



The Ocean Drilling Program's drill ship (left) has deployed several "CORK" observatories in seafloor boreholes to study the circulation of subsurface fluids (see map below), including the one above in Hole 858G off the Pacific Northwest coast.

# Plugging the Seafloor with CORKs

## *A window into the plumbing system hidden beneath the ocean's floor*

**Keir Becker**, Professor, Rosenstiel School of Marine and Atmospheric Science, University of Miami

**Earl E. Davis**, Senior Research Geophysicist, Pacific Geoscience Centre, Geological Survey of Canada

**H**idden beneath the seafloor throughout most of the world's oceans lies a massive, dynamic plumbing system that is a central component of our planet's inner workings.

Heated and under pressure, seawater and other fluids flow and percolate up, down, and through myriad layers of subsurface rock formations. At volcanically active mid-ocean ridges, where hot magma rises from the mantle to create new seafloor, this circulation vents heat from the earth's hot interior. It plays an important role in regulating the chemical balance of the oceans and in forming huge ore deposits. At subduction zones, where old seafloor collides with an overriding tectonic plate and sinks back down to the mantle, fluid pressures within subsurface

formations are believed to be an important factor in triggering many of the world's largest and most damaging earthquakes. Fluid flow beneath the seafloor also may help create the conditions that allow vast microbial communities to thrive in subsurface formations. And it affects the migration of oil and gas and the formation of another common, potentially energy-producing hydrocarbon: gas hydrates.

These are ice-like deposits of crystallized methane and water that form under higher pressures and frigid deep-sea temperatures.

Though we know that fluid flow beneath the ocean basins is fundamental and important, our ability to study conditions and processes that occur beneath the seafloor has been limited. To gain a window onto this relatively inac-



cessible domain, we took advantage of holes drilled deep into the ocean bottom by the international Ocean Drilling Program (ODP). The drilling thus did double duty—extracting scientifically valuable seafloor specimens, while simultaneously giving us an entryway for hydrologic experiments within subseafloor formations.

In a previous issue of *Oceanus* (Vol. 36, No. 4) we reported on our early efforts to seal two ODP holes and install instruments in them to create long-term observatories to investigate subseafloor fluid circulation. We called these observatories “CORKs” for Circulation Obviation Retrofit Kits, playing on the obvious analogy of a cork sealing a bottle. For our studies, we had to reseal boreholes because ODP holes left open act as shunts between the oceans and subseafloor formations and disrupt natural hydrological processes. Within the resealed holes, we suspended strings of sensors that were linked to a long-term data logger on the seafloor that could be accessed with a human-occupied or remotely operated vehicle. To date, our sensor strings have been relatively simple. They have included one pressure gauge at the seafloor and one in the sealed hole, temperature sensors distributed down within the holes, and, in some instances, fluid sampling devices near the bottoms of the holes.

Our initial installations were quite successful, and we and our growing group of CORK collaborators have gone on to deploy similar instrumentation in a total of 11 sites (see map opposite) in three representative types of seafloor hydrological environments: spreading centers, where new seafloor is spreading outward from mid-ocean ridges (ODP Holes 857D and 858G), young mid-ocean ridge flanks (395A, 1024C, 1025C, 1026B, 1027C), and accretionary prisms, where sediments scraped off descending seafloor plates accumulate in front of overriding plates, like debris in front of a locomotive’s cowcatcher (889C, 892B, 948D and 949C). The CORK program has been an important contribution toward fulfilling the initiative, highlighted in ODP’s current Long-Range Plan, for long-term in situ monitoring of geological processes. We gratefully acknowledge solid, forward-looking support from our funding agencies: the National Science Foundation, the Geological Survey of Canada, and the French Institute of Research and Exploration of the Sea (IFREMER), as well as ODP’s planning body, the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES).

We emphasize the words “forward-looking,” because the CORKs, like other observatories discussed in this issue, require investments not only in equipment and infrastructure, but also in time. They require waiting, possibly for years, before significant results become available. But eight years have now passed since our initial installations, and we have accumulated a growing body of important findings.

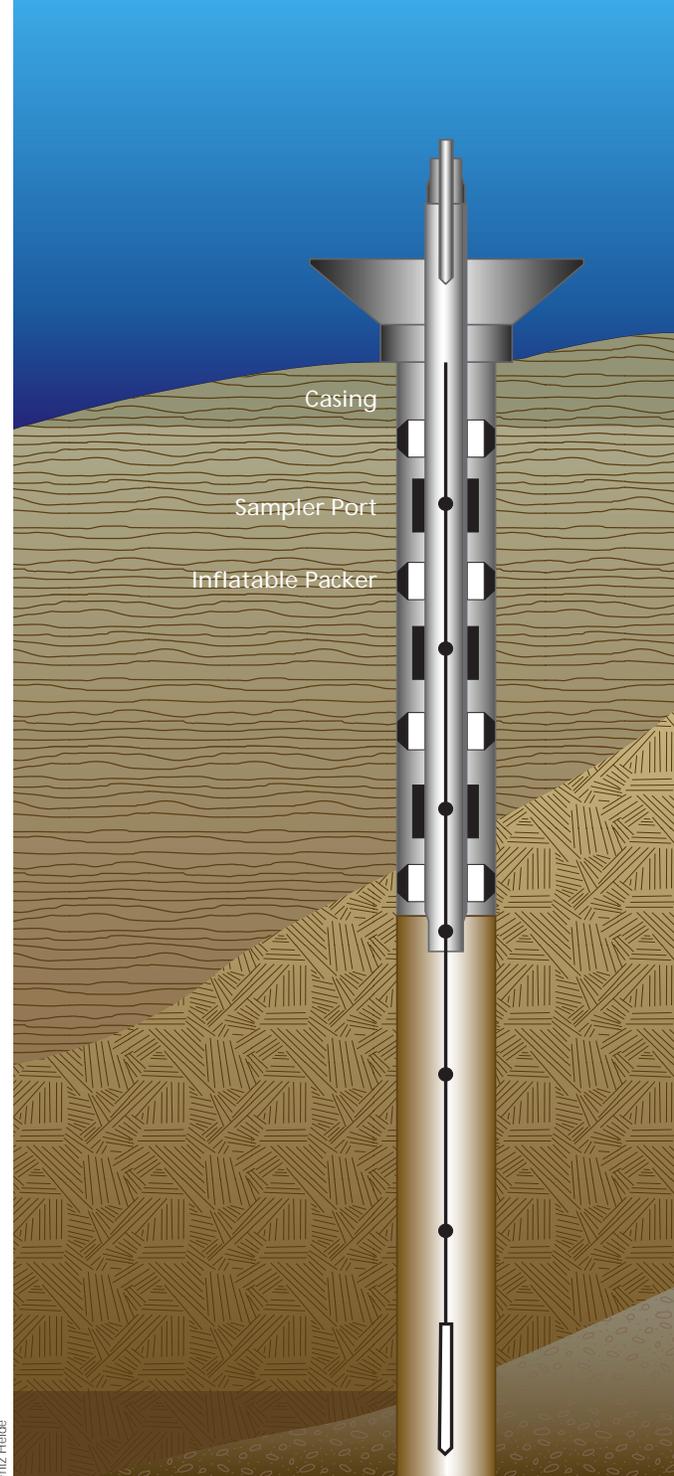
They are collected in a recent workshop report available on the Internet site of the JOIDES Long-Term Observatories Program Planning Group ([vertigo.rsmas.miami.edu/ltoppg.html](http://vertigo.rsmas.miami.edu/ltoppg.html)). Among our more important findings, we have shown that:

- High fluid pressures can build up in the decollement, or plate boundary fault, at subduction zones (Hole 949C in the Barbados prism). This fluid pressure surely is a factor in the genesis of earthquakes that are so common in subduction zones.

- Fluids—driven by small pressure gradients—circulate laterally over many kilometers through the very highly permeable sediments of young oceanic crust in upper “basement” formations beneath the seafloor. This finding gives us a first glimpse of the mechanics of the subseafloor plumbing system, which, among other things, may prove important to vast subseafloor microbial ecosystems.

- Tides in the ocean exert periodic loads on the seafloor that propagate down into sediment and rock layers beneath the seafloor to varying degrees depending on the hydrological and elastic properties of the formations. This unexpected tidally driven flow in the subsurface may play an important role in regulating important subseafloor chemical interactions between fluids and rocks and in maintaining an environment to host microbiological communities. It could also mean that subseafloor formations serve to dissipate a modest amount of tidal energy.

CORKs may represent the best option for in situ sampling of fluids below the seafloor, which has



*A new generation of Advanced CORKs will be deployed, starting in 2001. These will have inflatable packers that isolate separate zones in subseafloor formations so that different processes occurring within each zone may be identified.*

*Aboard the ODP  
drillship JOIDES  
Resolution, rough-  
necks position a  
CORK observatory  
in a long segmented  
drillpipe leading to  
a borehole in the  
seafloor.*



Keith Becker

proven very elusive to date. Five of the CORKs presently deployed include long-term self-contained fluid samplers suspended within the sealed holes to sample formation fluids (as opposed to the seawater used in the drilling process). Four were just recovered this past September using WHOI's submersible *Alvin* and the wireline Control Vehicle of Scripps Institution of Oceanography's Marine Physical Laboratory (MPL). With access to the sealed holes via a valve at the seafloor, our installations are also excellent for setting up long-term experiments to produce and sample subseafloor formation fluids. Our experience now allows us to predict in which settings sealed holes are likely to produce fluids naturally. In other cases we can take advantage of what we have learned about tidal effects on subseafloor fluid flow to produce subseafloor fluids at the valves.

We are gratified at the success of the CORK effort, and are particularly excited to be involving a widening circle of collaborators, ranging from physical oceanographers interested in our deep ocean tidal records to

microbiologists interested in microbial systems hosted within the subseafloor formations that we access with the CORKs. However, we recognize that the 1991–1997 CORK design has a key scientific limitation: Until now, our design incorporated a single seal near the top of the hole, and thus our sensors integrate signals from the full range of formations that the hole penetrates beneath the seafloor. But in reality, subseafloor formations are not uniform. Our results and many other lines of evidence clearly indicate that permeability and fluid flow in various subseafloor formations varies because of intrinsic permeability differences in formations or because flow is channeled in discrete faults and fractures.

So we have proposed a new generation of “Advanced CORK” observatories starting with deployments planned for 2001. The next major advances in our understanding of subseafloor hydrology will come not only from expanding the range of in situ measurements and sampling devices incorporated in our sensor strings, but also and more importantly, from incorporating a capability to isolate many separate zones within the subseafloor formations and take measurements in each of them (see diagram, page 15).

Our funding agencies and JOIDES support this strategy, and we are simultaneously developing two technological approaches to implement this multi-sealing capability: a multi-packer instrumented casing system deployed by the ODP drill ship, and a wireline instrumented multi-packer system deployed by the MPL Control Vehicle. The first deployments of the former are scheduled for spring 2001 on ODP Leg 196 in two holes in the Nankai Trough subduction system off Shikoku Island, Japan (site of the Kobe earthquake). First deployments of the latter are scheduled for winter 2001 in a pair of existing young crustal holes in the Panama Basin (504B and 896A).



Keith Becker

*CORK assemblies  
await deployment  
aboard JOIDES  
Resolution.*