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VOLUME 168

SCIENTIFIC RESULTS

HYDROTHERMAL CIRCULATION IN THE OCEANIC CRUST: EASTERN FLANK OF THE JUAN DE FUCA RIDGE

Covering Leg 168 of the cruises of the Drilling Vessel *JOIDES Resolution,*
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Andrew T. Fisher, Earl E. Davis, John V. Firth,
Eva M. Andersson, Kan Aoike, Keir Becker, Kimberly A. Brown, Martine D. Buatier,
Marc Constantin, Henry Elderfield, Carlos A. Gonçalves, Jens S. Grigel, Arlëne G. Hunter,
Atsuyuki Inoue, Roisin M. Lawrence, Robert D. Macdonald, Pietro Marescotti, Jeffrey T. Martin,
Christophe Monnin, Michael J. Mottl, Daniel F.C. Pribnow, Joshua S. Stein, Xin Su, Yue-feng Sun,
Michael B. Underwood, David A. Vanko, Geoffrey Wheat
Shipboard Scientists

John V. Firth
Shipboard Staff Scientist

Prepared by the
OCEAN DRILLING PROGRAM
TEXAS A&M UNIVERSITY

Christine M. Miller and Lorri L. Peters
Volume Editors

in cooperation with the
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Foreword

By the National Science Foundation

The National Science Foundation is proud to play a leading role in partnership with the U.S. oceanographic community in the operation and management of the Ocean Drilling Program (ODP). We are equally proud of the cooperation and commitment of our international partners, who contribute both financial and intellectual resources required to maintain the high quality of this unique program. The Ocean Drilling Program, like its predecessor, the Deep Sea Drilling Project (DSDP), is a model for the organization and planning of research to address global scientific problems that are of high priority internationally and of long-term interest to the scientific community and general public.

Major scientific themes guiding the development of specific drilling cruises range from determining the causes and effects of oceanic and climatic variability to understanding the circulation of fluids in the ocean crust and the resultant formation of mineral deposits. Although such studies are at the forefront of basic scientific inquiry into the processes that control and modify the global environment, they are equally important in providing the background for assessing man's impact on the global environment or for projecting resource availability for future generations.

The transition from the DSDP to the ODP was marked by a number of changes. The 471-foot *JOIDES Resolution,* which replaced the *Glomar Challenger,* has allowed larger scientific parties and the participation of more graduate students, a larger laboratory and technical capability, and operations in more hostile ocean regions. The *JOIDES Resolution* has drilled in all of the world's oceans, from the marginal ice regions of the Arctic to within sight of the Antarctic continent. Over 1,200 scientists and students from 26 nations have participated on project cruises. Cores recovered from the cruises and stored in ODP repositories in the United States and Europe have provided samples to an additional 1,000 scientists for longer term postcruise research investigations. The downhole geochemical and geophysical logging program, unsurpassed in either academia or industry, is providing remarkable new data with which to study the Earth.

In 1994, NSF and our international partners renewed our commitment to the program for its final phase. Of the 20 countries that supported ODP initially, only one, Russia, has been unable to continue for financial reasons. As the reputation and scientific impact of the program continue to grow internationally, we hope to add additional members and new scientific constituencies. This global scientific participation continues to assure the program's scientific excellence by focusing and integrating the combined scientific knowledge and capabilities of its member nations.

We wish the program smooth sailing and good drilling!

Neal Lane
Director
National Science Foundation
Arlington, Virginia

Foreword

By Joint Oceanographic Institutions, Inc.

This volume presents scientific and engineering results from the Ocean Drilling Program (ODP). The papers presented here address the scientific and technical goals of the program, which include providing a global description of geological and geophysical structures including passive and active margins and sediment history, and studying in detail areas of major geophysical activity such as mid-ocean ridges and the associated hydrothermal circulations.

The Ocean Drilling Program, an international activity, operates a specially equipped deep-sea drilling ship, the *JOIDES Resolution,* which contains state-of-the-art laboratories, equipment, and computers. The ship is 471 feet (144 meters) long, is 70 feet (21 meters) wide, and has a displacement of 18,600 short tons. Her derrick towers 211 feet (64 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 51 and a ship's crew (including the drill crew) of 62. The size and ice-strengthening of the ship allow drilling in high seas and ice-infested areas as well as permit a large group of multidisciplinary scientists to interact as part of the scientific party.

Logging, or measurements in the drilled holes, is an important part of the program. ODP 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 Formation MicroScanner is available for high-resolution imaging the wall of the hole, 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 wall of the hole, and a vertical seismic profiler can record reflectors from below the total depth of the hole.

The management of the Ocean Drilling Program involves a partnership of scientists and governments. International oversight and coordination are provided by the ODP Council, a governmental consultative body of the partner countries, which is chaired by a representative from the United States National Science Foundation (NSF). The ODP Council periodically reviews the general progress of the program and discusses financial plans and other management issues. Overall scientific and management guidance is provided to the operators of the program by representatives from the group of institutions involved in the program, called the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES).

The Executive Committee (EXCOM), made up of the administrative heads of the JOIDES institutions, provides general oversight for ODP. The Science Committee (SCICOM), with its advisory structure, is made up of working scientists and provides scientific advice and detailed planning for the Ocean Drilling Program. SCICOM has a network of panels and committees that screen drilling proposals, evaluate instrumentation and measurement techniques, and assess geophysical survey data and other safety and siting information. SCICOM uses the recommendations of the panels and committees to select drilling targets, to specify the location and major scientific objectives of each two-month drilling segment or leg, and to provide the science operator with nominations for co-chief scientists.

Joint Oceanographic Institutions, Inc. (JOI), a nonprofit consortium of U.S. oceanographic institutions, serves as the National Science Foundation's prime contractor for ODP. JOI is responsible for seeing that the scientific objectives, plans, and recommendations of the JOIDES committees are translated into scientific operations consistent with scientific advice and budgetary constraints. JOI subcontracts the operations of the program to two universities: Texas A&M University and Lamont-Doherty Earth Observatory of Columbia University. JOI is also responsible for managing the U.S. contribution to ODP under a separate cooperative agreement with NSF.

Texas A&M University (TAMU) serves as science operator for ODP. In this capacity, TAMU is responsible for planning the specific ship operations, actual drilling schedules, and final scientific rosters, which are developed in close cooperation with SCICOM and the relevant panels. The science operator also ensures that adequate scientific analyses are performed on the cores by maintaining the shipboard scientific laboratories and computers and by providing logistical and technical support for shipboard scientific teams. Onshore, TAMU manages scientific activities after each leg, is curator for the cores, distributes samples, and coordinates the editing and publication of scientific results.

Lamont-Doherty Earth Observatory (LDEO) of Columbia University is responsible for the program's logging operation, including processing the data and providing assistance to scientists for data analysis. The ODP Data Bank, a repository for geophysical data, is also managed by LDEO.

Core samples from ODP and the previous Deep Sea Drilling Project are stored for future investigation at four sites: ODP Pacific and Indian Ocean cores at TAMU, DSDP Pacific and Indian Ocean cores at the Scripps Institution of Oceanography, ODP and DSDP Atlantic and Antarctic cores through Leg 150 at LDEO, and ODP Atlantic and Antarctic cores since Leg 151 at the University of Bremen, Federal Republic of Germany.

Scientific achievements of ODP include new information on early seafloor spreading and how continents separate and the margins evolve. The oldest Pacific crust has been drilled and sampled. We have new insights into glacial cycles and the fluctuations of ocean currents throughout geological time. ODP has also provided valuable data that shed light on fluid pathways through the lithosphere, global climate change both in the Arctic and near the equator, past sea-level change, seafloor mineralization, the complex tectonic evolution of oceanic crust, and the evolution of passive continental margins.

Many of the scientific goals can be met only with new technology; thus the program has focused on engineering as well as science. To date, ODP engineers have demonstrated the capability to drill on bare rock at mid-ocean-ridge sites and have developed techniques for drilling in high-temperature and corrosive regions typical of hydrothermal vent areas. A new diamond coring system promises better core recovery in difficult areas. In a close collaborative effort between ODP engineers and scientists, a system has been developed that seals selected boreholes ("CORKs") and monitors downhole temperature, pressure, and fluid composition for up to three years. When possible, ODP is also taking advantage of industry techniques such as logging while drilling, to obtain continuous downhole information in difficult-to-drill formations.

JOI is pleased to have been able to play a facilitating role in the Ocean Drilling Program and its cooperative activities, and we are looking forward to many new, exciting results in the future.

James D. Watkins
Admiral, U.S. Navy (Retired)
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 extensive research in various aspects of scientific ocean drilling. The authors of the papers published in this volume have enabled future investigators to gain ready access to the results of their research, and I acknowledge their contributions with thanks.

Each paper 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 at least one revision cycle before being accepted for publication. We seek to maintain a peer-review system comparable to those of the most highly regarded journals in the geological sciences.

Each *Scientific Results* volume has an Editorial Review Board that 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 volume has an ODP staff editor who assists with manuscripts that require English-language attention and who coordinates volume assembly.

Scientific Results volumes may also contain short reports of useful data that are not ready for final interpretation. Papers of this type are called Data Reports and include no interpretation of results. Data Report papers are read carefully by at least one specialist to make sure they are well organized, comprehensive, and discuss the techniques or procedures thoroughly.

To acknowledge the contributions made by this volume's Editorial Review Board, the Board members are designated Editors of the volume and are so 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 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 their generous contribution of time and effort, which ensures that only papers of high scientific quality are published in the *Proceedings.*

Paul J. Fox
Director
Ocean Drilling Program
Texas A&M University
College Station, Texas

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Damon A.H. Teagle
Harold J. Tobin
Wuchang Wei

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OPERATING INSTITUTION

College of Geosciences
Texas A&M University
College Station, Texas

David B. Prior
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OCEAN DRILLING PROGRAM

Paul J. Fox
Director

Jack G. Baldauf
Deputy Director

Richard G. McPherson
Administrator

Brian Jonasson, Manager
Drilling Services

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Thomas A. Davies, Manager
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LOGGING OPERATOR

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

David Goldberg, Head

* At time of publication.

PARTICIPANTS ABOARD THE *JOIDES RESOLUTION* FOR LEG 168*

Andrew T. Fisher
Co-Chief Scientist
Earth Sciences Department
University of California, Santa Cruz
Santa Cruz CA 95064
USA

Earl E. Davis
Co-Chief Scientist
Pacific Geoscience Centre
Geological Survey of Canada
PO Box 6000
Sidney BC V8L 4B2
Canada

John V. Firth
Staff Scientist
Ocean Drilling Program
1000 Discovery Drive
College Station TX 77845-9547
USA

Eva M. Andersson
Organic Geochemist
Department of Geology and Geochemistry
Stockholm University
S-10691 Stockholm
Sweden

Kan Aoike
Physical Properties Specialist
Ocean Research Institute
University of Tokyo
1-15-1 Minamidai Nakano-ku
Tokyo 164
Japan

Keir Becker
JOIDES Logging Scientist
Rosenstiel School of Marine and Atmospheric Science
Division of Marine Geology and Geophysics
University of Miami
4600 Rickenbacker Causeway
Miami FL 33149-1098
USA

Kimberly A. Brown
Sedimentologist
Scripps Institution of Oceanography
Mail Code 0208
University of California, San Diego
La Jolla CA 92093
USA

Martine D. Buatier
Sedimentologist
Laboratoire de Sédimentologie et Géodynamique
Université de Lille I
URA 719 UFR des Sciences de la Terre
F-59655 Villeneuve d'Ascq
France

Marc Constantin
Petrologist
Department of Geology
University of Toronto
22 Russell Street
Toronto ON M5S 3B1
Canada

Henry Elderfield
Inorganic Geochemist
Department of Earth Sciences
University of Cambridge
Cambridge CB2 3EQ
United Kingdom

Carlos A. Gonçalves
LDEO Logging Scientist
Borehole Research
Department of Geology
University of Leicester
Leicester LE1 7RH
United Kingdom

Jens S. Grigel
JOIDES Logging Scientist
University of Bremen
Fachbereich 5
PO Box 330440
Federal Republic of Germany

Arlëne G. Hunter
Petrologist
Department of Earth Sciences
University of Leeds
Leeds LS2 9JT
United Kingdom

Atsuyuki Inoue
Sedimentologist
Department of Earth Sciences
Chiba University
Chiba 263
Japan

Roisin M. Lawrence
Paleomagnetist
Department of Geology
Duke University
PO Box 90229
Durham NC 27708-0229
USA

Robert Macdonald
Visiting Engineer
Pacific Geoscience Centre
Geological Survey of Canada
PO Box 6000
Sidney BC V8L 4B2
Canada

*Addresses at time of cruise.

Pietro Marescotti
Petrologist
Dipartimento Scienze della Terra
Univerità di Genova
C. so Europa, 26 IT-16132 Genova
Italy

Jeffrey T. Martin
Physical Properties Specialist
School of Earth and Atmospheric Science
Georgia Institute of Technology
Atlanta GA 30331-0340
USA

Chirstophe Monnin
Inorganic Geochemist
Laboratoire de Géochimie
Université Paul Sabatier
38 rue des Trent-Six Ponts
31400 Toulouse
France

Michael J. Mottl
Inorganic Geochemist
Department of Oceanography/SOEST
University of Hawaii at Manoa
1000 Pope Road
Honolulu HI 96822
USA

Daniel F.C. Pribnow
Physical Properties Specialist
Department of Geology and Geophysics
University of Utah
717 Browning Building
Salt Lake City UT 84112
USA

Joshua S. Stein
Physical Properties Specialist
Earth Sciences Department
Earth and Marine Sciences Building
University of California, Santa Cruz
Santa Cruz CA 95064
USA

Xin Su
Paleontologist (nannofossils)
GEOMAR
Christian-Albrechts-Universität
Wischofstrasse 1-3, Gebaude 4
D24148 Kiel
Federal Republic of Germany

Yue-feng Sun
LDEO Logging Scientist Trainee
Borehole Research Group
Lamont-Doherty Earth Observatory
Columbia University
Palisades NY 10964
USA

Michael B. Underwood
Sedimentologist
Department of Geological Sciences
University of Missouri, Columbia
101 Geology Building
Columbia MO 65211
USA

David A. Vanko
Petrologist
Department of Geology
Georgia State University
Atlanta GA 30303-3083
USA

Geoffrey Wheat
Inorganic Geochemist
West Coast National Undersea Research Center
Moss Landing Marine Laboratories Ship Operations
7700 Sandholdt Road, Building D
PO Box 475
Moss Landing CA 95039-0475

SEDCO OFFICALS

Captain Anthony Ribbens
Master of the Drilling Vessel
Overseas Drilling Ltd.
707 Texas Avenue South, Suite 213D
College Station TX 77840-1917
USA

Robert C. Caldow
Drilling Superintendent
Overseas Drilling Ltd.
707 Texas Avenue South, Suite 213D
College Station TX 77840-1917
USA

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