

PROCEEDINGS OF THE OCEAN DRILLING PROGRAM

VOLUME 169S INITIAL REPORTS SAANICH INLET

Covering Leg 169S of the cruises of the Drilling Vessel *JOIDES Resolution*,
Victoria, British Columbia to Victoria, British Columbia, Sites 1033-1034,
15-21 August 1996

Brian D. Bornhold, John V. Firth,
Louise M. Adamson, Jack G. Baldauf, Andréé P. Blais,
Marcus Elvert, P. Jeff Fox, Richard Hebda, Alan E.S. Kemp, Kathryn Moran, Jennifer H. Morford,
David C. Mosher, Yves T. Prairie, Ann D. Russell, Peter Schultheiss, Michael J. Whiticar
Shipboard Scientists

Ellen Cowan, Gabriel Filippelli, Joris Gieskes, Junichiro Ishibashi, Rachael H. James,
G.D. Jensen, Melissa McQuoid, Robert Reid
Post-leg Contributors

John V. Firth
Shipboard Staff Scientist

Prepared by the
OCEAN DRILLING PROGRAM
TEXAS A&M UNIVERSITY

Georgia L. Fox
Volume Editor

in cooperation with the
NATIONAL SCIENCE FOUNDATION
and
JOINT OCEANOGRAPHIC INSTITUTIONS, INC.

Reference to the whole or to part of this volume should be made as follows:

Print citation:

Bornhold, B., Firth, J.V., et al., 1998. *Proc. ODP, Init. Repts.*, 169S: College Station, TX (Ocean Drilling Program).

Shipboard Scientific Party, 1998. Sites 1033 and 1034. In Bornhold, B., Firth, J.V., et al., *Proc. ODP, Init. Repts.*, 169S: College Station, TX (Ocean Drilling Program), 11–61.

CD-ROM citation:

Bornhold, B., Firth, J.V., et al., 1998. *Proc. ODP, Init. Repts.*, 169S [CD-ROM]. Available from: Ocean Drilling Program, Texas A&M University, College Station, TX 77845-9547, U.S.A.

Shipboard Scientific Party, 1998. Sites 1033 and 1034. In Bornhold, B., Firth, J.V., et al., *Proc. ODP, Init. Repts.*, 169S, 11–61 [CD-ROM]. Available from: Ocean Drilling Program, Texas A&M University, College Station, TX 77845-9547, U.S.A.

WWW citation:

Bornhold, B., Firth, J.V., et al., 1998. *Proc. ODP, Init. Repts.*, 169S [Online]. Available from World Wide Web: <http://www-odp.tamu.edu/publications/169S_IR/169STOC.HTM>. [Cited YYYY-MM-DD]

Shipboard Scientific Party, 1998. Sites 1033 and 1034. In Bornhold, B., Firth, J.V., et al., *Proc. ODP, Init. Repts.*, 169S, 11–61 [Online]. Available from World Wide Web: <http://www-odp.tamu.edu/publications/169S_IR/CHAP_02.PDF>. [Cited YYYY-MM-DD]

Effective Publication Dates of ODP *Proceedings*

According to the International Code of Zoological Nomenclature, the date of publication of a work and of a contained name or statement affecting nomenclature is the date on which the publication was mailed to subscribers, placed on sale, or when the whole edition is distributed free of charge, mailed to institutions and individuals to whom free copies are distributed. The mailing date, *not the printed date*, is the correct one.

The mailing dates of recent *Proceedings of the Ocean Drilling Program* are as follows:

Volume 167 (*Initial Reports*): September 1997
Volume 168 (*Initial Reports*): October 1997
Volume 170 (*Initial Reports*): December 1997
Volume 155 (*Scientific Results*): November 1997
Volumes 156/150X (*Scientific Results*): November 1997
Volume 158 (*Scientific Results*): February 1998

Distribution

Copies of this publication may be obtained from Publications Distribution Center, Ocean Drilling Program, 1000 Discovery Drive, College Station, Texas 77845-9547, U.S.A. Orders for copies will require advance payment. See current ODP publication list for price and availability of this publication.

Printed March 1998

ISSN

Printed volume: 0884-5883; CD-ROM volume: 1096-2522; WWW volume: 1096-2158
Library of Congress 87-642-462

Printed in Canada by Friesens

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 post-cruise 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* (Sedco/BP 471), 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 PCOM 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.

OCEAN DRILLING PROGRAM*

MEMBER ORGANIZATIONS OF THE JOINT OCEANOGRAPHIC INSTITUTIONS FOR DEEP EARTH SAMPLING (JOIDES)

University of California at San Diego, Scripps Institution of Oceanography

Columbia University, Lamont-Doherty Earth Observatory

University of Hawaii, School of Ocean and Earth Science and Technology

University of Miami, Rosenstiel School of Marine and Atmospheric Science

Oregon State University, College of Oceanic and Atmospheric Sciences

University of Rhode Island, Graduate School of Oceanography

Texas A&M University, College of Geosciences and Maritime Studies

University of Texas at Austin, Institute for Geophysics

University of Washington, College of Ocean and Fishery Sciences

Woods Hole Oceanographic Institution

Australia/Canada/Chinese Taipei/Korea Consortium for Ocean Drilling, Department of Primary Industries and Energy (Australia), Department of Energy, Mines and Resources (Canada), National Taiwan University in Taipei, and Korean Institute for Geology, Mining and Minerals

European Science Foundation Consortium for Ocean Drilling (Belgium, Denmark, Finland, Iceland, Italy, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and Turkey)

Federal Republic of Germany, Bundesanstalt für Geowissenschaften und Rohstoffe

France, Institut Français de Recherche pour l'Exploitation de la Mer

Japan, University of Tokyo, Ocean Research Institute

United Kingdom, Natural Environment Research Council

PRIME CONTRACTOR

Joint Oceanographic Institutions, Inc.
Washington, D.C.

Nicklas Piasis
Interim Director, Ocean Drilling Programs

OPERATING INSTITUTION

College of Geosciences and Maritime Studies
Texas A&M University
College Station, Texas

David B. Prior
Dean

OCEAN DRILLING PROGRAM

Paul J. Fox
Director

Timothy J.G. Francis
Deputy Director of Operations

Jack G. Baldauf
Deputy Director of Services

Richard G. McPherson
Administrator

Brian Jonasson, Manager
Drilling Services

Russell B. Merrill, Manager
Information Services

Ann Klaus, Manager
Publication Services

Thomas A. Davies, Manager
Science Services

LOGGING OPERATOR

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

David Goldberg, Head

PARTICIPANTS ABOARD THE JOIDES RESOLUTION FOR LEG 169S*

Brian D. Bornhold
Chief Scientist

*Pacific Geoscience Centre
Geological Survey of Canada
P.O. Box 6000
9860 West Saanich Road
Sidney, British Columbia V8L 4B2
Canada
bornhold@pgc.emr.ca*

John V. Firth
Staff Scientist

*Ocean Drilling Program
Texas A&M Research Park
1000 Discovery Drive
College Station, Texas 77845-9547
U.S.A.
john_firth@odp.tamu.edu*

Louise M. Adamson
Organic Geochemist

*Pacific Geoscience Centre
Geological Survey of Canada
P.O. Box 6000
9860 West Saanich Road
Sidney, British Columbia V8L 4B2
Canada
adamsonL@ios.bc.ca*

Jack G. Baldauf

ODP/TAMU Science Operations
*Representative: Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station, Texas 77845-9547
U.S.A.
jack_baldauf@odp.tamu.edu*

André P. Blais
Sedimentologist

*Geological Survey of Canada
369-601 Booth Street
Ottawa, Ontario K1A 0E8
Canada
ablais@gsc.emr.ca*

Marcus Elvert

Organic Geochemist
*GEOMAR Research Center
Christian-Albrechts-Universität zu Kiel
Building 5
Wischhofstrasse 1-3
24148 Kiel
Federal Republic of Germany
melvert@geomar.de*

P. Jeff Fox

ODP/TAMU Headquarters
*Representative: Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station, Texas 77845-9547
U.S.A.
jeff_fox@odp.tamu.edu*

Richard Hebda
Paleontologist (Palynology)

*Royal British Columbia Museum
Victoria, British Columbia V8V 1X4
Canada*

Alan E.S. Kemp
Sedimentologist

*Department of Oceanography
University of Southampton
Southampton Oceanography Centre
European Way
Southampton SO14 3ZH
United Kingdom
aesk@soc.soton.ac.uk*

Kathryn Moran

Physical Properties Specialist
*Stratigraphic Correlator: Atlantic Geoscience Centre
Bedford Institute of Oceanography
Geological Survey of Canada
P.O. Box 1006
Dartmouth, Nova Scotia B2Y 4A2
Canada
moran@agc.bio.ns.ca*

Jennifer H. Morford
Inorganic Geochemist

*School of Oceanography
University of Washington
Box 357940
Seattle, Washington 98195-7940
U.S.A.
morford@u.washington.edu*

David C. Mosher

Physical Properties Specialist
*Pacific Geoscience Centre
Geological Survey of Canada
P.O. Box 6000
9860 West Saanich Road
Sidney, British Columbia V8L 4B2
Canada
mosher@pgc.emr.ca*

Yves T. Prairie

Microbiologist
*Département des Sciences Biologiques
Université du Québec à Montréal
Box 8888
Station A
Montréal, Québec H3C 3P8
Canada
prairie.yves@uqam.ca*

Ann D. Russell

Inorganic Geochemist
*Department of Geology
University of California, Davis
Davis, California 95616
U.S.A.
russell@geology.ucdavis.edu*

* Addresses at time of cruise.

Peter Schultheiss
Physical Properties Specialist
GEOTEK Ltd.
3, Faraday Close
Drayton Fields
Daventry, Northants
NN11 5RD
United Kingdom
peter@geotek.co.uk

Michael J. Whiticar
Organic Geochemist
School of Earth and Ocean Sciences
University of Victoria, British Columbia
P.O. Box 3055
Victoria, British Columbia V8W 3P6
Canada
whiticar@uvic.ca

ENGINEERING PARTICIPANTS

Brian Jonasson
ODP/TAMU Engineering
Representative: Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station, Texas 77845-9547
U.S.A.
brian_jonasson@odp.tamu.edu

Rolf Amlé
Sondenfelds Representative
Sondenfeldske
Radhusgt 23
P.O. Box 752
Sentrum, Oslo 0106
Norway

Erik A. Hanssen
Parvus Engineer
The Parvus Corporation
1214 Wilmington Avenue
Salt Lake City, Utah 84106
U.S.A.
parvus@parvus.com

Kenneth E. Otto
Parvus Engineer
The Parvus Corporation
1214 Wilmington Avenue
Salt Lake City, Utah 84106
U.S.A.
parvus@parvus.com

OBSERVERS

Robert Corell
Observer (NSF)
National Science Foundation
4201 Wilson Boulevard
Arlington, Virginia 22230
U.S.A.
rcorell@nsf.gov

J. Paul Dauphin
Observer (NSF)
Ocean Drilling Program
National Science Foundation
4201 Wilson Boulevard
Arlington, Virginia 22230
U.S.A.
jdauphin@nsf.gov

William Dietrich
Public Relations
The Seattle Times
P.O. Box 70
Seattle, Washington 98111
U.S.A.
bdie-new@seattimes.cgn

Robert A. Duce
Observer (Texas A&M)
College of Geosciences and Maritime Studies
Texas A&M University
College Station, Texas 77843
U.S.A.
rduce@ocean.tamu.edu

Masanori Kyo
Observer (Visiting Engineer)
Japan Marine Science and Technology Center
2-15 Natsushima-cho
Yokosuka 237
Japan
Japankyom@jamstec.go.jp

Larry Pynn
Public Relations
The Vancouver Sun
Vancouver, British Columbia
Canada
lpynn@wimsey.com

Shinichi Takagawa
Observer (Visiting Engineer)
Japan Marine Science and Technology Center
2-15 Natsushima-cho
Yokosuka 237
Japan
takagawa@jamstec.go.jp

POST-LEG 169S CONTRIBUTORS

Ellen Cowan
Department of Geology
Appalachian State University
Boone, North Carolina
U.S.A.

Gabriel Filippelli
Department of Geology
Indiana University/Purdue University, Indianapolis
Indianapolis, Indiana
U.S.A.

Joris Gieskes
Inorganic Geochemist
*Scripps Institution of Oceanography
University of California, San Diego
9500 Gilman Drive
La Jolla, California 92093-0215
U.S.A.
jgieskes@ucsd.edu*

Junichiro Ishibashi
Inorganic Geochemist
*Laboratory for Earthquake Chemistry
Faculty of Science
University of Tokyo
731 Hongo
Tokyo 113
Japan
iishi@eqchem.s.utokyo.ac.jp*

Rachael H. James
Inorganic Geochemist
*Department of Geology
Wills Memorial Building
University of Bristol, Queens Road
Bristol BS8 1RJ
United Kingdom
r.h.james@bris.ac.uk*

G.D. Jensen
*Pacific Forestry Centre
Forestry Canada
Victoria, British Columbia
Canada*

Melissa McQuoid
*Biology Department
University of Victoria
Victoria, British Columbia
Canada*

Robert Reid
*Biology Department
University of Victoria
Victoria, British Columbia
Canada*

SEDCO OFFICIALS

Captain Edwin G. Oonk
Master of the Drilling Vessel
*Overseas Drilling Ltd.
707 Texas Avenue South, Suite 213
College Station, Texas 77840-1917
U.S.A.*

Wayne Malone
Drilling Superintendent
*Overseas Drilling Ltd.
707 Texas Avenue South, Suite 213
College Station, Texas 77840-1917
U.S.A.*

ENGINEERING AND OPERATIONS PERSONNEL

Gene Pollard	Operations Manager
Leon Holloway	Development Engineer

TECHNICAL AND LOGISTICS PERSONNEL

Jim Briggs	Engineering Technician
Cesar Flores	Marine Computer Specialist
Tim Fulton	Marine Laboratory Specialist (Photographer)
Edwin Garrett	Marine Laboratory Specialist (Paleomagnetism)
Dennis Graham	Marine Laboratory Specialist (Underway Geophysics)
Gus Gustafson	Marine Laboratory Specialist (Downhole Tools)
Michiko Hitchcox	Marine Laboratory Specialist (Yeoperson)
Jonathan Krebs	Schlumberger Logging Specialist
John Lee	Marine Laboratory Specialist (Chemistry)
Kevin MacKillop	Marine Laboratory Specialist (Physical Properties)
Lorriane Southey	Marine Laboratory Specialist (Curator)
Eric Meissner	Marine Electronics Specialist
Bill Mills	Laboratory Officer
Mike Moore	Marine Laboratory Specialist (Storekeeper)
Dwight Mossman	Marine Electronics Specialist
Heidi Pass	Marine Laboratory Specialist
Chieh Peng	Marine Laboratory Specialist (Chemistry)
Don Sims	Marine Laboratory Specialist (Assistant Lab Officer, Thin Sections)
Joel Sparks	Marine Laboratory Specialist (X-ray)
Barry Weber	Marine Computer Specialist

Ocean Drilling Program Publication Services Staff*

Publication Services Manager

Ann Klaus

Editorial Supervisor/Publications Specialist

M. Kathleen Phillips

Senior Editor

Angeline T. Miller

Editors

Georgia L. Fox

Jennifer A. Marin

Christine M. Miller

Ruth N. Riegel

Susan E. Swanson

Chief Production Editor

Jennifer Pattison Rumford

Production Editors

Karen O. Benson (this volume)

Amy Brundeen

Patrick H. Edwards

Jaime A. Gracia

Senior Publications Coordinator

Gudelia ("Gigi") Delgado

Publications Coordinator

Rose Pandolph Sauser

Copier/Distribution Specialist

Ann Yeager

Chief Illustrator

Deborah L. Partain

Illustrators

L. Michelle Briggs (this volume)

Coleena Burt

Wei Cheng

Nancy H. Luedke

Prime Data Coordinator

Katerina E. Petronotis

Production Assistants

Marianne Gorecki

Mary Elizabeth Mitchell

Student Assistants

Marla Barbéy, Dusty Carroll, Jaime Collins, Theresa Elam, Kerry Newman

Publisher's Notes

This publication was prepared by the Ocean Drilling Program, Texas A&M University, as an account of work performed under the international Ocean Drilling Program, which is managed by Joint Oceanographic Institutions, Inc., under contract with the National Science Foundation. Funding for the program was provided by the following agencies at the time of this cruise:

Canada/Australia Consortium for the Ocean Drilling Program, Department of Energy, Mines and Resources (Canada), and Department of Primary Industries and Energy (Australia)

Deutsche Forschungsgemeinschaft (Federal Republic of Germany)

European Science Foundation Consortium for Ocean Drilling (Belgium, Denmark, Finland, Iceland, Italy, The Netherlands, Norway, Spain, Sweden, Switzerland, and Turkey)

Institut Français de Recherche pour l'Exploitation de la Mer (France)

National Science Foundation (United States)

Natural Environment Research Council (United Kingdom)

University of Tokyo, Ocean Research Institute (Japan)

Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the National Science Foundation, the participating agencies, Joint Oceanographic Institutions, Inc., Texas A&M University, or Texas A&M Research Foundation.

Abbreviations for names of organizations and publications in ODP reference lists follow the style given in *Chemical Abstracts Service Source Index* (published by American Chemical Society).

The printed version of the *Proceedings of the Ocean Drilling Program* series will end with *Initial Reports* Volume 175 and *Scientific Results* Volume 169S. Beginning with *Initial Reports* Volume 176 and *Scientific Results* Volume 169, all *Proceedings* volumes will be published on CD-ROM and the World Wide Web <<http://www-odp.tamu.edu/publications/>>.

Initial Reports—CD-ROM format: ISSN 1096-2522

WWW format: ISSN 1096-2158

Scientific Results—CD-ROM format: ISSN 1096-2514

WWW format: ISSN 1096-7451

*At time of publication.