GEOSCIENTIST

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The Fellowship Magazine of the Geological Society of London

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[THE FUTURE OF GEOSCIENCE – WHAT LIES AHEAD?]

GEOSCIENCE, TECHNOLOGY AND SOCIETY

Jonathan Turner on a major project to dispose of the UK's nuclear waste

THE ENERGY GROUP
A new direction for one of the Society's Specialist Groups

GEOSCIENCE IN CRISIS
It's up to all of us to act, say University of Hull geologists

TIME FOR A REBOOT?
Florence Bullough reports from a recent online meeting

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Cover image: Drilling shot holes for tunnel blasting, Aspö hard rock laboratory, southern Sweden. © courtesy SKB

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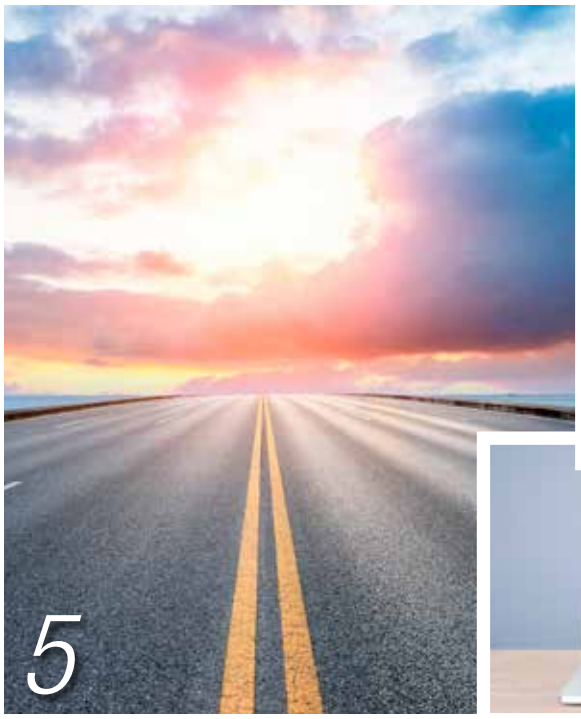
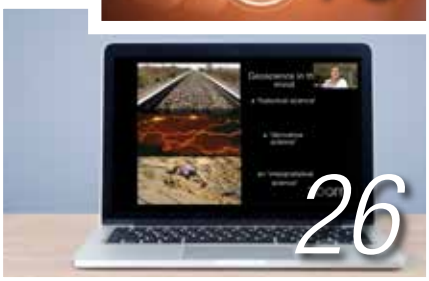




ON THE COVER:

10 DEEP GEOLOGICAL DISPOSAL: GEOSCIENCE, TECHNOLOGY AND SOCIETY
Jonathan Turner reports on Radioactive Waste Management's project to dispose of the UK's nuclear waste – one of the largest environmental projects ever undertaken in the UK

FEATURE

REGULARS

The Geological Society

ES³ Earth Science, Systems and Society

Call for Chief Editor - ES³

The Geological Society of London (GSL) is looking for the first Chief Editor for its **new journal,** *Earth Science, Systems and Society (ES³)* – due for launch in January 2021.

ES³ will be a **fully open access, online only journal**, publishing timely and topical research of high importance across the breadth of the geosciences. As a new journal, an early priority will be in establishing ES³ with a strong and inclusive profile across the geoscience communities, within academia and industry.

The Chief Editor will be enthusiastic about the subject scope, the editorial values and aspirations for the journal, and come with a vision for how to implement these as part of an ambitious and forward-thinking programme for publishing. Ideally, the Chief Editor will have previous experience of a lead editorial role.

An annual travel stipend will be available to support attendance at conferences and events for journal advocacy and development work. ES³ will be a global journal and applicants do not need to be based in the UK or GSL Fellows, but they should be willing to become a Fellow if successfully appointed to the role.

Please email **David Boyt** (david.boyt@geolsoc.org.uk) for more information and how to apply.

> TOO OFTEN WE ARE VIEWED AS PART OF THE PROBLEM, RATHER THAN THE SOLUTION, AND WE MUST FIND A WAY TO COMMUNICATE THE LATTER MORE EFFECTIVELY

FROM THE EDITOR'S DESK:

WHAT LIES AHEAD

The Geological Society's motto, coined more than 200 years ago, is 'whatever is under the Earth.' I've long thought it could be due an update. Poetic though it is, most would agree that the remit of geologists lies far beyond what lies beneath our feet - as July's launch of NASA's Perseverance rover, on its way to take soil and rock samples on Mars, attests.

In recent months, the geological community has been turning its mind more and more to what lies ahead. Student numbers, as this month's Soapbox by geologists at the University of Hull reminds us, are falling, and our science continues to struggle with a startling lack of diversity. In June, the Society co-hosted what might be referred to as a crisis summit – The Future of Geoscience brought together over a thousand participants online to discuss the problems facing the geosciences and how we might respond. In a report from that meeting in this month's issue, Florence Bullough sums up some of the conversations which took place and asks: is it time to rebrand geoscientists as 'key workers for the planet'?

Our main feature this month outlines one of the forms that work will take – the critical task of dealing with the nation's radioactive waste. Deep geological disposal is a fascinating example of the way in which geology intersects with engineering, technology and, not least, science communication – Jonathan Turner of Radioactive Waste Management brings us the latest on the project. Meanwhile, the Society's Petroleum Group reports on a new direction as it becomes the Energy Group, focusing on all forms of energy production, including renewables.

All sorts of ideas and projects have been proposed as a way to tackle declining student numbers, but it seems generally agreed that part of the problem is one of perception – geoscientists have long been associated with industries which are now viewed as contributors to the planet's woes. Too often we are viewed as part of the problem, rather than the solution, and we must find a way to communicate the latter more effectively.

Those industries, of course, remain critical as we work towards net-zero, but what matters is communicating the huge range of opportunities that are out there, for those who want to take a different path. Some readers may recall comments made in 2013 by then Secretary of State for Work and Pensions Iain Duncan Smith, who criticized a geology graduate who had refused an unpaid work placement at Poundland. 'Smart people' he told the Andrew Marr show, should ask themselves on their next shopping trip 'who is more important, the geologist, or the person who stacked the shelves?'

Our response – an opportunity not to be missed – was headlined 'We're not above shelf stacking, say geologists', followed by an explanation of the many different ways geologists have contributed to the food supply chain. 'Without geologists' said then Secretary of Foreign & External Affairs Alan Lord, 'there would be no way to supply supermarkets with produce, no transport for customers or staff – no shelves, in fact.'

I'm not suggesting 'We're not above shelf stacking' as a new Society strapline (although it does have quite a ring to it.) But perhaps, particularly given the year we've all had, 'Key workers for the planet' might not be a bad place to start.

Sarah Day FGS, EDITOR - sarah.day@geolsoc.org.uk @geowriter @geoscientistmag

SOCIETY *NEWS*

STATEMENT ON DIVERSITY, EQUALITY AND INCLUSION

To coincide with the release of the Royal Society of Chemistry's Joint commitment for action on inclusion and diversity in publishing, the Society has released a statement on diversity, equality and inclusion, reinforcing our dedication to making the geoscience community accessible for all.

The Geological Society condemns discrimination in any form and, through our Code of Conduct, requires all Fellows to encourage and assist in the development of a safe, diverse and inclusive workforce. We are firmly committed to improving access and opportunities in the geosciences, and in 2014 signed the Science Council's Declaration on Diversity, Equality and Inclusion. We track our progress yearly through the Progression and Diversity Framework. The Society is improving on a number of fronts, but we realise that there is still considerable work to do.

At present, we are:

- Monitoring diversity in award and research grant recipients, and working to ensure that nominations and submissions reflect the whole of the geoscience community
- Rolling out guidance for improving diversity in conference speakers and attendees
- Redeveloping our membership model to ensure it is inclusive
- Signing on to the Royal Society of Chemistry's Joint commitment for action on inclusion and diversity in publishing
- Revising our Code of Conduct to address abusive or discriminatory behaviour outside of professional settings
- Requiring our Fellows to cultivate an environment of respect and inclusivity in our Society and in public and professional environments
- Working with a number of organisations to create a more equal and welcoming geoscience community at the student, early career and professional level
- Creating a more robust reporting structure to ensure that our External Relations Committee, and hence our Council, have clear oversight of diversity initiatives

Although we always look to the future of geology, we should not ignore the past and the legacy of the Society's early Fellows and contributors. With this in mind we are undertaking a review of our collections and their associations. We will release any new perspectives as our knowledge develops.

We welcome the numerous initiatives and petitions around diversifying the geosciences that have come to prominence in recent days, and look forward to enacting changes in both the short and long term to ensure that our Society and our profession are welcoming and inclusive for all.

SOCIETY AWARDS 2021 – INVITATION TO NOMINATE

Fellows of the Society are invited to submit nominations for the Society's awards for 2021.

We are committed to seeing the diversity of our awardees increase, by broadening the demographics of those put forward for our medals and funds. We are also particularly keen to receive nominations for the funds which recognise excellent contributions by early career geoscientists.

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

The guidance documents and pdf booklet give the criteria and explain how to go about nominating a person you feel is deserving of a Society award.

Please send nominations to the Awards Secretary no later than **noon on Wednesday, 30 September 2020**.

PUBLIC LECTURE SERIES

Virtual Public Lecture: Getting inside the heads of early vertebrates

Speaker: Sam Giles, University of Birmingham
Location: Online
Date: 2 September
Time: 2.30pm BST

Further information

Vertebrates have an evolutionary history of nearly half a billion years, with fossils instrumental in understanding how the group became so hugely successful. This talk will explore how CT scanning is being used to study the braincases of ray-finned fishes, providing an insight into their explosive diversification some 350 million years ago.

The lecture will be streamed online using Zoom. TO book your virtual ticket, and for more information, please visit **www.geolsoc.org.uk/earlyvertebrates**

Contact: The Geological Society, Burlington House, Piccadilly, London W1J 0BG
T: **+44 (0) 20 7434 9944** E: **conference@geolsoc.org.uk**

What your society is doing at home and abroad

SOCIETY JOINS THE COUNTDOWN TO MARS

In July, we joined in with the excitement surrounding the launch of NASA's Mars Exploration Programme, which will take the Perseverance rover to the red planet to collect rock and soil samples for a possible return to Earth. We hosted a Q&A with a number of planetary geologists on our social media channels, to answer some of the many questions people have about Mars and planetary geology. Here are just some of the questions and answers:

Q: What are the chances of Mars being hit by an asteroid?
A: The surface of Mars is covered by impact craters, formed from asteroids hitting the surface. Most of the larger ones are really old, but Mars is still hit by small asteroids today. Luckily, the chances of Perseverance being hit by one is very low.
– @JoelMDavis, Natural History Museum.

Q: If Mars is red because its visible exterior is rich in iron and has rusted, how has this oxidation process occurred if there is no oxygen on Mars?
A: There are very very small amounts of oxygen in Mars' atmosphere today, but this wasn't always the case. There was likely liquid water on the surface of Mars across its early history and this water could be trapped in the atmosphere. Rain or extended breakdown of water vapour in the atmosphere (which would break down into oxygen and hydrogen) would create iron oxide on the surface. There's actually a recent theory that studies if Martian dust storms could contribute to the surface oxidation.
- @sarahmotaghian, Imperial College London

Q: Will Curiosity rover and the Perseverance rover see each other on Mars?
A: No, not unless they drive for a very long time in the right direction! The landing sites of Curiosity rover (Gale crater) and Perseverance rover (Jezero crater) are more than a thousand kilometres apart. Since it landed in 2012 Curiosity rover has driven less than 30 km in total, because it has been busy collecting scientific data. Even when the rovers are on the move, they have to drive very slowly (centimetres per hour) to make sure they don't hit anything or fall over. So, both rovers could drive for decades towards each other but never meet before they die.
- Lydia Hallis, University of Glasgow.

Q: Is there any tectonic activity on Mars?
A: There isn't any tectonic activity on Mars, but there are lots of volcanoes that were active in the past. The NASA Insight rover currently on Mars has a suite of instruments that will help us understand more about the interior of Mars.
- Sarah Boazman, Natural History Museum/University College London.

2021 YEAR OF SPACE

2021 will be the Geological Society's Year of Space – to find out more or get involved, email **outreach@geolsoc.org.uk**

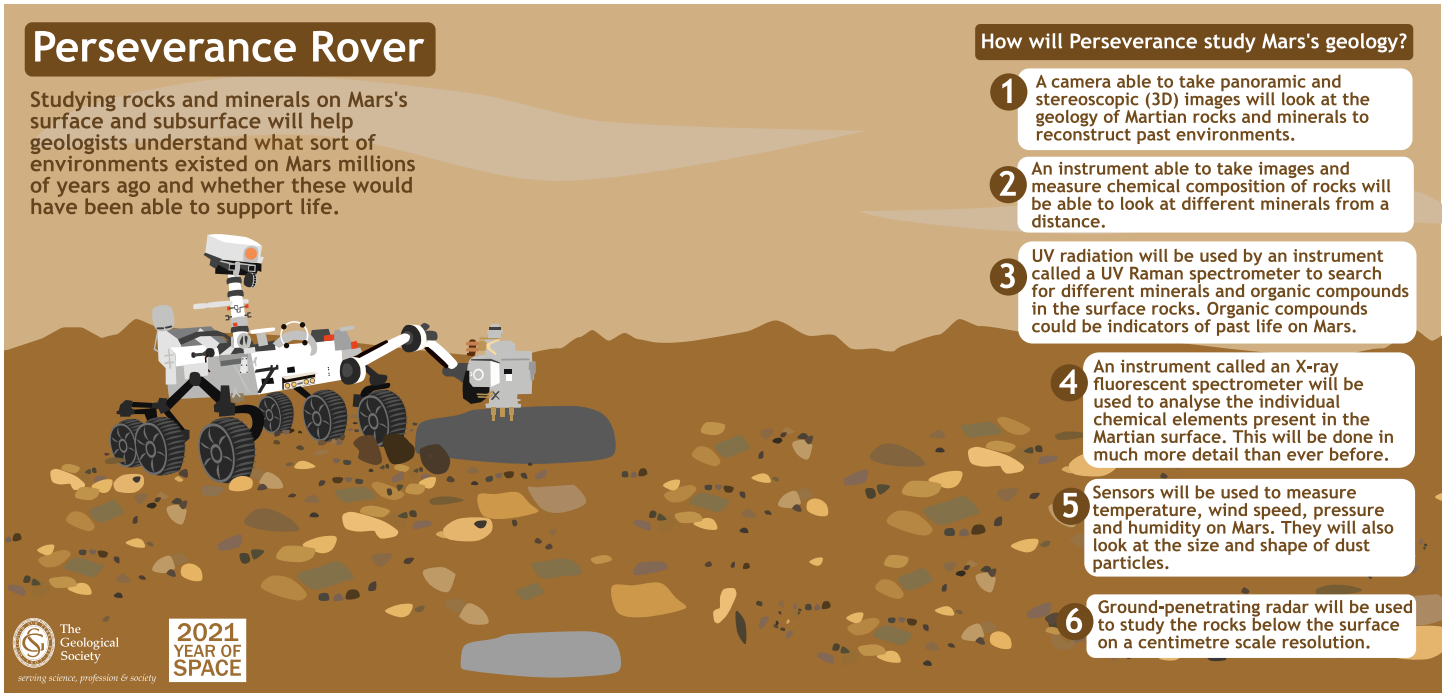


Image: Classroom resource created by the Geological Society's Education Team

The future of geoscience

UK geoscience is in crisis, and it's up to all of us to act, say geologists at the University of Hull

The geology programmes at Hull have grown rapidly since their establishment in 2013, led by a dynamic, collegial and gender-balanced team of academics. But, like many across the country, we are under threat.

Student enrolment is falling dramatically, and the subject is suffering a perception problem due to its association with traditional extractive industries and lack of diversity. The failure of central lobbying to ensure that geoscience remained prominent and valued in the school curriculum leaves us all with a major challenge. Geology degrees are relatively expensive, requiring essential fieldwork and laboratory training, and the collapse in student recruitment now threatens their viability.

Societal challenges

It is ironic that this is occurring at a time when the world needs skilled geoscientists more than ever. The great societal challenges of the 21st century, and many of the UN Sustainable Development Goals, are related to Earth science: increasing vulnerability to geological hazards; increasing need for renewable energy and the capture of anthropogenic carbon, increasing demand for rare minerals and metals to support modern technology; increasing need to sustainably manage water resources as our climate changes. Furthermore, the geological past can provide the only analogues available for understanding the present and future impacts of climate change.

Heads in the sandstone

With its long tradition of excellence in geology, the UK should be at the forefront of addressing these emerging challenges. Doing so would simultaneously emphasise geology's relevance, improve its image, and hopefully boost its recruitment. However, many in positions of power seem to be sticking their heads in the sandstone, whilst other countries recognise the value of investing in training the geoscientists of the future.

The provision of geology teaching in schools has declined dramatically in recent years (see Boatright et al., *Geoscientist* 29 (8), 2019). If they aren't already, university geology departments are going to have to find ways to recruit more students who haven't had prior exposure to the subject. Despite the great work they do, school and college geology teachers have limited time, resources and power to bring about systemic change. To do so requires a focal point, an influential and progressive organisation to speak truth to power, around which the geoscience community can rally.

Next steps

The first step must be for geology educators at all levels to join with learned societies, employers, and other institutions to promote a new vision of geoscience for future generations. This includes creating engaging, up-to-date, open-access resources and communicating to school and college pupils, in STEM and other subjects, that geology is a viable and environmentally responsible option.

We need academics, professionals, postgraduates, undergraduates and passionate non-professionals to work with schools, particularly in previously neglected areas. We need greater diversity in our subject, representative of the different social classes, genders, and ethnic backgrounds of the modern UK. Perhaps most importantly, we need to advocate the vital role of geoscience in tackling the climate crisis to fundamentally change the public perception of our discipline.

Geology may be rooted in the past, but its greatest value lies in the future. We must work together as a community to find new ways to develop and resource this crucial effort. If we do not, an educational crisis will become an existential one.

By Anna Bird, Bryony Caswell, Dave Bond, Eddie Dempsey, Natasha Dowey, Liam Herringshaw, Mike Rogerson, Mike Widdowson and Rebecca Williams; Geology academic staff at the University of Hull

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 **sarah.day@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).

> WITH ITS LONG TRADITION OF EXCELLENCE IN GEOLOGY, THE UK SHOULD BE AT THE FOREFRONT OF ADDRESSING THESE EMERGING CHALLENGES

Image: *Student fieldwork in Almeria, University of Hull.*

The Geological Society

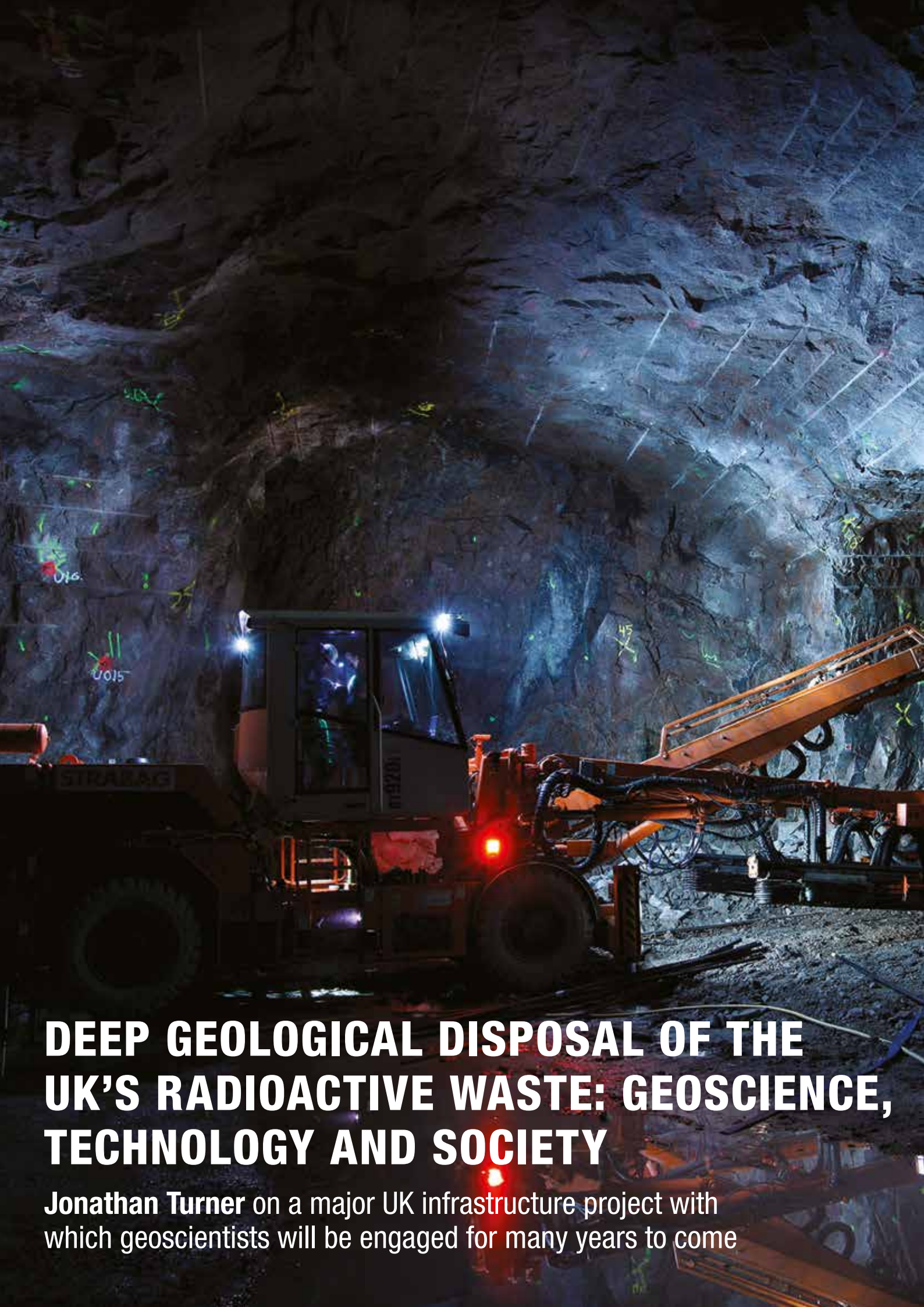
serving science, profession & society

Geological Society Virtual Careers Days 20-23 October 2020

Sponsors Required

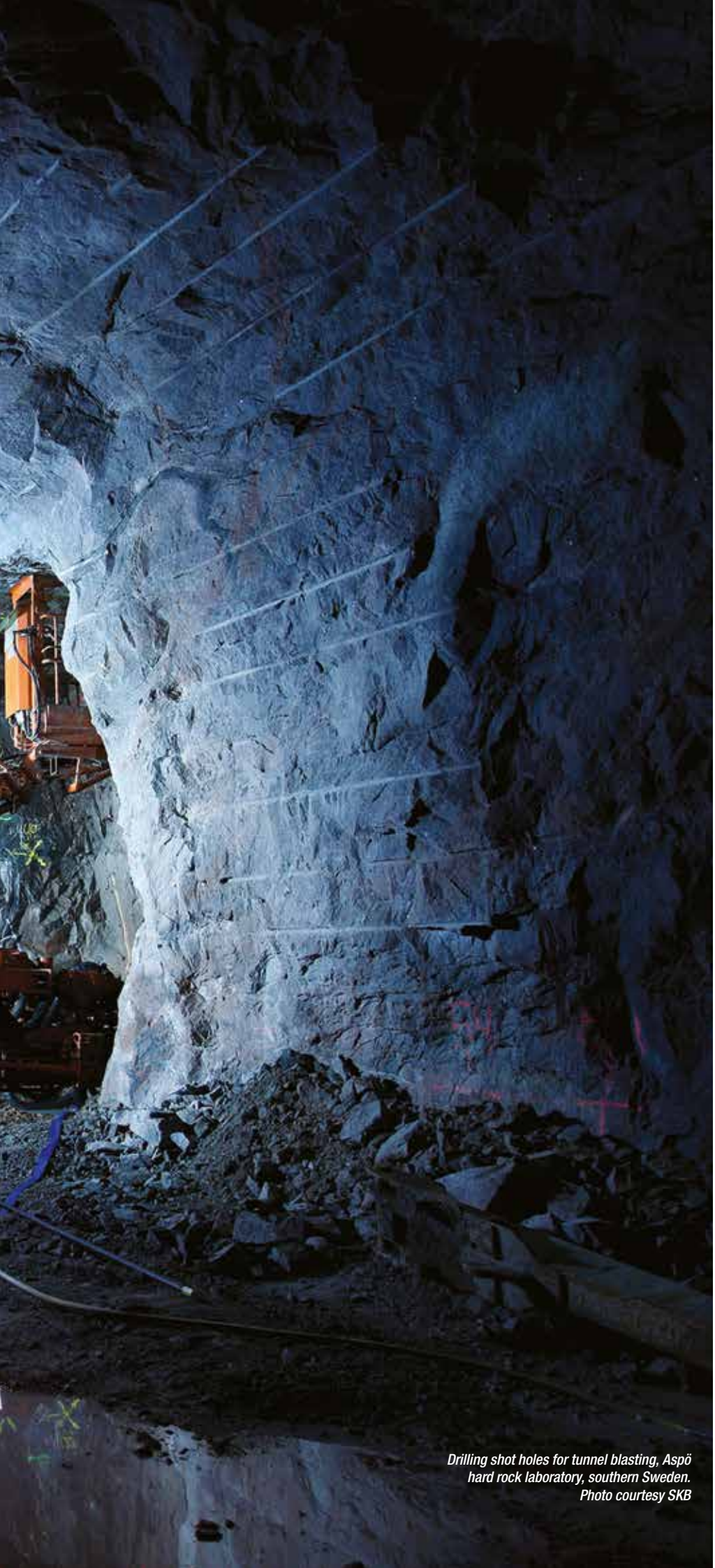
Sponsorship of the Geological Society's Careers Days 2020 event will provide your organisation with an opportunity to promote the benefits of a geoscience-related career to the next generation, engaging you with a relevant future audience, whilst contributing to Social Responsibility objectives. We are seeking both Headline Partners and Supporting Organisations for this event to bring it to as many students as possible.

@geolsoc
#GSLCareers20
Contact :jenny.boland@geolsoc.org.uk



DEEP GEOLOGICAL DISPOSAL OF THE UK'S RADIOACTIVE WASTE: GEOSCIENCE, TECHNOLOGY AND SOCIETY

Jonathan Turner on a major UK infrastructure project with which geoscientists will be engaged for many years to come



Drilling shot holes for tunnel blasting, Aspö hard rock laboratory, southern Sweden. Photo courtesy SKB

The UK has had a nuclear industry since 1945, which means we have been accumulating radioactive waste for more than 70 years. How we safely dispose of that waste is one of the nation's most important challenges, requiring a unique blend of science, technology, social science, design and engineering.

Radioactive Waste Management Limited (RWM), a subsidiary of the Nuclear Decommissioning Authority, is engaged in delivering one of the largest environmental projects ever undertaken in the UK: a deep geological disposal facility (GDF) in which higher activity radioactive waste from England and Wales will be disposed of permanently.

Many of the core geoscience skills developed by mainstream Earth sciences degree courses are central to radioactive waste disposal whilst others are taught less widely. This article aims to give a flavour of the range of geoscience skills needed to support the GDF programme as well as providing an introduction to some of the 'whats' and 'whys' of radioactive waste disposal.

What are the main functions of a geological disposal facility?

The nature of radioactive decay means that higher activity waste needs to be contained for a sufficient period to allow it to decay to background levels. Though this is a long time period from the human perspective, it is geologically quite short. A GDF is highly engineered such that it does not require any post-closure monitoring; its underpinning functions are to contain radioactive materials deep underground for hundreds of thousands of years such that they cannot migrate to the surface, and to isolate radioactive waste from surface processes, such as continental glaciations and sea level change, and from future generations mining into it (Fig. 1).

What is the nature of radioactive waste?

The UK's long involvement in commercial nuclear power, and medical and defence applications of radioactivity, means we have a diverse range of legacy ▶

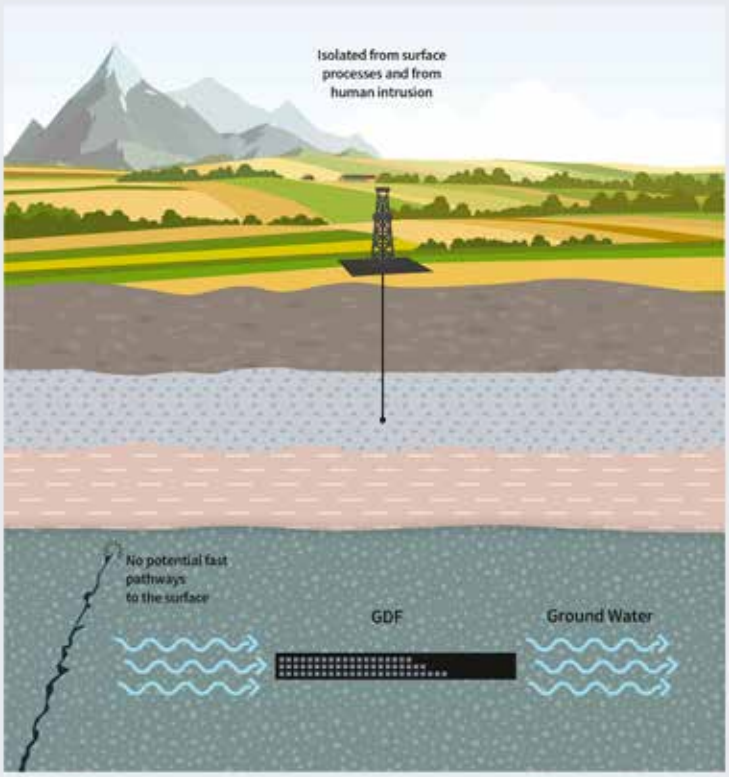


Figure 1: Underpinning principles of deep geological disposal: long-term containment of radionuclides, and isolation of the radioactive waste from natural surface processes and from future generations mining into it. The geological configuration depicted here is of Higher Strength Rocks overlain by a potentially sealing succession of Lower Strength Sedimentary Rocks, including claystone. It is just one example of several configurations that could be suitable for GDF construction

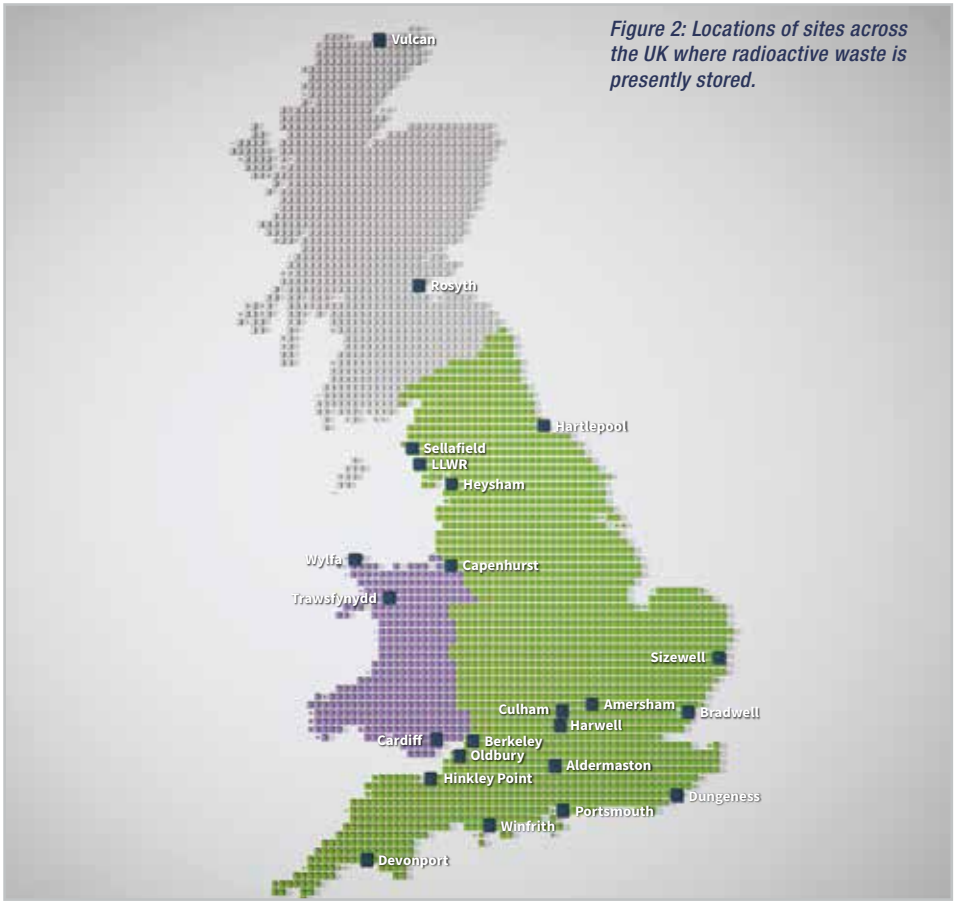


Figure 2: Locations of sites across the UK where radioactive waste is presently stored.

▶ waste to manage. There are two broad categories of higher activity waste – relatively small volumes of heat-generating, high-level waste created by the reprocessing of spent nuclear fuel, and larger volumes of cooler, intermediate-level waste.

The GDF inventory also includes a small amount of low-level waste which is not suitable for disposal at existing surface facilities. This material presently exists either in storage, or within facilities around the country (Fig. 2) which are operating today but will need to be dismantled and their waste managed. As a permanent disposal solution requiring no ongoing human intervention, a GDF relieves the enduring cost burden of ensuring the safety and security of storing legacy higher activity waste in interim storage facilities above ground.

RWM must also be prepared to manage wastes that may arise in the future, such as unreprocessed spent fuel and the waste that would arise from a future nuclear build programme of up to 16 gigawatt electrical. RWM's plans make provision to dispose of up to 750,000m^3 of packaged higher activity waste, equivalent to a single cube whose sides are equivalent to the height of the Queen Elizabeth Tower (Big Ben). As well as the permanent disposal of legacy higher activity waste a deep geological disposal programme therefore allows the UK to prepare for the responsible future management of waste arising from proposed new nuclear energy developments.

Government policy

Radioactive waste is a devolved issue. Scottish policy is that the long-term management of higher activity waste should be in near-surface facilities located as close as possible to the site where the waste was produced.

UK and Welsh Government policy for geological disposal of higher activity radioactive waste has established a consent-based process for identifying potential GDF sites. Successful GDF delivery requires three key ingredients: a willing community, a suitable site including its deep geology, and suitably packaged waste. Public engagement is a central component of RWM's work and represents a significant challenge, not just the issues surrounding "nuclear" but also building a broad understanding of the

evolution of the GDF environment up to a million years after its closure.

Since the current site selection process launched in late 2018 (early 2019 in Wales) RWM has been engaging with the public and a wide range of other stakeholder groups to raise awareness and build a greater understanding of the issue of long-term radioactive waste management. This engagement is aimed at opening up more detailed local discussions with communities that may be interested in finding out more about what hosting a GDF could mean for their local area. RWM is agnostic about the 'best geology' and the 'best site' and will not be in a position to start evaluating in detail the suitability of potential sites until strong community partnerships are established.

National Geological Screening

RWM has produced a suite of National Geological Screening information, underpinned by detailed British Geological Survey reports, that gives communities a flavour of how their local geology could contribute to the safety of a GDF. A diverse range of geological settings could be suitable for GDF construction and illustrative concepts have been developed for various disposal methods. They are based on a representative range of host rock types and their geotechnical properties.

As well as helping to raise awareness, the National Geological Screening provides one of the most comprehensive compilations of UK subsurface geology for general use. The information is based on public domain data and is supported by bespoke maps, tables and explanatory videos that describe the geology of the 13 British Geological Survey regions within England, Wales and Northern Ireland. Note that while the Northern Ireland Executive jointly published the 2014 White Paper that commissioned the National Geological Screening, they have not produced any final policy on GDF siting and there is no active siting process taking place in Northern Ireland.

The screening work is described under the headings: Rock Type, Structure, Hydrogeology, Natural Processes (mainly ice ages and earthquakes) and Resources. The National Geological Screening maps include the inshore area, comprising

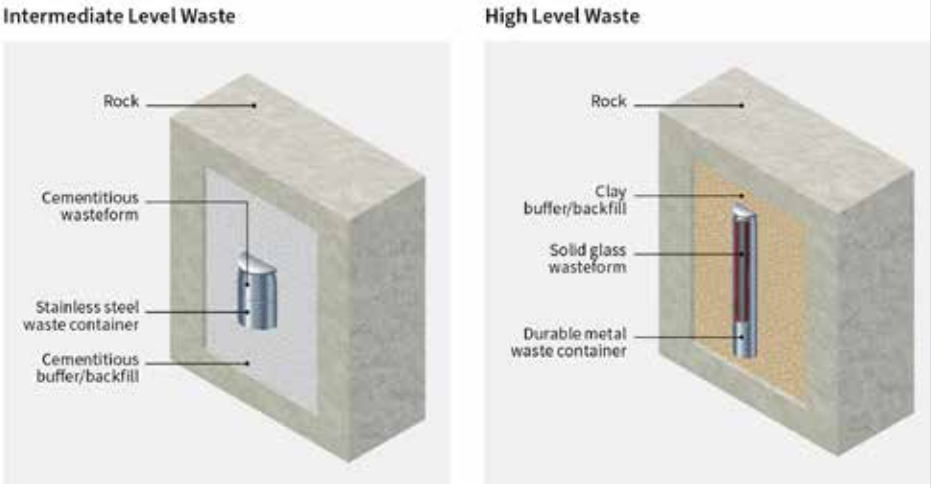


Figure 3: Cutaways showing typical elements of the engineered barrier system for intermediate level waste (left) such as irradiated graphite, and high-level waste (right) such as vitrified reprocessed fuel

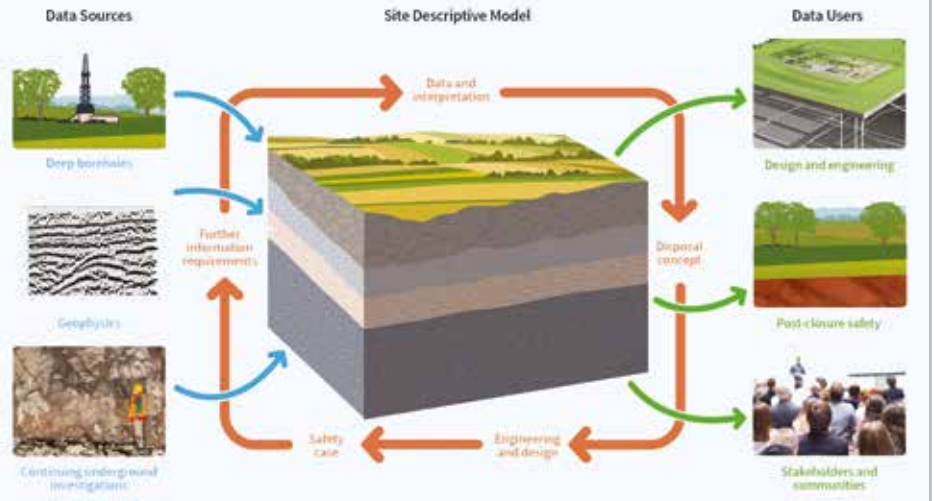


Figure 4. Site Descriptive Model (SDM) represented schematically by the 3D visualisation in the centre. Cycles of data acquisition-concept selection-design and safety cases-information requirements are represented by the brown arrows surrounding the SDM. Blue arrows show the main sources of data that inform the SDM with the green arrows denoting its main users

Crown Estate land up to 22km from the coast, beneath which a GDF could be accessed via a ramp extending from an onshore surface site.

Characteristics of potential host rocks for a geological disposal facility

In keeping with deep geological disposal programmes around the globe, RWM identifies three broad categories of potential host rock: i) lower strength sedimentary such as the Middle Jurassic claystones in which France and Switzerland intend to construct their GDFs, ii) rock salt like the Permian evaporites in which the Waste Isolation Pilot Plant has operated in New Mexico since 1999, and iii) higher strength rocks such as massive and slaty metasediments, and the Archaean granitoids in which the Finnish GDF is being constructed, with the Swedish facility proposed in similar rock.

The National Geological Screening maps show where the three host rock types are expected to be present in the depth range 200m-1000m; an interval that must avoid the effects of glacial erosion and is deeper than potable groundwater resources. The maps also show major structures such as zones of folding and faults with throws of 200m or more, and areas that have been intensively exploited for resources (e.g. coal, metals, oil and gas). Many coal mines and oil and gas fields are places where boreholes, shafts, ramps, and underground tunnels interfere with natural groundwater systems, thus creating potential pathways to the surface from depth. Consequently they are less likely to be suitable places to ▶

construct a GDF.

Rock salt and lower strength sedimentary host rocks are relatively weak and therefore present a greater engineering challenge during the operational life of the GDF. They are characterised by permeabilities that are very low (claystone) or near-zero (salt) such that radionuclides in groundwater and gas move only very slowly, mainly by diffusion. Salt and claystone therefore provide an effective barrier to the migration of potentially harmful radionuclides.

Higher strength rocks are stronger and therefore easier to operate in, but they often contain networks of interconnected fractures that can provide pathways for movement of groundwater and gas. In the event that RWM is engaged in community partnerships in areas that include fractured higher strength rocks, methods have been developed to describe and model fracture systems that are similar to those applied by the oil and gas industry to characterise fractured reservoirs.

Site descriptive models

A key component of RWM's disposal concept is the multi-barrier system in which the natural geological barrier works together with engineered barriers (Fig. 3), such as the solid wasteforms, canisters, bentonite buffer, specially designed backfill materials, and plugs and seals. The design of the multi-barrier system is based on information obtained from detailed characterisation of site-specific geology. Site descriptive models of the near-surface, and deep geology and biosphere, will be based on data from surface mapping, seismic surveys and deep boreholes (Fig. 4). They will yield among the most highly resolved descriptions of the subsurface in the UK.

In some geological configurations, especially layered sedimentary sequences, bespoke seismic data tuned to optimise imaging at GDF depths will enable RWM to make detailed assessments of the structure and distribution of lithotypes, and even pore fluid types and elastic properties, before deep boreholes are drilled. For example, in Switzerland 3D seismic surveys were used to characterise the geology of the three sites now being tested with a campaign of deep boreholes.

The picture that emerges from geophysics will be augmented by information that can only be obtained from borehole samples, such as hydrogeochemistry (e.g. pH, EH, sulphides, oxygen, microbes), geotechnical and thermal properties, and groundwater flow tests. Throughout the construction and commissioning phases of the GDF programme, continuing underground investigations will lead to further refinement of the site descriptive model, testing the veracity of its predictions against observations.

The site descriptive models will therefore synthesise all the key information at each site, allowing RWM to satisfy regulators and other stakeholders of both the operational safety of a GDF and the long-term post-closure integrity of the multi-barrier system. Moreover the models will be a powerful tool for communicating progress with the site characterisation phase to the general public and to potential GDF host communities.

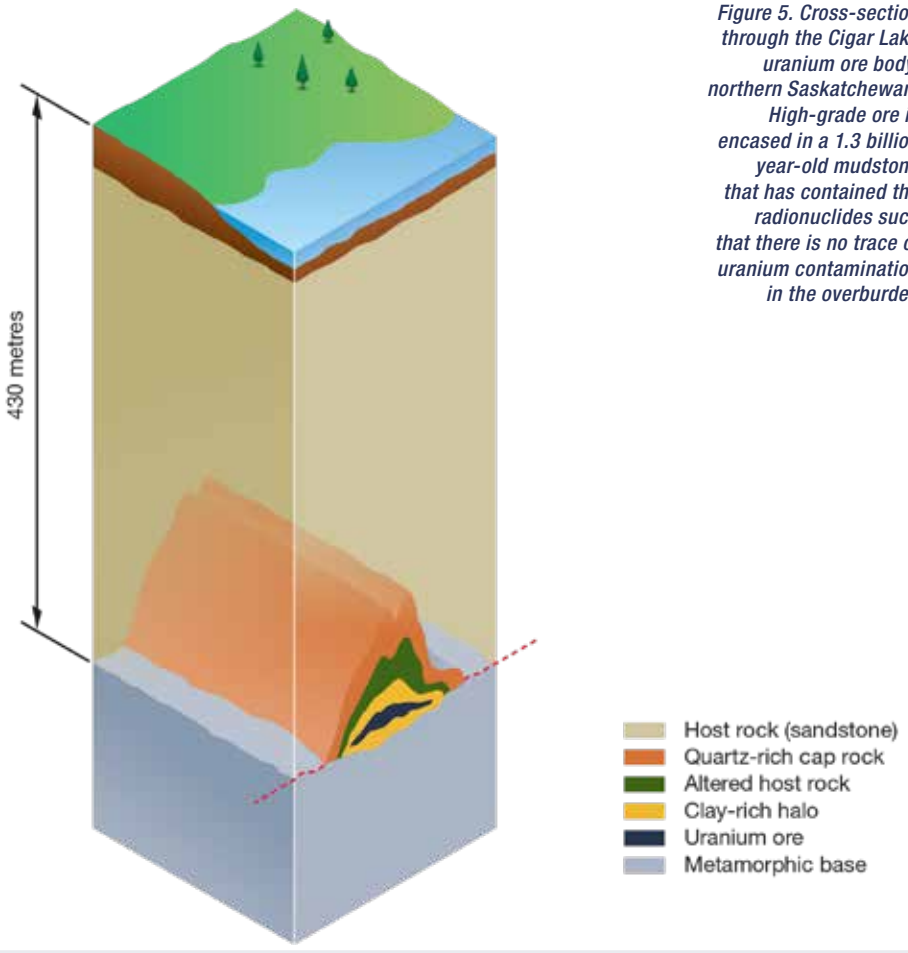


Figure 5. Cross-section through the Cigar Lake uranium ore body, northern Saskatchewan. High-grade ore is encased in a 1.3 billion year-old mudstone that has contained the radionuclides such that there is no trace of uranium contamination in the overburden

Analogues

GDF delivery is an ambitious and challenging programme, envisioning some 150 years of site characterisation, construction, operation and decommissioning, and a post-closure safety case extending hundreds of thousands of years into the future. So it is natural to ask: "Has it been done before?". Yes it has, by other industries – individual tranches of the GDF programme are comparable in scale and complexity to recent major infrastructure projects such as the Channel Tunnel and Queensferry crossing.

There are good examples from nature of the soundness of the general concept of isolating materials deep underground over geological time periods. Cigar Lake in northern Saskatchewan (Fig. 5) is the world's largest high-grade (~20%) uranium mine. The ore is encased in a 1.3billion year-old mudstone yet with no trace of uranium contamination in the overburden or at the present surface. In oil and gas fields around the world, rock salt and low-permeability mudstones are implicated in trapping extensive columns of buoyant hydrocarbons in the deep subsurface for millions of years.

What are other countries doing?

Almost every nation that has made a decision on long-term management of its radioactive waste legacy has selected deep geological disposal as the preferred

solution, and several are at variously advanced stages of delivering GDFs – in Sweden (SKB), Finland (Posiva), France (ANDRA), Switzerland (Nagra) Canada (NWMO), Japan (NUMO) and others around the world. In the USA the Department of Energy's Waste Isolation Pilot Plant in New Mexico has operated since 1999.

Sweden and Finland have relatively small and uncomplicated inventories dominated by spent fuel. Both countries are seeking to develop GDFs at depths of some 500m in fairly sparsely fractured granitoid rocks. Their current proposals are based on disposal concepts in which fuel assemblies are hermetically sealed in 5cm-thick copper canisters up to 5m long, with a post-closure design life of thousands of years. The canisters will be emplaced in 50cm-thick sleeves of bentonite that swell during post-closure re-saturation, creating a low-permeability buffer that isolates the copper canisters from minor amounts of groundwater within the Archaean granitoid host rocks at these sites. SKB and Posiva have invested considerable effort characterising groundwater flow through fracture networks in the vicinity of their proposed GDFs, and understanding how the fractures behave in the in situ stress field.

In France and Switzerland, site characterization programmes are focused on very low permeability Callovian-Oxfordian mudstone host rocks such as the Swiss *Opalinuston*. In France, ANDRA presently operate a 500m-deep underground rock laboratory at Bure in the south-eastern Paris basin, close to where they are seeking a licence to construct a GDF. French law requires ANDRA to be able to retrieve the waste after it has been disposed of. Consequently they have developed a bespoke disposal concept in which robots will emplace carbon steel canisters nose-to-tail within 100m-long horizontal tunnels, and which are capable of being extracted decades later.

In the Alpine foredeep of northern Switzerland Nagra have acquired and interpreted high-quality 3D seismic data in three areas. In 2019 they commenced a deep drilling campaign such that in the next few years they will be in a position to recommend to Swiss government their favoured site for a GDF.

In the USA the Waste Isolation Pilot Plant is the only operating deep geological disposal repository for radioactive waste and has been receiving low heat-generating transuranic materials from US defence programmes since 1999. The facility was closed between 2014-2017 following a salt-haul truck fire in the mining operations, and an unrelated waste packaging fault within a disposal area caused by incorrect packaging of waste at source. Waste is transported by specialist trucks from across the country and is transferred underground for disposal only a few days after arriving at the plant. The facility is constructed beneath the Permian basin of south-eastern New Mexico within flat-lying beds of halite and potash salts more than 550m thick. Salt creates an extremely dry environment devoid of groundwater and its tendency to creep under deep crustal pressures means that after the vaults have been decommissioned the halite closes in and seals the waste.

A new opportunity for UK geoscience

Deep geological disposal of radioactive waste is one of the UK's most challenging major infrastructure programmes with direct bearings on the current debate on our energy future and how we can safely manage existing nuclear risks. The programme to deliver a GDF will evolve to become one of the prime investments in the UK subsurface and it has the potential to capture the national imagination and build public confidence in responsible stewardship of the subsurface. The GDF programme offers exciting possibilities for the career development of current and future generations of geoscientists.

Jonathan Turner is Chief Geologist at Radioactive Waste Management Limited.

Deep borehole drilling in the Alpine basin of northern Switzerland, part of site characterisation work that will help to identify the most suitable site for a geological disposal facility. Photo courtesy Nagra

View looking up the shaft of the underground rock laboratory at Bure, in Callovian-Oxfordian claystone some 500m beneath the south-eastern Paris basin. Photo courtesy ANDRA

THE ENERGY GROUP AND ITS TRANSITION

Kirstie Wright and **Caroline Gill** on the newly repositioned Energy Group and how supporting the energy transition is crucial to the future of geoscience

Geological evidence shows that CO_2 has a major effect on the climate system, with human activities responsible for recent warming. No other issue is so pressing for the human race, with the potential to disrupt our society on such a fundamental level.

The 2015 Paris Agreement sought to limit net anthropogenic greenhouse gas emissions in order to keep global average temperature below 2 °C of pre-industrial levels, and pursue efforts to limit the increase to 1.5 °C, to substantially reduce the risks and effects of climate change. In 2019, the UK government committed to the UK becoming net zero by 2050, by increasing the contribution of renewables to our energy supply and decreasing carbon emissions from the fossil fuel industry.

The Petroleum Group of the Geological Society of London has always endeavoured to remain relevant to an ever-evolving industry and constantly changing geopolitical environment. We recognise it is time for our Group to take a proactive role in the wider energy transition and we have therefore taken the decision to broaden our scientific remit and become the Energy Group of the Geological Society.

The origins of the Energy Group

The Petroleum Group has been the Geological Society of London's special interest group in Petroleum Geoscience for the last 40 years. In that time, the group has held over 285 scientific meetings, produced 60 Special Publications and complied 25 Petroleum Geoscience thematic sets. Subjects covered have ranged from advances in subsurface technology, evaluation of new and existing regional exploration to developments in geological and geophysical science. We continually strive to deliver high quality, leading edge petroleum geoscience, striking a balance between academic research and applied industrial studies.

> ONE OF THE GREAT CHALLENGES OF OUR TIME IS TO MOVE OUR MINDSET FROM EXPLORING AND EXPLOITING OUR PLANET, TO ITS STEWARDSHIP AND SUSTAINABILITY. TO THIS END, THE GEOLOGICAL SOCIETY'S MOVE TO DEVELOP AN "ENERGY GROUP" TO REPRESENT THE BROAD SPECTRUM OF EARTH SCIENCES IN ENERGY GENERATION, TRANSMISSION AND STORAGE AND THE MANAGEMENT OF ITS WASTE PRODUCTS SUCH AS CARBON AND RADIOACTIVE WASTE, IS A MAJOR AND ADVENTUROUS STEP INTO THE FUTURE
>
> MICHAEL DALY, PRESIDENT OF THE GEOLOGICAL SOCIETY OF LONDON

For the past 30 years we have also held an Annual Dinner and Awards to celebrate advancements in petroleum geoscience, awarding a total of 48 medals to recognise excellence at various career stages. Our medals will transition with us into the Energy Group Awards and will celebrate those individuals who are excelling across the energy sector in both academia and industry. As we evolve, our dinner will change, but will still provide the opportunity to celebrate our industry and those who are contributing to it.

The need to evolve

As the Energy Group, we will encompass all geoscience aspects of the full cycle delivery of energy to society. This includes, but is not limited to, petroleum, carbon capture, utilisation and storage, radioactive waste disposal, geothermal energy and the role of geoscience in renewable energy sources.

Meanwhile, petroleum geoscience will remain an integral component of our scientific programme. With fossil fuels currently contributing approximately 43.8 % to the energy consumed in the UK and petrochemicals fundamental in producing the raw materials used in renewable technology and society, they will play a significant part in the energy ▶

mix over the coming decades.

We also want to support current and future geoscientists by being a forum for subsurface-based, energy-related skills and demonstrate how geological science can meet the challenges of the future. Early career geoscientists entering the petroleum industry today will be essential in both optimising existing hydrocarbon resources and facilitating the energy transition. As the Energy Group, we will maximise opportunities where there is significant overlap between the specific skills developed in the petroleum industry and key components of the energy transition, promoting events where we can learn and move forward together. Geoscience professionals working in oil and gas have a key role to play in the future energy mix, by offering some of the UK's most innovative, risk-aware, problem solvers to the technologies of the future.

To be able to support our transition to the Energy Group, we will also be soliciting nominations for committee members with knowledge and experience of non-hydrocarbon related energy geoscience. The committee consists of up to 20 members, elected each year from both industry and academia, with nominations closing on the 25th September 2020. This will ensure that the group offers relevant lectures, workshops, and conferences as part of our annual events programme. To develop a scientific programme that represents the expanded scope of the Energy Group, we encourage the submission of technical conference proposals that showcase the role of geoscience in the energy transition, together with those that continue to lead the way in cutting edge petroleum geoscience.

> IT'S IMPORTANT AS WE FACE THE ENERGY TRANSITION TO CONSIDER THE WHOLE ENERGY SYSTEM AS ONE RATHER THAN ITS COMPONENTS. WE NEED TO SEE THE BIGGER PICTURE BUT WITH PETROLEUM PART OF THE INTEGRAL CONVERSATION ESPECIALLY AS WE WELCOME A NEW GENERATION INTO OUR WORLD
>
> INGRID DEMAERSCHALK, COMMITTEE MEMBER

Securing the future

Much of the world's future energy supplies will be dependent on the unique skills we possess as geoscientists. We are positioning the Energy Group of the Geological Society to lead the way by adapting to these challenges, actively engaging in the transition towards a carbon neutral environment and assisting in combating climate change.

We invite the geoscience community to support our efforts as the Energy Group by joining the group, nominating committee members and suggesting technical meeting proposals. Preparations are already underway to develop a conference exploring the role of geoscience in Carbon Capture, Storage and Utilisation, which will form the cornerstone of the late 2021/2022 programme.

We hope you will join us on this exciting new journey, as together we continue to explore and innovate in the constantly evolving energy sector!

Figure 1: We endeavour to remain relevant to an ever-evolving industry, with our technical meetings exploring the latest in geoscience, such as the 2018 Janet Watson Meeting on The Impact of Big Data in Geoscience, held at the Geological Society of London, Burlington House

> AS THE ENERGY SECTOR CONTINUES TO EVOLVE AND CHANGE AS PART OF AN ENERGY TRANSITION, ITS NEED FOR GEOSCIENCE INCREASES AND CHANGES TOO. BECOMING THE ENERGY GROUP ALLOWS US TO BE MORE INCLUSIVE AND REPRESENTATIVE OF THE WIDER GEOLOGICAL COMMUNITY WORKING IN THE ENERGY SECTOR
>
> DAVID MCNAMARA, COMMITTEE MEMBER

Dr Kirstie Wright, Communications Officer of the Energy Group

Dr Caroline Gill, Chair of the Energy Group

> WHILST RECOGNISING THE DIFFERING VIEWS OF OUR MEMBERSHIP, THERE WAS OVERWHELMING SUPPORT FOR THE PROPOSED BROADENING OF OUR REMIT, DEMONSTRATING THE WILLINGNESS AND COMMITMENT WITHIN OUR INDUSTRY TO SUPPORT THE ENERGY TRANSITION. I LOOK FORWARD TO SUPPORTING THE ENERGY GROUP LONG INTO THE FUTURE

LUCY WILLIAMS, CHAIR OF THE PETROLEUM GROUP 2018-2019

FURTHER READING

The Geological Society of London Statement on Climate Change (2010) and Addendum (2013): www.geolsoc.org.uk/climaterecord

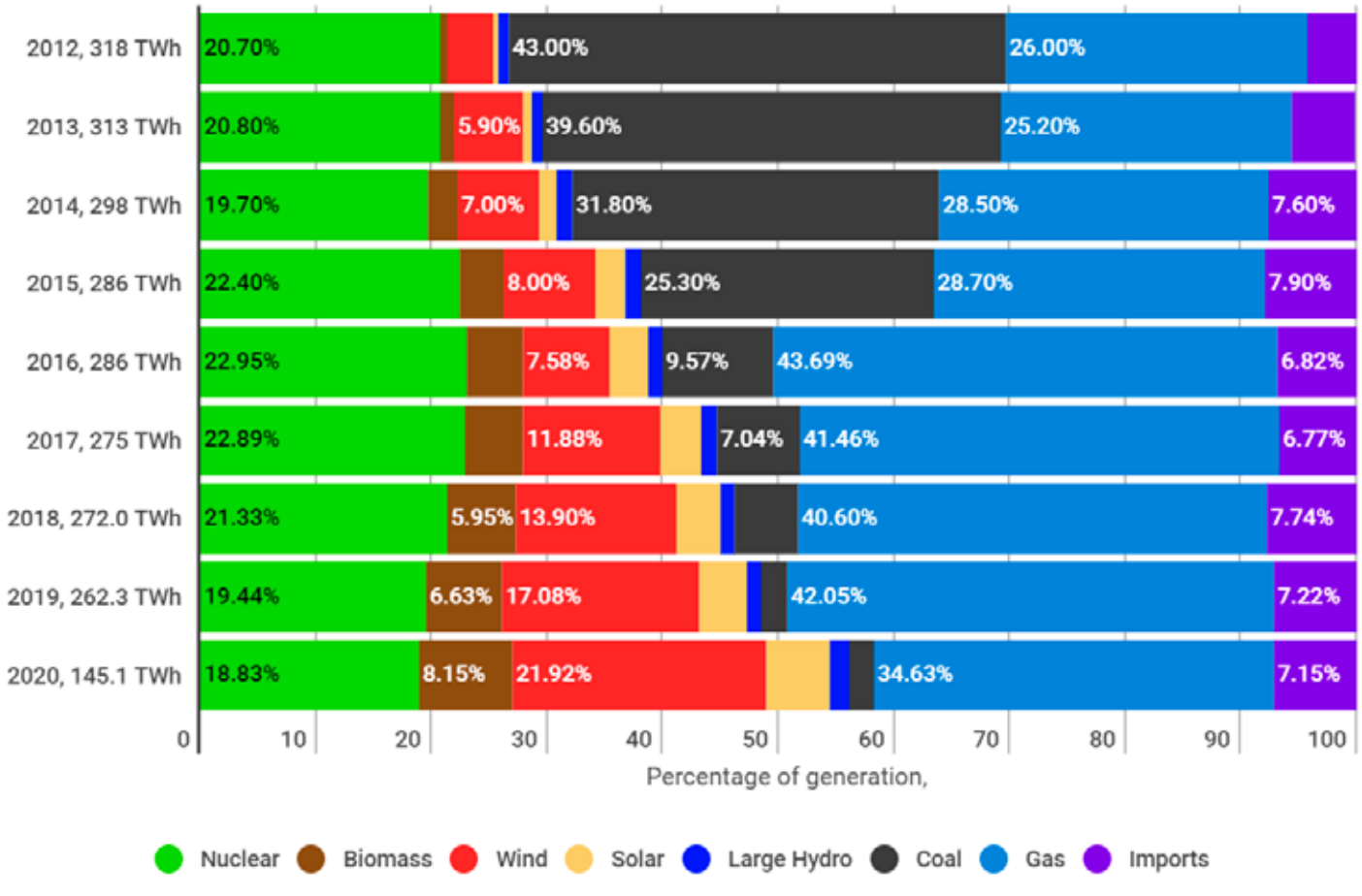
The Paris Agreement 2015: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

My Grid GB https://mygridgb.co.uk

Energy Group Website: www.geolsoc.org.uk/energygroup

Figure 2: The 30th Anniversary Annual Dinner and Awards, held in 2019 in the Jerwood Gallery at the Natural History Museum, during the installation of Luke Jerram's Museum of the Moon. Our annual event will transition with us into the Energy Group Dinner and Awards to celebrate our industry and those who are contributing to it

Figure 3: The breakdown of the UK energy mix between 2012-2020, clearly indicating a growing increase in renewables, such as wind, solar and hydro, and the changing contribution of fossil fuels from coal to gas. In 2020 the contribution of fossil fuels (gas, coal and fuel imports) amounting to approximately 43.8 %. Image used with permission of Dr Andrew Crossland, My Grid GB.



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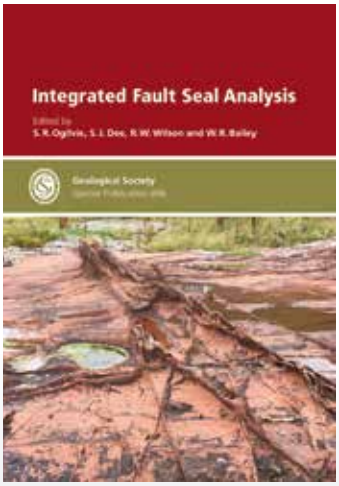


Integrated Fault Seal Analysis

Edited by S. Ogilvie, J.L. Urai, S. Dee, R.W. Wilson, W. Bailey

Faults commonly trap fluids such as hydrocarbons and water and therefore are of economic significance. During hydrocarbon field development, smaller faults can provide baffles and/or conduits to flow.

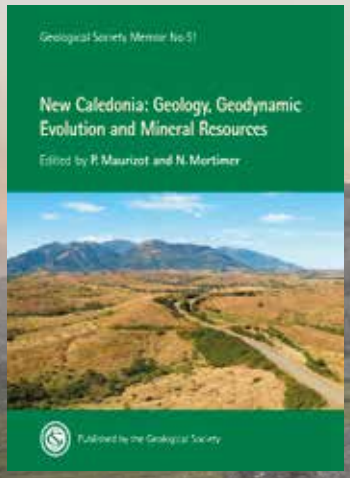
View on the online bookshop: **www.geolsoc.org.uk/sp496**

Geological Hazards in the UK: Their Occurrence, Monitoring and Mitigation

Edited by D.P. Giles and J.S. Griffiths

The UK is perhaps unique globally in that it presents the full spectrum of geological time, stratigraphy and associated lithologies within its boundaries.

View on the online bookshop: **www.geolsoc.org.uk/SPE29**



New Caledonia: Geology, Geodynamic Evolution and Mineral Resources

Edited by P. Maurizot and N. Mortimer

This memoir summarizes the current knowledge of New Caledonia's geology, geodynamic evolution, and mineral resources, based on published and unpublished information.

View on the online bookshop: **www.geolsoc.org.uk/M0051**

For more information on recent publications please visit:

www.geolsoc.org.uk/bookshop

Image: Staple Tor © Wayne Brittle

Due to the ongoing situation with Covid-19 and acting on advice from the UK Government, the Society's offices in London and Bath are closed at time of writing. Unfortunately, this is impacting some of our upcoming events – we are rescheduling and adapting to virtual events where possible.

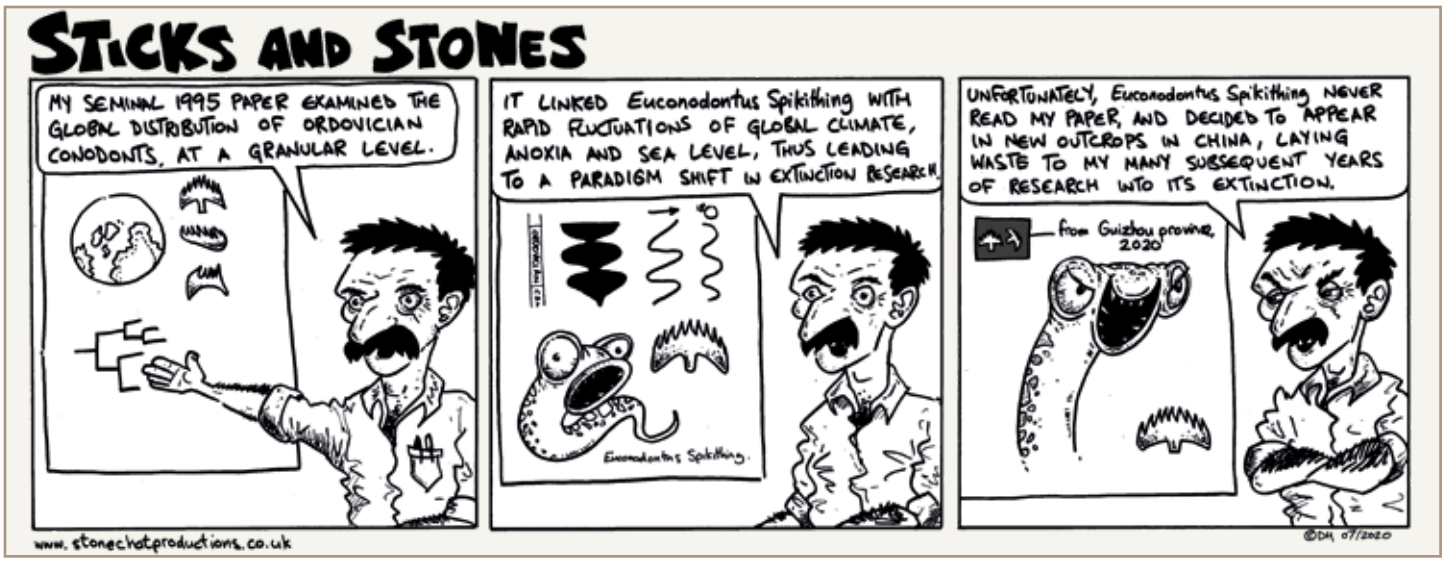
Please visit www.geolsoc.org.uk/events for the latest updates. If you have any questions about upcoming events, please contact conference@geolsoc.org.uk.

VIRTUAL EVENTS

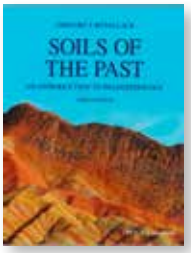
MEETING	DATE	VENUE AND DETAILS
Geopoetry 2020	1 October	Workshop, Geology walk **Venue**: Taking place remotely **W:** https://www.geolsoc.org.uk/geopoetry2020
GSL Public Lecture: Lost in translation – why talking about geoscience is so difficult	12 October	Lecture **Venue:** Taking place remotely **W:** www.geolsoc.org.uk/lostintranslation
Mineral resources estimation: recent advances and current best practice	19 October	Conference **Venue:** Taking place remotely **W:** www.geolsoc.org.uk/10-gsl-mineral-resource-estimation-2020

RESCHEDULED EVENTS

MEETING	NEW DATE	VENUE AND DETAILS
Plastics in the Environment	15 March 2021	Conference **Venue:** Burlington House, London **W:** www.geolsoc.org.uk/plastics2021
Core Values: the role of core in 21st century reservoir characterisation	5-7 May 2021	Conference **Venue:** Burlington House, London **W:** www.geolsoc.org.uk/05-rescheduled-pg-core-values-2021
Engineering Group Annual Field Meeting: The engineering geology of canals, Somerset – the William Smith legacy	2-4 July 2021	Field trip **Venue:** Swan Hotel, Wells, Somerset **W:** https://www.geolsoc.org.uk/07-rescheduled-eg-field-meeting-2021
William Smith Meeting – Mapping of our world and others	19-21 October 2021	Conference **Venue:** Burlington House, London **W:** www.geolsoc.org.uk/wsmith21



Soils of the Past: An Introduction to Palaeopedology (Third Edition)



The word "Palaeopedology", the study of ancient soils, comes from the Greek word for "ground" and not the Latin word for "pedestrians", which is appropriate for this subject because it is anything but pedestrian. The book, and the field itself, have come a long way since the "labour of love" that was the first edition in 1989, in the infancy of the research into this fascinating topic. Ideas and concepts have since been applied from soils of the past to the landscapes encountered during the exploration of Mars and to new discoveries of fossil soils from the Precambrian, presenting us with new information on weathering in the early solar system, and research and studies into fossil soils have advanced our understanding of global climate change.

The book, acknowledging the huge journey its subject has made, states: "This third edition can finally be regarded as a textbook for the established field of palaeopedology". And although it is just such a textbook, it is so much more besides.

It is a comprehensive volume, with clear and accessible narrative, usefully illustrated and with a decent use of tables, covering every relevant aspect of soils and fossil soils imaginable. And with its 20 pages of encyclopaedic glossary, 85 pages of references (which capture everything ever written about fossil soils worth knowing), and a similarly thorough index, it is indeed an excellent reference text which is easy to search.

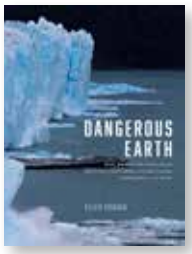
As an engineering geologist, for the most part, I find that soil is something to be scraped out of the way, so I was fascinated to spend some time considering soil forming processes, how soils are altered after burial, and (usefully) how to spot a paleosol in the sedimentary record. I will never look in the same way again at that seemingly ordinary-looking grey shale in a rock core section with fossil root traces: It was once a soil, and paleoenvironmental reconstruction can be undertaken based on a huge amount of data just taken from the roots. The chapter on "Soils of other worlds" gives "clues to conditions during the first 700 million years or so of Earth history unrecorded in sedimentary rocks" and is a rich vein of food for thought.

This marvellous reference is much more than a text book for students of the subject. It both presents, and is part of, the history of the study of palaeopedology itself.

Reviewed by ***Catherine Kenny***

SOILS OF THE PAST: AN INTRODUCTION TO PALAEOPEDOLOGY (THIRD EDITION)
By GREGORY J. RETALLACK, 2019 Published by: John Wiley and Sons Ltd 225pp (pbk) ISBN: 978-1-119-53040-4 **List Price: £69.95**

Dangerous Earth: What We Wish We Knew about Volcanoes, Hurricanes, Climate Change, Earthquakes, and More



If there is one main thread in Dr Ellen Prager's book it is that the main threat to humanity is climate change. Not only is climate change itself dangerous, but it also exacerbates or influences many other natural hazards. It does that either directly, such as making weather hazards more extreme and unpredictable or causing rising sea levels that will increase tsunami hazards, or indirectly as when humans are forced by changing climate to move to areas that have high risk of being affected by other natural hazards.

The book is small, but it contains a wealth of information. It has five chapters, excluding the introduction and conclusion. Climate change, volcanoes, earthquakes and tsunamis, and hurricanes get one chapter each while rogue waves, landslides, rip currents, sinkholes and sharks are all covered together in one chapter. Dr Prager admirably manages to convey what we know, but also – as implied by the title - what we wish we knew, about how to predict and mitigate the impact of natural hazards in a language easily accessible to a lay person.

The author has a background in marine science and has solid professional experience in academia, consultancy and popular science writing. This serves her well because of the by necessity wide scope of this book. The book covers the most recent advances in natural hazard prediction. However, she demonstrates with great clarity how much we still do not understand.

Does the book have any flaws? Not many. It was perhaps unfortunate to include sharks in the list of natural hazards, because, as the author herself makes clear, they are not. The book has an extensive list of resources, but lacks an index.

Considering the width of the topics covered in this very short volume some things just had to be left out. I will not go into what, because that would give an unfair impression of an otherwise very comprehensive book that manages to go into surprising depth on the topics included. The one hazard that I felt could have been added is forest fires. Due to climate change these events have become more notable recently, and even if many of them are due to human agency, their effects can be as devastating as any other natural hazard.

I would recommend this interesting and important book to anyone. Natural disasters happen, and while they are not all driven by climate change, the effects of many of them are exacerbated by it.

Reviewed by ***Lars Backstrom***

DANGEROUS EARTH: WHAT WE WISH WE KNEW ABOUT VOLCANOES, HURRICANES, CLIMATE CHANGE, EARTHQUAKES, AND MORE
By ELLEN PRAGER, 2020. Published by: The University of Chicago Press 229pp (hbk) ISBN: 9780226541693
List Price $25. W: https://press.uchicago.edu

Applied Concepts in Fractured Reservoirs

Understanding the influence of fractures on the storage and movement of fluids in the subsurface is a key component of resource exploitation and management. This includes oil, gas, water and geothermal energy as well as waste disposal. This book addresses the geological analysis of fractures and, although 'concepts' appears in the title, it includes a great deal of practical information

that can be applied in working practice.

The book is divided into three sections that can be summarised by the first word of each section title; Understanding, Measuring and Effects. The first section covers the theoretical and observational background to fractures in terms of their nomenclature, characteristics and mechanics of formation. These concepts are clearly described and form a good basis for the observational techniques described in the next section.

The second section describes the practical description of fractures in core and includes advice on the equipment to use as well as logging techniques and the type of data to record. This is the most useful section of the book and provides an excellent guide to dealing with fractures in core, something that requires a different approach from field-based analysis. Outcrop analogues studies to complement the core observations are also described.

The third, briefer, section covers the effects of natural fractures and discusses their influence on permeability and anisotropy of reservoirs. The geomechanical response to pressure drawdown and fluid injection is also covered. The interaction of natural fractures with induced hydraulic fractures also gets a mention.

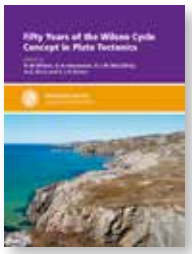
Covering every aspect of fractured reservoirs in a single volume would be impossible; a OnePetro search returning over 28000 results. The book distils useful information for the geologist but also shows where geophysical and engineering disciplines are linked, as successful fractured reservoir analysis requires. The strength of the book is that it provides practical advice for anyone seeking to study fractured core. It is very clearly illustrated throughout with plenty of examples of different fracture types, both in the field and the core store.

The book is an excellent companion to the authors' 'Atlas of Natural and Induced Fractures in Core'; together they make a valuable resource for anyone venturing into the core store. As someone who has spent many years describing fracture systems in core I can thoroughly recommend this book as an excellent primer, regardless of the type of study being undertaken, be it commercial or driven by scientific curiosity.

Reviewed by ***Tim Needham***

APPLIED CONCEPTS IN FRACTURED RESERVOIRS
By JOHN C. LORENZ & SCOTT P. COOPER, 2020. Published by: John Wiley & Sons Ltd. 211pp (hbk) ISBN: 9781119055860 **List Price £100.00**
W: https://www.wiley.com

Fifty Years of the Wilson Cycle Concept in Plate Tectonics



Over fifty years ago, the eminent Canadian geophysicist John Tuzo Wilson published his seminal paper in Nature posing the question 'Did the Atlantic close and then re-open?' This work provided a synthesis of the geological history represented by the rocks of the Atlantic region, from the distribution and changes in rock types, fossil faunal realms, deformation styles and geometry, mountain building episodes, palaeomagnetism and palaeoclimatic evidence preserved in both the eastern and western sectors of the region. Wilson's hypothesis argued that an ocean basin has a lifespan with several defined stages from opening, through development, to final closing and the destruction of the basin.

This work led to the conceptual framework of the 'Wilson Cycle': the repeated periodic opening and closing of ocean basins along old orogenic belts as a key process in the assembly and breakup of supercontinents. The Wilson Cycle concept has proved immensely important to both geoscientific theory and practice and has fundamentally influenced our overall contextual view of the geological evolution of the Earth and its lithosphere, providing significant insight and understanding of the physical processes that control mantle convection and plate tectonics.

Written in the established GSL Special Publications series format, the 20 papers presented in this volume includes both thematic and review papers covering various aspects of the Wilson Cycle concept. Introduced with a contextual overview paper, the research contributions are arranged into six thematic sections: (1) the Classic Wilson versus Supercontinent Cycles, (2) Mantle Dynamics in the Wilson Cycle, (3)Tectonic Inheritance in the Lithosphere, (4) Revisiting Tuzo's question on the Atlantic, (5) Opening and Closing of Oceans, and (6) Cratonic Basins and their place in the Wilson Cycle.

The volume provides an excellent synthesis of the historical context and current research efforts within the field. All contributions are well written and edited, concisely laid out with clear and appropriate figures, photographs and data tables. Many are presented in colour and enhance the understanding of the textual details. The volume is a comprehensive contribution and the editors are to be congratulated. A recommended read and authoritative reference work.

Reviewed by ***Mark Griffin***

FIFTY YEARS OF THE WILSON CYCLE CONCEPT IN PLATE TECTONICS By R.W. Wilson, G.A. Houseman, K.J.W. McCaffrey, A.G. Doré and S.J.H. Buiter (editors). Geological Society of London Special Publication No 424. 2019. Geological Society of London. ISBN 978-1-78620-383-0. ISSN 0305-8719. Hbk. 490 pp. **List Price £140.00, www.geolsoc.org.uk**

BOOKS FOR REVIEW

Please note, there may be a delay in supplying review copies whilst our offices are closed due to COVID-19. Please contact **sarah.day@geolsoc.org.uk** if you would like to supply a review. See a full, up-to-date list at **www.geolsoc.org.uk/reviews**

- **Cretaceous Climate Events and Short-Term Sea-Level Changes,** by M. Wagreich et al (eds), Geological Society of London SP498, 266pp, hbk.
- **Passive Margins: Tectonics, Sedimentation and Magmatism,** by K. R. McClay & J. A. Hammerstein (eds), Geological Society of London SP476, 447pp, hbk.
- **Post-Archean Granitic Rocks: Petrogenetic Processes and Tectonic Environments,** by V. Janousek et al. (eds), Geological Society of London SP491, 298 pp, hbk.
- **Subaqueous Mass Movements and their Consequences: Advances in Process Understanding, Monitoring and Hazard Assessments,** by A. Georgipoulou et al. (eds), Geological Society of London SP500, 639pp, hbk.

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Online exhibitions

The Library's online exhibitions highlight various treasures from the Geological Society's special collections, and shed light on some of the most important figures in the history of geology. Our new exhibition, The First Women, celebrates just a few of the firsts achieved by women in both the science of geology and at the Geological Society. www.geolsoc.org.uk/Library-and-Information-Services/Exhibitions

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The Geological Society

serving science, profession & society

GEOPOETRY 2020

– Edinburgh –

Scottish Energy Forum

1 October 2020

HERIOT WATT UNIVERSITY

Scottish Poetry Library

Scottish Energy Forum

Taking place virtually - Zoom

This event is to follow up the first Geological Society of London's GEOPOETRY day in 2011. Rocks have long inspired poets (refer to Burns' *"O my Luve's like a red, red rose"* poem of 1794):

"Till a' the seas gang dry, my dear,
And the rocks melt wi' the sun"

To the present day poets are similarly inspired. Michael McKimm's *Fossil Sunshine* (2013) and *"MAP, Poems after William Smith's Geological Map of 1815"* (2015) showed how geological subject matter from Geopoetry 2011 could inspire poets: "...the poems here make Smith's map anew in moving and surprising ways." The Jurassic Coast Poems (2017) by Sarah Acton, the Jurassic Coast resident poet, shows continued inspiration:

"We hear the red rock
Speak in ripples"

This gathering, to be held on National Poetry Day (1st October, 2020) is hosted by the Geological Society of London (in conjunction with the Central Scotland Group), The Scottish Poetry Library and the Edinburgh Geological Society and will bring together poets and geoscientists to further encourage the rocks to speak.

Activities Include:

- Schools Geopoetry competition winners.
- Poets and Geologists telling their stories about rocks, poems and influences interspersed with readings (SPL) with contributions by **Sarah Acton** (Poet in Residence, Jurassic Coast), **Michael McKimm** (Geological Society) and **Norman Bissell** (Scottish Centre for Geopoetics).
- Geopoetry Workshop: individuals present poems for discussion and feedback.
- Edinburgh/Scottish Poets with geological gifts, **Ken Cockburn** (Edinburgh Poetry Tours), at Panmure House.

Proposed themes and activities

The organisers will be seeking contributions, which will form the basis of a programme of talks, walks, readings and workshops and ultimately a publication, in the following areas:

- **Geo-themes:** poetry about rocks, geologists, geological sites
- **Geo-images:** poetry that uses earth and ocean images
- **Geology and Society:** poetry drawn from earth and society interaction
- **Geoscience and the poetic form:** Geopoets' influences, inspirations, histories

www.geolsoc.org.uk/geopoetry20

Organising Committee

Patrick Corbett, Heriot-Watt University [p.w.m.corbett@hw.ac.uk]
Stuart Harker, Consultant
Phil Ringrose, Equinor/NTNU, Norway
Bob Gatliff, BGS
Michael McKimm, EGS
Asif Khan, Scottish Poetry Library
Peter Anning, Central Scotland Regional Group (GSL)
Dorrik Stow, Heriot-Watt University
Tim Duffy, BGS
Lara Reid, Friends of Hugh Miller Society
Norman Bissell, Scottish Centre for Geopoetics

Geoscience and the future – time for a reboot?

Is our science in crisis? Florence Bullough reports from a recent virtual summit held to address the future of the geosciences

In early June, more than 1000 geoscientists came together for a virtual summit to discuss and debate new directions for geoscience in the context of the energy transition and a post-Covid world. Streamed live on YouTube, 'The Future of Geoscience' was organised by The Geological Society and Terrafirma founder Tom Backhouse, and addressed growing concerns over a drop in student enrolment and the need to engage more school-age children in geoscience.

These are not wholly new concerns, but the rapidly shifting backdrop of the post-Covid recovery and the agility needed to meet both the Paris Agreement and the UK's net-zero goals made this an important moment to bring the community together.

Setting the scene

The Geological Society's former President, Nick Rogers, set the scene, outlining the crisis in student numbers enrolling for geoscience courses. He also raised the challenges that the subject faces in terms of a critical lack of diversity amongst both students and professionals. In the context of the recent Black Lives Matter protests around the world, the urgency of addressing this disparity has only become more clear. It was widely agreed that the geoscience community needs to look very hard, at all levels, at ways the subject can be more welcoming to a broader sector of society.

Issues of perception

There were a number of discussions around the perception of geoscience and how it marries to the diversity of careers that will be needed to meet the world's biggest challenges. Our science is suffering a major image problem and as a community, we haven't done enough to promote what we offer. Geoscientists have a major role to play in the delivery of net-zero, in the provision of mined materials for the energy transition and in sustainable development. Nevertheless, the image of the subject for many remains one of helping to create the problem, through the development of oil, gas and mineral resources. As GSL Council member Helen Smyth said, we need to reframe geoscientists as 'key workers for the planet' and highlight the important role we need to play both now and in the future.

So why the disconnect? How can we change the perception? Many people raised the lack of exposure to geology that children get in school; whilst children might first encounter geology through fossils and dinosaurs, the next time they are likely to hear about it is either through catastrophic hazards such as earthquakes and volcanoes or through the oil and gas industries.

The first panel agreed that the perception issue was more than just a marketing problem, and that as a community we need a meaningful and genuine reform of the sector. GSL Council member Joel Gill added that going forward, geoscientists will need a wider variety of skills, and will need training in stakeholder mapping tools, communication and public affairs if we are to help meet many of the challenges set out in the UN Sustainable Development Goals. We also need to do more to develop our public engagement strategies, beyond peer-to-peer engagement.

Data sharing

There was a useful discussion around the perception of geoscience in business. In particular, how can geoscience information, which is critical for many industries, be usefully transformed for users outside the field. As one panel member noted, 'being able to predict the subsurface is an amazing thing, but sharing data is hard'. Data and knowledge is packaged into information and decision making and so effort is required to bridge the communication gap.

Reframing geoscience towards future challenges will require an interdisciplinary approach and a commitment to working beyond silos. This may in the future include more blended, solution focused degree programmes. Geoscience is already more interdisciplinary than some sciences but it needs modernising. Geoscience data is at the heart of many issues such as climate change, but we need to get better at translating the skills and information.

Addressing diversity

How can this be achieved? The group agreed that diversity in role models is important for generating interest from a wider cross-section of society: people cannot be what they cannot see. Drawing from a wider group will also lead to better solutions and innovation through diversity of thought. Significant improvements to diversity and inclusion will require leadership from major geoscience organisations, many of whom are already engaged in diversity initiatives, as well as individual action across the community. But it will need to happen at all levels. As things stand, we are not succeeding in engaging diverse communities and we are not hearing from diverse communities enough.

What's behind the fall in student enrolment?

So why are enrolment numbers dropping, just at a time when geoscientists are becoming more critical? Some of this is attributed to the decline of the Geology A Level and the tightening up of the school curriculum, which leaves little room for additional subject areas. But the geoscience community must bear some of the blame and responsibility for improving the situation.

One of the panel members, a geography teacher, noted that there is a lack of awareness of geoscience at school level but that also that the curriculum is currently very full. Even where there is interest, teachers' confidence in teaching geological aspects of the syllabus is a major issue. Fieldwork can also be seen

as a major barrier, both for inclusivity and achieving diversity but also in the time it takes out of a school day.

Should we be thinking more radically about how to include geoscience in everything - from science and geography (particularly linked to cities) to poetry and creative writing in English? We will need to think broadly and innovatively about how to introduce geoscience into children's education, if we are to increase awareness from an early age.

Does geoscience need a reboot?

The final session opened with a presentation from geologist and broadcaster Iain Stewart which kicked off a fascinating debate about how the downturn could be addressed. Iain argued that geology needs a reboot and that we need to focus on what we alone can deliver compared to other disciplines. Geoscientists think in a unique and important way - it's not only a historical science but also a derivative and interpretive one. As Iain put it, 'we steal from everywhere and meld it together!'

Subsurface science is only going to get more important in the context of a growing population, supporting sustainable development and preventing dangerous climate change. We are now approaching 'the age of insertion' - putting things back under the surface, such as CO_2 through carbon capture and storage and radioactive waste, for the benefit of society. It is this type of insight and knowledge that sets geoscientists apart from geographers and surface scientists.

Perhaps a new approach would be to adopt a position of 'Earth stewardship', branding geologists as 'key workers for the planet'. As geologists, we understand the planet in its totality and we also understand its boundaries. Finding a balance between using the planet's resources and environmental protection is vital, with an important role for geoethics, and as geologists we are uniquely positioned to do this. Addressing diversity in our ranks and appealing to a broader section of society will be critical to developing this holistic approach.

Florence Bullough is Head of Policy and Engagement at the Geological Society

Iain Stewart speaking at the Future of Geoscience Summit

DISTANT THUNDER

Etheldred at home

Geologist and science writer Nina Morgan explores the home life of 'the first lady geologist'

On 4 September, 1830, Etheldred Benett [1775 – 1845], already well known for her fossil collection and contributions to Cretaceous biostratigraphy, was busy writing a friendly letter to George Goldie [1784 – 1853], secretary of the Yorkshire Philosophical Society. In the letter she promises to send a large basketful of fossils 'selected for that purpose' to The York Museum, once they are 'ticketted and properly packed'. At the same time, she provides a fascinating glimpse into her home life.

Born into a wealthy family, Benett never married and enjoyed the wealth and independence to pursue her interests. In 1802 she moved to Norton House in Norton Bavant, near Warminster, where she lived with her sister, Anna Maria, for the rest of her life. Benett was inspired to begin fossil collecting in around 1809 by the botanist and geologist Aylmer Bourke Lambert [1761 – 1842], the half-brother of her sister-in-law. Apart from visits to London and to the Dorset Coast, she didn't travel much. Instead, she purchased high quality fossils from local collectors, and collected fossils herself on summer holidays to the Dorset Coast.

Although she published very little, she was meticulous in her documentation and her personal collection attracted many geological visitors. A number of her specimens appeared in James Sowerby's [1757 – 1822] 1812 publication, *The Mineral Conchology of Great Britain*. Among her numerous geological correspondents was Gideon Mantell. Mantell became a lifelong friend and recorded that the pair corresponded 'without interruption, for more than 25 years'. In his obituary of Ethedred Benett Mantell noted that:

'In private life this excellent lady was highly respected and beloved by a large circle of friends, for her sincerity of manners and never-tiring charity and benevolence.'

Behind the public face

But what was she like as a person? There are few clues. In a diary entry for 20 April 1819, Mantell notes that Mrs Mantell thought of 'Miss B as a very engaging and interesting woman.' The only image of her is a silhouette portrait which, Etheldred complained, '...will [not] give you the least idea of me .. and makes me look at least ten years older than I am.' Her surname was – and is! – commonly misspelled. And because of her unusual Christian name, she was often assumed to be a man. In 1836, she was made a member of the Imperial Natural History Society of Moscow, and was annoyed to discover that her diploma was made out to 'Dominum' [Master] Etheldredus Benett. The British Museum also wrote to Etheldred Benett Esq. to thank her for the donation of her book on fossils which she presented to one of the librarians 'telling her it was written by myself'.

Like all women of the time, she also suffered because many of the scientific societies did not admit women. But she appreciated the few that did. In her letter to Goldie she writes:

" I admire your liberal regulations with regard to Ladies, and if I lived within reach I should assuredly avail myself of it."

And she adds some insight into her home life by noting that:

" My Sister enjoys her normal good health but is gardening mad a Mania which prevails to a great extent in this neighbourhood."

Taking advantage

It also seems that Etheldred wasn't above a bit of penny-pinching. Her brother John [1773 – 1797] was a Whig MP for Wiltshire from 1819 – 1852, so entitled to free postage. In his diary entry for 19 September 1819, Mantell notes: "Received a letter from Miss Benett ... the letter was franked by her brother." Her letter to Goldie was similarly franked. Perhaps she felt that her brother's position entitled her to the nineteenth century equivalent of 'unlimited broadband'!

Silhouette of Etheldred Benett, [?1837]. Published in: H B Woodward, 'History of Geology' (1911). One of the only three known likenesses of Benett, made during a trip to Bath. (Reproduced by permission of the Geological Society of London)

End notes: Sources for this vignette include: a letter from Benett to Goldie dated 4 Sept 1830 from the YPS Archives held in the Borthwick Archive at the University of York; Torrens, H.S. *et al.*, 2000, Etheldred Benett of Wilshire England, the first lady geologist, *Proc. Acad. Nat. Sci Philadelphia*, **150**, pp. 59- 123; the DNB entry for Etheldred Benett by Hugh Torrens; Obituary Miss Etheldred Benett, by Gideon Mantell, *London Geological Journal*, **1**, p. 40, 1846; The Journal of Gideon Mantell edited by E.C. Curwen, OUP, 1940

* **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

Print copies available

The following are available to any interested readers – please contact John Parker (email: jremparker@aol.com). Free to a good home (personal or institutional).

Marine and Petroleum Geology, Volumes 1 – 18, 1984 – 2001
Petroleum Geoscience, Volumes 1 – 24, 1995 – 2018

Pass on something wonderful

We are celebrating national Remember A Charity Week this 7 – 13 September.

Remember A Charity is a consortium of over 200 charities working to promote the benefits of gifts in Wills. Each year in September the consortium – of which the Geological Society is a member – holds a special awareness week to encourage more people to consider leaving a gift in their Will to charity, after they've taken care of family and friends.

Gifts in Wills allow charities to continue providing vital services, and the Geological Society is no exception. Did you know that the creation of our Publishing House was made possible thanks to a legacy donation?

A small gift in your Will, once you've taken care of loved ones, can help continue the Geological Society's work for generations to come. As a registered charity (number 210161) every gift makes a huge difference - even 1% (so those closest to you inherit 99%) or a modest sum of money will leave a lasting impact.

REMEMBER A CHARITY IN YOUR WILL WEEK
7-13 September 2020

Leaving a gift in your Will may also reduce your rate of inheritance tax. The lower tax burden can mean that more is received by the eventual beneficiaries of your estate.

If you would like to find out more about leaving a gift in your Will, please get in touch with Jenny Boland, Head of Development by calling + 44 (0) 20 7434 9944 or email jenny.boland@geolsoc.org.uk

The Society notes with sadness the passing of:

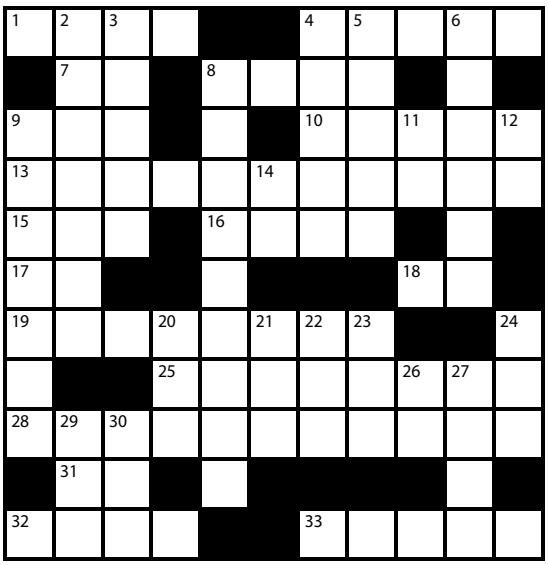
Brooks, John
Bennison, George
Cambray, Frank W*
De Wit, Maarten*
Douglas, Tom*
Greenleaves, Keith*
Hawkins, Kevin*
Ralph, William Thomas*
Walton, Derek*
Weeks, Alan*
Worthington, Paul F

In the interests of recording its Fellows' work for posterity, the Society publishes obituaries online, and in Geoscientist. Bold, recent additions to the list; * Fellows for whom no obituarist has been commissioned; § biographical material lodged with the Society.

If you would like to contribute an obituary, please email sarah.day@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.

Crossword



Across
1 See 29 Down
4 "____Kea" highest volcano on Big Island (5)
7/11 A monster hunting anime warrior from the planet Myce (4)
8 An opening into a mine (4)
9 Colloquially, small gravel size (3)
10 Covered in loose, weathered material (5)
13 The Hawaiian Islands for example (11)
15 County of Hawai'i (3)
16 Vector operator describing the rotation at a point (4)
17/31 Intergovernmental organizations (4)
18 See 12 Down
19 A discussion with participants in concentric circles (8)
25 Ropy lava (8)
28 Common name for the tree source of 8d's cure (11)
31 See 17
32 Luminous spheroid of plasma held together by its own gravity (4)
33 See 24 Down

Down
2 Polish dumplings (7)
3 Edible plant of the goosefoot family (5)
4 "The _____" play by Moliere (5)
5 More or less circular reef around a lagoon (5)
6 Large Indian antelope (6)
8 Creator of the first synthetic cure for leprosy (5,4)
9 Plate on which the Hawaiian Islands stand (7)
11 See 7 Across
12/18 A smarter than average bear (4)
14 Element 94 (2)
20 Hydraulic Power Unit (3)
21 Unit of resistance (3)
22 To invite or court (3)
23 "Location" of the Cosmic Horseshoe (3)
24/33 Landform rising from the ocean floor (8)
26 Wells once found in Bromley (1,1)
27 Setting for Camus'"The Plague" (4)
29/1 An area of the mantle where magma rises (7)
30 Advertising Standards Authority (3)

By Bindweed

Solutions August| Across: **1** Bee-fly **7** en **9** Orion **10** Abaca **14/13** John Tyndall **15** bostryx **18** Roo **19** OR **19/4** Eunice Foote **22** RSJ **23/12/34** Corral **25** anew **28** williwaws **30** Mercalli **32** urea **33** Earl **35** sandbox **Down**: **1** borborygmus **2** errors **3** Ei **5** In **6** LBJ **7** echo **8** nanofossils **11** Aore **16** ru **17** Xi **21** Chewie **24** NiCad **26** nil **27** Wa **28** Wren **29** la **31** Era

OBITUARY Miles Francis Osmaston 1925 - 2019

A prolific author with wide ranging interests, who always sought to engage with others

Miles Osmaston was born on 15th July 1925 in Petworth, Sussex. His mother had returned to England from India with her young son Henry to give birth to Miles, but the family then returned to join his father, Arthur, who was working for the Indian Forest Department, one of several family members to do so[1]. By 1928 Miles was back in England, being educated privately until he was sent to a prep school in Seaford aged eight.

Education

When he was aged 10, Miles was seriously ill with osteomyelitis. After 10 weeks in hospital followed by 15 months in a clinic in Alton and a period of schooling at home, he was eventually fit enough to resume his education, aged 15, at Radley College, Oxfordshire. Not being eligible for National Service on health grounds, he went straight to Oxford University, graduating in 1949 with a degree in Engineering Science. Following a year at Durham University, he took a job with Mullard/Philips who manufactured radio valves, but was later involved in aircraft engineering and airborne weapons development until a change in government policy put an end to this work.

Imperial College

This led to a complete change of direction and to studies at Imperial College in 1966 investigating the internal structure of the Earth, what was to become known as plate tectonics. In time, to quote from his website (http://osmaston.org.uk/) , he pursued in parallel his '… interests, both in fundamental physical-astrophysical dynamical matters (including gravitation) and in the Earth's internal behaviour and evolution, as evidenced by plate dynamical behaviour…'.

> OF HIS WORK AS A SCIENTIST, PROF E.H. (ERNIE) RUTTER SAID THAT MILES WAS A '... MAN WHO RESPECTED THE SCIENTIFIC VIEWS OF OTHERS AND ALWAYS SOUGHT TO ENGAGE. HE HAD SCIENTIFIC VIEWS ON GEOSCIENCE ISSUES THAT WERE OFTEN TANGENTIAL TO THE MAINSTREAM BUT HE ALWAYS SOUGHT TO FOUND HIS THINKING IN SOLID SCIENCE. HE HAD A WIDE APPRECIATION OF MANY ASPECTS OF THE PHYSICAL SCIENCES.

Miles was elected Fellow of the Geological Society in November 1966, presenting his first paper at a meeting the following year. He was a Fellow of the Royal Astronomical Society from 1992 and was a member of the European Geosciences Union from 2007, the Geochemical Society from 2004 to 2016 and the European Association of Geochemistry from 2006 to 2016.

Publications

He was a prolific author. Nearly 150 papers and abstracts are listed on his website, among the first being a paper published in *Nature* in 1967 on 'Core convection, the Earth's figure and continental drift', followed in 1971 by one in *Tectonophysics*. He continued to publish and also present papers at conferences until a few years prior to his death, when his health prevented this.

Of his work as a scientist, Prof E.H. (Ernie) Rutter said that Miles was a '... man who respected the scientific views of others and always sought to engage. He had scientific views on geoscience issues that were often tangential to the mainstream but he always sought to found his thinking in solid science. He had a wide appreciation of many aspects of the physical sciences.'

Miles passed away on 3rd May 2019. He married Margaret (née Whitworth) in Great St. Mary's, Cambridge in 1956, and she survives him along with his daughters Mary and Liz and son John.

By Wendy Cawthorne, with assistance from Mary Osmaston, Liz Hampshire and Nigel Osmaston.

1. Osmaston, H. (1989) The Osmaston family: foresters and imperial servants. *The Commonwealth Forestry Review*, 68(1), pp. 77-87

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 Sarah Day at the Society.

The Geological Society

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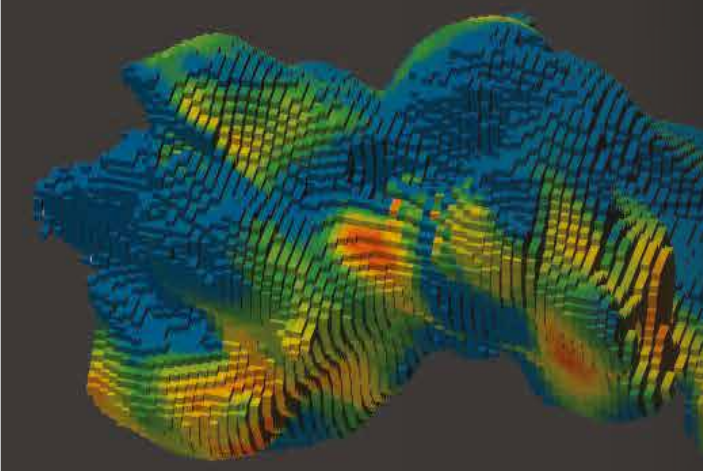
Mineral Resource Estimation:

Recent Advances and Current Best Practice

V I R T U A L C O N F E R E N C E

19 October 2020



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

As part of the conference, we will explore topics from the following broad areas:

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

Co-Convenors and Keynote Speakers

Ben Lepley Senior Resource Geologist

Lucy Roberts Principal Resource Geologist

James Catley Resource Geologist

Further information

For further information please contact:

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

T: 0207 434 9944

E: conference@geolsoc.org.uk

Web: www.geolsoc.org.uk/events

Follow this event on Twitter: #gslminerals20

Registration Open

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