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

Supplemental data on the volume CD-ROM were provided by the authors and may not conform to ODP publication formats.

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).

This volume includes a site map showing the drilling locations for this leg and maps showing the drilling locations of all Ocean Drilling Program (ODP) and Deep Sea Drilling Project (DSDP) drilling sites in PDF. These maps were produced using Generic Mapping Tools (GMT) of Paul Wessel and Walter H.R. Smith (gmt.soest.hawaii.edu).

Cover photograph is of middle Eocene radiolarians from ODP Site 1217, Leg 199. Radiolarian ooze are the characteristic sediment of the Eocene in the eastern equatorial Pacific. Image taken by Isabella Raffi.
FOREWORD

By Joint Oceanographic Institutions, Inc.

This volume presents scientific and engineering results from the Ocean Drilling Program (ODP). These results address the scientific and technical goals of the program, which are focused on the study of the dynamics of Earth's interior and environment, the evolution of oceanic crust, the fluctuations of climate, and the study of the Earth's deep biosphere.

Although ODP ended operations in 2003, science results from ODP's expeditions on the JOIDES Resolution continue to emerge. The results represent the contributions of scientists and research institutions from 22 ODP member countries. International oversight and coordination of the program was provided by the ODP Council, which was made up of representatives from the member countries. Scientific and management guidance was provided by representatives from the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES).

Joint Oceanographic Institutions, Inc. (JOI), a nonprofit consortium of 29 U.S. oceanographic institutions, serves as the National Science Foundation’s prime contractor for ODP. JOI implemented scientific objectives, plans, and recommendations of the JOIDES committees through subcontracts to Texas A&M University (TAMU) for science operations and to Lamont-Doherty Earth Observatory (LDEO) of Columbia University for geochemical and geophysical well-logging services.

JOI, TAMU, and LDEO worked together successfully for many years to manage the Ocean Drilling Program. We look forward to many exciting discoveries and continued international collaboration on the Integrated Ocean Drilling Program as we further our scientific mission.

Steven R. Bohlen
President of the Joint Oceanographic Institutions and Executive Director of the Ocean Drilling Programs
Washington, D.C.
PREFACE

THE VOYAGES OF DISCOVERY

The *Scientific Results* volumes of the *Proceedings of the Ocean Drilling Program* are about Earth and her oceans. These volumes contain contributions to a better understanding of the history of our planet through time. This exploration of Earth’s past is based on scientific analyses of layers of strata sampled by the *JOIDES Resolution* at key locations throughout the global ocean. These volumes are a tribute to the scientific exploration carried out by the men and women who contributed to these voyages of discovery. Like the pioneering exploration and research of Captain Cook aboard the first *Resolution*, these volumes are a credit to the human spirit, which sees no boundaries.

The papers in this volume are published in a new online format that will be archived on CD-ROM. The *Proceedings* contents are available to students, scientists, and the public throughout the world. Volumes, once housed in the libraries of the member nations of the Ocean Drilling Program (ODP), are now published on the Internet for a worldwide audience and are also available in CD-ROM format. This electronic publication enables future investigators to gain easier access to the results of ocean drilling research. I acknowledge and thank the authors for their contributions and willingness to participate in this new venture in our successful transition to electronic publications.

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 investigated area. ODP staff coordinate the peer-review process and also edit and produce each paper.

Each *Scientific Results* volume contains one leg synthesis paper and other peer-reviewed papers that present the results of extensive research in various aspects of scientific ocean drilling related to each leg. Each paper submitted to a *Scientific Results* volume undergoes rigorous peer review by at least two specialists in the author’s research field. Volumes may also contain short reports of useful data. These Data Reports do not include interpretation of results and are peer-reviewed by at least one specialist. We seek to maintain a peer-review system comparable to those of the most highly regarded journals in the geological sciences.

To acknowledge the contributions made by this volume’s Editorial Review Board, the Board members are designated Editors of the volume. Reviewers of manuscripts for this volume, whose efforts are so essential to the success of the publication, are listed without attribution to any particular manuscript.

On behalf of ODP and now the Integrated Ocean Drilling Program, the successor to ODP, I extend sincere appreciation to the members of the Editorial Review Board and to the reviewers for generously contributing their time and effort. This process ensures that only papers of high scientific quality are published in the *Scientific Results* volumes.

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DEDICATION

CATHERINE NIGRINI 1939–2005

Our dear friend and colleague Catherine Nigrini (née Clark), born in Toronto, Ontario, died peacefully in her sleep due to complications from lung cancer on the morning of Thursday, 13 January 2005. This was a sad day for the scientific community and especially for the radiolarian community. She was predeceased by her husband, Andrew, and is survived by her daughter, Jennifer, and her son, Peter.

Cathy completed her primary education at Branksome Hall, Toronto, Canada. She earned a Bachelor’s of Science in Geology in 1962 at Trinity College, University of Toronto, and was awarded the Coleman Gold Medal for Geological Sciences. In the summer of 1962 she carried out initial investigations of Radiolaria in the experimental MOHOLE cores for William R. Riedel, Scripps Institution of Oceanography (SIO). Four years later she received her Ph.D. in Micropaleontology from the University of Cambridge. From 1964 to 1965 she worked as a postgraduate research geologist at SIO, engaged in investigation of radiolarians in pelagic sediments from the Indian and Atlantic Oceans. From 1965 to 1968 Cathy was a Visiting Scholar and Research Associate at Northwestern University, where she continued her detailed stratigraphic studies of radiolarians in Quaternary sediments at selected localities in the three major ocean basins. She was closely associated with William R. Riedel and many others at SIO and the Deep Sea Drilling Project (DSDP) during her productive paleontological career.

As a Consulting Micropaleontologist or Associated Investigator, Cathy participated on numerous U.S. National Science Foundation (NSF)-sponsored projects with William R. Riedel, SIO; as a Consulting Micropaleontologist for the CLIMAP Project, and for James P. Kennett, Graduate School of Oceanography, University of Rhode Island, on the NSF-sponsored “Cenozoic Paleoceanography” project; as an Associate Investigator and Consultant with David A. Johnson, Woods Hole Oceanographic Institution, on several NSF-sponsored projects; and as a Consultant for Joseph J.
Morley, Lamont-Doherty Geological Observatory, Columbia University, for the Joint Oceanographic Institutions/U.S. Science Support Program (JOI/USSSP) project: “North Pacific Neogene Biostratigraphy and Paleoceanography: Analysis of Leg 145 Sediments.” She was principal investigator on the JOI/USSSP project “Biostratigraphic Study of Radiolarians” for ODP Legs 150 and 165.

Cathy published numerous papers, adding greatly to the knowledge of Cenozoic radiolarians, both in respect to taxonomy and to biogeographic and stratigraphic distributions. She participated in six oceanic research voyages and was one of the first women to sail on the Glomar Challenger (1968, DSDP Leg 2, from Hoboken, New Jersey, to Dakar, Senegal). This journey produced fundamental evidence for the existence of seafloor spreading and for the theory of plate tectonics. In later years she sailed on the Glomar Challenger (DSDP Legs 23 and 85) and the JOIDES Resolution (ODP Legs 117 and 199), examining radiolarians from the Arabian Sea and the central equatorial Pacific. These investigations established which taxa were related to upwelling conditions and thus can be used to identify assemblages indicative of regional upwelling. Cathy was also an invited foreign participant in the JADE/SHIVA cruise of the French research vessel Marion Dufresne in the Pacific and Indian Oceans, working closely with Jean Pierre Caulet and other scientists as a visiting professor at Laboratoire de Geologie at the Museum National d’Histoire Naturelle, Paris.

Since Cathy first met Ted Moore, when she was a postdoc at SIO and Ted was a graduate student, they worked together on several projects, including Leg 199. One of the enduring legacies of Leg 199 will undoubtedly be the revision of tropical radiolarian biostratigraphy. The opportunity to tie radiolarian biostratigraphic events directly to magnetochronology provides the first direct ties between the tropical siliceous microfossil record and the absolute timescale of the Paleogene. A remarkable number of problems, such as evaluating diachrony of extinction events and discovering connections between evolution and tectonics, can be addressed with a highly calibrated timescale of biological evolution. Thus, the recovery of continuous sedimentary records with uninterrupted sets of distinct Cenozoic geomagnetic polarity chronos from the paleoequatorial Pacific Ocean proved to be a major success of Leg 199 in the placement of new constraints on the late Paleocene and early Eocene equatorial position using paleomagnetic and micropaleontologic indicators.

Throughout her career Cathy realized the necessity and usefulness of taxonomic guides to aid radiolarian workers through the cumbersome systematics to uniform species concepts applicable to modern practice of paleontology. In 1979, together with Ted Moore, she published “A Guide to Modern Radiolaria,” followed in 1984 by “A Guide to Miocene Radiolaria” with Gail Lombari. Under a contract with ODP, Cathy initiated the preparation of a volume containing stratigraphic range charts and a catalog of Cenozoic radiolarian photographs and descriptions. This volume, “Cenozoic Radiolarian Stratigraphy for Low and Middle Latitudes,” was accompanied by a set of 60 prepared radiolarian zonal reference slides to be kept on board the JOIDES Resolution. In 2001, this informative and useful tool for sea-going and novice Cenozoic radiolarian paleontologists was added to the ODP Web site (www-odp.tamu.edu/publications/tnotes/tn27/index.html). Cathy’s notion to build a relational radiolarian database, to capture all available knowledge for the next generation of paleontologists and stratigraphers, is well under way in collaboration with Jean Pierre Caulet. The
RadWorld database currently contains references to the original descriptions and type species of 2527 genera and the original descriptions of almost 7000 species of Radiolaria, data that are updated on the Museum National d’Histoire Naturelle, Paris (www.mnhn.fr/mnhn/geo/radworld/radworldsite/page2.html), and the Radiolaria Organization (www.radiolaria.org/search.htm) Web sites.

Cathy spent 28 years in the United States living in Lexington, Massachusetts, and La Habra, California. During this time she was active in the lives and education of her two children through parent-teacher organizations, volunteering in the schools, and working in the high school library system. Five years ago Cathy and her husband Andy came home to Canada, settling in Canmore, Alberta. Cathy spent equal time pursuing her love for radiolarians, the database RadWorld, quilting, hiking in the Canadian Rockies, and traveling. She held many volunteer positions throughout her career. Since moving to Canmore she dedicated a great deal of her time to the development of the Canmore Museum and Geoscience Centre.

Cathy spread sunshine wherever she walked. A brilliant scientist and very positive and insightful person, she taught us many valuable lessons, particularly organizational skills, attention to detail, and a sense of perfection and has earned an everlasting place in our hearts. She will be sorely missed by her family, friends, and colleagues, who have enjoyed her friendship and benefited from her guidance.
CD-ROM CONTENTS: SYNTHESIS AND CHAPTERS

SYNTHESIS

1. Leg 199 Synthesis: evolution of the Equatorial Pacific in the Early Cenozoic
   Mitchell Lyle and Paul A. Wilson
   doi:10.2973/odp.proc.sr.199.201.2006

CHAPTERS

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2. Integrated Stratigraphic Correlation and Improved Composite Depth Scales for ODP Sites 1218 and 1219
   Heiko Pälike, Ted Moore, Jan Backman, Isabella Raffi, Luca Lanci, Josep M. Parés, and Thomas Janecek
   doi:10.2973/odp.proc.sr.199.213.2005

BIOSTRATIGRAPHY

3. Cenozoic Radiolarian Biostratigraphy: A Magnetobiostratigraphic Chronology of Cenozoic Sequences from ODP Sites 1218, 1219, and 1220, Equatorial Pacific
   Catherine Nigrini, Annika Sanfilippo, and Theodore J. Moore Jr.

4. Data Report: Late Oligocene and Early Miocene Radiolarians, Sites 1218 and 1219, Central Pacific
   Shin-ichi Kamikuri, Hiroshi Nishi, Theodore C. Moore, Catherine A. Nigrini, and Isao Motoyama
   doi:10.2973/odp.proc.sr.199.212.2005

5. Data Report: Late Eocene–Early Oligocene Radiolarians, ODP Leg 199 Holes 1218A, 1219A, and 1220A, Central Pacific
   Satoshi Funakawa, Hiroshi Nishi, Theodore C. Moore, and Catherine A. Nigrini
   doi:10.2973/odp.proc.sr.199.216.2006

6. Oligocene and Earliest Miocene Diatom Biostratigraphy of ODP Leg 199 Site 1220, Equatorial Pacific
   John A. Barron, Elisabeth Fourtanier, and Steven M. Bohaty
   doi:10.2973/odp.proc.sr.199.204.2004
7. **Data Report: Paleocene/Eocene Benthic Foraminifers, ODP Leg 199 Sites 1215, 1220, and 1221, Equatorial Central Pacific Ocean**  
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8. **Data Report: Oligocene Benthic Foraminifers from the Eastern Equatorial Pacific, Sites 1218 and 1219, ODP Leg 199**  
Hiroyuki Takata and Ritsuo Nomura  
doi:10.2973/odp.proc.sr.199.224.2005

9. **Silicoflagellates Recovered from the Deep Sea, ODP Leg 199 Site 1219, East Equatorial Pacific**  
Robb Engel and Kevin McCartney  

10. **Data Report: Silicoflagellates and Ebridians Recovered from Leg 199 Sites 1218, 1220, and 1221, Eastern Equatorial Pacific**  
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11. **Data Report: High-Resolution Mineralogy for Leg 199 Based on Reflectance Spectroscopy and Physical Properties**  
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13. **Velocity and Density of Paleogene Equatorial Sediments: Variation with Sediment Composition**  
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19. **Data Report: High-Resolution Benthic Foraminiferal Stable Isotope Stratigraphy across the Oligocene/Miocene Boundary at Site 1218**  
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22. **Phosphorus and Barite Concentrations and Geochemistry in Site 1221 Paleocene/Eocene Boundary Sediments**  
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24. **Biogenic Sedimentology of Radiolarian Assemblages in a Middle Eocene Diatom-Rich Unit from the Eastern Equatorial Pacific: ODP Leg 199, Site 1219**
   Torsten H. Steiger

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   Mitchell Lyle, Fredrick Prahl, and Margaret Sparrow
doi:10.2973/odp.proc.sr.199.207.2006
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ODP Leg 199 Site Map
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