

# PROCEEDINGS OF THE OCEAN DRILLING PROGRAM

## VOLUME 106/109 SCIENTIFIC RESULTS

### MID-ATLANTIC RIDGE

Covering Legs 106 and 109 of the cruises of the Drilling Vessel *JOIDES Resolution*,  
St. John's, Newfoundland, to Malaga, Spain, Sites 648-649,  
27 October 1985-26 December 1985  
Dakar, Senegal, to Bridgetown, Barbados, Sites 395, 648, 669, and 670,  
17 April 1986-19 June 1986

#### Leg 106

Robert S. Detrick, Jose Honnorez, Andrew C. Adamson, Garrett W. Brass, Kathryn M. Gillis,  
Susan E. Humphris, Catherine Mevel, Peter S. Meyer, Nikolai Petersen, Martina Rautenschlein,  
Tsugio Shibata, Hubert Staudigel, Anita L. Wooldridge, and Kiyohiko Yamamoto

#### Leg 109

Wilfred B. Bryan, Thierry Juteau, Andrew C. Adamson, Laurie K. Autio, Keir Becker,  
M. Mansour Bina, Jean-Philippe Eissen, Toshitsugu Fujii, Timothy L. Grove,  
Yozo Hamano, Rejean Hebert, Stephen C. Komor, Johannes Kopietz,  
Kristian Krammer, Michel Loubet, Daniel Moos, and Hugh G. Richards  
*Shipboard Scientists*

Andrew C. Adamson  
*Shipboard Staff Scientist*

Editorial Review Board:  
Andrew C. Adamson, Keir Becker, Wilfred B. Bryan,  
Robert S. Detrick, Jr., Jose Honnorez, Thierry Juteau

Prepared by the  
OCEAN DRILLING PROGRAM  
TEXAS A&M UNIVERSITY

Norman J. Stewart  
*Volume Editor*

in cooperation with the  
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and  
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# Foreword

By the National Science Foundation

The scientists of the Ocean Drilling Program (ODP) have embarked on what could prove to be one of the most important earth science initiatives of the decade—an initiative rivaling in scope and impact the exploration of the frontiers of outer space. The program explores our planet's last frontier—the Earth's structure and history as it is revealed beneath the oceans. The scope of the program's scientific goals excites the imagination, challenges the intellect, and enhances the spirit of cooperation among peoples in countries around the world.

Between 1872 and 1876, HMS *Challenger* undertook the world's first major oceanographic expedition. That expedition greatly expanded man's knowledge of the world's oceans and revolutionized our ideas about planet Earth. From 1968 to 1983, another ship named *Challenger* logged more than 375,000 miles on 96 voyages across every ocean for the Deep Sea Drilling Project (DSDP), operated by Scripps Institution of Oceanography. Among the project's many remarkable discoveries were the confirmation of seafloor spreading and the establishment of the relative youth of the seafloor, thus verifying the dynamic and changing nature of the Earth's crust.

Today, the Ocean Drilling Program, which began in 1983, brings new resources to bear on scientific ocean drilling. A new drillship is in operation—the *JOIDES Resolution*—one of the world's most modern and best equipped drillships with enhanced capability for drilling and coring in polar areas and rough weather, expanded laboratory space, facilities for more scientists, and a major drill-hole logging program. The name of the ship was derived from the international scientific partnership that directs the program—the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES)—and from the flagship of Captain Cook's second voyage to the Pacific Ocean in the late 18th century. Texas A&M University is responsible for science operations in the program, and Lamont-Doherty Geological Observatory is responsible for the logging program.

The Ocean Drilling Program truly has international participation. In 1975, the International Phase of Ocean Drilling began with member nations—the U.S.A., U.S.S.R., the Federal Republic of Germany, Japan, the United Kingdom, and France—all providing funds and scientific guidance for the project. Today, ODP partners include the U.S.A., the Canada/Australia Consortium for the Ocean Drilling Program, France, the Federal Republic of Germany, Japan, the United Kingdom, and the European Science Foundation, which represents Sweden, Finland, Norway, Iceland, Denmark, Belgium, the Netherlands,

Spain, Switzerland, Italy, Greece, and Turkey. The National Science Foundation, with funds contributed by the United States and international partners, supports the scientific operations and planning for the ODP through a contract with Joint Oceanographic Institutions, Inc. (JOI).

The information gained by the program leads to a better understanding of the Earth and its dynamic processes. Drilled sediment cores and logs reveal clues to past climatic history and tie into parallel studies of paleoclimates from glacial ice cores drilled on the continents. Understanding these sediment cores will enable scientists to complete the map of major geologically active regions of the Earth, and to identify processes that lead to dynamic change such as earthquakes, volcanic eruptions, and mountain and continental growth. We are far from being able to predict such changes accurately now; but with the new tools and understanding, the accuracy of such predictions can be improved. This better understanding of the Earth's system(s) will allow us to identify regions of potential mineral and energy resource development, an issue of worldwide human interest. The Ocean Drilling Program is not in itself aimed at finding resources, but the knowledge of the Earth's processes that is gained through such a basic research program will inevitably provide pieces of information required for such resource discovery and exploitation.

The program is fully under way in its aim to further the understanding of the Earth's dynamic systems. People of our planet will benefit directly and indirectly from this research in both their daily living and work activities. This multinational endeavor will perhaps foster other cooperative efforts in science or among societies. The Ocean Drilling Program has distinguished ancestors in the original *Resolution* and *Challenger* expeditions and the Deep Sea Drilling Project. The National Science Foundation is proud to be playing a leading role in this program, and we are looking forward to significant and innovative science for many years to come.



Erich Bloch  
Director  
National Science Foundation

Washington, D.C.

# Foreword

By Joint Oceanographic Institutions, Inc.

This volume presents results from the Ocean Drilling Program (ODP), where scientists use a specially equipped ocean drilling ship to sample and measure the properties of the submerged part of the Earth's crust. These data are then synthesized with other information to yield new insights into earth processes.

These results address the scientific goals of the program, which include providing a global description of geological and geophysical structures and materials, studying in detail areas of major geophysical activity such as mid-ocean ridges and the associated hydrothermal circulations, and studying passive and active continental margins. In addition, the ODP data support the study of sea-level and ocean-circulation changes, the effects of the Earth's orbital variations on climate, and the study of processes and mechanisms of evolution from the biological records in the cores which are recovered from drilling.

The Ocean Drilling Program is a partnership of scientists and governments. Overall scientific policy and management guidance is provided by Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES), which consists of committees and panels made up of representatives of the participating institutions and other scientific and engineering experts. The JOIDES Executive Committee (EXCOM) provides general oversight; the JOIDES Planning Committee (PCOM) is the focal point for all scientific planning for the ODP and is key to the scientific success of the program.

The PCOM has a network of panels and working groups which screen drilling proposals, evaluate instrumentation and measurement techniques, and assess geophysical survey data and other safety and siting information. PCOM uses the recommendations of these panels and committees to select drilling targets, to specify the major scientific objectives of each two-month drilling segment or leg, and to provide the science operator with nominations for co-chief scientists. The science operator, Texas A&M University, in turn is responsible for planning the detailed ship's operations, actual drilling schedules, and final scientific rosters, which are developed in close cooperation with PCOM and the cognizant panels.

Many of the scientific goals can be met only with new technology. Thus the program has identified engineering goals, which include the ability to start a hole and to core on bare rock at mid-ocean ridge sites, to drill in high-temperature and corrosive regions typical of hydrothermal areas, and to core in high latitudes with minimum interference from high seas and sea ice. To meet these needs, the program operates a specially equipped drillship, the *JOIDES Resolution*, which contains laboratories and equipment that are state-of-the-art, and carries a major new logging program.

The ship, registered as SEDCO/BP 471 after her owners and her length in feet (144 meters), is 70 feet (21 meters) wide, and has a displacement of 16,595 long tons. Her derrick towers 200 feet (61 meters) above the waterline, and a computer-controlled dynamic-positioning system stabilizes the ship over a specific location while drilling in water depths up to 27,000 feet (8230 meters). The drilling system collects cores from beneath the seafloor with a derrick and drawworks that can handle 30,000 feet (9144 meters) of drill pipe. More than 12,000 square feet (1115 square meters) of space distributed throughout the ship is devoted to scientific laboratories and equipment. The ship sails

with a scientific and technical crew of 50 and a ship's crew of 65.

Logging is a major part of the overall operation. The program provides a full suite of geochemical and geophysical measurements for every hole deeper than 1300 feet (400 meters). For each such hole, there are lowerings of basic oil-industry tools: nuclear, sonic, and electrical. In addition, a borehole televiwer is available for imaging the well-bore wall, a 12-channel logging tool provides accurate velocity and elastic property measurements as well as sonic waveforms for spectral analysis of energy propagation near the well bore, and a vertical seismic profiler records reflectors from below the total depth of the hole.

Texas A&M University serves as science operator for the Ocean Drilling Program. In this capacity, they operate and staff the drillship to collect cores from JOIDES-designated sites from around the world. The science operator also ensures that adequate scientific analyses are performed on the cores by maintaining the shipboard scientific laboratories and by providing logistical and technical support for shipboard scientific teams. Onshore, Texas A&M manages scientific activities after each leg, is curator for the cores, distributes samples, and coordinates the editing and publication of the scientific results. Lamont-Doherty Geological Observatory (LDGO) of Columbia University manages the program's logging operations, which include processing the data and provision of assistance to scientists in data analysis. The ODP Data Bank, a repository for geophysical data, is also managed by LDGO. Core samples from ODP and the previous Deep Sea Drilling Project are stored for future investigation at three sites: ODP Pacific and Indian Ocean cores at Texas A&M University, ODP and DSDP Atlantic and Antarctic cores at Lamont-Doherty Geological Observatory, and DSDP Pacific and Indian Ocean cores at Scripps Institution of Oceanography.

International oversight and coordination are provided by the ODP Council, a governmental consultative body of partner country representatives, chaired by the United States, which periodically reviews the general progress of the program and discusses financial plans and other management issues. Joint Oceanographic Institutions, Inc., a nonprofit consortium of U.S. oceanographic institutions, serves as the National Science Foundation's prime contractor and manages the ODP. JOI is responsible for seeing that the scientific objectives and plans are translated into scientific operations consistent with JOIDES recommendations and budgetary constraints.

Scientific achievements of the ODP already include new data on early seafloor spreading and how continents separate and their margins evolve. We have new insight into glacial cycles and the fluctuations of currents throughout geological time. Technical achievements include the first bare-rock coring, and logging data more accurate and complete than ever before. JOI is pleased to have played a facilitating role in the Ocean Drilling Program.



D. James Baker  
President  
Joint Oceanographic Institutions, Inc.

Washington, D.C.

# Preface

The *Scientific Results* volumes of the *Proceedings of the Ocean Drilling Program* contain specialty papers presenting the results of up to one and one-half years of research in various aspects of scientific ocean drilling. I acknowledge with thanks the authors of the papers published in this volume, who thereby have enabled future investigators to gain ready access to the results of their research.

Each of the papers submitted to a *Scientific Results* volume undergoes rigorous peer review by at least two specialists in the author's research field. A paper typically goes through one or more revision cycles before being accepted for publication. Our goal is to maintain a peer-review system comparable to those of the most highly regarded journals in the geological sciences.

The Editorial Review Board for a *Scientific Results* volume is responsible for obtaining peer reviews of papers submitted to the volume. This board usually is made up of the two co-chief scientists for the cruise, the ODP staff scientist for the cruise, and one external specialist who is familiar with the geology of the area investigated. In addition, the ODP staff editor assigned to the volume helps with any manuscripts that require special attention, such as those by authors who need assistance with English expression.

*Scientific Results* volumes may also contain short reports consisting of good data that are not ready for final interpretation. Papers in this category are segregated in a section in the back of the volume called Data Reports. Although no interpretation is permitted, these papers ordinarily contain a section on methodology or procedures. Data Report papers are read carefully by at least one specialist to make sure they are well organized, comprehensive, and discuss the techniques thoroughly. A paper that has undergone regular peer review is not eligible for later consideration as a Data Report.

In acknowledgment of the contributions made by this volume's Editorial Review Board, names of the individual Board members are listed on the title page. Reviewers of manuscripts for this volume, whose efforts are so essential to the success of the publication, are listed in the front portion of the book, without attribution to a particular manuscript.

On behalf of the Ocean Drilling Program, I extend sincere appreciation to members of the Editorial Review Boards and to the reviewers for giving so generously of their time and efforts in ensuring that only papers of high scientific quality are published in the *Proceedings*.



Philip D. Rabinowitz  
Director  
Ocean Drilling Program  
Texas A&M University  
College Station, Texas



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College Station, Texas

Melvin Friedman, Principal Investigator

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Borehole Research Group  
Lamont-Doherty Geological Observatory  
Columbia University  
Palisades, New York

Roger N. Anderson, Head

## **PARTICIPANTS ABOARD JOIDES RESOLUTION FOR LEG 106**

Robert S. Detrick  
Co-Chief Scientist

*Graduate School of Oceanography  
University of Rhode Island  
Kingston, Rhode Island 02881*

Jose Honnorez  
Co-Chief Scientist

*Rosenstiel School of Marine and Atmospheric Science  
University of Miami  
4600 Rickenbacker Causeway  
Miami, Florida 33149*

Andrew C. Adamson  
ODP Staff Scientist/Igneous Petrologist  
*Ocean Drilling Program  
Texas A&M University  
College Station, Texas 77843*

Garrett W. Brass  
Geochemist

*Ocean Drilling Program  
National Science Foundation  
1800 G Street, NW  
Washington, D.C. 20550*

Kathryn M. Gillis  
Igneous Petrologist

*Department of Geology  
Dalhousie University  
Halifax, Nova Scotia B3H 3J5  
Canada*

Susan E. Humphris  
Igneous Petrologist

*Department of Chemistry  
Woods Hole Oceanographic Institution  
Woods Hole, Massachusetts 02543*

Catherine Mevel  
Igneous Petrologist

*Laboratoire de Pétrologie Métamorphique  
Université Pierre et Marie Curie  
4 Place Jussieu  
75230 Paris 05  
France*

Peter S. Meyer  
Igneous Petrologist

*Department of Geology and Geophysics  
Woods Hole Oceanographic Institution  
Woods Hole, Massachusetts 02543*

Nikolai Petersen  
Paleomagnetist

*Institut für Geophysik  
Universität München  
Theresienstrasse 41  
D-8000 München 2  
Federal Republic of Germany*

Martina Rautenschlein  
Igneous Petrologist

*Max-Planck-Institut für Chemie  
Abteilung Geochemie  
Postfach 3060  
D-6500 Mainz  
Federal Republic of Germany*

Tsugio Shibata  
Igneous Petrologist

*Faculty of Science  
Okayama University  
3-1-1 Tsushimanaka  
Okayama 700  
Japan*

Hubert Staudigel  
Igneous Petrologist

*Geological Research Division  
Scripps Institution of Oceanography  
University of California, San Diego  
La Jolla, California 92093*

Anita L. Wooldridge  
Paleomagnetist

*Rosenstiel School of Marine and Atmospheric Sciences  
University of Miami  
4600 Rickenbacker Causeway  
Miami, Florida 33149*

Kiyohiko Yamamoto  
Physical Properties Specialist

*Faculty of Science  
Tohoku University  
Sendai, Miyagi Pref., 980  
Japan*

### **SEDCO OFFICIALS**

Captain Ed Oonk  
Master of the Drilling Vessel

*Underseas Drilling, Inc.  
707 Texas Avenue South  
Suite 103D  
College Station, Texas 77840-1917*

Robert Caldwell  
Drilling Superintendent

*Underseas Drilling, Inc.  
707 Texas Avenue South  
Suite 103D  
College Station, Texas 77840-1917*



**ODP ENGINEERING AND OPERATIONS PERSONNEL**

Stanley T. Serocki                      Supervisor of Drilling Operations  
Steven P. Howard                      Special Tools Engineer  
Terry L. Brittenham<sup>a</sup>                      Drilling Consultant  
Earle E. Derry<sup>b</sup>                              Logger

<sup>a</sup> *Southern International, Inc.*  
4401 Northwest 4th Street  
Suite 121  
Oklahoma City, Oklahoma 73107.

<sup>b</sup> *Schlumberger Offshore Service*  
Houston Offshore District  
8460 Gulf Freeway  
Houston, Texas 77017.

**ODP TECHNICAL AND LOGISTICS PERSONNEL**

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Mark P. Dobday                              Marine Technician  
John R. Eastlund                              System Manager  
Burnette W. Hamlin                              Laboratory Officer  
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William G. Mills                              Laboratory Officer  
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Michael C. Reitmeyer                              Electronics Technician  
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Christian M. Segade                              Marine Technician  
Katie K. Sigler                              Chemistry Technician  
Donald R. Sims                              Marine Technician  
John D. Tauxe                              Marine Technician

## **PARTICIPANTS ABOARD JOIDES RESOLUTION FOR LEG 109**

Wilfred B. Bryan  
Co-Chief Scientist

*Department of Geology and Geophysics  
Woods Hole Oceanographic Institution  
Woods Hole, Massachusetts 02543*

Thierry Juteau  
Co-Chief Scientist

*Laboratoire de Pétrologie  
Université de Bretagne Occidentale  
6 Avenue Le Gorgeu  
29287 Brest  
France*

Andrew C. Adamson

ODP Staff Scientist/Igneous Petrologist  
*Ocean Drilling Program  
Texas A&M University  
College Station, Texas 77843*

Laurie K. Autio

Geochemist  
*Department of Geology and Geography  
Morrill Science Center  
University of Massachusetts  
Amherst, Massachusetts 01003*

Keir Becker

Downhole Instrumentation/Packer Specialist  
*Rosenstiel School of Marine and Atmospheric Science  
University of Miami  
4600 Rickenbacker Causeway  
Miami, Florida 33149*

M. Mansour Bina

Paleomagnetist  
*Laboratoire de Géomagnétisme  
Université Pierre et Marie Curie  
4, Avenue de Neptune  
94107 St. Maur des Fosses  
France*

Jean-Philippe Eissen

Igneous Petrologist  
*ORSTOM  
B.P. A5, Noumea  
New Caledonia*

Toshitsugu Fujii

Igneous Petrologist  
*Earthquake Research Institute  
University of Tokyo  
1-1-1 Yayoi, Bunkyo-ku  
Tokyo 113  
Japan*

Timothy L. Grove

Igneous Petrologist  
*Department of Earth, Atmospheric and Planetary Sciences  
Massachusetts Institute of Technology  
Cambridge, Massachusetts 02139*

Yozo Hamano

Paleomagnetist  
*Earthquake Research Institute  
University of Tokyo  
1-1-1 Yayoi, Bunkyo-ku  
Tokyo 113  
Japan*

Rejean Hebert

Igneous Petrologist  
*Département de Géologie  
Université Laval  
Quebec G1K 7P4  
Canada*

Stephen C. Komor

Igneous Petrologist  
*U.S. Bureau of Mines  
Avondale Research Center  
4900 LaSalle Road  
Avondale, Maryland 20782*

Johannes Kopietz

Magnetometer and Temperature Logging Specialist  
*Bundesanstalt für Geowissenschaften und Rohstoffe  
Stilleweg 2  
D-3000 Hannover 51  
Federal Republic of Germany*

Kristian Krammer

Magnetic Susceptibility Specialist  
*Institut für Geophysik  
Universität München  
Theresienstrasse 41  
D-8000 München 2  
Federal Republic of Germany*

Michel Loubet

Geochemist  
*Laboratoire de Minéralogie  
Université Paul Sabatier  
38 Rue des 36 Ponts  
31400 Toulouse  
France*

Daniel Moos

Logging Scientist/Physical Properties Specialist  
*Borehole Research Group  
Lamont-Doherty Geological Observatory  
Columbia University  
Palisades, New York 10964*

Hugh G. Richards  
Igneous Petrologist  
*Department of Geology  
The University  
Newcastle upon Tyne NE1 7RU  
United Kingdom*

Captain Gerard Kuster  
Master of the Drilling Vessel  
*Underseas Drilling, Inc.  
707 Texas Avenue South  
Suite 103D  
College Station, Texas 77840-1917*

Rod McQuaig  
Drilling Superintendent  
*Underseas Drilling, Inc.  
707 Texas Avenue South  
Suite 103D  
College Station, Texas 77840-1917*

#### **ODP ENGINEERING AND OPERATIONS PERSONNEL**

Steven P. Howard	Supervisor of Drilling Operations
Andy Housley <sup>a</sup>	Special Tools Engineer
Bob Rawls <sup>b</sup>	Drilling Consultant
Christoph Czora <sup>c</sup>	Downhole Magnetometer Engineer
Stephen Diana <sup>d</sup>	Logger

<sup>a</sup> 2709 Silver Maple Drive  
Bryan, Texas 77803.

<sup>b</sup> Southern International, Inc.  
4401 Northwest 4th Street  
Suite 121  
Oklahoma City, Oklahoma 73107.

<sup>c</sup> Bundesanstalt für Geowissenschaften und Rohstoffe  
P.O. Box 51 01 53  
D-3000 Hannover 51  
Federal Republic of Germany.

<sup>d</sup> Schlumberger Offshore Service  
369 Tristar  
Webster, Texas 77017.

#### **ODP TECHNICAL AND LOGISTICS PERSONNEL**

Wendy J. Autio	Marine Technician
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