GEOSCIENTIST

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The Fellowship Magazine of the Geological Society of London

@geoscientistmag

THE RED PLANET

[2021: THE YEAR OF SPACE]

VISITING MARS
Robotic vs human exploration

RESEARCH INSIGHTS
Interviews with three inspiring planetary geoscientists

FROM WET TO RED
The martian climate decoded

Geoscientist is the Fellowship magazine of the Geological Society of London

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Cover image: The Mars rover. Elements of this image furnished by NASA and then is addapted and enhanced. ©Shutterstock

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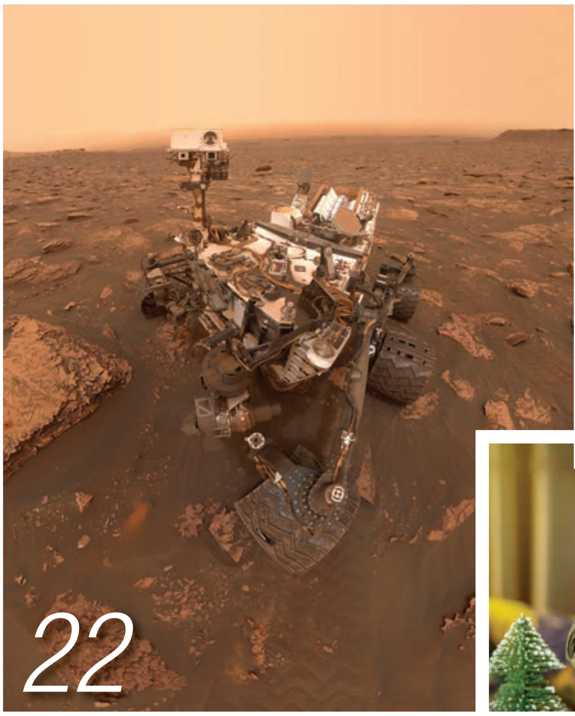

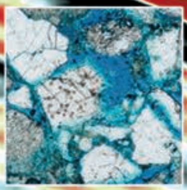
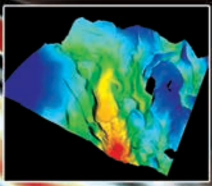
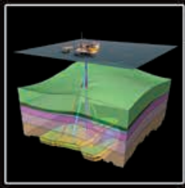

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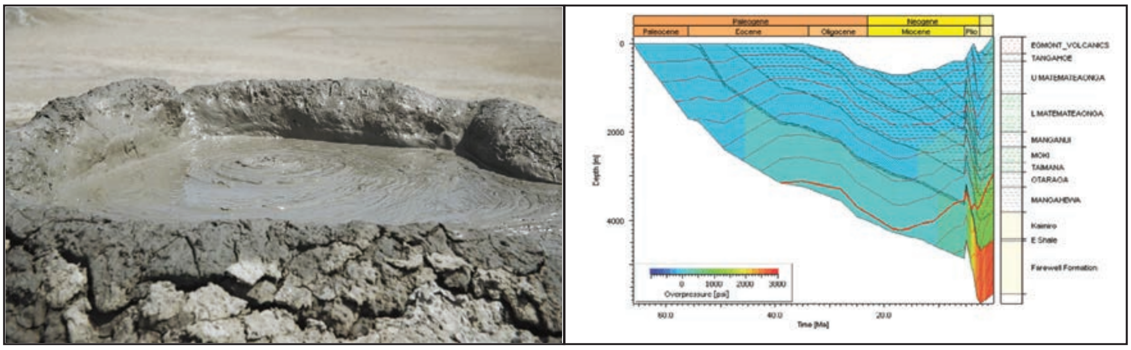
Confirmed New Date

Geopressure 2021

Managing Uncertainty in Geopressure by Integrating Geoscience and Engineering

23-26 March 2021

Virtual Conference and Masterclass



The organisers invite contributions within any aspect of geopressure but are particularly interested in the various phases of pore fluid pressure prediction, modelling and overpressure evaluation to manage uncertainty during the life cycle of a well. Suggested themes and sessions include:

- Pore Pressure and stress, especially complex stress regimes
- Impact of machine learning on PPFG
- Well engineering and PPFG
- Injecting fluids underground (including CO2)
- Coupling of Pore Pressure and FG including depletion and closing the drilling window
- Seal capacity and relationship with PPFG
- PPFG issues in mature basins (including abandonment/decommissioning)
- Classic case studies, including Macondo and LUSI mud volcano
- Pore pressure as an exploration and prospectivity tool.
- Geopressure in mature basins – lessons learnt
- Pore pressure in active tectonic basins
- Unconventional stress regimes

Event Details:

23-25 March 2021: Conferece

26 March 2021: Best practice for PP and FG - Mastery Class - Led by Richard Swarbick

Further Information:

For more information please contact sarah.woodcock@geolsoc.org.uk or visit the event website: https://www.geolsoc.org.uk/03-rescheduled-pg-geopressure-2021

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#EGGeopressure21

"2021: OUR YEAR OF SPACE… AND TRANSFORMATION"

FROM THE EDITOR'S DESK:

ALL CHANGE, ALL CHANGE

Back in 2017, we asked you, our Fellows, for your views on *Geoscientist* magazine. Using a readership survey conducted by the company *Research by Design*, we wanted to understand how the magazine is viewed and used, and the extent to which our Fellows have an emotional attachment to it. The results of the readership survey were clear: *Geoscientist* magazine is a cherished member benefit and one to which Fellows turn to keep abreast of broader scientific developments, share opinions and engage in debate.

Many were satisfied with the magazine layout, but it was perceived as somewhat outdated, cluttered and in need of modernisation. And, while nowadays people increasingly seek their scientific information via the web, our website rated poorly, with less than half of the survey respondents ever looking at *Geoscientist* Online.

We've worked hard over the past few years to bring you more of the science and discussion you enjoy, but changes in the editorial team and a stint on maternity leave for me mean it's taken some time for us to respond to your feedback in a significant way.

I am happy to report that this is set to change in 2021. As discussed by our Editor-in-Chief, Andy Fleet (page 7), *Geoscientist* will undergo a major overhaul in the coming months. We will soon have a new-look, modern *Geoscientist* website that we hope the community will be eager to engage with often. The revamped website will not simply be a digital version of the print magazine. Rather, it will offer interesting and varied content that complements the more traditional articles and reports featured in print. We will add new content frequently, thereby keeping you regularly informed, as well as providing more high-quality science and a rapid service for our authors.

The printed magazine will undergo a significant redesign to modernise its look and feel, while retaining the existing vibrant mix of news, science, opinion and events. Monthly issues have served us well, but in terms of environmental sustainability, we can no longer justify producing more than 12,000 print copies of the magazine each month that are largely just recycled. Instead, beginning in March 2021, you will receive a high-quality issue of the print magazine every quarter.

Next year (and beyond) will also be a time of momentous transformation for the entire Society. Over the past several months, the Society has undergone an in-depth strategic review to assess our future directions. The review is now complete and on page 8 Megan O'Donnell and Richard Hughes provide a summary of the outcomes. The vision for our future is ambitious and bold, and if we can achieve all that we set out to, we will be stronger and more relevant for it.

2021 will also be a scientifically exciting year for the Society—our Year of Space! Flo Bullough gives a small taster of the events we have planned around this theme on page 7. To whet your appetites, we hope you enjoy this final monthly issue of *Geoscientist*, which is themed around the always captivating planet Mars.

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

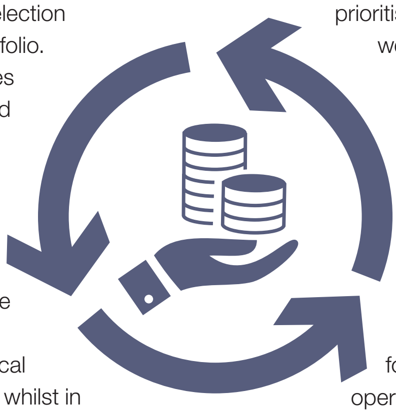
SOCIETY*NEWS*

SOCIETY BUSINESS

RESPONSIBLE INVESTMENT POLICY

Council has recently approved a new policy for the Society's financial reserves that are invested to generate income and capital growth for the Society, writes Treasurer Graham Goffey.

The Society's directly held investment portfolio comprises mostly large, 'blue chip' companies. Under the responsible investment policy, environmental, social and governance (ESG) considerations are incorporated into the investment manager's selection of, and interaction with, companies within the portfolio. The policy is intended to reflect the Society's values of sustainability, responsibility and stewardship and to more explicitly align its investment portfolio with Paris Accord targets.



The extractive sector is a particular policy focus and the Society is clearly well placed to consider the crucial role of geoscientists and extractive companies in the responsible supply of sustainable energy and critical minerals through the energy transition and beyond. Demand is growing for critical minerals e.g. for electrification and power storage, whilst in the absence of radical demand reduction, continued investment is needed to meet global hydrocarbon demand for energy and feedstock for plastics, pharmaceuticals, fertilisers, etc.

The energy transition requires a focus on demand reduction and science-based policies that ensure emissions from domestic and industrial activity are substantially reduced, not simply offshored. The use of carbon capture and storage (CCS) to reduce net global emissions has long been advocated by the Society, which recognises that extractive companies are best positioned through expertise and capital to deploy CCS. Gas is also likely to be utilised with CCS in the production of decarbonised 'blue' hydrogen fuel, whilst extractive companies are increasingly aware of the need to reduce the carbon footprint of their activities. The responsible investment policy will prioritise any Society investment holdings in this sector into well-managed, responsible companies undertaking or working towards sustainable extraction.

The Society will avoid investment in companies involved in certain emissions-intensive fossil fuel extraction and combustion activities, unless significant mitigating factors are identified; for example, emissions reduction via CCS. Investment exclusions are also applied to tobacco, alcohol, arms companies, etc. Preferred extractive companies are those working to appreciably reduce their carbon footprint and which are in the vanguard of strategic and operational change towards meeting Paris Accord goals.

Through its deep understanding of the critical role of the extractive and energy sectors, the Society is not anti-fossil fuels. Its investment policy reflects a balanced consideration of how to best achieve the Paris Accord targets and encourage progress towards meeting of the UN Sustainable Development Goals.

For full details of the Responsible Investment Policy, refer to www.geolsoc.org.uk/About/policies

RESEARCH GRANTS

Applications are invited for the 2021 round of the Society research grants. Please download the form from the Society Awards and Research Grants page at www.geolsoc.org.uk/grants where you will also find information about all the grants.

The Research Grants committee meets once annually. Applications must reach the Society no later than **12 noon on 8 February 2021** and must be supported by two Fellows of the Society who must each complete a supporting statement form. The committee will only consider complete applications on the appropriate form.

PUBLIC LECTURE SERIES

Virtual Public Lecture: 'Reading the ground' to reduce hazards and risks in engineering projects

Speaker: Andrew Hart, Atkins' Ground Engineering practice

Location: Online

Date: 3 December

Time: 6pm GMT

Further information

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

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 BUSINESS

THE FUTURE OF *GEOSCIENTIST*

2021 will see major developments in *Geoscientist*. Online delivery will increase, providing current news and allowing more opportunities for timely contributions from Fellows and others. Printed copies will be published quarterly, focus on in-depth features and aim to be quality issues that you want to return to and thumb well.

These changes have been planned for a number of reasons, and were considered and endorsed by Council in September. Firstly, the ways people access news have changed and continue to do so. Online access is now the first choice of most. There's an expectation of following developing news as it happens and discovering new findings as they are released. Online *Geoscientist* will aim to meet these expectations, developing with the Society's website and social media channels. Opinions and comments will be welcomed and build on the letters' section that is already a feature of the website.

Secondly, moving to quarterly issues of *Geoscientist* will enable us to focus our resources on a quality magazine that can take long, in-depth views of topics and provide wide perspectives, both visually and in scope. The contents of these issues will dovetail with the news and views on the website, and each issue will continue to be available online. The vibrancy of the new quarterly issues will be reinforced by a new design and production process, which has just been tendered for.

Lastly, and just as critically, the editorial team has been looking at how best to use its resources and find what savings can be made. Developing the magazine on-line and focusing on fewer, but quality, printed issues makes best use of the resources available. Fewer printed issues also reduce print and distribution costs, as well as environmental impacts, and you will have seen that the Society has offered for you to opt out of receiving a print copy.

I hope you will appreciate the reasons for the changes I have outlined above and be pleased with the results. *Geoscientist* depends on your interest, contributions and opinions. Please keep involved, feed us your ideas and let us know your views on the new developments as they unfold.

Prof. Andy Fleet, Editor-in-Chief, Geoscientist magazine

STICKS & STONES

This issue marks the final instalment our Sticks & Stones cartoon. Dalston, Gibbet, Morag and Edgar are off to pastures new, and you can find out what happens to them by visiting www.stonechatproductions.co.uk. On behalf of the Editorial Team and our Fellows, I offer sincere thanks to Dave Hughes for introducing us to these quirky characters (in whom I'm sure many of us recognise some familiar character traits) and for the regular chuckles.

Amy Whitchurch, Editor, Geoscientist magazine

THE YEAR OF SPACE

We are now at the eve of the Society's 2021 Year of Space. Back in July we celebrated the launch of the NASA *Perseverance* rover with an online Q&A with a group of planetary geologists (you can find the full Q&A on the Society's Instagram Stories https://www.instagram.com/geolsoc/), and now the rover is on its way to Mars where it is due to land on 18 February 2021. You can follow Perseverance's journey live on the NASA website (https://mars.nasa.gov/mars2020/)—as of November, *Perseverance* was travelling at an incredible 61,260 mph (relative to the sun)!

For the Society's Year of Space, we're still busy working on a number of projects and activities. We're excited to announce there will be an entire virtual lecture series on the '*The Geology of Other Planets: A geological journey through our solar system and beyond*'. Tune in as planetary geologists take you on a tour of the rocks and landscapes found on other planets and rocky bodies across the solar system and beyond! We'll learn about the geology of Mercury, our Moon, Mars, the asteroid belt and more in this fantastic lecture series open to all. Information on dates, speakers and how to register will be available on our website here: https://www.geolsoc.org.uk/space21.

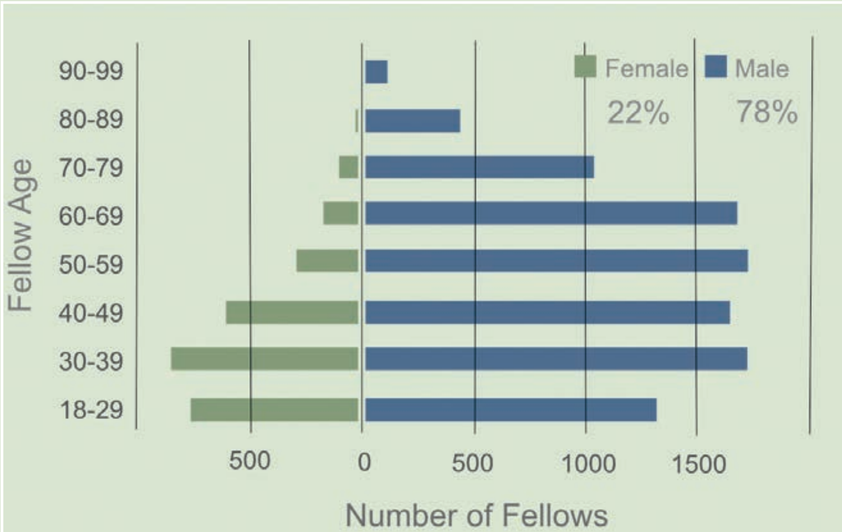
Along with this dedicated lecture series, there will also be some space-themed lectures as part of our popular Public Lecture series. The 2021 series will be held virtually and so will be available wherever you are! Stay tuned for announcements on our space-themed events as part of our regular research conference programme, including a 2-day conference on the *Moon and Early Earth* on 29-30 November 2021.

Look out for an extension to the 100 Great Geosites, but this time with sites in SPACE, as well as education and outreach activities, such as a workshop on planetary landscapes, education resources on planetary geology and some excellent fun facts about rocks across the solar system and beyond!

Flo Bullough, Head of Policy and Engagement

SOCIETY NEWS

LOOKING TO THE FUTURE: THE SOCIETY'S STRATEGIC OPTIONS REVIEW



Membership Demographics: Gender and age distribution

The Society's President, Mike Daly, recently reported that a 'Strategic Options Review' was underway to 'consider our future direction and specifically the relevance of our science and membership programmes' (Geoscientist 30(7), 16-19, 2020). Megan O'Donnell and Richard Hughes report on the outcomes of that review and the directions our Society will take.

Emerging challenges

Membership numbers have been in decline since their peak in 2017, and some demographics and marginalised groups are underrepresented. There is a perception that the Society has not kept up to date with emerging trends in the Earth sciences, and has a reputation for traditionalism and exclusivity that acts as a barrier to some.

Record low enrolments in Earth science degree programmes suggest a decreasing popularity of our science, and evidence suggests that the Society is falling out of favour with the next generation of Earth scientists, who communicate and network differently to their predecessors.

Strategic objectives

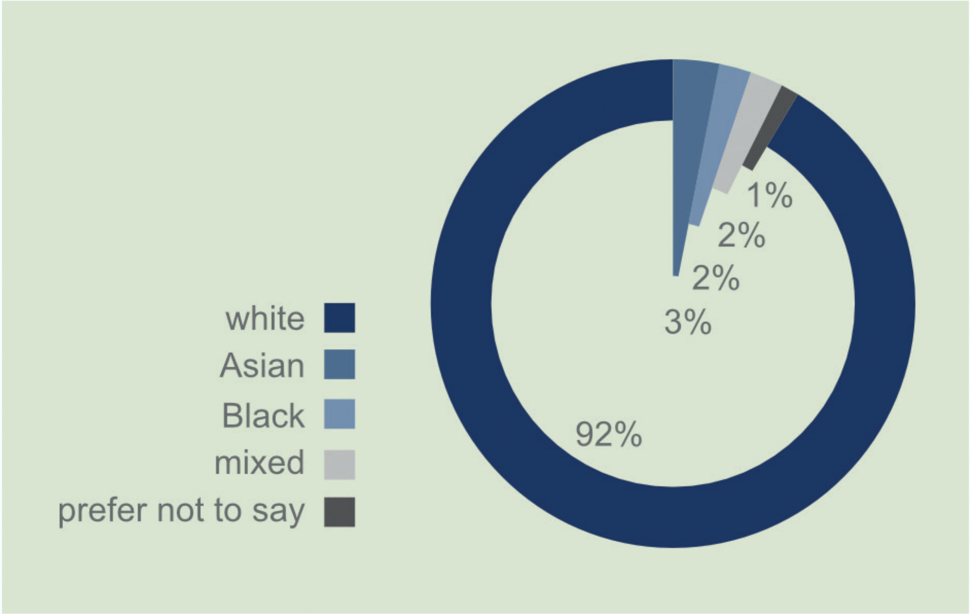
Over the past several months, a team of Society staff working with pro bono support from an international consultancy firm and extensive stakeholder input, sought to review and recommend the ways in which our Society could strengthen itself against these challenges. In September, the Society's Council agreed upon four key strategic objectives aimed at bringing new focus to the science programme, strengthening our existing professional development and education work, tackling diversity challenges and catalysing progress on key operational fronts.

> "THE SOCIETY'S MEMBERSHIP SHOULD REFLECT THE BREADTH OF OUR COMMUNITY, OFFERING A 'HOME' FOR EVERY EARTH SCIENTIST."

1. Advance multidisciplinary Earth science to inform global issues

In order to offer a high-profile and relevant science program that connects our members across key societal issues, drives innovation, investment and

What your society is doing at home and abroad



Membership Demographics: Ethnicity

collaboration, and informs public debate, the Society will bring new focus to five key science themes: geohazards, geoengineering and georesilience; climate & environmental change; the energy & materials transition; planetary science; and digital & technological innovation in the Earth sciences.

2. Support professional development, careers and education in Earth science

Advocating for the Earth sciences and communicating the societal relevance of the discipline to prospective students will be integral to fostering a diverse, inclusive and high-calibre future generation of experts. Stronger links with academic institutions will be key, supporting educators, researchers and technicians by offering an accessible Society membership structure for all.

The Society recognises its pivotal role in supporting the education and development of Earth scientists across the breadth of the education spectrum. Its unique position as the accreditor of degree courses, as well as the sole offering body for professional qualifications such as Chartered Geologist, provides a strong basis upon which to guide the subject and its practitioners to excellence at every stage in their career.

3. Be the inclusive and collaborative home for UK Earth scientists, and increase our international orientation

The Society's membership should reflect the breadth of our community, offering a 'home' for every Earth scientist. To do this, we need to establish both mechanisms and initiatives to drive change, and we welcome input from those already active in this area. Deploying an equitable and accessible membership model is the Society's greatest priority in this area, and a review and consultation period is underway. Specifically, the Society recognises the need to attract and retain female, Black, Asian, and minority ethnic Earth scientists across the breadth of its membership to claim a truly inclusive and representative community.

4. Become a dynamic and responsive organisation with a strong digital identity

The Covid-19 pandemic has accelerated the adoption of digital solutions at a revolutionary pace. The Society will be challenged to meet its members' rapidly evolving expectations for virtual conferences, field trips and meetings, digital networking platforms and discussion forums. Prioritising digital solutions that drive member engagement and enable sector-wide participation will be key.

Finally, adopting a consistent and strong visual brand across the Society's many communication channels will enable the Society to stand out clearly, professionally, and recognisably as the national body.

Optimism

The four strategic priorities outlined above build upon and bring focus to our 2017-27 strategy. They were developed following detailed research, extensive consultation, reflection, and robust discussion. We head towards 2021 with pride in our accomplishments and with great optimism for our future. We hope you will join us on our journey towards a new future for the Society, confident of its place in the Earth sciences ecosystem.

SOCIETY *NEWS*

What your society is doing
at home and abroad

GEOCONSERVATION COMMITTEE MEMBER MATTHEW PARKES

The Society is saddened to hear of the sudden passing of Dr Matthew Parkes. Matthew was Assistant Keeper for Earth Science collections at the National Museum of Ireland and a long-serving member on the Society's Geoconservation Committee, as well as the Geological Curator's Group where he was chairman until 2019. His areas of expertise were Irish collections, palaeontology and geology, and his passions included promoting Ireland's geological and mining heritage through publication and outreach activities.

One of his greatest legacies is the Irish national programme of County Geological Audits, which Matthew initiated in 2004 with the publication of counties Sligo and Carlow. He continued to have a central role in each County Audit to the present day and was the author of several follow-up outreach books and exhibitions.

He was also instrumental in securing Ireland's only geological monument, the Valentia Tetrapod Trackway in Kerry, through the purchase of the site by the Government of Ireland.

Matthew held numerous offices throughout his career: he was a proactive, long-term Irish representative with the European association for the conservation of geological heritage (ProGEO); a Chairman of the Mining Heritage Trust of Ireland (MHTI); and the Editor of Earth Science Ireland.

Matthew was a founding member of the Institute of Geologists of Ireland (IGI) and was involved in several IGI working groups, including the Ethics Committee on which he had served on since 2010.

In terms of his work with the Society, his efforts in helping to put together the 2018 Geoconservation Annual Gathering Dublin, where he worked closely with Society staff, were critical in the facilitation of discussions and the sharing of geoconservation projects and challenges across the island of Ireland, as well as the sharing of best practice for geoconservation practitioners.

The Society extends its sincere condolences to his colleagues, friends and family.

Flo Bullough, Head of Policy and Engagement

THE ROYAL COMMISSION FOR THE EXHIBITION OF 1851

The President of the Society is an ex-officio Commissioner of the Royal Commission for the Exhibition of 1851. Applications are open for their various awards, including Research Fellowships. For further information please go to: **www.royalcommission1851.org/awards/**

CHRISTMAS AND NEW YEAR CLOSURE

The Society (London and Bath) will close to Fellows at 15.00 on Thursday, 23 December, re-opening at 09.30 on Thursday, 7 January 2021.

Please note that due to Covid-19, visits are by pre-appointment only. Please see our website for more details: https://www.geolsoc.org.uk/contact

REMINDER: CALL FOR NOMINATIONS TO COUNCIL AND TO SERVE AS PRESIDENT

Fellows are reminded that the closing date for the receipt of nominations for Council and for President designate is **12noon on Friday, 8 January 2021.** You can play an active role in the delivery of the Society's strategy, with opportunities to influence a refreshed and forward-looking Strategy and science programme, to facilitate the communication of science to the media, public and policy makers, and to the certification of best practice in education and the profession.

Council appointment is open to any Fellow irrespective of age, gender, employment or career stage. Nominations from candidates with trustee experience and expertise in scholarly publishing and fundraising are particularly welcome. We strongly encourage nominations from post-doctoral researchers, early and mid-career academic scientists.

Council convenes five times a year (usually Wednesday): four of those meetings take place in the afternoon 14.00 - 17.00. In addition, there is normally a two-day meeting, usually in late September, to discuss strategic issues. All members of Council also serve on one of the standing committees which usually meet three or four times a year. Currently all meetings are held virtually and virtual attendance will continue to be an option. The typical time commitment is eight to ten days annually for ordinary members of Council.

The President-designate nominees will have distinguished themselves in their chosen sector of geosciences and will have achieved further recognition in industry, academe or government. The President chairs the Council meetings and the Elections and Awards Committees, and has the option to introduce some of the public lectures which are held at Burlington House. The presidential term is June 2022- June 2024 and could involve in the order of ~25 days work a year preparing for and chairing Council and general engagement in Society business. The year preceding (June 2021-June 22) they serve as President designate.

Details of the process and the nomination forms for Council and for the position of President-designate are located on the Governance section of the website. Here you can also see the names of those members of Council due to retire at the AGM in June 2021. Please visit the Governance section of the website: **www.geolsoc.org.uk/councilelection**s or for further queries or additional information please contact **christinamarron@geolsoc.org.uk**

Corporate Patrons

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

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

Benefits

As a not-for-profit organisation, the Society greatly values our Corporate Patrons and we offer a wide range of benefits in return for support.

These include employee use of our prestigious central London premises in Burlington House, invites to exclusive networking events, special rates on conference attendance, access to one of the largest geoscience libraries in the world and other rewards.

'Access to the Society's historic venue and the unique networking opportunities provided by the Society are all immensely valuable. Even more importantly, we are proud to be associated with an organisation that is relevant to our business and championing the future of geosciences in this ever-changing world.'

Iain Bartholomew
Subsurface Director, Siccar Point Energy

Please get in touch

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

Image: © Alberto Restifo

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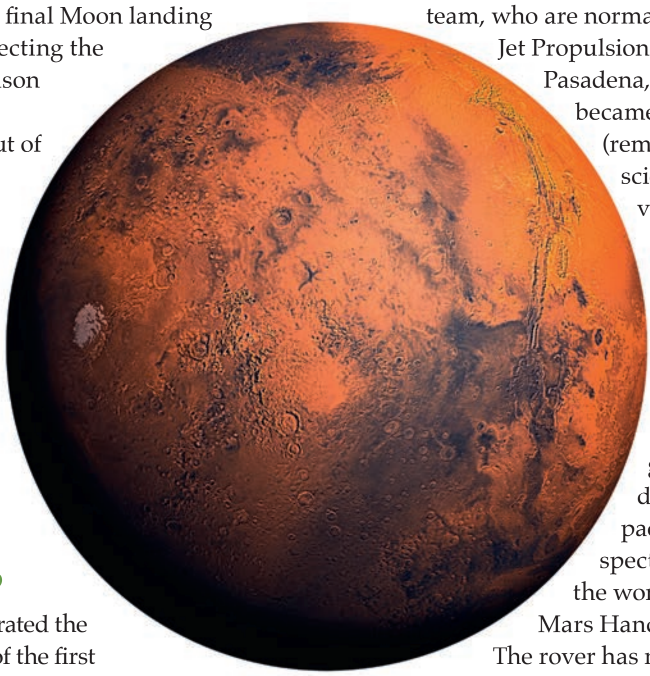
Geological appropriation?

Roger Dunshea questions whether manned missions to Mars are worth the cost, given technological capabilities

The pandemic-induced lockdown has given some of us more time to explore new interests. Lunar and martian geology tickled my fancy. Back in the mid-1970s, as an undergraduate at Liverpool University, I had the pleasure of examining some anorthosite samples collected during the Apollo 17 mission—NASA's final Moon landing in 1972. After collecting the samples, Dr Harrison Schmidt, the only geologist astronaut of the programme (who incidentally 'bumped' a physicist from the launch team) was filmed throwing his rock hammer far across the lunar surface!



Scientific exploration?

Last year we celebrated the 50th anniversary of the first Moon walk, when Neil Armstrong stepped off the Eagle Lunar Module. The overall aim of the Apollo programme, as stated by President John F. Kennedy in 1961, was "... landing a man on the Moon and returning him safely to the Earth". Another mission goal was scientific exploration that included the collection of lunar samples and, indeed, Neil's first action on the lunar surface was to scoop a wee pouch of Moon soil. In reality, of course, the mission was above all about politics, national rivalries and the military industrial complex. It was not driven primarily by geological and related scientific enquiry. Geology was appropriated to help justify the costly programme to the US tax payer.

Is history repeating itself? In September 2019, at a press briefing with Australian Premier Scott Morrison, President Trump exclaimed " 'Hey, we've done the moon. That's not so exciting.' So we'll be doing the moon. But we'll really be doing Mars". In a chat about rockets and commerce, Trump signalled his intent for manned missions to Mars.

Robotic geologists

Over on the Red Planet, the *Curiosity* rover is still going strong on its fourth Martian year and counting. During lockdown, the *Curiosity* team, who are normally based at the Jet Propulsion Laboratory in Pasadena, California, became home workers (remote working of a scientific survey vehicle averaging 140 million miles away on the Red Planet with family in the room must be great fun). The rover is a geologist's dream machine, packed with a drill, spectrometers and the wonderfully named Mars Hand Lens Imager. The rover has now also been programmed with artificial intelligence to select its own target areas. *Curiosity* is essentially a robotic geologist and has been a fantastic success in revealing the geology of Mars.

The current pandemic has fundamentally reset our thinking on the use of remote working, artificial intelligence and digitalisation in many fields—amazing technical opportunities lie ahead. With such developments, a future *Curiosity* type rover would certainly deliver much more science and for much fewer bucks than sending humans to Mars. We must guard against our science being appropriated again for tenuous political justification.

Roger Dunshea holds a number of non-executive roles in the UK public sector and his main geological interest is the Moine Supergroup.

Further Reading list available online.

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?

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

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> "A FUTURE *CURIOSITY* TYPE ROVER WOULD CERTAINLY DELIVER MUCH MORE SCIENCE AND FOR MUCH FEWER BUCKS THAN SENDING HUMANS TO MARS"

Latest News from the Publishing House

Understanding the Earth: the contribution of Marie Tharp

By Bettie Matheson Higgs

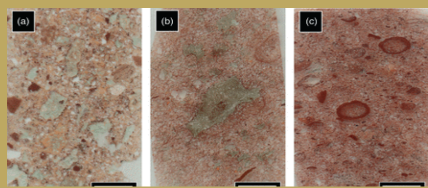
Marie Tharp worked all her life as a geoscientist, and for the most part for the recognition and benefit of her male colleagues. She was employed to assist researchers at Columbia University. Her male colleagues readily used her ingenuity and insights without giving her recognition. Marie tolerated this at first but eventually began to ask for recognition for her own work. Her most influential work was the production of physiographical maps of the ocean floor.

Read more on the Lyell Collection
sp.lyellcollection.org/content/early/2020/10/12/SP506-2019-248

The Mesoproterozoic Stac Fada Member, NW Scotland: an impact origin confirmed but refined

By G. R. Osinski, L. Ferrière, P. J. A. Hill, A. R. Prave, L. J. Preston, A. Singleton and A. E. Pickersgill

The origin of the Stac Fada Member has been debated for decades with several early hypotheses being proposed, but all invoking some connection to volcanic activity. In 2008, the discovery of shocked quartz led to the hypothesis that the Stac Fada Member represents part the continuous ejecta blanket of a meteorite impact crater, the location of which was, and remains, unknown. In this paper, we confirm the presence of shock-metamorphosed and -melted material in the Stac Fada Member.



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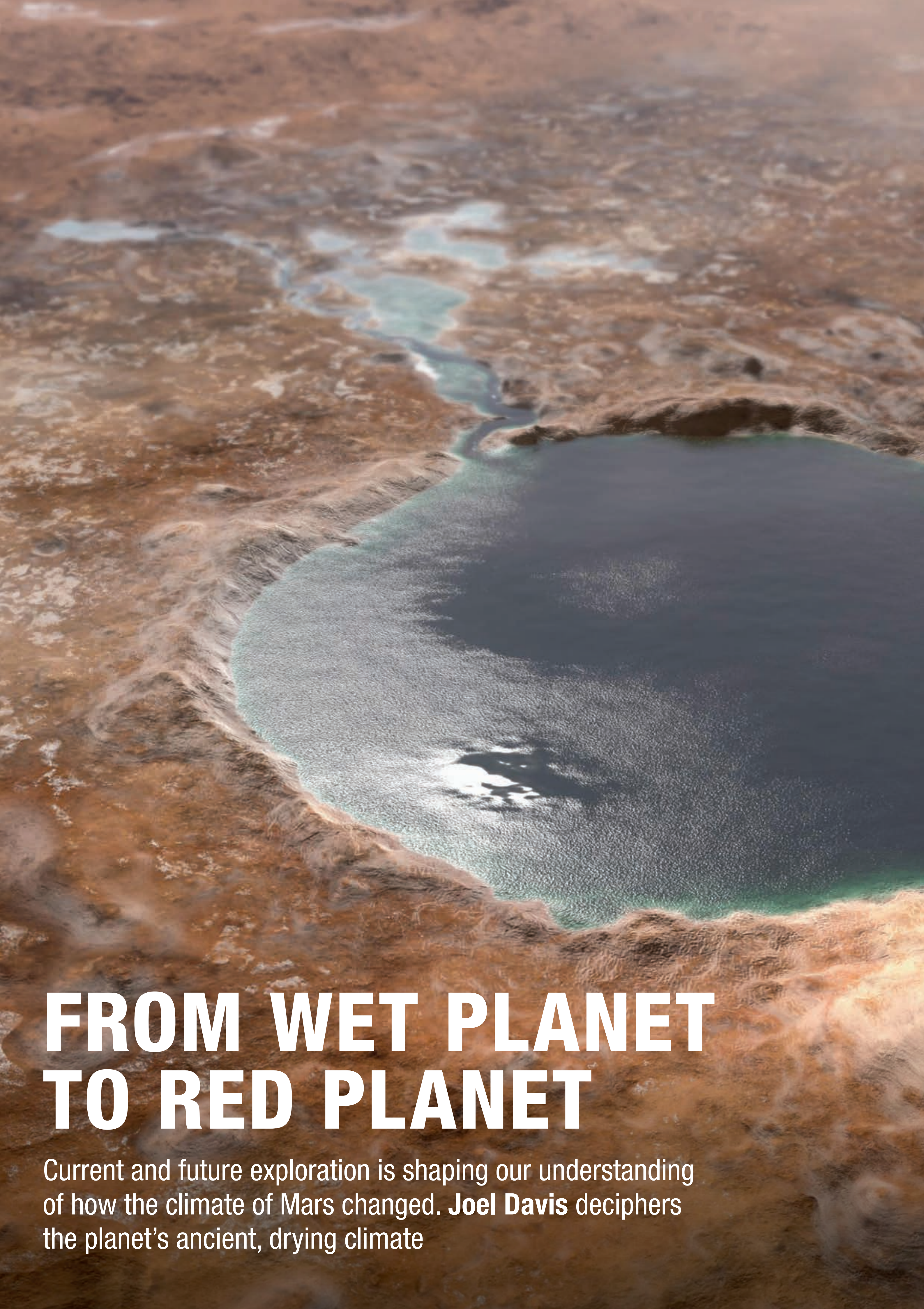
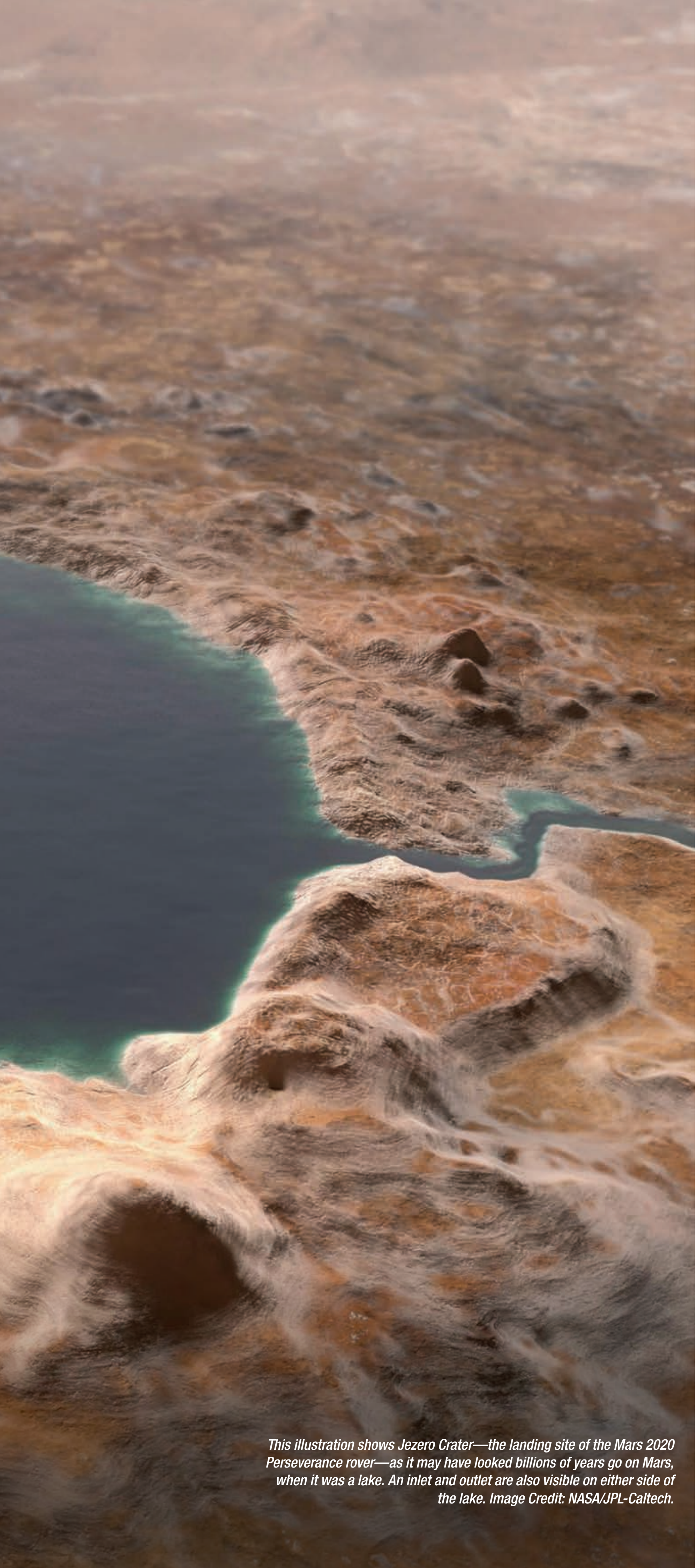


FROM WET PLANET TO RED PLANET

Current and future exploration is shaping our understanding of how the climate of Mars changed. **Joel Davis** deciphers the planet's ancient, drying climate



This illustration shows Jezero Crater—the landing site of the Mars 2020 Perseverance rover—as it may have looked billions of years go on Mars, when it was a lake. An inlet and outlet are also visible on either side of the lake. Image Credit: NASA/JPL-Caltech.

It has been an exciting year for Mars exploration. 2020 saw three spacecraft launches to the Red Planet, each by different space agencies—NASA, the Chinese National Space Administration, and the United Arab Emirates (UAE) Space Agency. NASA's latest rover, *Perseverance*, is the first step in a decade-long campaign for the eventual return of samples from Mars, which has the potential to truly transform our understanding of the still scientifically elusive Red Planet. On this side of the Atlantic, UK, European and Russian scientists are also getting ready for the launch of the European Space Agency (ESA) and Roscosmos *Rosalind Franklin* rover mission in 2022.

The last 20 years have been a golden era for Mars exploration, with ever increasing amounts of data being returned from a variety of landed and orbital spacecraft. Such data help planetary geologists like me to unravel the complicated yet fascinating history of our celestial neighbour. As planetary geologists, we can apply our understanding of Earth to decipher the geological history of Mars, which is key to guiding future exploration. But why is planetary exploration so focused on Mars in particular? Until recently, the mantra of Mars exploration has been to follow the water, which has played an important role in shaping the surface of Mars. Liquid water is also thought to be key to the formation and evolution of life. However, it is not the present martian environment that shows the richest evidence for water—it is the ancient geological past.

Today, Mars is a cold, hyper-arid desert. Its surface is mostly covered by a thin layer of iron oxide dust, giving the Red Planet its characteristic red-orange hue, visible even with the most basic of telescopes from Earth. And we know that Mars is dry—the pressure from its thin CO_2 atmosphere is so low that liquid water at most latitudes would instantly boil to vapour. Towards the poles, water-ice is stable in the shallow sub-surface of the martian regolith and thick water-ice caps cover both the north and south poles. But liquid water, for the most part, is not thought to be stable anywhere ▶

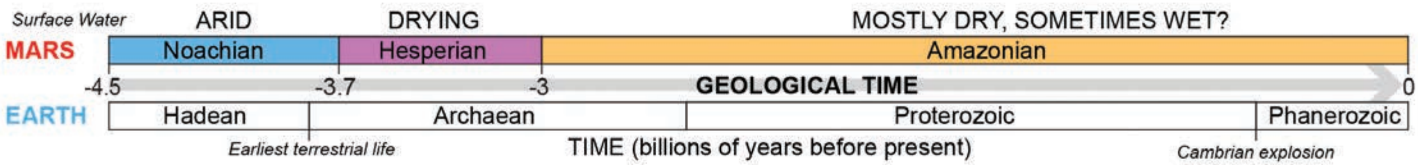


Figure 1: Geological time scale of Mars (and its inferred climate) compared to Earth

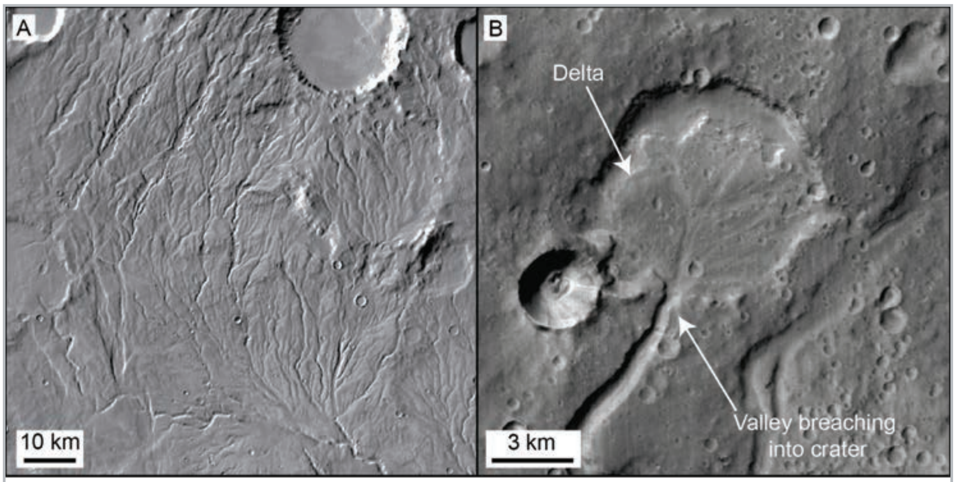
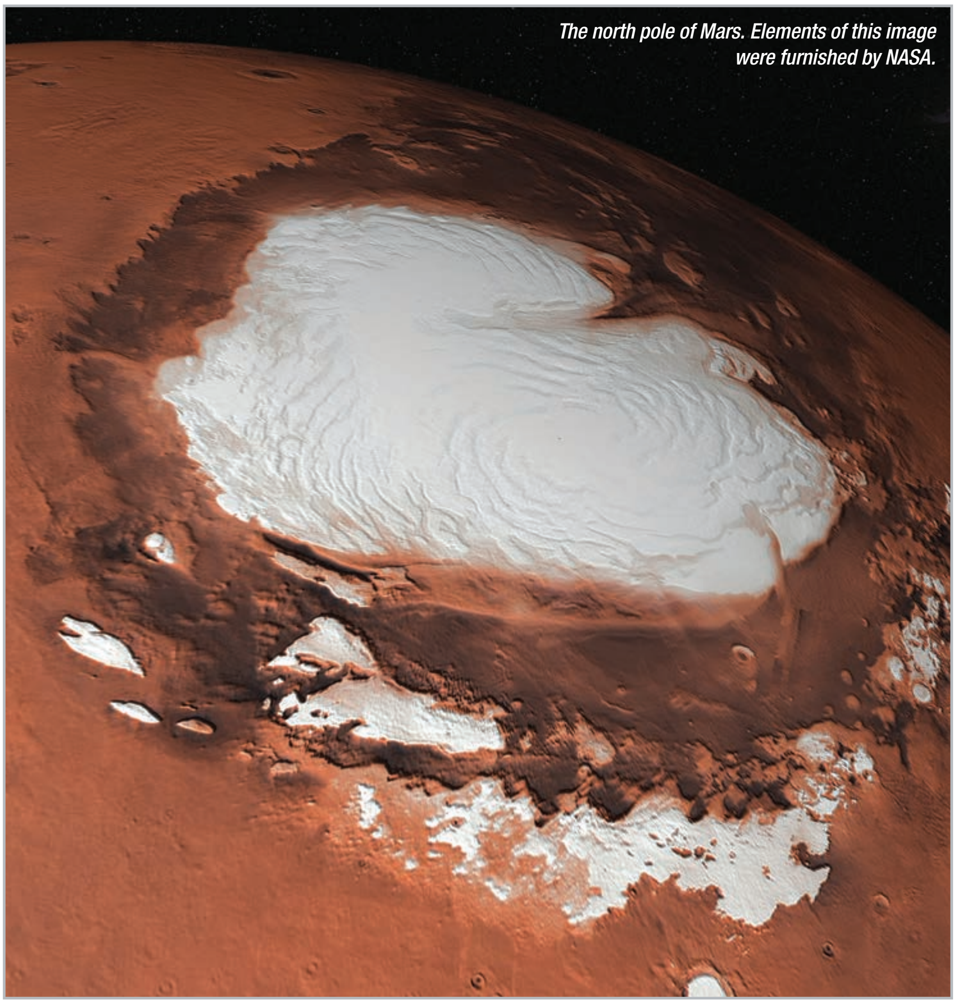


Figure 2: (A) Satellite image of a valley network on Mars with multiple branching tributaries, a former river system. Inferred flow direction is from the top to the bottom of the image. Credit: NASA/JPL/ASU. (B) Satellite image of valley network breaching into impact crater, likely the site of a palaeo-lake. A delta has formed at the breach. Credit: NASA/JPL/MSSS



The north pole of Mars. Elements of this image were furnished by NASA.

across the planet. The geology of Mars today tells us that in the ancient past, Mars was a very different place.

Water on Noachian Mars

Nearly four billion years ago, in the early days of the Solar System, the surface of Mars was being re-sculpted by volcanism and intense impact cratering. This geological period on Mars is known as the Noachian, spanning from the planet's formation around 4.5 billion years ago (Ga) to about 3.7 Ga (Fig. 1). Unlike on Earth, geological periods on Mars are determined from the density of impact craters on surfaces (with more impact craters accumulating over time). Surfaces are then assigned absolute ages by calibrating to the Moon, where surfaces have been dated using the Apollo samples.

Around half of the martian surface is Noachian aged and across most of these surfaces we see strong evidence for liquid water. Cutting across many Noachian surfaces are what we as Mars geologists colloquially refer to as the "valley networks". When viewed from orbit, these valley networks are linear to branching erosional troughs that follow topography. They resemble river valleys on Earth and are thought to have formed in a similar manner, through precipitation and water erosion (Fig. 2). The largest valley networks form systems up to 5,000 km long, equivalent to many continental-scale drainage basins on Earth.

We have known about these valley networks since the Viking era of Mars exploration in the 1970s. Although there was initially some discussion about whether these features could have formed via other mechanisms (such as lava), it is now generally accepted that they formed via water erosion. However, it is unclear how long these features took to form. The valley networks have not fully eroded the Noachian landscape (many ancient impact craters are still preserved), which suggests that they were only active for geologically brief periods of time, perhaps as little as a

> UNTIL RECENTLY, THE MANTRA OF MARS EXPLORATION HAS BEEN TO FOLLOW THE WATER, WHICH HAS PLAYED AN IMPORTANT ROLE IN SHAPING THE SURFACE OF MARS. LIQUID WATER IS ALSO THOUGHT TO BE KEY TO THE FORMATION AND EVOLUTION OF LIFE. HOWEVER, IT IS NOT THE PRESENT MARTIAN ENVIRONMENT THAT SHOWS THE RICHEST EVIDENCE FOR WATER—IT IS THE ANCIENT GEOLOGICAL PAST.

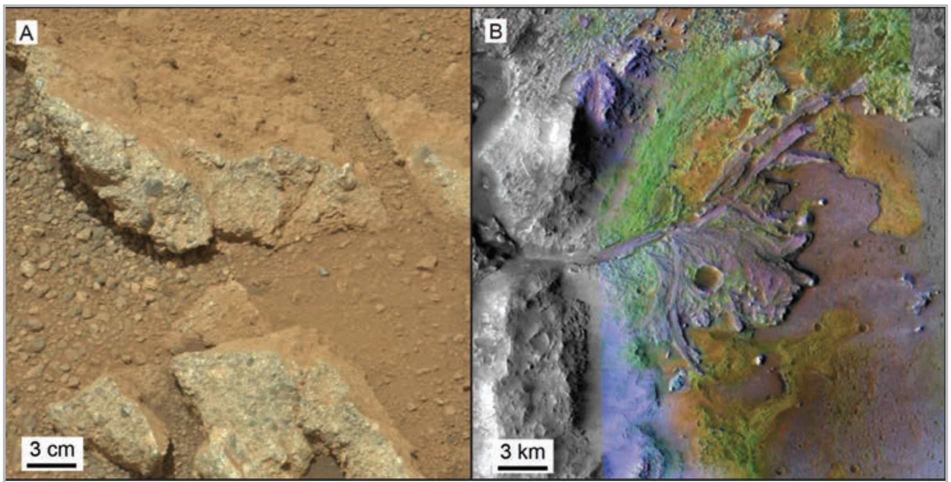


Figure 3: (A) Image from the Curiosity rover of a conglomerate in Gale crater, likely deposited by an ancient river. Credit: NASA/JPL/MSSS. (B) False colour satellite image of the delta in Jezero crater, the future landing site of NASA's Perseverance rover. The false colours indicate variations in composition. Credit: NASA/JPL/ASU

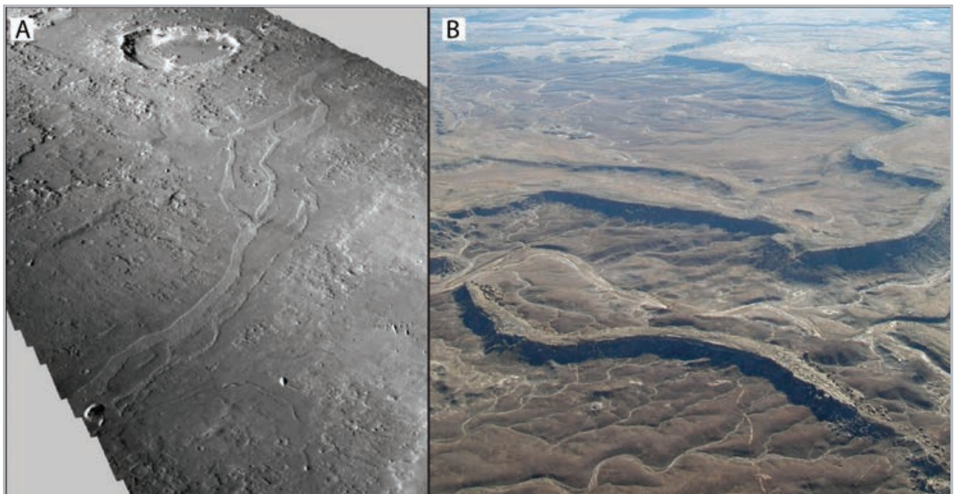


Figure 4: (A) 3D perspective view of a 100-km-long ridge system on Mars, interpreted as exhumed river channel sediment (an "inverted channel deposit"). Credit: NASA/JPL/MSS/Matt Balme. (B) Aerial view of Jurassic river channel deposits in Utah, USA, preserved as a ridge. Credit: Rebecca M.E. Williams

few thousand years or maybe as long as ten million years—either way, a small fraction of the total time in the Noachian.

Excitingly, valley networks have been observed to intersect impact craters, suggesting that in the Noachian water may have pooled in the craters to form a lake (Fig. 2). Gale crater, the exploration site for the *Curiosity* rover since 2012, is one of these palaeo-lakes (Fig. 3; although it is unclear if Gale represents a Noachian lake or is younger in age). At least 200 large palaeo-lakes have been identified on the surface of Mars so far. In many, we find fan-shaped sedimentary deposits, interpreted as ancient river deltas that formed within crater lakes. These deltas are defined by the branching remains of channels and meanders, and are considered a prime target for the detection of ancient life on Mars due to the ability of deltas to concentrate potential organic matter. However, in Earth's rock record it is rare for such deltaic deposits to be preserved in planform (that is, where their shape from above is still recognisable), so we have a limited understanding of how much geological time these features represent. NASA's *Perseverance* rover will begin to explore one of these ancient deltas at Jezero crater in 2021 (Fig. 3).

Another unusual landform found on Noachian surfaces are "inverted channel deposits". These features are amalgamations of river channel sediment that became resistant to erosion and are now preserved as ridges in the landscape instead of depressions (Fig. 4). River channel deposits preserved as ridges seems unusual, but similar features exist in deserts on Earth: in Oman, Egypt, and the American southwest. Much of my own research is devoted to the investigation of these fascinating features, which cross the boundary between geology and geomorphology. Whilst the valley networks represent upland, erosional rivers, we think that the inverted channel deposits were the lowland, depositional rivers set within alluvial floodplains. Like many features on Mars, we are only beginning to understand the formation of the inverted channel deposits, but they could potentially represent millions of years of geological time, perhaps even more than the valley networks. Many of these inverted channel deposits are found adjacent to phyllosilicate-bearing rocks, which formed in the presence of water. Phyllosilicates and other aqueous minerals are particularly common on Noachian surfaces; significant amounts of water would have been required to alter Mars's basaltic crust and generate these minerals.

Taking a step back, when viewing Mars as a whole, we can see that chains of valley networks and palaeo-lake basins flow northwards, possibly representing the remains of a planet-wide hydrological cycle. These systems converge on the edge of Mars's northern lowlands—a huge basin that makes up one third of the martian surface (Fig. 5). There is ample discussion about whether this hemisphere-spanning basin once contained an ocean-sized body of water; ▶

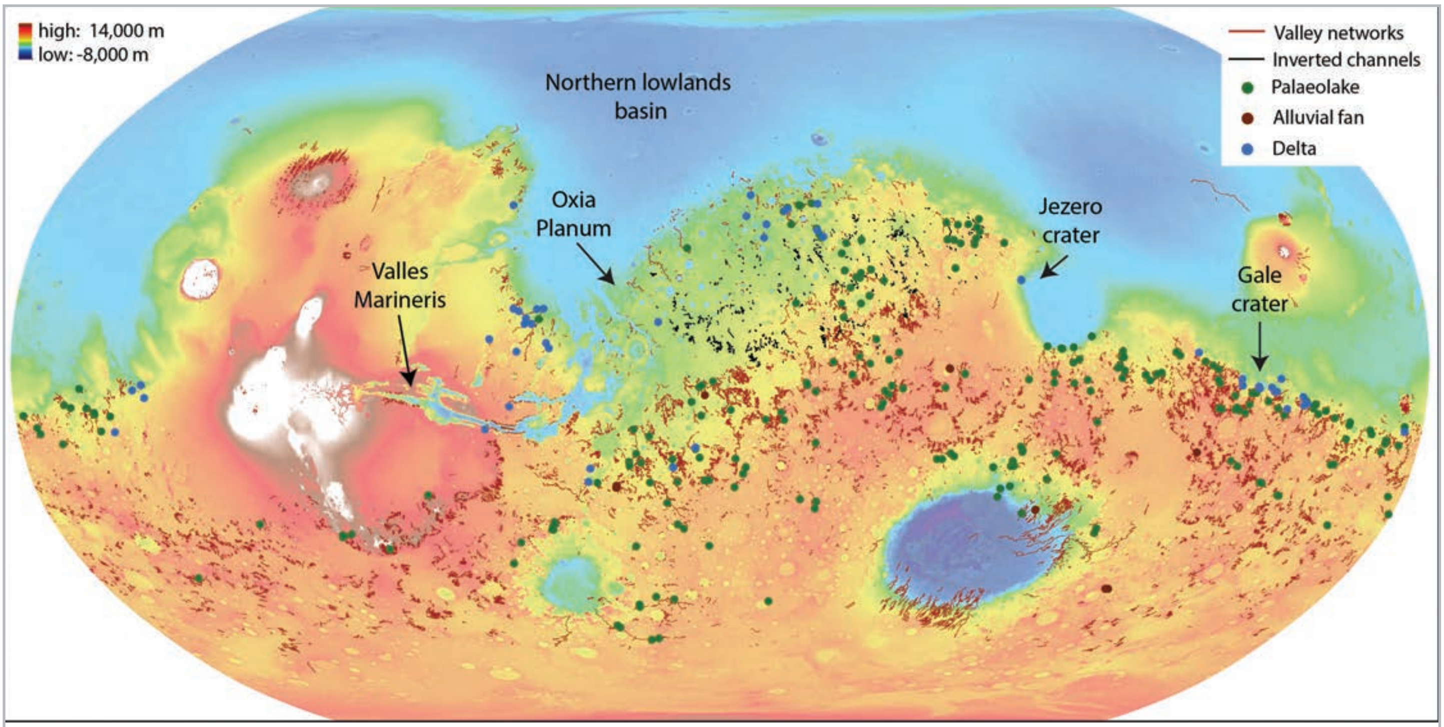


Figure 5: Topographic map of the surface of Mars. Most of the features formed by water are concentrated on the oldest, Noachian terrains, and converge on Mars's northern lowland basin. Credit: NASA/JPL/GFSC

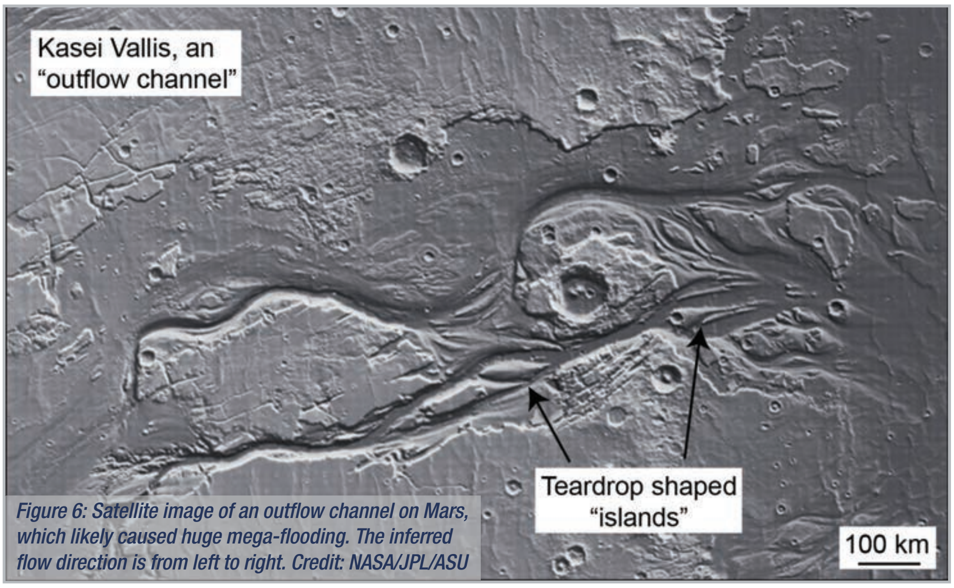


Figure 6: Satellite image of an outflow channel on Mars, which likely caused huge mega-flooding. The inferred flow direction is from left to right. Credit: NASA/JPL/ASU

▶ indeed, it is almost completely unknown whether there was enough water on the surface of Mars to fill such a vast basin. However, detailed analysis of Mars's geology can provide a framework to begin to address this fascinating question. My colleagues and I recently investigated an ancient delta deposit located at the end of a large valley network system called Hypanis Vallis, at the edge of the northern lowlands basin. The geology of the Hypanis delta suggests that it formed into a large body of water and grew in response to a falling water level—a receding northern ocean perhaps? Luckily for us, in 2023 the *Rosalind Franklin* rover will land at location called Oxia Planum, on the margins of the northern plains, so answering this question about the existence of an ancient Noachian ocean may not be too far off.

The Mars climate problem

There is abundant geological evidence from both orbiting spacecraft and rovers for water in the Noachian. But how was liquid water able to exist on ancient Mars when today it cannot?

A commonly held assumption is that Mars had a thicker atmosphere in the Noachian than it does at present, and that some sort of CO_2-H_2O greenhouse effect raised the surface temperatures above freezing. Hence, Noachian Mars is often referred to as being "warm and wet". Measurements by NASA's MAVEN spacecraft indicate that the Noachian atmosphere was about 1 bar pressure, similar to Earth today (Mars is 0.006 bars currently), and composed of CO_2, most of which has since been lost to space. This loss of CO_2 to space also explains why we do not see extensive deposits of carbonate on Mars, the sedimentary sink for CO_2 on Earth. Mars's early atmosphere could have been shielded from removal by an ancient magnetic field, or perhaps CO_2 was continuously resupplied by volcanic gases. However, our problems in understanding the Noachian palaeo-climate are just beginning.

Although we can see extensive evidence for liquid water in Mars's Noachian rock record, we still do not fully understand the environment and climate that allowed it to exist. When climate modellers try to reconstruct the ancient Noachian palaeo-climate, the models often fail to show mean annual surface temperatures above freezing.

This issue largely comes from the "faint young Sun paradox", which is the idea that the Sun was much less luminous in its early history and so Mars received even less heat than it does today, and which the proposed greenhouse effect was unable to compensate for. So where does that leave liquid water in the Noachian? Well, an alternative scenario is that water on Noachian Mars was mostly frozen, locked up in thick ice caps in the high-elevation regions around the equator. Melting would only occur due to localised and brief episodes of heating, such as from volcanism or impact cratering. However, it is unclear whether these brief melting episodes in this "icy highlands" scenario are sufficient to explain Mars's Noachian geological record. Both the "warm and wet" and "icy highlands" scenarios are end members; the Noachian may have actually been somewhere in between these models—perhaps "occasionally warm and wet" is a better descriptor.

After the Noachian

Another major question that planetary geologists like myself are interested in is what happened to Mars after the Noachian? The fact that so much of this ancient geology is preserved for us to study today suggests that erosion after the Noachian was very slow. Correspondingly, we see a lot less evidence for long-lived liquid water in the geologically younger surfaces, which are divided into the Hesperian (~ 3.7-3.0 Ga) and Amazonian (~ 3.0-0 Ga) periods. The Hesperian and Amazonian geological records suggest that Mars became increasingly dry. This is the case at Gale crater, where we see temporal transition in the rock record from phyllosilicates (formed in the presence of water) to iron oxide (formed anhydrously). One idea to explain this is that following the Noachian, the removal of Mars's early thick atmosphere reached a point where it was no longer able to sustain liquid water for long periods of time. However, that is not to say that water was absent completely after the Noachian.

If we look at Hesperian surfaces, we see that many of them are cut by huge channel systems (Fig. 6). These features, known as outflow channels, strongly contrast with the valley networks in that they are hundreds of kilometres wide and thousands of kilometres long—individually! The outflow channels typically branch around teardrop shaped former islands, indicating that they had immense erosive power and probably required huge volumes of water to form. We can often trace the origin of the outflow channels to a single source region, which has led many to suggest that they formed by the rapid release of sub-surface water or the melting of large volumes of ice in mega-flooding events, an order of magnitude larger than the biggest floods we know of on Earth. However, these mega-floods were probably brief events, perhaps lasting as little as a few days, and do not necessarily require a warm climate to sustain them. Instead, the mega-floods may have been triggered by large volcanic eruptions or impact events.

> THERE IS ABUNDANT GEOLOGICAL EVIDENCE FROM BOTH ORBITING SPACECRAFT AND ROVERS FOR WATER IN THE NOACHIAN. BUT HOW WAS LIQUID WATER ABLE TO EXIST ON ANCIENT MARS WHEN TODAY IT CANNOT?

Within Mars's equatorial canyon system, Valles Marineris, we can see numerous, conical alluvial fans along the canyon walls (Fig. 7). On Earth (for example, in Death Valley, USA), alluvial fans form sub-aerially ▶

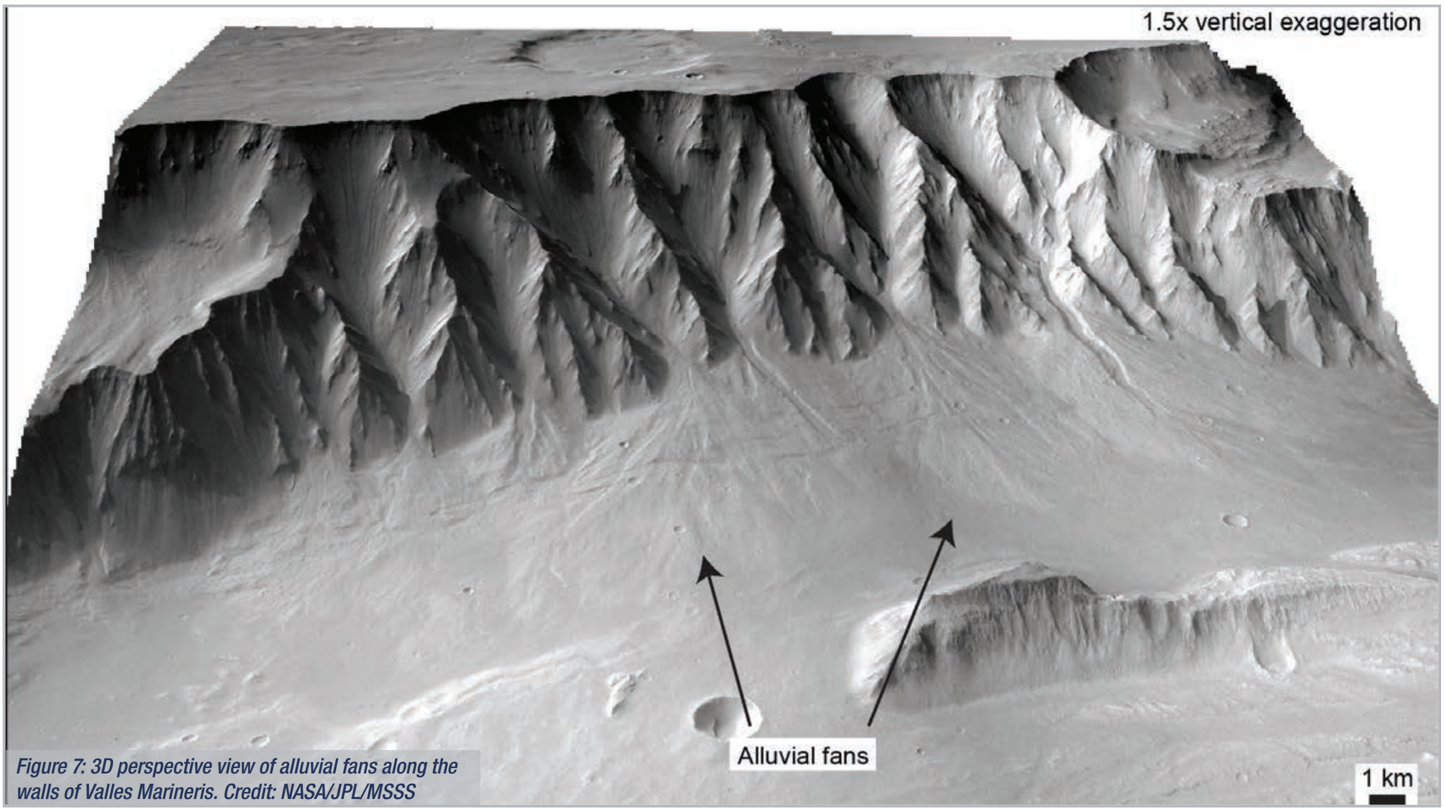


Figure 7: 3D perspective view of alluvial fans along the walls of Valles Marineris. Credit: NASA/JPL/MSSS

▶ in mountainous regions, driven by the episodic flow of water and sediment down a slope and into a dry basin, where it forms a fan. Interestingly, these alluvial fans are believed to have formed after the mega-flooding events and it is not entirely clear how the martian climate was able to sustain them. One idea is that local micro-climates may have existed in Valles Marineris and could sustain liquid water, leading to intermittent, geologically brief "wet episodes", in an otherwise dry climate. There are many other features recorded in the Hesperian and Amazonian surfaces that suggest that these intermittent "wet episodes" affected other regions of Mars as well. Although we do not see the global networks of former rivers that we do on Noachian surfaces, both Hesperian and Amazonian terrain show some evidence for the influence of liquid water, albeit a declining one. However, as we approach the geologically recent past, we see more and more evidence that Mars became entirely frozen, paving the way for today's hyper-arid surface environment.

Future exploration

Deciphering the ancient martian palaeo-climate and its evolution through time is one of the reasons why extensive, in situ rover investigations of the planet's Noachian geology are necessary. Indeed, both *Perseverance* and *Rosalind Franklin* will explore Noachian-age sites at Jezero and Oxia Planum, respectively. Despite their age, the rocks at Jezero and Oxia Planum may also record evidence that can explain how the climate of Mars changed after the Noachian, and whether liquid water continued to be available intermittently.

Perseverance could reveal whether the Noachian-age lake at Jezero crater was covered by ice, a possibility under the "icy highlands" scenario. *Perseverance* will also be the first spacecraft to investigate examples of inverted channel deposits and these deltaic landforms in situ. Excitingly, found at Jezero (and rarely for Mars) are deposits of carbonate-bearing rocks. Investigating how these carbonates formed and whether they were sequestered from an early, CO_2-rich atmosphere will provide key insight into the nature of the Noachian climate and its decline. One of the end goals of *Perseverance* is to cache various samples for eventual return to Earth. Having Noachian samples of known geological context finally in our hands will significantly advance our understanding because we will be able to establish absolute ages for events on Mars (as was the case with the Lunar Apollo samples).

The geological environment at Oxia Planum is less clear: it is set within a topographic basin that may have once hosted a lake or been on the margins of an ocean-sized body of water. Oxia Planum is also rich in phyllosilicate-bearing rocks, which for their formation required significant amounts of water to alter Mars's basaltic crust. But, like many things about Mars, exactly how these phyllosilicates formed is far from clear. The UK is leading the development of *Rosalind Franklin's* Panoramic Camera, which will be able to determine the composition and geological context of these aqueous minerals. Detailed mapping using orbital images, such as from the Colour and Stereo Science Imaging System (CaSSIS; Fig. 8), of both sites is currently underway to provide important geological context and to establish the locations of target outcrops for investigation, prior to landing.

Mars exploration is now moving towards the direct detection of ancient life, and this is the main objective of both *Perseverance* and *Rosalind Franklin*. However, establishing geological context for the local, regional, and global environment is imperative to enable us to confidently support any potential "life" claim. Mars, originally believed to have been a barren, volcanic landscape, is now proving to have a complex stratigraphy, rich in water-formed sedimentary rocks. For me as geologist, the exciting thing about both these upcoming rover missions is that they will be roving across and sampling the Noachian. They will be able to finally provide ground truth to our orbital observations and unravel the four-billion-year-old mystery of the Noachian climate and how it changed.

Figure 8: False colour CaSSIS image of Oxia Planum, the landing site for the Rosalind Franklin rover in 2023. The dark material to the left is thought to be mafic, volcanic material, whereas the orange and blue materials are hydrated phyllosilicate minerals, formed in the presence of water. Credit: ESA/University of Bern/UoA-Jason Perry

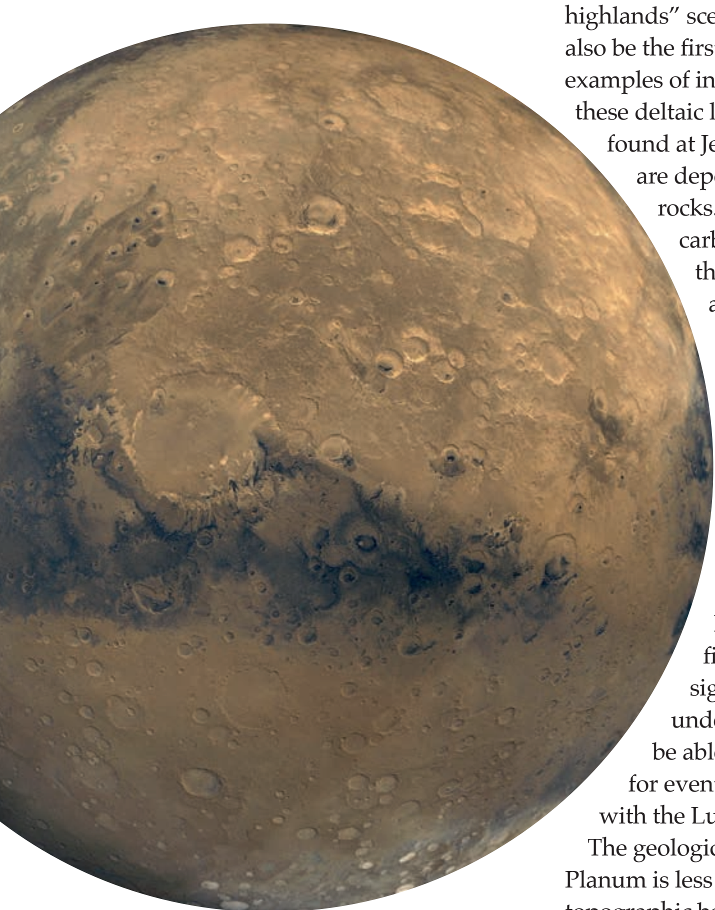
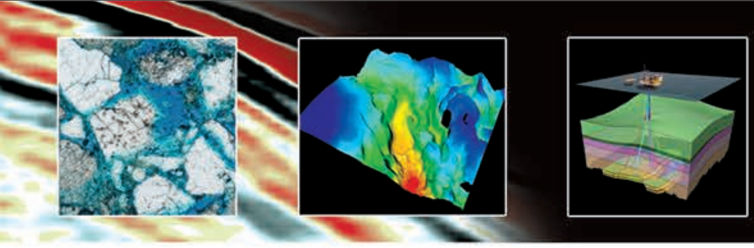


Photo: NASA/JPL-Caltech/USGS

Dr Joel Davis is a postdoctoral research assistant in the Department of Earth Sciences, Natural History Museum London



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Core has traditionally played a key role in the characterisation of conventional and unconventional hydrocarbon reservoirs, from exploration to mature production. It is the only means by which to observe and make measurements on actual reservoir rock. However, the recent oil industry downturn has driven many to question the value of taking core, due to the associated increased costs and potential risks to well operations. In tandem, advances in other reservoir visualisation techniques, such as seismic and borehole imaging, have been used to give weight to the contention that coring is an increasingly redundant means of characterising reservoirs.

Through four main themes this 5-day conference will aim to redress the balance in this debate by exploring the role core can, or should, play in the 21st century exploration to production cycle:

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For further information:

For more information, please contact Sarah Woodcock, sarah.woodcock@geolsoc.org.uk or visit the conference website: https://www.geolsoc.org.uk/05-rescheduled-pg-core-values-2021

MISSIONS TO MARS

'It is pretty special to get new views of martian vistas—it truly feels like exploration.'

A self-portrait of NASA's Curiosity rover taken on Sol 2082 (June 15, 2018). A Martian dust storm has reduced sunlight and visibility at the rover's location in Gale Crater. Credit: NASA/JPL-Caltech/MSSS

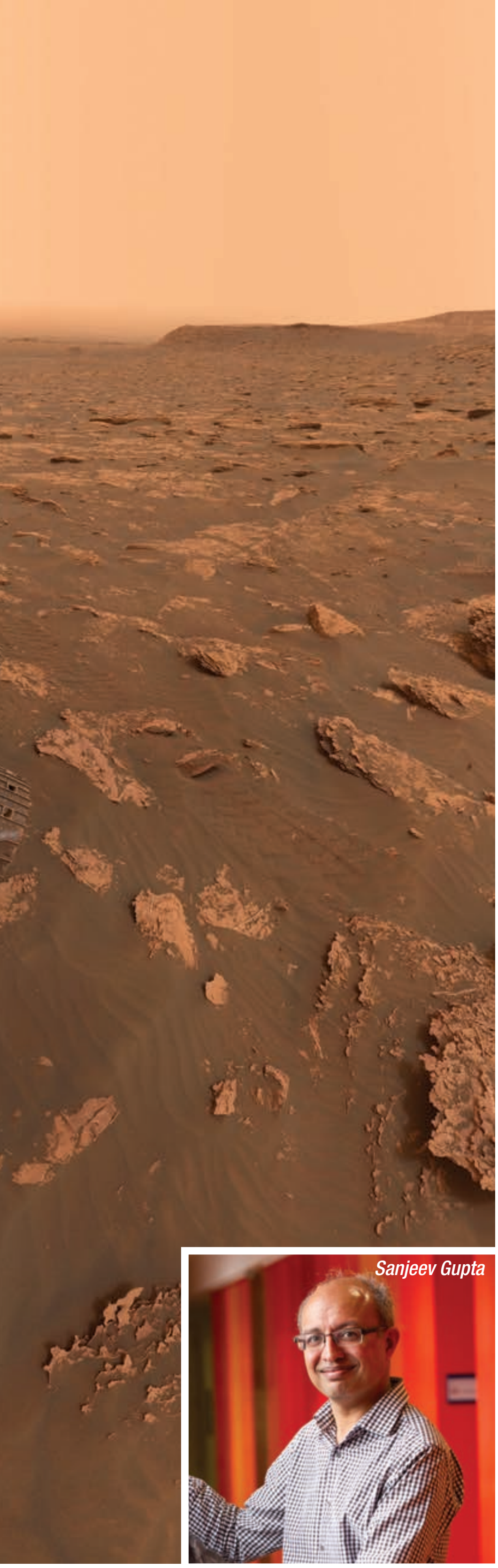
In August 2012, NASA's *Curiosity* rover touched down in Gale crater, Mars, after a 350-million-mile journey lasting more than 8 months. Sanjeev Gupta, Professor of Earth Sciences at Imperial College London, is an Earth and planetary scientist who researches modern and ancient environmental change on Earth's surface and on Mars. He is one of the scientists working on the *Curiosity* rover mission—still active after 8 years on Mars.

'On the *Curiosity* mission, I have two roles. Firstly, I am one of the sedimentologists and stratigraphers on the mission, and my job is to work with other team members in reconstructing the ancient palaeoenvironments from Gale crater strata and to determine the habitability of early Mars.

'I am also one of the strategic planners for the mission, what we call a Long Term Planner. For this role I integrate between the science team and engineers in building strategic plans for exploration and scientific observations and experiments.'

Exploration

Since the 1960s, humans have been exploring Mars with an increasingly sophisticated series of probes, landers and rovers. In that time, we've learned a huge amount about the planet's geological history, composition and potential for life. Among the missions currently operating alongside *Curiosity* are NASA's InSIGHT (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) lander, which is studying the interior of Mars, and MAVEN (Mars Atmospheric and Volatile EvolutioN), an



Sanjeev Gupta

orbiter studying the Martian atmosphere.

'We have learnt enormous amounts about Mars in the light of recent missions, such as *Curiosity*, MAVEN and InSIGHT' says Sanjeev. '*Curiosity*'s big finding has been the discovery of 'smoking gun' evidence for active surface water flow on Mars—rivers transporting rounded pebbles and cobbles 3.5 billion years ago, and the presence of lakes in Gale crater at that time that likely existed for at least hundreds of thousands , if not millions of years. We have also discovered organic compounds in Martian mudstone samples.'

As well as the *Curiosity* rover, Sanjeev is also working on *Perseverance*, NASA's latest rover mission launched in July and expected to land in February next year, and the ExoMars *Rosalind Franklin* rover, a joint mission between the European and Russian space agencies, planned to launch in 2022. As one of the Long Term Planners for NASA's *Perseverance* mission to Jezero crater, he has been working with the science team to develop investigation strategies for exploring deltaic strata in the crater.

'The *Perseverance* rover will be coring and caching rock samples for future return to Earth. When analyzed in Earth laboratories, scientists will be able to look for chemical and textural evidence for past life. Moreover, investigation of the geochemistry and mineralogy of samples will tell us invaluable information about the geological and atmospheric evolution of Mars.

We also hope to be able to collect samples that could be age dated back on Earth so that we can begin to construct a robust timeline for Mars—something that is lacking. In the ESA / Roscosmos ExoMars mission, the *Rosalind Franklin* rover will drill up to 2 m into the martian subsurface, well below the radiation damage zone, to look for organics in martian rock samples.'

Martian vistas

Curiosity has become known for the incredible panoramic images of Mars it has captured, as well as for the first 'selfies' to be taken on Mars—created by stitching together numerous images taken by the handlens camera located at the end of its robotic arm. The panoramic images we've become used to seeing in the news are captured by the Mast Camera (Mastcam), which recently captured a mosaic made up of one hundred images that contained 1.8 billion pixels.

'Mastcam images are typically put together by a small group of people. When I dial into daily operations, I will look over a Navigation Camera panorama taken at the end of a drive the previous day. I and other team members will use this to identify and target areas, rock outcrops, landscape features etc., that we are interested in getting a photo mosaic of. We will make suggestions to the engineers of the Mastcam team, who will construct framework for a possible panorama to be taken by the Mastcam cameras based on individual image frames.

'Usually we have to decrease the size of the mosaic because of data volume constraints or issues with how long the mosaic will take in terms of time. When the image frames come down, one of the Mastcam engineers will put the images together into a mosaic, though this is often done automatically.

'It is pretty special to get new views of martian vistas—it truly feels like exploration.'

Sample return

Alongside the incredible images and scientific data already being collected, Sanjeev is hopeful that, in time, it will be possible to bring samples from Mars back to Earth.

'This is the plan! The *Perseverance* rover is collecting and caching rock samples, which is the first step in the Mars Sample Return mission concept. The idea is that around 2026, a mission will be sent to Mars that will contain a Sample Fetch rover that will retrieve the cached samples, take them back to the lander and the samples will be launched into Mars orbit in a Mars Ascent Vehicle. Then, perhaps in 2030, a third mission will retrieve the samples from Mars orbit and bring them back to Earth!'

It wasn't until the final Apollo mission that a geologist was sent to the surface of the Moon--Apollo 17's Harrison Schmidt, who is now an Honorary Fellow of the Geological Society and was instrumental in sample collection and documentation during that mission. It may be some time yet before we can send humans to Mars, but Sanjeev believes that when we do, geologists may be at the front of the queue.

'I think it will definitely happen and perhaps the key scientists on that first mission will be geologists. Whilst we can do a lot with a rover on Mars, we really need geologist astronauts to explore the complexity of Mars's evolution.'

In the meantime, the scope of what can be achieved remotely is growing all the time, and the teamwork involved in planning missions is one of Sanjeev's favourite parts of the job.

'I really like doing rover operations and working with the science and engineering team in planning what we will do on Mars the following day and the next days ahead.

'We all know each other quite well now despite having worked predominantly online for the past 8 years. It's great working with such an amazing group of people!'

Interview by Sarah Day

THE BUILDING BLOCKS OF LIFE

'As long as I can remember, I have loved space. I used to climb out on the roof to just stare at the stars.'

An artist's impression of the Rosalind Franklin rover on the surface of Mars. Credit: ESA/ATG medialab

Sara Motaghian is studying for a PhD in Space and Planetary Science at Imperial College London and the Natural History Museum London. Her research involves working on some of the instruments that will be incorporated into the *Rosalind Franklin* rover, as part of the ExoMars mission. The rover, scheduled to launch in 2022, will travel across the martian surface collecting samples using a drill and analysing them—the first time a rover has combined the capabilities of travelling across the planet's surface and studying it at depth.

'The *Rosalind Franklin* rover is unique' Sara says, 'because it includes a 2m subsurface drill, allowing us to search far enough below Mars's harshly irradiated surface. The spectral instrumentation I work on is used to understand the surface of Mars and find the best sites to look for signs of life before we can select a drill site.'

Search for life

A joint project of the European Space Agency (ESA) and the Russian Space Agency (Roscosmos), the overarching aim of the ExoMars project is to search for evidence of past or present life on Mars. The rover had been scheduled to land in July of this year, but after testing issues with its parachute, the launch window was delayed until late 2022. If successful, *Rosalind Franklin* could be landing on a relatively busy planet—as well as NASA's *Curiosity* rover, which continues to be operational, two more rovers are currently en route to Mars: China's *Tianwen-1* and NASA's *Perseverance*.

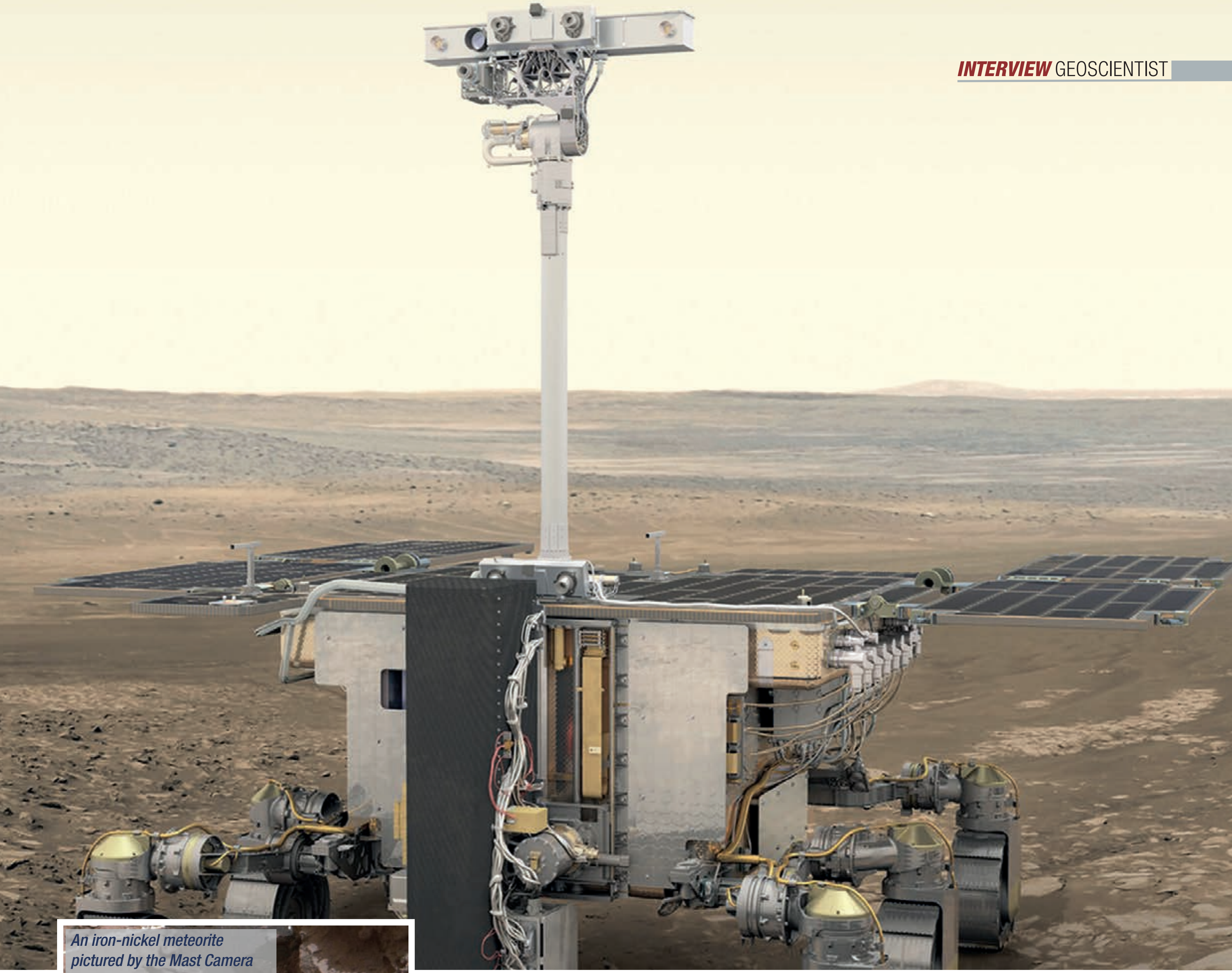
'There are a few reasons why Mars remains a popular exploration target' Sara says. 'One is the search for life: we think Mars was probably once quite habitable, so it's a good candidate to search for past life in our solar system. Another is its accessibility: Mars's location (and lack of super high pressure) makes it one of the best planetary bodies to explore with the technology we have and are working on now. And Mars is the most realistic target for human exploration in the near (ish) future. But I'm in favour of missions to everywhere!

'There are still a lot of unknowns about Mars. We think Mars was once similar to early Earth, so understanding Mars's formation, evolution and eventual divergence from Earth could help us understand our own planet better.'

Meteorites

One of the focuses of Sara's research is the search for meteorites on Mars. Over 50 meteorites have been discovered by rovers, and ExoMars hopes that *Rosalind Franklin* can add to the list. Once a meteorite has landed on the surface of a planet, it is subject to the planet's atmospheric conditions. An iron meteorite on Earth, for example, would quickly rust in an oxygen and moisture rich atmosphere. The condition of meteorites found on Mars, then, can tell us a lot about the planet's history.

'Meteorites on Mars give us an incredible insight into so many questions' Sara says. 'We can use where they are, their size and abundance to understand the atmosphere across history at a rover's' location. The way



An iron-nickel meteorite pictured by the Mast Camera (Mastcam) on NASA's Curiosity Mars rover on October 30 2016, informally named 'Egg Rock' for a site in Maine. Credit: NASA/JPL-Caltech/MSSS

they weather and erode can tell us about the regional climate and its history. Meteorites on Mars act like a sort of witness plate across geological time.'

Meteorites found on Mars may also help with the central question the ExoMars project hopes to explore: has there ever been life on Mars?

'Chondritic meteorites (those which haven't been modified by either melting or differentiation of the parent body) are a possible explanation of the delivery mechanism for the building blocks of life on Earth, and this could also be the case for Mars.

'On Earth, chondritic meteorites have even been found (in Mars analogue locations) to provide within them a habitable environment for Earth's microbial life!'

Opportunities

Sara says one of her favourite moments of her career so far has been working with the martian meteorite collection at London's Natural History Museum, and its curator, Dr Natasha Almeida.

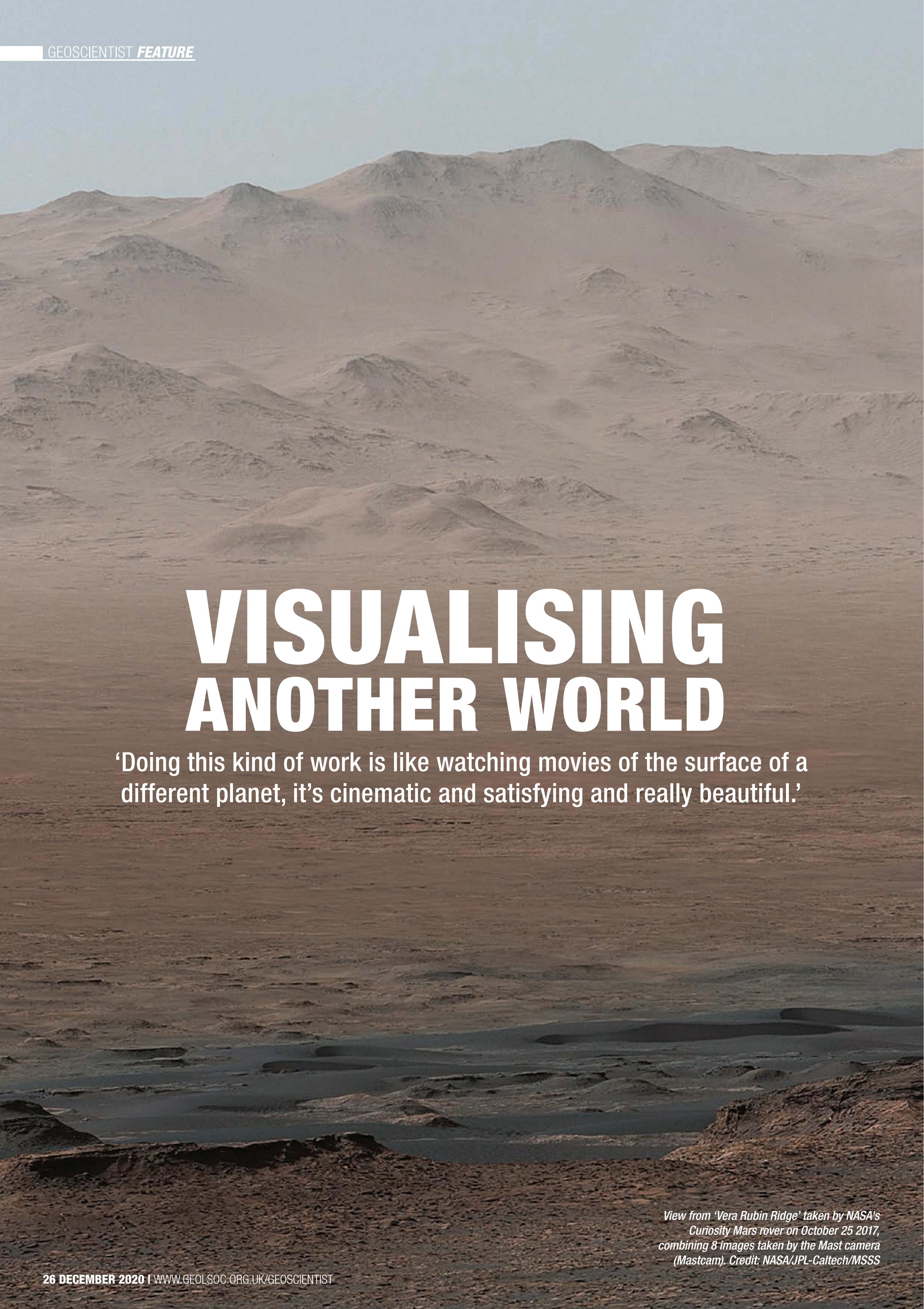
'It's wild to be able to hold something like that in your (gloved) hand, a little piece of Mars. Working on a PhD gives you access to incredible opportunities: meeting other scientists, working on the Roving With Rosalind Outreach project, sitting in on meetings where they are deciding the future of solar systems exploration, using instruments (well, emulators) that will be sent to Mars… it has been incredible.'

Sara Motaghian holding a lunar meteorite at the 50th Lunar and Planetary Science Conference

If all goes to plan, *Rosalind Franklin* will land on Mars in mid-2023, in search of—like its namesake—the building blocks of life.

'One of the main threads throughout space research is whether we are alone in the universe. It's an incredibly difficult question to answer, and the potential evidence is very complex, but my hope would be for ExoMars to find some evidence of past life on Mars.'

Interview by Sarah Day



VISUALISING ANOTHER WORLD

'Doing this kind of work is like watching movies of the surface of a different planet, it's cinematic and satisfying and really beautiful.'

View from 'Vera Rubin Ridge' taken by NASA's Curiosity Mars rover on October 25 2017, combining 8 images taken by the Mast camera (Mastcam). Credit: NASA/JPL-Caltech/MSSS

Divya Persaud is a PhD researcher at University College London, where she is working on processing, visualizing and analysing 3D Mars orbital and rover imagery.

'My thesis encompasses processing 3D imagery of the *Curiosity* rover landing site, Gale crater, and visualizing these datasets to investigate possible stratigraphy. This has involved processing different sets of remote sensing imagery into 3D models, validating them, and building mosaics.

'The final part of the project has been using one 3D model to look at exposed layers in a channel that cuts through Gale crater, which is a unique opportunity to probe into the geologic past of Mars and perhaps the history of water in Gale. In this role, I've also been affiliated with the *Rosalind Franklin* rover PanCam team, helping with simulations of rover operations ahead of the rover launch.

'I don't think there's any single day I don't pause and drink in this very lucky experience.'

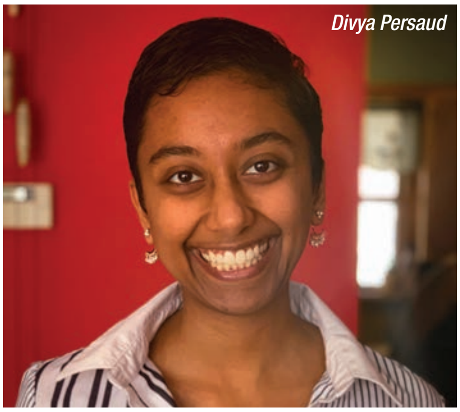
Earth parallels

Although she has always been fascinated by the idea of studying rocks on other planets, Divya began her career, like many planetary scientists, by studying Earth.

'I wanted to have a solid basis in the Earth sciences. Before and during my degree I sought research experiences, from summer internships to an assistantship in my department, to explore planetary science and gauge whether I wanted to really pursue it in grad school and in which subfield. These were really formative experiences, and I was able to see first-hand how research in remote sensing, geophysics, and planetary geology happens, and the team-driven nature of mission work, which was incredibly exciting. One internship, at the SETI Institute, involved using 3D images to analyze craters on the icy moons of Saturn—I realized then that I wanted to work with images to understand the surfaces of planets. So, I finished my degree and applied to PhD programs in planetary geology with a focus on remote sensing.'

Though they are worlds apart, a geological understanding of our own planet is essential to understanding Mars.

'Our understand of geology on Earth is the basis of everything we do in planetary geology—even if gravity, chemistry,


Divya Persaud

different atmospheres or magnetospheres importantly impact geology, the principles of geology are much the same because of how physics and chemistry work. And when we look at these differences, Mars is a lot more similar to Earth, especially looking at 'fossilized', water-driven features on Mars, than somewhere like the Moon or Europa.

'So, understanding, for example, how a high-energy flooding event might be expressed in landforms, or how we might ascertain a lake environment in an exposure of sediment really helps to get an idea of geological events on Mars.'

What are the limits on what we can visualize remotely?

'There are definitely limits—our best resolution remote imagery is 25 cm/pixel, which is fantastic but there is limited coverage and 25 centimetres is still pretty large scale to, say, sedimentologists! And rover imagery is really limited as well. This is one of the reasons why creative methods, like 3D imaging, are helpful to squeeze out as much information as possible. But this is no discredit to the really amazing global imagery that we have of Mars, which has revealed a historically and presently dynamic world.'

Teamwork

The teamwork involved in planetary missions particularly comes into play when it comes to selecting landing and exploration sites. Despite their long journey to Mars, once a rover touches down it may only travel a few miles across the surface of the planet, so the starting point and each 'step' has to be carefully selected.

It's a really community-driven process!' Divya says. 'Different teams or proponents for different regions will put forth an area of interest, typically with in-depth analysis from remote sensing data to build a case for scientific interest. There is usually a series of workshops over the course of more than a year, during which these cases are discussed, and the options are pared down until the team makes a definite choice based on the potential science return but also possible hazards and other problems for rover operations.

'These areas of interest are usually already interesting to the community—places with exciting results or interesting features, sometimes held over from previous selection processes—so there is some difficulty especially when people are, naturally, really excited and emotional about somewhere they want to see in depth with a rover! And it can be difficult to balance the scientific potential with rover safety.'

Big questions

With more rovers planned and en route to Mars, Divya is hopeful that they will help us answer some of the biggest questions about the Red Planet.

'A big question about Mars history is how long water persisted on the surface—whether it was punctuated activity with dry seasons lasting millennia, or sustained for a long period of time, and if so, for how long and when. The latter scenario could possibly provide enough time for basic life to evolve. I'm interested in any answers towards this mystery! And, of course, if there's fossilized life that we can detect with rovers! I'm also really fascinated by ice-driven processes, such as glaciers, and how future remote sensing imagery can illuminate the role of subsurface water ice on Mars.'

An important part of planetary research for Divya is sharing that work with others – something for which 3D imagery is particularly effective.

'As I've said, I feel supremely lucky. I think what is really exciting, though, is knowing that I can also show these places to people—that I can help to grow people's understanding and appreciation of what I call our 'cosmic neighborhood.' So, on the one hand, it's really exciting and pleasing to look at images that very few people have looked at, and in unique, 3D perspectives, but I'm passionate about making sure that non-scientists get access to this feeling of awe, which I think is important for space scientists to think about in our work.'

Interview by Sarah Day

The Geological Society

serving science, profession & society

The role of subsurface research labs in delivering net zero:

realising the potential of UKGEOS

3-4 February 2021

Virtual Event

Main Convenor:

Mike Stephenson (British Geological Survey)

Co-convenors:

Mike Spence (British Geological Survey)
Zoe Shipton (University of Strathclyde)
David Manning (University of Newcastle)
Linda Stalker (CSIRO, Australia)

Further information:

For further information about the conference please contact:

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

T: 020 7434 9944
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A range of energy resources, infrastructures and technologies are likely to be required as part of the transition to a low carbon energy system and net zero. Many of these resources are likely to have impacts on or implications for, the subsurface. Against this background, the purpose of the new £31 million UK Geo-energy Observatories (UKGEOS) is to facilitate research that improves understanding of subsurface energy developments, mass and energy transfer in coupled systems, and their impacts on the subsurface and surface and consequently their interactions with the wider energy system. The conference will bring together scientists from the UK and internationally, to talk about their experience with subsurface facilities, to examine the capacity of the UKGEOS facilities, to develop and stimulate research directions, to link these to decarbonisation policy and regulation, and to stimulate international collaboration in geo-energy.

Call for Abstracts

We invite oral and poster abstract submissions for the meeting, and these should be sent in a Word document to conference@geolsoc.org.uk by Wednesday 15th December 2020. Abstracts should be approximately 250-350 words and include a title and acknowledgement of authors and their affiliations.

The Geological Society

serving science, profession & society

2021 YEAR OF SPACE

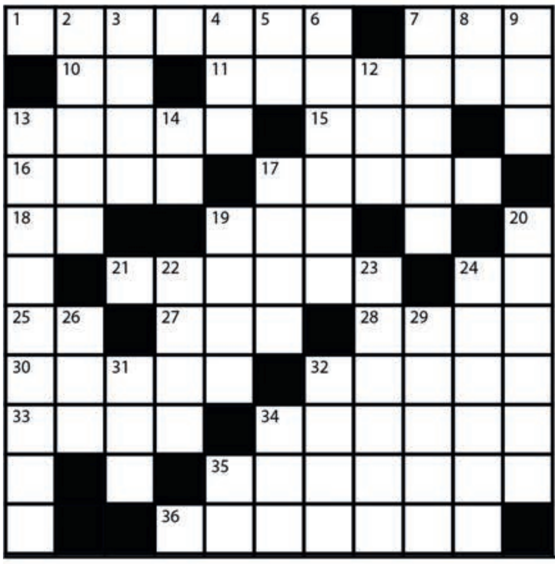
CALENDAR

Due to the ongoing public health risk posed by COVID-19, all GSL events and venue hire bookings at time of writing are being held virtually, in line with Government advice. Please visit www.geolsoc.org.uk/events for updates.

VIRTUAL EVENTS

MEETING	DATE	VENUE AND DETAILS
Forensic Geophysics & Forensic Geoscience 2020	2 Dec	Conference **W:** www.geolsoc.org.uk/NSGG-FCC
NWRG: The last day of the dinosaurs	3 Dec	Evening meeting **W:** www.geolsoc.org.uk/nwrg-last-day-of-the-dinosaurs

Crossword

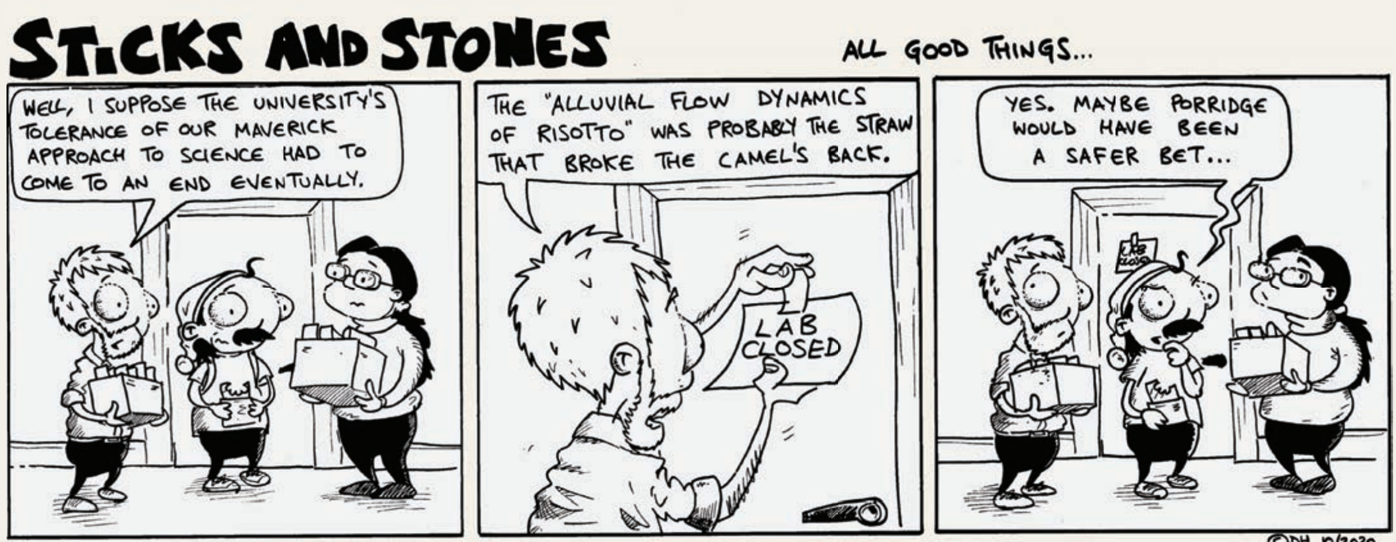


Across
1 Coleoptera (7)
7 Wet, fine-grained sediment (3)
10 Anno Domini (2)
11 Small block of frozen water (3,4)
13 According to Andrews, goes with tea and jam (5)
15 Type of arhythmic dancing (3)
16 Sicilian volcano (4)
17 A Shaw may be this (5)
18 Expression of surprise (2)
19 Groundwater fed bog (3)
21 Type of rhinestone (6)
24/9 Bird at the water's edge (5)
25 Very hard pencil (2)
27 CGS unit of radiation dosage (3)
28 Perfectly exact (2,1,1)
30 Flat, round felt hat (5)
32 Number of rods in a furlong (5)
33 A banded silicate mineral (4)
34 Having more pines (6)
35 Genus of gastropods with spiral shells (7)
36 Non-Darwinian origin of species (7)

Down
2/32 "-----", wind and "----", three elements of the ancient world (5,4)
3 Shale overlying the Penrith Sandstone (4)
4 Cover for 12d (3)
5 Postal district in central London (2)
6 Saloon Cars (6)
7/24 Rivers after heavy rainfall for example (5,6)
8 Mining municipality in the Kolubara Basin (2)
9 See 24 Across
12 A metal recepticle (3)
13 Young male littoralists (5,4)
14 The world's most commonly used battery (2)
17 A stratum of ore (4)
19 Divider on the neck of a guitar (4)
20 Goddess with a tail and long ears (6)
22 Large cretaceous therapod (1,3)
23 Basic units of geology (6)
24 See 7
26 Female bird (3)
29 Small antelope aka the palebuck (5)
31 Scandinavian knotted rug (3)
32 See 2
34 Female swan (3)
35 Seventh note of the sol-fa scale (2)

By Bindweed

Solutions November| **Across**: **1** APB **6** PCB **9** OR **10/12D** Prairie Evaporite **12** emulsor **13** oda **14** vet **15** alas **17** katipo **20** polyhalite **21** elytra **23** reeve **25** AMF **27** kia **28** Nome **31** ear **32** Engels **33** mRNA **Down: 2** pomelo **3** brutal **4** apse **5** carnallite **6** profit-taker **7** CID **8** Beano **11** ro **16** sylvine **17** kae **18/26** tiyin **19** Permian **22** afara **24** en **29** ol **30** ms



That's all folks! Thanks for reading. For more info on what happened next go to stonechatproductions.co.uk

MEETING REPORT

The Myth of Utopia

Richard Norris calls for realism when addressing the challenges associated with the transition to green energy supply

The world is embarking on a monumental energy transition with the aim of decarbonizing the global energy infrastructure. While essential, we must not underestimate the scale and difficulty of this transition. Currently 85% of global energy supply comes from fossil fuels. In addition to replacing this existing energy supply with greener, cleaner options, we will simultaneously need to increase the absolute amount of energy available to society due to an expanding global population that is becoming more urbanised and aspires to greater affluence.

In many mainstream media, public opinion and political landscapes, there is a "techno-optimist" belief that replacing fossil fuels with greener and cleaner alternatives will be nothing more than a technological challenge. Moreover, it is widely stated that this cleaner future will also be cheaper, which has the implicit assumption that our lifestyles will be the same or better. In reality, the transition to greener energy sources will require a significant societal shift to a more sustainable way of life addressing both the supply and demand sides of the energy equation. In July 2020, I gave a presentation to the Geological Society Business Forum that outlines some of the challenges that realistically lie ahead.

Invisible energy

Energy has become invisible in modern society. For many decades in developed countries, and increasingly everywhere, access to secure and affordable energy has become the norm. So normal in fact that it is only ever noticed on the rare occasions when the system has a problem.

Basic economic theory all but ignores the role of energy, focusing on land, labour and capital. The fact that the edifice of modern economics has been built over the last 200 years coinciding with the industrial revolution, during which time technology has provided access to ever better energy supplies, may explain the lack of attention paid to energy as an input.

The economy seems to revolve around goods and services, money, debt, fiscal and monetary policy and so on. Yet, if you spend money, the goods and services you purchase or use will have an energy footprint. If you save money, the bank will lend it to businesses that sell goods or services with an energy footprint. While debt was not the subject of our discussion, it clearly accelerates energy use by creating money in the "now".

Energy is the economy

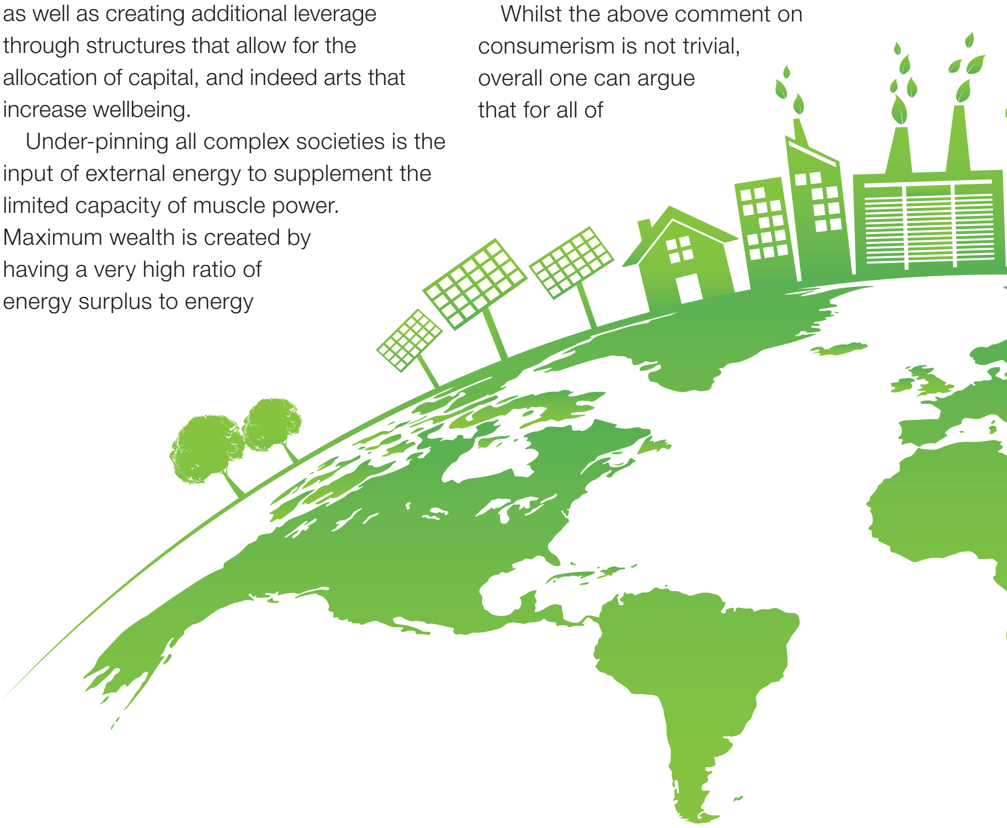
The use of energy above and beyond simple muscle-power provides enormous leverage to society. When subsistence agriculture generates excess through innovation and technology, it allows members of society to do things other than work in the fields. Inevitably this leads to a positive feedback loop in which those liberated workers produce more technology, as "craftsmen", as well as creating additional leverage through structures that allow for the allocation of capital, and indeed arts that increase wellbeing.

Under-pinning all complex societies is the input of external energy to supplement the limited capacity of muscle power. Maximum wealth is created by having a very high ratio of energy surplus to energy input. In the words of a leading academic and author on the subject of energy, Vaclav Smil: "Energy is the Economy".

The last 70 years have been characterized by a very high net-energy ratio as we have exploited coal, oil, gas and nuclear sources. Abundant and cheap energy provides leverage; we consume roughly 2,500 kilocalories per day as food, but use something like 70-200 times more than this as external energy: that is the petrol in our cars, electricity and gas in our homes, as well as the energy embodied in every good or service we use. The availability of cheap energy has facilitated the consumer society that we have today.

It is no coincidence that human history took a radical new path when the combustion of coal was harnessed via the steam engine. Enormous productivity increases happened through mechanization, and whilst work conditions were grim, overall society got richer.

Whilst the above comment on consumerism is not trivial, overall one can argue that for all of



the current angst, modern society is hugely improved on that of the past. Indeed, every Human Development Index, such as infant mortality, longevity, vaccination rates, poverty rates and deaths from natural disasters, has improved over time and is correlated with wealth and energy use.

Costing the Earth

Addressing the price of energy is highly complex and politically charged. It is argued that the current cost of energy is artificially low, given that fossil fuels get a "free ride" by distributing all their negative externalities to the global population, whether that be by particulates pollution or greenhouse-gas emissions. This argument is clearly correct, but must also be balanced with the positive impacts impacts, such as the creation of wealth. It seems there is an in-built assumption that we can have all the good, without the bad, by simply transitioning to greener, cleaner and cheaper energy.

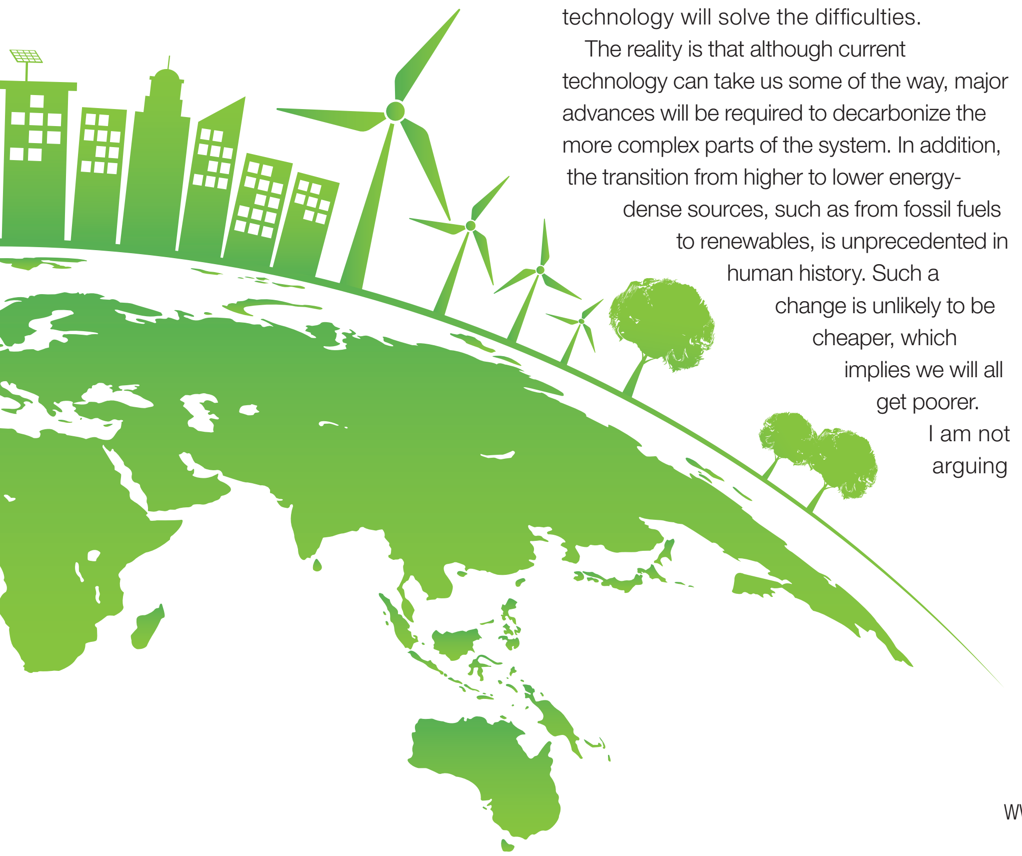
Simply swapping out dirty energy sources for clean ones will not fix the broader issue of the unsustainability of modern consumerist societies. The implication is that lifestyles have to be dramatically down-graded. Protesting in favour of this is easy; actually making significant lifestyle choices much less so. Indeed, the yellow-vest movement in France in 2018-19 was triggered by proposed increases in fuel costs, despite these being for the greater good of funding the energy transition.

Technology will save us

All Malthusian predictions of an end to growth have been left in the dust of progress. With technological advances, we have been able to harness more and more energy, as well as accessing the required raw materials, leading to the widespread view that technology will save us again.

For the energy transition, reporting on the role of technology is slightly schizophrenic in so much as it alternates between two mutually exclusive positions. Either "the technology exists, it just requires the political will" or the next "silver bullet" technology will solve the difficulties.

The reality is that although current technology can take us some of the way, major advances will be required to decarbonize the more complex parts of the system. In addition, the transition from higher to lower energy-dense sources, such as from fossil fuels to renewables, is unprecedented in human history. Such a change is unlikely to be cheaper, which implies we will all get poorer. I am not arguing against the transition to cleaner energy. Rather, I wish to highlight that the reasons for progressing the transition are more complex than simply carbon emissions. Whether we like it or not the era of cheap energy and a high net-energy surplus is drawing to a close. We have exploited most of the easily accessible and cheap sources of oil and gas. The remaining fossil resources, which will be necessary in even the most rapid-transition scenarios, will be more difficult and expensive to access. The on-going transition to renewable energy sources is currently priced by the energy inputs, which are dominantly hydrocarbons. Somewhat counter-intuitively, we need to maximize new renewable energy whilst we still have the luxury of cheap hydrocarbons.



The other side of the coin

If technology does not deliver new and better energy sources, then significant societal changes will be needed. All of the efforts on the energy supply side will need to be matched by planned, rather than chaotic, reductions in per capita consumption. We can envisage far more sustainable and comfortable, but less excessive and less wasteful lifestyles. How we make this transition on the demand side is an area of study mostly ignored in the rush to transition the energy supply side, but of growing importance.

Energy fundamentally underpins affluent lifestyles. The myth is that we can transition from our current fossil-fuel dominated situation to cleaner alternatives without any negative change in our lifestyles. For that to happen, the new energy landscape must be no less expensive than the current one. But is that going to be possible? And if it isn't, how is the energy transition to be achieved without social and political unrest?

Dr Richard Norris is a Fellow of the Canadian Global Affairs Institute and managing partner at Pandreco Energy Advisors. The full talk is available online: https://www.geolsoc.org.uk/expired/07-energy-in-society-2020

PEOPLE NEWS

DISTANT THUNDER All I want for Christmas...

Geologist and science writer Nina Morgan examines some interesting ideas for educational Christmas presents

With the holiday season approaching, many parents, relatives and friends may be giving some thought to that annual corundum: choosing entertaining, yet educational, toys for children. This sort of debate has been going on for a very long time.

In May 1854, the English sculptor and natural history artist, Benjamin Waterhouse Hawkins [1807–1894] read a paper to the Royal Society for the Encouragement of Arts, Manufacturers and Commerce titled: On Visual Education as Applied to Geology. In his lecture, he discussed the methods and motivation behind the life-size models of dinosaurs he created for display in the Crystal Palace Park in South London. These state-of-the-art models, devised in consultation with the leading experts of the day, including the anatomist and palaeontologist, Richard Owen [1804–1892], were designed to educate as well as entertain. Now restored and again open to public view, they create as much excitement today as they must have done when first installed in 1854.

Educational ideas

Listening to Hawkins's lecture gave Richard Dawes [1793–1867] Dean of Hereford Cathedral, an idea. Dawes, a strong supporter of the teaching of science to children, declared that he:

"...should be glad to see those models multiplied at a price which enable them to be introduced into village and ordinary schools." As everyone could not visit the Crystal Palace, he therefore hoped that "specimens like those before them might be rendered attainable by those in remote and secluded districts, who would not have the advantage of witnessing the splendid and gigantic illustration of the extinct creation of the early ages of the world which would be there exhibited..."

This idea was favourably received by others present, and suggestions for how this might be achieved were offered. One participant suggested that lighter and less brittle materials such as papier-mâché could be used, and that the models might be scaled down to a smaller size. For example:

"...the Iguanodon might, for instance, be reduced to the proportions of something like two or three feet in length, and the other animals in like proportion."

For his part, Hawkins stated his readiness to:

"lend his aid in carrying out the suggestions made for multiplying the models in a form which would render them attainable and useful to society at large..."

Major expansion

It's not too much of an exaggeration to say the toy industry took up these educational ideas with gusto and ran with them. Scaled-down dinosaur models made of plastic, wood or other materials, along with an associated plethora of dinosaur books, games and dinosaur-themed merchandise designed for children sell in their millions. Seasonal dinosaur-themed merchandise will surely be popping up beneath a Christmas tree or in a shop window near you. Not that this is necessarily a bad thing. Many geologists and other scientists trace their early interest in science to gifts of similar sorts of educational toys.

Risk assessment

But there is a catch. As a Mr Harry Chester, another (and perhaps more timid) member of the Society pointed out in the discussion that followed Hawkins's lecture:

"...there was one form of illustration which he hoped this subject would not receive, but which he feared would be the case, that was, that these monsters would find their way into their carpets and paper hangings. He would ask what would be the consequence if a gentleman of not very strong nerves, on plunging into his bath found the bottom of it ornamented with some of these horrid-looking animals. "

As all who have encountered the hard plastic of a stray Lego brick—a popular modern educational toy—while stumbling bare-footed across a living room floor in the dark will testify: Mr Chester makes a serious point. Educational toys can present a real danger to life and limb!

Best wishes to all for a safe and happy holiday season.

End notes: Sources for this vignette include: Hawkins, B. W., *J. Soc. Arts*, **vol 2,** pp 444–449, 19 May 1854; and Wikipedia entries for Benjamin Waterhouse Hawkins, Richard Owen and Richard Dawes. For information about visiting the Crystal Palace dinosaurs see: https://cpdinosaurs.org/visit/

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

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

Celebrating fifty years of the Tectonic Studies Group

Sue and Jack Treagus reminisce on the birth of TSG

From our combined memories, we think the idea for the Tectonic Studies Group (TSG) was born from a meeting between Robin Nicholson (d.2015) and John Ramsay in 1968. Robin subsequently wrote to every geology department in Britain with a structural geologist, while John took the idea to the Geological Society of London. The inaugural TSG meeting, hosted by John, took place at Imperial College London in December 1970.

The theme of the meeting was 'The Study of Folds'. Speakers, who included research students, as well as university lecturers and professors, were allotted 45 minutes each. Among them was Sue Treagus (née Beech) giving her first conference talk. At this meeting, John Ramsay was appointed chairperson and Derek Powell the secretary, and it was agreed that TSG would meet annually. The meeting ended with a party at John Ramsay's house in Notting Hill. One of us remembers dancing.

The following year, Robin Nicholson and Jack Treagus organised the first open programme meeting of TSG, which was held in Manchester, again shortly before Christmas. Thereafter, annual meetings were held at different university locations throughout Britain. During its first decade, TSG facilitated the exchange of many ideas and spawned collaborations such as the partnerships between the universities of Liverpool and Leeds, as well as friendships that persist to this day.

Despite shortening talks as demand grew, with just 15 minutes allocated to speakers at the 1978 Liverpool meeting, two days became insufficient to accommodate the growing TSG membership, which included many from mainland Europe. In 1984, the annual December meeting was expanded to three days of talks, with additional workshops and fieldtrips, and this format has continued ever since. In addition to annual meetings, TSG hosted or sponsored many thematic conferences, at the Geological Society, at university venues, and sometimes in collaboration in overseas locations.

As numbers grew and subject matters broadened, the demand for programme space became competitive, with research students given precedence for talks, and some having to accept poster space in lieu of a talk. The 1987 meeting, back in Manchester again, marked a peak in TSG attendance, with a turnout of 350 people, 200 of whom enrolled for the conference dinner. These high numbers reflected the expanding and collaborative nature of structural and tectonics research in academia and the petroleum industry during the 1980s. By the end of the decade, numbers at the annual meetings began to decrease, perhaps the result of the freezing of academic appointments at UK universities, as well as rationalisation of geology departments and some reining back of oil-industry-funded research.

By 1990, there was vigorous debate about how TSG might attract greater numbers, with suggestions to use keynote speakers. This move was opposed by many, who wished to maintain the tradition that our annual meetings provide opportunities for students, academics and industry professionals regardless of rank. Quoting John Ramsay: "TSG has always tried to encourage and to give the floor to young researchers to put forward their views and findings, and not to give preference to more experienced 'oldies'". This tradition continues, supported by TSG medals and prizes awarded to postgraduates.

TSG continues today and welcomes new members. For more information, see: https://www.geolsoc.org.uk/tsg

Susan H. Treagus & Jack E. Treagus were formerly in the Department of Earth Sciences, University of Manchester

The full version of this personal history of TSG is published online. Editor.

The Society notes with sadness the passing of:

Allen, John R. L.
Bennison, George
Billing, Ian *
Copponex, Jean-Pierre *
De Wit, Maarten*
Dickins, Dennis*
Douglas, Tom*
Fookes, Peter
Greenleaves, Keith*
Hawkins, Kevin*
Jackson, David Ian *
Max, Michael David
McKean, James
Mudge, David Charles
Naldrett, Anthony James
Parkes, Matthew
Rostron, Brian*
Ralph, William Thomas*
Spink, Andrew
Symes, Douglas Kean *
Thomas, Michael
Weeks, Alan*
Woodland, Bertram George *
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 geoscientist@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.

OBITUARY Anthony James Naldrett (1933-2020)

One of the world's best-known geologists through his work on magmatic sulphide deposits, his teaching, and his service to international societies

Tony spent his early life in Surrey and attended St. Paul's School in London. After two years military service in the RAF where he learnt to fly Meteor jets, he went to Trinity Hall, Cambridge in 1953. Because of his rowing prowess he was selected for the 1st VIII, which meant spending afternoons on the river. He only studied geology with chemistry and physics because it fitted his schedule, but he loved the subject and a geologist he became.

Ore geology

Tony emigrated to Canada in 1957 and spent two years with Falconbridge Nickel as a mine geologist in Sudbury. Feeling he needed to learn more about ore deposits he enrolled at Queen's University in Kingston, Ontario where he completed his M.Sc. and Ph.D. From 1964, Tony spent three years as a postdoctoral fellow at the Geophysical Laboratory in Washington, learning experimentation on metallic sulfides at high temperatures and applying this knowledge to real ore systems. The approach combining the theoretical with the practical was to define the direction of his future career.

Following an informal visit to the University of Toronto in 1966, Tony was immediately offered a job as an Assistant Professor, becoming a full professor in 1972. He remained at the University for 31 years until his retirement in 1998. He was highly regarded for his dedicated teaching and for building world-class geochemical analytical facilities. His graduate students and postdoctoral fellows are in academia around the world, or captains in industry, and in government. Tony's work on komatiites in Canada, led to an invitation in 1972 from CSIRO in Perth, to spend a sabbatical year working on a nickel deposit in Western Australia. An invitation to spend six months at the Bushveld Research Institute at Pretoria in 1979-1980 was a pivotal point in his career. He was perhaps one of the first westerners to visit to Noril'sk, and his work on this deposit formed the basis of a book published in Russian, Chinese and English. Tony cites his work on Noril'sk and on the Bushveld as his best work.

Over an outstanding academic career, Tony carried out seminal research on the origins of many of the world's major magmatic Ni-Cu-PGE deposits globally. His research on most of the world's magmatic sulfide ores has culminated in the authoritative Magmatic Sulfide Deposits: Geology, Geochemistry, and Exploration (2013).

Tony also consulted for and held Directorships of several companies. He served on editorial boards and international panels, and was the chief scientific advisor to the Canadian delegation to UNESCO. Tony was President of the Mineralogical Association of Canada (1982-83), the International Mineralogical Association (1998-2002), the Society of Economic Geologists (1991-1992) and the Geological Society of America (2001-02).

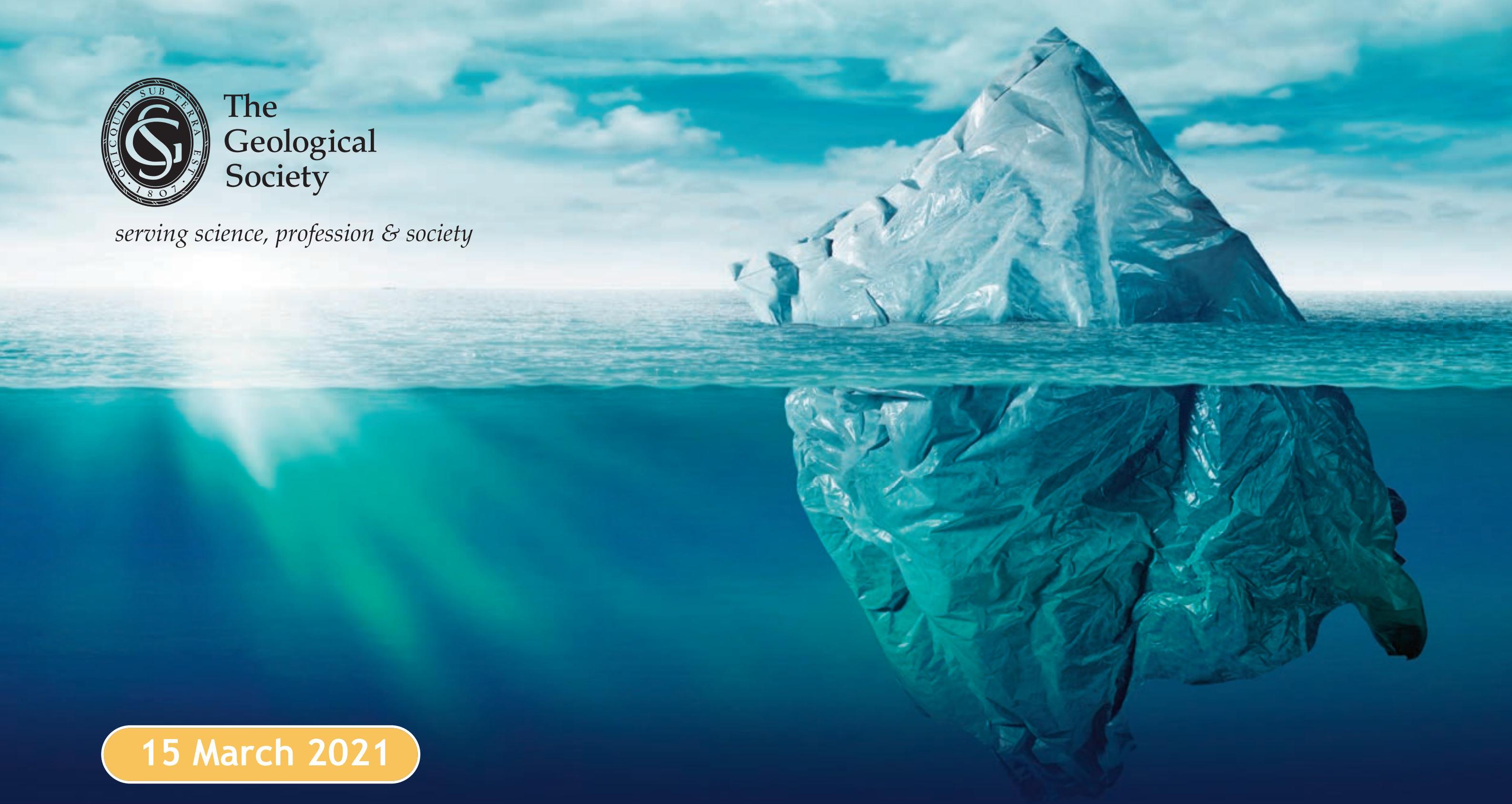
Accolades

Tony won numerous medals and accolades across the world. He was awarded a DSc from Laurentian University (2000) and from the University of Pretoria (2001). He was an Honorary Research Fellow at the Natural History Museum, London (2009-2012), a Fellow of the Geological Society of London and a Chartered Geologist (2004), as well as a Finniston Distinguished Lecturer (2006). In 2004, the IMA Commission on New Mineral Names, accepted Naldrettite (Pd_2Sb) as a new mineral, named in Tony's honour.

Tony was a very social individual who enjoyed a glass of wine. He was always ready to discuss ideas and gave freely of his time. He had huge energy, lived life to the full and was a great raconteur, always ready with a story. He leaves a legacy that will live on in the work of his associates and students. He is survived by his sister Frances, his three daughters Penny, Anne and Jennifer, and two granddaughters.

By Judith Kinnaird

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 geoscientist@geolsoc.org.uk



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15 March 2021

Plastics in the Environment

VIRTUAL CONFERENCE

Primary Convenors

Wes Fraser (Oxford Brookes University)
Gordon Inglis (University of Southampton)
Bryne Ngwenya (University of Edinburgh)

Further information

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

T: 0207 434 9944

E: conference@geolsoc.org.uk

W: https://www.geolsoc.org.uk/plastics2021

Follow this event on Twitter: #plastics21

The accumulation of plastic debris in the environment is a global problem which may have detrimental impacts on ecosystem health. Plastics are now widely enough distributed that they may also act as an anthropogenic marker horizon in the future rock record. However, there are still many outstanding questions regarding the: 1) source, 2) transfer, 3) degradation, 4) persistence and 5) measurement of plastics in the environment.

This one-day meeting will bring together researchers from a diverse range of disciplines (e.g. hydrology, sedimentology, geochemistry, earth science, biology) to discuss the fate of plastics in terrestrial, freshwater and marine environments.

This meeting seeks to foster conversation between these different communities to facilitate a more holistic approach towards understanding plastic in the environment.

Call for Abstracts

We invite oral and poster abstract submissions for the meeting, and these should be sent in a Word document to conference@geolsoc.org.uk by Thursday 28 January 2021. Abstracts should be approximately 300 words and include a title and acknowledgement of authors and their affiliations.

PESGB

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