Tristan Caro | Curriculum Vitae

Contact

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Research Interests

Key terms: stable isotope probing, multi-omics, microscale chemical imaging.

Measuring the speed of life: applying stable isotope probing methodologies *in situ* to quantitatively describe microbial activity in response to local geochemistry; expertise in single-cell isotopic analyses of C, H, and O isotope ratios to sensitively measure microbial anabolic rates in natural systems; particularly experienced in rock-hosted groundwater, permafrost, and soil; use of mass spectrometry tools (GC-MS, GC-P-IRMS, nanoSIMS) to quantify microbial activity and lipid biomarkers, use of metagenomics (Illumina, ONT) and metabolomics to describe microbial communities and processes, use of microspectroscopy tools (Raman, XRF, XANES) to identify and characterize mineralogical and organic biomarkers in environmental samples.

The intersection of the microbiome and global change: applying studies of microbial habitability and activity to quantify microbial contributions to biogeochemical cycling, with specific focuses on carbon, methane, and OM.

Education

2024 **Ph.D. in Geology**
University of Colorado, Boulder

2024 **Ph.D. Certificate in Interdisciplinary Quantitative Biology**
University of Colorado, Boulder

2018 **B.A. in Molecular & Cell Biology**
University of California, Berkeley

Research

2024 – current **Foster & Coco Stanback Postdoctoral Fellow**
California Institute of Technology
Investigating soil microbiome responses to hydroclimate volatility with SIP-enabled multi-omics
Advisors: Alex Sessions, Smruthi Karthikeyan

2019 – 2024 **Graduate Researcher**
University of Colorado, Boulder
Thesis: *From soil to subsurface: microbial growth under energy limitation*
Advisors: Alexis Templeton, Sebastian Kopf

2017 – 2019 **Research Technician**
University of California, Berkeley
Microbial succession in Bradford Pear phyllosphere during fire-blight infection
Advisor: Britt Koskella

2018 **Research Associate (Summer Intern)**
NASA Ames Synthetic Biology Lab
Developing the M. extorquens modular cloning system for astronaut use on ISS
Advisor: Jonathan Galazka

2017 **Research Associate (Summer Intern)**
NASA Ames Aerobiology Lab
Preparing S. cerevisiae for Artemis I mission with polar stratospheric ballooning
Advisors: David J. Smith, Sergio Santa-Maria

Publications

*Lead or co-lead author

Submitted

***Caro TA**, Kashyap S, Maloney AE, Hoyt DW, Hoehler T, Templeton AS. Massive variation in microbial carbon assimilation and energy flux in actively serpentinizing rocks. (In Review. Pre-print available upon request).

***Caro TA**, Maloney AE, McFarlin JM, Jech SD, Barker A, Douglas T, Barbato R, Kopf SH. Microbial resuscitation and growth rates in deep permafrost: lipidomic stable isotope probing results from the permafrost research tunnel in Fox, Alaska. (In Review. Pre-print available at https://www.biorxiv.org/content/10.1101/2025.01.20.633952v1).

Des Marais DJ, **Caro TA**, Dhingra R, Fox AC, Galloway T, Mackey TJ, Osterhout J, Pasterki MJ, Theiling BP. Stable isotope abundance patterns as potential biosignatures. Astrobiology. (Accepted, *Astrobiology*, Pre-print available upon request).

In Prep

***Caro TA**, Kashyap S, Ellison ET, Kainz, S, Templeton AS. Organic and mineral sulfidization in actively serpentinizing rocks revealed by x-ray absorption spectroscopy. (In prep, draft).

Kashyap S, **Caro TA**, Templeton AS. Microbial growth rates captured using Raman-SIP reveal a highly active and productive subsurface biosphere fueled by serpentinization. (In prep, draft).

Rozmiarek KS, Schambach J, Bennet H, Yang J, Ricken B, Mays WD, **Caro TA,** Jones T, Smallwood CR. Soil incubations linking volatilomics to microbiomes reveals temperature dependent methanogen shifts in methane hotspot soils. (In prep, draft).

Published

***Caro TA**, Kashyap S, Brown G, Chen C, Kopf SH, Templeton AS. Single-cell measurement of microbial growth rate with Raman microspectroscopy. FEMS Microbiology Ecology. 2024 Sep 1;100(9):fiae110.

Foley MM, Stone BWG, **Caro TA**, Sokol NW, Koch BJ, Blazewicz SJ, et al. Growth rate as a link between microbial diversity and soil biogeochemistry. Nat Ecol Evol. 2024 Sep 18;1–9.

McKaig J, ***Caro TA**, Burton D, Tavares F, Vidaurri M. Chapter 10: Planetary Protection—History, Science, and the Future. Astrobiology. 2024 Mar;24(S1):S-202.

Chou L, Grefenstette N, Borges S, **Caro TA**, Catalano E, Harman CE, et al. Chapter 8: Searching for Life Beyond Earth. Astrobiology. 2024 Mar;24(S1):S-164.

Templeton AS, **Caro TA**. The Rock-Hosted Biosphere. Annual Review of Earth and Planetary Sciences. 2023;51(1):493–519.

***Caro TA**, McFarlin J, Jech S, Fierer N, Kopf S. Hydrogen stable isotope probing of lipids demonstrates slow rates of microbial growth in soil. Proceedings of the National Academy of Sciences. 2023 Apr 18;120(16):e2211625120.

McKaig J, **Caro TA**, Hyer A, Talburt ED, Verma S, Cui K, et al. A High-Altitude Balloon Platform for Space Life Sciences Education. Gravitational and Space Research. 2019 Nov 27;7(1):62–9.

Jaing C, Thissen J, Morrison M, Dillon MB, Waters SM, Graham GT, **Caro TA**, et al. Sierra Nevada sweep: metagenomic measurements of bioaerosols vertically distributed across the troposphere. Scientific Reports. 2020 Jul 24;10(1):12399.

***Caro TA**, Wendeln M, Freeland M, Bryan N, Waters SM, McIntyre A, et al. Ultraviolet light measurements (280–400 nm) acquired from stratospheric balloon flight to assess influence on bioaerosols. Aerobiologia. 2019 Dec 1;35(4):771–6.

Software

* Lead dev.

2024 OpenWGL: The Open-Source Well Geochemistry Logger
***Caro TA**, Brodsky HF, Ellison ET
https://github.com/tacaro/OpenWGL

2024 IsoCRDS: Read, map, and analyze cavity ringdown spectroscopy data
***Caro TA**, Kopf SH
https://github.com/KopfLab/isoCRDS

2023 ggstackplot: Create overlapping stacked plots
Kopf SH, **Caro TA**, McFarlin JM, Raberg J
https://ggstackplot.kopflab.org/index.html

Fellowships & Awards

2025 Linde Discovery Award
Ronald and Maxine Linde Center for Global Environmental Science

2025 Division Research Award
Geological and Planetary Sciences Division, California Institute of Technology

2024 Foster & Coco Stanback Postdoctoral Fellowship
California Institute of Technology, Division of Geological and Planetary Sciences.

2024 Editor's Choice Article. FEMS Microbiology Ecology
for "*Single-cell measurement of microbial growth rate with Raman microspectroscopy"*

2022 Lewis and Clark Field Research Award in Astrobiology
American Philosophical Society

2021 Penny Patterson Research Award
University of Colorado Boulder, Department of Geological Sciences.

2021 Department Research Award
For *"Quantification of microbial activity through combined Raman spectroscopy and nanoscale mass spectrometry"*
University of Colorado Boulder, Department of Geological Sciences.

2020 National Science Foundation Graduate Research Fellowship.
For "*Quantifying microbial growth rates with stable isotope lipidomics"*

2019 Interdisciplinary Quantitative Biology Fellowship.
University of Colorado Boulder, BioFrontiers Institute.

Grants + Proposals

2025 **Wilf Discovery Fund in the Search for Life, Water, or Habitable Worlds**
Keck Institute for Space Studies (Awarded)
Expanding concepts of habitability: aerotrophy
PI: Alex Sessions, Co-PI: Tristan Caro
(Primary writing contribution)

2024 **Stanford Synchrotron Radiation Lightsource (In Review)**
Halogenated organic matter as a fingerprint of microbial degradative processes
PI: Tristan Caro, Co-PI: Alex Sessions, Smruthi Karthikeyan, Woodward Fischer
(Primary writing contribution)

2021 **Stanford Synchrotron Radiation Lightsource (Awarded)**
Identifying sulfur speciation within low-temperature serpentinites
PI: Alexis Templeton, Co-PI: Tristan Caro, Srishti Kashyap, Eric Ellison
(Primary writing contribution)

2020 **NASA Exobiology Program (Awarded)**
Targeted Life Detection in Subsurface Serpentinites
PI: Alexis Templeton, Co-PI: Eric Boyd, Sebastian Kopf
(Writing and preliminary data contribution)

Field Work

California Precipitation Experiments. Oct. 2024 – Current. Southern California.
Design, installation, and instrumentation of rainfall manipulation experiments in California grasslands for deployment of in-situ multi-omics tools.

Oman Drilling Project. January 2023. Sultanate of Oman.
Discrete interval sampling of subsurface groundwater, anaerobic SIP incubation setup, on-site geochemical analysis, low-biomass DNA extraction.

CRREL Permafrost Tunnel. August 2021. Fox, Alaska.
Permafrost sediment core recovery, peat sampling, organic geochemical characterization

International Geobiology Summer Course. Summer 2021. California.
Mono Lake water column sampling, sediment coring, for metagenomics and SIP experiments

Oman Drilling Project. February 2020. Sultanate of Oman.
Sampling of subsurface groundwaters with packer system for biological and geochemical analysis.

Colorado Soil Project. Aug 2019 – Jul 2020. Boulder County, Colorado.
Collection of soil cores for lipid SIP incubation.

Berkeley Pear Tree Pathology. 2017 – 2019 Field Seasons. Berkeley, California.
Sampling of urban Bradford Pear foliage for culturing and DNA sequencing.

High Altitude Balloon (HAB) Campaigns (NASA Ames Aerobiology Lab). 2017 – 2019.
21 HAB launches carrying biological sampling payloads and sensor arrays to mid-stratosphere.

Teaching

University of Colorado, Boulder

Spring 2023	Teaching Assistant, GEOL 5700 – Data Visualization
Fall 2022	Student, GEOL 5123 – Teaching in Post-Secondary Science Education
Spring 2020	Teaching Assistant, GEOL 3320 – Principles of Geochemistry*
Fall 2020	Teaching Assistant, GEOL 4716 – Environmental Field Geochemistry*

*Course Eval Results: https://tinyurl.com/us6wmz44

NASA Ames Research Center

Summer 2018	Intern Coordinator, Space Life Sciences Training Program

University of California, Berkeley

Spring 2017	Teaching Assistant, CHEM 1AL – General Chemistry Lab
Spring 2017	Teaching Assistant, EE199 – Amateur Radio Lab

Students Advised

Nick Shepherd, Front Range Community College, 2023. Summer intern. Now at Colo. State Univ.
Sabrina Kainz, CU Boulder, 2022 - 2023. Lab assistant. Now PhD student at U. Washington
George Brown, CU Boulder, 2022 - 2023. Undergraduate statistics assistant. Now in industry.
Claudia Chen, CU Boulder, 2022 - 2023. Undergraduate statistics assistant. Now in industry.

Sarah Leather, CU Boulder, 2022. Summer intern. Now at USGS, Lakewood CO.
Josie Marquez, CU Boulder, 2021. McNair Scholar Mentor. Now at USGS, Lakewood CO.

Service

Community + Outreach

2022 – 2024 **Lead organizer**, *Geobiology Supergroup Seminar*
Campus-wide geobiology speaker series at CU Boulder.

2024 **Educator**, *Earth Mysteries and Histories, CU Boulder*.
Public outreach, education, and exhibits in geobiology.

2023 **Graduate mentor**, *Geo-Launchpad.*
An Earth science research internship program for community college students. Led student research trips to acid mine drainage sites in Colorado.

2023 **Co-chair, Co-organizer**, *Rocky Mountain Geobiology Symposium*

2022 – 2023 **Led** a departmental project to revise field safety and inclusivity guidelines, compiling a best practice guide and codes of conduct.

2020 – 2023 **Co-Founder, Organizer**, *Geo+*
A group for LGBTQ+ students in Earth Sciences at CU Boulder. Led community events and trainings on LGBTQ+ inclusivity in class and field settings.

Professional

2024 – **Collaborator, Extant Life Volumetric Imaging System.** NASA JPL.

2019 – **Member, NASA NFoLD Early Career Council**

2019 – 2023 **Chapter Editor, The Astrobiology Primer v3.0.**

2020 – 2022 **Collaborator, Ocean Worlds Life Surveyor.** NASA JPL.

2020 – 2021 **Life Detection Knowledge Base Stable Isotopes Working Group.** NFoLD.

Journal Peer Reviewer

Nat. Comms. (2), PNAS (1), ISMEJ (1), Applied and Environmental Microbiol. (2), JGR Biogeosci. (1), GCA (1), EGU Sphere (1), Front. Microbiol. (1), JoVE (1), Soil Biol. And Biochem. (1)

Technical Skills

Lipidomics and geochemistry

Gas chromatograph (GC) with flame ionizing detector coupled to a mass spectrometer; GC-isotope ratio mass spectrometer; cavity ringdown spectroscopy (Picarro, LiCOR); headspace gas chromatograph (GC-FID/TCD/RGD); accelerated extraction systems (MARS/ASE); lipid extraction from environmental samples, derivatization, solid phase extraction by polarity, ion chromatography of aqueous solutes.

Sequencing analyses

Metagenomic sequencing (Illumina, ONT), assembly/binning/analysis, 16S amplicon sequencing and analysis, genome annotation and phylogeny construction, DNA extraction and PCR.

Microscale Imaging and Spectroscopy

Raman microspectroscopy; nanoscale secondary ion mass spectrometry; synchrotron-based x-ray absorption spectroscopy (Stanford Synchrotron Radiation Lightsource); epifluorescence and confocal fluorescence microscopy, fluorescence in situ hybridization.

Computational Tools

R (Advanced); Arduino C++ (Advanced); Slurm and HPC tools (Intermediate); Python (Intermediate)

Community White Papers

NASA Decadal Astrobiology Research and Exploration Strategy

A Search for Life in the Universe Advances Life on Earth. Fontana et al. 2025. (Submitted).

NASEM 2023 Decadal Survey

On the Past, Present, and Future Role of Biology in NASA's Exploration of our Solar System. Hand et al. 2021. Bulletin of the AAS. https://doi.org/10.3847/25c2cfeb.1f3849db

Building Consensus, Collaboration, and Capability for Ocean Worlds Field Science. Stern et al. 2021. https://doi.org/10.3847/25c2cfeb.18c74be0

White Paper Towards a Fuller Understanding of Icy Satellite Seafloors, Interiors, and Habitability. Byrne et al. 2020. https://doi.org/10.48550/arXiv.2007.09728

Abstracts + Presentations

Invited Talks

Investigating soil microbiome responses to hydroclimate volatility with SIP-enabled multi-omics. *Gordon Conference in Geobiology*. January 2026. (Ventura, CA)

Microbial carbon assimilation at the energetic limits of life in the serpentinite-hosted subsurface. *NASA PCE3 Seminar Series*. June 2024. (Online)

Lipidomic hydrogen stable isotope probing demonstrates slow rates of microbial growth in soil. *Goldschmidt Geochemistry Conference*. July 2023. (Lyon, France)

Tracking slow microbial growth with lipidomic hydrogen stable isotope probing. Geoclub Seminar, *California Institute of Technology*. May 2022. (Pasadena, CA)

Tracking slow microbial growth with lipidomic hydrogen stable isotope probing. *Lawrence Berkeley National Laboratory*. August 2022. (Online)

Contributed, Presenting Author

Caro TA, Sessions AL, Karthikeyan S. Investigating soil microbiome responses to hydroclimate volatility with SIP-enabled multi-omics. Poster at Goldschmidt Geochemistry Conference. July 2025. (Prague, Czech Republic).

Caro TA, McFarlin JM, Maloney AE, Jech SD, Barker AJ, Douglas TA, Barbato RA, Kopf SH. Microbial resuscitation and growth rates in deep permafrost. Talk at American Society for Microbiology. June 2025. (Los Angeles, CA).

Caro TA, Sessions AL, Karthikeyan S. Investigating soil microbiome responses to hydroclimate volatility with SIP-enabled multi-omics. Poster at American Society for Microbiology. June 2025. (Los Angeles, CA).

Caro TA, Kashyap S, Kopf SH, Templeton AS. Microbial anabolic activity in serpentinite-hosted aquifers revealed by nanoSIMS-SIP: implications for targeted life detection strategies on Mars. Talk at Astrobiology Science Conference. May 2024. (Providence, RI)

Caro TA, Kashyap S, Kopf SH, Templeton AS. Microbial carbon utilization preferences in serpentinite-hosted aquifers: implications for astrobiology and carbon sequestration. Poster at Gordon Research Conference/Seminar in Geobiology. January 2024. (Galveston, TX)

Caro TA, Kashyap S, Kopf SH, Templeton AS. Single-cell measurement of microbial growth rate with Raman spectroscopy. Talk at Front Range Isotope Day. August 2023. (Boulder, CO)

Caro TA, Kashyap S, Kopf SH, Templeton AS. Single-cell measurement of microbial growth rate with Raman spectroscopy. Talk at Rocky Mountain Geobiology Symposium. April 2023. (Boulder, CO)

Caro TA, McFarlin JM, Jech SD, Fierer N, Kopf SH. Lipidomic hydrogen stable isotope probing demonstrates slow rates of microbial growth in soil. Poster at Front Range Microbiome Symposium, April 2023, (Fort Collins, CO)

Caro TA, Templeton AS, Kopf SH. Lipidomic hydrogen stable isotope probing for quantification of exceptionally slow microbial growth rates in situ. Talk at MicroEnergy Workshop, September 2022. (Sønderborg, Denmark)

Caro TA, McFarlin JM, Fierer N, Templeton AS, Kopf SH. Lipidomic hydrogen stable isotope probing for quantification of exceptionally slow microbial growth rates in situ. Talk at Astrobiology Science Conference, May 2022. (Atlanta, GA)

Caro TA, McFarlin JM, Fierer N, Kopf SH. Lipidomic hydrogen stable isotope probing for quantification of exceptionally slow microbial growth rates in situ. Poster at Front Range Microbiome Symposium, April 2022. (Fort Collins, CO)

Caro TA, McFarlin JM, Fierer N, Kopf SH. Lipidomic hydrogen stable isotope probing for quantification of exceptionally slow microbial growth rates in situ. Poster at Rocky Mountain Geobiology Symposium, September 2021. (Golden, CO)

Caro TA, McKaig JM. The changing landscape of planetary protection policy. American Society of Gravitational and Space Research, November 2020. (Denver, CO). Talk at Astrobiology Science Conference, June 2019. (Seattle WA)

Caro TA, Smith DJ. Ultraviolet Light measurements (280-400nm) acquired from stratospheric balloon flight to assess influence on bioaerosols. Talk at American Society of Gravitational and Space Research, November 2019. (Denver, CO)

Additional

Templeton AS, Kashyap S, **Caro TA**, Ellison ET. Microbial hydrogen consumption dynamics in peridotite rocks. Goldschmidt Geochemistry Conference. August 2024. (Chicago, IL).

Kashyap S, **Caro TA**, Templeton AS. Estimating microbial growth rates using Raman-SIP in a subsurface rock-hosted biosphere. Gordon Geobiology Conference. July 2024. (Galveston, TX).

Kashyap S, **Caro TA**, Templeton AS. Estimating microbial growth rates using Raman-SIP in a subsurface rock-hosted biosphere. Gordon AEM Conference. January 2024. (Galveston, TX).

Templeton AS, Ellison ET, Glombitza C, Hoehler T, Rempfert KR, **Caro TA**, Kashyap S, Sepulveda J, Boyd E. Sulfur biomineralization of peridotites undergoing low-temperature serpentinization. Goldschmidt Geochemistry Conference. July 2022. (Honolulu, HI).

Templeton AS, Rempfert KR, Nothaft DB, Fones E, Ellison ET, Kraus EA, Glombitza C, Boyd ES, Hoehler TM, Morono Y, Spear JR, Colman DR, Kashyap S, **Caro TA**, Thieringer P, Mayhew LE, Greenberger RN, Ehlmann BL, Kelemen PB, Matter JM. Identifying the distributions activities, adaptations, and signatures of microbial life inhabiting alkaline fluids and actively serpentinizing ultramafic rocks. The Astrobiology Science Conference. May 2022. (Atlanta, GA).

Schaible MJ, Szeinbaum N, Rodriguez LE, Colón-Santos S, Vazquez-Salazar A, Vincent L, Todd Z, Gozdag GO, Thweatt J, Styczinsky MJ, Chou L, Grefenstette N, **Caro TA**, McKaig JM. The Astrobiology Primer 3.0: Overview, Organization, and Collaboration Opportunities. The Astrobiology Science Conference. May 2022. (Atlanta, GA).

Templeton AS, Rempfert KR, Nothaft DB, Fones E, Ellison ET, Kraus EA, Glombitza C, Boyd ES, Hoehler TM, Morono Y, Spear JR, Colman DR, Kashyap S, **Caro TA**, Thieringer P, Mayhew LE, Greenberger RN, Ehlmann BL, Kelemen PB, Matter JM. Identifying the distributions, activities, adaptations, and signatures of microbial life inhabiting alkaline fluids and actively serpentinizing ultramafic rocks. The Astrobiology Science Conference (AbSciCon). May 2022. (Atlanta, GA).