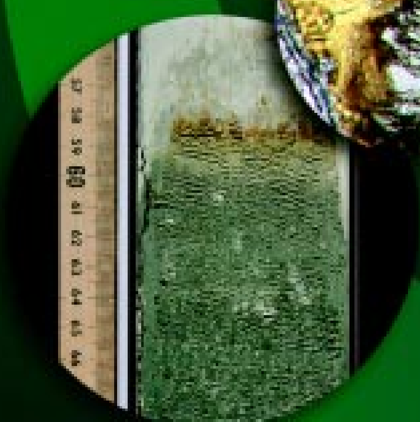
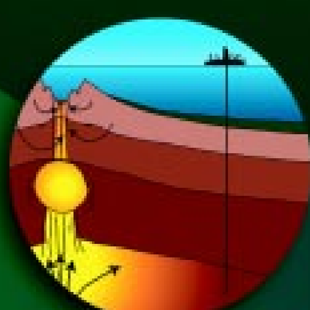
United States Participation in the

Integrated Ocean Drilling Program

2003-2013



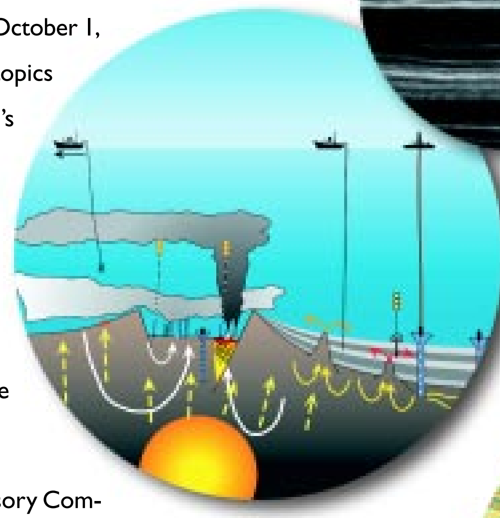


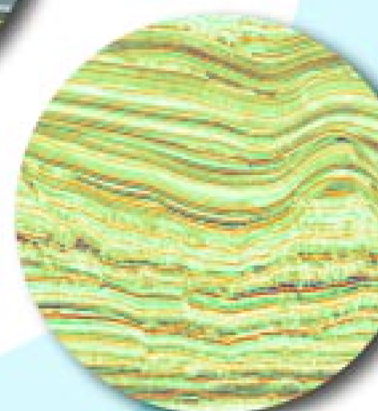
Opposite Page. Top: Ultrahigh resolution marine sedimentary records provide opportunities to evaluate the global operation of the ocean-atmosphere system on human time scales. This laminated sedimentary sequence recovered from the Saanich Inlet off Vancouver Island is an example of a marine core revealing sub-annual climate information. Figure courtesy of Brian Bornhold, Geological Survey of Canada and John Firth, Ocean Drilling Program. **Middle:** A wide array of borehole, seafloor, and sea-surface experiments could be integrated within one or more crustal settings to determine fluid-flow pathways within the oceanic crust at a mid-ocean ridge. Multidisciplinary experiments such as this will help leverage the maximum possible scientific return from drilling. Figure modified from the COMPLEX report, JOI, May 1999. **Bottom:** High-resolution seismic records, such as this section of the New Jersey slope, document the regional history of sedimentation, and are required to site drill holes and avoid potential drilling hazards. Figure courtesy of Gregory Mountain, Lamont-Doherty Earth Observatory.

The Integrated Ocean Drilling Program...

is an international scientific venture addressing global Earth system problems, enhancing progress in a broad range of programs in basic and applied research, information technology, and science education. IODP will collect samples of sediments, rocks, biota, and fluids from beneath the seafloor in environments and at depths never before attempted, and deploy state-of-the-art downhole-measurement devices and long-term seafloor observatories. IODP's exploration relies on multiple drilling platforms with global access, including a non-riser drillship provided by the United States, a riser drillship provided by Japan, and mission-specific platforms, all using the most advanced sampling and observing technologies available. IODP begins on October 1, 2003.

U.S. Leadership in IODP





The Integrated Ocean Drilling Program (IODP), which begins on October 1, 2003, will contribute fundamental scientific knowledge to the topics of climate change, geologic hazards, energy resources, and Earth's environment. These are global issues that directly affect our nation's health and prosperity and require integrated, international solutions. The scientific and organizational framework for IODP's first decade is described in its Initial Science Plan (ISP), *Earth, Oceans and Life: Scientific Investigation of the Earth System Using Multiple Drilling Platforms and New Technology* (see www.iodp.org).

The Joint Oceanographic Institutions/United States Science Advisory Committee (JOI/USSAC) has reviewed the ISP's goals and has evaluated how scientific ocean drilling achievements to date have set the stage for this new age of exploration and discovery. We endorse and promote full U.S. participation in IODP. Strong U.S. leadership in IODP will ensure that the best science is pursued, innovation is incorporated, technical operations run smoothly, and scientific exploration culminates in synthesis and integration. Implementing IODP's vision requires significant subseafloor sampling, measurements, and experiments conducted from multiple platforms. U.S. leadership begins with U.S. provision of one principal drilling vessel for the program supported by multi-year U.S. funding contributions to IODP's annual operating costs.

U.S. scientific achievement in the international IODP will depend on a strong national program to support the participation of individual U.S. scientists. In the past this has included support for U.S. scientists to participate in drilling expeditions, to research and publish scientific results, to develop drilling-related technology, to characterize the seafloor prior to drilling, to participate in workshops and international planning activities related to scientific ocean drilling, and to pursue a targeted array of educational programs. This support has been provided by the National Science Foundation (NSF) through grants for unsolicited proposals and through a cooperative agreement with Joint Oceanographic Institutions (JOI). JOI is advised on the allocation of these support funds by JOI/USSAC, a committee of volunteer scientists, which is currently considering the elements of a new U.S. science support program.

Peggy Delaney

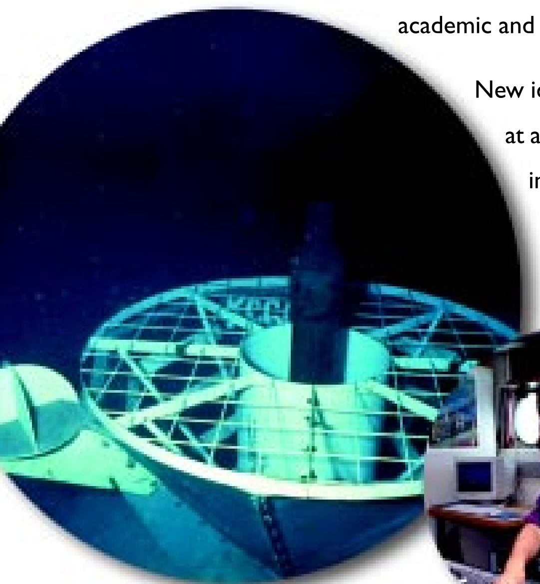
Margaret L. Delaney

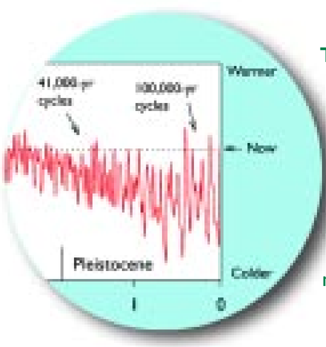
Chair, on behalf of the JOI/U.S. Science Advisory Committee

U.S. Participation

IODP will provide samples and data to significantly advance our understanding of fundamental geoscience problems. An expanded capability to drill, core, and conduct downhole experiments will encourage imaginative tests of existing ideas and will germinate novel hypotheses. U.S. scientists can participate in IODP in numerous ways and at all levels. The most active and direct way is as a shipboard scientist on one of IODP's drilling platforms; no prior seagoing experience is required. Marine technicians will operate equipment in the dozen or more shipboard laboratories on the two major vessels, permitting scientists to concentrate on data analysis, integration, and initial publication of scientific results. Shore-based scientists can acquire and analyze IODP samples and data by requesting material from the appropriate IODP core and digital data repositories. U.S. scientists will benefit from international research collaborations and from potential partnerships between academic and industry scientists built around mutual interests.

New ideas and approaches to solving Earth system problems can be incorporated into the program at any time. Writing a proposal or serving on an IODP panel or as a reviewer requires only interest in the application of scientific ocean drilling to solve geoscience problems and the scientific and technical expertise to provide guidance to help the program's structure make the best decisions. All submitted proposals will be peer reviewed by IODP panels and by outside experts (see www.iodp.org/isas), ensuring that the best science drives the program. By blending new scientific perspectives and technology with international collaborations, IODP will create numerous opportunities for participation by U.S. scientists in an increasingly broad range of disciplines.





Top: A key IODP goal is to use boreholes to understand subseafloor fluid flow by directly sampling the fluids and by conducting borehole experiments. Scientists from the United States and Canada worked with Ocean Drilling Program (ODP) engineers to develop the "CORK," which keeps ocean water from flowing into the borehole, and which records *in situ* borehole conditions (e.g., temperature and pressure). New "Advanced" CORKs are being developed for IODP. Photo courtesy of Keir Becker, University of Miami. **Middle:** Shipboard scientist working in a *JOIDES Resolution* shipboard laboratory. **Bottom:** Geochemical analysis of microfossils preserved in Pacific sediments shows climate fluctuations over the last several million years. While preliminary analysis of samples is made on board ship, more detailed sample analyses are made in onshore laboratories. Figure courtesy of Alan Mix, Oregon State University.

IODP
Initial Science Plan

IODP Science Themes

- The Deep Biosphere and the Subseafloor "Ocean"
- Environmental Change, Processes, and Effects
- Solid Earth Cycles and Geodynamics

Scientific plans for the first ten years of the new Integrated Ocean Drilling Program were distilled from a multi-year, international, collaborative effort involving extensive U.S. participation. IODP's three principal scientific themes and eight initiatives address fundamental questions about Earth history and processes, and are linked to major issues such as climate, energy, and geologic hazards. Progress on these themes and initiatives requires access to global samples of sediments, rocks, fluids, and biota buried at great depth below the seafloor. Some studies also require *in situ* geophysical measurements or long-term observatories emplaced in deep seafloor boreholes, which can only be accomplished by scientific ocean drilling.

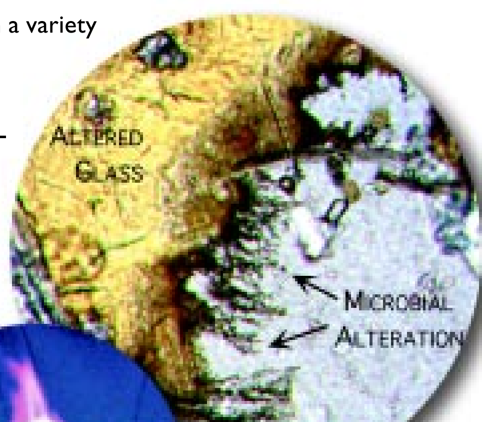
The Deep Biosphere and the Subseafloor "Ocean"

Initiatives

- Deep Biosphere
- Gas Hydrates

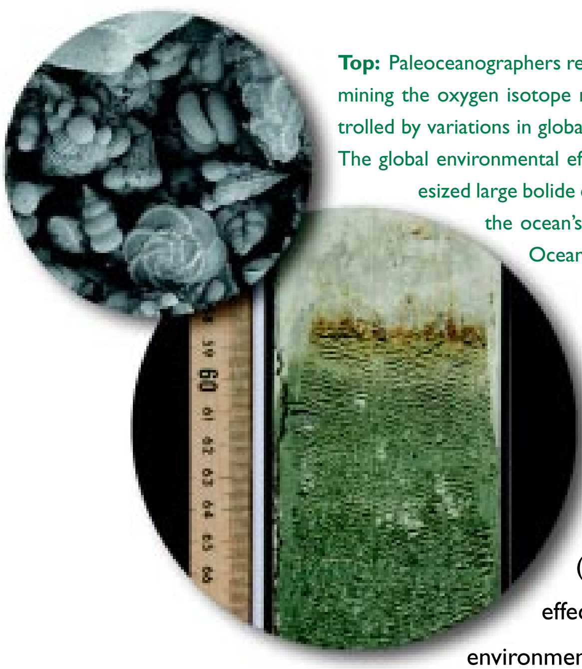
Fluids and gases occupying and flowing through fractures and pore spaces in the seafloor have an impact on a wide range of physical, biological, and geochemical processes. Water in the subseafloor transports heat and chemicals through virtually every marine geologic environment. Fluids in oceanic sediments and crust that enter subduction zones periodically weaken earthquake-generating faults in these areas, and they can support an extensive microbial population. Gases (such as methane) produced by microbial activity and by thermal maturation of organic matter combine with water to form enormous reservoirs of gas hydrate and associated free gas. The deep biosphere may comprise as much as two thirds of Earth's entire bacterial biomass, and gas hydrates may contain twice the carbon of all known hydrocarbon resources. Quantifying the role of water in the deep biosphere and in gas-hydrate generation requires drilling deeply, using the IODP's capabilities to continuously sample sediment, rock, and interstitial fluids at substantial depths and in a variety of environments.

Scientists have just begun to study the effects of changes in seawater temperature, pressure, pH, and redox potential on the quantity and variety of microbes in the subseafloor. Basic research must focus on microbial community structures, turnover rates, and adaptation to a wide range of energy sources. Isolation of bacteria from extreme environ-



Top: Example of microbially mediated alteration of volcanic glass from a core sample. Drilling data support the notion that deep microbes may comprise as much as two-thirds of Earth's entire bacterial biomass. Image courtesy of ODP Leg 187 Science Party. **Bottom:** Because of the large amount of methane in gas hydrates, they have been called "the ice that burns." Core analysis suggests that global warming of the surface and deep ocean by 3° to 7° precipitated the massive release of methane from marine sediments into the atmosphere and a major extinction event at about 55 million years ago. Photo courtesy of Marta Torres and Anne Trehu, Oregon State University.

ments such as active hydrothermal fields provided enzymatic catalysts for the polymerase chain reaction used in genetic research and the biotechnology industry. Microbial genotypes older than 5 million years, preserved deep below the seafloor, remain largely unexplored. Gas hydrate research in IODP will aim to quantify the rate at which gas is generated, determine the link between the gas and the organic carbon source material as well as the microbial community, quantify the rates of gas migration through the sediments, and establish the mechanisms of gas entrapment in seafloor sediments. Gas hydrate destabilization may be linked to submarine landslides and global changes in climate through the release of methane, a potent greenhouse gas.



Top: Paleoceanographers reconstruct past changes in environmental conditions by determining the oxygen isotope ratio of microfossils' calcium carbonate shells, which is controlled by variations in global ice volume, sea surface temperature, and salinity. **Bottom:** The global environmental effects of some meteorite impact events, such as the hypothesized large bolide collision with Earth 65 million years ago, are well-preserved in the ocean's sediment. Photos courtesy of Richard Norris, Woods Hole Oceanographic Institution.

Environmental Change, Processes, and Effects

The threat of global warming presents the United States with a serious and controversial political-economic issue, but instrumental records of climate are far too short (~100 years) to discriminate clearly between natural variability and anthropogenic effects. Ocean sediments, at all water depths, contain an important archive of Earth's environmental change. Analysis of this record has contributed significantly to our understanding of the causes and consequences of natural variability in climate and ocean biogeochemistry. Information from sediment cores has provided hard evidence that Earth has experienced periods of extremely warm climates comparable to, or exceeding, those predicted for our immediate future. Recent discoveries demonstrate that climate can shift far more abruptly than previously thought, with some transitions to warmer climates occurring in less than a decade.

Initiatives

- Rapid Climate Change
- Extreme Climates

Deciphering the history, impacts, and implications of global environmental change requires detailed sampling of high-quality marine records. Some mechanisms of change are internal to Earth's system (e.g., tectonic uplift of mountain belts), and others are external (e.g., the effects of Earth's orbital variations on insolation). Sediments recovered in a greater variety of oceanic environments, from the equatorial to subpolar regions and the largely unsampled Arctic Ocean, will permit exploration of the interplay of these mechanisms in initiating global environmental change, the global propagation of these changes, and the circumstances that reduce or amplify the effects of environmental change. IODP will investigate how extreme perturbations of climate, including unusually warm intervals and rapid transitions, trigger changes in sea-surface temperature, deep-water circulation, biogeochemical cycling, community evolution, and extinction. The resolution of IODP sediment records must be able to resolve environmental variability at time-scales approaching that of present-day instrumental records of climate and biogeochemical change, providing an indispensable context for evaluating contemporary anthropogenic effects on the environment.

Solid Earth Cycles and Geodynamics

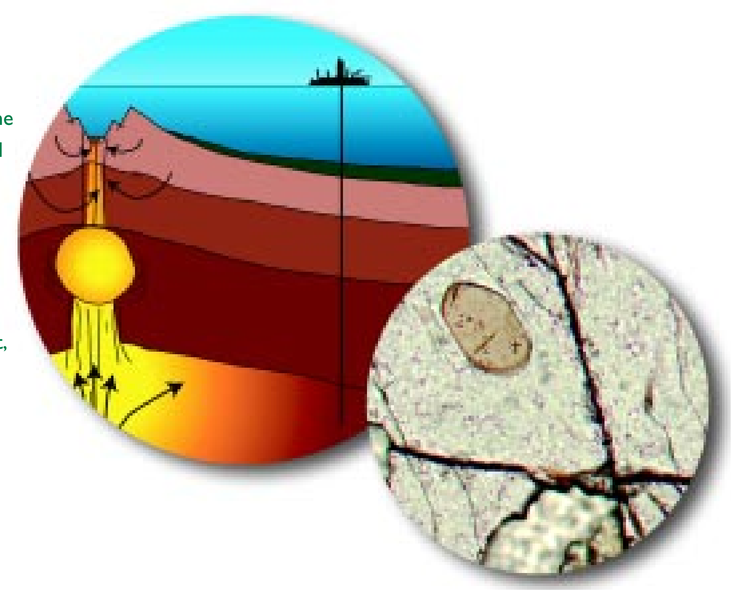
Motion of Earth's lithosphere is a driving force for global change on both geologic and human time scales. The creation and evolution of oceanic crust affects geochemical interactions among Earth's mantle, crust, hydrosphere, atmosphere, and biosphere. Continental breakup forms sedimentary basins that host many of the world's most productive petroleum reservoirs. Voluminous eruptions of magma, which produce large igneous provinces, contribute to shifts in global climate. In addition, events of tremendous destructive power (earthquakes, volcanic eruptions, tsunamis) punctuate the solid Earth cycle every year; their environmental effects can be both dramatic and profound.

Oceanic crust records a 200-million year history of upper mantle melting and thus contains important information about mantle flow and motion within Earth's interior. To date marine sampling programs have concentrated on younger portions of that record, covering the upper 30% of the total crustal depth range. Samples of oceanic crust across broader and deeper ranges could revolutionize our view of mantle melting and flow. Such samples will also shed light on poorly understood geochemical interactions between the mantle and crust, clarify the three-dimensional nature of hydrothermal circulation, and help resolve apparent discrepancies between rock stratigraphy and seismic stratigraphy.

Of more immediate concern is that virtually all of the major metropolitan areas within California, the Pacific Northwest, and Alaska fall within zones of high risk for large-magnitude earthquakes and/or violent volcanic eruptions. Although present-day plate motions can be monitored accurately using modern geodetic instruments, prediction of sudden strain releases requires fundamental knowledge of *in situ* physical and chemical conditions in fault zones that lead up to sudden rupture. Similarly, measurements of volatile fluxes through subduction zones could improve our ability to understand and predict explosive volcanic eruptions in the Aleutian Islands and Cascade Range. In addition to obtaining samples, IODP drilling will emplace borehole observatories that will provide long-term monitoring of fluid flow and strain release, contributing significantly to our understanding of these processes.

Initiatives

- Continental Breakup and Sedimentary Basin Formation
- Large Igneous Provinces
- 21st Century Mohole
- Seismogenic Zone



Top: IODP's 21st Century Mohole initiative will directly sample rocks from the lower crust and upper mantle, which has never before been achieved. Drilling and geophysical logging in this seafloor environment will open a window into Earth's interior and should provide new constraints on Earth's evolution. Figure courtesy of Yoshiyuki Tatsumi, Kyoto University. **Bottom:** A basaltic melt inclusion, 0.1 mm long, trapped in an olivine crystal from a drillhole on the Southeast Indian Ridge. Such inclusions frequently record early stages of magma evolution. IODP's non-riser and riser drillships will permit enhanced core recovery in these difficult, hard-rock environments. Image courtesy of ODP Leg 187 Science Party.

Enhanced
Coring, Drilling, and Recovery

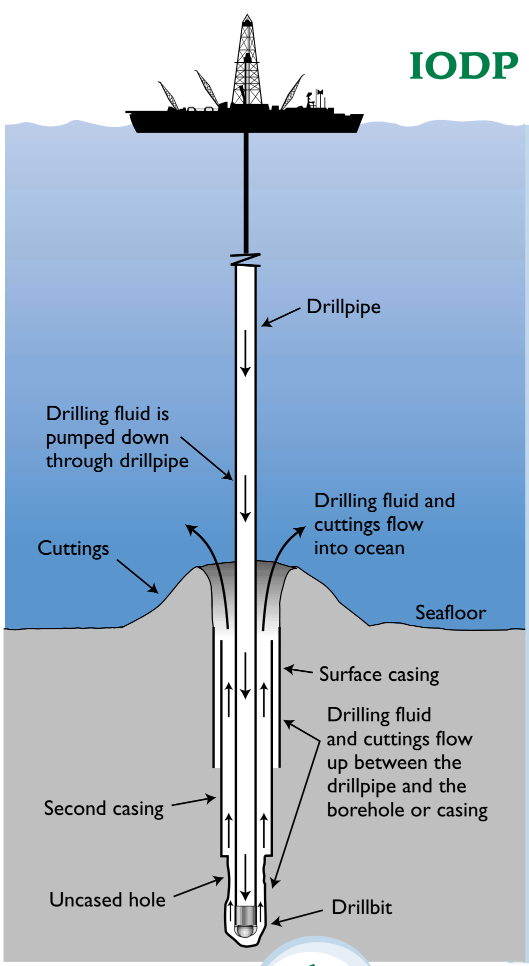
Conceptual Design Committee (CDC)

JOI/USSAC appointed the CDC to define the performance specifications for IODP's new, non-riser vessel. The complete report is available at www.joi-odp.org/USSSP/cdc. This report has been offered for international comment through the IODP planning structure.

Achieving a majority of U.S. scientific goals in IODP will require year-round operation of a non-riser drilling vessel capable of global operation in a wide range of water depths. As part of its initial commitment to the IODP planning process, NSF plans to seek the resources to provide capitalization costs for the non-riser vessel. NSF intends to issue a request for proposals for the vessel in early 2002, and this vessel should be ready for international program operations in 2005.

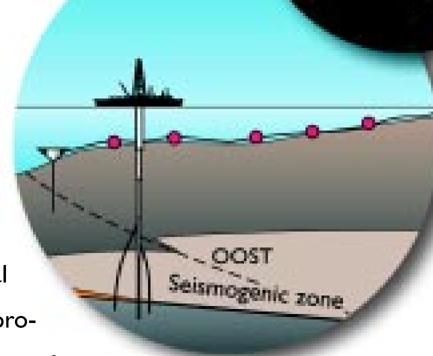
The U.S. scientific drilling community recommends that the non-riser scientific drilling vessel be of a class similar to the ODP's drillship, *JOIDES Resolution*, but with significantly enhanced coring and drilling capabilities. The vessel's enhanced capabilities will permit scientific advances that have, to date, been limited by technology. The shipboard laboratory and office space of this U.S.-supplied vessel would be 50% greater than currently available on *JOIDES Resolution*, allowing capture of important and ephemeral core-based properties at sea. While the use of multiple platforms will be coordinated by IODP's international science advisory and management structures, to maximize operational efficiency and scientific return, the United States would be responsible for operating the new non-riser, continuous coring vessel.

IODP Non-Riser Drilling Platform



	CDC Vision
Operating region	global
Standard Leg Duration	up to 8 weeks without resupply/port call
Laboratories	1800 m^2 of versatile space
Special Use Container Labs	space for 5 standard laboratory vans
Geophysics Lab	50 m^2 at stern
Accommodation	60 scientists and technicians
Drilling/Coring/ Capabilities	• continuous sampling • stable holes • minimal disturbance and contamination of cores • high recovery in all subseafloor environments
Downhole Measurements	availability of a wide range of downhole logging tools
Maximum Deployable Drillstring Length	11000 m (water depth + seafloor penetration)
Water Depth — Operational Limits	10's of m to 7000 m
Penetration Depth	> 2000 m

Top: Engineers connecting cables to borehole seismometers emplaced by ODP in support of the Ocean Seismic Network, one of several new ocean observatory initiatives. Photo courtesy of ODP. **Bottom:** IODP's Seismogenic Zone initiative, which will permit an enhanced understanding of *in situ* conditions leading up to fault rupture at subduction zones, addresses several MARGINS program objectives. OOST is an out-of-sequence thrust fault, which may slip to generate tsunamis. Figure reprinted from the COMPLEX report, JOI, May 1999.



Common Goals

IODP will provide numerous opportunities to collaborate with other U.S. scientific programs and with industry. Scientific ocean drilling sediment cores provide long and continuous records of climate fluctuations in support of our country's global environmental change programs. Currently, scientific ocean drilling technology can provide researchers with samples of gas hydrate, an important potential energy resource, from the subseafloor at *in situ* pressures. Microbes recovered from deep below the seafloor by scientific ocean drilling may be a source of new biomaterials and ideas for the biotechnology and pharmaceutical industries. Drilling is required for installing borehole observatories that will monitor pore pressure, temperature, stress and strain, and fluid chemistry at great depth below the seafloor, providing critical data to programs studying tectonically active continental margins and global seismic activity. As hydrocarbon exploration within the U.S. Exclusive Economic Zone expands into deeper water, opportunities for intellectual and technological collaboration with the offshore drilling industry should grow. Scientific ocean drilling recovers continuous sections and pristine samples, and obtains measurements, that would otherwise be inaccessible to these programs.

Program Links

NSF Program or Initiative	Scientific Objectives	IODP Drilling Connections
Biocomplexity in the Environment	sample the products of complex interactions among human, biological, geological, and climate systems over extended periods of time, and characterize the dynamics of biogeochemical cycles	acquire samples of solids, fluids and biota
Earth System History (ESH)	determine Earth's response to rapid climate change, extreme warm conditions; evaluate Arctic paleoclimate	acquire high-resolution sediment cores
Life In Extreme Environments (LexEn)	understand microbial systems on Earth, particularly with respect to mechanisms that allow survival under extreme conditions	acquire samples of solids, fluids, biota from great depths; *in situ* measurements
MARGINS	understand the evolution of rifted continental margins, sedimentary systems from source to sink, seismogenic zone dynamics, and cycling of solids, aqueous fluids, and gases throughout subduction zones	use non-riser and riser drilling platforms for sample acquisition (including fluids); *in situ* measurements, borehole observatories
Ridge Interdisciplinary Global Experiments (RIDGE)	characterize the eruptive history of mid-ocean ridges and explore the extent of the subseafloor biosphere in igneous rock	acquire borehole samples; install borehole observatories
Observatories	understand mantle dynamics, Earth's deep interior, plate deformation, subseafloor fluid flow	acquire borehole samples; install borehole observatories

Education and Outreach

Because of its interdisciplinary nature and its diverse international flavor, IODP is an ideal mechanism for teaching Earth system science to U.S. students and teachers at all curriculum levels. Through a comprehensive education and outreach program, IODP will inform the public of important discoveries that connect them more closely to the environment and that can be used to invigorate classroom experiences. Many IODP scientific themes, such as global environmental change, deep biosphere, earthquake initiation and crustal rupture, energy and mineral resources, and high-latitude exploration, are relevant to issues currently facing humankind. Discussion and analysis of these issues can be brought into the classroom or home by innovative communication of IODP results. Potential delivery mechanisms include using the drilling platforms as distance-learning classrooms and developing instruction modules using visualization technology, virtual shipboard laboratories, and digital libraries.

During IODP, the U.S. scientific ocean drilling community plans to continue several successful JOI/USSAC educational programs. These programs include support for graduate fellowships, a distinguished lecturer series, and an undergraduate trainee program. A U.S. program of science support will continue the tradition of sailing graduate students and post-doctoral researchers on virtually every drilling leg. Often, the national and international scientific collaborations that are cultivated by these students on board ship last a lifetime.

Top: ODP undergraduate student trainee, Ericka Olsen of the University of Pennsylvania, examines a core as it goes through *JOIDES Resolution's* cryogenic magnetometer. Ericka worked as a paleomagnetist on an expedition to the Japan Trench. **Middle:** The JOI/U.S. Science Support Program supported development of two interactive, educational CD-ROMs geared toward high school students and undergraduates. Accompanying teachers' manuals provide additional supporting documentation and classroom exercises. **Bottom:** Advances in wireless communication will permit IODP to link drilling platforms and scientists to the world, enhancing a variety of education and public outreach activities such as simulations of shipboard activities via virtual reality, distance learning programs, and real-time links from drilling platforms to home or school desktop computers.

Joint Oceanographic Institutions is a consortium of U.S. academic institutions that brings to bear the collective capabilities of the oceanographic institutions to plan and manage ocean science research. Established as a private, nonprofit corporation in 1976, JOI facilitates and fosters the integration of program and facility requirements for the oceanographic community, makes the case for support, and arranges for appropriate management either through individual institutions or by JOI itself. Currently, JOI manages the international Ocean Drilling Program (ODP), the U.S. Science Support Program associated with ODP (JOI/USSSP) and the Secretariat for the Nansen Arctic Drilling Program.

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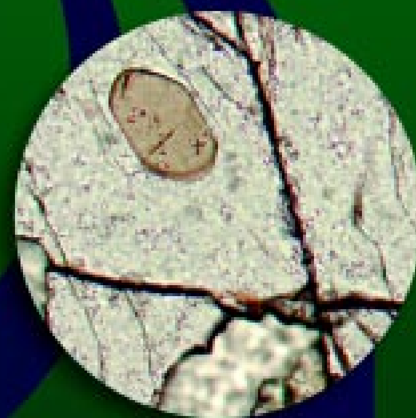

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