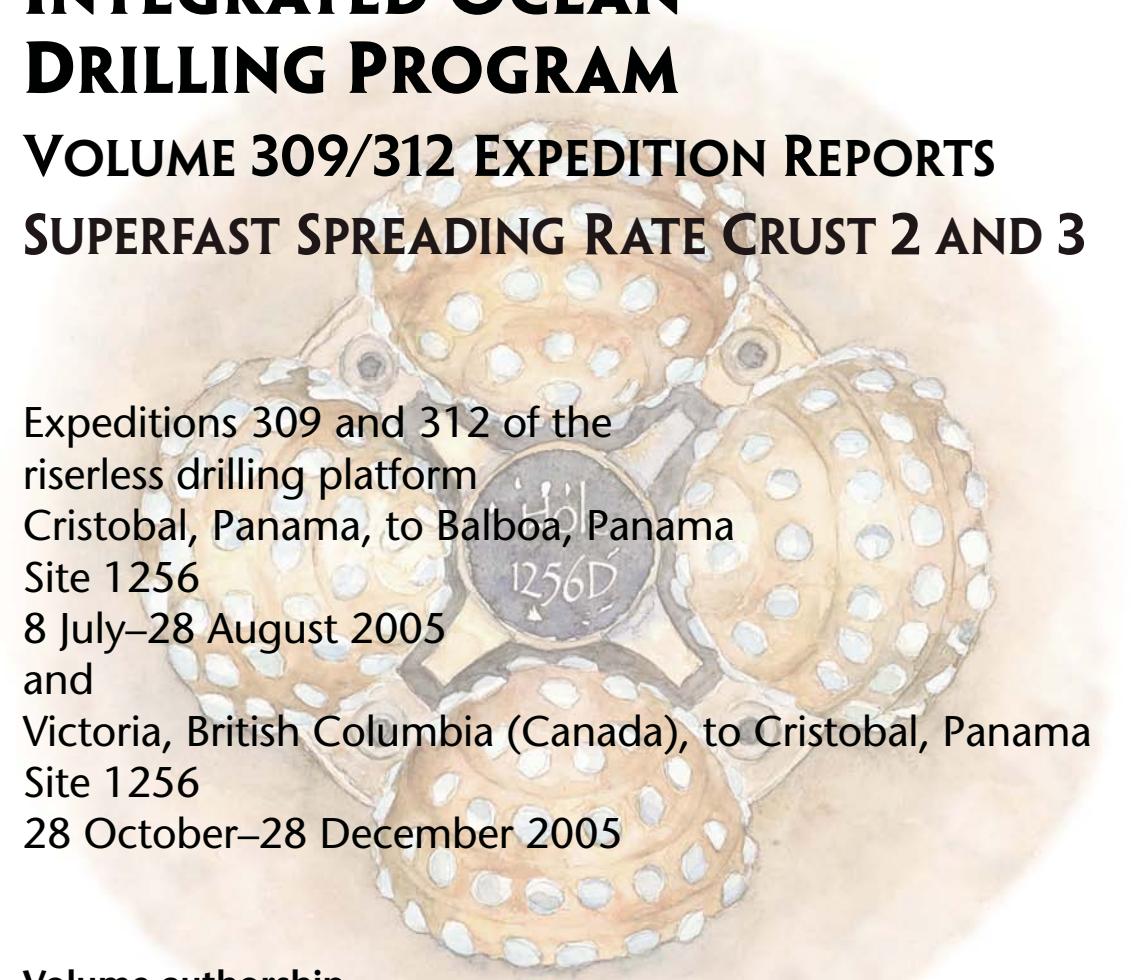
Proceedings of the Integrated Ocean Drilling Program

Volume 309/312 Expedition Reports

Superfast Spreading Rate Crust 2 and 3



Expeditions 309 and 312 of the
riserless drilling platform
Cristobal, Panama, to Balboa, Panama
Site 1256
8 July–28 August 2005
and
Victoria, British Columbia (Canada), to Cristobal, Panama
Site 1256
28 October–28 December 2005

Volume authorship
Teagle, D.A.H., Alt, J.C., Umino, S.,
Miyashita, S., Banerjee, N.R., Wilson, D.S.,
and the Expedition 309/312 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:

European Consortium for Ocean Research Drilling (ECORD)

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

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

National Science Foundation (United States)

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 **iodp.ldeo.columbia.edu/DATA/IODP**. 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**

Some close-up core photographs have been tonally enhanced to better illustrate particular features of interest.

Cover illustration, by Christine Laverne, is a watercolor of a C-9 drill bit.

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 the most ambitious ocean exploration and drilling program ever undertaken. With multiple platforms and multiple partners, our research spans the globe and truly represents international collaboration and diplomacy among scientists and nations interested in attaining scientific goals.

The *Proceedings* present the scientific and engineering results of IODP drilling projects, each an important component of an international program designed to better understand Earth, its environmental changes and processes, the deep biosphere, and climate change.

The collective effort required to conduct each IODP expedition is colossal. Beginning with scientists who submit ocean drilling research proposals, there are others who 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. There are onboard logistics to manage and critical communications to coordinate among various academic institutions, governments, and national science organizations. And the resulting data must be managed and made accessible to scientists, particularly those who will prepare future proposals. Every aspect of planning an IODP expedition takes a village—or several. There are many participants and many more stakeholders.

Ocean-drilling achievements, however complex, help us understand extraordinary linkages and interpret relationships as they exist in various parts of the Earth system. Achievements in two legacy drilling programs (the Ocean Drilling Program and Deep Sea Drilling Program) 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—scientific information at the foundation of our current drilling program.

IODP drilling platform operations are conducted by three Implementing Organizations (IOs). Riserless platform operations are conducted by the JOI Alliance, comprising the Joint Oceanographic Institutions, 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, 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. At the start of this drilling project, IODP involved 20 nations.

The discoveries discovered 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 Culture, Education, Sports, Science and Technology, and other IODP members. The material is based upon research supported under Contract OCE-0432224 from NSF.

Manik Talwani
President & Chief Executive Officer
Integrated Ocean Drilling Program Management International, Inc.
Washington, D.C.
www.iodp.org

Integrated Ocean Drilling Program

Integrated Ocean Drilling Program Management International, Inc.

Web site: **www.iodp.org**

IODP-MI
815 Connecticut Avenue, NW, Suite 210
Washington DC 20006
USA
Tel: (202) 465-7500; Fax: (202) 955-8363
E-mail: **info@iodp.org**

IODP-MI
CRIS Building, Room 05-101
Hokkaido University
N21W10 Kita-ku, Sapporo 001-0021
Japan
Tel: (81) 11-738-1075; Fax: (81) 11-738-3520

IODP-MI member organizations*

Alfred-Wegener-Institute für Polar und Meeresforschung, Germany

British Geological Survey, United Kingdom

Cardiff University, United Kingdom

Columbia University, Lamont-Doherty Earth Observatory, USA

Federal Institute of Technology (ETH), Switzerland

Florida State University, USA

Hokkaido University, Japan

Institut für Meereswissenschaften, Department of Marine Environmental Geology (IFM-GEOMAR), Germany

Institut de Physique du Globe de Paris, France

Institut Universitaire Européen de la Mer, France

Japan Agency for Marine-Earth Science and Technology, Japan

Kochi University, Japan

Kyushu University, Japan

National Institute of Advanced Industrial Science (AIST), Japan

Oregon State University, USA

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 Michigan, USA

University of Rhode Island, USA

University of Southampton, United Kingdom

University of Texas, 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@exchange.edinburgh.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: **tim.brewer@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/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 City
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: JOI Alliance

Web site: **www.iodp-usio.org**

IODP-USIO Systems Integration Contractor

Joint Oceanographic Institutions, Inc.
1201 New York Avenue, NW, Suite 400
Washington DC 20005
USA
Tel: (202) 232-3900; Fax: (202) 462-8754
E-mail: **info@joiscience.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 309/312 science party*

Damon A.H. Teagle
Co-Chief Scientist (Expedition 309)
School of Ocean and Earth Science
National Oceanography Centre
University of Southampton, European Way
Southampton SO14-3ZH
United Kingdom
dat@noc.soton.ac.uk

Susumu Umino
Co-Chief Scientist (Expedition 309)
Department of Biology and Geosciences
Shizuoka University
Ohya 836
Shizuoka 422-8529
Japan
sesumin@ipc.shizuoka.ac.jp

Jeffrey C. Alt
Co-Chief Scientist (Expedition 312)
Department of Geological Sciences
University of Michigan
1000 North University
Ann Arbor MI 48109-1005
USA
jalt@umich.edu

Sumio Miyashita
Co-Chief Scientist (Expedition 312)
Department of Geology
Niigata University
8050 Ikarashi
Niigata 950-2181
Japan
miyashit@geo.sc.niigata-u.ac.jp

Neil R. Banerjee
Staff Scientist/Expedition Project Manager (Expeditions 309 and 312)
Integrated Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station TX 77845-9547
USA

Present address:
Department of Earth Sciences
University of Western Ontario
London ON N6A 5B7
Canada
neil.iodp@gmail.com

Expedition 309 scientists

Florence Einaudi
Logging Staff Scientist
Laboratoire de Géophysique et d'Hydrodynamique en Forage
ISTEEM, cc 056
34095 Montpellier Cedex 5
France
florence.einaudi@dstu.univ-montp2.fr

Akram Belghoul
Logging Trainee
Laboratoire de Géophysique et d'Hydrodynamique en Forage
ISTEEM, cc 056
34092 Montpellier Cedex 5
France
belghoul@dstu.univ-montp2.fr

Carole Cordier
Igneous Petrologist
Earth Sciences
Universite de Bretagne Occidentale, IVEM
1 Place Copernic
UMR 6538 Domaines Océaniques
29280 Plouzané
France
carole.cordier@sdt.univ-brest.fr

Laura Crispini
Structural Geologist
Dipartimento per lo Studio del Territorio e delle sue Risorse
Università degli Studi di Genova
Corso Europa 26
16132 Genova
Italy
crispini@dipteris.unige.it

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

Laura Galli
Metamorphic Petrologist
Department of Earth Sciences
Università degli Studi di Milano
Via Mangiagalli, 34
20133 Milano
Italy
lauragalli1@alice.it

Yongjun Gao
Geochemist/Igneous Petrologist
Department of Geosciences
University of Houston
4800 Calhoun Road, SR1 Building
Houston TX 77204
USA
yongjungao@uh.edu

Jörg Geldmacher
Igneous Petrologist
IFM-GEOMAR
Leibniz Institute for Marine Sciences Kiel
Wischhofstrasse 1-3
24148 Kiel
Germany
jgeldmacher@ifm-geomar.de

Lisa A. Gilbert
Physical Properties Specialist
Maritime Studies Program
Williams College and Mystic Seaport
75 Greenmanville Avenue
Mystic CT 06355
USA
lisa.gilbert@williams.edu

Emilio Herrero-Bervera
Paleomagnetist
Hawaii Institute of Geophysics and Planetology
University of Hawaii at Manoa
Petrofabrics and Paleomagnetics Laboratory
1680 East West Road
Honolulu HI 96822
USA
herrero@soest.hawaii.edu

Sara Ann Holter
Student Trainee
Department of Geology
University of St. Thomas
2115 Summit Avenue
St. Paul MN 55105
USA
sara.holter@gmail.com

Christine Laverne
Metamorphic Petrologist
Université Paul Cézanne Aix-Marseille III
Laboratoire de Pétrologie Magmatique-Case 441
Faculté des Sciences de Marseille Saint Jérome
Avenue Escadrille, Normandie Nieman
13397 Marseille Cedex 20
France
christine.laverne@univ.u-3mrs.fr

Haroldo L. Lledo Vasquez
Inorganic Geochemist
Geological Sciences and Environmental Studies
Binghamton University
4400 Vestal Parkway East
Binghamton NY 13902-6000
USA

Present address:
Department of Geoscience
University of Las Vegas
4505 Maryland Parkway
Box 454010
Las Vegas NV 89154-4010
USA
haroldo.lledo@UNLV.edu

Sedelia Rodriguez Durand
Igneous Petrologist
Department of Earth Sciences, PC 344
Florida International University
University Park Campus
11200 Southwest 8th Street
Miami FL 33199
USA

Present address:
Lamont-Doherty Earth Observatory of Columbia University
61 Route 9W, PO Box 1000
Palisades NY 10964
durand@ldeo.columbia.edu

Tetsuya Sakuyama
Inorganic Geochemist
Earth and Planetary Science
University of Tokyo
7-3-1 Hongo
Bunkyo-ku, Tokyo 113-0033
Japan
tetsuya-saku@eps.s.u-tokyo.ac.jp

Takashi Sano
Igneous Petrologist
College of Environment and Disaster Research
Fuji Tokoha University
325 Ohbuchi
Fuji 417-0801
Japan
sano@fuji-tokoha-u.ac.jp

Christopher E. Smith-Duque
Metamorphic Petrologist
School of Ocean and Earth Science
University of Southampton
European Way
Southampton SO14 3ZH
United Kingdom
csd2@noc.soton.ac.uk

Masako Tominaga
Physical Properties Specialist
Department of Oceanography
Texas A&M University
3F Oceanography Building
3146 TAMU
College Station TX 77843-3146
USA
masako@ocean.tamu.edu

Teacher at Sea

Alan C. Gelatt
Romulus Central School
5705 Main Street
Romulus NY 14541
USA
Work: (866) 810-0345
agelatt@rcs.k12.ny.us

Expedition 312 scientists

Marc Reichow
Logging Staff Scientist
Department of Geology
University of Leicester
University Road
Leicester LE1 7RH
United Kingdom
mkr6@le.ac.uk

Ryo Anma
Structural Geologist
Graduate School of Earth and Environmental Sciences
University of Tsukuba
Ten-no dai 1-1-1
Tsukuba, Ibaraki 305-8572
Japan
anma@arsia.geo.tsukuba.ac.jp

Paola Tartarotti
Structural Geologist
Department of Earth Sciences
Università degli Studi di Milano
Via Mangiagalli, 34
20133 Milano
Italy
paola.tartarotti@unimi.it

Eugenio A. Veloso Espinosa
Paleomagnetist
Graduate School of Life and Environmental Sciences
University of Tsukuba
Tennodai 1-1-1
Tsukuba Science City, Ibaraki 305-8572
Japan
eveloso@arsia.geo.tsukuba.ac.jp

Douglas S. Wilson
Geophysicist
Department of Geological Sciences
University of California, Santa Barbara
1006 Webb Hall
Santa Barbara CA 93106-9630
USA
dwilson@geol.ucsb.edu

Julie Carlut
Paleomagnetist
Laboratoire de Geologie
École Normale Supérieure
24 rue Lhomond
75231 Paris
France
jcarlut@geologie.ens.fr

David M. Christie
Igneous Petrologist
College of Oceanic and Atmospheric Sciences
Oregon State University
104 Ocean Administration Building
Corvallis OR 97331-5503
USA
dchristie@coas.oregonstate.edu

Rosalind Coggon
Igneous Petrologist
Department of Geological Sciences
University of Michigan
1000 North University
Ann Arbor MI 48109-1005
USA
rmc01@soc.soton.ac.uk

Laura Galli
Structural Geologist
Dipartimento di Scienze della Terra
Università degli Studi di Milano
Via Mangiagalli 34
20133 Milano
Italy
lauragalli1@aliceposta.it

Nicholas W. Hayman
Structural Geologist
Division of Earth and Ocean Sciences
Duke University
Box 90227, 103 Old Chemistry Building
Durham NC 27708
USA
hayman@duke.edu

Nobuo Hirano
Inorganic Geochemist
Graduate School of Environmental Studies
Tohoku University
6-6-20 Aza-Aoba, Aramaki
Aoba-ku, Sendai 980-8579
Japan
nhirano@mail.kankyo.tohoku.ac.jp

Stephanie Ingle
Inorganic Geochemist
Department of Oceanography/SOEST
University of Hawaii at Manoa
1680 East-West Road, Post 606
Honolulu HI 96822
USA
ingle@hawaii.edu

Juergen Koepke
Igneous Petrologist
Institut für Mineralogie
Universität Hannover
Callinstrasse 3
30167 Hannover
Germany
koepke@mineralogie.uni-hannover.de

Christine Laverne
Metamorphic Petrologist
Laboratoire de Pétrologie Magmatique, Case 441
Université Paul Cézanne Aix-Marseille III
Faculté des Sciences et Techniques
Avenue Escadrille Normandie-Niemen
13397 Marseille Cedex 20
France
christine.laverne@univ.u-3mrs.fr

John MacLennan
Igneous Petrologist
School of Geosciences
University of Edinburgh
West Mains Road
Edinburgh EH9 3JW
United Kingdom
john.maclennan@ed.ac.uk

Sally Morgan
Metamorphic Petrologist
School of Earth Sciences
University of Leeds
Leeds, West Yorkshire LS2 9JT
United Kingdom
sally@earth.leeds.ac.uk

Natsuki Neo
Inorganic Geochemist
Department of Geology
Niigata University
Faculty of Science
2-8050 Ikarashi
Niigata 950-2181
Japan
f05j007a@mail.cc.niigata-u.ac.jp

Sung-Hyun Park
Igneous Petrologist
School of Earth and Environmental Sciences
Seoul National University
Building 25-1, Room 318
Sillim-dong, Gwanak-gu
Seoul 151-747
Korea

Present address:
Korea Polar Institute, KOPRI
Songdo Techno Park
7-50 Songdo-dong
Yeonsu-gu
Incheon 406-130
South Korea
shpark314@kopri.re.kr

Birgit Scheibner
Igneous Petrologist
Institut für Mineralogie und Geochemie
Universität Karlsruhe
Fritz-Haber-Web 2
76131 Karlsruhe
Germany
bscheib@gwdg.de

Stephen A. Swift
Physical Properties Specialist
Department of Geology and Geophysics
Woods Hole Oceanographic Institution
MS 24
Woods Hole MA 02543
USA
sswift@whoi.edu

Damon A.H. Teagle
Metamorphic Petrologist
School of Ocean and Earth Science
University of Southampton
National Oceanography Centre
Waterfront Campus, European Way
Southampton, England SO14-3ZH
United Kingdom
dat@noc.soton.ac.uk

Anahita A. Tikku
Physical Properties Specialist
Department of Earth and Environmental Sciences
Rensselaer Polytechnic Institute
2C01 Jonsson-Rowland Science Center
110 8th Street
Troy NY 12180-3590
USA
tikkua@rpi.edu

Masako Tominaga
Geophysical Core Scanner Specialist
Department of Oceanography
Texas A&M University
3F Oceanography Building
3146 TAMU
College Station TX 77843-3146
USA
masako@ocean.tamu.edu

Eugenio A. Veloso Espinosa
Structural Geologist
Graduate School of Earth and Environmental Sciences
University of Tsukuba
Tennodai 1-1-1
Tsukuba Science City, Ibaraki 305-8572
Japan
eveloso@arsia.geo.tsukuba.ac.jp

Douglas S. Wilson
Paleomagnetist
Department of Geological Sciences
University of California, Santa Barbara
1006 Webb Hall
Santa Barbara CA 93016-9630
USA
dwilson@geol.ucsb.edu

Toru Yamasaki
Igneous Petrologist
Department of Earth and Planetary Sciences
Hokkaido University
Graduate School of Science
N 10, W 8
Sapporo, Hokkaido 060-0810
Japan
toru@ep.sci.hokudai.ac.jp

Shusaku Yamazaki
Igneous Petrologist
Department of Geology
Niigata University
Faculty of Science
2-8050 Ikarashi
Niigata 950-2181
Japan
shu-saku@mvd.biglobe.ne.jp

Educators

Suzanne O'Connell
Department of Earth and Environmental Sciences
Wesleyan University
265 Church Street
Middletown CT 06579-0139
USA
soconnell@wesleyan.edu

Hideo Sakurai
The Japan Science and Technology Corporation
National Museum of Emerging Science and Innovation
2-41, Aomi, Koto-ku
Tokyo 135-0064
Japan

Operational and technical staff

Transocean officials

Expeditions 309 and 312

Alexander Simpson
Master of the Drilling Vessel
Overseas Drilling Ltd.

Wayne Malone
Drilling Superintendent
Overseas Drilling Ltd.

IODP-USIO shipboard personnel and technical representatives

Expedition 309

Paula Clark
Marine Computer Specialist

Trevor J. Cobine
Research Specialist: Physical Properties

Lisa K. Crowder
Assistant Laboratory Officer

Klayton Curtis
Marine Laboratory Specialist: Paleomagnetism

John Eastlund
Applications Developer

Javier Espinosa
Schlumberger Engineer

Kevin Grigar
Operations Superintendent

Ted Gustafson
Marine Laboratory Specialist:
Downhole Tools/Thin Sections

Burnette W. Hamlin
Laboratory Officer

Michael J. Hodge
Marine Computer Specialist

Leah Shannon Housley
Imaging Specialist

Eric L. Jackson
Marine Laboratory Specialist: X-Ray

Jan Jurie Kotze
Marine Instrumentation Specialist

William Mefferd
Laboratory Specialist: Underway Geophysics

Debbie Partain
Yeoperson

Chieh Peng
Assistant Laboratory Officer

Pieter Pretorius
Marine Instrumentation Specialist

Tomoyuki Tanaka
Marine Laboratory Specialist: Core

Paula Weiss
Marine Curatorial Specialist

Bradley Weymer
Marine Laboratory Specialist:
Underway Geophysics/Core

Robert M. Wheatley
Laboratory Specialist: Chemistry

Expedition 312

Timothy Bronk
Marine Laboratory Specialist: Chemistry

Trevor J. Cobine
Research Specialist: Physical Properties

Lisa K. Crowder
Assistant Laboratory Officer

Klayton Curtis
Marine Laboratory Specialist: Paleomagnetism

Javier Espinosa
Schlumberger Engineer

Toru Fujiki
Marine Laboratory Specialist: Core

Ronald M. Grout
Operations Superintendent

Ted Gustafson
Marine Laboratory Specialist:
Downhole Tools/Thin Sections

Burnette W. Hamlin
Laboratory Officer

Michael J. Hodge
Marine Computer Specialist

Dwight Hornbacher
Applications Developer

Leah Shannon Housley
Imaging Specialist

Eric L. Jackson
Marine Laboratory Specialist: X-Ray

Douglas A. Johnson
Headquarters Representative

Jan Jurie Kotze
Marine Instrumentation Specialist

Virginia Ann Lowe
Yeoperson

Chieh Peng
Assistant Laboratory Officer

Michael Petersen
Marine Computer Specialist

Pieter Pretorius
Marine Instrumentation Specialist

Alexander Roth
Marine Laboratory Specialist: Core

Paula Weiss
Marine Curatorial Specialist

Bradley Weymer
Marine Laboratory Specialist:
Underway Geophysics/Core

Robert M. Wheatley
Laboratory Specialist: Chemistry

IODP-USIO Publication Services staff*

Katherine Bastian
Editorial Assistant

Karen Benson
Production Specialist II

Mary Chapman
Production Specialist I

Gudelia ("Gigi") Delgado
Senior Publications Coordinator

Patrick Edwards
Production Specialist III

Jaime A. Gracia
Supervisor of Production

Lauren Gracia
Student Assistant

Cassandra Harashe
Student Assistant

Jenni Hesse
Editor

Jennie L. Lamb
Graphics Specialist II

Shana C. Lewis
Editor

Ginny Lowe
Reports Coordinator

Nancy H. Luedke
Graphics Specialist II

Amy McWilliams
Editor

Angeline T. Miller
Manager of Publication Services

Linda Orsi
Graphics Specialist II

Deborah L. Partain
Supervisor of Graphics

Lorri Peters
Supervisor of Editing

M. Kathleen Phillips
Publications Specialist

Barbara Riggs-Turner
Administrative Assistant

Jennifer Pattison Rumford
Electronic Publications Specialist

Kenneth Sherar
Production Specialist II

Ann Yeager
Distribution Specialist

* At time of publication.

Acknowledgments

The Expedition 309/312 shipboard scientists thank all the members of the *JOIDES Resolution* crew for making our adventure to Site 1256 a formidable engineering accomplishment, a great scientific achievement, and a most enjoyable experience. We thank Captain Alex Simpson and the officers and crew for twice taking us safely to and from Site 1256 and for holding the ship above 6°44.163'N, 91°56.061'W for over 12 weeks. Rui Felix and the Catermar staff kept us very well fed and freshly washed and folded. The barbeques and the sumptuous Thanksgiving and Christmas feasts are treasured highlights.

It has been a great pleasure to work with the IODP-TAMU technicians, and Assistant Laboratory Officiers Lisa Crowder and Chieh Peng did an exemplary job of keeping the core and samples ticking through the lab stack. Instruments ran smoothly; thousands of samples were photographed, cut and curated, ground, dissolved, and analyzed. Many thanks to Yeopeople Debbie Partain (Expedition 309) and Ginny Lowe (Expedition 312) for keeping us organized, collated, and artistically arranged. The scientists greatly appreciate their patience with our tardy submissions of the expedition chapters. Special thanks to Paula Weiss for her curatorial efforts, all accomplished with serene calmness despite the complete coverage of some critical core pieces by plagues of sample request spots.

The Expedition 309/312 shipboard science parties were greatly saddened to hear of the passing of Paula Clark (1964–2006) while hiking in the Azores, in October 2006. Paula was a Marine Computer Specialist on IODP Expedition 309. She had recently completed a Master's degree in Geophysics at Texas A&M that included a project completed during her free time on Expedition 309 with the Physical Properties group. She began working for ODP in 1998 and filled a variety of roles during her years of service, including Computer Specialist, Research Assistant, and Data Librarian, making her an important resource to her colleagues. Paula is remembered for being a helpful and enthusiastic shipmate, as well as a dear friend. She is deeply missed.

Ted Gustafson made countless beautiful, polished sections—many of them large and complex. His perseverance with the capricious water-sampling temperature probe, together with Jurie Kotze and Pieter Pretorius, allowed us to take excellent samples of the Hole 1256D borehole fluid. Marine Computer Specialists Mike Hodge, Paula Clark, and Mike Petersen kept the network running smoothly. John Eastlund (Expedition 309) and Dwight Hornbacher (Expedition 312) nursed and resuscitated Janus throughout both expeditions. Javier Espinosa, the Schlumberger engineer on both expeditions, ensured that we recovered an excellent suite of wireline logs, images, and seismic profiles of the upper ocean crust penetrated by Hole 1256D.

Funding for the DMT 360° core scanner on Expeditions 309 and 312 was provided by a Natural Environment Research Council (U.K.) Integrated Ocean Drilling Program Directed Science Programme Urgency Grant (NE/D001277/1 to Teagle/Brewer) and the generous support of the School of Ocean and Earth Science, University of Southampton; the Department of Geology, University of Leicester; and the U.S. National Science Foundation, through the Integrated Ocean Drilling Program (Texas A&M University) and the United States Science Support Program (Joint Oceanographic Institutions, Inc.).

Our greatest debt of gratitude is to the Transocean rig floor teams, under the supervision of Operations Superintendent Wayne Malone, and tool pushers Joe "Bubba" Attyde and Pete Christie, for their heroic accomplishment of deepening Hole 1256D down to the gabbros. Twice during Expedition 309 prompt recognition and diagnosis of damage to the bottom-hole assembly and drill string prevented major loss of equipment into Hole 1256D, which would have seriously curtailed our progress to the gabbros. The slow penetration, low recovery, and loss of cones and teeth from the drill bit while drilling the nearly impenetrable granoblastic dikes during Expedition 312 led some scientists to feel that the elusive gabbros would never be reached. The Herculean efforts of the rig floor teams to recover the junk, clean the hole, and progress onward toward the gabbros and their "get it done" attitude persist as a huge inspiration to all members of the science party.

Expedition 312 was the last U.S. Implementing Organization cruise of the first phase of the Integrated Ocean Drilling Program and the final scientific drilling voyage of the *JOIDES Resolution* before she undergoes major refit and renaming. The *JOIDES Resolution* has been a maritime home away from home for innumerable crew and scientists since the beginning of the Ocean Drilling Program in 1985, and the successful accomplishment of the longstanding scientific ocean drilling goal of coring down to gabbros is a fitting finale to the *JOIDES Resolution*'s achievements and the first phase of IODP.

Dedication

The IODP Expedition 309/312 shipboard scientists dedicate this volume to the Transocean operations and rig floor team of the *JOIDES Resolution*.

Hole 1256D penetrates >1250 m into previously "undrillable" Pacific basement and remains clear of debris, ready for deepening on future expeditions. This is a major engineering accomplishment and a milestone in scientific ocean drilling. Hole 1256D is now the fourth deepest hole drilled into oceanic basement and the second deepest penetration into intact ocean crust, shallower only than Deep Sea Drilling Project/Ocean Drilling Program Hole 504B. Importantly, Hole 1256D provides the first complete section of the upper oceanic crust from the erupted lavas, through the sheeted dikes, and into gabbros. Such a section has been one of the major desires of marine geologists and geophysicists since the inception of scientific ocean drilling in 1968.

Contents

Expedition reports

Chapters

Core descriptions

Visual core descriptions (VCDs), thin sections, and digital images are included in this section. VCDs and thin sections are combined into one PDF file each.

Expedition research results

Data reports

Titles are available in **HTML** pending completion of the volume.

Syntheses

Titles are available in **HTML** pending completion of the volume.

Supplementary material

Hard rock logs are presented as supplementary material in Excel 97/98 spreadsheet format. Images in PDF format of raw visual core descriptions (HRVCDs) are also presented as supplementary material. 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 format. These maps were produced using Generic Mapping Tools (GMT) of Paul Wessel and Walter H.F. Smith (**gmt.soest.hawaii.edu**).

IODP Expedition 309/312 site map

IODP map (Expeditions 301–312)

ODP map (Legs 100–210)

DSDP map (Legs 1–96)

Expedition-related bibliography

IODP/ODP publications

Scientific Prospectus

Alt, J.C., Miyashita, S., Teagle, D.A.H., Umino, S., Miller, D.J., Banerjee, N., and the Expeditions 309 and 312 Project Team, 2005. Superfast spreading rate crust 2 and 3. *IODP Sci. Prosp.,* 309/312. **doi:10.2204/iodp.sp.309312.2005**

Preliminary Reports

Expedition 309 Scientists, 2005. Superfast spreading rate crust 2: a complete in situ section of upper oceanic crust formed at a superfast spreading rate. *IODP Prel. Rept.,* 309. **doi:10:2204/iodp.pr.309.2005**

Expedition 309 and 312 Scientists, 2006. Superfast spreading rate crust 3: a complete in situ section of upper oceanic crust formed at a superfast spreading rate. *IODP Prel. Rept.,* 312. **doi:10:2204/iodp.pr.312.2006**

Shipboard Scientific Party, 2003. Leg 206 Preliminary Report. *ODP Prelim. Rpt.,* 106 [Online]. Available from World Wide Web: **http://www-odp.tamu.edu/publications/prelim/206_prel/206PREL.PDF.**

Scientific Drilling Journal

Pending

Proceedings volumes

Teagle, D.A.H., Alt, J.C., Umino, S., Miyashita, S., Banerjee, N.R., Wilson, D.S., and the Expedition 309/312 Scientists, 2006. *Proc. IODP,* 309/312: Washington, DC (Integrated Ocean Drilling Program Management International, Inc.). **doi:10.2204/iodp.proc.309312.2006**

Teagle, D.A.H., Wilson, D.A., Acton, G.A., and Vanko, D.A. (Eds.), in press. *Proc. ODP, Sci. Results,* 206: College Station, TX (Ocean Drilling Program).

Alt, J.C., and Laverne, C., 2006. Data report: chemical compositions of secondary minerals from Site 1256 basement, ODP Leg 206. *In* Teagle, D.A.H., Wilson, D.A., Acton, G.A., and Vanko, D.A. (Eds.), *Proc. ODP, Sci. Results,* 206: College Station, TX (Ocean Drilling Program), 1–16. **doi:10.2973/odp.proc.sr.206.003.2006**

Coggon, R.M., Teagle, D.A.H., Cooper, M.J., Hayes, T.E.F., and Green, D.R.H., in press. Data report: compositions of calcium carbonate veins from superfast spreading rate crust, ODP Leg 206. *In* Teagle, D.A.H., Wilson, D.A., Acton, G.A., and Vanko, D.A. (Eds.), *Proc. ODP, Sci. Results,* 206: College Station, TX (Ocean Drilling Program), 1–6.

Expedition 309/312 Scientists, 2006. Expedition 309/312 summary. *In* Teagle, D.A.H., Alt, J.C., Umino, S., Miyashita, S., Banerjee, N.R., Wilson, D.S., and the Expedition 309/312 Scientists. *Proc. IODP,* 309/312: Washington, DC (Integrated Ocean Drilling Program Management International, Inc.). **doi:10.2204/iodp.proc.309312.101.2006**

Expedition 309/312 Scientists, 2006. Methods. *In* Teagle, D.A.H., Alt, J.C., Umino, S., Miyashita, S., Banerjee, N.R., Wilson, D.S., and the Expedition 309/312 Scientists. *Proc. IODP,* 309/312: Washington, DC (Integrated Ocean Drilling Program Management International, Inc.). **doi:10.2204/iodp.proc.309312.102.2006**

Expedition 309/312 Scientists, 2006. Site 1256. *In* Teagle, D.A.H., Alt, J.C., Umino, S., Miyashita, S., Banerjee, N.R., Wilson, D.S., and the Expedition 309/312 Scientists. *Proc. IODP,* 309/312: Washington, DC (Integrated Ocean Drilling Program Management International, Inc.). **doi:10.2204/iodp.proc.309312.103.2006**

Jiang, S., and Wise, S.W., Jr., in press. Upper Cenozoic calcareous nannofossil biostratigraphy and inferred sedimentation, ODP Leg 206, East Pacific Rise. *In* Teagle, D.A.H., Wilson, D.A., Acton, G.A., and Vanko, D.A. (Eds.), *Proc. ODP, Sci. Results,* 206: College Station, TX (Ocean Drilling Program).

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

Laverne, C., 2006. Data report: chemical composition of unusual Ti hydrogarnets from the deepest volcanic rocks cored in ODP Hole 1256D (Leg 206). *In* Teagle, D.A.H., Wilson, D.A., Acton, G.A., and Vanko, D.A. (Eds.), *Proc. ODP, Sci. Results,* 206: College Station, TX (Ocean Drilling Program), 1–6.

Shipboard Scientific Party, 2003. Leg 206 summary. *In* Wilson, D.S., Teagle, D.A.H., Acton, G.D., et al., *Proc. ODP, Init. Repts.,* 206: College Station, TX (Ocean Drilling Program), 1–117.

Shipboard Scientific Party, 2003. Explanatory notes. *In* Wilson, D.S., Teagle, D.A.H., Acton, G.D., et al., *Proc. ODP, Init. Repts.*, 206: College Station, TX (Ocean Drilling Program), 1–94.

Shipboard Scientific Party, 2003. Site 1256. *In* Wilson, D.S., Teagle, D.A.H., Acton, G.D., et al., *Proc. ODP, Init. Repts.,* 206: College Station, TX (Ocean Drilling Program), 1–396.

Tartarotti, P., Crispini, L., Einaudi, F., and Campari, E., in press. Data report: reoriented structures in the East Pacific Rise basaltic crust from ODP Hole 1256D, Leg 206: integration of core measurements and electrical-acoustic images. *In* Teagle, D.A.H., Wilson, D.A., Acton, G.A., and Vanko, D.A. (Eds.), *Proc. ODP, Sci. Results,* 206: College Station, TX (Ocean Drilling Program).

Wilson, D.S., Hallenborg, E., Harding, A.J., and Kent, G.M., 2003. Data report: site survey results from cruise EW9903. *In* Wilson, D.S., Teagle, D.A.H., Acton, G.D., et al., *Proc. ODP, Init. Repts.,* 206: College Station, TX (Ocean Drilling Program), 1–49.

Wilson, D.S., Teagle, D.A.H., Acton, G.D., et al., 2003. *Proc. ODP, Init. Repts.,* 206: College Station, TX (Ocean Drilling Program).

Journals/Books*

Busigny, V., Laverne, C., and Bonifacie, M., 2005. Nitrogen content and isotopic composition of oceanic crust at a superfast spreading ridge: a profile in altered basalts from ODP Site 1256, Leg 206. *Geochem. Geophys. Geosyst.,* 6. **doi:10.1029/2005GC001020**

Laverne, C., Grauby, O., Alt, J.C., and Bohn, M., 2006. Hydroschorlomite in altered basalts from Hole 1256D, ODP Leg 206: the transition from low-temperature to hydrothermal alteration. *Geochem. Geophys. Geosyst.,* 7:Q10O03. **doi:10.1029/2005GC001180**

Teagle, D.A.H., Wilson, D.S., Acton, G.D., and the Leg 206 Scientific Party, 2003. ODP Leg 206: upper oceanic crust formed at a superfast spreading rate. *JOIDES J.,* 29(2):13–17.

Teagle, D.A.H., Wilson, D.S., Acton, G.D., and the ODP Leg 206 Shipboard Party, 2004. The "Road to the MoHole" four decades on: deep drilling at Site 1256. *Eos*, 85:521,530–531.

Wilson, D.S., Teagle, D.A.H., Alt, J.C., Banerjee, N.R., Umino, S., Miyashita, S., Acton, G.D., Anma, R., Barr, S.R., Belghoul, A., Carlut, J., Christie, D.M., Coggon, R.M., Cooper, K.M., Cordier, C., Crispini, L., Durand, S.R., Einaudi, F., Galli, L., Gao, Y., Geldmacher, J., Gilbert, L.A., Hayman, N.W., Herrero-Bervera, E., Hirano, N., Holter, S., Ingle, S., Jiang, S., Kalberkamp, U., Kerneklian, M., Koepke, J., Laverne, C., Vasquez, H.L.L., Maclennan, J., Morgan, S., Neo, N., Nichols, H.J., Park, S.-H., Reichow, M.K., Sakuyama, T., Sano, T., Sandwell, R., Scheibner, B., Smith-Duque, C.E., Swift, S.A., Tartarotti, P., Tikku, A.A., Tominaga, M., Veloso, E.A., Yamasaki, T., Yamazaki, S., and Ziegler, C., 2006. Drilling to gabbro in intact ocean crust. *Science,* 312:1016–1020. **doi:10.1126/science.1126090**

Ziegler, C.L., and Murray, R.W., Hovan, S.A., and Rea, D.K., submitted. Resolving eolian, volcanogenic, and authigenic components in pelagic sediment from the Paciifc Ocean. *Earth Planet. Sci. Lett.*

Conferences*

Laverne, C., Alt, J.C., Banerjee, N.R., Coggon, R., Teagle, D.A.H., Wilson, D.S, Acton, G.D., and the Leg 206 Shipboard Scientific party, 2003. Le puits DSDP/ODP 504B a eu un petit frère: naissance du puits ODP/IODP 1256D dans le bassin du Guatemala en Décembre 2002. Altération de la croüte océanique. [paper presented at SGF Special Session Océans et ophiolites, Brest, 3–5 March, 2003].

Directory structure*

- **309312.PDF** (Preliminary pages and table of contents)
- **README.TXT** (Information about the volume DVD-ROM)
- **ACROREAD** (Acrobat Reader installation software and instructions for different platforms)
  - **MAC_OS**
  - **UNIX**
  - **WINDOWS**
  - **README.TXT**
- **EXP_REPT** (Expedition Reports section of *Proc. IODP*. 309/312)
  - **CHAPTERS** (Expedition Reports chapters)
    - **0912_101.PDF** (Expedition 309/312 summary)
    - **0912_102.PDF** (Methods)
    - **0912_103.PDF** (Site 1256)
  - **CORES** (Visual core descriptions, thin section data tables, and digital core images)
    - **1256_1.PDF** (Site 1256, Expedition 309)
    - **1256_2.PDF** (Site 1256, Expedition 312)
    - **IMAGES** (PDF files of core images)
  - **MOVIES** (QuickTime movies)
    - **VIDEO1.MOV**
    - **VIDEO2.MOV**
    - **VIDEO3.MOV**
    - **VIDEO4.MOV**
    - **README.TXT**
  - **OVERSIZE** (Large-format files of data tables)
    - **0912_101** (Summary chapter files)
    - **0912_103** (Site 1256 chapter files)
  - **TABLES** (ASCII files of data tables)
    - **0912_103** (Site 1256 chapter files)
- **SUPP_MAT** (Supplementary material)
  - **LOGS** (Hard rock logs: alteration, distribution, vein, breccia, deformation intensity, photomicrograph, piece, plutonic alteration, scan, structure, and thin section logs in Excel)
    - **309ALT.XLS**
    - **309DIST.XLS**
    - **309VEIN.XLS**
    - **312ALT.XLS**
    - **312VEIN.XLS**
    - **BRECLOG.XLS**
    - **DEFINT.XLS**
    - **PHOTOLOG.XLS**
    - **PIECELOG.XLS**
    - **PLUTLOG.XLS**
    - **SCANLOG.XLS**
    - **STRUCTUR.XLS**
    - **TSECTLOG.XLS**
  - **STR_VCD** (PDF files of raw visual core descriptions)
    - **SITE1256** (Hole 1256D files)
  - **README.TXT**

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

Directory structure (continued)