Integrated Ocean Drilling Program Expedition 327 Scientific Prospectus

Juan de Fuca Ridge-Flank 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

Andrew T. Fisher
Department of Earth and Planetary Sciences
University of California, Santa Cruz
1156 High Street
Santa Cruz CA 95064
USA

Takeshi Tsuji
Graduate School of Engineering
Kyoto University
C1-1-110 Kyotodaigaku-Katsura
Nishikyo-ku, Kyoto 615-8540
Japan

Kusali Gamage/Katerina Petronotis
Expedition Project Manager/Staff Scientist
Integrated Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA

Published by
Integrated Ocean Drilling Program Management International, Inc.,
for the Integrated Ocean Drilling Program

Publisher's notes

Publisher's notes

Citation:
Fisher, A.T., Tsuji, T., and Gamage, K., 2010. Juan de Fuca Ridge-Flank 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. *IODP Sci. Prosp.,* 327. doi:10.2204/iodp.sp.327.2010

Distribution:
Electronic copies of this series may be obtained from the Integrated Ocean Drilling Program (IODP) Scientific Publications homepage on the World Wide Web at **www.iodp.org/scientific-publications/.**

This publication was prepared by the Integrated Ocean Drilling Program U.S. Implementing Organization (IODP-USIO): Consortium for Ocean Leadership, Lamont-Doherty Earth Observatory of Columbia University, and Texas A&M University, as an account of work performed under the international Integrated Ocean Drilling Program, which is managed by IODP Management International (IODP-MI), Inc. Funding for the program is provided by the following agencies:

National Science Foundation (NSF), United States

Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan

European Consortium for Ocean Research Drilling (ECORD)

Ministry of Science and Technology (MOST), People's Republic of China

Korea Institute of Geoscience and Mineral Resources (KIGAM)

Australian Research Council (ARC) and New Zealand Institute for Geological and Nuclear Sciences (GNS), Australian/New Zealand Consortium

Ministry of Earth Sciences (MoES), India

Disclaimer

This IODP *Scientific Prospectus* is based on precruise Science Advisory Structure panel discussions and scientific input from the designated Co-Chief Scientists on behalf of the drilling proponents. During the course of the cruise, actual site operations may indicate to the Co-Chief Scientists, the Staff Scientist/Expedition Project Manager, and the Operations Superintendent that it would be scientifically or operationally advantageous to amend the plan detailed in this prospectus. It should be understood that any proposed changes to the science deliverables outlined in the plan presented here are contingent upon the approval of the IODP-USIO Science Services, TAMU, Director in consultation with IODP-MI.

March 2010

Abstract

Integrated Ocean Drilling Program (IODP) Expedition 327 is a critical part of a long-term multidisciplinary experiment that builds from technical and scientific achievements and lessons learned during Ocean Drilling Program (ODP) Leg 168 and IODP Expedition 301. The main goal of this experiment is to evaluate formation-scale hydrogeologic properties (transmission and storage) within oceanic crust; determine how fluid pathways are distributed within an active hydrothermal system; establish links between fluid circulation, alteration, and geomicrobial processes; and determine relations between seismic and hydrologic anisotropy. During Expedition 327 we will install subseafloor observatories in two new holes in oceanic crust (at proposed Site SR-2); replace an observatory in an existing hole (ODP Site 1027) to facilitate long-term monitoring; recover and replace an instrument string deployed in one of the Expedition 301 subseafloor borehole observatories (CORKs); and complete remedial cementing of another Expedition 301 CORK that is not sealed at the seafloor. Following Expedition 327, submersible expeditions will allow us to conduct single- and cross-hole hydrologic experiments using a complete network of six observatory systems that use CORKs as perturbation and monitoring points. This expedition will be dominated by subseafloor observatory installation operations, and hence science activities will consist of ~200 m of basement coring at proposed Site SR-2 and ODP Site 1027, downhole logging, and drill string hydrologic testing. Expedition 327 will also include an international education and outreach program intended to develop tools and techniques that facilitate the communication of exciting scientific drilling results to a broad audience, build educational curricula, and create media products that will help achieve critical outreach goals.

Schedule for Expedition 327

Integrated Ocean Drilling Program (IODP) Expedition 327 is based on IODP drilling Proposal 545 (available at **iodp.tamu.edu/scienceops/expeditions/juan_de_fuca.html**). Following ranking by the IODP Science Advisory Structure, the expedition was scheduled for the R/V *JOIDES Resolution*, operating under contract with the U.S. Implementing Organization (USIO). At the time of publication of this *Scientific Prospectus*, the expedition is scheduled to start in Victoria, Canada, on 5 July 2010 and end in Victoria, Canada, on 4 September 2010. A total of 54.4 days will be available for the drilling, coring, and downhole measurements described in this report (for the current detailed schedule, see **iodp.tamu.edu/scienceops/**). Further details about the analytical facilities aboard the *JOIDES Resolution* and the USIO can be found at **www.iodp-usio.org/.**

Introduction

Fluid flow within the volcanic oceanic crust influences the thermal and chemical state and evolution of oceanic lithosphere and lithospheric fluids; the establishment and maintenance of subseafloor microbial ecosystems; the diagenetic, seismic, and magmatic activity along plate-boundary faults; the creation of ore and hydrate deposits both on and below the seafloor; and the exchange of fluids and solutes across continental margins (e.g., Alt, 1995; Huber et al., 2005; Parsons and Sclater, 1977; Peacock and Wang, 1999). The global hydrothermal fluid mass flux through the upper oceanic crust rivals the global riverine fluid flux to the ocean and effectively cycles the volume of the oceans through the crust once every 10^5–10^6 y (Elderfield and Schultz, 1996; Johnson and Pruis, 2003; Mottl, 2003). Most of this flow occurs at relatively low temperatures, far from volcanically active seafloor-spreading centers where new ocean floor is created. This "ridge-flank" circulation can be influenced by off-axis volcanic or tectonic activity but is driven mainly by the rise of lithospheric heat from below the crust. Although the average maximum age at which measurable heat is lost advectively from oceanic lithosphere is 65 Ma (Parsons and Sclater, 1977), many sites remain hydrologically active for tens of millions of years beyond this age, with circulation largely confined to basement rocks that redistribute heat below thick sediments (Fisher and Von Herzen, 2005; Von Herzen, 2004).

Despite the importance of fluid-rock interactions in the crust, little is known about the magnitude and distribution of critical hydrologic properties; the extent to which crustal compartments are well connected or isolated (laterally and with depth); the rates and spatial extent of ridge-flank fluid circulation; or the links between ridge-flank circulation, crustal alteration, and geomicrobial processes. Expedition 327 is a critical part of a long-term experimental program that began nearly two decades ago and that has included several survey, drilling, submersible, and remotely operated vehicle (ROV) expeditions; observatory and laboratory testing, sampling, and monitoring; and modeling of coupled fluid-thermal-chemical-microbial processes. Expedition 327 builds on technical and scientific achievements and lessons learned during Ocean Drilling Program (ODP) Leg 168 (Davis, Fisher, Firth, et al., 1997), which focused on hydrothermal processes within uppermost basement rocks and sediments along an age transect, and IODP Expedition 301 (Fisher, Urabe, Klaus, et al., 2005), which penetrated deeper into the crust at the eastern end of the Leg 168 transect (Fig. F1). Both expeditions installed subseafloor borehole observatories (CORKs) in basement holes to allow borehole conditions to recover to a more natural state after dissipation of disturbances caused by drilling, casing, and other operations; to provide a long-term monitoring and sampling presence for determination of fluid pressure, temperature, composition, and microbiology; and to facilitate the completion of active experiments to resolve crustal hydrogeologic conditions and processes (Fisher et al., 2005). Subsequent ROV and submersible expeditions downloaded data from the Leg 168 and Expedition 301 CORKs and replaced batteries, loggers, and sampling systems at the seafloor and downhole.

The primary goals of Expedition 327 are to (1) drill two new basement holes, core and wireline log one of these holes across a depth range of 100–360 meters subbasement (msb), conduct a 24 h pumping and tracer injection test, and install multilevel CORKs; (2) recover an existing CORK installed in a shallow basement hole during Leg 168, deepen the hole by 40 m, and install a new multilevel CORK with instrumentation; (3) recover and replace an instrument string deployed in one of the Expedition 301 CORKs; and (4) complete remedial cementing of another Expedition 301 CORK that is not sealed at the seafloor.

Later submersible expeditions will use these CORKs as perturbation and monitoring points for single- and cross-hole experiments. Expedition 327 will also include an international education and outreach program intended to develop tools and techniques that facilitate the communication of exciting scientific drilling results to a broad audience, build educational curricula, and create media products (photographic, sound, video, and web based) that help achieve critical outreach goals. Secondary objectives of Expedition 327 include coring at sedimentary sites where recovered material may provide insights into hydrothermal conditions and processes within the underlying basaltic crust.

Background

Geological setting and earlier work

Many studies summarize the geology, geophysics, and basement-fluid chemistry and hydrogeology of young seafloor on the eastern flank of the Endeavour segment of the Juan de Fuca Ridge (JFR) (e.g., Davis et al., 1989, 1992; Elderfield et al., 1999; Fisher et al., 2003; Hutnak et al., 2006; Mottl et al., 1998; Stein and Fisher, 2003; Wheat and

Mottl, 1994; Wheat et al., 2000, 2003, 2004). Topographic relief associated with the JFR axis and abyssal hill bathymetry on the ridge flank have helped trap turbidites flowing west from the continental margin (Fig. F1). This has resulted in the burial of young oceanic basement rocks under thick sediments. Sediment cover is regionally thicker and more continuous to the east, but there are seamounts and smaller basement outcrops located as far as 100 km east of the spreading center, north and south of the Expedition 327 work area. Regional 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. Low-permeability sediment limits advective heat loss across most of the ridge flank, resulting in strong thermal, chemical, and alteration gradients in basement.

Leg 168 completed a transect of eight sites across 0.9–3.6 Ma seafloor, collecting sediment, rock, and fluid samples; determining thermal, geochemical, and hydrogeologic conditions in basement; and installing a series of CORK observatories in the upper crust (Davis, Fisher, Firth, et al., 1997). Two of the Leg 168 observatories were placed in 3.5–3.6 Ma seafloor in Holes 1026B and 1027C, near the eastern end of the drilling transect (Fig. F1). Expedition 301 returned to this area and drilled deeper into basement, sampled additional sediment, basalt, and microbiological materials, replaced the borehole observatory in Hole 1026B, and established two additional CORK observatories at Site U1301 for use in long-term three-dimensional hydrogeologic experiments (Fisher, Urabe, Klaus, et al., 2005).

Before Leg 168 there was a largely two-dimensional view of the dominant fluid circulation pathways across the eastern flank of the JFR, with recharge occurring across large areas of basement exposure close to the ridge (near the western end of the Leg 168 transect) and then flowing toward the east. Some results from Leg 168 are consistent with this view, including seafloor heat flow and basement temperatures that increase and basement fluids that are warmer and more altered farther to the east along the drilling transect (Davis et al., 1999; Elderfield et al., 1999; Stein and Fisher, 2003). However, Leg 168 results also revealed inconsistencies with this conceptual model of large-scale hydrogeologic flow. Although basement fluids warm and age along the western end of the Leg 168 drilling transect with increasing distance from the ridge (from Sites 1023 to 1025), fluids are younger with respect to ^{14}C at the next nearest site to the east (Site 1031) and even younger farther to the east (Site 1026), despite being warmer and more altered (Elderfield et al., 1999; Walker et al., 2007). In addition, reexamination and collection of additional bathymetric data along the western end of the Leg 168 transect show that basement outcrops to the north and south could allow hydrothermal fluids to recharge and discharge, with flow occurring largely perpendicular to the transect (Hutnak et al., 2006). Leg 168 results also present the vexing problem of explaining where fluids flowing toward the east at the western end of the Leg 168 transect might exit the crust (Davis et al., 1999).

Regional site surveys in preparation for Expedition 301 focused on and near basement outcrops that could be fluid entry and exit points to and from the crust that allow hydrothermal flows to bypass generally thick and impermeable sediments (Fisher et al., 2003; Hutnak et al., 2006; Zühlsdorff et al., 2005). Thermal data suggest a significant component of south–north (ridge parallel, along strike) fluid flow in basement at the eastern end of the Leg 168 transect, an interpretation consistent with geochemical studies (Walker et al., 2007; Wheat et al., 2000). Bathymetric, sediment thickness, and heat flow data near the western end of the Leg 168 transect are consistent with a significant component of north–south fluid flow in basement in this area (Hutnak et al., 2006). Numerical models created to simulate outcrop-to-outcrop hydrothermal circulation between the Grizzly Bare and Baby Bare outcrops—separated by 52 km in the along-strike direction—and to estimate the nature of basement properties that would allow these inferred patterns and rates of fluid circulation show that outcrop-to-outcrop hydrothermal circulation can be sustained when basement permeability is $\geq 10^{-12}$ m^2. At lower permeabilities, too much energy is lost during lateral fluid transport for circulation to continue without forcing, given the limited driving pressure difference at the base of recharging and discharging fluid columns (Hutnak et al., 2006). In addition, fluid temperatures in upper basement are highly sensitive to modeled permeability. When basement permeability is too high (10^{-10} to 10^{-9} m^2), fluid circulation is so rapid that basement is chilled to temperatures below those seen regionally (modeled values of 20°–50°C). A good match is achieved to observed upper basement temperatures of 60°–65°C when lateral basement permeability is 10^{-11} m^2.

Drill string packer experiments in upper basement during Expedition 301 indicate a layered crustal structure, with permeabilities of 10^{-12} to 10^{-11} m^2 (Becker and Fisher, 2008). Additional hydrogeologic analyses completed using the formation pressure response to the long-term flow of cold bottom seawater into basement at Site U1301 in the 13 months after drilling, as observed at Site 1027 (2.4 km away) (Fisher et al., 2008), suggest large-scale permeability at the low end of or below values indicated by packer testing. Results from both sets of measurements, as well as the difference between these permeability estimates and others based on modeling and analyses of formation responses to tidal and tectonic perturbations, may be reconciled by azimuthal anisotropy in basement hydrogeologic properties. The hypothesis that basement permeability is anisotropic is also consistent with preferential flow in the north–south direction at both ends of the Leg 168 transect, based mainly on thermal and chemical observations, and will be tested directly during and after Expedition 327, when multidirectional cross-hole experiments are run using a network of sealed borehole observatories.

Seismic studies/site survey data

Two site surveys were completed in 2000 in support of Expeditions 301 and 327. The ImageFlux survey was completed with the R/V *Sonne*, including collection of nearly 500 lines of seismic data and extensive hydrosweep coverage (Zühlsdorff and Spiess, 2006). The RetroFlux expedition was completed on the R/V *Thomas G. Thompson*, with a focus on coring and heat flow and limited acquisition of hydrosweep data (Fisher et al., 2003; Hutnak et al., 2006; Wheat et al., 2000). Finally, a 2002 expedition of the R/V *Maurice Ewing* collected multichannel seismic (MCS) data mainly across the JFR, with one line positioned to cross Leg 168 and Expedition 301/327 drilling sites (Carbotte et al., 2008; Nedimovic et al., 2008). This seismic line also crosses the secondary Deep Ridge (DR) sites. Collectively, these data provide clear drilling targets for Expedition 327 operations.

Conversions from two-way traveltime between the seafloor and top of basement to sediment thickness were developed by Davis et al. (1999) using drilling results from Leg 168 (Davis, Fisher, Firth, et al., 1997). Shipboard velocity measurements made on recovered sediments were combined to generate an equation for time–depth conversion. This conversion was shifted linearly to force a fit through basement depths determined during drilling, with a resulting sediment velocity range of 1500–1700 m/s. For Expedition 327, the greatest uncertainty in estimating depths for drilling target goals from seismic data comes from picking targets on a narrow basement peak where the upper basement surface is somewhat irregular. However, experience from Leg 168 and Expedition 301 shows that these picks have uncertainties equivalent to ±5 m to basement.

The supporting site survey data for Expedition 327 are archived at the **IODP Site Survey Data Bank.**

Expedition objectives

Primary scientific objectives

The primary scientific objectives of Expedition 327 are listed below, in a rough order of priority, although changes in the detailed operational plan are expected based on weather, hole conditions, actual time requirements for individual operations, and other factors (Table **T1**). The maximum lateral distance between primary work sites is 2.4 km, so we expect to move frequently between sites to take advantage of favorable weather conditions and time savings that may be afforded by avoiding unnecessary pipe trips.

The primary work area for Expedition 327, including Sites 1027 and U1301 and proposed Site SR-2, is referred to as the Second Ridge (SR) area (Fig. **F1**) because these sites are located on or adjacent to the second major buried basement ridge east of the JFR. All of the highest priority objectives for Expedition 327 are to be achieved through work in the SR area. Secondary objectives may be achieved during Expedition 327 at the sedimented regions adjacent to Grizzly Bare (GRB) outcrop, above the first buried basement ridge (FR) east of the JFR, and above a series of more deeply buried ridges (DR) to the east of the SR area (Fig. **F1**).

1. Proposed Site SR-2

We will drill two new basement holes at Site SR-2, ~200 m south-southwest of Hole 1026B and ~800 m north-northwest of Hole U1301B, where sediment thickness is ~255 m. Seismic coverage in this area is detailed (Fig. **F2**), and holes will be located along the peak of the buried basement ridge (Fig. **F3**), much like Holes U1301A and U1301B (Fig. **F4**) and Hole 1026B (Fig. **F5**). Hole SR-2A will be the deepest of the two new holes, but this hole can be used as the shallowest completion if poor hole conditions or other operational problems necessitate it. The sedimentary section and the uppermost 100 m of basement will be drilled and cased in this hole but not cored. Coring will occur only within the interval of ~100–260 msb, with the final hole depth determined by hole conditions and time remaining during the expedition. The open basement interval in this hole will be wireline logged with a single string (see **"Logging/downhole measurements strategy"**), tested for permeability using the drill string packer, and instrumented with a multilevel CORK. This and other CORKs deployed during Expedition 327 will include instruments to monitor formation fluid pressure and temperature, sample fluids (using downhole and wellhead OsmoSamplers), and provide growth substrate for microbes inhabiting the basement aquifer.

Hole SR-2B will be the shallowest of the new basement holes. The sedimentary section and the uppermost ~30 m of basement will be drilled and cased in this hole, and additional drilling below casing will open the hole to ~70 msb. There will be no coring or wireline logging in Hole SR-2B. A 24 h pumping and tracer injection experiment will occur in Hole SR-2B, and then this hole will be instrumented with a CORK. This CORK will be similar to that installed in Hole SR-2A, except that it will monitor a single basement interval.

2. Hole 1027C

We will recover an existing CORK in Hole 1027C, core and deepen the hole by ~40 m, extending it to ~60 msb, and deploy a multilevel CORK to monitor and sample basement fluids. If there is sufficient time we may complete hydrologic (packer) tests within the new basement interval in this hole before setting the CORK in place, but no wireline logging or other downhole experiments are planned.

3. Hole U1301B

We will recover the CORK instrument string deployed in Hole U1301B, which researchers were unable to recover during submersible operations in summer 2009, and deploy a replacement instrument string, including thermal sensors, fluid samplers, and microbial growth substrate.

4. Hole U1301A

We will complete remedial cementing operations in Hole U1301A with the goal of sealing this system at the seafloor, isolating the open hole at depth from the overlying ocean.

Primary education and outreach objectives

The primary scientific objectives of Expedition 327 will be achieved concurrently with an extensive education and science communication program involving 6–7 shipboard science educators, communicators, writers, and media developers and hundreds of additional personnel on shore (classroom students, teachers, museum visitors, families, etc.). Working alongside the science party, shipboard educators will advance the scientific goals of the expedition and of IODP in general by communicating its importance to a broad external audience and engendering understanding and enthusiasm for scientific exploration, ocean drilling, and subseafloor observatories.

Earlier full-length scientific ocean drilling expeditions included a single teacher at sea, who focused on a subset of similar objectives, whereas shorter expeditions or transits included a larger number of educators, who participated in shipboard activities while limited, if any, science operations were performed. In contrast, Expedition 327 will be the first full-length ocean drilling expedition to include a broader education, outreach, and communication program. While on board, participants will complete an intensive short course on marine geology and hydrogeology, take part in a seminar series from the scientists about their research, and offer a seminar series on science communications to assist shipboard scientists in sharing their research and creating effective broader impacts for nonscientific audiences. This on-board education team will also produce podcasts and videos, articles for mainstream media outlets and Web sites, a regular schedule of live video conferences to audiences on shore, daily blogs, Facebook and Twitter updates, photo-based documentary journals to be published during or after the cruise, graphic novel–style books, classroom curricula, journal articles, and videos for YouTube, among other products. Because of the nature of collaborative research in education circles, sailing multiple educators as a team provides a unique opportunity for creating innovative science communication products.

Secondary scientific objectives

If the primary scientific objectives are completed or we cannot complete some of these objectives and time still remains during the expedition, we may attempt to achieve secondary scientific objectives. These objectives involve mainly sediment coring, sampling, and measurements, prioritized in this order:

5. Proposed Sites GRB-1, GRB-2, and GRB-3

Sedimentary (advanced piston corer [APC]/extended core barrel [XCB]) coring and heat flow measurements at proposed Sites GRB-1A, GRB-2A, or GRB-3A (Fig. **F6**) may take place with the goal of documenting evidence for hydrothermal recharge adjacent to Grizzly Bare outcrop, as hypothesized from pore water and formation fluid compositions from the north and heat flow and modeling studies of the corridor that extends ~50 km north from Grizzly Bare outcrop.

6. Proposed Site FR-1

Sedimentary (APC/XCB) coring and heat flow measurements at proposed Site FR-1 (Fig. **F7**) may take place to evaluate the nature of sedimentary properties and basement fluid compositions along a short transect of holes, including locations where there is known hydrothermal seepage.

7. Proposed Sites DR-1 and DR-2

Sedimentary and basement (rotary core barrel [RCB]) coring and heat flow measurements at proposed Sites DR-1 or DR-2 (Fig. **F8**) may take place to extend the Leg 168 transect to the east and assess the nature of crustal evolution at greater temperatures, basement ages, and depths of basement burial.

Work at GRB and FR sites could occupy ≤3–4 days, whereas coring at the DR sites would require at least 11 days to reach basement because of greater sediment thickness.

CORK configurations

The CORKs to be deployed during Expedition 327 differ in configuration depending on their intended use and the expected hole geometry, but they have several design elements in common (Fig. **F9**). CORKs are designed to seal open holes so that thermal, pressure, and chemical conditions can equilibrate after the dissipation of drilling disturbance. CORKs also facilitate the collection of fluid and microbiological samples as well as temperature and pressure data using autonomous samplers and data logging systems and serve as long-term monitoring points for large-scale crustal testing. Expedition 327 CORKs will include a seafloor reentry cone and casing hanger(s); concentric (nested) casing strings that penetrate through sediments and allow access to underlying basement; a series of seals (both between casing strings and between casings and the formation) that hydraulically isolate the open crustal interval at depth from the overlying ocean; downhole and seafloor instrumentation for collection of samples and data; and a seafloor wellhead that includes valves, fittings, electrical connections, and a landing platform so that the observatory can be serviced by submersible or ROV, allowing samples and data to be retrieved without recovery of the complete observatory assembly.

Expedition 327 CORKs differ somewhat from earlier systems. All CORKs will use a two-packer system for each borehole seal at depth. A hydraulic packer (inflated by pumping during deployment) will be supplemented with a swellable packer; adjacent hydraulic and swellable packer elements will be run in tandem. The hydraulic packer will provide an immediate seal to monitor short-term formation pressure response and limit the continued inflow of cold bottom water, whereas the swellable element will provide assurance that the seal lasts for at least several years. All Expedition 327 CORKs will be configured with a mixture of sample and monitoring lines with different diameters and construction materials to meet particular purposes. These CORKs will include three perforated drill collars at the bottom of the inner CORK casing to provide ~10,000 lb of weight that will help to pull the CORKs into the holes. The perforated collars and a section of perforated 5½ inch casing above the collars will be coated with nonreactive material to reduce the extent of contamination resulting from interactions between borehole fluids and steel. The CORKs to be installed at proposed Site SR-2 include a lateral casing section that extends at an angle from below the seafloor seal to a 4 inch ball valve placed in a wellhead instrument bay above the seafloor seal ("L-CORK") (Fig. **F9**). This ball valve will be opened by submersible or ROV after a year of system equilibration to allow free flow of overpressured basement fluids, which will permit large-volume sampling and a cross-hole hydrogeologic experiment.

The Hole SR-2A CORK will have two monitored intervals at depth, extending to a maximum depth of ~515 meters below seafloor (mbsf) (~260 msb) (Fig. **F10**). Both basement intervals will be monitored for pressure, and a three-way valve at the seafloor will permit spot measurement of the interval isolated within the annular gap between the 10¾ and 16 inch casing strings. Fluids from both depth intervals in basement will be sampled using seafloor OsmoSampler systems installed on the wellhead, and a separate polytetrafluoroethylene (PTFE, a Teflon variant) sampling line will be dedicated for microbiological sampling. A landing seat will be placed at depth inside the 4½ inch inner CORK casing for future deployment of a bottom plug, but no bottom plug will be deployed during Expedition 327 so that this hole can be used for the long-term free-flow experiment by opening the wellhead ball valve.

The Hole SR-2B CORK is preferred for use in the long-term cross-hole experiment, but the L-CORK design used here will also be used in Hole SR-2A for redundancy. The Hole SR-2B CORK will have one monitored interval at depth, extending to a maximum depth of ~325 mbsf (~70 msb) (Fig. **F11**). The basement interval will be monitored for pressure, and a three-way valve at the seafloor will permit spot measurement of the interval isolated within the annular gap between the 10¾ and 16 inch casing strings. Fluids from depth in basement will be sampled using seafloor OsmoSampler systems installed on the wellhead, and a separate PTFE sampling line will be dedicated for microbiological sampling. A landing seat will be placed at depth inside the 4½ inch inner CORK casing for future deployment of a bottom plug, but no bottom plug will be deployed during Expedition 327 so that this hole can be used for the long-term free-flow experiment using the wellhead ball valve. The CORK instrument string that hangs inside the 4½ inch casing will contain a combination of OsmoSamplers for collection of fluids and gases, microbial growth substrate, and autonomous temperature loggers.

The Hole 1027C CORK will have two monitored intervals at depth, extending to a maximum depth of ~675 mbsf (~60 msb) (Fig. **F12**). The basement intervals will be monitored for pressure, and a dedicated pressure gauge will also be used to monitor the interval isolated within the annular gap between the 10¾ and 16 inch casing strings (to evaluate mechanical system compliance). Fluids from depth in basement will be sampled using seafloor OsmoSampler systems installed on the wellhead, and a separate PTFE sampling line will be dedicated for microbiological sampling. Two landing seats will be placed at depth inside the 4½ inch inner CORK casing, and two internal plugs will be deployed to assist with isolation of the different depth intervals in basement. Both basement intervals will be monitored using instruments inside the 4½ inch CORK casing, with perforated and coated casings providing borehole fluid access to the samplers deployed on the instrument string. The CORK instrument string will contain a combination of OsmoSamplers for collection of fluids and gases, microbial growth substrate, and autonomous temperature loggers.

Operations plan/drilling strategy

Target depths for Expedition 327 operations are listed in Table **T2.** Planned operations are summarized in Table **T3.** The expedition will begin with a jet-in test at proposed Site SR-2, followed by emplacement of a reentry cone and a 20 inch conductor casing. This cone and casing system will be used to establish the deep basement hole (Hole SR-2A). Should drilling problems occur in the first hole, a second attempt at a “deep” installation can be initiated, and the first attempt will become the “shallow” basement penetration (Hole SR-2B). A more traditional operations strategy would begin with sediment coring, but this approach is not planned for Expedition 327 for several reasons. First, we already have a good understanding of sediment thickness and properties on the basis of extensive site survey data and previous work at nearby Sites 1026 and U1301. Second, we would like to wait to dedicate time to sediment coring until we have greater confidence in achieving high-priority basement and observatory operations.

After installation of the cone and surface conductor casing in Hole SR-2A, we will drill with a 21½ inch underreamer through ~255 m of sediment to the basement contact. We will then drill with a 21½ inch bicenter bit through another ~20 m of the uppermost basement and run and cement a 16 inch surface casing. To minimize the risk of the casing strings and reentry cone sinking below the mudline (as happened during Leg 168 and Expedition 301), the casing will be held for 8 h while the cement hardens. This will complete Stage 1 operations in Hole SR-2A.

Once the casing hanger is released and the drill pipe is pulled out of the hole, the vessel will be offset 30–40 m to the planned location of Hole SR-2B, and we will repeat the emplacement of the reentry cone and 20 inch casing. This will be followed by drilling, emplacement, and cementing of the 16 inch casing string. This will complete Stage 1 operations in Hole SR-2B.

Upon returning to and reentering Hole SR-2A, the cement will be drilled out, and drilling will continue with a 14¾ inch tricone bit to penetrate quickly through the most unstable zone in upper basement to ~360 mbsf. For this effort we will use a bottom-hole assembly (BHA) that consists of extra 8¼ inch drill collars to ensure that only slick pipe is exposed to the unstable formation while the top of the BHA remains above the basement contact. The 10¾ inch casing will be run and cemented into place. We will install this casing without stopping to install the cementing manifold and subsea release system in order to ensure rapid emplacement of the casing string and unimpeded landing of the 10¾ inch casing hanger. Cement with lost-circulation materials (LCM) will be pumped into the bottom of the hole and allowed to set. This will complete Stage 2 operations in Hole SR-2A.

The vessel will then return to Hole SR-2B, where we will reenter the hole and drill ahead with a 14¾ inch tricone bit to ~290 mbsf. The 10¾ inch casing will be run and cemented into place. This will again be accomplished using an extended-length BHA and without the cementing manifold. This will complete Stage 2 operations in Hole SR-2B.

After dynamically positioning the ship once again over Hole SR-2A, the cement plug will be drilled out and coring will begin using a standard 9⅞ inch bit and the RCB system. We anticipate 160 m of penetration to ~520 mbsf, but we may core somewhat more or less basement depending on rates of penetration, drilling conditions, and the nature of the rocks recovered. We anticipate a bit replacement trip to reach total depth.

Once total depth is achieved in Hole SR-2A, the hole will be logged with one deployment of a wireline logging string designed to identify optimal placement of straddle packers as well as basic formation properties of the oceanic crust (see **"Logging/ downhole measurements strategy"**). Three sets of packer experiments will be conducted in the open hole. Once those tests are complete, the open hole depth will be verified before deploying a CORK-II observatory. The CORK-II will be configured to isolate two intervals of upper basement and will include wellhead fluid samples and pressure gauges, as well as downhole temperature sensors, fluid samplers, and microbiological incubation substrate (Fig. **F10**). A landing platform will be deployed following CORK installation. This will complete Stage 3 operations in Hole SR-2A.

Upon completion of operations in Hole SR-2A, we will move to Hole 1027C and recover the CORK system currently installed in the reentry cone. We will then run in with an RCB assembly, clean up the hole, and core from 635 to ~675 mbsf. Wireline logging of the short basement interval is possible but unlikely. We will reenter the hole to conduct open-hole straddle packer tests (two sets) and then deploy a CORK-II system that will isolate two intervals of uppermost basement (Fig. **F12**). The CORK-II will include wellhead fluid samples and pressure gauges, as well as downhole temperature sensors, fluid samplers, and microbiological incubation substrate. A landing platform will be deployed following CORK installation.

The vessel will return to Hole SR-2B, and we will reenter the hole and drill out cement with a 9⅞ inch tricone bit before continuing to drill to ~325 mbsf. A 24 h tracer injection experiment will be conducted before the hole is reentered with a tricone bit. This will verify depth and clean out the hole before the third and final CORK-II observatory is deployed (Fig. **F11**). The CORK-II will be configured to isolate one interval of upper basement and will include wellhead fluid samples and pressure gauges, as well as downhole temperature sensors, fluid samplers, and microbiological incubation substrate. A landing platform will be deployed following CORK installation. This will complete Stage 3 operations in Hole SR-2B.

Following completion of operations in Hole SR-2B, we will position the ship over Hole U1301B in order to reenter the hole and retrieve the existing thermistor string and replace it with a new one. Afterward, we plan to position the vessel over Hole U1301A and attempt remedial cementing operations at the reentry cone/casing hanger interface. Note that operations in Holes U1301A and U1301B may be completed during calm conditions earlier in the expedition based on the schedule and success of earlier operations.

If time permits, we will address secondary objectives involving sediment coring. This could include complete or spot coring by APC/XCB at proposed Sites GRB-1, GRB-2, GRB-3, or FR-1 or RCB coring at proposed Sites DR-1 or DR-2. Work at secondary sites will occur only if we have completed all primary objectives or are unable to complete primary objectives and additional time remains. Sediment coring will be accompanied by measurements of sediment temperatures using the Sediment Temperature Tool (SET) or the third-generation advanced piston corer temperature tool (APCT3).

Logging/downhole measurements strategy

The principal objectives of the Expedition 327 wireline logging program are to (1) identify suitable depth intervals for setting the inflatable and swellable packer elements for use during hydrogeologic testing and CORK installation, and (2) expand on the Leg 168 and Expedition 301 work in quantifying crustal lithostratigraphy, alteration, and hydrogeologic and petrophysical properties. Downhole logging data can help define structural and lithologic boundaries, delineate fracture densities and orientations, identify water flow pathways, assess variations in alteration, and be compared to results of laboratory core analyses. Logging data will also complement core measurements when recovery is poor. We will also use the logging line to deploy CORK instrument strings by way of an electronic release in lieu of the hammer release system used during Leg 168 and Expedition 301. Hydrogeologic tests in basement will be run to assess ease of fluid flow through basement and the nature of connections between different parts of the volcanic crust at a scale of meters to kilometers. In situ measurements at secondary sedimentary sites will be used to determine the thermal state of sediments and underlying volcanic crust and to estimate rates of fluid seepage in sediments and lateral flow within basement.

Wireline logging

A single tool string deployment is planned for the 9⅞ inch hole section in the basement of proposed Hole SR-2A. Time and conditions permitting, we may collect a similar suite of downhole logging data after deepening Hole 1027C. However, there will only be a short section of open hole below the casing, and at this stage in the expedition we are unlikely to be comfortable using contingency time for secondary objectives.

The tool string we will use will consist of caliper, image, and density measurements. The Hostile Environment Litho-Density Sonde (HLDS) can provide a single-arm long-axis caliper in addition to standard formation density measurements. Additional caliper data will be acquired by the Environmental Measurement Sonde (EMS), which also measures mud temperature, and the Ultrasonic Borehole Imager (UBI). When run at a speed that ensures high vertical resolution, the UBI's ultrasonic image can deliver a borehole interpretation comparable to or better than that acquired by standard IODP resistivity imaging tools. Spectral gamma ray measurements (K, U, and Th) can be acquired by the Hostile Environment Gamma Ray Sonde (HNGS), and we may include a spontaneous potential (SP) tool. The Logging Equipment Head-Q Tension (LEH-QT) cablehead can transmit downhole tension measurements, and the General Purpose Inclinometry Tool (GPIT) can provide downhole acceleration and orient the UBI images. Detailed descriptions of wireline tools and applications are provided at **iodp.ldeo.columbia.edu/TOOLS_LABS/index.html.** The estimated time for the logging string deployment, from rig-up to rig-down, is <9.5 h. An additional 4.5–6.5 h will be needed for hole conditioning, RCB bit release, reentry, and so on.

Deployment of CORK instrument strings

CORK instrument strings will deployed using the wireline logging cable, winch, and cablehead along with a MultiFunction Telemetry Module (MFTM) being developed by Lamont-Doherty Earth Observatory (LDEO) and an Electronic Release System (ERS) being developed by Stress Engineering. This new deployment technique should be an improvement over previous methods and offer further control and constraint because downhole cable tension will be read and interpreted at surface in real time.

Hydrogeologic experiments

We will run short-term drill string packer experiments in the deeper of the two new basement holes, Hole SR-2A, to determine near-borehole hydrogeologic properties. This will provide a useful comparison to similar measurements made in nearby Hole U1301B and at the few other upper basement sites worldwide where such experiments have been completed. The packer will be inflated at one or more locations at depth to test hydrogeologic properties between the packer setting depth and the bottom of the hole, and the packer will be set in casing above the open hole to test the complete open interval. Each of these tests will last 1 h, with an additional hour of recovery time between tests, and multiple pumping rates will be used at each packer setting depth.

In addition, we will run a longer hydrogeologic experiment in the shallower of the new basement holes, Hole SR-2B. There will be a short interval of open basement in this hole, which is expected to be cavernous where it is not cased, so we will use a new approach for these experiments. Instead of using the drill string packer, we will use a casing running tool that will be landed in the casing hanger at the top of the 10¾ inch casing. The contact between the casing running tool and the hanger will provide a hydraulic seal. A "stinger" of drill pipe will extend below the casing running tool and penetrate just past the shoe for the 10¾ inch casing so that fluid pumped into the open hole will be in immediate contact with the surrounding formation. This pumping experiment will last 24 h, more than 20× as long as any other packer tests run to date during scientific ocean drilling. In addition, during this pumping experiment we will pump a mixture of hydrologic tracers along with the surface seawater normally used as a drilling fluid. These tracers, including SF_6, rare earth elements, and fluorescent spheres and stained cells, will be pumped into the formation in Hole SR-2B, and the fluid chemistry in surrounding CORK observatories will be monitored for the following 3–4 y, allowing assessment of the rates and patterns of fluid circulation in basement.

Rig Instrumentation System (RIS) data will be acquired and used in real time to facilitate drilling, packer test, and tracer injection operations. Surface data—including but not limited to drilling rate of penetration (ROP), surface weight-on-bit, and surface torque—will be viewed on monitors while drilling and made available for download immediately following operations. These data will be used to help determine the depth of competent basement rock and may be used to identify bit trips, packer intervals, logging deployments, and hole total depth.

During packer tests and tracer injection experiments, pump rate and standpipe pressure will be monitored to determine and control flow rates and volumes. These data will also be downloaded and evaluated in relation to pressure responses from collocated and nearby instruments.

In situ sediment thermal measurements

If secondary priority sediment coring is completed at GRB, FR, or DR sites, we will also collect in situ sediment temperatures. We will use the APCT3 tool in portions of hole cored with the APC. The SET will be used in portions of hole (just above basement) cored with the APC/XCB system and in places cored with the RCB.

Risks and contingency

There are a number of risks to achieving the primary and secondary objectives of this program.

Poor hole conditions in basement

Past experience drilling basement in this area shows that hole conditions in upper basement can be poor, especially the uppermost 100 m at the locations proposed for Holes SR-2A and SR-2B, which are located along the same buried basement ridge as Sites 1026 and U1301. This is the primary reason for drilling through the uppermost 100 m of basement with a tricone bit in the basement holes, without coring, and installing 10¾ inch casing as soon as possible. Poor hole conditions and rubbly basement may also prevent sealing the base of the 10¾ inch casing with cement, which is why we have developed a mechanical casing seal system for use between the 16 and 10¾ inch casing. We still plan to pump cement with LCM at the base of the 10¾ inch casing, but this will be done after the casing is installed and (presumably) sealed against the 16 inch casing. The risk of poor hole conditions will also be mitigated by using a BHA that puts drill collars in the open hole across the entire length of exposed rock. This will prevent rubble from falling into the hole on top of the drill collars, a strategy that worked extremely well during Expedition 301. We are less concerned about poor hole conditions in the uppermost 100 m of basement at Site 1027. Drilling and coring at this site during Leg 168 was highly successful and showed that basement at this location is more altered and cemented than it is at nearby Sites 1026 and U1301. For this reason, we plan to core the interval between 19 and 59 msb in Hole 1027C.

Poor hole conditions could also make deployment of new CORKs challenging if instruments deployed within these CORKs extend into open hole. For this reason, we plan to deploy all CORK instrumentation so that it resides inside perforated casing rather than in open hole. We note that even in Hole U1301B, where hole conditions were generally good at depth during Expedition 301, there was apparently some collapse of basement rocks over the years between instrument string deployment in 2004 and the attempt to recover this string by submersible in 2009.

Poor weather/sea state

Many of the borehole operations, including installation of casing and cementing, packer experiments, and deployment of CORKs and instrument strings, are sensitive to ambient weather and sea state. Operations using the drill string in close proximity to installed CORK systems, including cementing planned for Hole U1301A and string recovery in Hole U1301B, may be especially difficult to complete if weather or sea conditions are unfavorable. We will pay careful attention to existing and forecasted weather and sea conditions and adjust operations accordingly so that we have the best opportunity to complete delicate operations when conditions permit. Even when weather and sea conditions are favorable, care must be taken to avoid damaging the CORK wellheads as part of planned operations. There will be particular risks when the BHA is positioned close to a wellhead, either immediately before or immediately after reentry. Particularly when reentering adjacent to the CORK in Hole U1301A, the ship may need to be offset slightly away from the wellhead just before removing the BHA from the cone so that it does not swing into the wellhead when it is free of the cone. It may be difficult to see the platform and wellhead clearly during these operations.

Difficulty sealing CORK observatories

We have learned from past experience that it can be challenging to seal CORK observatories, but the new approach planned for Expedition 327 (using both a casing seal and cementing with LCM at depth) should prove more effective than approaches taken during earlier expeditions. In addition, we have designed CORK instrument strings to be heavier to help hold the CORK plugs in place despite elevated (natural) formation fluid pressures in basement. Finally, we will take a more aggressive approach to use of LCM while completing remedial cementing activities in Hole U1301A than was taken during Expedition 321T.

Sampling and data sharing strategy

Shipboard and shore-based researchers should refer to the IODP Sample, Data, and Obligations policy posted on the Web at **www.iodp.org/program-policies/.** This document outlines the policy for distributing IODP samples and data to research scientists, curators, and educators. The document also defines the obligations that sample and data recipients incur. The Sample Allocation Committee (SAC; composed of the co-chief scientists, staff scientist, and IODP curator on shore and curatorial representative on board ship) will work with the entire scientific party to formulate a formal expedition-specific sampling plan for shipboard and postcruise sampling.

Shipboard scientists are expected to submit sample requests (at **smcs.iodp.org/**) three months before the beginning of the expedition. Based on sample requests (shore based and shipboard) submitted by this deadline, the SAC will prepare a tentative sampling plan, which will be revised on the ship as dictated by recovery and cruise objectives. The sampling plan will be subject to modification depending upon the actual material recovered and collaborations that may evolve between scientists during the expedition. Modification of the strategy during the expedition must be approved by the co-chief scientists, staff scientist, and curatorial representative on board ship.

The minimum permanent archive will be the standard archive half of each core; whole-round samples are exempt from this rule. On this expedition, we anticipate substantial whole-round core sampling for hydrologic, geochemical, and microbiological investigations. Sampling may be particularly intense near the sediment/basement interface at one or more sites and within particular intervals in basement. Approximately 200 m of basement coring is planned at Sites SR-2 and 1027 (primary sites), and sediment coring will take place at the secondary sites only if time permits, providing as much as several hundred meters of material.

All sample frequencies and sizes must be justified on a scientific basis and will depend on core recovery, the full spectrum of other requests, and cruise objectives. Some redundancy of measurement may be unavoidable, but minimizing the duplication of measurements among the shipboard scientific party and identified shore-based collaborators will be a factor in evaluating sample requests.

References

Alt, J.C., 1995. Subseafloor processes in mid-ocean ridge hydrothermal systems. *In* Humphris, S.E., Zierenberg, R., Mullineaux, L., and Thomson, R. (Eds.), *Seafloor Hydrothermal Systems: Physical, Chemical, Biological and Geological Interactions within Hydrothermal Systems*. Geophys. Monogr., 91:85–114.

Becker, K., and Fisher, A.T., 2008. Borehole packer tests at multiple depths resolve distinct hydrologic intervals in 3.5-Ma upper oceanic crust on the eastern flank of Juan de Fuca Ridge. *J. Geophys. Res., [Solid Earth],* 113(B7):B07105. **doi:10.1029/2007JB005446**

Carbotte, S.M., Nedimovic, M.R., Canales, J.P., Kent, G.M., Harding, A.J., and Marjanovic, M., 2008. Variable crustal structure along the Juan de Fuca Ridge: influence of on-axis hot spots and absolute plate motions. *Geochem., Geophys., Geosyst.,* 9:Q08001. **doi:10.1029/2007GC001922**

Davis, E.E., Chapman, D.S., Forster, C.B., and Villinger, H., 1989. Heat-flow variations correlated with buried basement topography on the Juan de Fuca Ridge flank. *Nature (London, U. K.),* 342(6249):533–537. **doi:10.1038/342533a0**

Davis, E.E., Chapman, D.S., Mottl, M.J., Bentkowski, W.J., Dadey, K., Forster, C., Harris, R., Nagihara, S., Rohr, K., Wheat, G., and Whiticar, M., 1992. FlankFlux: an experiment to study the nature of hydrothermal circulation in young oceanic crust. *Can. J. Earth Sci.,* 29(5):925–952.

Davis, E.E., Chapman, D.S., Wang, K., Villinger, H., Fisher, A.T., Robinson, S.W., Grigel, J., Pribnow, D., Stein, J., and Becker, K., 1999. Regional heat flow variations across the sedimented Juan de Fuca Ridge eastern flank: constraints on lithospheric cooling and lateral hydrothermal heat transport. *J. Geophys. Res., [Solid Earth],* 104(B8):17675–17688. **doi:10.1029/1999JB900124**

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

Elderfield, H., and Schultz, A., 1996. Mid-ocean ridge hydrothermal fluxes and the chemical composition of the ocean. *Annu. Rev. Earth Planet. Sci.,* 24(1):191–224. **doi:10.1146/annurev.earth.24.1.191**

Elderfield, H., Wheat, C.G., Mottl, M.J., Monnin, C., and Spiro, B., 1999. Fluid and geochemical transport through oceanic crust: a transect across the eastern flank of the Juan de Fuca Ridge. *Earth Planet. Sci. Lett.,* 172(1–2):151–165. **doi:10.1016/S0012-821X(99)00191-0**

Fisher, A.T., and Von Herzen, R.P., 2005. Models of hydrothermal circulation within 106 Ma seafloor: constraints on the vigor of fluid circulation and crustal properties, below the Madeira Abyssal Plain. *Geochem., Geophys., Geosyst.,* 6(11):Q11001. **doi:10.1029/2005GC001013**

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

Fisher, A.T., Davis, E.E., Hutnak, M., Spiess, V., Zühlsdorff, L., Cherkaoui, A., Christiansen, L., Edwards, K., Macdonald, R., Villinger, H., Mottl, M.J., Wheat, C.G., and Becker, K., 2003. Hydrothermal recharge and discharge across 50 km guided by seamounts on a young ridge flank. *Nature (London, U. K.),* 421(6923):618–621. **doi:10.1038/nature01352**

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

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

Huber, J.A., Johnson, H.P., Butterfield, D.A., and Baross, J.A., 2006. Microbial life in ridge flank crustal fluids. *Environ. Microbiol.*, 88(1):88–99. **doi:10.1111/j.1462-2920.2005.00872.x**

Hutnak, M., Fisher, A.T., Zühlsdorff, L., Spiess, V., Stauffer, P.H., and Gable, C.W., 2006. Hydrothermal recharge and discharge guided by basement outcrops on 0.7–3.6 Ma seafloor east of the Juan de Fuca Ridge: observations and numerical models. *Geochem., Geophys., Geosyst.,* 7(7):Q07O02. **doi:10.1029/2006GC001242**

Johnson, H.P., and Pruis, M.J., 2003. Fluxes of fluid and heat from the oceanic crustal reservoir. *Earth Planet. Sci. Lett.*, 216(4):565–574. **doi:10.1016/S0012-821X(03)00545-4**

Mottl, M.J., 2003. Partitioning of energy and mass fluxes between mid-ocean ridge axes and flanks at high and low temperature. *In* Halbach, P.E., Tunnicliffe, V., and Hein, J.R. (Eds.), *Energy and Mass Transfer in Marine Hydrothermal Systems:* Berlin (Dahlem Univ. Press), 271–286.

Mottl, M.J., Wheat, G., Baker, E., Becker, N., Davis, E., Feely, R., Grehan, A., Kadko, D., Lilley, M., Massoth, G., Moyer, C., and Sansone, F., 1998. Warm springs discovered on 3.5 Ma oceanic crust, eastern flank of the Juan de Fuca Ridge. *Geology,* 26(1):51–54. **doi:10.1130/0091-7613(1998)026<0051:WSDOMO>2.3.CO;2**

Nedimovic, M.R., Carbotte, S.M., Diebold, J.B., Harding, A.J., Canales, J.P., and Kent, G.M., 2008. Upper crustal evolution across the Juan de Fuca Ridge flanks. *Geochem., Geophys., Geosyst.,* 9(9):Q09006. **doi:10.1029/2008GC002085**

Parsons, B., and Sclater, J.G., 1977. An analysis of the variation of ocean floor bathymetry and heat flow with age. *J. Geophys. Res., [Solid Earth],* 82:803–827. **doi:10.1029/JB082i005p00803**

Peacock, S.M., and Wang, K., 1999. Seismic consequences of warm versus cool subduction metamorphism: examples from southwest and northeast Japan. *Science,* 286(5441):937–939. **doi:10.1126/science.286.5441.937**

Stein, J.S., and Fisher, A.T., 2003. Observations and models of lateral hydrothermal circulation on a young ridge flank: numerical evaluation of thermal and chemical constraints. *Geochem., Geophys., Geosyst.,* 4(3):1026. **doi:10.1029/2002GC000415**

Von Herzen, R.P., 2004. Geothermal evidence for continuing hydrothermal circulation in older (>60 Ma) ocean crust. *In* Davis, E.E., and Elderfield, H. (Eds.) *Hydrogeology of the Oceanic Lithosphere:* Cambridge (Cambridge Univ. Press), 414–450.

Walker, B.D., McCarthy, M.D., Fisher, A.T., and Guilderson, T.P., 2007. Dissolved inorganic carbon isotopic composition of low-temperature axial and ridge-flank hydrothermal fluids of the Juan de Fuca Ridge. *Mar. Chem.*, 108(1–2):123–136. **doi:10.1016/j.marchem.2007.11.002**

Wheat, C.G., and Mottl, M.J., 1994. Hydrothermal circulation, Juan de Fuca Ridge eastern flank: factors controlling basement water composition. *J. Geophys. Res., [Solid Earth],* 99(B2):3067–3080. **doi:10.1029/93JB01612**

Wheat, C.G., Elderfield, H., Mottl, M.J., and Monnin, C., 2000. Chemical composition of basement fluids within an oceanic ridge flank: implications for along-strike and across-strike hydrothermal circulation. *J. Geophys. Res., [Solid Earth],* 105(B6):13437–13447. **doi:10.1029/2000JB900070**

Wheat, C.G., Jannasch, H.W., Kastner, M., Plant, J.N., and DeCarlo, E.H., 2003. Seawater transport and reaction in upper oceanic basaltic basement: chemical data from continuous monitoring of sealed boreholes in a ridge flank environment. *Earth Planet. Sci. Lett.,* 216(4):549–564. **doi:10.1016/S0012-821X(03)00549-1**

Wheat, C. G., Mottl, M.J., Fisher, A.T., Kadko, D., Davis, E.E., and Baker, E., 2004. Heat flow through a basaltic outcrop on a sedimented young ridge flank. *Geochem., Geophys., Geosyst.,* 5(12):Q12006. **doi:10.1029/2004GC000700**

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

Zühlsdorff, L., and Spiess, V., 2006. Sedimentation patterns, folding, and fluid upflow above a buried basement ridge: results from 2-D and 3-D seismic surveys at the eastern Juan de Fuca Ridge flank. *J. Geophys. Res., [Solid Earth]*, 111(B8):B08103. **doi:10.1029/2004JB003227**

Table T1. Proposed site and hole locations for primary and secondary operations during Expedition 327. (**See table notes.**)

Site/Hole	Latitude	Longitude	Seismic line	CDP/TR
SR-2	47°45.662′N	127°45.674′W	GeoB00-482	CDP 439
Hole 1027C	47°45.387′N	127°43.867′W	GeoB00-203	CDP 741
Hole U1301A	47°45.210′N	127°45.833′W	GeoB00-466	CDP 557
Hole U1301B	47°45.228′N	127°45.827′W	GeoB00-466	CDP 556*
GRB-1A†	47°17.237′N	128°2.137′W	GeoB00-170	CDP 2837
GRB-2A†	47°17.302′N	128°2.032′W	GeoB00-170	CDP 2819
GRB-3A†	47°17.434′N	128°1.823′W	GeoB00-170	CDP 2783
FR-1A, C†	47°54.105′N	128°33.468′W	InLine 44 (GeoB00-365)	TR 426
FR-1B†	47°54.132′N	128°33.591′W	InLine 44 (GeoB00-365)	TR 410
DR-1A†	47°38.810′N	127°26.999′W	EW0702 Line 1	CDP 3070
DR-2A†	47°37.449′N	127°20.049′W	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. † = secondary sites.

Table T2. Depths in meters below rig floor (mbrf), meters below seafloor (mbsf), and meters subbasement (msb) for key drilling targets and operational systems to be used during Expedition 327. (See table note.)

	Depth (mbrf)	Depth (mbsf)	Depth (msb)	Comments
Hole SR-2A (deep)				
Seafloor depth	2670.0	0.0	–255.0	Approximate
Basement depth	2925.0	255.0	0.0	
20 inch hole	2935.0	265.0	10.0	Underream
18-1/2 inch hole	2940.0	270.0	15.0	Bicenter
14-3/4 inch hole	3025.0	355.0	100.0	Tricone
9-7/8 inch hole/coring	3185.0	515.0	260.0	Cored interval ~100–260 msb
20 inch casing shoe	2710.0	40.0	–215.0	Jet in
16 inch casing shoe	2935.0	265.0	10.0	Cement across sediment/basement interface
10-3/4 inch casing shoe	3015.0	345.0	90.0	Casing seal at top, run without cement retainer
4-1/2 inch casing end	3165.0	495.0	240.0	
Upper DS packer seat	3005.0	335.0	80.0	Packer set in casing for short-term test
Lower DS packer seat	3165.0	495.0	240.0	Packer set in to-gauge open hole
Upper CORK packer seat	3005.0	335.0	80.0	Packer set in casing, defines upper limit to monitoring
Lower CORK packer seat	3165.0	495.0	240.0	Packer set in to-gauge open hole, defines upper limit of lower interval
Hole SR-2B (shallow)				
Seafloor depth	2670.0	0.0	–255.0	Approximate
Basement depth	2925.0	255.0	0.0	
20 inch hole	2935.0	265.0	10.0	Underream
18-1/2 inch hole	2940.0	270.0	15.0	Bicenter
14-3/4 inch hole	2955.0	285.0	30.0	Tricone
9-7/8 inch hole (no coring)	2995.0	325.0	70.0	Drilled interval ~30–70 msb (no coring)
20 inch casing shoe	2710.0	40.0	–215.0	Jet in
16 inch casing shoe	2935.0	265.0	10.0	Cement across sediment/basement interface
10-3/4 inch casing shoe	2945.0	275.0	20.0	Casing seal at top, run without cement retainer
4-1/2 inch casing end	2975.0	305.0	50.0	
Casing running tool	2670.0	0.0	–255.0	Use casing running tool for 24 h pumping experiment
CORK packer seat	2935.0	265.0	10.0	Packer set in casing, defines upper limit to monitoring
Hole 1027C				
Seafloor depth	2667.0	0.0	–613.7	Approximate
Basement depth	3280.7	613.7	0.0	
TD, Leg 168	3299.7	632.7	19.0	
Top sill	3242.5	575.5	–38.2	Drillers records, Leg 168
Bottom sill	3257.7	590.7	–23.0	Drillers records, Leg 168
14-3/4 inch hole	3252.1	585.1	–28.6	Into sill, not true basement
9-7/8 inch hole (RCB)	3299.7	632.7	19.0	Leg 168
9-7/8 inch hole (RCB)	3339.7	672.7	59.0	IODP Juan de Fuca 2010 goal for open hole
16 inch casing shoe	2704.6	37.6	–576.1	Jet in
10-3/4 inch casing shoe	3245.7	578.7	–35.0	Casing set in sill above true basement
4-1/2 inch casing end	3330.7	663.7	50.0	
Upper DS packer seat	3235.7	568.7	–45.0	Packer set in casing for short-term test
Lower DS packer seat	3287.0	620.0	6.3	Packer set in uppermost true basement
Upper CORK packer seat	3257.0	590.0	–23.7	Packer set in sill, defines upper limit to monitoring
Lower CORK packer seat	3287.0	620.0	6.3	Packer set in true basement, defines upper limit of lower interval

Note: DS = drill string, CORK = subseafloor borehole observatory, TD = total depth, RCB = rotary core barrel.

Table T3. Operations and time estimates for Expedition 327. (See table notes.) (Continued on next page.)

Site	Latitude, longitude	Seafloor depth (mbrf)	Operations description	Transit (days)	Ops (days)	Logging (days)
Victoria, B.C.			Start of Expedition (need full 5.0 days in port) (5 Days)	In Port		
			Transit ~191 nmi to Site SR-2A @ 10.5 kt	0.8		
SR-2A	47°45.662′N,	~2670	SR-2A: Hole A (Stage 1):		7.5	0.0
(deep)	127°45.674′W		Conduct jet-in test (1.1 days)			
basement at ~255 mbsf			Deploy reentry cone, jet-in 36 m 20" csg (to ~40 mbsf)			
			Drill 21-1/2" hole with underreamer to basement contact (~255 mbsf)			
			Drill 21-1/2" hole with bicenter bit into basement (~275 mbsf)			
			Deploy 16" csg, land hanger in reentry cone, place shoe at ~270 mbsf			
			Cement csg shoe, hold csg for 8 h, release csg hanger, flush pipe, POOH			
			Subtotal days on site: 7.5			
			DP offset ~0.1 nmi to Site SR-2B	0.0		
SR-2B	47°45.662′N,	~2670	SR-2B: Hole A (Stage 1):		6.4	0.0
(shallow)	127°45.674′W		Deploy reentry cone, jet-in 36 m 20" csg (to ~40 mbsf)			
basement at ~255 mbsf			Drill 21-1/2" hole with underreamer to basement contact (~255 mbsf)			
			Drill 21-1/2" hole with bicenter bit into basement (~275 mbsf)			
			Deploy 16" csg, land hanger in reentry cone, place shoe at ~270 mbsf			
			Cement csg shoe, hold csg for 8 h, release csg hanger, flush pipe, POOH			
			Subtotal days on site: 6.4			
			DP offset ~0.1 nmi back to Site SR-2A	0.0		
SR-2A	47°45.662′N,	~2670	SR-2A: Hole A (Stage 2):		6.2	0.0
(deep)	127°45.674′W		RIH, reenter, run to TD, drill out SSR plug, cement, POOH			
basement at ~255 mbsf			Change BHA, RIH, reenter, trip to TD at ~270 mbsf			
			Drill 14-3/4" hole with tricone bit to ~360 mbsf, displace with heavy mud, POOH			
			Make up/RIH with ~355 m 10-3/4" csg (w/seal sub assembly), reenter, land, release hanger			
			POOH, change BHA, RIH, reenter, run to TD, cement csg shoe (U-tube), POOH (flush DP) (no cementing manifold/SSR)			
			Subtotal days on site: 6.2			
			DP offset ~0.1 nmi back to Site SR-2B	0.0		
SR-2B	47°45.662′N,	~2670	SR-2B: Hole A (Stage 2):		4.5	0.0
(shallow)	127°45.674′W		RIH, reenter, run to TD, drill out SSR plug, cement, POOH			
basement at ~255 mbsf			Change BHA, RIH, reenter, trip to TD at ~270 mbsf			
			Drill 14-3/4" hole with tricone bit to ~290 mbsf, displace with heavy mud, POOH			
			Make up/RIH with ~285 m 10-3/4" csg (w/seal sub assembly), reenter, land, release hanger			
			POOH, change BHA, RIH, reenter, run to TD, cement csg shoe (U-tube), POOH (flush DP) (no cementing manifold/SSR)			
			Subtotal days on site: 4.5			

Table 3 (continued).

Site	Latitude, longitude	Seafloor depth (mbrf)	Operations description	Transit (days)	Ops (days)	Logging (days)
			DP offset ~0.1 nmi back to **Site SR-2A**	0.0		
SR-2A	47°45.662′N,	~2670	**SR-2A: Hole A (Stage 3):**		12.2	
(deep)	127°45.674′W		RIH with RCB C4 bit, center bit, drill out cement to ~360 mbsf			
			RCB core from 360 to 520 mbsf @ 2 m/h ROP (2 bit runs)			
basement at ~255 mbsf			Wiper trip, displace hole with heavy mud, POOH, release bit at seafloor			
			Reenter, rig up, wireline log with triple combo, rig down, POOH with drill pipe, pump pig, POOH			0.4
			Straddle packer pump tests w/ 3 sets (36 h), sinker bar depth check, POOH			
			Run CORK II (4-1/2" and 2 packer pairs), deploy Osmosampler and ROV platform			
			Subtotal days on site: 12.6			
			DP offset ~0.1 nmi to **Site 1027**	0.0		
1027	47°45.387′N,	2667	**Hole 1027C:**		6.9	
	127°43.867′W		Engage and recover original CORK and data logger			
true basement at 613.7 mbsf			Clean up hole and RCB core from 635 to ~675 mbsf (1 bit run)			
			Sweep hole, conduct wiper trip, POOH			
			Make up straddle packer, clean out bit, RIH, reenter, packer tests (2 sets) 24 h			
			Depth check with sinker bar string, POOH			
			Run CORK II (4-1/2" + 2 packer pairs), deploy Osmosampler and ROV platform			
			Subtotal days on site: 6.9			
			DP offset ~0.1 nmi back to **Site SR-2B**	0.0		
SR-2B	47°45.662′N,	~2670	**SR-2B: Hole A (Stage 3):**		7.6	
(shallow)	127°45.674′W		RIH with 9-7/8" tricone bit, drill out cement, drill to ~325 mbsf, POOH			
basement at ~255 mbsf			RIH, reenter, conduct 24 h flow test with csg running tool, POOH			
			RIH, reenter with tricone bit, clean up hole, sweep hole 2x volume, POOH			
			Run CORK II (4-1/2" + 1 packer pair), deploy Osmosampler and ROV platform (57 h)			
			Subtotal days on site: 7.6			
			DP offset ~0.1 nmi to **Site U1301**	0.0		
U1301	47°45.228′N,	2671	**Hole U1301B:**		1.7	0.0
	127°45.827′W		Reenter and attempt recovery of installed thermistor string, POOH			
			Make up/deploy replacement thermistor string, POOH			
	47°45.210′N,	2667	**Hole U1301A:**		1.0	0.0
	127°45.833′W		RIH for additional remedial cementing operations (use cement with LCM)			
			POOH and secure rig for transit to port			
			Subtotal days on site: 2.7			
			*** * * Includes ~29 hr of undefined contingency time for expedition * * ***			
			Transit ~191 nmi to **Victoria, B.C.** @ 10.5 kt	0.8		
Victoria, B.C.			**End of Expedition**	**1.6**	**54.0**	**0.4**
			Subtotal On-Site Time:	**54.4**		
			Total Operating Days:	**56.0**		
			Total Expedition Including (5.0 day) Port Call:	**61.0**		

Notes: DP = dynamic positioning. RIH = run in hole, POOH = pull out of hole. BHA = bottom-hole assembly, RCB = rotary core barrel. ROV = remotely operated vehicle. LCM = lost cementing materials. Seafloor depth is prospectus water depth + 11.0 m adjustment to rig floor (drillers depth). R/V *Atlantis* with *Alvin* research submersible and Neptune cable laying activities may take place during operations and must be coordinated. Possible use of bicenter bit for hole opening sedimentary section vs. underreamer and running tool for drill pipe for bicenter use in basement requires discussion. Extra long BHA/drill collar strings will be used to keep slick pipe in hole for all basement drilling/coring. Replacement of Hole 1026B CORK required ~2.7 days (without deepening the hole 40 m and without logging).

Figure F1. Site maps for Expedition 327 operations. **A.** Regional index map. SR = Second Ridge (primary site); GRB = Grizzly Bare, FR = First Ridge, DR = Deep Ridge (secondary sites). Area within white dashed box is shown in (B). **B.** Bathymetric map of SR and GRB areas. Locations of basement outcrops and ODP/IODP sites are also shown. **C.** Detailed bathymetric map of SR area, including local outcrops and ODP/IODP sites. **D.** Detailed basement relief map from bathymetric and seismic data made by "stripping off" the sediment cover above the volcanic crust. Holes 1026B, 1027C, U1301A, U1301B, and proposed Site SR-2 are shown.

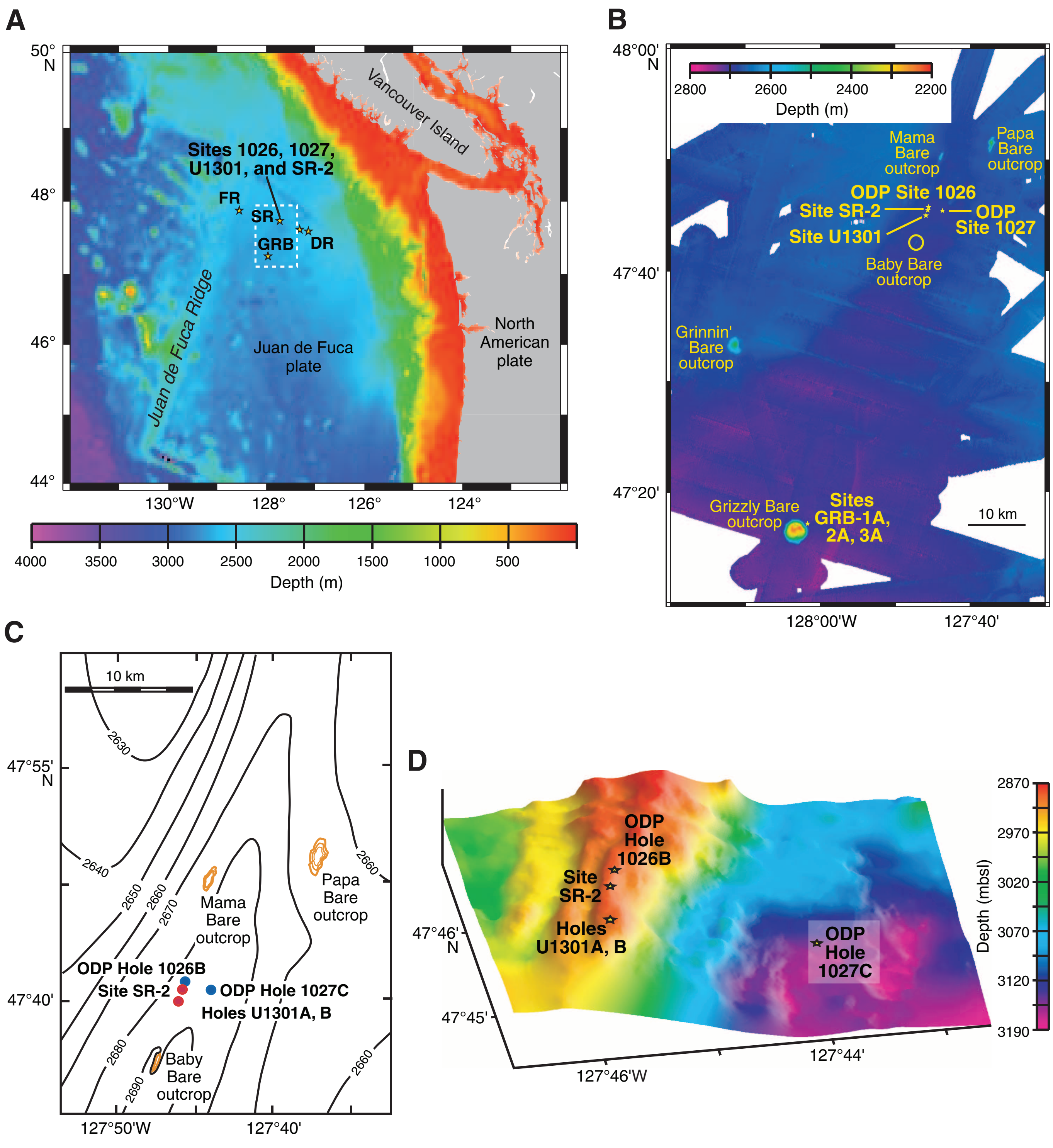


Figure F2. Track chart showing seismic line locations in the Second Ridge area, where the highest priority Expedition 327 operations will occur. Thick dashed lines show locations of seismic Lines GeoB00-203 (ODP Hole 1027C), GeoB00-482 (proposed Site SR-2), and GeoB00-466 (Holes U1301A and U1301B). Seismic data collected along the track lines shown were collected during the 2000 ImageFlux expedition (V. Spiess, chief scientist) (Zühlsdorff et al., 2005).

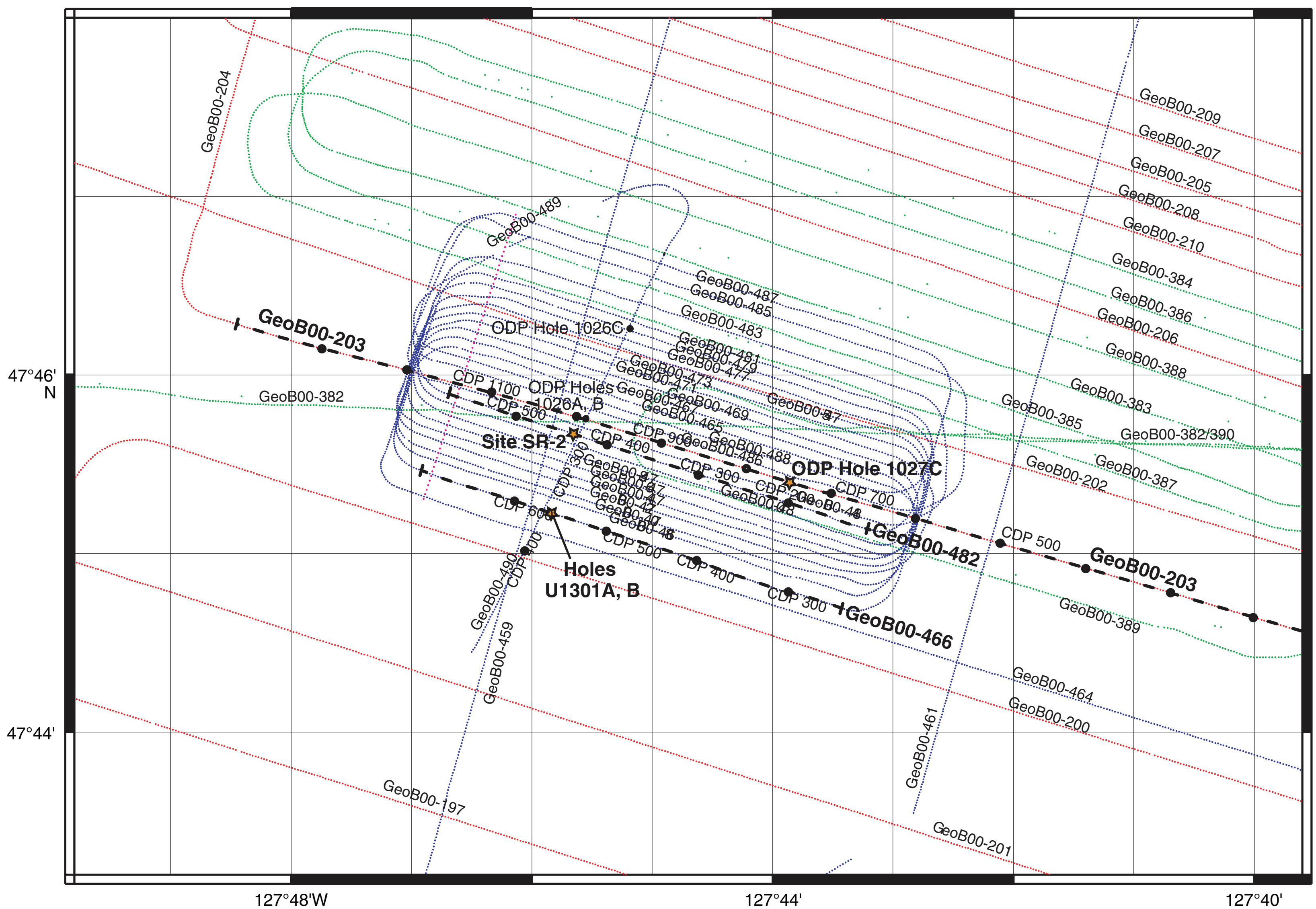


Figure F3. Seismic Line GeoB00-482 showing proposed location of Hole SR-2A. Hole SR-2B will be offset from this location by ~30–40 m.

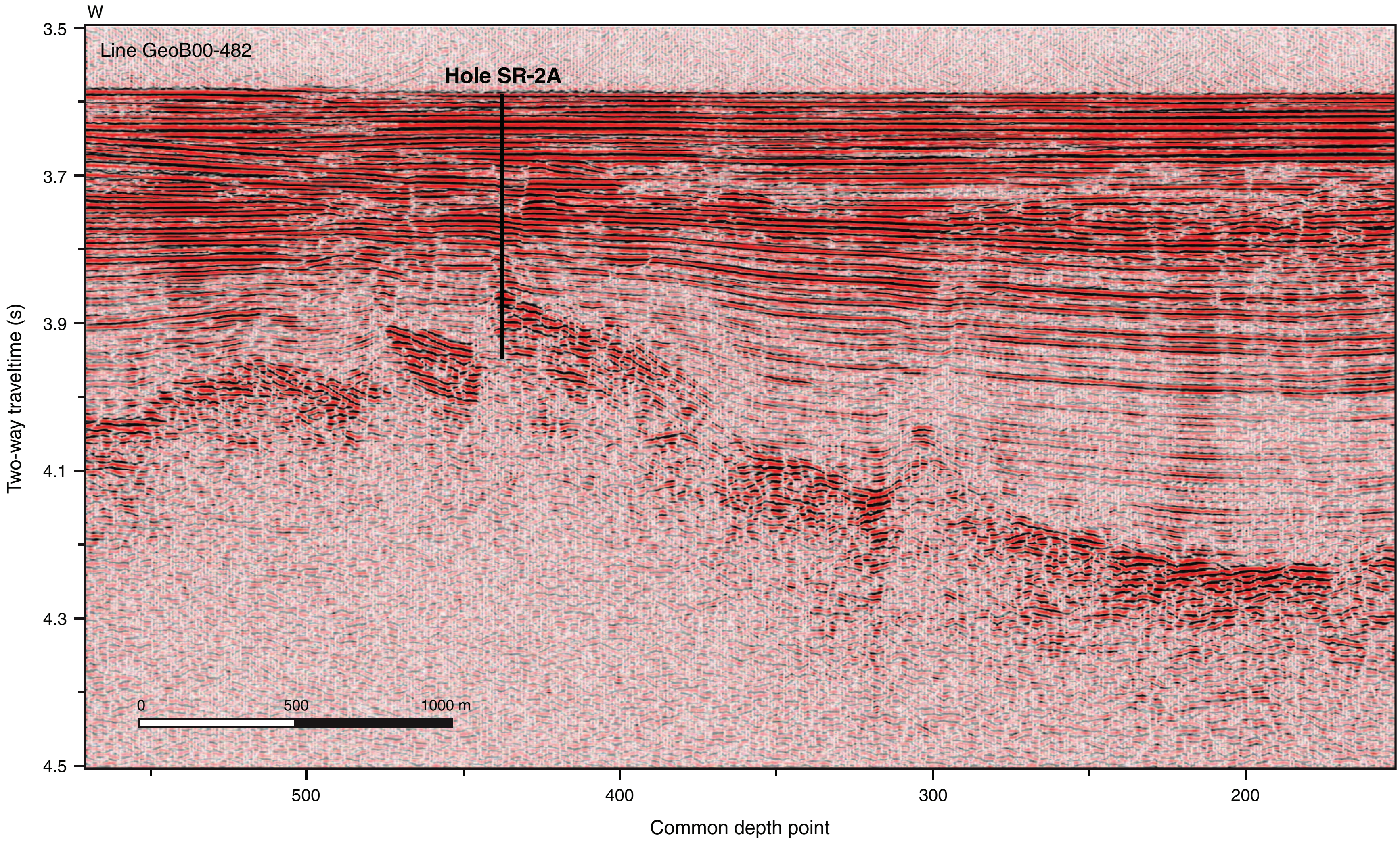


Figure F4. Seismic Line GeoB00-466 showing location of Holes U1301A and U1301B, offset by ~35 m.

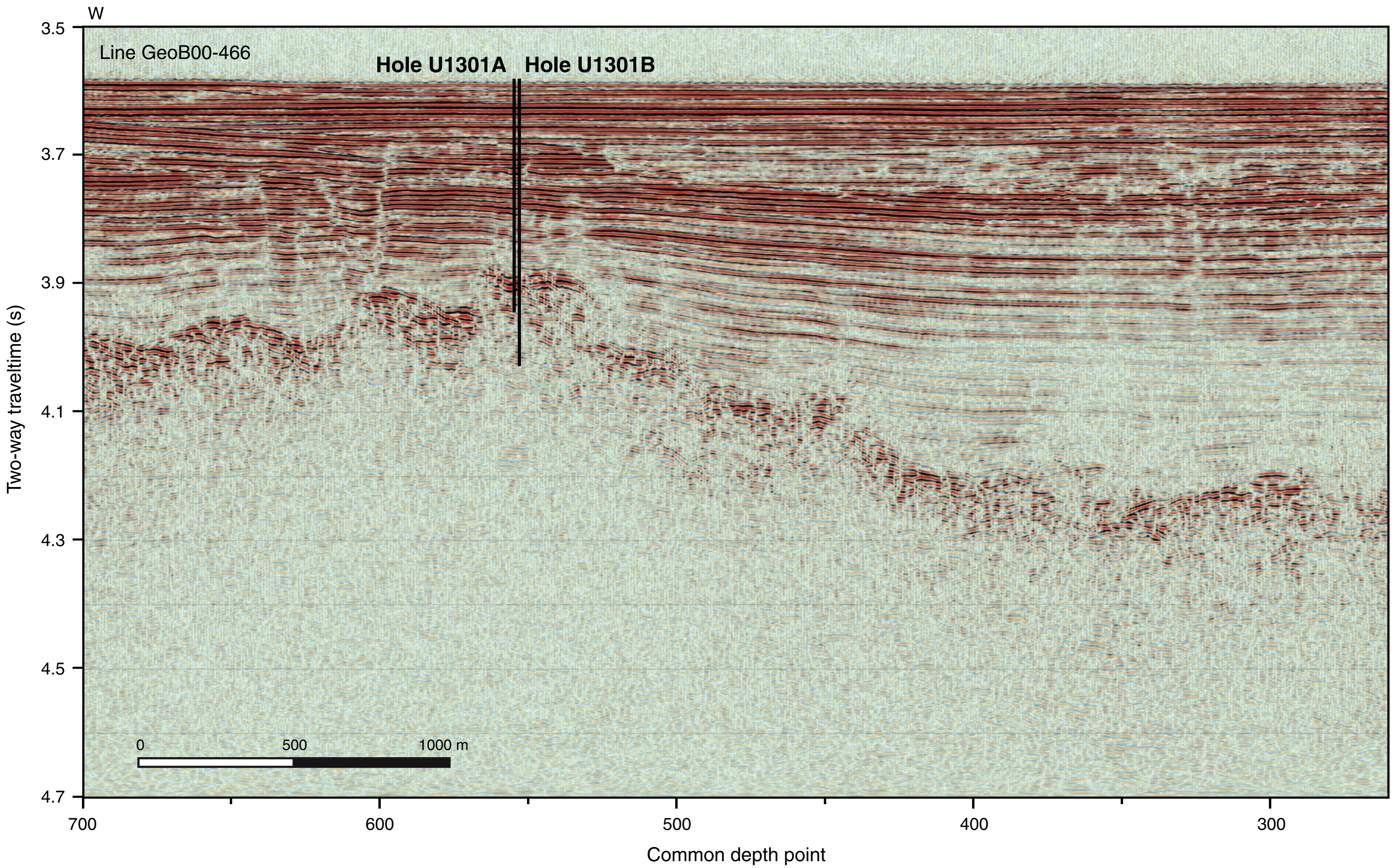


Figure F5. Seismic Line GeoB00-203 showing location of ODP Holes 1026B and 1027C.

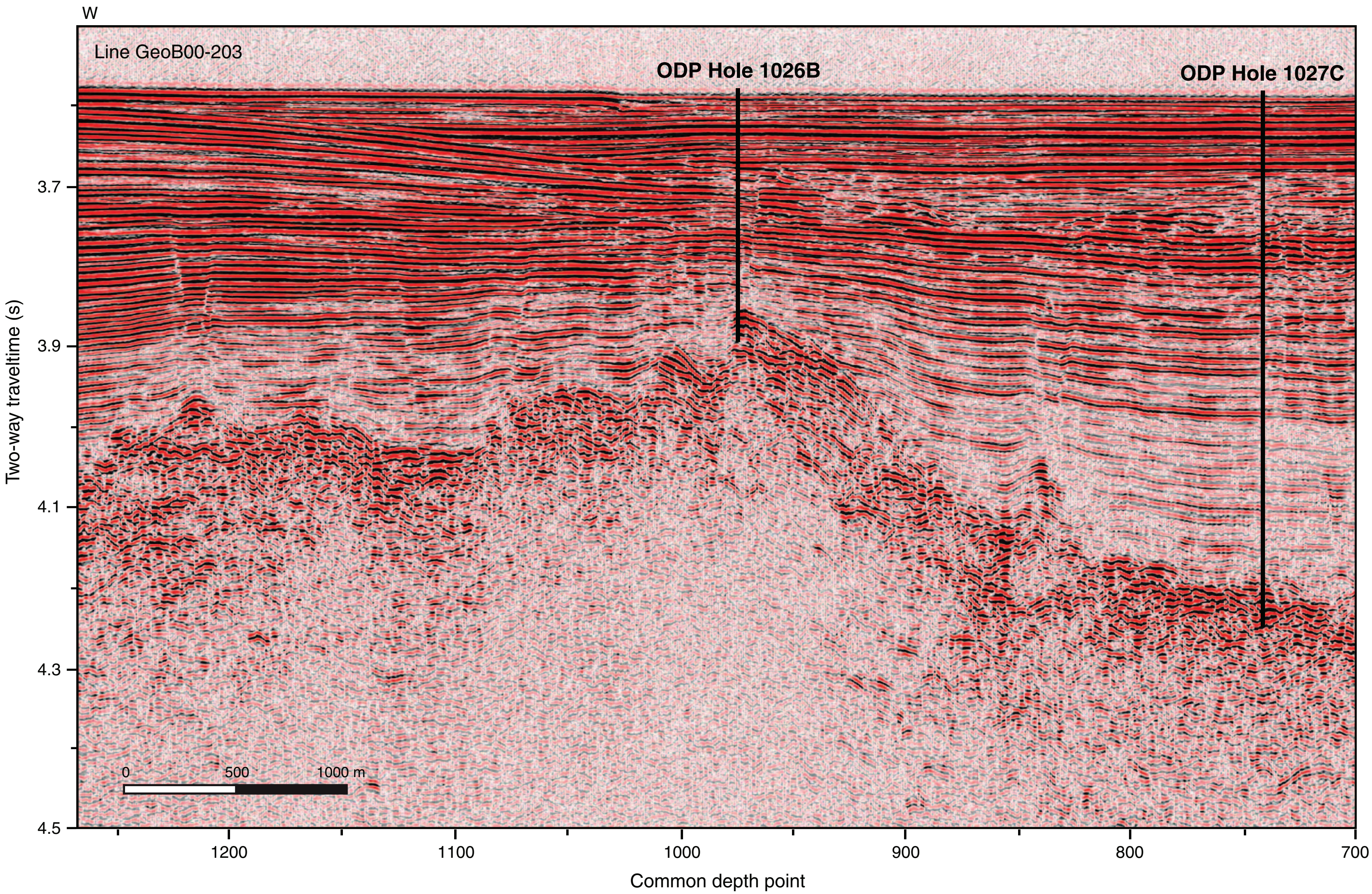


Figure F6. A. Track chart of area surrounding Grizzly Bare outcrop. **B.** Seismic Line GeoB00-170 showing locations of secondary proposed Grizzly Bare (GRB) outcrop sites.

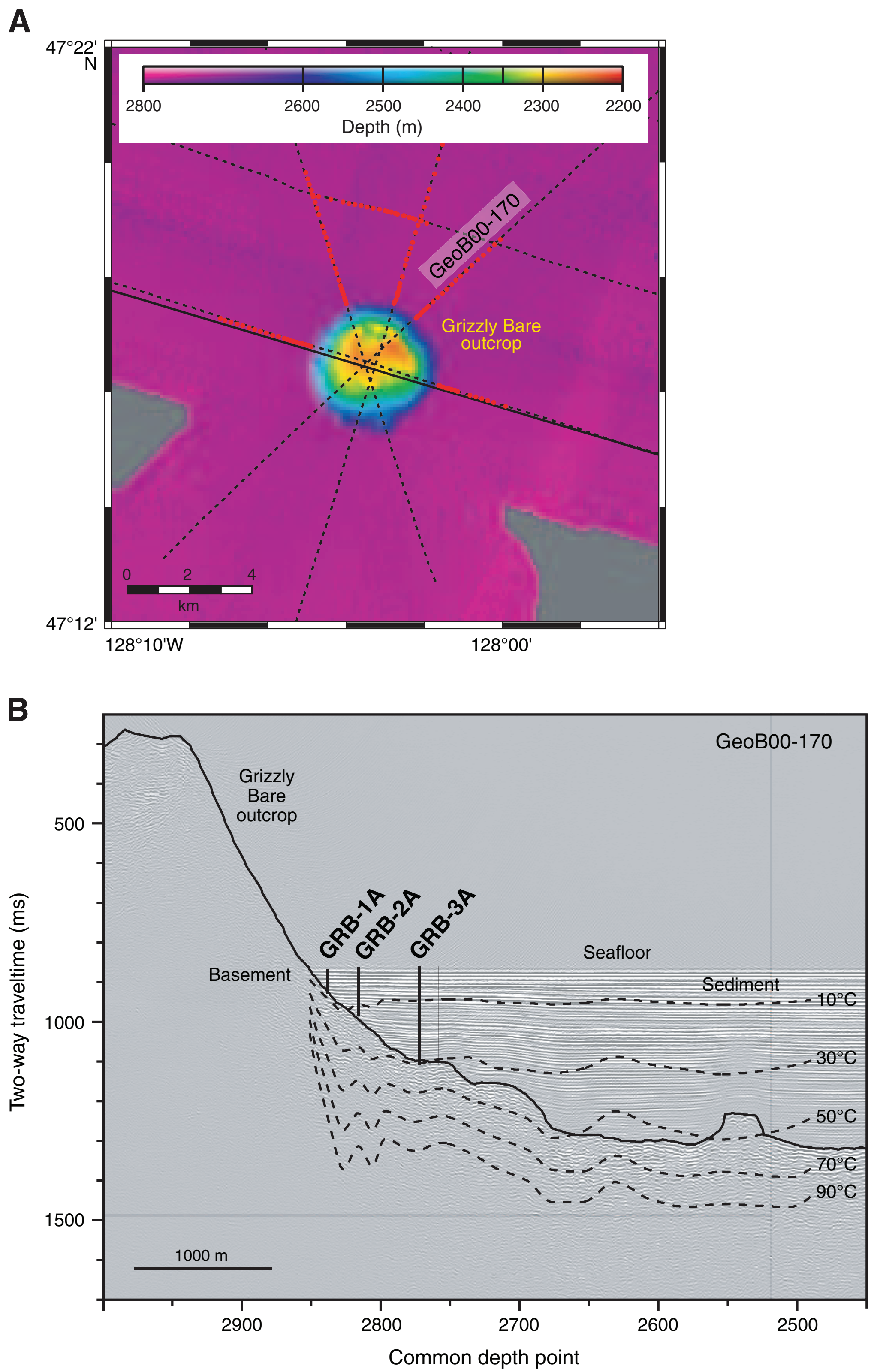
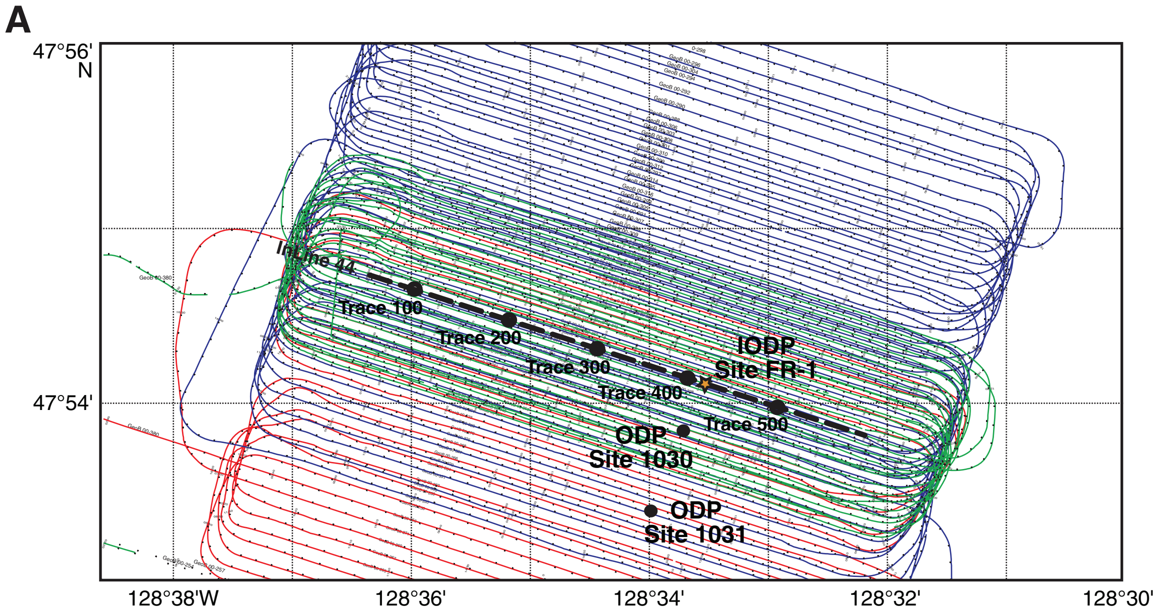


Figure F7. (**A**) Track chart and (**B**) seismic line Trace 44, derived from quasi three-dimensional analysis of a closely spaced network of lines, showing secondary proposed Site FR-1.



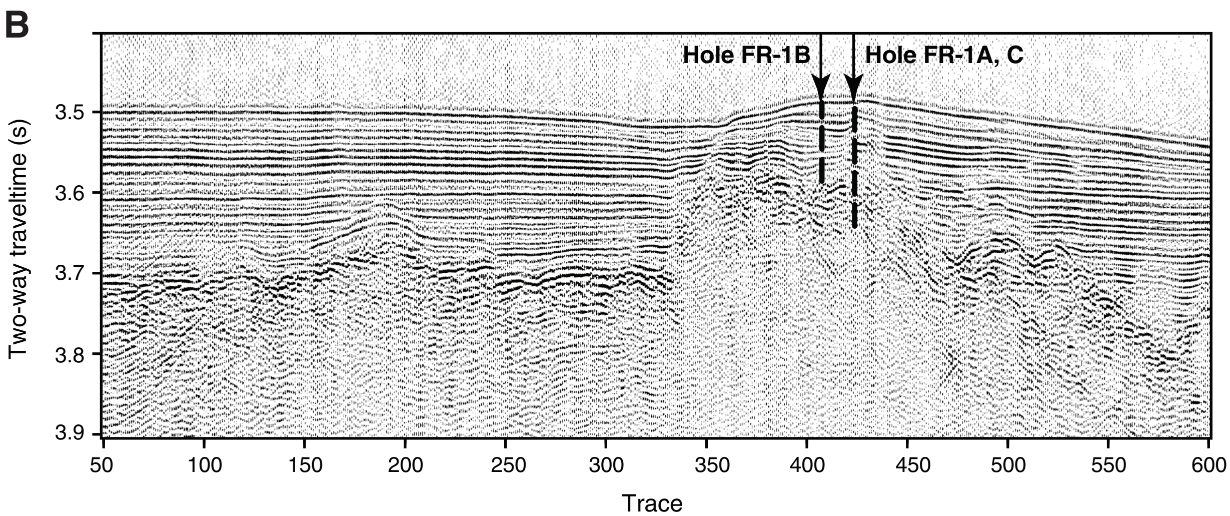


Figure F8. (**A**) Track chart and (**B**) seismic Line EW0207-01 showing locations and depth to basement at secondary proposed Sites DR-1 and DR-2.

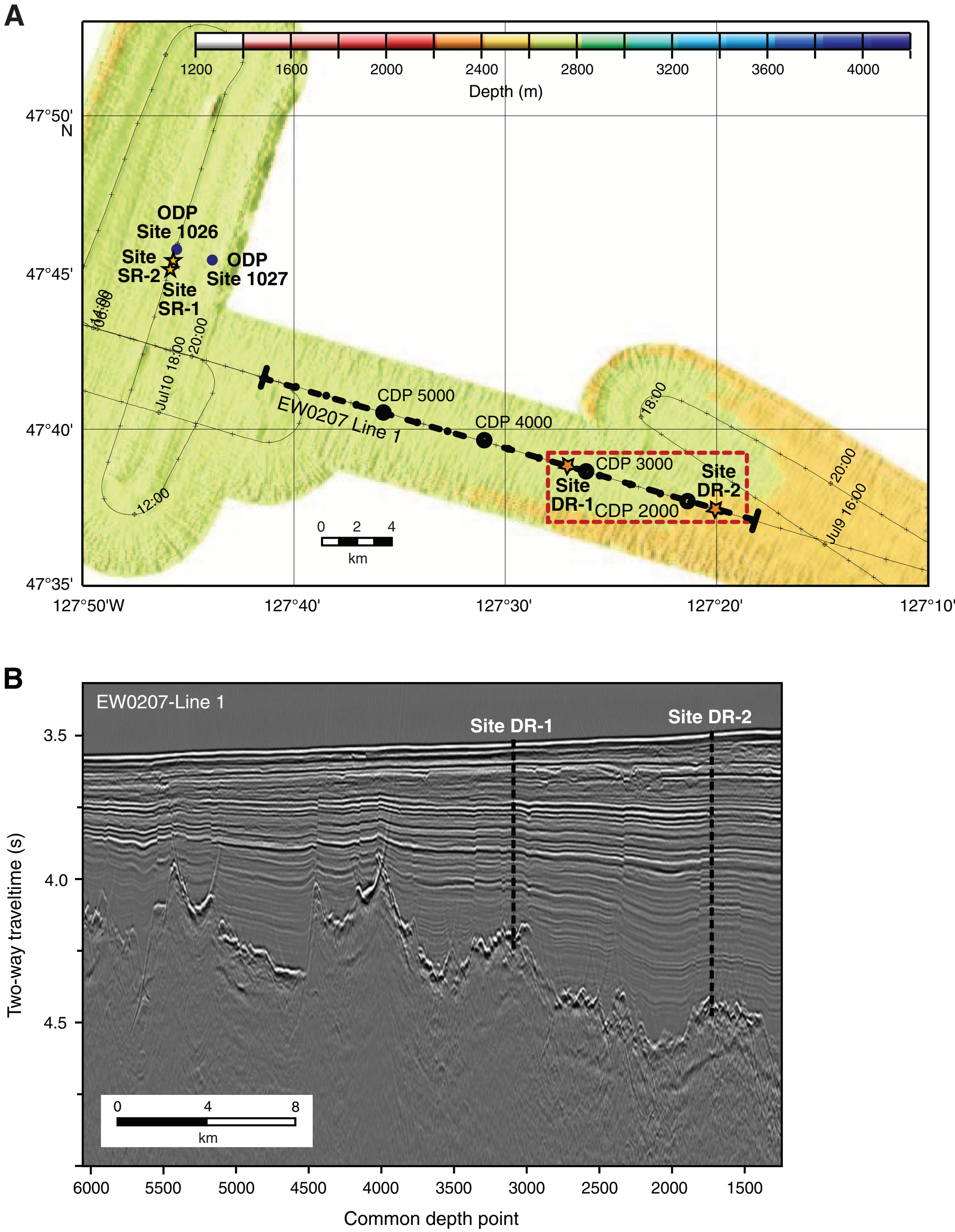


Figure F9. Generic schematic (not drawn to scale) of CORK observatory with four concentric casing strings, one set of packers at depth, and an "L-CORK" design with a lateral casing section extending from the inner 4½ inch CORK casing and coming up the free-flow ball valve at the wellhead. This schematic shows a CORK very similar to the one that will be deployed in Hole SR-2B. The CORKs in Holes SR-2A and 1027C will have two sets of packers, and the CORK in Hole 1027C will have three rather than four concentric casing strings because the conductor casing will be 16 inches in diameter.

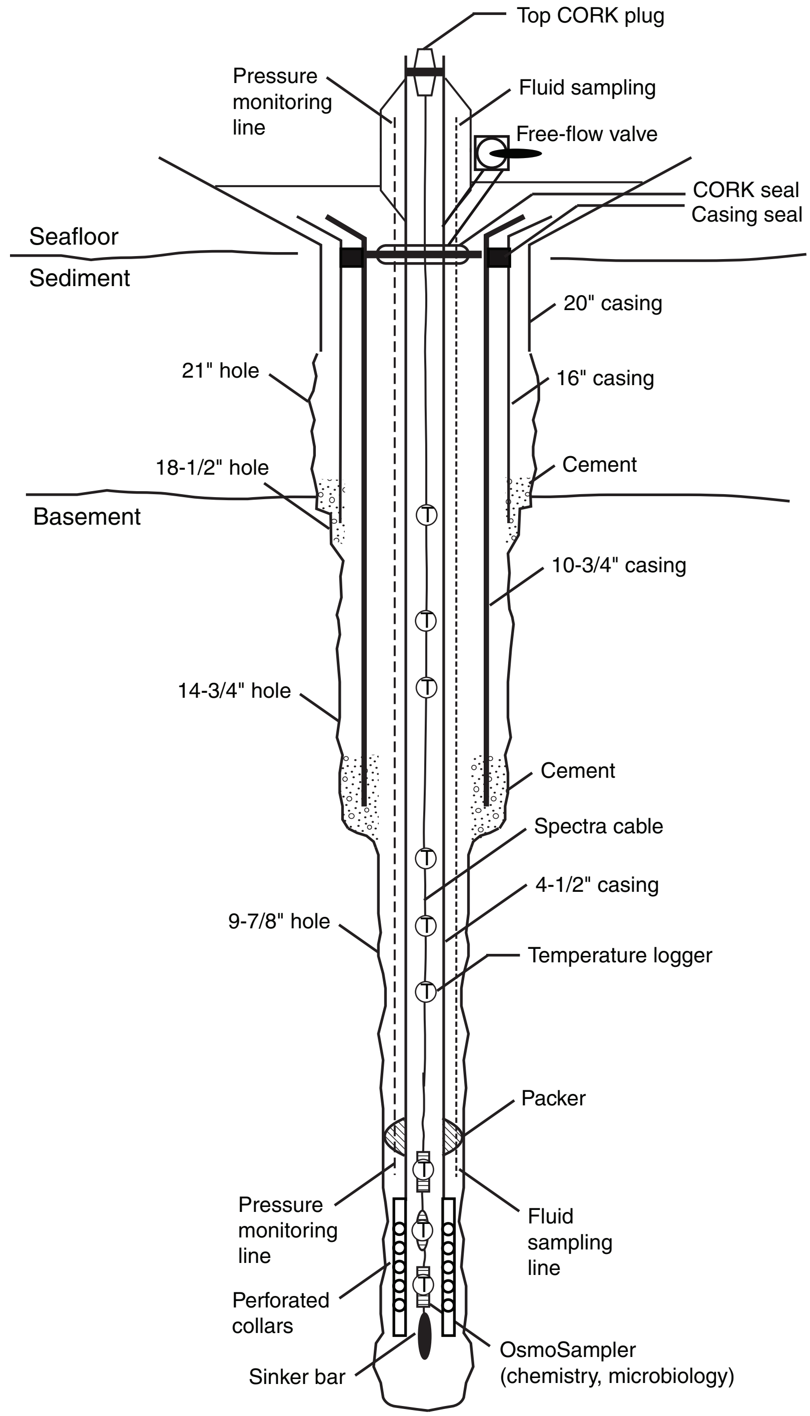


Figure F10. Sketch of CORK layout in Hole SR-2A, drawn roughly to scale with depth. MBIO = microbiology, OS = OsmoSampler.

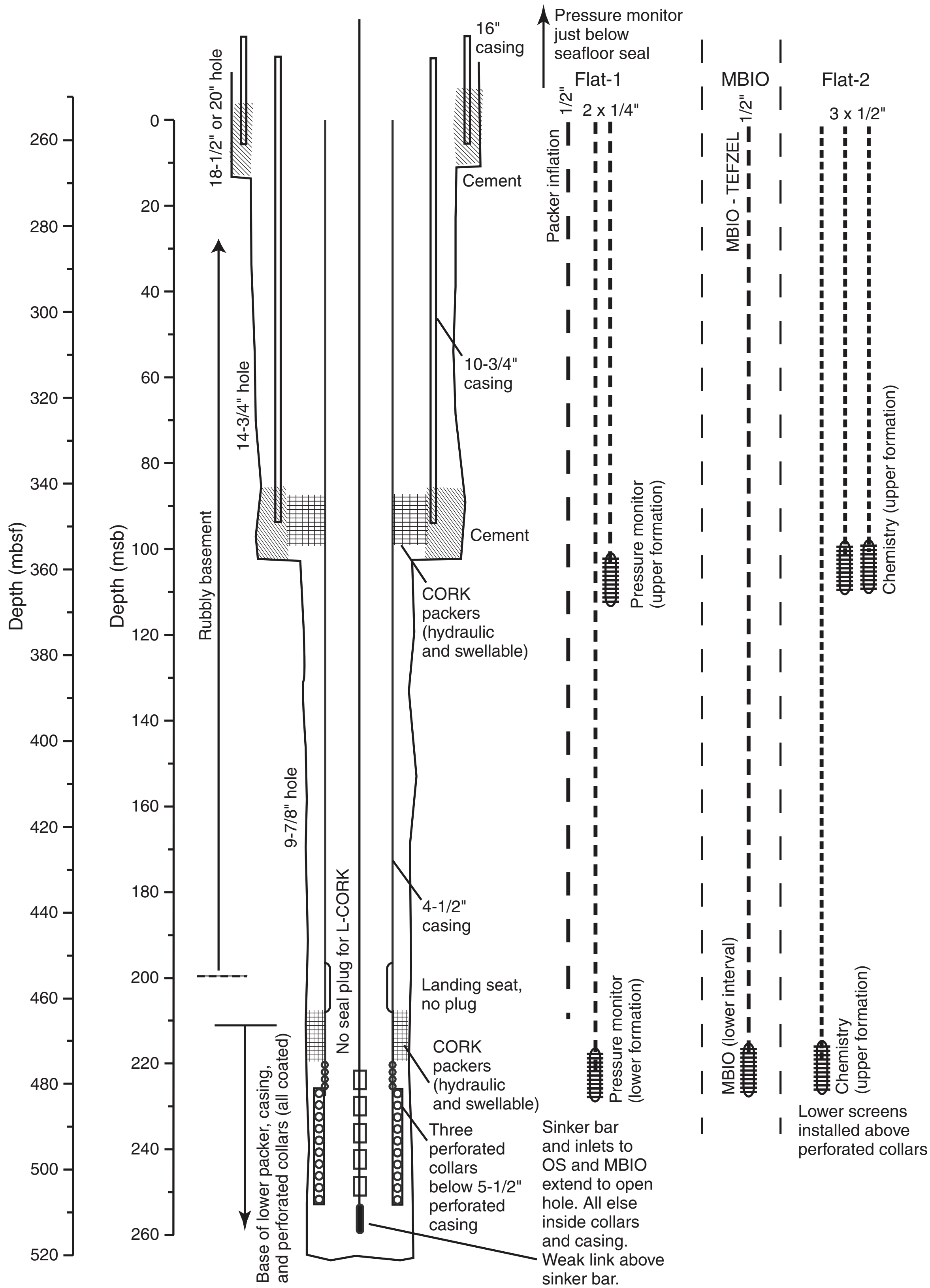


Figure F11. Sketch of CORK layout in Hole SR-2B, drawn roughly to scale with depth. MBIO = microbiology, OS = OsmoSampler.

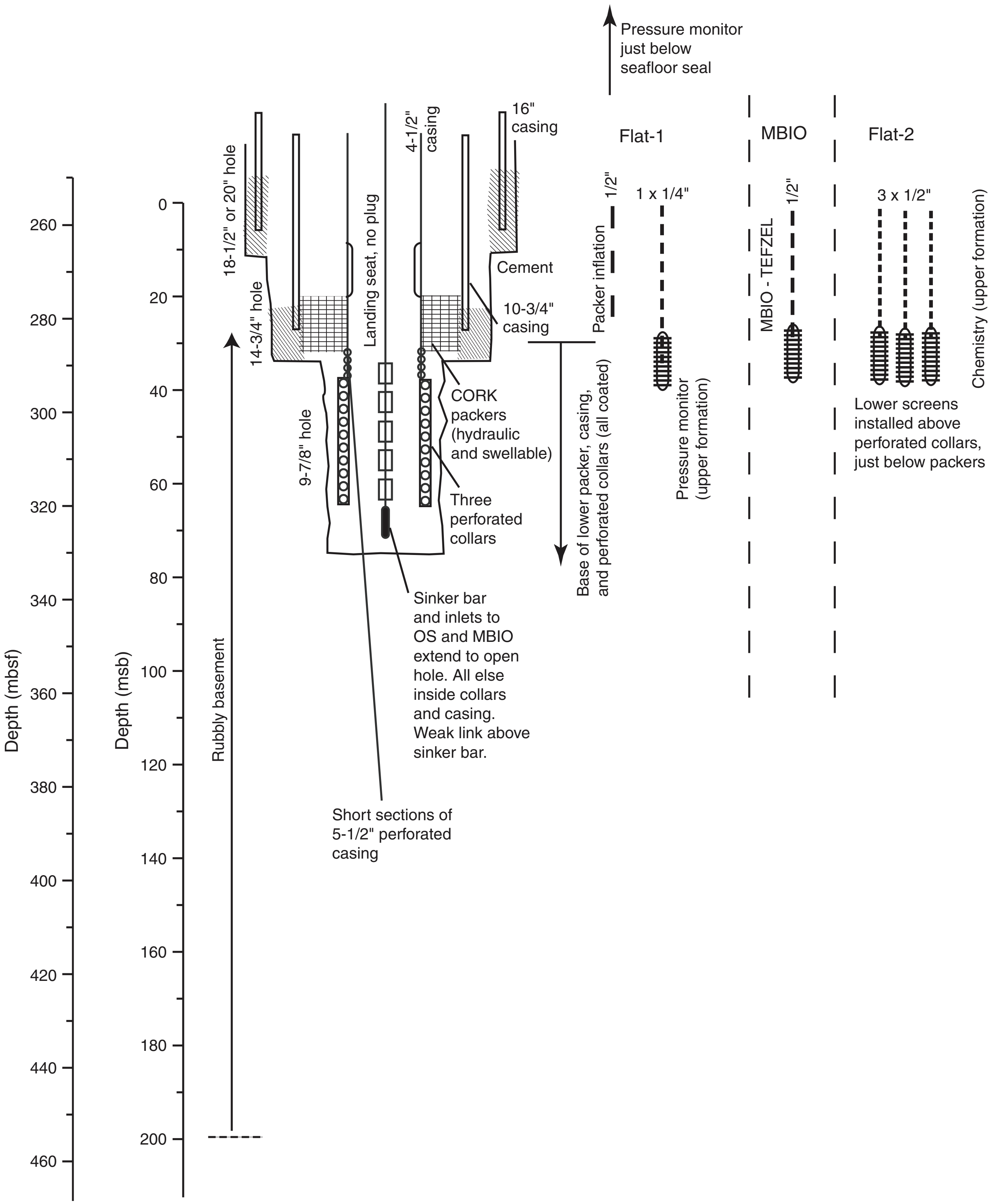
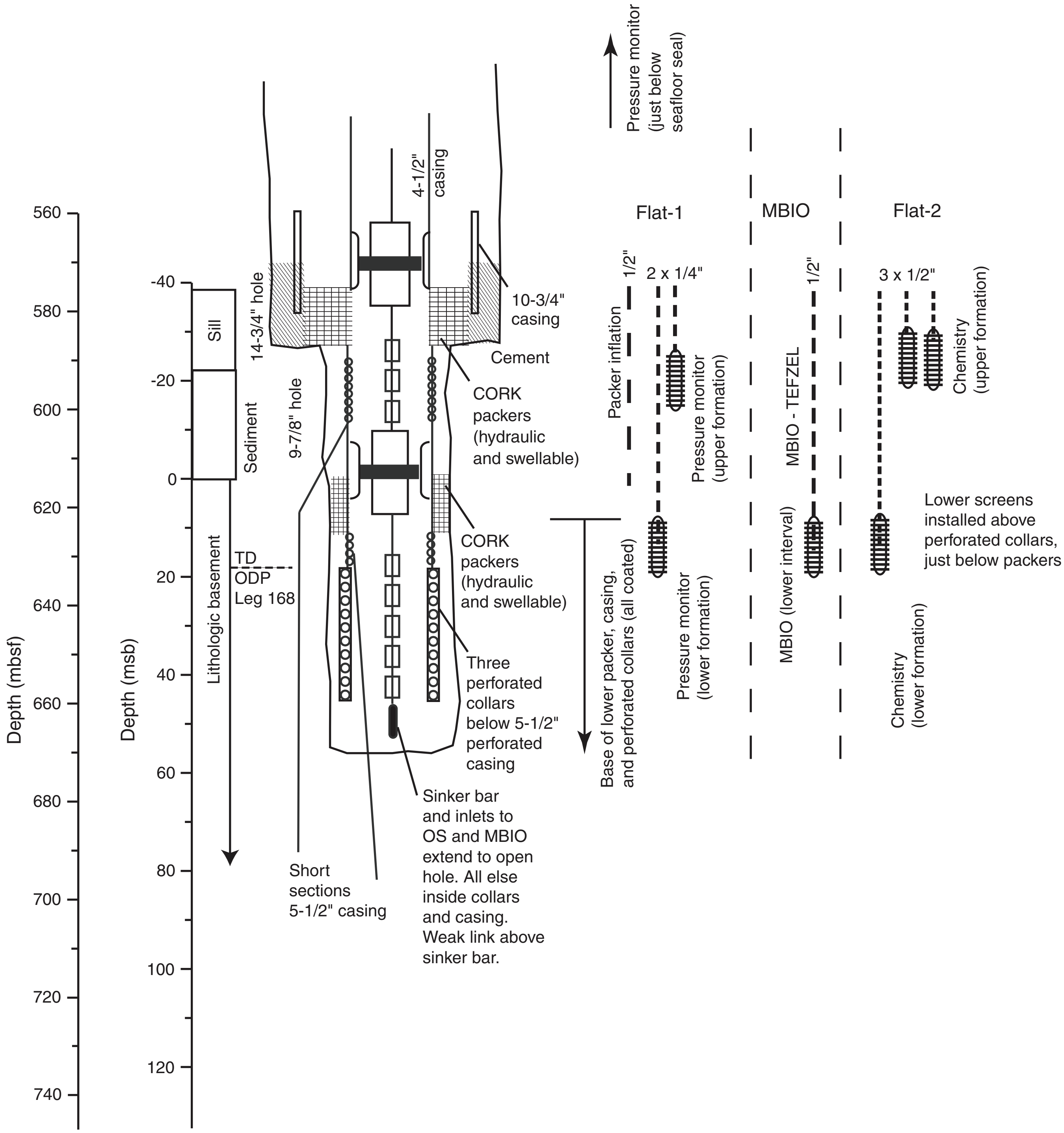


Figure F12. Sketch of CORK layout in Hole 1027C, drawn roughly to scale with depth. TD = total depth, MBIO = microbiology, OS = OsmoSampler.



Site summaries

Proposed Site SR-2A

Priority:	Primary
Position:	47°45.662′N, 127°45.674′W; approved for 500 m radius surrounding position
Water depth (m):	2670
Target drilling depth (mbsf):	520
Approved maximum penetration (mbsf):	855
Survey coverage:	GeoB00-482: CDP 439 (Track Map Fig. **F2**, Seismic Profile Fig. **F3**)
Objective:	• Characterize upper basaltic crust and hydrologic properties • Conduct cross-borehole hydrologic and geochemical experiments • Install long-term borehole observatory (pressure, geochemistry, microbiology)
Drilling and Logging program:	• Core into upper basement • Conduct wireline logging and packer experiments • Install borehole observatory (CORK) See **"Operations plan/drilling strategy," "Logging/downhole measurements strategy,"** and Table **T3**
Nature of rock anticipated:	Turbidites (sand, silt, clay) and hemipelagic mud, overlying basalt

Site summaries (continued)

Proposed Site SR-2B

Priority:	Primary
Position:	47°45.662′N, 127°45.674′W; approved for 500 m radius surrounding position
Water depth (m):	2670
Target drilling depth (mbsf):	325
Approved maximum penetration (mbsf):	855
Survey coverage:	GeoB00-482: CDP 439 (Track Map Fig. F2, Seismic Profile Fig. F3)
Objective:	• Characterize upper basaltic crust and hydrologic properties • Conduct cross-borehole hydrologic and geochemical experiments • Install long-term borehole observatory (pressure, geochemistry, microbiology)
Drilling and Logging program:	• Core into upper basement • May conduct packer experiments • Install borehole observatory (CORK) See "Operations plan/drilling strategy" and Table T3
Nature of rock anticipated:	Turbidites (sand, silt, clay) and hemipelagic mud, overlying basalt

Site summaries (continued)

Proposed Site ODP Hole 1027C

Priority:	Primary
Position:	47°45.387′N, 127°43.867′W
Water depth (m):	2669
Target drilling depth (mbsf):	Reoccupy existing borehole; new penetration from 635 to ~675 mbsf
Approved maximum penetration (mbsf):	Pending approval
Survey coverage:	GeoB00-203: CDP 741 (Track Map Fig. F2, Seismic Profile Fig. F5)
Objective:	• Characterize upper basaltic crust and hydrologic properties • Conduct cross-borehole hydrologic and geochemical experiments • Install long-term borehole observatory (pressure, geochemistry, microbiology)
Drilling and Logging program:	• Remove existing borehole observatory (CORK) • Deepen hole • May conduct packer experiments • Install new long-term borehole observatory See "Operations plan/drilling strategy" and Table T3
Nature of rock anticipated:	Basalt

Site summaries (continued)

Proposed Site U1301A

Priority:	Primary
Position:	47°45.210′N, 127°45.833′W
Water depth (m):	2611
Target drilling depth (mbsf):	Not applicable; reoccupy existing borehole; no new penetration
Approved maximum penetration (mbsf):	Not applicable; reoccupy existing borehole; no new penetration
Survey coverage:	GeoB00-466: CDP 557 (Track Map Fig. **F2,** Seismic Profile Fig. **F4**)
Objective:	Long-term monitoring of pressure, geochemistry, and microbiology
Drilling and Logging program:	Conduct remedial cementing operations See **"Operations plan/drilling strategy"** and Table **T3**
Nature of rock anticipated:	Not applicable; reoccupy existing borehole; no new penetration

Site summaries (continued)

Proposed Site U1301B

Priority:	Primary
Position:	47°45.228′N, 127°45.827′W
Water depth (m):	2611
Target drilling depth (mbsf):	Not applicable; reoccupy existing borehole; no new penetration
Approved maximum penetration (mbsf):	Not applicable; reoccupy existing borehole; no new penetration
Survey coverage:	GeoB00-466: CDP 556. 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. (Track Map Fig. F2, Seismic Profile Fig. F4)
Objective:	Long-term monitoring of pressure, geochemistry, and microbiology
Drilling and Logging program:	Recover and replace instrument string See "Operations plan/drilling strategy" and Table T3
Nature of rock anticipated:	Not applicable; reoccupy existing borehole; no new penetration

Site summaries (continued)

Proposed Site GRB-1A

Priority:	Secondary
Position:	47°17.237′N, 128°2.137′W
Water depth (m):	2660
Target drilling depth (mbsf):	59 (50 m sediment, 9 m basement)
Approved maximum penetration (mbsf):	Pending approval
Survey coverage:	GeoB00-170: CDP 2837 (Track Map and Seismic Profile Fig. **F6**)
Objective:	Define changes in chemical and microbial processes in a crustal fluid recharge zone at Grizzly Bare outcrop
Drilling and Logging program:	• APC to refusal and time permitting one XCB core into basaltic basement • Sediments: core sediment section for geochemical and microbiological experiments, temperature measurements (SET, APCT3). See **"Operations plan/drilling strategy"** and Table **T3**
Nature of rock anticipated:	Turbidites (sand, silt, clay) and hemipelagic mud, overlying basalt

Site summaries (continued)

Proposed Site GRB-2A

Priority:	Secondary
Position:	47°17.302′N, 128°2.032′W
Water depth (m):	2660
Target drilling depth (mbsf):	109 (100 m sediment, 9 m basement)
Approved maximum penetration (mbsf):	Pending approval
Survey coverage:	GeoB00-170: CDP 2819 (Track Map and Seismic Profile Fig. F6)
Objective:	Define changes in chemical and microbial processes in a crustal fluid recharge zone at Grizzly Bare outcrop
Drilling and Logging program:	• APC to refusal and time permitting one XCB core into basaltic basement. • Sediments: core sediment section for geochemical and microbiological experiments, temperature measurements (SET, APCT3). See "Operations plan/drilling strategy" and Table T3
Nature of rock anticipated:	Turbidites (sand, silt, clay) and hemipelagic mud, overlying basalt

Site summaries (continued)

Proposed Site GRB-3A

Priority:	Secondary
Position:	47°17.434′N, 128°1.823′W
Water depth (m):	2660
Target drilling depth (mbsf):	209 (100 m sediment, 9 m basement)
Approved maximum penetration (mbsf):	Pending approval
Survey coverage:	GeoB00-170: CDP 2783 (Track Map and Seismic Profile Fig. **F6**)
Objective:	Define changes in chemical and microbial processes in a crustal fluid recharge zone at Grizzly Bare outcrop
Drilling and Logging program:	• APC to refusal and time permitting one XCB core into basaltic basement. • Sediments: core sediment section for geochemical and microbiological experiments, temperature measurements (SET, APCT3). See **"Operations plan/drilling strategy"** and Table **T3**
Nature of rock anticipated:	Turbidites (sand, silt, clay) and hemipelagic mud, overlying basalt

Site summaries (continued)

Proposed Site FR-1A

Priority:	Secondary
Position:	47°54.105′N, 128°33.468′W; approved for 500 m radius surrounding position
Water depth (m):	2600
Target drilling depth (mbsf):	110
Approved maximum penetration (mbsf):	110
Survey coverage:	InLine 44, TR426 (Track Map and Seismic Profile Fig. F7)
Objective:	Core a short series of sediment and shallow basement holes along the first buried basement ridge east of the spreading center to evaluate sediment properties, document fluid chemistry and evidence for along-strike fluid flow, and determine the nature of hydrothermal alteration and microbiology in uppermost basement. Sediment thickness is 40-60 m where basement comes closest to the seafloor.
Drilling and Logging program:	• APC/XCB and RCB core through sediments and into uppermost basement • Core into upper basement • Collect temperature measurements (SET, APCT3) See **"Operations plan/drilling strategy"** and Table T3
Nature of rock anticipated:	Turbidites (sand, silt, clay) and hemipelagic mud, overlying basalt

Site summaries (continued)

Proposed Site FR-1B

Priority:	Secondary
Position:	47°54.132′N, 128°33.591′W; approved for 500 m radius surrounding position
Water depth (m):	2600
Target drilling depth (mbsf):	110
Approved maximum penetration (mbsf):	110
Survey coverage:	InLine 44, TR410 (Track Map and Seismic Profile Fig. F7)
Objective:	Core a short series of sediment and shallow basement holes along the first buried basement ridge east of the spreading center to evaluate sediment properties, document fluid chemistry and evidence for along-strike fluid flow, and determine the nature of hydrothermal alteration and microbiology in uppermost basement. Sediment thickness is 40–60 m where basement is closest to the seafloor.
Drilling and Logging program:	• APC/XCB and RCB core through sediments and into uppermost basement • Core into upper basement • Collect temperature measurements (SET, APCT3) See **“Operations plan/drilling strategy”** and Table **T3**
Nature of rock anticipated:	Turbidites (sand, silt, clay) and hemipelagic mud, overlying basalt

Site summaries (continued)

Proposed Site DR-1

Priority:	Secondary
Position:	47°38.810′N, 127°26.999′W; approved for 500 m radius surrounding position
Water depth (m):	2600
Target drilling depth (mbsf):	660
Approved maximum	660
Survey coverage:	EW0702 Line 1, CDP 3070 (Track Map and Seismic Profile Fig. **F8**)
Objective:	Drill into deeply buried basement ridge 125 km from the spreading center, where basement temperatures may approach 100°C, to evaluate the influences of hydrothermal circulation on crustal evolution and microbiology. Sediment thickness is 610 m, and basement penetration will be 20–50 m.
Drilling and Logging program:	• RCB core through 610 m of sediment and into uppermost basement • If time allows, install cone and casing through sediment • Collect temperature measurements (SET) See **"Operations plan/drilling strategy"** and Table **T3**
Nature of rock anticipated:	Turbidites (sand, silt, clay) and hemipelagic mud, overlying basalt

Site summaries (continued)

Proposed Site DR-2

Priority:	Secondary
Position:	47°37.449′N, 127°20.049′W; approved for 500 m radius surrounding position
Water depth (m):	2600
Target drilling depth (mbsf):	940
Approved maximum	940
Survey coverage:	EW0702 Line 1, CDP 1720 (Track Map and Seismic Profile Fig. **F8**)
Objective:	Drill into deeply buried basement ridge 145 km from the spreading center, where basement temperatures may approach 140°C, to evaluate the influences of hydrothermal circulation on crustal evolution and microbiology. Sediment thickness is 890 m, and basement penetration will be 20–50 m.
Drilling and Logging program:	• RCB core through 910 m of sediment and into uppermost basement • If time allows, install cone and casing through sediment • Collect temperature measurements (SET) See **"Operations plan/drilling strategy"** and Table **T3**
Nature of rock anticipated:	Turbidites (sand, silt, clay) and hemipelagic mud, overlying basalt

Expedition scientists and scientific participants

The current list of participants for Expedition 327 can be found at **iodp.tamu.edu/scienceops/precruise/juandefuca/participants.html.**