

ANNUAL REPORT ON GEOTRACES ACTIVITIES IN UNITED KINGDOM

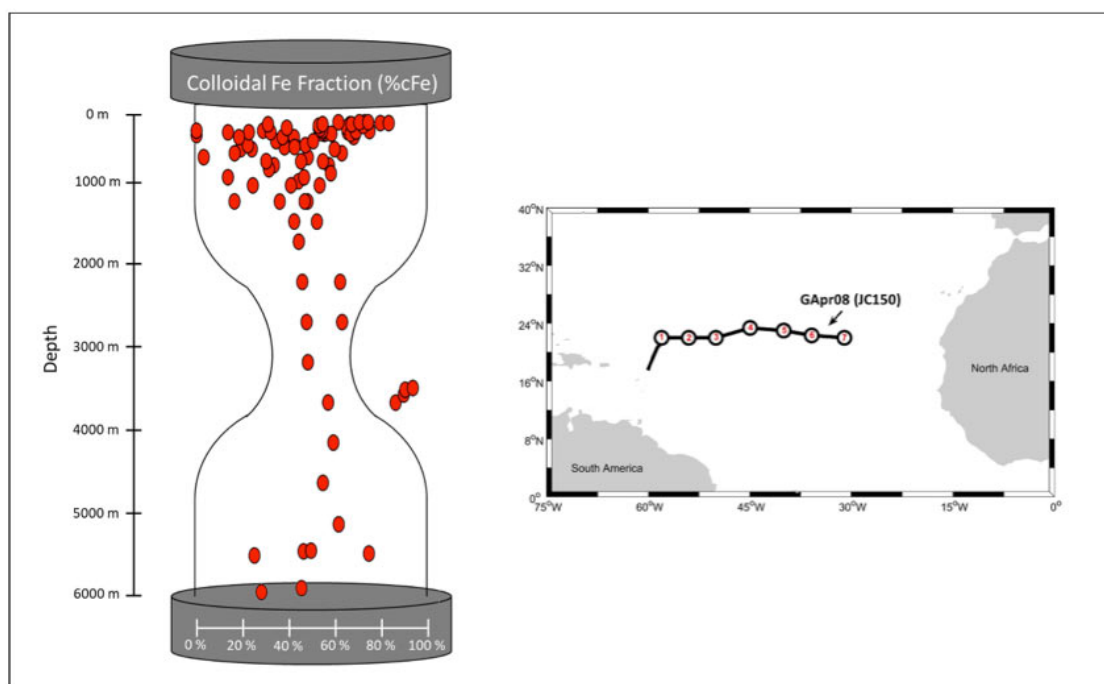
April 1st, 2019 to March 31th, 2020

New scientific results

The Colloidal Hourglass: North Atlantic iron distribution controlled by dynamic colloidal phase

K. Kunde and colleagues (2019) show that a highly dynamic colloidal iron phase in the upper ocean and at the seafloor boundary controls the distribution of dissolved iron at key sources and sinks across the subtropical North Atlantic Ocean, while the ocean interior is marked by an equilibrium partitioning between the soluble and colloidal phases. These processes result in size-fractionated iron distribution resembling an hourglass shape of the colloidal iron fraction (%cFe) of the dissolved pool against depth. In addition, high-resolution surface sampling revealed a strong, dust-derived gradient of surface dissolved iron concentrations that resulted in a “high dust, high %cFe” and “low dust, low %cFe” pattern across the basin. A global comparison of colloidal and dissolved iron reveals that this effect extends to the mesopelagic, where the lithogenic nature of a region is imprinted on the colloidal partitioning signature.

Kunde et al. (2019), Global Biogeochemical Cycles.



Figures: (Left) The fraction of colloidal Fe to the dissolved Fe pool across the GApr08 section forms an hourglass shape against depth. Dynamic Fe cycling in the upper ocean and near the seafloor is reflected in the large range of %cFe, while the tight partitioning in the less dynamic ocean interior forms the neck of the hourglass. The four data points outside this pattern are from the Snakepit hydrothermal source on the Mid-Atlantic Ridge (Station 4) with almost 100% cFe. (Right) Map of the subtropical North Atlantic showing the cruise track and station locations of the GApr08 section (research cruise JC150).

<https://www.geotraces.org/the-colloidal-hourglass-north-atlantic-iron-distribution-controlled-by-dynamic-colloidal-phase/>

Further highlight from ZIPLoC GEOTRACES Process Study (GApr08).

Strong species-specific and zonal gradients in concentrations of metalloenzymes reveals differing control of trace metals iron and phosphorus on PhoX and PhoA respectively, and niche differentiation in phosphorus acquisition strategies for Prochlorococcus and Synechococcus.

Highlight from FRidge GEOTRACES section (GA13).

Large variability in dFe/xsHe measured along a section of the MAR, shows that accounting for vent specific geochemistry will be important in further constraining the hydrothermal Fe flux, in particular the frequency of tectonic (TAG) vs magmatic (Rainbow) vent sites along ridge axes. Large fluxes of iron observed at all hydrothermal vents sampled.

The causes of the 90 ppm glacial atmospheric CO₂ drawdown still strongly debated.

Khatiwala et al. (2019), Science Advances.

<https://www.geotraces.org/the-causes-of-the-90-ppm-glacial-atmospheric-co2-drawdown-still-strongly-debated/>

Upwelled hydrothermal iron stimulates massive phytoplankton blooms in the Southern Ocean.

Ardyna et al. (2019), Nature Communications.

<https://www.geotraces.org/the-causes-of-the-90-ppm-glacial-atmospheric-co2-drawdown-still-strongly-debated/>

Fate of different iron phases along the Lena river plume in the Arctic Ocean.

Conrad et al. (2019), Biogeosciences.

<https://www.geotraces.org/fate-of-different-iron/>

GEOTRACES related cruises

- Gideon Henderson's team (University of Oxford) took place in a 2-day cruise on the Namibian margin to collect waters, particles, and sediments for a study of metal-organic associations on a Namibian fisheries vessel (in collaboration with ETH Zürich team).

New projects and/or funding

- Claire Mahaffey (University of Liverpool), Joanne Hopkins and Maeve Lohan (NOC) won funding for a cruise to the Barents Sea in summer 2021 to investigate nitrogen and iron fixation in the Arctic Ocean (NARC); Natural Environment Research Council (NERC) standard grant, awarded in summer 2019

Outreach activities conducted

- Kate Hendry and Hong Chin Ng (University of Bristol): Pint of Science – Frozen Oceans
<https://pintofscience.co.uk/event/frozen-oceans>

- Susan Little (UCL) wrote an article based on attending a RMetSoc meeting on ‘The Pliocene: The last time Earth had >400 ppm of Atmospheric CO₂’.

Little, S. (2020). *Message in a fossil? Lessons from the last plants on Antarctica*. *Weather*, 75(1), 30-31.

- Tina van de Flierdt (Imperial College London) co-organised a stand on ‘Blast from the Past’ at the Inaugural Exhibition Road Festival in London (29-30 June 2019) and gave a ‘exploration talk’ on her Antarctic work to the public.

Susan Little (UCL) and many other enthusiastic volunteers from a range of UK institutions participated in the two-day activity. The festival attracted over 60,000 visitors.

<https://www.imperial.ac.uk/news/191847/earth-planets-great-exhibition-road-festival/>

<https://www.imperial.ac.uk/news/193776/great-exhibition-road-festival-2019-earns/>

- Tina van de Flierdt (Imperial College London) participated in a panel discussion with 17 year old pupils in the context of the Sutton Summer School to discuss how she became a scientist and what her science entails

Other GEOTRACES activities

- Maeve Lohan (NOCS, co-chair) and Tina van de Flierdt (Imperial College London, committee member) attended a Standards & Intercalibration (S&I) meeting in Norfolk, Virginia, 12-13 June 2019.
- Maeve Lohan (NOCS, S&I co-chair) Alessandro Tagliabue (University of Liverpool, DMC co-chair) attended a DMC meeting in Hobart, Australia, 7-8 September 2019.
- Maeve Lohan (NOCS), Tina van de Flierdt (Imperial College London), Alessandro Tagliabue (University of Liverpool) and Gideon Henderson (University of Oxford) attended the annual SSC meeting in Hobart, Australia, 9-11 September 2019
- Maeve Lohan (NOCS), Tina van de Flierdt (Imperial College London) and Alessandro Tagliabue (University of Liverpool) attended and presented at local workshop on ‘Southern ocean biogeochemistry’ in Hobart, Australia (12-13 September, 2019)

New GEOTRACES and GEOTRACES relevant publications (published or in press)

- Archer, C., Vance, D., Milne, A., Lohan, M.C. (2020), The oceanic biogeochemistry of nickel and its isotopes: New data from the South Atlantic and the Southern Ocean biogeochemical divide, *Earth and Planetary Science Letters*, 535, 116118-116118, <https://doi.org/10.1016/j.epsl.2020.116118>.
- Artigue, L., Lacan, F., van Gennip, S., Lohan, M., Wyatt, N.J., Woodward, E.M.S., Mahaffey, C., Hopkins, J., Drillet, Y. (2020), Water mass analysis along 22°N in the subtropical North Atlantic for the JC150 cruise (GEOTRACES, GApr08), *Deep Sea Research I*, 158, <https://doi.org/10.1016/j.dsr.2020.103230>.
- Blaser, P., Frank, M., van de Flierdt, T. (2019), Revealing past ocean circulation with neodymium isotopes, *Pages Magazine*, 27(2), 54-55, <https://doi.org/10.22498/pages.27.2.54>.
- Clough, R., Lohan, M., Ussher, S., Nimmo, M., Worsfold, P. (2019), Uncertainty associated with the leaching of aerosol filters for the determination of metals in aerosols

particulate matter using collision/reaction cell ICP-MS detection, *Talanta*, 199, 425-430, <https://doi.org/10.16/j.talanta.2019.02.067>.

- Hatton, J.E., Hendry, K.R., Hawkings, J.R., Wadham, J.L., Opfergelt, S., Kohler, T.J., Yde, J.C., Stibal, M., Žárský, J.D. (2019), Silicon isotopes in Arctic and sub-Arctic glacial meltwaters: The role of subglacial weathering in the silicon cycle, *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 475, 20190098, <https://doi.org/10.1098/rspa.2019.0098>.
- Held, N.A. Webb, E.A., McIlvin, M.M., Hutchins, D.A., Cohen, N.R., Moran, D.M., Kunde, K., Lohan, M.C., Mahaffey, C.M., Woodward, E.M.S., Saito, M.A. (2020), Co-occurrence of Fe and P stress in the natural populations of the marine diazotroph *Trichodesmium*, *Biogeosciences*, 17, 2537-2551, <https://doi.org/10.5194/bg-17-2537-2020>.
- Hendry, K.R., Cassarino, L., Bates, S.L., Culwick, T., Frost, M., Goodwin, C., Howell, K.L. (2019), Silicon isotopic systematics of deep-sea sponge grounds in the North Atlantic, *Quaternary Science Reviews*, 210, 1-14, <https://doi.org/10.1016/j.quascirev.2019.02.017>.
- Hendry, K.R., Huvenne, V.A., Robinson, L.F., Annett, A., Badger, M., Jacobel, A.W., Ng, H.C., Opher, J., Pickering, R.A., Taylor, M.L., Bates, S.L., Cooper, A., Cushman, G.G., Goodwin, C., Hoy, S., Rowland, G., Samperiz, A., Williams, J.A., Achterberg, E.P., Arrowsmith, C., Brearley, J.A., Henley, S.F., Krause, J.W., Leng, M.J., Li, T., McManus, J.F., Meredith, M.P., Perkins, R., Woodward, E.M.S. (2019), The biogeochemical impact of glacial meltwater from Southwest Greenland, *Progress in Oceanography*, 176, 102126, <https://doi.org/10.1016/j.pocean.2019.102126>.
- Khatiwala, S., Schmittner, A., Muglia, J. (2019), Air-sea disequilibrium enhances ocean carbon storage during glacial periods, *Science Advances*, 5(6), eaaw4981, <https://doi.org/10.1126/sciadv.aaw4981>.
- Kunde, K., Wyatt, N.J., González-Santana, D., Tagliabue, A., Mahaffey, C., Lohan, M.C. (2019), Iron distribution in the subtropical north Atlantic: the pivotal role of colloidal iron, *Global Biogeochemical Cycles*, 33, 1532-1547, <https://doi.org/10.1029/2019GB00632>.
- Martiny, A.C., Lomas, M.W., Fu, W., Boyd, P.W., Chen, Y-L.L., Cutter, G.A., Ellwood, M.J., Furuya, K., Hashihama, F., Kanda, J., Karl, D.M., Kodama, T., Li, Q.P., Ma, J., Moutin, T., Woodward, E.M.S., Moore, J.K. (2019), Biogeochemical controls of surface ocean phosphate, *Science Advances*, 5 (8), eaax0341, doi:10.1126/sciadv.aax0341.
- Ng, H.C., Cassarino, L.A., Pickering, R.A., Woodward, E.M.S., Hammond, S., Hendry, K. (2020), Sediment efflux of silicon on the Greenland margin and implications for the marine silicon cycle, *Earth and Planetary Science Letters*, 529, 115877, <https://doi.org/10.1016/j.epsl.2019.115877>.
- Pratt, N., Chen, T., Li, T., Wilson, D.J., van de Flierdt, T., Little, S.H., Taylor, M.L., Robinson, L.F., Rogers, A.D. and Santodomingo, N. (2019), Temporal distribution and diversity of cold-water corals in the southwest Indian Ocean over the past 25,000 years, *Deep Sea Research Part I: Oceanographic Research Papers*, 149, 103049, <https://doi.org/10.1016/j.dsr.2019.05.009>.
- Schlosser, C., Karstensen, J., Woodward, E.M.S. (2019), Distribution of dissolved and leachable particulate Pb in the water column along the GEOTRACES section GA10 in the South Atlantic. *Deep Sea Research I* 148, 132-142, <https://doi.org/10.1016/j.dsr.2019.05.001>.

- Shoenfelt, E., Winkler, G., Annett, A.L., Hendry, K.R., Bostick, B.C. (2019), Physical weathering intensity controls bioavailable primary iron(II) silicate content in major global dust sources'. *Geophysical Research Letters*, 46, 10854-10864, <https://doi.org/10.1029/2019GL084180>.
- Struve, T., Wilson, D.J., van de Flierdt, T., Pratt, N., Crocket, K.C. (2020), Mid-Holocene Expansion of Pacific Deep Water into the Southern Ocean, *Proceedings of the National Academy of Sciences*, 117 (2), 889-894, <https://doi.org/10.1073/pnas.1908138117>.
- von Strandmann, P.A.E.P., Hendry, K.R., Hatton, J.E., Robinson, L.F. (2019), The response of magnesium, silicon and calcium isotopes to rapidly uplifting and weathering terrains: South Island, New Zealand'. *Frontiers in Earth Science*, 7, <https://doi.org/10.3389/feart.2019.00240>.
- Vance D. and Little S.H. (2019), The History, Relevance, and Applications of the Periodic System in Geochemistry. In: Mingos D. (eds) *The Periodic Table I. Structure and Bonding*, vol 181. Springer, Cham. https://doi.org/10.1007/430_2019_44.
- Vance, D., de Souza, G., Zhao, Y., Cullen, J., Lohan, M. (2019), The relationship between zinc, its isotopes and major nutrients in the North-East Pacific. *Earth and Planetary Science Letters*, 525, <https://doi.org/10.106/j.epsl.2019.115748>.
- Wang, Q., Zhou, L., Little, S. H., Liu, J., Feng, L., & Tong, S. (2020), The geochemical behavior of Cu and its isotopes in the Yangtze River, *Science of The Total Environment*, 728, 138428, <https://doi.org/10.1016/j.scitotenv.2020.138428>.

Completed GEOTRACES and GEOTRACES relevant PhD or Master theses

- PhD - Allison Bryan (2019). '*Cadmium isotope signatures in modern sediments and waters as a potential tracer for paleoproductivity*'. University of Oxford. Thesis advisors: Gideon Henderson and Don Porcelli.
- PhD – Jade Hatton (2019). '*Silicon cycling in subglacial environments.*' University of Bristol. Thesis advisors: Kate Hendry and Jemma Wadham. https://research-information.bris.ac.uk/files/201326183/Thesis_July2019_Final.pdf
- PhD – Holly Welsby (2019). '*Feeding the Ocean? A biological mediation of estuarine silicon.*' University of Bristol. Thesis advisors: Kate Hendry, Rupert Perkins, Marian Yallop, Sandra Arndt. https://research-information.bris.ac.uk/files/218675200/Final_Copy_2019_10_01_Welsby_H_PhD.pdf.
- PhD – Alexander Matthew Griffiths (2020). '*Tracing water masses and pollution in the Southern Ocean using neodymium and lead isotopes.*' Imperial College London. Thesis advisors: Mark Rehkämper and Tina van de Flierdt.
- PhD – Naomi R.A. Pratt (2020). '*Deglacial Southern Ocean change: a cold-water coral investigation.*' Imperial College London. Thesis advisors: Tina van de Flierdt and Susan Little.
- MSci (2019) – Joe Nathan. '*Constraining the oceanic barium inventory with first isotopic composition data for the Amazon and Lena River.*' University of Oxford.
- MSci (2019) – Rob Paver (2019). '*Barium isotopes in tropical corals calibrated to ambient seawater*'. University of Oxford.

SELECTED GEOTRACES and GEOTRACES relevant presentations in international conferences

Advances in Marine Biogeochemistry, UEA, UK, 24-27 June 2019

- Alex Baker, Matthew Humphreys (UEA), Amber Annett (Southampton) and Will Homoky (University of Leeds) convened the meeting (a celebration of Tim Jickells)
- A. Milne, T. Conway, C. Schlosser, S. John, E.P. Achterberg, M. Lohan, 'Iron along the UK GEOTRACES South Atlantic transect.'
- M. Lohan, A. Lough, W. Wang, C. Demsay, A. Tagliabue, 'Trace metal supply from the Mid-Atlantic Ridge.'
- K. Kunde, N. Wyatt, D. González-Santana, A. Tagliabue, C. Mahaffey, M. Lohan, 'The pivotal role of colloidal iron in the dusty subtropical North Atlantic.'
- N. Wyatt, A. Lough, J. Resing, M. Lohan, A. Tagliabue, 'Hydrothermal venting as a globally significant source of zinc to the oceans.'

Gordon Research Conference in Chemical Oceanography, Holderness, NH, USA, 14-19 July 2019

- Susan Little (UCL) gave an invited talk on 'Tuning our Time Machines: Stable Isotopes in Palaeoceanography'.
- Mark Moore (University of Southampton) gave an invited talk on 'The Importance of Maximum Biological Stoichiometries in a Nutrient Co-Limited Ocean'.
- Alessandro Tagliabue (University of Liverpool) was discussion leader for 'Biogeochemical Signatures and Processes'.
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- N. Wyatt, A. Lough, J. Resing, M. Lohan, A. Tagliabue, 'Hydrothermal venting as a globally significant source of zinc to the oceans.'
- K. Kunde, N. Held, C. Davis, N. Wyatt, R. McIlvin, M. Woodward, M. Saito, A. Tagliabue, C. Mahaffey, M. Lohan, 'Trace metal availability for alkaline phosphates: A proteomic perspective from the oligotrophic North Atlantic.'
- A. Lough, N. Wyatt, C. Demasy, O. Moore, J. Resing, A. Tagliabue, M. Lohan, 'Iron supply for the Mid-Atlantic Ridge to the North Atlantic Ocean: GEOTRACES GA13.'

Goldschmidt conference, Barcelona, Spain, 18-23 August 2019

- Amber Annett (NOC) co-convened GEOTRACES session 10k: 'Trace Metal Cycling and Radioisotope Tracers of Ocean Biogeochemistry (GEOTRACES)'.
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- S. Little, L. Chen, K. Kreissig, S. Severmann, J. McManus, 'Isotopically light Cd in sediments underlying oxygen deficient zones'.
- W. Wang, R. James, A. Lough, H. Goring-Harford, M. Lohan, D. Connelly, 'Impact of hydrothermal venting on iron and chromium supply to the North Atlantic Ocean.'

Ocean Sciences, San Diego, USA, 16-21 February 2020

- C. Mahaffey, C. Davis, N. Held, M. Saito, K. Kunde, N. Wyatt, B. Twining, M. Woodward, A. Tagliabue, M. Lohan, 'Zinc, iron and phosphorus co-limitation in the ocean: Insights from proteomics.'
- K. Kunde, N. Held, C. Davis, N. Wyatt, R. McIlvin, M. Woodward, M. Saito, A. Tagliabue, C. Mahaffey, M. Lohan, 'Trace metal availability for alkaline phosphates: A proteomic perspective from the oligotrophic North Atlantic.'

- M. Lohan, A. Lough, D. González-Santana, A. Tagliabue, J. Resing, 'Iron supply from Mid-Atlantic Ridge to the North Atlantic Ocean.'
- W. Wang, A. Lough, T. Mellett, D. González-Santana, R. James, A. Tagliabue, M. Lohan, 'Constraining ocean hydrothermal iron using iron isotopes.'
- N. Wyatt, A. Lough, J. Resing, M. Lohan, A. Tagliabue, 'Hydrothermal venting as a globally significant source of zinc to the oceans.'

Submitted by Tina van de Flierdt (tina.vandeflierdt@imperial.ac.uk).