FRED RICHARDS

Imperial College Research Fellow, Imperial College London

Geophysicist and geologist with expertise in geodynamics, palaeoclimate, mineral physics and surface processes.

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Tel: +44 (0)73 6881 8674 Date of Birth: 17/01/1991 Nationality: British

ACADEMIC POSITIONS

Oct 2019 – Present: Department of Earth Science and Engineering, Imperial College London.
Imperial College Research Fellow

Evidence of Success: Three manuscripts derived from this work have been published, including one invited submission, with two more in review (*Nat. Geosci.*; *EPSL; JGR: Solid Earth*; *PEPI*) and a further three to be submitted imminently (*Nature*; *GRL; Miner. Depos.*). I have received nine talk invitations (including SEG, SEDI, and ETH), an A$170,000 grant from Geoscience Australia, and an additional £10,000 for fieldwork in Greenland with my PhD student.

Research: Long-term sea-level variations and dynamic topography; 3D viscosity variation and glacial isostatic adjustment; lower mantle structure and dynamics; sediment-hosted mineral deposits; the lithosphere-asthenosphere system; impact of small-scale convection on margin evolution; influence of geodynamics and ice mass changes on Earth's orbital dynamics; landscape evolution modelling; geophysical, petrological and geomorphological investigation of mid-continent swells; and supercontinent insulation.

Funding: Imperial College London – ~£222,000

Key Collaborators: Mark Hoggard (ANU), Paula Koelemeijer (RHUL), Harriet Lau (Berkeley), Sia Ghelichkhan (ANU), Jacqueline Austermann (Columbia), Jerry Mitrovica (Harvard), Konstantin Latychev (Harvard), Gareth Roberts (Imperial), Saskia Goes (Imperial), Karol Czarnota (GA), Marthe Klöcking (Göttingen), Verónica Rodríguez Tribaldos (LBNL), Oliver Shorttle (Cambridge), Alistair Crosby (BP), Magdalena Scheck-Wenderoth (GFZ Potsdam).

Teaching and Supervision: I am lead supervisor of a NERC DTP student and two MSci students, with three manuscripts currently in preparation. I lecture, develop materials, and set assessments for undergraduate and graduate courses, and have received universally positive feedback. I have led groups on the Apennines virtual field course and co-wrote the geophysics section of the field guide.

Sep 2018 – Sep 2019: Department of Earth and Planetary Sciences, Harvard University.
Schmidt Science Fellow

Evidence of Success: Four peer-reviewed publications stemming directly from this work have now been published or accepted (*Nat Geosci*; *Ann. Rev. Earth Plan. Sci; GJI; Icarus*), plus two non peer-reviewed articles. This work has led to four invited talks (including AGU, EGU, and IUGG), has been covered in *The Economist* and *Scientific American*, and our sediment-hosted metal deposit research was estimated to be worth A$147-752 million to the Australian economy by independent consultancy, ACIL Allen.

Research: Interaction between mantle dynamics and palaeoclimate; sediment-hosted mineral deposits; and influence of geodynamics and ice mass changes on Earth's orbital dynamics.

Funding: Schmidt Futures & Rhodes Trust – $100,000

Key Collaborators: Mark Hoggard (ANU), Karol Czarnota (GA), Sia Ghelichkhan (ANU), Jerry Mitrovica (Harvard), Jacqueline Austermann (Columbia).

Teaching and Supervision: I advised and collaborated with two PhD students leading to two publications (Powell *et al.*, 2019, *J. Clim.*; Mitrovica *et al.*, 2020, *Ann. Rev. Earth Plan. Sci.*). A third is in preparation. I delivered a lecture on the stratigraphic record of dynamic topography for Jerry Mitrovica's graduate sea-level course, obtaining an excellent "Q" score from students (4.5 out of 5).

EDUCATION

Oct 2014 – Aug 2018: Bullard Laboratories, Department of Earth Sciences & Jesus College, University of Cambridge.
PhD Earth Sciences (Geophysics) – passed with no corrections.

Thesis: *Global Analysis of Predicted and Observed Dynamic Topography*

Supervisors: Prof. Nicky White & Dr. Paul Bellingham (ION Geophysical Ltd.)

Evidence of Success: My first publication was given the G^3 Editors' Highlight award for its innovative and integrated approach, and I published two further first-author publications before the end of my PhD. As a result of this work, I received a RAS Keith Runcorn Prize for best thesis in geophysics and planetary science (runner-up), and gave three invited talks at Imperial, Harvard and Columbia. In addition to a NERC PhD studentship (£14,000 p.a.+£10,000), and Jesus College Travel Grant (£500), my doctoral research was instrumental in securing the highly competitive Schmidt Science Fellowship and Imperial College Research Fellowship.

Funding: Natural Environment Research Council Earth System Science DTP – ~£60,000

Key Collaborators: Mark Hoggard (ANU), Sia Ghelichkhan (ANU), Jacqueline Austermann (Columbia).

Teaching and Supervision: I advised and collaborated with seven junior PhD and four MSci students, with co-created codes and data sets forming an integral part of to two publications (McNab *et al.*, 2018, G^3; Stephenson *et al.*, 2019, *EPSL*). I also tutored undergraduates (~8 hrs per term), demonstrated practicals (~2 hrs per week), and demonstrated on field trips (3 x Isle of Arran).

Oct 2010 – Jun 2014: Department of Earth Sciences & St. Anne's College, University of Oxford.
MSci Earth Sciences: 1st Class Honours – graduated top of the class.

MSci Project: *The Origin, Structural Evolution and Potential Field Signatures of the Tasmantid Seamount Chain* (supervised by Dr. Lara Kalnins & Prof. Tony Watts) – **highest mark in year (84%)**; findings published in G^3.

SELECTED AWARDS & HONORS:

2019–2023 1 of 20 selected for 4-year Imperial College Research Fellowship.

2018–2019 1 of 14 selected in inaugural class of Schmidt Science Fellows.

2018 Royal Astronomical Society Keith Runcorn Prize for best thesis in geophysics and planetary science – runner-up.

2017 G^3 Editors' Highlight for first-author research paper ("Cenozoic Epeirogeny of the Indian Peninsula").

2015 Jesus College Doctoral Research Grant.

2014–2018 Natural Environment Research Council PhD Studentship, Cambridge Earth Sciences Department.

2014 BP Prize for best MSci Project, Oxford Earth Sciences Department.

2013 Burdett-Coutts Prize for top mark in Final Honour School, Oxford Earth Sciences Department.

2013 Shell Prize for top mark in Geochemistry, Oxford Earth Sciences Department.

2011-2014 St. Anne's College & University of Oxford Scholarship for performance in examinations.

PUBLICATIONS

2021

1. Austermann, J., Hoggard, M. J., Latychev, K., **Richards, F. D.** & Mitrovica, J. X., The effect of lateral variations in Earth structure on Last Interglacial sea level, *Geophys. J. Int.*, **227**, pp. 1938-1960, doi: 10.1093/gji/ggab289.

2020

2. Richards, F. D., Hoggard, M. J., Crosby, A. G., Ghelichkhan, S. & White, N. J., Structure and Dynamics of the Oceanic Lithosphere-Asthenosphere System, *Phys. Earth Plan. Int.*, 106559, doi: 10.1016/j.pepi.2020.106559. Invited submission.

3. Richards, F. D., Hoggard, M. J., White, N. J. & Ghelichkhan, S., Quantifying the relationship between short-wavelength dynamic topography and thermomechanical structure of the upper mantle using calibrated parameterization of anelasticity, **125**, e2019JB019062, doi: 10.1029/2019JB019062.

4. Hoggard, M. J., Czarnota, K., **Richards, F. D.**, Huston, D. L., Jaques, A. L. & Ghelichkhan, S., Global distribution of sediment-hosted metals controlled by craton edge stability, *Nature Geoscience*, **13**, pp. 504-510, doi: 10.1038/s41561-020-0593-2.

5. Klöcking, M., Hoggard, M. J., Rodríguez Tribaldos, V., **Richards, F. D.**, Guimarães, J. A., Maclennan, J. C. & White, N. J., A tale of two domes: Neogene to recent volcanism and dynamic uplift of northeast Brazil and southwest Africa, *Earth Planet. Sci. Lett.*, **547**, 116464, doi: 10.1016/j.epsl.2020.116464.

6. Mitrovica, J. X., Austermann, J., Coulson, S. L., Creveling, J. R., Hoggard, M. J., Jarvis, G. T. & **Richards, F. D.**, Dynamic Topography and Ice Age Paleoclimate, *Ann. Rev. Earth Planet. Sci.*, **48**(1), pp. 585-621, doi: 10.1146/annurev-earth-082517-010225.

7. Ghelichkhan, S., Fuentes, J. J., Hoggard, M. J., **Richards, F. D.** & Mitrovica, J. X., The Precession Constant and its Long-Term Variation, *Icarus*, 114172, doi: 10.1016/j.icarus.2020.114172.

8. Czarnota, K., Hoggard, M. J., **Richards, F. D.**, Teh, M., Huston, D. L., Jacques, A. L. & Ghelichkhan, S., Minerals on the edge: Sediment-hosted base metal endowment above steps in lithospheric thickness, *Exploring for the Future: Extended Abstracts*, Geoscience Australia, Canberra, doi: 10.11636/134991.

9. Huston, D. L., Champion, D. C., Czarnota, K., Hutchens, M., Hoggard, M. J., Ware, B. D., **Richards, F. D.**, Tessalina, S. D., Gibson, G. M. & Carr, G., Lithospheric-scale controls on zinc-lead-silver deposits of the North Australian Zinc Belt: evidence from isotopic and geophysical data, *Exploring for the Future: Extended Abstracts*, Geoscience Australia, Canberra, doi: 10.11636/134276.

2018

10. Richards, F. D., *Global Analysis of Predicted and Observed Dynamic Topography* (Doctoral thesis), doi: 10.17863/CAM.31532.

11. Richards, F. D., Kalnins, L. M., Watts, A. B., Cohen, B. E. & Beaman R. J., The Morphology of the Tasmantid Seamounts: Interactions Between Tectonic Inheritance and Magmatic Evolution, *Geochem. Geophys. Geosyst.*, **19**, pp. 3870-3891, doi: 10.1029/2018GC007821.

12. Richards, F. D., Hoggard, M. J., Cowton, L. R. & White, N. J., Reassessing the Thermal Structure of Oceanic Lithosphere with Revised Global Inventories of Basement Depths and Heat Flow Measurements, *J. Geophys. Res.: Solid Earth*, **123**, pp. 9136-9161, doi: 10.1029/2018JB015998.

2016 **13. Richards, F. D.**, Hoggard, M. J. & White, N. J., Cenozoic Epeirogeny of the Indian Peninsula, *Geochem. Geophys. Geosyst.*, **17**, pp. 1525-2027, doi: 10.1002/2016GC006545.

UPCOMING PUBLICATIONS & PREPRINTS

14. Richards, F. D., Hoggard, M. J., Ghelichkhan, S., Koelemeijer, P. & Lau, H. C. P., Geodynamic, Geodetic and Seismic Constraints Favour Deflated and Dense-Cored LLVPs, *in review at Nature Geosci*. Preprint doi: 10.31223/X55601.

15. Hoggard, M. J., Shorttle, O., **Richards, F. D.**, White, N. J. & Maclennan J. C., Reconciling Geophysical and Geochemical Observations of Supercontinent Insulation, *in review at Earth Planet. Sci. Lett.* Bibcode: 2018EGUGA..20..513H.

16. Richards, F. D., Coulson, S. L., Austermann, J., Hoggard, M. J. & Mitrovica, J. X., The Impact of Mantle Dynamics on Australian Mid-Pliocene Sea-Level Records, *in prep. for submission to Nature*. Bibcode: 2021EGUGA..2312420R.

17. Ghelichkhan, S., Moore K. M., Hoggard, M. J., **Richards, F. D.** & Mitrovica, J. X., The Signal from Mantle Convection in Modern True Polar Wander, *in prep. for submission to GRL*. Bibcode: 2020AGUFMDI014..02G.

18. Huston, D. L., Champion, D. C., Czarnota, K., Duan, J., Hutchens, M., Paradis, S. G., Hoggard, M. J., Ware, B. D., Gibson, G. M., Doublier, M. P., Kelley, K. D., McCafferty, A. E., Hayward, N., **Richards, F. D.**, Tessalina, S. D. & Carr, G. R., Zinc on the edge: isotopic and geophysical evidence that cratonic edges control shale-hosted zinc-lead deposits, *in prep. for submission to Mineralium Deposita*. Bibcode: 2020AGUFMV007.0007H.

OTHER PUBLICATIONS

2021 **19.** O'Brien, A. C., Boubert, D., Bowman, D. M., **Richards, F. D.**, & Maunder, M., Pandemic Posters, *Astron. Geophys.*, **62**(1), pp. 19, doi: 10.1093/astrogeo/atab039.

20. Bowman, D. M., Maunder, M., **Richards, F. D.**, O'Brien, A. C., & Boubert, D., Hear it through the grapevine, *Astron. Geophys.*, **62**(4), pp. 12-14, doi: 10.1093/astrogeo/atab076.

FUNDING OBTAINED

2021–2024 **Geoscience Australia Exploring for the Future Grant (A$170,000) –** deciphering thermochemical structure of mantle lithosphere and its links with the location of critical mineral resources.

2019–2023 **Imperial College Research Fellowship (~£48,500 p.a. + £28,200 research expenses)** – impact of mantle dynamics and structure on mineral resource formation, landscape development, and ice sheet stability.

SSCP DTP Fieldwork Fund (£10,000) – secured to partially cover costs of field trip to East Greenland and cosmogenic nuclide exposure dating of rock samples.

2018–2019 **Schmidt Science Fellowship ($100,000)** – impact of dynamic topography on palaeo sea-level estimates.

2015 **Jesus College Travel Grant (£500)** – used to attend EGU 2015, Vienna.

2014–2018 **NERC PhD Studentship** (**£14,000 p.a. + £10,000 research expenses**)– global analysis of predicted and observed dynamic topography.

INVITED TALKS

(K) = *keynote or plenary*

2021 **Richards, F. D.**, Inferring upper mantle thermomechanical structure using calibrated parameterisations of anelasticity, GFZ Potsdam Basin Modelling Seminar, GFZ Potsdam, Potsdam (DE).

Richards, F.D., How high will sea-levels rise? Lessons from the geological record, Climate Change: Impacts and Innovations Virtual Conference in association with Schmidt Science Fellows.

2020 **Richards, F. D. (K)**, Gigayear stability of cratonic edges controls global distribution of sediment-hosted metals, Society of Economic Geologists Vision 2020 Meeting, Whistler (CA). Postponed to 2021.

Richards, F. D., Hoggard, M. J., Ghelichkhan, S. & Lau, H. C. P., What Are LLSVPs? Geodynamic Insights into Lower Mantle Chemistry and Structure, SEDI 2020, Taipei (TW).

Richards, F. D., Mapping Seismic Tomography into Earth Structure: Implications for Dynamic Topography, Lithospheric Stability, and Sea-Level Reconstructions, Bullard Laboratories Wednesday Seminar, University of Cambridge, Cambridge (UK).

Richards, F. D., Earth's Dynamic Topography: Implications for Mantle Structure and Sea-Level Records, Geophysical Fluid Dynamics Seminar, ETH Zürich, Zürich (CH).

Richards, F. D., Mapping Seismic Tomography into Upper Mantle Structure: Implications for Dynamic Topography and Sea-Level Reconstructions, Earth and Planets Seminar, Imperial College, London (UK).

Richards, F. D., Gigayear stability of cratonic edges controls global distribution of sediment-hosted metals, Mineral Deposits Group Seminar, Natural History Museum, London (UK).

2019 **Richards, F. D.**, Hoggard, M. J., Ghelichkhan, S. & Lau, H. C. P., What Are LLSVPs? Geodynamic Insights into Lower Mantle Chemistry and Structure, AGU Fall Meeting, San Francisco (USA), DI23A-03.

Richards, F. D., Hoggard, M. J., Ghelichkhan, S. & Lau, H. C. P., The Role of LLSVPs in Reconciling Observations and Predictions of Earth's Dynamic Topography, IUGG, Montréal (CA), IUGG19-3669.

Richards, F. D., Hoggard, M. J., Ghelichkhan, S. & Lau, H. C. P., Reconciling Observations and Predictions of Earth's Dynamic Topography, *Geophysical Research Abstracts*, **21**, EGU, Vienna (AT), EGU2019-3744.

Richards, F. D., Mapping Upper Mantle Heterogeneity and Its Impact on Dynamic Topography, Geodynamics Seminar, Lamont-Doherty Earth Observatory, Columbia University, Palisades (USA).

2018 **Richards, F. D.**, Reconciling Observations and Predictions of Earth's Dynamic Topography, BiSEPPS Seminar, Harvard University, Cambridge (USA).

Richards, F. D., Global Dynamic Topography and its Impact on Australian Sea-Level, Friends of PlioMax Meeting, Lamont-Doherty Earth Observatory, Columbia University, Palisades (USA).

Richards, F. D., Resolving Discrepancies Between Observed and Predicted Dynamic Topography, Earth and Planets Seminar, Imperial College, London (UK).

N.B. ***35*** *regular conference presentations at AGU (****22****), EGU (****9****), IUGG (****1****) and BGA (****3****) not shown.*

SELECTED MEDIA COVERAGE

2020 Scientific American: *"Science Pinpoints Global Metal Deposit Locations"*.
Eos: "Cratons Mark the Spot for Mineral Bonanzas".
Imperial College: *"Scientists find link between tectonic plate thickness and base metal deposits"*.

2019 The Economist: *"Ore bodies, it has been discovered, are not randomly distributed"*.
Mining Journal: *"The story behind one of the year's biggest discoveries"*

TEACHING & SUPERVISION

2019–Present *Imperial*
Principal PhD supervisor of James Hazzard, NERC-funded through Imperial College SSCP DTP.

Lecturer for 3rd-Year Continental Tectonics and MSci Basin Analysis courses. Received positive evaluations from students praising the structure of lectures, integration of computational tools (e.g., Jupyter notebooks), explanations of key concepts, and my checking in with each student to clarify material that they may have struggled with.

Designed and supervised two projects for Geology and Applied Computational Science for Engineering MScis.

2019 *Harvard*
Delivered guest lecture to graduate-level Sea Level Change course, receiving excellent student feedback ("Q" score of 4.5 out of 5).

2017 *Cambridge*
Delivered lecture to Part III undergraduates on residual depth anomalies and dynamic topography. Lecture was cited as reason for students applying to do MSci projects in our group.

Mentored, supervised and designed projects for 2 visiting PhD students from Madagascar working on landscape evolution of Tasmania and Southern Africa. Advised and collaborated with 5 other PhD students in my group.

2016–2017 Gave Bullard Laboratories computing talk and contributed several sections to computing guide.

2016 Mentored and supervised 4 MSci students during their final year research projects involving intracratonic basin analysis in Brazil, seismic oceanography in the Faroe-Shetland Channel and drainage inversion of China and Greece. Three received a First, the other received a high 2.1 (>65%), two continued to PhD level.

2014–2018 Tutored over 40 undergraduate students for Part II: Geophysics and Part III: Basin Analysis and Continental Tectonic, all achieved a 2.1 or higher in their end of year exams, including some with <50% in mocks.

2014–2018 Demonstrator for Part IB: Geophysics, Part II: Geophysics and Part III: Basin Analysis.

FIELD EXPERIENCE

2020 **Virtual Field Trip Demonstrating:** Demonstrator and group leader on Imperial's 4th-Year Apennines virtual field trip. Wrote summaries, practical sessions and Jupyter notebooks for geophysical element of the field course.

2018 **Geochronological Sampling and GPS Surveying:** Field assistant on 2-week trip to Bahamas to sample, survey and date MIS 5 corals and beach rocks on Eleuthera, in order to build chronology of sea-level change.

2016–2018 **Field Trip Demonstrating:** Demonstrator on University of Cambridge Isle of Arran Undergraduate Field Trip.

2015 **Geochronological Sampling, GPS and Drone Surveying:** Field assistant on 4-week trip to Madagascar GPS and drone surveying raised coral terraces, collecting basalt for rare-earth element inversion, corals for U-Th dating and granitic/gneissic samples for apatite fission track analysis (AFTA) and apatite-helium Geochronology (AHe).

2013 **Oceanography:** two-day long cruise to Bermuda Atlantic Time Series site, taking CTD measurements and learning how to process ADCP and multi-beam bathymetry data.

2012 **Bedrock Mapping**: 5-week long mapping project on Bracco Ophiolite in Liguria, Italy.

ACADEMIC SERVICE

2021 Lead session convenor: *DI006 - Deep Earth-Surface Interactions: Links between Earth's Internal Dynamics and Evolution of the Hydrosphere, Atmosphere and Biosphere* at 2021 AGU Fall Meeting, New Orleans (USA).

2020–Present Events Team Leader, Royal Astronomical Society Early Career Network.

Imperial College Earth & Planets Seminar organiser.

Imperial-MIT Seed Fund Review Panel member.

Imperial Schmidt Science Fellows Application Review Panel member.

2018–2019 Harvard University Graduate Student and Postdoc Seminar organiser.

2016–Present Peer Reviewer: *AGU Books*; *Earth-Science Reviews*, *Geochemistry, Geophysics, Geosystems*; *Geology*; *Geophysical Research Letters*; *Journal of Geophysical Research: Solid Earth*; *Marine Geophysical Research*; *Physics of the Earth and Planetary Interiors*, *Science Advances*.

OUTREACH & PUBLIC POLICY ENGAGEMENT

2021 Organised and chaired two careers events and a poster competition for the RAS Early Career Network.

Application shortlisted for Royal Society Pairing Scheme, which aims to build bridges between researchers and civil servants.

"How to become a Geologist" talk for School21 Career Paths (https://www.youtube.com/watch?v=l2jC5zz2o7s).

2020 Invited post on dynamic topography for EGU's Geodynamics blog.

"What's Our Planet Made Of?" outreach event at Hurlingham School.

Speaker at UCL Insight "Careers in Research within Academia" event.

2019 Co-organised AGU Fall Meeting Town Hall session entitled "Disaster Policies or Disastrous Policies? A Town Hall at the Junction of Natural Hazards, Society, Science Policy, and Communication".

Wrote article on science policy interaction for Schmidt Science Fellows website

2017 Organised and coordinated Planet Earth section of Cambridge Pint of Science festival; chaired "Breathe Easy: The Future of Energy Is Here" evening (16th May).

2016–2018 Workshops Coordinator for Cambridge University Science and Policy Exchange. Elected by committee of 12 peers; organised > 7 workshops for Cambridge students interested in science-policy interaction, 3 of which explored future of energy/Cleantech; successfully coordinated 4-member multicultural team; all have been oversubscribed and received excellent feedback; learnt to communicate science effectively to non-specialists in government and industry.

2015–2018 Helped contact speakers and find venues for Cambridge University Energy Network lectures and conferences.

REFEREES

Prof. Jacqueline Austermann, Assistant Professor, Department of Earth and Environmental Sciences, Columbia University.
Email: jackya@ldeo.columbia.edu, Tel: +1 845 365 8971.

Prof. Jerry X. Mitrovica, Frank Baird, Jr. Professor of Science, Department of Earth and Planetary Sciences, Harvard University.
Email: jxm@eps.harvard.edu, Tel: +1 617 496 2732.

Dr. Gareth G. Roberts, Senior Lecturer, Department of Earth Science and Engineering, Imperial College London.
Email: gareth.roberts@imperial.ac.uk, Tel: +44 (0)20 7594 7363.

Prof. Anthony B. Watts FRS, Professor of Marine Geophysics, Department of Earth Sciences, University of Oxford.
Email: tony@earth.ox.ac.uk, Tel: +44 (0) 1865 282121.

Prof. Nicholas J. White, Professor of Cymatogeny, Bullard Laboratories, Department of Earth Sciences, University of Cambridge.
Email: njw10@cam.ac.uk, Tel: +44 (0) 1223 337063.