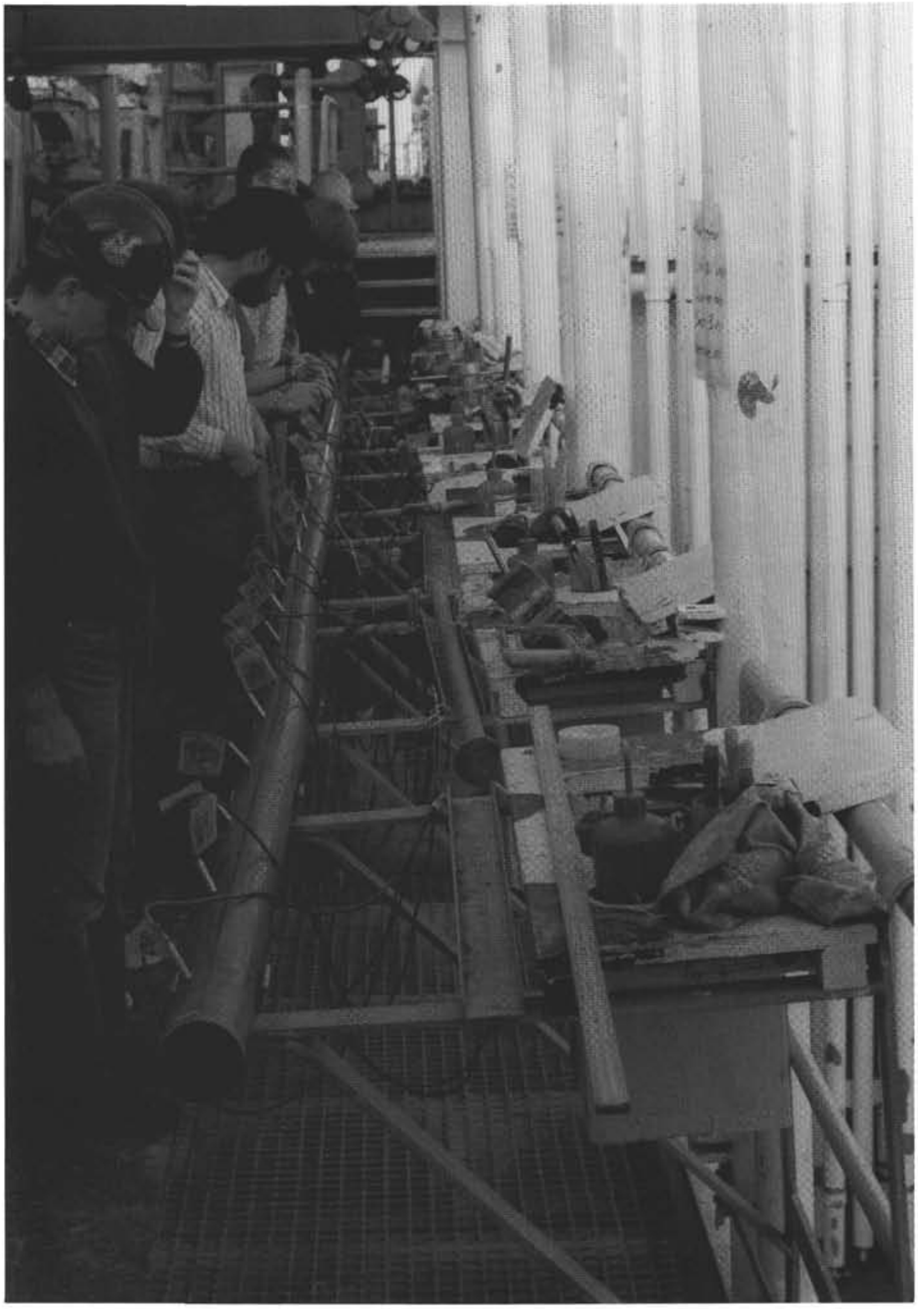

Photograph illustrating core temperature measurements being made on the catwalk of the *JOIDES Resolution* during Leg 164. Thirty thermocouple probes are inserted into the core through small holes in the core liner as the data are logged on a personal computer. Temperature measurements are useful for detecting gas hydrate because gas hydrate decomposition is endothermic. Thus, anomalously low temperatures may indicate areas where gas hydrate is decomposing or has decomposed.

PROCEEDINGS OF THE OCEAN DRILLING PROGRAM

VOLUME 164
INITIAL REPORTS
GAS HYDRATE SAMPLING ON THE BLAKE RIDGE AND CAROLINA RISE

Covering Leg 164 of the cruises of the Drilling Vessel *JOIDES Resolution*,
Halifax, Nova Scotia, to Miami, Florida, Sites 991–997,
31 October–19 December 1995

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

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Foreword

By the National Science Foundation

The National Science Foundation is proud to play a leading role in partnership with the U.S. oceanographic community in the operation and management of the Ocean Drilling Program (ODP). We are equally proud of the cooperation and commitment of our international partners, who contribute both financial and intellectual resources required to maintain the high quality of this unique program. The Ocean Drilling Program, like its predecessor, the Deep Sea Drilling Project (DSDP), is a model for the organization and planning of research to address global scientific problems that are of high priority internationally and of long-term interest to the scientific community and general public.

Major scientific themes guiding the development of specific drilling cruises range from determining the causes and effects of oceanic and climatic variability to understanding the circulation of fluids in the ocean crust and the resultant formation of mineral deposits. Although such studies are at the forefront of basic scientific inquiry into the processes that control and modify the global environment, they are equally important in providing the background for assessing man's impact on the global environment or for projecting resource availability for future generations.

The transition from the DSDP to the ODP was marked by a number of changes. The 471-foot *JOIDES Resolution,* which replaced the *Glomar Challenger,* has allowed larger scientific parties and the participation of more graduate students, a larger laboratory and technical capability, and operations in more hostile ocean regions. The *JOIDES Resolution* has drilled in all of the world's oceans, from the marginal ice regions of the Arctic to within sight of the Antarctic continent. Over 1,200 scientists and students from 26 nations have participated on project cruises. Cores recovered from the cruises and stored in ODP repositories in the United States and Europe have provided samples to an additional 1,000 scientists for longer term post-cruise research investigations. The downhole geochemical and geophysical logging program, unsurpassed in either academia or industry, is providing remarkable new data with which to study the Earth.

In 1994, NSF and our international partners renewed our commitment to the program for its final phase. Of the 20 countries that supported ODP initially, only one, Russia, has been unable to continue for financial reasons. As the reputation and scientific impact of the program continue to grow internationally, we hope to add additional members and new scientific constituencies. This global scientific participation continues to assure the program's scientific excellence by focusing and integrating the combined scientific knowledge and capabilities of its member nations.

We wish the program smooth sailing and good drilling!

Neal Lane

Neal Lane
Director
National Science Foundation
Arlington, Virginia

Foreword

By Joint Oceanographic Institutions, Inc.

This volume presents scientific and engineering results from the Ocean Drilling Program (ODP). The papers presented here address the scientific and technical goals of the program, which include providing a global description of geological and geophysical structures including passive and active margins and sediment history, and studying in detail areas of major geophysical activity such as mid-ocean ridges and the associated hydrothermal circulations.

The Ocean Drilling Program, an international activity, operates a specially equipped deep-sea drilling ship, the *JOIDES Resolution* (Sedco/BP 471), which contains state-of-the-art laboratories, equipment, and computers. The ship is 471 feet (144 meters) long, is 70 feet (21 meters) wide, and has a displacement of 18,600 short tons. Her derrick towers 211 feet (64 meters) above the waterline, and a computer-controlled dynamic-positioning system stabilizes the ship over a specific location while drilling in water depths up to 27,000 feet (8230 meters). The drilling system collects cores from beneath the seafloor with a derrick and drawworks that can handle 30,000 feet (9144 meters) of drill pipe. More than 12,000 square feet (1115 square meters) of space distributed throughout the ship is devoted to scientific laboratories and equipment. The ship sails with a scientific and technical crew of 51 and a ship's crew (including the drill crew) of 62. The size and ice-strengthening of the ship allow drilling in high seas and ice-infested areas as well as permit a large group of multidisciplinary scientists to interact as part of the scientific party.

Logging, or measurements in the drilled holes, is an important part of the program. ODP provides a full suite of geochemical and geophysical measurements for every hole deeper than 1300 feet (400 meters). For each such hole, there are lowerings of basic oil-industry tools: nuclear, sonic, and electrical. In addition, a Formation MicroScanner is available for high-resolution imaging the wall of the hole, a 12-channel logging tool provides accurate velocity and elastic property measurements as well as sonic waveforms for spectral analysis of energy propagation near the wall of the hole, and a vertical seismic profiler can record reflectors from below the total depth of the hole.

The management of the Ocean Drilling Program involves a partnership of scientists and governments. International oversight and coordination are provided by the ODP Council, a governmental consultative body of the partner countries, which is chaired by a representative from the United States National Science Foundation (NSF). The ODP Council periodically reviews the general progress of the program and discusses financial plans and other management issues. Overall scientific and management guidance is provided to the operators of the program by representatives from the group of institutions involved in the program, called the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES).

The Executive Committee (EXCOM), made up of the administrative heads of the JOIDES institutions, provides general oversight for ODP. The Planning Committee (PCOM), with its advisory structure, is made up of working scientists and provides scientific advice and detailed planning. PCOM has a network of panels and working groups that screen drilling proposals, evaluate instrumentation and measurement techniques, and assess geophysical-survey data and other safety and siting information. PCOM uses the recommendations of the panels and committees to select drilling targets, to specify the location and major scientific objectives of each two-month drilling segment or leg, and to provide the science operator with nominations for co-chief scientists.

Joint Oceanographic Institutions, Inc. (JOI), a nonprofit consortium of U.S. oceanographic institutions, serves as the National Science Foundation's prime contractor for ODP. JOI is responsible for seeing that the scientific objectives, plans, and recommendations of the JOIDES committees are translated into scientific operations consistent with scientific advice and budgetary constraints. JOI subcontracts the operations of the program to two universities: Texas A&M University and Lamont-Doherty Earth Observatory of Columbia University. JOI is also responsible for managing the U.S. contribution to ODP under a separate cooperative agreement with NSF.

Texas A&M University (TAMU) serves as science operator for ODP. In this capacity, TAMU is responsible for planning the specific ship operations, actual drilling schedules, and final scientific rosters, which are developed in close cooperation with PCOM and the relevant panels. The science operator also ensures that adequate scientific analyses are performed on the cores by maintaining the shipboard scientific laboratories and computers and by providing logistical and technical support for shipboard scientific teams. Onshore, TAMU manages scientific activities after each leg, is curator for the cores, distributes samples, and coordinates the editing and publication of scientific results.

Lamont-Doherty Earth Observatory (LDEO) of Columbia University is responsible for the program's logging operation, including processing the data and providing assistance to scientists for data analysis. The ODP Data Bank, a repository for geophysical data, is also managed by LDEO.

Core samples from ODP and the previous Deep Sea Drilling Project are stored for future investigation at four sites: ODP Pacific and Indian Ocean cores at TAMU, DSDP Pacific and Indian Ocean cores at the Scripps Institution of Oceanography, ODP and DSDP Atlantic and Antarctic cores through Leg 150 at LDEO, and ODP Atlantic and Antarctic cores since Leg 151 at the University of Bremen, Federal Republic of Germany.

Scientific achievements of ODP include new information on early seafloor spreading and how continents separate and the margins evolve. The oldest Pacific crust has been drilled and sampled. We have new insights into glacial cycles and the fluctuations of ocean currents throughout geological time. ODP has also provided valuable data that shed light on fluid pathways through the lithosphere, global climate change both in the Arctic and near the equator, past sea-level change, seafloor mineralization, the complex tectonic evolution of oceanic crust, and the evolution of passive continental margins.

Many of the scientific goals can be met only with new technology; thus the program has focused on engineering as well as science. To date, ODP engineers have demonstrated the capability to drill on bare rock at mid-ocean-ridge sites and have developed techniques for drilling in high-temperature and corrosive regions typical of hydrothermal vent areas. A new diamond coring system promises better core recovery in difficult areas. In a close collaborative effort between ODP engineers and scientists, a system has been developed that seals selected boreholes ("CORKs") and monitors downhole temperature, pressure, and fluid composition for up to three years. When possible, ODP is also taking advantage of industry techniques such as logging while drilling, to obtain continuous downhole information in difficult-to-drill formations.

JOI is pleased to have been able to play a facilitating role in the Ocean Drilling Program and its cooperative activities, and we are looking forward to many new, exciting results in the future.

James D. Watkins
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Columbia University, Lamont-Doherty Earth Observatory

University of Hawaii, School of Ocean and Earth Science and Technology

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Oregon State University, College of Oceanic and Atmospheric Sciences

University of Rhode Island, Graduate School of Oceanography

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

University of Texas at Austin, Institute for Geophysics

University of Washington, College of Ocean and Fishery Sciences

Woods Hole Oceanographic Institution

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, Greece, Iceland, Italy, The Netherlands, Norway, Spain, Sweden, Switzerland, and Turkey)

Federal Republic of Germany, Bundesanstalt für Geowissenschaften und Rohstoffe

France, Institut Français de Recherche pour l'Exploitation de la Mer

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Publisher's Note

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*At time of publication.

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Smear-slide descriptions for:

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Thin-section descriptions for:

(For JOIDES Advisory Groups and ODP Sample and Data Distribution Policy, please see *ODP Proceedings, Initial Reports*, Volume 158, pp. 375–384.)

CD-ROM
Leg 164 Materials

There are two CD-ROMs in the back of this volume. One is a "data-only" CD-ROM containing depth-shifted and processed logging data provided by the Borehole Research Group at the Lamont-Doherty Earth Observatory. This CD-ROM also contains shipboard GRAPE (gamma-ray attenuation porosity evaluator), index property, magnetic susceptibility, and natural gamma data of cores collected on board the *JOIDES Resolution* during Leg 164. CD-ROM production was carried out by the Borehole Research Group at the Lamont-Doherty Earth Observatory, Wireline Logging Operator for ODP. The second CD-ROM contains an electronic version of the Leg 164 *Initial Reports* volume in Adobe Acrobat, tab delimited ASCII files of all the tables from the volume, and vane shear and index properties data for Sites 991 through 997.

Core Log and Core Data Directory Structure:

- NIH IMAGE directory
- GENERAL INFORMATION directory
  - Acronyms file
  - Compression documentation file
  - Format documentation file
  - Index file
  - Readme file
  - Software documentation file
- LOG DATA directory
  - HOLE number subdirectory
    - Conventional Logs subdirectory
    - Acronyms and units file
    - Compression documentation (when applicable)
    - Log Data subdirectories
      - Individual tool data files
      - Processing documentation
    - FMS and Dipmeter Data subdirectory
      - Dipmeter in ASCII format file(s)
      - FMS images in PBM (portable bit map—8 bit binary) format subdirectory
        - 1:1 ratio images subdirectory
          - Data files (every 10 m)
          - Raster documentation file
        - 1:10 ratio image subdirectory
          - Data files (every 100 m)
          - Raster documentation file
- CORE DATA directory
  - README document
  - CORELOG.MCD data file
  - SITE number subdirectory
    - HOLE number subdirectory
      - GRAPE data file
      - INDEX data file
      - MAGSUS data file
      - NATGAM data file
    - GRAPE documentation file
    - Index properties documentation file
    - Magnetic susceptibility documentation file
    - Natural gamma documentation file

The above structure is identical for each site and hole.

The INDEX.DOC file contains a summary of all the files loaded on the CD-ROM.

The software documentation file in the GEN_INFO directory contains information on which software packages work best to import PBM (portable bit map—8 bit binary) raster files. It also includes network sources for the graphics software and data compression information. The README file gives information on whom to contact with any questions about the production of or data on the CD-ROM.

All of the ASCII files (with the exception of the sonic waveform files [SWF files]) are tab delimited for compatibility with most spreadsheet and database programs.

Holes that have more than one logging pass with the same tools are labeled Main and Repeat for conventional logs, or Pass 1, Pass 2, etc., for FMS. If the files are not in separate directories they may just be annotated with "m" and "r" or "1" and "2" in the data filenames when there is room for only one character. Holes that have long logging runs are often divided into UPPER and LOWER directories. The files may just be annotated with "u" or "l" in the data filenames where space permits. Check the documentation file for a given directory if it is not clear to you.

In the FMS-PBM format directory there are two subdirectories: 1:1 ratio with maximum 10-m-long image raster files and 1:10 ratio with maximum 100-m-long image raster files. The image raster files are named according to their depth interval. The raster documentation files contain image file parameter information necessary for use with most graphic software packages.

Summary of Log Data:

- Hole 994C:
  - Conventional logs
  - Geochemical logs (element and oxide wt%)
  - Sonic waveforms
  - Temperature logs
- Hole 994D:
  - Conventional logs
  - Sonic waveforms
- Hole 995B:
  - Conventional logs
  - Geochemical logs (element and oxide wt%)
  - High-resolution logs
  - FMS data
  - Sonic waveforms
  - Temperature logs
- Hole 997B:
  - Conventional logs
  - FMS data
  - Geochemical logs (element and oxide wt%)
  - Sonic waveforms
  - Temperature logs

Summary of ODP Core Data:

- Site 991:
  - Hole A:
    - grape.dat
    - index.dat
    - magsus.dat
    - natgam.dat
    - pwave.dat
- Site 992:
  - Hole A:
    - grape.dat
    - index.dat
    - magsus.dat
    - natgam.dat
    - pwave.dat
- Site 993:
  - Hole A:
    - grape.dat
    - index.dat
    - magsus.dat
    - natgam.dat
    - pwave.dat
- Site 994:
  - Hole A:
    - grape.dat
    - magsus.dat
    - natgam.dat
    - pwave.dat
  - Hole B:
    - grape.dat
    - magsus.dat
    - natgam.dat
    - pwave.dat
  - Hole C:
    - grape.dat
    - index.dat
    - magsus.dat
    - natgam.dat
    - pwave.dat
  - Hole D:
    - grape.dat
    - index.dat
    - magsus.dat
    - natgam.dat
    - pwave.dat
- Site 995:
  - Hole A:
    - grape.dat
    - index.dat
    - magsus.dat
    - natgam.dat
    - pwave1.dat
    - pwave2.dat
  - Hole B:
    - index.dat
- Site 996:
  - Hole A:
    - grape.dat
    - index.dat
    - magsus.dat
    - natgam.dat
    - pwave.dat
  - Hole B:
    - grape.dat
    - index.dat
    - magsus.dat
    - natgam.dat
    - pwave.dat
  - Hole C:
    - grape.dat
    - index.dat
    - magsus.dat
    - natgam.dat
    - pwave.dat
  - Hole D:
    - grape.dat
    - index.dat

natgam.dat
pwave.dat
Hole E:
grape.dat
index.dat
magsus.dat
natgam.dat
pwave.dat
Site 997:
Hole A:
grape.dat
index.dat
magsus.dat
natgam.dat
pwave.dat
Hole B:
grape.dat
index.dat
magsus.dat
natgam.dat

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vs993a.txt
vs994c.txt
vs996a.txt
vs996b.txt
vs996c.txt
vs996e.txt
vs997a.txt

Index Properties Data Directory:

The ODP CD-ROM also contains index properties data for Sites 991 through 997.

ip991a.txt
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ip993a.txt
ip994c.txt
ip994d.txt
ip995a1.txt
ip995a2.txt
ip995b.txt
ip996a.txt
ip996b.txt
ip996c.txt
ip996d.txt
ip996e.txt
ip997a.txt
ip997b.txt

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