

PROCEEDINGS OF THE OCEAN DRILLING PROGRAM

VOLUME 102
Part A — INITIAL REPORT

BERMUDA RISE

Covering Leg 102 of the cruises of the Drilling Vessel *JOIDES Resolution*,
Miami, Florida, to Ponta Delgada, Azores, Site 418,
14 March 1985 – 25 April 1985

Matthew H. Salisbury, James H. Scott, Keir Becker, Wilhelm Bosum,
Cristina Broglia, Rick Carlson, Andrew Fisher, Joris Gieskes,
Mary Anne Holmes, Hartley Hoskins, Jacques Legrand, Dan Moos,
Domenico Rio, Ralph A. Stephen, and Roy Wilkens
Participating Scientists

Christian Auroux
Shipboard Science Representative

R. Marie Littleton
Editor

Prepared by the
OCEAN DRILLING PROGRAM
Texas A&M University
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:

Department of Energy, Mines and Resources (Canada)

Deutsche Forschungsgemeinschaft (Federal Republic of Germany)

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

National Science Foundation (United States)

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:

Salisbury, M. H., Scott, J. H., Auroux, C. A., et al., 1986. *Proc., Init. Repts. (Pt. A), ODP*, 102.

Auroux, C. A., and Stephen, R. A., 1986. Geophysical profiling, ODP Leg 102. *In* Salisbury, M. H., Scott, J. H., Auroux, C. A., et al., *Proc., Init. Repts. (Pt. A), ODP*, 102, ____-____.

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.

Distribution

Copies of this publication may be obtained from Publications Distribution Center, Ocean Drilling Program, 1000 Discovery Drive, College Station, Texas 77840. Orders for copies will require advance payment. See current ODP publication list for price and availability of this publication.

Printed December 1986

ISSN 0884-5883

Foreword

By 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 new 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.

With the publication of these first two *Initial Reports* (Part A) volumes of the Ocean Drilling Program *Proceedings*, the program can be said to be 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.

These volumes present the first set of 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.

Under the guidance of Texas A&M University, the conversion of the *JOIDES Resolution* to a scientific drilling ship was completed on schedule, and the new ship sailed on her maiden voyage in January 1985. The ODP is now well under way. As of this writing, the ship has already completed a sweep of the North Atlantic Ocean and the Mediterranean Sea, and is beginning work in the East-Central Pacific off the coast of Peru. Scientific achievements 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 in-

clude the first bare-rock coring, and logging data more accurate and complete than ever before.

With the publication of these first two *Initial Reports* (Part A) volumes of the ODP *Proceedings*, congratulations are due the international community of scientists and engineers and to the science and engineering operations team who have made the successful beginning of the program possible.



D. James Baker
President
Joint Oceanographic Institutions, Inc.

Washington, D.C.

OCEAN DRILLING PROGRAM

MEMBER ORGANIZATIONS OF THE JOINT OCEANOGRAPHIC INSTITUTIONS FOR DEEP EARTH SAMPLING (JOIDES):¹

University of California at San Diego, Scripps Institution of Oceanography

Columbia University, Lamont-Doherty Geological Observatory

University of Hawaii, Hawaii Institute of Geophysics

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, Department of Oceanography

University of Texas at Austin, Institute for Geophysics

University of Washington, College of Ocean and Fishery Sciences

Woods Hole Oceanographic Institution

Canada, Department of Energy, Mines and Resources

European Science Foundation Consortium for Ocean Drilling (ECOD), 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

United Kingdom, Natural Environment Research Council

OPERATING INSTITUTION

College of Geosciences
Texas A&M University
College Station, Texas
William J. Merrell, Principal Investigator

OCEAN DRILLING PROGRAM

Philip D. Rabinowitz
Director

Louis E. Garrison
Deputy Director

Sylvia DeVoge Herrig
Administrator

Robert R. Kidd, Manager
Science Operations

Archie R. McLerran, Manager
Engineering and Drilling Operations

Russell B. Merrill, 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 Anderson, Head

¹ Includes member organizations during time of cruise.

PARTICIPANTS ABOARD JOIDES RESOLUTION FOR LEG 102

Matthew H. Salisbury

Co-Chief Scientist
Deep Sea Drilling Project
University of California, San Diego
La Jolla, California 92093

James H. Scott

Co-Chief Scientist
U.S. Geological Survey, M.S. 964
Box 25046, Denver Federal Center
Denver, Colorado 80225

Christian Auroux

Sedimentologist/ODP Staff Scientist
Ocean Drilling Program
Texas A&M University
College Station, Texas 77843

Keir Becker

Downhole Hydrogeophysicist
Geological Research Division
Scripps Institution of Oceanography
La Jolla, California 92093

Cristina Broglia

Logging Specialist
Lamont-Doherty Geological Observatory
Columbia University
Palisades, New York 10964

Wilhelm Bosum

Downhole Magnetometer Specialist
Bundesanstalt für Geowissenschaften und Rohstoffe
D-3000 Hannover 51
P.O. Box 51 01 53
Federal Republic of Germany

Rick Carlson

Physical Properties Specialist
Department of Geophysics
Texas A&M University
College Station, Texas 77843

Andrew Fisher

Heat Flow Geophysicist
Rosenstiel School of Marine and Atmospheric Sciences
University of Miami
Miami, Florida 33149

Joris Gieskes

Inorganic Geochemist
Ocean Research Division - A-015
Scripps Institution of Oceanography
University of California, San Diego
La Jolla, California 92093

Mary Anne Holmes

Sedimentologist
433 Morrill Hall
Department of Geology
University of Nebraska
Lincoln, Nebraska 68588-0340

Hartley Hoskins

VSP Scientist
Ocean Industries Program
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

Jacques Legrand

Marine Engineer
Département Instrumentation et Equipements
IFREMER
B.P. 337, Brest 29273
France

Dan Moos

Logging Scientist
Lamont-Doherty Geological Observatory
Columbia University
Palisades, New York 10964

Domenico Rio

Paleontologist (nannofossils)
Istituto di Geologia
Via Kennedy, 4
43100 Parma
Italy

Ralph A. Stephen

VSP Specialist
Department of Geology and Geophysics
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

Roy Wilkens

Physical Properties/Logging Specialist
Earth Resources Laboratory E34-404
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Captain Ed Oonk

Master of the Drilling Vessel
Underseas Drilling
707 Texas Avenue South
Suite 103 D
College Station, Texas 77840-1917

Bob Caldow

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

ODP ENGINEERING AND OPERATIONS PERSONNEL

Jeffrey Edwards Fishing Tools Consultant
(GOTCO International, Inc.
P.O. Box 58267
Houston, Texas)

Glen Foss Operations Manager

Jeffrey Skelly Logger
(Schlumberger Offshore Service
Houston Offshore District
8460 Gulf Freeway
Houston, Texas 77017)

Patrick Thompson Special Tools Engineer

ODP TECHNICAL AND LOGISTICS PERSONNEL

Bettina Domeyer Marine Technician

John Eastlund Computer System Manager

Jenny Glasser Marine Technician

Leon Gove Oblique Seismic Experiment Technician
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

Burney Hamlin Laboratory Officer

Michiko Hitchcox Yeoperson

Harry ("Skip") Hutton Marine Technician

Daniel Larson Electronic Technician

Kevin de Mauret Photographer

Matthew Mefferd Marine Technician

Ewald Meyer Downhole Magnetometer Technician
(Bundesanstalt für
Geowissenschaften und Rohstoffe)
D-3000 Hannover 51
P.O. Box 51 01 53
Federal Republic of Germany

Bill Mills Senior Technician

Gail Peretsman Chemistry Technician

Joseph Powers Marine Technician

Michael Reitmeyer Electronic Technician

Kevin Rogers Marine Technician

Christian Segade Marine Technician

Katie Sigler Chemistry Technician

Donald Sims Marine Technician

John Tauxe Marine Technician

Ocean Drilling Program Publications Staff

Publications Supervisor
William D. Rose

Editors
R. Marie Littleton
William R. Winkler

Chief Production Editor
Raymond F. Silk

Production Editor
Mei-Chun Lee

Senior Photographer
John W. Beck

Photographer
Roy Davis

Manuscript Coordinator
Elsa Kapitan Mazzullo

Hole Summary Coordinator
Patricia M. Wunneburger

Publications Distribution Specialist
Fabiola M. Byrne

Chief Illustrator
Karen O. Benson

Illustrators
Garnet D. Gaither
Aida A. Prazak
Pamela Vesterby
Christine L. Yokley

Composer
Rhoda Segur

TABLE OF CONTENTS

VOLUME 102 — PART A

ACKNOWLEDGMENTS	1
SECTION 1: INTRODUCTION	
1. EXPLANATORY NOTES	5
Shipboard Scientific Party	
2. GEOPHYSICAL PROFILING, ODP LEG 102.....	7
C. A. Auroux and R. A. Stephen	
SECTION 2: SITE REPORT	
3. SITE 418: BERMUDA RISE.....	95
Shipboard Scientific Party	
APPENDIX	151
SECTION 3: INDEX	
INDEX	239
JOIDES ADVISORY GROUPS	241
SAMPLE-DISTRIBUTION POLICY	245

BACK-POCKET FOLDOUTS

VOLUME 102: CHAPTER 2: FIGURE 5: REAL-TIME ANALOGIC SEISMIC LINES RECORDED ON BOARD *JOIDES RESOLUTION* DURING LEG 102 (BOTH PARTS).

VOLUME 102: CHAPTER 3: PLATES 1-6:

 PLATES 1-3: LITHOLOGIC AND LOGGING DATA FROM BASEMENT ROCKS, HOLE 418A

 PLATE 4: LITHOLOGIC AND LOGGING DATA FROM SEDIMENTS, HOLE 418A

 PLATE 5: VARIABLE DENSITY PLOT OF FULL SONIC WAVEFORM FROM RECEIVER 3

 PLATE 6: LITHOLOGIC AND MAGNETIC LOGGING DATA FROM BASEMENT ROCKS AND LOWER SEDIMENTS, HOLE 418A

ACKNOWLEDGMENTS

We express our appreciation to Captain Ed Oonk and the officers and crew of the *JOIDES Resolution* for their considerable assistance during Leg 102. We also thank Burney Hamlin and the ODP marine technicians for standing watch and assisting in the labs. Michael Reitmeyer, Daniel Larson, and Patrick Thompson were, once again, most effective in preparing the tools and logging heads and in helping with electrical and mechanical matters. We also thank the SEDCO Drilling Superintendent, Bob Caldwell, and the ODP Cruise Operations Manager, Glen Foss, for their support and cooperation, which was essential for the leg to be a success, and Jeff Edwards for his advice during the retrieval operations. We are also grateful to Ewald Meyer and Jeff Skelly for their assistance during logging.

James Broda, Gordon Glass, Kenneth Griffith, Archie Roberts, and their team of mechanical and electrical technicians carried out highly effective air-gun and water-gun operations on the R/V *Fred H. Moore*. The water gun was borrowed from the U.S. Geological Survey-Woods Hole. Thomas Bolmer, David Senske, and Wayne Spencer ran laboratory watches on the R/V *Fred H. Moore*. Captain Bruce Collins and his mates on the R/V *Fred H. Moore* navigated shooting patterns extremely well. The operations of the *Moore* were supported by NSF grant no. OCE/8416633.

Behind the scenes, Mark Weiderspahn and William Robinson designed and wrote the digital acquisition system for the borehole seismometer, Warren Witzell maintained the tool, and Donald Koelsch gave essential electronic advice.

Frederick Hess, who designed and supervised the construction of the three-component borehole preamplifier, died a week before the cruise sailed. We regret that he was not able to see the results of his work.

Finally, we acknowledge the help of the ODP Publications staff in the preparation of this volume.