Radiochemistry data for fluids sampled from the Lost City Hydrothermal Field at the Atlantis Massif in 2018

Website: https://www.bco-dmo.org/dataset/864434
Data Type: Cruise Results
Version: 1
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Project
» Collaborative Research: Investigating the Lost City as an ultramafic urban center of the subseafloor, fueled by energy and carbon from the mantle (Lost City Limits to Life)

Contributors	Affiliation	Role
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Abstract

This dataset includes radiochemistry data for fluids from 7 vent sites (Marker 2, Beehive, Marker 8, Marker 3, Calypso, Marker C. and Sombrero) at the Lost City Hydrothermal Field at the Atlantis Massif (30N, Mid-Atlantic Ridge). Fluid samples were collected in September 2018 during the AT42-01 expedition of the R/V Atlantis with the remotely operated vehicle (ROV) Jason II.

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Coverage

Spatial Extent: **N**:30.12435475 **E**:-42.11929812 **S**:30.1237 **W**:-42.1206786
Temporal Extent: 2018-09-16 - 2018-09-21

Methods & Sampling

Fluid samples were collected in September 2018 during the AT42-01 expedition of the R/V *Atlantis* with the remotely operated vehicle (ROV) *Jason II* using the Hydrothermal Organic Geochemistry (HOG) sampler that shunts fluid from a titanium intake into pre-cleaned Kynar® bags (Lang and Benitez-Nelson, 2021). Fluid samples were collected into either 2-liter (L) or 11-liter (L) kynar bags that were acid washed (10% HCl soak overnight, followed by thorough rinsing, overnight Milli-Q soak, and further rinsing).

As an initial exploratory test, two fluid aliquots (0.500 L each) from Marker C (J2-1110-LV16) and Sombrero (J2-1111-LV16) were processed at sea before freezing. Radium in the fluid (Raw) was directly co-precipitated with 5 milliliters (mL) of 1M barium nitrate and 25 mL of saturated sodium sulfate, which quantitatively removes radium with the barium sulfate (BaSO4) precipitate from seawater (van der Loeff and Moore, 1999). Although the samples were not filtered, no significant particles were observed prior to precipitation. The BaSO4 precipitates were stored and measured onshore multiple times by gamma-ray spectrometry beginning two weeks later.

On shore, six additional vent fluid samples (0.100 to 0.500 L) were selected for analysis: a duplicate sample from Sombrero (J2-1111-LV16) and single samples from Marker 2 (J2-1107-Chem7), Beehive (J2-1108-Chem3), Marker 8 (J2-1110-Chem5), Marker 3 (J2-1111-Chem4), and Calypso (J2-1108-Chem7). The frozen samples were thawed and the liquid was transferred to a beaker. In some cases, particles that settled quickly were observed in the bottom of the beaker. These particles were not quantified or analyzed. After decanting, the liquid volume was measured and the samples were pH-adjusted to ~7 with 1N HCl as necessary. These six samples were slowly filtered (< 1 L min-1) by gravity through a column containing 15 g of manganese dioxide-coated acrylic fiber (Mn-fiber), which preferentially removes radium, thorium, and actinium from the fluid (Moore 1976, 2008). The efficiency of removal was evaluated by passing each filtrate through a second column of new Mn-fiber.

The two exploratory fluid samples processed at sea were measured in the lab by gamma spectrometry. The activity (decays per minute or dpm) of 223Ra from the sample from Marker C was identified based on characteristic 223Ra and progeny gamma peaks at 144, 155, 269, 271, and 402 keV (Firestone, 1999). This sample was recounted four times over the next 60 days to confirm the presence of dissolved 223Ra (223Raw) based on its 11.4 day half-life. Each measurement agreed within 5% of the others when corrected for 223Ra decay. Final 223Ra activity of this sample is based on the mean of five decay-corrected measurements (16 to 60 days since collection) of the combined 269+271 keV peaks; the error of the measurement is the standard deviation of these measurements. The five counting periods fit an exponential curve (activity versus time) with a half-life of 11.5 days. The exploratory sample from Sombrero was recounted one time. The 223Raw is based on the decay-corrected first measurement; the error is based on the net number of counts recorded in the 269+271 keV peak. The gamma detector was calibrated using a 227Ac standard precipitated with BaSO4 prepared from a solution described by Le Roy et al. (2019). There was no measurable peak at 238 keV where the 228Th - 224Ra couple has a characteristic gamma peak. Because 223Ra has daughters that produce gamma rays in the 351 keV region, where normally 214Pb is measured as a 226Ra proxy, samples were aged for more than three months until all 223Ra had decayed before remeasurement for 226Ra. Measurements made after three months had no activity in the 269+271 keV region, meaning 227Ac (half-life = 21.7 y), the grandparent of 223Ra, was below detection in the two exploratory samples.

The 223Raw activities of six additional samples were determined using a Radium Delayed Coincidence Counter System (RaDeCC system; Moore and Arnold, 1996). This system identifies 224Ra (half-life = 3.66 d) and 223Ra based on the coincidence timing of their decay products. The 223Ra efficiency was determined by the procedure of Moore and Cai (2013) and was verified using a 227Ac standard described by Le Roy et al. (2019). After extraction of the radium, the Mn-fibers were rinsed with de-ionized water and dried with compressed air to achieve an approximate 1:1 fiber to moisture weight ratio. The six fluid samples were counted within a month of collection. Only 223Ra was determined due to 224Ra decay prior to analysis. Most samples were recounted for 900 to 1200 minutes two to four times over the next two weeks to follow the characteristic 223Ra decay. For samples measured multiple times, the decay-corrected mean of these measurements was taken as the final activity; the error of the measurement was taken as the standard deviation of the multiple decay-corrected measurements. One sample recorded zero counts for 223Ra during a 1200-minute period. The 223Ra for this sample is therefore considered to be below the detection limit (bdl). None of the reprocessed samples contained more than 2% of the activity of the initial column, indicating the first extraction was close to 100%. After these initial counts, the Mn-fiber samples were stored for five months to allow all initial 223Ra to decay and were then measured again to determine 227Ac and 228Th (Shaw and Moore, 2002).

After RaDeCC analysis was completed, Ra was leached from the Mn-fiber with a solution of 1N hydroxylamine hydrochloride and 1N hydrochloric acid (van der Loeff and Moore, 1999). Radium was co-precipitated with BaSO4 as described for the initial fluid samples and measured by gamma ray spectrometry (Moore, 1984) to quantify long-lived Ra isotopes, similar to the process followed for the exploratory fluid samples. The low activities required five to eight-day counts. We only used the 351 keV peak to calculate 226Ra. No peaks above background appeared in the 228Ra, 228Th, or 227Ac regions of the spectra. The gamma detector was calibrated with NIST standard solutions for 226Ra and 228Ra in a BaSO4 matrix.

Data Processing Description

Data Processing:
HYPERMET software (Phillips and Marlow, 1976) was used in data processing.

Errors are expressed as 1σ. Some samples were likely contaminated by particles (denoted using an asterisk (*)), others were based on very few net counts (Measured_227Ac_water and Measured_228Thw). Some sample measurements were below detection level (denoted by "bdl").

BCO-DMO Processing:
- Adjusted field/parameter names to comply with BCO-DMO naming conventions;
- Missing data identifier "--" replaced with "nd" (BCO-DMO's default missing data identifier);
- Created separate columns for the error values associated with "Measured_223Ra_water" and "Measured_226Ra_water";
- Added a conventional header with dataset name, PI names, version date.

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Data Files

File
Lost_City_Fluids_Radium.csv(Comma Separated Values (.csv), 1.29 KB) MD5:ecbae8dd99c64e2f76dd094091c65098 Primary data file for dataset ID 864434

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Related Publications

Firestone, R.B., Shirley, V.S., Baglin, C.M., Chu, S.Y.F., & Zipkin, J. Revay, Zs. (Ed.). (1997). The 8th edition of the Table of Isotopes. Hungary: Springer.
Methods

Lang, S. Q., & Benitez-Nelson, B. (2021). Hydrothermal Organic Geochemistry (HOG) sampler for deployment on deep-sea submersibles. Deep Sea Research Part I: Oceanographic Research Papers, 173, 103529. doi:10.1016/j.dsr.2021.103529
Methods

Le Roy, E., Sanial, V., Lacan, F., van Beek, P., Souhaut, M., Charette, M. A., & Henderson, P. B. (2019). Insight into the measurement of dissolved 227Ac in seawater using radium delayed coincidence counter. Marine Chemistry, 212, 64–73. doi:10.1016/j.marchem.2019.04.002
Methods

Moore, W. S. (1976). Sampling 228Ra in the deep ocean. Deep Sea Research and Oceanographic Abstracts, 23(7), 647–651. doi:10.1016/0011-7471(76)90007-3
Methods

Moore, W. S. (1984). Radium isotope measurements using germanium detectors. Nuclear Instruments and Methods in Physics Research, 223(2-3), 407–411. doi:10.1016/0167-5087(84)90683-5
Methods

Moore, W. S. (2008). Fifteen years experience in measuring 224Ra and 223Ra by delayed-coincidence counting. Marine Chemistry, 109(3-4), 188–197. doi:10.1016/j.marchem.2007.06.015
Methods

Moore, W. S., & Arnold, R. (1996). Measurement of 223Ra and224Ra in coastal waters using a delayed coincidence counter. Journal of Geophysical Research: Oceans, 101(C1), 1321–1329. doi:10.1029/95jc03139 https://doi.org/10.1029/95JC03139
Methods

Moore, W. S., & Cai, P. (2013). Calibration of RaDeCC systems for 223Ra measurements. Marine Chemistry, 156, 130–137. doi:10.1016/j.marchem.2013.03.002
Methods

Moore, W. S., Frankle, J. D., Benitez-Nelson, C. R., Früh-Green, G. L., & Lang, S. Q. (2021). Activities of 223-Ra and 226-Ra in Fluids From the Lost City Hydrothermal Field Require Short Fluid Residence Times. Journal of Geophysical Research: Oceans, 126(12). Portico. https://doi.org/10.1029/2021jc017886 https://doi.org/10.1029/2021JC017886
Results

Phillips, G. W., & Marlow, K. W. (1976). Automatic analysis of gamma-ray spectra from germanium detectors. Nuclear Instruments and Methods, 137(3), 525–536. doi:10.1016/0029-554x(76)90472-9 https://doi.org/10.1016/0029-554X(76)90472-9
Methods

Shaw, T. J., & Moore, W. S. (2002). Analysis of 227Ac in seawater by delayed coincidence counting. Marine Chemistry, 78(4), 197–203. doi:10.1016/s0304-4203(02)00022-1 https://doi.org/10.1016/S0304-4203(02)00022-1
Methods

Van der Loeff, M. M. R., & Moore, W. S. (n.d.). Determination of natural radioactive tracers. Methods of Seawater Analysis, 365–397. doi:10.1002/9783527613984.ch13
Methods

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Parameters

Parameter	**Description**	**Units**
Sample_Name	sample name	unitless
Vent	vent site	unitless
ISO_DateTime_UTC	Date and time of sample in format: YYYY-MM-DD	unitless
Latitude	latitude North	decimal degrees
Longitude	longitude East (West is Negative)	decimal degrees
Depth	water depth	meters
Average_T	Average temperature while sample was collected	degrees celcius
Highest_T	Highest recorded temperature while sample was collected	degrees celcius
pH_25_degreesC	pH as determined shipboard, at 25C, atmospheric pressure	unitless
Magnesium	concentration of magnesium ion in fluids	mmol per liter

Measured_223Ra_water	Measured Radium-223 activity in the fluids	decays per minute per liter
Measured_223Ra_water_err	standard error	units
Measured_226Ra_water	Measured Radium-226 activity in the fluids	decays per minute per liter
Measured_226Ra_water_err	standard error	units
Measured_227Ac_water	Measured Actinium-227 activity in the fluids	decays per minute per liter
Measured_228Thw	Measured Thorium-228 activity in the fluids	decays per minute per liter
Endmember_223Ra_water	Calculated activity of Radium-223 in pure endmember hydrothermal fluid	decays per minute per liter
Endmember_226Ra_water	Calculated activity of Radium-226 in pure endmember hydrothermal fluid	decays per minute per liter
Activity_ratio_223Ra_226Ra_water	Activity ratio of 223Radium / 226 Radium in fluids	unitless

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Instruments

Dataset-specific Instrument Name	Gamma Spectrometer, ORTEC
Generic Instrument Name	Gamma Ray Spectrometer
Generic Instrument Description	Instruments measuring the relative levels of electromagnetic radiation of different wavelengths in the gamma-ray waveband.

Dataset-specific Instrument Name	Radium Delayed Coincidence Counter System (RaDeCC system)
Generic Instrument Name	Radium Delayed Coincidence Counter
Dataset-specific Description	Moore and Arnold, 1996
Generic Instrument Description	The RaDeCC is an alpha scintillation counter that distinguishes decay events of short-lived radium daughter products based on their contrasting half-lives. This system was pioneered by Giffin et al. (1963) and adapted for radium measurements by Moore and Arnold (1996). References: Giffin, C., A. Kaufman, W.S. Broecker (1963). Delayed coincidence counter for the assay of actinon and thoron. J. Geophys. Res., 68, pp. 1749-1757. Moore, W.S., R. Arnold (1996). Measurement of 223Ra and 224Ra in coastal waters using a delayed coincidence counter. J. Geophys. Res., 101 (1996), pp. 1321-1329. Charette, Matthew A.; Dulaiova, Henrieta; Gonneea, Meagan E.; Henderson, Paul B.; Moore, Willard S.; Scholten, Jan C.; Pham, M. K. (2012). GEOTRACES radium isotopes interlaboratory comparison experiment. Limnology and Oceanography - Methods, vol 10, pg 451.

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Deployments

AT42-01

Website	https://www.bco-dmo.org/deployment/782074
Platform	R/V Atlantis
Report	https://datadocs.bco-dmo.org/docs/Lost_City_Limits_to_Life/data_docs/AT42-01_Cruise%20Report_reduced.pdf
Start Date	2018-09-08
End Date	2018-10-01

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Project Information

Collaborative Research: Investigating the Lost City as an ultramafic urban center of the subseafloor, fueled by energy and carbon from the mantle (Lost City Limits to Life)

Coverage: Lost City Hydrothermal Field

NSF Award Abstract:
The vast majority of deep seafloor sediments are inhabited by microbial communities that survive under extreme energy limitation, with apparent generation times of centuries to millennia. Hydrothermal systems are a stark contrast to these energy-starved environments and may represent important, high-activity, 'population centers' in the oceanic subsurface. When rocks from the Earth's mantle are uplifted and exposed to water, the resulting reactions lead to acidic fluids with high concentrations of hydrogen. Under certain circumstances, small organic molecules such as methane can also form in the absence of biology. These compounds can provide energy to subseafloor microbial communities and, given the ubiquity of mantle rocks, such reactions may fuel a significant proportion of the active subsurface biosphere. The current project will characterize the

microbial communities inhabiting an iconic example of this type of system, the Lost City Hydrothermal Field, using a remotely operated vehicle. The ghostly spires of Lost City are highly telegenic and have been featured in professional documentaries. The high definition underwater video footage collected during the expedition will provide the raw material for an 8 week educational training program in digital media focused on kindergarten through 12th grade high school students and undergraduate students. The resulting short documentaries will be published on YouTube and the Utah Education Network.

Mantle rocks comprise significant portions of the seafloor, and microbial communities hosted within them may be important mediators of carbon and energy exchange between the deep Earth and the surface biosphere. Upon tectonic uplift and exposure to water, the serpentinization of these materials releases potential energy in the form of hydrogen, methane, and heat, and further reaction of these products can sustain the abiogenic synthesis of small organic molecules. Recent studies have highlighted, however, the lack of alkalithermophiles that are capable of survival at the high pH (9-11) and elevated temperatures found in these systems. The almost complete lack of carbon dioxide (CO2) represents a second, and possibly more significant, limitation to growth. To better understand the extent of the serpentinite subsurface, this project will address the question: What limits biological activity in the serpentinite subsurface? Specifically, the proposed work will test the hypotheses: (1) microbial diversity spans a wider range of temperature-pH conditions than currently recognized and (2) the scarcity of CO2 is a key biological limitation to serpentinization-driven ecosystems that can be overcome by the metabolic activity of one or a few foundation species. These hypotheses will be tested during a 20 day (10 days on site) expedition to the Lost City Hydrothermal Field, focusing on fluids as windows to the subsurface biosphere. The sampling approach will capitalize on the differences in temperature, carbon availability, and microbial activity across the field. The analytical approach will integrate multidisciplinary techniques performed on replicate subsamples and feature the application of next-generation sequencing technologies to these marine serpentinizing fluids for the first time. This study will generate extensive sequence data from environmental DNA, environmental mRNA, and single-cell genomes, allowing us to identify the in situ expression of metabolic pathways and the genomics of active single cells. These efforts will be closely linked with a thorough characterization of carbon in these fluids that will focus on identifying available substrates (e.g. methane, CO2, organic acids) and on characterizing biomarkers that reflect specific metabolic pathways (e.g. lipids, amino acids).

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1536702
NSF Division of Ocean Sciences (NSF OCE)	OCE-1736321

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