G E O P H Y S I C I S T S

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Eight AGU members are among the 20 recipients of the Aldo Leopold Leadership Fellowship for 2011. The Leopold Leadership Program at Stanford University's Woods Institute for the Environment, Stanford, Calif., provides two weeklong intensive training sessions to help environmental scientists enhance their skills in communicating science to diverse audiences such as policy makers and journalists.

The AGU members who received the 2011 fellowship are **Elizabeth Canuel**, professor of marine science, Department of Physical Sciences, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Va.; **Greg Characklis**, associate professor, Department of Environmental Sciences and Engineering, University of North Carolina at Chapel Hill; **Hope Jahren**, professor, Department of Geology and Geophysics, University of Hawai`i at Manoa; **Raghu Murtugudde**, professor, executive director of the Chesapeake Bay Forecast System, Department of Atmospheric and Oceanic Science, University of Maryland, College Park; **Ted Schuur**, associate professor of ecosystem ecology, Department of Botany and Zoology, University of Florida, Gainesville; **Valeria Souza,** Investigadora Titular C, Evolutionary Ecology, Universidad Nacional Autónoma de México; **Jack Williams**, Bryson Professor of Climate, People, and the Environment, Department of Geography and Center for Climatic Research, University of Wisconsin-Madison; and **Dawn Wright**, professor of geography and oceanography, Department of Geosciences, Oregon State University, Corvallis.

In Memoriam

Celso S. Barrientos, 74, 3 November 2010, Ocean Sciences, 1963
Paul William Caton, 72, 14 October 2010, Seismology, 1973
Claire B. Davidson, 21 October 2010, Hydrology, 1983
Charles W. Dubs, 89, 31 October 2010, Magnetospheric Physics, 1975
Kathleen A. Franzen, 15 October 2010, Earth and Space Science Informatics, 2007
Jack Hannaford, 78, 29 April 2010, Hydrology, 1963
Jessica N. Roark, 26, 22 August 2010, Biogeosciences, Global Environmental Change, Hydrology, 2009
Donald Satterlund, 82, 4 December 2010, Hydrology, 1958
Melvin E. Stern, 81, 2 February 2010, Fellow, Physical Oceanography, 1988
Kyle V. Tietze, 26, 13 November 2010, Atmospheric Sciences, 2008

FORUM

The Need for Scientific Ocean Drilling

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Mark Twain once said, "I was seldom able to see an opportunity until it had ceased to be one." The scientific community could soon miss an opportunity in ocean drilling.

A recent article in *Eos* by D. K. Smith et al. (Ocean drilling: Forty years of international collaboration, *Eos, 91*(43), 393–394, 2010) summarized the history of scientific ocean drilling and presented an overview of the Integrated Ocean Drilling Program (IODP) as it currently operates. IODP will end in 2013, and an ambitious science plan is being developed to launch a new drilling program. Some people have asked, Given the program's past successes, why do we need more scientific ocean drilling?

The simple answer is that drilling is the only way to directly access the Earth beneath the ocean—a capability that is fundamental if we are to advance our understanding of dynamic Earth processes on geological to societal time scales. Scientific ocean drilling began with sampling of the ocean crust in the 1960s. Although it did not achieve its eponymous goal of drilling through the Earth's crust into the Mohorovičić discontinuity, Project Mohole opened an exploratory window into subseafloor records of global processes and Earth history that changed the way Earth system science is conducted and made possible a series of wide-ranging and profound advances in our understanding of the Earth. These include successful testing of plate tectonics theory, documenting the origin of ice ages and the history of carbon dioxide (CO_2) concentrations in the atmosphere and ocean, characterizing global sea level history, developing and evaluating models for lithospheric creation and evolution, the beginning of quantifying mechanisms for triggering earthquakes and other geohazards, and assessing the limits of life in the deep biosphere.

These and other studies have served society by providing practical knowledge for decision makers, educators, and industry. For example, understanding past sea level changes guides the search for energy resources. Knowing why climate changed in the past informs projections of future conditions. Understanding the mechanisms by which earthquakes are triggered and release energy is essential for improving hazard assessment and planning.

Furthermore, scientific ocean drilling creates opportunities, leverages scarce resources, and distributes benefits across numerous disciplines. Ocean drilling trains students and researchers at all professional stages, helping them to develop interdisciplinary skills; facilitates international collaboration; and captures the imagination of the public. Ocean drilling empowers individual investigators and small teams by providing access to state-of-the-art tools and expertise to address global questions.

Scientific ocean drilling has never been more relevant, more essential, or more transformational than it will be in the next 10–20 years. But its future is uncertain, particularly given the shaky state of the global economy and limitations in scientific research budgets.

What If There Were No Scientific Ocean Drilling Program?

Consider the consequences for the Earth, ocean, and life sciences of having no drilling capability. Researchers, students, and educators would be deprived of access to samples and data that cannot be obtained through any other means, and would be unable to develop new subseafloor observatory and experimental systems. Fundamental hypotheses about how the Earth works, many derived from remote sensing of its interior, could not be directly tested. While there remains considerable information to be mined from existing ocean drilling cores and data, there would be virtually no opportunity to investigate newly identified drilling targets, apply improved sampling and measurement techniques to collect higher-quality materials and data, or install borehole instruments for monitoring geologic hazards and active chemical, biological, hydrological, and tectonic processes.

Without scientific ocean drilling, there would be no ability to exploit the long-term, high-resolution climate archive in the oceans. Reconstructing continuous past climate records would be limited to ice sheet cores, which go back only about 1 million years; lake cores; and shallow marine sediment cores limited to a maximum of about 50–60 meters with modern technology (e.g., using the R/V *Marion Dufresne* and the R/V *Knorr*). Ocean drilling has made possible the development of an orbitally tuned time scale that reaches back over 45 million years, and additional drilling is planned to push this understanding back into the Cretaceous (145–65 million years ago). Without ocean drilling, records of past warm periods in Earth's history that most closely resemble conditions predicted for the next few centuries would be virtually inaccessible, and models that predict future climate and sea level change would be much harder to test, calibrate, or, most important, improve. This would significantly limit advances in paleoceanography, paleoclimatology, and climate dynamics.

Earth scientists and others have long sought to complete a full penetration of the ocean crust, the formation of which comprises the (volumetrically) most important magmatic process on the planet. Ocean drilling now has the technology to make this vision a reality. Without the ability to drill deep holes into crust and mantle rocks, future research would be limited largely to geophysical imaging, dredging of surface rocks, and examination of in situ sections in tectonically anomalous regions where deeper parts of the crust and the upper mantle are exposed at the seafloor. While uplifted fragments of old oceanic crust in ophiolite sequences on land provide complementary information, in situ stratigraphic sections of oceanic basement to test models of formation and evolution of the crust under different magmatic and tectonic conditions would not be obtainable.

Recent ocean drilling expeditions have facilitated major advances in the life sciences, including the discovery of a massive hidden biome buried alive below the ocean floor. Researchers have just begun to explore this largely unknown biological reservoir and can only speculate as to what it means for the function of the Earth system as a whole. The second ocean drilling expedition dedicated to the study of subseafloor life was recently completed in the western Pacific Ocean, and the third, planned for later this year, will install a series of long-term borehole observatories designed to elucidate the activity and function of subseafloor life in the volcanic upper crust. Without scientific ocean drilling, studies of this kind would be impossible, and the function, limits, and consequences of the deep biosphere would remain enigmatic.

Over the past decade, advances in subseafloor borehole observatories have transformed the nature of scientific inquiry during ocean drilling. It is now possible to quantify in situ conditions; examine properties that link subseafloor hydrogeology to mechanical, thermal, chemical, and microbiological processes; and measure system responses to natural and induced perturbations. Through this extended use of boreholes as natural laboratories, the community is poised to address critical questions concerning vast global fluid flow through oceanic lithosphere, its influence on the deep biosphere and carbon cycling and sequestration, and the nature and distribution of strain accumulation and release at plate boundaries. Without scientific ocean drilling, these innovative, emerging approaches would be stalled before reaching their full potential, leaving no opportunity for strategic placement of new boreholes as part of broader experiments.

A Vision Beyond 2013

The science plan for a new ocean drilling program is nearing completion. This plan focuses on a suite of urgent, fundamental, and societally relevant scientific problems. They include pressing questions about the sensitivity of Earth's climate system to variations in atmospheric greenhouse gas concentrations; the response of life to environmental forcing; the interactions of Earth's crust and mantle with the oceans and atmosphere; slope instabilities and mechanisms of earthquake triggering and other geohazards; the potential for long-term storage of excess CO_2 in subseafloor reservoirs; and the motions of fluids that lead to vast flows of heat, chemicals, and microbial materials.

The science plan also recognizes that there will continue to be substantial overlaps and valuable synergies with other Earth, ocean, and life science initiatives around the world. While these collaborations may take many forms, ocean drilling will be particularly important in seafloor observatory programs, especially in characterization and long-term monitoring of subseafloor physical, chemical, and biological processes and in active experimentation. A strong foundation of observatory science in coordination with other international programs must be a priority.

While the plan for scientific ocean drilling beyond 2013 proposes to break new ground scientifically and technically, it also retains key elements that have made past drilling programs successful. The new program will maintain access to multiple drilling platforms, managed by national and international teams for the benefit of and access by the community at large. The program will consider proposals developed by independent teams of researchers, each of which will be evaluated through peer and panel review and feedback. The best ideas will find a place on the drilling schedule, and the program will remain flexible and ready to adapt to new discoveries and paradigms. Most important, scientific ocean drilling will drive transformational discovery through sampling, monitoring, and active experimentation. Continued access to ocean drilling capabilities is essential if we are to advance our understanding of dynamic Earth processes on geological to societal time scales.

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