THE MAGAZINE OF THE GEOLOGICAL SOCIETY OF LONDON

GEO SCIENTIST

SUMMER 2024

SHRINKING, WRINKLING, COOLING MERCURY

A PLANET IN CONTRACTION

RACE FOR RESOURCES
Energy metals and geopolitics

CRITICAL MINERALS
The UK Opportunity

DECOLONISING EARTH SCIENCE
Our past can shape the future

SOCIETY AWARDS
Pioneering geoscientists

23 - 24 September 2024

Unlocking the Potential of Salt Tectonics in the Energy Transition

What is it?

Attend this comprehensive two-day conference at Burlington House, London, which will go into the transformative influence of salt tectonics on the energy transition.

This conference is designed to collectively advance knowledge and contribute to sustainable solutions for the challenges posed by salt tectonics in the modern world, by bringing together a diverse audience of academic and industry professionals. It will be a dynamic convergence of expertise, encouraging collaboration, innovation and a holistic comprehension of how salt basins influences mining, energy and related industries.

Advancements in characterising composition, understanding internal salt deformation, decoding the evolution of salt structures and understanding the behavior of salt during operation and abandonment of caverns are crucial for the future energy transition. Salt basins can serve as storage sites for hydrogen, CO_2 and waste and offer enhanced geothermal energy potential in and around salt bodies; and the significance of salt tectonics in achieving energy transition goals cannot be overstated.

The conference will explore:

- Latest research in understanding salt-related deformation
- Innovative energy plays
- Its role in both short-term and long-term energy and waste storage

How do I register?

Members of the Geological Society can access preferential rates which can be further enhanced with the Group Booking discount. Register as a group and benefit from up to 20% off. Secure your space today
www.geolsoc.org.uk/09-Salt-Tectonics-24

Organisers

The Geological Society Conference Department
Dr. Gonzalo Zamora (Fellow of the Geological Society) - Repsol, Spain
Dr. Oliver Duffy - Chevron, Houston, USA
Dr. Oriol Ferrer - Geomodels Research Institute - University of Barcelona, Spain
Dr. Sian Evans - University of Oslo, Norway
Dr. Lorena Moscardelli – Bureau of Economic Geology, University of Texas at Austin, USA
Dr. Heijn van Gent - State Supervision of Mines, The Hague, Netherlands

Further information

W: www.geolsoc.org.uk/09-Salt-Tectonics-24
E: conference@geolsoc.org.uk
T: +44 (0) 207 434 9944
A: Conference Office, The Geological Society, Burlington House, Piccadilly, London, W1J 0BG, UK

Want to be involved?

Submit an abstract before *15 June 2024*.
Find out more via the event page
www.geolsoc.org.uk/09-Salt-Tectonics-24

Follow the event on Social Media:
#SaltTectonics24

The Geological Society

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Editor's welcome

SHRINKING, wrinkling planets, racing for resources, unravelling revolutions, shaping the future… This edition of *Geoscientist* helps convey the remarkable variety and significance of our science, with interviews and articles that take us from thermochemical piles lurking at Earth's deepest mantle depths to tectonism in the innermost reaches of our Solar System, from Earth's deep biosphere to the search for exoplanetary life, from the hazardous processes that create Earth's crust and our mineral resources to the complexities surrounding the discovery and exploitation of those resources – past, present, and future.

> **"Andy's clear-headed and reflective approach to decisions on content, publishing and various tenders will be greatly missed"**

This edition is the penultimate published with Andy Fleet's thoughtful input. After six years supporting and advising our editorial team, Andy will step down following the Annual General Meeting on 12 June. It has been wonderful working with Andy – his clear-headed and reflective approach to decisions on content, publishing, and various tenders, as well as to numerous thorny problems will be greatly missed. On behalf of the editorial team, advisory panel, and the whole Society, we offer Andy our heartfelt thanks and wish him an enjoyable and relaxing retirement.

We are delighted to announce that from September, and following a vote at the upcoming AGM, Ruth Allington will take over from Andy as Editor-in-Chief (ably supported by David Shilston who has agreed to stay on as Deputy Editor-in-Chief).

An Engineering Geologist by training, Ruth is, of course, familiar to us all having been President of the Society for the past two years. Moving from the Presidency into the Editor-in-Chief role means that Ruth brings an in-depth understanding of the Society and how it currently functions, the Fellowship more broadly, as well as the challenges and opportunities we face. Not to mention, Ruth's expert mediation skills will be invaluable.

Besides the opportunity to vote on *Geoscientist*'s new Editor-in-Chief, the AGM offers a review and discussion of the Society's many brilliant activities in 2023 (as highlighted in the Annual Review), as well as the chance to elect new Council members and Officers (see page 16 for details). The meeting will be followed by President's Day (our annual celebration of trailblazing people from across the geoscience community), which will be Ruth's last in her role as President. On page 18, Ruth discusses her pride and immense joy at having led the Society over the past two years, while on page 20, our incoming President, Jon Gluyas, discusses his aspirations for his upcoming term. For those who enjoy audio content, you can listen to the full, extended interviews with both Ruth and Jon via our podcast series at **www.geoscientist.online/section/podcast**.

As most of you will now know, the Society, together with the other courtyard societies, recently secured our lease to stay at Burlington House over the long term (p 6), and we look forward to again welcoming you to our London home for the AGM and Awards Ceremony in June. However, both events are hybrid, giving the option of virtual attendance for Fellows, family, and friends who cannot join the celebrations in-person. Read on for full details of the events, including interviews with some of our inspiring awardees.

AMY WHITCHURCH
EXECUTIVE EDITOR

Corporate Patrons

Join us as a Corporate Patron and demonstrate your commitment to the Earth sciences

The Geological Society has a membership of c.12,000 geologists and scientists from across the globe. We also have a number of Corporate Patrons: companies from geology-related fields, who wish to support our work and potentially pursue their own corporate social responsibility objectives through an official association with the Society.

Benefits

As a not-for-profit organisation, the Society greatly values our Corporate Patrons and we offer a wide range of benefits in return for support. These include employee use of our prestigious central London premises in Burlington House, invites to exclusive networking events, special rates on conference attendance, access to one of the largest geoscience libraries in the world, plus much more.

"Ikon Science, deeply immersed in subsurface science, has long championed the Geological Society's initiatives for advancing Earth knowledge, science education and professional excellence among scientists. Through impactful programs, they support and educate members and future geoscientists, contributing to sustainable interaction with our world. We sponsor the Geological Society to support the industry beyond our niche in geophysics, geomechanics and subsurface data management."
- Daniel Swann, Marketing Manager EAME, Ikon Science

Please get in touch

To find out more about the Corporate Patrons scheme, please contact our Development Team on **+44 (0)20 7434 9944** or email **development@geolsoc.org.uk**

The Geological Society

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Burlington House ❖ Piccadilly ❖ London ❖ W1J 0BG ❖ UK

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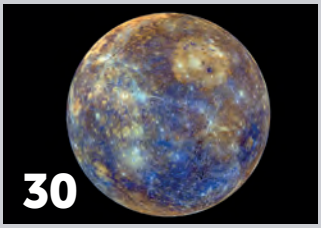

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NEWS

SOCIETY AND COMMUNITY UPDATES

GEOSCIENTIST EDITOR-IN-CHIEF

Following an open call for applications, Ruth Allington will take on the role of *Geoscientist* Editor-in-Chief, following confirmation via vote at the AGM on 12 June.

READ MORE at Geoscientist.Online

Thousands of people visit Burlington House every year to attend conferences, meetings, public events and exhibitions, to use the library and to view our collections

Burlington House lease

The Geological Society announces the agreement of a 999-year lease ending uncertainty about its occupancy of its London premises

THE GEOLOGICAL SOCIETY has agreed with our landlord, HM Government, to purchase a 999-year lease for our premises at Burlington House in Piccadilly, London.

This new arrangement was negotiated in partnership with our neighbours the Royal Society of Chemistry, the Royal Astronomical Society, the Linnean Society of London, and the Society of Antiquaries.

The Geological Society will pay £5.5 million in instalments over ten years. This will be paid from existing reserve funds. We will retain a healthy level of reserves throughout the ten-year period, after which there will be no further lease payments and we will occupy the premises rent free.

This is an important development because it provides security to our occupancy of our London site. The rent has risen steeply and it would have been unsustainable to remain at the property in the long run without this change to the leasehold arrangement.

Our governing Council, along with our Finance & Planning Committee, carefully researched and considered various options including relocating to new premises or remaining under the previous lease. We concluded that staying at Burlington House on the new terms agreed was the best option for the long-term interests of the Society and those it serves.

Thousands of people visit Burlington House every year to attend conferences, meetings, public events and exhibitions, to use the library and to view our collections. Security of tenure will enable us to make the building more welcoming and accessible, as well as more environmentally sustainable. It also enables us to move forward and focus on our charitable and strategic goals, investing in growth, and conducting activities across the whole of the UK and beyond.

We would like to thank those who have supported the Geological Society in pursuing this matter, including Fellows, friends, and those in Parliament and government who have made such efforts to reach a positive outcome. We look forward to welcoming many more thousands of visitors to Burlington House over the coming decades, and continuing to provide a base for geoscience to thrive.

If you have any further questions, please get in touch via **burlingtonhouse@geolsoc.org.uk** or visit our Burlington House FAQs page at: **www.geolsoc.org.uk/About/The-Geological-Society-and-Burlington-House/FAQs**

RUTH ALLINGTON
President
KEITH MYERS
Treasurer

Students were tasked with identifying a suitable site for a wind farm near the fictional town of Quinnston

Schools Geology Challenge 2024

This March, the Education Team hosted the 2024 Schools Geology Challenge final

THE SCHOOLS GEOLOGY Challenge is an annual competition for students aged 16 to 18. Students are given the chance to showcase their passion for geoscience and teamwork, as well as their presentation skills. The competition is open to students studying geology, geography, or science subjects. Schools enter the challenge through a qualifier round in which teams produce a piece of media for an online audience on any geoscience topic of their choice. The top ten teams are then invited to the grand final at Burlington House to complete a problem-solving activity based on real-world issues, presenting their findings to the competition judges.

This year, the students were tasked with identifying a suitable site for a wind farm near the fictional town of Quinnston. Using a geological map and a cross section of the bedrock, students had to consider whether the geology of the area was suitable to support large wind turbine infrastructure. Students also had to comment on the environmental and social impacts of their recommended wind farm location, given the general proximity to the local town and a neighbouring national park, home to a protected bird species – all while keeping their project in budget!

Students then presented their findings to our panel of judges. This year our Schools Geology Challenge judges Roni Savage, Antony Benham and Edith Brazier had expertise in geotechnical engineering, minerals and mining, and environmental engineering.

The 2024 Schools Geology Challenge winners were The Tiffin Girls' School, who impressed the judges with their geoscience knowledge and teamwork, taking home our coveted amethyst trophy and £500 towards geoscience education at their school.

Runners up this year were Runshaw College and The Sixth Form College Farnborough, who won £200 each for their school.

Thank you again to all who took part and to our wonderful judges!

To find out more about the Schools Geology Challenge and how to enter in 2025, visit **www.geolsoc.org.uk/geochallenge**

JOIN THE PUBLICATIONS & INFORMATION COMMITTEE

The Publications and Information Committee is on the hunt for new members! If you're interested in learning about publishing, from a unique insider perspective, then we welcome expressions of interest to join the group. The Society publishes a broad range of journals, some of which are very new (*Earth Science, Systems and Society* and *Geoenergy*), as well as a large number of books on our Lyell Collection platform.

Being part of the committee means getting involved in the publishing world, understanding how it works, the challenges we face and need to overcome – both as a Society and a society – with regards to written and open science, and much more. There is also room for people interested in library and information services. Get in touch with **Maggie.Simmons@geolsoc.org.uk** to find out more.

We publish a number of books such as *Special Publications* and *Memoirs* as well as some new series: our more technical *Geoscience in Practice* volumes, and the new open science series *GeoHorizons* in partnership with the American Geophysical Union. If you want to join our Books Editorial Committee then get in touch with **David.Boyt@geolsoc.org.uk**.

PROF DANIEL LE HERON
Secretary, Publications

More than 3,200 people visited Burlington House to see a replica *Megalosaurus* skeleton and take part in a series of themed events

Megalosaurus Month

FEBRUARY 2024 WAS *Megalosaurus* Month at the Geological Society; a festival celebrating the 200th anniversary of the first scientific description of a non-avian dinosaur by our very own former president and first Oxford Professor of Geology, William Buckland [1784 – 1856]. His paper, *Notice on the Megalosaurus or great Fossil Lizard of Stonesfield*, was presented at a meeting of the Geological Society on 20 February 1824.

The Society celebrated this important moment in the history of science with an exhibition based around a replica *Megalosaurus* skeleton, hosted in our Upper Library, and a plethora of dino-related activities for which we welcomed over 3,200 people into our historic Burlington House building.

Each day saw something new as activities appealed to a range of interests and ages. From lino-printing workshops and life drawing classes, half-term children's activities and school's workshops, a recreation of Buckland's teaching room from Oxford University, networking receptions for students and an incredibly popular Public Lecture that saw more than 500 people register – it was a month to remember.

Dino Discovery Zone and school workshops

Over February half-term we offered free dino activities for children and their families. Each child was given their own 'Dinosaur Passport' in which each page held a different activity to complete. Activities included learning about dinosaur teeth and the food they eat, how to dig up and record fossils, understanding dinosaur communication and creating their own dinosaur. Importantly, we wanted the children to have fun and feel inspired by getting up close and personal to our *Megalosaurus* and other exciting fossils.

Children were able to get up close and personal to our *Megalosaurus* and other exciting fossils

Our fantastic Education Team held school workshops where children learnt about the different types of fossils, and were encouraged to think about how different parts of fossils can tell us important information about the food dinosaurs ate, the sounds they might have made, and the environments they lived in. In total, over 500 children enjoyed our free dino activities at Burlington House.

Life (death) drawing classes

In these artistic sessions, participants were encouraged to engage with the grand setting of the Library and its atmospheric light and shadow to create dramatic sketches of the *Megalosaurus* skeleton with geologist and artist Emma Theresa Jude. Emma skilfully led the

participants, encouraging them to engage with different techniques and to capture the skeleton from different perspectives. Often all that could be heard during the classes was the sound of charcoal gently rubbing on paper, as participants immersed themselves in their work. The results were amazing.

FIND OUT MORE about *Megalosaurus* Month at www.geolsoc.org.uk/Policy-and-Media/Outreach/Megalosaurus-Month-2024

Lino print workshop

The skill of printing and the ability to accurately replicate scientific drawings was revolutionary for their distribution and played an important role in the sharing of knowledge globally, contributing to the advancement of science.

The lino print session began with an overview of the importance of printing, with the participants then taken step-by-step through the process. Participants carefully chose a focus point of the *Megalosaurus*, first drawing it before tracing it onto lino and carefully beginning to carve. The group then took it in turns to add ink to the lino, and excitedly watched their designs come to life.

Student networking

Geoscience students were invited to Burlington House to enjoy a viewing of the *Megalosaurus* and to network with fellow students and staff members. Our student members impressed us with their enthusiasm and took part in activities and crafts including making their own dinosaur jewellery.

Public lecture

Our *Megalosaurus* Month Public Lecture, *Dinosaurs: Changing views in the last 200 years*, was delivered by Professor Michael Benton OBE and was our most popular Public Lecture to date, with over 500 registrations.

Professor Benton is a palaeontologist who studies dinosaurs and mass extinctions. One of his great discoveries was to kick off a new field of research in determining the colour of dinosaurs – rated as one of the top scientific discoveries of the 2010s. He was awarded an OBE in 2021 for his work in the public understanding of science, and was elected Fellow of the Royal Society in 2014 for his fundamental contributions to understanding the history of life. He is fascinated by the transformation of palaeobiology from a speculative subject to testable science.

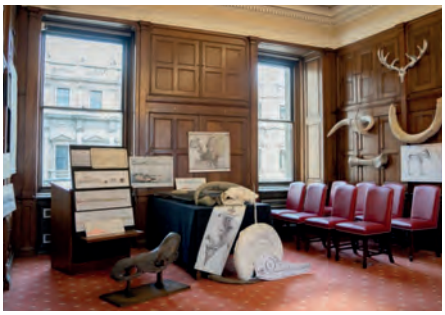
It was fantastic to have his expertise form part of *Megalosaurus* Month and captivate such a large audience alongside a special introductory reading of William Buckland's *Notice on the Megalosaurus or great Fossil Lizard of Stonesfield*, 200 years after it was first presented at the Geological Society in 1824.

Buckland's teaching room

We were delighted to welcome Dr Susan Newell to give a talk focusing on a celebrated print from 1823 that shows William Buckland teaching in the Ashmolean Museum in Oxford.

What appears to be a straightforward representation of an academic teacher in his lecture room, surrounded by specimens and illustrations, conceals a more complex story interwoven with concerns around patronage, showmanship, romance, and the pressing need to convince audiences of the importance of the new science of geology.

For this immersive event, the audience were seated in a recreation of Buckland's teaching room in our Upper Library.



Megalosaurus Month activities included a reconstruction of William Buckland's teaching room (top), half-term school workshops (centre), and lino printing (bottom)

Megalosaurus resources

- **Download our free *Megalosaurus* poster (and other educational posters) at www.geolsoc.org.uk/Posters**
- **Catch up on the *Megalosaurus* Month Public Lecture at www.youtube.com/watch?v=Z2SeoG3-mKo**

To find out more about our school workshops, free educational resources, geoscience careers, public lectures, or to become a student member, visit www.geolsoc.org.uk

ABOVE: The History of Geology Group reenacts one of the most important meetings of the early Geological Society, which took place in February 1824. From left, Henry Warburton (Vice-President), Rev. William Buckland (President), and Rev. William Daniel Conybeare

LEFT: Reenacted carte de visites of Rev. William Daniel Conybeare (left) & Rev. William Buckland (right)

A bicentenary reenactment

BETWEEN 1816 and 1828, the Geological Society occupied premises at 20 Bedford Street, Covent Garden. One of the most famous of the meetings held there took place on Friday 20 February 1824 when two ground-breaking papers on fossil reptiles were read to a packed house.

The Rev. William Buckland, Reader in Mineralogy and Geology at Oxford University, and the Geological Society's new President (it was his first meeting in that role), gave an account of some remarkably large fossil bones, including a spectacular lower jawbone, all of which had been found at Stonesfield near Oxford. Buckland named the beast to which these relics belonged *Megalosaurus*, or great fossil lizard. It was the first scientific description of a dinosaur – although that particular term was not coined until 1842 by Richard Owen.

The Rev. William Daniel Conybeare gave a detailed anatomical description, and conjectured the mode of life, of the first complete *Plesiosaurus* – often referred to as a 'sea monster' – that had been discovered in Dorset two months earlier by Lyme Regis fossilist Mary Anning.

Conybeare read his paper first. Buckland had arranged to "borrow" the actual fossil specimen before it was delivered to its new owner, the Duke of Buckingham. However, when the 10ft 6in long *Plesiosaurus* skeleton finally arrived from Lyme Regis, after ten days on a ship stuck on a sandbank at the mouth of the Thames, it proved so large that they could not get it up the narrow stairs. So, whilst Buckland gave his paper in the upstairs meeting room, Conybeare had to speak to the assembled in the hallway!

On 20 February 2024, the History of Geology Group descended upon 20 Bedford Street (now home to the Club for Acts and Actors) to stage a reenactment of that momentous meeting on the very spot where it had taken place 200 years earlier. Once again it was a packed house that included the current President of the Geological Society, who saw and heard "appearances" from Henry Warburton (a Vice-President), William Buckland and William Daniel Conybeare. They were only upstaged by the magnificent 10ft 6in *Plesiosaurus* fossil, on which Conybeare proceeded to lecture, and by the menacing dentition of the *Megalosaurus* jaw, which Buckland waved around with his characteristic enthusiasm.

Reenactments of Rev. William Buckland (left), Mary Anning (centre), and Rev. William Daniel Conybeare (right)

In 1824, meetings of the Geological Society remained closed to women (they were not admitted until 1904), but towards the end of the reenactment Mary Anning turned up at the door, hoping to look at her specimen and congratulate the Rev. Conybeare on his fine scientific account of the "sea monster". Fortunately, in these more tolerant times, no one objected to her presence!

Professor Hugh Torrens has suggested that this was a very important meeting, and arguably of foremost importance amongst the meetings of the early Geological Society. The History of Geology Group is very grateful to the Club for Acts and Actors for accommodating the reenactment. To do so 200 years to the day on the very premises where the original meeting took place made for a truly momentous, entertaining, and geo-historical event.

DUNCAN HAWLEY
Chair, History of Geology Group

ARE YOU INTERESTED IN GEOLOGICAL TIME?

If so, you are invited to apply for election to the Stratigraphy Commission of the Geological Society.

The Stratigraphy Commission is an active group who, in addition to representing the UK stratigraphical community, regularly publishes books and papers (such as a recent book on stratigraphical techniques; www.geolsoc.org.uk/GIP001). Our members are drawn from industry, academia, and the public sector.

The Commission provides a great opportunity to work with fellow geologists, network, add a national committee to your portfolio and develop new ideas. We meet about three times a year, mostly online, and occasionally face-to-face. Between meetings, activities include preparing materials for publications, liaison with other stratigraphical bodies, and maintenance of the website. We have also recently initiated a project on public understanding and outreach.

We are seeking a diversity of applicants.

Preferred attributes:

- Have worked on/are working on an aspect of UK stratigraphy and/or have particular stratigraphical expertise or interests not currently covered by the group.
- Willingness to be active and get involved.
- New ideas to ensure that stratigraphy and the geological timescale, which underpins all aspects of geology, both advances and is clearly communicated.

To express an interest, please contact Angela.Coe@open.ac.uk providing either a link to an informative personal website and/or a 200-word statement.

For more information, please visit: www.geolsoc.org.uk/Groups-and-Networks/Commissions/Stratigraphy-Commission

ANGELA L. COE
Chair of the Stratigraphy Commission

Fluvio-deltaic strata of Carboniferous age at Howick Bay, Northumberland, UK

Stratigraphy Commission

MISS MOLECULE & FRIENDS

Free educational resources to inspire and engage young people into STEM subjects

MISS MOLECULE & FRIENDS is a series of inspirational digital resources, aligned to the school curriculum, to be used independently by teachers, parents, and the public to educate and inform children aged between 9 and 11 years. The resources cover a variety of subjects and industries related to renewable energy, critical minerals, sustainability, biodiversity, and wellbeing.

Through animation and real-life interviews, the resources tackle the circular economy, as well as the wider picture of climate change and economic benefits associated with our natural resources.

The first episode features Lithium – where it comes from, is found, and what it is used for – and includes interviews with Cornish Lithium who explain their sustainable extraction methods being pioneered in Cornwall.

Cornish Lithium are using the resources as part of their community and educational outreach programmes in schools and local community groups, helping local people get excited about their heritage and the role that mineral extraction could play in Cornwall's future. Zoe Richardson, who works in Engagement & Outreach at Cornish Lithium, says: "Miss Molecule is a great resource highlighting the role of Cornwall in addressing climate change, and provides real-life industry examples, which allow teachers and educators to deliver these lessons in an engaging manner."

The project is a collaboration between Studio Wallop, Cornish Lithium and GeoScience Limited. We thank The Institute of Engineering and Technology and the Institution of Mechanical Engineers for funding an episode of Miss Molecule & Friends.

To view the resources and keep up to date with new episodes, please visit: www.missmolecule.co.uk

SUZIE DOE
Visual Communications & Outreach, GeoScience Limited

EARTH'S CANVAS

GEOLOGISTS ARE CREATIVE souls at heart. Our first steps as beginner geologists are often taken on field sketching, on sketches of fossils or thin sections, and on sheet after sheet of beautiful paper maps – and I think it's rare to find a geologist who doesn't bring creativity to bear in their daily work! Geology has long inspired creativity too, going back from the first uses of geological pigment as medium, through geology as a subject in arts, music, and poetry, all the way to contemporary and experimental works inspired by Earth.

With this in mind, lead convenor Lucy Williams initiated the Earth's Canvas conference, an interdisciplinary symposium taking place on 17-18 September 2024 at the Geological Society, covering the intersection between geology and the literary, musical and visual arts (and anything else in the field of creativity). The response to an open call for submissions has been phenomenal, and we cannot wait to see the range of works, talks, films, performances, and workshops that have been proposed.

Poet Patrick Corbett, who organised the hugely successful Geopoetry symposium, will lead the poetry and literature theme, Guitarist Steve Garrett is convening music, song, and sound sessions as well as an evening of performance, and I, in my capacity as a fine artist, will coordinate a programme of artists' talks as well as turning Burlington House into an exhibition space for the occasion. The team is rounded out by Peter Dolan, ably in charge of raising funds for the event and we are supported by Emelia Spofforth-Jones and Elisha McCowan from the Events Team. We look forward to welcoming you as a delegate.

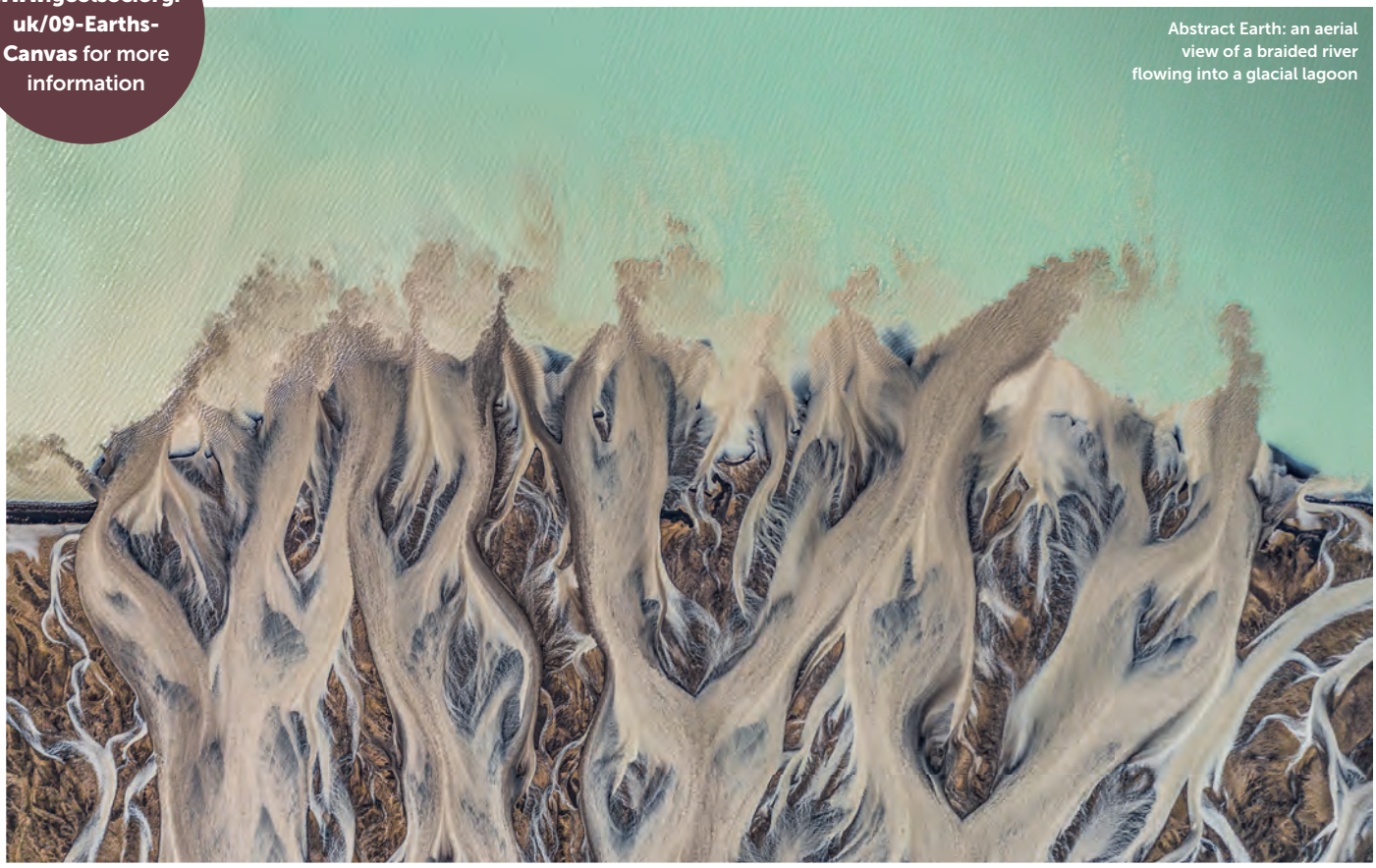
EMMA THERESA JUDE
Geologist and Fine Artist, and member of the Convening Panel

CONFERENCE BURSARIES & SPONSORSHIP

Through the support of the Curry Fund of the Geologists' Association, the conference is happy to offer a number of bursaries to cover travel and attendance; details of how to apply are on the conference webpage.

We are seeking sponsorship and patronage from individuals and organisations – if you have long considered yourself a patron of the geological arts, do get in touch via conference@geolsoc.org.uk.

VISIT www.geolsoc.org.uk/09-Earths-Canvas for more information



Abstract Earth: an aerial view of a braided river flowing into a glacial lagoon

PATRICK COX APPOINTED AS MANAGING DIRECTOR OF INTERA GEOSCIENCES UK

After three decades of delivering remote support to clients in the UK, INTERA is launching a new subsidiary, INTERA Geosciences UK Ltd. As Managing Director, Patrick Cox brings a wealth of experience, combining executive leadership with exceptional technical expertise, positioning him as an ideal leader to spearhead INTERA's efforts to provide geoscience-based solutions to address complex challenges in the UK and nearby European countries. Find out more at **www.intera.com**

RESEARCH GRANTS 2024

We were delighted to see Research Grant applications maintain similar levels to last year, with the Research Grants Committee panel considering 29 and recommending 16 applications, totalling £27,859.50.

The Geological Society offers sincere congratulations to this year's recipients. To see the full list of successful applicants, please visit www.geolsoc.org.uk/grants.

We thank the Jeremy Willson Charitable Trust, Jeremy Ingham Fund, and Robert Scott Memorial Award for their continued support, and the Research Grants Committee members for their time and expertise.

To register your interest to be part of next year's Research Grant Committee, please email grants@geolsoc.org.uk

Geological Society training courses

IN 2021, FOLLOWING a successful trial, the Geological Society introduced its highly anticipated training courses. These courses have since become a cornerstone of knowledge dissemination within the geological community, covering a spectrum of topics ranging from hydrogeology and geotechnical studies to geohazards.

Whilst research knowledge and experience can be communicated via technical publications, CPD training courses allow for interaction and discussion, and thereby provide a more thorough and up-to-date understanding of the subject matter.

Course participation surged in 2023, with over 800 enthusiastic delegates joining. This widespread interest reflects industry's recognition of the invaluable insights and skills that can be gained from comprehensive training programmes taught by industry and academic experts.

The Training Course Committee is keen to assist with the training requirements of as many sectors as practicable. If you feel your sector or discipline is currently unrepresented in terms of CPD training provision, please contact the committee with your training needs (and likely number of delegates), so that we can explore options for course provision.

“The Society's training courses have become a beacon of excellence within the geological community. Their success, marked by increasing participation and the positive impact on professional development, reaffirms the Society's dedication to advancing geological knowledge and fostering a community of skilled and knowledgeable practitioners”

COLIN SERRIDGE
Training Course Committee Member

To propose a potential new training course, email training@geolsoc.org.uk

THE CHARTERSHIP BULLETIN

SUPPORTING PROFESSIONAL DEVELOPMENT

Continued Professional Development

CPD IS A valuable tool to help you proactively plan and progress your career in Earth science, from post-graduation to retirement. CPD allows you to demonstrate how you, as a professional geoscientist, maintain and develop the standards of technical and professional competence required for your work and area of expertise. As well as broadening your knowledge, CPD gives assurance to employers, clients, partners, peers and to society that you, as a Chartered person, are professionally competent.

A Plan-Act-Reflect cycle can help you steer and monitor your training and personal development. Plan your training needs for the year, act on the plan and reflect on the learning outcomes (what you have achieved and what impact this may have on your work) – and keep a record of this. CPD records are required to maintain Chartered status and can be logged using 'My GSL'.

Several Society Training Courses and thematic conferences contribute towards CPD. For more, visit: **www.geolsoc.org.uk**

Assessor tips

The role and value of CPD within the Chartership application process

YOUR CPD RECORD should reflect the stage of your career progression and address the full range of Chartership competencies, that is, activities beyond geoscience learnings such as industry awareness, technology developments, business skills, management skills, HS&E learnings, coaching and mentoring. The record should include any mandatory training, certification or recertification that is required for your role.

CPD records for 'on the job' activities should include things that are new to you such as learning about a new area of geoscience, taking the lead on a project, using a new evaluation technique or presenting at a project meeting or conference. You are likely to be questioned on your CPD record during your Chartership interview, so be prepared to talk about your recent activities and future plans.

DAVID LAWTON BSc, MSc, CGeol, FGS
Milnwood Partners

A CPD RECORD is not a work diary. Instead, it should reflect work that is new for you; presents a challenge; is an expansion of professional experience; or includes contributions to the profession outside of paid employment. Carrying out a routine task, for instance a drilling project but in a new geological environment, offers valid CPD.

Use your judgement as to the amount of time claimed for CPD. For a new experience or project, it is valid to claim almost all the time involved. For subsequent similar projects, reduce the hours claimed as you become less challenged.

It is good to see an interest in geological fields outside of your paid employment, demonstrated by, for example, reading, attendance or involvement at meetings, or promoting Earth science at schools.

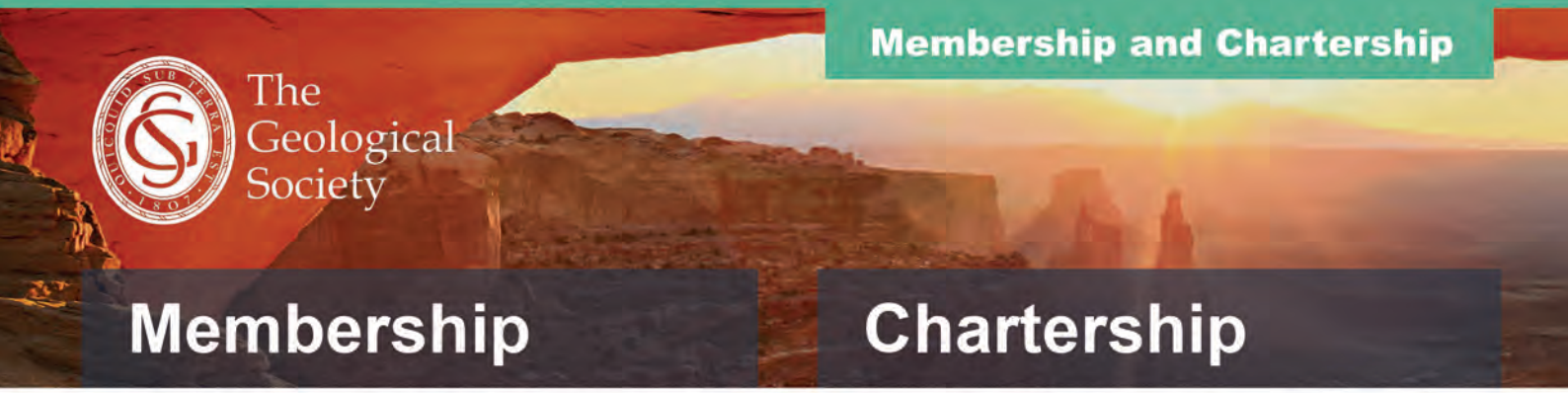
DUNCAN WARDROP BSc, CGeol, CEng, CSci, MIMMM, FGS
Wardrop Minerals Management

CGeol insights

I found the Chartership process challenging but recognise how much it taught me. Initially, I underestimated the importance of maintaining my CPD record, viewing it as a simple list of my experiences without considering the significance of how these contributed to my professional development. Now, I appreciate how documenting and reflecting on CPD activities enhances our understanding and growth, highlights our achievements and provides inspiration for further development. Following the advice of my Assessor, I approached my reflections as if I was writing a diary, assessing my feelings, potential improvements and anticipated outcomes.

I now act as a mentor and workshop leader supporting my colleagues on their own Chartership journeys.

CHARLOTTE USHER
BSc, MGeophys, PhD, CGeol, FGS
RSK Geophysics



The Geological Society

Membership and Chartership

Membership

Being a member of the Geological Society gives you access to a wealth of benefits to help you throughout your career.

- Special rates on events
- Lyell Collection content
- Exclusive networking groups
- Geoscientist magazine

- Preferential rates for events and Training Courses, including complimentary access to the annual *GeoFutures* symposium and FREE access to virtual events for student members
- Access to over 500 publications in the Lyell Collection, including the Book Archive
- Use of one of the finest collections of geoscience literature in the world through the library at Burlington House; with access to additional spaces for study and meeting
- The opportunity to advance your professional development with networking via the Early Career Network, Regional and Specialist Groups
- Up to 50% discount on books and more in the online bookshop
- Over 40,000 maps available to borrow, covering the whole of the Earth, from the beginnings of geology to modern mapping
- A quarterly copy of Geoscientist magazine delivered to your door; featuring a mix of science, opinion, news and more

www.geolsoc.org.uk/membership

Chartership

As a member you can also utilise the Society's Chartership opportunities; putting you a step ahead and improving your career prospects.

www.geolsoc.org.uk/chartership

Once an experienced Chartered Fellow, you can take the next step by becoming a Chartership Assessor and gain extra benefits:

- Demonstrate your seniority
- Give back to the Earth sciences community
- Contribute to your CPD record to maintain Chartered status by reviewing applications
- Also benefit from 50% off the Fellow rate for one of the Geological Society's Training Courses
- Expand your knowledge of the innovative work emerging throughout the sector
- Gain valuable interviewing experience
- Enjoy networking opportunities with other experienced professionals

www.geolsoc.org.uk/Membership/Chartership-and-Professional/Chartership-Assessors

Register for online Chartership training sessions at www.geolsoc.org.uk/chartershipguidance

7 June - 2pm BST - Assessor training
10 June - 8am BST - Assessor training
10 June - 12pm BST - Assessor training
3 July - 12:30pm BST - Chartership applicant talk and Q&A
9 July - 10:30am-4pm BST - in person annual training day for Chartership Assessors
10 July - 1pm BST - Chartership applicant drop-in session for the 1 August application deadline

Read the Society's Annual Review and Financial Report for 2023 at **www.geolsoc.org.uk/annual summaries**

ANNUAL GENERAL MEETING 2024

THE AGM will take place on Wednesday 12 June 11:00-12:30 (GMT+1) and will be a hybrid meeting allowing for in-person and online attendance.

Details on how to register to attend the AGM are available on our website www.geolsoc.org.uk/06-AGM-2024. If you would like further information on how to register, please email secretary@geolsoc.org.uk or call 020 7434 9944.

Agenda

In line with bye-law 9.2, the agenda for the AGM is presented as follows:

Apologies
Minutes of the AGM held on 14 June 2023
Appointment of Scrutineers for the ballots for Council and Officers
Ballot for Council
Ballot for Officers

Annual Report and Accounts for 2023
- President's Report
- Secretaries' Reports
- Treasurer's Report
- *Geoscientist* Report and appointment of new Editor-in-Chief

Comments from Fellows
Deaths
Appointment of Auditors
Scrutineers' report on the ballot for Council
Any other business

ELECTION RESULTS

THE ADVISORY ballot for Council, conducted by Civica Election Services, closed on 31 March 2024. The turnout was 17.1%.

There was a total of 1,983 valid votes cast for the six vacancies on Council. Of the eight candidates who took part, the six candidates who received the most votes are:

Candidates
John Davies
Dr Andrew Dobrzański
Leanne Hughes
Dr Ilias Karapanos
Louisa McAra
Dr Kevin Stephen

These six candidates will go forward for election as Council members at the AGM. We would like to give thanks to the two other candidates who stood in the ballot for their interest to serve on Council.

We would like to take this opportunity to give warmest thanks to the Council members standing down at the AGM: Ruth Allington (President), Prof Jim Griffiths (Professional Secretary), Prof Mark Allen, Pete Loader, Dr Amanda Owens and Lucy Thomas.

NOTIFICATION OF OFFICERS FOR 2024/2025

At the AGM, Fellows will be asked to elect the following members of Council as Officers for 2024/2025:

President:	Prof Jon Gluyas
Vice-President:	Martin Griffin (EDI)
	Gemma Sherwood (Regional Groups)
Secretaries:	Dr Neil Frewin (Professional Matters)
	Prof Jennie Gilbert (Science)
	Dr Michael Kehinde (Foreign & External Affairs)
	Prof Dan Le Heron (Publications)
Treasurer:	Dr Keith Myers

FUTURE MEETING DATES

COUNCIL AND ORDINARY GENERAL MEETINGS:
2024: 10 July, 25 September, 27 November
2025: 5 February, 23 April, 24 June
ANNUAL GENERAL MEETING & PRESIDENT'S DAY:
2025: 11 June

Upcoming Training Courses

Site Investigation: A Practical Guide

Ground investigation can be bewildering and challenging. There are a multitude of methods, tests and procedures, which do not always deliver what is expected or of use. In recent times, there have also been several new and revised standards.

This course is devised to provide the facts surrounding ground investigation regarding different methods, tests and procedures, so that informed choices can be made to enable efficient and appropriate investigation to be planned and executed. It will also discuss the new standards to help guide individuals thorough the sometimes bewildering number of Eurocodes British Standards and Codes of Practice that have been published.

During each session, the presenter will bring his own practical experiences to the discussion to provide real examples of some of the techniques which may be encountered.

Each session is focused on a particular element of the site investigation process.

Date: 3 September - 3 December 2024
Length: 6 virtual modules, 2 in-person modules
Speaker: Peter Reading
Registration: *www.geolsoc.org.uk/09-Site-Investigation-All-Modules-2024*
Members get 50% off at registration!

An Introduction to Carbon Capture & Storage (CCS)

This course will cover the role of CCS within decarbonisation as an aspect of earth system science; why CCS is necessary; how CO_2 is captured in industrial processes and how it can be used industrially; the factors affecting geological storage; how CO_2 stores are monitored for leakage; how CCS will be regulated; how CCS will pay for itself; and the social licence for CCS.

These are issues that are as important as the technical issues, in that any of them can be a showstopper for CCS.

It satisfies a part of the market that is not currently catered for: the wider science, risks, financing, planning and social licence aspects of CCS.

The course will be delivered in simple non-technical language suitable for non-specialists, and will have a strong international and global south emphasis with case studies of non-European, non-North American CCS and will touch on the role of CCS in development country energy transition.

Date: 2 - 3 October 2024
Length: 2 virtual half-days
Speakers: Dr Mike Stephenson
Registration: *www.geolsoc.org.uk/09-CCS-24*
Members get 50% off at registration!

Pride and pressure

"I've given quite a lot of time and energy, and it's repaid me in spades because I've so enjoyed it", says **Ruth Allington** as she reflects on her time as President

What achievements are you most proud of from your time as President?

I'm proud of so much – not of what I've done, but of what's happened. The most amazing thing is that we've finally negotiated a long lease with the government to stay at Burlington House. This issue started probably back in the 1990s. Our security of tenure was a really live topic back then. An arbitration found in favour of government so we had no choice but to sign up to our current lease, which escalated the rents to a point where it was untenable. So, the Courtyard Societies – ourselves, the Linnean Society of London, the Royal Astronomical Society, the Society of Antiquaries, and the Royal Society of Chemistry – have been negotiating together for years. I'm very proud to be the President who put their name on the Heads of Terms on behalf of the Geological Society, alongside the Presidents and CEOs of the other Courtyard Societies. And it's a wonderful time for it to happen – this year is the 150th anniversary of us moving into Burlington House, so it just seems really fitting. It's been a huge distraction, and finally the planets have aligned.

I'm so proud of all the staff. Working with the staff brings me such a lot of joy – seeing them thrive, supporting them, whilst trying not to be too demanding when our enthusiasm runs away with us. I'm very proud of the way that's working – with excellent leadership from the senior team and lots of commitment, expertise, and enthusiasm. But that's not down to me; I'm just lucky enough to be in the seat when this is working well.

I've been very lucky as President to have taken over at a time when we were coming out of pandemic restrictions. I've had the joy of getting involved in live events. *Megalosaurus* Month, in February, has been a particular highlight because it brought together lots of wonderful things – I've been lino printing and charcoal drawing (inspired by the *Megalosaurus*), and attended the public lecture given by Professor Mike Benton, and the reading of the Buckland paper during a fantastic reenactment organised by the History of Geology Group at 20 Bedford Street, where the Geological Society was located 200 years ago. Burlington House has been filled with the sound of children, families, couples, and individuals who came in off the street to see the *Megalosaurus* skeleton in the upper library or get involved in organised activities.

Tell us about your time as a Fellow and how the Society has changed

I joined the Society around 1981. In my first month of employment, my boss sent me to the Engineering Group Annual Conference. I was nervous because I was very young and had no idea what to expect, but I was made ever so welcome by the Engineering Group and the community. And that hasn't changed. People are welcomed in by the groups that they identify with – the Specialist Groups or the Regional Groups, the Council and so on. That interaction was wholly in-person in the past, so the pace was a little different.

That welcome into the community was very important to me. It was the beginning of growing a wonderful network of contacts, colleagues and friendships that I absolutely cherish. So that's a constant thread. And I just got stuck in. I became Secretary of the Engineering Group and then Chair. I was on Council, I was Professional Secretary, Vice President for Regional Groups, and then I was the Society delegate to the European Federation of Geologists, which I thoroughly enjoyed. Now I've been back on Council as President. That would have been astonishing to 22-year-old me when I first joined the Society. When I read the names of the first 110 Presidents and the two women who've gone before me – Janet Watson and Lynne Frostick – being the third woman seems extraordinary. Of course, it's ridiculous that there have only been three women, but it is fantastic to be in that number and I hope it will become regular and normal for women to be President of the Geological Society.

What are the most important challenges the Society faces?

I think it's to do with making an impact in modern society, where geoscience is so important to making the changes we need to make as a human race to adapt and live sustainably on the planet.

There's the challenge of navigating the difficult narratives around climate change, the energy transition, mining critical minerals and so on. There seems to be a very binary debate. A lot of shouting, but no dialogue. There's

JOIN THE AWARDS CEREMONY

The Society Awards and Funds for 2024 are presented on President's Day on 12 June 2024.

Attendance at this hybrid event is free for all Fellows for virtual or in-person attendance*. The presentation of the awards commences at 14:00 (GMT+1).

After the awards presentation, our four senior medallists (Dr Jacqueline Skipper, Prof David Pyle, Prof Lynne Frostick and Prof Trond Helge Torsvik) will present talks from 15:30-17:30 (GMT+1).

For more details, or to register to attend, visit: **www.geolsoc.org.uk/06-Presidents-Day-2024**.

** In-person attendance is limited to the lecture theatre's capacity. There is a nominal charge to attend the optional lunch and/or evening drinks reception with the award winners. Details are on the event webpage.*

If further information is required, please email ***secretary@geolsoc.org.uk.***

“Working with the staff brings me such a lot of joy – seeing them thrive, supporting them, whilst trying not to be too demanding when our enthusiasm runs away with us”

“Megalosaurus Month has been a particular highlight,” says Ruth.

a lot of finger-pointing but somehow, whilst calling to account bad, unethical practice, we also need to be an agent of change and support. The vast geoscience workforce needs to get bigger and deploy itself in changing ways – and all of that needs support, not only for the science, but for training, university departments, people's careers, and professional development. The young people who are rightly so angry about what generations before have brought about in the world – environmental damage, the inexorable march of human-caused climate change – are the agents for change. But if placard waving and demonstrations are the only tools in your toolbox as a change agent, you don't get very far. A more potent change, I think, would be to get stuck in by being educated in geoscience or the many other disciplines that are essential to meeting climate and decarbonisation challenges, particularly critical minerals challenges, so as to be the workforces of the future, the thinkers of the future, the policymakers of the future grounded in excellent science.

Making the Geological Society thrive depends not only on its staff but most particularly on the Fellows who volunteer and get involved. Whilst our volunteers and the things they achieve are extraordinary, we have to work harder than we might think, given the apparent ease of communications. I think one of the biggest challenges of our time is being so connected electronically and so disconnected emotionally. The effort we need to put in to having good-quality connection is so important and so enormous. What's wonderful about working in a hybrid way is that once you've met somebody and made a good-quality connection, this amazing electronic connection is helpful to sustain your collaboration or friendship. But creating those effective personal and professional connections and relationships is where we need to work hard. What's changed is the pressure practitioners are under. Now, emails being on phones and so on puts people under pressure to be available 24/7. In the past, if you went to a conference, you'd be having conversations and participating in sessions without the distraction of receiving messages or making telephone calls.

What geoscience developments are you excited about?

I'm really excited about the emergence of interest in the arts and geoscience, and the way they interact. The Society's two-day conference, *Earth's Canvas*, in September will explore this and bring creative people together with geoscientists and creative geoscientists. Across the courtyard, the Royal Academy of Arts and our fellow Courtyard Societies have the most amazing histories and artifacts – it's an extraordinary ecosystem of arts and scientists, sciences, civilization, the history of civilization. All of that helps to connect our science to society and brings so much pleasure.

I'm always excited to hear about the extraordinary research people do. That's why I've always loved President's Day – hearing from the people receiving medals and awards, and the wonderful citations about their work. And celebrating all this with the people in the room, accompanied by their family, friends, and colleagues. It's so impressive, especially hearing about what the younger people are doing. Just extraordinary. And so we're looping straight back to what makes me proud.

Ruth Allington is an Engineering Geologist and qualified mediator and facilitator, and the outgoing President of the Geological Society.

This is an edited excerpt from the podcast episode Geo Conversations: Ruth Allington. Listen to the full interview at Geoscientist.Online

Behind the oak door

Incoming President, **Jon Gluyas**, discusses his career, experiences working with the Society, and what his time as President might hold

The limestone pavement at Ingleborough, looking towards Whernside in the Yorkshire Dales. It was during a Scout camping trip to Whernside that Jon became hooked on geology

What first drew you to geology?

A friend at school gave me a little piece of galena. It was only about 2 cm long, but the weight fascinated me, as did the metallic lustre. I then consumed the contents of any geology book I could find, such as the little colour Hamlyn Guides for rocks, minerals, and fossils. Later, on a Scout camping trip in Yorkshire, I signed up for geology and got to see the Lower Carboniferous limestones of Whernside and tracked the line of the Dent Fault – I was hooked! I also become the first Scout to obtain the Geology Badge.

At school, a few of us lobbied for and got lessons in O-Level geology. I was desperate to go to university and learn more about Earth. Despite my German master suggesting that there was "fat chance" of me studying geology at university, I went to Sheffield to study undergraduate geology, and to Liverpool for a PhD.

I was then ready to go to work and joined BP. Starting in Aberdeen in December 1981, I lived and worked around the world on exploration and production projects, in China, Norway, and Venezuela. After 15 years with BP, I moved into the independent sector, eventually forming Acorn Oil & Gas, which became the first company in the UK to go back into a completely abandoned North Sea field and get it going again – something that has become commonplace over the last 20 or 30 years.

I began to realise that, despite the positive influence petroleum use has had on global development, emissions of CO_2 and other greenhouse gases are impacting the climate and acidifying the oceans. When Durham University approached me about taking up the new Chair in Geoenergy, Carbon Capture & Storage, it was difficult to say no. For me, it was like opening Pandora's box. I started to look at the energy transition and how scientists could support that, which ultimately led me to leadership of Durham Energy Institute, the mission of which is to help deliver net zero on a local-to-global scale in line with the Sustainable Development Goals from the UN. That's been a massive change in my career, and a positive way of thinking about how geoscience can serve society without it costing the Earth. I'd like future generations to enjoy the Earth as much as I have.

What geoscience developments are you excited about?

As an undergraduate, I wrote an essay on meteorite geochemistry and the geology of the Solar System. What planetary missions have shown over the last few years is that my essay was completely wrong! We've learned so much about the moons of Saturn and Jupiter and the icy worlds beyond Uranus, Neptune, and Pluto. Those missions are some of the most exciting scientific developments we've seen on a global scale in my lifetime.

I'm now involved with the search for natural hydrogen. If we can find it in substantial quantities and displace some petroleum use, it could change the world in a positive way. I'm also intimately involved with the development of geothermal energy in the UK, something that's not been done in any appreciable amount until very recently. Here we could see the whole of heating in the UK supplied by low-grade geothermal heat instead of burning gas.

Which experiences will be useful for your role as President?

My career has taken me around the world. I've had the good fortune to work with different people and cultures, and to see the world from different perspectives. I've worked with some phenomenal teams and people, and learnt to look after those I work with and, on occasion, help them into their next role. I think these experiences will be useful for helping the Society develop its offerings to both Fellows and the greater breadth of society.

How has the Society changed during your time as a Fellow?

I first joined in 1978, at a time when the main benefit was access to the journals and library. The Society has evolved since then. I've participated

in dozens of conferences and events, and what we see nowadays is a much wider offering, not just for Fellows, but for the public as well.

I served on Council from 2003 until 2007, and then again since June 2023. What struck me the second time is how well the whole team seems to gel together, the innovations generated by interacting more with our neighbours and society in general, and the openness with which people talk about the challenges. It's been a bit of a revelation. The Society is forward looking and the opportunity to help folk understand what Earth does for them is really positive.

What are the most important challenges the Society faces?

There are several challenges but they are part and parcel of what geoscience as a whole faces today. I'm not sure we know who we are; we call ourselves geologists, geophysicists, geoscientists... A number of times I've been asked, "What's the difference between an Earth scientist and a geoscientist?", and I've struggled sometimes to give an adequate answer.

People don't recognise what geoscience and Earth does for them. The reality is that if we don't grow it, we mine it. The homes we live in, the vehicles we travel in, the energy we take for granted, all come from a hole in the Earth. It's our place to show society just how important Earth is for them. Without that recognition, society will continue to be profligate with their use of resources.

We also need to get the message across of how much fun you're going to have learning about Earth. Look at the great interest shown by the public on topics such as dinosaurs, meteorites, and planetary geology. These are really engaging topics, so let's work with that.

What do you hope to achieve during your Presidency?

I'm looking forward to being President with a little trepidation. I recognise that the Presidency is a very large job, much larger than I probably anticipated. It's great to be in the company of some phenomenal geoscientists, and taking over from Ruth, who has been an amazing President, will be tough. My memory also goes back to past Presidents such as Charles Curtis, Wally Pitcher, Tony Harris, and, more recently, my mentor and friend, Bryan Lovell, who made a real difference. I hope to be able to add to that.

What I hope to achieve is reaching out. Improving the understanding of geoscience and, as a consequence, improving the numbers of people who are interested in geoscience and recognise it as a key part of today's society. There's great opportunity – whether it's government, schools, retired folk, anyone – to learn a bit more about geoscience. So, what I'd like to see over the next few years is removing some of the mystery from what's behind our old solid oak door on Piccadilly that leads into Burlington House. Let's show the world what goes on and share it with them.

Professor Jon Gluyas is the incoming President of the Geological Society, and Chair in Geoenergy, Carbon Capture & Storage at Durham University, UK.

This is an excerpt from the podcast episode Geo Conversations: Jon Gluyas. Listen to the full interview at ***Geoscientist.Online***

GEOLOGICAL SOCIETY AWARDS AND FUND WINNERS

WE OFFER UTMOST congratulations to our 2024 Award and Fund recipients:

AWARD	NAME AND AFFILIATION
Wollaston Medal	Prof Trond Helge Torsvik, University of Oslo
Lyell Medal	Prof Lynne Frostick CBE, University of Hull
Murchison Medal	Prof David Pyle, University of Oxford
William Smith Medal	Dr Jacqueline Skipper, Geotechnical Consulting Group LLP
Sue Tyler Friedman Medal	Dr Martina Kölbl-Ebert, Ludwig-Maximilian University of Munich
Dewey Medal	Prof Rob Strachan, University of Portsmouth
Coke Medal	Prof Iain Stewart, Royal Scientific Society, Jordan
Distinguished Service Award	Jennifer Brzozowska, Oil and Gas Authority (Retired)
R H Worth Award	Prof John Howell, University of Aberdeen
Bigsby Medal	Prof Daniela Schmidt, University of Bristol
Wollaston Fund	Dr Jennifer Jenkins, Durham University
Lyell Fund	Dr Leonardo Muniz Pichel, University of Bergen
Murchison Fund	Dr Lara Mani, University of Cambridge
William Smith Fund	Dr Luke Wedmore, Verisk Extreme Event Solutions
President's Award	Princess Aira Buma, University of Cambridge
President's Award	Mónica Alejandra Gómez Correa, Universität Hamburg and GeoLatinas

The fourth revolution

Plumes, plates, and climate. **Trond Torsvik** is working to decipher the Earth system as a whole and, ultimately, what makes Earth so uniquely habitable in our Solar System

"A FOURTH revolution is underway," explains Trond Torsvik, Professor of Geodynamics at the University of Oslo, Norway.

"Over the last century our description of the movement and deformation of Earth's outer layer evolved from the hypothesis of Continental Drift (1915) into Seafloor Spreading (1962) and then to the theory of Plate Tectonics (1967) – a theory as fundamentally unifying to the Earth Sciences as Darwin's Evolution Theory is to Life Science. Now Plate Tectonics is being subsumed into a new framework of Mantle Dynamics, linking surface volcanism and mantle plumes, and perhaps explaining plate motions both quantitatively and dynamically."

Trond is currently focused on this fourth revolution, attempting to gain a bigger-picture understanding of the links between deep and shallow Earth processes, but his passion for Earth science was initially sparked by palaeomagnetism.

Palaeomagnetism

Originally primarily interested in mathematics, Trond trained in military marine navigation before discovering a fascination for geophysics and geology while studying for his undergraduate degree at the University of Bergen in 1978.

"I became passionately interested in geomagnetism and notably how we could use Earth's magnetic field (palaeomagnetism) to reconstruct continents in the deep past. My training in marine navigation required a fundamental knowledge of differential geometry (Euler's theorem), so in a sense I went from steering boats to reconstructing continents."

Trond's earliest work focused on regional plate reconstructions and palaeogeography. However, by pairing palaeontological time constraints with palaeomagnetic data, and using plate reconstruction software that Trond himself developed, the work evolved into global palaeogeographic reconstructions covering the past half a billion years of our planet – all of which are synthesised in the remarkable, ambitious, and beautifully illustrated book *Earth History and Palaeogeography*, which Trond wrote together with Robin Cocks (Torsvik & Cocks 2016, Cambridge University Press).

An incomplete theory

Trond's research is motivated by fundamental gaps in our understanding of how surface and deep mantle process are linked: "Plate tectonics and the Wilson cycle were recognised as key elements of geodynamics in the 1960s. Plate Tectonic Theory was extremely successful in providing a framework for understanding deformation and volcanism at plate boundaries, and allowed us to understand how continent motions through time are a natural result of heat escaping from Earth's deep interior. Plate tectonics was, however, an incomplete theory: For instance, we lacked a generally accepted mechanism that explains plate tectonics in the framework of mantle convection, and the origin of intra-plate volcanism such as hotspots and large igneous provinces (LIPs) was controversial."

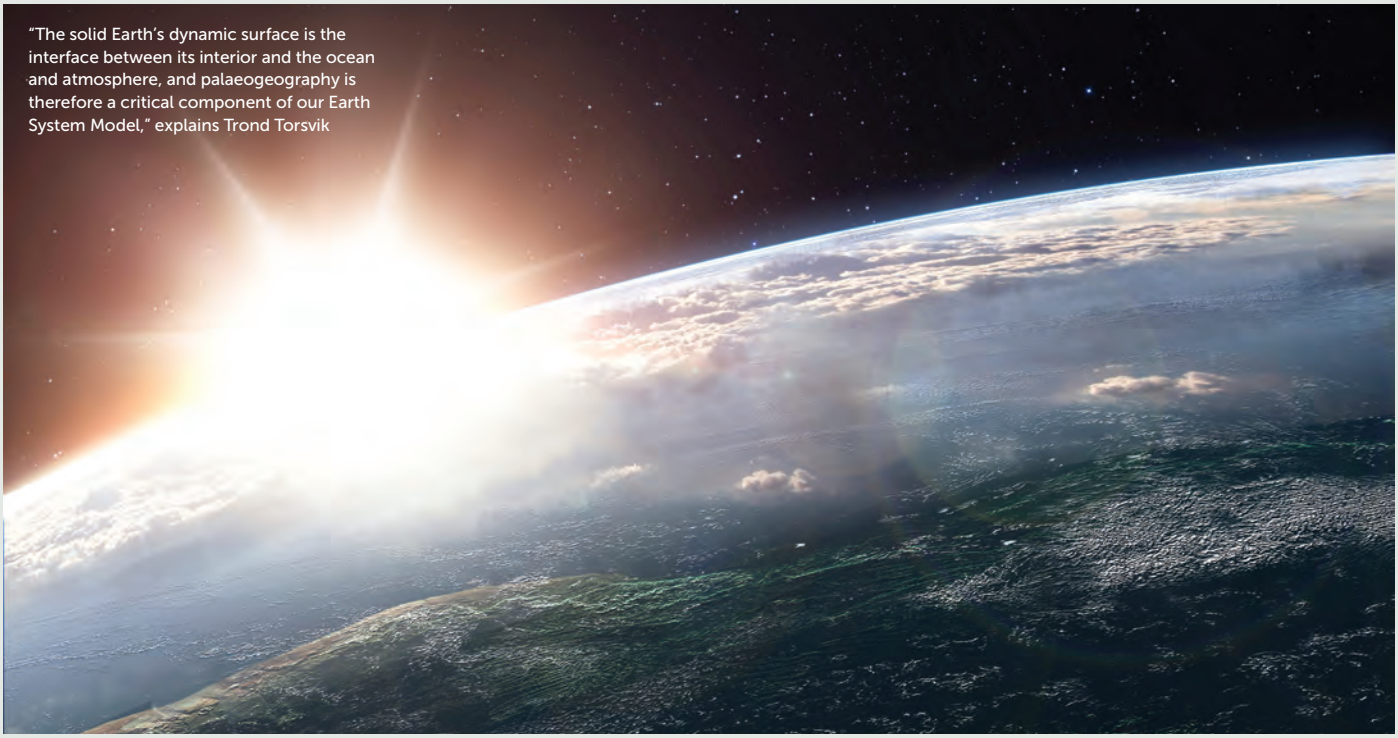
> **"The constellation of environmental conditions that allowed life to arise from inanimate matter via abiogenesis is still among the greatest unknowns in science"**

Drawing links between surface and lithospheric processes and the mantle is extremely challenging. However, Trond and his colleagues made this feasible by deriving the longitude-calibrated maps (that is, absolute reconstructions) of ancient continents from before the Cretaceous (achieved, in part, because of an increased understanding of the dynamics of true polar wander), and combining these with more detailed images of Earth's deep mantle. Seismic tomography reveals the presence of two so-called large low shear-wave velocity provinces, which extend laterally for thousands of kilometres and sit above the core-mantle boundary in diametrically opposite positions (one beneath Africa, one beneath the Pacific). The provinces are interpreted by some as piles of thermally and/or chemically distinct material, possibly relics of Theia, the planetary body that is thought to have collided with Earth to form our Moon, or a graveyard for slabs of cold, dense subducted oceanic lithosphere. As Trond explains, the seismic tomographic images provide compelling evidence that the edges of these provinces or piles are key sites for mantle-plume generation.

Awards 2025: Invitation to nominate

Fellows of the Society are invited to submit nominations for the Society's Awards and Funds 2025. We warmly encourage nominations representative of all demographics, and in particular nominations for our Early Career Funds to recognise outstanding contributions by early career scientists.

For more information, visit **www.geolsoc.org.uk/About/Awards-Grants-and-Bursaries/Society-Awards**. Please contact **secretary@geolsoc.org.uk** with any queries.



"The solid Earth's dynamic surface is the interface between its interior and the ocean and atmosphere, and palaeogeography is therefore a critical component of our Earth System Model," explains Trond Torsvik

"These thermo-chemical provinces on the core-mantle boundary have been semi-stable for 300 million years, possibly for 540 million years and longer, and their edges are the dominant sources of the plumes that generate LIPs, hotspots and kimberlites. LIPs provide a direct link between plume-generating processes in the deepest mantle and the atmosphere and biosphere, enabling us to develop an Earth model, not only integrating plate tectonics and mantle dynamics, but also the ancient environmental and climatic evolution."

Whole Earth system

To gain a more holistic picture of Earth evolution, Trond is now taking his research one step further and using carbon-cycle modelling to probe the effects of plate tectonics and palaeogeography on climate changes over the past 540 million years.

"The solid Earth's dynamic surface is the interface between its interior and the ocean and atmosphere, and palaeogeography is therefore a critical component of our Earth System Model. Full-plate palaeogeographic models developed over the past decade enable direct estimation of surface-mantle fluxes to inform time-dependent models for water cycling between Earth's surface and interior, and to estimate plate tectonic degassing (a source of CO_2). Our palaeogeographic models have now also been extended to include the regions that defined exposed and flooded land through time, and thus allowing us to parameterise silicate weathering (a sink for CO_2) for 3D climate and carbon-cycle simulations."

Trond is currently Director of a new Centre for Planetary Habitability (PHAB) at the University of Oslo, the prime endeavour of which is to recognise and characterise the key conditions that make a planet habitable.

"The constellation of environmental conditions that allowed life to arise from inanimate matter via abiogenesis is still among the greatest unknowns in science. Earth is the only planet on which life is known to have originated and appears unique in many ways, including the presence of abundant surface water (life's medium), a large moon, a long-lived magnetic field, and plate tectonics. Yet, which of these and other characteristics are essential for its long-term habitability? Equally, how have Earth's physical and chemical attributes, and thus our planet's proclivity for life, evolved? How can we recognise distant worlds around other stars that have been or could be habitable? These questions, and a new understanding of planetary habitability unfolding from them, are especially important as we now embark on an unprecedented era of exploration and discovery of extra-solar planetary systems."

Trond Torsvik is Professor of Geodynamics and Director of the Centre for Planetary Habitability at the University of Oslo, Norway, and the 2024 recipient of the Geological Society's Wollaston Medal.

Interview by Amy Whitchurch

Icelandic insights

Due to scant monitoring, volcanic activity in Iceland's interior is poorly understood compared to neighbouring parts. **Jennifer Jenkins** aims to change that by leading a seismic deployment across the island's heart

THE SPECTACULAR eruptions on the Reykjanes Peninsula, which have been ongoing since 2021, have once again turned the world's attention to Iceland, land of fire and ice. As one of the most volcanically active regions on the planet, much of the country, particularly in the south and north, is closely monitored by the nation's seismic network. However, vast, mostly ice-covered swathes of the island's heart are sparely instrumented and understudied. Central Iceland may be comparatively less active but, as Jenny Jenkins, Assistant Professor at Durham University explains, that doesn't mean there is nothing going on.

"There are several active volcanoes covered by glaciers with associated geothermal systems, and persistent seismicity has been observed over the past several decades. But because of the limited number of nearby seismic instruments, very little is known about the causes of this seismicity (and there may well be a lot more of it than we are currently capable of recording), or the internal structure or hazard level of the volcanoes in this area."

This summer, Jenny, together with collaborators at the University of Iceland and Iceland Geosurvey, will lead an expedition to deploy seismometers through the remote Central Icelandic Highlands.

"Our new network will allow us to record small local earthquakes currently below the level of detection, locate them with a high degree of accuracy, and analyse their source characteristics to work out what's causing them. Is it movement of magma, or geothermal fluids and gases, or the accommodation of tectonic motion across the boundary of a proposed microplate?

"We will also use recordings of continuous seismic background noise to image the subsurface – by identifying regions where seismic waves travel particularly fast or slow, we can learn about the internal structure of volcanoes in the area. Finally, recording of distant global earthquakes will allow us to image the large-scale crustal structure, to explore how it changes as you move gradually away from the centre of the Icelandic hotspot (which is potentially caused by a mantle plume), and consider what this structure tells us about how crustal formation processes vary with changing melt sources."

Fagradalsfjall volcano, Reykjanes Peninsula, Iceland, in 2021. While this region is well monitored by the country's seismic network, Iceland's ice-covered Central Highlands are not – something that Jenny and her colleagues aim to rectify during an expedition in summer 2024

This will be Jenny's first opportunity to lead a seismic deployment. Come summer, she will also be seven months pregnant, which she says, "adds another layer of complications to the planning!" – complications that will be eased by her great field team and supportive collaborators.

Order from chaos

Beyond Iceland, Jenny's observationally focused work uses seismic data to unravel goings on within the entire planet – from the formation and deformation of Earth's crust to the temperature, compositional variation and structure of the mantle.

"I find it amazing that thousands of recordings of tiny ground motions at Earth's surface can provide us with insights into the deep structures and processes within our planet. I love looking at complex noisy data and gradually finding ways of pulling out signals and detailed information from what at first just looks like a big mess."

Despite some assumptions that new evidence may largely just support already well-understood processes, Jenny finds that new data frequently counter expectations.

"What usually follows is me trying to work out if I have just made some mistake, or done my analysis wrong. Eventually, I have to accept that the data show that things aren't exactly how we thought they were. Once you start looking for alternate explanations that do fit your observations, that's when things get really exciting. Maybe my interpretations aren't correct and someone else one day will come up with a better explanation – if and when that happens, I look forward to seeing what ideas they come up with."

Inspiring others

On discovering geophysics at undergraduate level, Jenny realised that her passions for physics, maths and geology could be combined: "I love this rather niche subject that lets me apply physics and maths to better understand the planet we live on." Jenny shares her enthusiasm for geophysics by teaching undergraduate courses at Durham University, courses which include fieldwork and geophysical data collection in local areas, giving the students opportunities to work with local people on real problems such as, "Is there a permeable area of the subsurface beneath this embankment that could explain flooding problems? Is there really a Roman road running through this field as suggested on historic maps?"

Some of the students' dissertation projects have led Jenny in unexpected research directions: "An initial student survey opened up surprising new collaborative opportunities with the Engineering Department. I am currently working with colleagues to adapt standard geophysical electrical imaging methods to monitor water infiltration and damage in heritage masonry bridges!"

Despite the wide applicability and critical importance of geophysical methods and knowledge, as with many subfields of geoscience, geophysics is currently suffering recruitment problems in the UK.

"Our new network will allow us to record small local earthquakes currently below the level of detection," explains Jennifer Jenkins

"I love looking at complex noisy data and gradually finding ways of pulling out signals and detailed information"

"It's an interesting and important subject that can provide students with key skills and knowledge needed to address the Sustainable Development Goals and implement a green energy transition, and employers are keen to hire geophysics graduates. Yet our courses have consistently low or declining numbers.

"With the British Geophysical Association, I'm leading a project to promote geophysics in high school. We're starting by collecting data from representatives throughout the educational pipeline (teachers, high school students, undergraduates, graduates, and geophysics companies), in an attempt to answer questions such as: What are the awareness levels of geophysics in high school? Is the subject viewed as too specialised? Are students put off by the thought of fieldwork? Are they worried it's too hard or too easy? Are they worried it won't lead to a good career? Do they think that geophysicists only work in the oil industry, with the oft-associated negative connotations? By learning the answers to these questions, we can begin to address the issues."

As the current Equality, Diversity and Inclusivity (EDI) Officer for the British Geophysical Association, and as a member of Durham's Earth sciences departmental committee for EDI, Jenny also devotes significant energy to collecting and analysing data on student welfare, and designing policies to help those who need support. With these efforts, Jenny hopes to build the appeal of and inclusivity within geophysics, and ultimately to share the subject she so loves with many more people.

Jennifer Jenkins is an Assistant Professor of Earth Science at Durham University, UK, and the 2024 recipient of the Geological Society's Wollaston Fund.

Interview by Amy Whitchurch

VIEWPOINT

SEND YOUR LETTERS TO **GEOSCIENTIST@GEOLSOC.ORG.UK** AND TWEET US AT **@GEOSCIENTISTMAG**
FOR GUIDANCE ON SUBMITTING A COLUMN, SEE **GEOSCIENTIST.ONLINE**

COLUMN

Want to join the debate? Email geoscientist @geolsoc.org.uk

Think twice

Despite the current downturn in student enrolment numbers, Davide Elmo urges universities to look at longer-term trends and think twice before closing geoscience programmes

Enrolment in geology and Earth science programmes has steadily decreased over the past ten years. My analysis of publicly available enrolment data from 2010 until present suggests that this trend extends across the Global North (Fig. 1). However, the historical data also show that a similar decline has occurred twice in the past 50 years. In an analogy between enrolment data and Earth's mass extinction events (the study of geology is not possible without considering geological time), we need to look at the historical patterns behind enrolment data and consider aspects that transcend national boundaries to understand what is happening presently in the academic world.

The problem is certainly complex – various factors contribute to declining enrolment, such as educational emphasis, career perception, relevance, media representation, perceived difficulty, global issues, and information accessibility.

A lack of interest in geoscience may be systemic due to geology and Earth science programmes becoming less visible and accessible to students. Anecdotally, it is reasonable to state that students' exposure to the geosciences in American and Canadian schools is dramatically low. Data from the UK suggest a more direct association – the numbers of students enrolling in geoscience programmes dropped dramatically following changes to the National Curriculum and the Education Reform Act of 1988, which gave schools greater independence, but reduced students' exposure to

geology earlier in the school curricula. Additionally, while geoscience courses in the Global North were previously highly sought by international students, the globalisation of education creates challenges in attracting international students who now have access to good universities in their own countries. Think for a moment about the size of universities in China – not just departments! – dedicated to the study of geology and Earth sciences.

The perception of limited career opportunities in geology or the misconception that geology leads only to careers in traditional fields such as mining and oil exploration might deter some students. Concerns about Earth's climate have given rise to climate anxiety, particularly among high school and university students, yet few are interested in studying the disciplines – geology and Earth science – that hold the key to understanding how our planet has responded, is responding, and might respond to climate change. Similarly, few individuals express an interest in studying the disciplines – engineering geology and geological engineering – that are key to engineering our response to significant climate events, or those disciplines that will provide the mineral resources required to reduce our carbon emissions.

> **"Geology and Earth science hold the key to understanding how our planet has responded, is responding, and might respond to climate change"**

Connecting geology to current global challenges like climate change and resource management could make the subject more appealing and pertinent to prospective students. However, these educational recruitment efforts will be to no avail if there are no sufficient (and rewarding) employment opportunities for new graduates because economics certainly plays a role. For example, when comparing US geoscience enrolment data to economic indicators such as private investment in the mineral resources industry (specifically the US oil and gas extraction and mining exploration budgets; EIA, 2015, Lui, 2021), a striking similarity emerges. Peaks in enrolment correspond (or slightly lag behind) peaks in extraction and exploration budgets, implying that the economics of the mining and oil and gas sectors drive the demand for geology and Earth science graduates.

Given rising demands for natural resources (due in part to the energy transition) and thus rising investment, enrolment cycles will continue. Assuming we are now nearing the end of Event 3 in figure 1, the question is not whether a new Event 4 will occur in the future but rather what its amplitude will be.

Notwithstanding the complexity of the problem, enrolment data should never become the deciding metric to establish the importance of an academic programme, and university administrators should not look at enrolment data as if they are a popularity contest. Closing geology and Earth science programmes is short-sighted. In an era dominated by social media, where everyone fixates on "likes" and "followers", it is important to recognise that the significance of an academic subject may not always align with its popularity. Instead, we must prioritise knowledge that holds intrinsic value for the sustainable understanding and utilisation of our planet's vital resources.

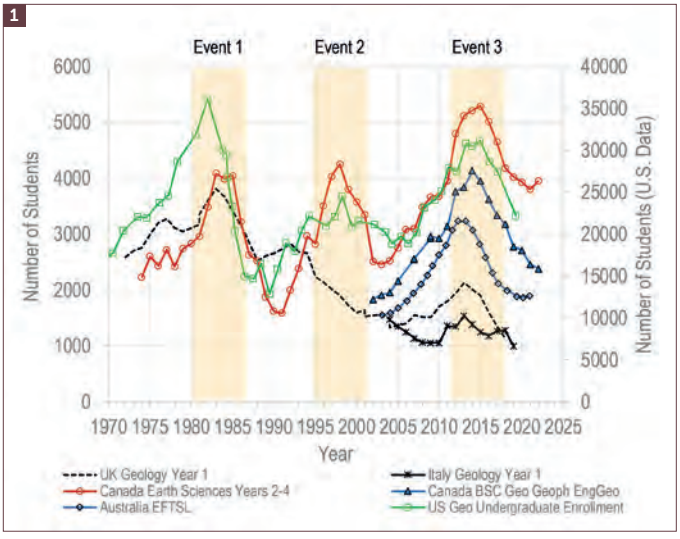


Figure 1: Enrolment numbers in geology and Earth science programmes for various countries in the Global North. EFTSL, Equivalent Full-Time Student Load. *(Data from publicly available sources provided in further reading. © Davide Elmo)*

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FURTHER READING
A full list of further reading is available at geoscientist.online.

- Boatright, D. et al. (2019) *Geoscientist* 29(8), 16-19
- Bonaccorsi, E. et al. (2020) *European Geologist*, 50
- EIA (2015) Sustained low oil prices could reduce exploration and production investment. The US Energy Information Administration; www.eia.gov
- Jermyn, C. et al. (2023) J Geol Soc India 99, 151–155
- Keane, C., (2022) Geoscience Currents Data Brief 2022-010. AGI; www.americangeosciences.org
- King, C. & Jones, B. (2011) *Geoscientist* 21(5), 19-21
- Liu, V. (2021) Global exploration budget for metals. S&P Global Market Intelligence; www.spglobal.com
- Mining.com (2023) Urgent action is needed to stem a slump in geoscience graduates globally; www.mining.com
- The Geological Society & UGUK (2020) Enrolment in crisis: A UK-wide strategy for exciting, engaging and retaining students in the geosciences; www.geolsoc.org.uk

LETTER

Changing perceptions

DEAR EDITORS,

I found the articles on declining geoscience student enrolment numbers in the winter 2023 edition of *Geoscientist* very interesting and agree something needs to be done to improve matters. There seems to be a belief among many people that geoscientists are only involved in oil and gas exploration and are therefore evil!

We must raise awareness of the diverse nature of the subject and the varied ways in which geoscientists are important, such as mineral exploration for resources (including those required for the energy transition) and large infrastructure projects (such as the siting of wind farms).

I don't think that it should necessarily be at the top of the agenda to get geology taught in schools as a specific GCSE or A-Level course. The academics I've known were most interested in students who had a thorough grounding in mathematics, physics, and chemistry. Geology can be incorporated in other school courses, including geography. The Society's Earth Science Ambassadors can also help raise the profile of the fundamentals of geology (rather than focusing only on environmental issues and climate change), though the scheme should be expanded beyond London.

Government needs to be better educated too. There are too few scientists in positions of power and influence in both local and national government. I was shocked to discover that there is no longer an All-Party Parliamentary Group for geoscience. While the latest register lists a few environmental groups, there is nothing akin to Earth science or geology.

WENDY REES (NÉE CAWTHORNE)
Ex-Geological Society Library staff

COLUMN

Working together

Learned Societies must unite to win trust and achieve the energy transition, argues Mark Steeves


It is critical to win support from the public

The Geological Society Business Forum (GSBF) was created to raise the profile of the geosciences and Geological Society in the business world. The GSBF also aims to attract support for the Society, for example from organisations beyond those immediately associated with the extractive industries. When I began my involvement with the Society in 2006, while working (as a non-geologist) for HSBC Insurance Brokers' Energy Practice, I assumed that it would be simple to secure the backing of diverse organisations. The hard truth, though, is that it has been very difficult.

Of course, we have won support from wide-ranging types of industry, particularly in the form of sponsorship for GSBF events, but we've seen little long-term commitment. I wonder if this is due in part to an ill-founded attitude towards those who do or have worked in the extractive industries – a kind of casual prejudice. That animosity extends beyond activists.

This view is devoid of understanding of, for instance, how a tropical fruit salad travelled to a local supermarket in the middle of winter and stayed so fresh, or where the gas comes from that heats 85% of the UK's homes. So that we can bring reason and hands-on knowledge to the fore, it is critical to win attention and support from the public, and especially from the commentariat. Not least it needs to be understood that the extractive industries don't stand in the way of progress, of new technology, of less dependence on hydrocarbons, or of the energy transition. But it also needs to be understood that none of these things are achieved with the stroke of a pen or the waving of a magic wand.

Learned Societies must be more assertive, and more accessible to the public. They also need – I believe – to co-operate more with each other. We must contribute to the arrest and reversal of the polarisation of society, which can only be achieved by working together.

MARK STEEVES
Director Samphire & Associates Ltd, Co-Founder and Committee Member of the Geological Society Business Forum

Training Courses

New Training Course series:
Geological Hazards

When: Standalone modules

24 June:	Coal Hazard
1 July:	Problematic Soils - Quick Clays and Collapsible Soils
4 July:	Problematic Soils - Swell/ Shrink Soils
8 July:	Glacial Hazards
18 July:	Problematic Soils - Peat

... with further modules to be announced

Where: virtual - Zoom

Registration: www.geolsoc.org.uk/TrainingCourses

Fellows can access up to 50% off Training Courses as part of their membership benefits. This discount can be applied on top of the group booking rate for further savings.

Group bookings:
- 5-9 delegates: 20% off
- 10-14 delegates: 25% off
- 15 delegates or more: 30% off

Contact **training@geolsoc.org.uk** to find out more

#GSLTraining

The Geological Society

A new series of individual Online Training Courses is coming to you in June! These standalone courses will focus on different geohazards...

A geological hazard (geohazard) is the consequence of an adverse combination of geological processes and ground conditions, sometimes precipitated by anthropogenic activity.

To understand geohazards and mitigate their effects, expertise is required in the key areas of engineering geology, hydrogeology, geotechnical engineering, risk management, communication and planning, supported by appropriate specialist knowledge of subjects such as seismology and volcanology.

The study and assessment of geohazards into the wider social context will help the engineering geologist to better communicate the issues concerning geohazards in the UK to the client and the wider public.

This series of individual Training Courses will be delivered by various speakers. The courses will be held virtually from 4pm-5:30pm BST.

Overview:

- **Coal Hazard:** this course will go into mining subsidence plus fault reactivation
- **Problematic Soils - Quick Clays and Collapsible Soils:** this course will go into the presence of quick clays in the UK
- **Problematic Soils - Swell/Shrink Soils:** this course aims to present the viewer with a basic understanding of shrink-swell soils
- **Glacial Hazards:** this course will illustrate the relic glaciogenic hazards potentially encountered in Quartenary terrains and the diagnostic characteristics that the geoscientist should be aware of during the site investigation process
- **Problematic Soils - Peat:** this course will review the engineering background to peat behaviour and considers ways these hazards may be mitigated

Figure 1: Mariner 10 orthographic photomosaic of the southern hemisphere of Mercury. The planet has a diameter of 4,879.4 km.

SHRINKING, WRINKLING, COOLING MERCURY

DESPITE SURFACE TEMPERATURES REACHING UP TO 430°C, THE PLANET CLOSEST TO OUR SUN IS SLOWLY COOLING. BENJAMIN MAN USES EVIDENCE OF RECENT, WIDESPREAD TECTONISM TO SHOW THAT MERCURY IS CONTRACTING →

AS ONE of the five planets of our Solar System visible to the naked eye, Mercury has been known since antiquity. However, Mercury remains the least explored of the terrestrial, rocky planets because its proximity to the Sun makes it difficult to observe using optical telescopes. To date, only two spacecraft have visited Mercury: in 1974, NASA's Mariner 10 spacecraft provided the first glimpse of Mercury's surface (Fig. 1), imaging about 45% of the surface during its three flybys; while NASA's MESSENGER (Mercury Surface, Space Environment, Geochemistry and Ranging) spacecraft, which orbited the planet between 2011 and 2015, mapped the entire surface. A third mission is on its way; the European Space Agency (ESA) and the Japanese Aerospace Exploration Agency's (JAXA) joint mission, BepiColombo, will arrive at Mercury in late 2025.

The Mariner 10 images unveiled a surface similar to the Moon's: barren, dull, grey, and heavily pockmarked by craters. One crucial difference, however, was the identification of extensive scarps and scarp systems (Fig. 2) that snake their way across Mercury's surface. Attributed to tectonism, (Murray et al., 1974) comparison with those observed on other planetary bodies showed that Mercury's scarps were far more abundant and grander in scale.

> **"The Mariner 10 images unveiled a surface similar to the Moon's: barren, dull, grey, and heavily pockmarked by craters"**

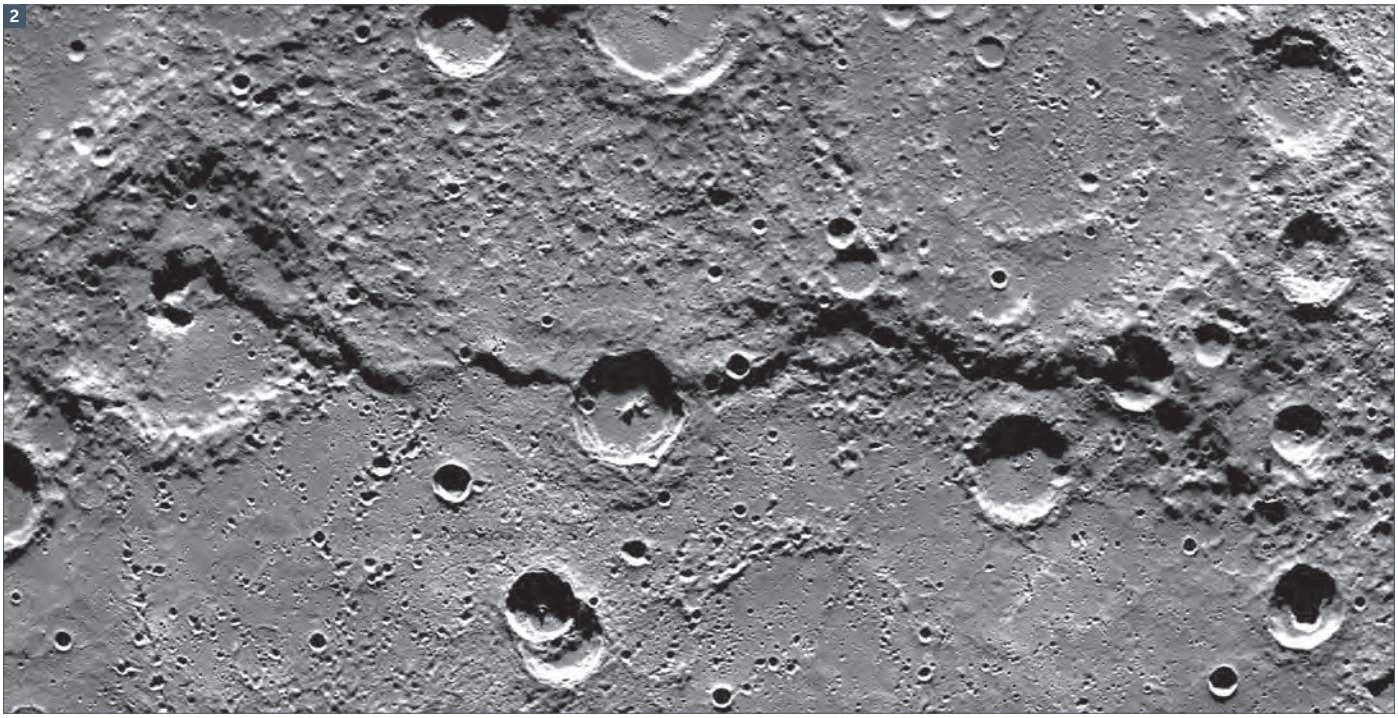
While the Mariner 10 images highlighted the dominance of compressional structures caused by crustal shortening (see Box 'Compressional structures'), evidence for widespread, recent compressional tectonism was lacking.

To test whether Mercury is experiencing considerable contraction, I worked together with a team at the Open University, UK, University of Nantes, France, and ESA to carry out a global survey of shortening structures using MESSENGER imagery (Man et al., 2023a). We found extensive evidence for widespread, geologically recent contraction, supporting the idea that Mercury continues to shrink, wrinkle, and cool.

A second look

Less than half of Mercury's surface was imaged during Mariner 10's three flybys. The abundance of compressional structures implied their presence across the planet's entire surface, but this could not be confirmed for three decades. The unimaged half of Mercury remained shrouded in mystery until the arrival of →

Figure 2: MESSENGER image showing the escarpment Victoria Rupes. This long scarp formed from the cooling and contraction of Mercury. Image is 500 km across, with the crater in the centre measuring approximately 40 km in diameter.



COMPRESSIONAL STRUCTURES

The Mariner 10 images revealed three morphological types of compressional structure, all of which showed no apparent trends in orientation and were occasionally observed truncated by craters, suggesting that they formed early in the planet's history.

Lobate scarps

Lobate scarps (Fig. 3A) are asymmetric escarpments with gentle back slopes and steeper fronts (Strom et al., 1975) and are the most commonly observed compressional structure on Mercury. Linear or arcuate in plan view, lobate scarps commonly span tens or hundreds of kilometres in length and up to a couple of kilometres in height. These structures are theorised to represent the surface manifestations of thrusts or reverse faults produced by compressional stresses.

Wrinkle ridges

Wrinkle ridges (Fig. 3B) are linear or sinuous antiforms that can braid and re-join when viewed planimetrically. In cross-section, they can have asymmetric or symmetric profiles and are generally morphologically complex compared to lobate scarps (Plescia & Golombek, 1986). Akin to the Moon, wrinkle ridges on Mercury are typically observed on the surface of geomorphologically smooth plains and are attributed to thrusts that do not break the surface and thrust-related folding. Wrinkle ridges vary in size; the largest named wrinkle ridge, Schiaparelli Dorsum, is 374 km long.

High-relief ridges

High-relief ridges (Fig. 3C) resemble much larger versions of wrinkle ridges, generally spanning hundreds of kilometres in length and up to two kilometres in height. Typically symmetric in profile and bounded by lobate scarps (Massironi & Byrne, 2015). High-relief ridges are commonly observed transitioning into lobate scarps, which suggests that they are a morphological variant and therefore likely another expression of thrusting and folding.

3

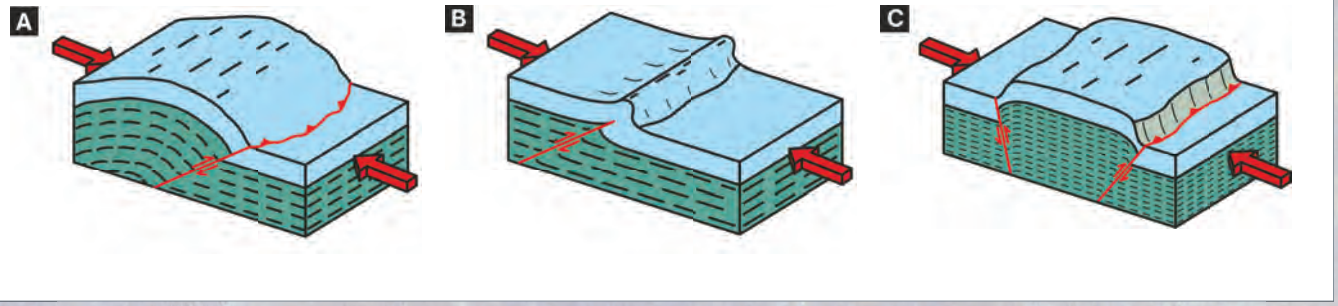
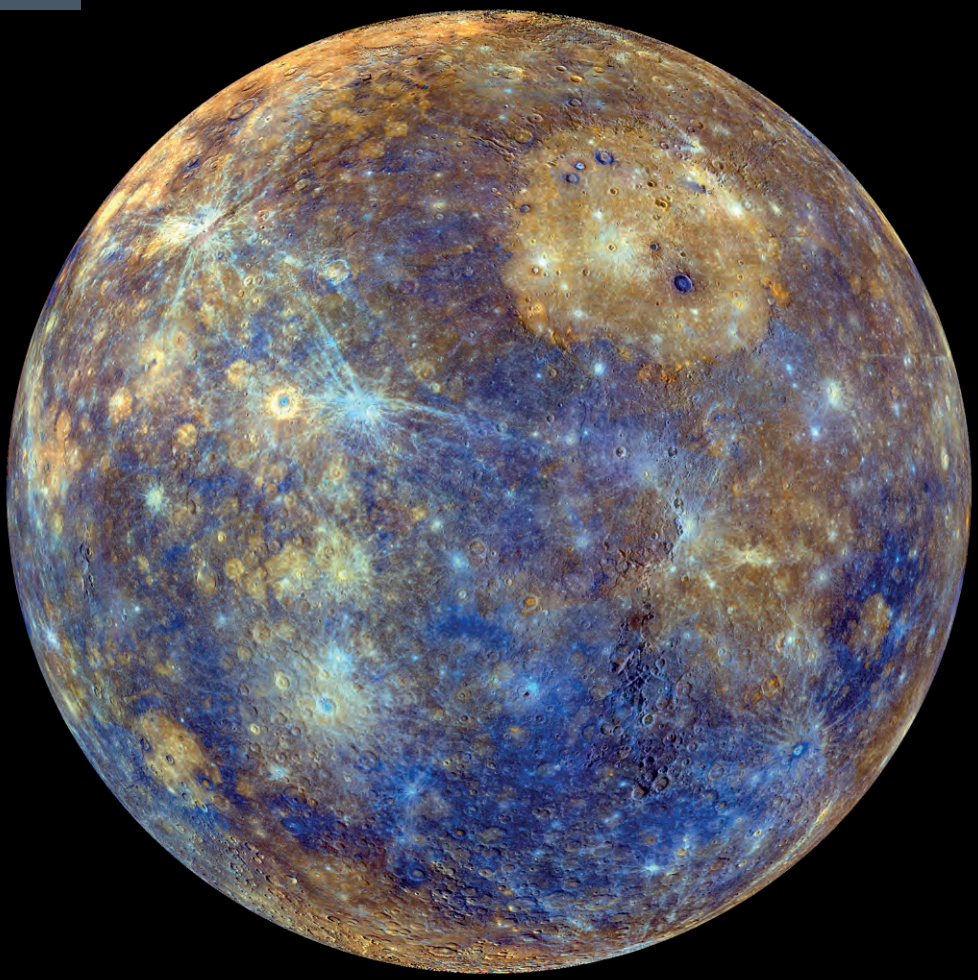


Figure 3: Schematic diagrams of Mercury's compressional tectonic structures. (A) Lobate scarp; (B) Wrinkle ridge; (C) High-relief ridge. Colour scheme illustrates structures and does not represent Mercury's geology. The diagrams are at different scales. High-relief ridges are the largest structures and can be comprised of lobate scarps. Wrinkle ridges are commonly the smallest structures out of the three.

An enhanced colour map of Mercury captured by MESSENGER



A colourful view of Mercury produced from the colour base map imaging campaign during MESSENGER's primary mission

FORMATION THEORIES

Four main theories explain the abundance and distribution of compressional structures on Mercury: global contraction, tidal despinning, true polar wander, and mantle convection.

Global contraction

Cooling of the planet's interior could cause global contraction. Early geochemical processes, such as a phase change from liquid to solid within part of Mercury's large metallic core, would have resulted in a decrease in the planet's radius (Strom et al., 1975), and so too would cooling of the lithosphere and contraction of the crust (Solomon, 1976).

Tidal despinning

If Mercury rotated faster earlier in its history (Dombard & Hauck, 2008), the planet would have a more pronounced equatorial bulge as a result of greater centrifugal force. To accommodate this more oblate spheroid shape (similar to a satsuma in terms of aspect ratio), different tectonic structures with preferred orientations would form. Over time, tidal-despinning, where Mercury's rotation slowed down, would cause the equatorial bulge to relax, with the planet losing oblateness, but the global population of tectonic structures with preferred orientations would remain (Melosh, 1977).

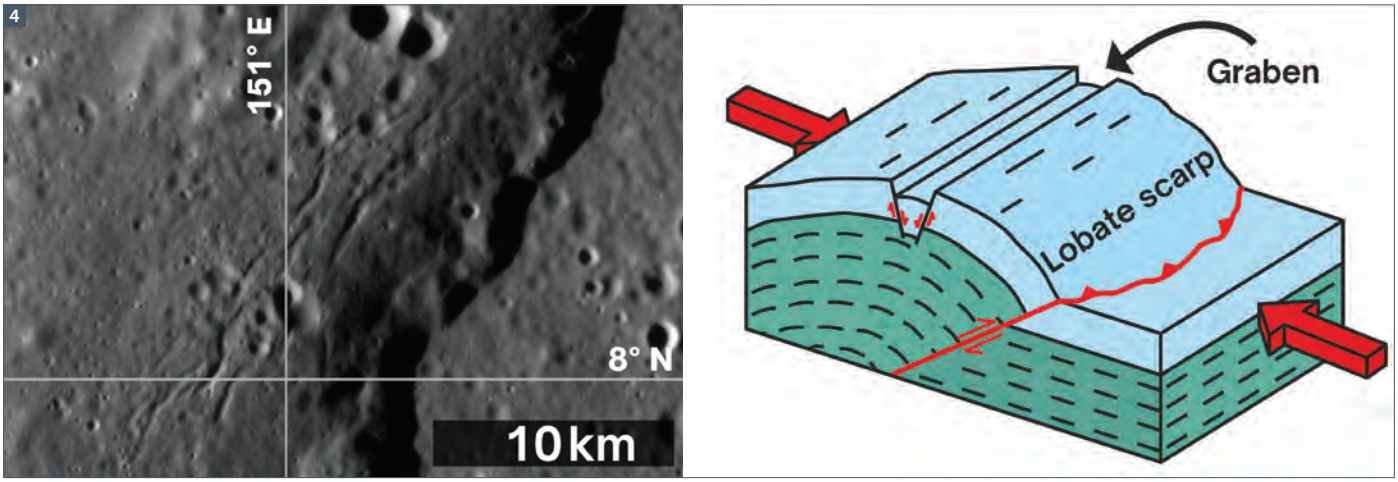
True polar wander

In a similar vein to tidal-despinning, true polar wander can be explained as the reorientation of Mercury, where changes in the planet's rotation lead to the geographic location of the north and south poles changing, similar to a ball spinning and wobbling on the end of a finger. True polar wander leads to a redistribution of a planet's mass, which can affect tectonic processes on a global scale. Since a planet's spin evolves temporally, a variety of tectonic structures will form to accommodate this (Keane & Matsuyama, 2017).

Mantle convection

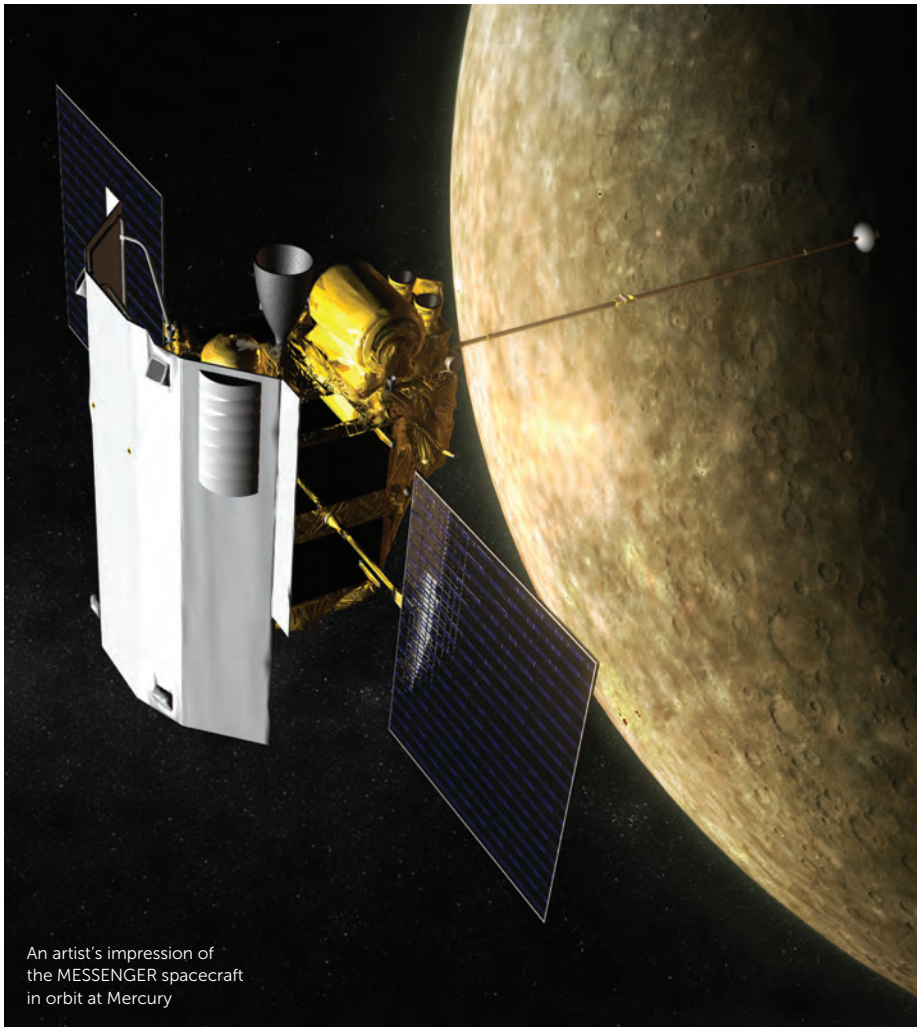
Current or past mantle convection on Mercury is predicted to be weak given the planet has a thin mantle thickness of around 400 km. Mercury also has a thin lithosphere, so it is possible that stresses caused by mantle convection could have influenced the formation of tectonic structures (King, 2008), however to what degree is not clear. When dense mantle layers sink into less-dense layers, it can produce instabilities that cause complete mantle overturn (Mouser & Dygert, 2023). Upwellings generated by overturn are hypothesised to produce significant stresses at the base of the lithosphere, inducing the propagation of tectonic structures at the surface.

Figure 4: Grabens discovered on the scarp Alvin Rupes. Grabens (and neighbouring horsts) are observed on top of the larger compressional structure (left panel). Schematic illustration of graben formation (right). *(Original MESSENGER image from NASA/JHUAPL/CIW; Left panel modified from Man et al. (2023a) Nat. Geosci. 16, 856–862; doi.org/10.1038/s41561-023-01281-5 published open access under a CC BY 4.0 license https://creativecommons.org/licenses/by/4.0/).*



MESSENGER, the first spacecraft to orbit the planet and image the entire globe in monochrome and colour. The probe confirmed that tectonic structures are present at all latitudes and longitudes, and are observed cross-cutting all types of geomorphological units and landforms.

While MESSENGER revealed that Mercury's tectonic structures are globally distributed, they are not uniformly distributed. There are marked concentrations of structures, particularly in expanses of smooth plains in the northern hemisphere, and there appears to be latitudinal trends in the orientation of structures. The most widely accepted explanation for the formation of these compressional structures is global contraction caused by cooling of the planetary interior. However, alternative theories exist (see Box 'Formation theories'). Regardless of the formation mechanisms, scientists studying Mercury mostly agree that tectonism is likely still ongoing today.

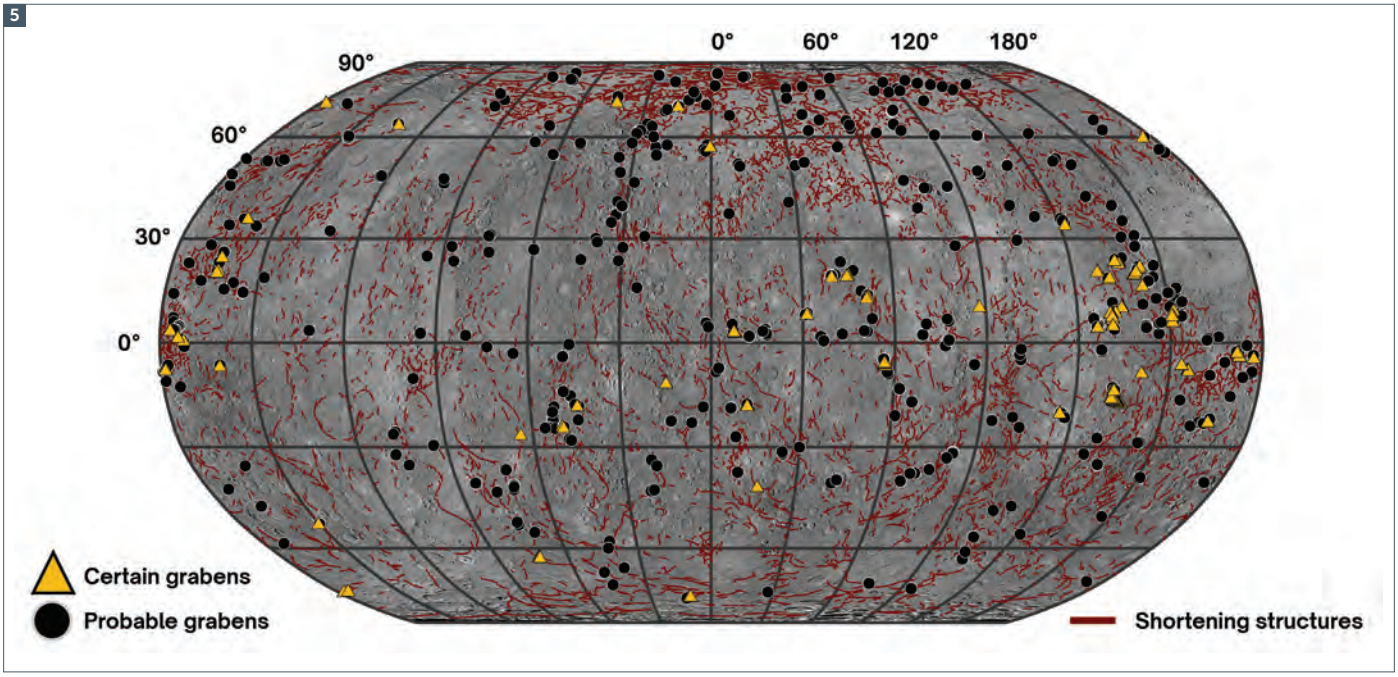


An artist's impression of the MESSENGER spacecraft in orbit at Mercury

With mapping comes discovery

Analysis of MESSENGER images and data is still ongoing, with the only evidence of recent tectonism previously being the discovery of 39 small (<10 km) pristine scarps in the northern hemisphere of →

Figure 5: Global population of grabens associated with shortening structures. Yellow triangles represent grabens we are confident with, whilst black circles represent probable grabens – structures that fulfil the morphological and positional requirements to be a graben, but are just beyond the resolution to be definitively confirmed. Red lines represent Mercury's global population of shortening, or compressional, structures (excluding basin-specific structures).
(Original MESSENGER image from NASA/JHUAPL/CIW; Figure originally published in Man et al. (2023a) Nat. Geosci. 16, 856–862; doi.org/10.1038/s41561-023-01281-5 published open access under a CC BY 4.0 license https://creativecommons.org/licenses/by/4.0/).



Mercury (Watters et al., 2016) and 14 lobate scarps observed cross-cutting Kuiperian aged (≈280 million years old) craters (Banks et al., 2015). Until now, conclusive evidence for geologically recent tectonism (within the past few hundreds of millions of years) across Mercury's globe has been on a very small scale, implying localised contraction. Whilst mapping a previously uncharted region of Mercury, the Neruda quadrangle (Man et al., 2023b), I was captivated by a large lobate scarp system that extended beyond the borders of my mapping area. Whilst tracing this system, I made the serendipitous discovery of not one, but two sets of grabens (depressed blocks of material bordered by roughly parallel normal faults) situated on two different prominent lobate scarps, one of which is shown in figure 4.

Grabens are formed by tensional stresses, but these extensional features can form locally from continued strain of a parent structure under compression

> **"I made the serendipitous discovery of not one, but two sets of grabens situated on two different prominent lobate scarps"**

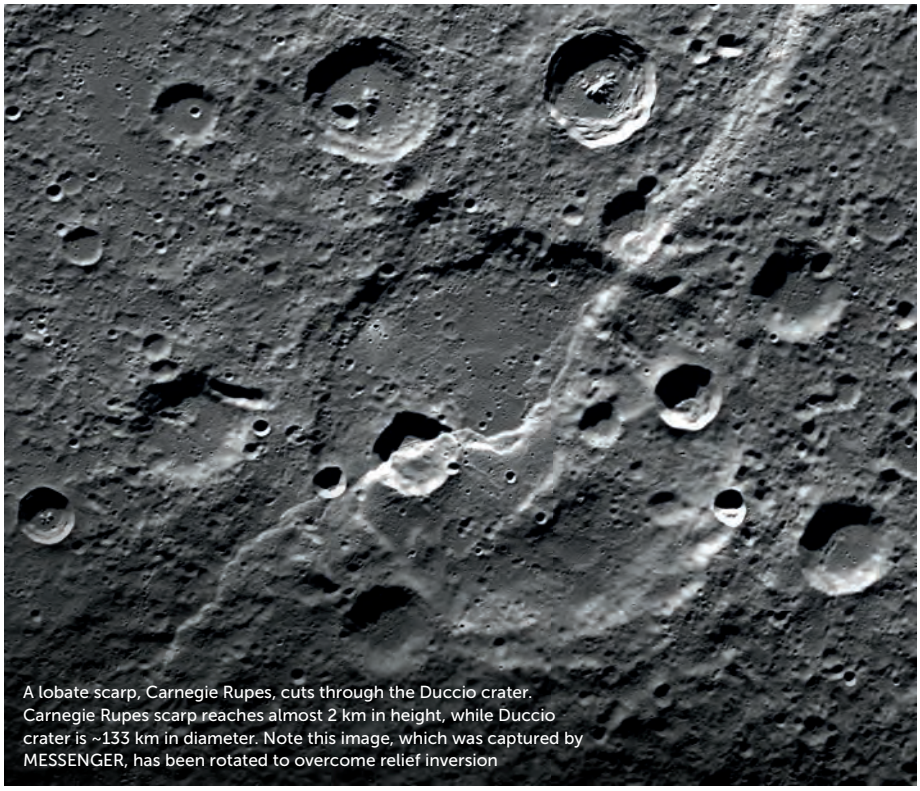
(Fig. 4). The grabens I discovered were relatively small scale and shallow – tens of kilometres long, tens of metres deep, and generally less than one kilometre wide – and in relatively pristine condition. Given their unspoilt appearance, my colleagues and I soon realised that these structures were likely to be geologically young. Such small structures would not survive impact gardening, where micrometeorite bombardment gradually overturns the top layer of a planet's surface, or topographic diffusion, where new crater formation erases the signature of other topographic features. Consequently, we set out to undertake a global survey for grabens located atop compressional structures.

Recent tectonism

We started by re-mapping all of Mercury's compressional tectonic structures. We then looked at over 27,000 images with the highest spatial resolution (≤150 m/pixel) obtained by MESSENGER and discovered hundreds of grabens associated with mapped compressional structures (Fig. 5).

The presence of so many newly discovered grabens on top of compressional structures provides crucial evidence that tectonism on Mercury is widespread and geologically recent. To augment our interpretation, we measured the lengths and depths of the newly discovered grabens to

“Our results show that grabens are mostly shallow and young, many of them likely having formed in the past few hundreds of millions of years”



A lobate scarp, Carnegie Rupes, cuts through the Duccio crater. Carnegie Rupes scarp reaches almost 2 km in height, while Duccio crater is ~133 km in diameter. Note this image, which was captured by MESSENGER, has been rotated to overcome relief inversion

understand their ages. Continuous impact gardening on the surface of Mercury distributes regolith (rocky, soil-like material) over craters and into depressions like grabens.

We measured the lengths of the shadows cast by the grabens to determine their current depth using trigonometry. Then, using fault displacement-length scaling relationships that are well documented on Earth (Cowie & Scholz, 1992), we estimated the original depth of the graben. By working out the difference between the current and original depth of the graben, hence the amount of regolith that had infilled the graben, we were able to work out how long it would take for a graben to be infilled, using a realistic infilling rate for Mercury. Consequently, we were able to calculate the age of the grabens.

Our results show that grabens are mostly shallow (tens of metres deep) and young, many of them likely having formed in the past few hundreds of millions of years. With this evidence of widespread young tectonism in the form of grabens atop parent compressional structures, the most plausible cause for continued strain is ongoing global contraction, indicating that Mercury's interior is still cooling and the planet contracting.

Out of the formation theories discussed, our results support global contraction being the main driver of tectonism at the present day. Alternative mechanisms (tidal despinning, true polar wander, mantle convection and overturn) likely influenced the initial formation, distribution, and orientation of structures early in Mercury's history. Global contraction is postulated to have reactivated many of the early structures and that is why we see a global population of thrusts faults rather than many different types of faulting. With BepiColombo beginning its science campaign in early 2026, and with improved spatial resolution of images and digital elevation data, I am confident that many more grabens will be resolved and discovered, supporting our theory that recent tectonism on Mercury is not just widespread but global.

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FURTHER READING
A full list of further reading is available at geoscientist.online.

- Cowie, P.A. & Scholz, C.H. (1992) J. Struct. Geol. 14, 1149-1156
- Davies, M.E. et al. (1978) *Atlas of Mercury*, NASA Science and Technical Information Office, 128 pp.
- Dombard, A.J. & Hauck, S.A. (2008) Icarus 198, 274-276
- Grott, M. et al. (2011) Earth Planet. Sci. Lett. 307, 135-146
- Keane, J.T. & Matsuyama, I. (2017) EPSC Abstracts. pp. EPSC2017-415
- King, S.D. (2008) Nat. Geosci. 1, 229-232
- Man, B. et al. (2023a) Nat. Geosci. 16, 856-862
- Man, B. et al. (2023b) Lunar and Planetary Science Conference. pp. 1-2
- Massironi, M. & Byrne, P.K. (2015) In: *Encyclopedia of Planetary Landforms*, Springer New York, pp. 932-934
- Melosh, H.J. (1977) Icarus 31, 221-243
- Murray, B.C. et al. (1974) Science 184, 459-461
- Plescia, J.B. & Golombek, M.P. (1986) Geol. Soc. Am. Bull. 97, 1289-1299
- Solomon, S.C. (1976) Icarus 28, 509-521
- Strom, R.G. et al. (1975) J. Geophys. Res. 80, 2478-2507
- Tosi, N. et al. (2013) J. Geophys. Res. E Planets 118, 2474-2487
- Tosi, N. & Padovan, S. (2021) In: *Mantle Convection and Surface Expressions*, American Geophysical Union, pp. 455-489.

THE GLOBAL RACE FOR CRITICAL RESOURCES

Nick Gardiner discusses energy metals and geopolitics

IN JUNE 2023, my colleagues and I rolled up to the front gates of a lithium mine near Dorowa in Eastern Zimbabwe. Our vehicles were quickly surrounded by at least 50 local men who were looking for work and had assumed that we were in some way associated with the Chinese-owned mine – of course we weren't. I chatted to a few of the men and explained that we were just passing through. In fact, we were scoping out the mine for ourselves. We left our vehicles on foot to make a foray along the high fence boundary and assess the size of the operation.

Lithium is the current poster-child for the so-called critical metals. Critical metals (minerals) are broadly defined as those commodities with growing economic and/or industrial importance, but with insecure or volatile supply. Zimbabwe probably has Africa's biggest lithium resources. In December 2022, the country announced a ban on the export of unrefined lithium ore to deter illegal mining, and to keep processing, and hence jobs and revenue, in the country. In 2023, lithium became Zimbabwe's third biggest export after gold and Platinum Group Elements (PGEs; Chingono, 2023), making the country Africa's biggest lithium producer.

The mine we visited on that day boasted a new processing plant, and our assessment was that it was much too big in scale to be solely built for the locally mined pegmatite (pegmatites are the main hard-rock source of lithium, see Fig. 1 and box 'Lithium formation'). The mine is sited close to a main road that goes via the border town of Mutare into Mozambique and thence onto the port of Beira, enabling raw materials produced in landlocked Zimbabwe to be exported, typically to China. As such, the operation

Tin-bearing pegmatite cutting through county rock in the Uis district, Namibia

is strategically sited to process raw lithium ore from other mining projects within Zimbabwe prior to export.

While many African nations have long asserted varying degrees of control over their natural resources, mainly via mining codes, licences, and royalty structures, countries such as Zimbabwe are now taking the next steps to realising the full potential of their critical resources, and embarking on or encouraging development of these deposits. Chinese investors, in particular, have been quick to work with African partners on this development. In Zimbabwe, over the past few years, Chinese companies have spent over US$1billion buying lithium projects (Gbadamosi, 2023), including the major pegmatite deposits of Arcadia and Bikita. In contrast, there has been relatively little Western investment – not least due to various sanctions placed on the country by the EU, UK, and US from the 2000s onwards (Dendere, 2022). The emergence of China as an economic competitor, and its readiness to use metals supply as an economic weapon, means the pressure is now on Western governments to secure their own critical metals supply in the global race for resources.

Supply volatility

Arguably the biggest technological barrier to the decarbonisation of global energy is the supply of key energy metals, including lithium, copper, nickel, and cobalt. Lithium, often referred to as 'white gold', is the commodity considered among the most crucial for the energy transition, as well as one of the most critical of the battery metals.

A critical mineral or metal is variably defined as that which has economic and industrial importance resulting in growing demand, but which suffers from insecure supply chains, often hindered by →

> **“Chinese companies have been assiduously acquiring lithium projects, although not necessarily harmoniously”**

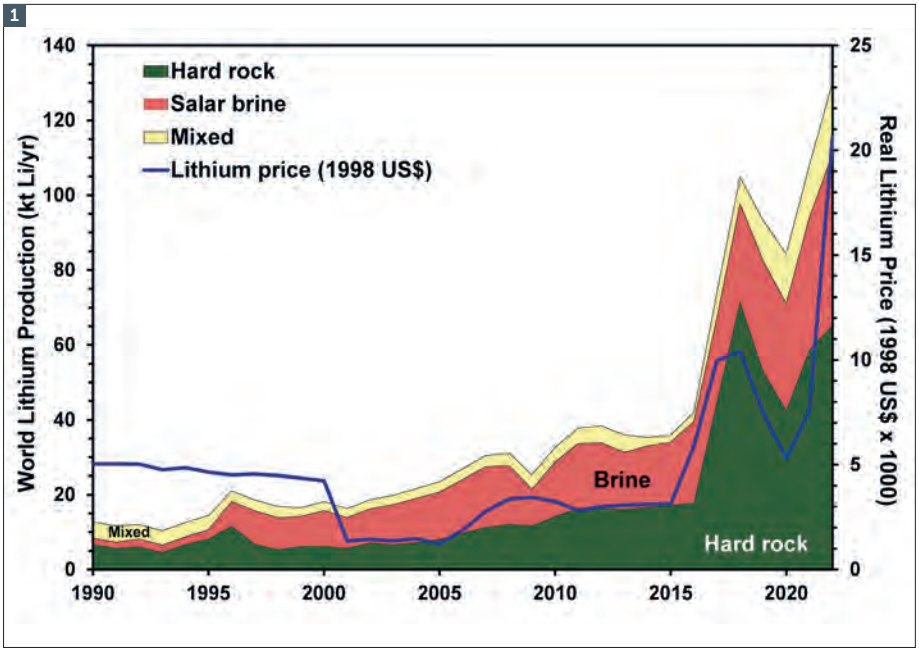

Figure 1: Lithium production from 1990 until 2022 by deposit type, and lithium-concentrate price. *(Figure reproduced from Gardiner et al. (2024) Geoenergy 2(1); https://doi.org/10.1144/geoenergy2023-0 and originally adapted from Mudd (2021) Sustainability 13(19), 10855; https://doi.org/10.3390/su131910855, both published open access under CC BY Creative Commons Licence.)*

geopolitical interests. A key societal goal is to reduce the risks associated with the supply of critical metals, which is achieved by freeing bottlenecks in their supply chains. This could be accomplished, for example, by: increasing mine supply across a wider range of mining jurisdictions; improving processing technology; and improving licence-to-mine success. From a geoscientific perspective, this means building better metallogenic models of deposit formation at a range of scales to aid exploration, understanding mineralogy for metallurgical advances, and in environmental monitoring. (Since geologists are often the first boots-on-the-ground, we also need to understand and act on environmental, social and governance considerations as well, which are often the biggest barriers to mine project success.)

A notable feature of many critical metals such as lithium is their small-scale of production. For example, annual mined tonnages of lithium, tungsten, and tin are approximately 1% of that for copper. Such small scale means the supply pipeline of these metals can be rapidly transformed for the better or worse with one new mine coming onstream, or one country blocking exports; or that a country can become a significant player in that commodity through the development of one or two major mines. These vulnerabilities are true of the entire supply chain, including the downstream processing and refining stages. Thus, these commodities tend to acutely suffer from price and supply volatility, which makes them risky investments and arguably hinders strategic investment, all of which ensures they continue to be classified as critical (Gardiner et al., 2024; see box ‘Metal criticality’).

Geological serendipity

It is perhaps a serendipitous feature of geology, coupled with historical mining activities and past and present geopolitics, that much of the metal resources on which the energy transition depends are now being explored for and extracted from the Global South, in particular the African continent.

In June 2023, Namibia followed Zimbabwe’s lead in banning the export of unprocessed critical metals including lithium. Namibia is another mining jurisdiction that is exceptionally endowed in a variety of pegmatite-hosted mineral resources, traditionally mined for uranium, tin, and tantalum, but which is now a key region for lithium prospecting. As for Zimbabwe, in Namibia, Chinese companies have been assiduously acquiring lithium projects, although not necessarily harmoniously. Things came to a head in October 2023 when the Namibian government ordered their police to stop the Chinese-owned company Xinfeng Investments, the owner of the Kohero lithium mine which is located about 250 km northwest of the capital Windhoek, from transporting or exporting any lithium ore (Nyaungwa, 2023) by blocking and turning back trucks that were heading towards the port of Walvis Bay. This was the latest scuffle in an ongoing dispute between the government and Xinfeng Investments, after earlier allegations of illegal exportations of lithium ore and using small-scale mining permits to develop their deposit (denied by the miner).

Strong governance frameworks for natural resources are already in place in many African nations. However, these case studies highlight that nations such as Zimbabwe and Namibia are now realising the full benefits and potential of their critical mineral resources, and are taking more assertive steps to maximise →

LITHIUM FORMATION

Lithium deposits fall into three main categories: (1) salar deposits formed from lithium-bearing groundwater brines; (2) hard-rock deposits, mainly lithium-rich pegmatites; and (3) clay-rich sedimentary deposits (Bowell et al. 2020). The latter deposit type has yet to be economically proven at an industrial scale and, while lithium derived from salars (found mainly in South America) remains important, since 2018, global supply of lithium has increasingly come from pegmatites (Fig. 1).

Pegmatites – such as those found in Zimbabwe – are coarse-grained igneous rocks that are geologically enigmatic. These minor granitic intrusions, perhaps only tens to hundreds of metres in length, can be variably enriched in economic metals such as lithium, tin, tantalum, caesium, and the rare earth elements. They can be complexly zoned in terms of their mineralogy and hence metal endowment, and their small size and complexity can lead to extraction challenges in terms of tricky economics of scale and grade control, and a short mine life. However, they can often form in swarms, with tens to upwards of a hundred or more intrusions clustered together, and thus for prospectors may represent classic 'elephant' country – find one economic lithium pegmatite and the hope is others are nearby.

However, there remains a fundamental debate as to whether enriched pegmatites reflect minor melt extraction from a parental granite – and thus form from late-stage magmatic processes – or whether their genesis is via low-degree partial melting of country rocks, typically clay-rich metasediments (e.g. Shaw et al., 2022; Koopmans et al., 2024). Both are plausible petrological mechanisms to produce minor, enriched melts. Further, many pegmatite fields are not associated with any obvious parental granite or, where granites do appear in spatial association, the granites are often somewhat older than the pegmatites. Thus debate around the formation mechanisms continues, and this remains an active area of research with a number of groups in the UK and beyond.

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Uis district, Namibia

Tin-bearing pegmatite cutting through county rock in the Uis district, Namibia (with person for scale)

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the economic and social benefits associated with mining and downstream processing – that is, efforts to domicile more of the value chain. Such efforts might eventually include the need for African countries to work together and to build continent-wide infrastructure, such as more strategically sited refining plants and smelters, and better roads and transportation links to ports.

The story of lithium pegmatites in Zimbabwe and Namibia is an exemplar of the global race for resources. Zimbabwe has the geological potential to be a major producer of lithium, with commensurate benefits for its societal and technological development. However, to reap such benefits requires not only good infrastructure but also good governance (for a discussion on how an abundance of resources can go very wrong in Africa, see Burgis, 2015). There have been, for example, reports of Zimbabwe's raw lithium export ban being circumvented by military-linked companies (Deutsche Welle, 2023). Further, the recent collapse in lithium prices – from a high of US$80,000/MT in December 2022 to ca. US$20,000/MT towards the end of last year – only serves to underline that lithium projects can be risky investments vulnerable to unfavourable economic shifts, which compounds the jurisdiction risks operating in countries like Zimbabwe. Until recently, many pegmatite projects were brownfield sites, that is, existing tin or caesium mines that were being re-evaluated for their lithium potential. However there are signs that despite at times challenging headwinds, the industry is now moving into

Fieldwork in central Zimbabwe

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METAL CRITICALITY

Metal 'criticality' is a sliding scale and depends on a number of factors. Criticality is also of key importance when considering political and investment risks. In our recent research (Gardiner et al., 2024), we explore the concept of lithium criticality, by gazing a decade forward to assess various scenarios under which lithium might become either uncritical – thereby trending towards being a 'normal' metal – or indeed become even more supply constrained and hence über-critical, possibly leading to substitution efforts towards alternative technologies and hence alternative metals. Our scenarios include: *business as usual*, whereby pegmatites and brines continue to be the principal sources of lithium; *lithium-rich clays coming onstream*, which would significantly improve the tonnage and geographic spread of lithium supply; and a *black swan event*, which by its very nature is an unpredictable event, but could include a war, or critical mineral supply being used as an economic weapon (such as the 2023 example of China placing export restrictions on the minor metals gallium and germanium, which are used in high-end graphic microchips and semiconductors; Trench & Sykes, 2023).

Fundamentally, our work highlights that a key issue with small-scale critical metals such as lithium is that there is often a timing mismatch between relatively slow-responding supply versus dynamic changes in demand, which leads to price and supply volatility and can make the economics around mine projects fragile.

For an overview of geoscience's various roles in the energy transition, read Gardiner, N.J. et al (2023) Geosciences and the energy transition. *Earth Science, Systems and Society* 3; **doi.org/10.3389/esss.2023.10072**

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Hunting for outcrops, Bulawayo region, Zimbabwe

a greenfields exploration phase globally, with the aim of new mine development specifically for lithium production – both in places like Western Australia (Phelps-Barber et al., 2022), but also in countries like Zimbabwe and Namibia and beyond.

Collective effort

Belated recognition in many Western governments and transnational organisations of the importance of securing medium- to long-term supply of a range of metals, for the energy transition in particular, means that critical metals have rapidly risen up policymakers' agendas. The UK, EU, US, Canada, and Australia have recently released or updated their versions of critical mineral strategies and/or watchlists, and are now seeking alliances and agreements with receptive countries, agreements that aspire to underpin metal supply security, while also investing in research projects aimed at identifying and exploiting critical mineral resources closer to home (e.g. Müller et al., 2023), and/or improving recycling approaches. However, given the strategic investments in mining, processing, and refining already made by China, Western nations are arguably at least a decade behind. All of this piles pressure on Western nations and companies to develop their own robust supply chains.

Colleagues and I have current research projects in both Zimbabwe and Namibia and we hope our collective academic efforts, alongside those of other researchers in the UK and internationally, will help us better understand the geological evolution and processes leading to mineralised granites and pegmatites, to ultimately help exploration companies target them. It is impossible to work in countries such as Namibia and Zimbabwe and not realise the potential of natural resources to underpin their development, be that in revenue; in education, training, and jobs; and in environmental protection. Despite the myriad of challenges associated with the development of any mine, there is huge potential for lithium in many African countries (Goodenough et al., 2021). The hope is that any challenges can be overcome and the countries themselves can better prosper from their natural resources.

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FURTHER READING

A full list of further reading is available at geoscientist.online.

- Bowell, R.J. et al. (2020) *Elements* 16(4) 259-264
- Burgis, T. (2015) *The Looting Machine*. Harper Collins, 336pp.
- Chingono, N. (2023) Zimbabwe lithium export earnings treble as projects take off. Reuters, 1 November 2023; www.reuters.com
- Dendere, C. (2022) Zimbabwe: The Long Shadow of Sanctions. In: *The Southern Mirror* by Balfour, R. et al. (Eds). Carnegie Europe 29; https://carnegieeurope.eu
- Gardiner, N.J. et al. (2023) *Earth Science, Systems and Society* 3
- Gardiner, N.J. et al. (2024) *Geoenergy* 2(1)
- Gbadamosi, N. (2023) Africa Brief: Zimbabwe's 'White Gold'. Foreign Policy, 16 August 2023; https://foreignpolicy.com
- Goodenough, K. et al. (2021) Lithium resources, and their potential to support battery supply chains, in Africa. British Geological Survey, 21pp. (Unpublished); https://nora.nerc.ac.uk/id/eprint/530698/
- Hairsine, K. (2023) Lithium mining in Africa reveals dark side of green energy. Deutsche Welle 16 November 2023; www.dw.com
- Koopmans, L. et al. (2024) *Geology* 52(1), 7-11
- Mudd, G. M. (2021) Sustainability 13(19), 10855
- Müller, A. et al. (2023) Geological Society, London, Spec Pub 526, 193-218
- Nyaungwa, N. (2023) Namibia orders police to stop Chinese firm's lithium exports. Reuters 24 October 2023; www.reuters.com
- Phelps-Barber, Z. et al. (2022) *Applied Earth Science* 131(2), 100-113
- Shaw, R.A. et al. (2022) *The Canadian Mineralogist* 60, 957-987
- Trench, A. & Sykes, J. (2023) Strictly Boardroom: Global focus turns to gallium and germanium. MiningNews.Net 17 July 2023; www.miningnews.net

Stone walling

Nina Morgan considers a Roman legacy

Hadrian's Wall, built to secure the Roman Empire's north-western border in the province of Britannia, is now a UNESCO World Heritage Site

APART FROM SANITATION, medicine, education, wine, public order, irrigation, roads, a fresh-water system, and public health – what have the Romans ever done for us? Well, along with providing an often-quoted catchphrase from the Monty Python film *The Life of Brian*, the Romans also produced the first geological cross-section across the width of England, in the form of Hadrian's Wall.

The construction of the Wall began in AD 122 on the orders of the Emperor Hadrian. It extends for 80 Roman miles (73.5 miles or 118.25 km in modern terms) across England from Wallsend on the River Tyne in the east to Bowness-on-Solway in the west. Because the Romans relied on locally available materials, the stones used vary along the length of the Wall – the Wall reflects the geology of the surrounding areas and provides a life-size geological cross-section. In addition, the milecastles (MC) and turrets along the Wall make navigation easy for geologists and serve as a handy aid for mapping today.

The man who saved the Wall

This geological gem was nearly lost over the years because the stones it was made from were often plundered as a handy source of building material. The walls of many buildings along the length of the Wall demonstrate just how often builders took advantage of this free source of ready-dressed building stone. But for the foresight of John Clayton [1792 – 1890] the Wall might have disappeared altogether.

Clayton, a solicitor, then Under Sheriff and later Town Clerk of Newcastle, jointly inherited the Chesters Estate, near milecastle (MC) 27 of Hadrian's Wall. As a long-serving, prosperous, and powerful civic leader, Clayton was not always popular during his lifetime. But historians and lovers of the countryside have a lot to thank him for. Clayton had a strong interest in history, particularly the Romans, and carried out excavations for 50 years. He took an active interest in preserving Hadrian's Wall and the stone it was built of.

Clayton began purchasing land around the Wall in 1834. By the time of his death in 1890 he owned five forts and almost 32 km (20 miles) of the Wall between Acomb (near MC 26) and Cawfields (MC 42) built on the limestone, mudstone, flags, sandstone, seat earth and coal laid down during the Lower Carboniferous Dinantian Epoch. He then went about conserving and rebuilding sections of the Wall using the original Roman stone. By ending quarrying and the reuse of Roman stone in new buildings, he saved large sections of the Wall from destruction.

Although his maternal grandmother, Bridget Atkinson, was an enthusiastic shell collector, and another relative was a keen naturalist, Clayton himself was apparently not specifically interested in geology. But his work to preserve Hadrian's Wall certainly demonstrated that you don't have to be a geologist to appreciate the value of conserving Britain's geological heritage!

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Acknowledgements
This vignette was inspired by an essay by Derry Brabbs included in the book *Icons of England* by Bill Bryson (Ed.) Think Publishing Limited 2008, 176 pp. Thanks to Dr Frances McIntosh, Collections Curator for Hadrian's Wall and the North East, English Heritage, who provided additional information for this text.

FURTHER READING
A full list of further reading is available at geoscientist.online.

- Johnson, G.A.L. (1997) *Geology of Hadrian's Wall*. GA Guide 5, 989 pp.
- Peacock, S. (2021) *Geology for Walkers*. Independently published, 183 pp.; www.thestonetrust.org
- Sawyer, E. (2015) John Clayton (1792–1890). Oxford Dictionary of National Biography; www.oxforddnb.com
- The Clayton Collection of Roman Antiquities; claytonromantrust.online
- The Conservation Volunteers (2024) *Walls in the Landscape*; conservationhandbooks.com

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UNEARTHED

Parys Mountain, in Anglesey, Wales, has been mined for copper since the early Bronze Age and, during the 18th century, was one of the largest copper mines in the world. Critical minerals such as copper are essential to the green economy, so the UK is looking to develop secure supply chains

CRITICAL MINERALS: The UK Opportunity

Eileen Maes details discussions dedicated to highlighting the UK's opportunities in developing alternative critical mineral supply chains

Critical minerals are the building blocks of our modern and future green economy. They're needed to manufacture everything from computers to electric vehicle (EV) batteries, solar panels to wind turbines. But unforeseen developments and geopolitical tensions such as the COVID-19 pandemic and Russo-Ukraine War are demonstrating more than ever the vulnerability of our critical mineral supply chains.

In the past few months, China has imposed export restrictions on graphite, gallium, and germanium. Indonesia, too, continues to restrict nickel exports to develop its domestic downstream sector (*The Economist*, 2023). To showcase what the UK has to offer in the mission to develop alternative critical mineral supply chains, and to bring together international partners to promote collaboration, the Critical Minerals Association (CMA UK) and Geological Society Business Forum (GSBF) hosted their 3rd Annual Conference, *The UK Opportunity for Critical Minerals*, in November 2023.

The meeting attracted a diverse and international audience of over 300 delegates, bringing together innovators, explorers, chemists, policymakers, investors, miners, recyclers, processors, parliamentarians, researchers, lawyers, environmentalists, and many more to discuss the importance of building supply chain resilience, and how policy can enable UK industry to achieve its Green Industrial Revolution and net-zero ambitions. Due to unprecedented interest, the meeting venue in Burlington House was expanded to include both the Geological Society and Royal Society of Chemistry – further highlighting the opportunities for cross-sector collaboration on critical minerals.

Top of the agenda

In an opening address, Kirsty Benham (CMA UK) highlighted the Association's work and international expansion, with CMA having launched sister associations in Australia and the US, as well as the Critical Minerals International Alliance. In the UK, the CMA (UK) has been pivotal in uniting the critical minerals value chain (which includes production, distribution, disposal, recycling etc.) and amplifying their voices to be at the forefront of influencing policy. The conference was inaugurated with a breakfast reception at the House of Commons hosted by Cherilyn Mackrory MP, Chair of the All-Party Parliamentary Group for Critical Minerals, as well as an opening keynote speech from Nusrat Ghani MP, then Minister of Business and Trade. Minister Ghani reassured that critical minerals are "firmly at the top of her agenda", and that the UK undoubtedly has the potential to become a global player in the development of alternative critical mineral supply chains.

A new world

As the race to net zero gathers pace, demand for critical minerals will increase four-fold by 2050 (IEA, 2022). Given this trajectory, the development of diverse, resilient, and responsible critical mineral supply chains is a paramount task for governments and industries around the world. The Minerals Security Partnership (MSP), for instance, is a coalition between 13 nations and the European Union (EU) which aims to catalyse public and private investment into the development of alternative critical minerals supply chains. Recently the MSP has expanded to include a new member, India; a US-UK Critical Minerals Agreement was announced in June 2023; and additional UK critical minerals partnerships have been struck with Canada, South Africa, Saudi Arabia, Zambia, and Kazakhstan.

"The UK brings a lot to the table," said Rachael Parrish (Foreign Service Officer, US Department of State) alongside panel speakers Matthew Hatfield (Critical Minerals Lead, Department for Business & Trade), Marcin Zydowicz (Trade Commissioner, Energy & Mining, Canadian High Commission), and Ana Nishnianidze (Commissioner, UK & Ireland, Australian Trade & Investment Commission), who highlighted the UK's unique 'convening power', rich manufacturing and mining history, and world-leading finance, research and innovation.

Government leaders from Canada and Australia who attended the meeting also illuminated the abundant opportunities that exist in their jurisdictions for critical minerals extraction, processing, and recycling. The Honourable Ralph E. Goodale (High Commissioner for Canada in the UK) spoke of Canada as the "destination of choice" for investment given its secure and sustainable sourcing, outstanding mining expertise, strong Environmental, Social, and Governance (ESG) credentials, extensive technological and manufacturing capabilities, and long history of close collaboration with the UK. David Stewart (Agent-General, Queensland), the Honourable George Pirie (Minister of Mines, Ontario), Ranj Pillai (Premier, Yukon), and Nathalie Camden (Deputy Minister of Mines, Quebec) also discussed the unique qualities of their respective regions.

> **"Demand for critical minerals will increase four-fold by 2050"**

Dylan Geraets (Mayer Brown) provided an overview of the EU's Critical Raw Materials Act and how it is equipping the bloc with the tools to ensure a secure and responsible supply of raw materials. He outlined measures including the Act's differentiation of critical and strategic minerals, shorter planning and permitting timeframes, and clear benchmarks for domestic capacities.

Saudi Arabia is another nation dramatically ramping up its investments into critical minerals. In 2023, Saudi Arabia signed a bilateral critical minerals agreement with the UK, as well as an additional four nations following the success of their *3rd Future Minerals Forum* in Riyadh in February 2024. His Excellency Khalid Al-Mudaifer (Vice-Minister for Mining Affairs) elaborated on the rich and untapped geological potential of the region, how ESG is being promoted and embedded in their supply chains, and how his government draws on global expertise to ensure its investments create new value chains to diversify supply for everyone.

Many countries across the African continent also have rich geological potential for critical minerals, including for rare-earth elements, graphite, cobalt, copper, and platinum-group metals. These countries will be looking to develop their resources to boost economic growth and improve standards of living. In another panel discussion titled "A Just Transition in Africa", Baroness Northover (House of Lords), Stacy Hope (Women in Mining, ERM, Fair Cobalt Alliance), Madeline R. Young (University of Exeter), Veronica Bolton Smith (The Connect Africa Network), and Joseph Mansour (Critical Minerals Delivery Lead, Foreign, Commonwealth and Development Office) explored how foreign nations should work with resource-rich developing nations to →

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It was standing-room only for some delegates during the CMA UK and GSBF's 3rd Annual Conference, *The UK Opportunity for Critical Minerals*. Unprecedented interest and attendance levels meant the venue was expanded to include both the Geological Society and Royal Society of Chemistry buildings in Burlington House

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Sarah Gordon, co-founder of Satarla and Responsible Raw Materials, leads a roundtable discussion on Environmental, Social and Governance (ESG) issues

ensure extraction is in line with the goals of socio-economic growth and sustainable development.

"It's not just a matter of mining more and mining better," said Joseph, "but moving those [resource-rich developing nations] up the value chain themselves. It is incumbent on countries like the UK, who will mostly be a consumer nation, to ensure that this 'resource boom' works for the benefit of resource-rich countries." Joseph went on to outline the compatibility of the UK and Africa – many of what African nations and businesses are missing are the biggest strengths of the UK, particularly in geological exploration and mining finance.

"Africa needs to be part of a strategy with the rest of the world," added Veronica. "It shouldn't be dictated to. It needs to make its own agenda and attract investors in that way." These discussions led to a dynamic debate about China's policy of 'non-interference' on the continent, whether it is truly appealing to African governments, and what the West can and should do to offer an alternative method of investment. While the panellists disagreed about the benefits of China's approach, they found consensus on the value of the UK "showing rather than telling" what it can bring to the table.

The UK opportunity

After an insightful overview of the UK's mining history and some of the ongoing projects at the British Geological Survey (BGS), Kathryn Goodenough (BGS) provided an overview of the Critical Minerals Intelligence Centre (CMIC; ukcmic.org) – a group led by the BGS with support and funding from the Department for Business and Trade. The CMIC recently published a report on a revised methodology for measuring criticality (Josso, 2023). Across the globe, assessments of mineral criticality are flexible, and are differentiated and adapted to reflect differing national needs and objectives. The CMIC's report reviews existing methodologies, presents a more harmonised approach, and expands the list of proposed UK candidate materials from 26 to 82.

But to attract investment, the UK needs more than a criticality methodology— it needs to display conditions for stability and predictability, and government plays a vital role in providing a reliable concierge service to demonstrate support to business. A panel comprising Eva Marquis (Camborne School of Mines), Richard Williams (Cornish Metals), Nick Pople (Northern Lithium), and Charles Pembroke (ERM), and chaired by Mike Armitage (GSBF), discussed mineral rights, planning and permitting, and developing local infrastructure and utilities. Charles highlighted that over 40% of delayed or failed mining projects in the UK blame issues with planning and permitting, which breeds a damaging uncertainty in the business environment. The panel emphasised how planning regulations should be streamlined (especially for strategic projects), data from geological surveys should be updated and made accessible to the public, and "willpower and funding" from local planning authorities is transformative in corroborating the success of mining projects.

Moreover, the UK is home to world-class universities and research institutions that specialise in geoscience, mining, metallurgy, and materials engineering. Innovation will be key to developing technologies that lower carbon emissions, boost recycling capability, and enable material substitution and novel extraction methods for critical minerals. Dan Smith (University of Leicester), Sheena Hindocha (Innovate UK KTN), Nic Stirk (Materials Nexus), Christian Peters (Seloxium), and

Sabine Anderson (SRK Consulting) discussed the importance of innovation and scientific collaboration in the development of alternative critical mineral supply chains. "Building trust so there is enough information sharing" between different actors and sectors is crucial to addressing this problem, said Christian. Bridging the skills gaps to sustain the UK's place in the global value chain is also essential, yet the UK is currently struggling with a shortage of skills needed across a multitude of disciplines.

Integration & collaboration

New challenges for the critical minerals sector emerge every day. One, for instance, is the rise in popularity of products like disposable vapes that possess lithium-ion batteries, but which are not widely or systemically recycled. Regulations need to be updated to encourage investment in and growth of the recycling industry, as the UK cannot meet the material demands of net zero by primary extraction alone. Panellists Julie-Ann Adams (European Electronics Recyclers Association), Lilia Guittari-Lickovski (Department for Business and Trade), Chris O'Brien (AMTE Power) and Ros Lund (Coal Authority) led a discussion on the current obstacles and opportunities for waste recycling in the UK, including slow permitting times relative to other countries, a lack of production of agglomerates on an economically viable level, and the lack of an end-of-life plan for products reaching the market today. A later panel discussion led by Margery Ryan (Johnson Matthey), and featuring Anna Gibbs (Phillips66), Luke Hampton (Society of Motor Manufacturers & Traders) and Grant Smith (Less Common Metals), also highlighted how current trade and taxation policies in the UK do little to support the use of recycled materials in downstream manufacturing.

"There was a strong emphasis on the importance of ESG"

Lucy Smith (Materials Processing Institute), David Payne (Mineral Products Association), Izzi Monk (Royal Society of Chemistry), Sarah Connolly (Innovate UK) and Jacqui Murray (National Manufacturing Institute Scotland) then turned the discussion to cross-sector collaboration. Lucy emphasised that cross-sector dialogue is not only vital to the achievement of the UK's critical minerals needs, but to the establishment of a circular economy. The panellists illustrated examples of successful collaboration from the site scale with co-production of materials, to the international scale with multinational companies using their influence to create roadmaps for industry. The panel also emphasised that greater transparency and data sharing encourages more collaboration through trust, and illuminates where value can be generated.

In talks around responsible financing, Amanda van Dyke (ARCH Emerging Markets Partners), Fiona Clouder (ClouderVista, Appian Capital Advisory LLP), Christophe Roux (Société Générale), Jamie Strauss (Digbee) and Sarah Gordon (Satarla) celebrated London as an excellent city for finance, with a long history serving as an international economic centre for commodities trading. More recently, London has become a hub for ESG organisations who are driving big transformations in industry. The panel detailed how critical minerals investors can work responsibly and sustainably, for instance by investing in all areas of the minerals value chain.

Throughout the day there was a strong emphasis on the importance of ESG – the acronym was uttered in every presentation and panel discussion. It is increasingly difficult for mining companies to raise funds without exhibiting strong ESG credentials; investors carry out vigilant due-diligence processes to avoid financing projects that will not succeed in the long term. As a result, ESG is the best way to add longevity and value to projects. Speakers also highlighted that investment should be targeted towards countries and communities that are under-developed to precipitate and influence a global shift towards a more resilient and diversified economy, and thus a more sustainable future.

Unanimous was the sentiment that the UK is a country with great promise in growing downstream mineral supply chains. Its impressive research and development and rich industrial history has established chemical and downstream manufacturers for rare-earth elements, graphite and more. Downstream manufacturers are also beginning to interact and work more with raw material producers, something that has seldom happened before, evidencing a change in industry and a shift towards circularity. Though it is impractical for the UK to compete against China on critical minerals, the UK must cooperate with domestic industry and its international allies to onshore and diversify as much supply as possible, to ensure that its critical mineral supply chains are as responsible, transparent, and resilient as they can be. The journey to net zero cannot be pursued half-heartedly.

EILEEN MAES
Critical Minerals Association, UK

This is an edited and modified version of the CMA blog post "CMA (UK) & GSBF 3rd Annual Conference: The UK Opportunity for Critical Minerals", published in December 2023 and available at www.criticalmineral.org/post/cma-uk-gsbf-3rd-annual-conference-the-uk-opportunity-for-critical-minerals

FURTHER READING
A full list of further reading is available at geoscientist.online.

- Department for Business and Trade (2023) Policy paper: Advanced manufacturing plan. UK Government, November 2023; www.gov.uk
- IEA (2022) The Role of Critical Minerals in Clean Energy Transitions. International Energy Agency Publications, March 2022; www.iea.org
- Josso, P. et al. (2023) British Geological Survey Open Report, OR/23/044. 93pp; www.ukcmic.org
- Liu, S. & Patton, D. (2023) China, World's top graphite producer, tightens exports of key battery material. Reuters, 20 October; www.reuters.com
- *The Economist* (2023) Indonesia embraces resource nationalism. *The Economist*, 26 January; www.economist.com

Industrial kimberlite diamond mining in the Kono District, Sierra Leone. Despite existing local knowledge, discovery of diamonds in Sierra Leone has been incorrectly credited to British geologists since the 1930s

Decolonising UK Earth Science

Rebecca Williams, Keely Mills and Anya Lawrence reflect on the recent Decolonising UK Earth Science workshop and how examining our past can shape the future of geoscience

THE FOUNDATIONS of a subject shape the way in which knowledge is created and who is allowed to generate and access this knowledge. The historical roots of modern, western geology lie in early colonial principles; reflecting Europe's colonial expansion throughout the 18th to 20th centuries (Rogers et al., 2022). In the UK, many institutions, including the Geological Society, British Geological Survey (BGS), and several universities, came to prominence during a time when geological exploration for resource extraction was a powerful tool in colonial expansion. The Arts and Humanities and Natural Environment Research Councils (AHRC and NERC) project '*Decolonising UK Earth Science pedagogy – from the hidden histories of our geological institutions to inclusive curricula*' (which ran from January 2022 until October 2023; ukri.org) aimed to collaboratively explore how the foundations of Earth science were built and how this legacy creates modern-day inequity in our discipline. In this context, decolonisation involves an examination of the limitations, biases, and omissions within Earth science curricula, with the aim of creating a more inclusive and just education system. By decolonising Earth science curricula (what we teach) and pedagogy (how we teach), we can work toward dismantling inequity.

In September 2023, the Decolonising UK Earth Science team (www.decolearthsci.com) held a workshop to share insights from the project and invite others to share their experiences. Held at the BGS in Keyworth, Nottingham, the diverse range of speakers included decolonial scholars, historians, and Earth scientists. There were 50 registrants, from the UK and 14 other countries, spanning academia, industry, and the museum sector, including the Society, NERC, BGS, and Royal Geographical Society with the Institute of British Geographers.

Decolonising the curriculum

In a 2020 study, Marín-Spiotta and colleagues argued that any action to increase equity, diversity, and inclusion needs to start with an examination of the historical roots of contemporary exclusion and to specifically acknowledge the colonial past of the discipline. Momentum has been growing over the concept of decolonisation in the UK, with recent calls from scholars, student groups, and activists to decolonise our institutions and curricula. Decolonisation within the geosciences is a wide and growing field; with clear links to many fundamental areas of geoscience, such as mineral exploration, resource extraction, fossil collecting, and geological naming conventions. Partly due to the wide scope of the subject, many Earth scientists are unsure of what decolonisation means for the geosciences.

The 2022 update to the UK

Quality Assurance Agency's Subject Benchmark Statement for Earth Sciences, Environmental Sciences, and Environmental Studies urged these degrees to pay "due regard to decolonising the curriculum, including challenging conceptual frameworks and dismantling subject practices that perpetuate inequities", while the Society's degree accreditation asks that graduates have "global perspectives on the historical development of the geosciences and how these influence the modern discipline". Although there is a documented diversity crisis in Earth science in UK Higher Education (Dowey et al., 2021), Earth scientists of various underrepresented and intersecting identities have always existed; their histories have just been hidden.

Workshop discussions

At the workshop, Steven Rogers (Keele University) placed 'decolonising the curriculum' into the context of geoscience (for full discussion, see Rogers et al., 2022). Decolonising the curriculum is a concept concerned with epistemology (how knowledge was and is produced) and why we include or exclude certain knowledge within our discipline. Knowledge is powerful; excluding certain groups from creating or obtaining knowledge can leave them powerless, thus creating power imbalances that are perpetuated. Decolonising the curriculum is a complicated and varied concept, which is often misconstrued. It does not seek to ban certain works or authors, vilify past individuals, or erase the past. It is also not about looking to diversify for the sake of diversity – decolonising the curriculum is not an extended reading list!

Within geoscience, effectively decolonising the curriculum requires an exploration of the history of our subject in the context of ethics and social justice and recognising other knowledge systems. Alongside interrogating the bias of knowledge production in the Global North, considering global perspectives and indigenous knowledge will deepen geological understanding. Through challenging unethical practices, such as 'parachute science' (whereby science is conducted by researchers from another country with little local involvement) and illegal specimen extraction, we can teach students about land law and →

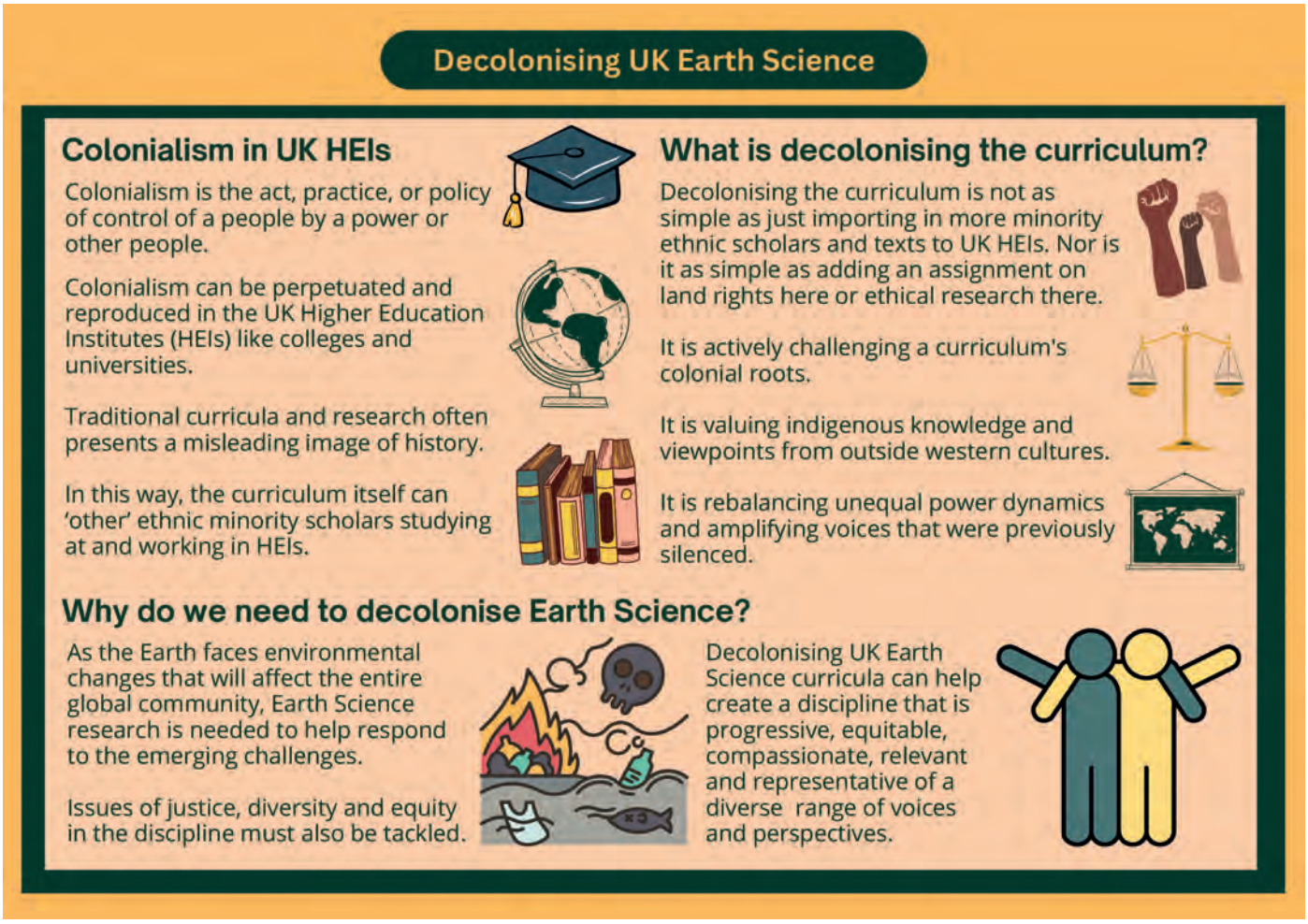

Figure 1: Infographic, which is an excerpt from one of the free educational resources available on the Decolonising UK Earth Science website, aimed at helping Earth science programmes introduce the topic of decolonisation. *(Credit: Anya Lawrence and the Decolonising UK Earth Science project)*

how concepts of land ownership differ. Exploring the historical economic drivers for resource extraction could also train our future geoscientists in responsible, sustainable extraction. As we seek to understand climate change through Earth's history, we can consider how climate change is not apolitical and address it as a social justice and colonial issue. Anya Lawrence (University of Hull) shared open educational resources (produced by the Decolonising UK Earth Science project) aimed at helping Earth science programmes introduce these topics (Fig. 1).

During a reflection session, panellists brought together their various approaches and aspirations for decolonising the curricula in their institutions. We heard from M. Satish Kumar (Queen's University Belfast), whose scholarship is grounded in colonial, postcolonial, and decolonial geographies; Natasha Dowey (Sheffield Hallam University) and Steven Rogers, Earth scientists who have adopted a decolonial approach within their own programmes; and Cassius Morrison (University College London), a palaeontology PhD student. A key theme of the discussion was that of decolonising the curriculum being a reflective process, and not a quick fix or a tick-box exercise. Other disciplines, such as geography, have been considering this concept for much longer than the geosciences and there are important insights to be learned from them. There is a rich literature exploring the links between geography, colonisation, and decolonisation, which has led to a reimagining of the discipline as one with dismantled power structures, fostering more hopeful geographies (Clayton & Kumar, 2019) where we go beyond including diverse voices to reimagining the discipline from diverse perspectives (Radcliffe, 2017). However, geography also reminds us that decolonisation should be radical, committing to anti-racism and taking apart colonial structures and practice to "establish a more progressive discipline" (Esson et al., 2017). The discussion highlighted two important

methods: the co-creation of material with students, which can enrich teaching for both students and teaching staff, and the opening of access to those who have been traditionally excluded from the discipline.

Historical perspectives

During Britain's industrialisation, British geologists were celebrated for their pioneering work and credited with the discovery of economically significant minerals in Africa. Munira Raji (University of Hull, now Plymouth) explored this history, revealing how archival research shows that many of these mineral resources were already used and mined locally and that local knowledge underpinned these resource 'discoveries'. Still, history has omitted the contributions of the Africans involved in these mineral discoveries and the existence of any indigenous geological knowledge. Furthermore, following 'discovery' by colonial powers, local use of these resources often ceased. For example, after the British geologist, Major John D. Pollet, reported the discovery of diamonds in Sierra Leone in 1930, digging for minerals by native Sierra Leoneans was made illegal by the colonial government of Sierra Leone. The government granted exclusive mining rights to the Sierra Leone Selection Trust, a subsidiary of the British-owned Consolidated African Selection Trust (Zack-Williams, 1982; Wilson, 2013). Munira Raji proposed that it is time to change the narrative from one of discovery to one of exploitation.

"As geoscientists, by reckoning with the colonial legacy of our past and its continued perpetuation, we can seek to normalise working with local knowledge, outside the boundaries of (Western) Earth science"

Understanding the past practices of Earth scientists can be key to improving how we behave in the future. Jenni Barclay (University of East Anglia; now University of Bristol) presented findings from the Curating Crises project (https://curatingcrises.omeka.net), which uses the example of volcanic crises in the Eastern Caribbean to explore UK colonial influences on the circulation of geological knowledge. Nick Evans (University of Hull) also argued that debates surrounding the decolonisation of Earth science need to expand their attention to geology beyond 1945, and not be confined to the Imperial era, since the role of geologists in the process of decolonisation post-World War II has received scant scholarly attention. As geoscientists, by reckoning with the colonial legacy of our past and its continued perpetuation, we can seek to normalise working with local knowledge, outside the boundaries of (Western) Earth science. In turn, this could lead to more ethical, equitable, interdisciplinary work, better preparing geoscientists for current global challenges. Keely Mills (BGS) discussed how the BGS is implementing these principles in their policies and ways of working.

Moving forwards

Reckoning with the history and present-day practices of Earth science was challenging, at times uncomfortable. But it also opened a positive discussion of how we can envisage the future of our discipline. Geology has been an important aspect in all global societies and will continue to be in the future. Many communities and cultures, past and present, have deep connections to geological locations, to fossils or minerals. Anjana Khatwa (Wessex Museums) closed the workshop by exploring the myriad ways that people connect to geology and the origins of our relationship with rock, in all its forms. There is much to learn from these connections, and they should give us pause for thought in geological teaching, research, exploration, and exploitation. Then too perhaps we can reimagine a more hopeful, inclusive Earth science discipline.

If these topics interest you, we are building a Decolonising UK Earth Science community. For links to our Discord server, social media, website, and free educational resources, visit: https://linktr.ee/decolearthsci

FURTHER READING
A full list of further reading is available at geoscientist.online.

- Clayton, D. & Kumar, M.S. (2019) J. Hist. Geogr. 66, 1-8
- Dowey, N.J. et al. (2021) Nat. Geosci. 14, 256-259
- Esson, J. et al (2017) Area 49.3, 384-388
- Lam, C. (2021) *Geoscientist* 31 (1), 36-39
- Marín-Spiotta, E. et al. (2020) Adv. Geosci. 53, 117-127
- Quality Assurance Agency for Higher Education (2023) Quality Assurance Agency Subject Benchmark Statement: Earth Sciences, Environmental Sciences and Environmental Studies; www.qaa.ac.uk
- Radcliffe, S.A. (2017) Trans. Inst. Br. Geogr. 42(3), 329-333
- Rogers, S. L. et al. (2022) Geosci. Commun. 5, 189-204
- Wilson, S. A. (2013) *GeoJournal* 78(6), 997-1012
- Zack-Williams, A. B. (1982) Merchant Capital and Underdevelopment in Sierra Leone. Rev. Afr. Political Econ. 25, 74-82

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FOR MORE INFORMATION on the Geological Society Business Forum, visit **www.geolsoc.org.uk**

Shifting focus

Mark Steeves highlights the changing focus of the extractive industries – and the Geological Society Business Forum – in our times

© Wolfgang Stemme from Pixabay

The (now decommissioned) Grohnde Nuclear Power Plant in Germany

SINCE ITS INCEPTION in 2011, the Geological Society Business Forum (GSBF), which aims to raise the profile of the geosciences and Geological Society in the business world, has been almost exclusively focused on the oil and gas industry and city audiences. However, given the complex energy challenges we now face, the GSBF has evolved to focus on energy more generally, and to connect with a wider audience that includes regulators, policymakers and the public more broadly. The GSBF now has a particular interest in energy production and the realities of the energy transition (including the critical minerals and mining required for this). This shift in focus was highlighted during two panel-discussion events on nuclear power and geothermal energy, held in September 2023.

Nuclear power

During the first event, *The Case for Nuclear Power in the Energy Transition*, Wade Allison (Emeritus Professor of Physics, University of Oxford) spoke passionately about the case for nuclear energy, while Mike Crawforth (Business Development Manager, Rolls-Royce) discussed small modular reactors, reminding us that Rolls-Royce has powered the UK's nuclear submarines since 1966 – the technology is well understood. Kirsty Gogan (Terra Praxis), an authority on social and political challenges, and Eluned Watson (Pinsent Masons), an expert on the regulatory environment, led a panel discussion, with wide audience participation. Gogan, with experience in 10 Downing Street during both the Blair-Brown and Cameron-Clegg prime ministerial years, touched on the poor record of successive governments in delivering nuclear power, with negative public perceptions partly to blame. One striking observation, which arose from a shipping conference that Gogan and Crawforth had earlier attended, was that the cruise-going public may change its mind when cruise ships become nuclear powered (which appears to be quite possible).

Geothermal energy

The second meeting, *Geothermal Energy in the Energy Transition*, opened by Mark Ireland (Newcastle University and incoming Chair of the Geological Society Energy Group), included a presentation from Ryan Law (Geothermal Engineering Ltd) on geothermal energy projects in Cornwall, and the wider potential in the UK, and an impassioned presentation from Rani Koya (Anteus Geothermal Ltd) that drew particular attention to the applicability of oil and gas industry strengths, including service industry capabilities, to the geothermal sector. Christian Bauer (Watson Farley & Williams) described the increasingly active geothermal industry in Germany, set against an urgent energy security challenge.

Outlook

A significant take-away message was the potential employment opportunities offered by the energy transition for those engaged in the oil and gas industry. This is particularly true for the geothermal industry – Anteus Geothermal is largely staffed by ex-hydrocarbon professionals. However, while the discussions around our energy future were inspiring, on the other side of the ledger is the impression that the time frames to economic viability and the parochial nature of many geothermal projects will not move the dial away from fossil fuels at the rate we might like.

MARK STEEVES
Director Samphire & Associates Ltd, Co-Founder and Committee Member of the Geological Society Business Forum, Chairman VSA Capital Group, and Chairman EnergyPathways

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The Geological Society Library is a specialised research resource which holds a unique collection of geoscience books, maps and journals, dating from the 16th century to the present day

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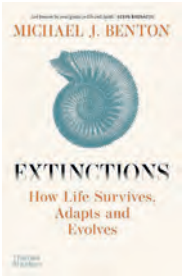
The Geological Society

EXTINCTIONS: HOW LIFE SURVIVES, ADAPTS AND EVOLVES

DETAILS

BY: Michael J. Benton (2023).
Thames & Hudson. 304 pp. (hbk)
ISBN: 9780500025468
PRICE: £25.00
www.thamesandhudsonusa.com



REVIEWED BY NAOMI DAWN

Extinctions – something dark and eerie comes to mind when we hear this word. Most books about extinctions cover what you would expect, detailing the consequences of cascading biogeochemical change or unwanted extraterrestrial rocky visitors on life that existed on our planet in deep time, but not this book. Here, the focus is on life, not death, during this lightspeed journey through its history on Earth.

Benton's brilliant writing style makes the book enjoyable to read for both palaeontology enthusiasts and Earth science novices. If you know all about the big five mass extinctions and hyperthermals already, you will be excited to know that they are painted here with broad brushstrokes only. However, the addition of the most current palaeontological discoveries will keep even the well-informed interested throughout. Benton does this with humour and has a refreshingly modern take on the key scientists who contributed to the field, and the weird and wonderful subjects of their discoveries. A novice, on the other hand, will be awestruck by the sheer scale of the story of life on our planet and how it survived and evolved over and over again, and left with their appetite whet for finding out more.

The overarching message of *Extinctions* is that our knowledge of past hyperthermals and often connected extinction events is the key to understanding the possible effects of anthropogenic climate change on species extant today. However, we are not met with horrifying scenes of a 'dicynodont world' or made to imagine swimming in a 'Strangelove ocean' 'under a green sky' to evoke a sense of guilt and grief. Instead, Benton describes what we know, but lets the audience decide and draw the conclusions. He tells us the science in an understandable manner for non-professional audiences. His story is laced with juicy anecdotes from the history of science and saturated with his genuine love for life, or, as E.O. Wilson would have called it, biophilia. This successfully turns a serious subject into a light read, which will no doubt resonate with every reader. *Extinctions* empowers the reader to act instead of paralysing them, and highlights the relevance of the Earth sciences in tackling one of the most pressing problems of our time.

THE LEWISIAN: BRITAIN'S OLDEST ROCKS

DETAILS

BY: Graham Park (2022).
Dunedin Academic Press. 336 pp. (hbk)
ISBN: 9781780460987
PRICE: £40.00
www.dunedinacademicpress.co.uk

REVIEWED BY CHRIS HAWKESWORTH

There is a particular interest in old rocks: whether they record different geological processes to the present and whether we can approach them in similar ways to younger rocks. Britain's oldest rocks, the Lewisian, are excellently exposed in the northwest corner of Scotland. They have been studied for two centuries and have often been at the forefront of debates about early Earth history. Park has been actively researching the Lewisian for over 60 years and, using his experience, this book reviews the progression of ideas on the Lewisian since the early 19th century.

The book addresses the early pioneers of Lewisian geology, data collection methods, and the development of models, which were, in turn, tested against the geological record. It covers many different areas of geology, from the role of igneous events, such as the Scourie dykes, in establishing the relative ages of different episodes, to the effect of the quantification of structural analysis in the 1950s. The application of geochemistry in constraining whether Laxfordian gneisses represented metasediments or a volcanic origin, and early analyses of Rare Earth Element patterns in gneisses are examined. A long-standing debate over the origin of layering in gneissic terranes being primary or the product of deformation is also detailed.

Radiometric dating revolutionised Earth science and it had a critical role in studies of the Lewisian, from the development of Ar dating in the 1950s, through to increasingly precise Pb-Pb and U-Pb geochronology. The final chapters provide a useful review of the present state of geochronology in the Lewisian and the advances in palaeomagnetism that allowed the Lewisian of northwest Scotland to be linked with other fragments of ancient crust.

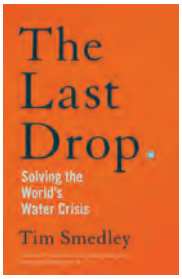
The Lewisian remains a classic area that provides a record of the evolution from granite-greenstone terranes to assemblages consistent with crustal thickening and plate tectonic processes. It has been influential in the development of ideas about Archaean geology, and fully warrants this history of the people, ideas, and controversies involved in Lewisian geology. The author is to be congratulated on his sure handling of these debates and discussions. The book is excellently presented, with a good balance of field photographs and clear and accessible diagrams. It is a welcome contribution for those interested in the development of ideas in Archaean geology and the part played by the rocks of northwest Scotland over the last 200 years.

→

THE LAST DROP

DETAILS

BY: Tim Smedley (2023).
Pan Macmillan and Picador. 416 pp. (hbk)
ISBN: 9781529058147
PRICE: £20.00 www.panmacmillan.com



REVIEWED BY RICHARD DAWE

Water stress is increasing worldwide, with pollution leading to water quality issues, over-abstraction leading to reservoirs drying out, and water shortages creating millions of climate refugees. In *The Last Drop*, journalist Tim Smedley explores water crises and their mitigation. Many issues arise through human mismanagement of water sources, the unpredictability of rain causing floods or droughts, and unsustainable groundwater pumping, often for agricultural needs. Smedley emphasises that the world isn't running out of water but that we are running out of potable water. Of the 1.4 billion km³ of water on Earth, 97.5% is seawater and, therefore, unfit for human consumption. Less than 0.5% is freshwater, with household tap water making up just 1% of this. Half a billion people already face severe water scarcity annually, which will worsen as global population grows. Hence, this book is timely.

Smedley interviews water experts, activists, and victims of water scarcity to tease out the problems and potential solutions. In the first half of the book, Smedley travels to Jordan, Ghana, the US, and elsewhere to explore the often-dire state of the situation. The second part of the book gives glimpses of hope. In Britain, creative farming practices, such as no-till and cover crops, could utilise the fact that soil holds eight times more water than all the world's rivers. Beaver rewilding also has the potential to enlarge wetlands. However, in India, China, the US, and South Africa, many major aquifers are diminishing, and more are sounding like growing disasters. Could seawater desalination be the saviour? Or would this exacerbate the ecological nightmare due to coastal effluent discharging? Smedley suggests that water capture from the humidity in the air could supply huge volumes of potable water, and that solar panels on the surfaces of water reservoirs, which could simultaneously slow down evaporation and generate electricity, might be beneficial.

Smedley emphasises that water (mis)management is often controlled by political and human greed and, now increasingly, changes in climate. He demonstrates vividly that looming global water scarcity will be disastrous for all, and we need novel ideas, good governance, and sustained political will. Repairing leaks, accurate metering, rainwater harvesting, rewilding, and native tree planting are possible directions. *The Last Drop* is essential reading for students, commentators and, in fact, all who want to become well-informed on the growing water crisis.

THE GREAT ORDOVICIAN BIODIVERSIFICATION EVENT

DETAILS

BY: A.W. Hunter, J.J. Alvaro, B. Lefebvre, P. Van Roy, & S. Zamora (eds.) (2022). Geological Society of London Special Publication No 485. 272 pp. (hbk)
ISBN: 9781786204073
PRICE: £160.00 (£80.00 for Fellows, £96.00 for other societies) www.geolsoc.org.uk

REVIEWED BY GORDON NEIGHBOUR

This weighty tome describes and elucidates the importance of the Great Ordovician Biodiversification Event, which occurred approximately 40 million years after the Cambrian Explosion. It brings to life the major changes that took place to the ecosystems and the replacement, albeit gradual, of a very distinctive Cambrian fauna. The book concentrates on a small area of the Anti-Atlas Mountains in Morocco, as such, it can only be seen as giving an overview of important biota and its importance in understanding the Great Ordovician Biodiversification Event.

As always with publications from this publisher, it is a multi-author book that has been edited by experts in the field. The papers presented are an excellent mixture of the geology of the area, detailed taxonomic overviews of the biota, and (for me, the most important chapter of all) the fossil trade from the area. The latter is something that needs to be discussed and may, at times, make for uncomfortable reading. However, it is important that we help countries preserve their rich geological heritage and find ways of supporting the populations in these areas. It is vital that we all, as professionals, support the development of workable legal frameworks for the advancement of our understanding. Indeed, seeing the excellent preparation of some of the fossils is a tribute to the artisan workers who specialise in this area.

The quality of the papers is superb. The diagrams and photographs are a standout feature of the book; their clarity brings the text to life and it is commendable to see the use of colour, which serves to enhance the experience for the reader. It discusses a wide variety of taxa, so one can follow one's own interests, for instance, the trilobites of the region, but also understand a certain taxa's place in the wider palaeodiversity of the area. Following on from the Cambrian Explosion, this is a valuable time for the biodiversification of our planet and it deserves a wide readership.

This book is an invaluable asset and contribution to our understanding of the Great Ordovician Biodiversification Event. It acts as a superb memorial to the work of Jacques Destombes, who provided the first detailed biostratigraphic framework for the Lower Ordovician of the Anti-Atlas. This is an excellent book and I cannot recommend it highly enough.

ROBIN COCKS (1938 – 2023)

A world-renowned brachiopod expert with an unparalleled legacy of taxonomic work

BY RICHARD FORTEY, LARS HOLMER, AND LEONID POPOV

*(Adapted from the original obituary: Fortey, R., Holmer, L. & Popov, L. (2023) BrachNet; **http://paleopolis.rediris.es/BrachNet/ANNONCES/OBITUARIES/Cocks.htm**)*

Pictured, above: Robin Cocks' contribution to brachiopod research was immense. Photo courtesy of Mark Cocks.

LEONARD ROBERT MORRISON "ROBIN" COCKS was arguably the world's most distinguished student of brachiopods, and his death on 5 February 2023 deprives the scientific world of a lifetime of expertise. During his many years at the Natural History Museum, Robin rose to become Keeper of Palaeontology (1986-1998). He never lost his enthusiasm for science, indeed, he was still working on new papers weeks before he died.

Brachiopod expert

Robin was educated at Felsted School before completing his National Service in Malaysia. After completing his geology degree at the University of Oxford, Robin completed a DPhil (1965) on Silurian rocks and fauna, supervised by Stuart McKerrow, who later became a friend and colleague. In the same year, Robin was employed by the British Museum (Natural History) (now the Natural History Museum) as Scientific Officer, studying the Palaeozoic and Mesozoic with Howard Brunton and Ellis Owen.

By the mid-1990s, Robin had become an expert on Ordovician and Silurian brachiopods, and eventually claimed to have named a new genus for every letter of the alphabet. His compass extended globally, from a secure base in the Silurian of Britain, to a series of papers on the Ordovician of Kazakhstan with long-term collaborator, Leonid Popov. Robin also became a central figure in the debate on the Silurian-Devonian boundary. A definitive volume of the *British Museum Bulletin*, edited by Robin in 1990, helped secure the international retention of the British names of the chronostratigraphic Silurian subdivisions.

A theme of Robin's research was palaeogeographical reconstruction using brachiopods and trilobites together to give new insights into the signatures of ancient continents and their margins. In the late 1990s, Robin worked with Trond Torsvik, whose computer modelling advanced palaeogeography understanding. The collaboration was summarised in a 2017 book that has already become indispensable to geologists globally. Robin also gathered specimens of the type species of brachiopod genera and made huge contributions to the *Treatise on Invertebrate Paleontology* on brachiopods.

Robin served many academic societies and international committees. On the palaeontological front, he is the only person who has been president of all the appropriate British learned societies. Robin served as president of the Palaeontological Association (1986-1988), president of the Palaeontographical Society (1994-1998), president of the Geological Society of London (1998-2000), and president of the Geologists' Association (2004-2006). Internationally, he was a voting member of the Silurian Subcommission of the International Union of Geological Sciences for many years and a Commissioner of the International Commission on Zoological Nomenclature for two decades.

Robin's contributions were recognised by the Geological Society by the award of their Coke Medal in 1995, the Dumont Medal of Geologica Belgica in 2003, and the Lapworth Medal of the Palaeontological Association in 2010. He was awarded an OBE in 1999.

Devoted family man

Robin coped with health problems that might have deterred a lesser soul. He underwent treatment for a facial cancer in 1984, then a jawbone replacement in 2006. Unfortunately, the latter caused secondary problems, including nerve damage and voice projection, all of which he ignored with great courage. Robin did not allow health impediments to interfere with his research, if anything, the brachiopods and palaeogeography kept him going. Away from work, he was a devoted family man and is survived by his wife Elaine (née Sturdy), three children, and eight grandchildren.

IN MEMORY OF...

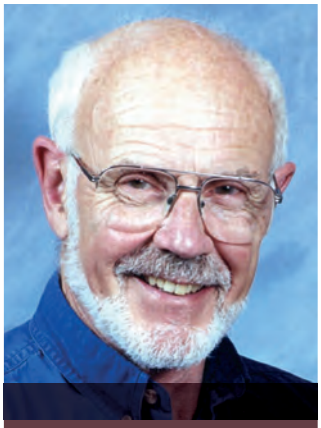
The Society notes with sadness the passing of:

- Balme, Basil E
- Blundell, Derek J
- Boylan, Patrick
- Brown, James
- Gee, David
- Gibson-Robinson, Christopher
- Golightly, Christopher
- Gossage, David
- Griffin, David Leon
- Lello, Alan Clive Nodes
- Leney, Peter
- Rainey, Tasman Paul
- Roach, Robert
- Rogers, Allan
- Rowell, Albert John
- Strachan, George
- Thomas, Ian Ashley
- Thomas, George Matthew
- Uyeda, Seiya
- Wells, Alan James
- Wright, Alan Edward
- Wright, Andrew
- Wright, Hedley
- Wright, Philip

ALBERT JOHN ROWELL (1929 – 2023)

Palaeontologist, curator, and teacher who contributed greatly to the scientific community

BY DAVID J. MCBRIDE, KEVIN R. EVANS, BRUCE S. LIEBERMAN, AND FEDERICO F. KRAUSE



Pictured above: Albert John Rowell was an exceptional teacher, valued as a mentor to his students for his thoughtfulness. Photo courtesy of Alison Nye.

ALBERT (BERT) JOHN ROWELL, Emeritus Professor of Geology, University of Kansas, and Emeritus Curator of Invertebrate Palaeontology, KU Biodiversity Institute and Natural History Museum, died at home on 28 September 2023 in Lawrence, Kansas at the age of 94.

Bert was born in Ely, Cambridgeshire, UK. He graduated from the University of Leeds with a BSc in Mining Engineering with First Class Honours in 1950 and a PhD in Geology in 1953. Between 1953 and 1955, he completed two years of National Service with the Corps of Royal Engineers and was deployed to Kenya as a troop commander.

His teaching career began at the University of Nottingham as Assistant Lecturer in Geology (1955), Lecturer (1956-1964), and Reader (1964-1967). From 1964 to 1965, Bert was a Visiting Professor at the University of Kansas. In 1967, he accepted the positions of Professor of the Department of Geology and curator of the invertebrate palaeontology division, KU Biodiversity Institute and Natural History Museum. In 1990, he was a visiting scientist with the British Antarctic Survey and Bye-Fellow of Robinson College, University of Cambridge. He retired in 1995.

Exceptional teacher

Bert was an exceptional teacher and mentor. His teaching was recognised in 1973 with the university-wide "Outstanding Classroom Teaching" award from Standard Oil (Indiana). He served as Chair of the graduate studies committee for the University of Kansas' Department of Geology for several years.

A highly successful researcher, Bert was continuously funded as a Principal Investigator by the National Science Foundation from 1968 to 1996. These grants supported studies in Antarctica, Newfoundland, and the Western US. Bert published more than 89 papers and was a principal author and editor for the first two-volume set of the *Treatise on Invertebrate Palaeontology for the Phylum Brachiopoda*. Likewise, he co-authored and co-edited the textbook *Fossil Invertebrates*. His published research topics include brachiopod systematics, development, ecology, and evolution; Cambrian stratigraphy and tectonics; Antarctic geology; and glacial geology of the English countryside.

“Bert’s research was funded by the National Science Foundation, which supported studies in Antarctica, Newfoundland, and the Western US”

Contributions

Bert served in key roles at the National Science Foundation including member of the Antarctic Earth sciences working group (1994-1997; Chair 1994-1996); member of the polar Earth sciences panel (1993); member of the Earth sciences advisory committee (1980-1982); member of the geology program panel (1979-1982; Chair 1980-1982). He served as editor of the *Journal of Systematic Zoology* (1971-1973); member of the International Geological Correlation Program working group for the Precambrian-Cambrian boundary (1978-1994), and Cambrian subcommission of the International Commission on Stratigraphy (1974-1995); and Associate Editor of *Lethaia* (1980-1991) and *Palaeobiology* (1978-1983). He was a Senior Fellow of the Geological Society of America and Fellow of the Geological Society of London. In 2000, he evaluated four research institutes for the Greek Ministry of Development. Following retirement, Bert made his eighth visit to Antarctica with Ohio State University.

Bert is survived by Marge, his wife of 69 years; daughter, Alison Jane Nye (Jim); son, Gareth Alwyn Rowell (Millisa); five grandchildren; six great-grandchildren; and his brother, Jack Allan Rowell. Bert was preceded in death by his sons, Ian and Colin, and granddaughters, Sally and Mhari.

↘ Contact

If you would like to contribute an obituary, please email the editor geoscientist@geolsoc.org.uk

↘ Roll of Honour

Deceased Fellows have their names and dates recorded in a Roll of Honour at www.geolsoc.org.uk/obituaries

"Embrace the uncertainty"

Listen to the extended podcast interview at Geoscientist.Online

→ DR KEVIN WONG is a Research Fellow at Deep Carbon Lab, University of Bologna, Italy

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Tell us about your research

I create computer simulations to determine the amount of hydrogen and methane gas being produced in the mantle from chemical reactions that happen between rocks and water. As a geochemist, I'm curious about the mantle; it's 30 km deep, which means that it's mostly inaccessible to us. There are two main philosophies geoscientists have for understanding the mantle. The first is to look at mantle rocks. Sometimes during tectonic processes, mantle rocks are brought up to the surface to form ophiolites, which we can study. This method is more top down. Conversely, my approach is based on past experiments that determined how different minerals behave under different temperatures and pressures. We now have numerical models based on the thermodynamic behaviour of these minerals, which I use to estimate how rocks behave under mantle pressures and temperatures, in a more bottom-up approach. The aim of my research group, Deep Carbon Lab, Bologna, is to tackle questions from these two different directions and hopefully end up somewhere in the middle. We can see where our models meet the actual rocks and what this can tell us.

What can we learn from researching mantle hydrogen and methane?

My research group received a European Research Council grant for the DeepSeep project in 2019 and formed the Deep Carbon Lab. We are particularly interested in hydrogen and methane generation. Methane is commonly found in natural gas, and there has been much discussion recently about hydrogen being used as a potential fuel for cars. In addition to being an anthropogenic source of energy, these two gases also act as sources of energy for microbial life. If you imagine a time in the past when Earth didn't have any oxygen in its atmosphere, all life on Earth had to "breathe" in the absence of oxygen. We believe that these forms of microbial life used gases such as hydrogen or methane as potential sources of energy. This microbial life may still persist today, particularly in settings such as mid-ocean ridges, but also in subduction zones. Understanding the reactions between mantle rocks and subduction zone fluids is therefore important for understanding the extent to which life may exist in the so-called deep biosphere, but also for understanding how life on Earth initially came to be.

What advice would you give to aspiring researchers and geochemists?
Embrace the uncertainty. My field of geochemistry has inherent error because we cannot directly access the mantle. As I build my computer models, I always question myself. But then I remember that no one has done this before, and that relaxes me. I start realising that whatever results I generate are brand new. These are brand new settings and rocks that we're modelling – it's best to hang on to that excited feeling.

Pictured above: Dr Kevin Wong, Research Fellow at Deep Carbon Lab, University of Bologna

What's your favourite thing about your research?

The implications my findings might have for early life. It's quite cool thinking about how the reactions I'm looking at might have been the driver or the energy source for the earliest forms of life on Earth. Another aspect I enjoy is that there is little research in this field. People have looked at geochemical reactions happening at mid-ocean ridge settings, such as the Lost City hydrothermal field in the Atlantic Ocean. However, the kind of subduction zone settings that I am looking at, which occur much deeper in Earth, have only been a subject of intense study since we received the research grant. The novelty of the field itself is something that keeps me working every single day.

From an Idea to a Published Issue

Every year, *Elements* publishes six thematic issues on subjects related to the general disciplines of mineralogy, geochemistry, and petrology. The editorial team looks for topics that

- are broadly related to mineralogy, geochemistry, and petrology
- are interdisciplinary
- represent established but progressing fields
- would be of interest to a broad cross section of readers
- have not been adequately represented by *Elements* before or have advanced considerably since the topic was previously covered

Each proposal is carefully evaluated by our editorial team for thematic scope, content, and authorship. Feedback is then provided to the proposers.

Once a proposal is accepted and included in the *Elements* lineup, the fun really begins! Over the subsequent 15–20 months, timelines and deadlines are set, authors are invited by the guest editors to write articles, and articles go through several stages of review (by external reviewers, by the guest and principal editors, and by the *Elements* editorial team). At the end of this process, the issue goes to press and is shipped to our over 16,000 readers.

Elements
An International Magazine of Mineralogy, Geochemistry, and Petrology

The journey from an idea to a published magazine involves many steps. The goal? A lineup of well-written thematic issues that readily conveys the exciting aspects of mineralogy, petrology, and geochemistry to specialists and non-specialists alike.

Call for Thematic Proposals

Would you like to read about a certain topic in *Elements*?
Do you think your research area would make a great thematic issue?

Submit a thematic proposal!

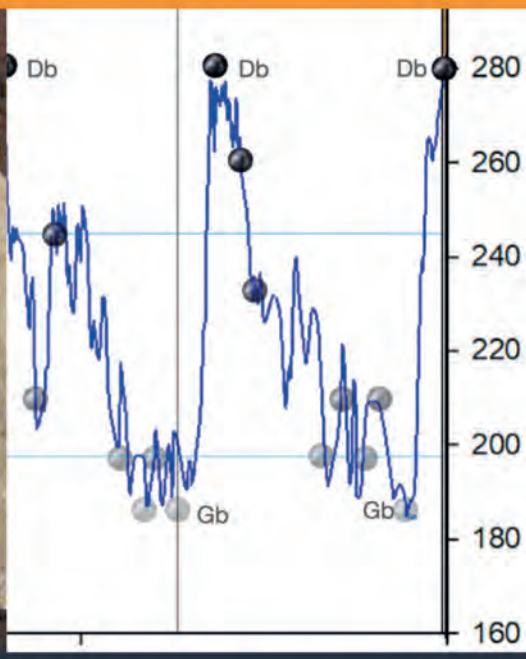
Elements has two annual submission deadlines each year:
February 25 and **August 25**.

For more information, visit:
http://elementsmagazine.org/publish-in-elements/.

We look forward to receiving your proposal!

Elements is jointly published by:

Conferences and events



17 - 18 September 2024

Earth's Canvas: Exploring Geology in Creativity

Organisers

Emma Jude - Fine Artist, Geologist
Lucy Williams - Rockhopper Exploration
Patrick Corbett - Scottish Centre for Geopoetics
Peter Dolan - Dolan & Associates Ltd
Steve Garrett - Musician, Earth scientist
Elisha McCowan - Geological Society
Emelia Spofforth Jones - Geological Society

Further Information

W: www.geolsoc.org.uk/09-Earths-Canvas
E: conference@geolsoc.org.uk
T: +44 (0) 207 434 9944
A: Conference Office, The Geological Society, Burlington House, Piccadilly, London, W1J 0BG, UK

Follow the event on Social Media: #GSLEarthsCanvas

What is it?

This unique 2 day event hosted at Burlington House, London, will bring together scientific and artistic disciplines to explore the impact of geology on creative observation, articulation, expression and outreach.

In-person presentations and performances will run in parallel with skills workshops along the following themes:

- Art, sculpture, illustration and installation
- Poetry and literature
- Music, song and sound

Cross-disciplinary presentations are also most welcome.

We hope that artists will share their creative process - from geological inspiration to final work - through presentation, Q&A or text; and that the event will inspire new connections and creations.

Banner image credit in order: Emma Theresa Jude, Words by Alyson Hallett carved by Alec Peever, Steve Garrett

How do I register?

Register to attend today at
www.geolsoc.org.uk/09-Earths-Canvas

Members of the Geological Society can access preferential rates which can be applied on top of the group booking discount. Book as a group and access up to 20% off.

Bursaries are available to help fund attendance for creators.

The Geological Society