Stable carbon isotopic composition of organic matter from seafloor basalts incubated with labeled bicarbonate from R/V Atlantis AT15-51, R/V Kilo Moana KM0923, and Maria S. Merian MSM20-5 cruises

Website: https://www.bco-dmo.org/dataset/660792
Data Type: Cruise Results
Version: 05 October 2016
Version Date: 2016-10-05

Project
» Primary productivity in young, oxic oceanic crust: rates of activity and autotrophic groups in subsurface and seafloor-exposed basalts from North Pond, Mid-Atlantic Ridge (Basalt carbon fixation)

Programs
» Center for Dark Energy Biosphere Investigations (C-DEBI)
» International Ocean Discovery Program (IODP)

Contributors	Affiliation	Role
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Dataset Description

Stable carbon isotopic composition of organic matter from seafloor basalts incubated with labeled bicarbonate from samples collected from the Juan de Fuca Ridge, Loihi Seamount, and North Pond.

Methods & Sampling

Acquisition methods are described in the following publication:
Orcutt, B.N., Sylvan, J.B., Rogers, D.R., Delaney, J., Lee, R.W., & Girguis, P.R. 2015. Carbon fixation by basalt-hosted microbial communities. Front. Microbiol. doi:10.3389/fmicb.2015.00904

In summary (excerpted from above):
Basalt samples used in this study were collected from three different crustal formation areas. One glassy, seafloor-exposed basalt came from the ASHES vent field in the Axial Seamount volcano caldera on the Juan de Fuca Ridge off the western coast of North America. The sample was collected in 2009 with the Alvin submersible during dive AD-4527 on RV Atlantis cruise AT15-51 (Sample JdF2009). The basalt piece had a thick (up to 1 cm depth) glassy rim overlying moderately to sparsely vesicular cryptocrystalline groundmass. A film of iron oxide discoloration was evident in the contact between the glass and groundmass. Two altered, seafloor-exposed basalts were collected from the Loihi Seamount off the coast of the big island of Hawai'i in October 2009 by ROV Jason-II during R/V Kilo Moana cruise KM0923: one from "Marker 2" in Pele's Pit on the

summit of the Loihi Seamount, and one from the Ula Nui vent field at the base of the Loihi Seamount. Sample Ula Nui, collected on dive J2-477, was glassy, highly vesicular, and friable, contained ~3 mm olivine phenocrysts, and displayed visible iron oxide staining. Sample Marker 2, collected on dive J2-481 from an area away from diffuse venting, was pillow basalt with an altered rind Finally, two seafloor-exposed rocks were collected from outcrops surrounding North Pond in April 2012 by ROV Jason-II on dives J2-626 and J2-627 during the MSM20-5 cruise on the R/V Maria S. Merian. The J2-626-R1 rock was a breccia of mm- to cm-sized clasts of aphanitic basalt in a greenish-gray matrix, while the J2-627-R3 rock was a highly serpentinized harzburgite (25–30% orthopyroxene surrounded by completely serpentinized olivine and with chrysotile-filled veins.

Upon retrieval of the samples, all seafloor-exposed rocks and surrounding water from the plastic sampling containers were immediately transferred to glass jars and placed at 4 degrees C until processing. Basalts were then transferred to ethanol- and flame-sterilized steel processing trays and subsampled with ethanol- and flame-sterilized chisels and tweezers. The experiments utilized the glassy rims of the basalts, which were removed, broken into smaller pieces (<1 cm diameter) and transferred to sterile glass serum vials (30–100 ml volume, depending on experiment) containing 0.2-mm-mesh filter-sterilized oxic bottom seawater. All samples were maintained at 4 degrees C.

Basalt fragments (5–20 cm3) were transferred to sterile and baked glass serum vials (to remove organics, vials had been heated to 500 degrees C for 2 h), which were filled to overflowing with sterile oxic seawater then sealed with autoclaved butyl rubber septa and aluminum crimp seals. Multiple replicate bottles were prepared for each sample to enable as many time series as possible with the limited sample volume, including a no-tracer-addition control.

Time series samples were injected with a small volume of 0.2-um filter-sterilized 13C-bicarbonate-labeled solution (in sterile filtered seawater) to achieve the following starting concentrations: JdF2009 incubations received a final concentration of 0.75 mM 13C-labeled bicarbonate against a background of seawater bicarbonate (~2 mM, or, 27% 13C label); the Ula Nui and Marker 2 rock incubations received a final concentration of 2.7 mM 13C-labeled bicarbonate in background bottom seawater (57% 13C label); and the seafloor-exposed North Pond basalt incubations contained a final concentration of 4.5 mM 13C-labeled bicarbonate in surface seawater (69% 13C label). Vials were incubated in the dark at 4 degrees C until sampling. At each time point, the vials were opened and rock fragments were transferred to sterile plastic centrifuge tubes and frozen for shore-based DNA and organic carbon extraction and analysis. For the JdF2009, Marker 2, and Ula Nui samples, time series were stopped after 1 h, 1 day, and 1 week of incubation. The North Pond samples were incubated for 2-weeks, 2-months, and 4-months intervals. Final concentrations of dissolved inorganic carbon were not measured, as rates of carbon consumption were presumed to be significantly slow compared to the bulk pool size.

The carbon content and stable carbon isotopic composition of biofilms on the incubated basalts were determined by IRMS analysis of subsamples of the basalts that had been stored frozen. Samples were analyzed using a Costech elemental analyzer in line with a Micromass Isoprime continuous flow stable isotope mass spectrometer. Results are presented in the standard δ notation, where isotopic ratios (R) are expressed in per mil (‰) differences relative to the conventional standard, the PeeDee Belemnite limestone. Although the instrument precision was established as 0.3‰, rates of change were conservatively assumed to be robust if there was more than a 2‰ difference between samples; values less than 2‰ difference are reported as below the detection limit (BDL).

Data Processing Description

BCO-DMO Processing:
- Added the following columns from information Orcutt et al. (2015) paper: cruise, dive, date, water_depth, depth_mbsf, lat, lon;
- replaced "b.d.l." with "BDL" (below detection limit), "n.a." with "na", "n.d." and blanks with "nd" (no data);
- replaced spaces with underscores in sample names.

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Data Files

File
stable_C_isotopes_basalt.csv (Comma Separated Values (.csv), 4.51 KB) MD5:1576c2bbc42917772828f57d219066cb Primary data file for dataset ID 660792

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Parameters

Parameter	Description	Units
incubation_sample	Name of sample set	unitless
cruise	Cruise identifier	unitless
dive	Dive identifier (A = HOV Alvin; J = ROV Jason)	unitless
date	Date of sample collection in yyyy-mm-dd format	unitless
water_depth	Depth of water	meters (m)
depth_mbsf	Depth of sample	meters below seafloor (mbsf)
lat	Latitude	decimal degrees
lon	Longitude	decimal degrees
incubation_time	Time of incubation	hours
org_C_wt	Weight percent of organic carbon in a sample	percent (%)
del13C	Stable carbon isotopic composition of basalt organic matter after incubation	per mil
ratio_13C_to_12C	Absolute ratio of carbon-13 to carbon-12 of basalt organic matter after incubation	unitless
d13C_to_12C	Change in ratio of carbon-13 to carbon-12 ration over incubation	unitless
d13C_per_rock	Change in nanograms (ng) of carbon-13 in organic matter per gram (g) of rock during experiment	ng 13C / g rock
d13C_per_rock_per_day	Change in nanomoles (nm) of carbon in organic matter per gram (g) rock per day	nmol C / rock / day

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Instruments

Dataset-specific Instrument Name	Costech elemental analyzer
Generic Instrument Name	Elemental Analyzer
Dataset-specific Description	Dried samples of basalt (20–70 mg) were placed into tin foil capsules for isotopic analysis of 13C/12C ratios. Samples were analyzed using a Costech elemental analyzer in line with a Micromass Isoprime continuous flow stable isotope mass spectrometer.
Generic Instrument Description	Instruments that quantify carbon, nitrogen and sometimes other elements by combusting the sample at very high temperature and assaying the resulting gaseous oxides. Usually used for samples including organic material.

Dataset-specific Instrument Name	Micromass Isoprime continuous flow stable isotope mass spectrometer
Generic Instrument Name	Isotope-ratio Mass Spectrometer
Dataset-specific Description	Dried samples of basalt (20–70 mg) were placed into tin foil capsules for isotopic analysis of 13C/12C ratios. Samples were analyzed using a Costech elemental analyzer in line with a Micromass Isoprime continuous flow stable isotope mass spectrometer.
Generic Instrument Description	The Isotope-ratio Mass Spectrometer is a particular type of mass spectrometer used to measure the relative abundance of isotopes in a given sample (e.g. VG Prism II Isotope Ratio Mass-Spectrometer).

Dataset-specific Instrument Name	ROV Jason
Generic Instrument Name	ROV Jason
Generic Instrument Description	The Remotely Operated Vehicle (ROV) Jason is operated by the Deep Submergence Laboratory (DSL) at Woods Hole Oceanographic Institution (WHOI). WHOI engineers and scientists designed and built the ROV Jason to give scientists access to the seafloor that didn't require them leaving the deck of the ship. Jason is a two-body ROV system. A 10-kilometer (6-mile) fiber-optic cable delivers electrical power and commands from the ship through Medea and down to Jason, which then returns data and live video imagery. Medea serves as a shock absorber, buffering Jason from the movements of the ship, while providing lighting and a bird's eye view of the ROV during seafloor operations. During each dive (deployment of the ROV), Jason pilots and scientists work from a control room on the ship to monitor Jason's instruments and video while maneuvering the vehicle and optionally performing a variety of sampling activities. Jason is equipped with sonar imagers, water samplers, video and still cameras, and lighting gear. Jason's manipulator arms collect samples of rock, sediment, or marine life and place them in the vehicle's basket or on "elevator" platforms that float heavier loads to the surface. More information is available from the operator site at URL.

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Deployments

AT15-51

Website	https://www.bco-dmo.org/deployment/660521
Platform	R/V Atlantis
Start Date	2009-08-20
End Date	2009-09-06

KM0923

Website	https://www.bco-dmo.org/deployment/660561
Platform	R/V Kilo Moana
Start Date	2009-10-01
End Date	2009-10-17

MSM20-5

Website	https://www.bco-dmo.org/deployment/555399
Platform	R/V Maria S. Merian
Report	http://dmoserv3.whoi.edu/data_docs/Huber/Fahrtbericht_MSM20_5_02.pdf
Start Date	2012-04-11
End Date	2012-05-10

AT15-51_Alvin_Dives

Website	https://www.bco-dmo.org/deployment/660901
Platform	Alvin
Start Date	2009-08-20
End Date	2009-09-06

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Project Information

Primary productivity in young, oxic oceanic crust: rates of activity and autotrophic groups in subsurface and seafloor-exposed basalts from North Pond, Mid-Atlantic Ridge (Basalt carbon fixation)

Coverage: Seafloor basalts from Juan de Fuca Ridge, Mid-Atlantic Ridge flank 22N, and Loihi Seamount

Project description obtained from C-DEBI:
We conducted stable carbon isotope incubations with four subsurface rocks and two seafloor-exposed rocks collected from the North Pond major program site during IODP Expedition 336 in 2011 and the MSM20-5 cruise in 2012, respectively. In combination with similar experiments done with basalts from the Loihi Seamount and the Juan de Fuca Ridge, our experiments document the potential for carbon fixation by basalt biofilm communities, providing the first empirical assessment of potential rates for this process. When scaled to the global production of oceanic crust, our results suggest carbon fixation rates that match earlier predictions based on thermodynamic calculations. Functional gene analyses indicate that the Calvin cycle is likely the dominant biochemical mechanism for carbon fixation in basalt-hosted biofilms. These results provide empirical evidence for autotrophy in oceanic crust, suggesting that basalt-hosted autotrophy could be a significant contributor of organic matter in this vast, dark environment.

Related Publications:
Orcutt, B.N., Sylvan, J.B., Rogers, D.R., Delaney, J., Lee, R.W. Girguis, P.R. 2015. Carbon fixation by basalt-hosted microbial communities. Frontiers in Microbiology, 6: 904.C-DEBI Contribution 277. doi:10.3389/fmicb.2015.00904

Note: This project was funded by a C-DEBI Research Grant.

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Program Information

Center for Dark Energy Biosphere Investigations (C-DEBI)

Website: http://www.darkenergybiosphere.org

Coverage: Global

The mission of the Center for Dark Energy Biosphere Investigations (C-DEBI) is to explore life beneath the seafloor and make transformative discoveries that advance science, benefit society, and inspire people of all ages and origins.

C-DEBI provides a framework for a large, multi-disciplinary group of scientists to pursue fundamental questions about life deep in the sub-surface environment of Earth. The fundamental science questions of C-DEBI involve exploration and discovery, uncovering the processes that constrain the sub-surface biosphere below the oceans, and implications to the Earth system. What type of life exists in this deep biosphere, how much, and how is it distributed and dispersed? What are the physical-chemical conditions that promote or limit life? What are the important oxidation-reduction processes and are they unique or important to humankind? How does this biosphere influence global energy and material cycles, particularly the carbon cycle? Finally, can we discern how such life evolved in geological settings beneath the ocean floor, and how this might relate to ideas about the origin of life on our planet?

C-DEBI's scientific goals are pursued with a combination of approaches:
(1) coordinate, integrate, support, and extend the research associated with four major programs—Juan de Fuca Ridge flank (JdF), South Pacific Gyre (SPG), North Pond (NP), and Dorado Outcrop (DO)—and other field sites;
(2) make substantial investments of resources to support field, laboratory, analytical, and modeling studies of the deep subseafloor ecosystems;
(3) facilitate and encourage synthesis and thematic understanding of submarine microbiological processes, through funding of scientific and technical activities, coordination and hosting of meetings and workshops, and support of (mostly junior) researchers and graduate students; and
(4) entrain, educate, inspire, and mentor an interdisciplinary community of researchers and educators, with an emphasis on undergraduate and graduate students and early-career scientists.

Note: Katrina Edwards was a former PI of C-DEBI; James Cowen is a former co-PI.

Data Management:
C-DEBI is committed to ensuring all the data generated are publically available and deposited in a data repository for long-term storage as stated in their Data Management Plan (PDF) and in compliance with the NSF Ocean Sciences Sample and Data Policy. The data types and products resulting from C-DEBI-supported research include a wide variety of geophysical, geological, geochemical, and biological information, in addition to education and outreach materials, technical documents, and samples. All data and information generated by C-DEBI-supported research projects are required to be made publically available either following publication of research results or within two (2) years of data generation.

To ensure preservation and dissemination of the diverse data-types generated, C-DEBI researchers are working with BCO-DMO Data Managers make data publicly available online. The partnership with BCO-DMO helps ensure that the C-DEBI data are discoverable and available for reuse. Some C-DEBI data is better served by specialized repositories (NCBI's GenBank for sequence data, for example) and, in those cases, BCO-DMO provides dataset documentation (metadata) that includes links to those external repositories.

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.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-0939564

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