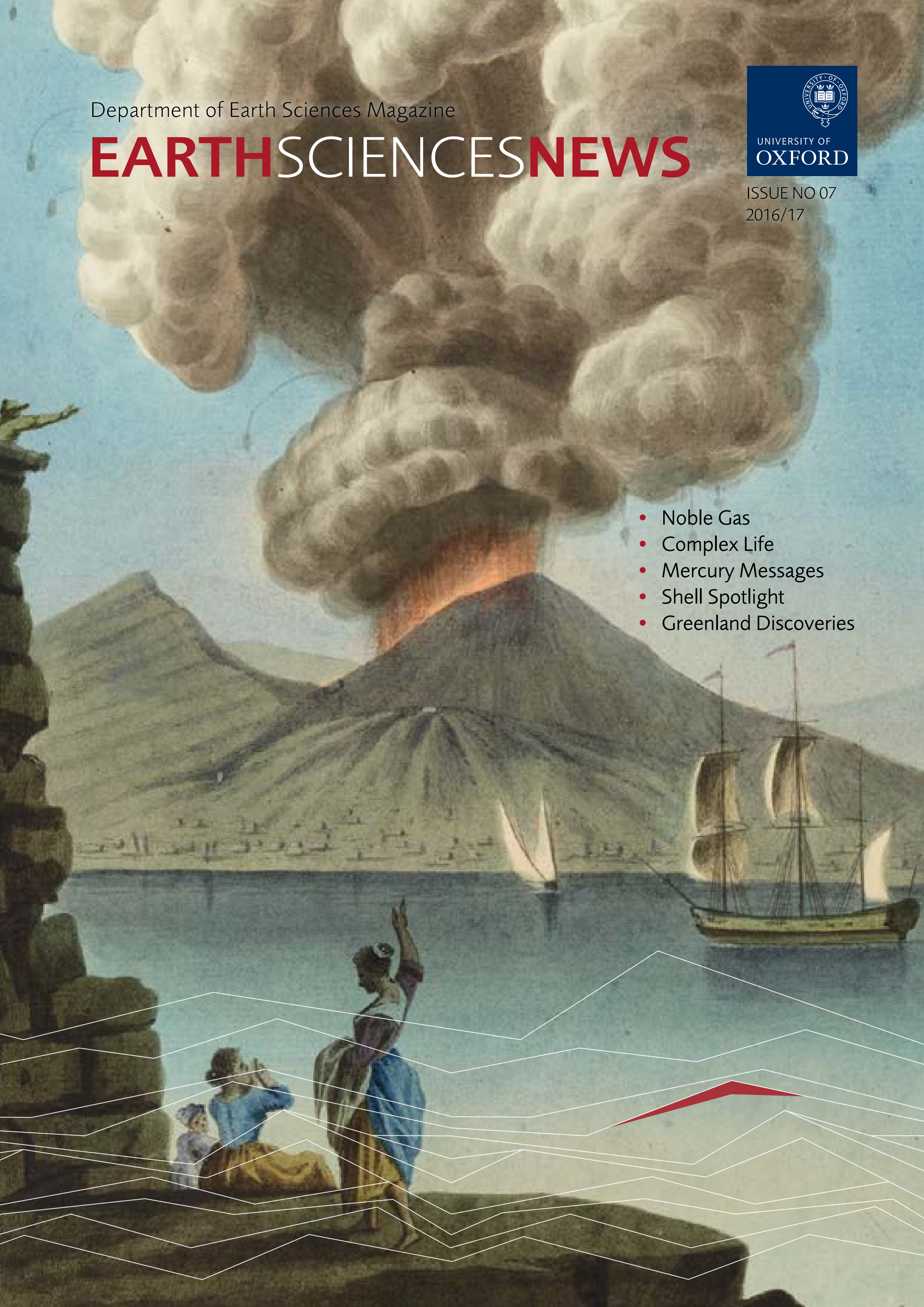


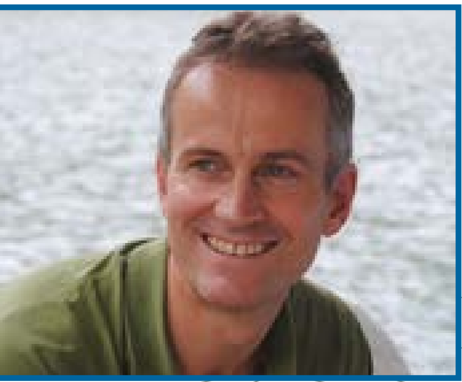
Department of Earth Sciences Magazine

EARTHSCIENCESNEWS

UNIVERSITY OF OXFORD

ISSUE NO 07
2016/17

- Noble Gas
- Complex Life
- Mercury Messages
- Shell Spotlight
- Greenland Discoveries



CHANGING TIMES

Professor Gideon Henderson
Head of Department

I'm writing as the academic year draws to an end, culminating last week with the department's annual finals party. This event celebrates student success– in exams, with their research, and in the field – and the range of awards reflects our links to industry, science organisations, and to history. We are grateful (as, I'm sure, are the students who receive the cheques) to BP, Güralp, Schlumberger, and Shell for their sponsorship of prizes, and for organisations including the International Seismological Centre, the Atomic Weapons Establishment, and the Met Office. Our history is clear in both our oldest prize – the Burdett Coutts Prize for best performance in third-year finals, funded by a gift to the Department made more than 100 years ago – and from the much more recent Keith Cox prize for field-work, which was awarded again this year by Keith's widow, Gillian.

It is good to remember the Department's long history and our successful navigation of past challenges as we look to the future. Britain's vote to leave the EU raises two issues for the department which closely mirror those faced by the nation as a whole: continued involvement in EU financial agreements and immigration.

In the last 5 years, 24% of our research funding has come from the EU, mainly from grants from the European Research Council to support basic and innovative research through funding of excellent individuals. The future of such EU science funding is not often written about in the wall-to-wall media coverage of Brexit, and sometimes dumped into the worryingly negative category of, "continued bills from the EU". We fervently hope, though, that the outcome of negotiations enable the UK to remain involved in EU science programmes. They come at a cost, but for the UK the benefits far outweigh this cost, both in straightforward financial terms and especially from our involvement in major science projects across the continent. Leading UK universities, and organisations such as the Royal Society, are making these arguments to government. For the department, the uncertain EU future makes it even more important to continue collaboration with the range of partners in industry and charity who also support our research.

Greater than the financial threat of Brexit is that posed by possible tightening of immigration controls. Science is international, and to excel requires an exchange of the best people between leading institutes around the world. At present, 22% of the department's research staff are from other EU countries, and 18% of our graduate students. We sincerely hope that our exit from the EU does not curtail our ability to benefit from the wealth of overseas talent.

It will not be me leading the department into the post-Brexit world. Heads of Department are five-year positions and I'm nearing the end of my stint. It has been a great privilege to lead the department; challenging, but often fun and fulfilling. I'll be taking a year of sabbatical in Zurich, spending it at one of only two Earth Science departments ranked above Oxford in this year's QS ranking of university departments (the other being Harvard). I pass the head-of-department baton to Chris Ballentine, who joined us from Manchester to take up the Chair of Geochemistry 4 years ago. Chris leads a dynamic research group pursuing a broad range of research (see overleaf), and he brings a wealth of leadership experience. He has recently been President of the European Geochemical Society, overseeing a period of substantial growth and increasing influence, and he now serves on the Board of Governors of the American Geophysical Union, the largest international geoscience organisation. The department will be in very safe hands.

Chris Ballentine

The job of HOD is only possible because of the huge support from so many people in the department. Keeping the department a happy and productive place involves faculty, technicians and administrative staff (and even the odd student!). There are too many people to thank them individually (this is not the Oscars), but in this publication I must thank Claire Grainger, who does such a tremendous job in editing this magazine, and running a dynamic programme of events for alumni (as well as programmes for prospective students, school kids, and the public).

Thank you, too, to all our alumni for your continued support for the department and interest in earth sciences. As a handful of faculty shared a mini-bus back to Oxford from London, after the alumni Planet-Ocean event last April, we talked about how enjoyable it is to hear what former members are up to, and to share our latest work with such an informed crowd. I look forward to continuing these conversations at future events.

A NEW TUTOR AT ST HUGH'S

Introducing Erin Saupe, Tutorial Fellow at St Hugh's College

Following the departure of Professor Matt Friedman to his native Michigan, we are delighted to introduce the new tutorial fellow for St Hugh's College, Erin Saupe. Erin takes on the title of Associate Professor of Palaeobiology, though she approaches the subject from a slightly different angle to her predecessor.

"My research probes the interactions between life and environments over geological time scales, integrating biological data with information from the fossil record to understand the controls on community and species' responses to environmental change. What makes species prone to extinction, and how does this vary through time? What factors control biological distribution, and how do Earth and environmental processes affect biological diversification? We're applying deep-time information to current problems of species conservation and changes in biodiversity in the face of rapid climate change."

Erin was initially drawn to the field through nature magazines. "As a child, I would marvel at images of red-eyed tree frogs, pangolins, tarsiers, fennec foxes, and jumping spiders. Protecting biodiversity is vital for our economy and for maintaining our food and medicine reserves, as well as preserving the sense of awe inspired by our flora and fauna."

The Minnesota native was educated at the College of St Benedict & St John's University in Minnesota, before pursuing a PhD at the University of Kansas, followed by a prestigious National Science Foundation Fellowship at Yale University. "I discovered a love of the duality of teaching and learning whilst mentoring graduate students at Yale. It's such a privilege to have a job that allows me to indulge my passions of photography, hiking and the natural world, in locations such as Spain, Argentina, and China. "

HUNTING FOR HELIUM

BY CHRIS BALLENTINE

Helium has been called the 'enabler of innovation and billion dollar industries'. Global use of helium today is estimated to be approximately 150 million cubic meters of gas per year. Liquid helium has unique thermal properties that make it irreplaceable in many cryogenic applications. Of particular note are the low temperature superconductors that enable the high magnetic fields in medical MRI (magnetic resonance imaging) scanners and control of high energy beam lines like the Large Hadron Collider at CERN. These and similar liquid helium applications make up about one quarter of helium use. The remainder includes applications of helium gas in the manufacture of electronics and semiconductors, welding, diving, airships and as a pressure and purge gas for rocketry.

Traditionally helium has been produced as a by-product during natural gas extraction. With demand starting to outstrip supply, concern is increasing that we may run out of this critical gas. Although there is some production from Canada, Australia and Poland, only Russia to date has significant known reserves that could plug the gap. Without new finds, global helium supply will be reliant on the financial stability of the liquid natural gas market and political stability of Qatar, Algeria and Russia. As I write, Saudi Arabia has just closed its land borders to Qatar, the export route used by Qatar helium trucks. Diversification of supply for European and US medical, science and industrial interests is essential. Rather than finding new helium by accident, we set out to prospect specifically for the gas, with our first promising location now identified in Tanzania. We hope this approach will ensure the future supplies of helium for science and society.

My Oxford 'Noble' research group uses the unique isotopic signatures of the inert gases (He, Ne, Ar, Kr, Xe) to identify the source, mass and flux of fluids controlling different geological systems. Jon Gluyas (then Head of Department at Durham University) and I had been discussing our mutual interest in subsurface fluid systems for some time when helium users in 2011 started to receive letters from suppliers cancelling orders. Helium production was not meeting demand. It seemed an obvious application to use helium-associated tracers to understand commercial helium occurrence. Jon and I teamed up and made a successful pitch to Statoil for funding to sponsor a PhD project.

The dominant source of terrestrial helium is stabilised α-particles produced by uranium and thorium decay. Commercial helium is only found in rare natural gas fields that have been 'enriched' in this radiogenic helium. Due to historic oversupply the serendipitous discovery of helium-rich natural gases has been able to supply world demand until now, and exploration strategies are very undeveloped. Using Helium's close association with hydrocarbons we adopted a similar approach to hydrocarbon exploration to identify for helium the processes controlling: i) source rock quality; ii) primary migration (release from source rock); iii) secondary migration (transport to trapping structure); iv) trapping (competence and timing of geological traps). Where all of these criteria are favourable, we have found a potential helium exploration target – and not necessarily where you would look for hydrocarbons.

We already know a lot about helium source rocks. In a separate Noble group project we have been studying deep mine fluids in the Canadian Precambrian shield. These intersect with fracture fluids rich in helium and nitrogen. Dr Oliver Warr (Noble Postdoc now at the University of Toronto), has shown that the deepest fluids (2.9km depth) may have a mean residence time of more than 2 billion years. Helium in these rocks just doesn't escape unless the system is seriously perturbed. Orogeny, rifting or volcanism provides the mechanisms to release the helium that has built up in the Precambrian rocks.

To investigate the secondary migration of helium, Di Danabalan (Durham and guest Noble PhD student) and I took a 2000 mile road trip to collect samples from helium rich gases in Kansas, Utah and Montana in the USA, crossing into Saskatchewan in Canada. Di's results show that in many of the systems sampled the helium is dissolved in the regional aquifers before other gases such as methane and/or carbon dioxide strip the helium from the water to form helium-rich gas fields. This is an essential exploration factor to take into account. The gas fields with the highest helium concentrations are dominantly helium and nitrogen only and very similar to the source rock analogue fluids found in the Canadian mines. Here they form a commercial gas field without the help of hydrocarbons or carbon dioxide.

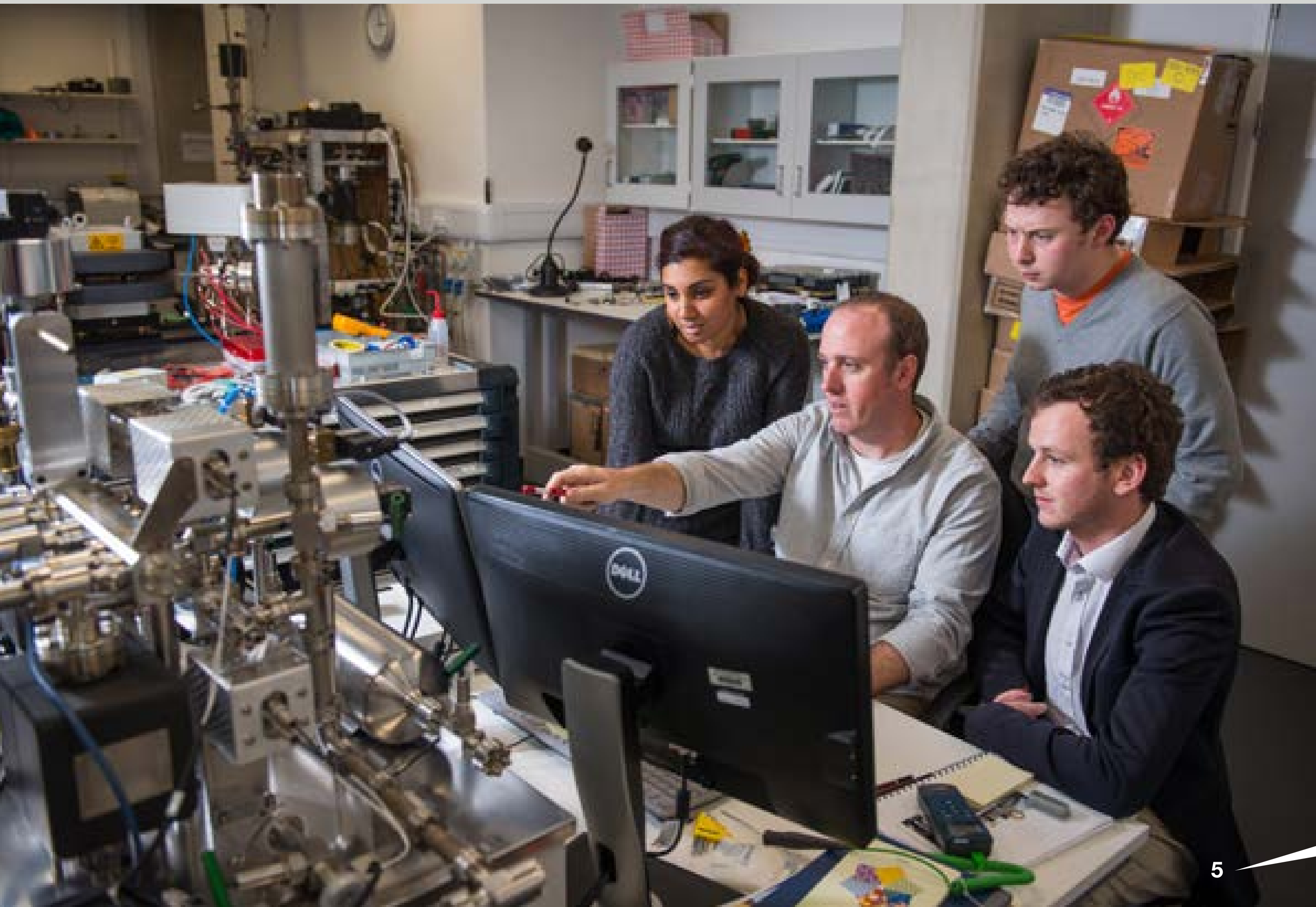
Left main pic: A fluid seep in Tanzania, exploited as a watering hole by the local farmers.

Left inset: Chris Ballentine testing the 'waters' of the seep.

Below: The 'helium dream team' at work in the lab in 2015.
L-R: Di, Pete, Oli and David.

Dr Pete Barry (Noble Postdoc, now USGS visiting Noble research fellow) joined the Noble team in 2014. With extensive experience of helium isotope analysis of volcanic gases in Tanzania he established our contact with Helium-one, a helium exploration start-up company working in Tanzania. It doesn't take too long to realise that the Tanzanian section of the East African rift has all of the ingredients for a prime helium exploration target: An ancient continental Craton (prime source rock), Rifting and associated volcanism (helium release), and sediment trapping structures within the rift basins. Pete led several expeditions with Helium-one to collect surface gas seeps from the rift, discovering gases that contained up to 10% by volume helium, with the remainder made up by nitrogen. These are similar to both the Canadian source rock study and the rare few nitrogen-helium producing gas fields in the USA. There is one big difference. The trapping structures identified by legacy seismics in the Tanzanian rift have the capacity to hold enough helium to supply the entire world demand alone for a decade.

There is still much to understand before the Tanzanian probable helium resource becomes a confirmed reserve, feasible for production. Our geochemistry is playing a role determining regional helium potential, identifying likely helium content of subsurface gases, understanding the risks and benefits of other subsurface gases occurrence, and linking macro-seep composition and soil gas anomalies to faulting/trapping structures. Ultimately though, it is only by drilling the most promising structures that this speculation be tested. Whatever the result we have made big step forward in understanding where to look next.



FUEL FOR COMPLEX LIFE

BY ROSALIE TOSTEVIN

The question of why it took so long for complex animal life to appear on Earth has puzzled scientists for a long time. Why, after three billion years of nothing more complex than algae, did a variety of animals suddenly start to appear on Earth? One argument has been that evolution simply doesn't happen very quickly. New evidence suggests that high oceanic oxygen levels 550 million years ago gave simple life-forms the fuel they needed to evolve skeletons, mobility and other typical features of modern animals.

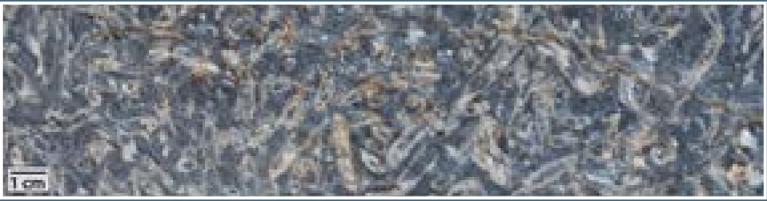
All animals require oxygen, to build essential organic compounds and to generate energy through respiration. But the amount of oxygen an animal needs varies hugely among species, depending on their body plan, size and lifestyle [1]. There is geochemical evidence for a rise in oxygen in the oceans around the time that the first complex animals appear [2], and this is sometimes proposed as a 'trigger' for their evolution. It been difficult to prove a causal link, partly because the oxygen demands of the earliest animals are unknown, making it difficult to assess whether rising oxygen levels were an important influence on their appearance and success.

Life may have begun as early as 3.8 billion years ago, but we don't see the first hints of animal life until 635 million years ago, in the form of hydrocarbons imprinted in the sediment [3]. These earliest animals were probably in the same phyla as sponges; simple animals that lack nervous, digestive or circulatory systems. The later Ediacaran Period (630-541 million years ago) saw the emergence of the first animal body fossils, mysterious and often unrecognisable forms known as the "Ediacaran biota". It wasn't until the closing curtain of the Ediacaran Period that the hallmark features of modern animals, such as motility and hard body parts, began to appear [4].

In today's ocean, oxygen poor waters tend to host smaller animals, with thinner shells, and commonly show lower diversity [1]. Large, fast moving animals, such as tuna, will alter their course to avoid oxygen-poor zones, but this results in predator-free environments where smaller animals may thrive [5]. What's more, simple sponges have been shown to function well in waters with as little as 1% of normal oxygen levels [6]. Living animals may not be good analogues for ancient animals, because they've had hundreds of millions of years to adapt to oxygen rich environments. The relationship between oxygen levels and ecology is complicated, and applying our understanding to Ediacaran animal communities, known only from their fossil record, is even more challenging.

Our research tries to unravel these relationships using a new approach. We looked at the sediments from an Ediacaran shelf sea, preserved in the sedimentary rocks of the Nama Group, Namibia.

Reef systems rising from the ancient seafloor. now preserved in the Namibian rock record.
Photo: Fred Bowyer



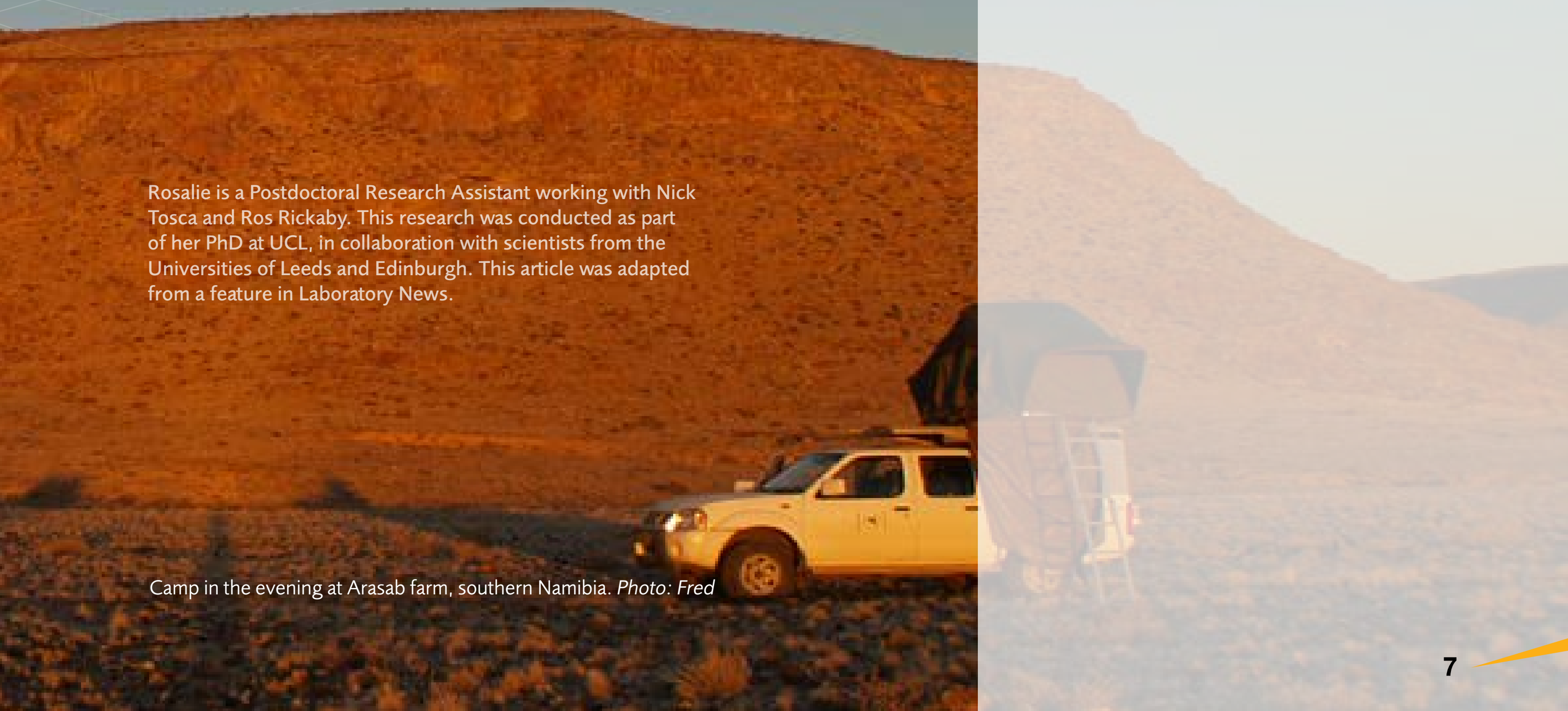
LEFT: Large Cloudina fossils. *Photo: Rachel Wood*

We characterised the distribution and size of fossils, as well as aspects of their ecology, such as the presence of multiple generations or the building of long-lived reefs [7]. We focussed in particular on the first skeletal animals, because skeleton building is a costly process that likely requires higher oxygen levels. Early skeletal animals show limited diversity in the Ediacaran, with only three types identified in the Nama Group; *Namapoikia*, *Cloudina* and *Namacalathus*. *Namapoikia* is an encrusting organism that can reach diameters of up to a meter. It's interpreted to be of the phylum Porifera (e.g. sponges) or Cnidaria (e.g. jellyfish and corals). *Cloudina* is built of funnel like structures, that stack together like ice cream cones, and is interpreted to be a Cnidarian. *Cloudina* has been documented forming modern-like animal reef systems, with individuals cementing to one another. The third type known from the Nama Group is *Namacalathus*, a stalked goblet shaped form, which may be a Cnidaria, or belong to the more derived *Lophophorates* (e.g. brachiopods and bryozoa).

We analysed levels of oxygen-sensitive chemicals, cerium and iron, in each layer of sediment, including fossil-bearing layers [8, 9]. These two chemical species have a unique response to rising oxygen levels. Build-ups of iron minerals in the sediment is a good indicator of fully anoxic (oxygen free) conditions in the water column above. Cerium, however, begins to build up under low oxygen, but not fully anoxic, conditions. Since the cycling of cerium is closely tied to manganese, this response likely occurs in waters with around 4% of modern oxygen levels. Sediments with neither cerium nor iron build ups are interpreted to be well-oxygenated, i.e. contain more than 4% of modern oxygen levels. Combining results from these two chemical systems, we were able to tease apart anoxic, low oxygen and well-oxygenated waters across an ancient shelf sea. We then tied this oxygen map directly to the ancient ecosystem.

We found that skeletal animals were largely confined to well-oxygenated waters. This suggests that they had fairly high oxygen demands. One consequence of this is that suitable habitats would have been in limited supply, because most of the shelf contained insufficient oxygen to support their energy-intensive, skeleton building lifestyle. Local oxygen levels may have controlled the distribution and success of animals through the Ediacaran and beyond. While this doesn't prove a causal link between a rise in oxygen and the first appearance of skeletal animals, it does mean that a global rise in oxygen levels (to at least 4% of modern levels) must be a pre-requisite for the appearance of skeletal life. Exactly when Earth's oxygen levels surpassed this crucial mark remains a challenge that we continue to work on.

Rosalie is a Postdoctoral Research Assistant working with Nick Tosca and Ros Rickaby. This research was conducted as part of her PhD at UCL, in collaboration with scientists from the Universities of Leeds and Edinburgh. This article was adapted from a feature in Laboratory News.



Camp in the evening at Arasab farm, southern Namibia. *Photo: Fred*

References

[1] Levin, LA. "Oxygen minimum zone benthos: adaptation and community response to hypoxia." Oceanography and Marine Biology: An Annual Review 41 (2003): 1-45.

[2] Knoll, Andrew H., and Erik A. Sperling. "Oxygen and animals in Earth history." Proceedings of the National Academy of Sciences 111.11 (2014): 3907-3908.

[3] Love, Gordon D., and Roger E. Summons. "The molecular record of Cryogenian sponges–a response to Antcliffe (2013)." Palaeontology 58.6 (2015): 1131-1136.

[4] Wood, Rachel. "Palaeoecology of Ediacaran metazoan reefs." Geological Society, London, Special Publications 448 (2016): SP448-1.

[5] Stramma, Lothar, et al. "Expansion of oxygen minimum zones may reduce available habitat for tropical pelagic fishes." Nature Climate Change 2.1 (2012): 33-37.

[6] Mills, Daniel B., et al. "Oxygen requirements of the earliest animals."Proceedings of the National Academy of Sciences 111.11 (2014): 4168-4172.

[7] Penny, A. M., et al. "Ediacaran metazoan reefs from the Nama Group, Namibia." Science 344.6191 (2014): 1504-1506.

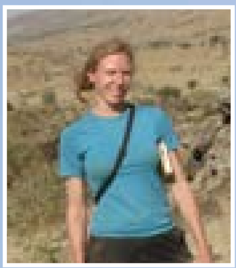
[8] Wood, R. A., et al. "Dynamic redox conditions control late Ediacaran metazoan ecosystems in the Nama Group, Namibia." Precambrian Research 261 (2015): 252-271.

[9] Tostevin, R., et al. "Low-oxygen waters limited habitable space for early animals." Nature Communications 7 (2016).

FIELD NOTES FROM AFAR

Volcanoes in the Main Ethiopian Rift: Past, Present and Future

BY KAREN FONTIJN (POSTDOCTORAL RESEARCH ASSISTANT)



The misery of the sleepless overnight flight is immediately forgotten by the warm greetings that await me outside Bole International Airport. We only saw each other last week, but Yelebe is clearly happy to finally welcome me in his home country. My field assistant Amde has found a replacement instructor for the geology field course he was supposed to lead this week, so he can accompany me again to the volcanoes of the Main Ethiopian Rift. Yelebe, Tim and myself are post-docs on the RiftVolc project which aims to understand the past, present and future of volcanic activity in the Main Ethiopian Rift. Where my role in RiftVolc is to study the frequency and magnitude of past volcanic activity by looking at the rocks, they are studying present-day deformation on a volcano- and rift-scale using seismometers and GPS stations. Tim wanted to install some new stations at the volcanoes that I urgently needed samples for: Bora-Borecha and Tullu Moye, so we agreed a deal: I could hop into their car and sample pumice whilst he and Yelebe would do their seismic thing. At the same time we would learn from each other and make a good impression on RiftVolc's external advisory board!

We have two more field assistants, Berhanu and Danny, both young researchers at the Institute of Geophysics, Space Science and Astronomy of Addis Ababa University, and two professional drivers, Eyaya and Solomon. The two cars are fully loaded with big boxes full of tools, batteries, GPS antennas, seismometers, laptops and lots of cables in all sorts of colours. In contrast, my field equipment looks rather pathetic: a small bag with a hammer, a tape measure, a trowel and a foldable shovel. Maybe I have a hand lens somewhere

First seismic station almost done!

that I might not even need. I do however have lots of sample bags that I intend to fill with pumice along this trip, so I'm sure I will get my revenge. So here we are then: geologists and geophysicists about to embark on a joint field trip. What could possibly go wrong?

I came to this area expecting to find young soils interbedded with a few pumice fall deposits resulting from moderate-scale explosive eruptions from the Bora-Borecha and Tullu Moye volcanic complexes. Along the Main Ethiopian Rift the volcanic centres have behaved quite differently in their most recent (post-caldera) stages of activity. Some have had pretty sizeable eruptions every few hundred to a thousand years, but not really anything gigantic, whereas others seem to have done very little in the recent past. There might be a spatial control over this behaviour, and the

Spectacular faulted landscape south of Ogolcho

Borecha volcano, source of many big explosive eruptions, each represented by one of the dark grey horizons in the dry river gorge.

results from this field trip should help me to constrain that better. Based on what I had read in some old reports and observed on satellite imagery, I expected Bora-Borecha and Tullu Moye to lie somewhere in the middle of the spectrum.

They don't. For three days in a row, in between helping out with some of the seismic work, Amde and I were treated to some of the biggest deposits of what seem to be relatively recent explosive eruptions we've seen along the rift. One section particularly puzzled us: at least 15 metres of mostly pumice fall and some flow deposits, all from the same eruption, exposed in a quarry that is visible from the main road. How did we miss this the last time we were here?! Are these the deposits from a hidden caldera that we didn't know about? Closer to the volcanoes we keep finding sequences of multiple metres-thick deposits of pumice falls and flows. Unfortunately we don't have time to map them all in detail but as far as reconnaissance fieldwork goes, this must be one of the most forgiving trips I've ever been on. Ar-Ar dating will hopefully tell us how old these deposits are and inform our future work in this region.

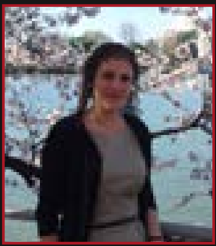
My last day is mostly spent deploying new stations. The first place is Gebi primary school, where I'm surprised to learn that more than 1,000 kids come to school. Not ideal for reducing seismic noise levels but the only place in this village where we can trust the equipment to be safe. The director asks if we could provide solar panels to support the science classes for the school, but this is unfortunately not possible on the RiftVolc grant. The science classes strike a chord with me, and I start thinking of ways to raise money for the solar panels, and promise to give an earth science class when I return. You never know, one of these 1000 kids might feel inspired to become a volcanologist one day. Africa needs its own volcanologists.

As we arrive for lunch in Iteya after our work at Gebi, the others have ordered injera, Ethiopia's staple food. It comes shaped like a pancake and is used to scoop up whatever else is on the plate. The highlight is gored gored, an Ethiopian delicacy of raw beef. Tim is doing the right faranji (foreign) thing and waits for our cooked meat, but I'm intrigued: Yelebe, an expat Ethiopian, and usually more careful with his food than I am, seems very excited about the gored gored. I decide it must be safe enough for me as well. In accepting a couple of lean pieces of beef, I win the Ethiopian hearts, and Yelebe jokes that I'm becoming Habesha (Ethiopian). No need to confess that my stomach tries to disagree the next day!

Ethiopian colleagues at their happiest with gored gored. From left to right: Yelebe, Amde, Berhanu, Danny, Solomon and Eyaya.

Many of the children around here show signs of dental fluorosis. This is a common sight in many parts of the East African Rift and is due to fluorine reaching from the volcanic rocks into the groundwater, and causing a long-term health hazard. Understanding the budgets and partitioning behaviour of fluorine and other volatiles and their controls on the eruptive styles at the peralkaline rift volcanoes and associated hazards is one of the key goals within RiftVolc.

REWRITING THE BOOK O



DR SHOSHANA Z. WEIDER
(WORCESTER, 2003)

Less than half of Mercury's surface was imaged with Mariner 10. The 1550-km-wide Caloris basin (radiating from centre left here) was seen in its entirety only once MESSENGER was in Mercury orbit. Credit: NASA/Jet Propulsion Laboratory.

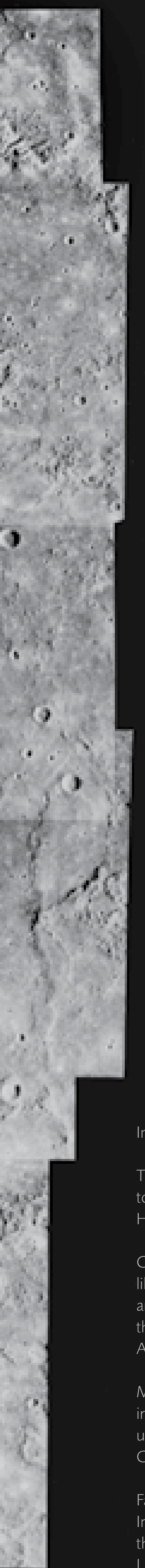
Mercury – the smallest and innermost planet – has long been one of the least understood components of our Solar System. Difficult to study from Earth because of its proximity to the Sun, Mercury had – until recently – been visited by only one spacecraft. In 1974–1975, NASA's Mariner 10 performed three 'flybys' of the planet, during which some rudimentary observations were made. Detection of Mercury's weak magnetic field suggested a partially molten core, and several species (including hydrogen, oxygen, and helium) were detected in the planet's 'exosphere'. However, the vagaries of Mariner 10's trajectory, coupled with the planet's tidally locked 3:2 spin-orbit resonance, meant that less than one half of Mercury's surface was seen from close range.

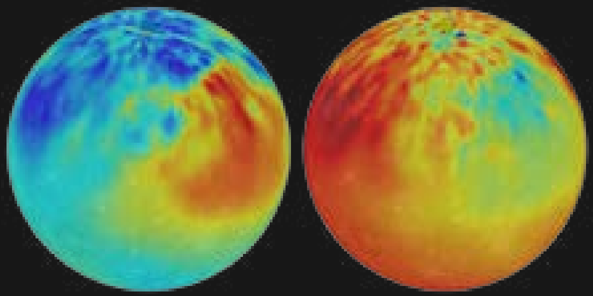
The Mariner 10 images revealed a grey surface, full of craters. Many planetary scientists wrote Mercury off as geologically similar to the Moon and not worthy of an extensive follow-up mission. But a committed and insightful group of scientists – led by Principal Investigator Professor Sean Solomon from the Lamont-Doherty Earth Observatory of Columbia University – were not so easily placated. They believed Mercury should not be so readily dismissed, and their dream of a new Mercury mission became a reality when the MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging) mission concept was chosen as the 7th NASA Discovery-class mission in 1999.

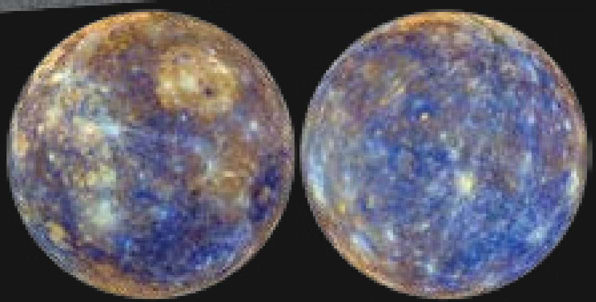
To answer eight primary science questions about Mercury and its geologic history, MESSENGER was originally designed as a one-year orbital mission (the orbital mission eventually lasted for more than four years, ending with impact into the surface once all the spacecraft's fuel had been spent). The extreme heat of Mercury's location, as well as the neighbouring Sun's huge gravitational pull, however, presented major engineering challenges. For one solution, a protective 'sunshield' for the spacecraft was created from a novel heat-resistant ceramic. In addition, MESSENGER's journey to Mercury was specifically designed to reduce the velocity of the spacecraft before orbital insertion (and the amount of fuel required). Following its launch in 2004, MESSENGER followed a circuitous route – via flybys of Earth, Venus, and Mercury itself – before entering orbit around Mercury on 18th March 2011.

Less than two months earlier, I had moved across the Atlantic Ocean to start work as a MESSENGER Postdoctoral Fellow at the Carnegie Institution of Science's Department of Terrestrial Magnetism in Washington, DC. I joined the MESSENGER Science Team, working with Dr Larry Nittler, to analyse and interpret data from the spacecraft's X-Ray Spectrometer (XRS). By using the Sun as a natural (albeit fluctuating) source of X-ray radiation, we used the MESSENGER XRS to quantitatively measure the major-element composition of the planet's uppermost surface. This planetary X-ray fluorescence technique has been used – with mixed success – to characterise airless bodies in the inner Solar System for many decades.

N MERCURY







Images from top:

The magnesium (left) and aluminum (right) concentration of Mercury's surface (both relative to silicon), as determined from MESSENGER X-Ray Spectrometer data. Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington.

Carnegie Rupes cuts through Duccio crater (133 km diameter). This lobate scarp (and others like it on Mercury) formed because of horizontal crustal shortening, in response to cooling and contraction of the planet's interior. Colours show topographic height, as measured by the Mercury Laser Altimeter on MESSENGER. Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington.

Mercury's Kertész crater (31 km diameter) is extensively covered in hollows – shallow, irregular depressions that were discovered in MESSENGER images and that appear to be unique to Mercury. Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington.

False colour maps of Mercury (created using images from MESSENGER's Mercury Dual Imaging System) that enhance the chemical, mineralogical, and physical differences between the rocks on the planet's surface. Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington.

With MESSENGER, however, we used this approach to map the entire surface of a planet for the first time.

The XRS and other geochemical data we obtained from MESSENGER have helped to constrain theories for Mercury's early history. Scientists have long puzzled over the reason for Mercury's high density and disproportionately large core. Some believe that the outer (i.e., less dense) parts of proto-Mercury were obliterated during a huge impact event. Our results, however, revealed that Mercury's surface has a rich inventory of volatile elements. Most notably, the sulphur content of Mercury's crust is about 10 times that of typical terrestrial rocks. We expect volatiles to have been lost during the immense heating that would have accompanied a giant impact. Instead, we think, the peculiar major-element composition of Mercury seems to be indicative of the original material that accreted to form the planet. The jury is still out on what those precursors were, but experimental data suggest something akin to enstatite chondrite meteorites could be the answer.

In addition to the XRS, MESSENGER carried a payload of six other scientific instruments to study all aspects of the planet and its surrounding environment. Some of the most exciting findings from the mission include: detection of surface water ice in permanently shadowed areas near to the poles; a magnetic dipole that is offset from the equator; confirmation that Mercury's surface was predominantly formed by volcanism, with later modification from impact craters and global contraction; and long-term observations of Mercury's dynamic and ever-changing exosphere and magnetosphere. Despite the many answers we now possess, MESSENGER has also given rise to a whole new list of (slightly) better-informed questions about Mercury that will hopefully be addressed by the forthcoming European Space Agency/Japan Aerospace Exploration Agency BepiColombo mission.

Moving to Washington and working on MESSENGER, as part of a hard-working and enthusiastic team, was an incredible and life-changing experience. The quantity and quality of scientific results that continue to stem from the mission is astounding. By studying Mercury for the first time in real detail, we are in a much better position to appreciate the full diversity of our Solar System. We have literally rewritten the book on Mercury. Put together by MESSENGER team members, *Mercury: The View After MESSENGER* will be published by Cambridge University Press in the coming months.

Read more about Mercury and MESSENGER:
messenger.jhuapl.edu

Shoshana Weider is a freelance science writer and editor, with an MEarthSci from Oxford and a PhD in lunar geology from Birkbeck College: shoshanazweider.com

THE SHELL-OXFORD RESEARCH COLLABORATION

When Professor Joe Cartwright joined the department in 2012, he took on the role of Shell Professor of Earth Sciences, a 5-year opportunity to establish a new laboratory for advanced geophysical interpretation of sedimentary basins. This laboratory now underpins a fundamental research programme in deformational and diagenetic processes in sedimentary basins, fracture systems in unconventional hydrocarbon reservoirs, and hydrocarbon migration and flow.

As Joe describes this unprecedented scale of collaboration, it is clear that the people matter as much as the science: "Fortunately, the lab's growing reputation has allowed us to attract students, researchers and industry collaborators from around the world. Postdoc Claudia Bertoni, and Visiting Professors Bruce Levell (St Catz 1972), Mike Daly and Erdem Idiz joined us from the oil and gas industry, which has injected an amazing breadth of experience into an academic research group. We have benefitted from industry-standard software from the likes of Schlumberger and Hampson Russell. The use of core samples and subsurface datasets from Shell and other petroleum exploration companies, has allowed our researchers to address societal problems and make a real impact both in practical terms and within the broader academic research remit of the department. We have welcomed graduate students funded by industry and governments in countries as far afield as Brazil, Mexico, Colombia, Jordan, Saudi Arabia and the UAE, as well as home-funded students through the NERC Centre for Doctoral Training in Oil and Gas. Over 5 years, we have had 12 undergraduates pursuing 4th year Masters projects with us. And of course, many of the department's alumni work in Shell and related companies, allowing us to collaborate with people such as Jack

"Over the last 5 years it has been fascinating to see Shell's involvement with Oxford turn from draft proposal into reality, and for that reality to evolve and enhance our understanding of the many complex processes at work in sedimentary basins across the world. The leading-edge research and seismic interpretation undertaken in the state-of-the-art Shell Geoscience Lab by a truly diverse team of graduates, post-grads and academics has significantly furthered our knowledge of continental margin and basin development, mudrock systems, metal isotopes and, importantly, their application to conventional and unconventional energy resources."

Jack Russell (Univ 1985)

L-R Bruce Levell (St Catz 1972), Jack Russell (Univ 1985), Harold Reading (Univ 1948) and Howard Johnson (St Peter's 1971) at the official opening in 2013.

Chantelle Roelofse (St Anne's 2011) discusses her 4th year project with postgraduate Isra'a Abu-Mahfouz (St Peter's 2014).

Russell (Univ 1985), Lorcan Kennan (Wolfson 1989) and Ben Stephenson (St Edmund Hall 1993), rekindling the relationships first established in the 1960s and '70s by Harold Reading. The collaboration with Shell extends beyond this lab with faculty members Hugh Jenkyns, whose work on Ocean Anoxic Events is key to a global understanding of hydrocarbon resources, Gideon Henderson (Hertford 1985), Don Porcelli, and Steve Hesselbo (now at Camborne School of Mines) all closely involved as lead researchers in sedimentology and geochemistry.

Over the past 5 years this wider group has been working on three main topics: fluid flow and hydrocarbon migration, fracture systems in shales, and global vs local factors controlling organic enrichment in mudrocks (source rock prediction). Research findings from these groups have not been in short supply, with a flood of important publications coming into the public domain in the final stages of the 5 year project. A recent paper by graduate student Weimu Xu, for example, revealed that ancient lakes in China had once been subjected to the same conditions as Oceanic Anoxic Events, the first time that lake sediments had been identified so precisely. Many of the results of the research have contributed to fundamental understanding of the Earth System, such as the Carbon Cycle, not just the specifics of how oil and gas are generated and trapped.

The Shell-Oxford Collaboration was initiated by a £5.9M grant from Shell International E&P B.V., and discussions are under way regarding a second phase which we'll report on in a future edition.

Find out more about the people and research on their website: shell.earth.ox.ac.uk

L-R: Head of Department Gideon Henderson (Hertford 1985), Executive Vice President UIU, Shell* Alison Goligher, Secretary of State for Energy and Climate Change* the Rt Hon Edward Davey, and Vice Chancellor of the University of Oxford* Andrew Hamilton at the launch of the Shell-Oxford Research Collaboration in May 2013. **Indicates no longer in stated role.*

"My project was working on data from another oil company, but I was able to use industry-standard software in the 3D Seismic Lab, and the postdocs in the group were super helpful for getting advice and help. The other great thing was that I could talk to industry experts - Joe Cartwright, Erdem Irdiz, Bruce Levell, and Jack Russell - about my work and/or future prospects"

Chantelle Roelofse, former 4th year Masters project (St Anne's 2011)

"I am grateful for this opportunity to develop my expertise in a field that I am passionate about. My DPhil project is part of the 'fractures in mudrocks' theme. The dataset that Shell-Jordan (JOSCO) has provided allows me to constrain the distribution and the timing of fractures, place fractures in a burial and uplift context and evaluate the effects of fractures on hydrocarbon migration and potential for economic production. I feel blessed to get the chance to represent Jordanian women everywhere, and in geology!"

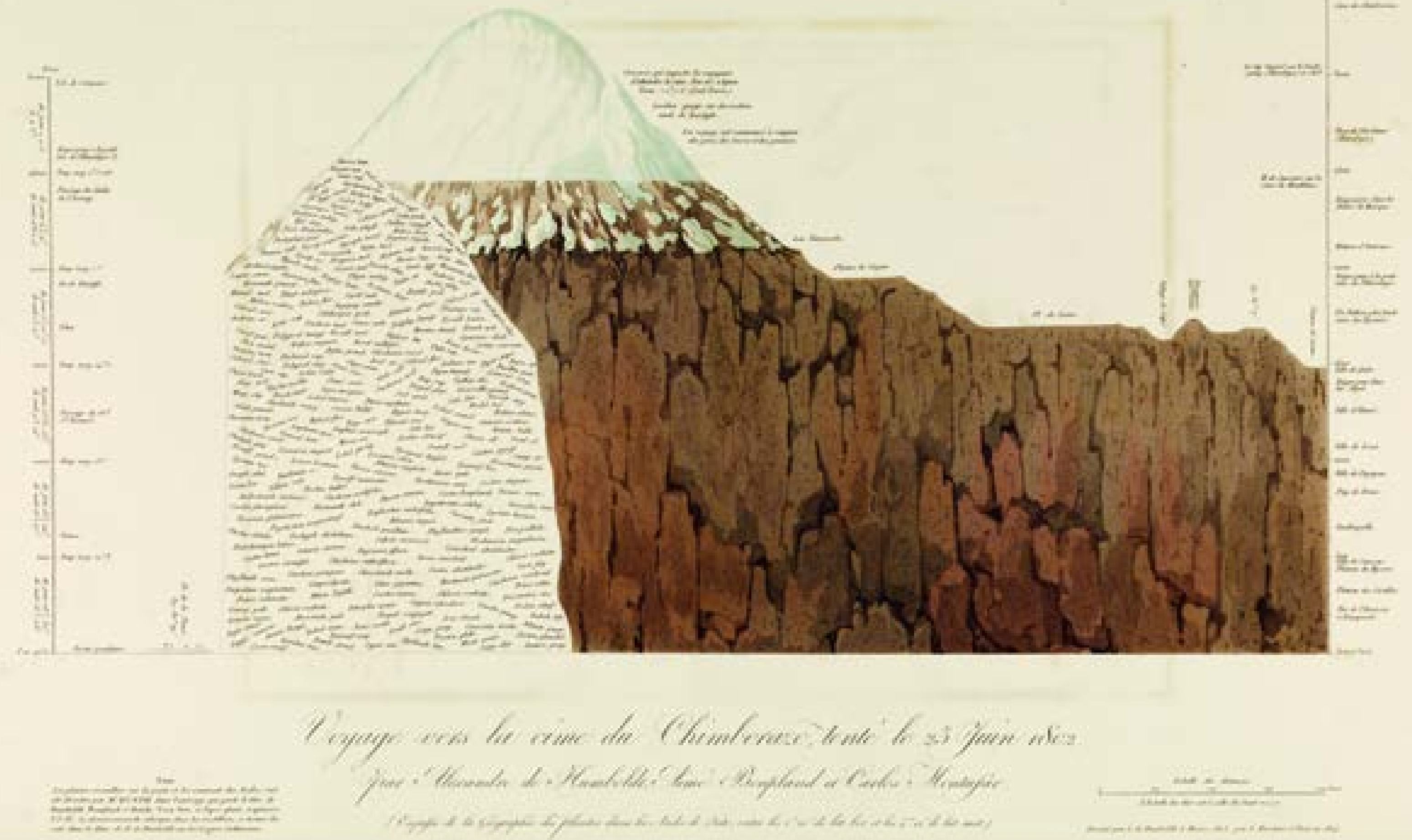
Isra'a Abu-Mahfouz, postgraduate (St Peter's 2014)

Postdoc Claudia Bertoni interpreting data with postgraduate James Scaife (Linacre 2013)

"Coming from an industry background, and with a PhD in Basin Dynamics, this opportunity to contribute to the set-up of a new collaborative research group in a world-class research institution while having available the expertise and data from Shell guaranteed the best of both worlds. The highlights of working in the group have been working with exceptionally talented researchers in Oxford and specialists in Shell, and access to state-of-the-art, industry-standard software and data. The diversity of projects also has been a bonus, ensuring a global view on specific research problems."

Claudia Bertoni, Postdoc

VOLCANOES AT THE BODLEIAN



Above: An infographic taken from Humboldt's Voyage aux régions équinoxiales du nouveau continent published in 1810.

Below: Eruption of Vesuvius on 9 August 1779, seen from Naples. Gouache by Pietro Fabris, from the supplement to the 1779 edition of William Hamilton's *Campi Phlegraei*. Hamilton (1730-1803) was a Scottish diplomat who was posted to Naples in the 18th century. He wrote a number of papers, books and letters documenting the 18th century eruptions of Vesuvius. *Campi Phlegraei* (meaning flaming fields) is a beautifully illustrated scientific treatise that contains 54 hand coloured plates by the artist Peter Fabris.

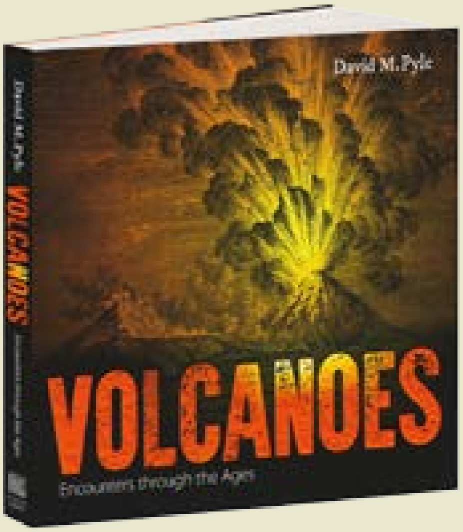
This year saw an Earth Sciences residency in the Bodleian Library's S.T. Lee Exhibition Hall. Professor David Pyle, senior research fellow at St Anne's College, took a sabbatical last year to prepare for 'Volcanoes: an exhibition'.

“I have always had a passion for connecting the general public with my research," explains David. “There is always a great appetite for stories about volcanoes, and the chance to develop a public exhibition around the Bodleian collections was an opportunity not to be missed."

The initial idea for the exhibition came about from conversations with Richard Ovendon, now Bodley's Librarian, and Maddy Slaven, Head of Exhibitions, who had an eye on using the newly refurbished Weston Library building to showcase a more diverse range of exhibitions than had previously been possible.

“Over the past 3 years I spent many happy hours in the Bodleian and tracked down a wealth of original materials that gave fabulous insights into volcanoes around the world. These included descriptions of eruptions by scientists, and the stories of encounters with volcanoes by authors, painters, and pirates as well as casual travellers."

The exhibition was feted by the national press, having been recommended by the Guardian as one of the best art and design exhibitions of 2017, and USA Today including it in their list of must-see museums in Europe this year. Highlights of activities that spun off around the exhibition included a 'hands on volcanoes' session in the Weston Library; linocut activities with the Oxfordshire Art Teachers' network, and a performance of seven 'world premieres' of musical compositions inspired by the exhibition. David also got a taste of the literary circuit, with talks at the Oxford Literary Festival and the Hay Festival; and in June, opened an exhibition on volcanoes created by children at a Bicester primary school.



Highlights of the exhibition included a burnt fragment of papyrus scroll from the ancient Roman town of Herculaneum, buried during the AD 79 eruption of Vesuvius, and accounts of the same eruption, in the Letters of Pliny the Younger, which in turn lent itself to the term 'Plinian eruption.' The Icelandic volcano of Eyjafjallajökull that caused so much disruption in Europe in 2010 appeared on a 1606 map of Iceland's volcanoes by Flemish map-maker Abraham Ortelius. Frankenstein also features: excerpts from the diary of Mary Bysshe Shelley describe the foul weather experienced on holiday by Lake Geneva during the 'year without a summer' of 1816, caused by the distant eruption of Tambora a year earlier.

"There's always something new to learn about volcanoes," he reminds us. "Around 600 volcanoes have erupted within the last 200 years, and 1,500 could erupt again within the next few decades. But we are never quite clever enough to work out what volcanoes will do next. The deadliest eruptions have often been of long-dormant volcanoes that burst back to life with little warning."

The exhibition is now closed, but the accompanying book *'Volcanoes: Encounters through the Ages'* can be purchased for £20 via the Bodleian online store: www.bodleianshop.co.uk/exhibition/volcanoes/volcanoes.html

Below: Cut-away image of Mount Etna, 1637, published in Athanasius Kircher's Mundus Subterraneus (1665). This influential work proposed that volcanoes were created where the earth's internal fires escaped at the surface.

INDEPENDENT RESEARCH FELLOWS

1. **Yves Plancherel** (NERC)

I am a "broad spectrum" marine biogeochemist with concurrent interests in physical oceanography and climate science. My current projects focus mainly on two scientific questions: 1) How are insoluble elements removed from the ocean and 2) What are the processes that control the properties and fate of deep ocean water masses. I approach these questions by exploring new chemical and isotopic tracers with a variety of tools ranging from circulation and biogeochemistry models, applying statistical data analysis techniques to environmental data and by making or stimulating new measurements as hypotheses develop.

2. **Kate Kiseeva** (NERC)

My research interests lie in the application of experimental petrology to global petrological problems. My lab-based experiments aim to understand geological processes, such as magma genesis, the formation of mineral deposits, or the metamorphism of rocks, which cannot be observed directly because they occur deep within the Earth. I am particularly interested in how a number of economically and geologically important chemical elements partition themselves between the silicates of the outer parts of the Earth and sulphides. This research helps to shed light on Earth's and Moon's bulk compositions, mantle and core geochemistry, generation of basaltic lavas as well as providing information for metallurgy, polymetallic ore deposits and platinum group element exploration.

3. **Will Homoky** (NERC)

I am interested in the dissolution and formation of rock minerals in the ocean, and their impact on the availability of biologically essential elements in the ocean. I examine marine sediments, pore waters, seawater and deep-sea hydrothermal vent discharges, to observe gradients in the physico-chemistry of major and trace elements. This includes stable- (e.g. iron) and radio- (e.g. radium) isotope variations, which are used to learn how, and how much, bio-essential nutrition passes in and out of the seafloor. Presently, I am exploring the use of radium isotopes and new sampling technology to study the ocean's bottom boundary layer, in an effort to quantify element exchanges in this region, to improve ocean biogeochemical models of the carbon cycle.

4. **Mike Cassidy** (NERC)

I completed my PhD at Southampton in 2012, where I used sedimentological, chronological and geochemical analyses on submarine cores and subaerial exposures to understand how volcanism on Montserrat in the Caribbean has evolved throughout its 2.5 Myr history. Since then my focus has been in understanding the eruptive behaviour of volcanoes using gas emission data, ash petrography and now increasing analytical and experimental petrology. My work has taken me volcanoes in Indonesia, Mexico, Iceland, Chile and the Caribbean and the goal of my future research is to understand the controls over volcanic explosivity.

The department hosts four NERC-funded Research Fellows, and two Junior Research Fellows funded by colleges. Here we introduce the range of research they undertake.

5. **Paula Koelemeijer** (University College)

I am a global seismologist, interested in the structure and dynamics of the deep Earth, primarily studying the core-mantle boundary using observations of whole Earth oscillations or normal modes. I studied at Utrecht University, before spending a year at the University of Cambridge working on my MSc thesis (2010). I completed my PhD in Cambridge in 2014, working with Arwen Deuss (Univ 1998) on observational and theoretical normal mode studies. In 2013 we published the first robust observations of Stoneley modes - normal modes that only exist at the core-mantle boundary. Our recent study of the density structure of the lowermost mantle using these modes was picked up by the Daily Mail, who liked our lava lamp analogy!

6. **Sam Giles** (Christ Church College)

I am a palaeobiologist, using x-ray tomography to study the evolution of the brain and its surrounding bone structure. My research focuses on ray-finned fishes, the largest living group of vertebrates which contains over 30,000 species. By comparing the brains of modern fish with 3D reconstructions of their ancestors, my research will help understand how the evolution of the brain contributed to the success of this group, with significant ramifications for understanding rates of gene mutation and evolutionary change. I completed my DPhil at St Hugh's in 2015, and was awarded a L'Oréal-UNESCO For Women in Science fellowship in 2016.

7. **John Wade** (NERC)

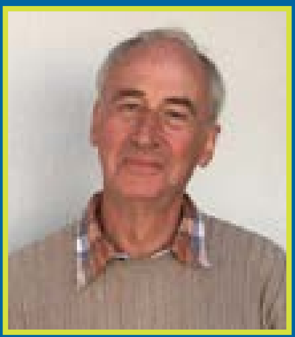
My research revolves around the chemical processes of planetary formation, particularly the effects of planetary differentiation on the distribution of elements in the Earth and the fate of water on planetary surfaces. To do this, I use a range of experimental techniques, from atmospheric pressure to pressures found at the Martian core-mantle boundary. Because experiments performed at very high pressures always result in small samples, my other research interest is the refinement of such analytical techniques. This is focused primarily on modeling the electron and X-ray transport in electron microscopes. I am passionate about outreach, and enjoy inspiring the next generation of students in earth and planetary science.

8. **Pete Barry** (USGS)

I am an isotope geochemist interested in fluids and gases from Earth's mantle and crust. My research spans both high- and low-temperature applications, including mantle plume-ridge interactions and the behaviour of volatiles in magmatic systems. The goal of this work is to understand the processes of subduction, mantle convection and surface volcanism, which control the redistribution of chemical constituents between the crust and mantle reservoirs. I also use noble gases and stable isotopes to understand the origin and migration history of hydrocarbons in the shallow crust - including the contamination role of fugitive gases in groundwater basins - which is the focus of my research fellowship with the USGS.

NEW EMERITUS PROFESSORS

This summer sees the retirement of a number of Faculty, whose lectures and tutorials have been staples for many of our students through the years. For these new Emeritus Professors, 'retirement' tends not to mean the farewell it might be in some industries, but rather a change in timetable, with less formal teaching and more time for research. Here we celebrate their careers and describe their plans for the future.



Hugh Jenkyns

Hugh stepped down as Tutorial Fellow at St Edmund Hall in 2015, after 37 years in that role. Having passed college responsibilities to Roger Benson and Richard Walker, and departmental teaching to Nick Tosca and Stuart Robinson, Hugh still participates in field excursions and maintains a research role within the Shell group, contributing to DPhil supervision, 4th year projects and various aspects of research in Mesozoic palaeoceanography and palaeoclimatology. He continues to have an interest in Italian geology, and Italian wines, as well as participating in on-going projects on the Jurassic and Cretaceous of South America.

Don Fraser

Don is stepping down from teaching, having been Tutorial Fellow at Worcester College since 1978. Over the course of 43 years (including two as a Junior Research Fellow at Merton, and two years as a Fellow at Wolfson), Don has tutored approximately 140 undergraduates and lectured to over 1140 as well as supervising MSc Geochemistry and DPhil postgraduates. Don remains active in research: a new EU Horizon 20:20 grant of €5M to the Departments of Chemistry and Earth Sciences will fund the "Ultrachiral" project, investigating the origins of biochirality. It will measure how organic molecules template on mineral surfaces and why meteorites like Murchison bring amino acids to Earth that have up to 20% enrichments of the left-handed L-enantiomers.

Dave Waters

Dave has been the stalwart of 'Met Pet' and Geological Maps teaching since 1989, and has led field courses in Arran, Cornwall and NW Scotland. He has worked with Mike Searle, Laurence Robb, John Dewey and generations of students on hard rock research in the department. Although he steps down from teaching and admin, he will continue with active research on the fundamental processes of metamorphism, and with development of his web-based resources. Beyond the department, Dave will retain an associate role (and an office!) in the Oxford University Museum of Natural History and Emeritus status at St Cross College.

ENDOWING THE FIELD TEACHING FUND

Students on the 2016 Dorset fieldtrip
Photo: Lauren O'Connor

Registered with FUNDRAISING REGULATOR

Without a doubt, the favoured moments of any Earth Scientist's career will include those spent in the field: making inferences about the rocks, and the processes that shaped them; whether for the first time in that location, or following in the footsteps of many.

Undergraduate fieldwork has a particular resonance among our many alumni, as the trips provide so much more than just pure geological experience: a chance for first years to bond, both as a group and with their lecturers; for second years to apply the knowledge that builds through the course to a mapping area of their own choice; for third years to help decide who to work with on a fourth year project. Tutors can often spot problems that might be masked in the rarified environment of Oxford. Tutees get to see them in a more relaxed, informal setting.

The skills learned in the field are valued by a wide range of employers. Teamwork, observation and deduction, analysis of imperfect or incomplete data, or on a bad day, simply preparation, endurance and perseverance: all these factors create graduates with aptitudes and ability to tackle the most pressing problems. From climate change to disaster modelling, HS2 to Mars rovers, our graduates are making a difference is a wide range of industries.

Which is why we're asking you to make a difference for future generations, by helping us endow the field teaching fund.

Over the past 8 years we have had wonderful support from many of our alumni. That support has helped grow the endowment from £36,000 when I took over as Head of Department to a pot which yields enough to fully cover the costs of the first year field trip to Pembrokeshire.

However, we're still a long way from our final target. Our aim this year is to endow the Arran field trip: the critical element before students go off to their own mapping field trips.

You will find a giving form enclosed with the magazine – please do consider what support you can give to help secure field teaching for future generations of earth scientists. Alternatively, you can give online at www.campaign.ox.ac.uk/earth-sciences, or consider leaving a legacy in your will.

On behalf of the field scientists of the future – thank you.

Students on the 2015 Arran fieldtrip

Mapping the Carboneras fault zone on the 2017 Spain fieldtrip

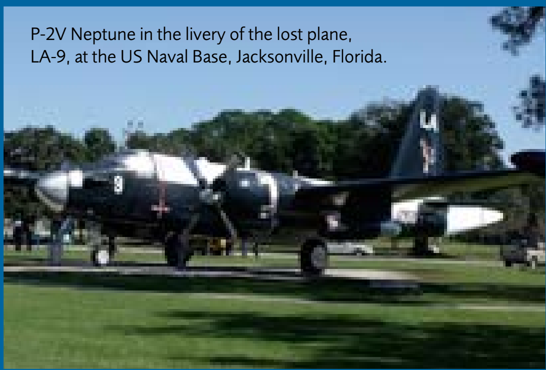
Students sketching the relationship between paleo-dunes and paleosols on the 4th year Bermuda trip

THE FIFTY-YEAR SAGA OF THE AIRCRAFT LA-9

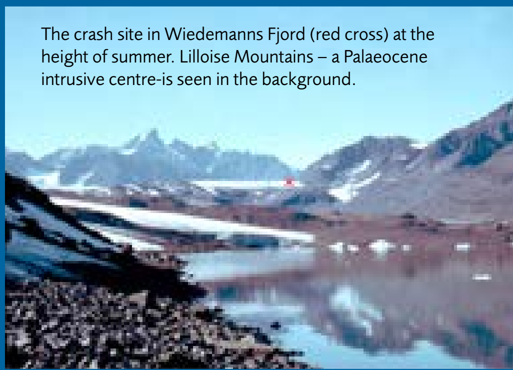
BY KENT BROOKS (LINACRE 1962)

The British East Greenland Expedition of 1966, led by W. A. Deer of Cambridge, included four Oxford geologists: Kent Brooks, David Bell (Trinity 1952), Brian (Fred) Atkins (Corpus Christi 1957) and Dave Parrish (Keble 1964).

Helicopter pilots Göran Lindmark and Calle Brett examine the crash site in 1995



P-2V Neptune in the livery of the lost plane, LA-9, at the US Naval Base, Jacksonville, Florida.



The crash site in Wiedemanns Fjord (red cross) at the height of summer. Lilloise Mountains – a Palaeocene intrusive centre-is seen in the background.

Kent (R) with David Bell in 2016

Frustrated in their attempts to reach the Lilloise Mountains on the opposite side of the mighty Kronborg Glacier, the team discovered a crashed US Navy plane with 12 bodies on board. Although the crash had taken place 4 years earlier, the location at an inland elevation on the glacier meant that the bodies were well preserved: almost mummified.

The American authorities in Iceland were informed in September 1966, and in November the news came that a recovery mission had taken place, and the crashed crew members had been buried in the Arlington National Cemetary.

No more was thought of the matter until 1995, when Kent Brooks happened to be flying in a helicopter in the Lilloise Mountains. He mentioned the aircraft wreck to the pilot, who flew over to look. Whereas in 1966 the fuselage had been in reasonable condition, the surface of the glacier was now strewn with debris, and during a pass at low height, human body parts were spotted.

Again the authorities were informed: this time the police in Nuuk, the captal of Greenland. However, they replied that they lacked resources to do anything at this very remote location.

After a couple of years, Kent was contacted by ex-CIA agent Bob Pettway who had been previously with the crew of the crashed plane – a Neptune P-2V used for submarine surveillance – when it was stationed at Rota in Spain. He wished to recover the remains of any servicemen who had not been brought home, but it was not until 2004 that he was able to convince the US Navy to locate and repatriate all the bodies.

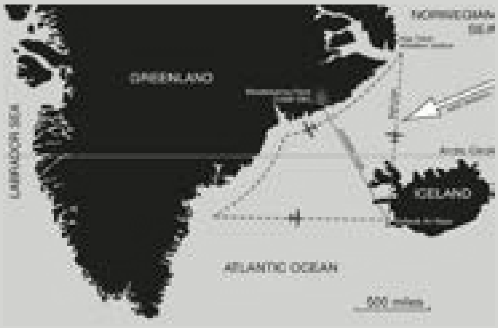
In 2009, the Navy commemorated the lost men by placing an identical plane on display at the US Naval Base at Jacksonville, Florida. Why had the bodies not been returned in 1966, at the time of the first recovery mission? As the Oxford experts warned, the time of year was too advanced and the crash site was covered with snow. A thorough search could not be carried out and the wreckage was blown up when as much as possible had been retrieved. This was the Cold War and the US Navy would not want their planes lying around to be examined by anyone.

What had happened to the plane?

This was the first flight of the plane from Keflavik, Iceland, after repositioning from Rota, Spain. Several of the crew were new including the navigator, Badger C. Smith. The weather was atrocious: gale force winds and heavy snow were reported from Kap Tobin, Greenland. The plane was to fly low – 2000ft – but even at this altitude visibility would have been zero for much of the time. After an hour a signal was received, but was thought to be in error as it lay to the west of the projected route. Signals ceased at 10:53 and an airborne search began. However, hampered by bad weather and poor visibility, their efforts were fruitless.

We must conclude that for some reason the plane had flown on an incorrect heading, possibly due to the magnetic declination which is high here, but low in Spain. Poor visibility would have further compounded this mistake, and the glacier would not have shown up on the ground proximity device.

The full text of this article, including the impact on the families of the downed servicemen, can be read on the website: www.earth.ox.ac.uk/greenland-aircraft



Stephen in the former department building, beside one of his beloved Greenland rocks, now on display in the Museum of Natural History

STEPHEN MOORBATH (1929 - 2016)

by Professor John Dewey

Professor Stephen Moorbath, FRS was a great geoscientist and renaissance man who spent the whole of his academic career in Oxford. He was born in Magdeburg, Germany, on the 9th May, 1929 and died in Oxford on 16th October 2016. The Nazis allowed him and his father to leave Germany in 1939 but his mother and sister were murdered in an extermination camp in 1942. After a short period in Brighton and Worthing, his father was sent to an internment camp in the Isle of Man. Stephen and his father then settled in Oxford where Stephen attended the Oxford Boys School with Ronnie Barker.

His first job was as a laboratory technician in the Oxford biochemistry Department. In 1948, he found employment at Harwell, who recognized his brilliant intellect and sent him to Oxford on a fully-paid scholarship to read chemistry. He soon discovered geology in an ancillary course and switched to read for a degree in geology; he received a top first in 1956. He stayed in Oxford to help Laurence Wager set up a mass spectrometer laboratory with a solid-source Metropolitan-Vickers MS-5, and began a D. Phil on lead isotopes in British galena deposits, which he completed in 1959. He joined the staff of the Geology Department and began the isotope work that was to lead to high international fame as the doyen of radiogenic isotope geology and rock dating.

His work was eclectic and profoundly clever; three great discoveries stand out among a host of others. First, in the early sixties, he, Bruno Gilleti, and Richard Lambert used the new Rubidium-Strontium technique to date suites of rocks from the Scottish Highlands where a number of fundamental controversies had arisen from generations of detailed mapping. They produced ages of 2.5 billion years and 1.7 billion years for, respectively, the Scourian and Laxfordian Complexes of the Lewisian basement, thus confirming the structural and metamorphic history deduced by Sutton and Watson. They also discovered an enigmatic Neo-Proterozoic age for the Knoydart pegmatite in the Moine Series, thus establishing a now widely-recognized yet enigmatic Knoydartian orogenic event over large areas of the Moine. Secondly, his isotopic work on volcanoes in the southern Andes with Wes Hildreth was linked, elegantly, with the control of height and form with petrology and geochemistry; high, more explosive, volcanoes arise from lower-temperature silicic crustal melts, whereas low volcanoes are made from higher -temperature mafic melts originating in the mantle. Thirdly, he and Paul Taylor worked with Vic MacGregor on the Pre-Cambrian rocks of Isua in southwest Greenland where they established a complex series of crust-forming igneous, structural, and metamorphic events in some of the world's oldest rocks.

Stephen loved words and the flow and beauty of language in many ways. On the serious side he was fascinated by linguistics and etymology, especially of the Baltic languages. With his prodigious memory, he could quote, flawlessly, huge tracts of Shakespeare and Chaucer. But also of course, we remember and cherish his frequent, apt, and clever use of the pun. He knew, intimately Mozart's and Alkan's music, most of which he could hum or whistle, called up at will. He had a lasting admiration for Sir Thomas Beecham, especially two of his opinions; that Wagner's music is much better than it sounds, and that Adrian Boult was a kind of musical Malcolm Sargent. Steve was a sophisticated intellectual who loved to acquire knowledge and understanding. His great success as an international scientist was his deep curiosity about everything and his fertile mind combined with care, precision, and detail.

His one weakness was the almond croissant, which he regularly sought and consumed in the pastry shop on the corner of Little Clarendon Street. I have an enduring image of Stephen from following him cycling into Oxford. The view from behind with his felt hat and pale raincoat was a close resemblance to Inspector Clouseau. Steve was a wonderful friend and geological companion who I miss very much.

DEPARTMENT NEWS
AND ALUMNI EVENTS


Roger Benson describes megafauna at the Planet Ocean event


Wattsfest - 50 years in Geoscience


Gideon with alumni in Houston


Students signing up for more information at the careers fair


Grotzinger describing a global straigraphy model for Mars

Alumni Weekend - Friday 16th September 2016

Heather Bouman, Associate Professor of Biogeochemistry at St John's College, and Helen Johnson, Associate Professor of Physical Oceanography at St Cross, presented 'Arctic change: rapid warming and its consequences,' discussing the ongoing and predicted changes in the Arctic and implications for ocean circulation, biology and global climate.

Tony Watts Fest - Monday 19th September 2016

Students, friends and colleagues of Professor Tony Watts organised a symposium to celebrate 50 years of his career in geosciences, with talks in the Museum of Natural History, a drinks reception at the department, and dinner at Worcester College.

Earth Sciences Careers Fair - Friday 21st October 2016

Alumni representing a number of different companies and industries were on hand to talk to students and postdocs about careers outside of academia. This year we were delighted to welcome representatives from BDO Mining, BP, CCS Solutions, Elsevier, ERC Equipoise, Horizon Nuclear Solutions, OUMNH, PESGB, RMS, Shell, Telespazio VEGA, as well as our own Careers Service.

London Panel Discussion – Thursday 2nd March 2017

Inspired by the BBC's "Planet Earth," our annual London event offered insight into the many aspects of our "Planet Ocean." Presentations by Faculty members Roger Benson, Hugh Jenkyns, Ros Rickaby and Helen Johnson took us from marine vertebrate evolution, through Ocean Anoxic Events, to changes in marine environments in the modern, and the implications for such changes in the future. Gideon Henderson gave a few insights into future research opportunities, including mining the oceans for minerals, medicines and more.

Lobanov-Rostovsky Lecture – 21st April 2017

Professor John Grotzinger, Fletcher Jones Professor of Geology and the Ted and Ginger Jenkins Leadership Chair in the Division of Geological and Planetary Sciences at Caltech, was Project Scientist of the Mars Science Laboratory mission from 2006 until the end of 2014. His talk provided insight into the geological findings and practical challenges of the Curiosity mission to Mars. The lecture was recorded and is available to view online: www.alumniweb.ox.ac.uk/earth/lobanov-rostovsky-lecture

Alumni catching up over dinner

Alumni Dinner

The 2017 Alumni Dinner was held at St Peter's College on Saturday 6th May, with St Peter's tutors past and present: current tutor Nick Tosca and fellow Joe Cartwright (Jesus 1977), Steve Hesselbo and Harold Reading. Reunion groups from the matriculation years of 1964, 1967, 1977, 1982, 1985 and 1997 were also joined by faculty old and new: David Bell, Jim Kennedy, Gideon Henderson, Don Fraser, Hugh Jenkyns, Conall Mac Niocaill and Stuart Robinson.

Houston Lecture – Friday 19th May 2017

Oxford's alumni group in Houston hosted Professor Gideon Henderson for a talk on climate change. The setting was the Alliance Francaise - appropriate as much of the talk centred on the Paris Climate Change talk. Thirty alumni from the Houston area attended with spouses, family and friends, including several alumni from the Department. University College was the best represented group.

DATES FOR YOUR DIARY

WatersGate - Monday 25th Sept 2017
In celebration of Dave Waters on the event of his forthcoming retirement from teaching, the department and OUMNH will be hosting a day of talks from former colleagues and students. A drinks reception and dinner will follow in the evening. Contact the Alumni Office for further information.

Geosciences Careers Fair - Michaelmas Term 2017
Whether your company is recruiting, you're looking for a new job yourself, or you would like to talk to our students about your career, our annual OUGS Careers Fair offers an afternoon of various industry insights, followed by Happy Hour.

To make sure you receive updates and notifications about these and other events, please make sure we have your email address and permission to email you! Drop Claire a line on **alumni@earth.ox.ac.uk**.

AWARDS & PRIZES

Professor Chris Ballentine – 2016 New Frontiers in Hydrocarbons (Upstream) award by ENI, and Elected to the Board of AGU in 2017

Professor Alex Halliday - 2016 AGU Harry H. Hess Medal and Elected to Academia Europea

Professor Gideon Henderson - 30th Annual Plymouth Marine Science Medal

Associate Professor Helen Johnson - MPLS Teaching Award

Professor Barry Parsons - 2017 Augustus Love Medal by the EGU

Professor Ros Rickaby - Lyell Medal of the Geological Society of London

Associate Professor Karin Sigloch – Elected Fellow of the Young Academy of Europe

Dr Sam Giles (St Hugh's 2011) - 2016 L'Oréal-UNESCO For Women in Science fellowship

Dr Jon Wade & Mrs Claire Grainger – VC's Outreach Award 2017

Postgraduates Isra'a Abu Mahfouz (St Peters 2014) and James King (Univ 2016) - AAPG grant awards

Postgraduate Lauren O'Connor (Univ 2014) - ESSAC research grant for IODP research cruise

Postgraduate Kuangdai Leng (Wolfson 2014) - Outstanding Student Paper Award at the 2016 Fall AGU Meeting

Postgraduate Zhijian (Clancy) Jiang (Linacre 2015) - Tang Oxford Award in Environmental Sciences

Postgraduate Tyler Ambrose (Linacre 2014) - Best Student Presentation award at the 2017 Metamorphic Studies Group meeting

4th Year Undergraduate, Penny Wieser (Worcester 2012) - Geologists' Association Ivor Tupper Prize

Workshop Apprentice, James King - 2016 Advanced Apprentice Award

Department of Earth Sciences – Double Gold Green Impact Award in Sustainability Showcase 2016

WE CAN'T ALL LEAVE A LEGACY QUITE LIKE BUCKLAND...

...OR HUTTON...

...BUT TOGETHER WE CAN PROTECT THE FUTURE OF FIELD TEACHING.

To learn more about the impact a gift in your will could have, or to find out how to remember the Department's work in your bequest, please contact:

The Alumni Relations Officer, Department of Earth Sciences, South Parks Road, Oxford OX1 3AN
Email: alumni@earth.ox.ac.uk   Call: +44 (01865) 429448

EARTHSCIENCES

Registered with FUNDRAISING REGULATOR

UNIVERSITY OF OXFORD