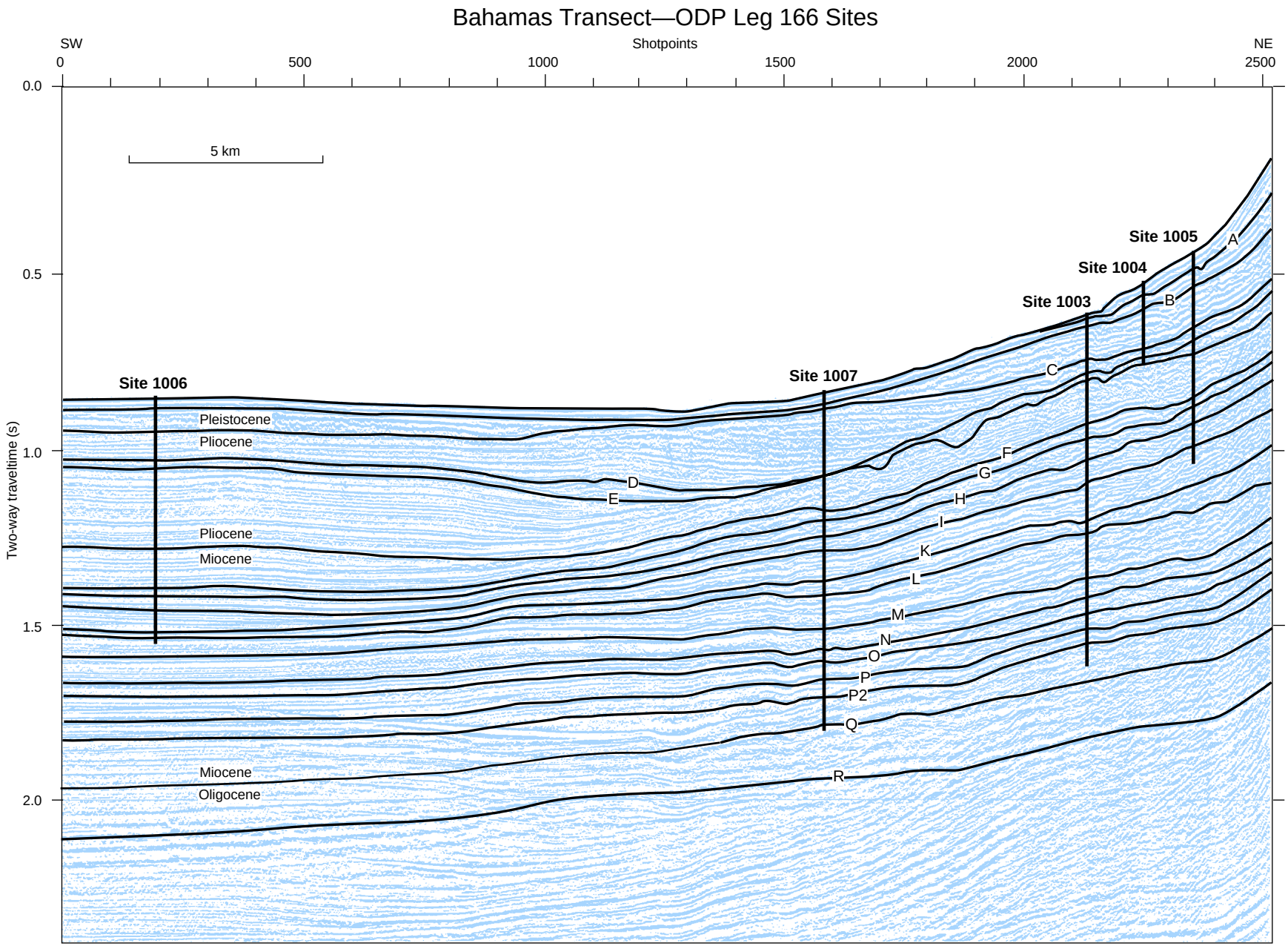

Part of seismic Line 106 displaying the Bahamas Transect from the upper slope of the Great Bahama Bank into the Straits of Florida. Five sites were drilled along this transect during Ocean Drilling Program Leg 166 to retrieve the sedimentary record of the sea-level changes in the Neogene and to assess fluid flow through the platform margin. Letters mark seismic sequence boundaries.

Table of Contents

PROCEEDINGS OF THE OCEAN DRILLING PROGRAM

VOLUME 166

INITIAL REPORTS

Bahamas Transect

Covering Leg 166 of the cruises of the Drilling Vessel *JOIDES Resolution*,
San Juan, Puerto Rico, to Balboa Harbor, Panama, Sites 1003–1009,
17 February–10 April 1996

Gregor P. Eberli, Peter K. Swart, Mitchell J. Malone,
Flavio S. Anselmetti, Kohsaku Arai, Karin H. Bernet, Christian Betzler,
Beth A. Christensen, Eric H. De Carlo, Pascale M. Déjardin, Laurent Emmanuel,
Tracy D. Frank, Geoffrey A. Haddad, Alexandra R. Isern, Miriam E. Katz,
Jeroen A.M. Kenter, Philip A. Kramer, Dick Kroon, Judith A. McKenzie, Donald F. McNeill,
Paul Montgomery, Seiichi Nagihara, Carlos Pirmez, John J.G. Reijmer,
Tokiyuki Sato, Niels H. Schovsbo, Trevor Williams, James D. Wright
Shipboard Scientists

Mitchell J. Malone
Shipboard Staff Scientist

Prepared by the
OCEAN DRILLING PROGRAM
TEXAS A&M UNIVERSITY

Jennifer A. Marin
Volume Editor

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

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:

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
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.

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

Eberli, G.P., Swart, P.K., Malone, M.J., et al., 1997. *Proc. ODP, Init. Repts.*, 166: College Station, TX (Ocean Drilling Program).

Shipboard Scientific Party, 1997. Site 1003. *In* Eberli, G.P., Swart, P.K., Malone, M.J., et al., *Proc. ODP, Init. Repts.*, 166: College Station, TX (Ocean Drilling Program), 71–151.

Electronic citation:

Eberli, G.P., Swart, P.K., Malone, M.J., et al., 1997. *Proc. ODP, Init. Repts.* [CD-ROM], 166. Available: Ocean Drilling Program, Texas A&M University, College Station, TX 77845-9547, U.S.A.

Shipboard Scientific Party, 1997. Site 1003. *In* Eberli, G.P., Swart, P.K., Malone, M.J., et al., *Proc. ODP, Init. Repts.* [CD-ROM], 166, 71–151. Available: Ocean Drilling Program, Texas A&M University, College Station, TX 77845-9547, U.S.A.

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 162 (*Initial Reports*): September 1996
Volumes 163/164 (*Initial Reports*): November 1996
Volume 165 (*Initial Reports*): February 1997
Volume 150 (*Scientific Results*): October 1996
Volume 151 (*Scientific Results*): December 1996
Volume 153 (*Scientific Results*): April 1997

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 July 1997

ISSN 0884-5883
Library of Congress 87-655-674

Printed in Canada by Friesens

The paper used in this publication meets the minimum requirements of American National Standard for Information Sciences–Permanence of Paper for Printed Library Materials, ANSI Z39.48–1984∞™

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 Planning Committee (PCOM), with its advisory structure, is made up of working scientists and provides scientific advice and detailed planning. PCOM has a network of panels and working groups that screen drilling proposals, evaluate instrumentation and measurement techniques, and assess geophysical-survey data and other safety and siting information. PCOM 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, 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.

David A. Falvey
Director, Ocean Drilling Programs

OPERATING INSTITUTION

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

Robert A. Duce
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 166*

Gregor P. Eberli
Co-Chief Scientist
RSMAS-MGG
University of Miami
4600 Rickenbacker Causeway
Miami, Florida 33149
U.S.A.

Peter K. Swart
Co-Chief Scientist
RSMAS-MGG
University of Miami
4600 Rickenbacker Causeway
Miami, Florida 33149
U.S.A.

Mitchell J. Malone
Staff Scientist
Ocean Drilling Program
Texas A&M University Research Park
1000 Discovery Drive
College Station, Texas 77845
U.S.A.

Flavio S. Anselmetti
Physical Properties Specialist
RSMAS-MGG
University of Miami
4600 Rickenbacker Causeway
Miami, Florida 33149
U.S.A.

Kohsaku Arai
Sedimentologist
Fuel Resources Department
Geological Survey of Japan
1-1-3 Higashi, Tsukuba
Ibaraki 305
Japan

Karin H. Bernet
Sedimentologist
RSMAS-MGG
University of Miami
4600 Rickenbacker Causeway
Miami, Florida 33149
U.S.A.

Christian Betzler
Sedimentologist
Geologisch-Paläontologisches Institut
Johann Wolfgang Goethe-Universität
D-60054 Frankfurt/Main
Senckenberganlage 32-34
Federal Republic of Germany

Beth A. Christensen
Stratigraphic Correlator
Department of Geological Sciences
University of South Carolina
Columbia, South Carolina 29208
U.S.A.

Eric H. De Carlo
Inorganic Geochemist
Department of Oceanography
SOEST
University of Hawaii
1000 Pope Road
Honolulu, Hawaii 96822
U.S.A.

Pascale M. Déjardin
Sedimentologist
Centre de Sédimentologie et de Géochimie de la Surface
CNRS
1 Rue Blessig
67084 Strasbourg Cedex
France

Laurent Emmanuel
Sedimentologist
Centre des Sciences de la Terre
University of Bourgogne
6 Boulevard Gabriel
F-21000 Dijon
France

Tracy D. Frank
Sedimentologist
Department of Geological Sciences
University of Michigan
2534 C.C. Little Building
425 E. University
Ann Arbor, Michigan 48109-1063
U.S.A.

Geoffrey A. Haddad
Sedimentologist
Department of Geology and Geophysics
Rice University
MS 126
6100 South Main Street
Houston, Texas 77005-1892
U.S.A.

Alexandra R. Isern
Physical Properties Specialist
Department of Geology and Geophysics
University of Sydney
Sydney, NSW 2006
Australia

Miriam E. Katz
Paleontologist (foraminifers)
Lamont-Doherty Earth Observatory
Columbia University
Room 202, NCL
Palisades, New York 10964
U.S.A.

* Addresses at time of cruise.

Jeroen A.M. Kenter
Physical Properties Specialist
Department of Earth Sciences
Vrije Universiteit
De Boelelaan 1085
1081 HV Amsterdam
The Netherlands

Philip A. Kramer
Inorganic/Organic Geochemist
Institute of Marine and Coastal Studies
Nova University
800 N. Ocean Drive
Dania, Florida 33004
U.S.A.

Dick Kroon
Paleontologist (foraminifers)
Department of Geology and Geophysics
Grant Institute
The University of Edinburgh
West Mains Road
EH9 3JW Edinburgh
Scotland
United Kingdom

Judith A. McKenzie
JOIDES Logging Scientist
Geological Institute
ETH-Zentrum
8092 Zürich
Switzerland

Donald F. McNeill
Paleomagnetist
RSMAS-MGG
University of Miami
4600 Rickenbacker Causeway
Miami, Florida 33149
U.S.A.

Paul Montgomery
Paleomagnetist
School of Environmental Sciences
University of East Anglia
Norwich NR4 7TJ
United Kingdom

Seiichi Nagihara
Physical Properties Specialist
Department of Geosciences
University of Houston
Houston, Texas 77204-5503
U.S.A.

Carlos Pirmez
LDEO Logging Scientist
Borehole Research Group
Lamont-Doherty Earth Observatory
Columbia University
Palisades, New York 10964-8000
U.S.A.

John J.G. Reijmer
Sedimentologist
GEOMAR Research Center for
Marine Geosciences
Christian-Albrechts-Universität zu Kiel
Wischhofstrasse 1-3, Gebäude 4
D-24148 Kiel
Federal Republic of Germany

Tokiyuki Sato
Paleontologist (nannofossils)
Institute of Applied Earth Sciences
Mining College
Akita University
Tegata-Gakuencho 1-1
Akita 010
Japan

Niels H. Schovsbo
Organic Geochemist
Geological Museum
University of Copenhagen
Oester Voldgade 5-7
DK-1350, Copenhagen K
Denmark

Trevor Williams
LDEO Logging Trainee
Leicester University Borehole Research
Department of Geology
Leicester University
Leicester, LE1 7RH
United Kingdom

James D. Wright
Paleontologist (foraminifers)
Department of Geological Sciences
Sawyer Environmental Research Center
University of Maine
Orono, Maine 04469
U.S.A.

SEDCO OFFICIALS

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

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

ODP ENGINEERING AND OPERATIONS PERSONNEL

Eugene Pollard	Operations Manager

ODP TECHNICAL AND LOGISTICS PERSONNEL

Miriam Andres	Marine Laboratory Specialist (Temporary)
Tim Bronk	Marine Laboratory Specialist (Chemistry)
Brad Cook	Marine Laboratory Specialist (Photographer)
Sandy Dillard	Marine Laboratory Specialist (Storekeeper)
Cesar Flores	Marine Computer Specialist (System Manager)
Margaret Hastedt	Marine Laboratory Specialist (Paleomagnetism)
Kuro Kuroki	Marine Laboratory Specialist (Assistant Laboratory Officer)
Monty Lawyer	Marine Laboratory Specialist (Underway Geophysics)
Jaque Ledbetter	Marine Laboratory Specialist (X-ray)
Greg Lovelace	Marine Laboratory Specialist (Physical Properties)
Erinn McCarty	Marine Laboratory Specialist (Curator)
Bill Mills	Marine Laboratory Specialist (Laboratory Officer)
Chris Nugent	Marine Laboratory Specialist (Downhole Tools)
Anne Pimmel	Marine Laboratory Specialist (Chemistry)
Jo Ribbens	Marine Laboratory Specialist (Yeoperson)
Bill Stevens	Marine Electronics Specialist
Mark Watson	Marine Electronics Specialist
Barry Weber	Marine Computer Specialist (System Manager)

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
Patrick H. Edwards (this volume)
Jaime A. Gracia
William J. Moran (this volume)
Nicole M. Papa

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
Coleena Burt
Katherine C. Irwin
Nancy H. Luedke (this volume)

Prime Data Coordinator
Katerina E. Petronotis

Production Assistants
Marianne Gorecki
Mary Elizabeth Mitchell

Student Assistants
Marla Barbéy, Dusty Carroll, Cariño Casas, Jaime Collins, Theresa Elam, Weyland M.A. Simmons

*At time of publication.

Publisher's Note

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).

Table of Contents