A Large Volume Deep-Ocean Sampler for Hydrothermal Fluids

Simple, Novel Design Allows Collection of Hundreds of Liters of Uncontaminated Fluid With Each Deployment

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The sampling of hydrothermal fluids for chemical and biological studies has been a major scientific goal since the discovery of deep-sea vents in the late 1970s. Standard sampling technology currently consists of small (~500 milliliters) fluid samples taken with discrete titanium vessels from an ROV or submersible. Such samples provide adequate volume for many bulk inorganic fluid composition studies, although the competition for aliquots of a few hundred milliliters between individual in-vestigators is often intense. As the understanding of hydrothermal systems has evolved, many key scientific questions now require measuring extremely dilute biological materials and organic chemical species.

The biochemical and isotopic composition of non-living organic matter carries a detailed molecular history of the biogeochemical system which produced it, including its biological and geochemical sources, fluid residence times and the ultimate origins of elemental building blocks. However, a minimum of tens of liters of fluid is needed for many of the most basic analyses of this kind, and up to hundreds of liters for the most detailed and powerful molecular-level stable isotopic ($\delta^{13}C$, $\delta^{15}N$) and radiocarbon ($\Delta^{14}C$) isotopic studies. Such volumes are far beyond the reach of conventional sampling systems. To be able to push the frontiers of understanding of such environments, we need to develop sampling technology for deep-sea marine hydrothermal systems with a capacity almost three orders of magnitude larger than those presently available for submersible and ROV use.

The solution was to design a robust and inexpensive barrel sampler capable of recovering ~200 liters (53 gallons) of non-contaminated fluid from a hydrothermal source in a single deployment. Developed for a National Science Foundation Life in Extreme Environments (LEXEN) cruise to the Juan de Fuca Ridge in September 2002, this new sampler successfully recovered a total of 775 liters of crustal fluids during six deployments, expanding the scope of potential scientific studies of hydrothermal systems to a totally new level.

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Background and Design Criteria

Current hydrothermal fluid sampling relies on very small volume (~500 milliliters) discrete titanium samplers (major and gas-tights) or manifold samplers that are expensive to build and complicated to maintain. It was clear that to rapidly recover large volumes of uncontaminated fluid with a minimum capital investment, a new approach was required. The new sampler had the following design criteria: sample fluid must not be chemically contaminated; internal surfaces must be resistant to potentially corrosive fluid; sampling rate must be controllable, so as not to overdrive the artesian flow of vent fluid and mix the target sample with ambient seawater; deployment and control must be via an ROV or submersible using existing deep-sea elevators; must be able to sample fluids up to 65° C; and must be robust, simple and inexpensive.

Design

The design satisfies these criteria by not driving sample fluid through a mechanical pump, but instead utilizing the pressure differential created when water is evacuated from a sealed barrel to "passively" fill a chemically inert sample bag. In the design, sealed plastic barrels are deployed full of freshwater, each containing an empty internal sample bag. The barrels are then recovered largely empty of background water but with full internal sample bags, eliminating void spaces and the associated need for expensive, high-strength machined housings. This design allows the housing and the majority of plumbing to be made from inexpensive PVC, since sampled fluid contacts only the Teflon® sampling tube and internal, storage bags.

For the sealed vessels, we used two inexpensive 30-gallon polyethylene

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liquid shipping barrels with compression-clamped seals and foam rubber O-rings. These barrels were lined with two-inch-thick open cell foam to cushion the full sample bags during recovery. The barrels were secured to the aluminum Woods Hole Oceanographic deep-sea elevator (for a full description, read the Woods Hole Oceanographic Institution's Technical Report WHOI-00-01). Bulkhead fittings were installed in each of the barrel lids to allow both the controlled evacuation of the background water and the filling of the sample bags while maintaining the barrel's overall seal.

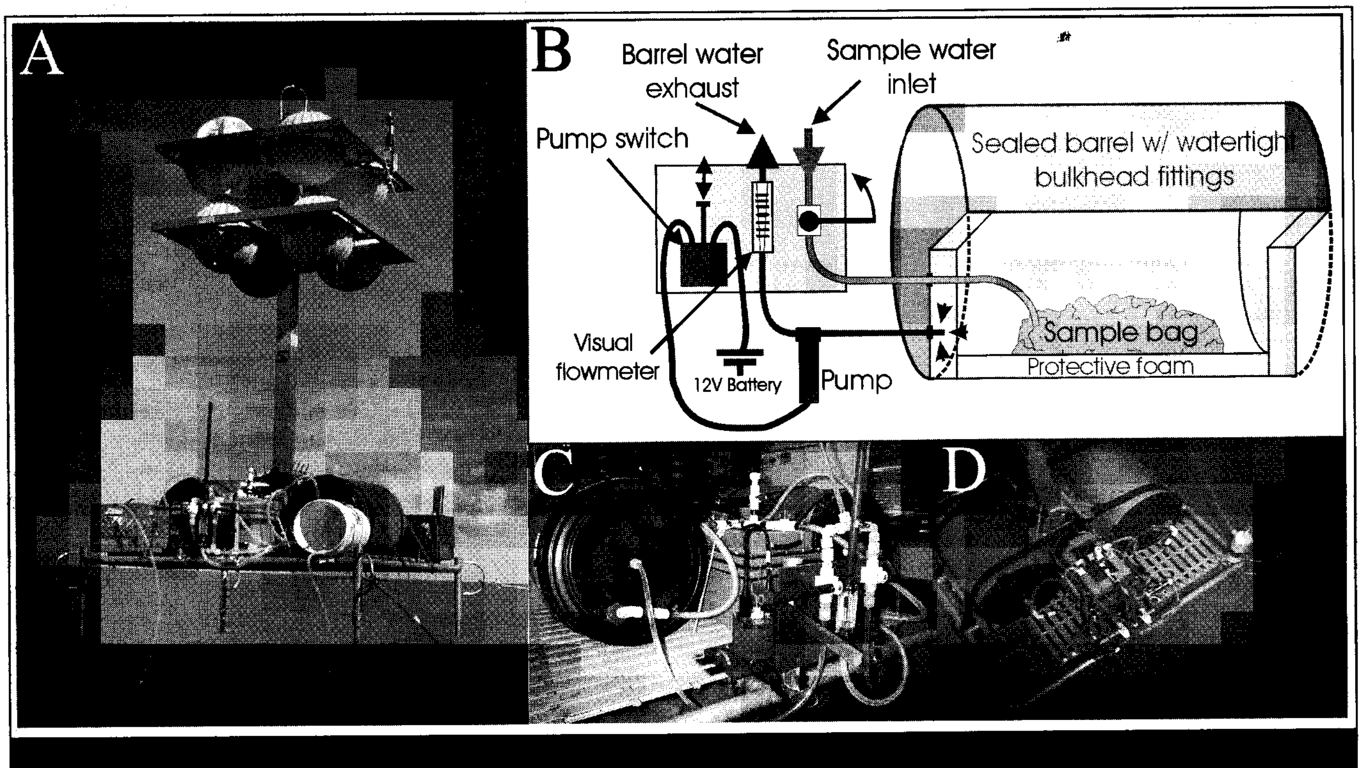
The only powered component of the system was the pump used to evacuate the background water from the barrels (Seabird underwater pump model SBE 5T). The SBE 5T is a small, 12-volt, full ocean depth pump with a centrifugal impellor magnetically coupled to the drive motor. The magnetic drive allows the impellor to be external to the titanium pressure housing, eliminating pressurized mechanical seals. This coupling also provides an overfill protection feature, since pumping resistance will increase until the magnetic drive slips, reducing the chance of rupturing full sample bags. Sampling rate is controlled both by on-deck adjustment and *in-situ* using the ROV manipulator. The impellor speed on the pump can be adjusted on deck between 1,300 and 4,500 revolutions per minute using an internal potentiometer. On the seafloor, valves for both barrel outflow and the sample inflow can be opened incrementally to control flow rates and prevent overdriving the venting fluid, which can dilute the target sample by entraining ambient seawater.

Power was provided by a DeepSea Power and Light 12-volt, 72 A/hr SeaBattery, which was salvaged from an obsolete instrument. For manual on/off operation using the ROV manipulator, a pressure-compensated toggle switch was developed by the University of Washington Ocean Engineering Department. The switches contain a simple and inexpensive 12-volt toggle encased in an oil-filled PVC housing. The switch is activated by a push/pull rod passing through a sealed bulkhead fitting in the top of the housing. Originally designed for less than 30 meters of water, the switches were modified by adding a larger oil-filled reservoir tube, thus expanding the operating depth range of the pressure compensator.

A manipulator command panel allowed mounting of the valves for both the barrel evacuation and fluid sampling systems, the pump on/off switch and a simple visual flow meter read by the ROV video system to determine the *in-situ* rate of sampling. This panel utilized a series of PVC levers in order to be easily operable by the manipulators of the ROV *Jason II*. Inert, easily cleaned materials (Teflon & Tedlar®) were used on the sample fluid plumbing, avoiding potential contamination—a serious issue for trace chemical and biological studies of a corrosive hydrothermal fluid.

Sampling Process

Readying the sampling package for deployment consists of cleaning and prepping the sample system, installing internal sample bags and charging the



(A) Barrel sampling package being brought aboard the research vessel after collecting over 160 liters of hydrothermal vent fluid. (B) Cartoon showing the simplicity of the sampling system. (C) Close-up of the manipulator command panel showing the sample valves with handles, the power switch and the visual flowmeter. (D) Barrel sampler deployed at ~2,100 meters depth.

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barrels with the fresh water to be evacuated. All internal plumbing that contacts sample fluid is acid-cleaned and washed with ultra-clean water. The cleaned system is then preloaded with a small, measured quantity of de-ionized water (~750 milliliters) to avoid both seawater intrusion and crimping of the Teflon tubing during descent. A valved PVC port installed for connection to a deck hose allows easy filling of the barrels with the water to be evacuated, and allows verification that neither air nor seal leaks exist. Before launch, the negative buoyancy of the entire elevator is calculated so that the ROV can reposition the system on the seafloor, within range of the sampling site.

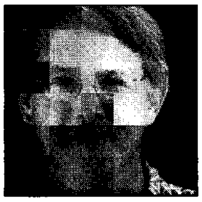
The ROV begins the operation by positioning the sampling tube, manually starting the pump to evacuate the barrels and opening the manifold valves to the internal sample bags. Partially closing these valves allows variation of the sampling rate to correspond to the vent's artesian flow. When the flow rate on the visual flow meter indicates a dramatic decrease, the barrels are empty of background water and the sample bags are filled. Closing all valves in the sampling system and turning off the pump completes the sampling operation, allowing the elevator to be acoustically or manually released from the seafloor and recovered by the surface ship. The multi-barrel design allows significant versatility, as each elevator deployment can collect either one large volume sample or discrete individual sub-samples from different sites. Once on deck, the sample bags are emptied by direct transfer (gravity feed or a peristaltic pump) to a ship-board lab for processing.

Conclusions

While still a prototype, this inexpensive large-volume sampler represents a powerful new tool to advance the understanding of seafloor hydrothermal environments. In one research cruise, the sampler successfully recovered a total of eight discrete, uncontaminated large-volume fluid samples ranging from 60 to 150 liters for biological and geochemical studies. For most sites, these samples represented at least two independent large volume samples from distinct crustal environments.

The total recovered volume during our cruise of 775 liters in six deployments represents substantially more hydrothermal fluid than is typically recovered during an entire field season by conventional equipment. The modular and open design proved extremely powerful in allowing easy shipboard modification and repair. The design is also extremely versatile, allowing, for example, the same equipment to be used for tracer studies by reversing the pump flow to inject solutions at a known rate, and suggesting a wide range of potential future users. /st/

Tor Bjorklund is an oceanographer (research scientist/ engineer) at the University of Washington. He has worked for Dr. H.P. Johnson studying the geophysical aspects of deep-sea hydrothermal systems for two years. In addition to aiding in the development of new and novel instrumentation, his responsibilities include cruise planning, data management and archiving, grant submissions and at sea research. Bjorklund's qualifications include a B.S. in physical oceanography from the University of Washington and a strong desire to use his mechanical abilities in hands-on ways to creatively solve oceanographic dilemmas.



Matthew McCarthy is an assistant professor of ocean sciences at the University of California, Santa Cruz. He got his start in marine science as an analytical chemist at the International Atomic Energy Agency Environmental Studies Laboratory studying mercury contamination in Medi-terranean seafood. After graduate studies at the University of Washington in marine organic geochemistry, he received postdoctoral fellowships in Paris Carnegie Geophysical Lab and as a SOEST Young Investigator Fellowship at University of Hawaii. McCarthy joined the faculty at the University of California, Santa Cruz in 2001.