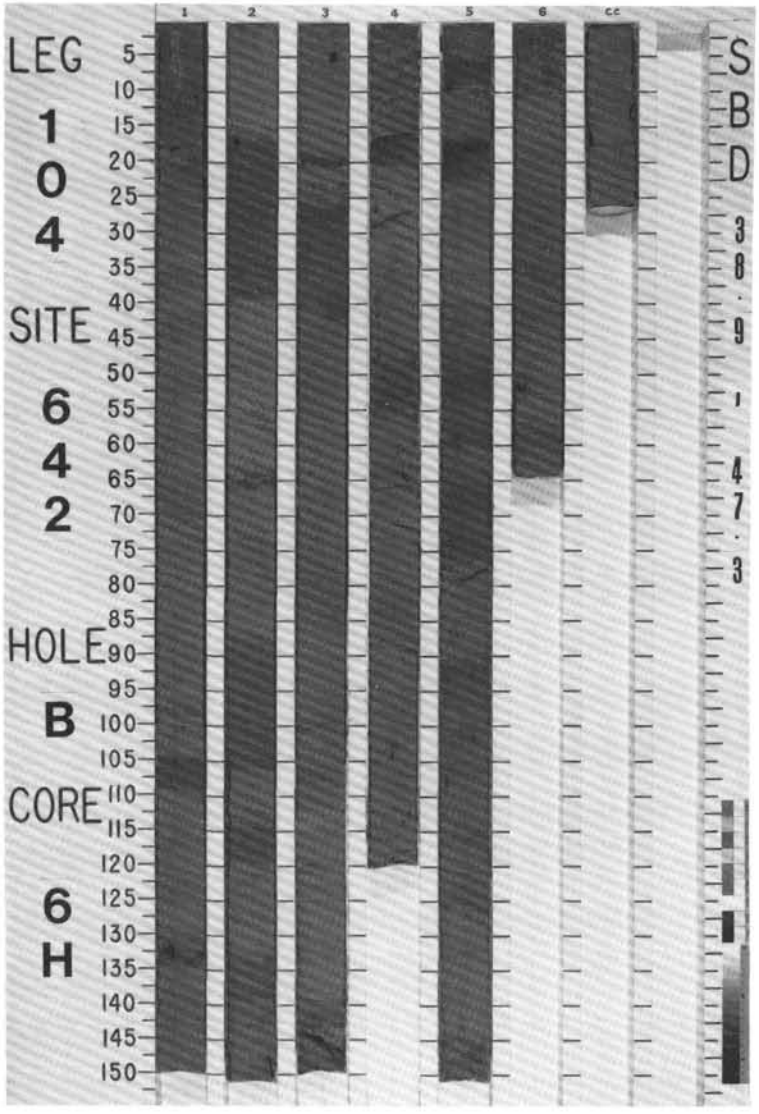

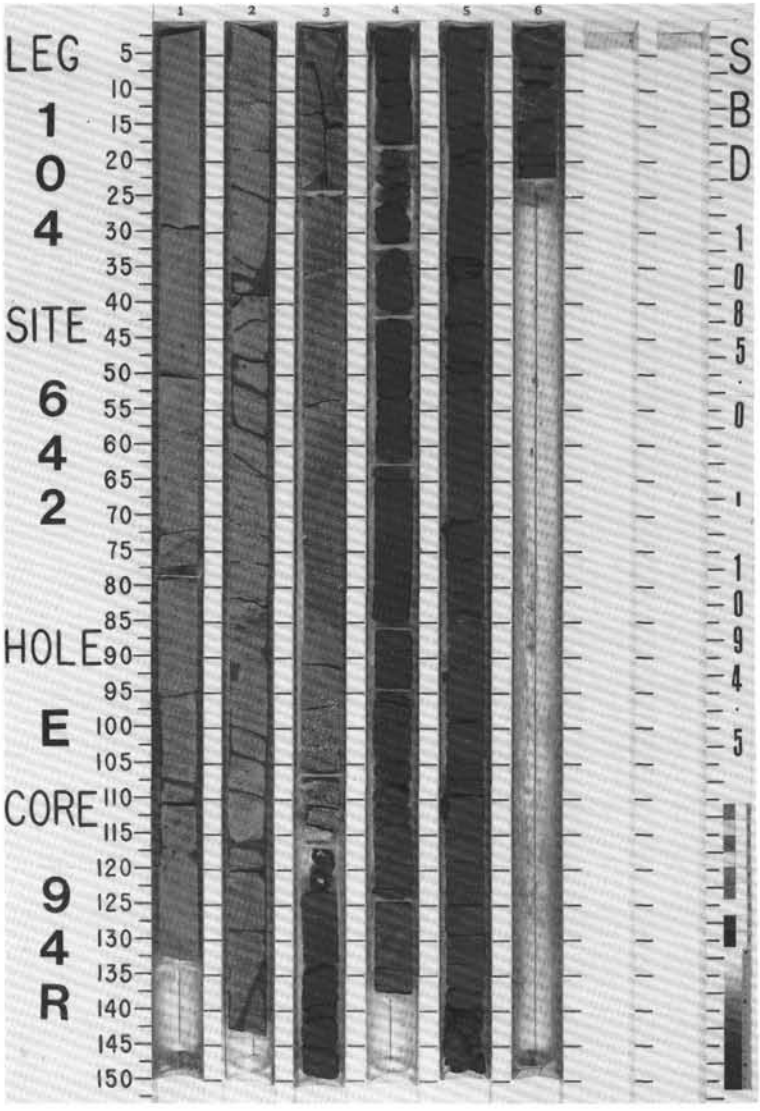

VOLCANIC MARGIN EVOLUTION AND CENOZOIC PALEOENVIRONMENT

Site 642 recovery includes Pliocene-Pleistocene, interbedded dark and light layers corresponding to glacial and interglacial fluctuations (Core 104-642B-6H) (left). Below the Cenozoic sediment cover, interbedded volcaniclastic and tholeiitic basalt flows form a wedge of seaward-dipping reflectors. The base of the dipping reflector sequence, marked by a local reflector K, is correlated with a thick ignimbrite unit (Core 104-642E-94R) (right) separating the overlying volcanics from dacitic and andesitic basalts below.

PROCEEDINGS OF THE OCEAN DRILLING PROGRAM

VOLUME 104
SCIENTIFIC RESULTS

NORWEGIAN SEA

Covering Leg 104 of the cruises of the Drilling Vessel *JOIDES Resolution*, Bremerhaven, Germany, to St. John's, Newfoundland, Sites 642–644, 19 June 1985–23 August 1985

Olav Eldholm, Jörn Thiede, Elliott Taylor, Colleen Barton, Kjell Bjørklund, Ulrich Bleil, Paul Ciesielski, Alain Desprairies, Diane Donnally, Claude Froget, Robert Goll, Rudiger Henrich, Eystein Jansen, Lawrence Krissek, Keith Kvenvolden, Anne LeHuray, David Love, Peter Lysne, Thomas McDonald, Peta Mudie, Lisa Osterman, Lindsay Parson, Joseph D. Phillips, Alan Pittenger, Gunnbjørg Qvale, Günther Schönharting, and Lothar Viereck
Participating Scientists

Elliott Taylor
Shipboard Staff Scientist

Prepared by the
OCEAN DRILLING PROGRAM
TEXAS A&M UNIVERSITY

William R. Winkler
Volume Editor

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

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Foreword

By the National Science Foundation

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

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

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

The Ocean Drilling Program truly has international participation. In 1975, the International Phase of Ocean Drilling began with member nations—the U.S.A., U.S.S.R., the Federal Republic of Germany, Japan, the United Kingdom, and France—all providing funds and scientific guidance for the project. Today, ODP partners include the U.S.A., Canada, France, the Federal Republic of Germany, Japan, the United Kingdom, and the European Science Foundation, which represents Sweden, Finland, Norway, Iceland, Denmark, Belgium, the Netherlands, Spain, Switzerland, Italy, Greece, and Turkey. The National Science Foundation, with funds contributed by the United States and international partners, supports the scientific operations and planning for the ODP through a contract with Joint Oceanographic Institutions, Inc. (JOI).

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

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

Erich Bloch
Director
National Science Foundation

Washington, D.C.

Foreword

By Joint Oceanographic Institutions, Inc.

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

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

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

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

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

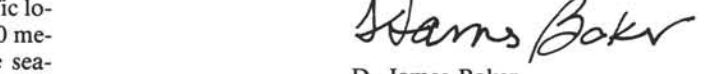
The ship, registered as SEDCO/BP 471 after her owners and her length in feet (144 meters), is 70 feet (21 meters) wide, and has a displacement of 16,595 long tons. Her derrick towers 200 feet (61 meters) above the waterline, and a computer-controlled dynamic-positioning system stabilizes the ship over a specific location while drilling in water depths up to 27,000 feet (8230 meters). The drilling system collects cores from beneath the seafloor with a derrick and drawworks that can handle 30,000 feet (9144 meters) of drill pipe. More than 12,000 square feet (1115 square meters) of space distributed throughout the ship is devoted to scientific laboratories and equipment. The ship sails with a scientific and technical crew of 50 and a ship's crew of 65.

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

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

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

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



D. James Baker
President
Joint Oceanographic Institutions, Inc.

Washington, D.C.

Preface

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

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

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

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 these 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

Aharon, Paul
Alt, Jeffrey
Anderson, Aubrey
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Wrenn, John

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

Thomas E. Pyle
Director, Ocean Drilling Programs

OPERATING INSTITUTION

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

Melvin Friedman, Principal Investigator

OCEAN DRILLING PROGRAM

Philip D. Rabinowitz
Director

Louis E. Garrison
Deputy Director

Sylvia Cecile DeVoge
Administrator

Audrey W. Meyer, Manager
Science Operations

Barry Harding, Manager
Engineering and Drilling Operations

Russell B. Merrill, Curator and Manager
Science Services

Robert E. Olivas, Manager
Technical and Logistics Support

LOGGING OPERATOR

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

Roger N. Anderson, Head

PARTICIPANTS ABOARD *JOIDES RESOLUTION* FOR LEG 104

Olav Eldholm
Co-Chief
Department of Geology
University of Oslo
P.O. Box 1047, Blindern
N-0136 Oslo 3
Norway

Jörn Thiede
Co-Chief
Geologisch-Paläontologisches Institut und Museum
Christian-Albrechts Universität
Olshausenstrasse 40
D-2300 Kiel
Federal Republic of Germany

Elliott Taylor
Staff Scientist and Physical Properties Specialist
Ocean Drilling Program
Texas A&M University
College Station, Texas 77843

Colleen Barton
Logging Scientist
Department of Geophysics
Stanford University
Stanford, California 94305

Kjell Bjørklund
Paleontologist (radiolarians)
Department of Geology, Section B
University of Bergen
Allegaten 41
N-5000 Bergen
Norway

Ulrich Bleil
Paleomagnetist
Fachbereich Geowissenschaften
Universität Bremen
Postfach 330440
D-2800 Bremen 33
Federal Republic of Germany

Paul Ciesielski
Paleontologist (diatoms/silicoflagellates)
Department of Geology
University of Florida
Gainesville, Florida 32611

Alain Desprairies
Sedimentary Petrologist
Laboratoire de Géochemie
Université de Paris-Sud
Batiment 504
91405 Orsay
France

Diane Donnally
Paleontologist (nannofossils)
Department of Geology
Florida State University
Tallahassee, Florida 32306

Claude Froget
Sedimentologist
Laboratoire Géologie Marine
Centre Université de Luminy
Case 901
13288 Marseille Cedex 9
France

Robert Goll
Paleontologist (radiolarians)
Department of Geology, Section B
University of Bergen
Allegaten 41
N 5000 Bergen
Norway

Rudiger Henrich
Sedimentologist
Geologisch-Paläontologisches Institut und Museum
Christian-Albrechts Universität
Olshausenstrasse 40
D-2300 Kiel
Federal Republic of Germany

Eystein Jansen
Paleontologist (planktonic foraminifers)
Department of Geology, Section B
University of Bergen
Allegaten 41
N-5000 Bergen
Norway

Lawrence Krissek
Sedimentologist
Department of Geology and Mineralogy
Ohio State University
Columbus, Ohio 43210

Keith Kvenvolden
Organic Geochemist
U.S. Geological Survey
345 Middlefield Road, M/S 999
Menlo Park, California 94025

Anne LeHuray
Petrologist
Lamont-Doherty Geological Observatory
Columbia University
Palisades, New York 10964

David Love
Petrologist
Department of Earth Sciences
University of Waterloo
Waterloo, Ontario N2L 3G1
Canada

Peter Lysne
Well Logging Specialist
6240 A
Geoscience Research Drilling Office
Sandia National Laboratories
Albuquerque, New Mexico 87101

Thomas McDonald
Organic Geochemist
Department of Oceanography
Texas A&M University
College Station, Texas 77843

Peta Mudie
Paleontologist (dinoflagellates and palynomorphs)
Geological Survey of Canada
Atlantic Geoscience Centre
Box 1006
Dartmouth, Nova Scotia B2Y 4A2
Canada

Lisa Osterman
Paleontologist (benthic foraminifers)
Department of Paleobiology NHB-E207
Smithsonian Institution
Washington, D.C. 20560

Lindsay Parson
Petrologist
Institute of Oceanographic Sciences
Brook Road
Wormley, Godalming
Surrey GU8 5UB
England

Joseph D. Phillips
Geophysicist
Institute for Geophysics
University of Texas at Austin
Austin, Texas 78751

Alan Pittenger
Physical Properties Specialist
Department of Oceanography
Texas A&M University
College Station, Texas 77843

Gunnbjørg Qvale
Paleontologist (benthic foraminifers)
Department of Geology
University of Oslo
P.O. Box 1047, Blindern
N-0136 Oslo 3
Norway

Günther Schönharting
Paleomagnetist
Institut for Almen Geologi
Kobenhavns Universitet
Østervoldgade 10
DK-1350, Copenhagen
Denmark

Lothar Viereck
Petrologist
Institut für Mineralogie
Ruhr Universität Bochum
Postfach 102148
D-4630 Bochum-Querenberg
Federal Republic of Germany

SEDCO OFFICIALS

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

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

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University of Texas at Austin
Austin, Texas 78751

Ocean Drilling Program Publications Staff

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ACKNOWLEDGMENTS

Leg 104 in the summer of 1985 was the first attempt of the Ocean Drilling Program (ODP) to bring the *JOIDES Resolution* into high northern latitudes and to carry out extensive coring and sampling operations. Due to the superb performance of the vessel and its crew under competent leadership of Captain Ed Oonk and Drilling Superintendent Bob Caldow, as well as the dedicated ODP scientific and technical staff headed by Operations Superintendent Glenn Foss, the Leg was a very successful scientific venture.

Most of the data and results of Leg 104 have been described earlier in the *Proceedings of the Ocean Drilling Program, Initial Reports*, Volume 104. In this volume, we present the results of more detailed and comprehensive interpretations of the Leg 104 material. Together with the information collected during Leg 38 of the Deep Sea Drilling Project, the Leg 104 data have provided a much improved understanding of the geological history of the Norwegian–Greenland Sea.

The Shipboard Scientific Party, having the privilege to participate in Leg 104 and in the subsequent analysis of data and samples, and the many shore-based investigators are grateful to a number of organizations and individuals for continued support and encouragement. We recognize in particular: a) the large number of funding agencies in the various ODP member countries; b) the staff of the ODP operational headquarters at Texas A&M University and the Downhole Measurement Group and East Coast Repository at Lamont-Doherty Geological Observatory; c) The JOIDES advisory panels, especially the Atlantic Regional Panel and the Norwegian Sea Working Group, which played an important role during the planning of the Leg.

The scientific articles in this volume have been reviewed by at least two outside referees. Their constructive criticism and evaluation of the submitted papers have greatly improved the scientific quality of the volume, a contribution which is gratefully acknowledged. The accepted manuscripts were prepared for publication by the staff of the ODP publication group, for whose patience and dedication we are indeed indebted.