Christopher T. Reinhard

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Research Interests

Chemical evolution of Earth's oceans and atmosphere; geoengineering of Earth's carbon cycle; long-term climate evolution on terrestrial planets;

Education

- 2012 – PhD, Earth Sciences, University of California, Riverside
- 2008 – MS, Earth Sciences, University of California, Riverside
- 2005 – BS, Ecology & Evolutionary Biology, University of Kansas

Professional Appointments

- 2020-present – Associate Professor, Georgia Institute of Technology
- 2014-2020 – Assistant Professor, Georgia Institute of Technology
- 2012-2014 – O.K. Earl Postdoctoral Fellow, California Institute of Technology
- 2006-2012 – Research/Teaching Assistant, University of California, Riverside

Selected Honors and Awards

James B. Macelwane Medal, American Geophysical Union, 2021
Cullen-Peck Scholar Award, 2020
Sigma Xi Young Faculty Award, 2020
SciAlog Fellowship, *Signatures of Life in the Universe*, 2020
Eric R. Immel Memorial Award for Excellence in Teaching, 2017
GSA Geobiology and Geomicrobiology Division Pre-Tenure Award, 2017
Alfred P. Sloan Fellowship in Ocean Sciences, 2015
O.K. Earl Postdoctoral Fellowship, California Institute of Technology, 2012
Dissertation Year Fellowship, University of California, Riverside, 2011
Geological Society of America Research Grant, 2011
European Science Foundation Travel Grant, 2010
John Dunham Field Fellowship, University of California, Riverside, 2009
Roland Blanchard Graduate Fellowship, University of California, Riverside, 2009
Chancellor's Distinguished Fellowship, University of California, Riverside, 2006
National Merit Scholarship, University of Kansas Endowment, 2000-2004

Funding

Institutional PI, Alternative Earths: How to Build and Sustain a Detectable Biosphere, ***National Aeronautics and Space Administration (NASA) Interdisciplinary Consortia for Astrobiology Research*** [$1,169,569 to Georgia Tech].

PI, Upside-Down Biospheres and the Remote Detectability of Life on Reducing Planets, ***National Aeronautics and Space Administration (NASA) Exobiology and Evolutionary Biology Program*** [$401,281 to Georgia Tech].

Institutional PI, Alternative Earths: Explaining Persistent Inhabitation on a Dynamic Early Earth, *National Aeronautics and Space Administration Astrobiology Institute (NASA-NAI)* [$1,808,339 to Georgia Tech].

PI, The role of the oceans in structuring Earth's surface oxygen cycle, *Alfred P. Sloan Foundation Fellowship in Ocean Sciences* [$50,000 to Georgia Tech].

Co-PI, Calibrating the chromium isotope system as a tracer of atmospheric oxygenation, *National Aeronautics and Space Administration (NASA) Exobiology* [$196,763 to Georgia Tech].

Co-PI, ELT Collaborative Research: Beyond the Boring Billion: Late Proterozoic Glaciation, Oxygenation and the Proliferation of Complex Life, *National Science Foundation (NSF)* [$198,190 to Georgia Tech].

Selected Invited Talks

"Ocean biogeochemistry and the evolution of the eukaryotic cell: Cause and consequence", Agouron Foundation Conference on The Origin of Eukaryotes, 2019

"Photosynthetic ecology and Earth system evolution", AGU Fall Meeting, 2018

"Nutrients, ecosystems, and the rise of eukaryotic life", Goldschmidt Annual Meeting, 2018

"Controls on the evolving scope of Earth's biosphere", Keynote, RFG2018, 2018

"Planetary methane cycling in deep time and beyond", UC Riverside Methane Cycle Symposium, 2018

"The importance of nutrients for Earth's carbon cycle", IRESS: Whole Earth Carbon Cycling – Bridging Academia and Industry, 2018

"Nutrients, ecosystems, and the chemical evolution of Earth's atmosphere", Gordon Research Conference – The Microbial Planet from Deep Time to Today, 2018

"The evolutionary geobiology of Earth's oxygen cycle", Stanford University, Department of Geological Sciences Seminar Series, 2017

"Nutrients, ecosystems, and the evolving detectability of Earth's biosphere", University of Washington Astrobiology Colloquium Series, 2017

"Nutrients, ecosystems, and the chemical evolution of Earth's atmosphere", Rice University, Department of Earth Sciences Seminar Series, 2017

"Isotopic and theoretical constraints on the evolving redox state of Earth's atmosphere", Keynote, Goldschmidt Annual Meeting, 2017

"Is animal evolution tied to oxygenation?", Point-Counterpoint Talk, 1st Geobiology Society Conference, 2017

"An ecophysiological throttle on Earth's early oxygen cycle", Goldschmidt Conference, 2016.

"Oxygen and the evolution of complexity", Duke University, Division of Earth & Ocean Sciences Department Seminar Series, 2016.

"A cryptic biosphere on the mid-Proterozoic Earth?", University of North Carolina at Chapel Hill, Department of Geological Sciences Colloquium, 2016.

"The importance of tectonics for the emergence and stability of planetary biosignatures", NExSS/NAI/NSF Joint Workshop: Consequences of Internal Planet Evolution for the Habitability and Detectability of Life on Extrasolar Planets, 2016.

"The evolution of Earth's oxygen cycle: Cause and effect", University of Cincinnati, Department of Geology Colloquium, 2015.

"Causal relationships between Earth's oxygen cycle and the evolution of complex life", Geological Society Annual Meeting, 2015

"The utility of chromium (Cr) isotopes as a redox tracer", GAC-MAC Joint Assembly, 2015

"A transition *metal* isotope perspective on Earth system evolution", University of Chicago, GeoSci Seminar, 2015.

"Reconstructing Earth's early sulfur cycle", Agouron Institute Symposium: The Sulfur Cycle, 2014.

"Ocean-atmosphere redox during Earth's middle age", Virginia Tech Geosciences Department Seminar, 2014.
"Stable chromium isotopes as an emerging paleoredox proxy", WHOI Seminar Series, 2012.
"Biological O_2 production during the Archean: The black shale record", Agouron Institute Symposium: Archean Biomarkers, 2012.
"Life and Earth's atmosphere", UCLA, Geochemical Tools in Paleoclimate and Geobiology, 2012.
"Reconstructing spatial and temporal variability in Precambrian ocean chemistry", California Institute of Technology GeoClub Seminar, 2011.
"Oxidative weathering and euxinia in the Late Archean", AGU Fall Meeting, 2009

Professional Affiliations

AAAS, American Geophysical Union, Geochemical Society, Geological Society of America

Selected Synergistic Activities

Science Organizing Committee, NASA Astrobiology Science Conference (AbSciCon), 2021
Editor, ***Geochemical Tracers in Earth System Science***, Cambridge University Press
Associate Editor, ***Paleoceanography and Paleoclimatology***
Science Organizing Committee, NASA Astrobiology Science Conference (AbSciCon), 2019
Steering Council, NASA Nexus for Exoplanet System Science (NExSS) (2018-present)
Science Organizing Committee, Comparative Climatology of Terrestrial Planets 3 (CCTP-3), 2018
Participant, NASA-NExSS Workshop Without Walls, *Exoplanet Biosignatures*
Invited Contributor, NASA-NExSS Workshop Without Walls, *Upstairs-Downstairs: Consequences of Internal Planet Evolution for the Habitability and Detectability of Life on Extrasolar Planets*
Panelist, NASA Exobiology Program
Panelist, National Science Foundation (NSF-SGP)
External Reviewer, National Science Foundation (NSF)
External Reviewer, European Research Council
External Reviewer, Petroleum Research Fund
External Reviewer, Israel Science Foundation
Session Chair, Goldschmidt Annual Meeting, 2017
Session Chair, American Geophysical Union Fall Meeting, 2016
Steering Committee, Southeastern Biogeochemistry Symposium, 2015
Invited Contributor, Agouron Institute Sulfur Cycle Symposium, Palos Verdes, 2014
Session Chair, Geological Society of America Annual Meeting, 2014
Beyond Habitability: Life and the Early Earth, NASA/Smithsonian Institution, 2014
Theme Team, 24th V.M. Goldschmidt Conference, 2014
NASA Astrobiology Roadmap Team, 2013-2014
Graduate Student Coordinator, 9th Annual SoCal Geobiology Symposium, 2012
Ocean Deoxygenation: Past, Present, and Future, NASA Ames Research Center, March 2010
Analyzing the Archean, European Science Foundation, Utrecht, Netherlands, June 2010
Supervisor, HSI-STEM Summer Bridge Research Program, UC-Riverside, 2009
Reviewer for:

Nature; Science; Science Advances; Nature Geoscience; Nature Communications; Proceedings of the National Academy of Sciences, USA; Earth and Planetary Science Letters; Proceedings of the Royal Society B: Biological Sciences, Geochimica et Cosmochimica Acta; Geology; Biogeosciences; GSA Bulletin; Precambrian Research; Geochemical Perspectives Letters; Astrobiology; Chemical Geology; Palaeogeography, Palaeoclimatology, Palaeoecology; Economic Geology; Journal of Paleontology

Manuscripts Accepted or In Review

Van de Velde, S.J., Hülse, D., **Reinhard, C.T.**, Ridgwell, A. (*In review*) Anoxic iron and sulphur cycling in the cGENIE.muffin Earth system model (v0.9.16). *Geoscientific Model Development*.

Ozaki, K., **Reinhard, C.T.** (*Accepted*) The future lifespan of Earth's oxygenated atmosphere. *Nature Geosciences*.

Peer-Reviewed Publications

[91] Wang, C., **Reinhard, C.T.**, Rybacki, K.S., Hardisty, D.S., Ossa Ossa, F., Wang, X., Hofmann, A., Asael, D., Robbins, L.J., Zhang, L., Planavsky, N.J. (2021) Chromium isotope systematics and the diagenesis of marine carbonates. *Earth and Planetary Science Letters*. **562**, 116824.

[90] Ozaki, K., **Reinhard, C.T.** (2021) The future lifespan of Earth's oxygenated atmosphere. *Nature Geoscience*. **14**, 138-142.

[89] Planavsky, N.J., Crowe, S.A., Fakhraee, M., Beaty, B., **Reinhard, C.T.**, Mills, B.J.W., Holstege, C., Konhauser, K.O. (2021) Evolution of the structure and impact of Earth's early biosphere. *Nature Reviews Earth & Environment*. **2**, 123-139.

[88] Van de Velde, S.J., **Reinhard, C.T.**, Ridgwell, A., Meysman, F.J.R. (2020) Bistability in the redox chemistry of sediments and oceans. *Proceedings of the National Academy of Sciences, USA*. **117**, 33043-33050.

[87] Fakhraee, M., Planavsky, N.J., **Reinhard, C.T.**. (2020) The role of environmental factors in the long-term evolution of the marine biological pump. *Nature Geoscience*. **13**, 812-816.

[86] **Reinhard, C.T.**, Olson, S.L., Turner, S.K., Pälike, C., Kanzaki, Y., Ridgwell, A. (2020) Oceanic and atmospheric methane cycling in the cGENIE Earth system model. *Geoscientific Model Developments*. **13**, 5687-5706.

[85] Szeinbaum, N., Nunn, B.L., Cavazos, A.R., Crowe, S.A., Stewart, F.J., DiChristina, T.J., **Reinhard, C.T.**, Glass, J.B. (2020) Expression of extracellular multiheme cytochromes discovered in a betaproteobacterium during Mn(III) reduction. *The ISME Journal*. doi:10.1111/1758-2229.12867.

[84] Robinson, T.D., **Reinhard, C.T.** (2020) Earth as an exoplanet. *In* Meadows, V.S., and Arney, G.N. (*eds.*) *Solar System Astrobiology*, University of Arizona Press.

[83] **Reinhard, C.T.**, Planavsky, N.J. (2020) Biogeochemical controls on the redox evolution of Earth's oceans and atmosphere. *Elements*. **16**, 191-196.

[82] Zhao, M., Zhang, S., Tarhan, L., **Reinhard, C.T.**, Planavsky, N.J. (2020) The role of calcium in regulating marine phosphorus burial and atmospheric oxygenation. *Nature Communications*. **11**, 2232.

[81] Cole, D.B., Mills, D.B., Erwin, D.H., Sperling, E.A., Porter, S.M., **Reinhard, C.T.**, Planasky, N.J. (2020) On the co-evolution of surface oxygen levels and animals. *Geobiology*. **18**, 260-281.

[80] Planavsky, N.J., **Reinhard, C.T.**, Isson, T.T., Ozaki, K., Crockford, P.W. (2020) Large mass-independent oxygen isotope fractionations in mid-Proterozoic sediments: Strong evidence for a low-oxygen atmosphere? *Astrobiology*. **20**, 628-636.

[79] Zaharescu, D.G., Burghelea, C.I., Dontsova, K., **Reinhard, C.T.**, Chorover, J., Lybrand, R. (2020) Biological weathering in the terrestrial system: An evolutionary perspective. *AGU Geophysical Monograph Series*. **251**, 3-32.

[78] Mänd, K., Lalonde, S.V., Robbins, L.J., Thoby, M., Paiste, K., Kreitsmann, T., Paiste, P., **Reinhard, C.T.**, Romashkin, A.E., Planavsky, N.J., Kirsimäe, K., Lepland, A., Konhauser, K.O.

(2020) Paleoproterozoic oxygenated oceans following the Lomagundi-Jatuli Event. *Nature Geoscience.* **13**, 302-306.

[77] **Reinhard, C.T.**, Planavsky, N.J., Ward, B.A., Love, G.D., Le Hir, G., Ridgwell, A. (2020) The impact of marine nutrient abundance on early eukaryotic ecosystems. *Geobiology.* **18**, 139-151.

[76] **Reinhard, C.T.**, Fischer, W.W. (2020) Mechanistic links between the sedimentary redox cycle and marine acid-base chemistry. *Geochemistry, Geophysics, Geosystems.* **20**, 5968-5978.

[75] Ostrander, C.M., Kendall, B., Olson, S.L., Lyons, T.W., Gordon, G.W., Romaniello, S.J., Zheng, W., **Reinhard, C.T.**, Roy, M., Anbar, A.D. (2020) An expanded shale δ^{98}Mo record premits recurrent shallow marine oxygenation during the Neoarchean. *Chemical Geology.* **532**, doi:10.1016/j.chemgeo.2019.119391.

[74] Zaharescu, D.G., Burghelea, C.I., Dontsova, K., Presler, J.K., Hunt, E.A., Domanik, K.J., Amistadi, M.K., Sandhaus, S., Munoz, E.N., Gaddis, E.E., Galey, M., Vaquera-Ibarr, M.O., Palacios-Menendez, M.A., Castrejón-Martinez, R., Rodán-Nicolau, E.C., Li, K., Maier, R.M., **Reinhard, C.T.**, Chorover, J. (2019) Ecosystem-bedrock interaction changes nutrient compartmentalization during early oxidative weathering. *Nature Scientific Reports.* **9**, doi:10.1038/s41598-019-51274-x.

[73] Colwyn, D.A., Sheldon, N., Maynard, J.B., Baines, R., Hofmann, A., Wang, X., Gueguen, B., Asael, D., **Reinhard, C.T.**, Planavsky, N.J. (2019) A paleosol record of the evolution of Cr redox cycling and evidence for an increase in atmospheric oxygen during the Neoproterozoic. *Geobiology.* **17**, 579-593.

[72] Thompson, K.J., Kenward, P.A., Bauer, K.W., Warchola, T., Gauger, T., Martinez, R., Simister, R.L., Michiels, C.C., Llirós, M., **Reinhard, C.T.**, Kappler, A., Konhauser, K.O., Crowe, S.A. (2019) Photoferrotrophy, deposition of banded iron formations, and methane production in Archean oceans. *Science Advances.* **5**, doi:10.1126/sciadv.aav2869.

[71] Ozaki, K., Thompson, K.J., Simister, R.L., Crowe, S.A., **Reinhard, C.T.** (2019) Anoxygenic photosynthesis and the delayed oxygenation of Earth's atmosphere. *Nature Communications.* **15**, doi:10.1038/s41467-019-10872-z.

[70] Wang, X., Glass, J.B., **Reinhard, C.T.**, Planavsky, N.J. (2019) Species-dependent chromium isotope fractionation across the Eastern Tropical North Pacific Oxygen Minimum Zone. *Geochemistry, Geophysics, Geosystems.* **20**, 2499-2514.

[69] Schwieterman, E.W., **Reinhard, C.T.**, Olson, S.L., Harman, C.E., Lyons, T.W. (2019) A limited habitable zone for complex life. *The Astrophysical Journal.* **878**, 19. doi:10.3847/1538-4357/ab1d52.

[68] Schwieterman, E.W., **Reinhard, C.T.**, Olson, S.L., Ozaki, K., Harman, C.E., Hong, P.K., Lyons, T.W. (2019) Rethinking CO antibiosignatures in the search for life beyond the solar system. *The Astrophysical Journal.* **874**, 9. doi:10.3847/1538-4357/ab05e1.

[67] Johnson, A.C., Romaniello, S.J., **Reinhard, C.T.**, Gregory, D.D., Garcia-Robledo, E., Revsbech, N.P., Canfield, D.E., Lyons, T.W., Anbar, A.D. (2019) Experimental determination of pyrite and molybdenite oxidation kinetics at nanomolar oxygen concentrations. *Geochimica et Cosmochimica Acta.* **249**, 160-172.

[66] Ozaki, K., **Reinhard, C.T.**, Tajika, E. (2019) A sluggish mid-Proterozoic biosphere and its effect on Earth's redox balance. *Geobiology.* **17**, 3-11 doi:10.1111/gbi.12317.

[65] Schwieterman, E.E., Lyons, T.W., **Reinhard, C.T.** (2018) Signs of life on a global scale: Earth as a laboratory for exoplanet biosignatures. *The Biochemist.* **40**, 22-27.

[64] Miyazaki, Y., Planavsky, N.J., Bolton, E.W., **Reinhard, C.T.** (2018) Making sense of massive carbon isotope excursions with an inverse carbon cycle model. *Journal of Geophysical Research.* **123**, 2485-2496.

[63] Stanton, C.L., **Reinhard, C.T.**, Kasting, J.F., Ostrom, N.E., Haslun, J.A., Lyons, T.W., Glass, J.B. (2018) Nitrous oxide from chemodenitrification: A possible missing link in the Proterozoic greenhouse and the evolution of aerobic respiration. *Geobiology.* **16**, 597-609.

[62] Bellefroid, E.J., v.S. Hood, A., Hoffman, P.F., Thomas, M.D., **Reinhard, C.T.**, Planavsky, N.J. (2018) Constraints on Paleoproterozoic atmospheric oxygen levels. *Proceedings of the National Academy of Sciences, USA.* **115**, 8104-8109.

[61] Planavsky, N.J., Cole, D.B., Isson, T.T., **Reinhard, C.T.**, Crockford, P.W., Sheldon, N.D., Lyons, T.W. (2018) A case for low atmospheric oxygen levels during Earth's middle history. *Emerging Topics in Life Sciences.* Doi:10.1042/ETLS20170161.

[60] Wang, X., Planavsky, N.J., Hofmann, A., Saupe, E.E., DeCorte, B.P., Philippot, P., LaLonde, S.V., Jemison, N.E., Zou, H., Ossa Ossa, F., Rybacki, K., Alfimova, N., Larson, M.J., Tsikos, H., Fralick, P.W., Johnson, T.M., Knudsen, A.C., **Reinhard, C.T.**, Konhauser, K.O. (2018) A Mesoarchean shift in uranium isotope systematics. *Geochimica et Cosmochimica Acta.* **238**, 438-452.

[59] Raiswell, R., Hardisty, D.S., Lyons, T.W., Canfield, D.E., Owens, J.D., Planavsky, N.J., Poulton, S.W., **Reinhard, C.T.** (2018) The iron paleoredox proxies: A guide to proper practice, pitfalls, and problems. *American Journal of Science.* **318**, 491-526.

[58] Hardisty, D.S., Lyons, T.W., Riedinger, N., Owens, J.D., Tang, T., Aller, R.C., Rye, D., Planavsky, N.J., **Reinhard, C.T.**, Gill, B.C., Masterson, A.L., Asael, D., Johnston, D.T. (2018) An evaluation of sedimentary molybdenum and iron as proxies for pore fluid paleoredox conditions. *American Journal of Science.* **318**, 527-556.

[57] Isson, T.T., Love, G.D., Dupont, C.L., **Reinhard, C.T.**, Zumberge, A., Asael, D., Gueguen, B., McCrow, J.P., Gill, B.C., Owens, J.D., Rainbird, R.H., Rooney, A.D., Stüeken, E.E., Konhauser, K.O., John, S.G., Lyons, T.W., Planavsky, N.J. (2018) Tracking the rise of eukaryotes to ecological dominance with zinc isotopes. *Geobiology.* **16**, 341-352.

[56] Meadows, V.S., Reinhard, C.T., Arney, G.N., Parenteau, M.N., Schwieterman, E.W., Domagal-Goldman, S.D., Lincowski, A.P., Stapelfeldt, K.R., Rauer, H., DasSarma, S., Hegde, S., Narita, N., Deitrick, R., Lyons, T.W., Siegler, N., Lustig-Yaeger, J. (2018) Exoplanet biosignatures: Understanding oxygen as a biosignature in the context of its environments. *Astrobiology* **18**, 630-662.

[55] Schwieterman, E.W., Kiang, N.Y., Parenteau, M.N., Harma, C.E., DasSarma, S., Fisher, T.M., Arney, G.N., Hartnett, H.E., Reinhard, C.T., Olson, S.L., Meadows, V.S., Cockell, C.S., Walker, S.I., Grenfell, J.L., Hegde, S., Rugheimer, S., Hu, R., Lyons, T.W. (2018) Exoplanet biosignatures: A review of remotely detectable signs of life. *Astrobiology* **18**, 663-708.

[54] Walker, S.I., Bains, W., Cronin, L., DasSarma, S., Danielache, S., Domagal-Goldman, S., Kacar, B., Kiang, N.Y., Lenardic, A., Reinhard, C.T., Moore, W., Schwieterman, E.W., Shkolnik, E.L., Smith, H.B. (2018) Exoplanet biosignatures: Future directions. *Astrobiology* **18**, 779-824.

[53] Olson, S.L., Schwieterman, E.W., **Reinhard, C.T.**, Ridgwell, A., Kane, S.R., Meadows, V.S., Lyons, T.W. (2018) Atmospheric seasonality as an exoplanet biosignature. *The Astrophysical Journal Letters* **858**, L14 doi:10.3847/2041/8213/aac171.

[52] Sheen, A.I., Kendall, B., **Reinhard, C.T.**, Creaser, R.A., Lyons, T.W., Bekker, A., Poulton, S.W., Anbar, A.D. (2018) A model for the oceanic mass balance of rhenium and implications for the extent of Proterozoic ocean anoxia. *Geochimica et Cosmochimica Acta* **227**, 75-95.

[51] Olson, S.L., Schwieterman, E.W., **Reinhard, C.T.**, Lyons, T.W. (2018) Earth: Atmospheric evolution of a habitable planet. *In* Deeg, H., Belmonte, J. (*eds.*), *Handbook of Exoplanets*, Springer.

[50] Zhao, M., Reinhard, C.T., Planavsky, N.J. (2018) Terrestrial methane fluxes and Proterozoic climate stability. *Geology* **46**, 139-142.

[49] Ozaki, K., Tajika, E., Hong, P., Nakegawa, Y., Reinhard, C.T. (2018) Effects of primitive photosynthesis on Earth's early climate system. *Nature Geoscience* **11**, 55-59.

[48] Cole, D.B., Wang, X., Qin, L., Planavsky, N.J., **Reinhard, C.T.** (2018) Chromium Isotopes. *In* White, W.M. (*ed.*), *Encyclopedia of Geochemistry*, Springer International. doi:10.1007/978-3-319-39193-9_334-1.

[47] Gaschnig, R., Reinhard, C.T., Planavsky, N.J., Wang, X., Asael, D., Chauvel, C. (2017) The molybdenum isotope system as a tracer of slab input in subduction zones: An example from Martinique, Lesser Antilles arc. *Geochemistry, Geophysics, Geosystems* **18**, 4674-4689.

[46] Konhauser, K.O., Robbins, L.J., Alessi, D.S., Flynn, S.L., Gingras, M.K., Martinez, R.E., Kappler, A., Swanner, E.D., Li, Y., Crowe, S.A., Planavsky, N.J., **Reinhard, C.T.**, Lalonde, S.V. (2017) Phytoplankton contributions to the trace-element composition of Precambrian banded iron formations. *GSA Bulletin* doi:10.1130/B31648.1.

[45] Saad, E.M., Wang, X., Planavsky, N.J., Reinhard, C.T., Tang, Y. (2017) Redox-independent chromium isotope fractionation induced by ligand-promoted dissolution. *Nature Communications* **8**, doi:10.1038/s41467-017-01694-y.

[44] Wu, W., Wang, X., Reinhard, C.T., Planavsky, N.J. (2017) Chromium isotope systematics in the Connecticut River. *Chemical Geology* **456**, 98-111.

[43] Reinhard, C.T., Olson, S.L., Schwieterman, E.D., Lyons, T.W. (2017) False negatives for remote life detection on ocean-bearing planets: Lessons from the early Earth. *Astrobiology* **17**, 287-297.

[42] Reinhard, C.T., Planavsky, N.J., Gill, B.C., Ozaki, K., Robbins, L.J., Lyons, T.W., Fischer, W.W., Wang, C., Cole, D.B., Konhauser, K.O. (2017) Evolution of the global phosphorus cycle. *Nature* **541**, 386-389.

[41] Robbins, L.J., Lalonde, S.V., Planavsky, N.J., Partin, C.A., Reinhard, C.T., Kendall, B., Scott, C., Hardisty, D.S., Gill, B.C., Alessi, D.S., Dupont, C.L., Saito, M.A., Poulton, S.W., Bekker, A., Lyons, T.W., Konhauser, K.O. (2016) Trace elements at the intersection of marine biological and geochemical evolution. *Earth-Science Reviews* **163**, 323-348.

[40] Olson, S.L., Reinhard, C.T., Lyons, T.W. (2016) Cyanobacterial diazotrophy and Earth's delayed oxygenation. *Frontiers in Microbiology* **7**, doi:10.3389/fmicb.2016.01526.

[39] Olson, S.L., Reinhard, C.T., Lyons, T.W. (2016) Limited role for methane in the mid-Proterozoic greenhouse. *Proceedings of the National Academy of Sciences, USA* **113**, 11447-11452.

[38] Reinhard, C.T., Planavsky, N.J., Olson, S.L., Lyons, T.W., Erwin, D.H. (2016) Earth's oxygen cycle and the evolution of animal life. *Proceedings of the National Academy of Sciences, USA* **113**, 8933-8938.

[37] Owens, J.D., Reinhard, C.T., Rohrssen, M., Love, G.D., Lyons, T.W. (2016) Empirical links between trace metal cycling and marine microbial ecology during a large perturbation to Earth's carbon cycle. *Earth and Planetary Science Letters* **449**, 407-417.

[36] Gilhooly III, W.P., Reinhard, C.T., Lyons, T.W. (2016) A comprehensive sulfur and oxygen isotope study of sulfur cycling in a shallow, hyper-euxinic meromictic lake. *Geochimica et Cosmochimica Acta* **189**, 1-23.

[35] Cole, D.B., Reinhard, C.T., Wang, X., Gueguen, B., Halverson, G.P., Lyons, T.W., Planavsky, N.J. (2016) A shale-hosted Cr isotope record of low atmospheric oxygen during the Proterozoic. *Geology* **44**, 555-558.

[34] Gueguen, B.G., Reinhard, C.T., Algeo, T.J., Peterson, L.C., Nielsen, S.G., Wang, X., Planavsky, N.J. (2016) The chromium isotope composition of reducing and oxic marine sediments. *Geochimica et Cosmochimica Acta* **184**, 1-19.

[33] Planavsky, N.J., Cole, D.B., Reinhard, C.T., Diamond, C., Love, G.D., Luo, G., Zhang, S., Konhauser, K.O., Lyons, T.W. (2016) No evidence for high atmospheric oxygen levels 1,400 million years ago. *Proceedings of the National Academy of Sciences, USA* doi: 10.1072/pnas.1601925113.

[32] Wang, X., Reinhard, C.T., Planavsky, N.J., Owens, J.D., Lyons, T.W., Johnson, T.M. (2016) Sedimentary chromium isotopic compositions across the Cretaceous OAE2 at Demerara Rise Site 1258. *Chemical Geology* **429**, 85-92.

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