730 h on 19 July.

## Hole U1301A CORK Installation

The final configuration of the CORK installed in Hole U1301A is shown in Figure **F14.**

After rigging up for running $4\frac{1}{2}$ inch casing, three 6 m long “slotted” pup joints were made up with a casing bull plug on the bottom. The bull plug had a bar welded across the face to prevent any instruments from passing out the bottom of the $4\frac{1}{2}$ inch casing string should the instrument string fail. The slots (cut with a plasma cutter) were put in the casing pups to allow free flow of formation fluids through the lower part of the instrumentation string. The landing sub was made up along with a single $4\frac{1}{2}$ inch casing packer. Three miniscreens were installed at the approximate center of the slotted casing joints (~10 m below the packer). Another four miniscreens were installed immediately below the packer. By 1200 h the lower ends of the umbilical lines were connected. The umbilical for this installation was left over from Leg 196. The Hole U1301A CORK used 278 m of umbilical, and 234 m of the Leg 196 umbilical remains on the drum for possible future use. The next 8 h were spent making up 18 joints of 4½ inch casing and two 6 m long pup joints, strapping umbilical lines to the casing, installing casing centralizers (~2 per joint; 48 total), making up the CORK running tool to the CORK head assembly, connecting the packer inflation hose from the running tool to the head, and making up the remaining BHA required for the deployment. The BHA consisted of the CORK running tool, five 8¼ inch drill collars, a TDC, and the usual two-stands of 5½ inch transition drill pipe.

The assembly was lowered into the moonpool, where a bent valve handle was replaced and a single osmotic sampler was attached. The moonpool doors were opened and the large camera/sonar sleeve was test fitted over the CORK head to ensure that there would be no interference passing over it when the time came for the camera to be lowered down the end of the 4½ inch casing for reentry. At 2000 h on 19 July we began lowering the CORK assembly to the seafloor. The camera was deployed, and at 0045 h on 20 July, Hole U1301A was reentered for the ninth time. The casing was lowered until just before landing into the 10¾ inch casing, and the top drive was picked up.

### *CORK Head Identification*

The CORK head deployed in Hole U1301A had a wide black stripe painted near the top of the structure just below the lugs used for engaging the CORK running tool. In the middle of the large black stripe was a small white stripe. Both stripes were painted circumferentially around the structure for additional identification.

### *Deployment of CORK Osmotic Sampler/Thermistor String*

At 0245 h we began making up the internal OsmosSampler/thermistor instrument string. This consisted of a lower sinker bar, four osmotic samplers, a lower “gravity plug” seal sub, a section of ⅜ inch spectra rope with two thermistors installed, another sinker bar, another section of spectra rope, and an upper “gravity plug” seal sub. The assembly was deployed at the rig floor by using two sheaves, two tuggers, and a series of rope “grippers” that were systematically braided onto the spectra rope and then removed prior to entry into the drill pipe. Once made up, the entire (~294 m long) assembly was lowered through the pipe and down inside the CORK using the core winch with a special sinker bar assembly consisting of three sets of wireline jars installed in series. A special "weakened" shear pin was installed in the overshot. Once landed in the CORK head, the instrument string was released by jarring and severing the shear pin. The sinker bar assembly was recovered and a packer setting go-devil was dropped down the drill string. This go-devil was used in the past as a backup way of inflating the 4½ inch casing packer should the seals in the CORK running tool "stinger" fail to seal properly. At 0745 h, after activating the AHC, the CORK head was landed in the 10¾ inch casing hanger. The 4½ inch casing packer was inflated with 600 psi pump pressure, and this pressure was held for 30 min. The camera was recovered and preparations were begun for deployment of the ROV/submersible platform.

### *Deployment of the ROV/Submersible Platform*

The ROV/submersible platform used on Hole U1301A was of the older design. It was made up of gray plate steel with holes cut in it to aid in the passage of water through the structure during deployment. This platform is distinctively different than the newer design deployed in Hole U1301B. The new platforms, although they are also gray in color, are made up of steel grating material and are not solid metal. One quadrant of the Hole U1301A platform was outlined with a black paint stripe to give the DP operators a directional orientation reference. On the surface of the platform there were two opposing black squares painted with white numbers "1301A."

The ROV/submersible platform was moved into the moonpool, and final assembly (bolting/welding) was completed. A newly designed mechanical platform deployment tool (see Fig. **F15**) was made up to the platform, and the assembly was deployed on the logging line via the new Schlumberger heave-compensated logging winch. In the past, the platforms were deployed using the logging line and a wire rope bridle attached to an acoustic release. Once landed, the platform was released by lowering a portable transducer over the side of the ship and sending a release command sequence to the subsea release system. The new mechanical system is designed to release the platform automatically as the deployment tool encounters the top of the CORK running tool. At 1400 h on 20 July the platform reached the CORK; however, the weight of the platform was not released. When the winch operator picked up, he had ~1300 lb of overpull. The cable was slacked off a second time and once again the winch operator picked up. This time, with a few hundred pounds of overpull, the tool came free and the static hanging weight indicated that the platform had been released. Upon recovery, one of the three arms on the running tool had bent. Two arms released properly and the third apparently hung up momentarily, which was long enough to put that portion of the mechanism in a bind. In retrospect, we believe one of the arms was hammered into place during attachment to the platform, and this is likely the one that did not release cleanly. The platform deployment tool has been repaired and the next time it is used more care will be given to making sure that the three engagement arms are fitted to the platform with the necessary clearance for a less forceful release. In addition, rather than landing the tool at the CORK head at a constant lowering speed, the winch will be stopped just above the head, allowing any platform "rocking" motion to settle out prior to continuing on over the running tool for release. Momentum is not required for a successful release, so a more gentle engagement during landing is desirable.

By 2400 h on 20 July the platform deployment tool had been recovered, and the camera was deployed to inspect the CORK installation. The installation appeared to be fine. The CORK running tool was quickly released and the drill string was retrieved. The camera was recovered and the coring line was deployed to recover the packer setting go-devil. To our surprise, the overshot contacted the packer setting go-devil at 1540 mbrf. Apparently the go-devil never properly seated in the CORK running tool as it was supposed to. Although this was a backup mechanism, there was still some concern as to why the go-devil hung up in the drill string. After taking measurements of the go-devil body we found that the upper diameter of the tool measured a larger diameter than the drill pipe drift used in "rabbiting" our drill pipe to ensure a clear bore. The investigation is continuing as to why this go-devil was designed the way it was. It was not used for the other three CORK deployments.

During the pipe trip the ship was moved 36 m back to Hole U1301B, and by 2400 h on 20 July all tools had been recovered, ending operations for Hole U1301A.

## Hole U1301B

### *Drilling out the 10¾ Inch Casing Shoe*

A 9⅞ inch tricone bit and drilling BHA was assembled and lowered to the seafloor. After deploying the camera and spacing out the drill string, Hole U1301B was reentered for the seventh time at 0525 h on 21 July. The pipe was lowered to bottom, the top drive was picked up, and the 10¾ inch casing shoe, SSR plug assembly, and remnant cement were drilled out. The rathole below the shoe appeared clean and no fill was encountered. Once on bottom we drilled another 1.0 m of new hole to provide some stabilization for the RCB core bit soon to follow. The hole was swept with 20 bbl of sepiolite mud, and the drilling assembly was recovered back on board ship by 1530 h on 21 July.

### RCB Coring in Basement—First Bit Run

A 9⅞ inch RCB (CC-7 style) coring bit was made up with a mechanical bit release (MBR) and the remaining subs associated with the RCB outer core barrel assembly. A six-stand BHA was made up and lowered to the seafloor. The unusual number of drill collars was to allow us to reach an adequate depth (100–150 m) on the first RCB bit run without exposing the top of the TDC to open and possibly unstable hole. Prior to reentry the drilling line was serviced (slip and cut), and at 2215 h on 21 July Hole U1301B was reentered for the eighth time.

After picking up the top drive, continuous RCB coring commenced at 0300 h on 22 July. Coring continued with variable parameters. Hole instability seemed to be associated with those portions of the hole where rapid penetration rates (4–6 m/h) were encountered. Core recovery also decreased in these "brecciated" intervals and the drilling torque became higher and erratic. To date we have been able to clean up these problem sections of hole. In the more massive portions of basement the ROP slowed down dramatically with progress in the 1.0–3.0 m/h range. The first bit run continued until 0300 h on 25 July, when Core U1301B-15R was recovered. This core was excellent with 9.6 m advanced and 4.92 m of fairly massive core recovered (recovery = 51.3%). The ROP for Core 15R averaged 1.5 m/h although major tidal influences (±2 m per day) continued to complicate our drilling depth references (see Fig. **F13**). Total depth achieved to this point was 3121.0 mbrf (453.2 mbsf). A total of 102.0 m was cored with the first bit achieving a recovery of 31.41 m (30.8%) and requiring 53.0 total bit rotating hours. The bit was pulled early to be conservative and ensure that the hole remained free of junk for additional bit runs. Recovery probably could be improved substantially by deploying barrels without core liners and by cutting half rather than full cores, but the scientists considered deep penetration to be equally important to good recovery.

A wiper trip was made back up to the 10¾ inch casing shoe and then back to TD, where ~7 m of fill was encountered. The fill easily washed away and the hole was swept with another 30 bbl of sepiolite mud.

### RCB Coring in Basement—Second Bit Run

Consideration had been given earlier to running a C-4 core bit in lieu of another C-7 style. The C-4 has a slightly longer tungsten carbide insert and may have achieved a slightly faster rate of penetration. Once the initial bit was recovered, however, that idea was abandoned. Although the bearings were in excellent condition, the cutting structure was not. All buttons were broken on the ID gage cutters and there were broken, chipped, or missing teeth on all other rows. The bit was considered junk. Because of the magnitude of broken teeth on the first bit, it was considered unwise to run a bit with longer teeth. Therefore, another new C-7 core bit was made up to a rebuilt MBR. Another three drill collars were picked up, enabling us to run a seven-stand BHA. This allowed us to core up to 186 m beyond the 10¾ inch casing shoe without exposing the smaller-diameter TDC to open hole. With the first bit advancing to 107.1 m beyond the shoe, the longer BHA would now allow us to core another 79 m. The pipe was lowered to bottom, and Hole U1301B was reentered for the ninth time.

While lowering the bit through the 10¾ inch casing, the driller noted that there was an obstruction inside the 10¾ inch casing at 2918.2 mbrf. Even setting down a weight of 30,000 lb down, the bit would not pass this point. The top drive was picked up and with only minimal rotation the bit passed through the spot with little problem. The driller picked up above the point and when he came down a second time, once again the interference was identified at exactly the same depth. We had not seen this phenomenon on either of our first two trips through the 10¾ inch casing string (later on we would find that this was the lower portion of the 10¾ inch casing that had backed off). Unable to do anything about the problem, we continued on to bottom washing and reaming from 3106.0 m to 3121.0 mbrf (TD). The hole was swept once more with 50 bbl of sepiolite mud and the center bit was recovered.

At 0030 h on 26 July we resumed RCB coring in basement. Coring proceeded well initially. Sepiolite mud sweeps (30 bbl) were pumped every connection. The hole appeared to be in good condition with no overpull or fill on bottom. Coring continued through Core 26R to 3186.8 mbrf (519.0 mbsf). When picking up off bottom after cutting Core 26R the driller noted 40,000 lb of overpull and high torque off bottom. The hole was swept with 30 bbl of sepiolite and the pipe was raised to 3157.0 mbrf before recovering Core 26R. Because the torque remained high, we elected to take time for hole cleaning and conditioning. We conducted a wiper trip up to the 10¾ inch casing shoe, noting overpulls of 50,000 and 30,000 lb at 3101.0 mbrf and 3073.0 mbrf, respectively. The hole was washed and reamed back to the bottom, where 12 m of soft fill was easily circulated out. Drilling torque returned to normal, and at 2230 h on 28 July we resumed RCB coring. By 0630 h on 29 July we had advanced the hole to 3200.0 mbrf (532.2 mbsf). The hole was swept with 30 bbl of sepiolite mud, Core 28R was recovered, and at 0815 h we began to retrieve the bit for our second bit change.

During the pipe trip the driller worked the pipe several times through the earlier identified trouble spot at 2918.2 mbrf (inside the 10¾ inch casing). The driller repeatedly raised and lowered pipe from above 2918.0 and down to 2924.0 mbrf (which was simply a convenient drill pipe connection) without incident. There was no indication of any residual problem in that area (see later problems with backed off 10¾ inch casing). At 1530 h on 29 July the bit was back on board and we began making preparations for making up the new coring BHA.

### *RCB Coring in Basement—Third Bit Run*

A new C-7 core bit was made up to another rebuilt MBR. An additional nine drill collars were picked up, enabling us to run a 10-stand BHA. This allowed us to advance the bit up to 268.5 m beyond the 10¾ inch casing shoe without exposing the smaller-diameter TDC to open hole. With the current total depth at 3200.0 mbrf we were able to core ~83 m deeper with this third bit for a total of ~350 m into basement. The pipe was lowered to the seafloor and Hole U1301B was reentered for the tenth time. While lowering pipe inside the casing the driller noted an obstruction at 2926.0 mbrf. This was 8 m lower than the previous encounter. The top drive was picked up and the camera was recovered. The pipe was rotated through the obstruction in the casing without difficulty. As before, the torque above and below that point was normal and consistent. The location of the trouble spot had moved down from 2918.2 on last (second) bit trip to 2926.0 mbrf. We speculated that the casing string was deflected because of an irregular and/or deviated hole and that the drill collars/drill pipe tool joints had been wearing a hole/slot (on low side) in the side of the casing at that depth. This also may have explained our lower than normal ROP. All of the WOB may not have been getting to the core bit if a tool joint was being held back by shouldering inside the casing. Later we determined that the lower part of the 10¾ inch casing had backed off and dropped down. After running the rest of the way to bottom, the hole was swept with 50 bbl of sepiolite mud and RCB coring was initiated. Coring continued until Core 36R was on deck at 1400 h on 31 July. We terminated coring, as we achieved the primary objectives of obtaining substantial penetration deeply into massive basement, and we felt it was wiser to save extra time to deal with any uncertainties associated with the remainder of the expedition objectives (this turned out to be a good move!).

### *Distress Call*

During the last few hours of coring in Hole U1301B, the ship's radio officer picked up a distress call communication between the U.S. Coast Guard (USCG) and a sailing vessel. The sail boat, with six people on board, was located ~31 nmi to the west of the *JOIDES Resolution* and was taking on water. We advised the USCG of our time to recover drill pipe and reach the location of the emergency. We also offered the use of our helideck and helicopter fuel if they were required for rescue operations. The USCG out of Port Angeles, Washington (USA), was handling the situation. We were not requested to cease operations and later information indicated that the vessel was not in danger of sinking and that their pumps (hand pumps and buckets) were keeping up with the ingress of water. Apparently, their powered bilge pump was not operational and the source of the leak was also unknown at the time. Ultimately, the USCG dispatched a fixed wing "Buffalo" aircraft to the scene and air dropped a pump to the sailboat. The vessel continued to its home port of Seattle, Washington (USA).

### Preparations for Wireline Logging

With the cutting of Core 36R the final depth of Hole U1301B was established at 3250.6 mbrf (582.8 mbsf). This yielded an ultimate penetration below the basement contact of 317.6 m. A wiper trip was made up to the 10¾ inch casing shoe and back to TD. No problems were experienced with the wiper trip. Only 8 m of soft fill was identified on bottom, and this was easily circulated out with a 50 barrel sepiolite mud sweep. The bit was pulled back up into the 10¾ inch casing and the earlier identified problem areas were checked by raising the bit past 2918.0 mbrf and lowering the bit down until it shouldered (took weight) at 2926.0 mbrf. As before, slight rotation with the top drive allowed the bit to pass and the string was free below this depth. The pipe trip out of the hole continued, and once clear of the reentry cone the ship was offset 20 m to the north. The shifting tool was lowered and at 0130 h on 1 August the bit was released from the drill string. The ship was positioned back over the hole, and at 0147 h on Hole U1301B was reentered for the eleventh time. The drill string was tripped to 2933.0 mbrf (265.2 mbsf) or slightly below the trouble spot inside the 10¾ inch casing. The top drive was once again used to rotate past this point. At 0415 h on 1 August we began rigging up the logging sheaves for wireline logging.

### Wireline Logging

The Schlumberger logging sheaves were rigged up, and at 0415 h on 1 August we began rigging up the first logging tool suite.

### Triple Combo

The first tool string included the Logging Equipment Head-Mud Temperature (LEH-MT), Hostile Environment Natural Gama Ray Sonde (HNGS), Hostile-environment Lithodensity Sonde (HLDS), Accelerator Porosity Sonde (APS), and SlimXtreme Array Induction Tool (QAIT). The first pass with this tool string reached a total depth of 3246 mbrf. The second pass reached a total depth of 3122 mbrf. The caliper arms were fully extended during the first pass at 3242 mbrf.

### Ultrasonic Borehole Imager (UBI)

The second tool string included the LEH-MT, Spectral Gamma Tool (SGT), General Purpose Inclinometer Tool (GPIT), and UBI. Second tool string deployment required slow deployment speeds because of low tool string weight. An obstruction was encountered in the hole at 3096 mbrf. There were two passes in open hole from ~3096 to 3021 mbrf before repositioning the open-ended pipe at 2914 mbrf. Two passes were made to log the casing interval from 3021 mbrf to seafloor. The UBI data were used to attempt to confirm the length of the gap between the two backed-off sections of 10¾ inch casing.

### FMS-Sonic

The third tool string included the LEH-MT, SGT, Dipole Sonic Imager (DSI), GPIT, and FMS. The third tool string deployment stopped at 2900 mbrf for recording uphole and downhole acceleration with the AHC on and off. An overpull of ~6000 lb was detected at ~3072 mbrf during the second pass. After the deployment the logging engineer had to cut off 150 ft of Hi-T logging line and rehead the rope socket because of several kinks in the cable.

### Vertical Seismic Profile

Even though the WST checked out several days prior to deployment, there were problems getting the tool to respond on deck prior to running in the hole. The back-up WST tool was deployed instead. While running in the hole with this tool the arms appeared to keep opening. The deployment took 2 h to reach the seafloor because of the tool's light weight. On several occasions descent was stopped to close the arm. The initial deployment speed was ~1000 ft/h, and this increased to 7700 ft/h with depth. Based on caliper observations, three potential intervals were identified for WST stations. Clamping and data were recovered at depths of 3075, 3050, and 3025 mbrf. While pulling out of the hole we slowed down to ~2500 ft/h to allow the rig floor crew to work on the AHC and then subsequently increased the speed to ~9000 ft/h. At the rig floor we noticed that at least one arm was fully extended although it had been previously closed before entering the pipe. In support of the VSP program the generator injector gun was used. The gun configuration consisted of a 45 $in^3$ generator volume, a 105 $in^3$ injector chamber volume, and a total pressure of 2000 psi. Data were recorded at 1 ms sampling interval, and the monitoring hydrophone was attached to the generator injector gun, which was placed 2 m below sea level. The delay time used for all shots was 40 ms, and the recording length was 5 s with a starting point at 0 ms.

At 1500 h on 2 August the logging sheaves were rigged down and the wireline logging program in Hole U1301B was completed.

## Transit from Hole U1301B to Hole 1026B for CORK Replacement

After the drill string was recovered and fifteen 8¼ inch drill collars were laid out, we began the 1.08 km DP move to Site 1026B to install a CORK in Hole 1026B. For details of the CORK replacement in Hole 1026B, see **"Site 1026,"** in Operations.

## Transit from Hole 1026B to Hole U1301B

After finishing the Hole 1026B CORK installation (1130 h on 5 August), we moved the ship back to Hole U1301B in DP mode while retrieving the CORK running tool. Once the running tool was secured on deck, the drilling line was serviced (slipped and cut).

### *Attempted Remedial Cementing of the 10¾ Inch Casing Gap*

This reoccupation of Hole U1301B was to make an attempt at doing some remedial cementing of the 10¾ inch casing that had backed off while RCB coring. A custom cementing assembly was designed and fabricated on board the ship. This consisted of a "stabbing sub" fabricated from an old head sub with the square rotary connection shoulder machined to a 45° taper, two stands of 8¼ inch drill collars, an internally blanked off head sub, a ported cementing sub fabricated from a 36 inch long 8¼ inch drill collar pup with three torch-cut 1¼ inch diameter holes, and two additional 8¼ inch drill collars. The remainder of the BHA was the typical TDC and two stands of 5½ inch drill pipe. The custom cementing assembly was lowered to the seafloor, and Hole U1301B was reentered for the twelfth time. The pipe was lowered to 2925.3 m, where the driller noted a weight decrease. Once again, this spot in the casing could not be passed without rotation. The top drive was picked up and the pipe was rotated easily into the lower portion of the 10¾ inch casing string. It should be noted that, based upon an inspection of the MBR recently pulled out of the hole after logging, the 10¾ inch casing string most likely backed off at the casing coupling, leaving the coupling at the top of the lower section of casing looking uphole. Once past the open section of casing, the pipe was lowered to the perceived depth of the 10¾ inch casing shoe at 3019.0 mbrf. At that point 15 bbl of high-viscosity bentonite gel mud was displaced into the hole. This was intended to help "float" the later displaced cement and keep it from falling downhole and out of the desired position. Bentonite gel mud was used for this so that we could keep freshwater- rather than seawater-based mud in the hole. Once the mud was displaced, the pipe was pulled back uphole and positioned so that the "ported sub" was located at ~2924 mbrf, or just a 1–2 m above the estimated depth of the backed-off casing coupling. A 6% mix of freshwater and bentonite gel mud was premixed and then mixed with class G cement to make up a 10 bbl, 15 ppg cement slurry. Once the bentonite-water combination was added to the cement, the mix became very thick and almost unpumpable. With the cementing units pumps straining, the slurry was eventually pumped into the pipe and displaced downhole with the rig pumps. The cement pill was preceded and followed with 10 bbl of fresh drill water to help isolate the cement slurry from the seawater. Once the cement was displaced into position in the hole, the drill string was pulled up again and the "ported sub" was repositioned at 2954.0 mbrf (the top of the calculated cement plug). A drill pipe cementing wiper dart was then pumped to bottom, stopping in the blanked-off sub located below the "ported sub." The drill string was then flushed thoroughly with seawater. The BHA was spaced out for this exercise so that while waiting for the cement to cure we could leave at least one stand of drill collars inside the lower section of 10¾ inch casing to try to keep it aligned with the upper portion of 10¾ inch casing above. While standing by waiting for the cement to harden, we circulated slowly at ~40 spm and rotated the pipe slowly at ~15–20 rpm. This was to ensure that we did not cement our BHA in the hole or at least to recognize if that began to happen. After waiting 7.75 h, we pulled pipe to 2900.0 mbrf and set back the top drive. The remainder of the drill string was then retrieved and the BHA was back on the rig floor at 1700 h on 6 August, completing the attempted remedial cementing operation. We then decided to conduct APC coring in Hole U1301C to give the cement additional time to harden.

## Hole U1301C

### *APC Coring*

A typical three-stand APC/XCB coring BHA was made up and the XCB/center bit and APC core barrels were spaced out. The APC core barrels to be used were dressed with liners and core catchers, and the drill string was lowered to 2652.1 mbrf, where the top drive was picked up and the pipe was spaced out for spudding. An APC core barrel was deployed via the core line, and with the bit positioned at 2663.0 mbrf Hole U1301C was spudded at 0010 h on 7 August. Core 1H recovered 5.08 m, establishing a seafloor depth of 2667.4 mbrf. We cored the sediment section in Hole U1301C to collect high-quality APC samples for geochemical and microbiological studies. We cored continuously from the seafloor to 119.1 mbsf (Cores 1H to 13H). After that, we alternately cored and drilled ahead without coring to ensure we had sufficient time to obtain samples from the deepest sediments. We penetrated a total of 265.3 m, cored 166.8 m, and recovered 143.29 m (86%). We pushed the APC coring system beyond its routine operational limits to obtain APC cores from the deepest sediments above basement. Cores 15H and 16H extended from 178.1 to 197.1 mbsf and recovered 11.87 m (62%). After drilling ahead to 235.8 mbsf, we took Cores 17H to 19H from 235.8 to 255.3 mbsf in the pelagic section just above basement. These cores recovered 24.19 m (85%) and terminated just decimeters above basement. The APC core barrels failed to achieve full stroke after Core 6H; however, good quality core samples were still obtained; we raised the bit ~1 m before shooting each core. The cores were heavily sampled for microbiological and geochemical studies on the catwalk. PFTs were pumped continuously for all APC cores. Five temperature measurements were attempted (APC temperature tool [APCT] and DVTP), but two of these yielded poor-quality data due to tool motion or due to being pushed into poorly consolidated formation sands. Upon completion of APC coring, a small cement plug was displaced at the base of the hole and the drill string was recovered back on board ship. By 1530 h on 8 August the APC coring BHA was back on board and preparations began for drilling out the cement placed earlier in Hole U1301B.

## Hole U1301B

### *Drilling out Cement and Checking Open Hole Depth*

After completing APC coring in Hole U1301C, we moved the ship in DP mode back to Hole U1301B. We planned to drill out the remedial cement displaced 2 days earlier. We hoped that our attempt to keep the cement in place across the 10¾ inch casing gap was successful. After lowering a tricone drill bit and drilling BHA to the seafloor we reentered Hole U1301B for the thirteenth time at 2125 h on 8 August. The bit was lowered without resistance until contacting the top of the lower section of 10¾ inch casing at the predictable depth of 2926.0 mbrf. The camera was recovered and the top drive was used to rotate slowly through this location and into the top of the lower casing section. As before, the entry into the lower casing was relatively easy and the remainder of the trip to total depth did not require any rotation. At no time was any cement contacted inside the casing string so the assumption was that our remedial cement went the same way as all the others—down the hole and into the formation. The pipe was advanced to 3175.0 mbrf, which was considered adequate as an open hole depth check because there were no plans to exceed this depth with the any part of the CORK installation. The hole was swept one final time with 30 bbl of sepiolite mud, the drill string was retrieved back on board at 0730 h on 9 August, and preparations for hydrologic (packer) testing began.

### *Hydrologic (Packer) Testing*

The TAM packer BHA was assembled with a single packer element, and the surface circulation equipment was successfully pressure tested in preparation for packer slug and flow testing. The drill string was lowered to the seafloor and Hole U1301B was reentered for the fourteenth time at 1310 h on 9 August. The pipe was advanced all the way to 3152.0 mbrf, placing the packer at the first set point of 3140.0 mbrf. No problems were experienced on the trip except for what has become the traditional rotation into the top of the lower 10¾ inch casing string at 2926.0 mbrf. The first packer slug/flow test was conducted from 1745 h on 9 August until 0215 h on 10 August. The packer was then deflated and the pipe was raised to the second packer test depth of 3110.0 mbrf. This second packer test was completed at 0700 h. The packer was again deflated and the pipe was raised to the third packer test depth of 3085.0 mbrf. This packer test was completed at 1200 h, the packer was deflated, and the pipe was raised for a fourth and final time to the last packer set depth of 3047.0 mbrf. The last packer set was to check for a good packer seat only, and no flow testing was conducted at this depth. By 1400 h on 10 August all packer work was completed and the packer go-devil was recovered. The top drive was set back and the pipe was recovered, clearing the seafloor at 1645 h. By 2100 h all packer components were laid out on the rig floor. The packer element, after four successful inflation cycles, appeared to be in surprisingly good condition. The element had a few minor cuts and abrasions, and there was a slight memory (set) to the elastomer; however, there was no major damage identified. Based on the data recovered with the downhole digital gauges all pressure tests appeared to be 100% successful.

### *Deployment of the CORK "Test" Casing String*

We decided that before assembling the entire CORK casing string, dual umbilicals, three packers, and head, we should run a test to ensure that the casing and bow-spring centralizers could be coaxed across the gap in the $10\frac{3}{4}$ inch casing and into the lower section. At 2100 h on 10 August we began rigging up the $4\frac{1}{2}$ inch casing running tools. The first order of business was to determine how much weight was required to compress the bow-springs on our new $4\frac{1}{2}$ inch bow-spring centralizers. A centralizer was test-fitted inside our remaining $10\frac{3}{4}$ inch casing hanger with attached $10\frac{3}{4}$ inch casing pup joint by making up a centralizer to a single joint of $4\frac{1}{2}$ inch casing. This was lowered into the hanger/pup assembly, which was secured at the center of the rotary table. The test was completed quickly, as the centralizer slid effortlessly into the casing, requiring only the weight of the $4\frac{1}{2}$ inch casing joint. The $10\frac{3}{4}$ inch casing hanger was laid out and assembly of the remaining $4\frac{1}{2}$ inch test casing string began. The test string consisted of a $4\frac{1}{2}$ inch casing bull nose, two joints of $4\frac{1}{2}$ inch casing (slick), one joint of $4\frac{1}{2}$ inch casing with two bow-spring centralizers installed 5 m apart (to emulate having a casing packer in between), two more joints of $4\frac{1}{2}$ inch casing (slick), a single $4\frac{1}{2}$ inch casing joint and 2 m long casing pup with spring centralizer installed over the connection, a crossover from the $4\frac{1}{2}$ inch casing eight-round thread (short) to a $5\frac{1}{2}$ internal flush (IF) thread, and a standard crossover sub from the $5\frac{1}{2}$ IF thread to the $5\frac{1}{2}$ full hole thread on the 5 inch drill pipe. The casing crossover was fabricated by boring out a retired saver sub to accept a $4\frac{1}{2}$ inch casing coupling and welding it inside and out. Welding was conducted with a pup joint installed in the coupling so as not to warp the coupling out of round. Once made up, the test string was lowered on the end of 5 inch drill pipe. The 5 inch pipe was used so as to more closely emulate the characteristics of the $4\frac{1}{2}$ inch casing string to be deployed with the real CORK assembly. Hole U1301B was reentered for the fifteenth time at 0435 h on 11 August. The test string was lowered to 2888 mbrf and the top drive was picked up. The string was then lowered to 2926 mbrf where several attempts were made to pass into the lower section of separated $10\frac{3}{4}$ inch casing. No progress was made using only up and down motion of the string. The top drive was then rotated very slowly and the string was worked up and down. It was interesting that the top drive would stall out without any WOB registering. Only very low torque was allowed to build up for fear of overtorquing the relatively weak eight-round casing connections. Once into the lower section of $10\frac{3}{4}$ inch casing, the end of the test string was advanced to 3002 mbrf, placing the 4½ inch casing test string and drill pipe crossover fully into the lower 10½ inch casing. The test string was then pulled back through the trouble zone and pulled back up to the surface. The seafloor was cleared at 0840 h, and by 1315 h on 11 August the casing test string was rigged down and the drill crew serviced the drill line (slip and cut).

### *Initial Deployment of the CORK Assembly*

Deployment of the Hole U1301B CORK assembly was the most complex and arduous of the expedition. The CORK assembly consisted of a 4½ inch casing bull plug with a 4 inch ID, two joints of slotted 4½ inch casing (slick) with Teflon shrink tubing installed over 30 ft of casing and couplings, one 4½ inch casing packer (number 1) with three miniscreens installed directly below, two bow-spring centralizers installed below the packer and one bow-spring stabilizer installed above the packer, a gravity plug landing sub, two joints of 4½ inch casing, one 4½ inch casing packer (number 2) with there bow-spring centralizers installed as on packer number 1, four joints of 4½ inch casing, one 4½ inch casing packer (number 3) with bow-spring stabilizers installed as on packers number 1 and number 2, 32 joints of 4½ inch casing, and the CORK head. Note that 28 bow-spring centralizers were installed over first 215 m (18 joints) of 4½ inch casing. Teflon stabilizers (three each) were used on the nineteenth and twentieth casing joints. A total of 44 fixed stabilizers were used on casing joints numbers 21–40 to 470.6 m. A special new umbilical was deployed along with a special fabricated microbiology hose. In addition, the CORK running tool was modified with a special lockout (shear pin) ring that requires 4000–6000 lb of down force before the J-tool will function and release. The numerous packers, complex umbilical, and microbiology hose connections, the special bow-spring centralizers, the centralizer locking rings, the welding of the centralizers to prevent rotation, and the 40 joints of 4½ inch casing led to an overall CORK assembly time of 22.25 h and required the assistance of numerous technicians and crew members; it took nearly three times longer than anticipated. At 1330 h on 12 August we began lowering the CORK assembly, and Hole U1301B was reentered for the sixteenth time at 1630 h on 12 August. We then carefully lowered the assembly into the hole. The camera system was left down until the first packer was safely through the level of the reentry cone's throat. It was then pulled up above the CORK head so as to not risk losing the camera system should a failure occur in the casing string being deployed (as ended up happening). As we continued to lower the CORK, it appeared that the CORK casing, bull nose, casing packers, and bow-spring centralizers passed easily through the gap in the 10¾ inch casing without incident. No rotation of the pipe was required. After picking up the top drive an additional joint of drill pipe was added to the drill string, placing the end of the CORK casing string at 3157 mbrf. This was ~12 m short of landing the CORK wellhead.

### *Open Hole Depth Check with Wireline Sinker Bar Assembly*

Because the OsmoSampler/thermistor string was destined to be deployed beyond the 4½ inch casing shoe (bull nose) into open hole, we decided to conduct an open hole depth check using a wireline sinker bar (2.125 inch outer diameter) string. The sinker bars were rigged up and lowered into the pipe at 2015 h on 12 August for this routine depth check. To our surprise, the sinker bars would not pass 2665 mbrf (seafloor at ~2667 mbrf). After repeated attempts to lower the wireline past this point, we decided to lower the camera system back down over the CORK head to assess the situation. Once the seafloor and reentry cone came into view we were greeted by a horrifying sight. A good portion of the 4½ inch casing, umbilical, and so on was piled up around the reentry cone; one end of the 4½ inch casing string with attached umbilicals could be seen extending from the throat of the reentry cone and draping over the outside edge. Another end of casing could be seen sticking up out of the seafloor sediment adjacent to the reentry cone. It was immediately apparent that one or more casing failures had occurred, leaving more than half of the deployed casing strewn about on the seafloor. With nothing else to be gained we retrieved the camera system and drill string. The CORK head was recovered with nothing attached to the lower end, and by 0600 h on 13 August it was laid out. One of the casing failures had occurred right at the coupling to the head itself. A portion of the pin thread from the last joint of 4½ inch casing was broken off inside the coupling and was recovered with the head. After review, it became apparent that this particular failure was because of excessive bending.

### *Seafloor Inspection of the Reentry Cone and Seafloor*

A short inspection BHA made up of a reentry cleanout bit and the transition stand of drill collars (two 8¼ inch drill collars and one TDC) was made up and lowered to the seafloor along with the camera system. At 1015 h on 13 August we began to survey the aftermath of the 4½ inch casing failure(s). One joint of 4½ inch casing with umbilicals still attached was observed extending out of the reentry cone throat and was draped over the edge of the cone. We followed this section out ~30 m from the reentry cone until we identified what appeared to be the end. Another joint with a visibly identifiable plastic (polyethylene) centralizer was seen laying directly adjacent and tangential to the outside edge of the reentry cone. Yet another joint of 4½ inch casing was observed sticking up out of the seafloor in close proximity to the Hole U1301A reentry cone. As part of our survey we moved 36 m back over to Hole U1301A and assured ourselves that the Hole U1301A CORK was still all right. Our best analysis of the failure at this time is that a bow-spring stabilizer either hung up momentarily in the throat of the reentry cone/casing hanger area or a buildup of friction from the multiple bow-spring stabilizers deployed caused the 4½ inch casing to buckle above the seafloor. This led to an immediate failure of one or more 4½ inch casing connections. The umbilical still appeared to be attached and acted as a tension member holding many, if not all, of the joints together. We confirmed that the end of the 4½ inch casing string had not yet reached the gap in the 10¾ inch casing string so that was ruled out as a possible cause. Our review of the rig instrumentation data remains inconclusive, and we have not yet been able to determine at what point in time the failure occurred, nor have we identified why we were not able to see the weight loss (~15,000 lb) that should have been associated with the failure. One explanation may be that the joints failed sequentially, and only small increments of weight were lost at a time. With the driller adding a stand of drill pipe at the same time, the gradual weight loss may have been masked. Analysis of the 1 s rig instrumentation data is ongoing, but it is clear that future CORK casing strings should be sufficiently weighted at the bottom to pull the casing into the hole. After satisfying ourselves that we had seen enough we began to recover the seafloor survey BHA and simultaneously designed/fabricated a wall hook–style fishing tool to be used in an attempt to drag the 4½ inch casing, umbilicals, packers, and so on out of the hole.

### *Fishing 4½ Inch Casing String*

A wall hook–style fishing tool was fabricated from 1¼ inch steel plate (Fig. **F16**) and welded to the same "jetting" sub used in fishing the aluminum reentry funnel in Hole 1026B earlier in the expedition. The new "rig-fabricated" fishing tool was made up to the transition string of drill collars (two 8¼ inch drill collars and one TDC). We tested how it would work on a 4½ casing pup joint on the rig floor. The fishing assembly was lowered to the seafloor. This time the top drive was not picked up so that once the fish was engaged the driller would not have to lower the pipe to remove the top drive. Instead, torque to engage the casing body was provided by roughnecks using rig floor chain tongs. The first few attempts to engage the casing were unsuccessful when the driller could not get the hook underneath the bow in the casing. Ultimately the casing was engaged at a spot just outside of the reentry cone rim. The entire time to hook the fish took <30 min. Estimates of the length of casing inside the reentry cone/casing varied from 200–250 m, so the drill pipe was raised to >300 m above the seafloor. The ship was then offset 300 m to the west of Holes U1301A and U1301B.

The pipe was lowered back to the seafloor, and another 30 min and 300 A of top drive torque were required to release the fishing tool from the casing string. Large amounts of casing and umbilical and a casing packer were identified piled up on the seafloor. The entire release operation required ~30 min. With the fish gone, the ship was moved back over the Hole U1301B coordinates and we were pleased to see that only a single joint of 4½ inch casing was sticking out of the seafloor adjacent to the reentry cone. Apparently, nearly the entire CORK string was dragged 300 m to the west of the operating area. The reentry cone appeared free of any obstacles. Satisfied that we had accomplished our goal, the pipe was retrieved the fishing BHA and the camera, and by 0600 h on 14 August the fishing assembly was laid out.

### *Open Hole Depth Check*

A used 9⅞ tricone drill bit was made up to a three-stand BHA and lowered to the seafloor, and Hole U1301B was reentered for the eighteenth time at 1030 h on 14 August. The pipe was lowered into the hole without any difficulty until reaching 2926 mbrf. Once again the top drive had to be picked up to rotate the pipe slightly and the bit dropped through into the lower section of 10¾ inch casing. Once through the casing gap the pipe was lowered without rotation or circulation, and 3245 mbrf was achieved by 1300 h without resistance. Total depth of the hole was 3250 mbrf; however, we stopped just shy of that depth to save the time of having to make up another stand of drill collars. A depth of 3245 mbrf was a more than adequate open hole depth check, as this depth was well below anything that would be deployed as part of the CORK installation. The bit was retrieved and back on board at 1800 h on 14 August. Preparations then began for the second deployment attempt of the U1301B CORK assembly.

### *Assembly of the Second Hole U1301B CORK*

To avoid the problem that caused our first attempted CORK installation to fail, we elected to add a significant amount of weight to the bottom of the 4½ inch casing string. This would be analogous to the BHA or drill collars that are run at the end of the drill string to keep from ever putting the drill pipe into compression. Compression, or "buckling" is what led to the failure of the 4½ inch casing string during the first deployment in Hole U1301B. The typical CORK string is not heavy enough for the driller to be able to tell if the string is going downhole or has hung up somewhere and the casing is buckling instead. The CORK for Hole U1301B consisted of the following: 4½ inch bull nose welded to the end of a stub of 5 inch drill pipe (1.97 m long), crossover sub, one 8¼ inch drill collar (with zip lift groove), two 3.05 m long

8¼ inch drill collar pup joints, one 4.58 m long × 8¼ inch drill collar pup joint (with zip lift groove), one 8¼ inch drill collar, two crossover subs, and one rig-fabricated crossover sub. The zip lift drill collars and two 3 m long drill collar pup joints were junk recovered with the Hole 1026B CORK and were drifted prior to use. This 32.5 m long CORK BHA added over 10,000 lb of weight to the end of the 4½ inch casing string and provided a much-needed aid to the driller while deploying the CORK. With the CORK BHA assembled we began making up the CORK casing string. The first casing packer was made up to the rig-fabricated crossover sub at the top of the CORK BHA. This was followed by the landing sub (for the lower gravity plug) and the first joint of 4½ inch casing. This allowed us to lower the casing packer into the moonpool area where four miniscreens were installed below the packer, and these were protected by installing a bow-spring centralizer. The Expedition 301 umbilical and the microbiology hose (Tefzel) were then both attached to the top of the first casing packer. The umbilical and hose were run simultaneously off their respective reels by using a wheel sheave for the hose and a banana sheave for the umbilical. Both sheaves were hung from the support beams directly below the rig floor rotary table. The next step was to make up two additional joints of 4½ inch casing followed by the second casing packer. Another four miniscreens were installed below the second casing packer, and after making up the microbiology hose and umbilical connections, we attached our final bow-spring centralizer. This was once again installed directly below the packer to help protect the miniscreens and to provide a smooth transition and guide for the 8 inch diameter packer element. Another 31 joints of 4½ inch casing were then assembled while the umbilical and microbiology hose were deployed along side. The umbilical and hose were made fast to the casing by stainless steel banding placed approximately every 2 m. This was also the case for the casing joints installed below and between the casing packers. Once the 4½ inch casing had been run, we changed out the elevator bales and picked up the CORK-II wellhead for Hole U1301B. The running tool was engaged by sliding it horizontally onto the CORK head while the latter was restrained within the confines of the pipe stabber. The end of the CORK head was prevented from moving by holding it with the pipe racker skate. The CORK wellhead/running tool assembly was then picked up vertically with the drawworks and we began to make up the lower connection to the top joint of 4½ inch casing. It was here that we realized that during the previous aborted deployment the lower end of the CORK body (made from 4½ inch casing) was slightly bent. This caused the head to wobble during make up and made it extremely difficult to make up the fine eight-round casing thread without cross threading. After several attempts the thread was made up tight and the connection was welded out top and bottom for added insurance. At this point the master bushings were pulled from the rotary table and the CORK wellhead was lowered into the moonpool area where the final umbilical and microbiology hose connections were made up. A stand of drill collars was made up to the top of the CORK running tool, and we then test-drifted the osmotic sampler sinker bar through the assembly to ensure that the bend in the CORK body would not interfere with the deployment of the instrument string later. Multiple packer inflation hoses were then installed from the CORK running tool to the top of the CORK wellhead, and three osmotic samplers were installed on the CORK head. During installation of the samplers a final plumbing inspection was conducted and it was noticed that one piece of tubing had been cut too short and had pulled away from the fitting. Approximately 1.25 h were required to cut a new piece of tubing and complete the plumbing. This included picking up the CORK head so all others could be checked. All were judged to be all right and we began to deploy the CORK assembly at 1430 h on 15 August.

### *Deployment of the CORK (Second Attempt)*

The drill string and camera were lowered to the seafloor, and at 1745 h on 15 August Hole U1301B was reentered for the nineteenth time. The CORK was lowered to 2926 mbrf where the bottom of the 10¾ inch casing gap was tagged at the usual depth. The string was picked back up approximately one single (~9.5 m) and the AHC was engaged. At the rig floor the pipe was marked off in four quadrants so that we could keep track of its rotational orientation. The string was then lowered a second time, once again tagging the top of the casing coupling. The pipe was raised and lowered twice. Each time the pipe was rotated ¼ turn using chain tongs. On the third attempt the nose of the CORK BHA slipped inside the lower backed-off 10¾ inch casing and the driller quickly continued to lower away to prevent pulling the pipe out on an up heave. This marked the first time that we had been able to pass into the lower casing section without having to use the top drive at ~50 rpm. Use of top drive rotation at any speed would have been extremely risky during the CORK deployment because it would have been quite easy to inadvertently unlatch the running tool and drop the entire assembly prematurely. In case we did have to use some top drive rotation a special modification to the running tool was made. This consisted of a shear ring that would lock the tool and prevent rotation until at least 6000 lb of download was applied. Although we felt this would help to mitigate some of the risk involved with using the top drive, we were all very much relieved that we were able to cross the casing gap without using the top drive. The next anxious moment was when the first casing packer crossed the gap. Although we felt reasonably confident that the bow-spring centralizers installed below each casing packer would guide the packers into the lower casing, we were still a bit apprehensive. These feelings soon passed when both casing packers crossed the gap without difficulty. The CORK string was advanced to 3165 mbrf, which was within 11.8 m of landing the CORK head, and at 2230 h on 15 August we paused to run an open hole wireline depth check in preparation for deploying the thermistor/osmotic sampler instrument string.

### *Deployment of the CORK Instrument String*

A sinker bar string was lowered through the CORK slowly at ~25 m/min so as not to inadvertently inflate the casing packers. The casing packers have check valves at the top that are set at a cracking pressure of 350 psi. Any pressure over this amount could have initiated packer inflation. The open hole depth check was terminated at 3200 mbrf, which was well below the depth to which the CORK instrument string was to be deployed. The sinker bars were recovered, and at 0230 h on 16 August we began assembling the Hole U1301B instrument string. This string was longer than the others deployed earlier in the expedition in Holes U1301A and 1026B. The same technique was used as was described for those earlier holes; however, it took a little longer. By 0545 h we had completed the assembly and began deploying the instrument string using the core line. This time a speed of 20 m/min was used so as not to float the lightweight Spectra (Tefzel) line or low-weight (60 lb) sinker bar. At 0845 h we reached what we thought was the landing point. After multiple attempts at jarring off we decided we had better recover the instrument string and inspect the Spectra rope. It was feared that the lightweight (neutrally buoyant) line could get underneath the upper gravity plug during the jarring operation and either become cut or prevent proper seating of the plug. The instrument string was brought back to the ship and a thorough inspection indicated that everything was all right. A longer piece of hose was put around the Spectra rope at the very top to stiffen the line and prevent the ability of the line to double back on itself. An inspection of the “weak” shear pin in the overshot assembly found that the pin had sheared through one shear plane; however, the other shear plane (the pin is in double shear) had tried to shear through the thicker portion of the pin rather than the weakened portion. It was determined that this occurred because the pin was not centered properly when installed in the overshot. The instrument string was deployed again and this time, at 1415 h, the gravity plugs were landed and the overshot was sheared off. By 1545 h the wireline was out of the hole and preparations began for advancing the CORK wellhead the remaining 11.8 m to the landing seat.

### *Final Landing of the CORK*

With the AHC engaged, the Hole U1301B CORK head was advanced the final distance and landed at 1600 h on 16 August. The final 11.8 m of advancement was not made without some concern. Several times the CORK acted as though it was setting down against a ledge, and each time the weight dropped off and the string began to advance again. A few minutes were taken to study the camera image and assure ourselves that the wellhead was resting in the proper location. We then pressured up the drill string to 1000 psi and proceeded to inflate the two casing packers. This process was expected to take a while because the packer penetrations were only single 3/8 inch lines. While retrieving the camera system, we maintained the 1000 psi pressure on the system to ensure that we had full expansion of the packers. With the CORK landed, the middle of each packer was located at 3140.0 mbrf (472.2 mbsf) or 207.0 m into basement and 3096.8 mbrf (429.0 mbsf) or 163.8 m into basement, respectively (Fig. **F17**). We bled off the pressure to the packers at 1700 h and at 1715 h on 16 August we prepared to deploy the ROV platform.

### *Deployment of the Hole U1301B ROV Platform*

The ROV platform was modified for this installation to allow for reentry and displacing cement into the reentry cone, hopefully sealing off the throat of the cone in the vicinity of the stacked casing hangers (Fig. **F18**). This was deemed necessary because the separated 10¾ inch casing allowed connectivity to the seafloor. This negated the zone isolation required for the long-term studies. The platform was also deployed differently in this hole. For the first time ever, the mechanical delivery system affectionately known as “Lula” (because of its resemblance to a lunar lander) was rigged below the camera frame. This negated the need to use the logging line and saved numerous hours in rigging. It took 30 min to attach Lula to the CORK platform and another 30 min to rig the VIT sleeve to Lula. The platform was lowered through the moonpool and lowered at a winch speed of ~30 m/min. The platform appeared to be rock stable during the deployment, and a picture-perfect simultaneous release of the three arms was witnessed real time using the camera. By 2130 h we had recovered and rigged down Lula, and we ran the camera back to bottom to review the installation and unlatch the CORK running tool. Lula had to be recovered before this operation because of the slings used in rigging the deployment tool to the VIT sleeve. There was too much danger of snagging something on the CORK head if we tried to lower down far enough to adequately observe the unlatching process. By 2230 h the camera was back down at the seafloor and we inspected the third and final successful CORK installation for Expedition 301. The running tool shear ring was not noticeable and the unlatching process proceeded without incident. Prior to recovering the drill string, a few minutes were taken to get a good look at the top of the 4½ inch casing joint that was protruding out of the seabed directly adjacent to the Hole U1301B reentry cone. This was considered a potential hazard to future ROV or submersible operations, and we planned to fish this pipe out and deposit it at the same place the rest of the casing string ~300 m west of Hole U1301B. The casing appeared to have a coupling looking up and this provided us with the information we needed to build the appropriate fishing tool (Fig. **F16**). The drill string was then tripped back to the surface, where the CORK running tool was removed.

### *Cementing the CORK Head Inside the Reentry Cone*

At 0415 h on 17 August a cementing diverter pipe was made up to the end of the drill string transition pipe. It was lowered into the opening in the Hole U1301B CORK-II ROV platform (Fig. **F18**) at 0900 h on 17 August. This was the twentieth and final reentry of Hole U1301B. Fifteen barrels of high-viscosity bentonite gel mud was displaced into the reentry cone, and this was followed immediately with 9 bbl of cement. This was the last of the cement that we had on board. The drill string was pulled out of the ROV platform and a drill string wiper dart was pumped down the drill string. The pipe was thoroughly flushed, and by 1430 h on 17 August the drill string was back and the cement diverter tool had been laid out.

### *Fishing the 4½ Inch Casing Joint*

A rig-fabricated fishing tool was fashioned (Fig. **F16**) from the hook tool used earlier to remove the aluminum reentry funnel from the top of the Hole 1026B CORK. A smaller insert was welded in to allow us to catch the coupling on the top of the 4½ inch casing joint. After making up the fishing tool the pipe was run back to bottom, and within 30 min the fishing tool was engaged on the fish and the casing joint was pulled out of the seafloor. The ship was offset 300 m west and the joint was deposited in the same graveyard as the other 4½ inch casing.

## ROV/Submersible Hazard Survey surrounding Holes U1301A and U1301B

With the fishing operation successfully concluded, we conducted a hazard survey with the camera system to identify any potential hazards that might pose a risk to future ROV or submersible operations at the site. A 100 × 100 m box was searched, along with two 200 m long approach paths from the north and the east. At 2300 h on 17

August the survey was completed, and by 0415 h on 18 August the drill string had been recovered back on board ship. While recovering the drill string, the ship was offset 20 m east of Hole U1301C to take the final cores of Expedition 301.

## Hole U1301D

Hole U1301D was APC cored to recover sediment from an interval that had not been cored in Hole U1301C. We offset the ship 20 m to the east of Hole U1301C, lowered an APC/XCB BHA to the seafloor, and started drilling ahead at 1600 h on 18 August. We drilled without coring from the seafloor to 120.0 mbsf using an XCB center bit. Cores 1H to 6H were taken from 120.0 to 177.0 mbsf and recovered 42.12 m (74%). PFT was pumped during all of the coring operations. We stopped coring once the depth objective was reached. The bit was retrieved and back on board at 0600 h on 19 August and we began securing the ship for the transit to Astoria, Oregon.

## Transit Hole U1301D to Astoria, Oregon

The transit to Astoria began at 0900 h on 19 August. The ship arrived at the pilot station outside the Columbia River bar at 0400 h on 19 August. Expedition 301 ended in Astoria, Oregon, with the first line ashore at 0700 h on 20 August.

# SITE 1026

## Transit to Hole 1026B

Following cementing of the 10¾ inch casing in Hole U1301B, we moved 0.55 nmi to Hole 1026B in DP mode while retrieving the drill string. We deployed a seafloor positioning beacon at 2356 h on 16 August.

## Hole 1026B

### *Minicone Removal*

During Expedition 301, our plan was to retrieve the Hole 1026B CORK that was installed during Leg 168 and install a new CORK-II. After Leg 168, an ~1.0 m diameter minicone was placed in the top of the CORK (Fig. F19) by submersible to facilitate wireline reentry during nondrillship operations (ROV or submersible). We had to remove it so it would not interfere with engagement of the CORK-pulling tool. Because we did not know what problems we might encounter when trying to remove the minicone, we wanted to try this early in the cruise so that we would have time to devise a solution. This minicone could not be removed by submersible. We fabricated a special fork-shaped, jetted fishing tool (Fig. F20) to remove the minicone. We could maneuver the tool by rotating the drill string and pumping seawater through a port on the back side of the tool to move the bottom of the drill string.

We slid the fork-shaped fishing tool around the CORK, raised it, and broke the minicone off at the base of the conical portion. The minicone fell and landed on the ROV platform, and we used the fishing tool to nudge it off onto the seafloor immediately beside the reentry cone (where it still remains). We felt that the lower tubular portion piece of mini cone remaining on top of the CORK head would not interfere with our ability to latch the CORK pulling tool to retrieve the old CORK. The entire minicone removal process only required ~15 min and then we retrieved the drill string. We finished the fishing operation at 1200 h on 17 July when the fishing fork was back on the rig floor.

## Transit from Hole 1026B to Hole U1301A

While retrieving the fishing BHA, we moved back to Hole U1301A (0.55 nmi) in DP mode. For a description of operations in Hole U1301A, see "Site U1301."

## Transit from Hole U1301B to Hole 1026B

After completing the logging operations in Hole U1301B, we moved the ship back (~0.55 nmi) to Hole 1026B in DP mode.

## Hole 1026B

### *Recovery of CORK Assembly*

We started assembling the CORK retrieving tool at 2330 h on 2 August. We engaged the CORK and extracted it from the reentry cone at 0545 h on 3 August. The CORK extraction and pick up of the ROV platform assembly was visually observed with the camera system prior to raising the entire assembly back to the ship. Once the recovered hardware reached the ship, we spent 3 h disassembling the structure and laying out all the various components (Figs. F21, F22); this was completed at 1500 h on 3 August. This included the ROV platform, which was cut off in the moonpool area, and the CORK head with drill collars attached below it were disassembled on the rig floor. The drill collars consisted of one 30 ft 8¼ inch drill collar, one 20 ft drill collar pup joint, two 10 ft drill collar pup joints, and one 20 ft knobby joint.

### Installation of New CORK-II

At 1500 h on 3 August, we began to prepare for assembling the new CORK-II. A 4½ inch casing packer was made up to a casing seal sub. We lowered to the moonpool where we attached three miniscreens just below the bottom of the packer. The lower end of the umbilical (leftover from ODP Leg 205) was attached to the top of the packer and we attached 14 joints (189.95 m) of 4½ inch casing. The umbilical was banded to the casing using plastic tie wraps and stainless steel banding. Thirty-six rigid casing centralizers were attached to the casing to protect the umbilical during deployment. We attached the CORK-II running tool to the top of the CORK-II head (Fig. **F23**), secured the head to the top of the 4½ inch casing string, and lowered it into the moonpool to make the final umbilical connections at the bottom of the head.

After making up a stand of 8¼ inch drill collars to the top of the CORK-II running tool, we connected the packer inflation hose from the running tool to the CORK-II head. Dual tethers were attached at 180° from the running tool to the quick disconnect on the top of the head; these are used to release the quick disconnect on the packer inflation line when the running tool is removed from the head after the CORK-II is fully installed.

We lowered the CORK-II assembly to the seafloor, deployed the camera/sonar system, and were prepared to reenter Hole 1026B to install the CORK-II at 0400 h on 4 August.

### Fishing a BioColumn Sampler from Reentry Cone

As we were preparing to reenter Hole 1026B with the fully assembled CORK-II, a ~1 m long(?), cylindrical, white foreign object was observed lying inside the reentry cone. We ultimately determined that the object was likely a BioColumn sampler lost (fell through a flow hole in the old-style ROV platform) during a submersible visit following ODP Leg 168 and prior to IODP Expedition 301. We had not seen this object during recovery of the original CORK because the view of the cone was blocked at all times by the ROV platform.

After meeting to discuss our options, we decided to retrieve the camera/sonar system and attach a grapple-fishing tool to the camera frame. We ran back down to the seafloor and attempted to fish the object out of the reentry cone. Unfortunately, when the grapple touched the object, it slid down the reentry cone and slipped into the throat of the cone. We recovered the camera/sonar system again, removed the grapple-fishing tool, and ran back to bottom to observe the reentry cone, thinking that the object might have fallen inside the casing and continued all the way to the bottom of the hole. Unfortunately, we could see that an object remained inside the throat of the reentry cone, likely resting on top of the casing hanger assemblies. We lowered the end of the CORK-II's 4½ inch casing into throat of reentry cone in an attempt to dislodge it so that it might fall freely to bottom of the hole. Instead, the casing worked past the object, so we pulled the casing back up and observed the object catching on the casing stabilizers, lifting it out of throat, but then falling off into the reentry funnel and sliding back into the throat of the reentry cone. This process repeated itself each time a casing centralizer was lifted out of the cone throat. We decided that we needed to try to another fishing tool, so we pulled the casing clear of the reentry cone at 1155 h on 4 August and recovered the camera/sonar system. We removed the grapple fishing tool and attached a modified wireline spear (added two sets of three 6 inch long hex head bolts welded at a 45° upward angle) to the camera/sonar system frame using a wire rope sling. This time we successfully engaged the object, pulled it from the reentry cone, and, while moving the ship 20 m away from the reentry cone, we observed the object being dragged through the seafloor mud. When we retrieved the camera/sonar system with the fishing tool, the object was missing; it had apparently dislodged during retrieval and fallen to the seafloor.

Once again we deployed the camera/sonar system, and we reentered Hole 1026B with the CORK-II assembly at 1850 h on 4 August. During reentry, we once again observed what appeared to be a white tubular object lodged inside the throat of the reentry cone. We continued to lower casing to 2849 mbrf; however, it was apparent by the drag that something was still inside the reentry cone assembly. When we pulled the casing back up through the reentry cone, we observed an object jammed onto one of the casing centralizers. We pulled the casing clear of the reentry cone at 1945 h on 4 August and offset the ship 35 m away from the hole to ensure that if the object fell off it would not go back into the hole. We inspected the object and verified that it was not the same one that had been removed in the earlier fishing operation, but it may have been a part of that assembly that had broken off. The new fish had what appeared to be a stainless steel T-handle. To remove the object, we worked the camera/sonar system up and down over it until it finally fell off. While offsetting the ship back to Hole 1026B, we observed the first fished object lying on the seafloor 20 m from hole; it appears that this object fell straight down.

Ultimately, we reentered Hole 1026B at 1945 h on 4 August and the casing, packer, and umbilical assembly was lowered to 2849 mbrf without meeting any resistance. The top drive was picked up and the casing was further lowered to 2859 mbrf just short of landing the CORK-II head in the reentry cone.

### Deploying the Instrument String Inside the 4½ inch Casing

The instrument string deployed inside the 4½ inch casing of the CORK-II consisted of a sinker bar, three OsmoSamplers, a lower seal (gravity) plug, Spectra rope, sinker bar, Spectra rope, and a top seal (gravity) plug. This was made up and deployed in the same manner as it was for the Hole U1301A CORK-II. Once the instrument string was installed, the CORK-II head was landed without difficulty. We inflated the single 4½ inch casing packer (without using a go-devil) and began preparing to deploy the ROV/ submersible platform.

### Deployment of the Hole 1026B ROV/Submersible Platform

Final assembly of the ROV platform was completed and the platform was deployed as before using the logging wireline and the mechanical deployment tool (Lula) (Fig. **F15**). When the mechanical deployment tool carrying the reentry cone touches down on the CORK-II head, the mechanical release is activated, releasing the platform, which free falls around the CORK-II down onto the top of the reentry cone.

The platform was successfully released without any of the difficulties we experienced when deploying the platform in Hole U1301A; repairs and modification to Lula prior to Site 1026 operation and modified deployment procedures were successful. We recovered Lula at 1015 h on 5 August. We then deployed the camera/sonar system to inspect the platform and CORK-II and to observe the release of the CORK-II running tool. When the camera reached the seafloor, we observed that the platform had not landed properly. However, one side of the platform hung up on the plate at the base of upper set of gussets on the CORK-II head during the free fall. After reviewing the engineering drawings of the CORK-II head and platform, it became clear that in some orientations it is possible for the platform to hang up on the CORK-II head. This can easily be prevented by installing three additional vertical gussets to the top of the CORK-II head. We modified the remaining CORK-II head assemblies.

We disconnected the running tool from the CORK-II head at 1125 h on 5 August. Strictly by chance, the camera/sonar system was aligned perfectly with the J-slot on the CORK-II running tool, and we were able to observe the un-jaying process. Once the running tool was released, we used the running tool to nudge the high side of the platform and it dropped into place on top of reentry cone at 1130 h. It should be noted that this was the first deployment of the considerably lighter (expanded metal) ROV platform design. This design flaw had existed in earlier CORK-II installation designs, but the greater weight of the earlier platforms probably was enough to overcome any momentary hangups. The installation of the new Hole 1026B CORK-II was successfully completed at 1130 h on 5 August. The final installation is shown in Figure **F24.**

## Transit from Hole 1026B to Hole U1301B

While retrieving the CORK-II running tool, we moved the ship 0.55 nmi back to Hole U1301B to attempt remedial cementing of the backed-off 10¾ inch casing string. For a description of operations in Hole U1301B, see **"Site U1301."**

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**Figure F1.** Regional bathymetric map showing major tectonic features and the locations of IODP Expedition 301 drill sites and the ODP Leg 168 drilling transect. Bathymetry from Smith and Sandwell (1997). FR = First Ridge, SR = Second Ridge, DR = Deep Ridge.

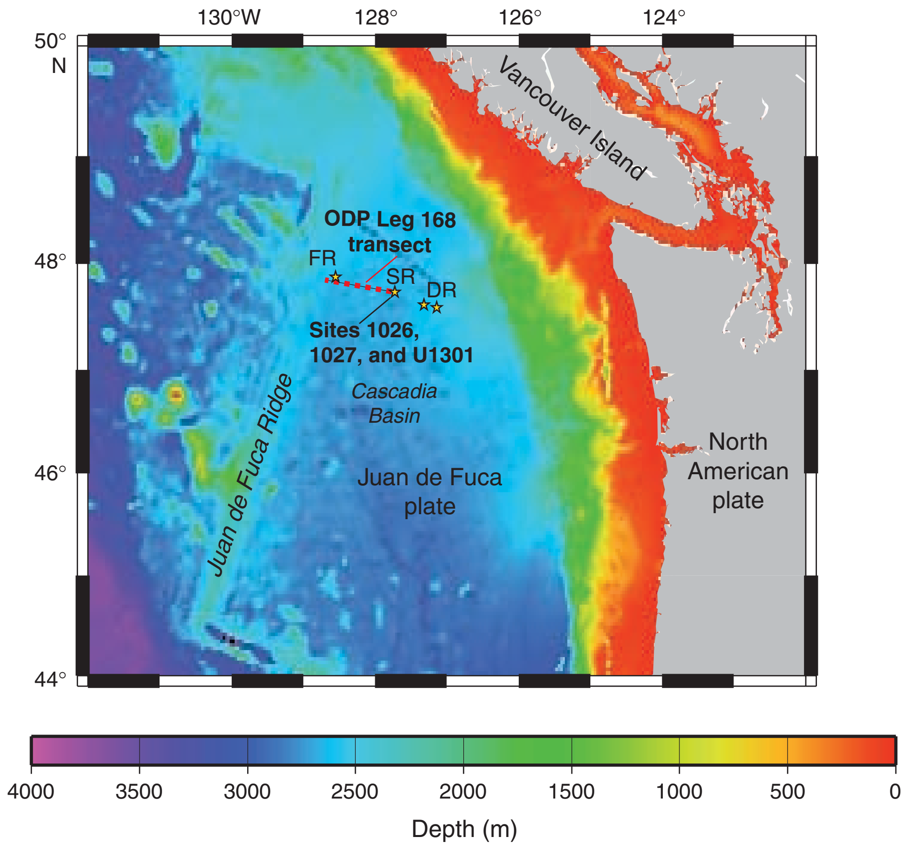

**Figure F2.** Summary of selected results from ODP Leg 168 and related experiments. **A.** Interpreted composite cross section from the active spreading center to the west, across the Leg 168 drilling transect, and continuing to the east. Vertical lines show locations of Leg 168 boreholes. Triangles at seafloor show locations of reentry cones and CORK observatories installed during Leg 168. CORK systems in Holes 1026B and 1027C were replaced during Expedition 301, and new CORKs were emplaced in Holes U1301A and U1301B, along the same buried basement ridge as Site 1026. **B.** Summary of thermal data. Solid circles are upper basement temperatures, based on in situ measurements and (in some cases) short extrapolations to basement depths. Open squares are heat flow values determined with Leg 168 temperature and thermal conductivity data, after applying temperature corrections and accounting for thermal conductivity anisotropy (Pribnow et al., 2000). Solid squares show the same values after correction for the effects of rapid sedimentation (Davis et al., 1999). Data from Sites 1030 and 1031 were not sediment-corrected because sediment cover is very thin and because the calculated correction is based on a one-dimensional approximation that is not valid where there are large variations in basement relief below thin sediments. The thin jagged line shows estimated heat flow values across the Leg 168 transect based on seismic and drilling data (Davis et al., 1999), after applying a sedimentation correction. The smooth dotted and dashed curves show lithospheric reference models by Parsons and Sclater (1977) and Stein and Stein (1994), respectively. **C.** Chemistry of basement fluids, as determined from extrapolation of basal pore fluid gradients to the basement depths and (in the case of Hole 1026B) from direct sampling of formation fluids. Magnesium data show fluid alteration largely as a function of reaction temperature (Davis, Fisher, Firth, et al., 1997; Wheat and Mottl, 1994). $^{14}C$ data show a consistent progression in apparent age from west to east at the western end of the transect, but samples from Sites 1031 and 1026 are considerably younger than waters to the west (Elderfield et al., 1999).

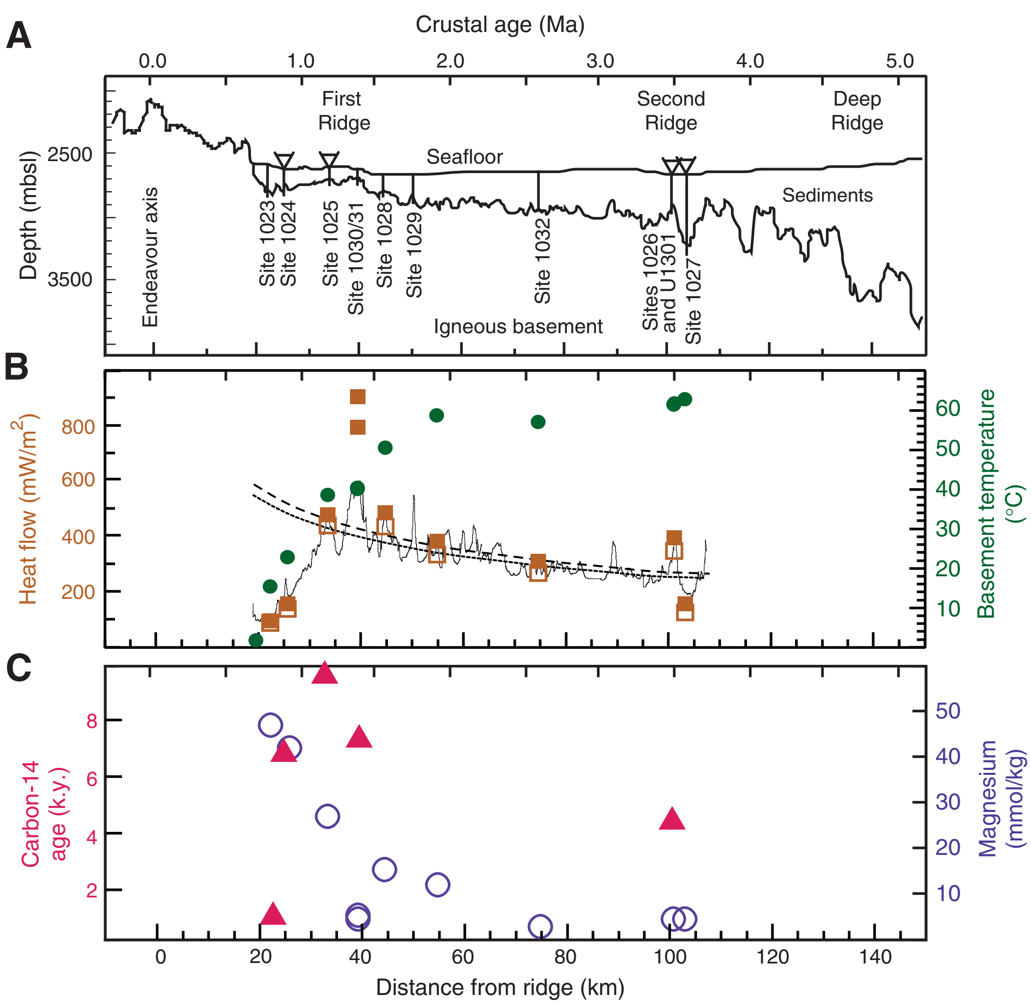

**Figure F3.** Second Ridge maps. **A.** Topographic map showing Second Ridge and surrounding region (modified from Fisher et al., 2003). Locations of ODP and IODP holes are shown, as are locations of outcrops that penetrate regionally continuous sediment cover. **B.** Basement map of Second Ridge drilling area, showing ODP and IODP hole locations. Data are based on bathymetry shown in A and interpretation of ~25 seismic lines collected during the 2000 *Sonne* expedition (ImageFlux). Holes at Site SR-2 will be drilled during a subsequent expedition.

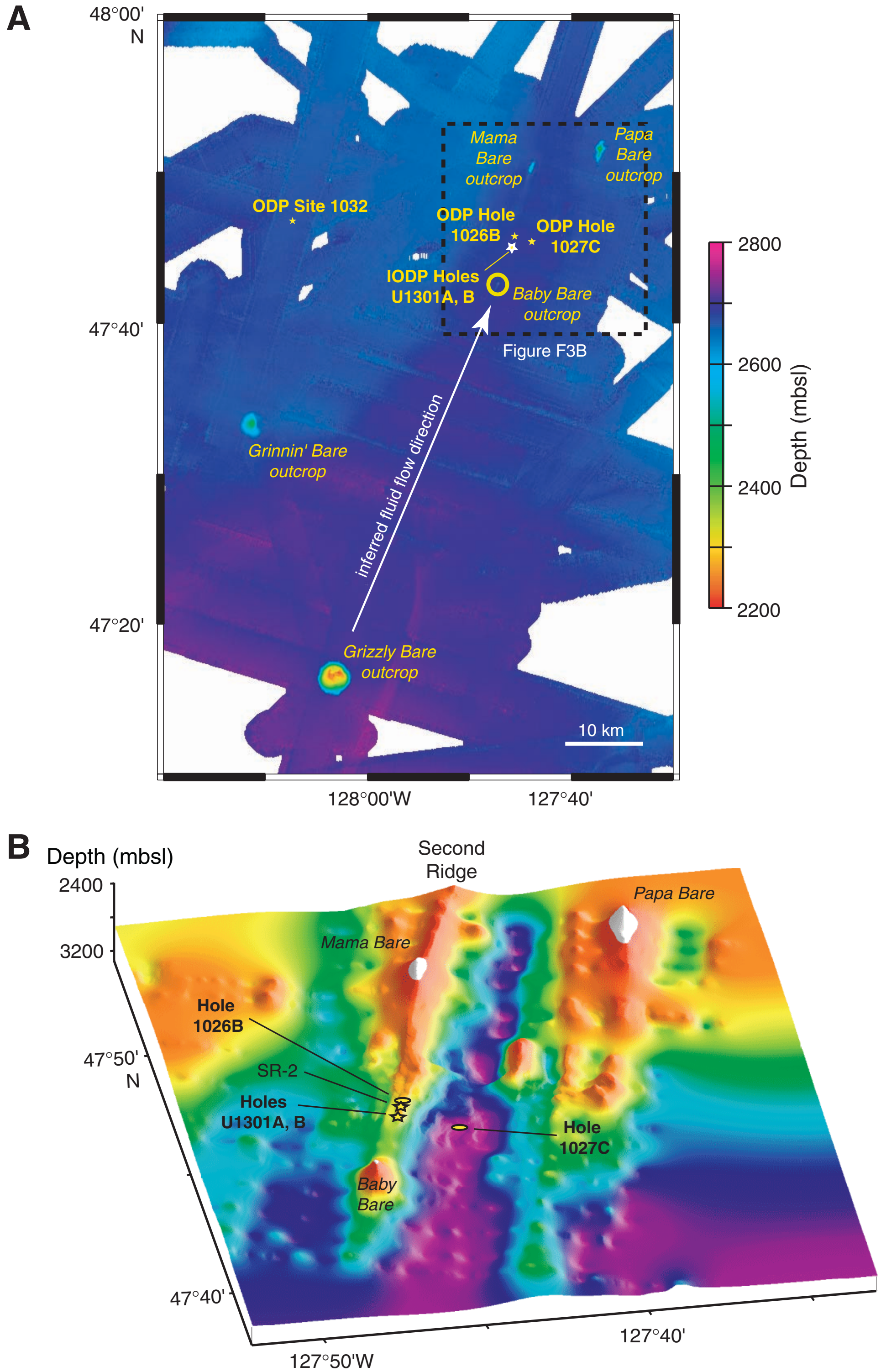

**Figure F4.** Examples of MCS seismic data from the 2000 ImageFlux survey (*Sonne*, SO149) showing locations of primary IODP Expedition 301 sites. **A.** Line GeoB00-446 across the southern part of Site U1301. Vertical lines indicate approximate total depth of Holes U1301A (shallower) and U1301B (deeper). **B.** Line GeoB00-203 across Sites 1026 and 1027. Vertical lines indicate approximate total depth of both holes. Characteristic basement and sedimentary structures are apparent in both lines.

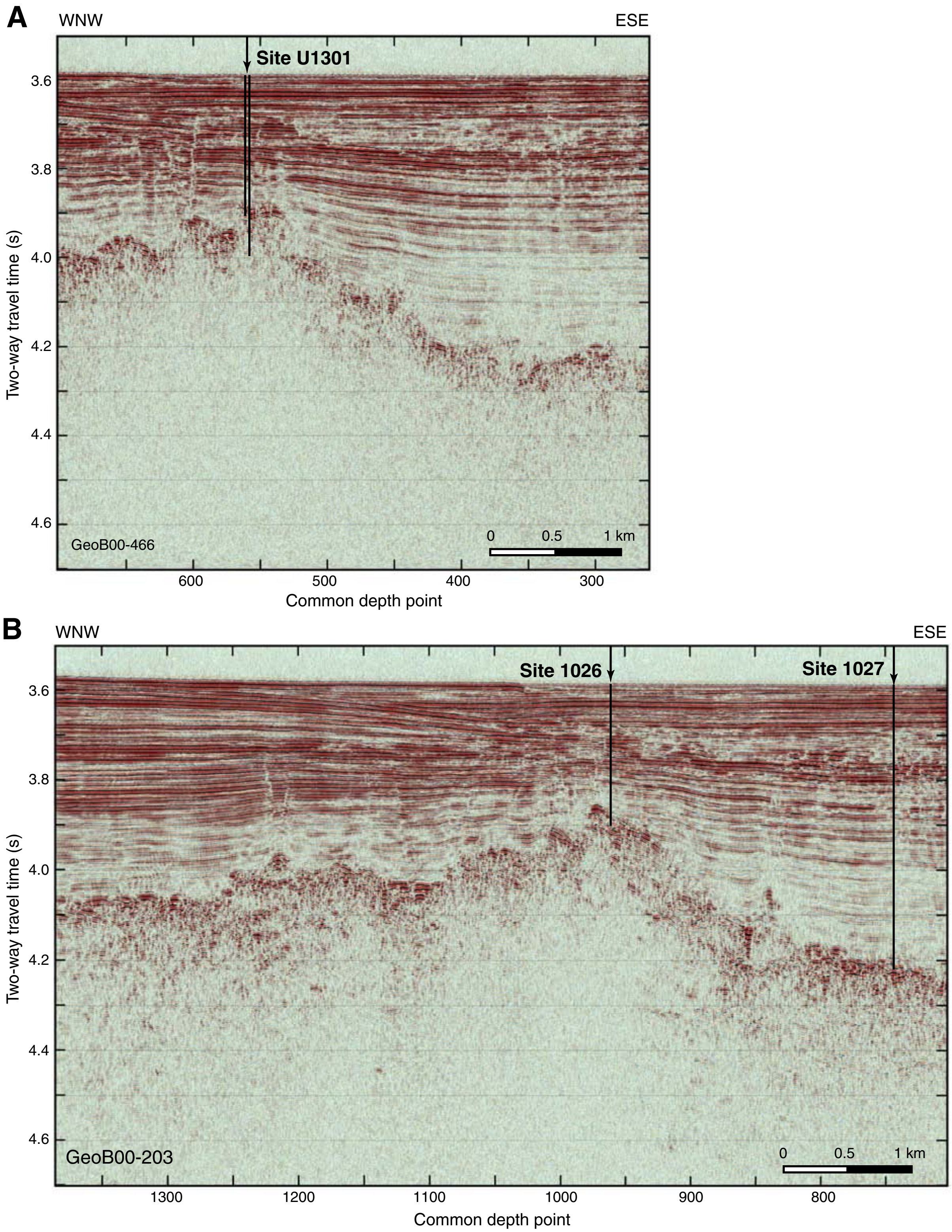

**Figure F5.** Permeability of upper oceanic crust versus crustal age and measurement scale prior to IODP Expedition 301. **A.** Permeability versus crustal age. Squares (red) show packer measurements, circles (blue) show results from temperature log (flow meter) experiments. Bars indicate uncertainties in crustal age and estimated bulk permeability. Dashed line shows crude permeability-age trend, with a rapid reduction during the first 4 m.y., followed by a maintenance of bulk permeability of ~$10^{-14}$ to $10^{-13}$ $m^2$. Data compiled from these studies and sources cited therein: Fisher (1998), Fisher and Becker (2000), Becker and Davis (2004). Additional data were collected in 165 Ma seafloor (Larson et al., 1993) but are not shown. Temperature data generally suggest permeabilities somewhat higher than do packer data. Shaded regions are results of calculations of permeability trends based on consideration of global heat flow data (Fisher and Becker, 2000). Borehole observations are consistent with global heat flow considerations until ~4 Ma, and then observations deviate from these predictions. This may occur because flow becomes more focused with age, as smaller pores fill. **B.** Permeability estimates from boreholes on the eastern flank of the Juan de Fuca Ridge, plotted as a function of measurement scale (solid symbols and blue shaded areas). Other shaded areas indicate compilations for fractured crystalline rocks (red bands, [Clauser, 1992]) and results from tests in fractured sedimentary rocks (green bands [Rovey and Cherkauer, 1995; Schulze-Makuch and Cherkauer, 1997]). IODP Expedition 301 and related experiments will help to elucidate the scaling of crustal permeability over the range indicated with the double-headed arrow, as discussed in the text and in later figures.

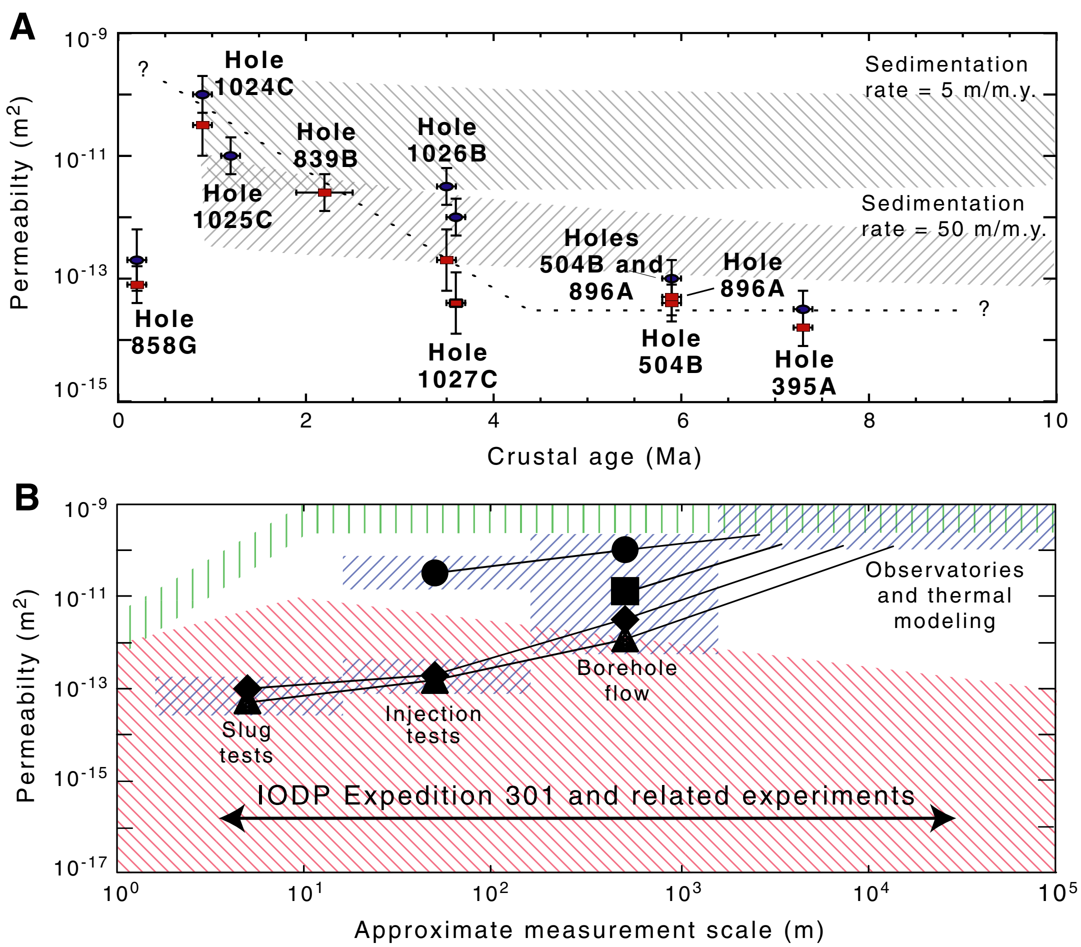

**Figure F6.** Crustal-scale hydrogeologic testing associated with IODP Expedition 301 and related experiments. **A.** Map view indicating spatial relations between CORK observatories (colored circles) in Holes 1026B, 1027C, U1301A, U1301B, planned Site SR-2, and nearby basement outcrops (gold bathymetric contours). Inset shows relative locations of pumping (P) and observation (O) wells for cross-hole experiments. Depth contours in meters. S = storativity, T = transmissivity. **B.** Calculated cross-hole responses to pumping and free-flow borehole experiments between wells at Sites SR-2 and 1026, separated by 200 m. **C.** Calculated cross-hole responses to pumping and free-flow borehole experiments between wells at Sites SR-2 and 1027, separated by 2200 m. Sites SR-2 and U1301 are 800 m apart, so the anticipated response is intermediate between the examples shown. Assumed formation properties are based on previously completed packer, free-flow, and CORK experiments. Differences in formation-scale values of T and S relative to those used would shift the curves as indicated by the arrows in A. Pumping tests in DSDP and ODP were typically only 20 min long (dotted vertical line); Expedition 301 tests were as long as 2 h. Future tests will begin with 24 h of pumping (dashed vertical line), and ultimately will last 1–2 y or more through venting of overpressured holes and pumping at the seafloor.

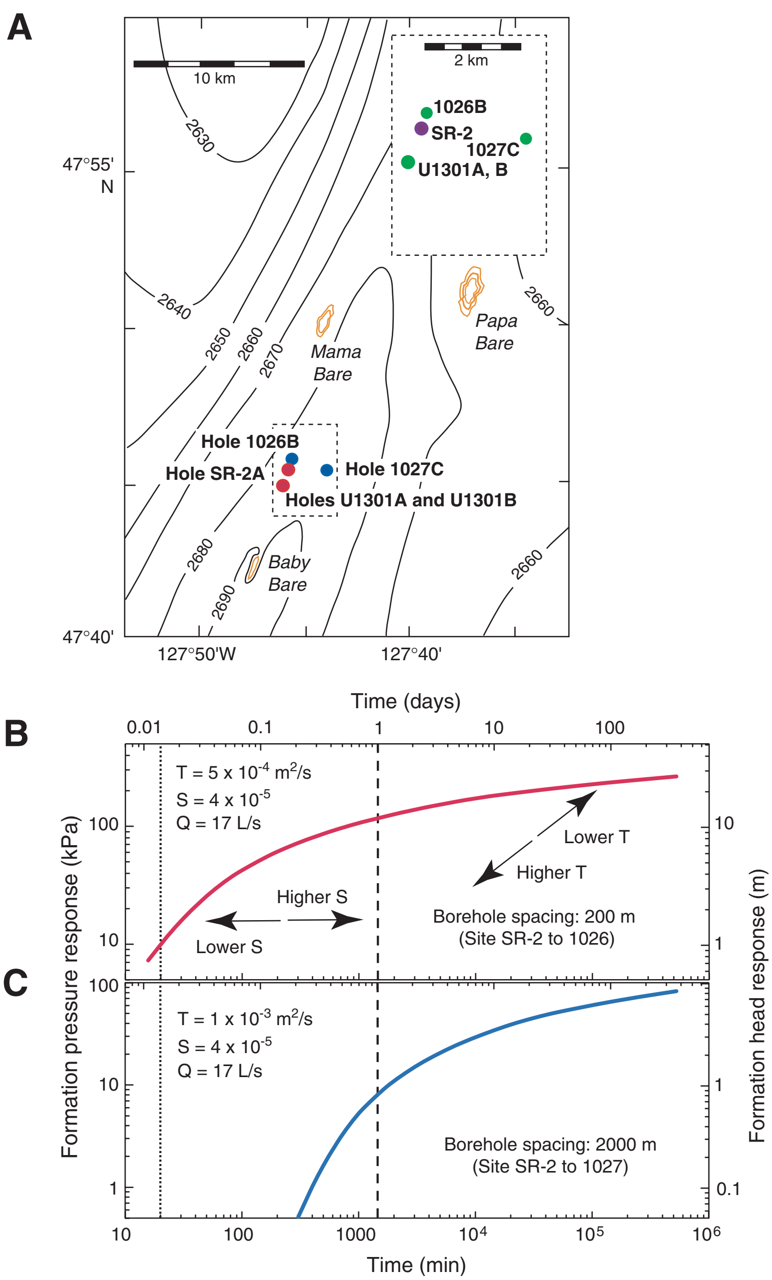

**Figure F7.** Cell density data from ODP sediment cores. Solid circles are data from ODP Leg 201 (D'Hondt, Jørgensen, Miller, et al., 2003) and dotted region shows 2-σ envelope around global compilation of previously censused ODP sites (Parkes et al., 1994). It is not clear whether this trend will be continued into basement, or if populations will be greater or less than projected, particularly within narrow zones that carry most of the hydrothermal flow. Long term monitoring and sampling within CORK observatories will provide the best opportunity to address this uncertainty.

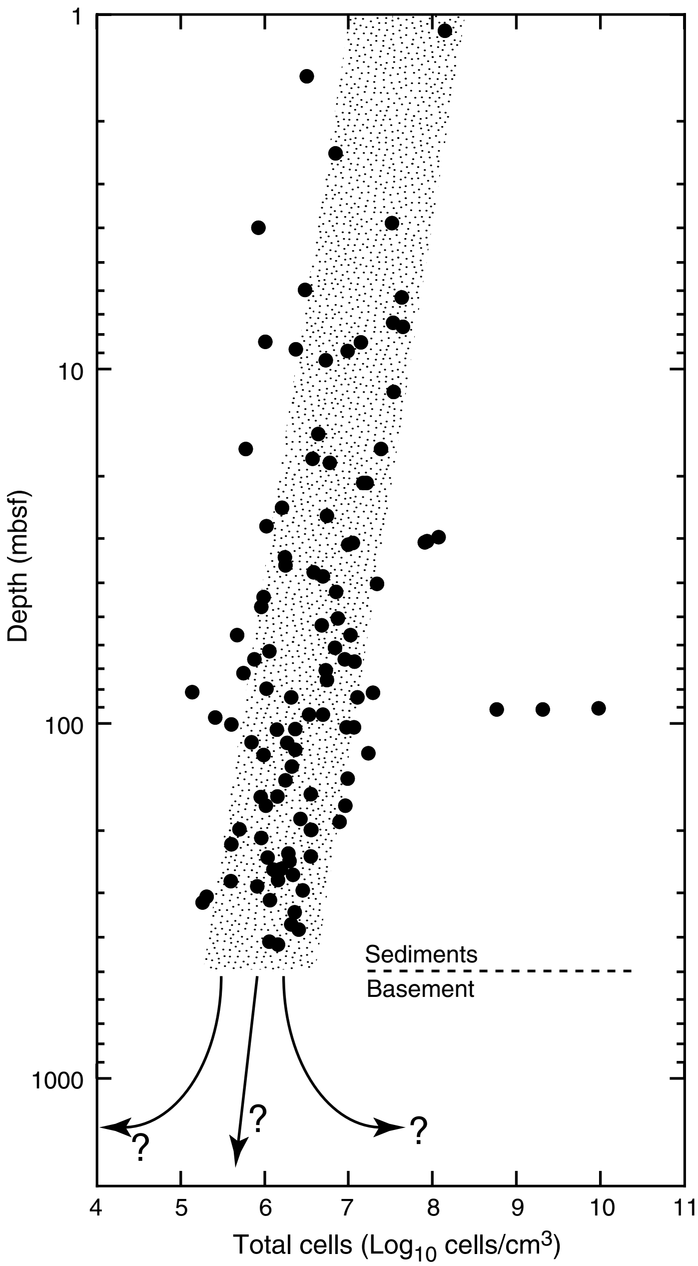

**Figure F8.** Cartoon illustrating selected features of the three CORK borehole observatory systems installed during IODP Expedition 301. Approximate total depths (TD) listed in meters subbasement (msb) are correct as shown, but drawings are not to scale and do not indicate precise locations of casing, cones, packers, sampling and monitoring lines, or downhole instruments. Hole 1026B was created during ODP Expedition 168, whereas Holes U1301A and U1301B were created during IODP Expedition 301. All three CORKs monitor multiple depth intervals. The CORKs in Holes 1026B and U1301A monitor shallowest basement and the zone between the casing packer and the seafloor CORK seal. The CORK in Hole U1301B monitors three basement intervals, with the uppermost interval including the interval that extends to the seafloor seal. Instruments deployed at depth in all three CORK systems include various numbers of osmotic samplers for fluid chemistry, microbiological incubation substrate, and autonomous temperature loggers distributed within basement. See Fisher et al. (in press) for additional details regarding CORK configuration and deployment.

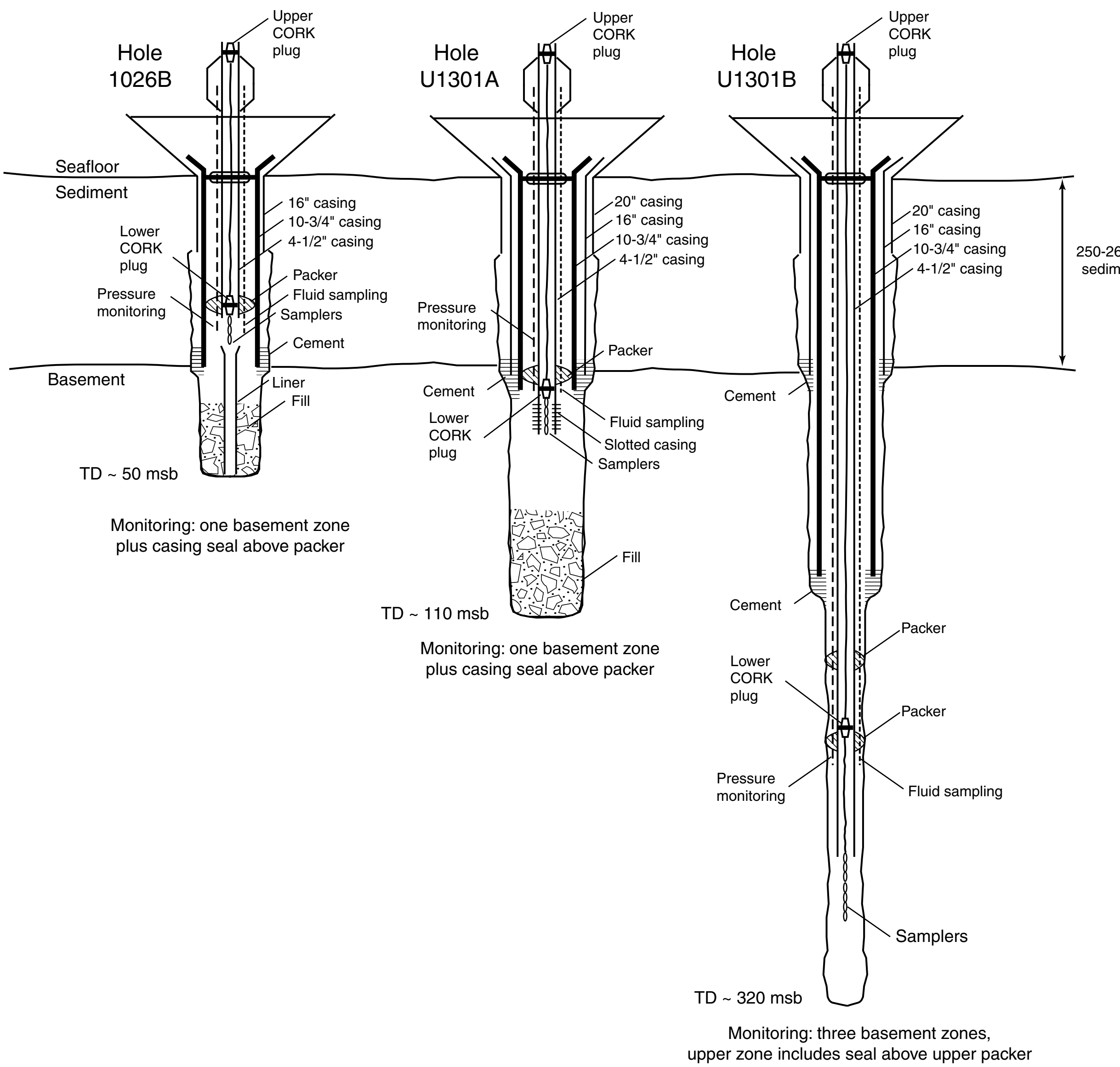

**Figure F9.** Penetration rates in Holes U1301A and U1301B while drilling with a 14¾ inch tricone bit in preparation for casing. Information was derived from recordings of bit depth made at 1 s intervals by the shipboard rig instrumentation system (RIS). Because motion of the drill string is not monotonically downward (intervals are drilled, reamed, and cleaned, and ship heave and tides also contribute to bit motion), RIS data required hand filtering and editing determination penetration rates. Gaps in the data occur near pipe joints and as a result of incorrect recordings of bit depth. msb = meters subbasement.

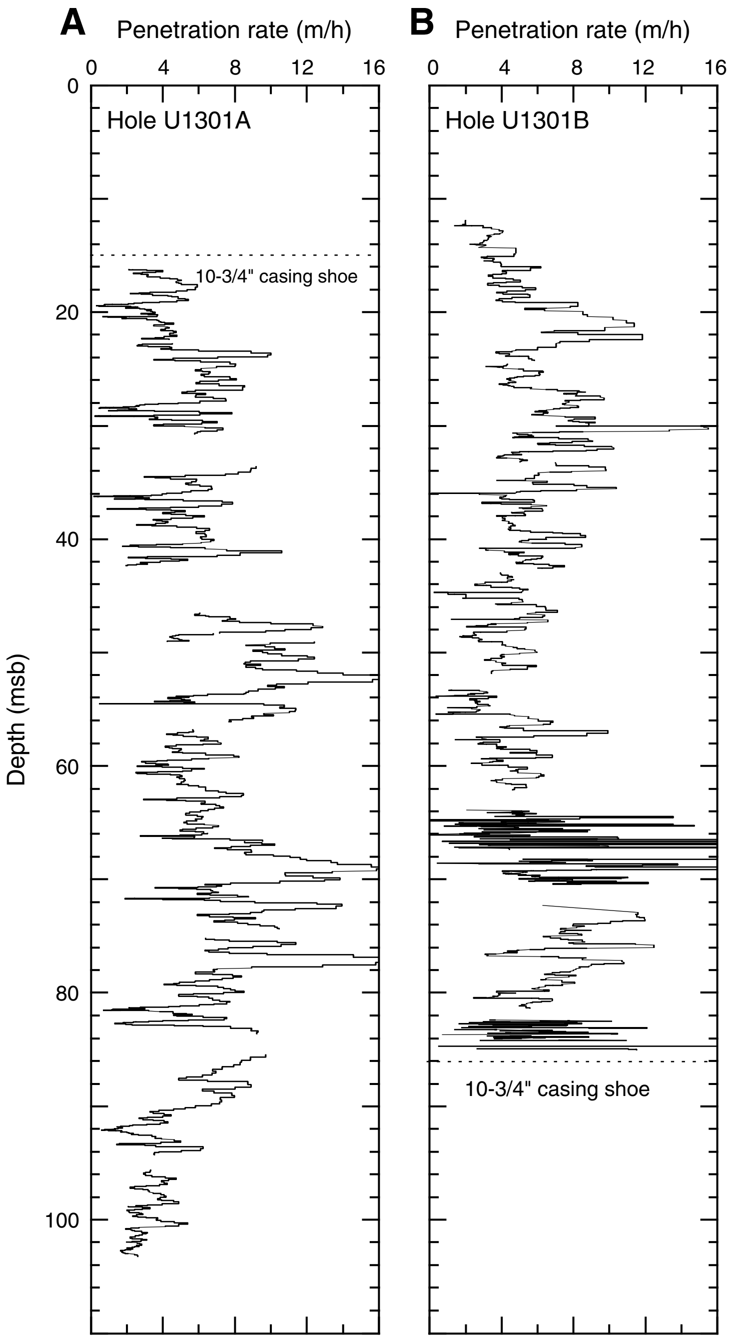

**Figure F10.** Summary of selected data from basement in Hole U1301B. Columns on the left show depth below seafloor, cored intervals, and recovery. Primary lithologies and lithologic units were defined on the basis of igneous petrology. The next five columns show wireline logging results. The caliper log is from the lithodensity tool, and the diameter of the drill bit and the maximum recommended packer inflation diameter (for both drill string and CORK packers) is shown for reference. Wireline bulk density data are compared to measurements of small hand samples. Resistivity data are from the near-borehole (~10 cm) and medium-penetration (~30 cm) electrode spacings. The spontaneous potential (SP) log is sometimes used as a hydrogeologic flow indicator, but data were collected in Hole U1301B very close to drilling and casing operations, before the hole had a chance for thermal equilibration, so SP variations may be more influenced by hole diameter than by fluid flow into or out of the formation. The sonic logging tool did not penetrate a borehole obstruction at 420 mbsf, but data collected in the upper part of the hole are in general agreement with both physical property measurements and an interval velocity determined from a vertical seismic profile (thin rectangle). Magnetic inclinations were determined on individual samples. Note change from dominantly positive magnetic inclinations in the upper 100 m of the hole, to mixed positive and negative inclinations in the lower part of the hole. Intervals tested with a drill string packer, and monitored by CORK observatories in Holes U1301A and U1301B, are shown in the last two panels. The primary depth scale (mbsf) is referenced to Hole U1301B, but packer and CORK depths for Hole U1301A are registered to the depth into basement (msb). Finally, the dotted band near 465 mbsf (210 msb) shows an apparent boundary between crustal intervals having distinct properties. (**Figure shown on next page.**)

**Figure F10 (continued).** (Caption shown on previous page.)

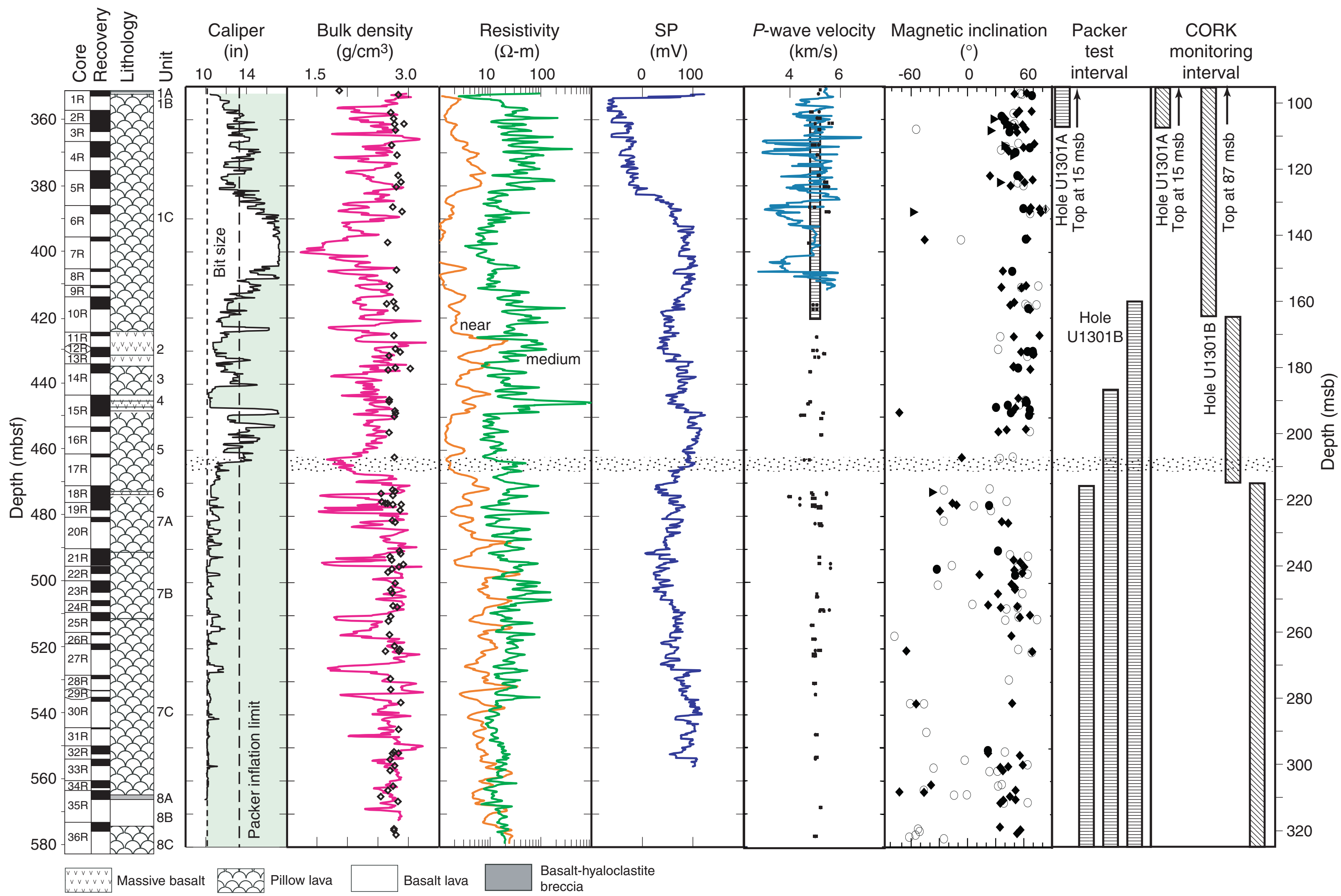

**Figure F11.** Hole U1301A reentry cone.

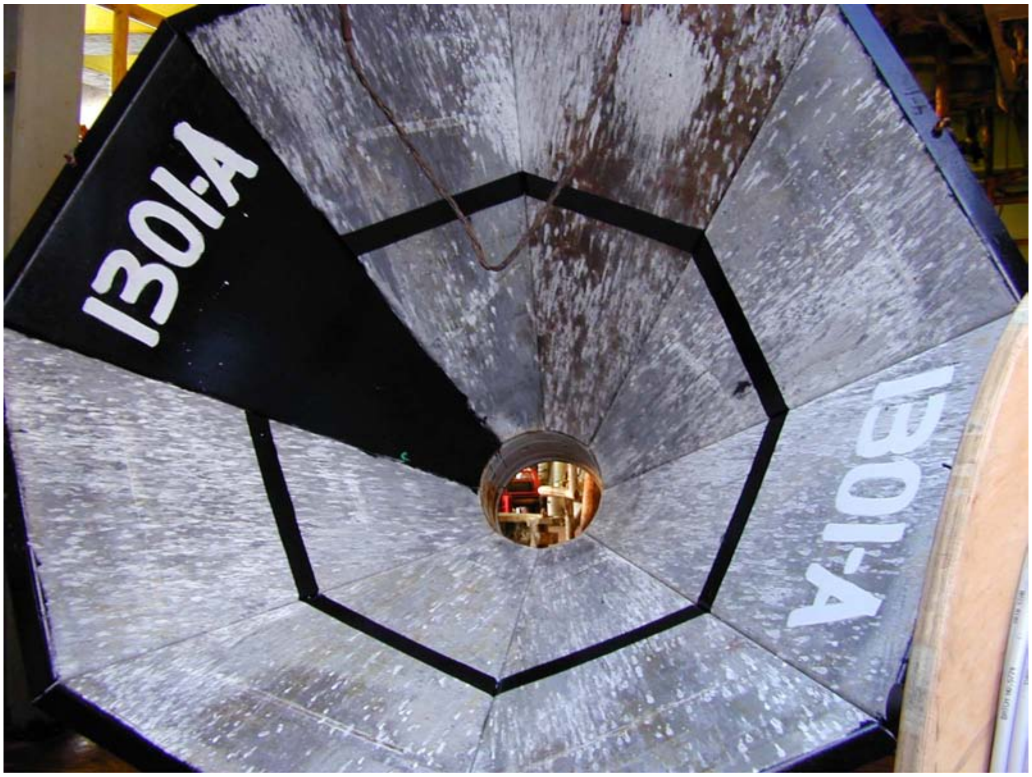

**Figure F12.** Hole U1301B reentry cone.

**Figure F13.** Calculated tides for the duration of Expedition 301 (top) and for a 1 day period (27 July 2004; bottom). Times shown are Universal Time Coordinated (UTC); ship local time is UTC –7.

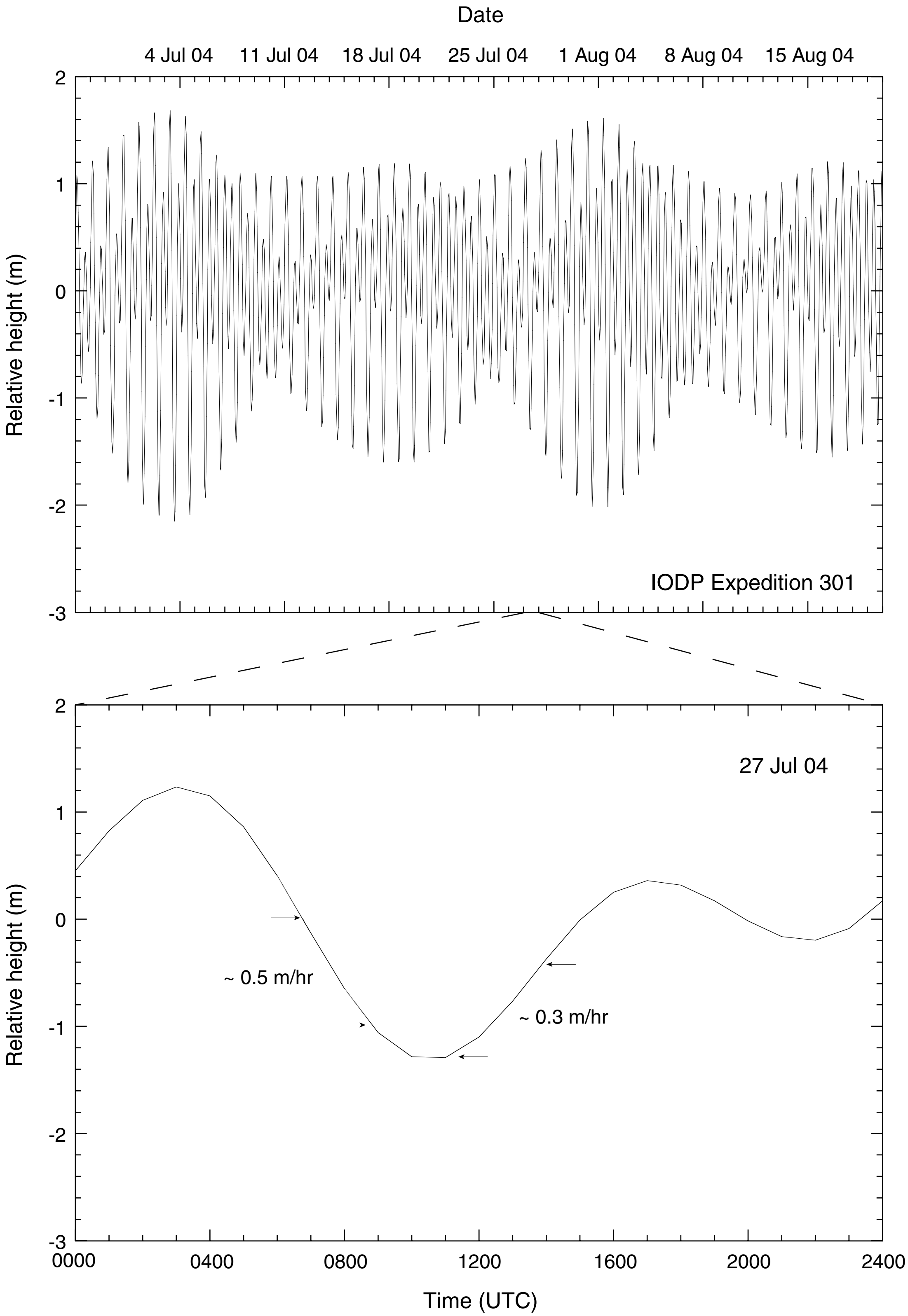

**Figure F14.** Schematic showing the Hole U1301A reentry cone and borehole casing (right), CORK borehole completion (center), and the instrument string deployed through the 4½ inch casing (left). ROV = remotely operated vehicle.

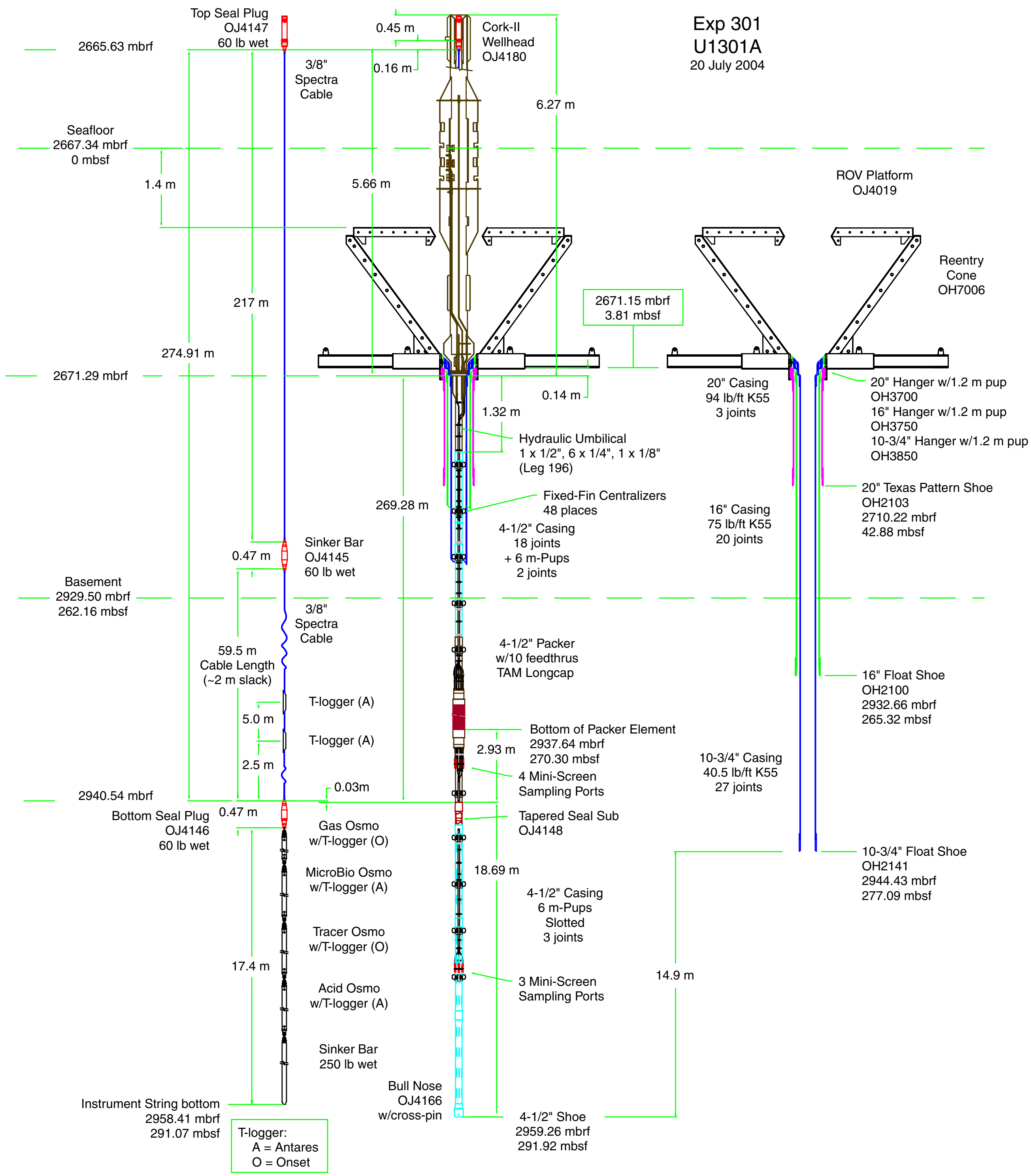

**Figure F15.** The wireline-conveyed mechanical deployment tool (Lula). **A.** The Lula shown in its open position before being placed around the drill string. When the legs on the bottom touch down on the top of the CORK head, the ROV platform is released. **B.** The logging wireline is attached to the top of the Lula and is used to lower the entire assembly to the seafloor. **C.** The Lula being latched into the center of the ROV platform.

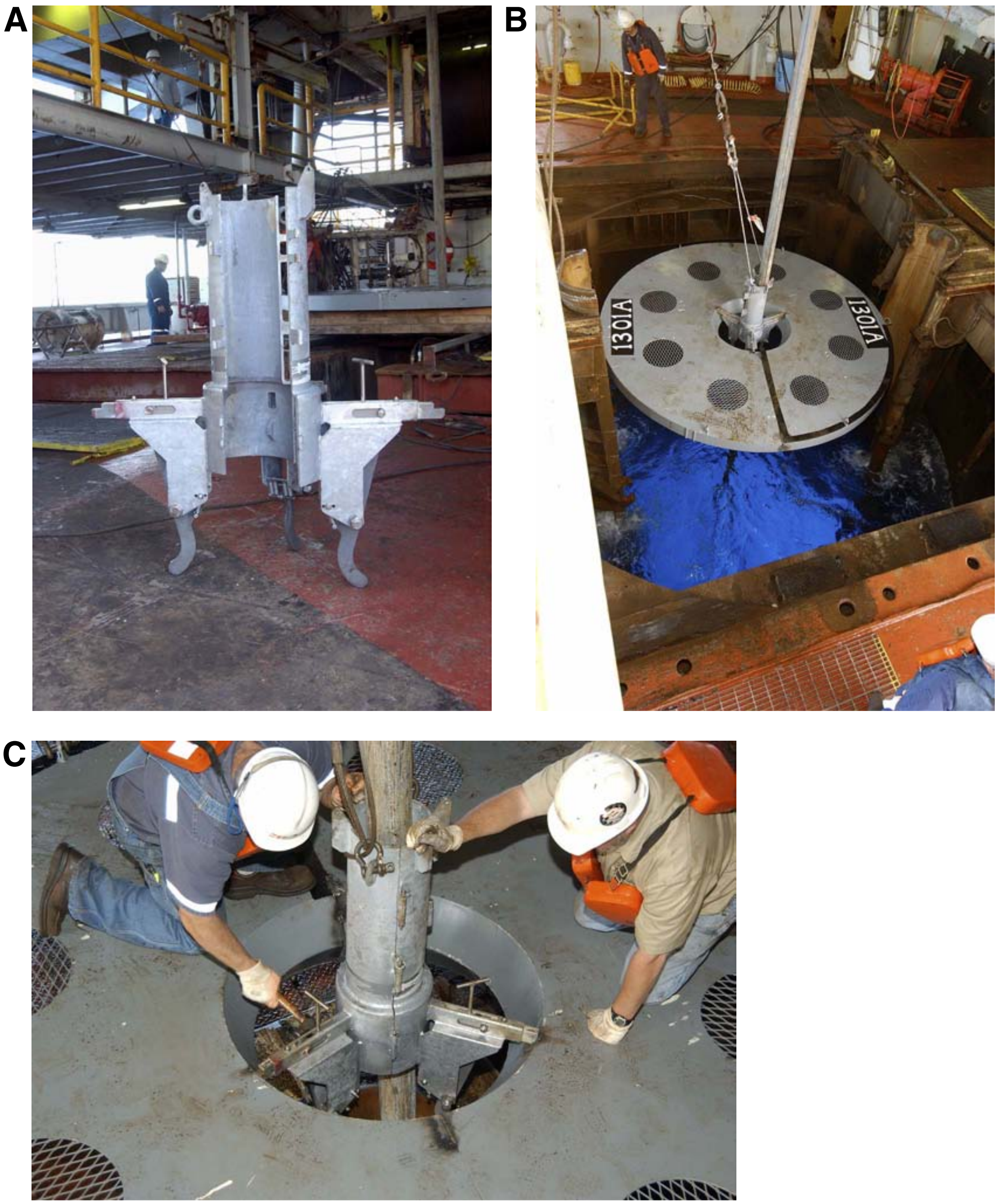

**Figure F16.** Fishing tool fabricated to retrieve the failed 4½ inch casing from inside the reentry cone and casing of Hole U1301B.

**Figure F17.** Schematic showing the Hole U1301B reentry cone and borehole casing (right), CORK borehole completion (center), and the instrument string deployed through the 4½ inch casing (left). ROV = remotely operated vehicle.

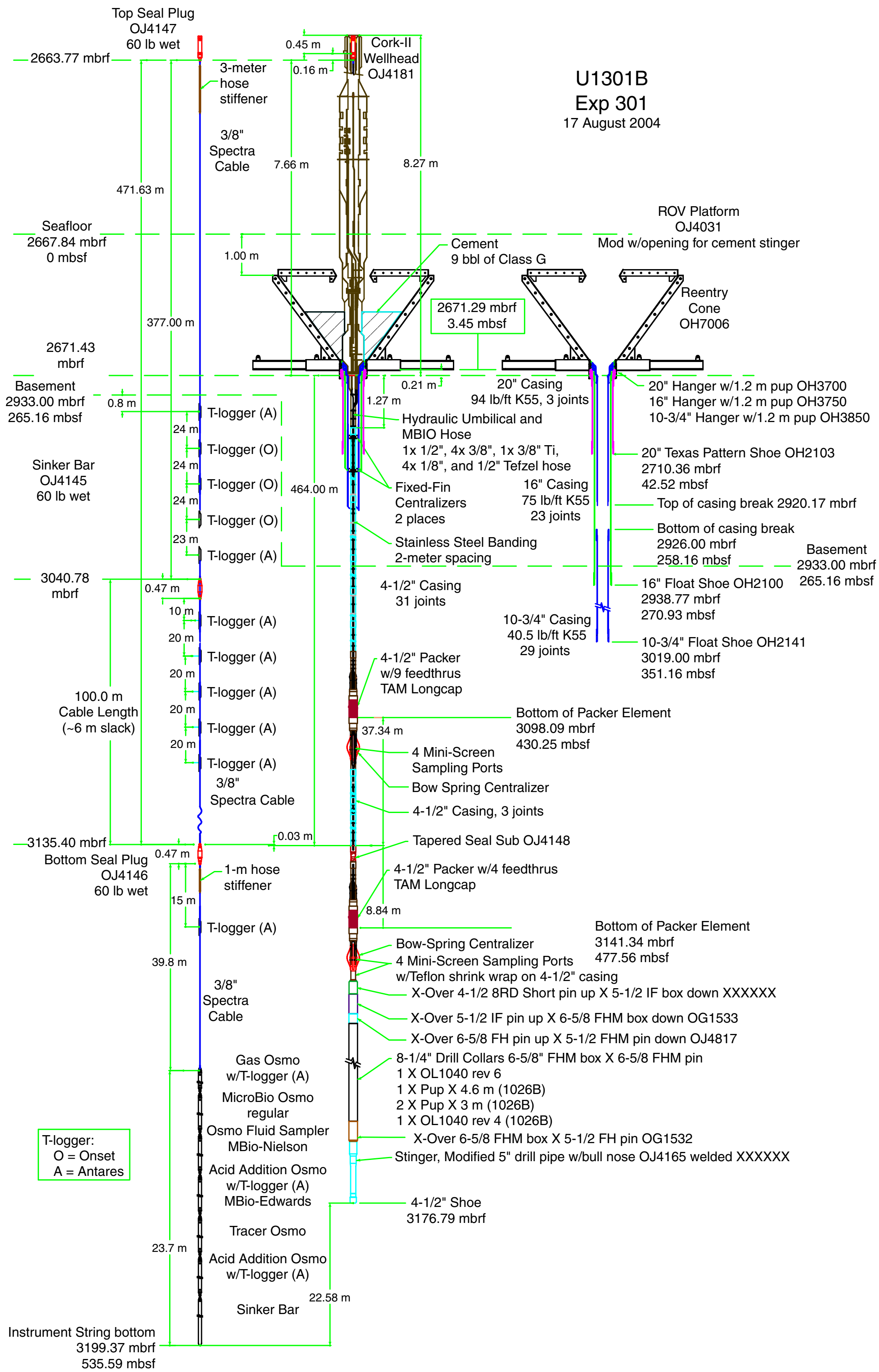

**Figure F18.** Hole U1301B ROV/submersible platform being prepared for deployment in the moonpool. We used the VIT subsea camera/sonar system to deploy the platform.

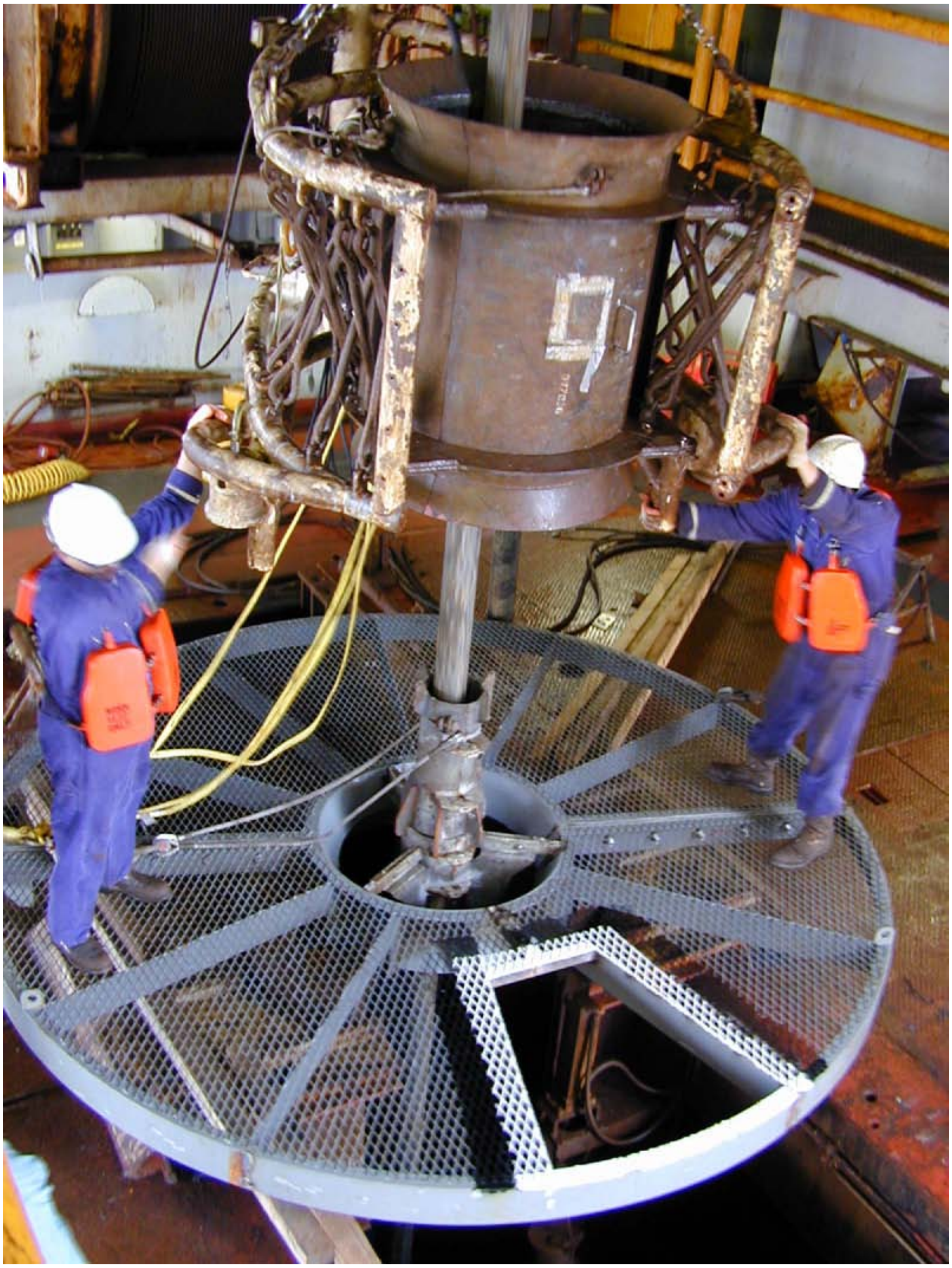

**Figure F19.** Photograph of Hole 1026B CORK installed during ODP Leg 168. An ~1 m diameter minicone (white cone-shaped object on top) was placed by submersible on top of the CORK head (brown vertical tubular shape in middle) to facilitate wireline reentry during nondrillship operations. This minicone had to be removed prior to retrieving the CORK and ROV platform (large, flat circular object surround the CORK head).

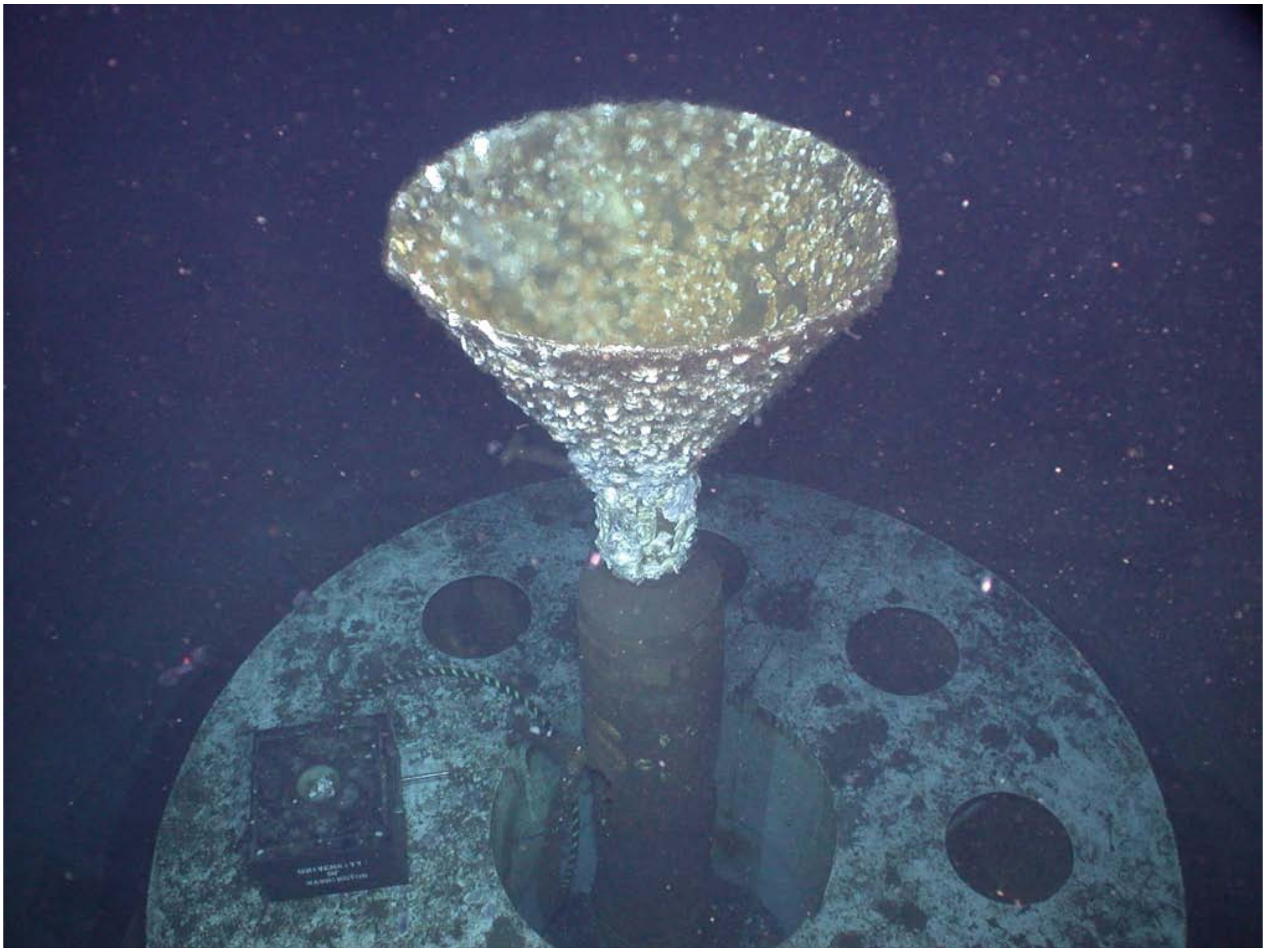

**Figure F20.** Fork-shaped fishing tool fabricated to remove the minicone in Hole 1026B. **A.** Construction of fishing tool. **B.** Deployment of fishing tool through the moonpool.

A B

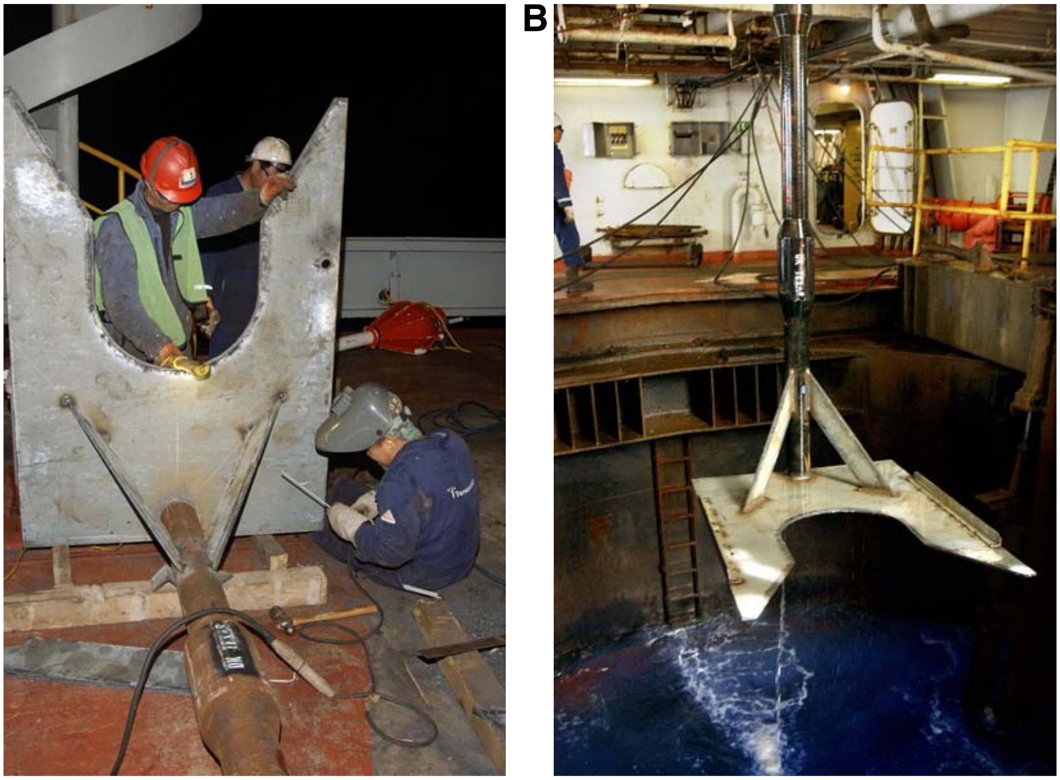

**Figure F21. A, B.** Retrieval of old Hole 1026B CORK and ROV platform through the moonpool. It was originally installed on ODP Leg 168. The brown pipe above the ROV platform is the CORK pulling tool, which has the old CORK head latched inside.

**Figure F22.** The old ODP Leg 168 CORK body on deck shortly after retrieval. **A.** Upper half of CORK head with sampling/monitoring port access. **B.** Lower part of CORK head. **C.** Lower half of CORK head. **D.** borehole seal—the lower right portion was exposed at above the seafloor; the upper left was sealed in the borehole.

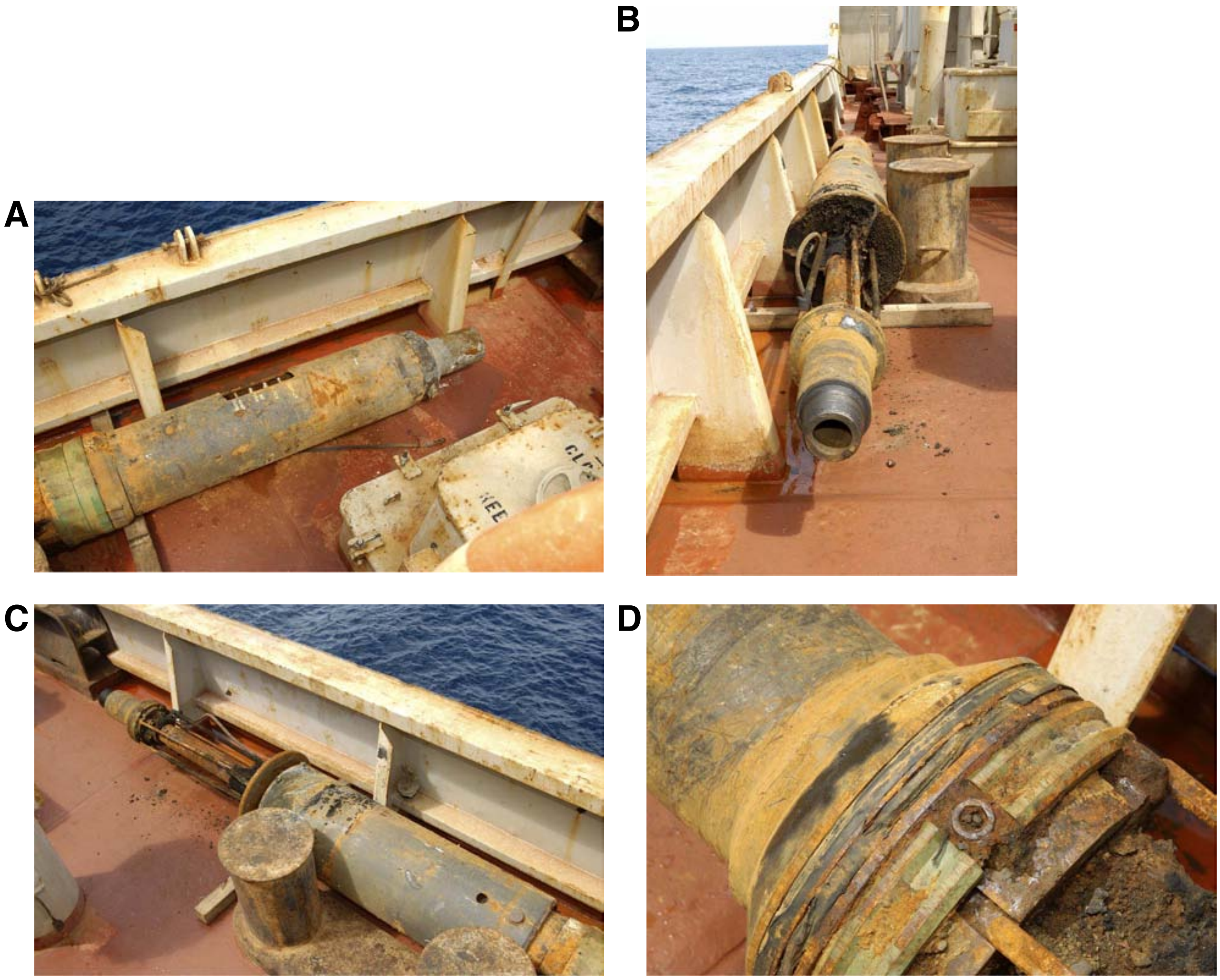

**Figure F23.** The new Hole 1026B CORK head being lifted into the derrick using the CORK running tool.

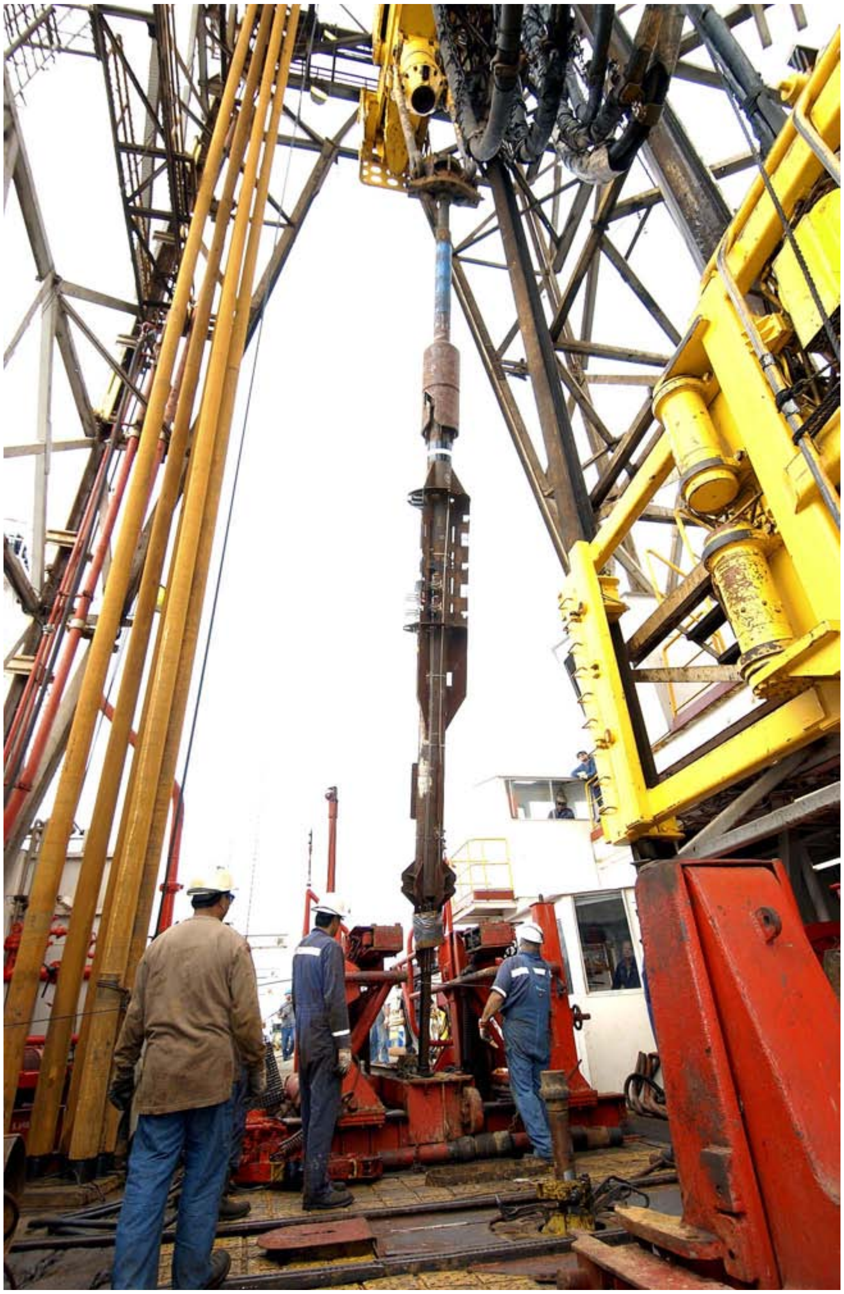

**Figure F24.** Schematic showing the Hole 1026B reentry cone and borehole casing (right), CORK-II borehole completion (center), and the instrument string deployed through the 4½ inch casing (left). ROV = remotely operated vehicle.

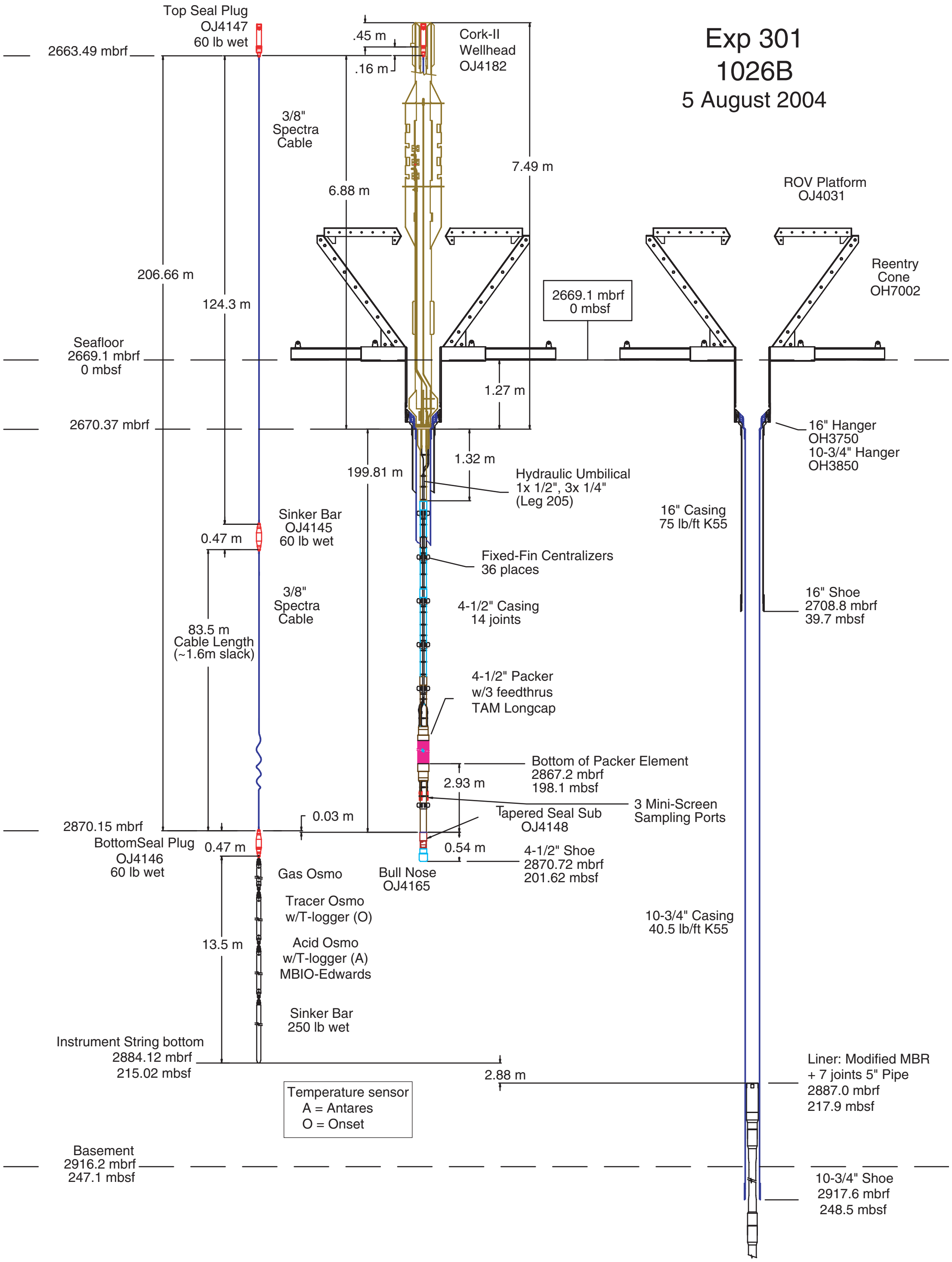

**Table T1.** Expedition 301 operational steps with start and end times and dates.

| Operational Task | Start Date (2004) | Start Ship time (local) | End Date (2004) | End Ship time (local) | Task time (hours) | Task time (days) |
|---|---|---|---|---|---|---|
| End Expedition 301 Port Call in Astoria, Oregon | | | 27 Jun | 0600 | | |
| Depart Astoria, Oregon, for Site U1301 | 27 Jun | 0600 | 27 Jun | 0830 | 2.50 | 0.1 |
| Cross Columbia River Bar | 27 Jun | 0830 | 27 Jun | 1030 | 2.00 | 0.1 |
| Transit ~172 nmi to Site U1301 (SR-1A) | 27 Jun | 1030 | 28 Jun | 0315 | 16.75 | 0.7 |
| Hole U1301A: | | | | | | |
| Jet-in test | 28 Jun | 0315 | 29 Jun | 0400 | 24.75 | 1.0 |
| Install reentry cone and 20 inch casing | 29 Jun | 0400 | 30 Jun | 0545 | 25.75 | 1.1 |
| Drill 20 inch hole in sediment with underreamer for 16 inch casing | 30 Jun | 0545 | 01 Jul | 1130 | 29.75 | 1.2 |
| Drill 20 inch hole in basement with bicenter bit | 01 Jul | 1130 | 02 Jul | 1345 | 26.25 | 1.1 |
| Install 16 inch casing | 02 Jul | 1345 | 03 Jul | 1230 | 22.75 | 0.9 |
| Drill 14-3/4 inch hole with tricone bit in basement for 10-3/4 inch casing | 03 Jul | 1230 | 06 Jul | 0400 | 63.50 | 2.6 |
| Install 10-3/4 inch casing | 06 Jul | 0400 | 08 Jul | 0800 | 52.00 | 2.2 |
| offset ship 36 m N13°E to Hole U1301B | | | | | | |
| Hole U1301B: | | | | | | |
| Install reentry cone and 20 inch casing | 08 Jul | 0800 | 09 Jul | 0900 | 25.00 | 1.0 |
| Repair underreamer | 09 Jul | 0900 | 09 Jul | 1645 | 7.75 | 0.3 |
| Drill 20 inch hole 11m into basement with bicenter bit and underreamer | 09 Jul | 1645 | 11 Jul | 0600 | 37.25 | 1.6 |
| Install 16 inch casing | 11 Jul | 0600 | 12 Jul | 0130 | 19.50 | 0.8 |
| Drill 14-3/4 inch hole with tricone bit in basement for 10-3/4 inch casing | 12 Jul | 0130 | 14 Jul | 0215 | 48.75 | 2.0 |
| Install 10-3/4 inch casing; unable to land, pull out of hole | 14 Jul | 0215 | 15 Jul | 0515 | 27.00 | 1.1 |
| Ream hole with 14-3/4 inch tricone bit | 15 Jul | 0515 | 16 Jul | 0500 | 23.75 | 1.0 |
| Install 10-3/4 inch casing | 16 Jul | 0500 | 17 Jul | 0045 | 19.75 | 0.8 |
| Equipment transfer by helicopter, 1100 hours on 16 July | | | | | | |
| Transit 0.55 nmi to Site 1026 in DP mode (during pipe trip) | 17 Jul | 0045 | 17 Jul | 0045 | 0.00 | 0.0 |
| Hole 1026B: | | | | | | |
| RIH/Fish aluminum reentry funnel/POOH | 17 Jul | 0045 | 17 Jul | 1200 | 11.25 | 0.5 |
| Transit 0.55 nmi to Site U1301 (during pipe trip) | 17 Jul | 1200 | 17 Jul | 1200 | 0.00 | 0.0 |
| Hole U1301A: | | | | | | |
| Drill out cement, check and clean hole to total depth | 17 Jul | 1200 | 18 Jul | 0315 | 15.25 | 0.6 |
| Hydrologic (packer) testing | 18 Jul | 0315 | 19 Jul | 1000 | 30.75 | 1.3 |
| Install CORK and ROV platform | 19 Jul | 1000 | 21 Jul | 0230 | 40.50 | 1.7 |
| offset ship 36 m back to Hole U1301B(during pipe trip) | | | | | | |
| Hole U1301B: | | | | | | |
| Drill out cement | 21 Jul | 0230 | 21 Jul | 1800 | 15.50 | 0.6 |
| RCB core to 582.8 mbsf | 21 Jul | 1800 | 31 Jul | 2245 | 244.75 | 10.2 |
| Wireline logging; four runs | 31 Jul | 2245 | 02 Aug | 2330 | 48.75 | 2.0 |
| Transit 0.55 nmi to Hole 1026B (during pipe trip) | | | | | | |
| Hole 1026B: | | | | | | |
| Recover CORK installed during Leg 168 | 02 Aug | 2330 | 03 Aug | 1500 | 15.50 | 0.6 |
| Install CORK (includes 15.75 h to fish obstruction in cone) | 03 Aug | 1500 | 05 Aug | 0415 | 37.25 | 1.6 |
| Deploy ROV platform | 05 Aug | 0415 | 05 Aug | 1615 | 12.00 | 0.5 |

## Table T1 (continued).

| Operational Task | Start Date (2004) | Start Ship time (local) | End Date (2004) | End Ship time (local) | Task time (hours) | Task time (days) |
|---|---|---|---|---|---|---|
| Transit 0.55 nmi to Hole U1301B(during pipe trip) | | | | | | |
| Hole U1301B: | | | | | | |
| Attempt to align and cement 10-3/4 inch casing | 05 Aug | 1615 | 06 Aug | 1700 | 24.75 | 1.0 |
| offset ship 100 m NNE (19°) of Hole U1301B | | | | | | |
| Hole U1301C: | | | | | | |
| APC core to ~265 mbsf, conduct 5 temperature measurements | 06 Aug | 1700 | 08 Aug | 1545 | 46.75 | 1.9 |
| offset ship back to Hole U1301B (during pipe trip) | | | | | | |
| Hole U1301B: | | | | | | |
| Open hole and check depth of hole | 08 Aug | 1545 | 09 Aug | 0730 | 15.75 | 0.7 |
| Hydrologic (packer) testing | 09 Aug | 0730 | 10 Aug | 2100 | 37.50 | 1.6 |
| Test CORK-II casing and spring centralizers across casing gap | 10 Aug | 2100 | 11 Aug | 1315 | 16.25 | 0.7 |
| Failed attempt to install CORK; 4-1/2 casing breaks below CORK-II head | 11 Aug | 1315 | 13 Aug | 0600 | 40.75 | 1.7 |
| Visually inspect failed CORK-II | 13 Aug | 0600 | 13 Aug | 1545 | 9.75 | 0.4 |
| Remove (fish) failed 4-1/2 inch casing from reentry cone | 13 Aug | 1545 | 14 Aug | 0600 | 14.25 | 0.6 |
| Check depth of hole with drill bit | 14 Aug | 0600 | 14 Aug | 1800 | 12.00 | 0.5 |
| Install CORK | 14 Aug | 1800 | 16 Aug | 1715 | 47.25 | 2.0 |
| Deploy ROV platform | 16 Aug | 1715 | 17 Aug | 0415 | 11.00 | 0.5 |
| Spot cement in reentry cone through ROV platform | 17 Aug | 0415 | 17 Aug | 1515 | 11.00 | 0.5 |
| Remove (fish) piece of failed 4-1/2 inch casing adjacent to reentry cone | 17 Aug | 1515 | 17 Aug | 2245 | 7.50 | 0.3 |
| Conduct seafloor hazard survey surrounding Holes U1301A and U1301B | 17 Aug | 2245 | 18 Aug | 1030 | 11.75 | 0.5 |
| Hole U1301D: | | | | | | |
| APC core 120–180 mbsf and secure for transit to Astoria, Oregon | 18 Aug | 1030 | 19 Aug | 0600 | 19.50 | 0.8 |
| Transit ~179 nmi to Astoria, Oregon | 19 Aug | 0600 | 19 Aug | 2245 | 16.75 | 0.7 |
| Totals: | | | | | 1288.8 | 53.7 |

Note: Local ship time = UTC –7.

**Table T2.** Hole locations during IODP Expedition 301 and related site locations.

| Site/Hole | Latitude (N) | Longitude (W) | Seismic line | CDP/TR |
|---|---|---|---|---|
| Hole U1301A | 47°45.210' | 127°45.833' | GeoB 00-466 | CDP 557 |
| Hole U1301B | 47°45.228' | 127°45.827' | GeoB 00-466 | CDP 556 |
| Hole U1301C | 47°45.280' | 127°45.800' | GeoB 00-468 | CDP 390 |
| Hole U1301D | 47°45.279' | 127°45.786' | GeoB 00-468 | CDP 390 |
| Hole U1026B | 47°45.757' | 127°45.548' | GeoB 00-203 | CDP 962 |
| Hole U1027C | 47°45.387' | 127°43.867' | GeoB 00-203 | CDP 741 |
| SR-2A | 47°45.662' | 127°45.674' | GeoB 00-482 | CDP 439 |
| FR-1A, C | 47°54.105' | 128°33.468' | InLine 44 (GeoB 00-365) | TR 426 |
| FR-1B | 47°54.132' | 128°33.591' | InLine 44 (GeoB 00-365) | TR 410 |
| DR-1A | 47°38.810' | 127°26.999' | EW0702 Line 1 | CDP 3070 |
| DR-2A | 47°37.449' | 127°20.049' | EW0702 Line 1 | CDP 1720 |

Notes: CDP = common depth point, TR = trace within 3-D seismic grid. Hole U1301B is offset 35 m on a heading ~N13°E from Hole U1301A. This offset is oblique to the strike of seismic Line GeoB00-466. The along-line distance is roughly equivalent to one shotpoint, as listed. Hole U1301C is offset 101 m on a heading ~N19°E from Hole U1301B. This offset places the hole slightly south of seismic Line GeoB00-468. The closest approach is 20 m offset from CDP 390, as listed. Hole U1301D was positioned 26 m on a heading of 107° from Hole U1301C. Position for Hole 1026B has been revised relative to that reported during ODP Leg 168. The difference (6.6 m) is attributed to improvements in the quality of commercially available differential GPS data during the 8 y between these expeditions. Work at Site SR-2A and Hole 1027C is planned for another drilling expedition based on proposal 545Full3, to be scheduled. Sites FR-1A, FR-1B, DR-1A, and DR-2A were second-priority sites for IODP Expedition 301 and are to be second-priority objectives for the second drilling expedition as well.