Boron isotopes in foraminifera from sediment cores and 2 pH scenarios from the R/V JOIDES Resolution cruises in Shatsky Rise (Pacific), Walvis Ridge (South Atlantic), atolls and guyots (OA Paleocene-Eocene project)

Website: https://www.bco-dmo.org/dataset/560566
Data Type: Cruise Results
Version: 1
Version Date: 2015-06-19

Project
» Establishing The Magnitude Of Sea-Surface Acidification During The Paleocene-Eocene Thermal Maximum (OA_Paleocene-Eocene)

Programs
» International Ocean Discovery Program (IODP)
» Science, Engineering and Education for Sustainability NSF-Wide Investment (SEES): Ocean Acidification (formerly CRI-OA) (SEES-OA)

Contributors	Affiliation	Role
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Abstract
Isotope data for delta-11B from late Paleocene-early Eocene planktonic foraminifera. The taxa analyzed include Morozovella velascoensis, Acarinina soldadoensis, and Subbotinae.

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Coverage

Spatial Extent: **N**:37.78 **E**:162.75 **S**:31.58 **W**:157.48
Temporal Extent: 2001-08-27 - 2001-10-23

Dataset Description

Isotope data for delta-11B from late Paleocene-early Eocene planktonic foraminifera. The taxa analyzed include Morozovella velascoensis, Acarinina soldadoensis, and Subbotinae.

These data were published in Penman, D. E., B. Hönisch, R. E. Zeebe, E. Thomas, and J. C. Zachos (2014), Rapid and sustained surface ocean acidification during the Paleocene-Eocene Thermal Maximum, Paleoceanography, 29, 357-369, doi:10.1002/2014PA002621.

Methods & Sampling

Samples were collected during Ocean Drilling Program (ODP) Leg 198, three holes were drilled at Site 1209 (Shatsky Rise, N. Pacific 32°39.1081'N, 158°30.3564'E) at a water depth of 2387 m [Bralower et al., 2002], equivalent to a paleodepth during the PETM of ~ 1900 m [Takeda and Kaiho, 2007].

Sediment samples, collected at 1-3 cm resolution across a 2m interval spanning the carbon isotope excursion (CIE), were washed and sieved, and specimens of the mixed-layer dwelling planktic species *Morozovella velascoensis* and *Acarinina soldadoensis* were picked from the 250-300 and 300-425 µm size fraction. On the basis of shell size-d13C relations, these species likely harbored photosynthetic algal symbionts and were thus restricted to the photic zone of the surface ocean [D'Hondt et al., 1994]. Additionally, specimens of the smooth-walled, thermocline-dwelling genus *Subbotina* were picked from the 250-300 µm size fraction. Isotopic depth ranking suggests that this taxon was nonsymbiotic and occupied the thermocline [Berggren and Norris, 1997]. Boron isotope analyses at Site 1209 were restricted to *M. velascoensis* and complemented by low-resolution d11B analyses of the same taxon from Sites 1263 (Walvis Ridge, Southeast Atlantic, 28°31.98'S, 02°46.77'E, 2717 m depth; paleodepth ~1500 m; [Zachos et al., 2004]) and 865 (Allison Guyot, Equatorial Pacific, 18°26.41'N, 179°22.24'W, 1518 m depth; paleodepth ~ 1400 m; [Bralower et al., 1995]) to evaluate whether the Site 1209 record is representative of a global signal or compromised by local or preservational effects.

Trace element data are generated from a Finnegan Element XR Inductively Coupled Plasma Mass Spectrometer monitoring masses 11B, 24Mg, 43Ca, 55Mn (to detect contamination from Fe, Mn oxides), and 238U. Inter- and intra- run variability will be assessed utilizing both a solid foraminiferal standard (mixture of crushed foraminifera that will be cleaned as samples) and a liquid consistency standard of similar composition as the dissolved foraminifera. The solid foraminiferal consistency standard composed of crushed and homogenized Globigerinoides sacculifer from core top KNR 110 2-58 STN40-2 (without final sac; B/Ca = 92 +- 8 µmol/mol). 13C and 18O data from the dual Inlet gas source mass spectrometer systems at the University of California Santa Cruz – Stable Isotope Laboratory are measured against reference gases which have been calibrated relative to international reference materials (NBS-19, NBS-18) obtained from the National Institute of Standards and Technology (NIST) and the International Atomic Energy Agency (IAEA) to ensure accurate measurement and reporting of isotope ratios for the selected samples. These same international standards are analyzed on a daily basis, typically at the start and finish of each analytical round. In addition, internal laboratory standards are analyzed at a much greater frequency during each analytical round to assess data quality during the course of each analytical round. The analytical error on standards measured during the course of analyses conducted for this project will be monitored and reported for each analytical round.

Boron isotope data will be generated from a Thermo TRITON Thermal Ionization Mass Spectrometer at LDEO and from Thermo NEPTUNE multi-collector inductively coupled mass spectrometers at UC Santa Cruz and LDEO. Sample preparation for all analyses will be done in a boron filtered ultraclean environment, to avoid laboratory contamination. The international boric acid standard NBS 951 obtained from NIST is routinely measured on the TIMS with each sample wheel and shows no long-term drift for this method. MC-ICP-MS analyses are subject to daily drift and standard bracketing with NBS 951 will be applied to monitor and correct for drift. Additional routine in-house standards include NBS 951 precipitated in a CaCO3 matrix and seawater. For MC-ICP-MS analyses a natural carbonate from the Geological Survey of Japan (GSJ) geochemical reference sample collection will be used as an additional standard to monitor B purification consistency. Despite standardization to the same boric acid standard, absolute 11B values by TIMS are often higher than those measured by MC-ICP-MS. However, Fig. 4 and an international laboratory intercomparison study (Foster, Hönisch et al., in prep.) confirm that the TPI 7220824 relative difference in foraminiferal and coral 11B over the same pH-difference (determined from laboratory cultures and glacial/interglacial sediment samples) is the same for both methods, thus allowing for sound comparison of data from both methods, as long as method-specific calibrations are applied. 11B of the foraminifer species used in this study can thus be calibrated with Paleocene (pre-CIE) samples using both techniques, and the same slope and inflection point of the delta-11B/pH relationship (Fig. 4) will then be applied to estimate the pH-change during and after the PETM relative to the Paleocene baseline.

c) Organization and progression of trace metal and isotope analysis
- Analysis of B/Ca, Mg/Ca, Mn/Ca and U/Ca will take place at the UCSC Marine Analytical Laboratory.

- Analysis of delta-13C and delta-18O will take place at the UCSC-SIL.
- Analysis of delta-11B will take place at the LDEO.

Relevant References:

Berggren, W. A., and R. D. Norris (1997), Biostratigraphy, phylogeny and systematics of Paleocene trochospiral planktic foraminifera, Micropaleontol, 43, 1-116.

Bralower, T. J., et al. (2002), Proceedings of the Ocean Drilling Program, Initial Reports, Ocean Drilling Program, College Station, Tex.

D'Hondt, S., J. C. Zachos, and G. Schultz (1994), Stable isotopic signals and photosymbiosis in Late Paleocene planktic foraminifera, Paleobiology, 20(3), 391-406.

Takeda, K., and K. Kaiho (2007), Faunal turnovers in central Pacific benthic foraminifera during the Paleocene-Eocene Thermal Maximum, Palaeogeogr. Palaeoclimatol. Palaeoecol., 251(2), 175-197.

Zachos, J. C., et al. (2004), Proceedings of the Ocean Drilling Program, Initial Reports, Ocean Drilling Program, College Station, Tex.

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Data Files

File
PETM_foram_geochem.csv (Comma Separated Values (.csv), 4.07 KB) MD5:0f3b6be78cdb54b3fd80710b4b131577 Primary data file for dataset ID 560566

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Parameters

Parameter	Description	Units
cruise_id	cruise identification	unitless
sample	sample identification	unitless
time_CIE	time since Carbon Isotope Excursion	thousands of years
time_interval	time interval of sample: Recovery/CIE/Pre-PETM (baseline conditions before onset of the Paleocene-Eocene Thermal Maximum)	unitless
size_class	size class of sieved sediment sample	micrometers
d11B	Boron isotopic composition	parts per thousand (per mil)
d11B_2std_err	2x standard error of delta Boron11	parts per thousand (per mil)

count	number of samples	each
temp	temperature	degrees Celsius
sal	salinity	parts per thousand
pK_B_70m	dissociation constant of boric acid at depth=70m	unitless
alpha	fractionation factor between borate and boric acid	unitless
epsilon	fractionation between borate and boric acid	permil
pH_780	calculated pH assuming initial pH=7.8	unitless; pH scale
pH_780_plus_stderr	calculated pH assuming initial pH=7.8 plus one standard error	unitless; pH scale
pH_780_minus_stderr	calculated pH assuming initial pH=7.8 minus one standard error	unitless; pH scale
pH_767	calculated pH assuming initial pH=7.67	unitless; pH scale
pH_767_plus_stderr	calculated pH assuming initial pH=7.67 plus one standard error	unitless; pH scale
pH_767_minus_stderr	calculated pH assuming initial pH=7.67 minus one standard error	unitless; pH scale

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Instruments

Dataset-specific Instrument Name	
Generic Instrument Name	Inductively Coupled Plasma Mass Spectrometer
Generic Instrument Description	An ICP Mass Spec is an instrument that passes nebulized samples into an inductively-coupled gas plasma (8-10000 K) where they are atomized and ionized. Ions of specific mass-to-charge ratios are quantified in a quadrupole mass spectrometer.

Dataset-specific Instrument Name	Mass Spec
Generic Instrument Name	Mass Spectrometer
Dataset-specific Description	Dual Inlet gas source mass spectrometer systems located at the University of California Santa Cruz – Stable Isotope Laboratory.
Generic Instrument Description	General term for instruments used to measure the mass-to-charge ratio of ions; generally used to find the composition of a sample by generating a mass spectrum representing the masses of sample components.

Dataset-specific Instrument Name	TI Mass Spec
Generic Instrument Name	Thermal Ionization Mass Spectrometer
Dataset-specific Description	Thermo TRITON Thermal Ionization Mass Spectrometer at LDEO
Generic Instrument Description	A Thermal Ionization Mass Spectrometer (TIMS) is an instrument that measures isotopic ratios after electrical excitation of a sample causes ionization of the isotopes.

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Deployments

JRES-198

Website	https://www.bco-dmo.org/deployment/521576
Platform	R/V JOIDES Resolution
Report	http://dmoserv3.whoi.edu/data_docs/OA_Paleocene-Eocene/Bralower_etal_2002_ODP_leg198_01_report.PDF
Start Date	2001-08-27
End Date	2001-10-23
Description	Cruise objective: To address the long-term climatic transition into and out of "greenhouse" climate and abrupt climatic events; to characterize changes in surface and deep waters, including vertical gradients of temperature, oxygenation, and corrosiveness. Drilling: In general, JOIDES resolution data can be found at the ODP/IODP data site hosted at TAMU: http://www-odp.tamu.edu/database/ **Methods & Sampling** 32° 39'N, 158° 30'E, North Pacific Start site:09/18/01 0800 End site: 09/23/01 0430 Time on site: 4:20:31

JRES-208

Website	https://www.bco-dmo.org/deployment/560597
Platform	R/V JOIDES Resolution
Start Date	2003-03-06
End Date	2003-05-06
Description	Cruise objective: Provide a detailed history of paleoceanographic variations and characterization of depth-dependent changes in deepwater chemistry and circulation associated with episodes of early Cenozoic climate change including EECO, PETM, and EOGM. Drilling : In general, JOIDES resolution data can be found at the ODP/IODP data site hosted at TAMU: http://www-odp.tamu.edu/database/

JRES-143

Website	https://www.bco-dmo.org/deployment/560731
Platform	R/V JOIDES Resolution
Start Date	1992-03-18
End Date	1992-05-19
Description	Cruise objective: To address a number of problems concerning guyot development including: timing and causes of platform drowning, timing and amplitude of sea level changes, and seamount latitude changes. Drilling: In general, JOIDES resolution data can be found at the ODP/IODP data site hosted at TAMU: http://www-odp.tamu.edu/database/

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Project Information

Establishing The Magnitude Of Sea-Surface Acidification During The Paleocene-Eocene Thermal Maximum (OA_Paleocene-Eocene)

Coverage: global

Extracted from the NSF award abstract:

At projected rates of anthropogenic carbon emissions, the pH of the surface ocean is expected to decline by 0.3 pH units by the end of this century, and 0.7 pH units by 2300. The only other time the ocean might have experienced a similar change in pH in the past is during the Paleocene-Eocene Thermal Maximum (PETM; 56 Mya) as a consequence of a massive carbon release, which also warmed the planet. The mass of carbon released is estimated to have been as large as that projected for the future but over thousands of years rather than centuries, thus allowing for greater buffering of the saturation state of the surface ocean. Nonetheless, planktonic calcifiers and coral reefs both experienced significant reductions in diversity, likely in response to a combination of factors, including pH and carbonate saturation state. Efforts to quantify changes in carbonate chemistry, however, have relied on indirect methods, that is with numerical models of the carbon cycle constrained by observations of changes in ocean carbonate chemistry such as carbon isotopes and the distribution of carbonate sediments. In computing the mass and rate of carbon release, the models also simulate changes in ocean pH and saturation state. While the range of model estimates continues to narrow, testing has been limited by the lack of more direct information on ocean carbonate chemistry, specifically changes in the pH and/or carbonate ion concentration.

To address this deficiency, a team of scientists from the University of California at Santa Cruz, the Lamont-Doherty Earth Observatory of Columbia University, and the University of Hawaii are conducting a 3-year study to quantify changes in the sea-surface carbonate chemistry during the PETM. The project will focus on the application of two boron-based proxies, B/Ca and B isotopes as recorded in planktonic foraminifera, to quantify pH and possibly carbonate ion concentration. The team will develop detailed proxy records for a number of globally distributed locations, with the goal of establishing regional anomalies in surface ocean carbonate

chemistry relative to longer-term trends. The data will be interpreted with numerical models utilizing information from laboratory-based calibration studies of modern foraminifera, and compared with plankton assemblage records. The results will also provide an independent means of testing model simulations of the rate and duration of carbon release, and ultimately the rise in atmospheric CO2.

Data from this project are published in:

Penman, D. E., B. Honisch, R. E. Zeebe, E. Thomas, J. C. Zachos. Rapid and sustained surface ocean acidification during the Paleocene-Eocene Thermal Maximum. Paleoceanography Volume 29(5),357–369, 2014. DOI: 10.1002/2014PA002621

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Program Information

International Ocean Discovery Program (IODP)

Website: http://www.iodp.org/index.php

Coverage: Global

The International Ocean Discovery Program (IODP) is an international marine research collaboration that explores Earth's history and dynamics using ocean-going research platforms to recover data recorded in seafloor sediments and rocks and to monitor subseafloor environments. IODP depends on facilities funded by three platform providers with financial contributions from five additional partner agencies. Together, these entities represent 26 nations whose scientists are selected to staff IODP research expeditions conducted throughout the world's oceans.

IODP expeditions are developed from hypothesis-driven science proposals aligned with the program's science plan *Illuminating Earth's Past, Present, and Future*. The science plan identifies 14 challenge questions in the four areas of climate change, deep life, planetary dynamics, and geohazards.

IODP's three platform providers include:

- The U.S. National Science Foundation (NSF)
- Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT)
- The European Consortium for Ocean Research Drilling (ECORD)

More information on IODP, including the Science Plan and Policies/Procedures, can be found on their website at http://www.iodp.org/program-documents.

Science, Engineering and Education for Sustainability NSF-Wide Investment (SEES): Ocean Acidification (formerly CRI-OA) (SEES-OA)

Website: https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503477

Coverage: global

NSF Climate Research Investment (CRI) activities that were initiated in 2010 are now included under Science, Engineering and Education for Sustainability NSF-Wide Investment (SEES). SEES is a portfolio of activities that highlights NSF's unique role in helping society address the challenge(s) of achieving sustainability. Detailed information about the SEES program is available from NSF (https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504707).

In recognition of the need for basic research concerning the nature, extent and impact of ocean acidification

on oceanic environments in the past, present and future, the goal of the SEES: OA program is to understand (a) the chemistry and physical chemistry of ocean acidification; (b) how ocean acidification interacts with processes at the organismal level; and (c) how the earth system history informs our understanding of the effects of ocean acidification on the present day and future ocean.

Solicitations issued under this program:
NSF 10-530, FY 2010-FY2011
NSF 12-500, FY 2012
NSF 12-600, FY 2013
NSF 13-586, FY 2014
NSF 13-586 was the final solicitation that will be released for this program.

PI Meetings:
1st U.S. Ocean Acidification PI Meeting(March 22-24, 2011, Woods Hole, MA)
2nd U.S. Ocean Acidification PI Meeting(Sept. 18-20, 2013, Washington, DC)
3rd U.S. Ocean Acidification PI Meeting (June 9-11, 2015, Woods Hole, MA – Tentative)

NSF media releases for the Ocean Acidification Program:

Press Release 10-186 NSF Awards Grants to Study Effects of Ocean Acidification

Discovery Blue Mussels "Hang On" Along Rocky Shores: For How Long?

Discovery nsf.gov - National Science Foundation (NSF) Discoveries - Trouble in Paradise: Ocean Acidification This Way Comes - US National Science Foundation (NSF)

Press Release 12-179 nsf.gov - National Science Foundation (NSF) News - Ocean Acidification: Finding New Answers Through National Science Foundation Research Grants - US National Science Foundation (NSF)

Press Release 13-102 World Oceans Month Brings Mixed News for Oysters

Press Release 13-108 nsf.gov - National Science Foundation (NSF) News - Natural Underwater Springs Show How Coral Reefs Respond to Ocean Acidification - US National Science Foundation (NSF)

Press Release 13-148 Ocean acidification: Making new discoveries through National Science Foundation research grants

Press Release 13-148 - Video nsf.gov - News - Video - NSF Ocean Sciences Division Director David Conover answers questions about ocean acidification. - US National Science Foundation (NSF)

Press Release 14-010 nsf.gov - National Science Foundation (NSF) News - Palau's coral reefs surprisingly resistant to ocean acidification - US National Science Foundation (NSF)

Press Release 14-116 nsf.gov - National Science Foundation (NSF) News - Ocean Acidification: NSF awards $11.4 million in new grants to study effects on marine ecosystems - US National Science Foundation (NSF)

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1220554

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