EXPANDING HORIZONS
THE GROUND ENGINEERING INSAR REVOLUTION

CITIZEN SCIENCE
Breathing fresh life into geoscience

FRESH GROUND
Finding Earth science in a coffee cup

SUBSURFACE SCIENCE
Subsurface research labs and net zero

SOCIAL VOLCANOLOGY
Q&A: the Saint Vincent eruption
SPACERACES
Postcards from our solar system

20 Aug to 8 Oct
9am - 6pm

A free Geological Society exhibition
www.geolsoc.org.uk-space21

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As I write, a helicopter just took off and landed on Mars. A helicopter! On Mars! Stories like this make me think of a response I saw once – I’ve long forgotten when and who from – to a complaint about the lack of wifi on a long-haul flight. “You’re sitting in a chair, thousands of feet above the ground, travelling at hundreds of miles an hour – and you’re unhappy about the wifi?”

It’s easy to take science and its miracles – I do think we can call them that, the true, real-world miracles of the modern era – for granted. Never more so than in the past year, when we’ve witnessed the extraordinary development of coronavirus vaccines at vastly accelerated speeds in what, to my mind, is one of the most amazing scientific achievements of our age.

Meanwhile, back on Earth, further changes, down to millimetres, on the development and potential of InSAR – a radar technique with the potential to measure millimetre-scale changes in deformation, with applications ranging from monitoring of natural hazards to tunnelling projects. Like the figure sitting in a chair in the sky, worrying about wifi, it’s incredible to think that there are satellites beyond the Earth’s atmosphere with the ability to detect the tiniest changes, down to millimetres, on the Earth’s surface.

And now they’ve gone and flown a helicopter on Mars.

In our summer issue, Jennifer Scoclar and colleagues report on the development and potential of InSAR – a radar technique with the potential to measure millimetre-scale changes in deformation, with applications ranging from monitoring of natural hazards to tunnelling projects. Like the figure sitting in a chair in the sky, worrying about wifi, it’s incredible to think that there are satellites beyond the Earth’s atmosphere with the ability to detect the tiniest changes, down to millimetres, on the Earth’s surface.

Meanwhile, back on Earth, further miracles are occurring. The UK’s vaccination programme continues at pace, promising news of a malaria vaccine has just broken, and the Biden administration has announced that the US will work to halve emissions by 2030. Optimism seems to be in the wind – I’m writing this outside a café, in the real world, wearing sunglasses! Underneath it, though, there remains a ripple of uncertainty and unease. The pandemic continues to spread rapidly in many parts of the world, and our hesitant emergence from months of lockdown feels fraught with uncertainty, as well as optimism, about what lies ahead.

Fellows may well be feeling a similar mix of optimism and uncertainty in relation to their Society and its future. In the last issue, we reported news of the Society’s campaign to remain at Burlington House, where we’ve been based since 1874. The situation remains unresolved, and with it, as reported in this issue, comes uncertainty over a future home for our extensive and valuable Library collections. At the same time a new Open Access Journal, a vibrant programme for the 2021 Year of Space, the reopening of our Library to visitors and a whole host of other good news stories in this issue speak to an optimistic future.

There’s been a lot of changes to this magazine as well – and we’re grateful to all of you who’ve taken the time to get in touch with us with feedback.

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There’s been a lot of changes to this magazine as well – and we’re grateful to all of you who’ve taken the time to get in touch with us with feedback, from enthusiastic thumbs up to constructive suggestions. Rest assured, we’re taking the latter on board, and we’re delighted by the former! In the meantime, don’t forget an important part of our role as an editorially independent magazine is to provide a forum for Fellows to feedback to the Society more broadly – if you have any questions, concerns or comments about any of the above, please do get in touch.

SARAH DAY, EDITOR
BECOME A FRIEND TODAY!

Friends of the Geological Society membership is open to all amateur, non-professional geologists. Become a member of the oldest geological society in the world. Support our mission to educate, inspire and inform about the Earth sciences, and learn about our exciting projects and the new research being done to address the intellectual and practical challenges of the 21st century.

Benefits include:
- Free access to the Fellows’ lounge in Burlington House
- Use of the Library for reference purposes
- Discounts on books and special publications
- A quarterly copy of Geoscientist magazine
- Access to Regional Group activities

For the full list of benefits and membership rates visit:
www.geolsoc.org.uk/friends

The Geological Society of London is a registered charity No 210161
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Spacescapes: postcards from our solar system

A free, outdoor, public exhibition is coming to the Burlington House Courtyard this summer!

We are incredibly excited to announce that this summer the Geological Society will be holding a free, outdoor, public exhibition at Burlington House as part of our 2021 Year of Space. ‘Spacescapes: postcards from our solar system’, will feature incredible, high-definition images of the landscapes and geological features seen around our solar system. The exhibition will open on Friday 20 August and will run for seven weeks, until Friday 8 October, with opening times of 9am until 6pm daily.

Let us take you on a journey through our solar system, stopping off to visit the Perseverance rover on Mars, impact craters on the Moon, mountains on Pluto and storms on Jupiter.
The exhibition will explore the ways in which understanding Earth can help us uncover the history of planetary bodies across our solar system and beyond. By comparing Earthly geological features with similar vistas found on other planets, we can piece together the history of the solar system and look to answer some of the mysteries of our universe.

Many of the landscapes on other planets appear alien compared to the environments we are familiar with on Earth. But if we look closely, we can recognise Earth-like features that we can study and interpret. Just like on Earth, rivers run into seas, mountains rise up from horizons, and vast plains are dotted with volcanoes or meteorite craters. Yet, as we travel further into space, mountains are composed of ice; rivers flow with liquid methane, rather than water; and volcanoes reach heights of 25 km, dwarfing Earth’s tallest volcano.

Throughout the history of space exploration, we have sent missions and probes to a staggering eight planets in our solar system, as well as numerous missions to the asteroid belt and other planetary bodies. Today, our ability to send automated rovers to Mars has ushered in an exciting new era for space exploration. The ability to collect and analyse Martian air and soil samples remotely from Earth, or on Earth in the future, is the true frontier of space science. These ground-breaking missions help us observe and understand processes on distant planets like never before.

The similarities and differences between our world and others are what enable planetary geologists to understand how other planets formed and have changed over time. Whether it’s volcanoes on Venus, storms on Jupiter or ice caps on Mars, prepare to be spellbound by the images in this unique display. We invite you to come along, take a selfie with NASA’s Perseverance Mars rover and learn about the fascinating features of our planetary neighbours.

Flo Bullough (Head of Policy and Engagement), Megan O’Donnell (Communications and Policy Officer), Rose Want (Education Officer), Alicia Newton (Director of Science & Communications) & Jenny Boland (Head of Development)
**Annual General Meeting**

THE AGM will be conducted virtually again this year on **Friday 25 June 2021**.

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

**AGM agenda**
- Apologies
- Minutes of the Annual General Meeting held on 4 June 2020
- Appointment of Scrutineers for the ballots for Council and Officers
- Ballot for Council
- Annual Report and Accounts for 2020
  - President’s Report
  - Secretaries’ Reports
  - Treasurer’s Report
- Comments from Fellows
- Report of Scrutineers on the ballot for Council
- Ballot for Officers
- Revised Fellowship category and fee structure proposals
- Deaths
- Appointment of Auditors
- Report of Scrutineers on the ballot for Officers
- Any other business

Provisional date of next Annual General Meeting: **7 June 2022**

Information on how to register to attend the AGM will be sent to all Fellows for whom we have a registered email address. If you do not receive an email or if you would like further information on how to register, please email christina.marron@geolsoc.org.uk

**President’s Day update**

**THE SOCIETY ANNOUNCED** the winners of its medals and funds for 2021 in the Spring edition: Prof David Pollard (Wollaston Medal); Prof Nicholas White (Lyell Medal); Prof Graham Pearson (Murchison Medal); Dr Philip Christie (William Smith Medal); Prof Sanjeev Gupta (Prestwich Medal); Prof Kenneth McCaffrey (Dewey Medal); Prof Chris Jackson (Coke Medal); Dr Helen Reeves (Coke Medal); Dr Sheila Peacock (Distinguished Service Award); Dr Anjana Khatwa (R H Worth Award); Prof Marie Edmonds (Bigby Medal); Dr Caroline Gill (Aberconway Medal); Dr Emma Liu (Wollaston Fund); Dr Luke Parry (Lyell Fund); Dr Andrew Thomson (Murchison Fund); Dr Fabian Wadsworth (William Smith Fund); Dr Finnigan Illsley-Kemp (President’s Award); and Dr Jazmin Scarlett (President’s Award).

The Awards will be presented at President’s Day on 25 June 2021 in a virtual ceremony. The presentations will be followed by talks from some of the medallists (see information box below). All Fellows are welcome to attend the events of President’s Day, in whole or part.

**REGISTRATION:**
The link for registration is available on the Awards pages of the Geological Society website and in our newsletters. Alternatively, please email christina.marron@geolsoc.org.uk

**PRESIDENT’S DAY 25 JUNE 2021**

3.30pm-4.45pm BST – Awards Ceremony

5pm-6.30pm BST – Senior medalists talks: Prof Graham Pearson (University of Alberta, Canada); Prof Nicholas White (University of Cambridge, UK); and Prof David Pollard (Stanford University, USA)

**FUTURE MEETING DATES**

**ORDINARY GENERAL MEETINGS:** 30 June 2021, 22 September 2021, 24 November 2021, 2 February 2022, 20 April 2022, 8 June 2022

**COUNCIL:** 30 June 2021, 22 and 23 September 2021 (residential), 24 November 2021, 2 February 2022, 20 April 2022, 8 June 2022

**NOTIFICATION OF OFFICERS FOR 2021/2022**

At the AGM, Fellows will be asked to elect the following members of Council as Officers for 2021/22:

**President:** Dr Michael Daly
**Vice-President:** Jessica Smith
**Secretaries:** Prof James Griffiths, Prof Robin Strachan, Dr Alexander Whittaker

**Secretary, Foreign & External Affairs:** Dr Joel Gill
**Treasurer:** Dr Keith Myers
SOCIETY’S AWARDS 2022: INVITATION TO NOMINATE

FELLOWS OF THE SOCIETY are invited to submit nominations for the Society’s awards for 2022.

We are committed to ensuring diversity of our awardees and expanding the demographics of those put forward for our medals and funds. We are particularly keen to receive nominations for the funds that recognise excellent contributions by early career scientists.

There is one standard nomination form for all of our awards with the exception of the President’s Award, which has its own form. Please visit: www.geolsoc.org.uk/About/Awards-Grants-and-Bursaries/Society-Awards

The guidance documents and PDF booklet give the criteria and explain how to go about nominating a person you feel is deserving of a Society award. If you have any further questions, please contact christina.marron@geolsoc.org.uk

ANNUAL FELLOWSHIP SUBSCRIPTIONS FOR 2022

AT ITS MEETING ON 7 APRIL, Council agreed a new Fellowship category and fee structure to be recommended for approval at the AGM. The details of the fee structure will be provided in the AGM papers that will be available in early June. A separate email communication will also go out to Fellows.

Since 2015 the annual increase in Fellowship Fees has been set with reference to the prevailing annual rate of Consumer Price Index (CPI) inflation when proposals are considered for the following year in March and April. The Consumer Prices Index (CPI) rose 0.7% in the 12 months to January 2021, but Council has recommended that there be no increase in 2022 in recognition of the challenging year and financial circumstances for many.

ELECTION RESULTS

THE ADVISORY BALLOT for Council, conducted by Civica Election Services, closed on 31 March 2021. The turnout was 20.4%.

A total of 2,173 valid votes were cast in favour of Ruth Allington for the role of President and her name will now go forward for election at the Annual General Meeting on 25 June 2021.

A total of 2,132 valid votes were cast for the other seven vacancies on Council. Of the 14 candidates who took part, the seven who received the most votes will go forward to the Annual General Meeting for election as Council members. These are:

<table>
<thead>
<tr>
<th>CANDIDATES</th>
<th>NO OF VOTES</th>
<th>% OF TOTAL VOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lucy Thomas</td>
<td>1,587</td>
<td>74.4%</td>
</tr>
<tr>
<td>Amanda Owen</td>
<td>1,195</td>
<td>56.1%</td>
</tr>
<tr>
<td>Martin Griffin</td>
<td>1,028</td>
<td>48.2%</td>
</tr>
<tr>
<td>Mark Allen</td>
<td>952</td>
<td>44.7%</td>
</tr>
<tr>
<td>Keith Myers</td>
<td>920</td>
<td>43.1%</td>
</tr>
<tr>
<td>Pete Loader</td>
<td>900</td>
<td>42.2%</td>
</tr>
<tr>
<td>Neil Frewin</td>
<td>749</td>
<td>35.1%</td>
</tr>
</tbody>
</table>

Andrew Dobrzanski, Tim Good, Benjamin Lepley, David McNamara, Stuart Mills, David Neave and Paul Winrow were unfortunately unsuccessful in this year’s Council ballot. We thank them for their interest in serving on Council and hope that they will consider reapplying on a future date.

We also warmly thank the Council members standing down at the next AGM: Tom Backhouse, Dr Andrew Bloodworth, John Booth, Graham Goffey, Prof Chris King, Prof Bryne Ngwenya, Mr Nik Reynolds and Dr Helen Smyth.

*Full results available on request

RESEARCH GRANTS 2021

THE RESEARCH GRANTS Committee met on 25 March and considered 12 applications from Fellows and non-Fellows. The committee agreed the award of 10 Society grants totalling £17,510, including the Robert Scott Memorial Award to one applicant. The Society is very grateful for the contributions made by the Jeremy Willson Charitable Trust, the Jeremy Ingham Fund and the Robert Scott Memorial Award. The Committee also considered the shortlisted applications from Fellows for the Zeiss-GSL scholarship with the 2021 scholarship being awarded to Kelsey Archer Barnhill. The Society is very grateful for the sponsorship of Zeiss GmbH. A full list of winners is available online. The Society offers its warmest congratulations to all the recipients.
Discovering forgotten histories

Cynthia Burek and Bettie Higgs, editors of the Society’s latest Special Publication, chat with Bethan Phillips, Commissioning Editor, and Lucy Pullen, Marketing Executive

THE GEOLOGICAL SOCIETY was founded in 1807, but sadly female geologists wouldn’t be welcome as Fellows for 112 years. In May 1919, the first eight female Fellows were elected and in 2019, we celebrated 100 Years of Female Fellows.

The Society’s newest Special Publication, number 506, Celebrating 100 Years of Female Fellows of the Geological Society: Discovering Forgotten Histories, presents the often untold stories of pioneering female geoscientists from across the world — women who navigated male-dominated academia and learned societies, experienced the harsh realities of Siberian field-exploration, or responded to the strategic necessity of the ‘petroleum girls’ in early American oil exploration and production.

Lucy Pullen and Bethan Phillips interviewed the editors of the volume, Cynthia Burek (Professor of Geoconservation, University of Chester) and Bettie Higgs (Senior Lecturer in Geology, University College Cork) and asked them about their experiences in geology, raising awareness of female geoscientists, editing the volume and future plans.

Cynthia and Bettie discuss how inspirational physical geology teachers, as well as childhood holidays collecting ‘stones’ on the beach and school field trips motivated their interest in geology. They also note how several key societal changes, such as the introduction of compulsory education for children, facilitated by the Education Act of 1870, were key moments for women in geology. But there is still work to do, and Cynthia and Bettie highlight the importance of building resources that document the stories, achievements and contributions of women in geology — which is one of the objectives of the new Special Publication.

Read the full discussion with Cynthia and Bettie on the Geological Society’s blog page here: https://blog.geolsoc.org.uk/2021/03/18/celebrating-a-centenary/

Special Publication 506, Celebrating 100 Years of Female Fellows of the Geological Society: Discovering Forgotten Histories, is available to purchase here: https://www.geolsoc.org.uk/SP506 and can be accessed via the Lyell Collection at: https://sp.lyellcollection.org/content/506/1

US honour for Brian Williams

Professor Brian P J Williams has been awarded the Grover E. Murray Memorial Distinguished Educator Award by the American Association of Petroleum Geologists (AAPG), in recognition of his ‘distinguished and outstanding contributions to geological education’. Congratulations to Brian for this prestigious award.

AUTHOR NAME CHANGE POLICY

The Geological Society is pleased to announce a new policy covering requests to change author names on published works. An author may choose to change their name for reasons that include (but are not limited to) gender identity, marriage or divorce, religious conversion, and other personal reasons. For authors making this choice, the Society now offers a route to updating published works and the relevant supporting systems and services.

The introduction of this policy is part of the Society’s broader commitment to supporting author inclusion, respecting the rights of authors to their own identities, and ensuring that authors receive credit for all their work.

To find out more and for details of the policy, please visit the Society’s website: www.geolsoc.org.uk/Publications/Publishing-policies/Author-name-change-policy

David Boyt (Head of Editorial Development)
The decarbonisation of electricity production, industry, transport and heating to meet both UK and international climate change targets is a major challenge, and geoscience has an important role to play. We are working to understand – and raise awareness of – the various ways that geoscience will underpin the energy transition. The Society does this work in collaboration with an advisory group of experts who make up our Decarbonisation Working Group.

As part of this work we are pleased to announce the publication of our latest policy and technology explainer ‘Geoscience and the hydrogen economy’. Geological skills and knowledge are particularly relevant to the use of hydrogen as a low-carbon alternative fuel, with the potential to reduce emissions from heavy industry, domestic heating, and transportation.

We also recently hosted an online webinar about the storage of hydrogen in caverns in collaboration with Supergen and Energy Research Accelerator. If you missed this, you can catch up in your own time at www.era.ac.uk/Hydrogen-Storage-in-Caverns-2021.

Read more at www.geolsoc.org.uk/hydrogen-economy

Megan O’Donnell (Communications & Policy Officer) & Flo Bullough (Head of Policy and Engagement)
THE 2020 LIBRARY REVIEW

At the end of 2019, Council commissioned a review of the Society’s Library and Information Services, and one year later approved a wide-ranging report on the future of those services. Neal Marriott, who served on the Library Review Working Group, explains the background to the review and outlines some of its recommendations.
VISITORS WHO SPEND any amount of time in Burlington House will find it hard not to be struck by the Society’s Library collections. Both the first floor Main Library and the ground floor Lower Library are impressive in their extent and presentation, and those setting foot in the Map Room may feel they have entered an Aladdin’s cave of geological treasures. Largely behind the scenes are extensive archive and special collections, and many more books and journals are held in storerooms, with material incapable of being stored in-house being securely retained off-site. Supporting all of this is a professional staff who provide the experience and expertise required to enable users to get the very most from the Library.

Library collections comprise over 300,000 volumes of books and serials, 40,000 map sheets and a wide range of historical and archival material. Operating such extensive collections, and associated services, brings its own challenges and comes at considerable cost, so in 2010 a wide-ranging review of Library services was undertaken, with the resulting recommendations for change having largely been implemented in the intervening years. However, as we stood on the brink of the 2020s, it was clear to Council that the Society faced a range of new and significant challenges (and, perhaps, opportunities) that force us to question how we can best deliver these services to Fellows in the future.

Challenges
In common with many learned and professional societies, the Geological Society is undergoing a period of financial pressure and uncertainty. Since 2017 our membership numbers have fallen slightly with a consequent loss of revenue; our established and profitable publishing model is facing the challenge of Open Access; and we have entered a period of escalating rent demands.

The challenges, however, are not solely financial.

“In exploring the challenges of running the service, we have also identified opportunities: to digitise and promote the best of our heritage collections; to increase digital access for all”
CONFERENCES & EVENTS

GSL EVENTS:

GSL Training – Geohazards
March – June
Registration open
https://www.geolsoc.org.uk/CPD-Geohazards-events-2021

Virtual Public Lecture: Martian Organics – Linking Meteorites and Mission Data
2 June 2021
Registration open
https://www.geolsoc.org.uk/06-gsl-public-lecture-june

Geoscience and the Energy Transition: Energy Transfer, Injection and Storage
7-8 June 2021
Registration open

ENERGY GROUP EVENTS:

28-30 September 2021
https://www.geolsoc.org.uk/09-rescheduled-pg-petroleum-systems-modelling-2021

Petroleum Geology of the Southern South Atlantic
6-8 October 2021
https://www.geolsoc.org.uk/10-Energy-Group-Southern-South-Atlantic

8th UK Geothermal Symposium
17 November 2021
https://www.geolsoc.org.uk/11-EG-Geothermal

For more information, please contact conference@geolsoc.org.uk

Image: Laminated sandstones on Gullane beach © Milena Farajewicz
The Geological Society of London. registered charity, number 210161
For well over a century the Geological Society has occupied its apartments in Burlington House and has enjoyed the space within which its Library collections can grow and be readily accessed by anyone visiting London. Now, our future occupation of Burlington House is in question and we must plan for the possibility of relocating to alternative accommodation elsewhere. As the Library currently occupies 47% of Burlington House floor space, and the size and location of possible future accommodation is as yet undetermined, a new review was an urgent requirement.

The brief from Council
At the end of 2019, Council commissioned a new review of Library and Information Services, which was announced to Fellows early in 2020. A Library Review Working Group was assembled and approved by Council, and comprised eight members drawn from both within and outside the Geological Society. Members were chosen from learned society, university and commercial backgrounds, and were selected for their experience and expertise in library use, management and development, publishing, the geosciences and finance.

The emphasis of the review was on considering future service provision, both in the case of remaining at Burlington House and of moving to a new location; the development of cost-effective services in light of changing Fellowship needs; and on future financial sustainability and affordability in the wider context of the Society’s charitable activities.

Work commenced early in 2020, examining existing evidence (relating to cost, usage, visitors etc.), interviewing expert witnesses and conducting a survey of the Fellowship. Council was kept informed of progress and the report and recommendations were received at its final meeting of 2020. The report was not considered in isolation, however, but in the context of a range of issues and new Society initiatives: the evolving financial situation and consequent redundancies late in 2020, including two members of Library staff, the emerging impact of COVID-19 on the Society and its Fellows; the review of the Society’s strategic priorities; and the ongoing review of Fellowship categories and benefits. It was in the context of these many challenges and opportunities that Council considered the review findings and recommendations and gave its approval on 25 November 2020.

Many users have already made the shift to accessing content online, but there are many other possible applications of technology that we have not yet taken advantage of. We are seeking to extend Library access and usage by exploiting technology.

Scarcity, value and usage
The Library’s holdings are extensive and complex, ranging all the way from rare or unique physical items on the one hand to cutting-edge electronic content on the other. Copies of William Smith’s maps are an obvious example of valued historical material, but there is much else besides: rare books dating as far back as the 16th century; special collections of prints, drawings and illustrations; geological maps from all areas of the world, many of which would be difficult or impossible to source elsewhere; and an extensive range of deposited papers from dozens of notable individuals. At the other end of the spectrum is current content, published electronically and delivered online to libraries across the world – where, in many instances, subscribers do not even receive print copies of the published content.

What is equally evident is the difference in usage levels of the Library collections, especially in relation to journals. Of the 600 or so journal titles listed as received by the Library, 30 or so titles accounted for around 80 percent of 2019 usage, while half of titles received no usage at all in that year. While many of our little-used titles incur no direct subscription charge (being received by exchange or as gifts), they do incur an overhead to receive, process, manage and store. Similarly, many of our older (though not necessarily rare) stored books and journals receive little or no use while occupying considerable space.
WILLIAM SMITH MEETING 2021

GEOLOGICAL MAPPING: OF OUR WORLD AND OTHERS
VIRTUAL CONFERENCE
19-21 OCTOBER 2021

Map-making is a fundamental tool for developing geological knowledge. This 3-day conference is an international celebration of geological mapping, its historical importance and future directions, and its use to deduce Earth and planetary evolution and processes in its wide context. The programme seeks to explore Earth's surface to subsurface realms, and beyond to extra-terrestrial bodies.

Confirmed Keynote Speakers
Kathryn Stack (Jet Propulsion Laboratory, NASA)
Marc St-Onge (Geological Survey of Canada)
Karen Hanghoj (BGS Director)
Clare Bond (University of Aberdeen)
Matt Balme (Open University)
John Dewey (University College, Oxford)
Mike Daly (President of the Geological Society)

Call for Abstracts
We invite oral and poster abstract submissions for the meeting, and these should be sent via filling out this form by 18 June 2021. Abstracts should be approximately 250 words and include a title and acknowledgement of authors and their affiliations.

Primary Convenors:
Sanjeev Gupta (Imperial College), Mike Searle (University of Oxford)
Rob Butler (Aberdeen University), David Schofield (BGS), Lucy Williams (Rockhopper Exploration)

Further information:
E: conference@geolsoc.org.uk
W: www.geolsoc.org.uk/wsmith21
T: #wsmith21
patterns and seek to extend access and usage by current non-users by exploiting the opportunities afforded by new and emerging technologies.

**Digital opportunities**
Many users have already made the shift to accessing content online, but there are many other possible applications of technology that we have not yet taken advantage of. Increased digitisation of valuable and historical material may not only assist with their preservation, but would enhance opportunities for education and outreach, as well as being potentially revenue generating. Digitisation can be costly but might be an area where Fellows’ bequests could make a real difference. Similarly, systematic digital capture of modern records would secure these records for the future and reduce the need for physical filing and storage.

There is evidence of some frustration from Fellows in their interaction with Society information systems, and it is recommended that single sign-on is implemented to simplify Fellows’ access across the website, Lyell collection and Library services, reducing the need to establish multiple logins for accessing these various online services.

As technologies develop (especially some of those applied by content publishers), user behaviour will continue to evolve, too. In particular, content users are on a trajectory of increasing independence in their research behaviour and should be supported in this journey by training and education.

**The journey to change**
The full report of the Library Review Working Group contains a very wide range of observations and recommendations, only a few of which are reflected in this brief article. The Society should take great pride in its Library and the expertise of its staff. In exploring the challenges of running the service, we have also identified opportunities: to digitise and promote the best of our heritage collections; to increase digital access for all; and to enhance Fellows’ experience of online Society services.

The report, however, is not a blueprint for action and further work is required to create a detailed implementation plan. At the time of writing, recruitment of a new Head of Library and Information Services is underway and, once in post, a priority will be the development of such a plan, building on the report and drawing on the expert views of staff.

Importantly, the Library is a service for Fellows and the views of Fellows are important. So, please do take the time to read the report and send your comments to the email address given below.

The report to Fellows was published on March 11 2020 in both full and concise forms and can be accessed at www.geolsoc.org.uk/Library-and-Information-Services/review. Fellows can submit comments to library.review@geolsoc.org.uk.

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**Library visitors and users**
The Library is visited around 3,000 times each year. While many of these visits are to consult collections, others are in search of a workspace to catch up on emails, prepare for meetings or to consult the Burlington House bookshop. However, the number of visits by Fellows is in decline and those visits are very unevenly spread – in 2019 visits were made by approximately 600 unique Fellows (~5% of membership), but with only a tenth of this number visiting five or more times.

However, the decline in physical visits does not tell the full story. For many years the Library has been operating the OpenAthens system, enabling remote access to online journals. Not only has the number of Fellows registering for this system been increasing steadily, but the number of articles accessed is climbing, too.

These trends in remote versus in-person use of the Library are in opposition to each other, but when combined it is thought that around 10% of the Fellowship make use of the Library. The final balance of service provision will need to take into account this shift in user behaviour.

Our Library staff are already offering support on this front and we should carefully consider how this can be further developed.

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These issues of scarcity, value and usage present us with significant challenges to be addressed both in the context of financial sustainability and the management of any move out of Burlington House. The number of journals subscribed to has already been appreciably reduced in line with the review’s findings of limited usage and in relation to a challenging 2021 budget. Recommendations have also been made to review the entire Library and archive collection to prioritise all materials held should the Society move from Burlington House to smaller premises where the space available for our collections may be substantially reduced.

**The Society’s Library is a geological treasure trove**
Deep geological disposal of radioactive waste: The role of geoscience

Monday 27 September 2021
9.30 am to 5.00 pm

Cloth Hall Court
University of Leeds
Quebec Street
LS1 2HA

A series of invited talks reviewing the critical role played by the geosphere in deep geological disposal of higher activity radioactive waste.

Provisional Programme includes

- Jon Gluyas (University of Durham, UK)
- Penny Harvey (University of Manchester, UK)
- Tim Vietor (Nagra, Switzerland)
- Neil Chapman (University of Sheffield, UK)
- Fiona McEvoy (BGS, UK)
- Jonathan Turner (RWM, UK)
- Kaj Ahlbom (SKB, Sweden)
- Lukas Pollock (BGR, Germany)

- Discussion panel chaired by Professor Chris Jackson, University of Manchester comprising a range of experts including: Professor Mike Daly, President, The Geological Society; Sir Keith O’Nions, FRS, Chair of BGS Board; Professor Cherry Tweed, Chief Scientific Advisor, RWM

Registration (free) is required for all attendees, to register please visit https://ygs-radwastedisposalgeo.eventbrite.co.uk
We need more open discourse on the physical challenges of fieldwork, aiming for greater inclusivity for aspiring geoscientists, suggests Simran Johal

There has been a lot of important discussion recently around inclusivity in fieldwork, in particular highlighting the barriers faced by LBGTQ+ and disabled geoscientists. Even for those who do not face such barriers, it can be hard to adapt to the fieldwork element of many courses.

When I first began my degree in geology, I was stepping into the unknown, but felt I was up for the physical challenge. However, while I was able to scrape through my first-year fieldwork on unforgiving Cornish cliffs unharmed, I struggled to keep up.

The next hurdle — a rite of passage for almost every UK geology student — was facing Scotland. I walked the escalators on the London underground in an attempt to train, but my fear of the tough Hebridean conditions on Cape Wrath in October led me to pass up that project for my independent geological field-mapping component.

After a few more field trips, I gained confidence in my physical abilities, but I regretted not taking that mapping opportunity and knew I’d missed out on a fundamental geological experience.

For my Master’s degree, I moved to Switzerland — a country where exercise is embraced and where I had free access to every sports facility imaginable. I took up strength training and swimming, and finally felt like I was making progress. For the first time, the physical element of field excursions didn’t faze me and I was eager to take part.

Physical fitness in geology is rarely discussed. It took me years to build my strength, agility, mobility and, most importantly, mental confidence. To help provide a more welcoming and supportive environment for students new to the geosciences, there should be more open discussion of the physical challenges associated with fieldwork, tips on how to prepare and reassurances that no student will be left behind.

SIMRAN JOHAL
Simran is currently completing her MSc in Engineering Geology at ETH Zurich
* simran0589@hotmail.com
@girlTravertine
The other day, I went to my bookshelf and pulled out a small book, with a simple dark green cover. The gold lettering read, Geological Sketches; its author was Archibald Geikie. The copy I have was published in 1892, almost 130 years ago. The first edition was published ten years before.

I was searching for whether Geikie said anything about geodiversity. I was not disappointed. The title of the last chapter is The Geological Influences that have affected the course of British History. A statement in the chapter’s first paragraph tells us Geikie was way ahead of today’s proponents of geodiversity: “Probably few readers realise how large an extent the events of history have been influenced by the geological structure of the ground whereon they have been enacted.”

He uses the geology of England and Scotland as an example to show how geology determined the cultural differences between the two countries: “But we should find that fundamentally the differences have arisen from the originally utterly distinct geological structures of the region.”

He concludes the paragraph with: “This diversity of structure initiated the divergences in human characteristics even in far prehistoric times, and it continues, even in spite of blending influences of modern civilisation, to maintain them down to the present day.”

Whilst Geikie did not coin the phrase geodiversity, he recognised that geology played a huge part in the development of nations and not just from a resource perspective. If we read his statements, geodiversity is more than the cradle for biodiversity and far more than geoheritage. Geodiversity has, and still does, define human and cultural diversity.

Geikie uses the geology of Scotland to show how geology determined the cultural differences between that country and England.
Thought-provoking content

DEAR EDITORS,

I really enjoyed both the new look and the new content of the Spring issue. Well done on including some really challenging and thought-provoking material.

JASON CANNING
Geoscience advisor at RPS Energy
and Chartered Geologist
The name British Geological Survey (BGS) was introduced in 1984 and that of its predecessor the Institute of Geological Sciences (IGS) in 1965. By the 1980s, the BGS was a very different organisation from that started by De La Beche 150 years earlier, wide-ranging in its activities, both onshore and offshore, and of global extent. Let us be clear that De la Beche began officially colouring in Ordnance maps of Devonshire for the Board of Ordnance in 1835, thus initiating the Geological Survey of the United Kingdom. Subsequently the Geological Survey of Great Britain and Ireland Act of 1845 was passed to “facilitate the Completion of a Geological Survey of Great Britain and Ireland”. Sir Roderick Murchison was appointed Director in 1855.

All this might seem irrelevant or simply a matter of semantics, but in the context of exploring past patronage and practice it is wise not to confute, by implication, the culture and actions of a modern organisation with those of its 19th century predecessors.

Andrew McMillan
Andrew was a Principal Geologist with the BGS for 36 years and retired in 2010.

Dear Editors,
I notice that ‘the winds’ are finally blowing through our Society resulting in the ‘toppling’ of De la Beche, Murchison and Agassiz. This follows hot on the heels of the removal of De la Beche’s name from those great institutions he founded: the British Geological Survey and the Royal School of Mines (now part of Imperial College London). It seems De la Beche’s mistake was to have inherited a slave plantation in Jamaica, and, ironically, when he lost its income, he made himself the first paid geologist, essentially establishing our profession as we know it today: no more a hobby of the ‘idle rich’.

Ironic too, in the ongoing battle against misogyny, is the role played by our ‘toppled heroes’ in the Mary Anning story, shortly to be portrayed in the film Ammonite. In that early 19th century society, where women were essentially either adornments or drudges depending on their social standing, Henry De la Beche was a true friend from Mary’s youth, encouraging her in the science and helping her financially with the proceeds of Duria Antiquior, his all-action painting – the first ‘palaeoart’ – which brought Mary’s fossils to life.

Roderick Murchison introduced Mary to his wife Charlotte and they formed a close friendship based on geologising – apparently even closer in the film; and Louis Agassiz, realising that Mary would not be acknowledged academically, named two species of fossil fish after her.

Martin Litherland OBE
Martin was a field geologist for the British Geological Survey in Botswana, Bolivia and Ecuador, before returning to the Keyworth office to launch a series of popular publications.
ONLINE TRAINING COURSES
To enhance the continuing professional development of geologists, the Geological Society will launch a number of training courses this autumn.
The courses will include topics ranging from geospatial site appraisal, geotechnical monitoring for infrastructure embankments, Earthworks, and applied structural geology and mapping.
https://www.geolsoc.org.uk/Events/Online-Training
conference@geolsoc.org.uk

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InSAR has gained recognition in civil engineering as a powerful tool for projects that involve tunnelling, such as London’s Crossrail.
Expanding horizons

Jennifer Scoular and colleagues report on the InSAR revolution in geoengineering, which is transforming detection of ground deformations in both urban and rural areas.
G

ROUND SURFACE
deformation is now routinely measured to millimetric precision using a family of remote sensing techniques known as Interferometric Synthetic Aperture Radar (InSAR; see boxes ‘What is InSAR’ and ‘What is interferometry’). The possibilities of InSAR first came to the attention of the wider scientific community when an interferogram showing ground movement caused by the 1992 earthquake in Landers, California, appeared on the front cover of Nature (Massonnet et al. 1993). That image was made using data from ERS-1, the first European Space Agency SAR satellite. Since then, multiple generations of SAR satellites have followed, offering improvements in temporal and spatial resolution, and opening a diverse range of applications. Here, we discuss some of those applications, using case studies ranging from central London, to rural Wales and the south coast.

London’s geology revealed
Over the last decade or so, InSAR has gained recognition within the civil engineering community as a powerful and cost-effective tool for detecting and monitoring ground deformation above tunnelling projects, particularly in urban areas. In London, its use gained recognition following the construction of the Jubilee Line Extension (1993 to 1999) and later during the Crossrail project, where tunnelling took place between May 2012 and May 2015, when clear settlement troughs were revealed. In the case of Crossrail, this was as a roughly east-west oriented ‘string’ of subsiding areas across central London (Bischoff et al. 2019).

InSAR can also be a valuable tool for engineering geologists to interpret ground conditions during the desk study phase of a project. After a decade of research, largely enabled by the British Geological Survey OpenGeoscience service (www.bgs.ac.uk/geological-data/opengeoscience/) and supported by major infrastructure projects, it has been shown that London’s subsurface is far more complex than previously recognised and contains multiple geotechnical hazards, which can cause significant risks for engineering projects.

These hazards include faulting, sand channels, drift filled hollows (DFH) and shrink-swell behaviour within the London Clay (Scoular et al. 2019). DFHs or ‘buried hollows’ are steep-sided depressions in the rockhead surface, caused by a complex interplay of natural processes (e.g. Toms et al. 2016). Up to 75 m deep and 90 to 475 m wide, they are typically infilled with sand and gravel. London’s dense urban fabric makes investigation and mapping of geohazards very challenging and thus new (previously unknown) DFHs are often revealed by site investigations or, in worst-case, are encountered during tunnelling and construction.

Spotting geohazards
InSAR could potentially be used to identify these geohazards prior to construction. For example, the presence of a DFH was confirmed through the use of InSAR.

Table 1: SAR satellite bands

<table>
<thead>
<tr>
<th>BAND</th>
<th>FREQUENCY</th>
<th>WAVELENGTH</th>
<th>PENETRATION</th>
<th>RESOLUTION</th>
<th>EXAMPLE SATELLITES</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-band</td>
<td>8 – 12 GHz</td>
<td>3.8 – 2.4 cm</td>
<td>Low</td>
<td>High</td>
<td>TerraSAR-X, COSMO SkyMed</td>
</tr>
<tr>
<td>C-band</td>
<td>4 – 8 GHz</td>
<td>7.5 – 3.8 cm</td>
<td>Medium</td>
<td>Medium</td>
<td>Sentinel-1, Radarsat-2</td>
</tr>
<tr>
<td>L-band</td>
<td>1 – 2 GHz</td>
<td>30 – 15 cm</td>
<td>High</td>
<td>Low</td>
<td>ALOS-2, SAOCOM</td>
</tr>
</tbody>
</table>

WHAT IS SAR?

SAR satellites use microwave radiation that can penetrate through clouds and operate day or night, irrespective of weather conditions. The satellite emits a pulse of radar energy, which is reflected by Earth’s surface and the satellite records the amplitude and phase of the returned signal. The amplitude is the strength of the reflected pulse and is influenced by the physical properties of Earth’s surface. The phase change between transmitted and received signals is proportional to the two-way travel distance divided by the transmitted wavelength, and it contains information from topography plus any change in the ground surface elevation. Satellite radar sensors have a side-looking geometry and the radar pulse intersects Earth’s surface at an angle known as the incidence angle (Fig. 1).

SAR sensors can operate at a variety of wavelengths, often referred to as bands, in the microwave portion of the electromagnetic spectrum used in each case. The wavelength determines how far it penetrates a medium (such as vegetation, soil and ice) and the spatial resolution of its imaging capability (Table 1: SAR satellite bands, left).
WHAT IS INTERFEROMETRY?

Radar interferometry exploits the interference between two nearly parallel beams of microwave energy to derive a map of the phase difference between two observations. The phase difference provides precise measurements of the relative distance between the sensor and the target object, using two or more SAR images, separated in time or space. Differential InSAR uses two InSAR images of the same area, acquired at different times. If the distance between the satellite and the ground changes between the images being acquired, a phase shift occurs (Fig. 1). The topographic component must be removed using either an external digital elevation model (DEM) or a third SAR image to make a topographic pair. If multiple interferograms are combined, a velocity map and time-series of deformation can be generated.

Over the past 30 years, many algorithms have been developed for time-series analysis. Persistent Scatterer Interferometry (PSI) was the first, in 1999, and is still one of the most commonly used (Ferretti et al. 1999, 2001). A scatterer is any object responsible for a measurable radar echo and Persistent Scatters (PS) are those that exhibit stable reflectivity values over long time periods. Common PS are man-made structures, such as buildings, streetlights and railway tracks, as well as natural targets, such as exposed rocks. Artificial targets called corner reflectors can also be used. Typically, vegetated landscapes, or areas where changes are being made to Earth’s surface, such as on active construction sites, do not produce PS. As well as the ground surface conditions, the spatial resolution of the SAR data, processing methodology selected and user experience can impact the results achieved.
The presence of faults can also be revealed using InSAR, often through the effect of changing groundwater levels, due to their ability to act as a barrier to flow. Dewatering in East London for Crossrail’s Limmo Shaft produced a subsidence bowl, which appears truncated at its western edge (Bischoff et al. 2019). The strike-slip Lee Valley Fault is interpreted to have impeded aquifer connectivity, and therefore settlement during dewatering (Fig. 3).

On a broader scale, the geometric arrangement of London’s fault network is also evidenced by separating the east-west and vertical components of PSI measurements (Mason et al. 2015). London’s surface can be seen to move as a series of discrete blocks, coincident with major elevational changes in the chalk subsurface. Morgan et al. (2020) correlate these two independent lines of evidence to provide indirect evidence of faulting (Fig. 4).

**InSAR in rural areas**

Until recently, applications of InSAR in rural settings have been limited to within semi-arid regions. Regular variation in soil moisture contents and vegetative land cover can obscure deformation measurements in more temperate regions such as the UK, often leading to noisy and unreliable

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**Figure 2:** (a) Map showing the location of profile A-West to A’-East and Persistent Scatterers point distribution at Newham Hospital. (b) Profile A-A’ showing variable subsidence over the time period 2010 to 2015, with greatest displacement to the east of the hospital building and in the car park (blue rectangle)
results. More recently, rural results have been drastically improved through careful processing of ‘Distributed Scatterers’ (DS). DS are contiguous clusters of points that individually behave more noisily than PS, yet accurate measurements of deformation can be achieved by statistically analysing and filtering these DS as a collective.

An example of deformation in a rural mining area is at Ffos-y-fran opencast coal mine in south Wales. The western side of the pit had undergone significant reclamation works prior to the measurement period, and in figure 5 widespread settlement of backfill material can be observed. Similar magnitudes of movement can be seen from the large spoil heaps to the east of the mine. The northernmost heap has a steep west-facing slope, which appears to be moving towards the satellite (blue), indicating material is moving downslope.

Figure 3: (a) Settlement due to dewatering for Crossrail at the Limmo Peninsula, East London. (b) Heave following the cessation of dewatering. Truncation of the area of deformation to the west is interpreted as a fault. Modified from Bischoff et al. Q. J. Eng. Geol. Hydrogeol. (2019); http://dx.doi.org/10.1144/qjegh2018-075

Figure 4: Fault map of London developed through coupling indirect evidence of faulting from chalk topography and InSAR. Modified after Morgan et al. Q. J. Eng. Geol. Hydrogeol. (2020); https://doi.org/10.1144/qjegh2018-193
The remaining areas of the spoil heap are all measured as moving away from the sensor, indicating settlement or material moving down east-facing slopes.

**Bespoke software**

These new DS techniques are used in bespoke software, such as ICSAR (developed at Imperial College London) and SqueeSAR™ (developed by TRE ALTAMIRA, Ferretti et al. 2011), to provide many more measurement points in rural areas. These could potentially unlock new and exciting opportunities for the use of InSAR. The improving rural InSAR performance offers the potential for accurate monitoring of geohazards and landform evolution, including active and historical mining; assessment of slope stability and subsidence risks; the effects of remediation and land reclamation works; and ‘baselining’ other ground deformation phenomena at project sites. For example, figure 6 shows the InSAR results for a landslide close to Blaina in Wales, where the ground is moving down the west-facing slope at 10-15 mm/yr.

Landslides in coastal areas can also be monitored with InSAR. Cow Gap (Fig. 7a) is an area of chalk cliffs south-west of Eastbourne, East Sussex (UK). The cliffs are part of an active rotational landslide, approximately 1,000 m in length and 200 m in width. The shore platform and cliffs are exposed to coastal processes and erosion.

Although ESA’s Sentinel-1 images are acquired at the same local time every day, tide times are variable and the radar cannot penetrate water. The scenes can therefore be filtered to include only those acquired within a two-hour window of low tide, when the shore platform is exposed and can be measured. The platform movements shown in figure 7 have been interpreted as the main body of the landslide moving downwards at about -9 mm/yr (Fig. 7b), and the toe of the landslide moving upwards at about +0.7 mm/yr (Fig. 7c). Some of the downward movement in figure 7b may be attributed to platform downwearing, but,
results from other parts of the cliff demonstrate that this process is unlikely to cause more than a few millimetres of erosion over the time period of this study (Mider et al. 2020).

Future of InSAR

InSAR technology started out as a research tool for seismic geohazards, but it has been developed and expanded into volcanic hazards, oil and gas, carbon sequestration, mining and now into engineering geology. As temporal resolutions improve with new satellite constellations, from every 35 days with ERS-1 in 1992 to every six days with Sentinels-1A & -1B, along with spatial resolution (X-band constellations) and with increasing ease of data access, the applications for InSAR keep growing. Recently launched and planned commercial small satellite constellations, such as ICEYE and Capella Space, will offer hourly revisit times and sub-metre resolution. New platforms for radars are also under development. Small unmanned aerial vehicles (UAVs) were traditionally associated with the defence industry, but recent technological developments, reduced costs and improved capabilities have seen their popularity dramatically increase. Ongoing research at Imperial College London involves development of UAVs as low-altitude radar platforms, providing the potential for UAV-borne InSAR. UAV-borne radar would bring improved temporal and spatial resolutions, and the potential for higher frequency signals, due to reduced atmospheric signal attenuation that comes with lower altitudes. However, new signal processing and adjustments to InSAR methodologies will be needed to account for variations in UAV flight path on repeat visits and GPS precisions.

Acknowledgements

The authors would like to thank TRE Altamira and CGG for providing data used in these case studies. Further thanks to our collaborators and funders: Thames Tideway East, Radioactive Waste Management, Brighton and Hove Council, EPSRC, Imperial College Skempton Award and Ground Evolution Monitoring and the other members of the ESGRG.

Jennifer Scoolar (pictured), Stewart Agar, Gosia Mider, Tom Morgan, Anthony Carpenter and James Lawrence are in the Department of Civil and Environmental Engineering, Imperial College London. Richard Ghail is in the Department of Earth Sciences, Royal Holloway, University of London. Philippa Mason is in the Department of Earth Science and Engineering, Imperial College London.

The work presented here was carried out by the Engineering Scale Geology Research Group (ESGRG), a multidisciplinary team at Imperial College London and Royal Holloway, University of London. ESGRG are currently writing the Construction Industry Research and Information Association (CIRIA) guidelines on ‘Earth observation and InSAR technology for civil infrastructure’ in collaboration with Sixense.
BREATHING FRESH LIFE INTO GEOSCIENCE

Involving non-scientists in research has a long pedigree in other fields, but uptake is slow and cautious in the Earth Sciences. With experience from western Nepal, Jonathan Paul describes how citizen science projects can be done...
In December 1900, the American ornithologist Frank Chapman proposed an alternative to Christmas ‘side hunts’ – a tradition in which Americans competed to kill the most birds, regardless of use, scarcity or beauty. What if, Chapman suggested, we count birds instead of killing them? On Christmas Day 1900, 27 observers participated, counting between them 18,500 birds belonging to 90 species. The count has since been held every winter – 2,615 ‘counters’ took part in the 2018-19 event. The Christmas Bird Count was one of the first of what have since become known as ‘citizen science’ projects.

It’s not surprising that citizen science has taken off in recent years. The explosion of new technology following the rise of the internet during the 1990s has enabled people to feel more interconnected. In the context of multiple global crises, of which the climate emergency and fallout from the Covid-19 pandemic are arguably the most important, this connectivity has helped us regain a sense of agency over events that perhaps seem frightening, inchoate and difficult to control. Since the term first emerged in the early 2000s, citizen science was immediately recognised as having the potential to mobilise people’s involvement in large-scale information gathering.

Getting it right
New technology, including increasingly sophisticated smartphone apps, has enabled citizen scientists to record millions of observations of, for instance, the occurrence of seismic activity (via accelerometers), landslides (from photos and videos), or even air and water quality. Non-scientist engagement in geoscience has perhaps been most pronounced...
in resilience-building efforts related to geohazards. The motivation for citizens taking part is clear: they help scientists take additional measurements to patch up data gaps, and in return the scientists will provide expert advice on how to stay safe.

It is important to recognise that our skills as geoscientists are not necessarily sufficient to render such engagement successful and useful. Citizen science is widely considered to be a sub-discipline that is very easy to do badly, but much harder to do well. Getting it wrong has consequences; it can lead to a lack of trust in the community towards governments or professional scientists.

The challenges of setting up a successful citizen science monitoring programme are numerous. Issues range from the need to provide incentives to participate, to the highly variable quality and fragmentary nature of citizen-collected datasets. The two greatest challenges for geoscientists are quite technical. First, we need to develop strict guidelines through which the uncertainty of data generated by non-scientists can be quantified. How can a lay person assess groundwater level or the clay content of a rock, for example? Such protocols could potentially address the second challenge: how do we convince decision makers and other geoscientists of the viability and quality of these data, to the extent that citizen observations can have a real impact on our projects – such as a flood early-warning system or a hydrogeological groundwater model.

There is great potential in the geosciences to transcend a traditional view of the smartphone-equipped citizen passively feeding data to a central database. Working closely with groups of non-scientists throughout the duration of a research project requires more money, careful thought and intensive collaboration with social scientists. The potential rewards, though, are rich, and could include capturing hitherto hidden local knowledge, permanent reductions in geohazard-related risks and improvements in community cohesion.

**Insights from western Nepal**

To date, relatively few citizen science projects have been conceived in developing countries, owing to a range of complex and interrelated hurdles including bureaucratic, financial and language barriers, hostile weather, and inaccessibility. In 2019, scientists from Imperial College London, UK launched a new initiative that focused on two secondary schools in mountainous, rural western Nepal (Fig. 1). The goal was threefold: to enhance science, technology, engineering and maths (STEM) teaching in a developing country context; to produce new geoscientific datasets; and to build

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**Figure 1: Map of western Nepal, showing the location of two secondary schools for our citizen science interventions (Sa = Saraswati School; Su = Sunkuda School)**
greater environmental awareness in the new generation of students. After working closely with local communities for several months, we found schools to be the most effective gateway to local people: teachers are often the most educated and respected community members, while students are enthusiastic receptors of new information, which is then transmitted to their parents. Also, schools offer ready-made organisation and a central forum to bring different local stakeholders together, which is comparatively rare, especially in developing countries. We started by developing lesson plans with schoolteachers. The content complemented the government-prescribed STEM curricula, but also introduced new material that was tailored for local relevance, such as methods for determining the degree of camber on local rice paddies due to rotational slumping, or measuring changes in river cross-sectional area and discharge through the Monsoon season. We worked with graphic designers in Kathmandu to generate visually appealing material, such as posters on the water cycle, and the causes and effects of mass movements. Teaching and question-and-answer sessions were delivered by a mixture of local schoolteachers, European and Nepali scientists, as well as student representatives. Each day included an outdoor practical component where students collected data. In one such experiment, students were trained to collect rainfall data using simple measuring cylinders. The data were used to forge a local link to the broader context of changing patterns of Monsoon rainfall due to climate change, and we found that the students’ data provided an excellent spatiotemporal fit to nearby automatic rain-gauge data (Fig. 2).

We sought to treat local stakeholders — mainly students and teachers — as equal partners, producing data of objective scientific value. In doing so, we ensured project sustainability beyond the fix-term funding typically associated with research projects in the UK. Specifically, we ensured that community level monitoring and analysis could continue after the funding runs out by meeting weekly with teachers and offering community ownership of scientific equipment, such as the automatic rain gauges and smartphones.

**Local relevance**

A critical step was to understand the motivation of non-scientist participants: Why should they care? How would ‘our geoscience’ affect their livelihoods? In geohazard research, the idea that a local community would somehow ‘be grateful’ for the presence of professional scientists is a misconception. In many areas that suffer multiple hazards, like western Nepal, local people rate the effects of hazards low on their list of priorities – well below ensuring a good harvest or raising children. So, we strove to make our research as locally relevant as possible. We sought to become embedded in the local community by using local suppliers or craftsmen to make certain pieces of geophysical survey equipment, as well as by having a PhD researcher living in the local community for several months.

**LESSONS LEARNT**

- It is important to be humble when liaising with local community members. H-values and impact factors are meaningless in this context.
- Keep an open mind regarding local geological conditions and don’t show up with preconceived ideas of local challenges (as we did: “you’re having these landslides because of over-zealous road building”).
- Local knowledge should be carefully incorporated wherever possible.
- The local people may have a shortlist of impossible-to-satisfy problems. Present the broad research aims and scientific possibilities at the very beginning of the project.
The best projects have their aims defined at the outset, and have project members that are proficient in both science and communication

eating communally with the school students and teachers, and sleeping in the school hall. We developed simple, low-cost sensors with practical, tangible use, such as river-level sensors that reported in real time. In remote regions where manual data collection was not feasible, local people were given a monthly stipend to maintain equipment or download data.

It is important to go beyond passive data collection and involve citizen scientists throughout the entire life cycle of a research project, from problem conception to the dissemination of results. It is useful to identify who makes decisions locally and to work closely with social scientists. At each of our study sites, we identified one or two significant people – often a head teacher, community or political leader – who acted as useful conduits to the broader community. By channelling our interactions through these people, and involving them in all our school activities, we were able to focus discussion on the specific needs and interests of disparate groups of other stakeholders, such as farmers, local government or those working in industry.

The future of participation
Relative to other disciplines, such as ecology or medicine, the uptake of citizen science has so far been rather limited in geoscience. Geoscientific data are often difficult to interpret intuitively, while measurements can be expensive, complex, spatially sparse and temporally dense. For these reasons, intensive scientific training and specialisation is still normally a prerequisite for data analysis. However, new technological developments can, to some extent, circumvent these limitations, paving the way for the more rapid uptake of citizen science. That said, geoscientists should recognise that the introduction of new smartphone apps is not a universal panacea: encouraging uptake of these apps is challenging, and many app-based projects have fared poorly because there are often few material incentives for participating.

While the exact form that citizen science takes varies widely, timely and accurate information can greatly assist geoscientists in completing research projects. In developing countries particularly, the future of citizen science lies in moving away from monitoring campaigns for geohazards towards a new model in which non-scientists are equal research partners who identify and help to solve local problems of research interest. Projects could involve observational campaigns (such as finding and documenting new springs, ore-bearing rock, or mass movements), community-level risk reduction and resilience building, or education (such as learning how to code while analysing locally collected seismological data). The participatory approach works best when there is active interest from the local community, so the benefits to local people must be highlighted. In Nepal, such benefits included enriched STEM teaching for local students, improved real-time monitoring of rivers and rainfall, as well as the potential for predictive models that could decrease risks associated with landslides and flooding in the future. The best projects have their aims defined at the outset, and have project members that are proficient in both science and communication, who approach the project with a clear willingness to listen and adapt.

Acknowledgements
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THE INTRODUCTION and growth of the railway network in the first half of the 19th century revolutionised travel and the transport of goods for many. One of the first to take advantage of the new possibilities was the geologist John Phillips [1800-1874].

John and Anne
Phillips, nephew of William Smith [1769-1839], the Father of English Geology, was orphaned at the age of eight, along with his younger sister Anne, and their younger brother, Jenkin. John was educated at Smith’s expense and learned about geology at his uncle’s knee. He was reunited with Anne in 1829. Neither married and they lived together until her death, with Anne serving as John’s housekeeper, moral support, confidant and geological companion.

John, the first keeper of the Yorkshire Museum, and later first keeper of the Oxford University Museum of Natural History, became a skilled palaeontologist, field geologist and prolific author. In 1835, after travelling by train for the first time, he also became a great train enthusiast, relishing the relative speed and the convenience of train travel, as well as the insights into landscape and geology it offered.

Marathon journey
In 1841, Phillips was on assignment mapping with the fledgling geological survey in southwest Wales. He expected the project to last several months, so rented a house in Tenby, and asked Anne, complete with Mary, her maid, and Cholo, their dog, to take the train to come and join him. It was a marathon journey, but having become very familiar with the train timetables, Phillips was able to write to Anne with very specific instructions about how to achieve it. It appears that neither John nor Anne liked to travel light.

“I shall say nothing about your things, except to advise you to have only two or three large packages, well and distinctly marked Miss P. for Bristol... For me... Bring all the papers [not omitting any] in the Cabinets of the anteroom... As to Instruments, bring the Max & Min Thermometer. A Hygrometer, my French Barometer, and Dipping ladle. I don’t recollect that I want any thing else very particularly. Oh! Yes. bring my uncle’s Life & his verses...”

Two days later John wrote to Anne to offer further advice:
’How you will bring poor Cholo I do not even conjecture. Perhaps they will let him be with you in the carriage. Pray have a good courage & then all will go right.’

Courage was certainly required, but Phillips’s advice was sound. Anne, complete with mountains of luggage, a maid, and their dog, arrived safely. How long it took them to recover from the journey is not recorded!

Acknowledgements:
I thank the archivist, librarian and Director at the Oxford University Museum of Natural History for providing access to Phillips’s letters.
SUPPORTING ENERGY TRANSITION, DIVERSIFICATION AND DECARBONISATION

High resolution, drone captured, digital outcrop model from Branscombe, Devon. The section is dominated by reddish brown mudstone (2) with a gypsum-rich horizon at the base of the section (1). Similar lithostratigraphic units may act as the seal for carbon capture and storage locations in the UK. RPS has a global digital outcrop reference database, highlighting the sedimentological, structural and stratigraphic features of many reservoirs and seals suitable for future carbon storage.

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For Earth and environmental scientists worldwide, COVID-19 has isolated us from the university laboratories and field sites where we would have been working, and lockdowns or post-lockdown restrictions have variably confined us to our homes. These difficult times challenge our ability to deliver both our research and teaching goals.

In work-from-home mode, it has become important to us to find pedagogic opportunities with the materials available to us. Of all the physico-chemical dynamics that can be found in microcosm in a household, we posit that coffee preparation presents an opportunity for direct Earth science application. Coffee-making can be a daily mindful lesson in fluid- and thermodynamics. Could the preparation of coffee at home be a delicious access point for home-schooling and university teaching?

Fabian Wadsworth and Jamie Farquharson muse on finding Earth science in a coffee cup

The moka pot can be thought of as a Darcy engine, after Darcy’s Law for fluid flow through porous media.
Fluid flow
Reactive fluid flow through porous media is a central theme across Earth, environmental and planetary sciences. The fundamentals can be taught and understood through percolative coffee preparation at home.

Whether you use a French press, a moka pot, pour-over techniques, or an espresso machine, most fresh coffee preparation involves moving hot liquid water through a pack of ground coffee particles, extracting on the way the stuff that makes coffee so potent and delicious. Therefore, fundamentally, coffee preparation techniques involve coupled advection-diffusion processes that are also commonplace throughout the Earth and environmental sciences. From gas exsolving and flowing through pore networks in stiffening magma, to the migration and extraction of oil, gas, water, and geothermal resources in crustal reservoir rocks, from fluid migration and lubrication along faults, to the formation and buoyant migration of melts during mantle melting or planet-scale differentiation. In all cases, coffee making can be a pedagogic and conceptual access point to understanding these scientific processes.

The moka pot
We take the moka pot as a case study. After the bottom chamber – an aluminium autoclave not dissimilar to the steel alloy high-pressure autoclaves used in experimental petrology – is part-filled with water and once the metal coffee basket is loaded with loose fine-ground coffee (typically ~ 50 μm radius particles), the pot can be screwed together and sealed, placed onto the stove, and heat can be applied to the base. Some minutes later an over-flowing stream of thick black coffee emerges spilling into the upper collection chamber, ready to be poured.

The ‘magic’ of the moka pot is perhaps that the pressure gradient driving the flow of water is provided by self-pressurisation of the air pocket above the water. Heat from below causes the evaporation of some amount of the water, increasing the mass of gas in the air pocket, which causes the pressure in the fixed gas volume to rise. Once the gas pressure rises sufficiently, it forces the water to be displaced downward, up through the internal spout, and into contact with the base of the ground coffee at sub-boiling temperatures. Water percolates through the tiny spaces between the small coffee particles. The flow is restricted by having to make its way through coffee in what is a ‘permeability limited’ system, which gives it time to cool off slightly. During the time the water is in contact with the coffee, it leaches out caffeine, flavour-compounds, and some solids or colloids from the ground coffee, before emerging into the collection cup at the top.

At a fundamental level, the moka pot could be described as a Darcy engine—after Darcy’s law for viscous fluid flow in porous media. The interested user could vary the grind size of the coffee, the relative volumes of water and gas, and the heating rate, to tune the average contact time between water and coffee particles (being careful to have a working pressure-release valve). Beyond the science, moka pot users are a romantic people who will be fondly familiar with the clackety-clack of the aluminium-on-aluminium as you screw together the top and bottom components of the pot, and the bubble and bubble of the so-called Strombolian phase at the end of the brew, signalling that it is ready. What better way to fuel an interest in the way physics and chemistry come together in geoscience, than by making coffee? ☕️

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Fabian is in the Department of Earth Sciences, Durham University. Fabian is a volcanologist with a passion for coffee. He is excited by the variety and complexity of fluid flow phenomena – in Earth and the kitchen.

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The portraits of the authors are thanks to Dr. Lucía Pérez Díaz
A S A WHITE, male, Pakeha New Zealander, I have worked internationally, both directly and indirectly, with indigenous people who have been colonised. Here I provide a summary of my experiences and recommendations for geoscientists who, for academic and business reasons, operate in areas that have colonised indigenous populations. 

The average white person from a traditionally white society or country does not fully appreciate the perspective of a minority or colonised person. Without a full understanding or appreciation of another perspective, it is difficult to bring a truly balanced view when dealing with issues related to colonised indigenous people. For example, many people don’t fully understand the contents of various UN agreements relating to indigenous communities or appreciate that many governments have signed up to these agreements, so often cannot implement those agreements well.

Considerations
From my experience, there are some important points to consider, particularly when working to extract resources in countries that were colonised at some stage:

• Resource and extraction industries were a part of the colonisation and theft of the lands of indigenous people.
• Indigenous people typically have a strong connection to the land and its resources, which are an integral part of their culture. No matter how long ago that land was taken from them,
or purchased from them generally at below-market value prices, they will still have a very strong connection to their lands.

• Many of these indigenous communities are now minorities in their homeland, and their governments typically put more emphasis on encouraging foreign investments to extract the natural resources than they do to protect and provide for their indigenous population’s values and beliefs.

• Government laws may appear to protect indigenous communities and the environment, but rarely do. Companies should not rely on compliance with such laws as evidence for ‘doing ethically right’ by indigenous people. This is often not enough.

• Many central governments do not create effective opportunities to resolve outstanding conflicts with indigenous communities on major grievances. Often central government legislation limits the ability for indigenous people to challenge the central government laws and policies relating to historic and current issues.

• In many pieces of legislation relating to the environment and mineral extraction, there are provisions for indigenous peoples to be consulted and engaged. In some jurisdictions, indigenous communities will use provisions in regional laws to frustrate approval processes in order to drag the central government into a discussion on other unrelated or indirectly related matters.

By considering the above points and learning more about these topics, geoscientists can help make a difference both within their organisations and while operating in countries that have been colonised. Of course, the responsibility must fall on all professionals working in the global resource extraction industry. However, geoscientists are involved in nearly every single resource extraction project in the world, they are present at the coalface and during the full cycle of such projects – geoscientists can make a difference.

**Individual responsibility**

Good environmental, social and governance practice can’t be left to the corporate sustainability team, or the health, safety, environment and quality team. Such practice needs to be understood by all staff operating in these environs. Every person has a responsibility to intervene and speak up, but few do. It is hard being a lone voice, but the more people there are actively thinking on these topics, the easier it is for all to speak up and do what’s right.

Imagine if someone, anyone, had spoken up and challenged Rio Tinto before they blew up a 46,000-year-old aboriginal cave system in Western Australia in 2020.

Indigenous people suffer minor, medium, and large indignations against their culture, values and beliefs every day. Geoscientists can help improve this situation by:

• Accepting that white people from predominantly white countries and communities view these topics through a white lens, but that by acknowledging this we can shift our perspectives and approaches.

• Assuming that with every new community we do not know enough.

• Learning about policies and legislation relating to indigenous people, such as those set by the International Finance Corporation or other good practice standards, and then doing more than the local laws require.

• Never accepting when an industry advisor or minerals extraction regulator tells you that there are no indigenous communities in your project area that are protected by national and international laws. There are almost always indigenous people affected by resource extraction projects, but it might be that they don’t meet a naïve or nuanced definition of an indigenous community of that person. Instead, seek independent advice from someone unrelated to the project.

• Spending time with locals to understand their views, values and culture.

• Ensuring that your project engages with any local indigenous populations, no matter what the national law says, and never assuming that the first people you speak with are the right or the only indigenous people affected.

• Informing local indigenous people of what you are doing on their lands, ensuring that no traditional sacred sites are desecrated, and ensuring they benefit in some way from the project that is taking place on their lands.

• Never assuming that indigenous communities can contribute resources to your project for free, and instead viewing these communities as an advisory resource that must be budgeted for, as per any other advisory resource, in your project.

By following the above considerations and recommendations, geoscientists can help be a part of protecting and strengthening the rights of indigenous people in their project areas.
RECENT research suggests that the effects of climate change are already tangible, making the requirement for net zero – the balance between the emission and removal of greenhouse gases to and from the atmosphere – more pressing than ever.

Geo-energy technologies in the subsurface, such as aquifer thermal energy storage, geothermal, compressed air energy storage and carbon dioxide storage, will be part of the solution. To make these technologies count, geoscientists need to test their ideas beyond laboratory-scale research and modelling and show that they work at full scale. Test sites for subsurface net zero technology are therefore essential.

Test sites
In geological decarbonisation technologies, the main questions surround our ability to characterise rocks geochemically and geomechanically, as well as to understand fluid flow. Yet, our knowledge of these processes beyond the laboratory scale is limited. We need to know how fractures and faulting, stratigraphy, permeability, porosity and shear strength influence the direct implementation of technology, and we need to understand these characteristics at realistic scales, from the micrometre to the kilometre scale. This is why test sites are so important.

In the disposal of radioactive waste, for example, we must test models and laboratory-derived results. Nuclear energy will contribute to low-carbon power production in the future, but nuclear power plants come with radioactive waste. In the UK, it is likely that by 2100, we will have 2.6 million tonnes of high-level radioactive waste that will need to be safely managed, probably within a geological disposal facility. Such facilities use engineered materials and structures, including concrete, metals and clays, as well as the surrounding geological environment as containment barriers. To safely and effectively contain waste, we need to understand the processes and timescales for the self-sealing of fractures in clay rocks, as well as the fate of repository-generated gases.

The fate of gases was investigated at the large-scale gas injection test (LASGIT) project at the Äspö Hard Rock Laboratory in Sweden. Test outputs have already confirmed early laboratory results on gas migration behaviour relating to dilatational pathways in bentonite and their impact on stress and pore-water pressures, helping to build the safety case.

The Glasgow UK Geoenergy Observatory was established in 2020 to investigate the use of coal mine water as a sustainable source of heat and to characterise the hydrogeology of flooded, abandoned coal mine workings. Many cities and towns in Britain are located on disused coalfields, and could provide a significant potential customer base for renewable heat energy schemes using abandoned coal mines. Information from the Glasgow Observatory will help us to understand the connectivity, flow and heterogeneity of the mine water system, as well as its response to small-scale heat and flow cycling, and will greatly improve the evidence base for coal mine geothermal and heat storage (Alison Monaghan, British Geological Survey).

**VIRTUAL CONFERENCE**

The virtual conference attracted attendees from across the world. It opened with a truly world-spanning talk on the value of test sites, delivered simultaneously by Sue Hovorka (The University of Texas at Austin) in Texas, USA and Linda Stalker (CSIRO) in Perth, Australia. To accommodate those calling in from East Asia, as well as North America, the talks were held between 10am and 3pm GMT.

The presentations covered aspects of carbon capture and storage, the UK Geoenergy Observatories project, international geothermal, heat storage, and radioactive waste test sites, the regulatory and policy needs for test sites, as well as the importance of public dialogue on geo-energy.

**To make these technologies count, geoscientists need to test their ideas beyond laboratory-scale research and modelling**

**Regulation and social acceptance**

In addition to providing data that aid implementation, geo-energy test sites may provide the scientific basis for regulation, in particular by helping to establish the balance between regulation that encourages the growth of new technology, while protecting the environment, property and people.

For example, Matthias Raab (CO2CRC Limited) and Peter Cook (University of Melbourne) described how developers at the Otway International Test Centre, located at a depleted natural gas field in Australia, worked with regulators to examine liability associated with long-term storage of sequestered CO₂ by researching the interactions between minerals and injected CO₂, and how this affects the long-term fate of CO₂ in the subsurface. Similarly, Alwyn Hart (Environment Agency, UK) and Mark Ireland (Newcastle University, UK) discussed how research at observatories like the Glasgow UK Geoenergy Observatory could aid the regulation of low-temperature geothermal energy (ground source heat) by providing insights on how quickly heat is replenished, as well as the environmental impacts.

Test sites can also help to ‘socialise’ geo-energy among the public. The success of geo-energy technologies relies heavily on public acceptance and support – as potential adopters, hosts, consumers and proponents (Jennifer Dickie, University of Stirling). Again, the Otway site is a good example. Developers worked closely with local communities to achieve community acceptance and even a local sense of pride in the research being done at the facility.

**Gaps**

During our discussions, two areas were singled out as potential gaps in our armoury of test facilities. The first concerns the realisation that for some subsurface technologies to be viable (such as low-temperature aquifer geothermal and heat/cool storage), they must operate in densely populated urban areas because low-grade heat will not be retained if transported far. So, low-cost, high-resolution, unobtrusive seismic and other monitoring will have to be developed for seismically noisy urban environments. How do we carry out monitoring and exploration in densely populated areas with sensitive or sceptical human populations? Do we need test sites that concentrate on subsurface monitoring, perhaps for several different kinds of technology?

The second gap concerns the need for test facilities to look at faults. If we want to use basins for geo-energy technology, we likely need to know much more about how faults reactivate and how they affect fluid flow. Faults are the locus for seismic events and can both allow and prevent fluid flow, meaning the occurrence of faults adds an element of risk. Do we therefore need a dedicated fault observatory, perhaps one that involves boreholes penetrating fault planes, allowing access to the rocks on the foot wall and hanging wall, where perturbations can be applied and changes measured and assessed?

**Investment**

We are acutely aware that in many ways our colleagues in astronomy, physics and engineering are well ahead of geoscience in using big infrastructure to solve big problems – like CERN or the Jodrell Bank Observatory do, for example. There is so much to gain by geoscientists coming together to tackle geoscience problems with big kit, but we need to encourage investment.

We can start by making alliances between similar test sites to encourage shared facilities and risk. We can then build best practice, joint strategies, data interoperability and international collaboration.

**MIKE STEPHENSON**

Mike is Executive Chief Scientist, decarbonisation and resource management, at the British Geological Survey.
What’s the current situation on Saint Vincent?
As of 9 April 2021, La Soufrière entered an explosive phase following effusive activity that began in late December 2020. This explosive phase is comprised of pulses of tephra ejection that generate ash columns, pyroclastic density currents and, due to rainfall, the remobilisation of volcanic material into lahars (volcanic mudflows).

What can the residents expect in the days and weeks following this explosive phase?
It is uncertain how long these explosions will go on for. However, with each explosion there will be ash fall and the wind direction will dictate where the ash falls.

What longer term impacts are expected?
We can expect an impact on the agricultural sector, due to burial of cultivatable land, damage to crops and agriculture-related buildings that are in the higher risk areas.

Tell us about Saint Vincent. How many people are living within the current ‘red zone’ and, alongside the risks, are there advantages to doing so?
Saint Vincent is quite small. A chain of extinct volcanoes runs from south to north and the active La Soufrière volcano is located in the far north of the island. The mountain range is montane rainforest and is home to the endemic Saint Vincent Parrot. There is a mixture pure white and black sand beaches.

Approximately 20,000 people live in the red zone. The main benefits of living here are the rich, fertile volcanic soil and building materials; however there are cultural benefits too, such as a sense of place, aesthetics and geo-cultural heritage.

How does this eruption compare with previous eruptions of La Soufrière?
Due to the amount of tephra and energy of the eruption, this event is being compared to the 1902 eruption, which was the deadliest in La Soufrière’s history, killing approximately 1,300 people.

Have there been efforts to raise awareness of volcanic risk in the area?
There have been tremendous efforts in the past 40 or so years to raise awareness about the volcanic risk of La Soufrière. In the past decade, two projects, STREVA and Volcano Ready Project, have driven capacity building.

What impact do you think this eruption will have on residents’ relationship to their environment?
Some people from the evacuated areas will be too scared to return home. Some may lose their livelihoods, especially persons in the agricultural sector. But, this may bring people and the nation closer together. It may also inspire a Vincentian to become a volcanologist, in the same way that stories of the 1979 and 1902 eruptions told by my family inspired me to become one!

Can you tell us more about your field, social volcanology?
Social volcanology is the research of how people live with active volcanoes, in particular with the associated surface processes and volcanic hazards.

Interview by Sarah Day

Dr Jazmin Scarlett is a historical and social volcanologist, whose research has focused particularly on the La Soufrière Volcano, Saint Vincent. She is a recipient of a 2021 President’s Award from the Geological Society.

Further reading:
A full list of further reading is available at geoscientist.online.
• STREVA (Strengthening Resilience in Volcanic Areas): https://streva.ac.uk/
Celebrating 100 Years of Female Fellowship of the Geological Society
Edited by C.V. Burek, B.M. Higgs
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MEASURES FOR MEASURE: GEOLOGY AND THE INDUSTRIAL REVOLUTION

DETAILS
BY: Mike Leeder (2020). Dunedin Academic Press, 272 pp. (hbk)
www.dunedinacademicpress.co.uk

REVIEWED BY LEIGH SHARPE
As geologists, we understand that the Carboniferous rocks of the Coal Measures were essential to the first Industrial Revolution. They determined its location, pace and extent. This book explains this relationship and the profound consequences to our landscape, society, culture and economics that followed.

An engaging narrative with cameos is used to frame the story, referencing the writings and eye-witness accounts of contemporary individuals. The geological firsts attributed to George Sinclair, whose work involved predicting where mineral resources could be found and easy won, were particularly insightful. Abraham Darby with his technological knowhow sparked the revolutionary blueprint, but he relocated to Coalbrookdale for a reason!

Professor Leeder’s vast knowledge comes to the fore in explaining the how, why and where. The answers, of course, are in the rocks, from the rise of forests, palaeoclimate and diagenesis to the Rheic Ocean’s demise and, finally, basin inversion. The richness of the geological story presented is like the creation of Pangaea itself – an impressive all-encompassing assemblage.

Contemporary artists’ depictions of industrialisation provoked much controversy. John Ruskin’s critiques exemplified the so-called ‘crisis in the sublime’ – were these works degrading of the natural world and the objectivity of landscape painting? Certainly, the sometimes idyllic depictions of working life belied the dystopian reality. The social legacy was, for me, most poignantly expressed by the lyrics of the song Trimdon Grange Explosion – little explanation is perhaps necessary. We learn of stories that today strike us with their great irony, including French geochemist Eblemen’s vital connections on the lifecycle of carbon that were published, but went unrecognised and lost to science for 140 years – a travesty, most probably.

Leeder’s finale is a comprehensive tour across nine of the former coal-based industrial regions to explain their individual geology and situational nuances. Interwoven with poetry, quotes and works of art, Measures for Measure will appeal to a wide readership. As the Black Country celebrates its recent UNESCO global geopark status, it is complementary and timely.

Whether a balance between narrative and textbook style is achieved, only the reader can decide. It is, however, an enjoyable and thought-provoking read and thoroughly recommended.

PURBeck STONE

DETAILS
ISBN: 9780995546364 PRICE: £35
www.dovecotepress.com

REVIEWED BY PATRICK CORBETT
This is a book on geology like no other. Treleven (Trev) Haysom is a tenth generation stone mason, who undoubtedly knows more about Purbeck Stone than any other living soul. With greatest respect to W.H. Auden, if ever there was a book to be called In Praise of Limestone, this must surely be it.

The title could be misleading as this book is much more than a description of Purbeckian Limestone. It includes marine Portland (Cliff Stone) and non-marine Purbeck (Inland Stone) without worrying too much where the Purbeckian-Portlandian stratigraphic boundary lies. The stones are introduced from the top down – unconventionally for geologists – which makes sense when you are digging from the surface. The stratigraphy is presented in such a bewildering array of masons’ names – Spangle, Thornback, Burr, New Vein – that for once the geologist is left floundering. The origins of these names are explained, when not lost to antiquity, and there is a logical order to their presentation.

For a geological specialist, many things are not addressed as might be expected: no stratigraphic column, no cross section, no scale bars to the figures; but Trev knows his geology – to the extent of using ‘geopetals’ in Salisbury Cathedral to address the way-up of the columns and cylinders used in the construction. His colleagues certainly have learned to know their ostracods.

The quarrymen are the main characters – the many recurring family names, their trace ‘fossils’ – the broaching, lettering, symbols, recorded in stone. It is amazing to think that 49 masons worked on Westminster Cathedral alone at the height of the industry. Trev knows their family lines and descendants personally, and navigates through all the variants of their first (nick)names, including who the individuals are in the old photographs.

The quarrymen know all about facies and diagenetic changes, as these aspects control the hardness and durability of the stone. The muddy rocks don’t get much of a mention and the distribution of silification and replacement would be very interesting to map out. One day perhaps this knowledge could also be captured, but for the moment geologists should welcome and be inspired by this very different view of a beloved and venerated rock.

The inexpensive volume is well produced with a lot of pictures, many from the author’s own collection. The increasing appreciation of the importance of one’s identity of place – geoidentity – make this a treasure trove. The book explains so much that I didn’t understand about the place I grew up in that has formed the bedrock of my life.
NEW CALEDONIA: GEOLOGY, GEODYNAMIC EVOLUTION AND MINERAL RESOURCES

DETAILS
FELLOW’S PRICE: £ 60
www.geolsoc.org.uk/M0051

REVIEWED
BY ROB BOWELL
New Caledonia is a small group of tropical islands in the south-western Pacific Ocean and is still a department of France. The archipelago is composed of several islands (the Loyalty Islands, Belep Islands, Ile des Pins, Grande Terre), reefs and lagoons. New Caledonia lies approximately 1,500 km east of Australia, 2,000 km north of New Zealand and just south of Vanuatu. The islands have had a long geological history that begins with Gondwana’s break up during the Mesozoic. The islands’ geology can be segregated into four major rock groups that were subject to accretion, subduction and obduction.

Such an active geological environment and complex history provides the basis for the development of the archipelago’s economic geology. The most important component of the mining industry in New Caledonia is nickel production from tropical laterites. These deposits are widespread, cover much of the ultramafic terranes and have been exploited for decades. Major projects include Goro and Koniambo, two of the largest nickel operations in the world. Other commercial operations produce cobalt and chromium, again as by-products of the ultramafic terranes.

This memoir provides a comprehensive summary of the current knowledge of New Caledonia’s geology, geodynamic evolution and mineral resources, based on a compilation of published and unpublished information. It comprises 10 research papers, each addressing a geological assemblage or topic. After an introductory chapter and a review of the published geodynamic models of evolution of the SW Pacific, chapters 3 to 5 focus on the main geological assemblages of Grande Terre: the Pre-Late Cretaceous basement terranes, the Late Cretaceous to Eocene cover, and the Eocene subduction-obludction complex – one of the largest and best-preserved in the world. Chapter 6 is devoted to the Loyalty Islands and Ridge. Chapter 7 deals with the mostly terrestrial post-obduction units including regolith. Chapter 8 deals with palaeobiogeography and discusses plausible scenarios of biotic evolution. Chapters 9 and 10 provide a comprehensive review of New Caledonia’s mineral resources.

The editors and authors are to be congratulated on such a large undertaking, particularly the senior editor who has co-authored all the chapters. The volume will interest stratigraphers, sedimentologists, marine geologists, palaeontologists, palaeoecologists, igneous and metamorphic petrologists, geochemists, geochronologists, and specialists in tectonics, geodynamic evolution, regolith development and economic geology.

SCOTLAND’S MOUNTAIN LANDSCAPES: A GEOMORPHOLOGICAL PERSPECTIVE

DETAILS
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REVIEWED
BY CHRIS JACK
I was keen to get my teeth into this book by well-known expert Professor Colin Ballantyne of the University of St. Andrews, because, as well as being a geologist, I am an (aspirant) mountaineer. I am pleased to say that I was not disappointed!

The book covers a wide range of topics. A general introduction to the geology of Scotland is valuable, both as the beginning of the geomorphological story and as a starting point for the non-specialist reader. This is followed by a comprehensive overview of the relevant geomorphological topics, covering the pre-glacial landscape, the Ice Age in Scotland, glacial and periglacial landforms, landslides, aeolian and fluvial landforms and example key sites. The book is very well illustrated with excellent colour photographs – particularly useful in a book that aims to explain geomorphological features (and it does no harm that Scotland’s beautiful mountains form the backdrop).

My favourite chapter was probably that on aeolian landforms, as this is a topic I know very little about and had never considered in the context of the Scottish mountains. However, thanks to this book, I now have some idea of how to recognise deflation surfaces, wind-patterned ground, turf-banked terraces and ventifacts.

The final chapter provides details of key sites that exemplify some of the features discussed in the book. For this reason alone I will be pleased to hold onto my review copy, so that I can visit these sites.

A couple of criticisms. Firstly, the blurb of the book states that it is written in clear, non-technical language. While, as a geologist, I found the book clear and accessible, I am not sure that a layperson would always find it so easy (although any difficulties would be overcome with reference to a geological dictionary). Secondly, some of the photographs would have benefitted from some mark-ups to assist non-Earth scientists. However, these minor quibbles are easy to overlook, given that Professor Ballantyne’s enthusiasm for the topic shines through the book.

I can easily recommend this book to geomorphologists looking for an accessible introduction to the mountains of Scotland, Earth scientists who love the mountains and mountaineers who have a keen interest in how their playground came to be.
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JOHN ALLEN was born in Birmingham, UK, to George and Alice Allen. John attributed his being drawn to the sciences as a schoolboy to regular visits to his step-grandmother on the coast at Freshfield, between Liverpool and Southport, as well as to a science fiction paper, *Modern Wonder*. At school in Edgbaston, Birmingham, John developed a flair for chemistry. Later, he began attending geology field trips with the Birmingham Literary and Philosophical Society.

Training and research
John read physics, chemistry and mining geology with geology at Sheffield University, graduating in 1955. He developed an interest in the Old Red Sandstone, with his contemporary, Beverly Halstead. After graduating, John remained at Sheffield to research the Old Red Sandstone of the Clee Hills, Shropshire, but never presented a thesis. He was awarded a DSc for published papers.

Perce Allen recognised John’s talents and offered him a research fellowship in sedimentology at the University of Reading, and so began a remarkable career. Initially, John worked on the Niger Delta where he began to appreciate the need for experimental work on, and later modelling of, sedimentary processes to complement field studies – a hallmark of the earlier part of his career.

John remained at Reading throughout his career, where he contributed enormously to the success of the Sedimentology Research Laboratory – a powerhouse of research. He became the first Director of the Postgraduate Research Institute for Sedimentology in 1988.

Sedimentology and geoarchaeology
Through experiments using flumes, John pioneered deciphering the physics involved in producing sedimentary structures and he took that understanding to the outcrop.

Besides a remarkable number of journal publications, John also produced a book on current ripples (1968); his seminal 1970 book *Physical Processes in Sedimentation* (a benchmark contribution for every sedimentologist) and his two-volume *Sedimentary Structures: their character and physical basis*.

John used his understanding of sedimentary structures to elucidate the classic continental successions of the Siluro-Devonian Old Red Sandstone of Wales and the Welsh Borderlands and the Catskills. He was one of the first to recognise the presence and importance of palaeosols in alluvial strata. John also studied a range of ancient marine and modern deltaic deposits. For his contributions to sedimentology, John was elected a Fellow of the Royal Society (FRS) in 1979.

Through his work on the Severn Estuary later in his career, John became more involved in geoarchaeology, publishing on Mesolithic, Roman and Medieval sites, as well as geological aspects of church architecture and gravestones. In 2018, John’s *Geology for Archaeologists* was published. As a mark of the esteem in which he was held, John was elected a Fellow of the Society of Antiquaries of London (FSA) in 1991.

Honours, service and impact
John received many honours including the Lyell Medal of the Geological Society of London (1980); the G. K. Warren Prize of the US National Academy of Sciences (1990); the Penrose Medal of the Geological Society of America (1996); SEPM’s Twenhofel Medal (1987), and the Sorby Medal of the International Association of Sedimentologists (1994).

John served on the Council of the Geological Society and on the Council of NERC.

John was a private person, but many speak with great fondness of their time with him. The numerous online tributes are evidence of the impact John had on so many lives and careers. John was a very good cook and he enjoyed live opera.

John died on 18 October 2020, after a short illness. He is survived by his wife Jean; his children Catherine, Hugh, James and Stephen, and five grandchildren.

“He was one of the first to recognise the presence and importance of palaeosols in alluvial strata”

The full versions of Fellows’ obituaries are available at www.geolsoc.org.uk/obituaries

Pictured, above: John received many honours throughout his distinguished career
PAUL FRANCIS WORTHINGTON was born in Preston, Lancashire, and remained proud of his northern English roots throughout his life.

After a degree in Maths and Physics at the University of Hull, he taught for a year at Kilburn Polytechnic in London. A late-night conversation at a party introduced him to geophysics, setting him on the path that defined his professional life.

Academia and industry

Paul’s academic career took him to an MSc in Geophysics at Durham University, then to the University of Birmingham, where he earned a PhD researching petrophysics, and met Catherine, his wife of almost 50 years. Paul started his technical career in the water industry, with five years in Pretoria, South Africa, where he became Chief Research Officer with the South African Council for Scientific and Industrial Research, and was awarded a DSc by the University of Pretoria.

On return to the UK, Paul spent two more years in the water industry before moving into the oil industry with BP in 1980. He became Head of Formation Evaluation at the BP Research Centre, promoting the use of theoretical petrophysics and core data to aid integrated reservoir characterisation. After BP, he joined consulting firm GaffneyCline, where he concentrated on equity redetermination and reserves estimation.

Paul was devoted to the pursuit of excellence and knowledge sharing. He published more than 100 peer-reviewed papers on engineering geoscience and petroleum unitization, and coedited four books on core and log analysis.

Several of Paul’s papers are considered seminal. He served the Society of Petrophysicists and Well Log Analysts (SPWLA) in many roles, including President (1985–86).

Paul was the recipient of numerous SPWLA awards for technical achievement and service, including the society’s top honour, the Gold Medal for Technical Achievement (2012).

From 1986 to 1992, Paul was Chair of the Downhole Measurements Panel of the International Ocean Drilling Program and was co-editor for a decade of Petroleum Geoscience for the Geological Society and European Association of Geoscientists and Engineers. He was also active in the London Section of the Society of Petroleum Engineers.

Formidable reputation

As a young man, Paul was a football goalkeeper of formidable reputation and a lifelong fan of Manchester United. Wherever he travelled, he would go to great lengths to do two things: watch the ‘Red Devils’ and attend Mass. The Catholic faith played a huge role in Paul’s life. He was an active parishioner of St Francis, Ascot, for almost 40 years and was honoured to become a Knight of the Equestrian Order of the Holy Sepulchre of Jerusalem.

Paul’s final academic achievement was consolidating the legal side of his unitization experience into a Master of Laws by Research at the University of Reading. This work, The Law on Petroleum Unitization, is published as his final legacy.

Paul is survived by his loving wife Catherine, his children Michelle, Mark and Tim, and his four grandchildren.
FRANK RHODES was the archetypal English gentleman and scholar. He made important contributions to palaeontology and achieved international prestige as a university teacher, administrator and policymaker, especially in the US, where he became a citizen and pursued most of his distinguished career.

Education and early career
Born in Warwickshire, UK, Rhodes was awarded three degrees by Birmingham University: BSc (1948), PhD (1950) and DSc (1963). He won a Fulbright Scholarship, spent at the University of Illinois, USA (1950-51), then taught at Durham University (1951-54).

He returned to Illinois as Assistant, then Associate Professor (1954-1956) and was appointed to the Chair of Geology in the University College of Wales, Swansea, in 1956, at the exceptionally young age of 29. In 1965, Rhodes was awarded a Visiting Research Fellowship by the US National Science Foundation, which he spent at Ohio State University. In 1967, he was elected Dean of Science at Swansea and was recipient of the Geological Society’s Bigsby Medal.

These periods of transatlantic peregrination were clearly beneficial to Rhodes’ research, now focused on the systematics, biology and biostatigraphic value of conodonts, complementing his expanding interests in broader evolutionary topics. The links established then provided research opportunities for research students and postdoctoral fellows, and led to fruitful collaborations with leading American palaeontologists and biostatigraphers, such as Harold Scott and Charles Collinson, several of whom spent sabbatical periods at Swansea during Rhodes’ 12 years’ tenure there.

Michigan and Cornell
In 1968, Rhodes joined the University of Michigan (Ann Arbor) as a Professor in the School of Geology and Mineralogy. He became Dean of their College of Literature, Science and the Arts in 1972, and served as Vice-President for Academic Affairs at Michigan from 1974 until 1977. He then became President of Cornell University, where he remained until his retirement in 1995 (as the longest-serving University Head in the Ivy League).

His time at Cornell was marked by innovation, enterprise and inclusiveness, significantly expanding the degree courses offered and enhancing recruitment of female and minority-group students and staff, alongside a much expanded range of the research topics pursued – all accomplished through greatly increased external funding. Rhodes built or strengthened academic links for Cornell with many overseas universities and research institutions, from Saudi Arabia to Cambridge, Hong Kong to Oxford, and was awarded some 35 honorary degrees and fellowships, including Honorary Fellowship of the Geological Society of London.

Rhodes became an influential member of the US National Academy of Sciences and was consulted on academic and scientific policy matters by four US Presidents. His eloquence and ability to convey complex concepts to lay audiences meant that even in retirement he was greatly in demand as a speaker, both in the USA and internationally.

Important contributions
Throughout his long career at Cornell, Rhodes continued to make important contributions in the fields of evolution, geology, palaeontology and the history of science, as encapsulated in a series of books and compilations including *The Evolution of Life*, *Language of the Earth*, and *Earth: A Tenant’s Manual*. He also contributed to several geology-related titles in the popular *Golden series* for younger readers.

Perhaps the most telling testimony to Rhodes’ academic standing, charismatic appeal and popular esteem is conveyed by the announcement made, shortly after his official retirement from Cornell, by the Mayor of Ithaca, New York, that his birth date would henceforth be celebrated annually in that city as Frank H.T. Rhodes Day!

Rhodes is survived by his wife Rosa, daughters Jennifer, Catherine, Penelope and Deborah, 11 grandchildren and one great granddaughter.
“I’m driven by creating change in our sector”

ANJANA KHATWA is a science presenter and museum learning professional. After 15 years managing and developing the Jurassic Coast World Heritage Site education programme, she is now Engagement Lead with Wessex Museums, as well as a freelance consultant. Anjana is recipient of the RH Worth Medal 2021 for services to geoscience education and outreach.

What’s a typical day for you?
I start my day by walking my daughter to school and chatting about all sorts of things, from earthquakes to Roblox. It never ceases to amaze me that even 20 minutes walking outside can have such a beneficial effect on your health and wellbeing.

My new job as Engagement Lead with Wessex Museums is based from home. I also work as a consultant and TV presenter – the latter being less glamorous than it sounds! Much of my day is spent in virtual meetings, delivering talks and training sessions focused on anything from science communication and engaging with nature, to diversity and inclusion. It’s inspiring work and those who have come to my sessions or worked with me know that I give so much of myself to the event. To recover from the fatigue of online working, I’ll often go for a run or a short walk to a nearby nature reserve to try to restore my energy.

What are you currently working on?
At Wessex Museums, I am innovating approaches in how to engage underserved audiences with our museums in these difficult times. One of our projects is helping a group of young Black people in an urban area learn about the impact of climate change on Brownsea Island. The group will be supported to create a response to this research and, excitingly, this will enter the permanent collections of Poole Museum.

I am in high demand as a speaker and panelist at conferences, so I have a variety of talks and workshops to develop for various clients on equality, diversity and inclusion. I’m also creating a short film for the Great Science Share, explaining how rocks are handheld time machines, so there is plenty of variety in my work!

What one piece of advice would you give to someone hoping to work in your field?
In the world of learning, engagement and science communication your greatest strength is your passion and creativity. Obviously, you need to have a decent understanding of the science, but, more importantly, you have to understand the needs of your audience and be adept enough to tailor content that excites and engages their attention and interest. This comes through experience, and every time you flunk and dive you learn and improve. I am fortunate enough to present science on TV to huge audiences now, but I started out with a classroom of sceptical trainee teachers and a chunk of rock! The loveliest feedback I get from audiences is that my infectious enthusiasm for rocks, fossils and landscapes is what inspires them to keep watching. Find that joy and always keep it alive because that is your greatest asset.

Pictured, above: Anjana says passion and creativity are the two most valuable qualities of science communicators.

Image credit: Rob Coombe/Lyme Regis Museum
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