



# **PROCEEDINGS OF THE INTEGRATED OCEAN DRILLING PROGRAM**

## **VOLUME 331 EXPEDITION REPORTS DEEP HOT BIOSPHERE**

Expedition 331 of the riser drilling platform  
Shingu, Japan, to Nagoya, Japan  
Sites C0013–C0017  
1 September–3 October 2010

### **Volume authorship**

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

Prepared by  
Japanese Implementing Organization, Center for Deep Earth Exploration (CDEX)  
at the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), and  
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# 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 GNS Science (New Zealand), 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., or Japan Agency for Marine-Earth Science and Technology.

Examples of how to cite this volume or part of this volume are available at [publications.iodp.org/proceedings/331/331bib.htm](http://publications.iodp.org/proceedings/331/331bib.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 at [sio7.jamstec.go.jp/](http://sio7.jamstec.go.jp/).

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

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

Cover photograph shows view of D/V *Chikyu* at port in Shimizu, Japan. Photo © JAMSTEC.

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## ISSN

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

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# 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 U.S. 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 (ESO), comprising the British Geological Survey, the University of Bremen, 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.

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\*At time of expedition.



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# Contents

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Expedition 331 Scientists

### Core descriptions

Visual core descriptions (VCDs), thin sections, and core images are included in this section. VCDs and thin sections are combined into PDF files for each site. The entire set of core images in PDF is available in the IMAGES directory.

**Site C0013**  
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[Visual core descriptions](#) · [Thin sections](#)

**Site C0015**  
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**Site C0016**  
[Visual core descriptions](#) · [Thin sections](#)

**Site C0017**  
[Visual core descriptions](#)



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# 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 alteration logs in Microsoft Excel format; Formation Microscanner images in .JPG and .TIF formats; scanning electron microscope images and accompanying files in .IMG, .EDS, .ASW, .INI, .ICO, .BMP, .JPG, and .TIF formats; and smear slide data in Adobe PDF format. 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/](http://gmt.soest.hawaii.edu/)).

[IODP Expedition 331 site map](#)

[IODP map](#) (Expeditions 301–327 and 331)

[ODP map](#) (Legs 100–210)

[DSDP map](#) (Legs 1–96)



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# Expedition-related bibliography

## IODP publications

### *Scientific Prospectus*

Takai, K., Mottl, M.J., and Nielsen, S., 2010. Deep hot biosphere. *IODP Sci. Prosp.*, 331. [doi:10.2204/iodp.sp.331.2010](https://doi.org/10.2204/iodp.sp.331.2010)

### *Preliminary Report*

Expedition 331 Scientists, 2010. Deep hot biosphere. *IODP Prel. Rept.*, 331. [doi:10.2204/iodp.pr.331.2010](https://doi.org/10.2204/iodp.pr.331.2010)

### *Scientific Drilling journal\**

Pending

### *Proceedings volume*

Takai, K., Mottl, M.J., Nielsen, S.H., and the Expedition 331 Scientists, *Proc. IODP*, 331: Tokyo (Integrated Ocean Drilling Program Management International, Inc.). [doi:10.2204/iodp.proc.331.2011](https://doi.org/10.2204/iodp.proc.331.2011)

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## Syntheses\*

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# Directory structure\*

<b>331.PDF</b> (Preliminary pages and table of contents)			
<b>README.TXT</b> (Information about the Expedition Reports DVD-ROM)			
<b>ACROREAD</b> (Acrobat Reader installation software and instructions for different platforms)	<b>MAC_OS</b>		
	<b>WINDOWS</b>		
	<b>UNIX</b>		
	<b>README.TXT</b>		
<b>EXP_REPT</b> (Expedition Reports section of <i>Proc. IODP, 331</i> )	<b>CHAPTERS</b> (Expedition Reports chapters)	<b>331_101.PDF</b> (Expedition 331 summary)	
		<b>331_102.PDF</b> (Methods)	
		<b>331_103.PDF</b> (Site C0013)	
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		<b>331_106.PDF</b> (Site C0016)	
		<b>331_107.PDF</b> (Site C0017)	
	<b>CORES</b> (Visual core descriptions, thin sections, and digital core images)	<b>CORC0013.PDF</b> (Site C0013)	
		<b>CORC0014.PDF</b> (Site C0014)	
		<b>CORC0015.PDF</b> (Site C0015)	
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		<b>CORC0017.PDF</b> (Site C0017)	
	<b>IMAGES</b> (PDF files of core images)		
	<b>OVERSIZE</b> (Large-format files of data tables)	<b>331_103</b> (Site C0013 file)	
		<b>331_104</b> (Site C0014 file)	
		<b>331_107</b> (Site C0017 file)	
	<b>SUPP_MAT</b> (Supplementary material)	<b>ALTMIN</b> (Alteration logs)	<b>C0013ALTMIN.XLSX</b> (Site C0013 log)
			<b>C0014ALTMIN.XLSX</b> (Site C0014 log)
<b>C0015ALTMIN.XLSX</b> (Site C0015 log)			
<b>C0016ALTMIN.XLSX</b> (Site C0016 log)			
<b>C0017ALTMIN.XLSX</b> (Site C0017 log)			
<b>FM_IMAGE</b> (Formation Microscanner images)		<b>C0013D-1H-1 3MBSF.JPG</b> (Hole C0013D image)	
		<b>C0014B-2H-10 14MBSF.JPG</b> (Hole C0014B image)	
		<b>C0014E-1H-6 22 MBSF.JPG</b> (Hole C0014E image)	
		<b>C0015B-1H-1 0.3MBSF.JPG</b> (Hole C0015B image)	
		<b>C0017A-1H-1 0.65MBSF.JPG</b> (Hole C0017A image)	
		<b>C0017C-1H-5 25MBSF.TIF</b> (Hole C0017C image)	
		<b>C0017C-1H-7 27MBSF.TIF</b> (Hole C0017C image)	
<b>SEM_IMAGE</b> (Scanning electron microscope images and accompanying files)		<b>C0013</b> (Site C0013 files)	
		<b>C0014</b> (Site C0014 files)	
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<b>SMEARSLD</b> (Smear slide data)		<b>TSSS_DESCRIP.PDF</b> (Smear slide file)	
<b>README.TXT</b>			
<b>MAPS</b> (Drilling location maps)		<b>331_MAP.PDF</b> (Expedition 331 site map)	
		<b>IODPMAP.PDF</b> (IODP map, Expeditions 301–327 and 331)	
	<b>ODPMAP.PDF</b> (ODP map, Legs 100–210)		
	<b>DSDPMAP.PDF</b> (DSDP map, Legs 1–96)		

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