PROCEEDINGS OF THE OCEAN DRILLING PROGRAM

VOLUME 105
SCIENTIFIC RESULTS

BAFFIN BAY AND LABRADOR SEA

Covering Leg 105 of the cruises of the Drilling Vessel *JOIDES Resolution*, St. John's, Newfoundland, to St. John's, Newfoundland, Sites 645–647, 23 August 1985–27 October 1985

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in cooperation with the
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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:

Srivastava, S. P., Arthur, M. A., Clement, B., et al., 1989. *Proc. ODP, Sci. Results*, 105: College Station, TX (Ocean Drilling Program).

Head, M. J., Norris, G., and Mudie, P. J., 1989. New species of dinocysts and a new species of Acritarch from the upper Miocene and lowermost Pliocene, ODP Leg 105, Site 646, Labrador Sea. *In* Srivastava, S. P., Arthur, M. A., Clement, B., et al., *Proc. ODP, Sci. Results*, 105: College Station, TX (Ocean Drilling Program), 453–466.

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 117 (*Initial Reports*): May 1989
Volume 118 (*Initial Reports*): April 1989
Volume 119 (*Initial Reports*); August 1989
Volume 101/102 (*Scientific Results*): December 1988
Volume 103 (*Scientific Results*): December 1988
Volume 104 (*Scientific Results*): Printed October 1989

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 October 1989

ISSN 0884-5891

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.

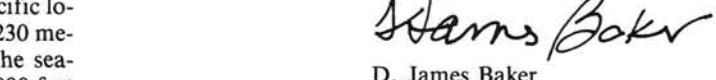
The ship, registered as SEDCO/BP 471 after her owners and her length in feet (144 meters), is 70 feet (21 meters) wide, and has a displacement of 16,595 long tons. Her derrick towers 200 feet (61 meters) above the waterline, and a computer-controlled dynamic-positioning system stabilizes the ship over 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
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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*.

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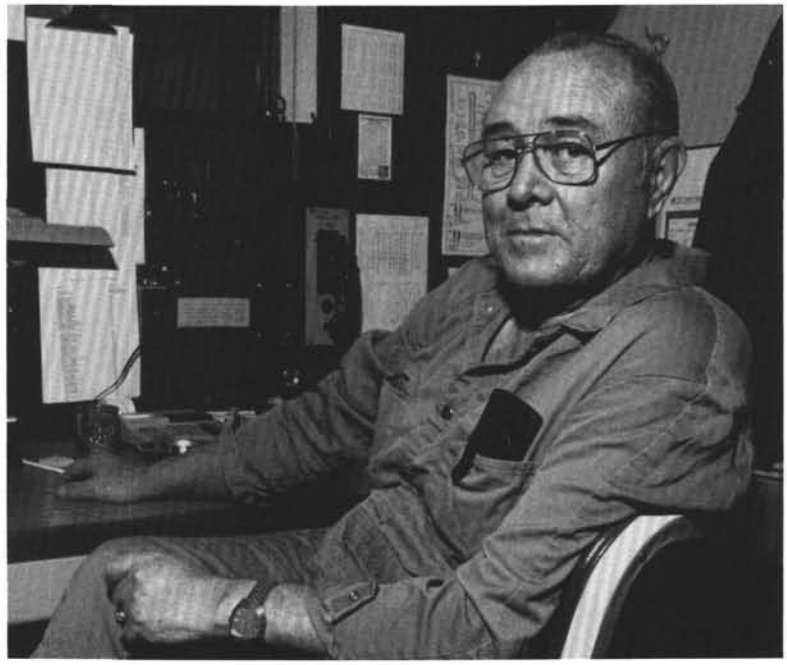

DEDICATION

The scientific party of ODP Leg 105 dedicates this volume of scientific drilling results to Lamar Hayes, the man who was, in large part, responsible for the success of drilling and sediment recovery during Leg 105 under extremely adverse conditions. To the great sorrow of the drilling community, Lamar died of a massive heart attack during Leg 120 in the high-latitude Indian Ocean on March 27, 1988. Lamar passed away while performing his usual technical miracles for the program at sea aboard the *JOIDES Resolution*. While at sea during Leg 105, Lamar was a constant source of inspiration and consolation to many of us. An early morning coffee and discussion of the latest drilling and/or weather conditions with Lamar was often the high point of a day. Lamar was always concerned with the satisfaction of the scientists—worrying as to how to increase core recovery, optimize time for logging, solve technical problems, and the like. But his concern went far beyond the duties associated with his position as Drilling Superintendent. Many of us, at one time or another, sought his counsel regarding problems at home or simply sat and discussed college football scores that came in over the radio, basked in the glow of his likeable manner, and chortled at his droll humor. Lamar also watched for signs of trouble in interpersonal relationships that commonly come up during 60-day stints at sea and attempted to head off such problems early. His constant monitoring of and comments on the quality of food served on the ship is well known. He seemed to feel that this is the single most important feature of life at sea, setting the tone for all else on the cruise.

Lamar did everything possible to help us to achieve our scientific objectives. One of his major accomplishments during Leg 105 was the development of a method for using the Advanced Piston Corer at high sea states in conjunction with the Heave Compensator and the coring winch. The main problem was to keep the sand line taut, which he did by adjusting the variac—maintaining tension on the coring line throughout the 6- to 8-ft vertical heave by adjusting the winch controls to hoist and holding them in a "stalled" position. Without this ingenious approach, we probably would not have obtained the high-quality APC cores for the upper part of the Eirik Ridge sequence at Site 646 or would have lost logging and/or deeper objectives because of the need to use the APC at the end of drilling at this site.

Lamar Hayes was an exceptional person, and he and his attention to our needs will be sorely missed in the drilling program. Perhaps somewhere up above, Lamar is plotting how to modify the weather to allow ease of drilling and recovery at high latitudes.

ACKNOWLEDGMENTS

Drilling in the high latitudes beyond the Arctic Circle has long been of high priority in the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES) drilling program. Leg 105 of the Ocean Drilling Program was designed to approach this objective and was devoted to drilling in the ice-infested waters of Baffin Bay and the storm-ridden region of the Labrador Sea. The leg originated as a result of numerous discussions and presentations to various JOIDES advisory panels by the Labrador Sea working group, who were the main proponents for drilling in these regions. We are grateful to the members of this working group, particularly to Felix Gradstein, Lubomir Jansa, Ken Miller, Al Grant, Peta Mudie, and John Pierce for their contributions toward fulfilling the drilling objectives.

The success of Leg 105 stems largely from the detailed seismic survey conducted in the Labrador Sea from the *Hudson* by the Geological Survey of Canada before the ODP cruise and the availability of Petro-Canada's multichannel seismic data for the Baffin Bay region, which helped us to establish priorities, choose scientific objectives, and establish the seismostratigraphy of these two regions, as well as to reassess the results of earlier Labrador Sea drilling in light of these data. We are thankful to these organizations for their help, and especially to Captain Fred Maugher and the crew of the *Hudson*.

We also acknowledge the assistance rendered by the Canadian Department of the Environment in providing ice-forecasting information before and during the cruise.

Ultimately, the success of Leg 105 owes much to the ingenuity and resourcefulness of Operations Superintendent Lamar Hayes and his associates who, with the aid of a capable SEDCO drilling crew, did a superb job in helping us achieve high core recovery during extremely adverse weather conditions. We are grateful to the ODP technical staff, without whose help we would not have achieved as much as we did. They did a fine job under the able guidance of Laboratory Officer Ted (Gus) Gustafson. At sea, Captain Gerard T. Kuster and his crew did a superb job keeping the ship on station in winds of up to 50 kt and in seas with 30-ft swells. We thank them for their great skill and for their help.

Our special thanks go to Brad Clement, the ODP staff scientist who ably organized and helped to run the cruise and who diligently processed and reviewed manuscripts for scientific content and expression. We also acknowledge the many reviewers of the original manuscripts, who provided scientific guidance. We are indebted to Sondra Stewart of ODP for her considerable editorial efforts and for her attempts to keep this volume on track. The help of Ray Silk, Susan Collinsworth, and Grace Riggan, ODP production staff, in preparing this volume for press is gratefully acknowledged.

We owe a great debt to many of our colleagues for their help and discussions, which contributed much to the success of this leg and to this volume. S. P. Srivastava wishes to thank the Geological Survey of Canada for supporting his participation in this leg and in the studies that followed the cruise. The U.S. workers also acknowledge grant assistance provided by JOI-USSAC that enabled them to complete the shore-based research reported herein.