# GeoCam

EARTH SCIENCES ALUMNI MAGAZINE

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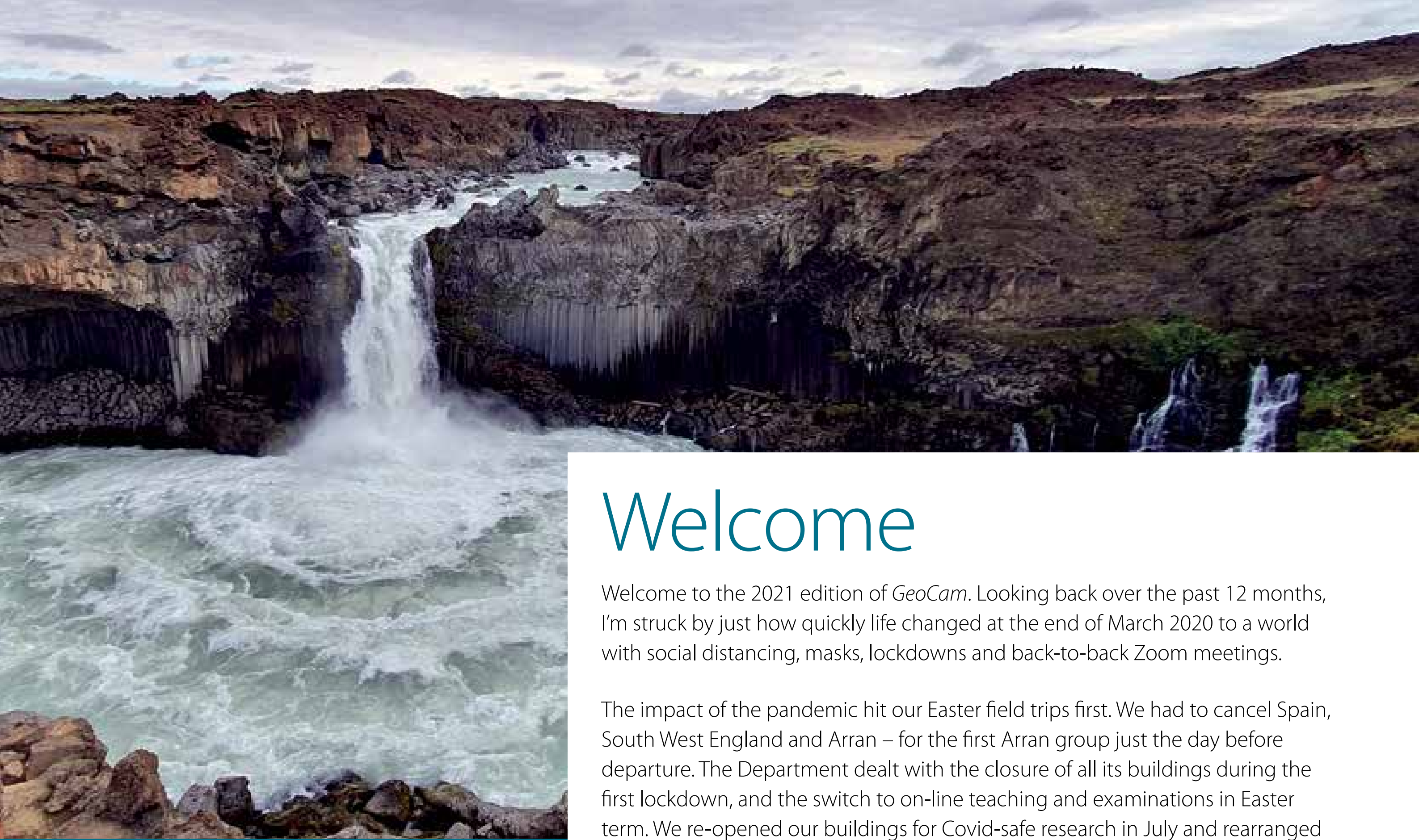
**NEWS**
## Is there life in the swirling clouds of Venus?

**FEATURE**
## In conversation with Sasha Turchyn

**RESEARCH**
## Radioactive waste disposal in the UK

UNIVERSITY OF CAMBRIDGE



# Welcome

Welcome to the 2021 edition of *GeoCam*. Looking back over the past 12 months, I'm struck by just how quickly life changed at the end of March 2020 to a world with social distancing, masks, lockdowns and back-to-back Zoom meetings.

The impact of the pandemic hit our Easter field trips first. We had to cancel Spain, South West England and Arran – for the first Arran group just the day before departure. The Department dealt with the closure of all its buildings during the first lockdown, and the switch to on-line teaching and examinations in Easter term. We re-opened our buildings for Covid-safe research in July and rearranged our teaching laboratories over the summer to enable a full programme of face-to-face teaching in Michaelmas term before returning to on-line learning for the third lockdown. Research activity continued alongside, despite unprecedented pressures on staff and students. We faced these challenges thanks to the hard work and dedication of everyone in the Department and the Sedgwick Museum.

In the light of all this, I could not be prouder of this year's GeoCam, which is as packed as ever with news, interviews, research highlights and research student tales from the frontline. We all deserve a break, so stick the kettle on, put your feet up and read all about it!

This issue demonstrates the many ways in which the Department fulfils its ambition to place fundamental science at the heart of addressing present and future societal challenges - whether by developing Artificial Intelligence methods to study flood risk or using our science to help achieve the transition to a net-zero future. Prof. Andy Woods' research using fluid dynamics to study aerosol transmission of infectious diseases in healthcare settings took on renewed significance and urgency in view of the Covid crisis and is a perfect example of how the transferable skills of a geoscientist can be put to unexpectedly good use.

As ever, we are very grateful for the support of our alumni community. Sadly, we have been forced to cancel our planned alumni day on the 15th of May. This year has been especially hard on our undergraduate and postgraduate student community, who have suffered from the loss of so many opportunities that past cohorts took for granted. With your support, the Department aims to mitigate some of these negative impacts, for example, by reorganising student field trips as soon as government restrictions allow. Please see our Fundraising page for details.

Here's to a safe and significantly less dramatic 2021! We hope to see you soon.

Yours

Richard

**Richard Harrison,** Head of Department

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*Cover Image: Drilling rig in Yukon against a backdrop of the Northern Lights.*

# The Oast House

**Head down Mill Lane towards the river or the Grad Pad, and glance to the right before the University Social Club. One building is out of the ordinary: the late 19th century Oast House.**

Hops were dried on the slatted upper floor of the kiln building above a wood-fired furnace at ground level. The pyramidal roof with its distinctive cowl drew the moist air up through the kiln. The dried hops were bagged in the adjacent stowage building, then sold to the city breweries, including one directly across Mill Lane.

The Department has used the Oast House for decades: first for Brian Harland's Spitsbergen collection, then for Tony Dickson's limestone cores. Since the Godwin Laboratory for Paleoclimate Research moved from the New Museums site to the Downing site in 2006, the Oast House has housed its large archive of marine sediment samples, box storage for sediment samples and a cold storage room for cores. The Godwin's James Rolfe explains: "We are continually adding to the archive, which is available to researchers to revisit past work or conduct new techniques on samples which have previously been studied."

*The Godwin Lab's Simon Crowhurst pictured on the stairs to the first floor of the Oast House, and in the store with boxes of sediment samples.*

# RESEARCH NEWS

## FOR ALL THE LATEST CAMBRIDGE EARTH SCIENCES RESEARCH NEWS VISIT WWW.ESC.CAM.AC.UK/NEWS

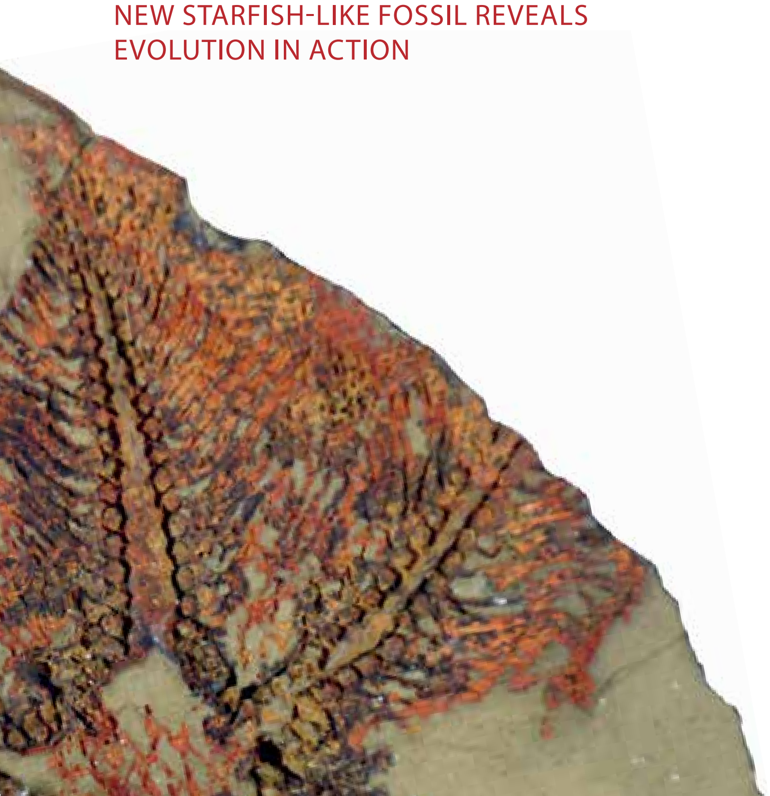
### LARGE TOPOGRAPHIC FEATURES CAUSED BY SUBTLE CHANGES IN THE UPPERMOST MANTLE

How does a plateau form in the middle of a plate without the help of tectonic forces? Recent work, led by Marthe Klöcking of the Australian National University while she was a Cambridge Earth Sciences PhD student with Nicky White and John Maclennan, suggests these extensive topographic features can be caused by subtle changes in the uppermost mantle. Klöcking's research shows that the movements of basin-and-swell topography in Angola and Brazil were caused by thinning of the underlying lithosphere coupled with small positive temperature anomalies in the asthenosphere.

Read more www.esc.cam.ac.uk/about-us/news/large-topographic-features-are-caused-by-subtle-changes-in-the-uppermost-mantle

© MARTHE KLÖCKING

### NEW STARFISH-LIKE FOSSIL REVEALS EVOLUTION IN ACTION



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Researchers from the University of Cambridge have discovered a fossil of the earliest starfish-like animal, which helps us understand the origins of the nimble-armed creature. The exceptionally preserved fossil, named Cantabrigiaster fezouataensis, which is roughly 480 million years old, was discovered in Morocco's Anti-Atlas mountain range. The prototype starfish, which has features in common with both sea lilies and modern-day starfish, is a missing link for scientists trying to piece together its early evolutionary history.

Read more www.esc.cam.ac.uk/news/new-starfish-fossil-reveals-evolution-action

*Cantabrigiaster* fezouataensis *from the Lower Ordovician (Tremadocian) Fezouata Shale, Zagora Morocco (Collections of the Claude Bernard University Lyon 1).*

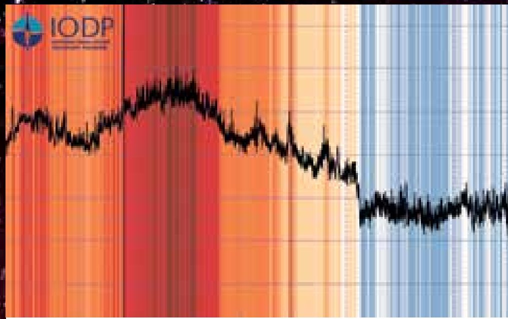
## FORECASTING ERUPTIONS WITH THE HELP OF DRONES

Specially-adapted drones, developed by an international team involving former University of Cambridge volcanologists, are transforming how we forecast eruptions by allowing close-range measurements of previously inaccessible and hazardous volcanoes.

“These aerial measurements are pushing the frontiers of the current state-of-the art in volcano monitoring”, said Emma Liu, previously a research fellow in the Department, and now a lecturer at University College London. The research brings together measurements from the air, earth and space to help us understand the contribution of volcanic emissions to the global carbon cycle.

Read more www.esc.cam.ac.uk/about-us/news/drones-advance-volcanic-monitoring







## A NEW CENOZOIC RECORD OF EARTH’S CHANGING CLIMATE SYSTEM

A team of international marine scientists, including Earth Sciences’ David Hodell, have built a new record of Earth’s temperature and glaciation for the past 66 million years, revealing the changing state of the climate system to a much greater degree of resolution than previous records. The team’s 66 million year-long record reveals a colourful barcode of changing climate states. “We can identify four key climate phases: hothouse, warmhouse, coolhouse and icehouse,” explains Hodell, "This classification has been known for some time, but now we are able to identify the fundamental states with statistical precision and reveal their characteristic dynamics.”

Read more www.esc.cam.ac.uk/about-us/news/record-earths-cenozoic-climate-reveals-role-of-polar-ice

## IS THERE LIFE IN THE SWIRLING CLOUDS OF VENUS?

The surface of Venus is so hot it can melt lead. The atmosphere is pretty inhospitable too – 96% of it is carbon dioxide and the rest nitrogen and sulfur dioxide. This might not sound like the sort of place to go hunting for life elsewhere in our Solar System. But back in September 2020 scientists detected a rare molecule – phosphine – in the clouds of Venus, hinting to the possibility of extra-terrestrial life.

Astronomers have long speculated that high clouds on Venus could offer a home for microbes – floating free of the scorching surface, but tolerating very high acidity. But, without evidence, the theory had remained the stuff of science fiction.

Dr Paul Rimmer, a postdoctoral researcher at the Department of Earth Sciences with affiliations at Cavendish Astrophysics and the MRC Laboratory of Molecular Biology, was involved in the discovery.

“This discovery brings us right to the shores of the unknown,” said Rimmer. “Phosphine is very hard to make in the oxygen-rich, hydrogen-poor clouds of Venus and fairly easy to destroy. The presence of life is the only known explanation for the amount of phosphine inferred by observations.”

Read more www.esc.cam.ac.uk/about-us/news/phosphine-clouds-suggest-venus-could-host-life

**NIENKE BLOM,** POSTDOCTORAL RESEARCH ASSOCIATE

# A DAY IN **THE FIELD:**
## FIELDWORK IN ICELAND WITH A COVID TWIST

On a grey early morning in mid-August, four Cambridge seismologists stand watery-eyed in the arrivals hall of Keflavík airport, Iceland. Outside, it is windy, wet and only seven degrees. So far, so normal: fieldwork in Iceland was never about the tan lines. However, things are not normal. The watery eyes are not a result of getting up so early, but of the recent nose prodding by diligent Icelandic Covid-19 testers. It is 2020, and a pandemic is raging. How did these people get here? How do you do fieldwork in a pandemic?

In February, it all seemed straightforward. An expedition leader had been appointed and a blueprint for the fieldwork was ready – after all, Cambridge seismologists have been conducting fieldwork in Iceland since the 1990s. Yes, the first cases of Covid-19 were already spreading out of China, but the news still seemed more like a reprieve from the eternal torrent of Brexit than something that could potentially endanger us all.

Soon enough, we found ourselves working from home, and with cases soaring across the globe, the idea of fieldwork in a different country seemed increasingly ludicrous. Zoom coffee meetings were set up to retain a sense of normality, but with little other than Covid to discuss, these quickly turned into extensive planning meetings with as many opinions as there were people involved. A core planning team was set up, while the rest received regular updates on potential fieldwork dates and backup plans in the light of ever-changing quarantine rules, travel bans, and issues with insurance and the shipment and delivery of instrumentation. Even after all the green lights had been given and flights had been booked, everybody still felt they'd only believe it when they set foot on Icelandic soil. As it turned out, one team member never made it there due to last-minute restrictions.

*Lava blocks are the most common weights used to keep the solar panels upright during powerful Icelandic storms.*

*Part of the team installing a new seismometer on the Reykjanes peninsula. From left to right: Tom Winder and Conor Bacon.*

*Nienke Blom finishing up checks at a new seismometer just north of the Bárðarbunga volcano which erupted spectacularly in 2014, and has recently shown renewed signs of inflation. A circle of stones is laid to mark where the seismometer is buried.*

The team: Thorbjörg Ágústsdóttir, Conor Bacon, Nienke Blom, Bryndís Brandsdóttir, Tim Greenfield, Nick Rawlinson, Heidi Soosalu, Sveinbjörn Steinthórsson, Omry Volk, Bob White and Tom Winder.

The core of the Icelandic fieldwork normally takes place in the Highlands – a difficult to reach, desert-like area the size of Switzerland with highly active volcanoes and at its centre Europe's largest glacier, Vatnajökull. After spending a few days preparing kit in the University of Iceland equipment store, the team loaded up several 4x4s and disappeared for a week or two into the land of No Mobile Signal. There they spent long days driving over rough tracks to remote seismometers, at night cooking and sleeping in mountain huts while also checking data quality and planning logistics for the next days.

This year, however, anyone staying in Iceland for longer than 10 days was required to have a second Covid test five days after arrival, which kept us near Reykjavík. Fortunately, this time was put to good use servicing and installing new seismometers on the Reykjanes peninsula, which had been undergoing a surge in seismic activity since early 2020.

Meanwhile, we waited anxiously for test results. For months, we had all exercised extreme caution, washed our hands raw, kept our distance from other human beings and worried about every sniffle and throat itch. Imagine, then, the sense of relief we felt when the final team member received their negative Covid test result. For the first time in months, we could sit together in cars, cook, pass each other tools, and in general live a relatively normal life. If anything, this fieldwork was a Covid holiday.

Meanwhile, Iceland showed its friendliest side. After the dreary start, we were treated to some of the best weather the regulars could remember. This resulted in beautiful panoramic views of Iceland's wild land and normally clouded-up summits – but also issues with meltwater-inflated rivers. Some of these could only be crossed thanks to the unmatched 4x4 skills of Sveinbjörn, the University of Iceland's field technician. Even then, two seismic stations initially had to be skipped, so that at the end of the trip part of the team had to cross the Highlands again to make a second attempt at collecting the precious data. This was completed successfully so that we returned to civilisation with a success rate (measured in months of usable seismic data) beyond our expectations.

After this simple and Covid-free life, the return to the real world was not without regret. Back to face masks and meticulous surface wiping, back to keeping a distance from friends and strangers alike, and back to worries about sniffles. The question remains: "What will fieldwork look like in 2021?"

**ANDY WOODS,** HEAD OF BPI, BP PROFESSOR

# Research at the BPI

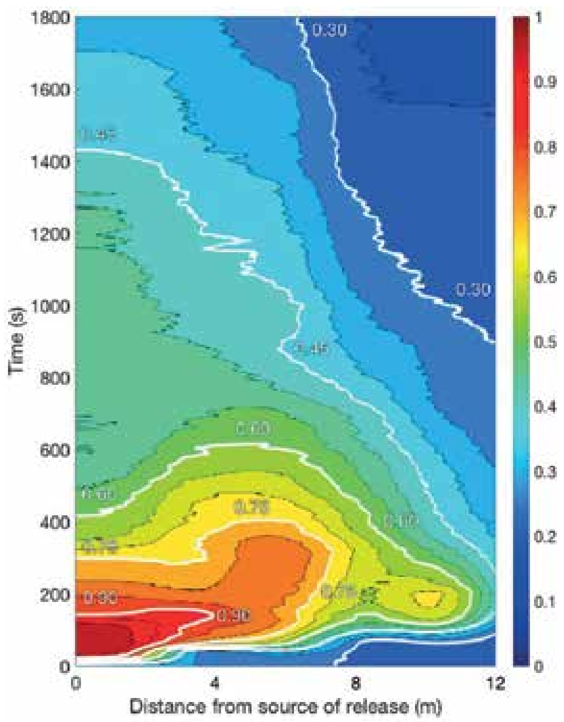
**The BP Institute for Multiphase Flow (BPI), established in 2000, has a wide range of research programmes exploring environmental, geological and industrial multiphase flow processes. Many of these have key elements of surface science and fluid-solid interactions at their core.**

Current work at the BPI includes research into the dynamics of volcanic ash plumes, the environmental impact of deep-sea mining, corrosion of paint on offshore wind turbines, dynamics of $CO_2$ during carbon sequestration, the climate challenges of the flow and melting of ice sheets, and the recirculation of heat and dissolved $CO_2$ between the deep and shallow ocean, and the dynamics of avalanches.

During the Covid-19 pandemic, new research has commenced exploring the path followed by airborne aerosols through buildings. Ventilation flows, large-scale convective flows and the mixing produced by people, influence the dispersion of airborne aerosols through buildings. This is of particular relevance for the transmission of Covid-19. As a simple model of aerosols, the dispersion of $CO_2$ released as a dilute cloud of gas has been monitored in several buildings, including Papworth Hospital, the Sedgwick Museum, the Seeley Library and the West Road Concert Hall.

Figures 1 and 2 show the spread of $CO_2$ along a corridor in Papworth Hospital. The ventilation flows carry the $CO_2$ over 10-12m along the corridor, while people moving up and down the corridor leads to additional mixing and an increase in the residence time of the $CO_2$ by more than a factor of two. Laboratory experiments in the BPI modelled this mixing of aerosols (Figure 3). A cylinder with a vertical axis moves back and forth along a channel filled with particle-laden fluid to model the mixing by an individual walking along a corridor filled with air containing aerosols. As the particles gradually settle to the floor, the ventilation flow from left to right gradually drives the particles along the corridor while the mixing by the cylinder causes the particles to mix into the new particle-free fluid. These results help inform Covid-19 secure design and operating protocols to minimise transmission through buildings.

*Fig. 1*
*Spread of a $CO_2$ pulse, injected bottom left, along a corridor (x axis) through time (y axis) with only weak ventilation. After 30 minutes (1800 secs) the $CO_2$ concentration at the release site has only dropped to 40% of its original value.*



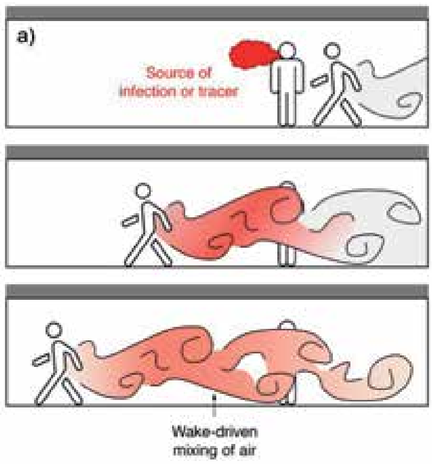




*Fig. 2*
*a) Cartoon of the mixing of air caused by a walking person.*

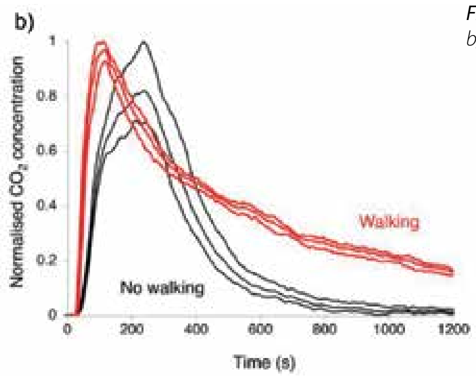
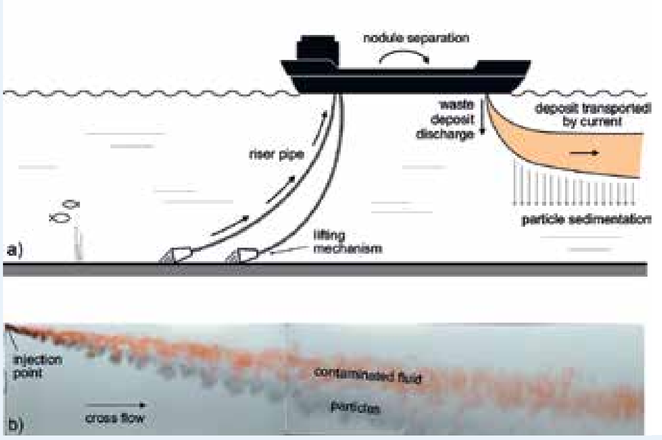



*Fig. 2*
*b) Concentration of $CO_2$ with time at three locations along a corridor, 2-6m from the $CO_2$ source, with and without someone walking back and forth every 30 seconds. The walking increases mixing and the residence time of the $CO_2$.*

*Fig. 4*
*a) Mining of deep-sea nodules, with resulting waste plume of suspended sediment.*

*b) Experimental particle plume injected into a cross flow, showing separation of particles from the contaminated fluid.*




During deep-sea mining, surface collection vessels can discharge waste sediment, creating a plume of sedimenting material in the ocean (Figure 4). Some minerals may dissolve into the water column from this plume. Experimental models of these plumes have shown how the plume fluid may separate from the particles at high level in the water column. This can produce zones of shallow contaminated water, while the particles eventually settle to the seabed. In some cases, the particles develop convective instabilities as they sink, resulting in regions with anomalously high sedimentation rates that could have an impact on seafloor ecosystems.

Work on carbon sequestration concentrates on where injected $CO_2$ flows in a porous formation (Figure 5). The challenge is to access the pore space in the formation in order to trap the $CO_2$. Sedimentary structures in the rock, including cross-bedding, layering and high permeability lenses, direct the flow through the path of least resistance, bypassing much of the formation, as may be seen in the idealised analogue bead pack experiment shown in Figure 5.

The work of the BPI around the challenges of the energy transition and its environmental impacts continues. There are exciting new projects on geothermal power generation, new models of enhanced carbon sequestration, novel designs for increasing battery storage in superconductors, hydrogen storage and transport, and the design of low energy and healthy buildings, as well as new projects relating to ice sheet ablation and migration, avalanche dynamics, and the remediation of contaminated water.

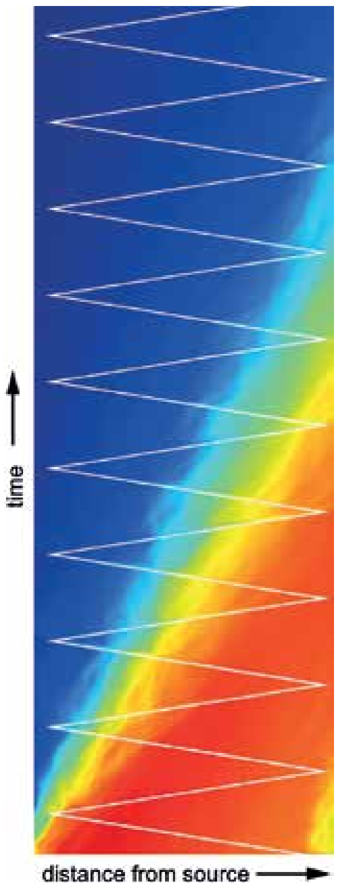
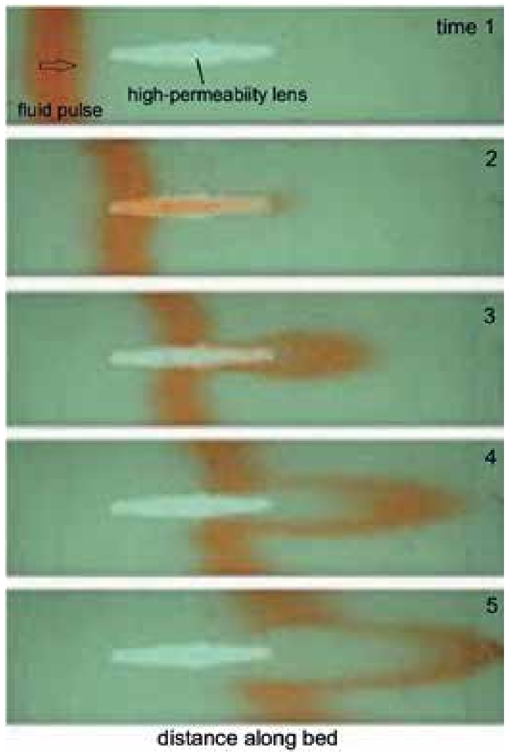



*Fig. 3*
*Concentration of particles along an experimental corridor (x axis) as a function of time (y axis) showing the change from concentrated (red) to dilute (blue) as clean ventilation air displaces a particle-laden cloud. The interface between the two zones becomes spread out as a result of mixing produced by a cylinder moving back and forth (white line) to model a moving person.*

*Fig. 5*
*Experiment modelling a fluid pulse (orange) being diverted with time into a high-permeability lens within a porous bed, leading to a limited sweep of the formation and reduction in the fraction of the pore space in the rock which actually stores $CO_2$.*



**IAN FARNAN,** PROFESSOR OF EARTH & NUCLEAR MATERIALS

# Radioactive waste disposal in the UK

Implementing the geological disposal of radioactive waste requires both a suitable site and a willing community. A detailed site assessment is necessary to determine whether the geology of the region where the volunteer community is located will be adequate for its safety function.

Where the retention properties of the geology are less favourable, as a detailed Safety Case for the Geological Disposal Facility (GDF) is developed, the engineered barriers and primary barrier waste forms will have a stronger role in containing the radionuclides over periods of several hundred thousand or even one million years.

During the past winter, the communities of Copeland and Allerdale in west Cumbria both volunteered to host the UK's GDF for radioactive waste. The suitability of the site's geology has been much discussed, particularly its ability to prevent the ingress of ground water that could transport radionuclides away from the site and into the biosphere. Research in the Department into fully understanding the mechanism of dissolution of the glass and mineral phases that contain the problematic radionuclides that may prevent any significant release for hundreds of millennia is providing key insights into an increasingly important aspect of geological disposal.

In the UK, special issues arise from choices made early in the development of nuclear energy. Second-generation, graphite-moderated, $CO_2$-cooled, AGR reactors deviated from the international trend of building light-water moderated and cooled PWR and BWR reactors. The UK reactors operate at higher outlet temperatures and remain the most thermodynamically efficient reactors. However, the high operating temperature and stainless steel, rather than zircaloy, cladding of the fuel raised safety questions about applying international research on disposing of light water reactor fuels. In addition, the choice of a magnesium aluminium alloy cladding for the fuel of the UK's first-generation of Magnox reactors creates significant compositional differences between the glasses produced by vitrification of waste from Magnox fuels compared with international waste glasses. Lastly, the fuel re-processing strategy has created a civilian stockpile of 140 tonnes of separated plutonium.

In order to move forward with the ultimate disposal of UK radioactive waste without replicating the huge research spend of overseas governments, the consequences of the differences between UK waste and similar international waste materials need to be researched. Much of the Department's contribution to current waste form research in the UK is dedicated to bridging this knowledge gap.

The RCUK GeoWaste consortium on UK spent fuel, led by the Department, and the Euratom H2020 project 'DISCO' on EU spent fuel disposal, funded a team including Earth Sciences' Ian Farnan, Aleksej Popel, Beng-Thye Tan and Emma Perry. The solubility of $UO_2$ is extremely low in a GDF environment. A GDF site at 500m–1000m below the Earth's surface is isolated from its oxidising atmosphere. Instead, reducing groundwater from natural sources and the corrosion of steel canisters leads to


*The Cumbrian coast near Sellafield.*

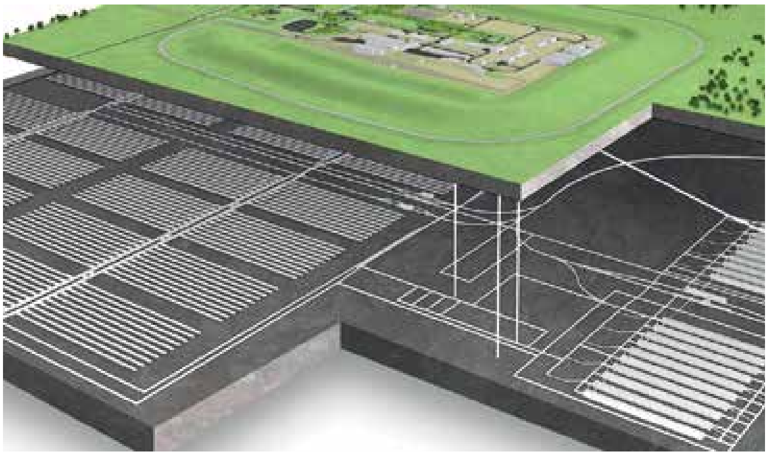




*Fig 1. Diagrammatic view of a Geological Disposal Facility (GDF) of the sort proposed in west Cumbria.*

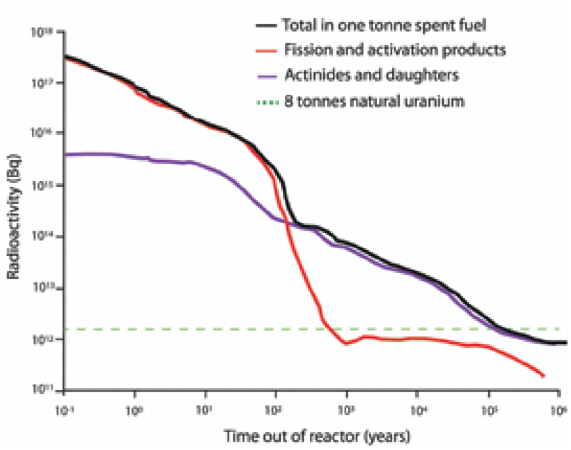



*Fig 2. Logarithmic plot of radioactivity vs time of one tonne of spent nuclear fuel. On shorter timescales, less than 300 years, the radioactivity is dominated by fission and activation products and drops by 3-4 orders of magnitude. This waste is destined for glass or to remain in the fuel. At longer timescales, actinides such as uranium or plutonium dominate and will decay over 100s of millennia. These will remain in the fuel or be prepared as poorly soluble mineral-based ceramic phases.*

uranium concentrations in solution of a few parts per billion. This was believed to result from an equilibrium between the water and an amorphous $U(OH)_4$ phase that formed on the surface of $UO_2$ that coated or 'passivated' the surface to prevent further dissolution. Using sophisticated model systems, and by imaging the reactions controlling the release of uranium from the fuel at an atomistic scale, our team has excluded the presence of $U(OH)_4$ and observed the presence of additional oxygen in surface layers of leached $UO_2$. Instead, they propose an alternative mechanism in which this $UO_{2+x}$ in the top few layers of the uraninite structure provides the barrier that prevents further oxidation and dissolution.

THE SUITABILITY OF THE SITE'S GEOLOGY HAS BEEN MUCH DISCUSSED, PARTICULARLY ITS ABILITY TO PREVENT THE INGRESS OF GROUND WATER THAT COULD TRANSPORT RADIONUCLIDES AWAY FROM THE SITE AND INTO THE BIOSPHERE

In comparison tests, UK radioactive waste glass was found to be less durable than international glasses in both initial and the long-term residual dissolution rates. The presence of magnesium (from the Magnox fuel cladding) and higher lithium content in the base glass were identified as potential culprits for this lowered aqueous durability, but no mechanism was known. By formulating simplified analogues of the UK glasses that tested compositional variations, and using isotope-specific techniques such as nuclear magnetic resonance and isotope geochemistry, a team[1] from the Department was able to identify the mechanisms by which magnesium is responsible for the more rapid long-term dissolution rate and how lithium increases the initial dissolution rate. Recent work has combined the Department's expertise in isotope geochemistry and glass dissolution to show that the same dissolution mechanisms operate in UK glass at both 40˚C and 90˚C. This important result allows the vast amount of accelerated dissolution test data collected over decades at 90˚C at Sellafield to be used in the Safety Case for a GDF where the temperature is ~40˚C once the thermal pulse from the radioactive waste has declined. Future projects will aim to understand the potential use of zirconolite mineral-based phases as the host for contaminated plutonium from the UK's civilian stockpile.

**https://www.gov.uk/government/news/rwm-welcomes-announcement-of-first-working-group**

**https://www.gov.uk/government/news/rwm-welcomes-launch-of-second-gdf-working-group**

1. Tom Goût, Madeleine Bohlin, Ed Tipper, Sambuddha Misra, Joe Lillington, Ian Farnan.

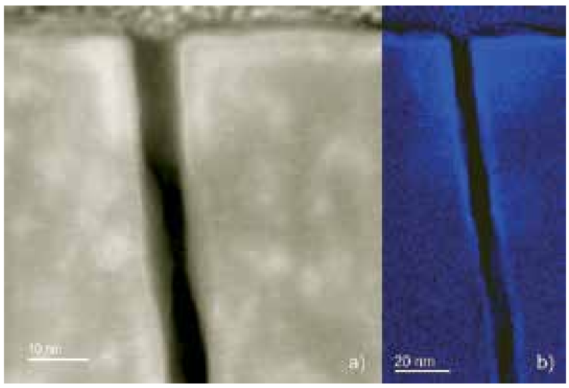



*Fig 3. (a) High-resolution transmission electron microscope image and (b) oxygen K-edge chemical image of a dissolution crack in a single crystal $UO_2$ film after leaching in anoxic water. A crystalline phase persists up to the surface of the crack, with no amorphous $U(OH)_4$ surface phase. Instead, the light blue colour (image b) shows the presence of additional oxygen in the crystalline surface of the crack, providing a passivation film to prevent further release of Uranium into solution.*

# IN CONVERSATION WITH Sasha Turchyn

Dr Sasha Turchyn joined the Department of Earth Sciences in 2007 and is currently a Reader in Biogeochemistry. She reflects on her life and work with Erin Martin-Jones.

## You're a biogeochemist, how does your work link these topics?

In the US, I call myself a geobiologist, but people in the UK don't use that term – here I am a biogeochemist! I study different aspects of the geological carbon cycle, but I am particularly interested in how carbon moves between the Earth's interior and surface reservoirs. I also think about how biology interacts with the carbon cycle – and the role microbial communities play in the movement of carbon between Earth's surface and its interior.

## So which discipline does your heart rest with?

I would say I'm a chemist – a light stable isotope geochemist – at heart, even though we do some microbiology in the lab. I didn't do a lot of chemistry whilst an undergraduate at Princeton University – my course had a strong geophysics focus – but when I took some geochemistry classes in my last year I loved them. I've always felt more comfortable with chemistry than physics, it's just felt more intuitive to me.

## What got you interested in Earth science?

Since a young age I have loved being outdoors – and I've always enjoyed maths and science, so when I discovered Earth science it really clicked for me. Inspiring teachers have also helped me along the way.

## You spent some time in industry before moving into academia?

I wasn't sure I wanted to do a PhD initially, so I worked for three years after graduating at Schlumberger on drill ships, mostly in the North Sea, as a Field Engineer. I enjoyed looking at the data we would generate during wireline logging. From then I knew I wanted a career where I could solve problems and experiment so I settled on research and getting a PhD. Although I've since worked on sediment-cores for my research and I am also on the facilities board for the European Consortium for Ocean Research Drilling (ECORD), I haven't been on deck since, although I'd consider going out again now that my children are a bit older.

## Has that love of problem solving come in handy since?

One of my professors I knew from my undergrad was moving to Harvard and said: "why don't you come and do a PhD with me?" Taking that opportunity was one of the best decisions I made. I started out as a palaeoceanographer – for my PhD I used oxygen isotopes in marine sulfate minerals to understand the sulfur cycle over the last 140 million years.

My PhD gave me free rein to test ideas in the lab and, although it was challenging at times, I got a lot of hands-on experience with the mass spectrometers. I have less time for lab work now, but I find it is one of the most satisfying parts of my research: setting a hypothesis, running the equipment, seeing the results come out.

## Was there a key person that helped you back into academia?

In the US you choose a supervisor rather than a project, and I was lucky that mine was so supportive – reassuring me that the classes wouldn't be too hard after spending time in industry. On my first day, he put four unsolved problems in front of me and said: "let's think about which one of these we want to solve." I went away and started to formulate ideas, test things out. The US system really encourages trial and error and I miss that process here in the UK, I think it turns out more inquisitive scientists.

## What do you particularly enjoy about your job?

I really enjoy interacting with the students. Since Covid, the Zoom meetings I have with my research group are the highlight of my week. We discuss and debate topics, read papers, and it gets me thinking about things in a different way. I direct studies in Natural Sciences and I am the Postgraduate Tutor at Trinity Hall – it's a big role, but pastoral support for postgraduate students is something I really care about.

## What are you researching at the moment?

Having started out as a palaeoceanographer, I've always had an interest in past changes. My research group are now spending more time thinking about questions in the modern environment.

We are covering a range of topics – from methane fluxes out of glaciated wetlands, to modelling carbon capture and storage, to investigating how carbon is stored and released in marine environments. We look at different time frames too, one postdoc is working on Paleoproterozoic sediments and another is studying the Cenozoic. At the core of our work is detailed geochemical analysis; using these detailed chemical signatures to trace how carbon moves around the Earth.

## What about your College role?

Coming from outside of Cambridge, I hadn't experienced the college system. I started my lectureship when my middle daughter was two months old and it was a year before I felt ready to get involved in a college. The Master asked when they interviewed me: "Why do you want to join a college?" I really wanted to experience Cambridge fully and I would have regretted not engaging with the college system.

My college is small and often it's all hands on deck, but I feel really appreciated in that small community.

**LIZ HIDE,** DIRECTOR, SEDGWICK MUSEUM

# Making **Earth Sciences** inclusive and welcoming

***We cannot be truly great as a university if we are not open to the social and cultural diversity of the world around us.*** (Vice-Chancellor Professor Stephen Toope, 2018)

Black Lives Matter protests following the death of George Floyd in Minnesota in May 2020 have raised global awareness and precipitated discussion and debate around the inequality and racism experienced by Black people and people of Colour throughout society.

Since then, the discussions have provided the opportunity for many organisations and institutions, including the University of Cambridge, to reflect on their own racial diversity, and to put in place measures to address this.

Here in the Department of Earth Sciences, this increased awareness of our lack of racial diversity comes at a time when we have also been thinking more widely about diversity, inclusion and representation, not just in terms of race, but also gender, disability, religion, sexual orientation, and socio-economic factors. We acknowledge that in the past the Department has not always addressed diversity effectively, and that this will have had considerable negative impacts on many people over many years. A growing commitment to making the Department an inclusive and welcoming place for all is coupled with a real need to ensure that Earth science is a relevant and welcoming discipline for the next generation of students. We are optimistic that we are now moving forward in effecting real, sustainable change across our Department, and contributing to a more diverse international Earth sciences community.

To make the Department inclusive, we must address a huge range of issues – from students unable to afford the cost of fieldwork and field equipment, to the lack of Black role models amongst academic staff. Physical access, in particular the lack of a suitable lift in the main Downing Street building, continues to be a concern, as do the challenges of career progression for women with children.

We are developing an action plan to guide our activities in the short, medium and long term. This is a substantial undertaking, and we want to work carefully and respectfully to ensure that it is a sustainable and meaningful process. Working with partners such as the Sutton Trust, who promote social mobility amongst young people, and the University's Equality and Diversity team, will be vital. There is considerable enthusiasm and commitment amongst research students and early career researchers, many of whom have self-organised anti-racism reading groups and other important initiatives already.

The University collates and analyses diversity data for staff and students, against which we can baseline our progress. We are also working with other Earth science departments to share data and understand successful initiatives that have been implemented elsewhere.

Equality and Inclusion work in the Sedgwick Museum will feed into this wider department action plan. The Museum is already involved in research into the legacies of enslavement in the Museum's collections, in showcasing women's and LGBTQ+ history, and in working to present a more diverse range of geologist role models for young people.

*Pride bear on the stairs.*

**CAT BODDY,** PART III EARTH SCIENCES 2019–20

# Life after graduating, and life before the Cambrian Explosion

© CAT BODDY

*Bradgate Park: Getting that face-to-(rock-) face contact in with Ediacaran rocks before such an activity was no longer permitted.*

Before the unprecedented months of virtual meetings in pyjama bottoms, I was happily enjoying my final year as an undergraduate. Whilst making the most of my time left in beautiful Cambridge and running the greatest student geological society there is (the unofficial title I awarded the Sedgwick Club), I found myself working on an interesting Master's project with Alex Liu.

My project looked at the global distribution of some of the first known macro-organisms, including the earliest known animals, during the Ediacaran period – just before the Cambrian Explosion. I started my research by compiling a database with all the Ediacaran macro-biota that I could find, and then used my QGIS skills to plot out the taxa distribution on different palaeogeographic reconstructions from the period.

When I first plotted up my data on a map, all I saw initially were coloured circles littered over it. But a pattern was starting to emerge. Alex and I noticed that the fossil groups with a bilateral symmetry (mirrored along a central axis) were all clustered within 30° of the equator, whilst all other groups had a global distribution. With the help of Zoology's Emily Mitchell we were able to use statistical analysis to confirm the signal was genuine.

At least some of the fossils in this group are considered to be stem bilaterian metazoans – distant relatives of modern animals which are bilaterally symmetric, including you, me and your pet (unless you have a jellyfish). The patterns we observe in this group of bilateral shapes therefore help us understand early bilaterian evolution and how we all began. Finding them only at low latitudes may suggest that they spread across the globe slower, or later, than other groups, or that their evolution favoured the warmer temperatures nearer the equator.

This was an incredible find and, once exams had passed, Alex and I discussed the possibility of writing it up into my first paper. Since my project, we've added new data to my database and re-run the graphs and tests. After identifying more interesting relationships, we are ready to publish our findings.

In December, I gave my first conference talk on our findings at PalAss. My talk went well – I definitely felt it was easier to present to my laptop screen instead of an audience, that way I couldn't tell if people were super-excited by my work or furrowing their brows! I happily assumed the former. After the talk, the chat was full of questions. It was great to see so many people interested in my work.


© CAT BODDY

*Here's me giving my first conference talk at this year's virtual PalAss, showing examples of bilateral fossils and where they might place on an evolutionary tree.*

I enjoyed experiencing the highs and lows of the paper writing process – I'm really excited the work will be out there for the world to see, and cannot thank Alex enough for his help and support. Although there were no coffee breaks in the common room, or visits to the library with Sarah and her box of sweets, it has given me the opportunity to hold onto Cambridge life just a little longer.

**OSCAR BRANSON,** LECTURER

# DOCTORAL TRAINING PROGRAMME in Artificial Intelligence for Environmental Risk

The Artificial Intelligence for Environmental Risk (AI4ER) doctoral training programme, hosted within the Department, has had an exciting start to its second year, welcoming 12 new multi-disciplinary MRes students who are taking a wide range of courses in machine learning and environmental science. These courses develop and hone the students' ability to understand and predict the natural environment from complex data, preparing them for their PhD projects next year. A real highlight of this programme is the academic diversity of these students, which makes them an ideal team for tackling complex environmental problems.

Alongside their first term lectures, the MRes students joined forces with the Environment Agency, an AI4ER partner, to work on a project about flooding. The Environment Agency were interested in the efficacy of natural flood management techniques applied across river basins in western England, but the patterns in the data were not straightforward – were these flood prevention measures working? They were keen to see what our students could come up with. For most of them, this was their first time interacting with complex natural data. It was also the first time most had encountered a project beyond a homework assignment and with real-world implications. Flooding has an immediate and profound effect on so many in the UK, and their findings had the potential to help address this. The students explored a variety of advanced machine learning techniques to predict flood levels from publicly available data, and tried to determine whether peak floods had been reduced after the new flood prevention measures were introduced. The students did a remarkably good job at predicting river flows, but ultimately there were insufficient data to answer the question they had been set. This in itself was a useful outcome, and they were able to identify key variables that the Environment Agency might monitor in future to identify which flood prevention measures are most effective.

Over the coming term, the MRes students will be working on two projects alongside their lectures in collaboration with the European Space Agency (ESA). The projects will use satellite data to look at problems within the broad categories of 'exposure' and 'biodiversity'.

Meanwhile, the 10 students who finished their MRes last year have begun their PhDs across five host departments. Their projects span space weather, renewable energy, climate modelling, weather forecasting and air pollution. These projects are applying leading edge computational approaches to address critical global environmental challenges, and we are excited to see where the students take them.

If you're interested in hearing more about the work these students (and others) are doing, the Cambridge Environmental Data Science Group (CEDSG) talks showcase a variety of this type of research from across the University.



**LIZ HIDE,** DIRECTOR, SEDGWICK MUSEUM

# RETHINKING **THE MUSEUM**

## The Sedgwick Museum in lockdown and beyond


**Photos of crowds of happy families and bumper visitor figures are what I might have liked to have been sharing with you about the Sedgwick Museum this year.**

With the Museum closed for more than half the year, and with substantial restrictions on visiting during much of the time we were open, the Museum team have thought hard about how the Sedgwick can continue to be an important and relevant place for researchers, students and the public. While there is no doubt that we have taken a big hit in terms of shop and visitor donation income, our year-long collections relocation has been substantially delayed, and – as I write in early January – there is no prospect of the Museum reopening until at least March, some extremely positive projects and activities have come out of the challenges of lockdown.

Our Gravel Hunters project has encouraged young people to find fossils in the everyday gravel around them, and our online exhibitions have showcased Daniel Field's research on the earliest modern bird, the Wonderchicken. Online drawing workshops with artist/geologist Emma Jude attracted participants from the US and Canada as well as closer to home. We have given online talks for U3A groups and a virtual museum tour as part of the popular Animal Crossing game, while our plastic dinosaurs and Lego Sedgbrick Museum have been a hit on social media. Our downloadable activities for teachers and home-schoolers have been promoted through the University of Cambridge Museums consortium and have also reached families who don't have digital access through inclusion in printed packs distributed through the City Council's food hubs.

The Museum reopened to the public on 24 September with full social distancing measures in place, free bookable timeslots and a one-way system. Finally, visitors could come and see the Wonderchicken for themselves. Instead of our usual gallery interactives, we offered visiting families a free activity pack, while during half-term we offered an exclusive opening for children on the autistic spectrum and their families. We used reopening as an opportunity to retrain staff in offering a warm welcome, which has resulted in very positive visitor feedback.

OUR GRAVEL HUNTERS PROJECT HAS ENCOURAGED YOUNG PEOPLE TO FIND FOSSILS IN THE EVERYDAY GRAVEL AROUND THEM, AND OUR ONLINE EXHIBITIONS HAVE SHOWCASED DANIEL FIELD'S RESEARCH ON THE EARLIEST MODERN BIRD, THE WONDERCHICKEN.

Of course, the Museum is not just about its public side – the vital work that the collections team does supporting research and teaching has been especially important as Department colleagues put together online teaching resources and look for student projects to replace fieldwork. We had originally anticipated that our new Collections Research Centre would be welcoming researchers later this year. Relocation of the rock collections continues well, but at a much slower pace as the fifty or so volunteers we had recruited and trained have not been able to help us.

This last year has demonstrated that the Museum is very much able to adapt and develop in response to the challenges presented. We have a really strong and resilient team, with a clear understanding of our role in supporting research, teaching and the public, and strong support from colleagues in the Department.

## RECENT NEWS & AWARDS

### new arrivals

**Nick Tosca** has been appointed as Professor of Mineralogy and Petrology. Nick was a student at Albany and Stony Brook, USA. He formerly spent time in Cambridge as a Research Fellow at Churchill, since when he has taught both at St Andrews and Oxford. Nick's research group works on the co-evolution of life and environments through Earth's early history. Combining lab experiments and theoretical modelling to understand the mineral products that make up ancient sediments. The group is now planning to apply these techniques to early sedimentary environments on Mars.

We also welcome **David Wallis** as a University Lecturer. David arrives after three years as Assistant Professor at Utrecht University, having formerly been an undergraduate in Durham, a postgraduate in Leeds and a postdoc in Oxford. He has formed the Microgeodynamics Group to tackle problems in rock deformation from the crystal-lattice to lithospheric-plate scales. In particular, he is combining microstructural analyses with rock deformation experiments to develop a new generation of microphysical models of deformation processes.

# The Geological Record

## Promotions

Congratulations to three newly promoted members of staff.

**John Maclennan** (Emmanuel, 1993 and Fellow of Emmanuel) has been promoted to a Professorship. He has been developing a global view of basaltic magmatism through studies of mid-ocean ridges, ocean islands and large igneous provinces, with Iceland being the natural focus of much of his work.

**Alex Copley** (Queens', 2004 and Fellow of Robinson) has been promoted to a Readership in Tectonics. Alex studies active tectonics from the scale of individual fault systems to mountain ranges. He uses seismology, InSAR, field and remote sensed geomorphology, and numerical modelling to understand active deformation of the continents and the rheology of the lithosphere.

**Alex Piotrowski** (Fellow of Murray Edwards) has been promoted to Reader in Palaeoclimatology. He uses geochemical tools such as radiogenic isotopes to reconstruct the past geochemistry of seawater and to better understand the link between ocean circulation and climate.

# Awards

Congratulations to four recipients of major honours.

**Marian Holness** (Clare, 1983 and Fellow of Trinity) has been made a Fellow of the Royal Society. Marian's research concentrates on processes during melting and solidification of rocks: the formation and segregation of crustal melts, and the evolution of the crystal mush formed within cooling magma chambers. She combines detailed observations of grain-scale microstructure with more conventional field observations and geochemical analysis.

**David Hodell** (Fellow of Clare) has been made a Fellow of the American Association for the Advancement of Science. David works on linking long-term climate cycles to the history of Earth's orbital geometry (the Milankovitch hypothesis). He uses deep-sea sediment cores to refine the Cenozoic climate record, and lake sediment cores and cave deposits to link Holocene climate change and cultural history of human civilisations such as the Maya, Khmer and Indus Valley.

**Nick McCave** (Emeritus Woodwardian Professor of Geology and Fellow of St John's) has been made a Fellow of the American Geophysical Union. Nick's research aims to understand how modern deep ocean circulation shapes the sea bed and controls the distribution of sediments. He then uses sediment core records to apply this understanding to the Pleistocene and Neogene. Nick's wider aim is to understand how climate change impacts the deep sea and vice versa.

**Marie Edmonds** (Jesus, 1994 and Fellow of Queens') has won the Joanne Simpson Medal from the American Geophysical Union. Marie researches the cycling of volatiles between the atmosphere and the mantle, and the role that magmatic volatiles play in melting, magma genesis, storage and transport, volcanic eruption style and climate modulation over a range of timescales. She has wider interests in igneous petrology, volcanology, modelling, volcanic hazards and instrumentation.

# Retirement

**Bob White** (Emmanuel, 1971) has spent most of his career in Cambridge, first as a student and research fellow, then as a member of the teaching staff. He has been Professor of Geophysics from 1989 till his retirement last September, and a Fellow of the Royal Society since 1994. Bob has led marine geophysical projects to the Atlantic, Indian and Pacific Oceans and on-land projects in Iceland, New Zealand, and the Faroes. Amongst his numerous research papers, he is best known for using geophysical evidence and melting models to show that flood basalts result from continental rifting above mantle plumes. Beyond the Department, Bob is an Emeritus Director of The Faraday Institute for Science and Religion which he founded with a colleague in 2006.

FOR ALL THE LATEST CAMBRIDGE EARTH SCIENCES BLOG POSTS VISIT BLOG.ESC.CAM.AC.UK

# FROM THE CAMBRIDGE **EARTH SCIENCES BLOG**

## ESCAPING THE PANDEMIC

### My experience as an exploration geologist in Yukon

**Ayesha Landon-Browne, first year research student**

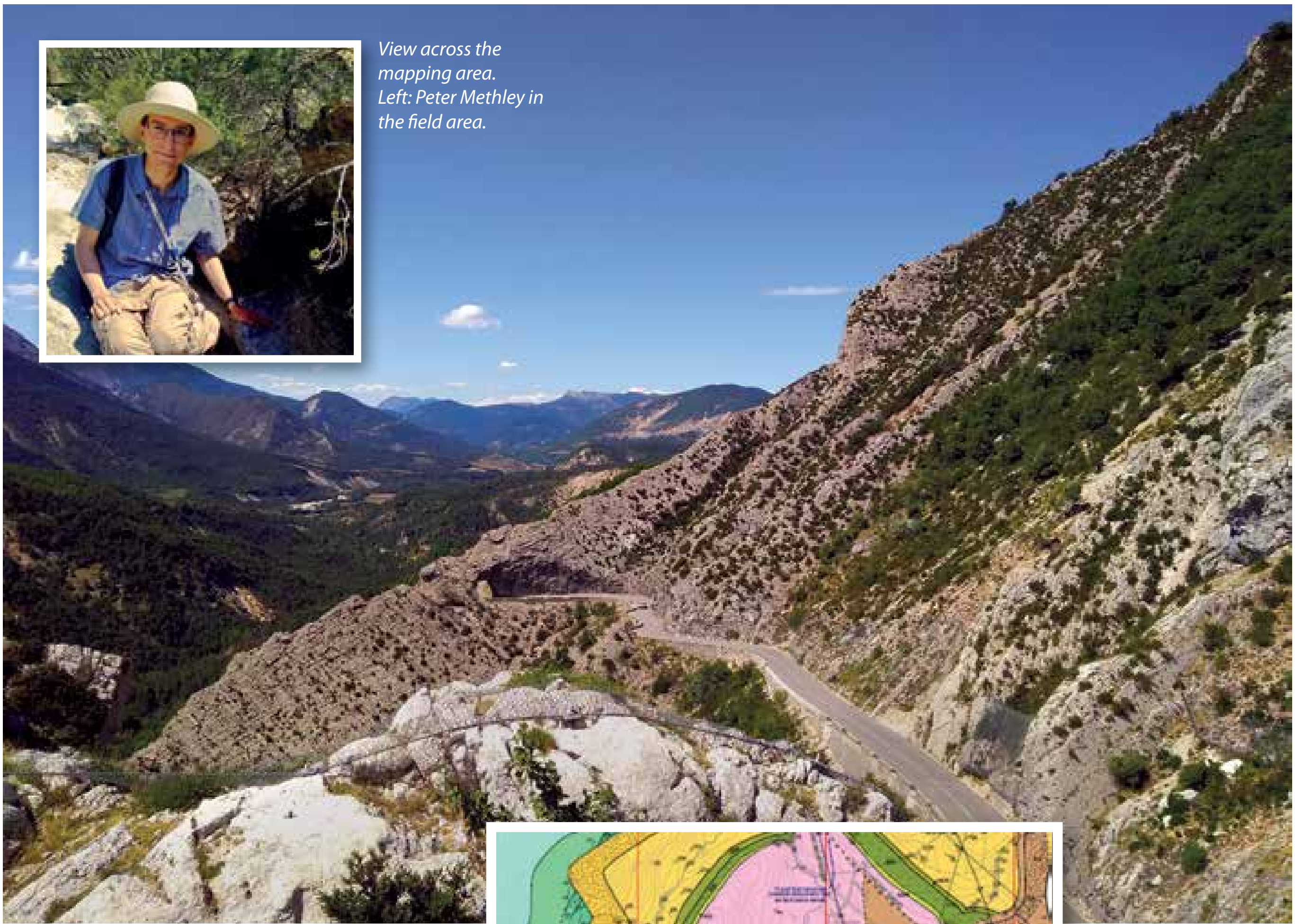
If you had the chance to escape from the ongoing pandemic to a remote exploration geology camp in northern Canada, 150km from the closest town and only accessible by helicopter, would you take it?

I came to Cambridge to start my PhD in January 2020 and, although I was warmly welcomed, things were at first pretty uneventful. However, this changed dramatically with the sudden onset of Covid-19. I chose to return home to Canada where I continued to work on what I still hope will be a lab-based PhD. However, there are, of course, limitations to research from a bedroom 5000km from Cambridge!

My luck changed when, a month after returning to Canada, I was given an opportunity to work as part of an exploration project – one I had previously worked with between October and December 2019. I leapt at the chance to get more experience in the field, and to escape to remote Yukon – far from the reaches of news and social media.

Read more blog.esc.cam.ac.uk/?p=1872#more-1872

*Main image: Helicopter transport into the Yukon base camp.*
*Below left: An exploration drill rig against a backdrop of the northern lights.*
*Below right: Ayesha lining up a new exploration drilling site.*

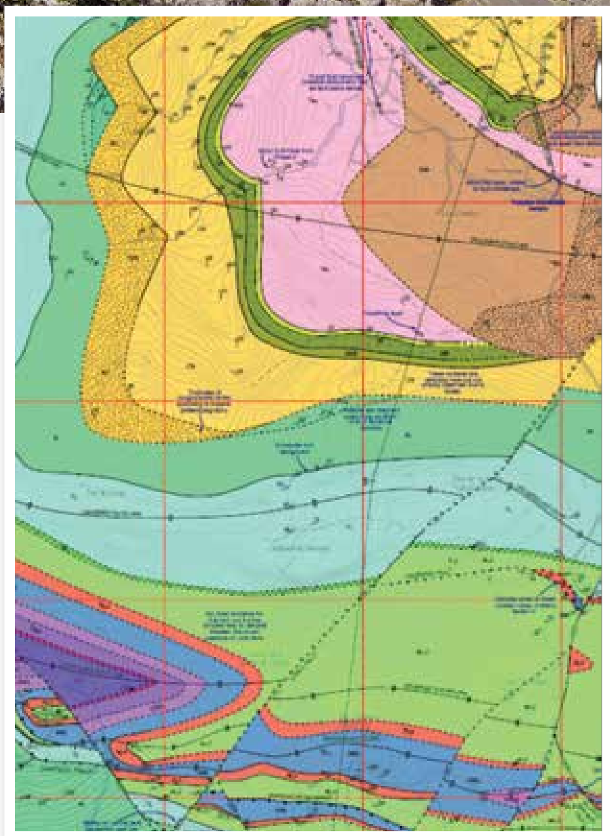


*View across the mapping area. Left: Peter Methley in the field area.*

## PRE-COVID MAPPING PROJECT WINS A NATIONAL AWARD

**Nigel Woodcock reports on the success of Peter Methley, Part III student**

Peter won this year's Dave Johnston prize of the Geological Society's Tectonic Studies Group, for his impressive 2019 project on an area around Castellane, in south-east France. This is the first time that a Cambridge project has won the prize in over twenty years of nominating our best project.



*Detail from Peter's final map.*

"We chose the area because it was relatively easy to travel to, had nice sunny weather (at least most of the time) and had interesting-looking structures on the existing geological map", Peter explains, prioritising his reasons in a time-honoured order.

"The views were spectacular, although they did come with the cost of having to climb 500-metre-high mountains on a regular basis. We also had plenty of time for non-geological fun; skimming stones on the nearby lake, swimming in the rain, riding a pedalo up the Gorges du Verdon or eating our way through the local shop's entire range of ice-cream! We even had time to go on some touristy road-trips to Cannes and Monaco (which both happen to be built on cool geology as well). Overall, mapping was a fantastic experience, and I wish I could go back there now!" says Peter with feeling, currently experiencing a Part III year done entirely under Covid restrictions.

Read more blog.esc.cam.ac.uk/?p=1949

# Make a world of difference in Earth Sciences

Donations from our alumni are increasingly important in adding value to our students' experience of Earth Sciences, whether through teaching or through research as a Part II or III undergraduate or post grad.

There are four alternative ways that you can allocate your gift:

- The **Earth Sciences Fieldwork Fund** helps maintain the Department's strong commitment to field teaching as a vital way of bringing lecture and practical material to life. Boosting fieldwork provision for all students who have missed field courses due to Covid restrictions will involve extra costs, which the fund can help with.

- The **Earth Sciences Student Support Fund** helps individual students struggling with the extra costs of doing an Earth Sciences degree. Our aim is for nobody to be disadvantaged because they can't afford a field course fee, or the cost of a laptop for remote learning for instance.

- The **Sedgwick Museum of Earth Sciences Fund** helps the Museum to care for and share its internationally important collections. The Museum has continued to provide access to its collections for researchers and students throughout the pandemic, while its targeted school and public programmes encourage the next generation of Earth Scientists.

- The **Earth Sciences General Fund** is unrestricted in its use. It can help to support all urgent or unexpected needs within the Department, which including topping up partially-funded postgraduate studentships, helping with travel to research labs, with new initiatives for lab equipment, and – most recently – adding cameras to microscopes to allow socially-distanced teaching.

You can donate online at **philanthropy.cam.ac.uk/give-to-cambridge/earth-sciences** or fill out the Donation Form inserted with this GeoCam.

For further information about donating to Earth Sciences or guidance on how to leave a gift, please do contact us.

Nigel Woodcock
**alumni@esc.cam.ac.uk**

Josh Bowerman
Senior Associate Director of Physical Sciences
**josh.bowerman@admin.cam.ac.uk**

# Thank you to our donors 2019–2020

We wish to thank alumni and friends who have generously made donations to the Department over the last year. Every effort has been made to ensure the list is accurate; do contact us if you believe we have made an omission.

We would also like to thank all those who made a gift to the Department anonymously.

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To keep in touch, make sure you update your contact details with us at:
**alumni.cam.ac.uk/contact/update-your-details**

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# Be part of the future with a gift in your Will

A gift to the Department in your Will could help the Department flourish far into the future. Such a gift can open up a world of opportunity for future students, researchers and academics. Many of our donors find that a gift in their Will is a good way to make a significant and lasting contribution.

For further information about the impact of a legacy and guidance on how to leave a gift to the Department of Earth Sciences please do contact us:

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The campaign for the University and Colleges of Cambridge