GEOSCIENTIST

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The Fellowship Magazine of the Geological Society of London

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[FOCUS ON GEOTHERMAL]

IS THE UK IN HOT WATER?

Nadia Narayan and colleagues assess the nation's karstic geothermal resources

VOLCANIC DANCE
Brendan McCormick Kilbride on fieldwork in Papua New Guinea

UNCONVENTIONALS
Technological advances in this flourishing sector

SUB-SURFACE STRATEGY
Peter Styles asserts the need for a UK plan on sub-surface use

Geoscientist is the Fellowship magazine of the Geological Society of London

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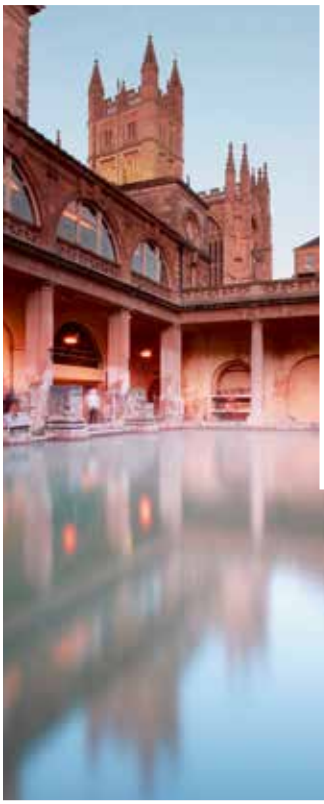

ON THE COVER:

FEATURES

REGULARS

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BRYAN LOVELL MEETING 2019

Role of geological science in the decarbonisation of power production, heat, transport and industry

21-23 January 2019 | **The Geological Society, Burlington House**

In the UK and elsewhere, decarbonisation of power production, industry, transport and heating to meet climate change targets is a major challenge and one that intrinsically involves the subsurface and geoscience.

Decarbonisation is central to Government and international policy and this three day conference will host national experts from industry, academia, and government to look at the geological and reservoir engineering aspects of the problem. The main objective will be to identify the high level barriers to progress and the main science questions - and begin a roadmap to solve the problems.

Convenors

Mike Stephenson (British Geological Survey)
Dave Schofield (British Geological Survey)
Sebastian Geiger (Heriot-Watt University)
Philip Ringrose (Statoil/NTNU)

Further information

For further information about the conference please contact:
Rhianna McLean, Conference Office, The Geological Society, Burlington House, Piccadilly, London W1J 0BG

T: 0207 434 0981

E: rhianna.mclean@geolsoc.org.uk

Web: www.geolsoc.org.uk/lovell19

Follow this event on Twitter: #lovell19

Keynote speakers confirmed

Spencer Dale, Group chief economist, BP; Chris Stark, Chief Executive, Committee on Climate Change; Nick Pidgeon, Cardiff University.

Other speakers confirmed

Martin Blunt, Frances Wall, Jonathan Turner, Seamus Garvey, Clair Gough, Sebastian Bauer, Martin Smith, Jon Gibbins, Jonathan Pearce, Stephen Bull, Thomas Koebel, Thomas Driesner, Adele Manzella, Henrik Solgaard Andersen, John Underhill, Ben Sovacool, Toby Peters.

Call for abstracts

Abstracts are invited from early career researchers who wish to exhibit posters at the conference. Posters that address any aspect of decarbonisation geoscience are encouraged, for example geothermal, gas storage, compressed air energy storage, critical metals, radioactive waste disposal, CCS, and bio-energy and CCS (BECCS). Abstracts should be approximately 500 words and include a title and acknowledgement of authors and their affiliations where possible. Please send your abstract as a Word document to rhianna.mclean@geolsoc.org.uk by 1 October 2018.

2019 YEAR OF CARBON

CONFERENCE

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serving science, profession & society

MSG

YEAR OF RESOURCES

Marine Minerals:
A New Resource for the 21st Century

31 October – 1 November 2018 | **The Geological Society, Burlington House, London**

Event partner: Marine Studies Group

Marine minerals activities are gathering pace. More and more entities are seeking licences from the International Seabed Authority (ISA) for manganese nodule exploration and mining in the North Pacific and for hydrothermal minerals exploration and mining on mid-ocean ridges worldwide.

The U.K. has an important role in marine minerals activities through its sponsorship of several exploration licences with the ISA and active marine minerals research by the NOC, BGS and Universities in U.K. waters and the North Atlantic and Pacific Oceans. Central themes of the Conference will include research on these increasingly important mineral deposits and their resource potential, together with mining and environmental considerations.

An important aspect of the conference will be panel led discussions surrounding the main themes of the conference and involving both speakers and audience. These will include the likely pace of marine minerals development, what needs to be done to ensure this can be achieved, can the resources be sourced in an environmentally and socially acceptable way and what are the legal and political ramifications.

Convenors

David Cronan (Imperial College London)
Robert Gatliff (BGS)
Bramley Murton (NOC)
Philomene Verlaan (University of Hawaii)

Further information

For further information please contact:
Georgina Worrall, Conference Office, The Geological Society, Burlington House, Piccadilly, London W1J 0BG

T: 0207 434 9944

E: georgina.worrall@geolsoc.org.uk

Web: www.geolsoc.org.uk/marineminerals18

Follow this event on Twitter: #marineminerals18

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IOM³

YEAR OF RESOURCES

Mineral Resource Estimation:
Recent Advances and Current Best Practice

22 October 2018 | **The Geological Society, Burlington House, London**

In an era of rapid technological innovation, opportunities exist to improve efficiency and quality of resource estimates; both developing trust and encouraging investment in mining projects. Forming part of the Year of the Resource, this conference aims to provide a forum for resource estimate practitioners to meet and discuss new developments and advances in mineral resource estimation and reporting.

Conference topics will include:

- Exploratory data analysis: analysis of geoscience data prior to use in a MRE including databasing, data quality analysis, utilising 'big data' and methods of critical evaluation.
- Geological modelling: methods and processes used for generating 3D models of geological features, including software advances and comparisons, how to integrate 'big data' and busting commonly encountered myths.
- Geostatistics and grade estimation: methods for estimating tonnage and grade/quality of a mineral deposit, including recent software advances, new techniques and comparisons of techniques in different mineralisation types. Reconciliation between estimates and production and ground truthing models.
- Resource reporting: methods used for generating mineral resource statements, including methods for demonstrating 'reasonable prospects for eventual economic extraction' (as defined in international reporting codes), including updates/comparisons of CRIRSCO standards and participating committees.

Convenors

Ben Lepley (SRK Consulting)
Lucy Roberts (SRK Consulting)

Further information

For further information please contact:
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Web: www.geolsoc.org.uk/mineralresource18

Follow this event on Twitter: #mineralresource18

Keynote speakers include:

- Mike Armitage, SRK Consulting
- Jacqui Coombes, Snowden

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2018 YEAR OF RESOURCES

Geology and the safe disposal of radioactive waste

Burlington House
London

26 October 2018
11:00 – 16:00

Free admission

Further details and registration at:
www.geolsoc.org.uk/RWM-Geo-Radwaste

Radioactive Waste Management

> COULD A RISE IN LOCAL GEOTHERMAL PROJECTS AND THE PROSPECT OF IMPORTED, VOLCANICALLY SOURCED ENERGY SIGNAL A GREATER ROLE FOR GEOTHERMAL IN THE UK'S ENERGY FUTURE?

FROM THE EDITOR'S DESK:

Geothermal-powered nation

The sound of drilling pierces the air in the typically tranquil town of Penzance, Cornwall—earlier this year, work began on a geothermal well that will tap water naturally warmed underground to supply the town's Jubilee swimming pool. Drilling a 1.4-km-deep well to heat part of a pool may seem indulgent, but the project raises the question of whether geothermal energy could realistically form a significant component of the UK's low-carbon future.

Geothermal power is usually associated with volcanic regions, but active volcanism isn't a pre-requisite. The temperature in Earth's crust naturally increases by about 25-30°C per kilometre, so by drilling a few kilometres down into naturally permeable or artificially fractured rocks, and then pumping water to the surface, we can tap a persistent heat source with scarce carbon emissions.

Swathes of Southampton are heated by geothermal energy supplied by the Wessex Basin aquifer and work is underway to create a similar district heat network in Stoke-on-Trent. Plans have just been approved to develop a geothermal research observatory in Glasgow, with the aim of understanding the potential for water in flooded, abandoned mine shafts to heat the city. And on page 10 of this issue, Nadia Narayan and colleagues discuss the prospect of Carboniferous Limestone karst as a geothermal resource for the nation.

Such projects can only meet a portion of the UK's energy needs because low geothermal gradients mean the wells can largely only be used for heat. To efficiently generate electricity requires high-enthalpy geothermal sources typically associated with active volcanism, which the UK does not have. But neighbouring Iceland does.

In 2009, the Icelandic Deep Drilling Project accidently struck a pocket of magma sitting just 2 km beneath Krafla Volcano. Steam streamed from the borehole. Rather than fill it, engineers cased the well and delivered the steam to the Krafla power plant, where it powered turbines and delivered an almost ten-fold increase in electricity compared to existing wells. Now, as part of the Krafla Magma Testbed project, volcanologists and geothermal engineers from around the globe are working with Iceland's Geothermal Research Group to investigate the feasibility of magma-powered geothermal energy—energy that could potentially be exported to the UK (though Brexit has put paid to further discussion of a seafloor cable between Iceland and the UK).

Development of the UK's geothermal resources has been slow, partly due to a cheap supply of fossil fuels from the North Sea. Given the growth of innovative local projects and emergence of several exciting research avenues, perhaps it's time to consider geothermal energy as a notable part of the UK's future energy mix.

DR AMY WHITCHURCH, EDITOR - amy.whitchurch@geolsoc.org.uk @geoscientistmag

SOCIETY *NEWS*

What your society is doing at home and abroad, in London and the regions

Call for nominations to Council and to serve as President

Would you consider standing for election to Council and contributing to the work of the Society, as a member of both Council and one or more of its committees? The application forms are included with this issue, writes Stephanie Jones.

Membership of Council enables you to influence the role of the Society in acting as a respected voice and serving science, the geoscience profession and society. You will play an active role in the delivery of the Society's strategy, and help to facilitate the communication of new science through engagement with policy makers, the media and the public, and the certification of best practice in education and the profession.

Each of the 23 members of Council is a trustee of the Society, accountable to the Fellows and to other stakeholders and regulators, such as the Charity Commission. The prime responsibility of the trustees is to oversee the affairs of the Society and to act prudently in the management of its financial resources.

Council meets five times a year, usually on a Wednesday. Four of those meetings take place in the afternoon beginning at 14.00 and finishing at 17.00. In addition, there is a two-day residential meeting, usually in late September, to discuss major strategic issues.

All members of Council also serve on one of the standing committees (External Relations, Finance & Planning, Professional, Publications & Information and Science). Standing committees usually meet three or four times a year, mostly in person but sometimes virtually. Council members are sometimes also asked to join other committees or short-term working groups. The typical time commitment is eight to ten days annually for ordinary members of Council.

Forms

Fellows have received two nomination forms with this month's *Geoscientist*—one for candidates for Council and the other for candidates for the position of President-designate. Details of the nomination process are on the forms and on the Governance section of the website, where you can also see the names of those members of Council due to retire at the AGM in June 2019 (www.geolsoc.org.uk/councilnominations2018).

As part of our commitment to ensuring a more diverse and inclusive Council, the Society particularly welcomes nominations from under-represented groups, allowing Council to better reflect the community it serves. Knowledge and experience of scholarly publishing and of fund-raising are also desirable.

Nominations must arrive **no later than noon on Friday, 4 January 2019**.

Council & OGMs

OGMS: 2018: 28 November **2019:** 6 February, 3 April
COUNCIL: 2018: 28 November **2019:** 6 February, 3 April

PUBLIC LECTURE SERIES

The future of plate tectonics: delving into the deep interior of our planet

Speaker: Phil Heron, Durham University
Location: Burlington House, London
Date: 16 October

Programme

- **Afternoon talk:** 14:30pm Tea & Coffee; 15:00 Lecture begins; 16:00 Event ends
- **Evening talk:** 17:30 Tea & Coffee; 18:00 Lecture begins; 19:00 Reception

Satellite Top Trumps: The Geological Edition

Speaker: Charlotte Bishop, Geological Remote Sensing Group
Location: Queen's University, Belfast
Date: 16 October

Programme

- **Evening talk:** 17:30 Tea & Coffee; 18:00 Lecture begins; 19:00 Reception

Further Information

Please visit **www.geolsoc.org.uk/gsllondonlectures18**. Entry by ticket only (contact the Society about four weeks before the talk). Due to popularity, tickets are allocated in a monthly ballot and cannot be guaranteed.

Contact: **Sarah Woodcock,** The Geological Society, Burlington House, Piccadilly, London W1J 0BG
T: +44 (0) 20 7432 0981 E: **receptionist@geolsoc.org.uk**

Membership renewals for 2019

Collection of membership renewal fees for 2019 has now started. An email communication has been sent to you at the address we have registered, with instructions on how to renew. If you do not have an email address registered with us a letter has been sent to you by post, and we encourage you to provide an email address for future correspondence.

For the last few years, many members have opted for paperless invoicing, with the majority choosing to pay online. This has significantly reduced the number of paper returns, contributing to the important objective of a reduced environmental footprint and improving the efficiency of payment processing, for the benefit of all. With this in mind, we feel the time is right to introduce paperless billing for the 2019 membership renewals. Fellowship cards will be sent to all Fellows who have paid and renewed by December 2018.

If you have not received an email regarding your membership renewals, please contact the Fellowship office on membership@geolsoc.org.uk for more details. We look forward to your continued membership and support of the Society.

Chartership Applications

Geological, not geotechnical competencies should be demonstrated, advises Bill Gaskarth.

Applications for CGeol by many engineering geologists still focus on geotechnical engineering and, similarly, many supporting documents are geotechnical engineering reports without reference to the geology underlying the projects. The title being applied for is Chartered Geologist—Scrutineers are looking for the demonstration of geological, not geotechnical competencies. Many applicants seem to ignore this. It is important for sponsors to advise applicants of the need to focus on their geological knowledge and its use.

The application forms for CGeol, CSci and the 20+ years' experience route have been updated and the new versions are now on the Society's web site.

Accreditation

The Dunelm Geotechnical and Environmental Training Scheme for Geoscientists has been accredited by the Society. It joins a growing list of accredited schemes that provide trainees with mentors and the opportunity to gain technical, professional skills and experience towards readiness for a Chartership application.

Progress is being made in discussions with representatives of the oil-and-gas industry towards the development of a competency management system for oilfield geoscientists. It is hoped that a training system might be accredited and professional competency register developed providing professional qualifications.

Mentoring

A few places are available on the Mentoring Workshop scheduled for October 19.

Contact the Chartership Officer (Chartership@geolsoc.org.uk) to book a place.

Society Discussion Group

Danny Clark-Lowes explains the benefits of the Geological Society Discussion Group (GSDG), a Specialist Group of the Society.

In which Specialist Group can you learn about the Quaternary opening of the Dover Straights, the lack of effective representation of science in Parliament, pingos (yes, you may have to Google it), managing geological risk, 'channel flow' as a tectonic mechanism for granite emplacement in the Himalayas—and get a chance to debate these issues?

The answer is the GSDG. Since late 2016, this newly-formed group has been holding dinner meetings at various London locations and these topics, plus many more, have been discussed.

The group aims to foster wide-ranging scientific discussion. Invited speakers give a brief introduction to a topical geological subject and promote discussion around the table.

The meetings, which take place about six times a year and are open to the entire Fellowship, are held at various London venues. The cost varies and some are kept deliberately low so as to encourage as wide a participation from the Fellowship as possible. Non-Fellow guests are also welcome. We often arrange a summer outing: last year we learnt about the geology of wine at Denbies winery, near Dorking, and this year we toured collections at the Natural History Museum that are not usually open to the public. For general information about the GSDG, contact Danny Clark-Lowes (Honorary Secretary); d.clarklowes@nubianconsulting.co.uk.

Malcom Brown listens to an explanation from Epifanio Vaccaro, Petrology Curator, Natural History Museum (Photo credit: © Danny Clark-Lowes).

Event

Charles Dickens: Man of Science 2-for-1 offer for Fellows

Fellows of the Geological Society can enjoy 2-for-1 entry to the exhibition *Charles Dickens: Man of Science* at the Charles Dickens Museum, London, writes **Michael McKimm**.

The exhibition reveals the celebrated 19th Century author not only as a scientific enthusiast, but as a key communicator of science in the Victorian age. A number of items from the Geological Society Library are on loan to the exhibition, including Henry De La Beche's drawings 'Duria Antiquor' and 'Awful Changes', William Buckland's *Bridgewater Treatise* and Roderick Murchison's own geological hammer.

The exhibition runs until Sunday 11 November at the Charles Dickens Museum, 48 Doughty Street, London, WC1N 2LX. (Tuesday-Sunday 10am-5pm (last entry 4pm)). To claim the 2 for 1 offer please purchase tickets in person at the museum, showing your GSL membership card (contact us if you do not have a membership card).

Find out more at **dickensmuseum.com/blogs/exhibitions/charles-dickens-man-of-science**

FROM THE LIBRARY

Online Library catalogue

Search the online catalogue of books, journals and maps held in the Geological Society Library. Fellows and Corporate Affiliate members can now login to the Library Catalogue to renew loans, view loan history, request items and create Favourite lists bit.ly/2Hj6jtH

E-Journals and e-books

Fellows of the Society can access over 100+ e-journals and e-books using Athens authentication. There is no charge to Fellows for this service. Visit www.geolsoc.org.uk/virtuallibrary to register.

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Latest news from the **Publishing House**

Jenny Blythe has the latest from the Geological Society Publishing House

The Bolca Lagerstätten: shallow marine life in the Eocene

By Matt Friedman and Giorgio Carnevale

The Eocene limestones around the Italian village of Bolca occur in a series of distinct localities providing a unique snapshot of marine life in the early Cenozoic. Famous for its fishes, the localities of Bolca also yield diverse invertebrate faunas and a rich, but relatively understudied flora. Most fossils from Bolca derive from the Pesciara and Monte Postale sites, which bear similar fossils but are characterized by slightly different taphonomic and environmental profiles. Although not precisely contemporaneous, the age of these principal localities is well constrained to a narrow interval within the Ypresian Stage, c. 50–49 Ma. This places Bolca at a critical time in the evolutionary assembly of modern marine fish diversity and of reef communities more generally.

➤ **Read full abstract and paper in the Lyell Collection** http://jgs.lyellcollection.org/content/175/4/569

New Collection

Tectonics and Petroleum Systems of East Africa Collection

This collection comprises all papers recently published in Petroleum Geoscience on the theme 'tectonics and petroleum systems of East Africa'. Compiled by guest editors Duncan Macgregor, John Argent and Pamela Samson, these partly result from the Geological Society of London's Petroleum Group conference in April 2016 on 'East Africa; From Research to Reserves'. The collection makes progress in constraining, but not firmly resolving, some of the key tectonic interpretations. There are still many tantalizing aspects of East African petroleum geology yet to be documented, however these papers represent a significant step in this process.

➤ **Read more here** www.lyellcollection.org/cc/tectonics-and-petroleum-systems-of-east-africa-collection

Whose Geology is it Anyway?

Peter Styles* questions who owns the land under our back gardens and whether it is being managed properly, or at all

You might think that you own the land under your back garden, but below soil level, you don't. The commercial sector, or UK PLC, own the mineral rights to the subsurface and I believe it is time for Government to develop a strategic plan for the utilisation of underground space. "If you can't grow it, you must mine it" is an old adage that is still pertinent!

I was Chair of a committee set up by DEFRA in 2006 to consider screening criteria that would apply to volunteer sites for the location of an underground geological repository for radioactive waste, to test the geological suitability for such a task: a ruling-out set of criteria.

Our terms of reference were to provide Government with advice on appropriate sub-surface scientific criteria to identify areas of the UK where it would be inappropriate to develop a geological repository.

The first priority was to protect our and future generation's water supplies. Secondly, we would avoid areas where those future generations (having forgotten our industrial history) might re-explore for resources.

Explaining these issues was complicated by the three-dimensional nature of geology. In the UK, a repository is likely to be excavated several hundred metres below Earth's surface. Hence, unsuitable geology at the surface, or at specific depths, is not necessarily a reason for exclusion.

We therefore recommended that criteria should be used to exclude areas where: all or part of the potential repository host rock would be provided by aquifers, or other permeable formations that might reasonably be exploited for water resources in the future; mineral resources are located at depths greater than 100 metres—coal, oil, gas, oil shales, and some metalliferous ores—to reduce the risk of intrusion into a geological repository by future generations seeking to extract resources (inadvertent intrusion); waste disposal or gas storage (and of course now carbon dioxide sequestration) is committed or approved; deep karstic formations and source rocks for thermal springs are known to exist.

It is time to relook at these issues because of a sea-change in resource availability provided by prospective shale-gas resources, which, based on evaluation by the BGS, may be very extensive, especially in Northern England. In addition, earlier this year Radioactive Waste Management Ltd announced their new initiative to locate suitable areas where community acceptability and geologic suitability converge.

Our 2007 report for DEFRA was predicated on the premise that the relatively limited geographical sources of onshore UK gas and oil would not prove problematic. However, applying these criteria in 2018, we would find considerable clashes between potential repository sites and shale gas exploration areas.

There will inevitably be clashes to come in desired and planned uses of the subsurface and it is incumbent upon UK Government to develop a prioritisation plan that mitigates or avoids these.

A 'Strategy for the Utilisation of the Sub-Surface' (SUSS!?) is required and I recommend that this begins (and is completed) as expeditiously as possible!

*Peter Styles is a Professor Emeritus at Keele University

SOAPBOX CALLING!

Soapbox is open to contributions from all Fellows. You can always write a letter to the Editor, of course, but perhaps you feel you need more space?

If you can write it entertainingly in **500 words**, the Editor would like to hear from you. Email your piece, and a self-portrait, to **amy.whitchurch@geolsoc.org.uk.** Copy can only be accepted electronically. No diagrams, tables or other illustrations please.

Pictures should be of print quality – please take photographs on the largest setting on your camera, with a plain background.

Precedence will always be given to more topical contributions. Any one contributor may not appear more often than once per volume (once every 12 months).

> "IT IS TIME TO RELOOK AT THESE ISSUES BECAUSE OF A SEA-CHANGE IN RESOURCE AVAILABILITY PROVIDED BY PROSPECTIVE SHALE-GAS RESOURCES
> **PETER STYLES**

IS THE UK IN HOT WATER?

In the midst of the UK's renewable energy revolution, **Nadia Narayan**, **Jon Gluyas** and **Charlotte Adams** aim to identify and quantify the nation's karst geothermal resources in Carboniferous Limestone

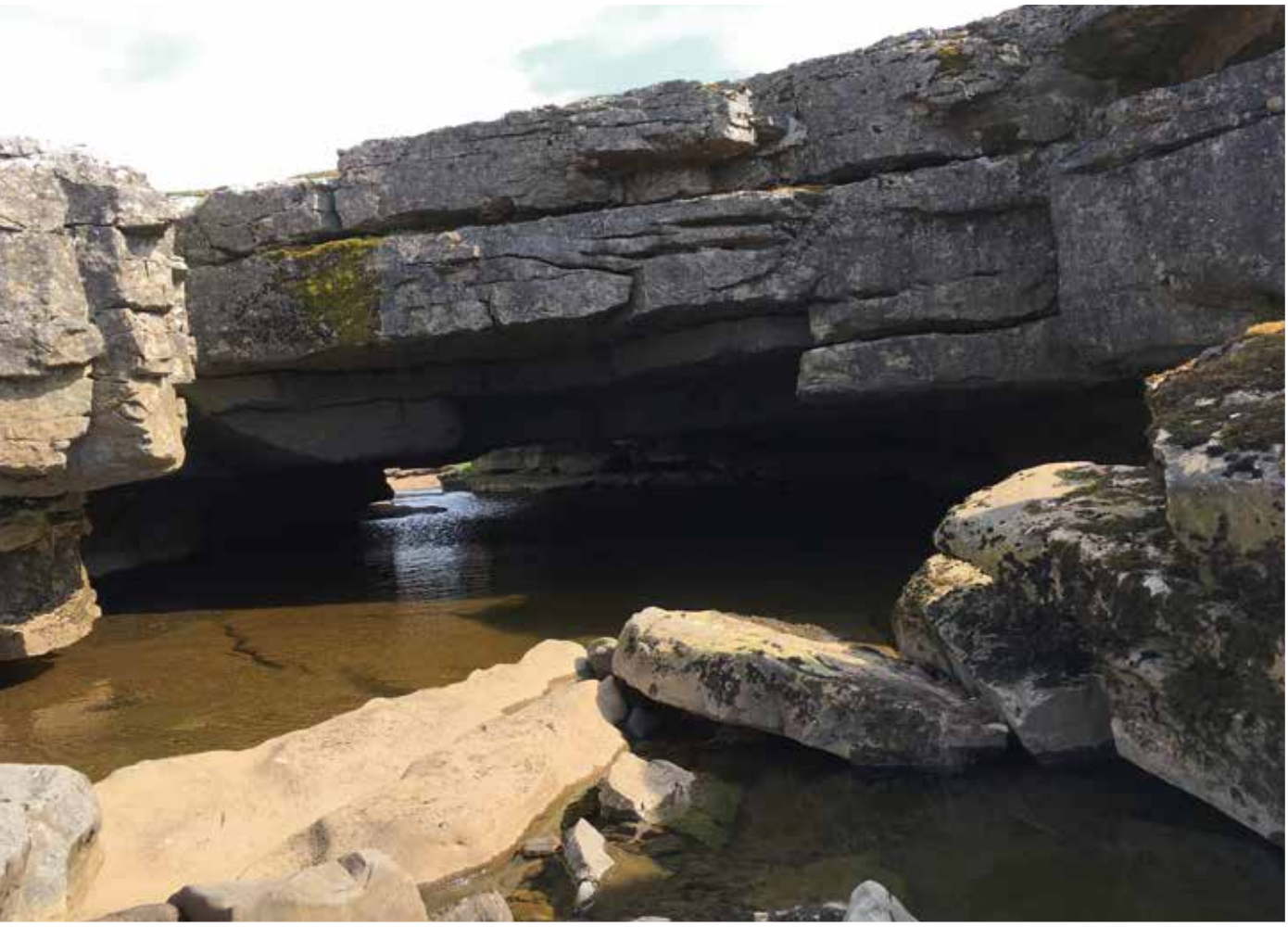
Rewind to 31st December 1973, the UK is experiencing an energy crisis. The Organisation of Petroleum Exporting Countries (OPEC) Arab oil states have imposed an oil embargo, causing a stock market crash. The coal miners are on strike in defiance of their low wages. Coal supplies are diminishing and tonight the lights go out. Commercial businesses will only be allowed to consume electricity three days a week. The UK is at its most vulnerable. What is the next move?

Reaction to a crisis

The events of 1973 placed the UK in an alarming position, refocusing attention on energy security and inciting a wave of investment into research and development programmes in renewable energy. Commencing in 1974, nationwide assessments of geothermal, wind, wave, solar, biomass (and continued interest in nuclear resources) were established. The geothermal assessment (1977-1984), conducted by the British Geological Survey and sponsored by the then Department of Energy and the Commission of European Communities, identified several deep geothermal targets in Mesozoic sedimentary basins and radiothermal granites but failed to quantify pre-Permo-Triassic prospects.

By 1994 the geothermal programme had come to an end, in part due to the lack of identifiable high-temperature resources, but also due to falling fossil fuel prices and the remarkable emergence of the UK's status as a large oil-and-gas-producing nation: increased investment in North Sea oil and gas production meant the UK

> ALTHOUGH HEAT CANNOT BE TRANSMITTED OVER THE SAME DISTANCE AS ELECTRICITY, GEOTHERMAL ENERGY IS ACCESSIBLE TO MANY AREAS OF THE UK AT REGIONAL SCALE



God's Bridge (natural limestone bridge) over the River Greta, Teesdale, Durham. Designated Site of Special Scientific Interest

became a net energy exporter in 1981, with a contribution of 4.6% indigenous oil to global production by 1985.

Yet, by 2004 the UK's oil and gas production had fallen such that both were again imported, returning to a situation that existed pre-1981 and pre-1997 during the cyclical years of plenty, the role of gas changed dramatically. It became, and still is, the mainstay of UK power production and further development of the national grid meant increased use of gas for heating in domestic and industrial settings. The current planned demise of coal and consequent loss of manufactured gas means that the UK is now highly dependent upon the security of natural gas supply and thus on imports.

A starring role

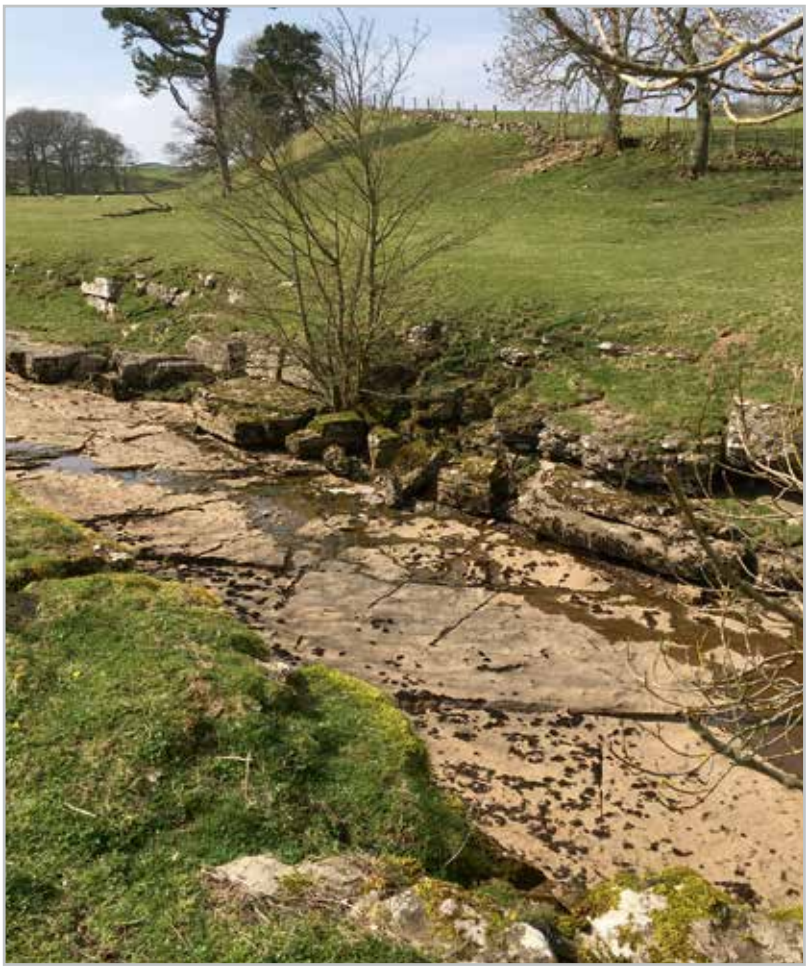
The security of imported energy supplies for power is important, but there is a lack of appreciation of the value of heat. 'Clean' nuclear energy and renewable wind and solar energy contribute significantly to today's electricity energy mix. With the phasing out of coal and the rise in wind power generation, it is no surprise that wind surpassed electricity production from coal in April 2016. Yet, almost 50% of the energy consumption in the UK is used for heat, which is still delivered by burning gas, oil and coal or by consumption of electricity. Only about 1.77% of energy consumption (for heat only) is that sold directly as heat from combined heat and power schemes.

The UK's approach to decarbonizing heat is to switch domestic and other heat production away from direct use of fossil fuels to electricity. In this way, greenhouse gases can be captured at source—the power station. However, electricity production from gas at the power station is only around 35% efficient; the remaining 65% of the energy liberated from burning the gas goes up the chimney (as unused heat). This is profligate use of energy when the same heat can potentially be sourced locally from geothermal systems.

Although heat cannot be transmitted over the same distance as electricity, geothermal energy is accessible to many areas of the UK at regional scale. Also, unlike wind energy or solar schemes, geothermal energy does not suffer the same intermittencies in production and has the ability to de-carbonise heat supply, with a potential role in providing baseload heat to commercial and residential areas.

The issues of supply security and ▶

Nadia Narayan, PhD student at Durham University, looking at Carboniferous Limestone at the Core Store Repository at the British Geological Survey, Keyworth



River Greta cutting through limestone in Teesdale during low flow. In this section of the river, the water follows a subterranean route, having been lost to upstream sinks

▶ meeting peak demand became real concerns again in March 2018, during periods of heavy snowfall across the UK. On Thursday 1st March, the National Grid declared a gas deficit warning—the first of its kind in almost a decade. A combination of the arrival of a Siberian cold front, theatrically nicknamed the 'Beast from the East', and shortages in gas imports left the National Grid experiencing a deficiency in UK supplies of ~50,000,000 m^3. Supplies made a rapid recovery by the Friday, but once again the UK had plummeted into uncertainty. With high dependency on gas imports and high heat consumption, there is a niche for geothermal energy to help tackle these issues.

Development of UK geothermal resources and their compatibility with district heat networks aligns well with government policy aspirations to supply 14-43% of total heat from buildings by district heat networks by 2050. Gluyas et al. (Keeping warm: a review of deep geothermal potential of the UK, 2018) estimate that geothermal exploitation has the capacity to satisfy the current heat demand for 100 years. This could offset the 160 million tonnes of CO_2 emitted from fossil fuels due to heat use. Yet, the 1970s-1980s geothermal assessment culminated in producing only a single deep-heat producing well in Great Britain, located in Southampton.

Success story

The Southampton-1 well was drilled to a depth of 1.8km to reach the target aquifer, the Triassic Sherwood Sandstone. The 76°C waters encountered began delivering heat energy in 1986 as part of the Southampton District Energy Scheme (operated by Engie), which utilizes geothermal energy and combined heat and power (CHP). The initiative was championed by Mike Smith (Director-Cities, Engie), an accountant, and other members of the Southampton City Council after the Department of Energy declined to fund a scheme considered to be lacking in commercial viability. Mike and his team lobbied the Department of Energy to drill the well, secured funding from the European Union and involved the technical expertise of the French company, Utilicom. Since its inception, the scheme has supplied heating and chilling capabilities (via absorption chillers) to offices, a hospital, a civic building, a

supermarket, hotels, the university, BBC studios, a swimming pool and more. Annually, the scheme saves 10,000 tonnes of carbon dioxide and generates >40 GWh of heat, 26 GWh of electricity and 7GWh of chilled water.

At least three further high-profile assessments—Barker *et al.* (2000), Sinclair Knight Merz (2012) and Atkins (2013)—have been conducted since 1986, with Barker et al. providing the most detailed evaluation of strata older than the Permian out of the three. Have we underestimated the potential of the Lower Carboniferous strata when virtually all warm springs (water issuing several degrees above local ambient temperature) circulate through here?

Karst of thousands

Journey through the caves in the Mendip Hills, Somerset and you will find yourself standing inside karst. Peer into a doline and you will be staring into the depths of time, made possible by karstic processes. Hike on top of the Great Scar Limestone at Malham Cove in Yorkshire and you will be standing on the clints of limestone pavement, riven with grykes—also karstic features. Karst varies considerably in form, but the fundamental process is the same. Broadly, carbonate karst describes a type of terrain typically formed by dissolution via carbonic acid sourced from rainwater and soil (respiring organic matter and decaying organisms) that exploits pre-existing weaknesses in the rock. Evaporites are also susceptible to karst development, albeit dissolving at a higher rate and by the process of disassociation. We can accurately predict temperature with depth, based on the geothermal gradient, but at depths in excess of 1km, permeability is not guaranteed. Buried karst is thus of interest for geothermal energy production because it has enhanced permeability that could reduce the need for hydraulic stimulation and lessen the risk of drilling a well that does not flow.

There are six basic criteria to consider for the development of karst. The primary factors are lithology and climate. In carbonates, purer limestones containing at least ~70% calcium carbonate are more likely to form karst than impure lithologies that may contain barriers to dissolution, such as clay minerals. Karst development is more likely in temperate to tropical and sub-tropical latitudes. During the deposition of Carboniferous Limestone, Great Britain resided at the equator—a perfect holiday destination consisting of exotic islands (or uplifted blocks) scattered across a tropical Rheic Ocean. At similar latitudes, present-day South China has developed spectacular examples of karst at the surface. At more temperate latitudes, limestone pavements outcrop in the Yorkshire Dales (Northern England), for example, which originated during Quaternary glaciation. Given the definition above, development of karst is likely in areas of high CO_2 soil concentration and high rainfall/water percolation.

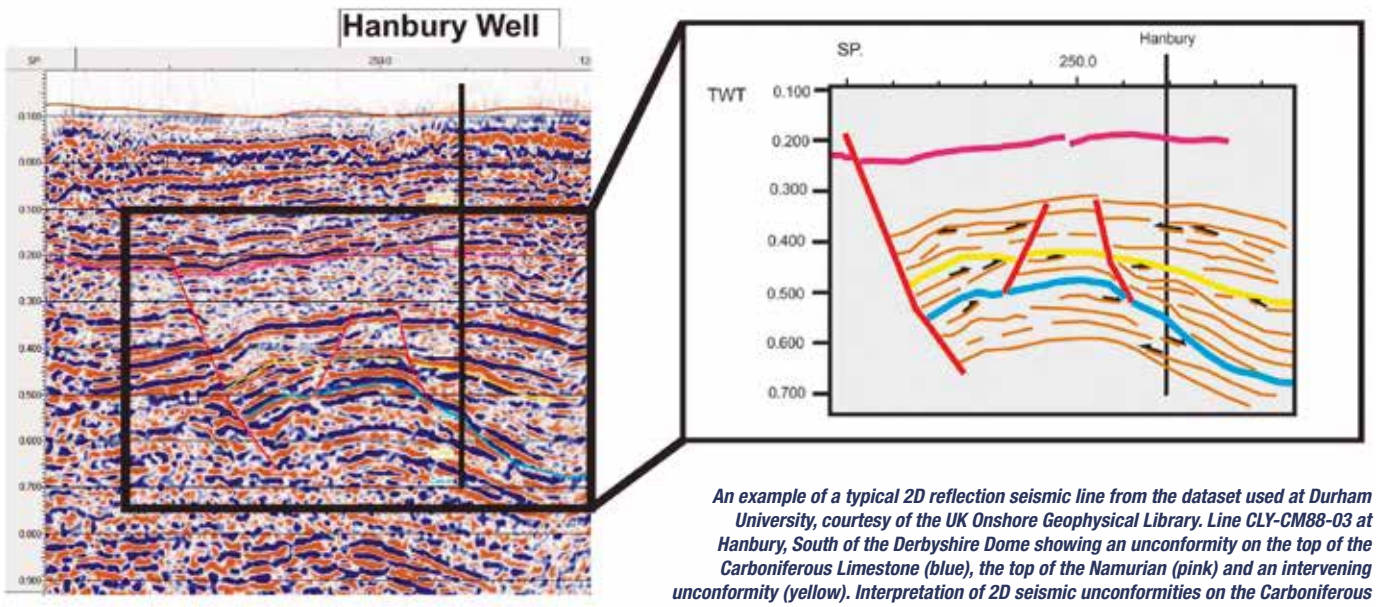
Extended exposure duration and the existence of a fracture network promotes karst development because there is a greater surface area for dissolution over longer periods of exposure. A steep gradient and change in relief are ideal for increased erosion and dissolution rates. Lastly, increased vegetation cover allows for greater CO_2 production as a result of various biogenic processes.

Collectively, the conditions described above are the optimum conditions for karst formation, but other processes, such as dolomitization, can also control the extent of karst.

Dawn of the geothermal industry

In Britain, most thermal spring waters are associated with secondary and tertiary porosity (fractures and karst) in Carboniferous Limestone. Supermarket-bought Buxton water may taste refreshingly cool, but the temperature at source is 27.5°C. Water supplying the thermal springs at Bath, Somerset, emanates at a temperature of approximately ~46°C through Triassic dissolution pipes interpreted by RW Gallois, in 2007, as collapse karst structures. Approximately 1,296m^3 of water emanates from the springs each day—equivalent to a hot bath per day for about 16,000 people.

The Bath spa springs have been the centre for human activity since at least ▶



An example of a typical 2D reflection seismic line from the dataset used at Durham University, courtesy of the UK Onshore Geophysical Library. Line CLY-CM88-03 at Hanbury, South of the Derbyshire Dome showing an unconformity on the top of the Carboniferous Limestone (blue), the top of the Namurian (pink) and an intervening unconformity (yellow). Interpretation of 2D seismic unconformities on the Carboniferous Limestone offer an initial idea of surfaces where karst may be potentially found

8,000 years BC. Legend has it that the springs were officially founded in 863 BC by a Prince Bladud, who was exiled for having contracted leprosy. After becoming a pig herder, the Prince's herd also developed leprosy. The pigs were cured when they began rolling around in the mud beside the spring waters, so the Prince eagerly followed suit. With his leprosy cured, his exile ended; he soon became King and built the city that we know today as Bath.

Many spring waters—historically and today—are associated with healing properties or rituals involving deities connected to the waters. Some people still make the pilgrimage to springs for their water supply. Societal benefits persist in the form of tourism. In 2015, there were 1 million visitors to the site of the Roman Baths, which is classified as a UNESCO World Heritage Site. Geothermal energy has clearly been incorporated and accepted into society for centuries.

Other thermal springs in Britain are documented at Taff's well in Wales, Hotwells in Bristol, and at Buxton (which involves a sandstone-carbonate karst conduit flow system) and Matlock Spa (exhibiting associations with deep evaporites) both in Derbyshire, to name a few. Equilibrium temperatures of these spring waters at depth are likely to differ from their surface temperature. Therefore, it is important to analyse and interpret the geochemistry of the waters when prospecting for a geothermal resource.

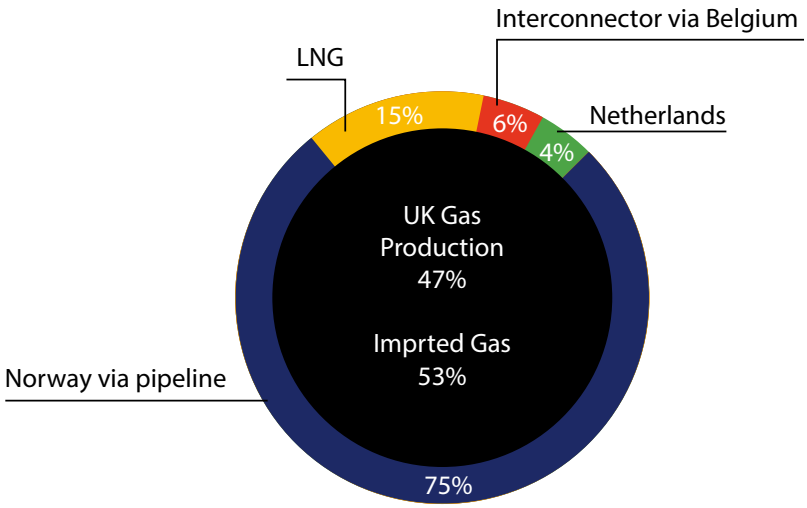
Oil industry

From an economical point of view, our relationship with karst dates back to the dawn of the nation's oil industry. A journey to the Oilwell Nursery Garden Centre (Tibshelf, Derbyshire) brings you to the doorstep of Britain's first oil well: Hardstoft-1. Drilled into the Hardstoft Anticline in 1919 in response to supply threats associated with the First World War, oil was struck at 3,070ft, within Carboniferous Limestone. The well produced about 28,000 barrels of oil until its decline in July 1945. A captivating account of "Hardstoft: Britain's First Oilfield" can be found in *Geoscientist* (March 2016, Volume 26, No. 2). Today, the well head still exists, along with the concrete platform remnant of the site of the nodding donkey.

This iconic cornerstone in the nation's energy industry proved the existence of sufficient secondary/tertiary porosity and permeability in Carboniferous Limestones to support commercial production of oil. Oil and gas drill data also show that water can flow freely through the strata at depth (e.g. drill stem tests in Welton B8, Northeast of Lincoln, East Midlands).

Prospecting in deep karst

In addition to mixing, spring waters often undergo conductive and convective heat loss during ascent, causing lower temperatures to be recorded at the surface. But, the spring water contains a geochemical fingerprint of its deeper origins, which can be used in prospecting to calculate the temperature at which the water equilibrated with the host rocks. There are various anion-cation ratios, such as Na-K-Ca, Na-K or Mg-Li indictors, that work as "geothermometers". At Durham University, this technique has been used in an initial survey of potential Carboniferous Limestone resources across Britain (the study has been limited to Britain because of the abundance of data here) and to demonstrate the viability of pursuing them. For example, a minimum reservoir



UK Gas production and Imported Supply 2017

Source of statistics: Department of Business, Energy & Industrial Strategy

UK Indigenous Gas Supply and Imports in 2017

Massive beds of the Great Scar Limestone Group near Malaham Tarn

equilibrium temperature of ~65°C was deduced for the Bath Spa spring waters.

Whilst research at Durham University focusses on the Carboniferous karst, geothermometry has also shown that older strata have potential for geothermal energy exploration. Springs waters from Builth wells springs in Wales, for example, reach the surface at temperatures of just 10-11°C, but anion-cation geothermometry analyses indicate that this water equilibrated at temperatures that may exceed 100°C at depth. Deep circulation in Wales is inferred in the published literature (Further Reading). At Durham a database of spring water chemistry, accumulated primarily through literature studies, water authorities and some field studies, has been compiled for the Carboniferous Limestone investigation.

Bath Spa springs indicate that karst can transport hot water and a primary factor of our project involves the identification of these permeable formations at depth. 2D onshore seismic data has been used to evaluate the distribution of post-Carboniferous Limestone unconformities in the geological record, based on the knowledge that karst can form during times of aerial exposure. The presence of an unconformity of any age overlying a limestone interval provides an ingress point for fluids that can dissolve the limestone and create karst. The karst itself may extend to areas unaffected by unconformities on the top surface of the limestone, but the presence of an unconformity above or nearby increases the chance of success when hunting for karst. Investigation into the number of opportunities for karst development and exploration is the driving force behind our project. For example, unconformable surfaces with karst development at the base of Triassic strata are present at Bath, but we also know they are present in the East Midlands area, where palaeokarst or ancient karst is identified (in conjunction with core data) at the base of a Namurian unconformity.

Petroleum well data are also essential for determining subsurface properties, because they can provide information on flow rates and well temperatures, and highlight the presence and heterogeneity of karst-fracture systems.

The combination of well, geochemical and seismic techniques allows identification of possible geothermal targets within the Carboniferous Limestone at depth at various locations across the UK. Once all elements of the project are collated, we aim to produce a blueprint of potential karst geothermal resources and will add to the already identified resource base, as detailed in Downing and Gray (1986) and subsequent publications. How big is the UK's karst geothermal resource? We can't yet answer that question but we anticipate that it is comparable to that identified in the Mesozoic sedimentary basins.

The UK is in the midst of a renewable revolution. The nation has harnessed the sun and tackled the wind. It is time to tame the Earth. ◆

FURTHER READING

A list of selected references may be read in the Online version of this article.

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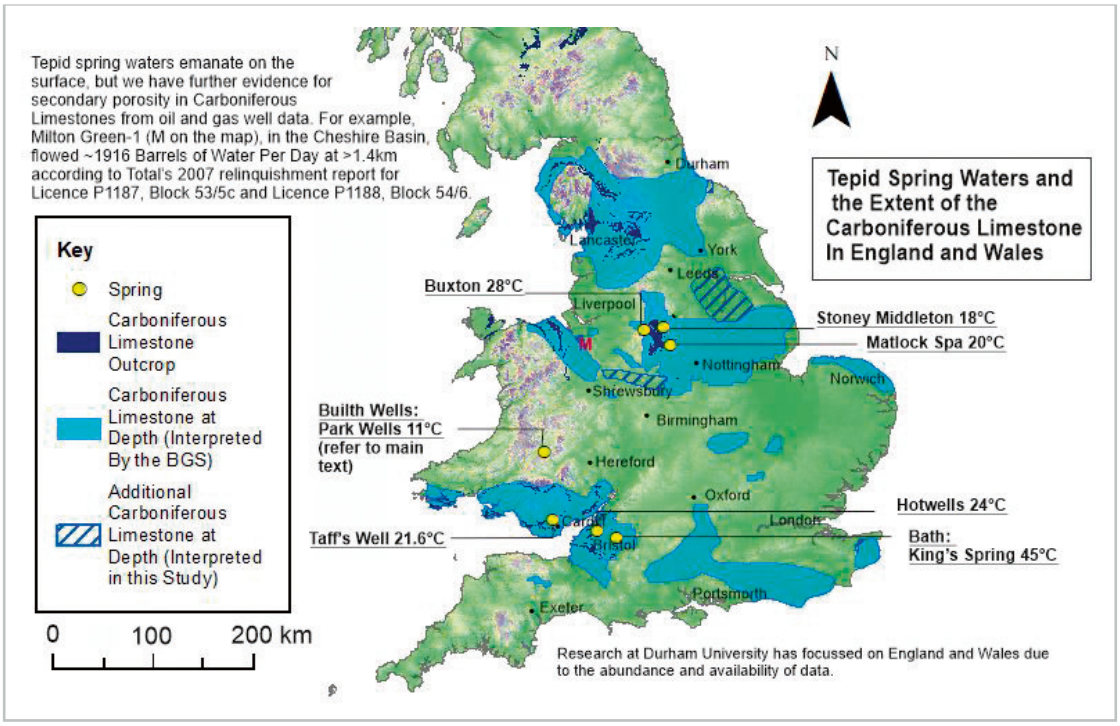


Extent of the Carboniferous limestone outcrop at surface and its equivalent at depth as interpreted by the BGS and this study. Several well-known thermal springs are hosted in the Carboniferous Limestone which also displays evidence of flow at depths exceeding 1km

DANCE ON A VOLCANO:
BAGANA, PAPUA NEW GUINEA

A view of Bagana volcano looking northeast from the outskirts of Wakovi village, Bougainville

Brendan McCormick Kilbride gives an account of fieldwork on an active volcano in the tropical rainforest of Papua New Guinea

Our first glimpse of Bagana volcano was an ominous silhouette just visible through the dense rainforest covering the shore to our left. As our boat sped round the headland into a wide sweeping bay, the volcano was laid bare before us, rearing high above the coastal plains. I was in Papua New Guinea as part of an international team making a month-long survey of gas emissions from several little-studied but highly active volcanoes. Bagana, located on remote Bougainville Island, is one of the world's preeminent sources of volcanic gas emissions and somewhere I had long wanted to visit.

VOLCANIC DEGASSING

Many volcanoes are constantly emitting gas, even when not erupting. Magma, the molten rock that drives eruptions, contains abundant dissolved water, carbon dioxide and sulfur dioxide. As magmas rise towards Earth's surface, the drop in pressure causes gas bubbles to begin growing. The ability of these bubbles to rise freely through the magma and escape into the atmosphere can strongly affect the explosivity of volcanic eruptions. Magmas with a higher gas content tend to cause more explosive, and therefore more dangerous, eruptions.

Bagana is an interesting case. Despite its enormous emissions of gas, the typical activity of the volcano is a sluggish effusion of lava flows in eruptions lasting months at a time. Overlapping lava flows have built the main cone of the volcanic edifice, which rises 1800 metres above sea level. If present eruption rates are typical, the entire volcano could have grown in mere centuries, according to a recent study by Geoff Wadge (University of Reading), myself and others. The mystery of Bagana is how such a gas-rich volcano maintains a dominantly effusive style of eruption, with only rare shifts towards a more explosive style. To answer this question, we are drawing on a range of techniques including satellite remote sensing, measurements of gas emissions in the field, and laboratory analyses of the lava and ash erupted from the volcano.

A REMOTE VOLCANO

Our team comprised myself and Lois Salem (University of Cambridge), Roberto D'Aleo (University of Palermo), Bo Galle, Santiago Arellano and Julia Wallius (Chalmers University of Technology), and local scientist Kila Mulina, from Rabaul Volcanological Observatory. None of us had visited Bagana before, and the excitement in the team only grew as we landed on Bougainville.

Bagana is a difficult volcano to reach. In the 1980s-1990s, a bloody civil war fought over issues of secession from Papua New Guinea precluded scientific expeditions to Bougainville and even today tensions over a mooted independence referendum remain high. From Buka—the temporary capital since the previous one, Arawa, was largely destroyed in the conflict—a four-hour boat trip along the southwest coast of the island takes you to the village and anchorage of Torokina. From here, we travelled inland, bouncing around in the back of a battered old Land Rover, fording rivers and brushing through the vegetation overhanging the muddy track. Our basecamp was Gotana, a village around 8km from the base of the volcano, and we were offered the shelter of a new schoolhouse under construction. Our first task on arrival was to visit the existing school, meet the Big Man and other villagers, and explain our interest in Bagana. The local children welcomed us with a song and talked excitedly of the volcano, which can be seen steaming on the horizon within a short walk from the village outskirts.

A DAY IN THE FIELD

Our tasks in the field were varied. We flew a series of drone flights over the lower slopes of the volcano, mapping the distribution and size of the lava flows with an onboard video camera for comparison to satellite observations being made by colleagues back in the UK. We also filmed ▶

A view of Bagana volcano with its characteristic strong summit gas plume from the southwest coast of Bougainville Island

Lois Salem and our guides from Wakovi village make their way across the surface of a debris avalanche that recently covered the approaches to Bagana

the volcano using cameras operating in the infrared and ultraviolet wavelengths. While the former gives information on the temperature of the lava flows, we use UV cameras to quantify sulfur dioxide gas emissions. Using another drone, this time with gas sensors on board, we made short flights through Bagana's gas plume to measure its chemistry. On two days, we trekked through the dense forest to reach the very foot of the volcano in order to collect samples of recently erupted lavas.

Working at the base of an active volcano is a hazardous pursuit and we were grateful for the advice of the villagers in Gotana, and Patsikopa and Wakovi, which lie even closer to Bagana's lower slopes. There was good reason to be cautious: an avalanche of volcanic debris, triggered by torrential rains, had recently swept down from high on the mountain and buried the surrounding countryside in metres of muddy ash and blocks of lava. Walking across this blasted landscape to reach the volcano, skirting the charred remains of ripped up trees, we were keenly aware that we could not be idle, but had to collect our samples quickly.

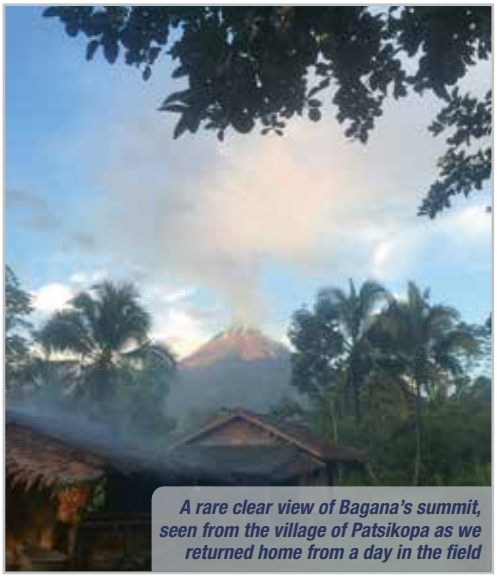
This was far from easy. Passing through the forest, we realised that small but swift-flowing streams around the base of the volcano were heated by subterranean geothermal activity, in places measuring as hot as 60 °C. We had to take extreme care fording these streams and avoiding the yellowish sulfurous mudflats on their banks. The lava flows themselves were

steep, rubbly and unstable, and we picked our way tentatively around them to gather our samples, all too aware that even a minor sprain would make for a highly difficult march home. Fortunately, we were well guided by our companions, and returned safely to the village, heavily laden with chunks of dark, crystal-rich lava.

A TROPICAL PARADISE

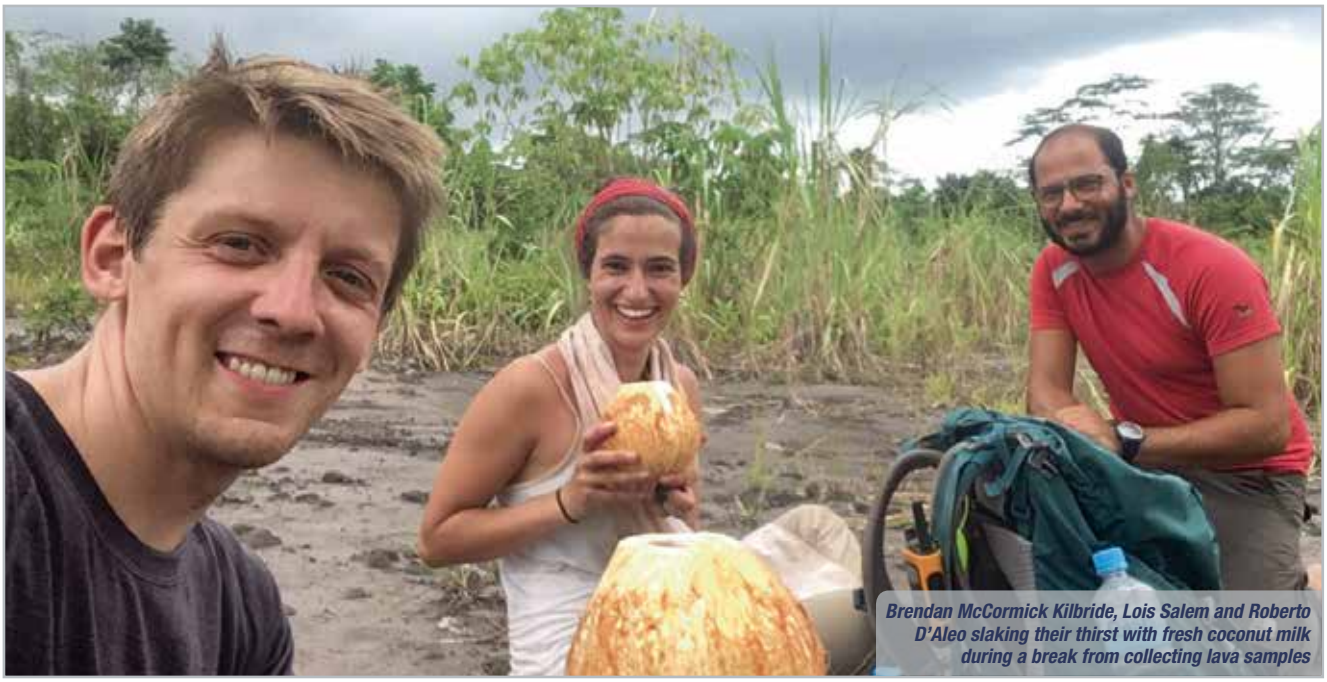
Our work on Bagana was not just an enthralling scientific experience, though we collected a wealth of exciting new data and our lava samples, which are now being analysed in labs in Cambridge and Zurich. We were warmly welcomed and supported in the field by our hosts in the villages around Bagana and are hugely in their debt for guiding us through the forest to the volcano, frequently in torrential rain storms. Those long hours spent on the march made this expedition the most physically challenging I have undertaken but the beauty of our surroundings more than compensated. I saw hornbills in the wild for the first time, a mating pair that soared above us on the desolate plain below the volcano, and fruit bats that swept low through the banana and *kaukau* farms on the edge of Gotana village. Each exhausting day ended with our team bathing in the swift river that flowed through the village, listening to the whirr and click of immense numbers of insects and amphibians in the trees around us. For supporting this expedition and the research that has followed, I am deeply indebted to the Geological Society of London's Elspeth Matthews Fund, and my other funders the Deep Carbon Observatory and the NERC COMET programme. ◆

Brendan McCormick Kilbride is a Research Associate in the Department of Earth Sciences, University of Cambridge, UK, and was a 2017 and 2018 recipient of the Geological Society of London's Elspeth Matthews Fund; e-mail: brendanvolc@gmail.com

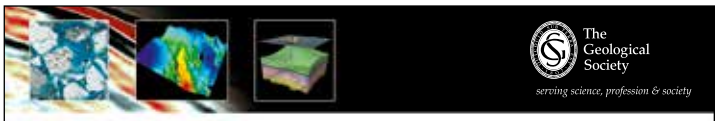


A rare clear view of Bagana's summit, seen from the village of Patsikopa as we returned home from a day in the field

Our party crossing the Torokina river on a fallen tree trunk



Brendan McCormick Kilbride, Lois Salem and Roberto D'Aleo slaking their thirst with fresh coconut milk during a break from collecting lava samples



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The Geology of Fractured Reservoirs

24-25 October 2018

The Geological Society, Burlington House, Piccadilly, London

A large proportion of the world's oil and gas is produced from fractured reservoirs, with new discoveries continuing to be made and put into development. This conference will explore the many ways in which the geology of fractures is fundamental to the understanding of fluid flow in the subsurface, and hence to predicting and monitoring reservoir performance.

Fractured reservoirs are those in which fractures have caused a significant increase in total permeability. Carbonate reservoirs, tight sandstone reservoirs, basement reservoirs and shale reservoirs are all commonly fractured, and present significant challenges to petroleum geologists. The focus of these challenges, but not their significance, changes throughout a field's life-cycle from exploration to production. Many geothermal reservoirs are also fractured, and share common challenges. This meeting will highlight how multidisciplinary work is essential to develop an applicable understanding of the behaviour of fractured reservoirs.

Themed sessions to include:

- Fracture properties at micro and well scale – detection and characterisation
- Fracture properties at reservoir to basin scale – from outcrops to seismic to regional models
- The flow behaviour of fracture systems – the interaction of fluids, rocks and stress
- The integration of data, disciplines and insights – advancing our knowledge of fractured reservoirs

Field trip:

We are proposing to have a conference Field Trip, Fractured Zechstein carbonates of NE England, in conjunction with this conference. For more information, or to register please visit the conference website: https://www.geolsoc.org.uk/PG-Fractured-Reservoirs or contact Sarah.woodcock@geolsoc.org.uk

For further information please contact:

Sarah Woodcock, The Geological Society, Burlington House, Piccadilly, London W1J 0BG.
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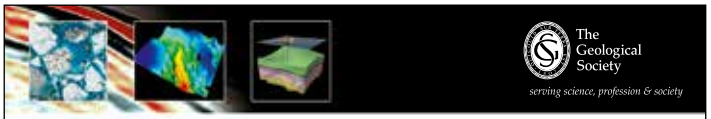

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Keynote Speakers:

A diverse set of keynote speakers are being solicited from across the community

Call for Abstracts – Deadline: 1 December 2018

Hydrocarbons in Space and Time

9-11 April 2019

The Geological Society, Burlington House, Piccadilly, London

The global endowment of hydrocarbons is markedly uneven both spatially and temporally. In the 1990s, several key papers recognised that distinct stratigraphic and paleogeographic trends exist and that this knowledge was an important guide to successful exploration. So, what has changed in 30 years?

The industry has moved into new frontiers and basins, drilled deeper, found new plays and gone through a revolution that has brought unconventional resources to the fore. It is therefore timely to consider how our knowledge of the distribution of hydrocarbons in time and space has changed. What new insights have we gained? Can this new understanding be used to be better at predicting new hydrocarbon discoveries?

This 3-day conference will seek to share recent advances and case studies and will be built around four main themes:

- The known global heterogeneity of hydrocarbon resources – including source rocks
- The controls on heterogeneity – including palaeoclimates and geodynamics
- The geological and data science tools to aid prediction
- What our present understanding means for future exploration

Event to be accompanied by a post-conference field trip to the Wessex Basin.

For further information please contact:

Sarah Woodcock, The Geological Society, Burlington House, Piccadilly, London W1J 0BG.
Tel: +44 (0)20 7434 9944 or email: sarah.woodcock@geolsoc.org.uk

For Abstract Guidelines, please download a copy from the website:
https://www.geolsoc.org.uk/PG-Hydrocarbons-in-Space-and-Time

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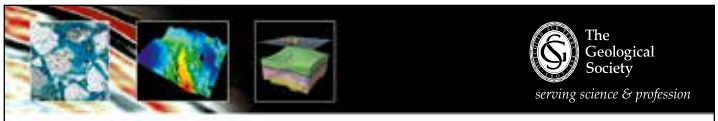

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Registration now open

Operations Geoscience Adding Value

7-8 November 2018

The Geological Society, Burlington House, Piccadilly, London

The main focus will be on the value operations geoscientists deliver and the pivotal role they play via the following topics:

- **The value of learning lessons well** – what is a lesson?; how are lessons learned and managed (e.g. avoiding non productive/invisible lost time)?; practical examples of lessons with demonstrable change; personal willingness to share failure/sub optimal performance
- **Risks and safety of operations** – identifying, managing, communicating risks and planning contingencies effectively
- **Formation pressure and geomechanics** – sharing good practice, techniques and knowledge, prediction and detection methods
- **The value of managing and interpreting data** – effective data management for field life, examples of cross company collaboration

Overarching themes:

- Value of these themes to **well life cycle**
- Sharing real world **examples and case studies**
- Importance of **personal behavioural skills** throughout (leadership, communication, relationship building and influencing others)
- Share good practice, showcasing **innovative approaches and technologies**

We look forward to active participation from our colleagues across subsurface, drilling and engineering disciplines to significantly broaden the main conference themes.

There will be a parallel poster session in the library.

For further information and registration please contact:

Sarah Woodcock, The Geological Society, Burlington House, Piccadilly, London W1J 0BG.
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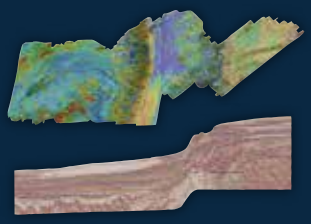
SEPM

Seismic Characterisation of Carbonate Platforms and Reservoirs

10-11 October 2018 The Geological Society, Burlington House, London



Fundamental advances in the seismic imaging and characterization of carbonate platform strata, including reservoir rocks, have revolutionized understanding of carbonate geomorphology, stratigraphy and reservoir architecture. This meeting aims to synthesize these innovative developments and explore the variety of carbonate characteristics that can now be interpreted from modern and reprocessed seismic data. It will discuss and illustrate how the technology can be used in exploration, development and production evaluations, as well as for understanding long-term and large scale forcing of carbonate platform development. The focus will be on practical geoscience applications and the meeting will provide a forum for lively interaction between the upstream oil industry, seismic contractors, and carbonate sedimentology researchers.

Convenors

Jim Hendry (Tullow Oil)
Pete Burgess (University of Liverpool)
Dave Hunt (Statoil)
Xavier Janson (University of Texas, Austin)
Valentina Zampetti (Shell)

Further information

For further information please contact:
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Conference Sessions

- Seismic Investigations of Platform Architecture and Development
- Seismic Data in Frontier Exploration for Carbonate Plays
- Extracting Geological Features Using Seismic Attributes and Blends
- Seismic Insights Into Carbonate Diagenesis and Fluid Flow
- Seismic Workflows and Advances in Inversion and Modelling
- Seismic Characterisation of South Atlantic Pre-Salt Carbonates
- Seismic Geomorphology and Seismic Facies Applied to Carbonate Depositional Processes and Products

YEAR OF RESOURCES

Keynote Speakers

James Bishop (Chevron) **Manuel Poupon** (Shell)
Jeroen Kenter (Total) **Lars Reuning** (RWTH Aachen)

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ENDORSED TRAINING/CPD

MEETING	DATE	VENUE AND DETAILS
Lapworth's Logs	n/a	Training. 'Lapworth's Logs' is a series of e-courses involving practical exercises of increasing complexity. **Contact:** Michael de Freitas or Andrew Thompson (First Steps Ltd) **E:** office@firststeps-geo.co.uk (mention Lapworth's Logs as the subject)

EVENTS

PLEASE NOTE THAT THERE ARE MANY MORE MEETINGS FOR WHICH WE DO NOT HAVE SPACE. ALWAYS CHECK WITH **WWW.GEOLSOC.ORG.UK/LISTINGS**

MEETING	DATE	VENUE AND DETAILS
ConfSeries 5th World Conference on Climate Change	4 Oct	**Venue:** Conference Series Ltd, London **Contact:** Mason Jones **E:** climatechange@conferenceseries.com **W:** https://climatechange.insightconferences.com/
Interplay of heatflow, subsidence and continental break-up: a case study workshop	8-9 Oct	**Venue:** Burlington House **Contact:** Sarah Woodcock **E:** sarah.woodcock@geolsoc.org.uk **W:** https://www.geolsoc.org.uk/PG-Heatflows
Seismic Characterisation of Carbonate Platforms and Reservoirs	10-11 Oct	**Venue:** Burlington House **Contact:** Georgina Worrall **E:** georgina.worrall@geolsoc.org.uk **W:** https://www.geolsoc.org.uk/carbonateplatforms18
AGCC 2018 Big Issues and Ideas in Geoscience	14-18 Oct	**Venue:** Adelaide Convention Centre, North Terrace, Adelaide, South Australia **Contact:** Bill Shaw **E:** claudia@ccm.com.au **W:** https://www.agcc.org.au/
MatSciEngg 2018	15 Oct	**Venue:** Radisson Blu Seaside Hotel, Helsinki **Contact:** Dave Stebenne **E:** stebennedave@gmail.com **W:** https://materialscience.materialsconferences.com
Exploration meets the City	17-18 Oct	**Venue:** Burlington House **Contact:** Julian Aldridge **E:** julian.aldridge@woodplc.com **W:** https://www.geolsoc.org.uk/FINEX-Exploration-meets-the-city

EXHIBITION REVIEW: Science made Visible

In a world of Facebook, Instagram and selfies, the power of the image has never been greater. However, the role of the image in the communication of science in Britain can be traced back over 350 years to the foundation of the Royal Society in 1660. The Society's weekly meetings and published *Philosophical Transactions* provided a new medium and network for the dissemination of scientific discoveries, along with illustrated descriptions of experiments, reviews of important new publications and translations of foreign ones.

A variety of graphic methods were used to explore, develop and propagate the ideas that drove the emergence of modern science. And, many original images from this revolutionary phase in the history of science are preserved in the archives of the Royal Society. Their current display is thanks to historians of science from the University of Cambridge and the librarians of the Royal Society.

Science made Visible in the Royal Society is well worth a visit to see these historic images drawn from human anatomy and the emerging sciences of natural history. Remarkable works by European luminaries such as Johannes Swammerdam (1637-1680), Antoni van Leeuwenhoek (1632-1723) and Agostino Scilla (1629-1700) can be compared with those of 'home-grown' pioneers, such as Isaac Newton (1643-1727) and Robert Hooke (1635-1703). Hooke's enormous 'pullout' engraving of a flea from his 1665 *Micrographia* is accurate enough to make anyone itch. Whilst many images are familiar from modern reproductions, seeing the originals and their 'original' reproductions still makes a big difference.

The remarkable accuracy of Scilla's illustrations of Cenozoic fossils is of palaeontological importance. When published in his 1670 book 'La vana speculazione disinginnata dal senso', they gave very visible support to his argument that fossils are the remains of once living organisms. Unusually for a collection of this time, Scilla's fossils and original drawings have survived thanks to the acquisitiveness of that virtuoso collector Dr John Woodward (1665-1728). Woodward bequeathed them to the University of Cambridge along with his magnificent collection of some 10,000 specimens, mostly fossils and minerals in their original cabinets. Back in Cambridge an interactive display in the Sedgwick Museum allows exploration of Scilla's collection in its 'virtual' entirety for the first time.

Reviewed by: ***Douglas Palmer***

SCIENCE MADE VISIBLE: AN EXHIBITION OF DRAWINGS, PRINTS, OBJECTS.
Exhibition at the Royal Society, 6-9 Carlton House Terrace, London SW1Y 5AG. T: 0207 451 2500. Open to the public until December 2018, Mon-Fri, 10am-5pm. (Image: Scilla's original drawing of a fossil jawbone and teeth of a shark-toothed dolphin *Squalodon* sp.)

The Value of Outcrop Studies in Reducing Subsurface Uncertainty and Risk in Hydrocarbon Exploration and Production

This volume is a collection of papers presented at a 2014 Geological Society of London conference. The objective is to reflect major advances in the analysis and integration of outcrop data as analogues for the subsurface, and the text does an excellent job of providing considerations and case studies.

The first paper addresses environmental health and safety fieldwork considerations. It initially appears out of place, yet contains a plethora of useful mandatory information to maximize safety during fieldwork. Adherence to its precepts could save someone's life.

Four papers address basin-scale projects: One for an onshore-to-offshore model in NW India; another for intravolcanic analogues on the Faroe Islands; a third for injecitite sandstones in the North Sea; and a final paper focused on complex sequence stratigraphy in Apennine foreland basins.

Reservoir-scale examples constrained using outcrop data are also considered. One paper discusses thin discontinuous facies of an Algerian gas reservoir, a second focuses on sequence analogues in offshore Trinidad, and a third examines Eagle Ford Shale outcrop analogues. The latter study is particularly interesting because it cleverly integrates outcrop-sourced gamma ray and geochemical data in a new regional sequence stratigraphic compilation.

Fieldwork techniques are discussed in a study outlining the critical differences between structural and sedimentological analogues. Structural analogues fall into two categories: 1) the direct use of structural analogues to compare field examples to the subsurface; and 2) the use of topology to study fault and fracture networks, and thereby understand the age and connectivity of structures, spatial variability, and structural scale.

The section on fieldwork techniques also includes a historical evolution of the British Geological Survey mapping programmes, most notably digital mapping and data collection via unmanned aerial vehicles, as well as discussion of the use of laser-scanned outcrop data to create static-flow CO_2 simulation models.

The final paper challenges the value of uncertainty characterization and our assumption that new data improves prospect risk. The authors argue instead that new information adds primary value in eliminating prospects and identifying new areas to examine.

Many of the regional cross-sections and stratigraphic sections are difficult to see due to extremely small text size. Putting an entire basin cross-section or well log in a half-page graphic renders them nearly useless. It would be helpful to provide digital copies of these graphics.

Despite these limitations, the volume contains many interesting papers that should be useful to anyone working a basin that requires the use of outcrop analogues to characterize limited and challenging subsurface geology.

Reviewed by: ***Thomas Hoak***

THE VALUE OF OUTCROP STUDIES IN REDUCING SUBSURFACE UNCERTAINTY AND RISK IN HYDROCARBON EXPLORATION AND PRODUCTION
Edited by M. BOWMAN, H.R. SMYTH, T.R. GOOD, S.R. PASSEY, J.P.P. HIRST & C.J. JORDAN. Geological Society of London Special Publication No 436, 2016. ISBN 978-1-78620-309-0. 268pp. hbk.
List Price: £ 90.00. Fellow's price: £ 45.00. W: https://www.geolsoc.org.uk/SP436

Encyclopedia of the Anthropocene

These five volumes weigh in at 7.5 kilos, the ~250 component articles taking up 2,175 pages. Yet, they represent just part of the near-cosmic expansion of information on the Anthropocene since this concept was proposed by Paul Crutzen and Eugene Stoermer in 2000, with one-and-a-half pages hidden away in the *Global Change Newsletter*. This was followed by Paul Crutzen's more visible, yet briefer, 2002 *Nature article*. In 2008, when this Society's own Stratigraphy Commission published the first geological analysis of the Anthropocene, a Google search would garner maybe a couple of dozen hits. One could read them in a day. Today, typing 'Anthropocene' into Google will yield some two million hits, ranging beyond geology into the social sciences, humanities and arts. It's now impossible to keep up, so an encyclopaedia is a good idea, as ready reference to this new scholarly cornucopia. How does this one measure up? Variably, I think. It has been a heroic effort to assemble the articles, drawn from hundreds of authors, and there's very useful material here. But there are also, almost inevitably – given the tight deadlines of modern publishing – omissions, duplications, quirks, and variability in depth of coverage.

I like Volume 1, covering geological patterns and energy. The material evidence for the Anthropocene as a geological unit is well covered. The authors include real expertise – Eric Wolff on the ice record, Ian Fairchild on speleothems, Neil Rose on the fly ash record. Clearly, not all of the pleas for copy were answered, so several sections have been written by the editors, notably the indefatigable Scott Elias.

Volume 2 covers climate change, a tricky topic for the Anthropocene. While climate drivers, notably atmospheric CO2 levels, have risen sharply to Pliocene levels, atmospheric temperature is only starting to rise, so far by just over 1° C, as most extra heat is still being absorbed by the oceans. This moving target is part of the anatomy of today's Anthropocene, and the chapter details ongoing processes, like shifts of species ranges, and regional differences.

Volume 3 covers biodiversity. Here, the focus is firmly on what is happening to the remains of 'wild' nature, covering conservation, extinction, invasive species and so on. All well, good and relevant, but there is little on the enormous scale and novelty of the new, species-poor biodiversity we are creating as food – the 'domesticated' animals that (with us) now comprise most terrestrial vertebrate biomass, and the burgeoning croplands that provide feedstock for them. There is an elephant in the room here, and it is being ignored.

Volume 4, on Anthropocene ethics, is similarly skewed. There is much on themes like environmental economics, justice, solidarity, resilience, postmodernism and the role of religions, but the focus is almost solely on societal cure for our environmental ills. There is little on the economic and social drivers that led to the global changes in the first place, or larger-scale conceptualizations thereof (such as the technosphere concept), which is somewhat like a doctor prescribing treatment without prior diagnosis.

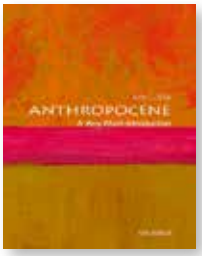
Volume 5 covers pollution, returning to more tangible evidence and detailing both organic and inorganic pollutants. Nice material here, too, but the haste in production (another Anthropocene characteristic?) is again seen in duplication of topics from Volume 1, such as ocean acidification and plastics.

On the whole, this is a useful addition to one's library, if one has £2,755 to spare. One might wait, though, for a new edition that covers those important missing themes. That might take this encyclopaedia to ten kilograms or more, and will require reinforcement of both bookshelves and bank balance. It does, though, reflect the scale of this new Anthropocene phenomenon.

Reviewed by: ***Jan Zalasiewicz***

ENCYCLOPEDIA OF THE ANTHROPOCENE
Edited by DOMINICK A. DELLASALA, MICHAEL I. GOLDSTEIN et al. Elsevier 2017. ISBN: 9780128096659. 2280 pp. **List Price: £2,755.00. W: www.elsevier.com/books/encyclopedia-of-the-anthropocene/dellasala/978-0-12-809665-9**

Anthropocene: A Very Short Introduction



Imagine a scientist in the distant future, studying the Earth. Some distant relative of humans perhaps, or something more exotic. They are tasked with defining the Earth's stratigraphic record. How similar would it be to humanity's effort? And would they notice a boundary around the time that homo sapiens arrived on the scene? Perhaps they would find disturbances in the carbon isotope record, or a sudden spike in a particular radioactive element across rocks of a certain age. Or maybe they would find nothing. Welcome to the problem of defining the current epoch: the Anthropocene.

In this Very Short Introduction, Professor Ellis illustrates the issues of establishing a new epoch beautifully and also gives an excellent history of the Anthropocene's development as an idea. From Paul Crutzen and Eugene Stoermer coining the term to the formation of a special working group of the Subcommission of Quaternary Stratigraphy, the conceptual development of this epoch is as interesting as the problem of defining it.

To mark the beginning of a new epoch, a universally agreed, isochronous, and measurable point in time must be agreed upon. Human influence on the environment has occurred since we first evolved. The discovery of fire, tool making, and hunting have all left their mark. Agriculture in its various guises has changed landscapes and ecosystems permanently. The industrial revolution has had a global influence and the effects of fossil fuel use dominate politics, science, and modern living today.

However, the complexities of human environmental influence do not make for an easy task and the evidence involved is a combination of the work of geologists, archaeologists, environmental scientists, philosophers, politicians, geographers, oceanographers… The list could go on. Anthropocene covers this evidence in great detail giving the reader plenty to think about, while always maintaining an ▶

objective view of the problem. Various, interesting nuggets of information are distributed throughout; did you know that there are around 5,000 natural minerals on Earth? Compare this to the 170,000 synthetic ones that have been identified.

What is the purpose of all this effort? We know that the planet is changing in response to our actions. Does defining an Anthropocene give humanity a wake-up call to preventing further climate change? Or does it merely assert dominance over nature? Perhaps we can answer these questions. Or maybe it is for the scientists of the distant future to uncover.

Reviewed by: ***Jonathan Scafidi***

ANTHROPOCENE: A VERY SHORT INTRODUCTION
by ERLE C. ELLIS, 2018. Published by Oxford University Press, 183pp (pbk) ISBN: 9780198792987 **List Price: £7.99. W: global.oup.com/**

Integrated Environmental Modelling to Solve Real World Problems: Methods, Vision and Challenges

The purpose of this volume is to present a comprehensive overview of Integrated Environmental Modelling (IEM). A burgeoning science area, IEM is used to solve complex environmental problems by linking individual models from different academic disciplines, using different types of input data. This approach, made possible by recent developments in IT technology, allows users to update or change individual modules of the IEM instead of the entire model.

The book is divided into four sections. The first section covers the fundamental principles of IEM and the second consists of case studies that present the state-of-the-art of IEM. The third part covers the human element in IEM, such as how human behaviour is included in IEM to aid policymakers. The fourth part details some of the technical challenges facing IEM developers, such as parallel computing, the linking of models with different time and spatial resolutions, error propagation, high-speed connections that allow sensor data to be read at run-time, and importantly, differences in terminology and definitions between different academic disciplines.The book chiefly addresses itself to geographers and geoscientists that wish to learn more about IEM, but could aid the insurance and reinsurance industries. A paper on the use of IEM in natural hazard modelling for the insurance industry brought me back to when I first joined the field of catastrophe reinsurance modelling, then without the benefits of IEM. Another group that would find this volume of interest are policymakers. Their increasing need to make strategic decisions based on complex environmental and human interactions can often result in cumbersome models. The denseness of the academic prose might represent a challenge for decision makers in business and public policy; because of this the volume runs the risk of not reaching all of its potential readerships. Although the book is excellently illustrated, some of the diagrams include small text, making it difficult to read. I hope these issues will be addressed in future publications.This book is fascinating and thought-provoking. It certainly makes a persuasive case of the vast possibilities IEM can offer and will be a useful resource for IEM developers.

Reviewed by: ***Lars Backstrom***

INTEGRATED ENVIRONMENTAL MODELLING TO SOLVE REAL WORLD PROBLEMS: METHODS, VISION AND CHALLENGES
by A.T. RIDDICK, H. KESSLER AND J.R.A. GILES (Eds) 2017. Published by: The Geological Society of London, SP408, 274pp. hbk. ISBN: 978-1-86239-687-6.
List Price: £90.00 Fellows' Price: £45.00.
W: www.geolsoc.org.uk/SP408

Tectonic Evolution of the Eastern Black Sea and Caucasus

Following a brief introduction that provides an overview over the area, this book is divided into two parts; the 'Caucasus' domain and the 'Black Sea' domain. As a whole the compilation of 15 papers provide a good, balanced overview of recent studies covering an area from northern Turkey to Crimea in the west, to NW Iran and Armenia in the east.

Contributions come from both western and eastern European academia, as well as from the near East. No less than 8 oil companies have sponsored the book, showing the significant interest of the area to the oil industry. The editors have included a good overview figure, appropriately positioned as figure 1, to guide the reader to the spatial extents of the included papers.

The region is an extremely complex area. It incorporates a long-lived convergence zone between plates, a recently enclosed ocean, as wells as an orogen that is still actively building. The book starts with reviews of the plate tectonic evolution of the area. Given the large amount of on-going discussion on this topic, it may have been appropriate to include additional, alternative models side-by-side.

The papers cover very diverse fields, from outcrop studies with fault and sedimentological mapping, to palaeomagnetism and volcanic geochemistry. In addition, there are several papers that include recent industry and academic seismic reflection and refraction lines. These display the marine geology of the eastern Black Sea and Sea of Azov and are explained nicely together with tectono-stratigraphic diagrams. As such the book covers the geology from surface to the shallow mantle. Early discussion of the Neoproterozoic to Paleozoic basement and sediments is included, but the main focus is the time span from Jurassic to Recent.

In general, the book's figures are of a high standard and easy to comprehend, albeit occasionally a bit too small for the amount of detail. I was particularly fond of the many field photographs that made me wish I had seen the outcrops myself! One paper even provides a free Google Earth file to aid future expeditions. Overall the book provides a good compilation of the tectonic geology of the area, is of high quality and is well worth the read for academics and as a key background reference for petroleum geoscientists.

Reviewed by: ***Douwe van der Meer***

TECTONIC EVOLUTION OF THE EASTERN BLACK SEA AND CAUCASUS
by M. SOSSON, R.A. STEPHENSON AND S.A. ADAMIA (Eds) 2017. Published by: Geological Society of London, SP 428, 368pp. hbk. ISBN978-1-86239-739-2.
List Price: £120.00 Fellow's Price: £60.00.
W: www.geolsoc.org.uk/SP428

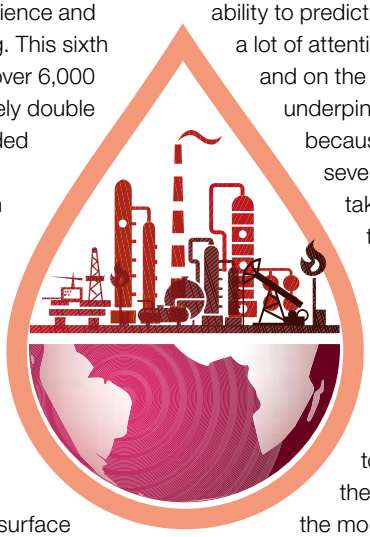
MEETING *REPORTS*

Unconventional is not unpredictable

Oil and gas industry experts met recently to discuss technological advances in the flourishing unconventional resource sector. Sam Green and Martyn Millwood Hargrave discovered that quantitative predictive approaches are reinvigorating the role of geoscience

The oil and gas industry is starting to recover from a long downturn. A surge in exploration and production has been fuelled largely by the exploitation of unconventional reservoirs, such as shale gas. The Unconventional Resources Technology Conference (URTeC; http://urtec.org/2018), held in Houston from 23 to 25 July 2018, encompasses all the many technologies involved in the burgeoning unconventional resources sector, including geoscience and subsurface engineering. This sixth annual assembly saw over 6,000 attendees, approximately double the number who attended in 2017, demonstrating the growth in interest in this uniquely focussed conference.

This year, more than any other previously, saw a significant number of presentations highlighting the value in building integrated, multi-disciplinary, sub-surface models and utilising technologies that allow for efficient and predictive data analysis, including the advance in data analytics using data science and machine learning. The talks highlighted the importance of being able to integrate data from multiple sources to build a coherent sub-surface model that captures the variation in multiple rock properties, lithology and kerogen, pore pressure and stress. Calibration of the seismic domain using sophisticated inversion prior to complex completion and hydraulic fracturing is proving crucial to effective exploration and exploitation of unconventional plays, particularly in the Delaware and Permian basins of Texas and New Mexico—the hot spot of world unconventional resources and very much the economic proving ground of new technologies.



Geomechanical models

There are many important factors that govern whether unconventional plays will be commercially successful or not. One that probably gathers the most focus is the fracturing characteristics of the rock itself. Building an accurate geomechanical model, one that defines the stress state (magnitude and azimuth) within any given interval, is critical to aid operators in the effective design of hydraulic fracturing programs. The topic of pore-pressure integration and, moreover, the ability to predict high pore pressure, received a lot of attention in the conference talks and on the show floor. Pore pressure underpins geomechanical models because it is a critical input, and several talks showed the value in taking a quantitative approach to pore-pressure prediction, which was previously often based on mud weights that are now known to be too simplistic with respect to the true pore pressure.

The other key element to geomechanical models is the ability to upscale, or apply, the models that were calibrated to the wells into the 3D seismic domain. Any rock physics or geomechanical model is dependent on the input parameters of compressional (Vp) and shear (Vs) seismic wave velocities, as well as density (Rho). However, the ability to accurately predict rock properties (facies, pressure, stress) away from the control wells is dependent on the accuracy of the seismic inversion, and accuracy can be reduced due to the presence of complex mixed facies. Fortunately, case studies presented at the conference used new technologies that allow for facies-dependent, elastic property volumes to be derived, leading to a significant increase in the accuracy and confidence of 3D geomechanical models.

Big data

Unconventional plays, in contrast to many conventional areas, have a large number of wells; there are tens of thousands of wells available across the Permian Basin, with up to a million more wells to be drilled over the next ten years. Analyses can be made from huge datasets, but the volume of data puts complete analysis beyond the capacity of the human interpreter. This is where the new domain of data science, underpinned by machine learning, can meaningfully help the industry.

Several presentations throughout the conference discussed this theme. The benefits were clear, focus on maximising value for the organisation by utilising machine learning to: build consistent petrophysical datasets saving human-years of time; quickly and reliably apply predictive models for key properties, such as facies, pressure, and stress, across all wells; aid in efficient drilling by classifying and avoiding drilling hazards; and chase new opportunities through missed play and missed pay identification.

After a fallow period for geoscience over the past few years, the key message from the conference was clear: new quantitative approaches to geoscience can add considerable economic value to unconventional operators by optimising well locations and enabling more cost-effective engineering and recovery.

> THE NEW DOMAIN OF DATA SCIENCE, UNDERPINNED BY MACHINE LEARNING, CAN MEANINGFULLY HELP THE INDUSTRY

Sam Green is Lead Geologist at Ikon Science; e-mail: sgreen@ikonscience.com

Martyn Millwood Hargrave is the Executive Chairman of Ikon Science; e-mail: mmhargrave@ikonscience.com

DISTANT THUNDER

Poetic license

Geologist and science writer Nina Morgan muses over a tombstone tale

In geology, as in life, things are not always what they seem. Ordinary visitors to the village of Carlops, in the Pentland Hills southwest of Edinburgh, might well have shied away when confronted with the geologist, and staunch Scottish Nationalist, Archie Lamont [1907-1985]. Remembered by his colleagues, Euan Clarkson, Professor Emeritus at Edinburgh University and Eric Robinson, who retired from University College London in 2001, as a huge shambling old man, with tiny round spectacles, a massive bald head and a spectacular white beard, Lamont was frequently taken for a tramp.

But behind the scruffy exterior was a first class mind. After initially studying Latin, Greek and English at Glasgow University, in his third year Lamont took up geology. He graduated with an MA in classics in 1928, then carried on to earn a First Class BSc in Geology. He went on to obtain a Demonstratorship and to become President of the Scottish Nationalist Association. He remained a fervent Nationalist for the rest of his life, but was forced to resign the Demonstratorship after a short time due to ill health. Once recovered, he went on to complete a PhD on Ordovician of the Girvan area in 1935, after which he worked in Dublin and Birmingham. On his return to Scotland in 1945 he was awarded a research fellowship at Edinburgh University and worked on the fossiliferous Silurian rocks of the Pentland Hills. But, by 1951 Lamont, having quarrelled with the then Professor, left Edinburgh University to plough his own furrow, pursuing a wide range of topics and founding and providing most of the copy for the *Scottish Journal of Science*.

Geology and Poetry

In 1943, Lamont published *Patria Deserta*, a slim volume of poetry that drew on his many interests. For example, his sonnet *Palaeosmilia*, dedicated to a fellow tombstone geologist, skilfully combined his interest in geology with philosophy:

Two hundred years did the
dark limestone hold
A script, but all the letters have been lost;
The dead lie nameless. Acids of mould,
Sharp agencies of wind, crystals of frost
The drifting rain, the sun the winter cold,
Splintering tightest atomies apart,
Shew forth the hidden threads of corals old
On the smooth stone traced
with minutest art.
Over the myriad centuries between
Nature remains thus faithful to her own,
Dissepiments like a thin veil are seen
About the theca of the hollow cone,
Calyx, tabulae, septa live again
Louder than bones and epitaphs of men.

Sight unseen

All very evocative, but Lamont later admitted in a letter to Robinson that the poem described a tombstone he'd never seen:

"Now the truth is I imagined that Tombstone, and used Palaeosmilia because it sounds like some smiling ancient Mona Lisa ... As Descartes said: 'Thought is perhaps even more important than fact at least in some stages of development' Maybe."

Instead, he revealed that the inspiration for the poem came from a tombstone in a churchyard in Durham described by the geologist, Hugh Miller [1802-1856]. In *First Impressions of England and the English People*, Miller muses "how much more indelibly nature inscribes her monuments of the dead than art" when describing a weathered gravestone which:

"...told that when it had existed as a calcareous mud deep in the carboniferous ocean, a species of curious zoophyte, long afterwards termed *Cyathophyllum fungites* [a rugose coral], were living and dying by myriads ; and it now exhibited on its surface several dozens of them, cut open at every possible angle, and presenting every variety of section, as if to show what sort of creatures they had been... Never was there ancient inscription held in such faithful keeping by the founder's bronze or the sculptor's marble ; and never was there epitaph of human composition so scrupulously just to the real character of the dead."

Tea with Archie

Lamont didn't restrict his poetic imagination solely to verse. He also, Robinson recalls, "introduced strange Scots names—like Haggis Rock [a conglomerate] and Shepherd's Tartan Rock [a black and white conglomerate] to the Silurian of the Southern Uplands."

A visit to Lamont's dwelling, Jess Cottage, Robinson reports, was quite an experience. "Surrounded by collections of fossils, rocks and all manner of things which he accumulated, strong tea with condensed milk from the tin was just one of the memorable courtesies extended to the visitor seeking assistance with due deference... he piled up the empty tins at the back as a kind of stratigraphy."

How future geologists will interpret this deposit remains to be seen. But says Robinson, "I can still taste the tea!"

End notes: Sources for this vignette include: Archie Lamont (1907-985) geologist and poet by Euan Clarkson, Proc. Geol. Soc. Glasgow 150th Anniversary Special edition, pp. 36-38; 2007-2008; Archie Remembered by Eric Robinson, *Edinburgh Geologist*, **42**, spring 2004; Eric Robinson, personal communication, 2018; and *First Impressions of England and the English People* by Hugh Miller, 1857.

* **Nina Morgan** is a geologist and science writer based near Oxford. Her latest book, *The Geology of Oxford Gravestones*, is available via www.gravestonegeology.uk

Geoscientists in the news and on the move in the UK, Europe and worldwide

Encouraging Young Geoscientists

GeoBus is an educational outreach organisation based at St. Andrews University, Scotland. A mobile classroom that visits schools all over Scotland, GeoBus has specially designed teaching aids to help explain to young people why geology is exciting. Founded in 2012, and with a sister organisation at University College London operating since 2016, GeoBus St. Andrews has provided encouragement and enthusiasm for Earth science, including geoscience and aspects of physical geography, to over 70,000 students.

GeoBus has three core aims: to support existing geoscience teaching with specialist resources and knowledge; to inspire students using teaching packages that cover recent research and the latest breakthroughs; and to provide a link between schools, academia and industry to encourage young people into geoscience and related careers.

Since 2015, geoscience subjects were removed from the Higher Level (16-18 years) teaching curriculum in Scotland. GeoBus helps to fill this gap. The demand from the schools remains at excellent levels—there is still interest, even if geoscience no longer forms part of the core curriculum.

As well as providing single and double period workshops at schools, GeoBus runs field trips and a field camp each year. Field camp activities include visiting important geological sites, as well as teaching rock identification, microscopy, mapping and field recording skills. These are vitally important skills for a geologist that, when provided at a young age, can enthuse and encourage students to follow their interest into the profession.

Quotes from some of the students and teachers who have taken part in GeoBus activities include:

"Great day for pupils. Presenters were excellent, good pace and variety. Will definitely book again." *Teacher, Glasgow Gaelic School: Drilling for Oil*

"I love GeoBus, thanks for taking us." *S4 pupil, Irvine Royal: Field Trip*

GeoBus is entirely funded by sponsorship, donations and fundraising activities. Significant contributions are required to allow GeoBus to continue to operate. Existing sponsorship agreements are coming to an end, which threatens the future of this invaluable organisation. If you are interested in helping, via sponsorship, donations or fundraising activities, please get in touch.

For more information see: **GeoBus.st-andrews.ac.uk**/ or contact Dr Jen Brooke (Education Coordinator): **GeoBus@st-andrews.ac.uk**.

Full day mapping complete! (Credit: GeoBus 2018)

The Society notes with sadness the passing of:

Barnes, Simon James *
Booth, Tony *
Bowen, Geoffrey Gordon *
Carmichael, David*
Casey, Raymond *
Fletcher, Brian *
Gladwell, David Robert *
Ince, David Martyn *
Llewellyn, Peter L
Lynch, Edward *
Kenna, Raymond *
Matheson, William *
Milward, Anthony Frederick *
Morgans, Michael William *§
Pegg, Eric Arnold *
Roberts, Brinley
Shrimpton, Godfrey *
Smith, Howard James *
Thomson, Martyn Hugh *

In the interests of recording its Fellows' work for posterity, the Society publishes obituaries online, and in Geoscientist. The most recent additions to the list are in shown in bold. Fellows for whom no obituarist has yet been commissioned are marked with an asterisk (*). The symbol § indicates that biographical material has been lodged with the Society.

If you would like to contribute an obituary, please email amy.whitchurch@geolsoc.org.uk to be commissioned. You can read the guidance for authors at www.geolsoc.org.uk/obituaries. To save yourself unnecessary work, please do not write anything until you have received a commissioning letter.

Deceased Fellows for whom no obituary is forthcoming have their names and dates recorded in a Roll of Honour at www.geolsoc.org.uk/obituaries.

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The Society operates a scheme for Fellows to deposit biographical material. The object is to assist obituarists by providing contacts, dates and other information, and thus ensure that Fellows' lives are accorded appropriate accurate commemoration. Please send your CV, publications list and a photograph to Amy Whitchurch at the Society.

Essential tips for a rock-solid geoscience PhD: Part II

*In the second of a three-part focus, **Melanie J Leng & Anson Mackay** advise on how to ensure your PhD experience is a good and productive one.*

We previously gave tips on how to choose the right project and supervisor, as well as how to manage the student-supervisor relationship and your time. Here we offer advice on the practical side of doing PhD research.

Training

Most geoscience PhD students have access to training courses and some will be compulsory. In the UK, Doctoral Training Partnerships collates training courses across universities to offer a wider choice and to facilitate cooperation and sharing of good practise. Funding bodies, such as NERC also offer training. You should take the initiative, know what courses are available and determine with your supervisor which are essential.

Organising your data

Train yourself to be competent in a data analysis package. R—free software for statistical computing and graphics—is probably essential, and will augment what you can do with your data. Coding for many geoscientists is vital, and increasingly code is required for peer-review, too. Your coding should be clean and really well annotated, so that you can understand what you have done and others can repeat it. Bespoke analytical packages are also important.

To present your data, become an expert in a drawing package. The learning curve with all new software packages is steep, but the view from the top is worth it. Gantt charts are useful to illustrate the start and finish dates of different elements of your work (at experiment to thesis scale); to break down your work into chapter/thesis sections (good for supervisory meetings); and to show the dependency of activities. Slack is a great way to interact with key members of your project team.

During your PhD you will read a lot. Even for experienced researchers, there is too much information out there. Be organised about your reading. It is critical to keep on top of references to read and cite—there are software packages to help with this. Keep PDF versions of key papers and annotate them as you go.

Backup your files on the university server (there will be a university policy), as well as other places, such as Dropbox and Google docs (and periodically update an external hard drive in case you lose internet access). Some data-storage platforms may not be particularly secure and specific restrictions might apply.

Presentations

Dissemination of knowledge is an essential part of the PhD process and you should try to give many presentations. This can be terrifying at first, so prepare well. Start local, presenting to your peers and supervisors, and work up, aiming for a big international conference. At conferences, presentations are given as talks or posters. Each have their strengths, so try both. Think about potential questions you may get from the audience and prepare a couple of slides to address those. You will likely have a tight travel budget, so discuss a strategy with your supervisor. Perhaps save for a major international conference in your third year (like the European Geosciences Union General Assembly). Many small grants are available for students, through your university or relevant associations and learned societies. Specialist organisation membership is usually cheap for students and you can attend their meetings and training courses.

Many people find public speaking daunting. Book a presenting course at your university and practise, practise, practise. Some people have debilitating stage fright or extreme anxiety. If this is you, seek help through your supervisor, the postgraduate office, and welfare office. There are tricks you can do to lessen the stress. Use presenting packages that allow presenter notes that the audience cannot see, or write out memory aides on small cards. The benefits of presentations are tangible and once accomplished, it feels amazing.

In your final year, consider organising a conference session with fellow early career researchers. Aim to get a diverse group of speakers together (reflecting especially on gender, ethnicity, stage of career) and consider publishing the session papers in a special journal collection. This will help you understand the publishing process and raise your profile.

Writing

Start early and write often. Your first major pieces will likely be a literature review and an annual report or transfer report (to transfer from MPhil to PhD). These should form the basis of a thesis structure, which you should plan from the start (including what data will go into what chapters, though this may change) and review regularly with your supervisor. Many universities now encourage a thesis composed of papers. Remember that papers are different to chapters, requiring a tighter writing style and having less room for descriptions and discussion. You'll also need all co-authors to consent on the content.

When writing papers, agree in advance what data you will include and who you need to co-author with. This can be tricky if you are part of a large multi-(inter)national project where data are owned by different people and may be ready for publication at different times. It is important to be clear about expectations of who will do what early on in the paper development.

Discuss with your co-authors which journal to submit to. Journals have different audiences and while impact factors are commonly looked at, by themselves they are not a measure of the quality of a journal or the papers they contain. You may wish to make your paper open access (OA), so that anyone can read your research, not just those who have access to personal or institutional subscriptions. Many subscription journals offer to make individual papers OA for a fee (article processing charge, or APC). Alternatively, there are a growing number of OA-only journals, where costs for article production and publication are borne by people paying an APC ('gold' open access). These can be very expensive, but such fees are usually dealt with by institutions, who reach agreements with funders to cover the

costs of publishing (for example, for NERC-funded PhD studentships, where the gold route maybe stipulated).

Alternatively, green OA allows you to deposit, for free, the final manuscript (after peer-review but before journal formatting) into an electronic repository (e.g. most institutions have their own repositories, as do funding bodies such as NERC). But copyright and embargo conditions may exist, and will depend on what contract you signed with the publisher of the journal. A few journals, such as *Volcanica*, are now appearing that offer diamond OA. Here papers are free to publish and to read, and the costs are covered by external investment. Finally, most journals now allow you to upload your draft manuscripts into a preprint repository such as EarthArXiv, where earlier versions of your work are free to download and be commented upon. Be aware that the field of publishing is rapidly changing, and you should keep informed about recent developments in Open Science.

We highly recommend, and your funding body may insist, that data be submitted to a data repository such as Pangaea, or NOAA. Make sure that as you collect and organise your data, metadata are considered carefully too.

Once you start publishing (including conference abstracts with ISBN numbers), set up Google Scholar and ORCID accounts (which will update automatically) for maximum outreach. Once a paper is out, consider blogging about it (for the non-specialist) or recording a video introduction (and link these activities to your social media). Many academics have their own social media profiles, such as ResearchGate or Academia. These networks can be really useful to connect with other scientists, but restrictions still exist on what papers can be uploaded.

If you are aiming for an academic position (a post-doc, fellowship, teaching fellow or lecturing position), you might want to undertake a thesis "by papers" and to therefore organise your research around a series of projects or experiments that can be published independently. Some universities require a traditional thesis, so you might have write your papers and then convert them into monograph-style chapters. It is easier to convert papers into chapters than vice versa, plus you will get more input and advice from co-authors on a paper than you would for your singled-authored thesis chapter.

If your institution allows a thesis by papers, the pros are: publications that greatly enhance your CV and greater input from co-authors in writing the papers. The downsides are: papers can be much harder to write than thesis chapters and will require more time; there is less room for speculation; negative results often do not make into a journal paper, whereas in a thesis chapter you can explore experiments that did and didn't work; you are at the whim of co-authors and their timetables; the more co-authors the more complex the writing (you have to satisfy them all). In the geosciences, multi-authored papers are the norm.

Finally, social media is a great way to practise writing, from 280-character tweets to longer blog posts. But we'll cover that in more detail in part III.

Look out for part III, which includes advice on outreach and how to plan for your career beyond the PhD, in the November issue of Geoscientist.

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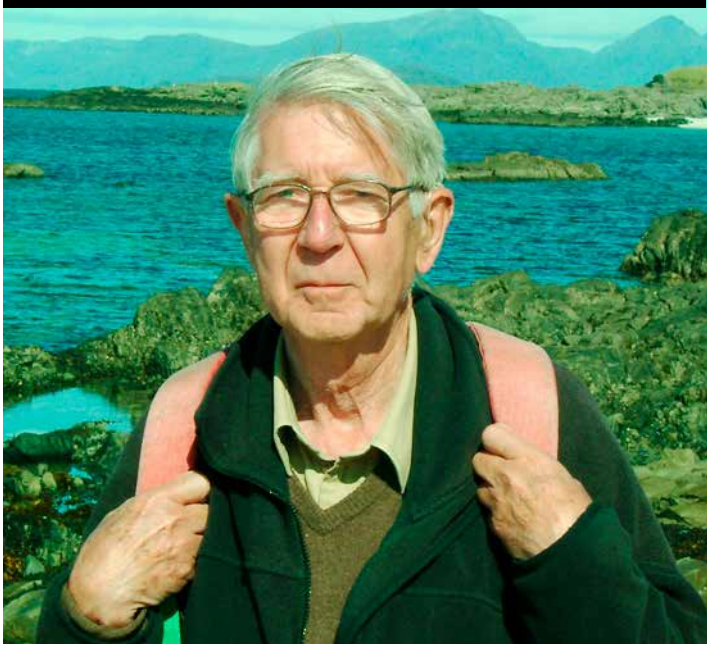
OBITUARY Charles Henry Emeleus 1930-2017

Distinguished field-based igneous petrologist who studied under Wager and was noted for his work on the Rum layered intrusion



Charles 'Henry' Emeleus came from County Antrim, Northern Ireland. He graduated with first-class honours in Geology, from Queen's University (Belfast) in 1952. His research interests in the British Palaeogene Igneous Province developed early in his career, when he remained at Queen's for a research MSc (1953) under the supervision of J E Richey. He subsequently received a DPhil from Oxford University in 1957, for his work on the Slieve Gullion centre, supervised by L R Wager.

Henry spent most of his career at Durham University, being promoted to Reader in 1979 and serving as Head of Department (1986-87). He retired in 1994, but remained very research-active and was awarded the Chancellors Medal of Durham University in 2014 and elevated to Emeritus Professor in 2016.

Field geologist

Henry's expertise encompassed the broad spectrum of igneous petrology. He was first and foremost a field geologist, and had long-term interests in the petrogenesis of Proterozoic syenites from the Gardar Province in southwest Greenland. His first of more than 15 expeditions to the region was in 1955, when he spent the summer mapping the Kûngnât Complex with B G J Upton.

Henry's earliest research on the Isle of Rum was published in papers, co-authored with C J Hughes and A C Dunham in 1957 and 1965 respectively, on the felsic intrusive rocks there. Over time his fascination with the layered intrusion developed and his life-long work, with co-workers and students, on various aspects of the layered cumulates is one of the main reasons Rum became one of the most well-known layered intrusions in the world.

Maps & memoirs

After retirement, Henry undertook a number of significant projects under contract to the British Geological Survey. In 1994, he produced the superb 1:20,000 map of the Isle of Rum, published by Scottish Natural Heritage, and now out of print. He also wrote numerous memoirs and texts on British igneous geology. Perhaps the most iconic are 'Geology of Rum and the adjacent Isles' (1997) and 'The Palaeogene Volcanic Districts of Scotland' (2005, co-authored with B Bell). These are superlative examples of accessible and informative scientific writing, and beautifully illustrated.

In recognition of his distinguished achievements over the course of his career, he received many awards and honours, including: a DSc from Queen's University (Belfast), the Clough Medal of the Edinburgh Geological Society (1994-95), the inaugural Collins Medal of the Mineralogical Society of Great Britain and Ireland (2010) and the Geological Society's Prestwich Medal (2016).

Railways

Henry's interests encompassed much more than the geosciences. When he was not thinking about geology he would be reading about railways or playing trains. His knowledge of railways was extensive and encyclopaedic.

Henry passed away on Saturday 11 November 2017. He will be remembered by all who knew him as a modest and gentle man, with a dry and ready sense of humour and a twinkle in the eye. He was generous to a fault with that most valuable of commodities: his time. His great knowledge and experience was always enthusiastically shared. A R McBirney once remarked that Henry '....never asserts himself, but when he says something, one should listen, because he knows what he is talking about.'

Perhaps the greatest legacy that he leaves to geology is the energy and enthusiasm he inspired and fostered in several generations of Earth scientists working in the arena of igneous petrology. He leaves behind his wife, Ruth, children Katherine, John and Lucy, and grandchildren. He will be greatly missed by all who knew him.

By Brian O'Driscoll, with Jon Gluyas and Madeleine Humphreys

* Edited for brevity in print. See the full version online *Editor*.

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