GeoCam

EARTH SCIENCES ALUMNI MAGAZINE

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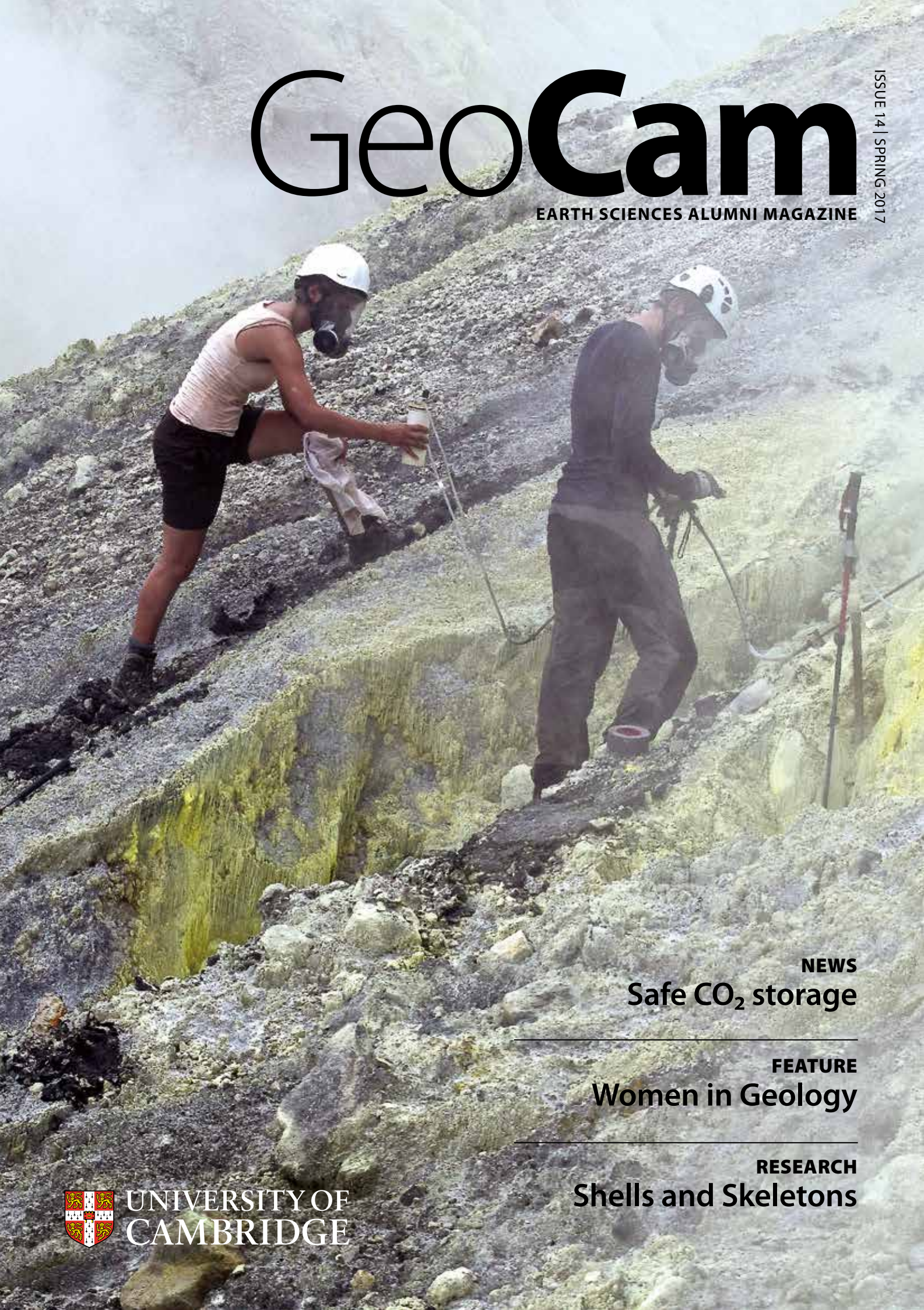

NEWS
Safe CO_2 storage

FEATURE
Women in Geology

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Shells and Skeletons

UNIVERSITY OF CAMBRIDGE

RESEARCH **NEWS**

FOR ALL THE LATEST EARTH SCIENCES RESEARCH NEWS, VISIT WWW.CAM.AC.UK/AFFILIATIONS/DEPARTMENT-OF-EARTH-SCIENCES

Research indicates safe storage of CO_2 underground possible

New research shows that natural accumulations of CO_2 trapped underground for around 100,000 years have not significantly corroded the rocks above, suggesting that storing CO_2 in reservoirs deep underground is much safer and more predictable over long periods of time than previously thought.

"Carbon capture and storage is seen as essential technology if the UK is to meet its climate change targets. A major obstacle to the implementation of CCS is the uncertainty over the long-term fate of the CO_2 which impacts regulation, insurance, and who assumes the responsibility for maintaining CO_2 storage sites. Our study demonstrates that geological carbon storage can be safe and predictable over many hundreds of thousands of years." Professor Mike Bickle, Director of the Cambridge Centre for Carbon Capture and Storage

READ MORE http:// goo.gl/r01v5S

Fossilised dinosaur brain tissue identified for the first time

Below: Image of the specimen

An unassuming brown pebble, found more than a decade ago in Sussex, has been confirmed by a team including Earth Sciences' David Norman and Alex Liu as the first example of fossilised brain tissue from a dinosaur.

The fossil displays distinct similarities to the brains of modern-day crocodiles and birds. Meninges – the tough tissues surrounding the actual brain – as well as tiny capillaries and portions of adjacent cortical tissues have been preserved as mineralised 'ghosts'.

READ MORE http:// goo.gl/GFJNCR

Artist's impression of Saccorhytus

Saccorhytus – humans' oldest known ancestor

Researchers have identified what they suggest is the earliest ancestor of humans – a microscopic, bag-like sea creature, which lived about 540 million years ago. *Saccorhytus*, named after its sack-like and elliptical body with a large mouth, was found in China.

If their conclusions, co-authored by the Department's Simon Conway Morris, are correct, then *Saccorhytus* was the common ancestor of a huge range of species, and the earliest step yet discovered on the evolutionary path that eventually led to humans.

READ MORE https://goo.gl/fOjkv6

Fingerprinting rare earth elements from the air

Vital to many modern technologies, yet mined in few places, 'rare earth elements' are in fact not that rare – just difficult to find in concentrations which are economic to mine. Researchers are investigating whether the remarkable properties of these materials can be used to track them down from the air.

Photomicrograph of a carbonatite – the main host of minerals with high REE concentrations

Over the past year, Drs Sally Gibson, Teal Riley and David Neave have been working together through a University of Cambridge–British Antartic Survey (BAS) Joint Innovation Project on a remote sensing technique that could aid the identification of REEs in rocks anywhere in the world. The project brings together expertise in remote sensing, geochemistry and mineralogy from both institutes to take advantage of the properties that make the metals so special.

READ MORE http:// goo.gl/crckT2

Welcome

I'm delighted to welcome you once more to GeoCam, where you'll find a little about what is going on in the department. For up to the minute news of our latest research, field trips and teaching initiatives, do take a look at the department web pages (www.esc.cam.ac.uk) if you get a chance.

This GeoCam is flavoured by the theme of "women in Earth Sciences", following our receipt of an Athena SWAN award during the last year. Athena SWAN is a national scheme that aims to encourage and advance gender equality in science, and to break down barriers to progression for all members of the department. It's fascinating to read of the early women pioneers in Cambridge geology: Mary Hughes and Gertrude Elles. I can't help but reflect on how they would react to the efforts we are making today to try and build family-friendly ways of working that free everyone to pursue the scholarship we treasure.

Last year James Jackson signed off his term as Head of Department with an article outlining our plans to bring "downtown" and "Bullard" together, at last, in a new building in north-west Cambridge. The concept for this new building has been scoped out over the past few months, and in the coming year you can expect to hear more details about those plans and how we hope to bring them to fruition. The site itself lies at the edge of a brand-new University community that is rapidly coming to life between Madingley Road and Huntingdon Road in north-west Cambridge. On its other flank lies the Institute of Astronomy, with whom we have an initiative involving a lectureship in exoplanetary geoscience. This is one of two new inter-department academic appointments that Earth Sciences will be making this year – the other is a collaboration with Materials Science, exploiting innovative imaging methods to understand geomaterials at the nanoscale. So the subject continues to develop in exciting ways, encompassing processes that range in scale from Ångstroms to Astronomical Units.

We live in interesting times, it seems, and despite current uncertainties, continue to look forward with hope and excitement this year. I hope to see many of you here in Cambridge at alumni events later in 2017, when I'll be pleased to update you with our latest news.

Simon

IN THIS ISSUE

COVER IMAGE: LOIS SALEM & BRENDAN MCCORMICK KILBRIDE COLLECTING GAS SAMPLES FROM THE FUMEROLE FIELD AT GARBUNA VOLCANO, WEST NEW BRITAIN.

TREKKING BAREFOOT THROUGH THE RAINFOREST ON A PATH MACHETED BY THE VILLAGE CHIEF AS HE WALKS JUST PACES AHEAD. JUMPING OVER SCALDING STREAMS, TIGHT-ROPE WALKING ACROSS A LOG BRIDGE ABOVE RIVER RAPIDS, PIGGY-BACKING ACROSS BOILING MUD POOLS, AND CLAMBERING OVER A MONTH-OLD VOLCANIC MUDFLOW, ALL WHILE BAGANA VOLCANO (BOUGAINVILLE, PAPUA NEW GUINEA) ERUPTS ASH A KILOMETRE ABOVE OUR HEADS.

A DAY IN **THE FIELD:**

Volcano hunting in Papua New Guinea

LOIS SALEM VOLCANOLOGY PHD STUDENT WORKING WITH DR MARIE EDMONDS

Left to right: The team preparing to fly the UAV over Gotana Village, Bougainville; Brendan measuring the temperature of boiling mud pools at Talasea, West New Britain; Tavurvur volcano degassing on the edge of Rabaul Caldera

Fieldwork in any active volcanic landscape is always impressive and exhilarating, but working on the very active volcanoes of Papua New Guinea, deep in often un-charted rainforest, takes volcanological fieldwork to another extreme. Co-organised by myself and the department's Brendan McCormick Kilbride in collaboration with the Rabaul Volcanological Observatroy (RVO) and researchers from Italy, Sweden, and the United States, the month-long expedition was unlike anything we had undertaken before. Our main objective was to study the gas emissions of active volcanoes in three locations around the country – Rabaul, West New Britain, and Bougainville. The workings of these volcanoes have been elusive until now, owing to their inaccessibility and to the expense of fieldwork in the region. Almost half a ton of equipment had to be carried to each location, often across solfatara-style degassing areas, inside precarious craters made of volcanic bombs, and for hours of trecking through rainforest downpours.

Our specific goal was to measure volcanic carbon emissions, as part of the ongoing international efforts of the Deep Carbon Observatory's DECADE programme. Traditionally this is done at a degassing vent on the volcano and either measuring in situ with a device called the MultiGas, or by recovering a sample of gas for chemical analysis in the lab. Clearly, entering a volcanic crater requires care and attention to levels of unrest, and we were all relieved when we had got our samples and retreated to a safe distance. Chemical analyses will be undertaken with colleagues at the Universities of Oxford and New Mexico.

Another goal was to test the use of unmanned aerial vehicles (UAVs, or drones) to study active volcanoes. Drones can take video footage to map recent deposits and even enter gas plumes to measure their chemistry. It was thrilling to pilot our quadcopter up the flanks of Bagana volcano and see rolling clouds of ash venting from a fissure high above us on the side of the edifice.

Our work depended on the support of our RVO colleagues, who are responsible for monitoring PNG's many active volcanoes, and the many locals who shared their homes and food with us. By travelling with RVO scientists we could get to otherwise inaccessible locations and draw on their great experience of these volcanoes. RVO input is particularly valuable for understanding recent activity, since regular direct observations of these remote volcanoes are otherwise only possible from space. We hope our research results will be useful to RVO and local communities in volcano risk management. We hope too that someday we can return to this beautiful country to study their volcanoes directly again.

We acknowledge funding from the Deep Carbon Observatory, the NERC Centre for Observation and Modelling of Earthquakes, Volcanoes, and Tectonics (COMET) and the University of Cambridge.

Twitter: @pngvolc16

Instagram: #pngvolc16

HIDDEN DEPARTMENT – The Workshops

From left to right Martin Walker, Charlie Aldous, Andrew Stephenson in the Wood Workshop

THE WORKSHOP TEAM, LED BY MARTIN WALKER, ARE INVALUABLE TO THE SMOOTH RUNNING OF THE DEPARTMENT AND HAVE A COMBINED TOTAL OF 70 YEARS' EXPERIENCE IN THE WORKSHOPS.

Chris Parish at work in the Engineering Workshop

The workshop area on the Downing Site includes an Engineering Workshop, a Wood Workshop and Cutting and Polishing Rooms. In addition to maintaining the fabric of the Department, members of the team work on a wide range of projects, including building display mounts for the Museum and cutting and polishing thin sections samples which will be very familiar to former students.

Chris Parish, who is currently adding to his expertise by undertaking a further City & Guilds electrical qualification, works closely with researchers to build equipment to aid their research, for example: sensors for the High Temperature Laboratory; and a transportable raft for the collection of river sediment samples. Andrew Pluck provides similar support for the research team at the BP Institute from a small engineering workshop located at the Bullard Laboratories.

DOUGLAS PALMER SEDGWICK MUSEUM

Athena SWAN Bronze Award

By the year 2000, at last, the recruitment of women into Earth Science in Cambridge reached parity with men in Part II of the Natural Sciences Tripos and at PhD level. But women's access to degree level geology in the University of Cambridge has taken over 150 years to achieve ever since the first geology syllabus was published in 1792 by the 6th Woodwardian professor, the Reverend John Hailstone.

Women in geology – past and present

At the time, there were no female students or staff in the University and even the Woodwardian Professorship was conditional upon bachelorhood or, as Adam Sedgwick ruefully noted in 1858 'Woodward put the ban of domestic sterility upon his Professor'. Women were not even allowed to be wives in this University context.

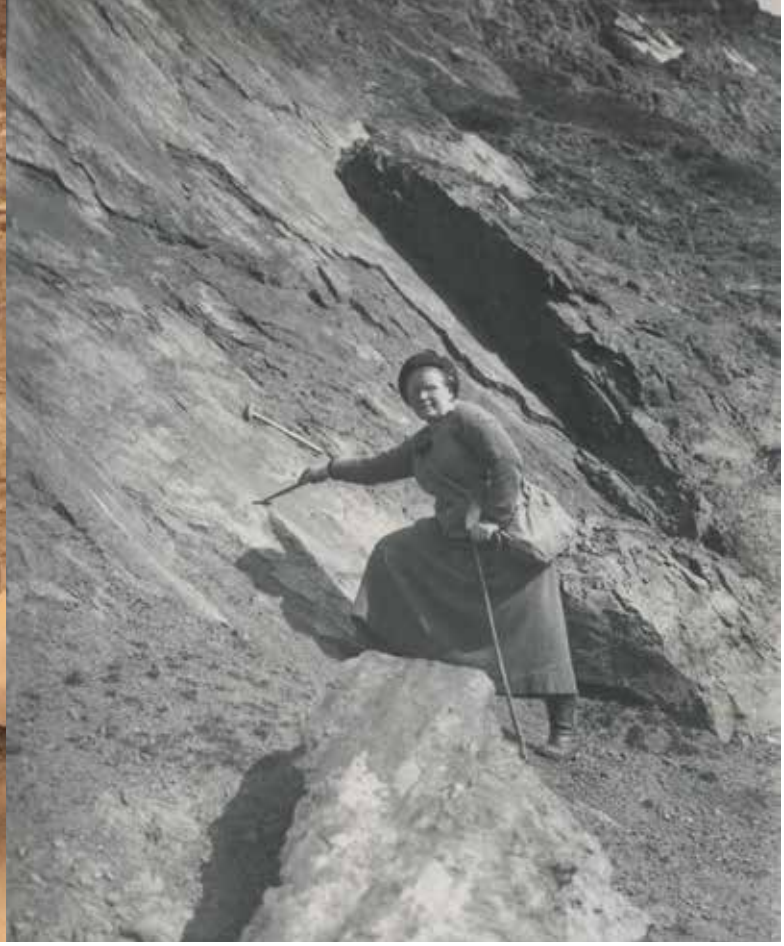
Throughout the succeeding 200 years, progress towards women's access to the academic study of Earth Sciences was painfully slow and erratic. Despite Hailstone's 1792 geological syllabus, formal teaching and examination of the subject only began in 1848 when the Natural Sciences Tripos was first introduced. However, women's access to the teaching of geology had to wait until 1870 and the foundation of the first women's colleges, Girton in 1869 and Newnham in 1871.

Even then, Cambridge was notoriously tardy in allowing women to take University exams (1881) and, despite passing the relevant exams, women were still not awarded degrees. There was a brief three year period from 1904-07, when Trinity College Dublin awarded degrees to 'Oxbridge' women who had passed degree level exams, but it was not until 1947 that Cambridge finally opened its degrees to women, many years after Oxford had done so in 1919.

However, the 19th-century saw significant contributions to the development of geology in the University and to the science in general by a number of women. These pioneers included a very independently minded Dorset woman, who had experienced life in the workhouse, an equally determined young woman from a Cumbrian vicarage and some very bright and well educated young women from more urban middle-class backgrounds.

The Department received an Athena SWAN Bronze Award in April 2016. The Athena SWAN Charter was established to encourage and recognise commitment to advancing the careers of women in science, technology, engineering, mathematics and medicine (STEMM).

Adam Sedgwick, Woodwardian Professor, who reportedly 'smited the hearts of all the ladies' at the 1837 Liverpool meeting of the British Association for the Advancement of Science.



Mary Anning (1799–1847)

Mary Anning is now well known as a fossil collector, having discovered some of the most spectacular fossils in the early development of palaeontology. Long before the dinosaurs were 'invented' she recovered, at considerable personal risk, the remains of giant marine reptiles, such as *Ichthyosaurus*, from the coastal cliffs of Jurassic strata around Lyme Regis in Dorset.

Brought up in rural poverty, Mary Anning's family eked out a precarious living by collecting and selling fossils. Some of the most scientifically important of these were bought by Adam Sedgwick for the Woodwardian (now Sedgwick) Museum, where they are still on display. Surviving correspondence with Sedgwick shows that Mary Anning's contribution was not just that of a collector but also an acute observer of these fossils. Her achievements have only been fully recognized in recent decades.

Since then many women, such as Gertrude Elles, have donated large collections to the Museum but mostly as a result of fieldwork connected with postgraduate research. The recruitment of women as undergraduate students of geology did not start until the latter part of the 19th-century. And then it was greatly facilitated by a vicar's daughter from Cumbria.

Mary McKenny Hughes (nee Weston, 1860–1916)

Brought up in a Cumbrian vicarage, Mary Caroline Weston was just 23 years old when she married the 51 year-old Thomas McKenny Hughes, the 8th Woodwardian professor, following a change in University rules, which allowed the Woodwardian professor to marry.

Within 6 years, 'Carrie' as she was known, demonstrated her acumen for geology by publishing her first paper in 1888. Just as important was her active participation in geological field trips, which provided chaperonage to the first generations of young women to study natural science in general, and geology in particular, in the decades before the First World War.

The success, as measured in academic publications, of British and especially Cambridge women geologists places them way ahead of the international league table of female geologists of the period.

Most famous of these academic pioneers was a young woman of Scots descent with straw coloured hair, freckled face and strikingly blue eyes – Gertrude Lilian Elles.

Gertrude Elles (1872–1960)

A Newnham College graduate 'Gertie' as she became known to generations of students was one of the so-called 'steamboat ladies' who got her degree from Dublin in 1895. She became the first female lecturer in the Geology Department in 1926 when women were first allowed to hold such academic posts. As a teacher she was reported to be 'marvellously clear and very, very fierce'. She was and still is internationally renowned for her pioneering work on fossil graptolites and she was awarded the MBE in 1920 for her war work as commandant of the 1st Borough Red Cross Hospital in Wordsworth Grove near Newnham College.

In 2013, fifty-three years after Gertrude Elles died, Marian Holness was the first woman to be appointed to a professorship in the Department of Earth Sciences. An igneous petrologist, Marian is interested in using the microstructures of rocks to unravel their history of solidification, using examples from South Africa, Greenland and Scotland.

Above left: A posthumous portrait of Mary Annning and her spaniel 'Tray'
Above middle: A young Mary McKenny Hughes with husband and son on a geological field trip to the Malverns, 1897
Above right: Dr Gertrude Elles shortly after being awarded the MBE for her hospital work in WWI
Background image: Mary Anning's 'rough scratch' of an 'Ichthy[osaur]'

LIZ HARPER
AFFILIATED LECTURER AND HONORARY CURATOR OF PALAEONTOLOGY, SEDGWICK MUSEUM

Researching out of their shells

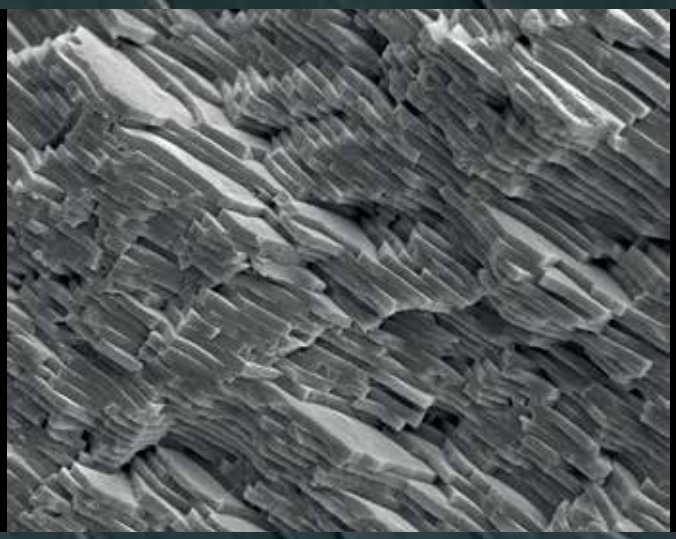
ANIMALS HAVE BEEN BUILDING SHELLS AND SKELETONS FOR OVER 540 MILLION YEARS. GEOLOGISTS LIKE THIS, BECAUSE BUILDING A HARD RESISTANT SHELL GIVES AN ANIMAL A HEAD START IN THE CHANCY BUSINESS OF BECOMING A FOSSIL.

These shells often provide key geochemical data about past environments. But there are other reasons to be interested in shells. How are shells built? What effects have changing conditions in the oceans had on the way species do this? How will they cope if current predictions for environmental change are correct?

Mollusc and brachiopod shells are composite materials of calcium carbonate (either calcite or aragonite) dispersed in an organic matrix laid down under the exquisite control of the organism. Using a combination of scanning electron microscopy, electron backscatter diffraction, X-ray diffraction and thermogravimetry we can explore the form of these composites and reveal the extraordinary diversity that nature has produced. All shell-producing molluscs and brachiopods have layered shells with at least two different microstructures showing contrasting crystallite arrangements and mineralogies. Working with histologists, physiologists and geneticists we are beginning to learn which groups secrete which structures and how this is achieved.

Although the organic fraction is small (0.1-10 per cent by weight) it has a fundamental role in controlling the way the crystalline shell is laid down. It is the organic molecules which determine the mineral used and, crucially, the microstructural arrangement of its crystals. In the few species where the organic matrix is barely discernible, the shell material is brittle and has a microstructure like inorganic diagenetic cements. The higher the organic content of a shell layer the more flexible it is and the more resistant it is to being dissolved. Such advantages come at a cost because it is the organic part of the shell that is metabolically most expensive to produce.

We suspect that shell is so expensive to produce that unnecessary biomineralization is suppressed. In a study of a polar clam that lives in shallow water around Antarctica, we found that long larval dispersions had led to populations from all sites having a uniform genetic structure. However the populations look rather different from one another. Those which live under permanent sea ice have thin fragile shells. Those that live in areas of seasonal melt and iceberg activity, and which



show frequent crushing damage, have thicker more robust shells. This is ecophenotypic variation; more expensive shells are only made where there is a selective advantage.

In a recent study of the bivalve tree of life we examined the genetics of over 100 living species and studied their anatomical and shell features. This included recording 17 different shell microstructural characters with a total of nearly 100 different character states. Thousands of permutations exist and 540 million years has seen many of them realised. However, patterns exist, reflecting either the ancestry of particular groups or adaptation to particular environments.

As geologists we tend to have a narrow view of shell make up. We see it in terms of preservation and think calcite is good and aragonite is bad. But all molluscs secrete aragonite and most of them do not bother with calcite. An interesting observation is that mother of pearl is the 'best' molluscan shell structure. It is tough, resistant and good at stopping cracks, and it is also the first to appear in the fossil record. Given that most shells need to be strong to resist predators, it is curious that most bivalves and snails have lost mother of pearl over their evolution. This loss happened relatively early on – before the arrival of crushing predators such as crabs and lobsters. Perhaps the evolutionary bolt was shot too soon. More 'modern' shells are thicker and less organic-rich, which may be a better "budget" solution.

Top right: Brachiopods and mussels living together in the intertidal zone (Stewart Island, New Zealand)

Bottom left: Cold Antarctic waters corrode away the shell even while the animal is alive. (Animal is about 2.5 cm across)

Bottom right: Tough and flexible. Scanning electron micrograph of mother of pearl (nacre). Each tablet is about 0.5 micron thick.

And what of the challenges from future oceans? We already know that molluscs living in fresh, deep or cold waters are prone to dissolution. Our seas are getting warmer and more acidic. We might predict that shells would become more difficult to secrete and also to maintain. Losing a few 100 microns a year off the shell may not matter much for an animal that lives only a few years but the individuals of many species live for tens or even hundreds of years. For these animals the threat of corrosive sea water is very real. In recent experiments by PhD student Emma Cross, two brachiopods (one Antarctic and one from temperate New Zealand) experienced life in the pH predicted for 'business as usual' end century conditions. They were able to grow and repair their shells normally and, despite showing surface corrosion intriguingly compensated for this by thickening their shells. After 540 million years and five mass extinctions, the great survivors continue.

A new species of bivalve, *Pleurolucina harperae*, has been named for Liz Harper. *Pleurolucina*, a new intertidal shallow water species of the lucinid bivalve from Curaçao, has an unusual shell microstructure.

READ MORE: http://zookeys.pensoft.net/articles.php?id=9569

HELEN WILLIAMS UNIVERSITY LECTURER, GEOCHEMISTRY

SQUEEZING SLAB SERPENTINITES

SUBDUCTION ZONES ARE A MAJOR ROUTE OF CHEMICAL INTERCHANGE BETWEEN THE EARTH'S SURFACE AND INTERIOR, WHEN WATER AND VOLATILES ARE RELEASED FROM THE SLAB AND OVERLYING SEDIMENTS AS THEY BECOME SUBJECT TO INCREASING TEMPERATURES AND PRESSURES DURING SUBDUCTION.

These slab-derived melts and fluids chemically alter the sub-arc mantle. These effects are ultimately reflected in the chemistry of arc lavas, which are generally oxidized, enriched in fluid-mobile and volatile elements and associated with major ore and porphyry deposits. The chemistry of these magmas is consistent with the oxidation of the sub-arc mantle by hydrous, sulfate- and carbonate-bearing fluids derived from the subducting slab, but the exact nature and origin of the melts and fluids leaving the slab is not well understood. This is an important problem, as the composition and chemistry of slab fluids will influence arc magma eruptive style, volcanic degassing processes, and the distribution of ore and porphyry deposits. Furthermore, many lines of evidence indicate that subduction has been taking place on Earth for the last ~ 3 billion years and it is an open question as to whether this can be linked to major changes in the chemistry of the Earth's atmosphere and oceans over this time.

In order to answer these questions we need to determine the nature of the fluids released from the slab to the sub-arc mantle. It is difficult to do this using the chemical compositions of arc lavas as these can be modified by magmatic differentiation and the incorporation of crustal material. Another problem is that it is very difficult to separate the "fluid" contributions of certain elements to the sub-arc mantle if these elements are already abundant there, as is the case for major elements such as iron or compatible elements such as copper. While the contribution of sediment-derived melts and fluids to subduction zones has been well studied, far less is known about the role of the subducting oceanic mantle lithosphere. For example, serpentinites – formed by the hydration of oceanic lithosphere – can contain up to 13 weight percent of water as well as carbon, sulfur and other fluid-mobile elements. Serpentinites are stable down to depths of 30-100 km and are thus a means of transferring water and other volatile elements either to the overlying sub-arc mantle, or, if these elements are retained in the slab, into the Earth's deep interior.

We have used iron and zinc stable isotope tracers to track serpentinite dehydration during slab subduction, as these systems are highly selective tracers of changes in iron and sulfur oxidation state in igneous rocks and fluids. We analysed residual slab samples from the Western Alps as well as samples of the sub-arc mantle from the Kohistan Arc, NW Pakistan. We found that serpentinite dehydration is accompanied by the loss of highly oxidised, sulfate bearing fluids from the slab. Sulfur seems to come from the breakdown of sulfide minerals in the oceanic lithosphere and their oxidation to fluid-mobile sulfates, decreasing the redox state of iron in the residual slab.

Our discovery that slab sulfides break down during subduction and serpentinite dehydration is important. It suggests that the precious metals such as gold, silver and copper, associated with sulfides in the oceanic slab are also transported by these sulfate-bearing fluids to the overlying plate. This process partly explains the remarkable association between convergent margins and the occurrence of major ore and porphyry deposits. Also, percolation of the sub-arc mantle by oxidizing slab fluids is a scenario that accounts for both the high Fe3+/Fetotal contents of arc lavas, as well as the high SO_2 and halogen contents of volcanic gases that influence the chemistry of our atmosphere. Finally, our results have shown that the process of serpentinite dehydration actually changes the nature of the residual slab that is ultimately recycled into the Earth's deep interior. This residual material may actually be quite reduced, rather than being oxidized, as might be expected from a rock formed through interaction between oceanic lithosphere with seawater.

Big questions remain. How has three billion years of subduction influenced the chemistry of the Earth's mantle and, by inference, that of the Earth's crust, oceans and atmosphere? Could the release of oxidized fluids from the slab contribute to large changes in the chemistry of the Earth's atmosphere and oceans, such as the abrupt increase in atmospheric oxygen 2.5 billion years ago? Our future work will test this hypothesis to see if we can find secular chemical changes associated with subduction. We then get closer to knowing whether plate tectonics was ultimately responsible for the development of Earth as a habitable planet.

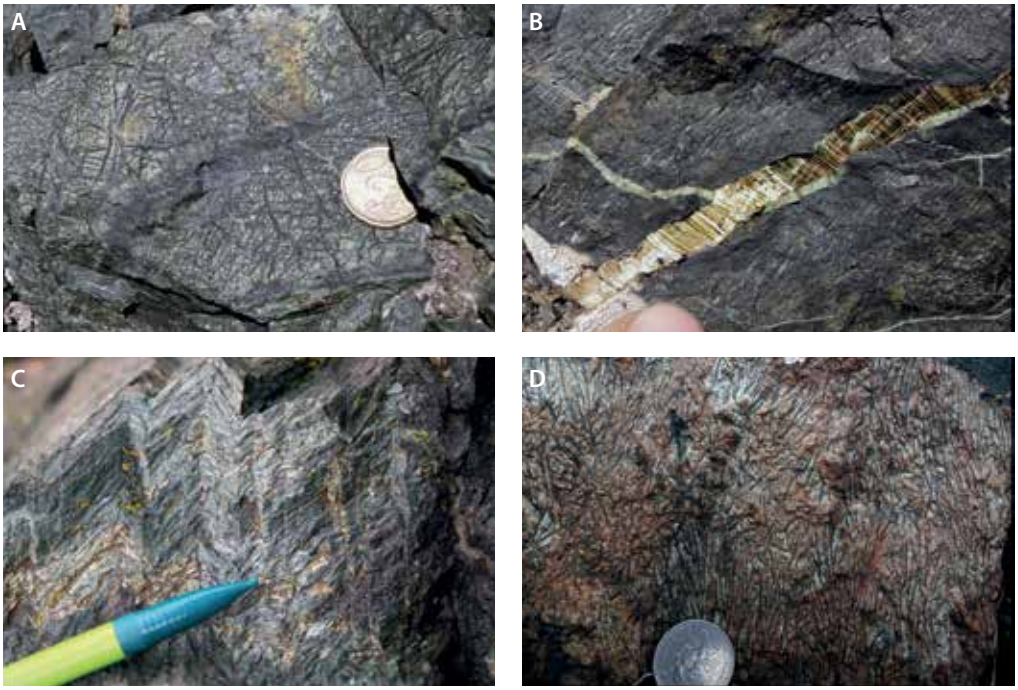


Fig 1: A–D: Progressively metamorphosed and deformed Alpine serpentinite samples

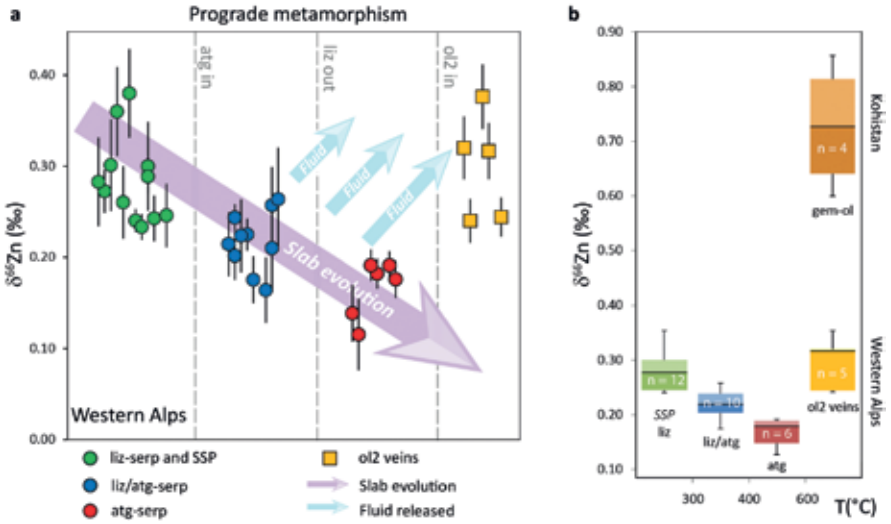


Fig 2: a) Prograde evolution of zinc isotopes (δ^{66}Zn) in serpentinites and peridotites from Western Alps ophiolites. Purple arrow shows Zn isotopic evolution of the slab during subduction (serpentinites, circle markers). Blue arrows show the inferred release of ^{66}Zn-enriched fluids during serpentinite dehydration and slab subduction (secondary olivine veins, square markers). SSP: slightly serpentinized peridotites. liz, atg: lizardite, antigorite-serpentinites. ol2 veins: prograde olivine veins. gem-ol: Kohistan arc gem olivines. b) Comparison of δ^{66}Zn evolution of Western Alps samples with Kohistan arc gem olivines with prograde metamorphism (as temperature). The box represents the 25th–75th percentiles (median is the bold horizontal line) and error bars the 10th–90th percentiles. Abbreviations as in (a)

GREG PALMER (KING'S COLLEGE 2013)
TIME TRUCK COMMITTEE MEMBER AND PART III STUDENT

Rocks and fossils on the road!

So how well did our activities go down last year? The feedback speaks for itself …

"I nearly forgot I was learning because I was having so much fun"

"I wish science was always this good!"

"When are they coming again?"

"I've realised I love rocks and want to be a geologist"

and from the teachers

"You have literally saved me hours of work and given the children a huge boost!"

"The Time Truck visit immersed the children in the world of fossils, minerals and evolution and left the children asking questions, inspired and eager to find out more. An excellent opportunity to inspire and engage the whole class."

FOR ALMOST 20 YEARS, EARTH SCIENCES STUDENTS AT THE UNIVERSITY OF CAMBRIDGE HAVE BEEN RUNNING TIME TRUCK, AN OUTREACH PROGRAMME WHICH PROVIDES INTERACTIVE AND HANDS-ON EARTH SCIENCES TEACHING TO SCHOOLS AND FAMILIES.

Founded in 1998 by a group of enthusiastic Sedgwick Club members as a contribution to the National Science Week, Time Truck became independent of the Sedgwick Club and made its name by visiting local schools. Every Spring a truck filled with exhibits would hit the road to inspire 7–11 year olds.

Over the years, the Time Truck committee has built up an impressive collection of models and displays to demonstrate geological processes and concepts in a way that is accessible to a young audience. The team works closely with the Sedgwick Museum, receiving training and borrowing specimens to take beyond the department and into the hands of lucky schoolchildren. We aim to spark an interest in science in a fun and practical way.

Recently, the Time Truck has become more of a Time Taxi, as the logistics of hiring and driving a truck have become complicated. Despite the present lack of a truck the programme lives on and our name is unchanged. Every year a new batch of keen volunteers get involved and 2016 was no exception.

A busy Lent term began with assisting "Hands-on Saturdays" in the Sedgwick Museum – helping explain rocks, fossils and minerals to visitors with special handling specimens. This serves as a great warmup for our annual primary school visits. During the final week of lectures, fifteen trusty undergrads gave up their time to visit more than 250 children in Years 3–6 across Cambridgeshire. We ran lots of handling and question and answer sessions with boxes of rocks, minerals, and fossils. We impressed the kids with massive dinosaur fossils and erupting model volcanoes. And we had a lot of fun along the way!

Images from the Time Truck archive, including the original truck



After the frantic week of school visits, March's Cambridge Science Festival provided the opportunity to round off Lent term with a whole day of handling and demonstrations in the department common room for the general public. Some of the children (and teachers!) were so enthusiastic after their school visits that they came along to the Science Festival too.

What next for Time Truck? With the support of the Education and Events Team in the museum we'll be running all our usual events in 2017. We'll be training new volunteers and helping with museum activities. We'll be visiting local schools again before Easter. There is never a shortage of teachers eager for us to visit their class, with the starting point being the long list of schools we couldn't make it to last year! The Cambridge Volcano Seismology group from the Bullard Labs. will be bringing their Explosive Earth exhibition to the Science Festival, and we intend to join them with our handling collections, models and new activities on geohazards.

We aim to begin to: involve more graduate students and staff in our outreach; reorganise our existing exhibits and develop new, up to date activities.

With luck in the not too distant future we can return to the glory days of having a van or truck to visit schools. This would not only allow us to take many more practical 'props' for our school sessions, but also reach areas and kids who've never had the chance to have such a fun hands-on experience with Earth Sciences before!

Do you want to support TimeTruck or share your ideas? Email the team at **timetruck@gmail.com**.

Mayfield Primary School tweet their appreciation following their 2016 visit

DOUGLAS PALMER SEDGWICK MUSEUM

HAMMERING IT HOME:
Tools of the geologist's trade

ARGUABLY, THE GEOLOGICAL HAMMER IS BY FAR THE OLDEST PROFESSIONAL TOOL. THE FIRST 'GEOLOGISTS' WERE SOME OF OUR EXTINCT HUMAN (HOMININ) RELATIVES WHO LIVED OVER 3.3 MILLION YEARS AGO ON THE SHORE OF LAKE TURKANA IN EAST AFRICA.

William Buckland caricatured in 'glacial' field kit for his role in the recognition of the 'Ice Age'

[*Face p.* 145.

The archaeological evidence shows that these hominins had enough geological knowledge to select the best available rocks for making the stone tools upon which they, and the evolution of early human culture, depended.

The hammer is still a basic tool for any field work that requires the sampling of Earth's rock materials. Weathered rock surfaces can provide only a certain amount of information; a freshly broken rock surface can do a great deal more. With practice and a good hand lens a field geologist can make a preliminary identification of a surprising number of rocks and minerals. The geological hammer is not only the oldest tool but also perhaps the most basic scientific instrument. In breaking a rock a geologist makes all kinds of judgments about the rock material from the way it breaks, the sound and even smell of the fracture.

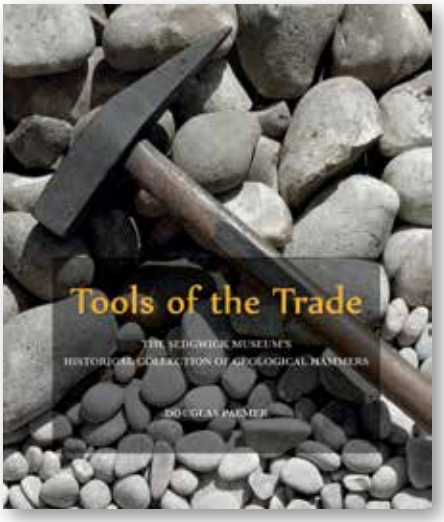
The Sedgwick Museum has a unique historical collection of geological hammers, some of which are currently on display in the Museum. They include hammers that belonged to pre-eminent 19th-century geologists, such as the Rev. Dr William Buckland (1784–1856), the Rev. Professor Adam Sedgwick (1785–1873), the Rev. Dr William Conybeare, (1787–1857) and Charles Lyell (1797–1875). There are also hammers belonging to more recent geologists, especially those with Cambridge connections whose careers reflect the development of geology in the University of Cambridge.

Foremost amongst these are the hammers belonging to Adam Sedgwick who was elected the 7th Woodwardian Professor in 1818 despite his lack of geological expertise. Sedgwick inherited John Woodward's bequest of some 9000 specimens in their original cabinets and a miscellany of other geological specimens. He also took the conditions of the professorship seriously, becoming one of the new 'brethren of the hammer' whose researches were transforming geology, its practice and teaching.

Within a decade or so Sedgwick established himself as one of the foremost geologists in Britain. He specialised in the mapping the 'terra incognita' of the 'Killas and Grauwacke' of Cumbria, Wales and Southwest England and helped carve the Cambrian and Devonian systems of strata out of their Palaeozoic rocks. In doing so, Sedgwick built up the geological collections to such an extent that in 1841 a Geological Museum was established to house them in the Cockerell Building behind Senate House.

By the time of Sedgwick's death in 1873, the Museum was again overcrowded. His Woodwardian successor, Thomas McKenny Hughes (1832–1917) spent 25 years establishing the present purpose-built Sedgwick Museum as a memorial to Sedgwick.

An illustrated booklet '*Tools of the Trade*', about the history of the collection and those geologists who donated their hammers, has been published by the Sedgwick Museum and available from the Museum shop:
www.sedgwickmusuem.org
T: +44 (0) 1223 333456



OBITUARIES

Henry Elderfield FRS 1943–2016

Harry and his identical twin John were born in a small North Yorkshire village. As John tells it, they had '*no fridge, no phone, no car, no indoor toilet, no heating except for coal fires, no hot water except what was boiled. But we did have the privilege of belonging to the last generation to be brought up without television … And we had the greater privilege of benefiting from the 1944 Education Act, which would make it possible for us to stay in school after the age of sixteen, and then go on to university*.' Having completed a chemistry BSc in 1965, Harry started his PhD in the Liverpool Oceanography Department, but soon obtained a research fellowship at Imperial College. By 1969 he was a lecturer at Leeds. In 1970, to complete the reverse of the normal running order, he got his PhD based on infra-red absorption spectroscopy in minerals; not on sea water. However, Harry was increasingly influenced by the Professor of Oceanography at Liverpool, the marine chemist John Riley.

In the 1970s Harry worked on iron-manganese sediments on land and in the ocean, strontium isotopes in pore waters, and the interaction between volcanic rocks and sea water. This work underpinned what he was to do in the next decade. In 1977 Harry appointed Mervyn Greaves as his research assistant, but then promptly departed on sabbatical leave to the University of Rhode Island.

Back at Leeds, Mervyn had worked on mass spectrometry with Chris Hawkesworth and was thus able to assist Harry in his next venture. This was the first measurement of rare earth elements in seawater. Harry and Mervyn showed that the distribution of rare earths, especially neodymium, could be used to characterise water masses in modern oceans and, via sediment records, past oceans.

In the 1980s Harry established the strontium isotope variations for seawater over the past 75 million years. He used strontium to prove large-scale flow of seawater through permeable oceanic rocks, with implications for understanding seawater chemistry as well as mountain building and weathering. He then led the UK contribution (BRIDGE) to international research on mid-ocean ridge processes. This involved many trips to sea and several dives to 3000 m depths in the research submersible *Alvin*. During this work, Harry left Leeds for Cambridge (in 1982), first as an Assistant Director of Research, then Professor of Ocean Geochemistry and Palaeochemistry and, in 1984, a Fellow of St Catharine's.

From the mid-90s onwards Harry developed proxies for ocean temperature and acidity leading to work on the impact of increasing atmospheric

Harry receiving the Challenger Medal, 2011, from Professor Hilary Kennedy, Bangor University. Hilary was a PhD student of Harry's at Leeds and a post-doc in Cambridge 1982–85

CO_2 on the oceans and climate. There can be few palaeoceanographic laboratories in the world that do not now use the magnesium to calcium ratio in foraminifera to determine past ocean temperatures. He and Jimin Yu demonstrated boron to be sensitive to the ocean pH, allowing the invasion of fossil-fuel derived carbon dioxide into ocean waters to be assessed.

Many honours came to Harry: Fellow of the Royal Society and of the American Geophysical Union, and half a dozen medals from geochemical and geological societies. As you might expect of this delightfully modest man, certificates and medals were absent from the walls of his office. What was present though were art exhibition posters: Harry had a very good eye, perhaps a family trait (brother John was Chief Curator at MoMA in New York).

Harry's legacy is a chemical toolbox for examining the ocean's past environmental parameters. Even more importantly, he leaves a cohort of more than 40 former research students active in research. At a September conference I ended a tribute to Harry by inviting anyone using his chemical proxy methods to stand up. Of 650 people, over 400 stood. Harry Elderfield has had a massive impact on the science of the environment, an impact that will long endure.

Nick McCave

A memorial symposium in honour of Harry Elderfield was held at St Catherine's College in October last year. Approximately 130 people attended, including 17 of Harry's former graduate students.

RECENT NEWS & AWARDS

The Geological Record

01

Alex Liu returns to the Department from the University of Bristol. Alex was a Junior Research Fellow at Girton College 2011–2014. He takes up a post as University Lecturer in Palaeobiology and Fellow of Girton College. Alex is currently working on various projects relating to the Ediacaran biota, in an attempt to better understand early animal evolution and its relationship to major geological events. Recent fieldwork has taken Alex to Newfoundland (Canada) and the Corumba region of Brazil to collect data and fossils, and most recently to microfossil localities in phosphorite mines in South China.

02 **Morag Hunter** (Emmanuel 1989), Department Teaching Fellow and Fellow of Girton College, left the Department at the end of 2016 to take up a post as Fundraising Officer with Bird Life International. Morag will continue in her role as Fellow and Director of Studies in Earth Sciences at Girton College. We wish Morag well in her new position.

03 2017 marks the 50th anniversary of the publication of **The North Pacific: an Example of Tectonics on a Sphere (*Nature, 216, 1276–80*)** by Dan McKenzie and Bob Parker. One of the seminal papers in the development of the theory of plate tectonics, McKenzie and Parker used Euler's theorem for motion on a sphere to present a mathematical resolution and a visual presentation of the motion of the Pacific plate relative to North America and Kamchatka. Their analysis of the plate's marginal slip vectors gave a relatively coherent global-scale picture of what is a complicated region of the crust. This provided convincing evidence for the motion of rigid plates on the surface of a sphere and for the correctness of what they called 'the paving stone theory of world tectonics'.

However, McKenzie and Parker were not alone in developing the theory. Within the plate tectonic zeitgeist of the time, Jason Morgan independently used similar mathematical

principles to come to a similar conclusion. As Dan McKenzie explains '*although Jason Morgan's paper was published after ours (Journal of Geophysical Research, 1968, 73, 1959-82), he has priority: He talked about his ideas at a conference in the spring of 1967, at a session at which I was present, but left before he talked*'.

The annual William Smith Meeting at the Geological Society London will this year mark **Plate Tectonics at 50** with a three day conference. Read more: **http://www.geolsoc.org.uk/wsmith17**

04

Congratulations to **Laura Briggs** (Newnham 2012) who has been awarded the 2016 BSRG Award for Undergraduate Sedimentology for her work on the Upper Carboniferous Bude formation. Laura graduated in June 2016.

05

Congratulations to **Nigel Woodcock** who has been awarded the Sorby Medal of the Yorkshire Geological Society. Nigel joins a distinguished list of medal recipients: **www.yorksgeolsoc.org.uk/EDITABLE/awards.pdf**

06 We welcomed **Professor Nick Rawlinson**, newly elected to the BP Foundation-McKenzie Professorship in Earth Sciences, to the Bullard Laboratories in January. Before coming to Cambridge to take up the chair, Nick was Professor of Geophysics at the University of Aberdeen for the preceding three years. He originally obtained his PhD from Monash University and went on to spend the next 12 years at the Research School of Earth Sciences, Australian National University, where he carried out both theoretical and field-based studies in seismology.

His research interests include seismic wave propagation, geophysical inverse theory, seismic tomography, continental tectonics and intra-plate volcanism. Amongst his other achievements, he initiated the largest transportable seismic array program in the southern hemisphere; has developed a variety of seismic imaging methods and software that is widely used in the seismology community; and has made fundamental contributions to the understandng of how the Australian continent has evolved.

07 **Owen Weller** (Pembroke 2006) returns to the Department, from the Geological Survey of Canada, as a University Lecturer and Fellow of Sidney Sussex College. Owen is currently working on a range of projects that integrate field, petrographic, phase equilibria and geochronological techniques to further our understanding of crustal metamorphic processes and their evolution through time. Recent fieldwork has taken Owen all over the Canadian Arctic, including Baffin Island and north-west Hudson Bay, where he has been investigating the Himalayan-scale Paleoproterozoic Trans-Hudson orogen, which has been exhumed from mid-crustal levels.

Explosive Earth at the Royal Society

FOR A WEEK IN EARLY JULY THE HALLS OF THE ROYAL SOCIETY IN LONDON RESOUNDED TO THE THUDS OF 2,000 PEOPLE AS THEY JUMPED AS HIGH AND AS HARD AS POSSIBLE.

Amongst them were children, their parents, Professors, FRSs and at least one Ambassador, all trying to get to the top of our 'Make a Quake' leader board.

The occasion was the Royal Society Summer Science Exhibition, showcasing the best of British scientific research. The Cambridge Volcano Seismology Group exhibit was on our studies of the 2014 Holuhraun eruption in Iceland. The week in London was the culmination of five months of preparation led with great energy by graduate student Jenny Woods, with software written by Tim Greenfield and Jonny Smith, and helped by a group of 27 folk who contributed by building and staffing the exhibit in rotation. Some 15,000 people passed through the exhibition.

To get a taste of what you may have missed watch the two minute video with its stunning eruption footage and browse the website at **www.esc.cam.ac.uk/ExplosiveEarth**

There you will find a set of simple experiments, each with a video display: great to show children and grandchildren, but often done for the secret enjoyment of the adults. They will remind you of why you love geology.

Bob White

List of donors 2015–2016

We wish to thank alumni and friends who have generously made donations to the Department in the last financial 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.

Risk Management Solutions (RMS)

Maria Andersson Bianchi	2004
James Banton	2004
Frances Barrigan	2001
Jenefer Brett	1994
Andrew Butler	1993
Daniel Chapman	2006
Michael Coffin	2004
Alistair Crosby	2002
Kirsty Dodds	2001
John Elliott	2001
Joanna Ellis	2001
Jonathan Farrant	2001
Isabel Fenton	2006
Marcus Flint	1980
Amanda Foan	2006
Rebecca George	2006
Alastair Graham	1972
Eleanor Green	2002
Jacob Hall	2001
Jillian Hegarty	2004
Virginia Hooper	2001
Corin Hughes	2000
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Barry Jefferies	1969
David Jenkins	1958
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Samantha Large	2001
Laura Lawton	2001
Lucy Leyland	2002
Peter Llewellyn	1957
Mark Logie	2004
Danielle Lopes	2006
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Earth Sciences on YouTube:
youtu.be/sUj4as55658
A brief look at the earth sciences course to encourage the next generation of Earth scientists.

Ways of staying in touch

We send our communications, including our termly Earth Sciences e-newsletter and e-invitations to events, using data held by the University Development and Alumni Relations Office (CUDAR). In addition to the communications from Earth Sciences, the University send their award winning termly Cambridge Alumni Magazine, a monthly e-bulletin and the rest of their alumni communications. You can let us know what our communications preferences are by contacting Alison at **alumni@esc.cam.ac.uk**

Our Data Protection Statement can be found at **www.alumni.cam.ac.uk/dataprotection.**

Forthcoming Alumni Events

In addition to our **Earth Sciences Alumni Day and Dinner** on Saturday 13 May 2017:

Monday 20 November 2017 **Alumni Panel Discussion at the Geological Society, London**

Earth Sciences alumni are warmly invited to join us for our third annual panel discussion at the Geological Society. Our expert panellists will give short talks and will then answer questions from the floor. Afterwards there will be drinks and canapés in the Lower Library, and a chance to meet fellow alumni and the panel informally.

Deep Geological Disposal

The safe disposal of high-level radioactive waste has been well researched and the international consensus is that deep geological repositories are the preferred method. Only a handful of countries however – Finland, Sweden, France and the US – have started building permanent storage facilities.

The panel will be chaired by Simon Redfern, Professor of Mineral Physics and Head of Department. Simon is a member of the Committee on Radioactive Waste Management providing independent advice to the UK Government on long-term management of radioactive waste, including storage and disposal.

Our panellists include Dr Ian Farnan, Reader in Earth and Nuclear Materials; Dr Nigel Woodcock, Emeritus Reader and and Dr Liz Harvey (Jesus 2003), Senior Consultant at Galson Sciences Ltd.

Notifications for this event are sent by email only. If you do not currently receive our e-invitations and would like to be added to the mailing list let Alison know, at **alumni@esc.cam.ac.uk**

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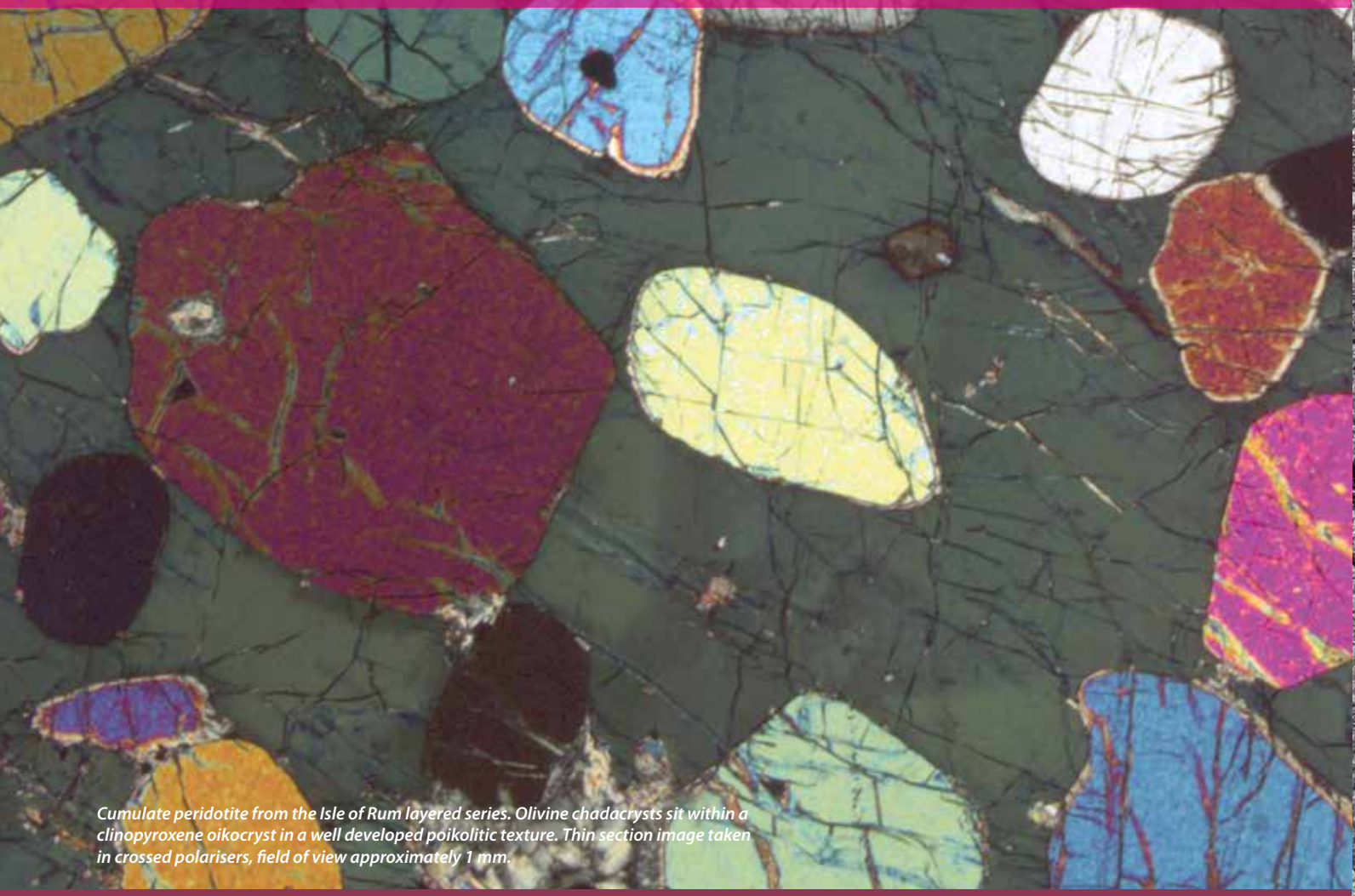
Be part of the future with a gift in your Will

A gift in your Will is a meaningful way to help the Department flourish far into the future, and for you to be able to make a significant and lasting contribution. Such a gift can open up a world of opportunity for future students, researchers and academics, helping to provide the environment and tools they need to continue to achieve great things.



Cumulate peridotite from the Isle of Rum layered series. Olivine chadacrysts sit within a clinopyroxene oikocryst in a well developed poikolitic texture. Thin section image taken in crossed polarisers, field of view approximately 1 mm.

For further information about the impact of a legacy, and guidance on how to leave a gift to the Department in your Will, please contact:

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Dear World...
Yours, Cambridge

The campaign for the University and Colleges of Cambridge