# PROCEEDINGS OF THE OCEAN DRILLING PROGRAM

## VOLUME 133
## SCIENTIFIC RESULTS
### NORTHEAST AUSTRALIAN MARGIN

Covering Leg 133 of the cruises of the Drilling Vessel *JOIDES Resolution*,
Apra Habor, Guam, to Townsville, Australia, Sites 811–826
4 August–11 October 1990


Judith A. McKenzie, Peter J. Davies, Amanda A. Palmer-Julson,
Christian G. Betzler, Thomas C. Brachert, Min-Pen Philip Chen,
Jean-Pierre Crumière, George R. Dix, André W. Droxler, David A. Feary,
Stefan Gartner, Craig R. Glenn, Alexandra Isern, Peter D. Jackson,
Richard D. Jarrard, Miriam E. Katz, Kenji Konishi, Dick Kroon, John W. Ladd,
José Manuel Martín, Donald F. McNeill, Lucien F. Montaggioni,
Daniel W. Müller, Sheraz Khan Omarzai, Chris J. Pigram, Peter K. Swart,
Philip A. Symonds, Keith F. Watts, Wuchang Wei
*Shipboard Scientists*

Amanda A. Palmer-Julson
*Shipboard Staff Scientist*





Prepared by the
OCEAN DRILLING PROGRAM
TEXAS A&M UNIVERSITY

Sondra K. Stewart and Jennifer A. Marin
*Volume Editors*

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:

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, Greece, 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.

It is recommended that reference to the whole or to part of this volume be made in one of the following forms, as appropriate:

McKenzie, J.A., Davies, P.J., Palmer-Julson, A., et al., 1993. *Proc. ODP, Sci. Results,* 133: College Station, TX (Ocean Drilling Program).

Martin, H.A., and McMinn, A., 1993. Palynology of Sites 815 and 823: the Neogene vegetation history of coastal northeastern Australia. *In* McKenzie, J.A., Davies, P.J., Palmer-Julson, A., et al, *Proc. ODP, Sci. Results,* 133: College Station, TX (Ocean Drilling Program), 115–128.

## 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:

Volumes 142/143 (*Initial Reports*): April 1993
Volume 144 (*Initial Reports*): July 1993
Volume 145 (*Initial Reports*): July 1993
Volume 129 (*Scientific Results*): December 1992
Volume 130 (*Scientific Results*): April 1993
Volume 131 (*Scientific Results*): April 1993

## 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 November 1993**

ISSN 0884-5891
Library of Congress 87-642-462

Printed in Canada by D.W. Friesen & Sons Ltd.

# Foreword

**By the National Science Foundation**

The Ocean Drilling Program (ODP) is a major component of the National Science Foundation's continuing commitment to the study of the geologic processes that have shaped our planet and modified its environment. The scientific problems being addressed range from the geologic history and structure of continental margins to the processes responsible for the formation and alteration of the ocean's crust. In a time of enhanced public and scientific interest in problems of global change, ODP provides critical data on changes in ocean circulation, chemistry, and biologic productivity and their relation to changes in atmospheric circulation and glacial conditions. The Ocean Drilling Program has a unique role in addressing these problems, since it is the only facility for continuously sampling the geologic record of the ocean basins, which cover 70% of our planet.

The ODP is the successor to the Deep Sea Drilling Project (DSDP), which was a global reconnaissance of the ocean basins. DSDP began operations in 1968 at Scripps Institution of Oceanography, using a 400-foot drillship, the *Glomar Challenger*. DSDP was supported initially by only the National Science Foundation, with extensive involvement of international scientists who were invited to participate on drilling cruises. As this international interest continued to grow in the early 1970's, formal participation in the project was offered to the international geoscience community. In 1975, five nations (France, the Federal Republic of Germany, Japan, the United Kingdom, and the Soviet Union) accepted this commitment to joint planning and conduct of the project, as well as to financial support for operations. This International Phase of Ocean Drilling (IPOD) continued to 1983. Although the *Challenger* had reached the limits of her capabilities, the remarkable scientific success of the DSDP and the new questions it had generated demanded a continuing capability for drilling in the oceans.

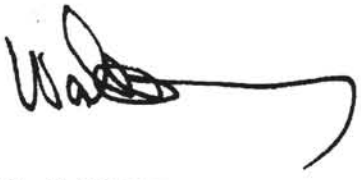
The Ocean Drilling Program was organized, international participation was coordinated, a new drillship (the *JOIDES Resolution*) was contracted and outfitted, and her first cruise sailed in early 1985, within 18 months of the retirement of the *Challenger*. This is a remarkable accomplishment that reflects the efforts and excellence of the Joint Oceanographic Institutions, Inc. (prime contractor for ODP), Texas A&M University (science and ship operator), Lamont-Doherty Earth Observatory (logging operator), and the international science community in organizing and planning the new program. It was argued in planning for the ODP that a larger drillship was required to provide space for the increasing U.S. and international demand for shipboard participation, improved and expanded laboratory capabilities, and improvements in coring and logging systems. A larger and better equipped vessel would also provide better stability and working conditions in high-latitude regions of the oceans. The success of the *JOIDES Resolution* has proven the wisdom of these early arguments.

ODP now has operated in all oceans except the ice-covered Arctic. We have drilled above the Arctic circle and within sight of the Antarctic continent. Over 1000 scientists from 25 nations have participated in the initial ODP cruises. The larger scientific parties have allowed an increased emphasis on student participation and training aboard ship. The state-of-the-art laboratories support rapid and complete initial analyses of samples that provide both scientific results and guide subsequent shore-based studies. Nearly 1000 additional scientists have used these data and requested samples from the program's core and data archives for continuing study. The geochemical and geophysical logging capability is unsurpassed in either academia or industry and has provided remarkable new data with which to study the Earth. New experiments to measure and monitor geologic processes have been deployed in ODP boreholes.

The international commitment to ocean drilling has increased in the ODP. In addition to our five partners in IPOD—France, the Federal Republic of Germany, Japan, the Soviet Union, and the United Kingdom—two consortia have joined ODP: Canada-Australia and the European Science Foundation (representing Belgium, Denmark, Finland, Greece, Iceland, Italy, The Netherlands, Norway, Spain, Sweden, Switzerland, and Turkey). The 20 countries of the ODP represent the community of nations that have a global interest in the geosciences and oceanography. This global scientific participation has assured the program's scientific excellence by focusing and integrating the combined scientific knowledge and capabilities of

the program's 20 nations. It has allowed problems of a global nature to be addressed by providing databases and background studies which are openly shared for planning and interpreting drilling results. It has eased problems of access to territorial waters, allowing comparative studies to be done among oceans. Finally, the international sharing of program costs has allowed this important and large program to proceed without detrimental impact to the research budgets of any one nation.

The Ocean Drilling Program, like its predecessor, DSDP, serves as a model for planning, conducting, and financing research to address problems of global importance. The National Science Foundation is proud to have a leading role in this unique international program, and we look forward to its continuing success.



Walter E. Massey
Director
National Science Foundation

Washington, D.C.

# 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 permitting 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 borehole televiewer is available for 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. 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.

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 three sites: ODP Pacific and Indian Ocean cores at TAMU, ODP and DSDP Atlantic and Antarctic cores at LDEO, and DSDP Pacific and Indian Ocean cores at the Scripps Institution of Oceanography.

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. 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 addition, ODP is cooperating closely with other geological and geophysical programs; for example, in 1991 the first hole was drilled by ODP for emplacement of a seismometer near Hawaii for the Ocean Seismic Network. 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 results to come.

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.

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

# REVIEWERS FOR THIS VOLUME

C. Geoffrey Adams
Neville F. Alley
John H.C. Bain
Paul A. Baker
Keir Becker
William A. Berggren
Daniel Bernoulli
Mark Boardman
Anne Marie Bodergat
Yvonne Bone
Timothy J. Bralower
Benjamin Buchbinder
Richard T. Buffler
William H. Busch
Jacques A. Butterlin
Robert M. Carter
James Channell
George C. Chaproniere
Patrick J. Coleman
Kathleen A. Dadey
Barrie Dale
Patrick de Dekker
Roy E. Dove
Gregor P. Eberli
Thomas W.D. Edwards
John V. Firth
Benjamin P. Flower
Karl B. Föllmi
Evan K. Franseen
Michael Fuller
Craig S. Fulthorpe
Brian M. Funnell
Anne F. Gardulski
Robert E. Garrison
Thomas G. Gibson
Joris M. Gieskes
Stephen Greenlee
David W. Haig
Rex Harland
Peter Hempel
R.A. Henderson
Emilio Herrero-Bervera
David A. Hodell
Michael J. Jackson
Noel P. James
Eric de Kaenel
Barbara H. Keating
Jock B. Keene
Kerry Kelts
John M. Kennard
W. David Kennedy
James P. Kennett
John W. King
Federico Krause
Lynton S. Land
James R. Lawrence
Tom S. Loutit
Michael K. Macphail
Kazumi Matsuoka
Clive McCann
Matthew J. McGlone
Brian McGowran
Gregory A. Mead
Allan J. Melillo
William J. Meyers
Isabel P. Montañez
Henry T. Mullins
David C. Nobes
Gunnar Olafsson
Jeffrey S. Oslick
Beth A. Palmer
Larry C. Peterson
Philippe A. Pezard
James Pospichal
Ellen Prager
Domenico Rio
Tsunemasa Saito
Katharina V. Salis
J. Frederick Sarg
Wolfgang Schlager
William V. Sliter
Peter Southgate
Lisa Tauxe
Elliott Taylor
Ellen Thomas
Elizabeth M. Truswell
Anne de Vernal
David K. Watkins
Amos Winter
Sherwood W. Wise, Jr.
Antoine A.H. Wonders
John H. Wrenn
Jijun Zhang

Publisher's Note: Current policy requires that artwork published in *Scientific Results* volumes of the *Proceedings of the Ocean Drilling Program* be furnished by authors in final camera-ready form.

# 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 Oceanography

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

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

European Science Foundation Consortium for Ocean Drilling, Belgium, Denmark, Finland, Iceland, Italy, Greece, 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

Russia, Academy of Sciences

United Kingdom, Natural Environment Research Council

## PRIME CONTRACTOR

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

Thomas E. Pyle
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

Philip D. Rabinowitz
Director

Timothy J.G. Francis
Deputy Director

Richard G. McPherson
Administrator

Jack G. Baldauf, Manager
Science Operations

Barry W. Harding, Manager
Engineering and Drilling Operations

Russell B. Merrill, Curator and Manager
Science Services

Robert E. Olivas, Manager
Technical and Logistics Support

John C. Coyne, Manager
Information 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 133*


Judith A. McKenzie
Co-Chief Scientist
*Geologisches Institut*
*Eidgenossische Technische Hochschule*
*Sonneggstrasse 5*
*CH-8092 Zurich*
*Switzerland*

Peter J. Davies
Co-Chief Scientist
*Division of Marine Geosciences*
*Bureau of Mineral Resources, Geology and Geophysics*
*P.O. Box 378*
*Canberra City, ACT 2601*
*Australia*

Amanda A. Palmer-Julson
ODP Staff Scientist/Sedimentologist/Physical Properties Specialist
*Ocean Drilling Program*
*Texas A&M University Research Park*
*1000 Discovery Drive*
*College Station, Texas 77845-9547*
*U.S.A.*

Christian G. Betzler
Paleontologist (foraminifers)
*Geologisch-Paläontologisches Institut*
*Johann Wolfgang Goethe-Universität Frankfurt*
*Senckenberganlage 32-34*
*D-6000 Frankfurt am Main 11*
*Federal Republic of Germany*

Thomas C. Brachert
Sedimentologist
*Institut für Geowissenschaften*
*Johannes Gutenberg Universität Mainz*
*Postfach 3980*
*D-6500 Mainz*
*Federal Republic of Germany*

Min-Pen Philip Chen
Physical Properties Specialist
*Institute of Oceanography*
*National Taiwan University*
*P.O. Box 23-13 Taipei*
*Taiwan, Republic of China*

Jean-Pierre Crumière
Organic Geochemist
*Laboratoire de Sédimentologie*
*Université Claude Bernard*
*27-43 Bd du 11 Novembre*
*F 69622 Villeurbanne*
*France*

George R. Dix
Sedimentologist
*Department of Geological Sciences*
*University of British Columbia*
*6339 Stores Road*
*Vancouver, British Columbia V6T 2B4*
*Canada*

André W. Droxler
Sedimentologist
*Department of Geology and Geophysics*
*Rice University*
*P.O. Box 1892*
*Houston, Texas 77251-1892*
*U.S.A.*

David A. Feary
Sedimentologist
*Division of Marine Geosciences*
*Bureau of Mineral Resources, Geology and Geophysics*
*P.O. Box 378*
*Canberra City, ACT 2601*
*Australia*

Stefan Gartner
Paleontologist (nannofossils)
*Department of Oceanography*
*Texas A&M University*
*College Station, Texas 77843*
*U.S.A.*

Craig R. Glenn
Sedimentologist
*Hawaii Institute of Geophysics*
*University of Hawaii*
*2525 Correa Road*
*Honolulu, Hawaii 96822*
*U.S.A.*

Alexandra Isern
Inorganic Geochemist
*Graduate School of Oceanography*
*University of Rhode Island*
*Narragansett Bay Campus*
*Narragansett, Rhode Island 02882-1197*
*U.S.A.*

Peter D. Jackson
Logging Scientist
*British Geological Survey*
*Keyworth, Nottingham NG12 5GG*
*United Kingdom*

Richard D. Jarrard
LDGO Logging Scientist
*Borehole Research Group*
*Lamont-Doherty Geological Observatory*
*Columbia University*
*Palisades, New York 10964*
*U.S.A.*

Miriam E. Katz
Paleontologist (foraminifers)
*Lamont-Doherty Geological Observatory*
*Columbia University*
*Palisades, New York 10964*
*U.S.A.*


* Addresses at time of cruise.

Kenji Konishi
Sedimentologist
*Department of Earth Sciences*
*Kanazawa University*
*Kanazawa City 920*
*Ishikawa*
*Japan*

Dick Kroon
Paleontologist (foraminifers)
*Grant Institute of Geology*
*University of Edinburgh*
*West Mains Road*
*Edinburgh EH9 3JW*
*United Kingdom*

John W. Ladd
Physical Properties Specialist
*Ocean Drilling Program*
*National Science Foundation*
*1800 G Street, NW*
*Washington, DC 20550*
*U.S.A.*

José Manuel Martín
Sedimentologist
*Departamento de Estratigrafía y Paleontología*
*I.A.G.M. Universidad Granada-C.S.I.C.*
*Campo de Fuentenueva s.n.*
*18002 Granada*
*Spain*

Donald F. McNeill
Paleomagnetist
*Division of Marine Geology and Geophysics*
*Rosenstiel School of Marine and Atmospheric Science*
*University of Miami*
*4600 Rickenbacker Causeway*
*Miami, Florida 33149-1098*
*U.S.A.*

Lucien F. Montaggioni
Sedimentologist
*Centre de Sédimentologie et Paléontologie*
*U.R.A. - C.N.R.S.*
*Université de Provence*
*Place Victor Hugo*
*13331 Marseille Cedex 3*
*France*

Daniel W. Müller
Sedimentologist
*Geologisches Institut*
*Eidgenossische Technische Hochschule*
*Sonneggstrasse 5*
*CH-8092 Zurich*
*Switzerland*

Sheraz Khan Omarzai
Paleomagnetist
*Earth Sciences Board of Studies*
*University of California, Santa Cruz*
*Santa Cruz, California 95064*
*U.S.A.*

Chris J. Pigram
Sedimentologist
*Department of Geology*
*Australian National University*
*G.P.O. Box 4*
*Canberra City, ACT 2601*
*Australia*

Peter K. Swart
Inorganic Geochemist
*Division of Marine Geology and Geophysics*
*Rosenstiel School of Marine and Atmospheric Science*
*University of Miami*
*4600 Rickenbacker Causeway*
*Miami, Florida 33149-1098*
*U.S.A.*

Philip A. Symonds
Geophysicist
*Division of Marine Geosciences*
*Bureau of Mineral Resources, Geology and Geophysics*
*P.O. Box 378*
*Canberra City, ACT 2601*
*Australia*

Keith F. Watts
Sedimentologist
*Department of Geology and Geophysics*
*University of Alaska*
*Fairbanks, Alaska 99775*
*U.S.A.*

Wuchang Wei
Paleontologist (nannofossils)
*Department of Geology*
*Florida State University*
*Tallahassee, Florida 32306*
*U.S.A.*

## SEDCO OFFICIALS

Captain Anthony Ribbens
Master of the Drilling Vessel
*Underseas Drilling, Inc.*
*707 Texas Avenue South*
*Suite 103D*
*College Station, Texas 77840-1917*
*U.S.A.*

Jack Tarbutton
Drilling Superintendent
*Underseas Drilling, Inc.*
*707 Texas Avenue South*
*Suite 103D*
*College Station, Texas 77840-1917*
*U.S.A.*

### ODP ENGINEERING AND OPERATIONS PERSONNEL

| | |
|---|---|
| Jack Pheasant | Development Engineer |
| Eugene Pollard | Operations Superintendent |

### ODP TECHNICAL AND LOGISTICS PERSONNEL

| | |
|---|---|
| Roger Ball | Electronics Technician |
| Daniel Bontempo | Marine Technician |
| Jim Briggs | Electronics Technician |
| Scott Chaffey | Chemistry Technician |
| Jo Claesgens | Yeoperson |
| Joe DeMorett | Marine Technician |
| Edwin Garrett | Computer System Manager |
| Burney Hamlin | Laboratory Officer |
| Gretchen Hampt | Curatorial Representative |
| Chester Jones | Marine Technician/Storekeeper |
| Kazushi ("Kuro") Kuroki | Marine Technician |
| Eric Meissner | Electronics Technician |
| Michael Moore | Marine Technician |
| Frank Peerderman | Marine Technician |
| Joan Perry | Marine Technician |
| Joe Powers | Assistant Laboratory Officer |
| Ahmet Tandircioglu | Marine Technician |
| John Tenison | Photographer |

## Ocean Drilling Program Publications Staff

*Publications Supervisor*
William D. Rose

*Chief Editor*
Lona Haskins Dearmont
Ann Klaus

*Editors*
Chryseis O. Fox
Eva M. Maddox
Jennifer A. Marin
Nancy K. McQuistion
Sondra K. Stewart

*Chief Production Editor*
Jennifer Pattison Hall

*Production Editors*
Jill K. Butler
Mauri L. Coulter
Jaime A. Gracia (this volume)

*Senior Publications Coordinator*
Janalisa Braziel Soltis

*Publications Coordinator*
Gudelia ("Gigi") Delgado

*Publications Distribution Specialist*
Fabiola Muñoz Byrne

*Data Entry/Copier Operator*
Amy Hernandez

*Senior Photographer*
John W. Beck

*Photographer*
Barry C. Cochran

*Chief Illustrator*
Deborah L. Partain

*Illustrators*
Melany R. Borsack
Michelle Cady
Michelle Curtis
Garnet D. Gaither
Linda C. Orsi

*Production Assistants*
Carrie R. Castillón
Mary Elizabeth Mitchell
Alexandra F. Moreno

# TABLE OF CONTENTS

## VOLUME 133—SCIENTIFIC RESULTS

### SECTION 1: BIOSTRATIGRAPHY AND PALEONTOLOGY



### SECTION 2: PALEOCEANOGRAPHY

## SECTION 3: SEDIMENTOLOGY AND SEISMIC STRATIGRAPHY

## SECTION 4: GEOCHEMISTRY AND DIAGENESIS



## SECTION 5: PALEOMAGNETISM

## SECTION 6: PHYSICAL PROPERTIES



## SECTION 7: SYNTHESES



## SECTION 8: DATA REPORTS

**Back-Pocket Foldouts**