

Max K. Lloyd

Department of Geosciences
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EDUCATION

- PhD Geochemistry, California Inst. of Technology, December 2017
Clumped and intramolecular isotopic perspectives on the behavior of organic and inorganic carbon in the shallow crust and deep biosphere.
Adv: John Eiler
- BA Geology, Amherst College, *summa cum laude*, 2012
Evaluating the regional extent, timing, and conditions of paleoproterozoic metamorphism in southwestern Montana.
Adv: Jack Cheney

PROFESSIONAL EXPERIENCE

- 2020 - Assistant Research Professor, Penn State
2018 - 2020 Agouron Geobiology Postdoctoral Fellow, UC Berkeley
2018 Postdoctoral Scholar, UC Berkeley
2012 - 2017 Research Assistant, California Inst. of Technology
2011 - 2012 Undergraduate Research Assistant, Amherst College
2011, summer Summer Student Fellow, Woods Hole Oceanographic Inst.
2009 - 2010 Undergraduate Research Assistant, Stanford University

PUBLICATIONS IN REVIEW OR IN PREP

2. **Lloyd, M.K.**, Ibarra, D.E., Pester, N.J., Seyfried, W.E., Chamberlain, C.P., Stolper, D.A. Triple oxygen isotope composition of the Oman ophiolite and modern hydrothermal fluids: implications for the oxygen isotope balance of the ocean. In review at *Geochimica et Cosmochimica Acta*.
1. **Lloyd, M.K.**, Stein, R.E., Ibarra, D.E., Barclay, R.S., Wing, S.L., Stahle, D.W., Dawson, T.E., Stolper, D.E. Global gradients in plant photorespiration rate from isotopic compositions of wood methoxyl groups. In prep for *Proceedings of the National Academy of Sciences*.

REFEREED PUBLICATIONS

18. Stolper, D.A., Pu, X., **Lloyd, M.K.**, Christensen, N.I., Bucholz, C.E., Lange, R.A., 2022. Constraints on Early Paleozoic Deep-Ocean Oxygen Concentrations From the Iron Geochemistry of the Bay of Islands Ophiolite. *Geochemistry, Geophysics, Geosystems*, 23, e2021GC010196.
17. Ibarra, D.E., Yanchilina, A.G., **Lloyd, M.K.**, Methner, K.A., Chamberlain, C.P., Yam, R., Shemesh, A., Stolper, D.A, *in press*, 2022. Triple Oxygen Isotope Systematics of Diagenetic Recrystallization of Diatom Opal-A to Opal-CT to Microquartz in Deep Sea Sediments. *Geochimica et Cosmochimica Acta*, 320, 304-323.
16. **Lloyd, M. K.**, Trembath-Reichert, E., Dawson, K.S., Feakins, S.J., Mastalerz, M., Orphan, V.O., Sessions, A.L., Eiler, J.M., 2021. Methoxyl Stable Isotopic Constraints on the Origins and Limits of Coal-Bed Methane. *Science* 374, no. 6569, 894–97.
15. Ryb, U, **Lloyd, M.K.**, Eiler, J.M, 2021. Carbonate Clumped Isotope Constraints on Burial, Uplift and Exhumation Histories of the Colorado Plateau. *Earth and Planetary Science Letters* 566, 116964.

14. **Lloyd, M.K.**, Eldridge, D.L., Stolper, D.A., 2021. Clumped $^{13}\text{CH}_2\text{D}$ and $^{12}\text{CHD}_2$ compositions of methyl groups from wood and synthetic monomers: methods, experimental and theoretical calibrations, and initial results. *Geochimica et Cosmochimica Acta* vol. 297, 233–275.
13. **Lloyd, M.K.**, McClelland, H.L.O., Antler, G., Bradley, A.S., Halevy, I., Junium, C.K., Wankel, S.D., Zerkle, A.L., 2020. The isotopic imprint of life on an evolving planet. *Space Science Reviews* vol. 216, 112.
12. Chamberlain, C.P., Ibarra, D.E., **Lloyd, M.K.**, Kukla, T., Sjostrom, D., Gao, Y., Sharp, Z.D., 2020. Triple oxygen isotopes of meteoric hydrothermal systems: implications for palaeoaltimetry. *Geochemical Perspectives Letters* 15, 6–9.
11. Chang, B., Li, C., Liu, D., Foster, I., Tripathi, A., **Lloyd, M.K.**, Maradiaga, I., Luo, G., An, Z., She, Z., Xie, S., Tong, J., Huang, J., Algeo, T.J., Lyons, T.W., Immenhauser, A., 2020. Massive formation of early diagenetic dolomite in the Ediacaran ocean: Constraints on the $\delta^{13}\text{C}$ dolomite problem. *PNAS* 117, 14005–14014.
10. Greule, M., Moossen, H., **Lloyd, M.K.**, Geilmann, H., Brand, W.A., Eiler, J.M., Qi, H., Keppler, F., 2020. Three wood isotopic reference materials for $\delta^2\text{H}$ and $\delta^{13}\text{C}$ measurements of plant methoxy groups. *Chemical Geology* 533, 119428.
9. Douglas, P.M.J., Moguel, R.G., Anthony, K.M.W., Wik, M., Crill, P.M., Dawson, K.S., Smith, D.A., Yanay, E., **Lloyd, M.K.**, Stolper, D.A., Eiler, J.M., Sessions, A.L., 2020. Clumped Isotopes Link Older Carbon Substrates With Slower Rates of Methanogenesis in Northern Lakes. *Geophysical Research Letters* 47, e2019GL086756.
8. Eldridge, D.L., Korol, R., **Lloyd, M.K.**, Turner, A.C., Webb, M.A., Miller, T.F., Stolper, D.A., 2019. Comparison of Experimental vs Theoretical Abundances of $^{13}\text{CH}_3\text{D}$ and $^{12}\text{CH}_2\text{D}_2$ for Isotopically Equilibrated Systems from 1 to 500 °C. *ACS Earth Space Chem.* 3, 2747–2764.
7. Xie, H., Ponton, C., Formolo, M.J., Lawson, M., Peterson, B.K., **Lloyd, M.K.**, Sessions, A.L., Eiler, J.M., 2018. Position-specific hydrogen isotope equilibrium in propane. *Geochimica et Cosmochimica Acta* 238, 193–207.
6. **Lloyd, M.K.**, Ryb, U., Eiler, J.M., 2018. Experimental calibration of clumped isotope reordering in dolomite. *Geochimica et Cosmochimica Acta* 242, 1–20.
5. Ryb, U., **Lloyd, M.K.**, Stolper, D.A., Eiler, J.M., 2017. The clumped-isotope geochemistry of exhumed marbles from Naxos, Greece. *Earth and Planetary Science Letters* 470, 1–12.
4. **Lloyd, M.K.**, Eiler, J.M., Nabelek, P.I., 2017. Clumped isotope thermometry of calcite and dolomite in a contact metamorphic environment. *Geochimica et Cosmochimica Acta* 197, 323–344.
3. Eiler, J.M., Clog, M., Lawson, M., **Lloyd, M.**, Piasecki, A., Ponton, C., Xie, H., 2017. The isotopic structures of geological organic compounds. *Geological Society, London, Special Publications* 468, 53–81.
2. Eiler, J., Cesar, J., Chimiak, L., Dallas, B., Grice, K., Griep-Raming, J., Juchelka, D., Kitchen, N., **Lloyd, M.**, Makarov, A., Robins, R., Schwieters, J., 2017. Analysis of molecular isotopic structures at high precision and accuracy by Orbitrap mass spectrometry. *International Journal of Mass Spectrometry* 422, 126–142.
1. Sousa, F.J., Saleeby, J., Farley, K.A., Unruh, J.R., **Lloyd, M.K.**, 2016. The southern Sierra Nevada pediment, central California. *Geosphere* GES01369.1.

**SEMINARS AND
SELECTED
CONFERENCE
ACTIVITY
(*INVITED)**

***Lloyd, M.K.**, Stein, R.E., Ibarra, D.E., Barclay, R.S., Wing, S.L., Stahle, D.W., Dawson, T.E., Stolper, D.E. 2022. Plant photorespiration reconstructed with isotopic clumping in wood methoxyl groups. Goldschmidt 2022 Session 11d: Organic geochemical tools for understanding climatic, chemical, and biological processes.

***Lloyd, M.K.**, 2022. Ophiolites, hydrothermal vents, and the triple oxygen isotope balance of Earth's oceans. Penn State Geosciences Geochemistry Seminar, March 2022

***Lloyd, M.K.**, 2021. Feedbacks between land plants and atmospheric pCO₂ revealed by clumped isotopes in modern and fossil wood. Penn State Geosciences Department Seminar, October 2021

***Lloyd, M.K.**, 2020. Isotopic evidence for pervasive methylotrophy in coals. Gordon Research Conference, Deep Carbon Section (Cancelled due to COVID-19).

Lloyd, M.K., 2019. Terrestrial climate records from clumped isotope compositions of wood methoxyl groups. Oral presentation at AGU Fall Meeting 2019, San Francisco, CA.

Lloyd, M.K., Ibarra, D.E., Chamberlain, C.P., Pester, N.J., Seyfried, W.E., 2019. Triple oxygen isotopes of fluids and solids from hydrothermal systems. Poster presentation at Goldschmidt 2019, Barcelona, Spain.

***Lloyd, M.K.**, 2019. The behavior of carbonates during burial diagenesis: Insights from a compilation of 1,500 clumped isotope compositions. International Clumped Isotope Workshop, Long Beach, CA.

***Lloyd, M.K.**, 2018. Clumped and position-specific isotopes and the global carbon cycle. International Space Science Institute Workshop, Bern, Switzerland.

***Lloyd, M.K.**, 2018. The C1 carbon cycle: Tracking the production and destruction of lignin methoxy groups with site-specific isotope analyses. Gordon Research Conference, Organic Geochemistry - August 2018.

***Lloyd, M.K.**, Dawson, K., Douglas, P.M.J., Eiler, J.M., 2018. How reversible is methylotrophic methanogenesis? Towards an isotopologue-specific understanding of methane metabolisms. Oral presentation at Goldschmidt 2018, Boston, MA.

***Lloyd, M.K.**, 2018. Intramolecular isotopic perspectives on the terrestrial carbon cycle from lignin methoxyl groups. CU Boulder Geobiology Seminar - February 2018.

Lloyd, M.K., Akker, V., Herwegh, M., and Eiler, J.M. (2017). Steady growth or fits and starts: observing the style of and controls on carbonate recrystallization in an Alpine fold and thrust belt. Oral presentation at AGU 2017, New Orleans, LA.

***Lloyd, M.K.**, 2017. Quantifying shallow crustal tectonic processes with clumped isotope thermometry. USC Lithospheric Dynamics Seminar - November 2017.

Lloyd, M., Trembath-Reichert, E., Feakins, S.J., Schimmelmann, A., Mastalerz, M., Sessions, A.L., and Eiler, J.M., (2017). Observing the biodegradation of complex organic substrates by site-specific isotopic analyses. Oral presentation at Goldschmidt 2017, Paris, France.

***Lloyd, M.**, 2017. The formation and degradation of organic polymers recorded by the 'clumped' isotopic compositions of methoxy groups. Princeton U. Geochemistry Seminar - February 2017.

***Lloyd, M.**, 2017. Transformations of carbonate + organic carbon in the shallow crust and deep biosphere recorded by multiply-substituted isotopologues. UC Berkeley Geochemistry Seminar - February 2017.

***Lloyd, M.**, 2017. Transformations of carbon(ate) in shallow crustal processes recorded by multiply-substituted isotopologues. Texas A&M Geochemistry Seminar - February 2017.

Lloyd, M., Feakins, S., Sessions, A., Schimmelman, A., and Eiler, J. (2016), Determination of clumped ¹³C-²H compositions of methoxyl groups in wood, lignin, and simple organic monomers. Poster presentation at 2016 Gordon Organic Geochemistry conference, Holderness, NH.

Lloyd, M. Eiler, J., and Nabelek, P. (2015), The clumped isotope geochemistry of dolomite and calcite in contact metamorphic environments. Oral presentation at Goldschmidt 2015, Prague, CZ.

Lloyd, M. and Eiler, J. (2014), Laboratory and natural constraints on the temperature

limit for preservation of the dolomite clumped isotope thermometer. Poster presentation at AGU Fall Meeting 2014, San Francisco, CA, 15-19 Dec.

Lloyd, M., Eiler, J., and Nabelek, P. (2014), Carbonate clumped isotope thermometry of the Notch Peak contact metamorphic aureole. Poster presentation at Goldschmidt 2014, Sacramento, CA.

Lloyd, M., Cheney, J., Harms, T., (2012), Evaluating the timing, conditions, and regional extent of paleoproterozoic metamorphism in southwestern Montana. Poster presentation at 2012 GSA Northeastern Section Meeting, Hartford, CT, 18-20 Mar.

Lloyd, M., Shimizu, N., Wang, Z., and Zheng., Y., (2011), Constraining cooling rates of UHP metamorphic rocks with closure temperature geospeedometry: a case study from the Dabie orogen. Oral presentation at 2011 AGU Fall Meeting, San Francisco, CA, 5-9 Dec.

FELLOWSHIPS AND GRANTS

ACS Petroleum Research Fund	2021–2023
“Experimental and environmental investigation of coal demethylation using position-specific isotope analyses” [\$110,000]	
Agouon Institute Postdoctoral Fellowship, UC Berkeley	2018–2020
“Development and application of a terrestrial thermometer for ancient greenhouse climates” [\$142,000]	
Walter F. Pond Prize, Amherst College Geology Department	2012
<i>For most distinguished senior honors thesis</i> [\$2,000]	
Summer Student Fellowship, Woods Hole Oceanographic Institute	2011
<i>Full support for a summer working in the ion microprobe lab at WHOI</i> [\$7,700]	
Richard M. Foose Award (2011), Amherst College Geology Department	2011
<i>Awarded in support of summer field research</i> [\$3,000]	

TEACHING EXPERIENCE

Courses taught:	
Chemical Processes in Geology (Geosc 202, 4 credits) Instructor	Fall 2022
Geoscience Data Analytics (Geosc 210, 3 credits) Co-Instructor	Fall 2022
Isotopes in Earth History (Geosc 497, 1 credits) Co-Instructor	Fall 2022
Isotope Biogeochemistry (Geosc 518b, 2 credits) Co-Instructor	Fall 2022
Earth’s Geochemical Cycles (Geosc 497, 3 credits) Instructor	Spring 2022
Chemical Processes in Geology (Geosc 202, 4 credits) Co-Instructor	Fall 2021
Geoscience Data Analytics (Geosc 210, 3 credits) Co-Instructor	Fall 2021
Earth’s Geochemical Cycles (Geosc 497, 3 credits) Instructor	Spring 2021

Compilation of Student Evaluations:

Semester	Course	Enrollment	Respondent Rate	Course Quality (Mode/Median) X out of 7	Instructor Quality (Mode/Median) X out of 7
Fall 2021	GEOSC 202	20	30%	7/7	7/7
Fall 2021	GEOSC 210	15	33%	7/7	multimodal/7
Spring 2022	GEOSC 497	7	71%	7/7	7/7

New courses developed at Penn State:

Earth's Geochemical Cycles (Geosc 497, 3 credits, sole developer)
 Geoscience Data Analytics (Geosc 210, 3 credits, co-developer)
 Isotopes in Earth History (Geosc 497, 1 credit, co-developer)
 Isotope Biogeochemistry (Geosc 518b, 2 credits, co-developer)
 Isotope Analytical Developments (Geosc 518d, 2 credits, co-developer)

Other teaching experience

Co-Teacher, ESPM-C225: Isotopics, UC Berkeley, 2019
 Teaching Assistant, Agouron International Geobiology Course, 2017
 Teaching Assistant, California Inst. of Technology, 2012-2017

- Courses: Metamorphic Petrology, Igneous Petrology, Radiogenic Isotope Geochemistry, Organic Geochemistry

Undergraduate Teaching Assistant, Amherst College, 2009-2012

- Courses: Introduction to Geology, Mineralogy, Metamorphic Petrology

MENTORSHIP

Graduate advisor:

Eric Hasegawa (PSU PhD '26; Co-advised with K. Freeman)
 Paul Volante (PSU MS '23; Co-advised with K. Freeman)

Committee member:

Youki Sato (PSU PhD '25)
 Ran He (PSU PhD '26)
 Emma Hartke (PSU MS '22)
 Kaitlin Taylor (PSU MS '22)

Undergraduate senior thesis mentor:

Austin Hull (PSU BS '23)
 Sarah Davis (PSU BS '23)
 Madalyn Reed (PSU BS '23)

Undergraduate research mentor:

Zoe Zenker, PSU, 2022–
 Korbinian Thalhammer, UC Berkeley, 2018–2020. Now PhD student at Caltech.
 Iure Teixeira, Caltech, 2015. Now PhD candidate at University of Sao Paolo
 Youry Aglyamov, Caltech, 2014. Now PhD candidate at Cornell.

SERVICE AND OUTREACH

Peer review of manuscripts:

Geochimica et Cosmochimica Acta (11); Journal of Geophysical Research: Solid Earth (2); Nature Geoscience (3); Nature Communications (2); Chemical Geology (2); Basin Research (2); Organic Geochemistry (1); Earth and Planetary Science Letters (1); Paleoceanography and Paleoclimatology (1); Journal of the Geological Society of London (1); Frontiers in Microbiology (1);

Peer review of proposals:

NASA Exobiology: Panelist (2021-2022) and External reviewer (2020)
NSF Low-Temperature Geochemistry: External reviewer (2020)

Session convener:

Goldschmidt 2022, 6b: Technological and methodological advances in isotope geochemistry
Goldschmidt 2018, 03g: Building the crust top to bottom: Linking thermal, chemical, and deformational histories with petrochronology, thermochronology, and novel low-T techniques

University service:

Non-Tenure Line Faculty Advisory Committee, College of Earth and Mineral Sciences: Secretary, 2021-2022; Member, 2020
Graduate Admissions Committee, Dept. of Geosciences: Member, 2020-2022

Other synergistic activities:

Lead author and editor of an online, open-access course on measuring (via Orbitrap-MS) and predicting isotopologue distributions in organic and inorganic molecules (in production)

PROFESSIONAL ACTIVITY **Reading Terrestrial Planet Evolution in Isotopes and Elements: Workshop** – International Space Science Institute, Bern, Switzerland, October 2018

International Clumped Isotope Workshop – IPGP, France, August 2017

Principles of Teaching and Learning in STEM – Caltech, California, Sept-Dec. 2015
Comprehensive course on the design and effective implementation of modern principles of STEM education in university-level courses.

Data Carpentry Workshop – Caltech, California, June 2015

Thermodynamic Modeling in Theriak Domino – UMass Amherst, January 2012

Professional affiliations: AGU, Geochemical Society, EAG

TECHNICAL EXPERIENCE

Gas-source IRMS: Comprehensive experience in the setup, maintenance, and operation of Nier-type electron-impact isotope ratio mass spectrometers (e.g., Thermo MAT 253, 253 Plus, Delta V). Uniquely proficient in the development, application, and interpretation of novel measurements of position-specific and multiply-substituted ('clumped') isotope compositions of unconventional analytes on next-generation ultra-high resolution mass spectrometers (e.g., Thermo MAT 253 Ultra, DFS, and Q Exactive Orbitrap).

GC-MS/GC-IRMS: Extensive experience in the maintenance and operation of gas chromatography systems for MS and IRMS applications. Especially skilled in the construction of new chromatographic systems and the development of new analytical procedures for unusual target molecules.

Numerical modeling: Proficient in the design and implementation of numerical finite-difference models for a variety of geochemical applications (e.g., heat flow, diffusion, isotopic exchange kinetics) in Scientific Python and Matlab.

Computation-intensive data analysis & database management: Extensive experience developing command-line and GUI-based software for the robust, streamlined extraction, computation, and analysis of complex isotope ratio mass spectrometry data in Python (some modules available at github.com/maxmansaxman).

Additional analytical & computational experience: SIMS, ICP-MS, EA-IRMS, TC/EA-IRMS, SEM, EMPA, XRD; ArcMap, Bash, R, HeFTy, Qtqt, Theriak-Domino