

Richard K. Bono, Ph.D.

Geological Sciences Degrees and Education

University of Rochester

Rochester, NY

Ph.D. in Geology, advised by Prof. John A. Tarduno

December 2016

- Title: "Paleomagnetic Investigations of Deep Time: Evolution and Dynamics of the Core, Mantle and Life"

M.S. in Geology, advised by Prof. John A. Tarduno

October 2011

- Essay topic: "Applied Secular Variation Studies: Characterizing Magnetic Field Behavior During the Mesozoic and Early Cenozoic"

B.S. in Geological Sciences with Geology Track

May 2010

- High Honors in Research, Senior Thesis: "Paleomagnetic results of Late Cretaceous Hansen Point volcanics, NW Ellesmere Island, Sverdrup Basin"; Lattimore Prize recipient

Institute for Rock Magnetism

Minneapolis, MN

Summer School of Rock Magnetism

Summer 2013

Michigan Technical University

Houghton, MI

Geology Field Camp in Kenya Participant

Summer 2009

Research Positions

Leverhulme Trust Early Career Postdoctoral Fellow, University of Liverpool

Starting Feb. 2021

Postdoctoral Research Associate, University of Liverpool

2018 – Jan. 2021

Postdoctoral Research Associate, University of Rochester

2017 - 2018

Fellowships and Awards

Early Career Fellowship, Leverhulme Trust, 3 years' salary and £6000/year research costs

Awarded 2020

Harold T. Stearns Fellowship Award, GSA, \$2500

2012

Lattimore Prize, University of Rochester, \$750

2009

Peer reviewed publications, presented talks and posters

Peer reviewed publications:

- D. G. Meduri, A. J. Biggin, C. J. Davies, R. K. Bono, C. J. Sprain, J. Wicht, *accepted*. "Numerical dynamo simulations reproduce palaeomagnetic field behaviour," *Geophysical Review Letters*, doi: 10.1002/essoar.10504074.2 (preprint).
- A. J. Biggin, R. K. Bono, D. G. Meduri, C. J. Sprain, C. J. Davies, R. Holme, P. V. Doubrovine, 2020. "Quantitative estimates of average geomagnetic axial dipole dominance in deep geological time," *Nature Communications* **11**, 6100, doi: 10.1038/s41467-020-19794-7.
- Y. Engbers, A. J. Biggin, R. K. Bono, 2020. "Elevated paleomagnetic dispersion at Saint Helena suggests long-lived anomalous behavior in the South Atlantic," *Proceedings of the National Academy of Sciences* **117** (31), p. 18258-18263, doi:10.1073/pnas.2001217117.
- R. K. Bono, A. J. Biggin, R. Holme, D. G. Meduri, J. Bestard, 2020. "Covariant giant Gaussian process models with improved reproduction of palaeosecular variation," *Geochemistry, Geophysics, Geosystems* **21** (8), e2020GC008960.
- J. A. Tarduno, R. D. Cottrell, R. K. Bono, *et al.*, 2020. "Paleomagnetism indicates that primary magnetite in zircon records a strong Hadean geodynamo," *Proceedings of the National Academy of Sciences* **117** (5), p. 2309-2318, doi:10.1073/pnas.1916553117.
- C. J. Sprain, A. J. Biggin, C. J. Davies, R. K. Bono, D. G. Meduri, 2019. "An assessment of long duration geodynamo simulations using new paleomagnetic modeling criteria (Q_{pm})," *Earth and Planetary Science Letters* **526**, 11578, doi:10.1016/j.epsl.2019.115758.
- R. K. Bono, J. A. Tarduno, H.-P. Bunge, 2019. "Hotspot motion caused the Hawaiian-Emperor Bend and LLSVPs are not fixed," *Nature Communications* **10**, 3370, doi:10.1038/s41467-019-11314-6.
- R. K. Bono, J. A. Tarduno, F. Nimmo, R. D. Cottrell, 2019. "Young inner core inferred from Ediacaran ultra-low geomagnetic field intensity," *Nature Geoscience* **12** (2), p. 143-147, doi: 10.1038/s41561-018-0288-0.
- R. K. Bono, J. A. Tarduno, R. D. Cottrell, 2019. "Primary pseudo-single and single-domain magnetite inclusions in quartzite cobbles of the Jack Hills (Western Australia): implications for the Hadean geodynamo," *Geophysical Journal International* **216**(1), p. 598-608, doi:10.1093/gji/ggy446.

- V. J. Hare, J. A. Tarduno, T. Huffman, M. Watkeys, P. C. Thebe, M. Manyanga, R. K. Bono, R. D. Cottrell, 2018. "New Archeomagnetic Directional Records From Iron Age Southern Africa (ca. 425–1550 CE) and Implications for the South Atlantic Anomaly," *Geophysical Research Letters* **45**, doi:10.1002/2017GL076007.
- R. K. Bono, J. A. Tarduno, M. S. Dare, G. Mitra, R. D. Cottrell, 2018. "Cluster analysis on a sphere: Application to magnetizations from Jack Hills metasediments, Western Australia," *Earth and Planetary Science Letters* **484**, p. 67–80, doi:10.1016/j.epsl.2017.12.007.
- R. K. Bono, J. Clarke, J. A. Tarduno, D. Brinkman, 2016. "A Large Ornithurine Bird (*Tingmiatornis arctica*) from the Turonian High Arctic: Climatic and Evolutionary Implications," *Scientific Reports* **6**, doi:10.1038/srep38876.
- M. S. Dare, J. A. Tarduno, R. K. Bono, R. D. Cottrell, J. S. Beard, K. P. Kodama, 2016. "Detrital magnetite and chromite in Jack Hills quartzite cobbles: Further evidence for the preservation of primary magnetizations and new insights into sediment provenance," *Earth and Planetary Science Letters* **451**, p. 298–314, doi:10.1016/j.epsl.2016.05.009.
- R. K. Bono, J. A. Tarduno, R. D. Cottrell, 2016. "Comment on: Pervasive remagnetization of detrital zircon host rocks in the Jack Hills, Western Australia and implications for records of the early dynamo, by Weiss et al. (2015)," *Earth and Planetary Science Letters* **450**, p. 406–408, doi:10.1016/j.epsl.2016.06.006.
- R. D. Cottrell, J. A. Tarduno, R. K. Bono, M. S. Dare, G. Mitra, 2016. "The inverse microconglomerate test: Further evidence for the preservation of Hadean magnetizations in metasediments of the Jack Hills, Western Australia," *Geophysical Research Letters* **43**, p. 4215–4220, doi:10.1002/2016GL068150.
- A. V. Smirnov, J. A. Tarduno, E. V. Kulakov, S. A. McEnroe, R. K. Bono, 2016. "Paleointensity, core thermal conductivity and the unknown age of the inner core," *Geophysical Journal International* **205** (2), p. 1190–1195, doi:10.1093/gji/ggw080.
- J. A. Tarduno, R. D. Cottrell, W. J. Davis, F. Nimmo, R. K. Bono, 2015. "A Hadean to Paleoarchean geodynamo recorded by single zircon crystals," *Science* **349** (6247), p. 521–524, doi: 10.1126/science.aaa9114.
- R. K. Bono, J. A. Tarduno, 2015. "A stable Ediacaran Earth recorded by single silicate crystals of the ca. 565 Ma Sept-Îles intrusion," *Geology* **43** (2), p. 131–134, doi:10.1130/G36247.1.

Presented talks and posters:

- R. K. Bono, *et al.*, 2021 (originally scheduled 2020). "DEEP thoughts: Insights on geomagnetic field evolution from models, and vice versa," 2020/2021 MagIC Workshop.
- R. K. Bono, *et al.*, 2020. "Covariance in the geomagnetic field: Linking dynamo simulations and giant Gaussian process statistical models," SEDI 2020, Taipei.
- R. K. Bono, *et al.*, 2019. "Testing the potential of statistical field models to characterize time-dependent behavior for the past 2 million years," AGU Fall Meeting, Abstract: GP41A-0769.
- R. K. Bono, *et al.*, 2019. "Beyond the Giant Gaussian: Next generation geomagnetic statistical field models," UK SEDI 2019, UCL.
- R. K. Bono, *et al.*, 2018. "Markov Chain Monte Carlo geomagnetic field models using paleomagnetic observations," AGU Fall Meeting, Abstract: GP43A-0762.
- R. K. Bono, J. A. Tarduno, R. D. Cottrell, 2018. "Magnetic Carriers in Metasediments of the Jack Hills (Western Australia): Constraints on Thermal History," 16th Castle Meeting, Checiny, Poland.
- R. K. Bono, A. J. Biggin, 2018. "Beyond Giant Gaussian Processes: New techniques for developing statistical field models," RAS Meeting, Dynamics and evolution of Earth's coupled core-mantle system.
- R. K. Bono, J. A. Tarduno, F. Nimmo, 2017. "Paleomagnetic evidence for a young inner core: ultra-low field 565 million years ago," AGU Fall Meeting, Abstract: DI33B-0418.
- R. K. Bono, J. A. Tarduno, 2017. "Linking the history of the Hawaiian Hotspot motion to Pacific plate evolution and deep mantle processes: new paleomagnetic data from Midway Atoll (~27 Ma)," GSA Cordilleran Section Annual Meeting, Abstract: 18-3.
- R. K. Bono, J. A. Tarduno, R. D. Cottrell, E. Thern, M. S. Dare, 2017. "The thermal and magnetic history of the Jack Hills metasediments and the nature of magnetic inclusions in their hosted zircons: Implications for Earth's earliest dynamo," 2017 MagIC Workshop.
- R. K. Bono, J. A. Tarduno, R. D. Cottrell, M. S. Dare, 2016. "The paleomagnetic record of Eoarchean to Hadean zircons: Magnetic hysteresis, imaging magnetic sources, micromagnetic modeling and constraining post-formation heating," AGU Fall Meeting, Abstract: GP22A-0007.
- M. S. Dare, R. K. Bono, J. A. Tarduno, R. D. Cottrell, 2016. "Directional cluster analysis on a sphere: Retrieval of Archean magnetic directions from data with high dispersion," AGU Fall Meeting, Abstract: GP31A-1296.

- R. K. Bono, J. A. Tarduno, A. V. Smirnov, 2016. "The Cambrian Earth: Rotation stability, a growing inner core, and buffeting by the solar wind," 4th Beijing Earth and Planetary Interiors Symposium.
- R. K. Bono, J. A. Tarduno, R. D. Cottrell, M. S. Dare, 2016. "Preservation of Archean to Hadean magnetizations in metasediments and single zircons of the Jack Hills, Western Australia," 4th Beijing Earth and Planetary Interiors Symposium.
- R. K. Bono, J. A. Tarduno, 2015. "Ediacaran paleomagnetic field records from Laurentia: Insights into the evolution of the diversity of life and Earth's deep interior," AGU Fall Meeting, Abstract: GP23B-1306.
- R. K. Bono, J. A. Tarduno, 2015. "The Nature of the Ediacaran to Early Cambrian Geomagnetic Field," Joint AGU/CGU Montreal Meeting, Abstract: GP22A-0004.
- R. K. Bono, J. A. Tarduno, 2015. "Preliminary Paleomagnetic Analysis of Mesosiderite Northwest Africa 8368," 46th Lunar and Planetary Science Conference, 1832, p. 2605.
- R. K. Bono, J. A. Tarduno, F. Nimmo, E. Scott, L. Ferrière, 2014. "Mixing of Impactor Liquid Cores and Planetesimals Constrained by Single Silicate Crystal Magnetism," AGU Fall Meeting, Abstract: P44A-0002.
- R. K. Bono, J. A. Tarduno, 2013. "Polar wander, rapid plate velocity, or an equatorial dipole: A single silicate crystal study of the ca. 565 Ma Sept Iles Intrusive Suite in Laurentia," AGU Fall Meeting, Abstract: GP12A-03.
- R. K. Bono, J. A. Tarduno, B. Singer, 2013. "Cretaceous magmatism in the High Canadian Arctic: Implications for the nature and age of Alpha Ridge," EGU General Assembly, EGU2013-11429.
- R. K. Bono, J. A. Tarduno, 2012. "New paleolatitude data from Midway Atoll: evidence for long-term stability of Earth's spin axis," GSA Annual Meeting, Abstract: T54-0002.
- R. K. Bono, J. A. Tarduno, R. D. Cottrell, P. Higgins, D. B. Brinkman, 2010. "Turonian Ultra-thermal Conditions as Recorded in the High Canadian Arctic: Faunal Controls and Tectomagmatic Boundary Conditions," AGU Fall Meeting, Abstract: PP11B-1441.
- R. K. Bono, J. A. Tarduno, R. D. Cottrell, 2009. "Rock and Paleomagnetism of Late Cretaceous-Paleogene Volcanic Rocks of Northern Ellesmere Island, High Canadian Arctic," AGU Fall Meeting, Abstract: GP13B-0776.

Co-authored presentations and posters:

- A. J. Biggin, A. van der Boon, L. Hawkins, D. Thallner, J. M. Grappone, R. K. Bono, *et al.*, 2020. "Strange fields: non-uniformitarian paleomagnetic records imply that the geodynamo process has been substantially perturbed on multiple occasions," AGU Fall Meeting, DI6-0014.
- C. J. Sprain, A. J. Biggin, R. K. Bono, C. J. Davies, *et al.*, 2020. "Assessing the Robustness of Long-term Field Variations in the Paleomagnetic Record," AGU Fall Meeting, GPE8-0004.
- D. G. Meduri, A. J. Biggin, C. J. Davies, R. K. Bono, C. J. Sprain, 2020. "Numerical Geodynamo Simulations Can Capture the Long-Term Variability of the Paleomagnetic Field," AGU Fall Meeting, DI6-0013.
- C.J. Sprain, R.E. Lamers, J.M. Feinberg, E. Hurst, A. J. Biggin, R. K. Bono, 2019. "Paleomagnetic Characterization of North American Clunker Deposits: Reliable Full Vector Recorders for the Quaternary," AGU Fall Meeting, GPE33A-0006.
- R. D. Cottrell, K. Lawrence, R. K. Bono, C. Johnson, J. A. Tarduno, 2019, "Evidence for a Late Lunar Dynamo," AGU Fall Meeting, GP43B-0794.
- A. J. Biggin, R. K. Bono, C. J. Sprain, *et al.*, 2019. "Integration of palaeomagnetic data and numerical dynamo simulations support a moderately dipolar geomagnetic field throughout Earth history," AGU Fall Meeting, DI14A-0008.
- J. A. Tarduno, R. D. Cottrell, R. K. Bono, F. Nimmo, 2019. "Geodynamo origin to inner core growth: Core chemical evolution traced by paleomagnetism," AGU Fall Meeting, DI13A-0006.
- J. A. Tarduno, R. K. Bono, 2019. "Hotspot and LLSVP wander," EGU General Assembly, EGU2019-3143.
- R. D. Cottrell, J. A. Tarduno, R. K. Bono, H. Oda, 2019. "Paleomagnetic remanence tests: the essentials for investigations of the ancient geodynamo held by single crystals," EGU General Assembly, EGU2019-8703.
- C. J. Sprain, A. J. Biggin, C. J. Davies, R. K. Bono, 2018. "Qualitative Paleomagnetic Geodynamo Modelling (QPM) criteria: How well do numerical geodynamo models reproduce the long-term paleomagnetic field?" AGU Fall Meeting, GP32A-0007.
- A. J. Biggin, C. J. Sprain, R. K. Bono, C. J. Davies, 2018. "Reducing the latitudinal-dependence of VGP dispersion using outputs from dynamo models," AGU Fall Meeting, GP43A-0761.
- J. A. Tarduno, R. K. Bono, 2018. "Hotspot and LLSVP Motion (Invited)," AGU Fall Meeting, GP23A-0001.
- W. Huang, J. A. Tarduno, R. D. Cottrell, R. K. Bono, E. Thern, 2018. "Unraveling Archean magnetic histories by a comparison of whole rock and single crystal analyses of granites from Western Australia," AGU Fall Meeting, GP21B-0645.

- R. D. Cottrell, J. A. Tarduno, R. K. Bono, H. Oda, 2018. "Microconglomerate tests establish magnetic fidelity of Hadean zircons," AGU Fall Meeting, GP11A-0008.
- A. J. Biggin, C. J. Sprain, R. K. Bono, C. J. Davies, M. Heimpel, R. Holme, 2018. "Detecting externally forced long term palaeomagnetic variations: insight from dynamo simulations," 16th Castle Meeting, Checiny, Poland.
- C. J. Sprain, A. J. Biggin, C. J. Davies, R. K. Bono, 2018. "Long-term variations in Earth's magnetic field: The development of a tool for the exploration of Earth's deep interior over geologic time," RAS Meeting, Dynamics and evolution of Earth's coupled core-mantle system.
- J. A. Tarduno, R. D. Cottrell, R. K. Bono, F. Nimmo, 2018. "Two-silicate crystal approach to paleomagnetism and inner core growth," EGU General Assembly, EGU2018-10509.
- J. A. Tarduno, R. K. Bono, 2017. "Hotspot motion caused the Hawaiian-Emperor Bend and LLSVPs are not fixed," AGU Fall Meeting, Abstract: GP21A-0008.
- J. A. Tarduno, E. G. Blackman, H. Oda, R. K. Bono, J. Carroll-Nellenback, R. D. Cottrell, F. Nimmo, 2017. "Earth's paleomagnetsphere and planetary habitability," AGU Fall Meeting, Abstract: P53E-2673
- J. A. Tarduno, V. J. Hare, R. D. Cottrell, T. Huffman, M. Watkeys, R. K. Bono, 2017. "An archeomagnetic record from southern Africa and its bearing on the history of the South Atlantic Anomaly," GSA Cordilleran Section Annual Meeting, Abstract: 45-3.
- J. A. Tarduno, R. D. Cottrell, R. K. Bono, E. Thern, 2016. "The first billion years of the geodynamo and its implications for the early core," AGU Fall Meeting, Abstract: DI42A-0007.
- R. D. Cottrell, J. A. Tarduno, R. K. Bono, E. Thern, S. K. Chhibber, 2016. "The Hadean to Paleoproterozoic geodynamo: microconglomerate tests from siliciclastic metasedimentary rocks from the Southern Cross Terrane of Western Australia," AGU Fall Meeting, Abstract: DI13A-2344.
- J. A. Tarduno, R. D. Cottrell, R. K. Bono, T. O'Brien, A. V. Smirnov, 2016. "The earliest magnetic fields of Earth and other solar system bodies," 4th Beijing Earth and Planetary Interiors Symposium.
- A. V. Smirnov, J. A. Tarduno, R. K. Bono, 2016. "Earth's core history: A paleomagnetic view," 4th Beijing Earth and Planetary Interiors Symposium.
- A. Smirnov, J. A. Tarduno, E. V. Kulakov, S. A. McEnroe, R. K. Bono, 2016. "Potential changes in stratification but no evidence for a Mesoproterozoic inner core age," EGU General Assembly, EGU2016-8829.
- R. D. Cottrell, J. A. Tarduno, R. K. Bono, M. S. Dare, 2016. "The inverse microconglomerate test: Definition and application to the preservation of Paleoproterozoic to Hadean magnetizations in metasediments of the Jack Hills, Western Australia," EGU General Assembly, EGU2016-9203.
- J. A. Tarduno, K. Walders, R. K. Bono, J. Pelz, R. Jacobs, 2015. "Evaluating Experience-Based Geologic Field Instruction: Lessons Learned from A Large Scale Eye-Tracking Experiment," AGU Fall Meeting, Abstract: ED33E-0002.
- J. A. Tarduno, R. D. Cottrell, R. K. Bono, M. Dare, 2015. "Evidence for a Hadean to Paleoproterozoic geodynamo: Implications for the survivability of planetary hydrospheres," AGU Fall Meeting, Abstract: P34C-0002.
- R. D. Cottrell, J. A. Tarduno, R. K. Bono, 2015. "Micro-conglomerate tests and the Hadean to Paleoproterozoic geodynamo as recorded in zircons of the Jack Hills," AGU Fall Meeting, Abstract: GP23B-1302.
- M. Dare, J. A. Tarduno, R. D. Cottrell, R. K. Bono, 2015. "Multi-scale analyses of magnetic carriers in the Jack Hills metaconglomerates, Western Australia: Further evidence for a primary magnetization," AGU Fall Meeting, Abstract: GP23B-1304.
- J. A. Tarduno, R. K. Bono, R. D. Cottrell, 2015. "Paleoproterozoic and Cambrian observations of the geodynamo in light of new estimates of core thermal conductivity," EGU General Assembly, EGU2015-8059.
- J. A. Tarduno, R. K. Bono, D. B. Brinkman, J. Clarke, P. Higgins, 2014. "The Ultra Warm Arctic Ca. 90 Million Years Ago: Testing Linkages with Volcanic CO₂ Outgassing," GSA Annual Meeting, Abstract: 106-13.
- J. A. Tarduno, R. K. Bono, 2014. "Hotspot Motion, Before and After the Hawaiian-Emperor Bend," AGU Fall Meeting 2014, Abstract: DI34A-0002.
- R. D. Cottrell, J. A. Tarduno, R. K. Bono, 2014. "Paleomagnetic measurements of Archean and Hadean zircons," AGU Fall Meeting, Abstract: GP53A-3752.
- J. A. Tarduno, R. K. Bono, R. D. Cottrell, L. Ferrière, E. R. D. Scott, 2014. "Paleomagnetism of the Eagle Station Pallasite," 77th Annual Meteoritical Society Meeting, 5453.
- B. Hu, T. P. Keane, R. K. Bono, J. A. Tarduno, B. B. May, N. D. Cahill; R. A. Jacobs, J. B. Pelz, 2013. "Eye Tracking in Geoscience: Data Registration and Visualization," AAPG Hedberg Research Conference, Reno, NV.
- J. A. Tarduno, B. Hu, B. B. May, K. M. Evans, R. A. Jacobs, J. B. Pelz, R. D. Cottrell, and R. K. Bono, 2012. "An Active Vision Approach to Understanding and Improving Visual Training in the Geosciences," GSA Annual Meeting, Abstract: 35-DP8.

- R. D. Cottrell, J. A. Tarduno, R. K. Bono, 2012. "Probing the Oldest Geodynamo," EGU General Assembly, EGU2012-12523.
- J. A. Tarduno, R. K. Bono, 2011. "Late Cretaceous to Paleogene plate motion, mantle flow and polar wander constrained by paleomagnetic data (Invited)," AGU Fall Meeting, Abstract: T33I-0004.

Service and Community Engagement

ETH Earth Sciences colloquium, invited speaker	November 2020
MagNetZ, online seminar series, co-organizer	Summer 2020 - present
RAS Discussion, "Observing and simulating Earth's core and the magnetic field", organizer	November 2019
Royal Society Summer Science Exhibition, "Magnetic to the Core"	July 2019
Victoria Gallery and Museum School Holiday Workshop	May 2019
Ness Botanic Gardens Family Science Fair	March 2019

Field Research, Travel, and Teaching Experience

Western Australia, Archean granites, cherts and conglomerates	Summer 2011, 2012, 2016
Canadian High Arctic, Cretaceous volcanics and paleoclimate	Summer 2012, 2015
Cornell University, FIB preparation and TEM study of silicate crystals	2014-2016
Northern Quebec, Ediacaran mafic intrusions	Fall 2012, 2014
FORC workshop, Institute for Rock Magnetism, Sante Fe, NM	Summer 2014
Cornell University, electron microprobe of silicate crystals	Fall 2013
Active geology of California, undergraduate field trip and geocognition study	Spring 2011-2013
Western Australia, Cretaceous volcanics	Summer 2012
UT Austin, high resolution CT scanning of Cretaceous Arctic fossils	Spring 2012
South Pacific, Cretaceous volcanics	Summer 2011
University of Hawaii Marine Core Repository, Midway volcanics	Spring 2011

Teaching Experience

<i>Undergraduate and Master's thesis co-supervisor</i>	Fall 2018
<i>Planetary Science, Instructor</i>	Fall 2015-2017
<i>Seminar in Paleomagnetism, Instructor/Teaching Assistant, SEM operator</i>	Fall 2014, Spring 2016
<i>Undergraduate geology field camp in the Canadian High Arctic, Teaching Assistant</i>	Summer 2012, 2015
<i>Marine Geophysics, Teaching Assistant, SEM operator</i>	Spring 2014
<i>Planetary Science, Teaching Assistant</i>	Fall 2012, 2013
<i>Earthquakes, Volcanoes and Mountain Ranges in California: A Field Quest, Teaching Assistant</i>	Spring 2011-2013
<i>Introduction to Geological Sciences, Teaching Assistant</i>	Fall 2010-2012
<i>Evolution of Earth History, Teaching Assistant</i>	Spring 2009-2012