

PROCEEDINGS OF THE OCEAN DRILLING PROGRAM

VOLUME 161 SCIENTIFIC RESULTS MEDITERRANEAN SEA II THE WESTERN MEDITERRANEAN

Covering Leg 161 of the cruises of the Drilling Vessel *JOIDES Resolution*,
Naples, Italy, to Málaga, Spain, Sites 974–979,
3 May–2 July 1995

Rainer Zahn, María Carmen Comas, Adam Klaus,
Charles Aubourg, Paul E. Belanger, Stefano M. Bernasconi, Winton Cornell,
Eric P. de Kaenel, F.D. de Larouzière, Carlo Doglioni, Heidi Doose, Hitoshi Fukusawa,
Mike Hobart, Silvia Maria Iaccarino, Peter Ippach, Kathleen Marsaglia, Philip Meyers,
Anne Murat, Gerard M. O'Sullivan, John P. Platt, Manika Prasad, William G. Siesser,
C. Gregory Skilbeck, Juan I. Soto, Kush Tandon, Masayuki Torii,
Jane S. Tribble, Roy H. Wilkens
Shipboard Scientists

Adam Klaus
Shipboard Staff Scientist

Editorial Review Board:
Rainer Zahn, María Carmen Comas, Adam Klaus

Prepared by the
OCEAN DRILLING PROGRAM
TEXAS A&M UNIVERSITY

Ruth N. Riegel
Volume Editor

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

Reference to the whole or to part of this volume should be made as follows:

Print citation:

Zahn, R., Comas, M.C., and Klaus, A. (Eds.), 1999. *Proc. ODP, Sci. Results*, 161: College Station, TX (Ocean Drilling Program).

Iaccarino, S.M., and Bossio, A., 1999. Paleoenvironment of uppermost Messinian sequences in the western Mediterranean (Sites 974, 975, and 978). In Zahn, R., Comas, M.C., and Klaus, A. (Eds.), *Proc. ODP, Sci. Results*, 161: College Station, TX (Ocean Drilling Program), 529–541.

CD-ROM citation:

Zahn, R., Comas, M.C., and Klaus, A. (Eds.), 1999. *Proc. ODP, Sci. Results*, 161 [CD-ROM]. Available from: Ocean Drilling Program, Texas A&M University, College Station, TX 77845-9547, U.S.A.

Iaccarino, S., and Bossio, A., 1999. Paleoenvironment of uppermost Messinian sequences in the western Mediterranean (Sites 974, 975, and 978). In Zahn, R., Comas, M.C., and Klaus, A. (Eds.), *Proc. ODP, Sci. Results*, 161, 529–541 [CD-ROM]. Available from: Ocean Drilling Program, Texas A&M University, College Station, TX 77845-9547, U.S.A.

WWW citation:

Zahn, R., Comas, M.C., and Klaus, A. (Eds.), 1999. *Proc. ODP, Sci. Results*, 161 [Online]. Available from World Wide Web: <http://www-odp.tamu.edu/publications/161_SR/16ITOC.HTM>. [Cited YYYY-MM-DD]

Iaccarino, S., and Bossio, A., 1999. Paleoenvironment of uppermost Messinian sequences in the western Mediterranean (Sites 974, 975, and 978). In Zahn, R., Comas, M.C., and Klaus, A. (Eds.), *Proc. ODP, Sci. Results*, 161: College Station, TX (Ocean Drilling Program), 529–541 [Online]. Available from World Wide Web: <http://www-odp.tamu.edu/publications/161_SR/VOLUME/CHAPTERS/CHAP_42.PDF>. [Cited YYYY-MM-DD]

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 173 (*Initial Reports*): July 1998
Volumes 174A/174AX/174B (*Initial Reports*): November 1998
Volume 175 (*Initial Reports*): November 1998
Volume 157 (*Scientific Results*): June 1998
Volumes 159/159T (*Scientific Results*): October 1998
Volume 160 (*Scientific Results*): September 1998

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 February 1999

ISSN

Printed volume: 0884-5891; CD-ROM volume: 1096-2514; WWW volume: 1096-7451
Library of Congress 87-642-462

Printed in Canada by Friesens

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
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*, 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 Science Committee (SCICOM), with its advisory structure, is made up of working scientists and provides scientific advice and detailed planning for the Ocean Drilling Program. SCICOM has a network of panels and committees that screen drilling proposals, evaluate instrumentation and measurement techniques, and assess geophysical survey data and other safety and siting information. SCICOM 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 SCICOM 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
Admiral, U.S. Navy (Retired)
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 extensive research in various aspects of scientific ocean drilling. The authors of the papers published in this volume have enabled future investigators to gain ready access to the results of their research, and I acknowledge their contributions with thanks.

Each paper 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 at least one revision cycle before being accepted for publication. We seek to maintain a peer-review system comparable to those of the most highly regarded journals in the geological sciences.

Each *Scientific Results* volume has an Editorial Review Board that 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 volume has an ODP staff editor who assists with manuscripts that require English-language attention and who coordinates volume assembly.

Scientific Results volumes may also contain short reports of useful data that are not ready for final interpretation. Papers of this type are called Data Reports and include no interpretation of results. Data Report papers are read carefully by at least one specialist to make sure they are well organized, comprehensive, and discuss the techniques or procedures thoroughly.

To acknowledge the contributions made by this volume's Editorial Review Board, the Board members are designated Editors of the volume and are so 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 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 their generous contribution of time and effort, which ensures that only papers of high scientific quality are published in the *Proceedings*.

Paul J. Fox
Director
Ocean Drilling Program
Texas A&M University
College Station, Texas

REVIEWERS FOR THIS VOLUME

Rainer Abart
David Balkwill
Frank Bassinot
Fernando Bea
Richard H. Benson
Christian Betzler
Jacques Bourgois
Bernardo Cesare
Hervé Chamley
Steven Clemens
Adrian Cramp
Cristino J. Dabrio
Tim Dooley
Ian Fitzsimons
Peter F. Friend
Michael Fuller
Stefan Gartner
Bernard A. Housen
Michael Howell
Miguel Huertas

Laurent Jolivet
Anne Marie Karpoff
Barry Katz
Eric Lichtfouse
Ralf Littke
Lidia Lonergan
Luc Lourens
Tim Lyons
Judith MacKenzie
Jonathan Martin
Alain Mascle
Jens Matthiessen
Alain Mauffret
Kitty Milliken
Patrick Monié
Daniel Moos
Julia Morgan
Alessandra Negri
Gomaa Omar
Torren Peakman

U. Pflaumann
Carlos Pirmez
David Pyle
Isabella Raffi
Carl Richter
E.J. Rohling
Peter Roth
Leonardo Sagnotti
Virginia Sisson
Philip Stauffer
Brian Taylor
Hans Thierstein
William Ussler
Giuliana Villa
Maren Voss
David Watkins
P.P.E. Weaver
Tobias Wolff
W. Jan Zachariasse

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 Oceanic and Atmospheric Sciences

University of Rhode Island, Graduate School of Oceanography

Texas A&M University, College of Geosciences

University of Texas at Austin, Institute for Geophysics

University of Washington, College of Ocean and Fishery Sciences

Woods Hole Oceanographic Institution

Australia/Canada/Chinese Taipei/Korea Consortium for Ocean Drilling, Department of Primary Industries and Energy (Australia), Department of Energy, Mines and Resources (Canada), National Taiwan University in Taipei, and Korean Institute for Geology, Mining and Minerals

European Science Foundation Consortium for Ocean Drilling (Belgium, Denmark, Finland, Iceland, Italy, The Netherlands, Norway, Portugal, 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

People's Republic of China, Marine High-Technology Bureau of the State Science and Technology Commission of the People's Republic of China

United Kingdom, Natural Environment Research Council

PRIME CONTRACTOR

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

Kathryn Moran
Director, Ocean Drilling Programs

OPERATING INSTITUTION

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

David B. Prior
Dean

OCEAN DRILLING PROGRAM

Paul J. Fox
Director

Jack G. Baldauf
Deputy Director

Richard G. McPherson
Administrator

Brian Jonasson, Manager
Drilling Services

Ann Klaus, Manager
Publication Services

Thomas A. Davies, Manager
Science Services

LOGGING OPERATOR

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

David Goldberg, Head

* At time of publication.

PARTICIPANTS ABOARD THE *JOIDES RESOLUTION* FOR LEG 161*

Rainer Zahn

Co-Chief Scientist

GEOMAR

Wischhofstraße 1-3

D-24148 Kiel

Federal Republic of Germany

María Carmen Comas

Co-Chief Scientist

Instituto Andaluz de Ciencias de la Tierra

CSIC

Universidad de Granada

Campus Fuentenueva

18002 Granada

Spain

Adam Klaus

Staff Scientist

Ocean Drilling Program

Texas A&M University Research Park

1000 Discovery Drive

College Station, TX 77845-9547

U.S.A.

Charles Aubourg

Paleomagnetist

Département de Géologie

Université de Cergy Pontoise

8, Le Campus

95011 Cergy Cedex

France

Paul E. Belanger

Paleontologist (foraminifers)

Hancock Field Station

39472 Highway 218

Fossil, OR 97830

U.S.A.

Stefano M. Bernasconi

Sedimentologist

Geologisches Institut

ETH-Zentrum

CH-8092 Zurich

Switzerland

Winton Cornell

Sedimentologist

Department of Geosciences

University of Tulsa

600 South College Avenue

Tulsa, OK 74104-3189

U.S.A.

Eric P. de Kaenel

Paleontologist (nannofossils)

Department of Geology, B-160

Florida State University

Tallahassee, FL 32306

U.S.A.

F.D. de Larouzière

LDEO Logging Scientist

Laboratoire de Mesures en Forage

Institut Méditerranéen de Technologie

Technopole de Château Gombert

F-13451 Marseille Cedex 20

France

Carlo Doglioni

Structural Geologist

Centro di Geodinamica

Università della Basilicata

Via Anzio

85100 Potenza

Italy

Heidi Doose

Organic Geochemist

Christian-Albrechts Universität zu Kiel

Olshausenstraße 40-60

24118 Kiel

Federal Republic of Germany

Hitoshi Fukusawa

Sedimentologist

Department of Geography

Faculty of Science

Tokyo Metropolitan University

Hachiohji, Tokyo 192-03

Japan

Mike Hobart

Physical Properties Specialist/Logging Scientist

Department of Geological Sciences

717 W.C. Browning Building

University of Utah

Salt Lake City, UT 84112-1183

U.S.A.

Silvia Maria Iaccarino

Paleontologist (foraminifers)

Istituto di Geologia

Università degli Studi di Parma

Viale delle Scienze, 78

43100 Parma

Italy

Peter Ippach

Volcanologist/Sedimentologist/Petrologist

GEOMAR

Wischhofstraße 1-3

D-24148 Kiel

Federal Republic of Germany

Kathleen Marsaglia

Sedimentologist

Department of Geological Sciences

University of Texas at El Paso

El Paso, TX 79968

U.S.A.

*Addresses at time of cruise.

Philip Meyers
Organic Geochemist
*Department of Geological Sciences
University of Michigan
C.C. Little Building
Ann Arbor, MI48109-1063
U.S.A.*

Anne Murat
Inorganic Geochemist
*Intechmer, B.P. 324
F-50103 Cherbourg Cedex
France*

Gerard M. O'Sullivan
Inorganic Geochemist
*Marine Geosciences
Department of Geology
University of Wales, College of Cardiff
P.O. Box 914
Cardiff CF1 3YE
United Kingdom*

John P. Platt
Structural Geologist
*Department of Geological Sciences
University College London
Gower Street
London WC1E6BT
United Kingdom*

Manika Prasad
Physical Properties Specialist
*Hawaii Institute of Geophysics and Planetology
University of Hawaii
2525 Correa Road
Honolulu, HI 96822
U.S.A.*

William G. Siesser
Paleontologist
*Department of Geology
Box 46-B
Vanderbilt University
Nashville, TN 37235
U.S.A.*

C. Gregory Skilbeck
Sedimentologist
*Department of Applied Geology
University of Technology, Sydney
P.O. Box 123
Broadway, NSW 2007
Australia*

Juan I. Soto
Science Observer
*Instituto Andaluz de Ciencias de la Tierra
CSIC
Universidad de Granada
Campus Fuentenueva
18002 Granada
Spain*

Kush Tandon
Physical Properties Specialist
*Department of Geology and Geophysics
Louisiana State University
Baton Rouge, LA 70803
U.S.A.*

Masayuki Torii
Paleomagnetist
*Laboratory of Rock and Paleomagnetism
Division of Earth and Planetary Sciences
Graduate School of Science
Kyoto 606-01
Japan*

Jane S. Tribble
Sedimentologist
*Department of Oceanography
1000 Pope Road
University of Hawaii
Honolulu, HI 96822
U.S.A.*

Roy H. Wilkens
Core-Log Correlation Specialist
*Hawaii Institute of Geophysics
2525 Correa Road
Honolulu, HI 96822
U.S.A.*

SEDCO OFFICIALS

Captain Edwin G. Oonk
Master of the Drilling Vessel
*Overseas Drilling Ltd.
707 Texas Avenue South, Suite 213D
College Station, TX 77840-1917
U.S.A.*

Wayne Malone
Drilling Superintendent
*Overseas Drilling Ltd.
707 Texas Avenue South, Suite 213D
College Station, TX 77840-1917
U.S.A.*

ENGINEERING AND OPERATIONS PERSONNEL

Leon Holloway

Operations Manager

ODP TECHNICAL AND LOGISTICS PERSONNEL

Mary Ann Cusimano

Marine Laboratory Specialist (X-ray)

Roy Davis

Marine Laboratory Specialist (Photographer)

John Dyke

Marine Laboratory Specialist (Storekeeper)

John Eastlund

Marine Computer Specialist

Edwin Garrett

Marine Laboratory Officer (Paleomagnetism)

Dennis Graham

Assistant Laboratory Officer (Underway Geophysics)

Gus Gustafson

Marine Laboratory Specialist (Downhole Measurements)

Burney Hamlin

Laboratory Officer

Michiko Hitchcox

Marine Laboratory Specialist (Yeoperson)

Rick Johnson

Marine Computer Specialist

Taku Kimura

Marine Laboratory Specialist (Physical Properties)

Chris Mato

Marine Laboratory Specialist (Curatorial)

Eric Meissner

Marine Electronics Specialist

Andrew Mikitchook

Marine Laboratory Specialist

Dwight Mossman

Marine Electronics Specialist

Chieh Peng

Marine Laboratory Specialist (Chemistry)

Phil Rumford

Marine Laboratory Specialist (Chemistry)

Don Sims

Marine Laboratory Specialist (X-ray)

Lorraine Southey

Marine Laboratory Specialist (Curatorial)

Ocean Drilling Program Publications Staff*

Publication Services Manager

Ann Klaus

Senior Production Editor

Jaime A. Gracia

Senior Publications Coordinator

Gudelia ("Gigi") Delgado

Senior Editor

Angeline T. Miller

Production Editors

Amy Brundeen

Production Assistant

Mary Elizabeth Mitchell

Editors

Phyllis M. Garman

Ginny Lowe

Susan Nessler

Ruth N. Riegel

John M. Scroggs

Patrick H. Edwards

Lea Elaine Green (this volume)

Distribution Specialist

Ann Yeager

Senior Illustrator

Deborah L. Partain

Publications Specialist

M. Kathleen Phillips

Assistant Editor

Eric Wilfong

Illustrators

Coleena Burt

Scott Elfstrom

Nancy H. Luedke (this volume)

Karen E. Wagner

Cheng Wei

WWW Administrator

Katerina E. Petronotis

Student Assistants

Theresa Elam, Edward Flax, Caressa F. Inman, Sonya Medina

*At time of publication.

PUBLISHER'S NOTES

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, Greece, Iceland, Italy, 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.

Current policy requires that all figures published in *Scientific Results* volumes of the *Proceedings of the Ocean Drilling Program* be provided by the authors.

Abbreviations for names of organizations and publications in ODP reference lists follow the style given in *Chemical Abstracts Service Source Index* (published by American Chemical Society).

The printed version of the *Proceedings of the Ocean Drilling Program* series will end with *Initial Reports* volume 175 and *Scientific Results* volume 169S. Beginning with *Initial Reports* volume 176 and *Scientific Results* volume 169, all *Proceedings* volumes will be published on CD-ROM and the World Wide Web <<http://www-odp.tamu.edu/publications/>>.

Initial Reports—CD-ROM format: ISSN 1096-2522

WWW format: ISSN 1096-2158

Scientific Results—CD-ROM format: ISSN 1096-2514

WWW format: ISSN 1096-7451

TABLE OF CONTENTS

VOLUME 161—SCIENTIFIC RESULTS

SECTION 1: SEDIMENTOLOGY/PHYSICAL PROPERTIES/TEPHRACHRONOLOGY

1. Petrography and mineralogy of the uppermost Messinian section and the Pliocene/Miocene boundary at Site 975, Western Mediterranean Sea 3
K.M. Marsaglia and J.S. Tribble
2. Mineral associations and geochemical indicators in upper Miocene to Pleistocene sediments in the Alboran Basin 21
F. Martínez-Ruíz, M.C. Comas, and B. Alonso
3. Sand provenance in the Alboran and Tyrrhenian Basins 37
K.M. Marsaglia, K.K. Latter, and V. Cline
4. Pliocene–Pleistocene sedimentary facies at Site 976: depositional history in the northwestern Alboran Sea 57
B. Alonso, G. Ercilla, F. Martínez-Ruíz, J. Baraza, and A. Galimont
5. The sedimentary record of the Alboran Basin: an attempt at sedimentary sequence correlation and subsidence analysis 69
J. Rodríguez-Fernández, M.C. Comas, J. Soría, J.A. Martín-Pérez, and J.I. Soto
6. Environmental significance of an uppermost Pliocene carbonate debris flow at Site 978..... 77
J.C. Braga and M.C. Comas
7. Description, classification, and origin of upper Pliocene–Holocene marine sediments in the Alboran Basin..... 83
C.G. Skilbeck and J.S. Tribble
8. Mineralogy and microfabric of sediment from the Western Mediterranean Sea 99
J.S. Tribble and R.H. Wilkens
9. Ferromagnetic and matrix susceptibilities in Pliocene–Pleistocene hemipelagic marls from the Western Mediterranean Sea 111
C. Aubourg, A. Murat, M. Torii, and O. Oufi
10. Fluid overpressures in western Mediterranean sediments, Sites 974–979 117
A. Revil, P.A. Pezard, and F.D. de Larouzière
11. Coring-induced magnetic fabric in piston cores from the western Mediterranean 129
C. Aubourg and O. Oufi
12. Chronology and composition of volcanoclastic ash layers in the central Tyrrhenian Basin (Site 974)..... 137
P. van den Bogaard, B. Mocek, and M. Stavesand

SECTION 2: BIOSTRATIGRAPHY/PALEONTOLOGY

13. Pleistocene calcareous nannofossil biostratigraphy and the western Mediterranean sapropels, Sites 974 to 977 and 979 159
E. de Kaenel, W.G. Siesser, and A. Murat

14. Biostratigraphy and paleoceanography of the Pliocene at Sites 975 (Menorca Rise) and 976 (Alboran Sea) from a quantitative analysis of the planktonic foraminiferal assemblages	185
F. Serrano, J.M. González-Donoso, and D. Linares	
15. High-resolution biostratigraphy at the Miocene/Pliocene boundary in Holes 974B and 975B, western Mediterranean	197
S.M. Iaccarino, M.B. Cita, S. Gaboardi, and G.M. Gruppini	
16. Neogene calcareous nannofossils: western Mediterranean biostratigraphy and paleoclimatology	223
W.G. Siesser and E.P. de Kaenel	
17. Image-analysis comparison of holotypes of the calcareous nannofossil genus <i>Scyphosphaera</i> . . .	239
W.G. Siesser and J.C. Marler	
SECTION 3: TECTONICS/STRUCTURAL GEOLOGY/PETROLOGY/GEOPHYSICS	
18. Metamorphism of calc-silicate rocks from the Alboran basement	251
V. López Sanchez-Vizcaíno and J.I. Soto	
19. Pressure-temperature evolution of the metamorphic basement of the Alboran Sea: thermobarometric and structural observations	263
J.I. Soto, J.P. Platt, M. Sánchez-Gómez, and J.M. Azañón	
20. The high-grade basement of the Alboran Sea: structural and PT evolution	281
G. Prosser, P. Spadea, and C. Doglioni	
21. Fission-track analysis of samples from the Alboran Sea basement.	295
A.J. Hurford, J.P. Platt, and A. Carter	
22. Ar-Ar dating of biotite and muscovite from Alboran basement samples, Site 976	301
S.R. Kelley and J.P. Platt	
23. Correlation between metamorphic rocks recovered from Site 976 and the Alpujárride rocks of the western Betics	307
M. Sánchez-Gomez, J.M. Azañón, V. García-Dueñas, and J.I. Soto	
24. Structure and tectonic stresses in metamorphic basement, Site 976, Alboran Sea	319
F.D. de Larouzière, P.A. Pezard, M.C. Comas, B. Célérier, and C. Vergnault	
25. Brittle deformation in the metamorphic basement at Site 976: implications for middle Miocene extensional tectonics in the Western Alboran Basin	331
M.C. Comas and J.I. Soto	
26. Pliocene to Holocene structure of the Eastern Alboran Sea (western Mediterranean)	345
J. Alvarez-Marrón	
27. Evidence for Miocene subduction beneath the Alboran Sea: ⁴⁰ Ar/ ³⁹ Ar dating and geochemistry of volcanic rocks from Holes 977A and 978A	357
K. Hoernle, P. van den Bogaard, S. Duggen, B. Mocek, and D. Garbe-Schönberg	
28. <i>Data Report: Major- and trace-element chemistry of Site 976 basement rocks (Alboran Sea)</i>	375
P. Spadea and G. Prosser	

SECTION 4: ORGANIC, INORGANIC, AND INTERSTITIAL WATER GEOCHEMISTRY

29. Sources, preservation, and thermal maturity of organic matter in Pliocene–Pleistocene organic-carbon-rich sediments of the western Mediterranean Sea 383
P.A. Meyers and H. Doose
30. Molecular indicators of the supply of marine and terrigenous organic matter to a Pleistocene organic-matter-rich layer in the Alboran Basin (Western Mediterranean Sea)..... 391
M. Hauschildt, J. Rinna, and J. Rullkötter
31. Carbon and nitrogen stable isotope ratios at Sites 969 and 974: interpreting spatial gradients in sapropel properties 401
J.C. Milder, J.P. Montoya, and M.A. Altabet
32. Carbon, sulfur, and oxygen isotope geochemistry of interstitial waters from the western Mediterranean 413
M.E. Böttcher, S.M. Bernasconi, and H.-J. Brumsack
33. Interstitial water chemistry in the western Mediterranean: results from Leg 161 423
S.M. Bernasconi
34. Bacterial profiles in deep sediments of the Alboran Sea, western Mediterranean, Sites 976–978 433
B.A. Cragg, K.M. Law, G.M. O’Sullivan, and R.J. Parkes

SECTION 5: PALEOCEANOGRAPHY AND PALEOCLIMATE

35. Paleoclimatic conditions during the Quaternary at Sites 976 (Alboran Sea) and 975 (Menorca Rise) inferred from the planktonic foraminiferal assemblages: basis for a biostratigraphy 441
D. Linares, J.M. González-Donoso, and F. Serrano
36. Quaternary marine and continental paleoenvironments in the western Mediterranean (Site 976, Alboran Sea): palynological evidence. 457
N. Combourieu Nebout, L. Londeix, F. Baudin, J.-L. Turon, R. von Grafenstein, and R. Zahn
37. Planktonic $\delta^{18}\text{O}$ records at Sites 976 and 977, Alboran Sea: stratigraphy, forcing, and paleoclimatic implications 469
R. von Grafenstein, R. Zahn, R. Tiedemann, and A. Murat
38. Paleoclimatology of the western Mediterranean during the Pleistocene: oxygen and carbon isotope records at Site 975. 481
C. Pierre, P. Belanger, J.F. Saliège, M.J. Urrutiaguer, and A. Murat
39. Planktonic $\delta^{18}\text{O}$ and $U^{k'}_{37}$ temperature estimates from organic-rich sediments at Sites 974 and 975, Tyrrhenian Sea and Balearic Rise 489
H. Doose, R. Zahn, S. Bernasconi, M. Pika-Biolzi, A. Murat, C. Pierre, and P. Belanger
40. Magnetic and microfaunal characterization of late Quaternary sediments from the western Mediterranean: inferences about sapropel formation and paleoclimatic implications 505
L. Capotondi and L. Vigliotti
41. Pliocene–Pleistocene occurrence of sapropels in the Western Mediterranean Sea and their relation to eastern Mediterranean sapropels 519
A. Murat

42. Paleoenvironment of uppermost Messinian sequences in the western Mediterranean (Sites 974, 975, and 978)	529
S.M. Iaccarino and A. Bossio	
43. The Messinian record of the outcropping marginal Alboran Basin deposits: significance and implications	543
J.M. Martín, J.C. Braga, and I. Sánchez-Almazo	

SECTION 6: SYNTHESIS

44. The origin and tectonic history of the Alboran Basin: insights from Leg 161 results	555
M.C. Comas, J.P. Platt, J.I. Soto, and A.B. Watts	

SECTION 7: INDEX

45. Index	583
-----------------	-----

BACK-POCKET MATERIALS

Oversized Figures

Chapter 44:

Figures 16–19. Multichannel seismic reflection profiles across the Alboran Sea obtained by the *Robert C. Conrad* in 1988 (Watts et al., 1993). Upper plots are original profiles; lower plots are draw-line interpretations.

Figure 16. Line 827. DSDP 121 projects penetration at Site 976 (located 8 km to the northeast).

Figure 17. Line 825.

Figure 18. Line 824.

Figure 19. Line 823 showing position of Sites 977 and 978.

CD-ROM

The “*Proceedings, Scientific Results*” CD-ROM contains an electronic version of the Leg 161 *Scientific Results* volume in Adobe Acrobat, as well as data sets and images not included in the printed volume (see directory contents below). The volume is designed for Adobe Acrobat Reader 3 software, which is supplied on the CD. All files with a .PDF extension should be viewed through Acrobat. Data files in ASCII format (files with .TXT extensions) should be opened through a spreadsheet or text-editing software application.

Contents of the 161_SR Directory:

ACROREAD.TXT (how to install Adobe Acrobat)
 ACROREAD (software for Acrobat Reader 3)
[README.PDF](#) (information about CD volume)
 README.TXT (information about CD volume)
 161SR.PDF (volume table of contents)
 VOLUME (Leg 161 *Scientific Results* volume files)
 PRELIM.PDF (volume preliminary pages)
 BACKPKT.PDF (volume back-pocket figures)
 CHAPTERS
 CHAP_###.PDF (44 volume chapters)
 CD_ONLY (extra data sets and images; see below for list of files)
 161INDEX.PDF (volume index)
 ODPINDEX (compiled *Proceedings* electronic index)

List of CD_ONLY files:

CHAP_04 (Chapter 4):
 04_03.TXT: Table 3. Textural and bulk mineralogical data recovered from Pliocene and Pleistocene sediments in the northwestern Alboran Sea (Hole 976B).
CHAP_07 (Chapter 7):
 07_01.TXT: Table 1. Raw data from ODP Alboran Sea samples.

07_02.TXT: Table 2. X-ray quantification data from ODP Alboran Sea samples.

CHAP_08 (Chapter 8):

APPEND_A: Appendix A. Digital backscattered electron image files collected at five magnifications (100×, 200×, 500×, 1000×, and 2000×) at a minimum of three randomly chosen locations (a, b, c) on each sample. The following list of .PDF files for sample 01_3_082 from Hole 974B serves as an example of the files to be found within the hole directories. Hole 974B was chosen for detailed image analysis, whereas samples of ~0.5, 2.0, and 5.0 Ma were taken from each of the other sites.

HOLE974B

01_3_082 (directory name refers to Core 1, Section 3, depth in section in centimeters)
 01H3A1K.PDF (file name refers to Core 1H, Section 3, location a, and a magnification of 1000×)
 01H3A200.PDF
 01H3A3K.PDF
 01H3A3K2.PDF

01H3A500.PDF
01H3B1K.PDF
01H3B200.PDF
01H3B2K.PDF
01H3B500.PDF
01H3C1K.PDF
01H3C200.PDF
01H3C2K.PDF
01H3C500.PDF
01H3S100.PDF
02_3_077
03_3_072
04_3_063
05_4_048
06_7_040
07_1_012
08_5_070
09_4_055
10_1_062
11_4_131
12_6_034
13_6_082
14_1_123
15_1_004
16_5_011
17_6_055
18_4_042
19_4_077
20_5_073
21_4_082
22_4_099
HOLE975B
06_5_042
15_3_132
32_5_050
HOLE976B
20_3_095
39_3_062
60_3_028
HOLE977A
14_5_028
31_5_072
55_5_138
HOLE978A
08_3_049
42_3_095
HOLE979A
14_3_071
15_3_080
40_3_080
APPEND_B: Appendix B. X-ray intensities of major phases.
08_APPB1.TXT: Appendix B1. Hole 974B bulk XRD data.
08_APPB2.TXT: Appendix B2. Hole 975B bulk XRD data.
08_APPB3.TXT: Appendix B3. Hole 976B bulk XRD data.
08_APPB4.TXT: Appendix B4. Hole 977A bulk XRD data.
08_APPB5.TXT: Appendix B5. Hole 978A bulk XRD data.
08_APPB6.TXT: Appendix B6. Hole 979A bulk XRD data.
CHAP_11 (Chapter 11):
11_01.TXT: Table 1. Anisotropy of magnetic susceptibility results.
CHAP_14 (Chapter 14):
14_01.TXT: Table 1. Site 975 composition of the assemblages of planktonic foraminifers.
14_02.TXT: Table 2. Site 976 composition of the assemblages of planktonic foraminifers.
CHAP_16 (Chapter 16):
16_02.PDF: Table 2. Calcareous nannofossils in Hole 974B.
16_03.PDF: Table 3. Calcareous nannofossils in Hole 975B.
16_04.PDF: Table 4. Calcareous nannofossils in Hole 976B.
16_05.PDF: Table 5. Calcareous nannofossils in Hole 977B.
16_06.PDF: Table 6. Calcareous nannofossils in Hole 978B.
16_07.PDF: Table 7. Calcareous nannofossils in Hole 979B.
CHAP_35 (Chapter 35):
35_01.TXT: Table 1. Sites 976 and 975: composition of the assemblages of planktonic foraminifers.
CHAP_37 (Chapter 37):
37_01.TXT: Table 1. Isotope data from Site 976.
37_02.TXT: Table 2. Isotope data from Site 977.
CHAP_38 (Chapter 38):
38_02.TXT: Table 2. Oxygen and carbon isotope compositions of *Globigerina bulloides* as a function of depth and extrapolated ages at Site 975 (Holes 975B and 975C).
CHAP_39 (Chapter 39):
39_01.TXT: Table 1. Sampled sapropel results.
CHAP_41 (Chapter 41):
41_01.TXT: Table 1. Total organic carbon results and lithologic code, Site 974.
41_02.TXT: Table 2. Total organic carbon results and lithologic code, Site 975.
41_03.TXT: Table 3. Total organic carbon results and lithologic code, Site 976.
41_04.TXT: Table 4. Total organic carbon results and lithologic code, Site 977.
41_05.TXT: Table 5. Total organic carbon results and lithologic code, Site 979.
41_07.TXT: Table 7. Detailed sapropel list, Site 974.
41_08.TXT: Table 8. Detailed sapropel list, Site 975.
41_09.TXT: Table 9. Detailed sapropel list, Site 976.
41_10.TXT: Table 10. Detailed sapropel list, Site 977.
41_11.TXT: Table 11. Detailed sapropel list, Site 979.