global climate change, there is considerable interest in environmental and climatic factors as drivers of change in older societies and cultures. If we can demonstrate a second instance of a volcanic eruption that had major human impacts at great distances, it may lead to a more careful search for coincidences between major volcanic eruptions and sudden disruptions of societies through time.

Acknowledgments

The authors thank Chester Dunning, Prudence Rice, Andres Tarand, Charles Walker, and Paul Warde for sharing their expertise and information. Jake Lippman acknowledges a travel grant from the President's Undergraduate Fellowship Program of the University of California.

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A New Long Coring System for R/V *Knorr*

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A new 46-meter-long coring system was tested successfully during cruise 191 of research vessel (R/V) *Knorr* in September 2007. During sea trials in water depths of 4.6 kilometers on the Bermuda Rise, coring operations from the vessel—operated by the Woods Hole Oceanographic Institution (WHOI)—successively recovered piston cores increasing in length from 26 to 38 meters, with sediment recovery at 85–89% of the core barrel length. An additional 25-meter core was recovered in 670 meters of water on the upper continental slope off New Jersey.

The Bermuda Rise location, which is a well-sedimented drift deposit at the northeastern margin of the rise, has been cored many times previously, including by R/V *Knorr*'s giant piston corer in 1973, by R/V *Marion Dufresne*'s Calypso corer in 1995, and by the Ocean Drilling Program's advanced piston corer (ODP/APC) in 1997. In comparing the sediment recovery of the systems, we determined that the WHOI long core recovered the stratigraphic section without any indication of stretching, effectively duplicating the results of the ODP/APC but without the unavoidable breaks between APC cores every 9.5 meters. In three deployments of the new corer, vertical compression occurred in the lower fourth of the core, while in two other deployments sediment recovery was undeformed for the full 38 meters of recovered sediment.

R/V *Knorr* (85 meters long, 2685 tons) underwent significant modifications in 2005 to handle the new coring system, which is more than half the length of the ship. Although Charles Hollister (former dean of the graduate program and vice president of the corporation at WHOI) had developed a long coring system for *Knorr* in the 1970s, the line tensions necessary to remove the corer from the seabed proved to be far too great for the existing winch and trawl wire. As a result, despite many successful deployments and core recoveries, every giant piston core system was eventually lost due to wire failure during operations.

The limiting component of the giant piston corer was the trawl wire, which, at the time (1970s), was a 5/8-inch-diameter steel cable. Current standard trawl wires on University-National Oceanographic Laboratory System (UNOLS) research vessels use smaller-diameter 9/16-inch wire. Simply using a larger steel wire is not a practical solution: When deployed to great ocean depths, the cumulative weight of the steel wire quickly exceeds its strength and is in danger of breaking even without any tension placed on it. The solution is to use a composite rope made of synthetic materials such as Kevlar, Plasma, or Vectran. These ropes are neutrally buoyant, and they can be manufactured in lengths suitable for deep ocean work. This is the approach used by the Calypso corer on R/V *Marion Dufresne*.

Unfortunately, as with wire, these synthetic ropes stretch under high tensions, posing a significant problem for piston coring. The new WHOI long core system uses a 2-inch-diameter rope blended of Vectran and Plasma braided with a torque-balanced, nonrotating construction. The rope is 7500 meters long and has a breaking strength of 360,000 pounds. The breaking strength is more than 10 times greater than the typical tensions experienced by the coring system, and its great strength limits stretching of the rope during coring. Shore-based testing prior to the sea trials documented that with 30,000 pounds of weight on the rope, a 5000-meter length of Plasma of this size should experience only 2 meters of stretch.

Principles of Piston Coring

Piston coring of any type involves releasing the corer at a predetermined height above the seafloor to initiate a free fall and penetrate the sediments. After release, the rope is attached only to the piston inside the core barrel and to the ship, but not to the corer itself. When the free-falling corer reaches the seafloor, the slackened rope tightens and keeps the piston stationary at the sediment-water interface while the corer continues to full penetration. Ideally, the internal piston should not change its position with respect to the sediments—that is, the piston should travel up the core barrel at the same rate that the corer penetrates down into the sediments. If the rope has stretched at all before the release of the corer, it will rebound after release. That rebounding would cause upward motion of the piston, resulting in stretching of the sediments. During field trials, the system's Vectran-Plasma rope minimized stretching and upward rebound of the piston, a result confirmed by independent accelerometers in the piston core head and the release system as well as by the undeformed nature of the recovered sediments.

Tensions during pullout from the sediment are an additional challenge to long coring because they may be sufficient to compromise the structural integrity and stability of R/V *Knorr*. Stability modeling by Glosten Associates, a marine architectural firm in Seattle, Wash., confirmed that the best location on the ship to bear the pullout load was the centerline at the stern, rather than along the starboard rail. A handling system was designed to deploy the corer from horizontal to vertical along the starboard rail, transfer the corer from starboard to stern, and lower the corer to the seafloor through a stern-mounted sheave system anchored to R/V *Knorr*'s frame. With the corer suspended in this manner, pullout tensions are countered by the fore-aft buoyancy of the entire vessel.

The major components of the handling system (Figure 1) include (1) a new A-frame mounted with a load transfer winch and a vertically mounted rigging boom; (2) a new stern-mounted grapple for transferring the corer from starboard to stern; (3) a new deck-mounted traction winch for the Vectran-Plasma rope; and (4) three new computer-controlled davit cranes along the starboard rail to raise and lower the corer between horizontal and vertical orientations.

The new corer has variable weight configurations from about 5000 to 25,000 pounds, determined by the core length and by the size and number of portable weights secured within the core head itself. Core barrels are Teflon-coated and come in three wall thicknesses that decrease from 1.125 inches at the top of the core string, where strength is at a premium, to 0.375 inches at the bottom. The entire length is lined with 10-foot lengths of threaded polyvinyl chloride (PVC) pipe that have an inside diameter of 4.375 inches. The inside diameter of the core cutter can be narrowed in increments of 0.0625 inches to reduce the diameter of the sediments entering the core barrel, thereby reducing friction and improving recovery.

During deployment, the corer is coupled to a release system containing an acoustic modem that, on command from the ship, can release the corer and initiate free fall; a high-frequency acoustic altimeter to determine the height above the bottom; and a drop-weight system to independently sense the seafloor. During the sea trials at Bermuda Rise, the altimeter failed to receive reflections far enough above the bottom to be useful. At the other test location, the upper continental slope off New Jersey, bottom reflections were clear and strong. We are still working to understand the reasons for this different response.

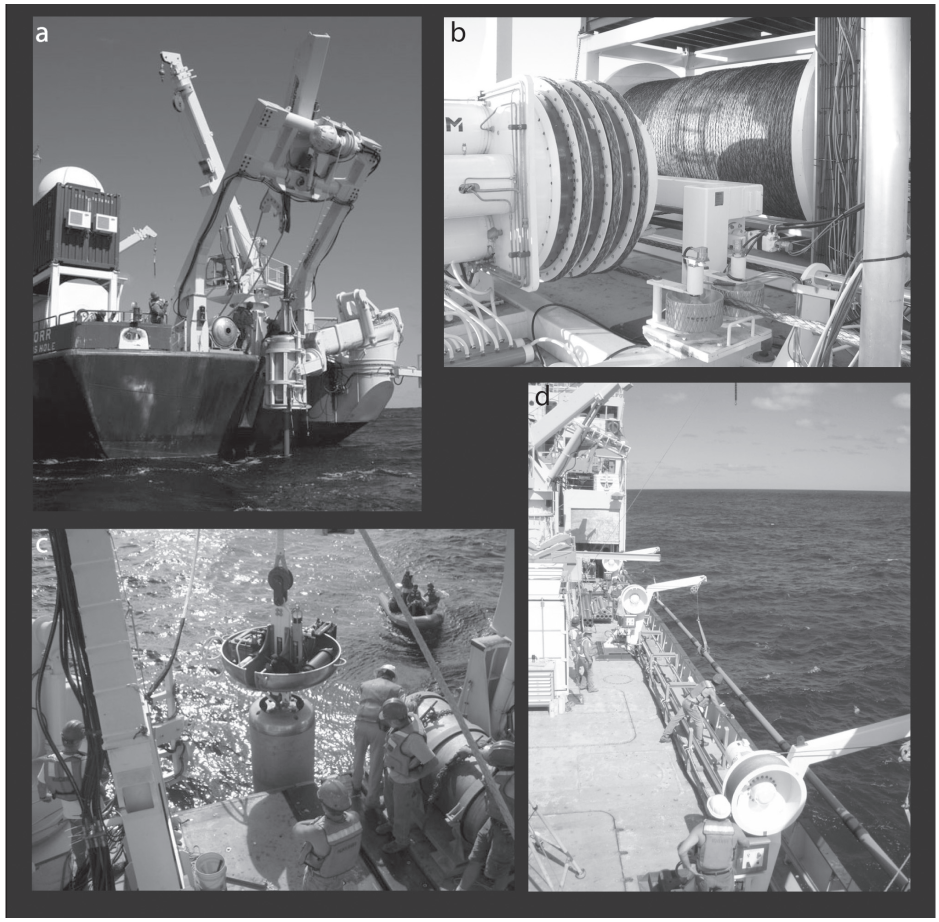

Fig. 1. The major components of R/V Knorr*'s new long core handling system: (a) stern view of the A-frame, boom sheave, and Lantec winch and stern-mounted grapple; (b) the traction winch and take-up drum for the Plasma rope; (c) the piston core head and release in vertical position, coupled and ready for lowering; and (d) the starboard davit cranes with a corer in horizontal position. Original color image appears at the back of this volume.*

Despite the problems with the altimeter, the complex handling and deployment system worked with great success during these sea trials, and we consider the new coring system ready for general use by the UNOLS research community. At this time, only R/V *Knorr* has been modified for handling this coring system, although with proper deck modification and strengthening any of the larger UNOLS vessels would be able to deploy the system. Two new research cruises are scheduled on R/V *Knorr* for early 2009. In preparation for these cruises, we plan to work on continued improvements to be sure the system satisfies the needs of the entire ocean sciences community. Further information about the system, an animation of the coring process, a full evaluation of coring performance, and information on how to use the system can be found at http://www.whoi.edu/projects/longcore/.

Acknowledgments

Financial support was provided by the U.S. National Science Foundation's Divisions of Ocean Sciences and Atmospheric Sciences, the Cecil and Ida Green Foundation, the Grayce B. Kerr Fund, and WHOI. We thank the marine and scientific personnel on cruise 191 of R/V *Knorr* for their professionalism, expertise, and dedication during the sea trials.

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