GEOSCIENTIST

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The Fellowship Magazine of the Geological Society of London

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Hero or Houdini?

The origin, transport and accumulation of helium

He

THE ANTHROPOCENE
Jan Zalasiewicz on the current stratigraphical state of play

ONLINE SPECIAL
'Sociohydrogeology' in water-stressed India

DEADLINE TIME
Ted Nield ponders 'anytime' submission

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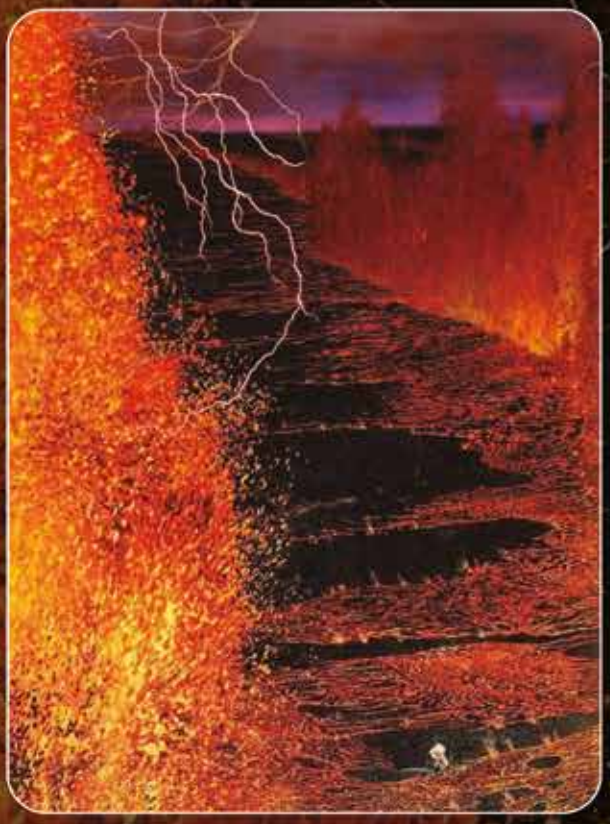
Lyell Meeting 2018

Mass extinctions: understanding the world's worst crises



7 March 2018

The Geological Society, Burlington House

The study of mass extinctions is one of the most interdisciplinary research areas within Earth and environmental sciences. Recent, major advances have come from a broad spectrum of fields, including atmospheric modelling, high-precision age dating, volcanology, geochemistry, stratigraphy and palaeontology. The 2018 Lyell Meeting aims to highlight these achievements and showcases the improved understanding we now have of the great environmental catastrophes of the past. The Meeting aims to encompass the full spectrum of crises seen in the Phanerozoic fossil record.

The 2018 Lyell Meeting provides a platform to assess the current stratigraphic and geochemical records of environmental change during mass extinction events and the role of atmospheric climate modelling in understanding the causes of the crises. The goal is to evaluate the relative importance of environmental changes in major episodes of species extinctions, and to further explore the mechanisms that link these proximal kill mechanisms to the ultimate drivers, such as large igneous province eruptions and meteorite impacts. This will be a rare opportunity to hear research developments happening in diverse disciplines applied to all mass extinction events.

Convenors:

Paul Wignall (University of Leeds, UK)
Dave Bond (University of Hull, UK)

Keynote Speakers:

Prof Mike Benton (University of Bristol)
Dr Sofie Lindström (Geological Survey of Denmark and Greenland)

Further information:

For further information about the conference please contact:

Naomi Newbold, Conference Office, The Geological Society, Burlington House, Piccadilly, London W1J 0BG
T: 0207 434 9944
E: naomi.newbold@geolsoc.org.uk
Web: www.geolsoc.org.uk/lyell18

Follow this event on Twitter #lyell18

Call for Abstracts:

We invite oral and poster abstract submissions for the meeting, and these should be sent in a Word document to naomi.newbold@geolsoc.org.uk by 1 December 2017. Abstracts should be approximately 250 words and include a title and acknowledgement of authors and their affiliations.

Geoscientist is the Fellowship magazine of the Geological Society of London

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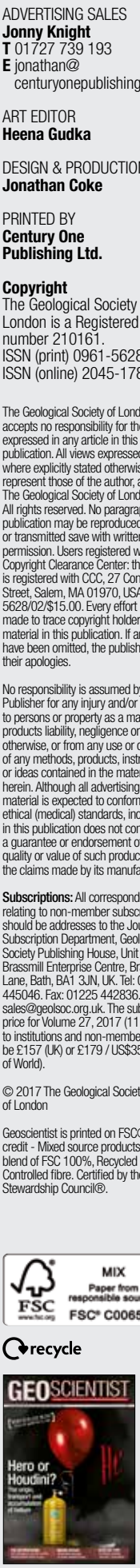

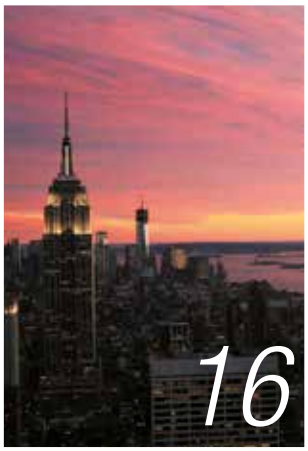

ON THE COVER:
10 HERO OR HOUDINI?

As the festive season approaches, you may think twice about those helium balloons...

FEATURES

REGULARS

ONLINE SPECIAL

SOCIO-HYDROGEOLOGY AND ITS APPLICATION IN INDIA by Shrikant Daji Limaye, Director of the Ground Water Institute, Pune. India.

The Geological Society

serving science, profession & society

Editor *Geoscientist* magazine

Salary: £40,000 - £45,000, negotiable

The Geological Society of London, a professional body and learned society, seeks to appoint an experienced science journalist/writer to be Editor of *Geoscientist*, the independent magazine of the Geological Society Fellowship. The post is full-time and based in Burlington House, Piccadilly, London.

Geoscientist (with *Geoscientist Online)* is a 32-page colour magazine distributed to the 12,000+ worldwide Fellowship of The Geological Society, the world's oldest national scientific and professional society for Earth sciences (founded 1807). Accountable to an Editor-in-Chief, who is traditionally a former President or senior Officer of the Society, the successful candidate will ideally be a science writer, having both a strong empathy for the membership and knowledge of earth sciences. He/she will have experience of editing with a record of sound writing and delivery. He/she will be able to communicate and inform across national and international communities.

Geoscientist magazine provides a mix of opinion, features, Society news, people news, obituaries and letters. It acts as the Fellowship's forum for discussion of the Society's activities and of its elected Trustees (President, Officers and Council). It has 11 issues per year. The magazine is produced externally on the Society's behalf. Issues of the magazine may be inspected online at www.geolsoc.org.uk/Geoscientist.

Key skills of the *Geoscientist* Editor role are to deliver effectively within the governance framework of a charitable organisation and to edit the Fellowship's magazine with that framework in mind.

The closing date for applications is 12 January 2017.

For more information and to apply, go to www.geolsoc.org.uk/editor.

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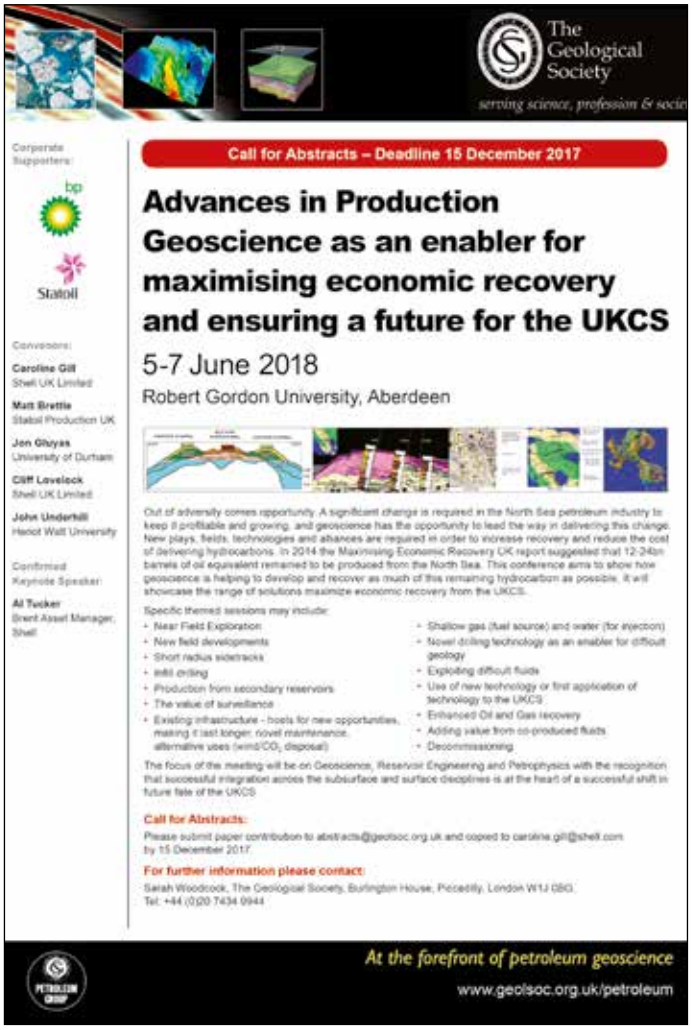


> I LOVE DEADLINES. I LIKE THE WHOOSHING SOUND THEY MAKE AS THEY FLY BY
> – DOUGLAS ADAMS

FROM THE EDITOR'S DESK:

Kill the deadline?

'Deadline', meaning a line that neither moves nor strays (OED) went dark in 1886, when it came to signify the line around a military prison beyond which prisoners could expect to be shot. It retains much the same grim finality for journalists, for whom the only excuse for missing one is being dead. It is no boast to say I have never missed a deadline. It is the way of one's people.

Other folks for whom, unlike Douglas Adams (see quote above) deadlines are more than mere aspirational targets – other people who really mean it - are administrators of scientific funding programs. No appeals. Lines must be drawn. "If we were to make an exception for you…" they say - hinting that life would become simply unliveable.

However, evidence reported in Science[1] has suggested that deadlines themselves, in the research-funding context, may in fact be more problem than solution. They create lumpy workflows, for one thing. In an already strained review system, having to make all the effort in two annual binges can't be good. And it may go further. Deadlines may actually generate more, and poorer, proposals.

Last year, the National Science Foundation (NSF) in Arlington, Virginia, heard from Geosciences Assistant Director Roger Wakimoto that removing deadlines and replacing them with an 'anytime' submission system caused the number of proposals received to drop by 59% - even more than the 50% drop experienced when a similar 'anytime' scheme was piloted in 2011 (in a small grant program for instruments and facilities).

Alex Isern, head of NSF's Surface Earth Processes section, eliminated the standard time-honoured bi-annual deadlines in four of her grant programs. She saw applications fall from 804 (in 2014) to 327 (April-March 2015). Moreover, the 'lost' proposals appeared to constitute 'the bottom 50%' – the long tail of half-baked proposals done in a rush at the last minute.

The new system meant that scientists (especially those in sciences like geology where deadlines can fall awkwardly with the field season) could bide their time, schedule the writing to suit their own timetables, and take greater pains. Success rates were expected to rise sharply as a result.

Are there drawbacks? Some scientists complained that deadlines 'motivated' them… To which Isern responded laconically that they now had '365 deadlines a year'. As for NSF, – its program managers may fear achieving higher success rates than their colleagues, because one criterion used historically to argue for higher budgets has been… pressure of applications. But clearly, if proposal pressure can be so easily manipulated, said Carol Frost, Head of Earth Sciences Division, "it is not a good metric".

Reference

1. No pressure: NSF test finds eliminating deadlines halves number of grant proposals by Eric Hand. Science 15 April 2016, Doi: 10.1126/science.aaf9925

• ***Editor's note:*** *We're not exactly the NSF, but the deadline for submitting proposals to the Society's Research Grants scheme is* ***1 February 2018*** *(see p. 6).*

DR TED NIELD NUJ FGS, EDITOR - TED.NIELD@GEOLSOC.ORG.UK @TedNield @geoscientistmag

SOCIETY *NEWS*

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

Research Grants

Applications are invited for the 2018 round of the Society research grants.

Please complete the form which can be downloaded from the Society Awards and Research Grants page at **W: www.geolsoc.org.uk/grants** where you will also find information about all the grants. The average award has been about £1000.

The Research Grants committee meets once annually. Applications must reach the Society no later than 1 February 2018 and must be supported by two Fellows of the Society who must each complete a supporting statement form. Only complete applications on the appropriate form will be considered.

Timothy Jefferson Fund

The Society will have one fund fewer to draw upon when the grants committee meets in February. Dr Timothy Hugh Jefferson (b. 1956) was a highly talented young geoscientist whose PhD focused on Antarctic palaeobotany. He was awarded the Palaeontological Association's Presidents Prize in 1982. Timothy tragically died in an avalanche while assisting a colleague in scientific work in the Cordillera Blanca in Peru in September 1983.

His family and friends endowed the Timothy Jefferson Research Fund. From an original donation in 1985 of £10,000, subsequently enhanced by donations from others, over the years the fund has yielded just under £40,000 in support of research, but is now spent out. The Society is very pleased that it has other funds to draw upon and is grateful to Timothy's father the Rev. Derek Jefferson and all the others whose generous helps to make this activity possible.

Stephanie Jones

➤ Further information on the Fund and the research uses to which it has been put can be found in the online version of this article. Editor.


Credit: Wikimedia Commons

LONDON LECTURE SERIES

Dangerous neighbours

Speaker: Jenny Barclay, Professor of Volcanology at the University of the East Anglia and the Principal Investigator of the STREVA (Strengthening Resilience in Volcanic Areas) Project.
Date: 11 December

Programme

- **Afternoon talk:** 1430pm Tea & Coffee: 1500 Lecture begins: 1600 Event ends
- **Evening talk:** 1730 Tea & Coffee: 1800 Lecture begins: 1900 Reception

Further Information

Please visit www.geolsoc.org.uk/gsllondonlectures17. Entry to each lecture is by ticket only. To obtain a ticket please contact the Society around four weeks before the talk. Due to the popularity of this lecture series, 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**

Council nominations – reminder

Fellows received a nomination form with the October issue of Geoscientist for the election of new Council members for 2018/2019. This year the Society particularly welcomes nominations from Fellows with knowledge and experience of scientific publishing, and of fundraising. Details of the process are on the forms and are also in the Governance section of the website. The closing date for the receipt of nominations is 5 January 2018.

FUTURE MEETINGS

Dates for meetings of Council and Ordinary General Meetings until June 2017 will be as follows:

- **OGMs:**
2018: 7 February, 4 April
- **Council:**
2018: 7 February, 4 April

The Royal Commission for the Exhibition of 1851

For reasons NOT lost in the mists of time (see Letters, Online), the President of the Society is an *ex officio* Commissioner of the Royal Commission for the Exhibition of 1851.

The Commission offers various research grants, details of which are on the website at: **W: http://bit.ly/2mtjpxK**.

Plate Tectonics at 50

The Geological Society has been celebrating 50 years of plate tectonics. Flo Bullough* has a round-up.

In December 1967, Dan McKenzie and Bob Parker published a paper in *Nature* – 'The North Pacific: an example of tectonics on a sphere'. This paper, building on work by many other scientists in preceding years, was arguably the crucial final step in establishing the paradigm of plate tectonics, providing a unifying context for Earth science that was rapidly accepted across the geological community.

Our celebrations culminated in September and October, with a host of events and initiatives across the Society. The William Smith Meeting was an exceptional event attended by over 200 people in Burlington House, joined online by over 600 individuals and organisations from 36 countries. It featured the William Smith Lecture, given by Dan McKenzie, and was covered on BBC radio, the BBC website and in a *Nature* editorial.

We launched the Dan McKenzie Archive website (**W: www.mckenziearchive.org**), and held an associated exhibition at Burlington House. We also organised a schools event on plate tectonics and mineral resources – one of over 50 events taking place across the country during Earth Science Week (7-15 October), the theme for which was 'Our Restless Earth' (See Photo competition, p26).

Plate Tectonic Stories

The Society also launched an online resource and competition entitled 'Plate Tectonic Stories', celebrating the role of narrative and storytelling in geology. The online resource tells the stories of 20 geological sites in the UK and Ireland that were shaped by plate tectonic processes. These sites have been 'twinned' with others around the world where similar tectonic processes and geological features can be observed in operation today.

See **W: www.geolsoc.org.uk/tectonicstories**.

For the Competition, we are inviting school students, members of the public and even enthusiastic geologists to tell us a plate tectonic story of their own, in any medium. You might take inspiration from one of the 20 sites already featured, or from one of the twinned sites, or from the many plate tectonic resources on the website - including the Dan McKenzie Archive or the 2017 photo competition.

The closing date for entries to the competition is 30 April 2018, so please do your creative best in telling stories about the impact of plate tectonics around the globe.

*** Flo Bullough** is the Society's Policy Officer

Opus DEI

Diversity, equality and inclusion (DEI) are among the values set out in the Society's 10-year strategy, writes George Jameson*.

The Society was a founding signatory to the Science Council's Declaration on DEI in October 2014, marking its commitment to ensuring that Earth science is open to all, and allowing everyone the opportunity to be part of our community.

With this in mind, we will regularly be updating Fellows on recent activities in this area. Recent highlights include:

- A collective benchmarking exercise, developed by the Royal Academy of Engineering and the Science Council, to assess, track and plan progress on DEI across professional science and engineering bodies.
- Hosting our first workshop to offer support to university Earth science departments working towards obtaining or renewing an Athena SWAN award, which recognises advancement of gender equality and other aspects of diversity – something we will repeat in 2018.
- The International Association for Geoscience Diversity (IAGD) became an 'Associated Society' of the Geological Society in September 2017. We are planning further shared activity to make Earth science accessible to people with disabilities.

➤ If you would like to share views and suggestions relating to DEI in Earth science, please contact us at E: diversity@geolsoc.org.uk.

***George Jameson** is a Society External Relations Officer

Programme: 2017

Meetings of the Geological Society Discussion Group (formerly the Geological Society Club) are 18.30 for 1900, when dinner is served. Attendance is open to all members of the Society. For up to date information concerning topics for discussion and speakers, please go to W: **http://bit.ly/2AhEZrf**

- **Wednesday 6 December.** Athenaeum (London SW1Y 5ER)
- **Wednesday 7 February.** Gay Hussar
- **Tuesday 24 April.** Burlington House
- **Thursday 14 June.** Athenaeum
- **Wednesday 12 September.** Gay Hussar
- **Wednesday 24 October.** Bumpkins
- **Wednesday 5 December.** Athenaeum

➤ Please contact Sarah Woodcock for more information and to make a reservation. E: sarah.woodcock@geolsoc.org.uk

Chartered Fellows' Newsletter


Credit: Ted Nield

This newsletter is produced five times a year following each set of Chartership Interviews, writes Bill Gaskarth, Chartership Officer.

It contains the names of all the newly elected Chartered Geologists and Chartered Scientists along with news items which would not reach the pages of *Geoscientist* e.g. Progress on the Society's application to the Engineering Council to become a Registered Body and hence be able to offer CEng to eligible Fellows; Dates of forthcoming mentoring workshops etc.

Some 20% of all Chartered fellows have indicated that they do not wish to receive mass mailings by email, and consequently the Newsletter is not currently being sent to them. If you are one such person but do nevertheless wish to receive the Newsletter, please let me know at **E: Chartership@geolsoc.org.uk**.

Fellows who were recently chartered, either as CGeol, CSci or EurGeol, were as follows. (This information was previously circulated in the October Newsletter.)

- **New CGeols:** Alexander Nicholas Al Nuaimi; Lee Alder Brown; Paiul Michael Conie; Neil James Dyer; Godwin Effiong Eton; James Edward Field; Andrew David Gibson; John Paul Heneghan; Martin Heys; Angela Hills; David Hopper; Dawn Elizabeth Houliston; Rhian Sara Kendall; Richard Henri Lagesse; Mike Robert Lelliott; Andrew John Oliver; Marc Protheroe; Timothy David Sylvester; Philip Richard Stewart; Helen Elizabeth Stockham; Mark James Stringer; Konstantinos Tsigkas; Rene Van Oorschott; Adam Robert Venn; David Lawrence Rollit Webster; Robert Paul Webster; Daniel John Welch.
- **CGeol by Reciprocity with the AAPG:** Paul Britt.
- **CSci:** Richard Hines; James David Griffiths.
- **EurGeol:** Neville Brookes; Shing Chung Markus Chan; Margaret C Manyanhair; Alessia Sgattoni; Lee Taylor.

Policy update

Consultation is open on two proposals relating to radwaste disposal, writes Adler deWind.

The UK Government is consulting on two proposals regarding a geological disposal facility (GDF) for the UK's higher level radioactive waste: a draft National Policy Statement and a draft policy on Working with Communities. For further details, go to W: **www.geolsoc.org.uk/consultations**.

Latest news from the **Publishing House**

Jenny Blythe has the latest from the Geological Society Publishing House

New Book: Engineering Geology and Geomorphology of Glaciated and Periglaciated Terrains: Engineering Group Working Party Report

The Engineering Group of the Geological Society Working Party brought together experts in glacial and periglacial geomorphology, Quaternary history, engineering geology and geotechnical engineering to establish best practice when working in former glaciated and periglaciated environments. The Working Party addressed outdated terminology and reviewed the latest academic research to provide an up-to-date understanding of glaciated and periglaciated terrains. This transformative, state-of-the-art volume is the outcome of five years of deliberation and synthesis by the Working Party. This is an essential reference text for practitioners, students and academics working in these challenging ground conditions. The narrative style, and a comprehensive glossary and photo-catalogue of active and relict sediments, structures and landforms make this material relevant and accessible to a wide readership.

- **Available to purchase as a hardcopy:** www.geolsoc.org.uk/spe28
- **Available in the Lyell Collection:** http://egsp.lyellcollection.org/content/28/1

The strength of earthquake-generating faults

By Alex Copley

This paper summarizes the observations and methods that have been used to study the strength of active earthquake-generating (seismogenic) faults. Indirect inferences based upon a range of geophysical and geological observations suggest that faults fail in earthquakes at shear stresses of less than c. 50 MPa, equivalent to effective coefficients of friction of less than 0.3, and possibly as low as 0.05. These low levels of effective friction are likely to be the result of a combination of high pore fluid pressures, which could be local or transient, and the frictional properties of phyllosilicate-rich fault rocks. The dip angles of new faults forming in oceanic outer rises imply that intrinsically low-friction fault rocks must control the fault strength in at least that setting. When combined with the much higher fault strengths inferred from borehole studies and some laboratory measurements, the observations are most consistent with weak faults embedded in strong surroundings, providing a clear reason for the prevalence of fault reactivation. However, the conditions required for the formation of new faults, and the reasons for an apparent wide variability in the degree of fault healing through time, remain unknown.

- **Read the open access paper in the Lyell collection** http://jgs.lyellcollection.org/content/early/2017/07/20/jgs2017-037

CPD for contaminated land risk

Chris Evans* says CPD is vital to his business and welcomes the formation of a Contaminated Land Group

My primary job is to be distinct from the range of 'consultants' available to clients - who in my case are predominantly small builders. In order to adequately address the growing requirements of contaminated land risk assessment, alongside the tightest budgets in civil engineering, I need to keep up good CPD - such as the latest regulatory requirements - as well as wielding the sharpest of quotation pencils.

Small builders are 12% of house developers, and the only organisations that can, or will, develop old garages, single-tank fuel stations or minor brownfield sites. Such plots are too cumbersome or piecemeal for larger developers and no local authority these days would have the means to consider them.

Delighted

How delighted I was, therefore, to hear the presentation that Anne Barker gave to the Yorkshire Regional Group in May. This interesting talk outlined the progress of contaminated land risk-assessment throughout her career as a senior Contaminated Land Officer. Then again, how distressed was I to find that there are potential moves afoot to remove the current planning requirements from larger developers. In the first case, why undermine what has become the beginning of an accepted risk assessment method? In the second case, cynically I believe any changes would be funded by those still left in the system.

What a fine example of CPD this talk was. All credit to Anne as a regulator, for openly describing the need to overhaul current guidelines, including industry profiles. I and so many others share a view that our industry needs training, if only to be fully aware of the potential unknowns which are of course the very core of good risk-assessment.

Clients

Going back to my valuable clients, the principal tool I have to develop our client base is trust. Yes, I am comfortable telling a client I am acquainted with a named contaminated-land officer, or time after time persevering to gain the funding for a Desk Study in addition to the Ground Investigation required by the planning condition. Yes, I know you can't properly do one without the other, but try telling a small builder that, especially if he has a list of 'consultants' who believe they can!

All power to the Geological Society for forming a Contaminated Land Group that, if nothing else, should be able to provide good CPD - most especially if this can lead to further and better development of appropriate guidelines and thereby client trust.

Finally, the personal cost of all of this CPD can be prohibitive; but I intend to fund travel and new courses by relinquishing other professional memberships - in my case, my CEng status. For those with several charterships who also struggle to finance their career, it is my view that the Geolsoc remains ahead of the game. Hopefully the continued development of the CGeol title will be more than enough to satisfy all regulators.

Credit: Shutterstock.com/Silent Corners

***Christopher Evans** BSc MSc FGS CGeol CEng (for the moment) E: rockreaders@gmail.com

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 **ted.nield@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).

> "FOR THOSE WITH SEVERAL CHARTERSHIPS WHO ALSO STRUGGLE TO FINANCE THEIR CAREER, IT IS MY VIEW THAT THE GEOLSOC REMAINS AHEAD OF THE GAME"
> CHRIS EVANS

HELIUM
HERO OR HOUDINI?

Diveena Danabalan and colleagues*
ponder the origin, transport and accumulation of that most elusive element

Helium is the second most abundant element in the universe, and yet here on Earth it is a more limited commodity. Supplies come from only four countries. The USA has dominated the market for decades but in the last few years it has been joined by Algeria, Qatar and Russia. Superficially, this would appear to be a good development, but supply of helium to the western world is precarious.

Why is this a problem? Helium is not only used in party balloons and advertising blimps. Cryogenics accounts for around 32% of global demand, with medical cryogenics (such as MRI scanners) becoming ever more important and abundant. For these there is no adequate substitute for He – it really is an elemental hero. The Large Hadron Collider, for example, requires 120 tonnes of superfluid helium to maintain its magnets at their operating temperature of 1.9K. A new truckload is required to arrive in Geneva each week, to top it up. Helium is also extensively used in arc welding, purging, leak detection, chromatography, superconduction, breathing mixtures, heat transfer, gas lift; and (extensively) as a purge gas in the oxygen/hydrogen propulsion units used for space rocketry and nuclear ICBMs. All current He reserves were discovered by accident. What is needed is a strategy for finding this precious commodity on purpose.

Reserves in the USA have declined significantly in recent years, while those in Qatar, although massive, are entirely dependent upon the Liquefied Natural Gas (LNG) market remaining robust, because helium is a by-product of the cryogenic process needed to produce

***Above:** Should we really be wasting helium in party balloons?*

> ALL CURRENT He RESERVES WERE DISCOVERED BY ACCIDENT. WHAT IS NEEDED IS A STRATEGY FOR FINDING THIS PRECIOUS COMMODITY ON PURPOSE

***Photos::** In October this year the Society was 210 years old. Ten years ago, we launched our Bicentenary Year with the release of 4567 helium-filled balloons. The balloons were made of biodegradable natural latex, and were released by permission of the CAA. But should we have worried just as much about the waste of precious He?*

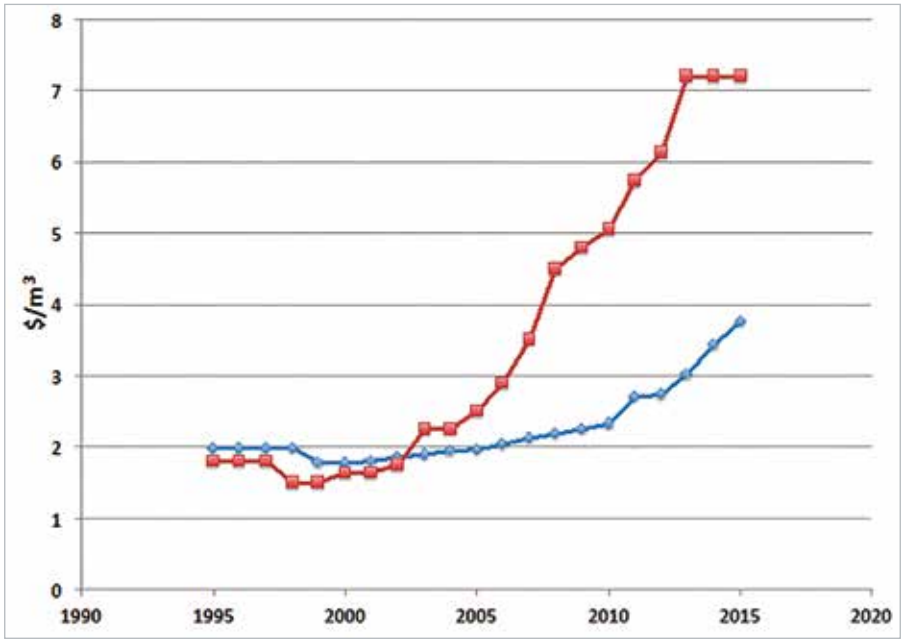
it. This, combined with the strategic risk of relying on a small number of geopolitically sensitive suppliers, makes western markets nervous. Indeed, typing 'helium' into a search engine produces a stream of articles about 'helium shortage'.

Recycling is becoming more common, but containing helium is difficult and leakage from storage inevitable – it is the ultimate 'Houdini' element. Once 'free', not even gravity impedes it. It even escapes the Earth's atmosphere and is lost to space – the very reason it is so rare on Earth.

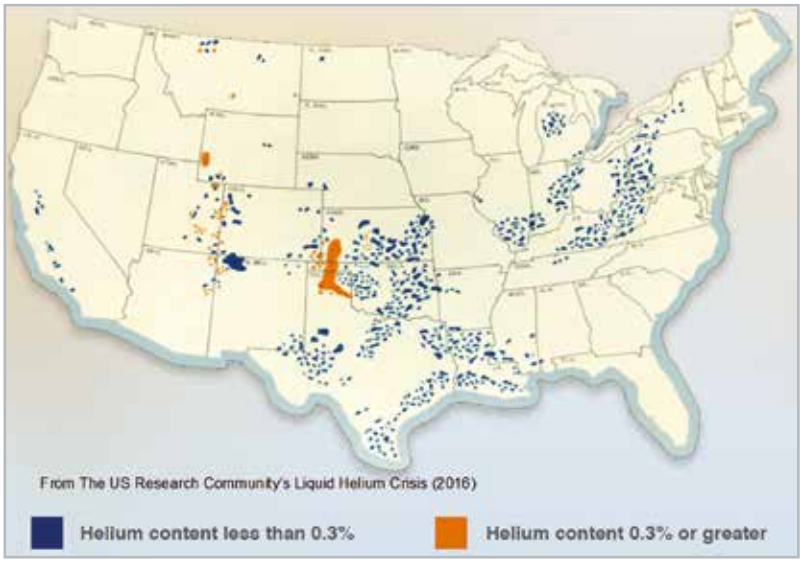
Current global helium, the result of serendipitous discoveries, is a by-catch from the search for petroleum. Indeed, it was one such chance discovery that first alerted John Gluyas to the problem. Back in 1999 John, an oil company geologist, changed employer; and the first new task awaiting him was to evaluate the plan for a gas field development in southern Asia. The plan was fine but he was intrigued by a single line in a table, labelled 'gas composition' listing He as a constituent gas. A quick bit of maths revealed that once the field was on production it would deliver c. 0.25 million standard feet per day of helium. This was globally significant. (Alas, ahead of any substantive plan to exploit it, an even bigger company took over, and it would seem nothing happened. The field is now on stream producing methane, nitrogen and a small proportion of helium.)

A few years before, in 1996, Chris Ballantyne was working in the University of Michigan and awarded a grant by the US Department of Energy to study the geochemistry of helium-bearing natural gases in the Hugoton-Panhandle natural gas field. There was little sense then that helium was running out, as demand had not yet accelerated to today's level – but the study (published in 2002) resulted in the most comprehensive understanding of commercial helium occurrence at that time.

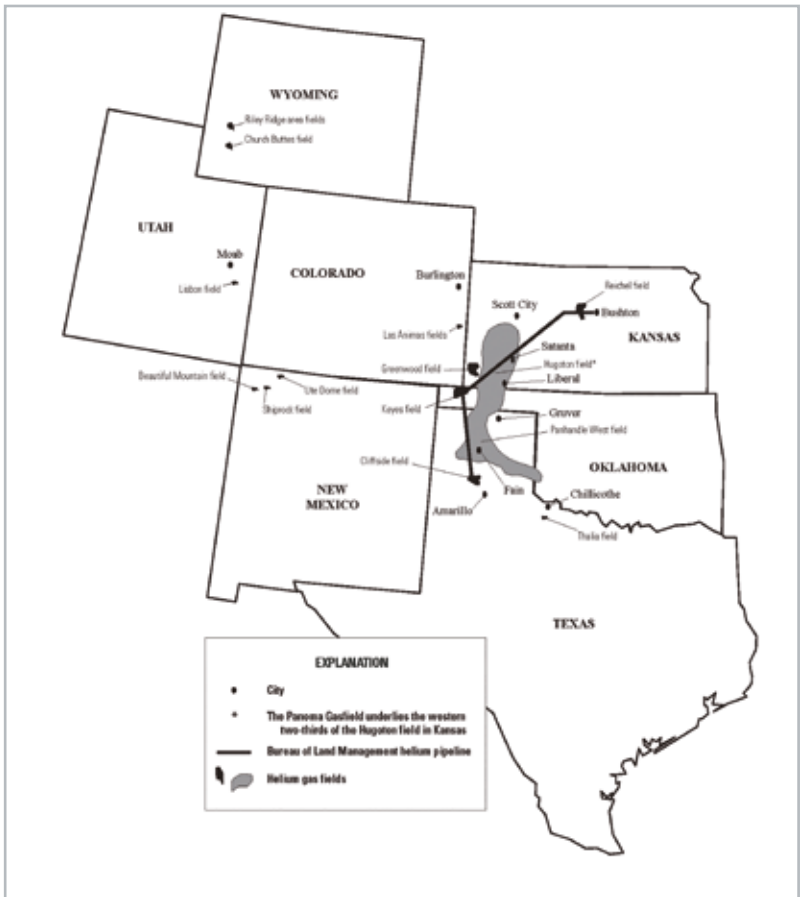
That you might be able to find helium on purpose remained a pipe-dream for a decade, before Gluyas and Ballantyne first discussed a possible helium exploration strategy. In December 2011 helium users in Europe and the US received letters from suppliers; helium was in short supply. This concentrated minds, and, early in 2012, the two pitched their idea to Statoil of Norway. Shortly after, a research award to develop a helium exploration strategy was awarded to the universities of Durham and Manchester, and I was ▶



Helium consumption in the US by sector



Helium content in US natural gas reserves



Map showing helium-rich gas fields and He processing plants in the United States, 2012. From USGS

subsequently appointed to undertake it. Statoil veteran Tony Doré quipped that it must have been the first time ever that Statoil had invested in anything with no calorific value!

Origins

Any exploration strategy must depend on an understanding of origins. Helium was first discovered in economic quantities in Dexter, Kansas, USA in 1903 where it was referred to as the 'gas which would not burn'. Analysis of the gas from this field found that it was dominated by nitrogen but also contained 1.84% helium by volume. Such an amount is uncommon; in most fields helium occurs in traces (0.05% or lower).

The discovery allowed its properties to be explored, which in turn led to its widespread use in physics and chemistry. Markets developed. Other discoveries were made, in Wyoming, Oklahoma, Texas, Kansas, New Mexico, Utah, Arizona, Montana and Colorado. Some fields contained up to 10% He by volume – significant, when the economic concentration for extractable He is 0.3% - at which level its value is about the same as the remaining 99.7% of the discovered gas volume (assuming this is saleable methane).

Other discoveries of helium-rich gas have also been made (in Canada, Algeria, Poland, Russia, Germany, Hungary, Romania, Qatar, Kazakhstan, India, Pakistan, China and the Timor Sea). However none of these new reserves currently matches the concentrations or volumes found in the USA. To date only 14 fields across 12 countries actively produce and contribute to the world's supply of the gas.

So, current reserves are set to decline

to critically low levels in a few tens of years. We have been failing to replace what we use. Recycling is minimal and largely unfeasible. Moreover, we suspect that many gas production companies are unwittingly venting He because they either do not test their gas or, if they do, fail to recognise its value. We have evidence that helium is indeed being vented from 'off-spec gas', rich in non-combustible compounds, during the clean-up process.

As a result, while global demand has steadily risen (proportional to a price increase of c. 175% in the last decade for Grade A helium), crude helium is now worth approximately 30 times the equivalent volume of crude methane, and has been priced as between $3.75/m^3 (raw He) and $7.21/m^3 (Grade A He, refined to a purity of c. 99.997% or better).

Where is helium found?

The two stable isotopes of He differ by only one neutron. On Earth, 4He is the most common and demands the majority of industrial interest. ^{3}He, the much rarer isotope (^{3}He/^{4}He$_{air}$ = 1.4x10-6) has limited specialist applications, not least in neutron detectors in airports, and a candidate for power generation though nuclear fusion power. ^{3}He is often referred to as 'primordial helium' due to the bulk of it being trapped in the mantle during the Earth's formation, with few mechanisms to produce it via radioactive-linked processes.

^{3}He/^{4}He in the Earth's mantle is enriched in ^{3}He relative to air (^{3}He/^{4}Hemantle = 1.12x10-6), and these higher isotopic 'mantle' ratios can be readily measured in hydrothermal systems at mid ocean ridges and many volcanic gases. However it remains at concentrations far too low to be naturally sourced, with commercial quantities limited to the (small) by-product of nuclear power plants.

Conversely, the more abundant isotope, ^{4}He, is produced by alpha decay of U and Th in the crust (the alpha particles stabilise to become ^{4}He), which is why it is also called 'radiogenic helium'. In this sense it is perfectly 'renewable', albeit only on a geologic timescale. Different rock types produce varying amounts of ^{4}He, depending on original concentrations of U and Th and age of the rock - with some of the highest production found in Precambrian crystalline terranes such as the Canadian Shield. So although helium's escapology puts quicksilver to shame, it is constantly being created.

Helium is found in groundwater, natural gas fields, ancient brines, fluid inclusions in ore deposits, hydrothermal fluids, igneous intrusions and rocks, oil field brines, lakes, ice sheets, oceanic sediments and coal measures. However, only a handful of natural gas fields contain enough He for extraction to be commercially viable.

Producing He-rich fields can be divided according to their primary gas component into three main types:

1. N_2-rich: - Harley Dome, Pinta Dome (USA)
2. CO_2-rich: – LaBarge, Doe Canyon (USA)
3. CH4-rich: - North Dome-South Pars (Qatar/Iran), Hugoton-Panhandle (USA), Hassi R'Mel (Algeria)

The helium system

Perhaps the fact that all helium has been discovered by accident while searching for petroleum holds the solution to exploring for helium deliberately. Long ago oil and gas companies ceased trusting to chance and developed an exploration method whereby a basin or area is assessed by considering potential source rocks and regional reservoir/seal combinations. In short, we adapted well-established hydrocarbon exploration protocols to make helium the target, and so devised the following questions:

1. How and where are helium generated (source rock)?
2. How is helium liberated from the source rock (primary migration)?
3. How does helium move significant distances from the source rock (secondary migration)?
4. How do pools of helium rich gas accumulate in the crust (trapping mechanisms)?
5. How are helium accumulations destroyed by nature (trap breaching and/or dissipation)?

We have already mentioned the source of helium being rocks, especially granites, rich in thorium and uranium. We have mainly addressed primary migration, secondary migration and how helium accumulates. To do this we sampled existing helium producing areas in the US Mid-West and Canada. We attempted

***Top, middle:** Large volumes of He are wasted, but **(Bottom)** the Editor has finally hit upon his escape plan (see advertisement, p. 4)*

> PERHAPS THE FACT THAT ALL HELIUM HAS BEEN DISCOVERED BY ACCIDENT WHILE SEARCHING FOR PETROLEUM HOLDS THE SOLUTION TO EXPLORING FOR HELIUM DELIBERATELY

(unsuccessfully) to sample known He-rich gas wells in Italy and South Asia. Finally and most recently, by teaming up with exploration company Helium-One, we sampled He-rich seams in the Tanzanian section of the East African Rift. All samples were subject to rigorous gas composition analysis and of the isotopic composition of the separated He, other noble gases and nitrogen.

From a helium-source perspective, it is clear that older granites have had the time to produce more helium than younger ones. The first step in exploring for He is therefore to look for Archaean granitic/crystalline terrain. However, age is not the only determinant of a viable source; primary migration from that source needs to have occurred. High energy alpha particles carve 10-20 micron length 'fission tracks' in the uranium and thorium-bearing minerals, along which He atoms can migrate. While it is not yet clear how efficiently He escapes from the crystal lattice, it is probably quite efficient. Gas will then accumulate in fluid inclusions and fractures within the host rock.

For He to escape from the (low permeability) inclusions and fractures, however, requires energy – typically, heat. This could come from rifting, subduction, volcanic activity or similar processes; but small, dispersed amounts of He are still probably hard to mobilise. We don't understand this primary release process very well; but is likely to be enhanced by the presence of a second carrier fluid or gas phase. Simply put, large amounts of fluid trapped in tight rock are easier to mobilise than small amounts, and any major gas or fluid phase would carry any helium with it.

Carrier

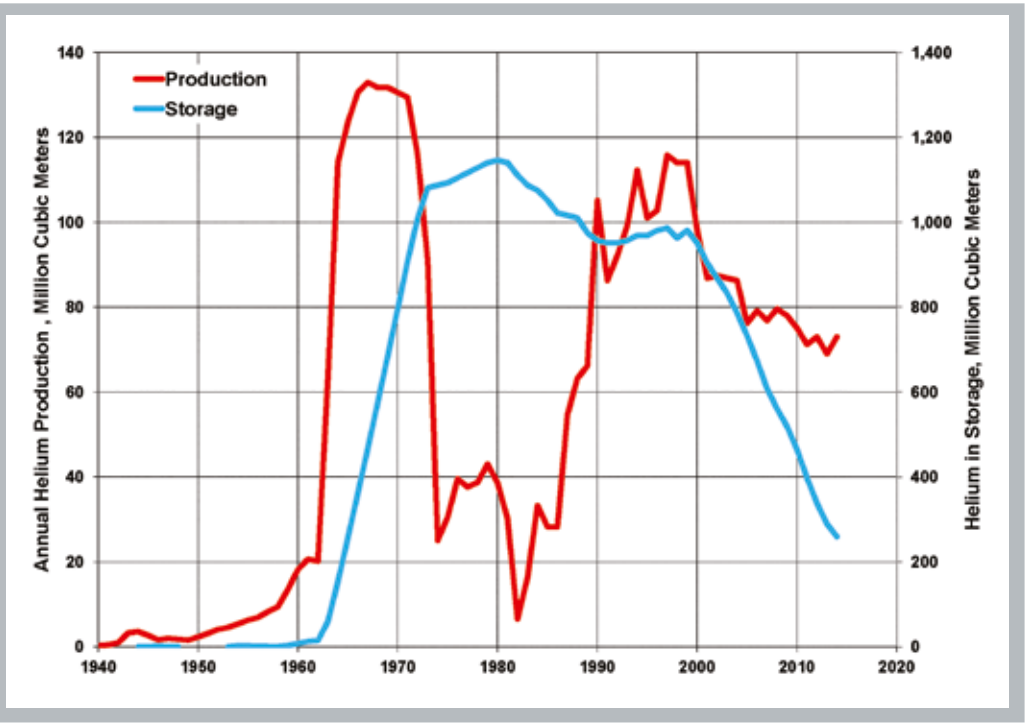
We think we know what the carrier phase is. High helium concentrations in natural gases are always associated with high concentrations of nitrogen ($N_2/{}_4He$ ratios are typically c. 10 to 50). Many natural gases that are nitrogen-rich contain little or no helium, though – which is simply explained by the fact that there are multiple sources of trapped nitrogen in sediments (e.g. petroleum source rocks and coal) from which N_2 can be released by increases in temperature and pressure.

Why radiogenic helium should be associated with non-radiogenic nitrogen is intriguing. It has been found that the isotopic composition of nitrogen associated with economic helium deposits is consistent with the range expected from low temperature metamorphism, and that crystalline rocks contain levels of nitrogen, often found as NH_4+ in clays, that would support observed $_4He/N_2$ ratios.

So, we think we have a basic idea of how helium and nitrogen are related, and how they escape from source rocks. What happens next?

Strong evidence from other noble gas isotopes (e.g. ^{20}Ne and ^{36}Ar, which only originate from air) that the admixture of helium and N_2 is dissolved in groundwater in overlying lithologies. This is a problem. We need enough nitrogen and helium dissolved in the water so that, when it ascends, the system depressurises enough to form a separate nitrogen-helium gas phase – before reaching any trap structures. This may indeed have occurred where pure N_2-He gas fields are found. However, it is also possible that the presence of significant concentrations of CO_2 or CH_4 in other helium-rich natural gas-trapping structures gives us an important clue to the nitrogen-helium migration story.

When groundwater that contains dissolved helium and N_2 is equilibrated with existing CO_2 or CH_4 gases, the insoluble helium and N_2 will exsolve from the groundwater into any pre-exsiting gas phase. In this case, a



Helium production and storage in the United States, 1940-2014 (data from USGS)

pre-existing gas phase composed of CO_2 or CH_4 is essential for 'stripping' groundwater containing accumulated but dissolved helium and N_2 into any existing trapping structure. This doesn't come without an added complication. Since CO_2 and CH_4 are some of the most prevalent gases in the subsurface, there is a risk is that where helium and N_2 accumulate, the helium can be diluted by large amounts of associated gases to non-commercial concentrations.

If we are relying on CH_4 and CO_2 to strip dissolved helium/nitrogen, we need to establish the 'goldilocks' zone, where the degree of dilution is 'just right'. For example: volcanic activity is a known source of high CO_2 gas fields. Therefore, in the right geological setting, the thermal aureole associated with magmatism may provide the heating needed to release helium from its source – but if the trap is too close to the volcanic centre, all you are likely to find is CO_2.

Once helium has migrated into a trap, the preservation of helium in that field depends on the rate at which helium is supplied to the deposit and the efficiency of the seal or trap to hold on to it.

What next?

Our database is growing but is still minute when compared with the accumulated knowledge for, say, petroleum exploration. We need to seek out and analyse more natural He occurrences to better understand migration and accumulation. We also still have to understand the systematics of helium accumulation destruction, and the temporal integrity of seals. More immediately (and certainly of more interest to many) will be our current work on mapping 'helium play fairways' around the globe. Where best might we explore for helium? Watch this space! ◆

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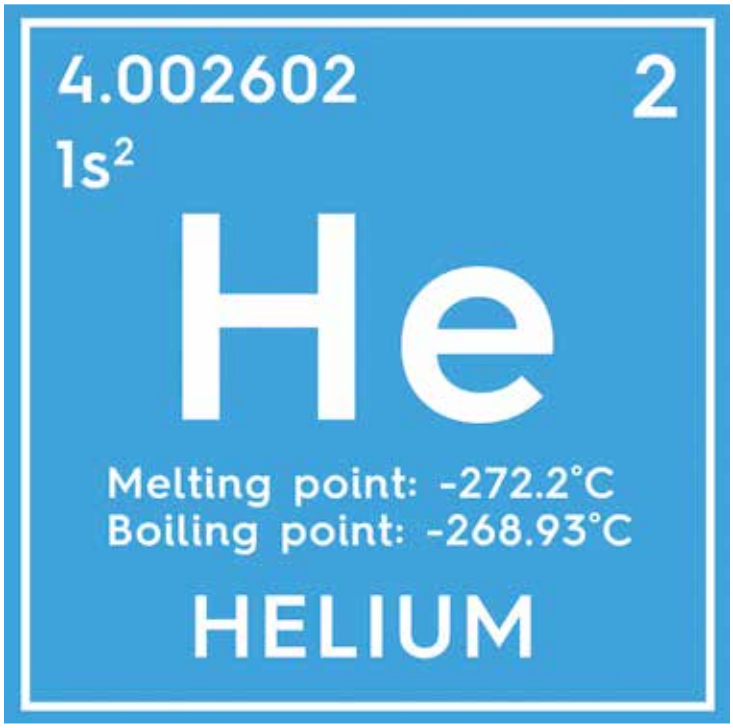


"WE NEED TO SEEK OUT AND ANALYSE MORE NATURAL HE OCCURRENCES TO BETTER UNDERSTAND MIGRATION AND ACCUMULATION"

THE GEOLOGICAL ANTHROPOCENE

BORN IN BURLINGTON HOUSE

Where are we with the 'Anthropocene'? **Jan Zalasiewicz***, Colin Waters, Mark Williams, Colin Summerhayes and Phil Gibbard explain….

Paul Crutzen, atmospheric chemist and Nobel Laureate, had a moment of irritation and inspiration at a scientific meeting in 2000 in Mexico. Even he probably had little idea how far his idea would travel.

A major player in Earth System science, deeply involved in the International Geosphere-Biosphere Program (IGBP), he had been listening with increasing discomfort to successive accounts describing the alarming rate and scale of global change in 'the Holocene'. No longer able to contain his feelings, he burst out: "Stop it! We're no longer in the Holocene but … (he paused) … the Anthropocene!".

Crutzen's neologism clearly crystallised an idea that had been developing (unconsciously, perhaps) among other researchers. When Crutzen returned home to Mainz, he found that the same word had been coined independently and used locally by US lake ecologist and diatom specialist Eugene Stoermer. Crutzen invited Stoermer to join him in proposing the term, in *IGBP Newsletter*, in an article invited, and edited, by Will Steffen (then IGBP Executive Director and key player in the subsequent development of the term among Earth System scientists). Two years later, Crutzen broadcast the term more widely in *Nature* (see Further Reading).

Livestock

The arguments used in both papers included massive change to some of the Earth's key geochemical cycles (especially of C, N and P), alteration of atmosphere and ocean chemistry, profound biosphere change including conversion of many natural habitats to farmland and a massive global increase in livestock, accompanied by accelerating extinctions, invasions, industrial-scale harvesting of sea-fish, damming of major rivers, etc.

All this meant the Earth System had been taken out of its 'normal' interglacial state, that the Holocene had ended - perhaps at around the time the Industrial Revolution started - and that a new epoch, the Anthropocene, had begun. The term quickly spread and began to be used in books and papers.

Cut, now, to Burlington House, 17 May 2006, and a meeting of the Geological Society of London's Stratigraphy Commission. One of us (JZ), as its (then) Chair, introduced a draft manuscript on the Anthropocene for consideration as a Commission publication. The term was just beginning to get enough visibility for stratigraphers to take notice, and its use in literature emerging from the IGBP was generally matter-of-fact - as if it were already an accepted term. However, it was still emphatically informal, having gone through none of the lengthy process of proposal, assessment and ratification by various bodies of the International Stratigraphic Commission, that formal chronostratigraphic terms (like Jurassic, Pleistocene, Toarcian etc.) needed to undergo. The Stratigraphy Commission is not an international body, so cannot 'adjudicate' – though it can pass comment. Perhaps somewhat to its own surprise, it agreed (by large majority) that the Anthropocene seemed 'geologically reasonable' and might be considered for formalization.

Planetary permanence

This Commission's cautiously-worded paper on the Anthropocene (authored by all but one of the 22 Commission members) was published in 2008 by the Geological Society of America. It attracted attention, because it made clear that the kind of global environmental changes listed by Crutzen and Stoermer could be permanently imprinted in the rock record and could become geology.

This potential planetary permanence of the consequences of human activities was seen as novel, coming even as a shock to many outside geology (and even to many geologists, who thought 'man' too puny to have lasting effects on the ▶

Above: ***The author with Paul Crutzen, taken at a working meeting on the Anthropocene at the Max Planck Institute for Chemistry, Mainz, March 2017***

> "THE TERM WAS JUST BEGINNING TO GET ENOUGH VISIBILITY FOR STRATIGRAPHERS TO TAKE NOTICE, AND ITS USE IN LITERATURE EMERGING FROM THE IGBP WAS GENERALLY MATTER-OF-FACT - AS IF IT WERE ALREADY AN ACCEPTED TERM"

Beach deposits at Kampot, Cambodia, with fish (A) and crab debris (B) discarded from a nearby market, along with diverse plastic waste (including bags C, bottles D, lids E, straws F, spoons G), cigarettes (H), pottery (I).... and dead rodent (J). Such diverse potential future fossil/ technofossil assemblages are typical Anthropocene indicators, and this deposit almost certainly includes future microfossils too, such as plastic microfibres and fly ash particles

▶ planet). As one result, the term began to be adopted and used in disciplines well beyond either geology or Earth Systems science (today garnering some two million Google hits, many in social sciences, humanities and arts).

As another result, there came an invitation from one of us (PG, then Chair of the Quaternary Stratigraphy Subcommission of the International Commission on Stratigraphy (ICS)), to set up a body (the Working Group on the 'Anthropocene', to which all five authors belong) to formally examine the evidence as to whether the Anthropocene might become part of the Geological Time Scale, and to make recommendations.

Since 2009 the group has been gathering evidence on what the Anthropocene might be, and whether it really could become a part of formal chronostratigraphy. The membership, currently 33, has an unusual composition in that classical stratigraphers make up only about half the group, the rest being Earth System scientists, ecologists, archaeologists, a soil scientist, oceanographers, historians – even an international lawyer. This is because the Anthropocene sits at the interface of geological and historical time, where modern Earth processes need 'translating' into appropriate forms of stratigraphy: landscape change into lithostratigraphy, chemical pollution into chemostratigraphy, biological change into biostratigraphy, and so on.

Solid

Despite this novel make-up, the consideration of 'human' phenomena and the very short time-spans, the Anthropocene still needs to be considered in terms of classical stratigraphy. So as well as being a potential epoch, a unit of time and process, it had to work as a physical unit of strata, a potential 'Anthropocene Series', just as the history of the Jurassic Period is inferred from the solid evidence of Jurassic System rocks.

So, are there sufficient strata to justify the Anthropocene? A case can be made for this. One feature of the Anthropocene is modern society's enormous expenditure of energy. It is estimated that humans have expended more energy (largely through fossil-fuel burning) since WWII than in the whole of the preceding Holocene. Part of this has gone towards powering the bulldozers and JCB diggers that have reshaped the landscape, at rates far more rapid than normal 'background' erosion and sedimentation.

A rough calculation of how much material is present in all these constructions and in waste by-products (including 'Artificial Ground') come to some 30 trillion tons – or some 50kg per square metre. Nor does this figure include 'classical' strata (lake and marine sediments, peat bogs, polar snow and ice etc.) which passively trap an array of stratigraphic proxy signals reflecting human impact, much of it novel (agricultural pollen, fly ash, microfossils, plastic). The Anthropocene does not lack for substance. But is it clearly distinct from the Holocene?

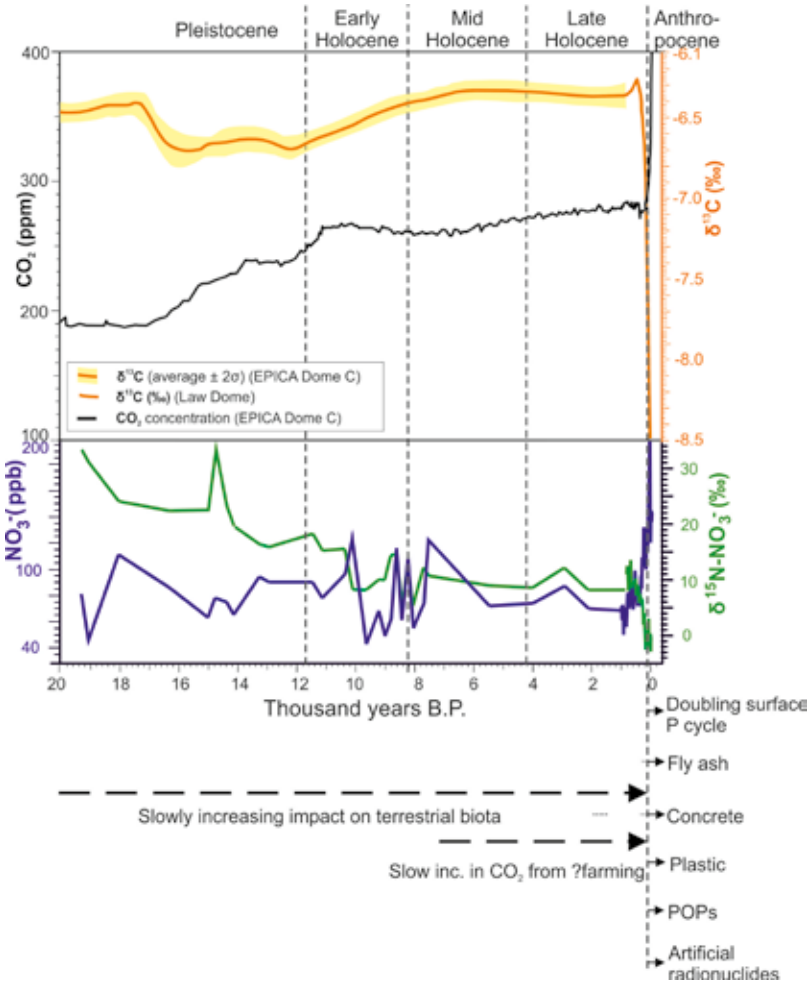
Anthropogenic influence has long been a feature of Earth history, from the rolling extinctions of large terrestrial mammals from the late Pleistocene, peaking some 10,000 years ago, and continuing subsequently. Farming, starting near the beginning of the Holocene, has dramatically altered landscapes worldwide, and artefacts are commonly found in Holocene strata.

The Holocene, while showing clear signs of human influence, was, until the late 18th Century, still displaying little overall change to fundamental cycles. Substantial human changes to ecosystems were largely land-based, with only incipient change in oceans. Negligible alteration of the global atmosphere or signal appears within ice-core record, other than a very slow and slight climb in atmospheric CO_2 levels from about 7000 years ago, perhaps due to early farming. Stratigraphically, almost all these human impacts were diachronous. Chronostratigraphical boundaries need to be globally synchronous.

Acceleration

Changes from the late 18th Century, though – particularly from the 'Great Acceleration' of the mid-20th Century - were completely different in scale and nature. Take the change to the carbon cycle. For most of the Holocene, atmospheric CO_2 levels stayed roughly constant, (260-280 ppm). Around the late 18th Century they began to rise, at first slowly, climbing steeply from the mid-20th to >400 ppm. This is >100 times faster than during the transition from Pleistocene to Holocene, which, stratigraphically, is captured by glacial ice strata and more generally through an equally striking change in carbon isotope ratios.

The change in the nitrogen cycle is yet more profound, and the mid-20th Century also marks the geologically almost instantaneous spread of plastics, concrete, industrial fly ash, many persistent organic pollutants, and a myriad invasive species around the world. This change to the Earth System is now at least partly irreversible (and so will influence the course of future stratigraphy) and has left a near-synchronous suite of fossilisable markers in recent strata – not least many rapidly evolving 'lineages' of 'technofossils' (pens,



Summary of some key Anthropocene signals (with the carbon isotope anomaly sharp enough to cut oneself on). Reproduced with kind permission, Current Anthropology (Chicago University Press)

Golden spike

The Working Group is now beginning a new proposal based, classically, on identification and selection of a Global boundary Stratotype Section and Point (GSSP) or 'golden spike'. The sharpest and most globally synchronous signal is probably the 'bomb spike' of artificial radionuclides released by atmospheric nuclear bomb tests. These spread quickly around the world, forming a distinctive marker in all sediments everywhere. The pros-and-cons of different environments – anoxic marine basins, lakes, corals, speleothems, peat bogs, glacial ice, trees and so on – have been assessed for their suitability for hosting an Anthropocene 'golden spike', prior to sifting through the many localities where the 'spike' might be placed.

We aim to prepare a formal proposal over the next few years. Geological Time Scale work notoriously takes place over a well-nigh geological timescale! Nevertheless, we hope there will be – in the not-too-distant future – a formal decision in sight for the Anthropocene saga, so powerfully shaped by its passage through Burlington House. ◆

Dedication

This article is dedicated to the memory of Alan Smith (1936-2017), long-standing member of the Stratigraphy Commission and co-author of the 2008 *GSA Today* paper, who throughout his life was a constant source of help and encouragement to us and to many others in the geological community.

bottles, cans, mobile phones etc.).

The Anthropocene has considerable geological reality. The evidence has been widely published and is now being gathered into one large book, for Cambridge University Press (2018). The interim recommendations of the Anthropocene Working Group (presented at the Cape Town IGC in 2016 and published in the journal *Anthropocene* in 2017) were that a proposal should be prepared for possible formalisation of the term 'Anthropocene' as part of the Geological Time Scale, as an epoch (and series), with a base/beginning somewhere in the mid-20th Century.

Formalisation is not guaranteed, and even if accepted, it may not emerge as an epoch/series; a subdivision of the Holocene (subseries or stage), might be preferred. The Geological Time Scale is designed to be stable, so that geologists may communicate across the world and between generations. Success means gaining a supermajority (>60%) of the relevant subcommission, and the entire ICS – as well as ratification by IUGS.

***Jan Zalasiewicz** is Professor of Palaeobiology at Leicester University
E: jaz1@leicester.ac.uk. He is also a member of Geoscientist's Editorial Board.

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The Calendar is even more abbreviated than usual in this issue.
Apologies for the date errors in the November issue.
– *Editor.*

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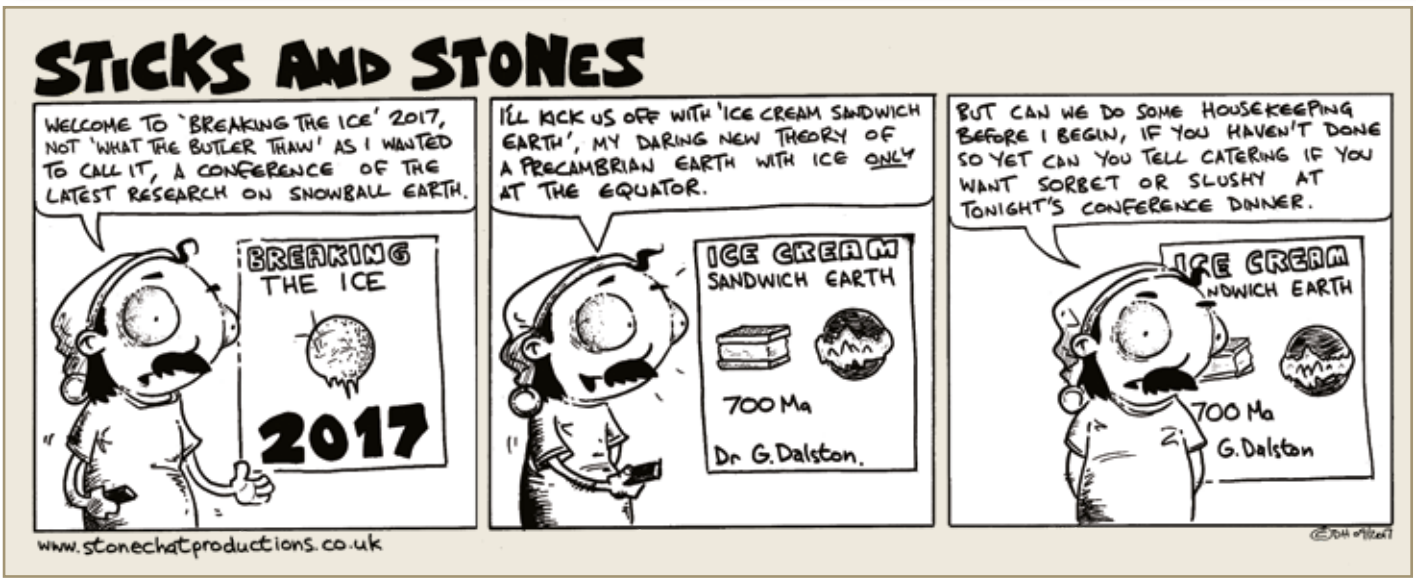
ENDORSED TRAINING/CPD

COURSE	DATE	VENUE AND DETAILS
Introduction to Micromine (Subsidised)	5-6 December	**Venue:** Micromine, 36 Whitefriars Street, London EC4Y 8BQ. **Fees:** £110 GBP. See website. **E:** mmuk@micromine.com
Resource Estimation in Micromine	7-8 December	**Venue:** Micromine, 36 Whitefriars Street, London EC4Y 8BQ. **Fees:** £500 GBP. See website. **E:** mmuk@micromine.com

DIARY OF MEETINGS 2017/2018

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

COURSE	DATE	VENUE AND DETAILS
Christmas Extravaganza! with Professor Iain Stewart	7 December	Venue: BGS, Keyworth. Time: 1800. Tickets required. **Contact E:** chris.smeathers@tarmac.com
SeismiCON 2017: 1st International Conference on Seismic ASRAnet Ltd	10-12 December	Venue: Jury's Inn, Wellesley Rd., London. **Cost:** £450. See website for details. **E:** seismicon@asranet.co.uk
Dangerous Neighbours GSL London Lecture	11 December	**Venue:** Burlington House. Two performances. For details, see p. ??
New UK Geotextile Standards Engineering Group, IGS	13 December	**Venue:** Burlington House. **Time:** 1730 for 1800. **Contact E:** Tom.Hall@mottmac.com
28th International Annual Conference Geological Remote Sensing Group Assessing Asbestos in Soil– What constitutes best practice? North West Regional	13-15 December	**Venue:** Lisbon, Portugal. See website for details. **Contact E:** treasurer@grsg.org.uk
JANUARY 2018		
Joint Conference 2018 Tectonic Studies & Metamorphic Studies groups.	14 December	**Venue: Williamson Lecture Theatre, Manchester University, Oxford Road, Manchester. Time: 1830. Contact Catherine Kenny E: geologicalsociety.northwest@gmail.com**
Industrial Geophysics Course for Environmental Geoscientists	3-5 January	**Venue: University of Plymouth. See website for details and registration. Contact E: TSG2018@plymouth.ac.uk**



Lithium

From Exploration to End-user

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Daniel Smith (The University of Leicester / MDSG)
Julian Aldridge (Wood plc / IOM3)
Jeremy Wrathall (Cornish Lithium)
Ali Dai (Chengdu Chemphys Chemical Industry)

Confirmed Speakers:

Jeremy Wrathall (Founder and CEO Cornish Lithium)
Ali Dai (Chengdu Chemphys Chemical Industry Co., Ltd)

Further information:

For further information about the conference please contact:

Georgina Worrall, Conference Office,
The Geological Society, Burlington House,
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Web: www.geolsoc.org.uk/lithium18

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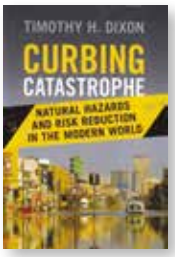
CHEMPHYS

Curbing Catastrophe



Natural hazards and risk reduction are such broad topics that any attempt to squeeze them into a single volume should backfire. Yet, written in an easy-to-read narrative style, each story in this book is presented in a compelling way that makes for a genuinely enjoyable and thought-provoking read.

It would certainly be impossible to cover the full topic in any depth. The author is a Professor in the School of Geosciences and Director of the Natural Hazards Network at the University of South Florida. He uses satellite geodesy and remote sensing data to study earthquakes and volcano deformation, coastal subsidence, groundwater extraction and glacier motion.

With this background one would expect the focus to be on the technical and scientific aspects of the hazards. However, this book actually covers these topics lightly. The level of detail is generally below that of undergraduate studies, and is really just to get non-technical readers up to speed ready for the main topics in the book: The importance of communication, the importance of understanding long-term processes, and the economic consequences of failure.

The book is based around case studies from the author's personal experience including the New Orleans flooding, the Haiti earthquake, the Fukushima nuclear accident, and climate change. Each case study is simply a medium for demonstrating failures in the main topics of the book and so are covered at various levels of detail, occasionally delving deep into areas of particular interest.

Recommendations are made throughout the book for scientists, engineers and politicians ranging from scientific communication to tax policy. Professor Dixon gives fantastic examples from his own scientific papers, showing how the cautious use of language in science communication blunts the message to the point where it becomes easy to ignore, and gives numerous examples of societal own-goals where poor planning is subsidised by taxpayers and a false sense of security is given to the people living in at-risk zones.

If you want to learn about the science of natural hazards, there are better sources. If you want to learn about communication of science and risk, or setting policy to reduce risk, this book is invaluable. You will take an entertaining and informative ramble through topics ranging from risk theory, the amount of caesium in wine, how vested interests bias the public discourse, the impact of building codes on fire safety, and the importance of companies confessing their errors openly and rapidly. This book will open your eyes.

Reviewed by: ***Ross Roberts***

CURBING CATASTROPHE: NATURAL HAZARDS AND RISK REDUCTION IN THE MODERN WORLD
by TIMOTHY H DIXON, 2017. Published by Cambridge University Press 33pp ISBN: 978-1-107-03518-8
List Price: £21.99 W: http://bit.ly/2Ar7Fy1

Quaternary Glaciation in the Mediterranean Mountains

This special publication by the Geological Society of London presents 14 original research papers in the field of Quaternary Glaciation in the Mediterranean Mountains. The key objective was to bring together the latest work from leading specialists and to set out the wider significance of their findings. It certainly streamlines the past and present research knowledge and research techniques of this field, and also assesses the prospects for new studies, and outstanding research problems in Quaternary glaciation in the Mediterranean mountains.

It is a fascinating read, covering such rich and significant archive of the majestic mountain landscape that surrounds the Mediterranean Sea. The collection of 14 papers has something for everyone and provides an excellent starting point for anyone interested in Quaternary Glaciation.

It covers well the background and history of this field of research - not only the science but the human element too, the people involved and their backgrounds, making for a vivid and engaging read. It is well ordered, with a logical structure moving clockwise from North Africa around the Mediterranean, enriched with high quality maps, diagrams, data-tables and schematic diagrams. Each paper complements the others and provides readers with the opportunity to recognise the different methods that are used in studying past glacial environments. It shows the importance of working together to develop our understanding of the world around us. Interestingly it has highlighted how the timings of glaciation in the Mediterranean mountains influenced patterns of Palaeolithic settlement.

Of particular interest to me (and the focus of the author of the foreword, Bruno Messerli's dissertation, 50 years previously) was the Sierra Nevada of Andalucia. With my mother recently moving to Spain, I was relishing the prospect of this book taking me on a journey through the glaciers of Spain, and I certainly wasn't disappointed. The writing is aimed at graduate level, but assumes little technical knowledge. Techniques used are well explained and the methodologies of dating and state of current research clearly graded. For each of the geographical regions the earliest known publication, the dating methods applied and the current state of research are summarised, allowing the reader to gain an overview - as well as to easily locate a specific research method, or region.

It is a timely publication, with the status of glaciers rapidly changing year-on-year, and acts as a great stimulus for future questions about the majestic mountain landscape of the Mediterranean margin.

Reviewed by ***Fiona Connor***

QUATERNARY GLACIATION IN THE MEDITERRANEAN MOUNTAINS
by P D HUGHES & J C WOODWARD (eds), 2017. Published by: Geological Society of London, Special Publications, 433. ISBN 978-1-86239-747-7
List price: £100.00. Fellows' Price: £50.00
W: www.geolsoc.org.uk/sp433

Archaeological and Forensic Applications of Microfossils

This Geological Society Publication for The Micropalaeontological Society presents 15 papers documenting the contribution of microfossils to archaeological and forensic study in relation to theory, method and interpretation. At 296 pages this volume is an engaging read with a wide range of topics and applications described

by many leading experts. The volume is divided into three sections covering palaeoenvironmental applications in archaeology, provenancing analyses applied to archaeology, and forensic applications.

The papers hang together well and generally follow a chronological theme. They have been written in an accessible style that will be helpful for the many archaeologists with non-specialist knowledge of environmental science. The breadth of papers will appeal to a wide readership, as will the importance of some of the discussion topics.

Although all the papers are strong, particular standouts for me were the use of foraminifera and ostracods for palaeoenvironmental and palaeoclimate reconstruction of the Lower Palaeolithic site at Boxgrove in MIS13 - c. 0.5 million years ago (Whittaker and Parfitt), the evidence presented for dry islands or islets in 'Doggerland' 80km off the British coast at the beginning of the Neolithic period (Geary *et al.*) - much later than any previous palaeocoastline models based on sea level index points - and the discussion of pollen and non-pollen palnynomorph evidence for early farming activity in Late Mesolithic pollen records (Innes and Blackford).

The range and number of authors underscores the importance of collaborative working and the interdisciplinary research that has allowed the study of microfossils to add so much to archaeology and forensics. Whether used for investigating the evolution of past landscapes, past activities and impacts of humans within and on the landscape, unravelling the interplay of humans, landscape, vegetation and climate, or in the conviction and prosecution of criminals, this important and up-to-date volume will form a regular work of reference for student and specialist alike.

The papers are predominantly UK-focused, although there are excursions into the countries of the Mediterranean fringe, including Italy, Macedonia and Israel. However, the findings discussed in many papers will be of interest to much more than a UK-only readership, given that the Palaeolithic, Mesolithic and Neolithic transition papers discuss important data of north-west European relevance, and the methodological issues tackled by most of the papers have a more universal application.

This eclectic collection of papers in a compact volume do an admirable job of highlighting the important, although sometimes overlooked, contribution microfossil studies make to many of our fundamental questions about the past, the evolution of landscapes and the solving of felonies, including war crimes. This volume will be placed on one of my more easily-accessed bookshelves.

Reviewed by: ***Clive Waddington***

THE APPROACHES AND FORENSIC APPLICATIONS OF MICROFOSSILS. A DEEPER UNDERSTANDING OF HUMAN HISTORY
Edited by: M WILLIAMS, T HILL, I BOOMER AND I WILKINSON 2017 Published for The Micropalaeontological Society by The Geological Society. ISBN: 978-1-78620-305-2
List Price: £100 Fellows price: £60.00
W: www.geolsoc.org.uk/TMS007

Volcanic Geology of São Miguel Island

The large-format memoir volume is made up of 22 separate stand-alone papers in which São Miguel's location and evolution, as well as the Azorean Archipelago as a whole, are explained with respect to the triple junction between the North American, Eurasian and Nubai plates, the Mid Oceanic Ridge and the Terceira Rift Zone.

Volcanism is still active on São Miguel. A brief description of the types of volcanoes, and the eruption types are presented. Volcanic and landslide hazards with respect to the geomorphology and geology of São Miguel are described, as are some eruptions and their consequences. A number of damaging landslides have occurred since colonization of the Azores began in the 15th Century. A series of maps depicts landslide hazard potential on the island, with a discussion on landslide-monitoring activities. Several historical accounts of damage caused by landslides to houses, villages and farms are also given.

The history of damaging earthquakes on or near São Miguel is discussed in depth. Modelling of seismic hazard, vulnerability and risk is discussed in relative detail, using modern seismic hazard and risk-assessment methods. One of the main reasons why the island displays high seismic risk with only a moderate level of seismic hazard, is that much of the older building stock was built from stone rubble, without the benefit of modern building codes.

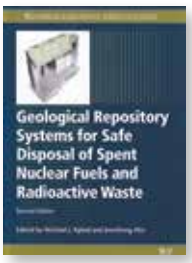
A discussion on degassing of carbon dioxide and radon from soil takes the reader from the subsurface and into several building types. Some information on the effects of environmental conditions and the concentration of CO_2 or radon in buildings is included. Mitigation of volcanic gases by the use of barriers and passive venting are the only gas-reduction techniques discussed.

Overall, I found this book to be an excellent general resource for the geology, seismicity, seismic hazards, volcanic hazards and related effects for São Miguel, as well as a basic resource for the geology of the eastern portion of the Azorean Archipelago.

Reviewed by: ***Robert Anderson***

VOLCANIC GEOLOGY OF SÃO MIGUEL ISLAND (AZORES ARCHIPELAGO) by J L GASPAR, J E GUEST, A M DUNCAN, F J A S BARRIGA AND D K CHESTER (eds) 2015. Published by: The Geological Society, ISBN: 978-1-86239-731-6
List Price: £95.00 Fellows Price: £47.50
W: https://www.geolsoc.org.uk/M0044

Geological Repository Systems



From the mid-20th Century, civil nuclear power generation, military R&D and nuclear weapons production, together with the widespread use of radioactive materials in medicine, academia and industry, have all have generated significant radioactive wastes of various forms, quantities and levels of radioactivity. Geological disposal has been selected, developed and implemented over the past 50 years by many nuclear 'active' nations, as the safest and most effective final disposal method for the management of these waste materials.

The volume presents 26

chapters arranged in five thematic sets. Chapters in Part One introduce the topic and context of geological disposal, providing an overview of near-surface, intermediate depth and deep borehole disposal (covering low, medium and high-level wastes).

Part Two describes the different types of repository systems (crystalline, clay and salt-hosted) and methods of repository site surveying and construction. Chapters in Part Three focus on the repository engineered barrier systems, covering nuclear waste canisters through to buffer and backfill materials. Finally, chapters in Parts Four and Five address aspects of repository safety, security and social 'acceptability', concentrating on repository performance assessment, radiation protection, environmental monitoring and social engagement. Each chapter contains its own individual reference section.

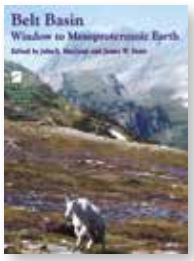
This is the second edition of this established reference work, and has been comprehensively revised, updated and expanded (the editors claim that some 25% of new material has been included on contemporary topics of importance). The volume critically reviews the current technologies and scientific methodologies relating to the long-term, safe geological disposal and management of nuclear wastes. In addition to scientific and technical aspects, the political, regulatory and societal issues involved are also discussed, using key examples to illustrate both international and national perspectives on issues raised.

The primary readership is anticipated to be practising geoscience professionals within both UK and international radioactive waste management industries. However, this volume also provides a rigorous and comprehensive public information source for the general scientific or environmentally concerned reader, and governmental or regulatory official requiring a thorough contemporary understanding of the scientific developments informing their decision-making. A recommended read and valuable reference work.

Reviewed by: ***Mark Griffin***

GEOLOGICAL REPOSITORY SYSTEMS FOR SAFE DISPOSAL OF SPENT NUCLEAR FUELS AND RADIOACTIVE WASTE (SECOND EDITION)
by MICHAEL J APTED & JOONHONG ANG (editors). Woodhead Publishing Series in Energy. 2017. Elsevier. ISBN 978-0-08-100642-9. Hbk. 802pp.
List Price: £290.00
W: www.elsevier.com/books-and-journals

Belt Basin: Window to Mesoproterozoic Earth



This book provides a detailed review of aspects of the Belt Basin, which covers around 200,000km^2 of Montana, Idaho and adjacent Canada. The basin fill is around 20km of mainly clastic sediments deposited between 1500 and 1370 Ma in an intracontinental rift basin that subsequently underwent numerous episodes of tensional, compressional and strike-slip tectonism and igneous activity until as recently as the Miocene. Despite metamorphism to greenschist grade, sedimentary structures are well preserved.

The first four papers examine aspects of stratigraphy and sedimentology, including whether the sediments were lacustrine or marine - not easy in successions where fossils are rare at best. Likely environments in parts of the basin were playa lakes and flash floods across land surfaces devoid of vegetation; but elsewhere, tidal to marine shelf environments are inferred.

The next four papers deal with the Lemhi sub-basin, whose 15km-thick succession is lithologically monotonous, completely lacking in fossils and repeatedly faulted, making correlation within it especially difficult. The last chapter considers the origin of strata-bound hydrothermal Co and Cu ores.

Three papers follow, covering aspects of geochemistry and geochronology. Chapter Nine examines the iron mineralogy in the lower part of the column, concluding that the water column was shallow and fully oxygenated but that sediments underwent diagenesis almost immediately in a sub- to anoxic sulphide-rich environment. The chapter goes on to consider the implications of this for early life forms. Chapter 10 discusses a major geochemical survey of Proterozoic mafic igneous rocks in the basin. Previously, only two LIPs were identified; new work recognises 17 different geochemical signatures.

The final three chapters cover geophysics and structural geology. They include a discussion of a deep, low resistivity layer identified on MT, which is nowhere exposed at surface but is believed to contain numerous repeated sulphide-rich layers emplaced during basaltic underplating of the attenuated continental crust during the basin's early history. Other chapters consider the development of early rift-defining growth faults, their later compressional reactivation, and the formation of large-scale gravity sliding of the thick carapace above a deep-seated intrusive magma wedge that migrated upwards and eastwards over a long period.

The book is well written and adequately illustrated, with many colour figures, but no index. Other recent books on the same general theme conclude that Early Proterozoic Earth closely resembled the Earth we know now. This volume reaches the same general conclusion but finds differences, and highlights them accordingly. I recommend it to those doing research in this fascinating period of geological history.

Reviewed by: ***Pete Webb***

BELT BASIN: WINDOW TO MESOPROTEROZOIC EARTH
by JOHN S MACLEAN AND JAMES W SEARS (eds) Published by: The Geological Society of America (SP 522). Publication date: 2016 ISBN: 978-0-8137-2522-2 (hbk) 384pp.
List price: £57.50; GS Fellows £40
W: www.geolsoc.org.uk/USPE522

BOOKS FOR REVIEW

Please contact **ted.nield@geolsoc.org.uk** if you would like to supply a review. You will be invited to keep the review copy. See a full up-to-date list at **www.geolsoc.org.uk/reviews**

- **NEW! Photo Atlas of Mineral Pseudomorphism** by J T Kloprogge & R Lavinsky Elsevier 2017281pp hbk
- **NEW! Geomechanics & Geology** by Turner JP et al (eds) 2017 Geological Society Special Publication 458 298pp, hbk
- **NEW! Archaeological Soil & Sediment Micromorphology** by Cristiano Nicosia & Georges Stoops (eds) 2017 Wiley Blackwell 476pp hbk
- **Monogenetic Volcanism** by Nemeth K et al. (eds), 2017 Geol. Soc. pub. Hse., SP #446 382pp hbk
- **Subterranean Norwich – the grain of the city**, by Matthew Williams. Lasse Press 160pp sbk
- **Geochemistry and Geophysics of Active Volcanic Lakes** by Ohba et al. GSL Publishing SP#437 295pp, hbk
- **Salt Tectonics - principles & practice** by Jackson PA and Huden MR. Cambridge University Press 2017 498pp, hbk
- **Chesapeake perspectives - decoding the deep sediments: Ecological History of Chesapeake Bay** by Grace Brush. 2017 Maryland Sea Grant 63pp sbk
- **Tectonics of the Deccan Large Igneous Province** by Mukherjee et al. (Eds), 2017. Geol Soc Spec Pub #445 363pp, hbk
- **Land Surface remote Sensing**, by Baghdadi N and Zribi M (eds). Elsevier 2017 342pp hbk

READERS' LETTERS

Geoscientist welcomes readers' letters. These are published as promptly as possible in Geoscientist Online and a selection printed each month. Please submit your letter (300 words or fewer, by email only please) to **ted.nield@geolsoc.org.uk**. Letters will be edited. For references cited in these letters, please see the full versions at **www.geolsoc.org.uk/letters**

Hot air, Rare Earths and markets

Sir, I was disappointed to see Chris Mackenzie perpetuating the 'wind turbines need rare earth magnets' myth (*Soapbox, Geoscientist 27.08 September 2017*).

Many people think rare earth materials are a necessary component of wind turbines, but the figures prove otherwise: only about two percent of the U.S. wind turbine fleet uses them. (W:www.aweablog.org/rare-earths-wind-turbines-problem-doesnt-exist/)

Rare earth elements like neodymium and dysprosium are used in a wide variety of products from iPhones and computers to flat screen TVs and certain types of batteries.

RICHARD BARNES

IN MEMORIAM WWW.GEOLSOC.ORG.UK/OBITUARIES

THE SOCIETY NOTES WITH SADNESS THE PASSING OF:

Booth, Tony *
Bridges, Paul *
Brooks, Michael
Chillingworth, Patrick Cecil
Hamilton *
Coombs, Douglas *
Drysdall, Alan Roy *
Elueze, Anthony Azbuike *
Fischer, Alfred*
Gardener, Roger *
Hallam, Anthony
Helm, Derick *
Howell, Frank Travis *
Kelly, Desmond Michael *
Laws, Michael James *
Leighton, James *
Marshall, Mr John A *
Matthews, Peter Elvor *
O'Reilly, Kevin J O *
Palmer, Stephen J *
Parr, Robert
Pipes, Kenneth P *
Rawcliffe, Eric *
Robson, David *
Shingleton, Sam *
Welland, Michael John Patterson
Whitlow, Roy *
Workman, David Richard
Young, Paul Ivor *

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 ted.nield@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**.

Photo competition

Three Sisters of Glencoe in Autumn: Milena Farajewicz

Clifftop bowling overlooking Loch Maree: Emma Smith

Limestone weathering, Gower: Kevin Privet

Sarah Day writes: Many thanks to everyone who entered the Earth Science Week photo competition!

We whittled down over 130 entries to a final winning 12, all of which feature in our 2018 calendar – on sale now at Burlington House or via our website.

The winners were:

- **1st:** Three Sisters of Glencoe in Autumn: Milena Farajewicz
- **2nd:** Clifftop bowling overlooking Loch Maree: Emma Smith
- **3rd:** Limestone weathering, Gower: Kevin Privet
- Midges and Rain, Glencoe: Mark Ainsley
- Sand Blown, Bridport West Bay: Giordano Battistel
- 'The Amphitheatre' near Giant's Causeway: Nigel Bell
- Mam Tor: Wayne Brittle
- Laminated sandstones on Gullane beach: Milena Farajewicz
- Lulworth Crumple: Mark Godden
- Assynt: Timothy Gregory
- Connemara National Park, County Galway: Ankit Verma
- Subterranean, White Scar Caves: Gina Williams

Earth Science Week took place on October 7-15, encompassing a huge range of events organised across the UK and Ireland. The week's theme this year ('Our Restless Earth'), helped to celebrate the 50th birthday of plate tectonic theory (see also P.7). All the winning pictures were featured by the Guardian and the *Daily Mail* online.

➤ Find out more at www.geolsoc.org.uk/earthscienceweek

70 years of service

The Geological Survey of Northern Ireland (GSNI) is celebrating 70 years of public service in 2017, writes Adler deWind.

A series of events has been held to celebrate GSNI's achievements and raise awareness of what the future holds for geoscience in Northern Ireland.

The Geoconservation Gathering was held, in conjunction with the Society's Geoconservation Committee, on 20 October at the Ulster Museum (Belfast). Tourism is one of Northern Ireland's strongest economic drivers, much of it associated with geological heritage. GSNI has played a key role in establishing and assisting many of Northern Ireland's natural attractions, including Giant's Causeway and Causeway Coast World Heritage Site, and the Marble Arch Caves UNESCO Global Geopark. The Gathering focused on how geoconservation and sustainable tourism can and should work, with examples from across the island of Ireland.

The launch of Northern Ireland's Geodiversity Charter had taken place just before. Written by Drs Kirstin Lemon and Sam Roberson of GSNI, the Charter follows the example of Scotland and England by setting out a clear ambition to recognise geodiversity as a vital and integral part of Northern Ireland's economy, environment, heritage and sustainable development. Over 20 organisations support the Charter, including the Geological Society. It is hoped that their collective voice will help maintain and enhance our geodiversity and lead to raised awareness, policy integration, enhanced conservation, and continued research.

Lemon, Team Leader of Information and Infrastructure at GSNI, told Geoscientist: "Understanding and managing Northern Ireland's geodiversity has never been so important. With increasing pressures on our resources and environment, we need to provide guidance on how to safeguard and manage this for current and future generations - and that's exactly what Northern Ireland's Geodiversity Charter aims to do."

Almost 50 people attended the Charter launch and the subsequent Gathering, including members of the public, representatives of academia and research, local government and public agencies, landowners, NGOs, and education.

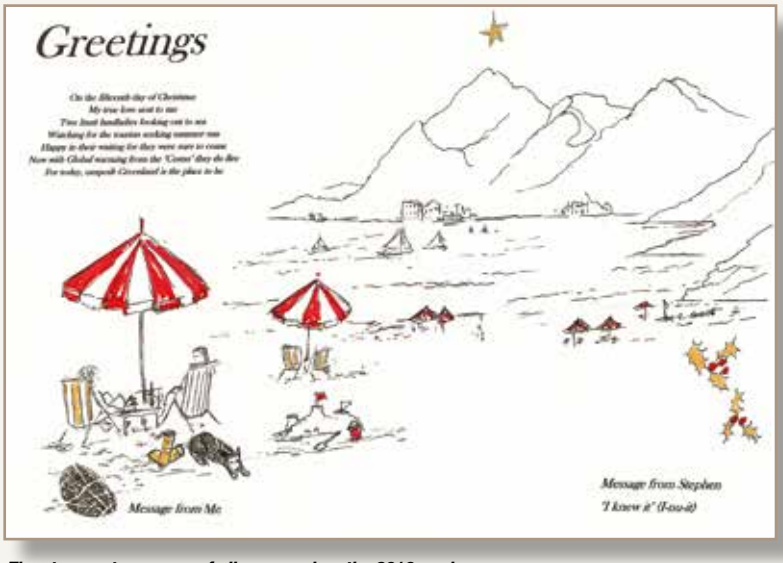
Geoscientists in the news and on the move in the UK, Europe and worldwide

DISTANT THUNDER — *Climate change comes to Bagley Wood*

Geologist and science writer Nina Morgan considers some new evidence for global warming

The village of Kennington south of Oxford has a reputation as a geological hotspot. From its epicentre in Bagley Wood Road, the village has provided the Department of Earth Sciences (formerly the Department of Geology and Mineralogy) at Oxford University with some of its top geological talent.

The list of luminaries includes the intrepid field geologist, J V Harrison [1892 - 1972]; geologist and petrographer Keith Cox [1933 – 1998], known for his work on flood basalts and kimberlites; geochronologist Stephen Moorbath [1929 – 2016], famous for his work in Greenland and the identification of the oldest rocks on Earth; and structural geologist and plate tectonics pioneer, John Dewey, born 1937 and still very much alive.



The strongest message of all appeared on the 2016 card, sent out after Moorbath's death in October 2016

Quality Street

Bagley Wood Road has also gained a reputation for the quality of its Christmas cards. J V Harrison, may have started the ball rolling. In the 1930s, before he arrived in Oxford, Harrison, known for his passion for undertaking field work 'under the most arduous conditions that could be arranged' began by producing Christmas cards illustrated by his photographs taken in the wilds of Persia. After he arrived in Oxford, these cards were replaced with gifts of Christmas trees cut from his property in Bagley Wood (see *Distant Thunder, Geoscientist 22.11*, December 2012).

Then in the late 1970s a new type of handmade Christmas card emerged from Bagley Wood Road. These unique and charming cards – each incorporating her fingerprint – were designed and produced by Stephen Moorbath's wife, Pauline, an artist with a qualification in industrial design who was then working for Pressed Steel as an exhibition designer and later for the Oxford Education Authority producing supplementary material for schools. A new design emerged yearly. For many years the creation of the cards was entirely down to Pauline, with Stephen adding handwritten notes to his friends and colleagues.

Evidence grows

However, once Pauline reached the end of a delightful 12-year series (representing the twelve days of Christmas) Stephen began to exert some influence on the design, and clear evidence of the effects of global warming began to emanate from Bagley Wood.

The card for the 'thirteenth day of Christmas' sent out in 2014, was illustrated by a giraffe, grazing on holly in Bagley Wood. The 'fourteenth day of Christmas' issued in 2015, hit home by featuring eight redundant reindeer. And the strongest message of all appeared on the 2016 card, sent out after Stephen's death in October. This card highlighted the effects of global warming in Greenland, one of his favourite places. Although this card features Pauline's signature fingerprint and charming art work, the subject matter and punning references in the text have Stephen's fingerprints all over it.

A very happy holiday season to all!

Acknowledgement
I thank Pauline Moorbath for telling me about the origin of the cards and Stephen's involvement, and for permission to reproduce one here; Philip Powell for drawing my attention to the cards; and Philip Powell and the late David Vincent for sharing their personal recollections of J V Harrison. Harrison's Christmas cards can be found in the Special Collections section of the BGS GeoScenic website W: http://geoscenic.bgs.ac.uk/asset-bank/action/viewHome.

* **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**

CAROUSEL

All Fellows of the Society are entitled to entries in this column. Please email ted.nield@geolsoc.org.uk, quoting your Fellowsip number.

◆ Jeremy Ingham

Jeremy Ingham has been appointed Director of Forensic Services at Capita Real Estate and Infrastructure. Based in their City of London office, he will be continuing his work as an expert witness specialising in construction materials technology.
W: http://bit.ly/2jtn1i4

OBITUARY Norman Edward Butcher 1928-2017

Geologist who studied Skaergaard under Lawrence Wager but who later became a leading student of the life and times of James Hutton

'A pseudo-Scot of Cornish ancestry, brought up in Kent, but with strong Yorkshire affiliations' is how Norman once described himself. Born in Chichester, he grew up in Folkestone and later Maidstone, where he attended the Grammar School. There, under Spitfire skies, he received a secure grounding in science. National Service saw him in Germany as a sergeant with the Royal Army Educational Corps, and, demobbed, he entered Sheffield University in 1948 to read chemistry.

A subsidiary subject was demanded of him and he chose geology. It was a life-shaping decision. The stratigraphic column supplanted the periodic table, and at the close of his first year he transferred into the honours course in geology. He was President of the University Geological Society (1951-52) and in 1952 was awarded a first class BSc in Geology.

Research

For two years he remained in Sheffield to investigate the western side of the Dartmoor Granite, and then in 1954 migrated to Queen's College, Oxford, as Hastings Senior Scholar. Under Professor Lawrence Wager, he studied clinopyroxenes of the upper part of the Skaergaard Intrusion in East Greenland - a region he actually visited in 2001 when he travelled with a Russian expedition. He developed a deep affection for Queen's College and in 1955

> "HIS RESPONSIBILITIES EXTENDED THROUGHOUT SCOTLAND AND BROUGHT HIM INTO CONTACT WITH HUNDREDS OF ENTHUSIASTIC STUDENTS OF HIS SCIENCE"

the College Chaplain (David Jenkins) officiated when Norman married Margaret Nutter who had been the first woman honours student of geology in Sheffield. Margaret and their three sons survive Norman.

Academia

In 1965 he joined the staff of the Department of Geology in the University of Reading. There he remained until 1969, but they were years of increasing friction. In 1970 he was happy to transfer his family to Edinburgh upon his appointment as Staff Tutor in Earth Sciences within the Open University. His responsibilities extended throughout Scotland and brought him into contact with hundreds of enthusiastic students of his science. It was work which Norman relished and he remained with the OU until his retirement in 1992. During 1983-85 he was President of the Edinburgh Geological Society.

Geological Society

Norman was elected FGS in 1951 and only rarely did a visit to London fail to bring him to Burlington House. During his Reading years he interested himself in the possibility of establishing a professional body to serve the needs of British geology and he convened a meeting to explore the matter. It took place in the Society's Council Room on 6 January 1964, but proved premature. Later, after the foundation of the Institute of Geologists in 1977, Norman greatly valued his post-nominal CGeol, and he also liked to advertise his Membership of the Royal Institution by means of an MRI.

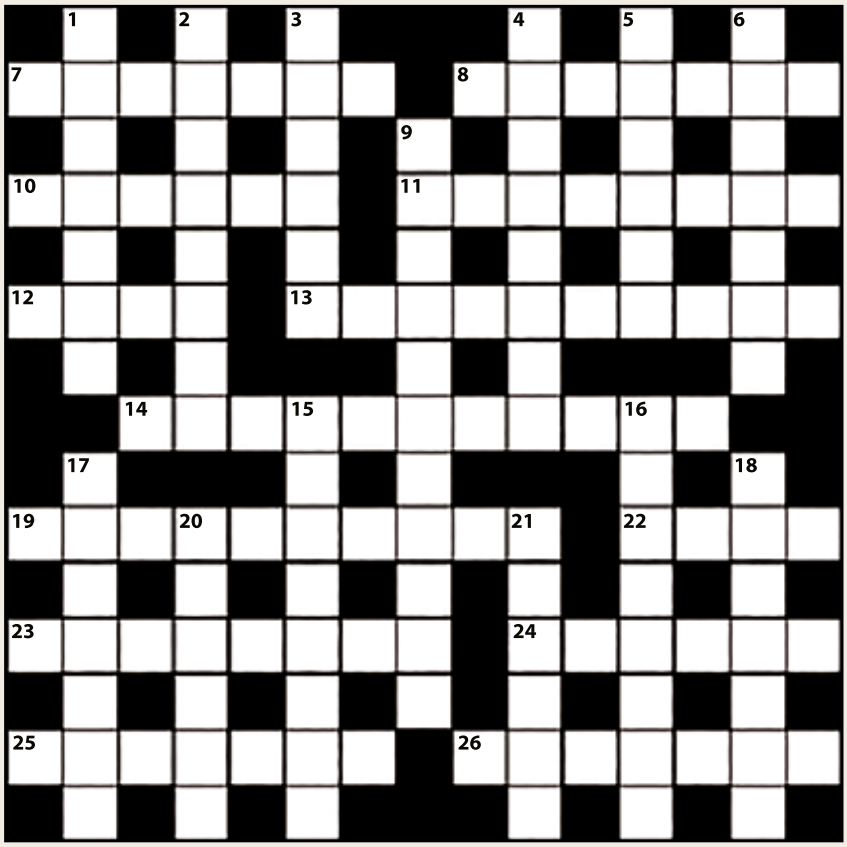
History of Geology

Norman was fascinated by the history of geology. In 1967 he organised, in Reading University Library, an exhibition illustrating the evolution of geological cartography, and after moving to Edinburgh he became a leading student of the life and times of James Hutton. It was his initiative which gave to Edinburgh the Hutton Memorial Garden, inaugurated in August 1997 upon the site of Hutton's former residence in St John's Hill.

By Gordon Herries Davies

HELP YOUR OBITUARIST 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 and accurate commemoration. Please send your CV and a photograph to Ted Nield at the Society.

CROSSWORD NO.221 SET BY PLATYPUS



ACROSS

7 To bond to metal ions via a polydentate ligand around a single atom (think crab claws) (7)
8 Features of the 'Temple' featured on Lyell's famous frontispiece (7)
10 Sodium carbonate decahydrate (hydrated soda ash) (6)
11 The other side of the fault from the one that dropped (8)
12 School whose playing fields make one frightfully brave (4)
13 An electrical insulator that can be polarized by an applied electric field. (10)
14 Summer version of 'hibernation' (11)
19 Upfolds (10)
22 Closed social group united by beliefs, personality, object or goal. (4)
23 Hard cheese (8)
24 Not on the coast (6)
25 Closely resembling (7)
26 High table land (7)

DOWN

1 Tuscan wine, 'nice' with human liver, apparently (7)
2 Capital of the region (1 down) (8)
3 Petrified by intoxication? (6)
4 Flies in the apothecary's send forth a stinking savour. (8)
5 Small flower (6)
6 Immature form of Girl Guide (7)
9 Coming on above, overlying, like strata (11)
15 Object believed to contain magical properties (8)
16 Rock consisting of algal balls (8)
17 East central Canadian province named for a Great Lake (7)
18 Undersurface of hind foot (7)
20 Written in metrical feet consisting of an unstressed and a stressed syllable, in that order (6)
21 17d lies in the middle of the Canadian one, for example. (6)

WIN A SPECIAL PUBLICATION!

The winner of the October Crossword puzzle prize draw was **Annika Schmitz of London.**

All correct solutions will be placed in the draw, and the winner's name printed in the March 2018 issue. The Editor's decision is final and no correspondence will be entered into.
Closing date - January 19.

The competition is open to all Fellows, Candidate Fellows and Friends of the Geological Society who are not current Society employees, officers or trustees. This exclusion does not apply to officers of joint associations, specialist or regional groups.

Please return your completed crossword to Burlington House, marking your envelope "Crossword". Do not enclose any other matter with your solution. Overseas Fellows are encouraged to scan the signed form and email it as a PDF to **ted.nield@geolsoc.org.uk**

Name .....

.....

Membership number .....

Address for correspondence .....

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Postcode .....

SOLUTIONS OCTOBER

Across:
7 Epibole **8** Creator **10** Glacis
11 Arsenate **12** Ebbs **13** Alexandria
14 Balkanising **19** Stonemason **22** Rohm
23 Clavicle **24** Schorl **25** Athlete **26** Faulted

Down:
1 Appleby **2** Abscissa **3** Alaska **4** Crystals
5 Maenad **6** Nostril **9** Paternoster **15** Kamacite
16 Narwhals **17** Otolith **18** Charter
20 Novels **21** Nosean

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THE JANET WATSON MEETING 2018

The Geological Society
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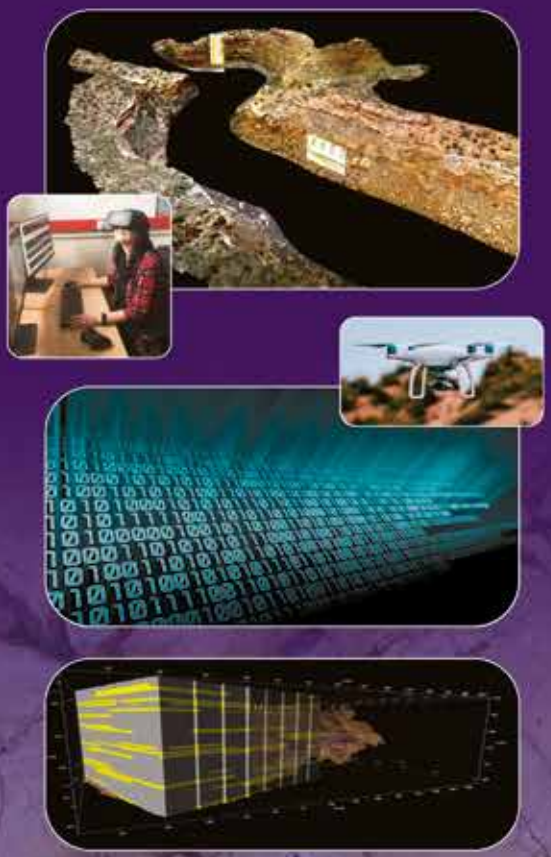
A Data Explosion: The Impact of Big Data in Geoscience

27 February – 1 March 2018

The Geological Society, Burlington House, London



The rise of 'Big Data' has been characterized by a rapidly increasing availability and diversity of data that will play a role in shaping the future of Geoscience Research and the Hydrocarbon Industry. The Geoscience community has been slow to embrace the Big Data technologies that are revolutionizing other sciences such as the pharmaceutical industry and medical research. Where advances in data acquisition and interpretation technologies are being made in academic Geoscience, progress in uptake has been hampered by unstructured data, stored in silos.

This three day meeting will bring together early career geoscientists with leading industry and academic experts to discuss the opportunities and challenges of Big Data and showcase advances in data collection and interpretation technology. It will present an opportunity to learn and collaborate between Geoscience and Computer Science on the subject of Big Data. This will be an excellent forum for networking and an opportunity for graduate students and young professionals to present their research. The conference offers more experienced hydrocarbon geoscientists new research, ideas and concepts and the chance to add their experience to a panel discussion.

Conference themes

- Opportunities and Challenges associated with Big Data in Geoscience
- Data standards, storage and security challenges
- Novel Approaches to data collection
- Technology Advances in interpretation and reservoir characterization, e.g. virtual geosciences.
- The future role of Big Data in academic and industry Geoscience

The final day of the conference is dedicated entirely to workshops and demonstrations of technology advances in Big Data on a variety of scales, from regional subsurface interpretation, to virtual fieldtrips and virtual outcrops, with special sessions on automated interpretation and artificial intelligence.

A panel discussion on 'The Future of Big Data' will be held at the close of the second day.

Call for abstracts

There is a call for abstracts and oral and poster contributions are invited. Abstracts should be sent in a Word document to naomi.newbold@geolsoc.org.uk by 1 December 2017. The abstract should be approximately 500 words and include a title and acknowledgement of authors and their affiliations where possible.

Further information

For further information about the conference please contact:

Naomi Newbold, Conference Office,
The Geological Society, Burlington House,
Piccadilly, London W1J 0BG

T: 0207 434 9944

E: naomi.newbold@geolsoc.org.uk

Web: www.geolsoc.org.uk/jwatson18

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