



PROCEEDINGS OF THE INTEGRATED OCEAN DRILLING PROGRAM

VOLUME 320/321 EXPEDITION REPORTS PACIFIC EQUATORIAL AGE TRANSECT

Expeditions 320 and 321 of the riserless drilling platform
from and to Honolulu, Hawaii (USA)

Sites U1331–U1336

5 March–4 May 2009

and

Honolulu, Hawaii (USA), to San Diego, California (USA)

Sites U1337–U1338

4 May–22 June 2009

Volume authorship

Pälike, H., Lyle, M., Nishi, H., Raffi, I., Gamage, K., Klaus, A.,
and the Expedition 320/321 Scientists

Published by
Integrated Ocean Drilling Program Management International, Inc.,
for the Integrated Ocean Drilling Program

Prepared by
U.S. Implementing Organization Science Services, Texas A&M University

Publisher's notes

Funding for the program was provided by the following agencies at the time of this expedition:

National Science Foundation (NSF), United States

Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan

European Consortium for Ocean Research Drilling (ECORD)

Ministry of Science and Technology (MOST), People's Republic of China

Korea Institute of Geoscience and Mineral Resources (KIGAM)

Australian Research Council (ARC) and New Zealand Institute for Geological and Nuclear Sciences (GNS), Australian/New Zealand Consortium

Ministry of Earth Sciences (MoES) India

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 participating agencies, IODP Management International, Inc., Consortium for Ocean Leadership, Lamont-Doherty Earth Observatory of Columbia University, Texas A&M University, or Texas A&M Research Foundation.

Examples of how to cite this volume or part of this volume are available at publications.iodp.org/proceedings/320_321/32021bib.htm.

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

The bulk of the shipboard-collected core data from this expedition is accessible from Integrated Ocean Drilling Program U.S. Implementing Organization (IODP-USIO) Science Services, Texas A&M University (TAMU), at iodp.tamu.edu/database/index.html. If you cannot access this site or need additional data, please contact:

Data Librarian

Integrated Ocean Drilling Program

Texas A&M University

1000 Discovery Drive, College Station TX 77845-9547 USA

Tel: (979) 845-8495; Fax: (979) 458-1617

E-mail: database@iodp.tamu.edu

A complete set of the logging data collected by ODP-USIO Science Services, Lamont-Doherty Earth Observatory (LDEO), is available at brg.ldeo.columbia.edu/logdb/. If you have problems downloading the data, wish to receive additional logging data, or have questions regarding the data, please contact:

Database Administrator

Borehole Research Group

Lamont-Doherty Earth Observatory of Columbia University

PO Box 1000, 61 Route 9W, Palisades NY 10964 USA

Tel: (845) 365-8343; Fax: (845) 365-3182

E-mail: logdb@ldeo.columbia.edu

Supplemental data were provided by the authors and may not conform to IODP publication formats.

Some close-up core photographs have been tonally enhanced to better illustrate particular features of interest. High-resolution images are available upon request.

Cover photograph shows the *JOIDES Resolution*. Photograph by Bill Crawford.

The Expedition Reports DVD-ROM contains software for Adobe® Reader® 9 for Windows®, Mac OS®, and Sun® Solaris® SPARC®. Some features may not work if lower versions of Adobe Reader are used. Adobe Reader Copyright © 1987–2010 Adobe Systems Incorporated. All rights reserved. Adobe, the Adobe logo, Acrobat, the Acrobat logo, and Reader are either registered trademarks or trademarks of Adobe Systems Incorporated in the United States and/or other countries. All other trademarks are the property of their respective owners.

ISSN

DVD:1930-1022; World Wide Web: 1930-1014



Foreword

By Integrated Ocean Drilling Program Management International, Inc.

The Integrated Ocean Drilling Program (IODP) is now in the latter half of its decadal program (2003–2013). As envisioned in the Initial Science Plan (ISP), IODP expeditions take advantage of three scientific ocean drilling platforms that enable us to cover unprecedented areas of wide oceans, from ice-covered shallow water to full ocean depths. Drilling miles of depth below seafloor, now part of IODP capabilities, is the major advance from the program predecessors, the Deep Sea Drilling Project and the Ocean Drilling Program. The living Earth is a dynamic system that is continuously evolving. IODP seeks to understand this complex and unique system through scientific ocean drilling, sampling, and experimenting in deep holes, along with advancement of related scientific disciplines. IODP is an international collaboration among scientists and nations with keen aspirations to attain the scientific goals of the ISP. IODP currently includes participating members from 24 nations.

The *Proceedings* present the scientific and engineering results of IODP drilling projects, each designed to better understand the past, present, and future of the Earth system.

IODP expeditions begin with scientists who submit research drilling proposals to test new and innovative ideas, then the proposals progress to international scientific advisors (Science Advisory Structure) who nurture, evaluate, rank, and prioritize proposals. Scientists also schedule the science operations, select science party members from scores of international scientists qualified to participate, plan platform operations, ready the drillship, and choose borehole locations. The science party, collectively and individually, conducts science on board and on shore. The co-chief scientists on each expedition are responsible for synthesizing the scientific results as hallmark of expedition.

Ocean-drilling achievements help us to understand and interpret phenomena in various parts of the Earth system. Achievements in the two legacy drilling programs have validated the scientific concepts behind plate tectonics, contributed to the understanding of ocean circulation changes, and extended our knowledge of long- and short-term climate change. IODP is truly an expansion and extension of the scientific research conducted by the legacy programs, engaging in cutting-edge research concerning topics of global importance.

IODP drilling platform operations are conducted by three Implementing Organizations (IOs). Riserless platform operations are conducted by the United States Implementing Organization (USIO), comprising the Consortium for Ocean Leadership, Inc., Texas A&M University through the Texas A&M Research Foundation, and Lamont-Doherty Earth Observatory of Columbia University. Riser platform operations are conducted by the Japan Agency for Marine-Earth Science and Technology through Japan's Center for Deep Earth Exploration in cooperation with the Center for Advanced Marine Core Research at Kochi University. Mission-specific platform operations are conducted by the European Consortium for Ocean Research Drilling (ECORD) Science Operator, comprising the British Geological Survey, Bremen University, and the European Petrophysics Consortium. The European IO currently represents the ocean-drilling efforts of 16 nations in Europe, plus Canada.

The discoveries presented in this volume build upon layers of knowledge and science developed over roughly the last fifty years. Expedition *Proceedings* are published by IODP Management International for IODP under the sponsorship of the U.S. National Science Foundation (NSF), Japan's Ministry of Education, Culture, Sports, Science and Technology, and other IODP members. The material is based upon research supported under Contract OCE-0432224 from NSF.

Kiyoshi Suyehiro
President & Chief Executive Officer
Integrated Ocean Drilling Program Management International, Inc.
Tokyo
www.iodp.org/



Integrated Ocean Drilling Program

Integrated Ocean Drilling Program Management International, Inc.

Web site: www.iodp.org/

IODP-MI

1001 Connecticut Avenue, NW, Suite 504
Washington DC 20036
USA
Tel: (202) 465-7500; Fax: (202) 955-8363
E-mail: info@iodp.org

IODP-MI

Tokyo University of Marine Science and
Technology
Office of Liason and Cooperative Research,
3rd Floor
2-1-6, Etchujima, Koto-ku, Tokyo 135-8533
Japan
Tel: (81) 3-6701-8-3181; Fax: (81) 3-6701-3189

IODP-MI member organizations*

Alfred-Wegener-Institute für Polar und
Meeresforschung, Germany

British Geological Survey, United Kingdom

Columbia University, Lamont-Doherty Earth
Observatory, USA

Federal Institute of Technology (ETH), Switzerland

Florida State University, USA

Hokkaido University, Japan

Liebniz, Institute of Marine Sciences (IFM-
GEOMAR), University of Kiel, Germany

Institut de Physique du Globe de Paris, France

Institut Universitaire Européen de la Mer (IEUM),
France

Japan Agency for Marine-Earth Science and
Technology (JAMSTEC), Japan

Kochi University, Japan

Kyushu University, Japan

National Institute of Advanced Industrial Science
(AIST), Japan

Rutgers University, USA

Texas A&M University, USA

Tohoku University, Japan

Tokai University, Japan

Universität Bremen, Germany

University of Bergen, Norway

University of California at San Diego, Scripps
Institution of Oceanography, USA

University of California at Santa Cruz, USA

University of Florida, USA

University of Hawaii, USA

University of Leicester, United Kingdom

University of Miami, USA

University of Southampton National Oceanography
Centre, United Kingdom

University of Texas at Austin, USA

University of Tokyo, Japan

University of Washington, USA

Vrije Universiteit, The Netherlands

Woods Hole Oceanographic Institution, USA

*At time of expedition.



Implementing organizations

IODP European Implementing Organization: European Consortium for Ocean Research Drilling, Science Operator (ESO)

Web site: www.eso.ecord.org/

IODP-ESO Coordinator: Science, Logistics, and Operations

British Geological Survey
Murchinson House
West Mains Road
Edinburgh EH9 3LA
United Kingdom
Tel: (44) 131-667-1000; Fax: (44) 131-668-4140
E-mail: ESO@bgs.ac.uk

IODP-ESO Petrophysics

European Petrophysics Consortium
Department of Geology
University of Leicester
Leicester LE1 7RH
United Kingdom
Tel: (44) 116-252-3611; Fax: (44) 116-252-3918
E-mail: sjd27@leicester.ac.uk

IODP-ESO Curation and Laboratories

Integrated Ocean Drilling Program
Bremen Core Repository
Center for Marine Environmental Sciences
DFG Research Center for Ocean Margins
Bremen University
Leobener Strasse
28359 Bremen
Germany
Tel: (49) 421-218-65561; Fax: (49) 421-218-98-65565
E-mail: BCR@marum.de

IODP Japanese Implementing Organization: Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

Web site: www.jamstec.go.jp/chikyu/eng/index.html

IODP-Japan Science Operator

Center for Deep Earth Exploration (CDEX)
Japan Agency for Marine-Earth Science and
Technology
Yokohama Institute for Earth Sciences
3175-25 Showa-machi
Kanazawa-ku, Yokohama
Kanagawa 236-0001
Japan
Tel: (81) 45-778-5643; Fax: (81) 45-778-5704
E-mail: cdex@jamstec.go.jp



IODP U.S. Implementing Organization

Web site: www.iodp-usio.org/

IODP-USIO Systems Integration Contractor

Consortium for Ocean Leadership
1201 New York Avenue, NW, Suite 400
Washington DC 20005
USA
Tel: (202) 232-3900; Fax: (202) 462-8754
E-mail: info@oceanleadership.org

IODP-USIO Science Services, LDEO

Lamont-Doherty Earth Observatory
of Columbia University
PO Box 1000, 61 Route 9W
Palisades NY 10964
USA
Tel: (845) 365-8672; Fax: (845) 365-3182
E-mail: borehole@ldeo.columbia.edu

IODP-USIO Science Services, TAMU

Integrated Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
Tel: (979) 845-2673; Fax: (979) 845-4857
E-mail: information@iodp.tamu.edu



Expedition 320/321 science party*

Expedition 320 scientists

Heiko Pälike

Co-Chief Scientist

School of Ocean and Earth Science
National Oceanography Centre, Southampton
European Way
Southampton SO14 3ZH
United Kingdom
heiko@noc.soton.ac.uk

Hiroshi Nishi

Co-Chief Scientist

Department of Natural History Sciences
Hokkaido University
Kita-10, Nishi-8, Kita-ku
Sapporo 060-0810
Japan
Present address (April 2010):
The Center for Academic Resources and Archives
Tohoku University Museum
Tohoku University
c/o Department of Geoenvironmental Science
Aramaki Aza Aoba 6-3, Aoba-ku
Sendai 980-8578
Japan
hnishi@m.tains.tohoku.ac.jp

Adam Klaus

Expedition Project Manager/Staff Scientist

Integrated Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA
aklaus@iodp.tamu.edu

Helen Evans

Logging Staff Scientist

Borehole Research Group
Lamont-Doherty Earth Observatory
of Columbia University
PO Box 1000, 61 Route 9W
Palisades NY 10964
USA
helen@ldeo.columbia.edu

Trevor Williams

Logging Staff Scientist

Borehole Research Group
Lamont-Doherty Earth Observatory
of Columbia University
PO Box 1000, 61 Route 9W
Palisades NY 10964
USA
trevor@ldeo.columbia.edu

Gary D. Acton

Paleomagnetist

Department of Geology
University of California, Davis
One Shields Avenue
Davis CA 95616
USA
gacton@ucdavis.edu

Paul Bown

Paleontologist (nannofossils)

Earth Sciences
University College London
Gower Street
London WC1E 6BT
United Kingdom
p.bown@ucl.ac.uk

Margaret (Peggy) Delaney

Inorganic Geochemist

Ocean Sciences
University of California, Santa Cruz
1156 High Street
Santa Cruz CA 95064
USA
delaney@ucsc.edu

Tom Dunkley Jones

Paleontologist (nannofossils)

Earth Sciences
University College London
Gower Street
London WC1E 6BT
United Kingdom
tom.dunkleyjones@ucl.ac.uk

*Addresses at time of expedition, except where updated by the participants.



Kirsty Edgar
Paleontologist (planktonic foraminifers)
School of Ocean and Earth Science
National Oceanography Centre, Southampton
European Way
Southampton SO14 3ZH
United Kingdom
kme@noc.soton.ac.uk

Peter Fitch
Physical Properties/Downhole Tools Specialist
Department of Geology
University of Leicester
University Road
Leicester LE1 7RH
United Kingdom
pjf5@le.ac.uk

Nikolaus Gussone
Inorganic Geochemist
Institut für Mineralogie
Westfälische Wilhelms-Universität Münster
Corrensstrasse 24
48149 Muenster
Germany
nikolaus.gussone@uni-muenster.de

Jens Herrle
Sedimentologist
Institute of Geosciences
Goethe University Frankfurt
Altenhoferallee 1
60438 Frankfurt
Germany
jens.herrle@em.uni-frankfurt.de

Kiseong Hyeong
Sedimentologist
Deep Sea Resources Research Center
Korea Ocean Research and Development Institute
ANSAN PO Box 29
Seoul 425-600
Korea
kshyeong@kordi.re.kr

Shin-ichi Kamikuri
Paleontologist (radiolarians)
Graduate School of Science
Hokkaido University
Kita-10, Nishi-8, Kita-ku
Sapporo 060-0810
Japan
kamikuri@geol.tsukuba.ac.jp

Junichiro Kuroda
Sedimentologist
Institute for Frontier Research on Earth
Evolution (IFREE)
Japan Agency for Marine-Earth Science and
Technology (JAMSTEC)
2-15 Natsushima-cho
Yokosuka 237-0061
Japan
kurodaj@jamstec.go.jp

Lizette Leon-Rodriguez
Paleontologist (planktonic foraminifers)
Department of Earth Science
Rice University
6100 Main Street, MS-126
Houston TX 77005
USA
lizette@rice.edu

Theodore Moore Jr.
Paleontologist (radiolarians)
Department of Geological Sciences
University of Michigan
1100 North University
Ann Arbor MI 48109-1005
USA
ted.moore@umich.edu

Brandon Murphy
Sedimentologist
Earth and Planetary Sciences
University of California, Santa Cruz
1156 High Street
Santa Cruz CA 95064
USA
bmurphy@es.ucsc.edu

Hideto Nakamura
Sedimentologist
Department of Natural History Sciences
Hokkaido University
Kita-10, Nishi-8, Kita-ku
Sapporo 060-0810
Japan
hideton@mail.sci.hokudai.ac.jp

Christian Ohneiser
Paleomagnetist
Geology Department
University of Otago
Leith Street Central
Dunedin
New Zealand
christian.ohneiser@otago.ac.nz

Carl Richter
Stratigraphic Correlator
Department of Geology and Energy Institute
University of Louisiana
PO Box 44530
Lafayette LA 70504-0002
USA
richter@louisiana.edu

Rebecca Robinson
Sedimentologist
Graduate School of Oceanography
University of Rhode Island
South Ferry Road
Narragansett RI 02882
USA
rebeccar@gso.uri.edu

Ken Sawada
Organic Geochemist
Department of Natural History Sciences
Hokkaido University
Kita-10, Nishi-8, Kita-ku
Sapporo 060-0810
Japan
sawadak@mail.sci.hokudai.ac.jp

Howie Scher
Physical Properties/Downhole Tools Specialist
Department of Geological Sciences
University of South Carolina
701 Sumter Street, EWS 617
Columbia SC 29208
USA
hscher@geol.sc.edu

Hiroyuki Takata
Paleontologist (benthic foraminifers)
Research Center for Coastal Lagoon
Environments
Shimane University
Nishikawatsu 1060
Matsue 690-8504
Japan
yu@soc.shimane-u.ac.jp

Thomas Westerhold
Stratigraphic Correlator
Center for marine Environmental Sciences
(MARUM)
University of Bremen
PO Box 330440
28334 Bremen
Germany
tho@uni-bremen.de

Paul A. Wilson
Sedimentologist
School of Ocean and Earth Science
National Oceanography Centre, Southampton
European Way
Southampton SO14 3ZH
United Kingdom
paw1@noc.soton.ac.uk

Yuhji Yamamoto
Paleomagnetist
Marine and Core Research Center
Kochi University
B200 Monobe
Nankoku-City
Kochi 783-8502
Japan
y.yamamoto@kochi-u.ac.jp

Education and Outreach

Leslie Peart
Staff Educator
Consortium for Ocean Leadership
1201 New York Ave NW, Fourth Floor
Washington DC 20005
USA
lpeart@oceanleadership.org

Expedition 321 scientists

Mitchell W. Lyle

Co-Chief Scientist

Department of Oceanography
Texas A&M University
TAMU 3146
College Station TX 77840-3146
USA

mlyle@ocean.tamu.edu

Isabella Raffi

Co-Chief Scientist

Dipartimento di Geotecnologie per l'Ambiente
e il Territorio
DiGAT—CeRS Geo
Università "G. D'Annunzio"
Campus Universitario
via dei Vestini 31
66013 Chieti Scalo
Italy

raffi@unich.it

Kusali Gamage

Expedition Project Manager/Staff Scientist

Integrated Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA

gamage@iodp.tamu.edu

Louise Anderson

Logging Staff Scientist

Department of Geology
University of Leicester
Leicester LE1 7RH
United Kingdom

lma9@le.ac.uk

Alberto Malinverno

Logging Staff Scientist

Borehole Research Group
Lamont-Doherty Earth Observatory
of Columbia University
PO Box 1000, 61 Route 9W
Palisades NY 10964
USA

alberto@ldeo.columbia.edu

Jan Backman

Paleontologist (nannofossils)

Department of Geology and Geochemistry
Stockholm University
SE-10691 Stockholm
Sweden

backman@geo.su.se

Catherine Beltran

Sedimentologist

Laboratoire Biominéralisations et
Paléoenvironnements (UPMC)
Université Pierre et Marie Curie
Case 116—4 Place Jussieu
75252 Paris
France

catherine.beltran@upmc.fr

William Busch

Physical Properties/Downhole Tools Specialist

Earth and Environmental Sciences
University of New Orleans
2000 Lakeshore Drive
New Orleans LA 70148
USA

wbusch@uno.edu

James Channell

Paleomagnetist

Department of Geological Sciences
University of Florida
241 Williamson Hall
Gainesville FL 32611-2120
USA

jetc@geology.ufl.edu

Pawan Dewangan

Physical Properties/Downhole Tools Specialist

National Institute of Oceanography
Dona Paula
Goa 403 004
India

pdewangan@nio.org

Hitoshi Hasegawa

Sedimentologist

Earth and Planetary Science
University of Tokyo
7-3-1 Hongo
Bunkyo-ku
Tokyo 113-0033
Japan

hase@eps.s.u-tokyo.ac.jp



Edmund Hathorne
Inorganic Geochemist
MARUM-Centre for Marine Environmental
Sciences
University of Bremen
Leobener Strasse
D-28359 Bremen
Germany

Present address (January 2010):
IFM-GEOMAR
Leibniz Institute of Marine Sciences
University of Kiel
Wischhofstrasse 1-3
D-24148 Kiel
Germany
ehathorne@ifm-geomar.de

Hiroki Hayashi
Paleontologist (planktonic foraminifers)
Interdisciplinary Faculty of Science and
Engineering
Shimane University
1060 Nishikawatsucho
Matsue City
Shimane 690-8504
Japan
hayashi@riko.shimane-u.ac.jp

Ann Holbourn
Paleontologist (benthic foraminifers)
Institut für Geowissenschaften
Christian-Albrechts-Universität zu Kiel
Olhausenstrasse 40
24098 Kiel
Germany
ah@gpi.uni-kiel.de

Steven Hovan
Sedimentologist
Department of Geoscience
Indiana University of Pennsylvania
114 Walsh Hall
Indiana PA 15705
USA
hovan@iup.edu

Koichi Iijima
Physical Properties/Downhole Tools Specialist
Institute of Biogeosciences
Japan Agency for Marine-Earth Science and
Technology
2-15 Natsushima-cho
Yokosuka 237-0061
Japan
kijima@jamstec.go.jp

Takashi Ito
Sedimentologist
Faculty of Education
Ibaraki University
2-1-1 Bunkyo
Mito
Ibaraki 310-8512
Japan
tito@mx.ibaraki.ac.jp

Katsunori Kimoto
Inorganic Geochemist
Institute of Observational Research for Global
Change (IORGC)
Japan Agency for Marine-Earth Science and
Technology
2-15 Natsushima-Cho
Yokosuka 237-0061
Japan
kimopy@jamstec.go.jp

Daniel Murphy
Sedimentologist
Department of Oceanography
Texas A&M University
MS 3146
College Station TX 77845
USA
dmurphy@ocean.tamu.edu

Kaoru Ogane
Paleontologist (radiolarians)
Institute of Geology and Paleontology
Tohoku University
Aoba 6-4
Aramaki, Aoba-ku
Sendai City 980-8578
Japan
ogane@mtc.biglobe.ne.jp

Oscar Romero
Paleontologist (diatoms)
Instituto Andaluz de Ciencias de la Tierra
Universidad de Granada
Campus Fuentenueva
18002 Granada
Spain
oromero@ugr.es

Leah Schneider
Paleontologist (nannofossils)
Department of Geosciences
Pennsylvania State University
509 Deike Building
University Park PA 16802
USA
lschneid@geosc.psu.edu



Appy Sluijs

Sedimentologist

Palaeoecology, Institute of Environmental Biology
Utrecht University
Laboratory of Palaeobotany and Palynology
Budapestlaan 4
3584CD Utrecht
The Netherlands
a.sluijs@uu.nl

Jun Tian

Stratigraphic Correlator

Laboratory of Marine Geology
Tongji University
Siping Road 1239
Shanghai 200092
PR China
tianjun@mail.tongji.edu.cn

Akira Tsujimoto

Sedimentologist

Department of Geosciences
Osaka City University
3-3-138 Sugimoto
Sumiyoshi-ku
Osaka 558-8585
Japan
tujimoto@sci.osaka-cu.ac.jp

Bridget Wade

Paleontologist (planktonic foraminifers)

Department of Geology and Geophysics
Texas A&M University
College Station TX 77843
USA

wade@geo.tamu.edu

Present address: (June 2010)
School of Earth and Environment
University of Leeds
Woodhouse Lane
Leeds LS2 9JT
United Kingdom

Roy Wilkens

Stratigraphic Correlator

Hawaii Institute of Geophysics and
Planetology
University of Hawaii at Manoa
1680 East West Road
Honolulu HI 96822
USA
rwilkens@hawaii.edu

Shinya Yamamoto

Organic Geochemist

Institute of Low Temperature Science
Hokkaido University
N19W8, Kita-Ku
Sapporo 060-0819
Japan
s.yamamoto@pop.lowtem.hokudai.ac.jp

Toshitsugu Yamazaki

Paleomagnetist

Geological Survey of Japan, AIST
1-1-1 Higashi, Tsukuba
Ibaraki 305-8567
Japan
toshi-yamazaki@aist.go.jp

Education and Outreach

Maarten in 't Hout

Videographer

Zcene Moving Media
Weverssingel 42-A3
3811 GK Amersfoort
The Netherlands
maarten@mvefilm.nl



Operational and technical staff

Transocean officials

Expedition 320

Alexander Simpson
Master of the Drilling Vessel
Overseas Drilling Ltd.

Wayne Malone
Drilling Superintendent
Overseas Drilling Ltd.

Expedition 321

Peter Mowat
Master of the Drilling Vessel
Overseas Drilling Ltd.

Tim McCown
Drilling Superintendent
Overseas Drilling Ltd.

Shipboard personnel and technical representatives

Expedition 320

Grant Banta
Marine Computer Specialist

Thomas Gorgas
Physical Properties Laboratory

Chris Bennight
Chemistry Laboratory

Ron Grout
Operations Superintendent

Gerald Bode
Curator

Kristin Hillis
Underway Geophysics Laboratory

Tim Bronk
Assistant Laboratory Officer

Michael Hodge
Marine Computer Specialist

Alwyn Burger
Marine Instrumentation Specialist

Dwight Hornbacher
Applications Developer

Trevor Cobine
Paleomagnetism Laboratory

Sarah-Jane Jackett
Core Laboratory

William Crawford
Imaging Specialist

Eric Jackson
X-Ray/Microbiology Laboratory

Lisa Crowder
Assistant Laboratory Officer

Kazushi Kuroki
Downhole Tools/Thin Section Laboratory

Roy Davis
Laboratory Officer

Don Sims Jr.
Database

Dean Ferrell
Drilling Engineer

Yulia Vasilyeva
Chemistry Laboratory

Clayton Furman
Schlumberger Logging Engineer

Kelly VonDrehle
Publications Specialist

Randy Gjesvold
Marine Instrumentation Specialist

Stephanie Zeliadt
Applications Developer

Expedition 321

Heather Barnes

Assistant Laboratory Officer

John Beck

Imaging Specialist

Lisa Brandt

Chemistry Laboratory

Chad Broyles

Curator

Etienne Claassen

Marine Instrumentation Specialist

David Fackler

Applications Developer

Kazuho Fujine

Chemistry Laboratory

Gus Gustafson

Downhole Tools/Thin Section Laboratory

Margaret Hastedt

Paleomagnetism Laboratory

Jurie Kotze

Marine Instrumentation Specialist

Zenon Mateo

Core Laboratory

Mike Meiring

Engineer

Erik Moortgat

Underway Geophysics Laboratory

Matt Nobles

Marine Computer Specialist

Bob Olivas

X-Ray/Microbiology Laboratory

Debbie Partain

Publications Specialist

Chieh Peng

Laboratory Officer

Steve Prinz

Assistant Laboratory Officer

Michael Storms

Operations Superintendent

Kerry Swain

Logging Engineer

Andrew Trefethen

Marine Computer Specialist

Maxim Vasilyev

Petrophysics Laboratory

Hai (James) Zhao

Applications Developer



IODP-USIO Publication Services staff*

Karen Benson
Production Specialist II

Molly Chamberlin
Student Assistant

Gudelia (“Gigi”) Delgado
Senior Publications Coordinator

Patrick H. Edwards
Production Specialist III

Lindsey Falco
Student Assistant

Tim Fulton
Graphics Specialist II

Jaime A. Gracia
Supervisor of Production

Sarah Gracia
Student Assistant

Kirstin Hein
Student Assistant

Jenni Hesse
Editor II

Rhonda Kappler
Graphics Specialist II

Laura Koehler
Graphics Specialist II

Shana C. Lewis
Editor III

Ginny Lowe
Reports Coordinator

Amy McWilliams
Editor III

Angeline T. Miller
Publication Services Manager

Erin O’Roke
Editor II

Deborah L. Partain
Supervisor of Graphics

Lorri Peters
Supervisor of Editing

M. Kathleen Phillips
Publications Specialist

Paul Pleasant
Graphics Specialist II

Kenneth Sherar
Production Specialist II

Jamie Smidt
Graphics Specialist II

Alyssa Stephens
Graphics Specialist II

Kelly VonDrehle
Graphics Specialist II

Crystal Wolfe
Production Specialist II

Ann Yeager
Distribution Specialist

*At time of publication.



Contents

Expedition reports

Chapters

[Expedition 320/321 summary](#)

H. Pälke, H. Nishi, M. Lyle, I. Raffi, K. Gamage, A. Klaus, and the Expedition 320/321 Scientists

[Methods](#)

Expedition 320/321 Scientists

[Site U1331](#)

Expedition 320/321 Scientists

[Site U1332](#)

Expedition 320/321 Scientists

[Site U1333](#)

Expedition 320/321 Scientists

[Site U1334](#)

Expedition 320/321 Scientists

[Site U1335](#)

Expedition 320/321 Scientists

[Site U1336](#)

Expedition 320/321 Scientists

[Site U1337](#)

Expedition 320/321 Scientists

[Site U1338](#)

Expedition 320/321 Scientists

Core descriptions

Visual core descriptions (VCDs), smear slide data tables, thin sections, chert/porcellanite logs, and digital images are included in this section. VCDs, smear slides, and thin sections are combined into a single PDF file for each site. The entire set of core images in PDF are available in the IMAGES directory.

Site U1331

[Visual core descriptions](#) · [Smear slides](#) · [Thin sections](#) · [Chert/Porcellanite log](#)

Site U1332

[Visual core descriptions](#) · [Smear slides](#) · [Thin sections](#) · [Chert/Porcellanite log](#)

Site U1333

[Visual core descriptions](#) · [Smear slides](#) · [Thin sections](#) · [Chert/Porcellanite log](#)



Site U1334

[Visual core descriptions](#) · [Smear slides](#)

Site U1335

[Visual core descriptions](#) · [Smear slides](#) · [Lithology log](#)

Site U1336

[Visual core descriptions](#) · [Smear slides](#) · [Thin sections](#) · [Chert/Porcellanite log](#)

Site U1337

[Visual core descriptions](#) · [Smear slides](#)

Site U1338

[Visual core descriptions](#) · [Smear slides](#)



Expedition research results

Data reports

Titles are available in [HTML](#) pending completion of the volume.

Syntheses

See “[Syntheses](#)” in the Expedition-related bibliography.

Supplementary material

Supplementary material for this volume includes biostratigraphy (age datums in Microsoft Excel and Word formats) and paleomagnetism data in Microsoft Excel. See [README.TXT](#) in the SUPP_MAT directory for a full listing of directories and files, or see the [Directory structure](#) for the names of the main subdirectories.

Drilling location maps

A site map showing the drilling locations for this expedition and maps showing the drilling locations of all Integrated Ocean Drilling Program (IODP), Ocean Drilling Program (ODP), and Deep Sea Drilling Project (DSDP) drilling sites are available in PDF. These maps were produced using Generic Mapping Tools (GMT) of Paul Wessel and Walter H.F. Smith (gmt.soest.hawaii.edu/).

[IODP Expedition 320/321 site map](#)

[IODP map](#) (Expeditions 301–312, 314–316, and 320–321)

[ODP map](#) (Legs 100–210)

[DSDP map](#) (Legs 1–96)



Expedition-related bibliography

IODP publications

Scientific Prospectus

Pälike, H., Lyle, M.W., Ahagon, N., Raffi, I., Gamage, K., and Zarikian, C.A., 2008. Pacific equatorial age transect. *IODP Sci. Prosp.*, 320/321. doi:10.2204/iodp.sp.320321.2008

Pälike, H., Lyle, M.W., Ahagon, N., Raffi, I., Gamage, K., and Zarikian, C.A., 2008. Pacific equatorial age transect addendum. *IODP Sci. Prosp.*, 320/321 addendum. doi:10.2204/iodp.sp.320321add.2008

Preliminary Reports

Pälike, H., Nishi, H., Lyle, M., Raffi, I., Klaus, A., Gamage, K., and the Expedition 320/321 Scientists, 2009. Pacific Equatorial Transect. *IODP Prel. Rept.*, 320. doi:10.2204/iodp.pr.320.2009

Lyle, M., Raffi, I., Pälike, H., Nishi, H., Gamage, K., Klaus, A., and the Expedition 320/321 Scientists, 2009. Pacific Equatorial Transect. *IODP Prel. Rept.*, 321. doi:10.2204/iodp.pr.321.2009

*Scientific Drilling journal**

Lyle, M., Pälike, H., Nishi, H., Raffi, I., Gamage, K., Klaus, A., and the IODP Expeditions 320/321 Science Party, 2010. The Pacific Equatorial Age Transect, IODP Expeditions 320 and 321: building a 50-million-year-long environmental record of the equatorial Pacific Ocean. *Sci. Drill.*, 9:4-15. doi:10.2204/iodp.sd.9.01.2010

Proceedings volume

Pälike, H., Lyle, M., Nishi, H., Raffi, I., Gamage, K., Klaus, A., and the Expedition 320/321 Scientists, 2010. *Proc. IODP, 320/321: Tokyo (Integrated Ocean Drilling Program Management International, Inc.)*. doi:10.2204/iodp.proc.320321.2010

Pälike, H., Nishi, H., Lyle, M., Raffi, I., Gamage, K., Klaus, A., and the Expedition 320/321 Scientists, 2010. Expedition 320/321 summary. In Pälike, H., Lyle, M., Nishi, H., Raffi, I., Gamage, K., Klaus, A., and the Expedition 320/321 Scientists, *Proc. IODP, 320/321: Tokyo (Integrated Ocean Drilling Program Management International, Inc.)*. doi:10.2204/iodp.proc.320321.101.2010

Expedition 320/321 Scientists, 2010. Methods. In Pälike, H., Lyle, M., Nishi, H., Raffi, I., Gamage, K., Klaus, A., and the Expedition 320/321 Scientists, *Proc. IODP, 320/321: Tokyo (Integrated Ocean Drilling Program Management International, Inc.)*. doi:10.2204/iodp.proc.320321.102.2010

Expedition 320/321 Scientists, 2010. Site U1331. In Pälike, H., Lyle, M., Nishi, H., Raffi, I., Gamage, K., Klaus, A., and the Expedition 320/321 Scientists, *Proc. IODP, 320/321: Tokyo (Integrated Ocean Drilling Program Management International, Inc.)*. doi:10.2204/iodp.proc.320321.103.2010

Expedition 320/321 Scientists, 2010. Site U1332. In Pälike, H., Lyle, M., Nishi, H., Raffi, I., Gamage, K., Klaus, A., and the Expedition 320/321 Scientists, *Proc. IODP, 320/321: Tokyo (Integrated Ocean Drilling Program Management International, Inc.)*. doi:10.2204/iodp.proc.320321.104.2010

Expedition 320/321 Scientists, 2010. Site U1333. In Pälike, H., Lyle, M., Nishi, H., Raffi, I., Gamage, K., Klaus, A., and the Expedition 320/321 Scientists, *Proc. IODP, 320/321: Tokyo (Integrated Ocean Drilling Program Management International, Inc.)*. doi:10.2204/iodp.proc.320321.105.2010

Expedition 320/321 Scientists, 2010. Site U1334. In Pälike, H., Lyle, M., Nishi, H., Raffi, I., Gamage, K., Klaus, A., and the Expedition 320/321 Scientists, *Proc. IODP, 320/321: Tokyo (Integrated Ocean Drilling Program Management International, Inc.)*. doi:10.2204/iodp.proc.320321.106.2010

Expedition 320/321 Scientists, 2010. Site U1335. In Pälike, H., Lyle, M., Nishi, H., Raffi, I., Gamage, K., Klaus, A., and the Expedition 320/321 Scientists, *Proc. IODP, 320/321: Tokyo (Integrated Ocean Drilling Program Management International, Inc.)*. doi:10.2204/iodp.proc.320321.107.2010

Expedition 320/321 Scientists, 2010. Site U1336. In Pälike, H., Lyle, M., Nishi, H., Raffi, I., Gamage, K., Klaus, A., and the Expedition 320/321 Scientists, *Proc. IODP*, 332/321: Tokyo (Integrated Ocean Drilling Program Management International, Inc.). [doi:10.2204/iodp.proc.320321.108.2010](https://doi.org/10.2204/iodp.proc.320321.108.2010)

Expedition 320/321 Scientists, 2010. Site U1337. In Pälike, H., Lyle, M., Nishi, H., Raffi, I., Gamage, K., Klaus, A., and the Expedition 320/321 Scientists, *Proc. IODP*, 332/321: Tokyo (Integrated Ocean Drilling Program Management International, Inc.). [doi:10.2204/iodp.proc.320321.109.2010](https://doi.org/10.2204/iodp.proc.320321.109.2010)

Expedition 320/321 Scientists, 2010. Site U1338. In Pälike, H., Lyle, M., Nishi, H., Raffi, I., Gamage, K., Klaus, A., and the Expedition 320/321 Scientists, *Proc. IODP*, 332/321: Tokyo (Integrated Ocean Drilling Program Management International, Inc.). [doi:10.2204/iodp.proc.320321.110.2010](https://doi.org/10.2204/iodp.proc.320321.110.2010)

Syntheses*

Pending

Journals/Books*

Pending

Conferences*

Pending

*The [Expedition-related bibliography](#) is continually updated online. Please send updates to PubCrd@iodp.tamu.edu.



Directory structure*

320321.PDF (Preliminary pages and table of contents)				
README.TXT (Information about the Expedition Reports DVD-ROM)				
ACROREAD (Acrobat Reader installation software and instructions for different platforms)	MAC WINDOWS UNIX README.TXT			
EXP_REPT (Expedition Reports section of <i>Proc. IODP, 320/321</i>)	CHAPTERS (Expedition Reports chapters)	2021_101.PDF (Expedition 320/321 summary) 2021_102.PDF (Methods) 2021_103.PDF (Site U1331) 2021_104.PDF (Site U1332) 2021_105.PDF (Site U1333) 2021_106.PDF (Site U1334) 2021_107.PDF (Site U1335) 2021_108.PDF (Site U1336) 2021_109.PDF (Site U1337) 2021_110.PDF (Site U1338)		
	CORES (Visual core descriptions, smear slide data tables, thin section data tables, lithology logs, and digital core images)	CORU1331.PDF (Site U1331, Expedition 320) CORU1332.PDF (Site U1332, Expedition 320) CORU1333.PDF (Site U1333, Expedition 320) CORU1334.PDF (Site U1334, Expedition 320) CORU1335.PDF (Site U1335, Expedition 320) CORU1336.PDF (Site U1336, Expedition 320) CORU1337.PDF (Site U1337, Expedition 321) CORU1338.PDF (Site U1338, Expedition 321) IMAGES		
	OVERSIZE (Large-format files of figures and data tables)	2021_101 (Expedition 320/321 summary files) 2021_103 (Site U1331 files) 2021_104 (Site U1332 files) 2021_105 (Site U1333 files) 2021_106 (Site U1334 files) 2021_107 (Site U1335 files) 2021_108 (Site U1336 files) 2021_109 (Site U1337 files) 2021_110 (Site U1338 files)		
	TABLES (ASCII files of data tables)	2021_103 (Site U1331 files) 2021_104 (Site U1332 files) 2021_105 (Site U1333 files) 2021_106 (Site U1334 files) 2021_107 (Site U1335 files)		
	SUPP_MAT (Supplementary material)	BIOSTRAT (Range charts and taxonomic lists in Excel)	RANGE_CH (Range charts) TAX_LIST (Taxonomic lists)	
		PALEOMAG (Paleomagnetic data in Excel)	U1331 (Site U1331 files) U1332 (Site U1332 files) U1333 (Site U1333 files) U1334 (Site U1334 files) U1335 (Site U1335 files)	
		README.TXT		
		MAPS (Drilling location maps)	320321_MAP.PDF (Expedition 320/321 site map)	
			IODPMAP.PDF (IODP map, Expeditions 301–312, 314–316, and 320–321)	
	ODPMAP.PDF (ODP map, Legs 100–210)			
	DSDPMAP.PDF (DSDP map, Legs 1–96)			

*Directory structure reflects the Expedition Reports content and volume material produced on DVD-ROM.

