

A Sea Change in Ocean Drilling

Scientists launch a new drill ship and ambitious research plans

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Science Magazine

In the early 1960s, geologists took their first shot at drilling all the way through Earth's crust and into its mantle with the Mohole Project. It turned out to be a disaster. Named for the Mohorovičić discontinuity, the boundary between the crust and mantle, the ambitious attempt to penetrate 6 kilometers of crustal rock was sunk by cost overruns and management problems and scrapped after a few test holes.

But out of that debacle came a highly successful international scientific endeavor. The decision to drill Mohole from a barge—to take advantage of the fact that the oceanic crust

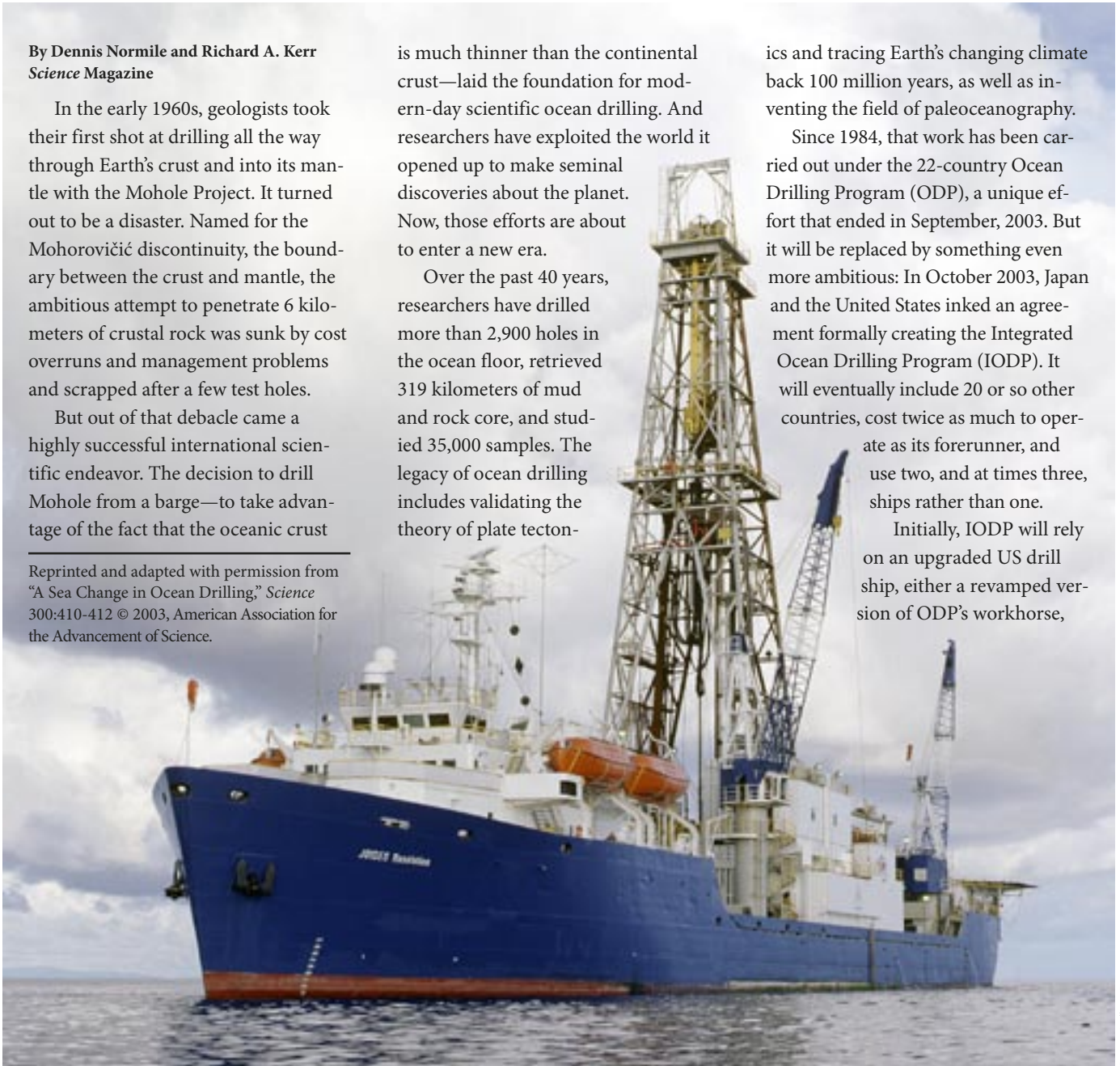
is much thinner than the continental crust—laid the foundation for modern-day scientific ocean drilling. And researchers have exploited the world it opened up to make seminal discoveries about the planet. Now, those efforts are about to enter a new era.

Over the past 40 years, researchers have drilled more than 2,900 holes in the ocean floor, retrieved 319 kilometers of mud and rock core, and studied 35,000 samples. The legacy of ocean drilling includes validating the theory of plate tecton-

ics and tracing Earth's changing climate back 100 million years, as well as inventing the field of paleoceanography.

Since 1984, that work has been carried out under the 22-country Ocean Drilling Program (ODP), a unique effort that ended in September, 2003. But it will be replaced by something even more ambitious: In October 2003, Japan and the United States inked an agreement formally creating the Integrated Ocean Drilling Program (IODP). It will eventually include 20 or so other countries, cost twice as much to operate as its forerunner, and use two, and at times three, ships rather than one.

Initially, IODP will rely on an upgraded US drill ship, either a revamped version of ODP's workhorse,



Ocean Drilling Program

Since 1985, the research vessel JOIDES Resolution has been the workhorse for scientific ocean drilling. Through 2003, the 470-foot-long ship with its 202-foot derrick has drilled more than 1,800 holes in the ocean crust and retrieved samples at some 670 sites.

the *JOIDES Resolution*, or a new vessel with similar capabilities. By late 2006, it will be joined by a brand-new ocean drilling vessel, Japan's *Chikyu*, equipped with technology that will allow it to literally break new ground.

Together, the two ships will enable earth scientists to bore more and much deeper holes than is currently possible and in locations that are now inaccessible. There are even going to be "mission-specific platforms" that will drill niche locations such as the icy Arctic Ocean and shallow coastal waters.

A new drillship for a new era

The biggest change in operational capabilities will come when the 210-meter, 57,500-ton, \$475 million *Chikyu* starts drilling. For all its achievements, the *Resolution* has serious limitations. It can't drill in shallow water or farther down than 2 kilometers. Nor can it tolerate the icy conditions of the Arctic Ocean. What's more, sedimentary basins have been largely off-limits because oil and gas deposits have posed safety and environmental hazards.

The *Chikyu* will overcome some of these constraints. It will have a second pipe, called a riser, that will enclose the drill pipe and allow circulation of a heavy but fluid drilling mud that will flush debris from deep holes and shore up unstable sediments. The arrangement will also protect against blowouts when the bit penetrates pressurized oil or gas deposits. Attempts at drilling very deep holes using the *Resolution* were frustrated by the friction and by debris piled up in the hole.

"Because of the capabilities of the riser vessel, [all sorts of drilling] projects will be more viable," said Hisatake Okada, a paleoceanographer at Hokkaido University in Sapporo.

But all of this comes at a steep price. The annual budget of ODP ran about \$80 million, with 60 percent of that sum put up by the US National Science Foundation (NSF) and the rest split among the other member countries. Countries spent additional funds to support scientists analyz-



Japan Marine Science and Technology Center and the Integrated Ocean Drilling Program

The Integrated Ocean Drilling Program's new drill ship Chikyu ("Earth" in Japanese) is launched in Tamano-shi, Japan, in January 2002. The 57,500-ton, 210-meter (689-foot)-long ship will be capable of drilling 7 kilometers (4.35 miles) below the seafloor—sufficient to reach the mantle. Its derrick was installed in September 2003 and after sea trials, Chikyu should be ready by late 2006.

ing drilling samples and data.

In comparison, IODP's annual operating budget is expected to start at \$160 million and rise depending on the amount and nature of drilling carried out. Japan and the United States will split at least two-thirds of the operating costs equally, with other countries providing the rest—and also funding mission-specific platforms.

Researchers are arguing that the scientific advances will be worth the price, from a better understanding of earthquake mechanisms and the history of global climate change to the discovery of new energy sources and unusual microbes for use in biotechnology. And governments so far seem convinced.

Exploring large igneous provinces

Ocean drilling's first significant achievement came in geophysics. "Past successes have changed our understanding of how Earth works," said oceanographer Larry A. Mayer of the University of New Hampshire, Durham. By dating rock recovered from numerous seafloor locations, researchers in the early 1970s confirmed the basic cycle of plate tectonics: New ocean crust forms at mid-ocean ridges and

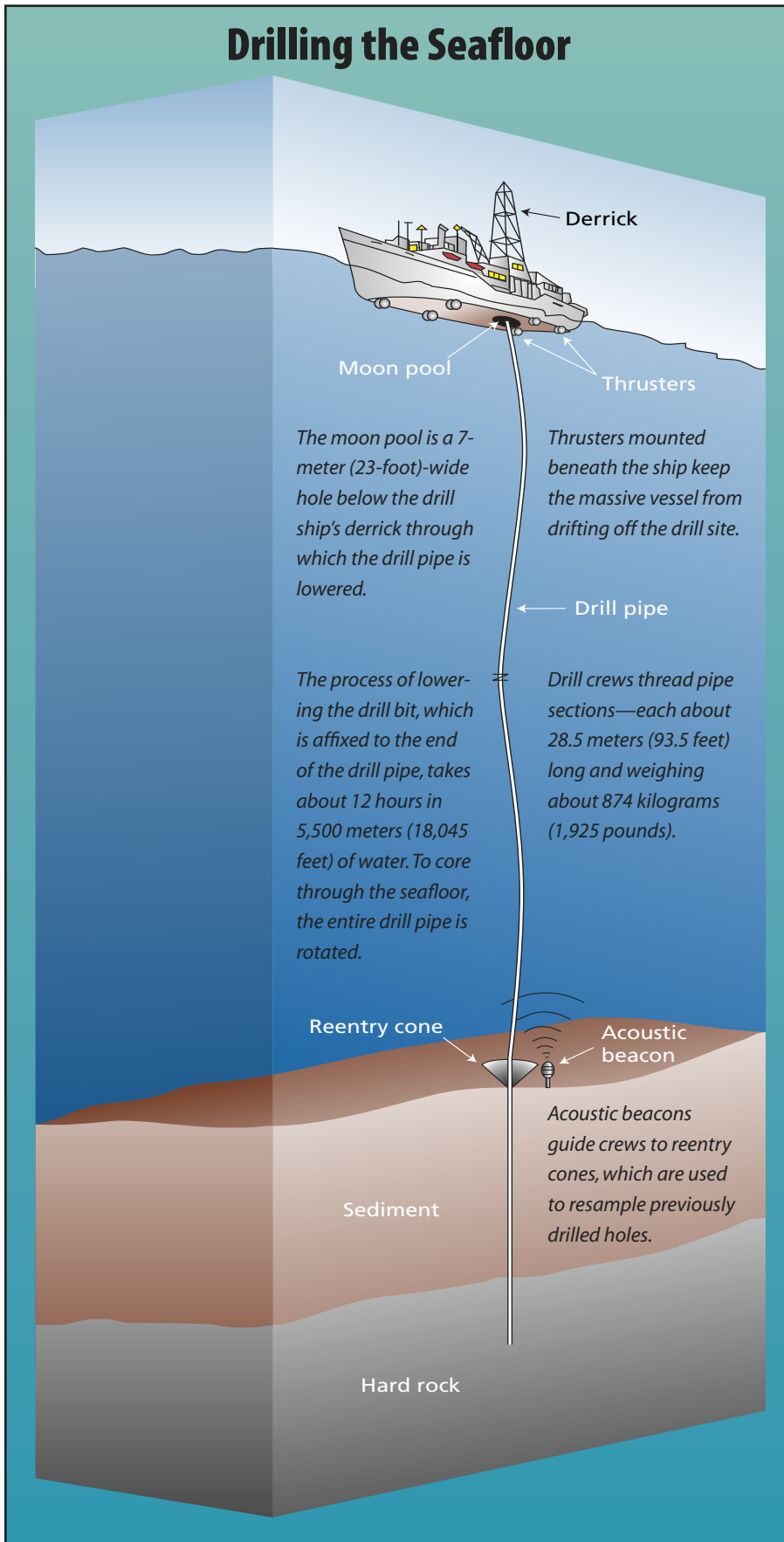
spreads outward toward deep-sea trench subduction zones. Crustal drilling also showed how great upwellings of hot rock, called plumes, could create chains of islands and seamounts such as Hawaii.

These discoveries have raised new questions about solid earth cycles and geodynamics, one of three broad themes in IODP's initial science plan. Earlier drilling showed that large parts of the crust were formed by anomalous volcanic events separate from plate tectonics.

Oceanic plateaus, so-called large igneous provinces, mostly formed during the mid-Cretaceous period 100 million to 140 million years ago when massive amounts of material burst through tectonic plates, venting heat and magmatic gases from Earth's interior. These features have as yet been barely sampled by drilling. Researchers hope that data from a combination of numerous shallow holes drilled by a riserless ship and deep holes drilled later by *Chikyu* may relate these events to Earth's evolution and reveal whether or not they triggered climactic changes that led to mass extinctions.

Another major geophysical target will be subduction zones, where the clash of sinking and overriding plates generates

Drilling the Seafloor



90 percent of the world's earthquakes.

Chikyu's first target, reached by consensus, will be the Nankai Trough subduction zone offshore of Honshu, Japan's main island.

Chikyu's riser will allow boring through the deep sedimentary deposits atop overriding plates. Those deposits were off-limits to the *Resolution* because of the danger of a blowout caused by inadvertently tapping into oil and gas deposits and by the depth of the fault target.

Gaku Kimura, a geologist at University of Tokyo, says *Chikyu* will also be able to install a new generation of instruments in the bore hole to monitor fault zone temperatures, stresses, deformation, and fluid pressures.

"This is a completely different scientific approach" to studying rock samples, said Kimura. "It's like the difference between studying a live human being and dissecting a corpse." An improved understanding of earthquake mechanisms could help Japan and other onshore communities assess the risk of future earthquakes.

IODP may even take another shot at penetrating the Mohorovičić discontinuity. With the lubricating drilling mud circulating through its riser, *Chikyu* should be able to reach 6 kilometers and into the upper mantle. Such a hole would help refine knowledge of the structure, composition, and physical properties of the oceanic crust.

Probing climate changes on Earth

Although geophysics was the prime motivation for the first ocean drilling cruises, scientists in other disciplines soon capitalized on the data obtained from the cores. "Paleoceanography is one of the strong successes of ocean drilling," said Jerry McManus, a paleoceanographer at the Woods Hole Oceanographic Institution in Massachusetts.

Paleoceanographers recognized that cores recovered from layered sediments provided clues to a variety of climatic phenomena, sometimes going back 120 million years. McManus credits ocean drilling with clinching the orbital theory of cli-

mate change over millions of years, when Earth's wobbling drove climate oscillations. It also documented extreme climates such as the thermal maximum of the late Eocene (55 million years ago) and rapid climate change.

But the use of drilling for paleoceanographic studies has been held back by the limitations of the *Resolution*. It cannot drill in water much shallower than 100 meters, ruling out the inner continental shelves and coral reefs that hold long records of climate and sea-level change. And it can't handle more than the passing bit of sea ice, which has kept it entirely out of the Arctic Ocean.

"You could lay out all the existing Arctic cores in my office," said oceanographer Theodore Moore of the University of Michigan, Ann Arbor. A successful mission to the deep Arctic, he said, would provide "an entire history from 50 million years ago to the present."

Under IODP's initial science vision, mission-specific platforms capable of



Ocean Drilling Program

Teams of scientists study seafloor core samples in sequence to reconstruct events and phenomena over millions of years of Earth history.

drilling in niche locations would play a major role in studying environmental change, processes, and effects. European scientists, for example, have obtained sufficient funding to send a drill ship to retrieve long sediment cores from the Arctic Ocean in the summer of 2004.

Seafloor fuel, sub-seafloor life

The third leg of the IODP scientific tripod, studying the deep biosphere and the sub-seafloor ocean, is also the newest. The original ocean drillers never imagined there could be life within the extreme temperatures, pressures, and chemical environments of the ocean floor. But reports of microbial colonies at seafloor vents and volcanic rifts demonstrated otherwise. Now some experts in extremophiles, as these microbes are called, believe that as much as two-thirds of Earth's microbial population may be buried in oceanic sediment and crust.

One major challenge will be to define the range of temperatures, pressures, chemistry, and other conditions under which these seafloor communities thrive and to map their geographical distribution. Researchers would also like to clarify whether these microbes get their nutrients from material that filters down from the

surface or from updrafts of fluids flowing through the interface between sediments and hard rock.

The findings "could revolutionize ideas about the origins of life," said Asahiko Taira, director-general of the Center for Deep Earth Exploration at the Japan Marine Science and Technology Center. Researchers also hope to add to the handful of industrially useful microbes already isolated from deep-sea regions.

Another underresearched area of inquiry is gas hydrates, deposits of ice-encapsulated methane. Although a potential new source of clean energy, they also could release a significant amount of greenhouse gases into the atmosphere if thawed as a result of global warming. Scientists want to learn how microbes generate the methane, how hydrates form, and whether methane can be produced at prices competitive with those of other fuels.

These intriguing questions weren't even on the radar screen of those working on the ill-fated Mohole Project. But if IODP comes up with some answers, its scientists will owe a debt of gratitude to those who conceived and carried out the first scientific attempt to probe what lies beneath Earth's oceanic crust.



Ocean Drilling Program

Rig floor personnel aboard JOIDES Resolution work round the clock recovering rock and sediments from the seafloor. Cruises usually last two months, with 50 scientists and technicians and 65 crew members aboard, including rig operators, catering crew, and merchant seamen.